# IMPROVING INSTRUMENTS:
## EQUATORIA, ASTROLABES, AND THE PRACTICES OF MONASTIC ASTRONOMY IN LATE MEDIEVAL ENGLAND


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This dissertation is submitted for the degree of Doctor of Philosophy

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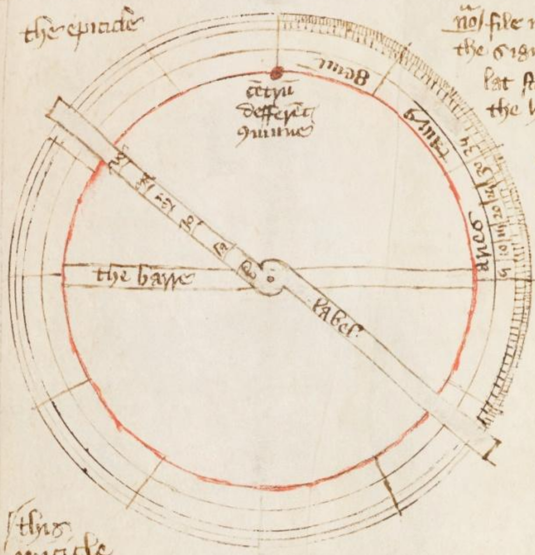
This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University of similar institution.

It does not exceed 80,000 words, including footnotes but excluding the appendix as approved by the Degree Committee of the Department of History and Philosophy of Science.




nota / file nat to ney thin zede cercle that is closere of the signes / lest the comune centre defferent breke but stonde a litel lowe as sheweth in direct of the hed of cancer

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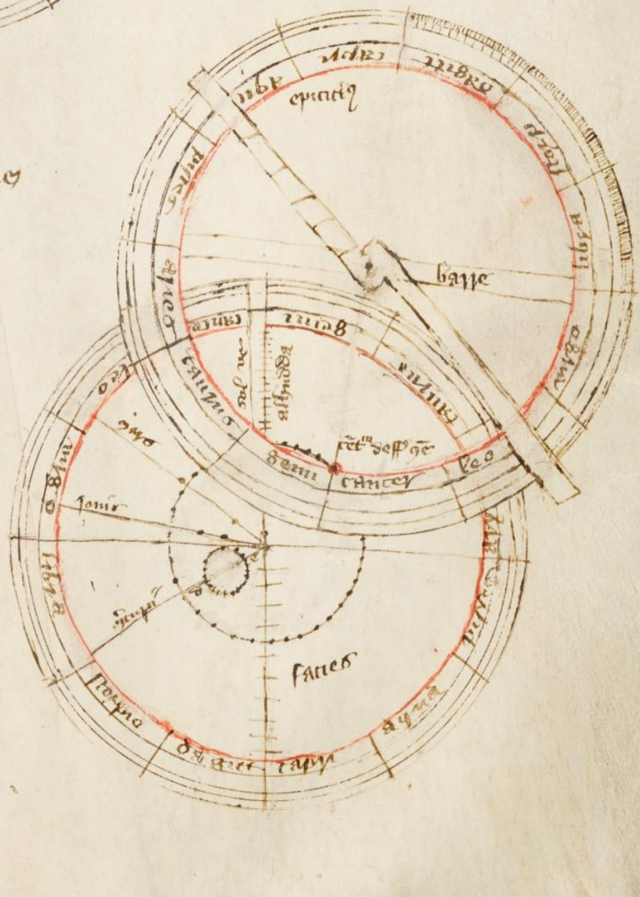
this epicicle is deuided & compased in alle thinges lik to the lymbe of thin equatorie / but it hath non encentrik of the sonne / the prikke that stant in the closere of the signes in direct of the ende of geis is the comune centre defferent

but natheles thus lith thin instrument whan thow makest equacion of thy mone




The *Equatorie of the Planetis*
Peterhouse, Cambridge MS 75.I, f. 74r.

Quaerite . . . facientem Arcturum et Orionem

Amos 5:6-8 (Vulgate)

Seek him that maketh the seven stars and Orion

Amos 5:8 (King James Version)

He who made the Pleiades and Orion

Amos 5:8 (New International Version)

# IMPROVING INSTRUMENTS: EQUATORIA, ASTROLABES, AND THE PRACTICES OF MONASTIC ASTRONOMY IN LATE MEDIEVAL ENGLAND

Histories of medieval astronomy have brought to light a rich textual tradition, of treatises and tables composed and computed, transmitted and translated across Europe and beyond. These have been supplemented by fruitful inquiry into the material culture of astronomy, especially the instruments that served as models of the heavens, for teaching and for practical purposes. But even now we know little about the practices of medieval astronomers: how they obtained and passed on their knowledge; how they drew up and used mathematical tables; how they drafted the treatises in which they found words to express their ideas and inventions for their particular audiences. This thesis uses a case study approach to elucidate these medieval astronomical practices.

Long thought to be a holograph manuscript in the hand of Geoffrey Chaucer, the *Equatorie of the Planetis* (Peterhouse, Cambridge MS 75.I) has recently been identified as the work of John Westwyk (d. c. 1400), a Benedictine monk of Tynemouth Priory and St Albans Abbey. His draft description of the construction and use of an astronomical instrument, with accompanying tables, provides an opportunity to reconstruct the practices of an unexceptional astronomer.

The first chapter of this thesis reconstructs Westwyk's astronomical reading and understanding, through an examination of the other manuscript that survives in his hand: a pair of instrument treatises by the outstanding monastic astronomer Richard of Wallingford. I show how Westwyk copied this manuscript in a monastic context, learning as he annotated texts and recomputed tables. In the second chapter I discuss the purposes of planetary instruments such as equatoria, their place among other astronomical instruments, and the physical constraints and possibilities experienced by their makers. Through this discussion I assess the craft environment in which Westwyk came to write his own instrument-making instructions. Chapters three and four assess Westwyk's language, explaining the basis for his choice to write a technical work in the vernacular, and analysing how his innovative use of Middle English furthered his didactic objectives. In the final chapter, I undertake a technical reassessment of the *Equatorie* treatise, an integrated analysis of the instrument with the somewhat neglected tables that Westwyk compiled alongside it. The thesis thus applies a range of methodologies to examine the practices and products of a single inexpert astronomer from all angles. It aims to show what an in-depth case study approach can offer historians of the medieval sciences.

# ACKNOWLEDGEMENTS

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I would like to thank my supervisor, Liba Taub, for first bringing the *Equatorie* to my attention, for introducing me to the possibilities of working with museums and their collections, and for encouraging me throughout my time in Cambridge. Likewise Nick Jardine, my advisor, has been very supportive in my attempts to understand the trepidation of the eighth sphere and the ablative of respect. I am very grateful to them both.

I have benefited hugely from the help of a large number of people who have provided expert advice, and of whose scholarship I remain in awe. Scott Mandelbrote shared his knowledge of the Peterhouse manuscripts, and wisely directed the Equatorie reconstruction project; in that project, Ben Blundell was an energising partner. Kari Anne Rand offered patient, encouraging advice on John Westwyk and his manuscripts; Jacob Currie lent his expertise on St Albans. Tessa Webber and Debby Banham provided palaeographic assistance, and my fellow Latin Therapists added tea, romance and grammatical precision. John Davis kindly shared the results of his XRF analyses, and Daniel Wagner offered timely trigonometric tuition. The family of Derek de Solla Price supplied abundant memories and memorabilia of their father. Katie Eagleton shared her knowledge of medieval instruments and the texts describing them, and Linda Voigts provided helpful advice on the vernacular and its users. I was fortunate to be able to refine my ideas at many workshops and conferences, and am grateful to innumerable inquisitive scholars who instigated or supported my attendance, asked thought-provoking questions, and corresponded thereafter; while it is invidious to name just a few individuals, I would particularly like to acknowledge the support of José Chabás, Karine Chemla, Margaret Gaida, Matthieu Husson, Boris Jardine, Rich Kremer, Jenny Rampling, Richard Thomason and Glen Van Brummelen. Susannah Gibson, Matthieu Husson, Peter Jones, Rich Kremer, Lea Olsan, Richard Oosterhoff and the members of the HPS History Workshop gave very helpful feedback on draft chapters.

The Department of History and Philosophy of Science has been a fantastic place to work for the past five years, and I would like to thank its administrative team, as well as the staff of the Whipple Library and Whipple Museum, especially Steve Kruse, Josh Nall and Claire Wallace. I have been fortunate in the assistance I have received from many other archives and repositories, and I would particularly like to thank the staff of: Cambridge University Library and the libraries of Corpus Christi, Gonville & Caius and Trinity Colleges; the Bodleian Library, Oxford, and the libraries of Corpus Christi and Merton Colleges (especially Julia Walworth); the libraries of the universities of Aberdeen and Salamanca; the Adler Planetarium, Chicago; the British Museum; and the Museum of the History of Science, Oxford (especially Silke Ackermann and Stephen Johnston).

I am most grateful for the support I have received in various forms from all at Peterhouse. And my final and greatest debt is owed to my family, who have fed, clothed and supported me, provided welcome distraction, and kept my feet warm through the years.

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# INTRODUCTION

> It is this love of the contemplation of the eternal and unchanging which we constantly strive to increase, by studying those parts of these sciences which have already been mastered by those who approached them in a genuine spirit of enquiry, and by ourselves attempting to contribute as much advancement as has been made possible by the additional time between those people and ourselves. We shall try to note down everything which we think we have discovered up to the present time; we shall do this as concisely as possible and in a manner which can be followed by those who have already made some progress in the field.
>
> Ptolemy, *Almagest* (c. 150 CE), I.1[1]

> If this single instrument contains in so small a frame the functions of each and every one of those [mentioned above], and perhaps also adds certain extra features, then its place among other instruments will not be undistinguished, especially since its design could direct the minds of many people to higher things.
>
> Richard of Wallingford, *Tractatus albionis* (1326), III[2]

Given the twelve centuries separating Ptolemy from Richard of Wallingford, it goes without saying that they were writing with different purposes, for different audiences engaged in different astronomical practices. Yet the second-century Alexandrian and fourteenth-century abbot of St Albans shared more than the theories of celestial motion which ruled western astronomy from their translation into Latin in the late twelfth century until their gradual displacement by the work of Copernicus, Tycho and Kepler. Both gave thought to how, and by whom, their ideas would be received; both hoped to provide their readers with an education not only mathematical, but also moral.[3]

Both, by the late middle ages, were probably more widely cited than read, and surely more read than understood. When the fifteenth-century abbot John Whethamstede wrote that 'we read that the Albion contains in itself the functions of all the other instruments,' he showed his respect for the achievements of his predecessor, and the similarity of his phrasing makes it highly likely that he had read and was paraphrasing Richard's treatise, but we can not be so sure that he grasped or employed its astronomical content.[4] Historians have done much to elucidate the links between the texts that were copied and transmitted across astronomical communities in monasteries, universities and other settings. Where those texts are annotated, they have drawn conclusions about how such texts were used. But we still know far too little about the levels of

[1] Ptolemy (1984), 37.
[2] North (1976), I. 340; my translation. Originals of quotations I have translated are found in appendix A.
[3] On the ethical purpose of Ptolemy's astronomical teaching, see Taub (1993). The caveat should be noted that presenting one's work as educational could be a *topos* for many astronomical writers. See Bernard (2014).
[4] British Library MS Cotton Nero C.VI, f. 149r.

understanding of medieval astronomers, how they obtained that understanding, and what they did with it. This thesis represents an attempt to fill that gap in our knowledge.

It builds on what has become known as the "practice turn" in history of science. The study of practices is now well established as a way of reconstituting past science "from inside" rather than from a present-centred perspective, but it is less popular for pre-modern science, perhaps because of a paucity of sources.[5] In particular, historians of early science have rarely been able to reconstruct the poorly documented practices of non-elites. Yet in order to assess the impact of important figures such as Ptolemy and Richard of Wallingford, it is necessary to evaluate their success in teaching the theories and skills they aimed to impart; such an evaluation must consider a range of possible audiences. It must also consider the media through which ideas were communicated and made useful: texts, tables, images, instruments.

This thesis will focus on these media. On the one hand, we shall explore the ways in which cosmological assumptions and devotional motivations, concerns about precision, the position of astronomy within the wider body of medieval learning, and intentions for the practical use of astronomical knowledge, were played out in the structures and designs of astronomical products.[6] On the other, such products will be seen to have shaped the learning and practical experiences of the people who engaged with them.[7] That is why this thesis is entitled *Improving instruments*: instruments had an important impact on the astronomical learning and practices of their users, but were themselves also subject to modification, partial or complete destruction, or re-combination, and were the sites where astronomers' ideas and innovations were played out.

Tracing the learning processes of medieval astronomers is particularly challenging. Much historical writing on the subject of "medieval learning" focuses on the content of medieval knowledge, without explaining in much detail how that knowledge was acquired, or discusses the delivery of knowledge – teaching – rather than its reception and absorption, which is true learning.[8] This is, of course, an evidential problem: even if we can be sure that a text purporting to be didactic really was intended for that purpose, it is far harder to know how it was actually used. Documents of learning contexts, generally produced by teachers, tend to reflect the transmission of didactic material rather than its reception.[9] This thesis sets out to analyse the processes of learning, as well as the body of knowledge that was learnt. It makes use of a manuscript that is simultaneously a pedagogical tool and a document of its author's learning processes. While not claiming to be comprehensive, it considers some of the techniques, such as

[5] Soler et al. (2014). See especially the contribution by Chemla.
[6] Murdoch (1975); Cadden (2013).
[7] Here I am drawing on actor-network theory; see, for example, Latour (2005).
[8] Murdoch and Sylla (1975).
[9] Bernard and Proust (2014).

collation of texts, (re)calculation of tables and production and use of instruments, through which astronomical knowledge was acquired and tested. It also considers the people who were learning while practising astronomy. This is a poorly defined group, united only by their comparative lack of expertise but perhaps sharing other characteristics, such as a freedom to experiment. They are not adequately described by established categories such as 'practitioner'. The word 'amateur' is useful, but problematic for medieval history because it is now so often antonymous to the modern 'professional'.[10] Where I use the term 'astronomers', this indicates an interest in studying the stars, but by no means implies professional standards or unity. Nor is this group well served by the separation of medieval scholars from craftsmen; the instruments of learning evince the parallel development of scholarly and craft skills, and instruments could be made in many places that might be thought the preserve of abstract thought.[11]

It is therefore vital to pay attention to the specific contexts in which texts and instruments were made and used, and learning took place.[12] These contexts were not only geographic and temporal, but linguistic, institutional, hegemonic and motivational. This thesis aims to take account of these local contexts, while focusing on one in particular: the vernacular astronomy of a Benedictine monk at St Albans monastery and Tynemouth priory, at the end of the fourteenth century. This was a time when the use of the vernacular for the sciences was beginning to flourish, and when texts on astronomical instruments were produced by and for astronomers at widely varying levels of ability.[13] Within the specific geography of late medieval England, these instruments were invented and used in three main institutional contexts: universities, monasteries, and the royal court. Of these, the first undoubtedly produced the most advanced mathematical astronomy. Two hundred years after its establishment, having recovered from the setbacks of the mid-century plagues and long before it was to acquire a reputation for ignorance of mathematical sciences, the University of Oxford was experiencing a peak of scientific production.[14] In the late fourteenth century Merton College alone boasted table- and instrument-makers of the calibre of John Killingworth, William Rede and Simon Bredon; the work of such

[10] The 'practitioners' of vernacular mathematics in the early modern period have been scrutinised in the work of E. G. R. Taylor (1954) and Stephen Johnston (1994). However, their interests are typically understood as largely practical, in opposition to the theoretical traditions of university mathematics (though Johnston (294-295) resists such a simplistic dichotomy). On the status of the amateur in modern science, see Berman (1975).

[11] The idea that previously separated groups of scholars and craftsmen came together to create modern science was pioneered by Edgar Zilsel (1942); see also Hall (1959). The "Zilsel Thesis" has recently been revised and promoted by Pamela Long (2011).

[12] Mosley (2007), 296.

[13] Voigts (1996); compare, for example, Richard of Wallingford's advanced *Tractatus albionis* (admittedly an early-fourteenth-century text) with Chaucer's accessible *Treatise on the Astrolabe*, or the complex but practically focused texts of the Parisian astrologer-craftsman Jean Fusoris.

[14] On the impact of the plague, see North (1987). Feingold (1984) has challenged the assumption that the 'modern science' of the seventeenth century owed nothing to Oxford, but the stagnation of the early modern universities is a theory that has proved hard to shift.

astronomers spread well beyond the confines of the university. By the end of the century, Cambridge too boasted its own astronomers in an incipient school led by John Holbroke (d. 1437). Holbroke was to become both master of Peterhouse and a royal chaplain, said to have been present at the birth of Henry VI in 1421, and the author of a horoscope for the future king's nativity.[15] Such connections between university and court were common, and astronomy was a popular pursuit at the English court from the time of Edward III.[16] Connections were also strong between the court and the principal monasteries, of which St Albans was certainly one. The abbots built close relationships with members of the royal family; the monastery's most significant patron in the late fourteenth century was perhaps Joan, Princess of Wales, whose interest in astronomy is evidenced by John Somer's dedication of his astronomical calendar to her in 1380.[17]

Monks had many reasons to be interested in astronomy. As members of an institution whose founder had stressed the importance of learning as holy work, they certainly valued a science enshrined in the *quadrivium* of mathematical arts.[18] Even if the monasteries' days at the forefront of western scholarship were over, late medieval monks still made strenuous efforts to celebrate the achievements of their forebears and maintain the culture of learning that they had established. This culture had particular characteristics, focused on collective endeavour, and often directed towards practical outcomes. Apart from the obvious importance for astronomy in timekeeping and regulation of the ecclesiastical calendar, it also had a place in monasteries' vital function as local medical centres.[19] And of course the capacity of this science to call attention to higher things, sometimes ridiculed in contexts where its students might be criticised for not keeping their feet firmly enough on the ground, was a primary asset in monasteries.[20]

In monasteries, as elsewhere, astronomy was not a monolithic science. Its forms and purposes varied; its products and practices were sometimes known as *astronomia* and sometimes *astrologia*. However, although distinctions were undoubtedly made between astronomy and astrology, these were fluid, and it is impossible to draw conclusions about definitions and attitudes from the use of just those words. Astronomy existed on a spectrum from the most abstract theoretical calculations to the most concrete practical questions, and an individual could have interests at both ends, each informing the other. Nor was cosmology, often portrayed as a

[15] Carey (1992), 145-153; Snedegar (2004).
[16] Carey (1987).
[17] Carey (1992), 48-49; Clark (2004), 34-37; Somer (1998), 2.
[18] *The Rule of Benedict*, chs. 47-48.
[19] Park (2013), 615-617.
[20] The story of the astronomer so busy looking at the stars that he falls into a well or ditch, whose earliest surviving version is in Plato's *Theaetetus* (174A, where the astronomer is Thales of Miletus), was popular at this time in both scholarly and less learned contexts. See Eagleton (2004), 1-2; 'The Miller's Tale', I.3457-61, in Chaucer (1988), 71.

philosophical discipline separate from mathematical astronomy, as distinct as is sometimes assumed. While treatises tended to address the two subjects separately, they were studied by the same people, and it is inconceivable that monks, studying biblical passages describing the substance and form of the heavens, would not have formed their own opinions on the implications of these.[21]

One area where astronomy, astrology and cosmology came together was in the design and use of instruments. The purposes of medieval astronomical instruments are much contested, and this thesis will not advance a generalised position. However, it is worth briefly surveying the arguments on each side of the debate. On one side, Derek Price's 'philosophy of scientific instruments' saw devices such as astrolabes as a symptom of medieval 'love of mechanism':

> They were tangible models that served the same purpose of geometrical diagrams or mathematical and other symbolism in later theories. They were embodied explanation of the way that things worked . . . As a matter of fact, the medieval terms for planetary simulations were *Theorik* and *Equatorie*; the brass devices went by the names we now use for abstract modelling. I suggest that tangible modelling as a species of comprehension comes nearer to the "purpose" of armillary spheres or star and earth globes than to imagine they had prime utility as devices for teaching or for reference.[22]

On the other side, Jim Bennett has emphasised that descriptions of late medieval instruments in use rarely support an interpretation that views them as models; he notes that 'the explanatory books of the time . . . concern themselves very much with doing rather than knowing,' incorporating instructions and worked examples to help users solve concrete problems.[23] Something of a middle way has been taken by Adam Mosley, who argues that 'not only did [users] frequently fail to respect a distinction between models and calculating aids, they tended to rely, sometimes explicitly, on a view that certain instruments utilized mathematically worked *in virtue* of modelling the universe.' Mosley suggests that 'instruments were employed, in pedagogic contexts, to demonstratively convey cosmological ideas as well as to teach particular operational procedures within the domain of mathematics.'[24] While I would endorse Mosley's position, I would add particular emphasis to his implication that uses – and interpretations – of instruments must be heavily context-dependent.[25] It is surely by integrating understanding of the contents and contexts of instruments that we will best understand each one's true purpose(s).

A range of interpretations is, of course, always possible, not least because users had a certain amount of choice about how to use instruments. An instrument such as an equatorium or astrolabe could be used to learn mathematical techniques, or about cosmological theories; it

[21] Here I am drawing on the caution of Stephen McCluskey (1998, x) and Bernard Goldstein (1980, 132), against the more rigid separation enforced by Edward Grant (1994, 36-37).
[22] Price (1980), 76.
[23] Bennett (2003), 136. Notwithstanding his title ('Knowing and Doing in the Sixteenth Century: What Were Instruments For?'), Bennett refers to some instruments that had changed little since the fourteenth century.
[24] Mosley (2006a), 194.
[25] Mosley (2007), 294-296.

could be an aid to religious contemplation; it could be a tool for computation of data to be used astrologically, or for some other more or less practical purpose; it could even be valued as an artefact of a great astronomer.[26] So even though John North is surely right to draw attention to the content of planetary instruments, pointing out that 'the equatorium [was], in effect, a movable scale-drawing . . . simulating not so much the planetary movements as the *diagrams* of the *Almagest*', when we examine particular equatoria in context the implication that they served primarily or solely to model theoretical concepts seems less compelling.[27] Where possible, the evidence of surviving instruments must be taken into account. The ways in which brass, wood and parchment were shaped to makers' purposes, or modified to suit the needs of later users, tells us a great deal that cannot be gleaned from descriptions or images.[28] But even where equatoria do survive – and they are few – they must be analysed in the context of their production and use.[29] This means examining them alongside the texts and tables that usually accompanied them.

Texts and tables could themselves be instruments.[30] They could be devised, developed and used in various ways, and astronomers often enjoyed significant flexibility in how they employed texts, tables and three-dimensional instruments together or separately.[31] This applies particularly to equatoria, which were astronomical computers devoid of any observational function (though they could be attached to other instruments, such as astrolabes, that did have such a function) and were dependent on the input of basic data, usually obtained from tables. Study of a particular monastic context where instruments were valued and used, where astronomical learning was respected, and where texts were carefully compiled and studied, can therefore tell us a great deal about late medieval astronomy, its students and users. This thesis focuses in depth on just such a context.

* * *

The value of a case-study approach should, by now, be clear. Focusing on one manuscript, one instrument, one individual, provides an opportunity to reconstruct scientific ideas and practices from inside; situating them in their intellectual context prevents such a viewpoint from

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26 On mathematical teaching techniques, see Burnett (1997). In a previous study (Falk, 2012) I considered the saints' days used on late medieval English astrolabes, and suggested that makers' choices reflected local devotional concerns. For reverence for Richard of Wallingford's achievements by his successors, see the St Albans chronicle *Gesta abbatum* (Walsingham, 1867), II. 182, 201, 207, as well as appendices 2-8 in North (1976), vol. III.
27 North (1976), II. 251, 261.
28 On the importance of, and different roles for, images (albeit mostly printed), see Jardine and Fay (2014), especially the contribution by Gessner. For what we can learn from damaged or modified instruments, see Greenblatt (1990) and Schaffer (2011).
29 Brown (2001).
30 The idea of an instrument as a separate category of object for scientific investigation is certainly post-medieval, as Warner (1990) makes clear. See also Cadden (2013), 250; Chabás (2012): 269–286.
31 Husson (2012).

becoming excessively internalist or content-focused. It allows detailed attention to be paid to practices including reading, writing and the production of objects (including books); and it allows the material forms of such objects to be explored.[32] The work of the St Albans monk John of Westwyk, who was both learning and teaching as he compiled, computed and composed tables, images and texts about instruments in Latin and the vernacular, is an ideal candidate for such an approach. His *Equatorie of the Planetis*, now in Peterhouse, Cambridge MS 75.I, has been intensively studied, yet there is much that has not been uncovered about this manuscript and its author.

The manuscript first appears in a catalogue of the library of Peterhouse, Cambridge, dated 1589, where it is described as 'Simon Bredon equat. Planet.'[33] (It had been there since at least c. 1535, when it had been examined by the antiquary John Leland in the course of his tour of England's libraries.)[34] The attribution to the Merton astronomer Simon Bredon was followed by all subsequent catalogues up to and including M. R. James's in 1899; James suggested that the manuscript contained 'directions for making an astrolabe (?).'[35] In December 1951 it was examined by Derek Price, then in the early stages of PhD research on the subject of 'The history of scientific instrument making.'[36] Noting that the treatise, which appeared to be an original composition, was written in Middle English and dateable to 1393, around the same time Geoffrey Chaucer wrote the *Treatise on the Astrolabe*, Price immediately suspected a connection with the great poet.[37] Realising that the manuscript contained no mention of Bredon, who was in any case dead by 1372, Price sought further evidence for his supposition, and discovered the word 'chaucer' half-hidden by the manuscript's nineteenth-century binding.[38] He changed the subject of his PhD to 'An Edition of MS 75 (i) in Peterhouse Library', and dedicated much of his thesis-edition, published by Cambridge University Press in 1955, to arguing for Chaucer's authorship of what Price christened *The Equatorie of the Planetis*.[39]

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[32] This approach is influenced by important recent works such as Secord (2000) and Heesen (2002).
[33] Peterhouse, Ward Library MS 400, f. 12.
[34] Leland (1774), IV. 22; Mandelbrote (2010), 32-33; Price (1955b), 6-10. Price suggested four possible donors: John Holbroke (mentioned above); John Warkworth (Master of Peterhouse 1473-1500); William Gage (who bequeathed the college an astrolabe and some books after 1500); and Roger Marchall (a fellow of Peterhouse c. 1437-60). Price suggested two items from a 1472 donation list in Marchall's hand (Clarke (2002), *CBMLC*, UC48.387 and 389) as possible candidates for MS 75.I, but as Voigts (1995a, 285-286) points out, there is no evidence of Marchall's involvement with this or any other vernacular text. On the connections between Holbroke, Marchall, and astronomy, see Carey (1992), 145-146.
[35] James (1899), 94; James's (?).
[36] Derek Price, Application for University of Cambridge, 23 February 1951, Cambridge University Archives BOGS 1 1953-4, Price D.J.
[37] Price (1975), 26-27.
[38] For Bredon's will, proved in 1372, see Powicke (1931), 82-86.
[39] R. F. Bennett, History Faculty Board memorandum R.S.524.388 (9 May 1952), Cambridge UA BOGS 1 1953-4, Price D.J. The story of Price's discovery and subsequent events is told in Falk (2014).

Although Price was cautious in his attribution, writing that 'it must be clearly understood that no *decisive* proof is being offered or even suggested . . . the ascription to Chaucer must remain tentative,' he was clearly confident that he was correct, seeking and gaining worldwide publicity for his discovery.[40] It is hardly surprising that scholars studying the manuscript since Price have mostly addressed the authorship question, about which scholarly opinion has been divided.[41] Although some historians of astronomy, such as John North, argued from the content of the manuscript and the lack of alternative candidates that Chaucer was a plausible candidate, most Chaucer scholars remained doubtful.[42] The consensus shifted decisively against Price's contention when Kari Anne Rand Schmidt published her thesis on the matter, which included a strong refutation of one of Price's most dramatic pieces of evidence, the palaeographic comparison of the single word 'chaucer' in the manuscript (see figure 1) with the same word, thought by some scholars to be in Chaucer's own hand, in a 1378 memorandum from the Wool Quay.[43] And the lack of an alternative candidate was remedied in 2014 when Rand identified the hand in the *Equatorie* as the same as Bodleian Library MS Laud Misc. 657, a copy of two works by Richard of Wallingford.[44] Laud Misc. 657 contains a note in the same hand as the main texts, identifying its donor (and scribe) as John of Westwyk, a monk of Tynemouth. Rand reconstructed Westwyk's life, showing that he had spent much of his life at St Albans, Tynemouth's mother house.

Rand's discovery allows this manuscript to be placed within its precise monastic context. Her identification of the author and another earlier text in his hand allows the present thesis to reconstruct the environment in which the *Equatorie* was composed, the training and interests of its author, and the range of possible audiences to which it was directed. However, to an extent the author's identity is irrelevant to the some of the most glaring gaps in our knowledge about

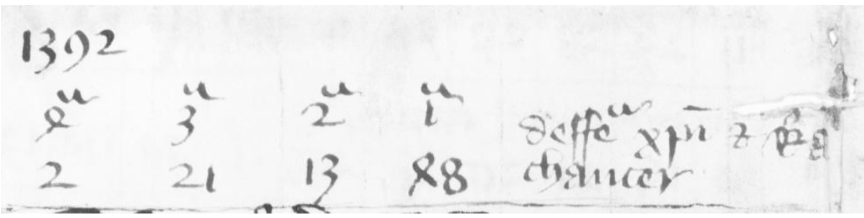

Fig. 1: The "Chaucer radix". Peterhouse, Cambridge MS 75.I, f. 5v. Image taken by Derek Price when the manuscript was disbound in 1952; reproduced by permission of the Price family.

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[40] Price (1955b), 149; 'Possible Chaucer Manuscript: Discovery at Cambridge', *The Times* (28 February 1952), was published less than three months after Price had first seen the manuscript. See Falk (2014), 116-117.
[41] A thorough summary of scholarly writing on the issue up to the early 1990s is provided in Rand Schmidt (1993), 3-14.
[42] North (1988), 169-181; Benson (1988), xxiii-xxiv. The only collection of Chaucer's works to include the *Equatorie* is that of John H. Fisher (1977). This has been maintained in the most recent (third) edition, Allen and Fisher (2012), 'because it may well be Chaucer's work, because it supplements his *Treatise on the Astrolabe*, and because it is otherwise not readily available.' (vii).
[43] Rand Schmidt (1993), 27-39.
[44] Rand (2015).

this manuscript, concerning its sources, structure and style. The research project which has led to this thesis began when the question of authorship was still unresolved; since that question had been thoroughly examined,[45] my intention in this thesis was always to focus on aspects of the manuscript which had been discussed only in passing, or not at all, by previous historians. These, it seemed from the outset, were the treatise's use of language, the relationship between it and the tables that accompany it, and the expertise necessary to produce it.

The last of these questions is clearly informed by our knowledge that it was written by John Westwyk, since the *Equatorie* treatise is almost certainly a holograph text: an original composition in the hand of its author.[46] That issue has been the subject of some debate, but the absence of copying errors, its orthographic consistency, and the myriad corrections, additions and glosses in the same hand make it highly likely that Westwyk composed the treatise himself, even if it was partly founded on translation of earlier texts.[47] Nevertheless, even without the name of its author, the internal evidence of the manuscript provides a great deal of evidence on the question of his expertise. And approaches to that question have hitherto been so concerned to prove or disprove Chaucer's authorship, that the evidence has not been treated holistically, and its potential to tell us more about the author's purposes and learning processes has not been realised. Likewise, the author's use of language has previously been discussed in detail, starting with the linguistic analysis which R. M. Wilson contributed to Price's edition of the manuscript, and continuing through many kinds of quantitative and qualitative study, but these have invariably been structured with the implicit or – more often – explicit goal of answering the authorship question.[48] More basic questions, such as why its author chose to write in English, who the audiences were for a scientific treatise in the vernacular, and how the author tailored his language to suit those audiences, have not previously been discussed.

The other gaps in the historiography of this fascinating manuscript relate to its technical content. This has been seriously addressed by three previous scholars, but even on this subject analyses have been coloured by the authorship question. So, although a large part of Price's work is taken up with a comprehensive analysis of the Peterhouse equatorium design and its place among related astronomical instruments, he paid little attention to the tables which comprise the bulk of the manuscript, apart from those parts he found useful for the attribution to Chaucer.[49]

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[45] The most recent treatment to that point was Arch (2005), which added little to the argument, but thus cemented the impression that there was little new to be said.

[46] Originality and authorship are problematic concepts for medieval texts, particularly technical ones where mutual influences are ubiquitous and hard to disentangle, but here I am only stating that the *Equatorie* is more than a simple copy or unedited translation. Medieval notions of authorship are explored in chapter 3 of this thesis (pp. 85-87).

[47] The evidence is discussed by Rand Schmidt (1993), 15-27; see also Wakelin (2014), 280-281.

[48] See, for example, Partridge (1992); Samuels (1983).

[49] Price (1955b), 75-92.

Next, Emmanuel Poulle discussed the *Equatorie* in his monumental study of late medieval and early modern planetary instruments; he is perhaps the only scholar to have entirely disregarded the authorship question.[50] Poulle's focus on the ways equatoria represented Ptolemaic planetary theory led him to examine the workings of the Peterhouse instrument in the context of similar late medieval equatoria, especially Campanus of Novara's influential design.[51] His summary of the Peterhouse design is quite thorough, but he draws few conclusions from his description and does not consider the design alongside its accompanying tables. Finally, John North discussed MS 75.I in a number of publications, most notably *Chaucer's Universe*.[52] In this book he reversed the negative verdict he had given on the authorship question in a three-part paper in *The Review of English Studies* nineteen years earlier; the majority of the chapter in the later work is dedicated to explaining and supporting his reasoning on this question.[53] This chapter contains the most extensive analysis yet published of the tables, but it too is directed largely towards asserting Chaucer's authorship and identifying evidence for the book's main objective of portraying Chaucer's astronomical knowledge and interests.[54]

Because previous studies of the equatorium and tables have all either been directed towards the issue of Chaucer's authorship, or (in Poulle's case) have treated the equatorium as an entirely decontextualised design, little attention has been paid to what the manuscript can tell us about its author's understanding, learning processes, interests and techniques. John North was unique in seeking to draw new conclusions about Chaucer from the manuscript; even then it was only as part of a much larger study into Chaucer's astronomy. For this reason, this thesis seeks to examine certain aspects of the manuscript that have not previously been considered, in order to build a better understanding of the astronomical environment that engendered it. The text of the treatise will, for the first time, be assessed alongside the tables that were evidently compiled to accompany it by its author, and were indispensable for the use of the instrument. John Westwyk's processes of composition, computation and editing will be examined in depth, analysing his skills – and mistakes – to paint a more detailed picture of the mind of this late medieval astronomical learner-teacher.

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[50] Poulle (1980), 161-165.
[51] For more on Campanus' equatorium, see Benjamin and Toomer (1971).
[52] North (1988).
[53] North (1969), especially 433-436.
[54] North (1988), 183-191.

This thesis will start by assessing the monastic setting for mathematical astronomy. Its first chapter uses John Westwyk's copy of Richard of Wallingford's *Tractatus albionis* as the basis for an analysis of the purposes and practices of astronomy in monasteries. I show that the version of the *Albion* that survives in Westwyk's hand in Bodleian Library MS Laud Misc. 657 is not a straightforward copy of adaptations made by an earlier Oxford scholar, as previous historians have supposed, but a collation of two versions of the treatise. Numerous small textual changes and additions, made in the process of compilation, testify to Westwyk's training, motivations and thought processes as he carried out the task of copying this most complex of medieval instrument treatises around 1380. I have also used statistical methods to reconstruct the computational procedures by which Westwyk produced new astronomical tables for the latitude of Tynemouth, showing him to be a highly competent mathematician. The practices of copying and compilation evident in this manuscript provide important evidence for Westwyk's astronomical understanding, and perhaps the learning processes of monks more generally.

The second chapter of this thesis discusses the materials, dimensions and forms in which instruments like the Albion and equatorie were made. I consider textual descriptions alongside surviving brass artefacts, re-examining the relationship between theoretical and physical models and giving overdue prominence to the concerns of medieval instrument-makers. I draw on insights from material culture studies to examine makers' choices, and discuss what the combination or juxtaposition of these instruments with astrolabes, which often necessitated compromises or modifications in the design of each, shows about their perceived functions and significance. I examine the calendars on the backs of astrolabes from this period, uncovering new evidence about the ways these were constructed, and use this to suggest new insights into the group of astrolabes that have been suggested as "Chaucerian". This analysis of the complex relationships between separate and combined instruments has implications not only for the ways we theorise and categorise instruments, but also for how we display them in museums.

In its third and fourth chapters, my thesis turns away from material culture to focus on language. I analyse John Westwyk's use of Middle English for didactic purposes in an age when the vernacular was beginning to flourish as a language of communication in the sciences. I discuss the precedents and influences for Westwyk's choice of language, as well as the possible audiences for a treatise on a scientific instrument in English. In the third chapter, I argue that Westwyk's use of the vernacular for *The Equatorie of the Planetis* was driven by philosophical, pedagogical and practical concerns, and show how his choice of language influenced the ways he expressed his ideas. In the fourth, I carry out a close reading of the *Equatorie* text to reveal

Westwyk's pedagogical and rhetorical techniques, and the ways he moulded Middle English vocabulary for his particular needs, drawing on Latin and Arabic where necessary.

The final chapter of my PhD thesis provides a close analysis of John Westwyk's astronomy. I evaluate the strengths and weaknesses of his equatorie design, and assess the extent to which he depended on other astronomers (many explicitly cited). Although this includes a substantial amount of technical analysis, I do not explain the functions of the equatorie in full, since this has already been done by Price and Poulle.[55] Rather, I focus on aspects of the design which are particularly revealing about their creator. I discuss his compilation and computation of astronomical tables, and for the first time I bring the tables and instrument together, analysing how they worked in combination and separately. I demonstrate that Westwyk was learning as he refined his instrument design and taught its principles to his readers; through this case study, I attempt to reconstruct some of the learning practices of non-elite astronomers in the later Middle Ages. Since this reconstruction depends on a holistic understanding of the environment in which Westwyk composed the *Equatorie of the Planetis*, I have placed this chapter last. (Readers seeking clarity on some technical point may wish to refer to this chapter during their reading of earlier chapters, but in general are encouraged to read it last.)

Thus each of the chapters of this thesis applies a different methodology: contextual, statistical, material, linguistic, pedagogical, mathematical. Together, I hope that they constitute a holistic, sharply focused case study. As a whole, this interdisciplinary research joins recent work that has challenged assumptions about a late medieval decline in monastic scholarship, and begins to add a hitherto neglected scientific dimension to that work.[56] My thesis aims to demonstrate the value of the case-study approach for reconstituting past science from inside, and thereby to show not only that the practices of non-elite, vernacular astronomy are worthy of scholarly attention, but also that amateurs such as John Westwyk were part of a small but closely knit astronomical community through which scientific ideas were creatively developed and communicated.

[55] Price (1955b), 93-118; Poulle (1980), 161-165.

[56] For example, Clark (2011) has challenged the orthodoxy of a late medieval decline in learning which we find in works such as Knowles (1957), but Clark's coverage of the sciences leaves much to be desired.

# Chapter One

## Writing astronomy in a monastic environment: how John Westwyk compiled his Wallingford

Much is unknown about the composition processes of medieval astronomical manuscripts. Although in-depth studies of the content of many treatises and tables have provided valuable evidence of their sources, influences and antecedents,[1] few studies have yielded insight into how drafts were composed, and numerical data computed or copied.[2] This is why Peterhouse, Cambridge MS 75.I is such an important document.[3] Almost certainly an author's or translator's holograph,[4] its many erasures, emendations and insertions in both text and tables are a priceless testament to the ways its writer went about drafting his explanation of how to make and use a planetary equatorium, and compiling tables for use with or alongside that instrument.

Following the manuscript's discovery by Derek Price in 1951, Peterhouse MS 75.I aroused particular interest owing to Price's argument that the treatise, which he named *The Equatorie of the Planetis*, was an autograph manuscript by Geoffrey Chaucer, perhaps a continuation of his *Treatise on the Astrolabe*.[5] (The former is securely datable to 1393, while the latter was most probably written in or from 1391.)[6] Price's always contentious suggestion was not disproved until very recently, when Kari Anne Rand showed that the hand in the *Equatorie* was the same as the main hand of another manuscript, Bodleian Library, Oxford MS Laud Misc. 657.[7] The latter manuscript bears a donor's note in the same hand, which states: 'Master John of Westwyke gave this book to [the priory of] God and the blessed Mary and St Oswyn, king and martyr, at Tynemouth; and to the monks serving God there.'[8] Rand was able to reconstruct much of the life of this John Westwyk, showing that he had probably been a monk first at St Albans, then at its dependent cell at Tynemouth, and later, having joined the army of Henry Despenser, bishop of Norwich, on a disastrous crusade in Flanders,[9] returned to St Albans, where he probably died soon after 1397. She argued that it was most likely that MS 657, which contains copies of the

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[1] In the area of astronomical instruments, perhaps the most important studies are those by Benjamin and Toomer (1971), and North (1976). On tables, the most significant recent work has been that of Chabás and Goldstein, especially (2003) and (2012).
[2] There are notable exceptions, most obviously where authors' or translators' holographs survive. See, for example, Jones (1990).
[3] The manuscript is now fully digitised and accessible online at http://cudl.lib.cam.ac.uk/collections/peterhouse.
[4] Rand Schmidt (1993), 15-27.
[5] Price (1955b), especially 156-159.
[6] Price (1955b), 151-153; North (1988), 63, 173-176; Reidy (1988), 1092. See discussion in chapter 3, pp. 82-83.
[7] Rand (2015).
[8] Bodleian Library, Oxford MS Laud Misc. 657, f. 1v.
[9] Westwyk is named as one of several monks from St Albans and its cells to take part in this expedition, in a frankly critical account by the Abbey chronicler Thomas Walsingham. See Walsingham (1867), II. 416.

*Albion* and *Rectangulus* instrument treatises of Richard of Wallingford (abbot of St Albans 1327-36), had been produced at St Albans shortly before Westwyk moved to Tynemouth around 1380.[10]

It is thus clear that, far from being produced in the same secular setting as the *Treatise on the Astrolabe*, the *Equatorie of the Planetis* was written by a monk. Yet MS Laud Misc. 657 can give us much more than the identity of the *Equatorie* author. Careful reading of this manuscript sheds light on the priorities and practices of monastic book production; close attention to the changes Westwyk made in collating and copying Richard of Wallingford's works allows us to understand his education and interests; and through this we may come to understand how, a decade later, this monk came to write an (at least partly) original instrument treatise.

Such an approach assumes that copying was not a transparent activity, a simple replication of the content of one manuscript on the thitherto blank folios of another. Rather, it often involved active engagement. To be sure, some writings – including parts of MS 657 – provide little discernible evidence of the copyist's mental activity. However, others allow us to reconstruct their writers' processes of goal-oriented reading, reproduction and reinterpretation. We shall see that even where, as in this case, the copyist was very respectful of his source texts, there is much to be learned from a close examination of what he did with them.[11]

## MS LAUD MISC 657: THE *ALBION* AND *RECTANGULUS*

At first sight, MS 657 is a fairly unexceptional manuscript, containing faithful copies of two popular treatises, a table of astrological houses in a different, contemporary hand,[12] and 49 empty pages across the 80-leaf codex. Rand suggested that the large number of empty pages point to 'an unfinished production and relatively easy access to parchment.'[13] The manuscript is not dated, though Westwyk's script, a relatively formal anglicana bookhand, supports a dating to the last quarter of the fourteenth century.[14] The texts of the *Rectangulus* and *Albion* treatises in this manuscript were collated by John North for his magisterial edition of the works of Richard of Wallingford, the abbot of St Albans whom Price (in his laudatory review of North's edition) described as 'the most important medieval mathematician and astronomer of England.'[15] These

[10] Rand (2015), 7, 13.
[11] This approach (and the title of this chapter) owe something to the work of Lisa Jardine and Anthony Grafton (1990), as well as (in the medieval context) Stock (1983).
[12] Coxe's (1858-1885) catalogue of Laudian manuscripts describes these vaguely as 'tabulae signorum zodiaci', which may account for their not having been discussed before now.
[13] Rand (2015), 3. Rand here gives full codicological information for this manuscript.
[14] Rand (2015, 3) and North (1976, II. 130) agree on this. The only other detailed examination of this manuscript is in Clark (1997); Clark suggests that the manuscript was copied between 1420 and 1440, but elsewhere states that Westwyk was working c. 1400 (319, 142).
[15] Price (1978), 219.

treatises were both widely copied, especially the *Albion*, which North described as 'Richard of Wallingford's most important achievement in astronomy' and which survives in at least 32 manuscripts.[16] The two treatises were written 'at the same time' in 1326,[17] and both describe the construction and use of instruments: the Albion is a complex equatorium, while the rectangulus was a form of torquetum. As North noted, the surviving copies of the *Rectangulus* differ little, and MS 657 is no exception to this.[18] *Albion*, however, presents a different case. Many of the surviving manuscripts contain an adapted version produced around 1430 by John of Gmunden;[19] what North judged to be 'the fundamental text' survives in nine copies (he deemed five of good quality, and collated three for his edition).[20] The form of the treatise in MS 657 is unique. Immediately above his donor's note, Westwyk noted:

> It should be known that Master Richard, abbot of the monastery of St Albans, first composed this book; and through it he devised and made that marvellous instrument which is called Albion. But afterwards a certain Simon Tunsted, professor of sacred theology, changed certain things not only in the book but also in the instrument, as will be clear to scholars in this book. Also, he added certain things.[21]

Simon Tunsted was a Franciscan who was active at Oxford in the 1350s and 1360s. Little is known about his writings, but the sixteenth-century historian John Bale highlighted his work in music and the seven liberal arts.[22] On the basis of Westwyk's note, North argued that the changes in *Albion* were Tunsted's work; North was mainly concerned to collate Richard of Wallingford's treatise and, understandably, did not examine each change in MS 657 or pay particular attention to this manuscript.[23] An alternative view was presented by James Clark, who wrote: 'based on, but apparently more advanced than Tunstede's work, Westwyk made arguments for how the construction and operation of the clock . . . might be made easier and more reliable.'[24] Clark did not provide any evidence for this assertion, and his confusion of the *Albion* with the clock Richard created for St Albans might give us cause to doubt his assessment of Westwyk's expertise.[25] Kari Anne Rand, in her recent article, took a plausible intermediate view: that while most of the changes were probably made by Tunsted, some at least were the

16 North (2005), 61; North (1976), II. fold-out table following p. 136.
17 Richard of Wallingford, 'Rectangulus', in North (1976), I. 406.
18 North (1976), II. 288.
19 North (1976), II. 131-132.
20 North (1976), II. 127-129.
21 MS Laud Misc. 657, f. 1v.
22 Bale (1990), 415. See also Sharpe (1997), 619; Jotischky (2004b).
23 North (1976), II. 130.
24 Clark (1997), 142.
25 This lamentably common confusion – perhaps first suffered by John Leland (1709, 404-405) – is worth noting because it has influenced several discussions of why the *Albion* spread so widely, including to Tynemouth. See, for example, Clark (2004), 149.

work of John Westwyk.[26] This chapter will build and expand upon her arguments. But first we must understand how and why this copy came to be made at St Albans.

## MONASTERIES, BOOKS, ASTRONOMY

The Rule of St Benedict had expressly prohibited the ownership of books by monks, and laid emphasis on biblical study as the core of monastic reading.[27] And the Rule remained the foundation and heart of life at St Albans in this period: Richard of Wallingford himself had written a commentary on its Prologue, and the constitutions of Thomas de la Mare, abbot in Westwyk's time (1349-96), emphasise that the Rule should be read repeatedly to novices, so they could understand fully what they were committing themselves to.[28] However, by John Westwyk's day devotional activity had blossomed and expanded to include an enormous breadth of scholarship. The statutes drawn up by the southern chapter of Benedictines at Reading in 1277 actively encouraged a wide range of study, both within the cloister and at the University of Oxford.[29] This was further promoted in Pope Benedict XII's 1336 Bull *Summi magistri*, which expressly ordained that instruction in the 'primitive sciences' of grammar, logic and philosophy should be provided in every monastery.[30] Benedict's maxim that 'the pearl of knowledge is obtained through the practice of reading' provided the justification for tremendous activity in the composition, acquisition, copying and study of books in the fourteenth century – an atmosphere which Clark, seeking to overturn assumptions about the declining intellectual life of English monasteries, has termed 'a monastic renaissance at St Albans.'[31] Abbot Thomas de la Mare built a new scriptorium and actively promoted the 1277 statutes: 'studying, reading and writing books; glossing, correcting, illuminating, and also binding,' ostensibly as an antidote to idleness.[32] And the occupants of the scriptorium had plenty of material to work with: the wealth, royal connections and geographical situation of St Albans permitted it easy access to ideas, texts and scholars from Oxford, Cambridge and London.[33]

Those ideas and texts included a significant amount of astronomy and astrology.[34] This was far from unusual in monasteries, which had been centres of astronomical scholarship before

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26 Rand (2015), 12-13.
27 *The Rule of Benedict*, chs. 33, 48.
28 Walsingham (1867), II. 207, 431.
29 Pantin (1927), 209-210.
30 Wilkins (1737), II. 588-613, esp. 594. This was paralleled by a drive to improve the education of parochial clergy in the first half of the fourteenth century (Logan, 2014).
31 Clark (2004).
32 Walsingham (1867), II. 433, III. 392-393. See also Doyle (1990), esp. 3-5.
33 Hunt (1978). On scholarship in London, see Galbraith (1941). On royal connections, see Clark (2004), 34-37; Carey (1992), 48-49.
34 Sharpe (1996), 538-585.

the foundation of universities and continued to be so, if in a reduced capacity, thereafter. Such scholarship went well beyond the practical timekeeping and computistical calculations of Bede (672-745): by 1100 Walcher, prior of Great Malvern, had carried out observations and computed lunar tables that far surpassed what was necessary to find the date of Easter (indeed they did not even give liturgically consistent results, as Walcher was well aware).[35] Moreover, Benedictine abbeys had been at the forefront of the adoption and development of astronomical instruments such as the astrolabe in western Christendom.[36] Such scholarly commitment must have had a range of motivations. The desire for precise timekeeping was surely one of those, important as it was for the symbolic value of order and authority, as well as the more immediate purpose of regulating monastic routines; it is not surprising that monasteries possessed a range of time-telling devices.[37] A second practical motivation could have been a drive towards enhanced astrology for medical purposes: the largest astrological libraries in this period were in religious houses, and the Benedictines had particular rules governing the dress to be worn and Biblical verse to be intoned when carrying out surgical procedures such as phlebotomy.[38] More difficult to assess is the balance between devotional and intellectual motivations: were monks driven by a desire to discover more about God's creation, an astrological interest in charting heavenly influences, or simple intellectual curiosity? These questions have been much debated, most notably in a fierce exchange between Edward Grant and Andrew Cunningham.[39] Cunningham has stressed the importance of 'the attempt to reach the life of the mind' underlying medieval treatises; insofar as this thesis elucidates the mind of John Westwyk, it may have something to add to the debate.[40] For now let us say only that, whatever their motivations, monks found themselves drawn to a wide range of astronomical and astrological material, not all of it wholly licit.[41]

Nonetheless, the interest in astronomy seems to have surpassed a normal level at St Albans. We see this in the manuscripts and catalogues that survive from the fourteenth century, which range from well-known texts by Macrobius or Menelaus of Alexandria to less common works by Arabic authors,[42] in the chronicles of the monastery, which rather unusually record the

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35 McCluskey (1998), 94-96, 180-184.
36 Burnett (1998).
37 Eagleton (2008), 122.
38 Carey (1992), 41-42; O'Boyle (2005), 14-15.
39 Cunningham (1991); Grant (1999); Cunningham (2000a), and further contributions in the same issue of *Early Science and Medicine*. I have analysed this debate in greater depth in an earlier dissertation, Falk (2012), especially 13-22.
40 Cunningham (2000a), 273.
41 Page (2013) discusses the magical texts collected by the Benedictine monks of St Augustine's, Canterbury. See also Edge (2014), 154-163.
42 Sharpe (1996), 561; Rouse and Rouse (1991), 258.

astronomical interests of a number of abbots and monks,[43] and in the windows installed in the conventual library by John Whethamsted, which featured Ptolemy and the ninth-century astrologer Albumasar amongst other luminaries of scholarship.[44] This heightened interest was probably due in part to the monastery's close links to the University of Oxford, the centre of English astronomy.[45] St Albans was not in the first wave of houses to send students to Gloucester College after its foundation as a Benedictine body in the 1280s, but after 1336, when the Bull *Summi magistri* called on monasteries to send one in twenty of their members to the *studia generalia*,[46] the abbots seem to have adopted this practice with great enthusiasm, sending more than thirty monks to study there between 1340 and 1420.[47] Few of these monks stayed long enough to take degrees, and they were expected to focus their studies on subjects likely to be useful in the monastery, but they still had freedom to develop their own intellectual interests, which often ranged widely.[48] The flow of students was accompanied by a flow of texts;[49] this was made more practicable in the case of astronomical works by the fact that St Albans was at almost the same latitude as Oxford.[50] The abbots of St Albans were clearly aware of the advantages of university education, as they were consistently generous benefactors to Gloucester College. Most notable was John Whethamsted, who had been prior of the college before his election as abbot in 1420, and who built the college library, donated his own books to its collection, and attracted the decisive patronage of Humphrey, Duke of Gloucester.[51] But the precedent was set by Whethamsted's predecessors: we learn from the Abbey chronicle that in John Westwyk's time abbot Thomas de la Mare supported the living expenses of scholars at Oxford, and paid to have their accommodation refurbished.[52] Such munificence must have contributed to the Abbey's reputation for scholarship at this time, [53] which may in turn have attracted new monks to the house, sometimes directly from Oxford.[54]

One such monk was Richard of Wallingford. He had studied at Oxford for six years before making his profession, and after only three years in St Albans returned to the university

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43 Walsingham (1867) II. 182, 201; British Library MS Cotton Claudius E.IV, f. 333r (smaller page glued in).
44 Oxford, Bodleian Library MS Laud Misc. 697, f. 27v.
45 North (1977); North (1987).
46 Wilkins (1737), II. 594-599.
47 Clark (2002), 840.
48 Greatrex (1997), 54-55; Greatrex (2011), 125-129, 144-145. A smaller page glued into British Library MS Claudius E.IV, f. 333r, lists the varied activities of the monks 'of our days,' including the astronomer and astrologer Simon Southerey, whose star table partially survives in Bodleian Library MS Digby 98, f. 32r.
49 Coates (1997), 81-83.
50 Bodleian Library MS Laud Misc. 674, ff. 73v-74r.
51 Léotaud (1997), 27-28; Carey (1992), 49, 55.
52 Walsingham (1867), III. 391.
53 Walsingham (1867), III. 410-411.
54 Clark (2004), 15.

for a further nine years, during which he completed his most important work.[55] The *Gesta abbatum* tells of his regret that he had left the cloister so early, and had become distracted by astronomy, geometry and music, leaving little time for philosophy and theology; it quotes a prayer of his, thanking God for taking him out of the world, that he might spend the rest of his life among servants of God.[56] On the other hand, North suggests that Richard's initial profession, at least, was 'a well-calculated move' by a poor scholar in need of financial support.[57] Either way, the effect of those turbulent weeks in September and October 1327, when abbot Hugh of Eversden died while Richard was visiting the monastery, and Richard was elected as his replacement (following energetic lobbying, and amid suspicions that his hesitation to accept the post was feigned), was to place a renowned Oxford scholar at the head of the monastery, thereby cementing a reputation for learning that would last through the next century and beyond.[58]

Richard of Wallingford is now most famous for the complex astronomical clock he designed for the south transept of the abbey church.[59] But Thomas Walsingham's *Gesta abbatum* suggests that Richard's contemporaries took a different view. Writing in the early 1390s (at almost exactly the time John Westwyk was composing his *Equatorie*), Thomas mentions the clock, but without any real emphasis or pride, perhaps because it received criticism for its great expense.[60] In contrast, several times he highlights Richard's achievements in astronomy, separately stressing the writings and instruments Richard composed.[61] Richard's works are enumerated: he compiled the statutes of the provincial chapter and of his predecessors; he wrote an outstanding commentary on the prologue to the Rule of St Benedict; and he compiled a short table of the privileges of the monastery. And among the many books and instruments of astronomy and geometry – in which sciences he is said to have excelled above all his contemporaries – the most noteworthy is not the clock, but the Albion.[62] Richard completed the *Tractatus albionis* in his final year at Oxford.[63] He was the first of many abbots to hold a university degree, so it is hardly surprising that, over the decades following his untimely death from leprosy

[55] Walsingham (1867), II. 182.
[56] Walsingham (1867), II. 182, 295.
[57] North (2005), 51. Knowles (1957, II. 39) considers it the fulfilment of 'a tacit bargain' with the prior of Wallingford who had sponsored his earliest studies.
[58] Walsingham (1867), II. 183-186.
[59] North (2005), 3.
[60] Walsingham (1867), II. 281-282.
[61] Walsingham (1867), II. 182, 201, 207.
[62] Walsingham (1867), II. 207. See also John Whethamstede's 'Invenire' (c. 1420-40), where Richard is named as the inventor of both the Albion and the astronomical clock; here too, greater emphasis is placed on the former. British Library MS Cotton Nero C.VI, f. 149r; see North (1976), III. 112-114; Eagleton (2004), 10-26. A fifteenth-century miniature illustrating the St Albans Book of Benefactors (British Library MS Cotton Nero D.VII, f. 20r) does show him with his clock, but in the *Gesta abbatum* (British Library Cotton Claudius E.IV, f. 201r) he is shown with an instrument very likely to be his Albion.
[63] Richard of Wallingford, 'Tractatus albionis', in North (1976), I. 340.

in 1336, the monks who benefited from the abbey's reputation for learning sought to honour, preserve and perhaps enhance this reputation by copying his most significant work.[64] At least three of the surviving copies of the *Albion* were produced at St Albans.[65] Thus, in addition to the divinely sanctioned monastic labour of reading, copying and correcting, the compilation of Richard of Wallingford's 'instrumentum mirificum' was a sign of the greatest respect for a superior, and a demonstration of the writer's humility, qualities that were both central to the Rule of St Benedict.[66]

## JOHN WESTWYK, COPYING AND COMPILATION

Armed with an understanding of the context in which John Westwyk made his copy of the *Tractatus albionis*, we may proceed to examine how he did so. We should begin by assessing the connection with Tynemouth. Drawing on the donor's note and a table of oblique ascensions, unique to this manuscript, which is for latitude 55° and names "tynemuth" in the heading, North and Clark suggested that MS 657 was copied at the northern cell.[67] Clark makes the same assertion about another copy of the *Albion*, in Corpus Christi College Oxford MS 144, but although that manuscript was certainly at Tynemouth in the mid-fifteenth century, there is no evidence of its having been produced there.[68] The tables of MS 144 and another manuscript that Clark attributes to Tynemouth, a calendar from the 1380s in Bodleian Library MS Digby 41,[69] are for latitude 51° 50', and in all three cases the quality of parchment makes it questionable that they originated at the famously inhospitable, poverty-stricken outpost.[70] Rather, it seems more likely that the manuscripts were produced at St Albans to be sent north. Thomas de la Mare, abbot of St Albans 1349-96, had spent nine years as prior of Tynemouth, working hard to protect the monastery and reconstruct its crumbling buildings;[71] he evidently retained an interest in it, so it seems plausible that he would support the building up of its library.[72] As monks were frequently sent north for various (often disciplinary) reasons, books could easily travel with them. It is not known when and where John Westwyk took his monastic vows, but it seems plausible that he

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[64] It might be noted that no complete copy of Richard's clock treatise survives; it was pieced together by North (1976, I. 441-526) from fragments in Bodleian Library MS Ashmole 1796, and other manuscripts.
[65] Bodleian Library MS Laud Misc. 657, ff. 2r-45r; MS Ashmole 1796, ff. 118r-159v; Corpus Christi College, Oxford MS 144 ff. 44r-78v.
[66] MS Laud Misc. 657, f. 1v; *The Rule of Benedict*, chs. 5, 7.
[67] MS Laud Misc. 657, ff. 1v, 42v; North (1976), II. 248; Clark (1997), 318-319.
[68] It may be worth noting that the diagram of the spiral on f. 59v (reproduced in figure 3 below) includes St Alban (22 June) among its saints' days, but not Tynemouth's patron St Oswine, though it does include St Cuthbert (20 March).
[69] Clark (1997), 321.
[70] On Tynemouth, see Rand (2015), 7-9, which draws on materials in Craster (1907). See also Walsingham (1867), III. 495.
[71] Walsingham (1867), II. 375-380.
[72] Walsingham (1867), II. 394.

was from the same manor of Westwyk (two miles west of St Albans) regained for the abbey by Thomas de la Mare,[73] and perhaps spent time at Gloucester College before being sent to Tynemouth around 1380.[74]

Notwithstanding the addition of the new table of oblique ascensions, which will be discussed fully below, the most noticeable characteristic of Westwyk's copy of the *Rectangulus* and *Albion* treatises is its faithfulness and accuracy. Faithful copies are rare among instrument treatises of this period: it seems copyists frequently wanted to personalise texts to reflect and demonstrate their own interests and understanding. An example of this is the *Quia nobilissima scientia astronomie* treatise, which exists in two mid-fourteenth-century copies, collated in appendix D. The content of this treatise (which cites the *Albion*) will be discussed in the next chapter, but a cursory inspection reveals how the copyist made changes throughout the text, altering the order, adding and removing certain passages of explanation, using a more active grammar, and changing numerical parameters. Moreover, when it came to tables, copyists frequently made mistakes in copying. The tables of houses at the end of MS 657 are a particularly striking example, littered with errors and omissions (see figure 8), but the monotony of copying apparently meaningless numbers often caused scribes to misread similar digits, or repeat or omit rows or columns.[75]

By contrast, John Westwyk's copying of the *Albion* and *Rectangulus* treatises is a model of painstaking precision. I tested this using a sample table (oblique ascensions for 51° 50') in five copies of the *Albion*; the table values were tested against each other, against the table in North's edition, and against values computed using the formulae in appendix C.5.[76] All the tables were found to be impressively accurate, with few copying errors in any of them. Two, in Laud 657 and Corpus Christi 144 – both St Albans productions – had no copying errors whatsoever; the third St Albans manuscript, Bodleian MS Ashmole 1796, had just one.[77] Moreover, both Corpus Christi 144 and Ashmole 1796 contain corrections, suggesting that the monastic scribes maintained impressive quality control over their tables. Thus, within a context of unusual reliability of copying, John Westwyk's work is especially accurate.

73 Walsingham (1867), III. 399.
74 We cannot be sure that Westwyk studied at Oxford; Clark (2000, 62) claims he was there c. 1400, but does not cite any evidence for this. It remains a reasonable possibility that he was there, but if so, it would have been in the 1370s. See also Rand (2015), 6-7.
75 On the mechanics (and tedium) of copying, see Parkes (2008), 63-69.
76 Bodleian Library MS Laud Misc. 657, f. 42r; Corpus Christi, Oxford MS 144, f. 78v; British Library MS Harley 80, f. 54r; Harley 625, f. 164r; Bodleian MS Ashmole 1796, f. 159r; North (1976), III. 96-97. There were more apparent copying or typographical errors in North's table than in any of the manuscripts! See appendix C.2.
77 Since values can legitimately vary between manuscripts, whether because they have been recomputed using a different method, or owing to (faithful) copying of errors in antecedent manuscripts, I have defined a copying error in a given manuscript as being a value that is both mathematically incorrect and unique to that manuscript.

The impression of a monk striving to do justice to the work of his illustrious forebear is even more apparent when we see how Westwyk copied the text of the *Tractatus albionis*. He was not simply faithful to the text: that kind of close copying is exemplified by the *Rectangulus*, in which Westwyk made only one change of any significance.[78] But in the *Albion* he went further: his copy seems to aim at faithfulness to the memory of Richard of Wallingford. John North thought that Westwyk's copying of two slightly different versions of section III.13 of the treatise was 'probably to be put down to an oversight on the part of the scribe – perhaps Simon [Tunsted] himself – who made the first copy.'[79] Yet close attention to MS 657 suggests that this was quite deliberate. From his first scribal note on folio 1v,[80] which stresses how Abbot Richard was the first to compose the marvellous Albion, before Simon Tunsted 'changed certain things not only in the book but also in the instrument, as will be clear to scholars in this book', Westwyk seems to have systematically collated Tunsted's adapted version alongside a copy of the original treatise. Indeed, his final phrase may have been intended to draw attention to his specific collation, rather than referring more generally to the *Albion*, thus making his intent explicit.[81] As Parkes, Hathaway and others have shown, this kind of *compilatio* was, by the later medieval period, respectable and popular.[82]

Although most of the differences between MS 657 and other copies of the *Albion*, such as the insertion in several places of appropriate references to Euclid's *Elements*, were almost certainly the work of Tunsted, some changes can be confidently ascribed to Westwyk, such as where he inserts the phrase 'concerning the circle on the first face of the first disc, *I found this* written in the other book' between the adapted and original versions of section III.1.[83] This is not simply a case of conscientiously copying out two versions and noting the differences; in places Westwyk clearly noted which version he preferred, perhaps according to which best described a physical instrument in his possession.[84] In what remains of this chapter, we shall consider what this work of copying and collation can tell us about Westwyk's expertise, and what he might have learned in carrying out this task.

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78 The title of chapter 4 (f. 47r) states that the rules are to be made 'ex latone', where other manuscripts have 'ex ere'. This very subtle change suggests a concern with the practicalities of making the instrument.

Westwyk's accuracy in copying the only table in the *Rectangulus*, the table of versed chords (ff. 51v-52r), is more open to question. Comparison of the versed chords and column of differences in the table with other manuscripts demonstrates that at least some errors were (faithfully) copied from his exemplar; others, however, may be his.

79 North (1976), II. 202;

80 quoted in full above (p. 15).

81 Kari Anne Rand (2015, 12n28) translates the final phrase as 'as will be clear to students of that book.' It is quite acceptable to translate 'isto libro' as 'this book': compare, for example, Westwyk's remark, on f. 44r, that the following passage should be placed at the beginning of the treatise: '*ista* clausula debet poni ante principium *istius* libri' (my emphasis).

82 Parkes (1976); Hathaway (1989).

83 MS Laud Misc. 657, f. 21r (my emphasis).

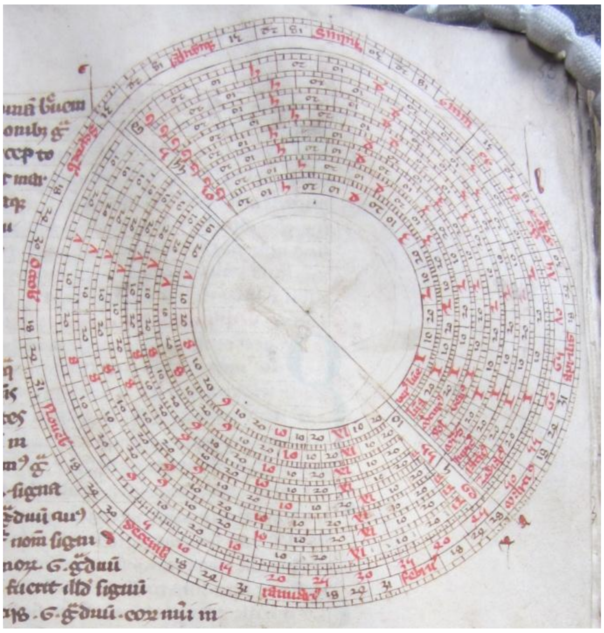
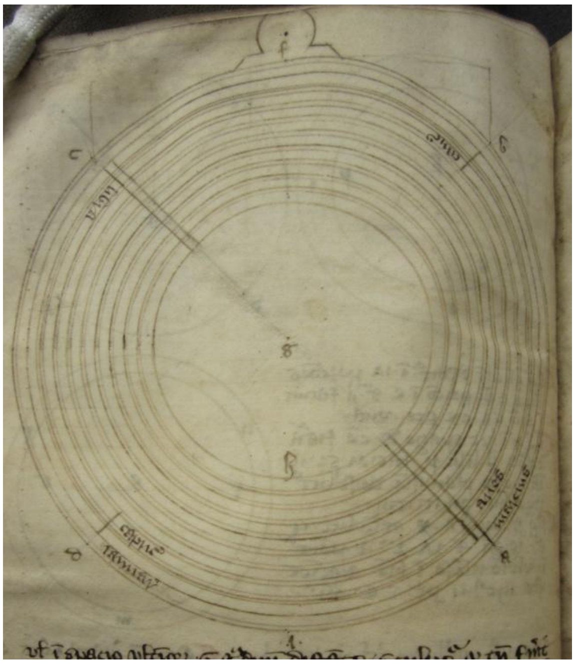
84 See, for example, comments on ff. 11r, 22v.

## COLLATION AND UNDERSTANDING

The possibility that Westwyk was referring to both an *Albion* and an albion when compiling his copy is suggested in several passages, such as when he comments, following Richard's remark in section III.4 about an alternative way to compute the solar mean motus using the circle engraved on the limb, that 'this conclusion is void, because this statement supposes that the circle of the year of the Sun, with the days of the months, is inscribed on the second limb just as on the first; which is not the case on our instrument, nor is it necessary, so it is best omitted.'[85] North pointed out that this remark was inconsistent with the corresponding passage in part II, detailing the construction of that part of the instrument, to which Simon Tunsted had made no change.[86] North assumed that this inconsistency was simply an error by Tunsted, and that may be correct; but it is possible that the editorial comment comes from Westwyk. There is no indication that he spotted the inconsistency between the two different sections; rather, it seems that he was reading the text with a physical instrument, and noticed that the method described was not possible on his instrument.

We have a clue to the possible size of Westwyk's albion – important to a monk who was later to show himself very concerned with the dimensions of instruments – in the opening section of part II. Where the original treatise stated that the albion was to be at least 12 inches in diameter, Westwyk's version changes this to 16; but the scribe then drew a caret, with the marginal addition 'vel 12'.[87] This could be explained as simple collation of the two versions, but the fact that this was a later addition makes one wonder whether it was prompted by comparison with a real instrument. The only extant albion is 12.8 (modern) inches in diameter.[88] On the other hand, North used a marginal gloss in an early-fifteenth-century hand in Corpus Christi 144, which refers in the present tense to 656 divisions in the margin of the spiral disc of 'the Abbot's albion', to suggest that that writer had seen Richard of Wallingford's own instrument, and that it was probably around 15 inches in diameter.[89] Since, as we have seen, the Corpus Christi manuscript was probably produced at St Albans before moving to Tynemouth by the mid-fifteenth century, the instrument referred to there might well be the same one seen by John Westwyk. Certainly on the following page the instrument made a difference to the scribal practice, as we find written 'note that the figure of the circles of the first limb of the first face should be in this space, but it is very plainly inscribed on the instrument, so it is omitted here.'[90]

[85] MS Laud Misc. 657, f. 22v.
[86] North (1976), II. 197.
[87] MS Laud Misc. 657, f. 10v.
[88] It is in the collection of the Museo Astronomico e Copernicano, at the Osservatorio Astronomico di Roma.
[89] North (1976), II. 181; Corpus Christi College, Oxford MS 144, f. 59v.
[90] MS Laud Misc. 657, f. 11r.

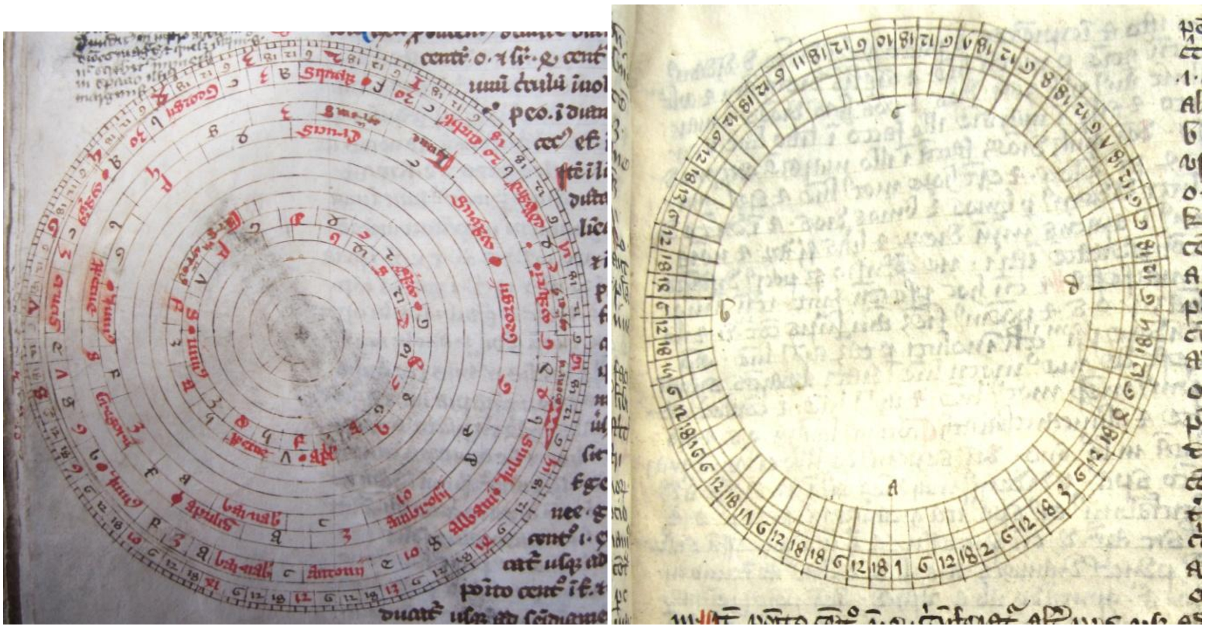
Figs. 2 and 3: The first limb of the first face of Richard of Wallingford's Albion. Oxford, Corpus Christi College MS 144, f. 55r; Bodleian Library MS Laud Misc. 657, f. 11v. By permission of the President and Fellows of Corpus Christi College, Oxford, and the Bodleian Libraries, University of Oxford.

On the following page is a partially complete diagram (with the size of the limb somewhat exaggerated, as is the case in all copies of this diagram); the circles have been traced out, but the scales have not been filled in (figure 3; cf. figure 2).

Only one other diagram is substantially incomplete in Westwyk's copy: the diagram of the spiral on the first face of the second disc (figure 5).[91] Discussing this difficult section of the treatise, North wrote that 'the figures in the manuscripts are of no assistance, being drawn somewhat – but not entirely – randomly';[92] it is possible that Westwyk experienced something of the same frustration, since he appears to have begun copying a diagram, before abandoning it. Both the fairly complete diagram in Corpus Christi 144 (figure 4) and Westwyk's version have an outer limb divided into 18 days, each subdivided into three divisions of six hours; Westwyk may have realised this was incorrect, though there is no evidence that this was why he failed to finish the diagram. (The 18-day divisions only occur in these two manuscripts, suggesting that Corpus Christi 144 may have been the exemplar that Westwyk was collating against Simon Tunsted's version of the treatise, at least for the diagrams.) An alternative explanation is offered by the comment in the following part of the treatise (III.4), that 'The abbot put the mean motus of the Moon on his spiral, but the elongation of the Moon from the Sun was put on the spiral on our instrument, since if the mean motus of the Sun is added to this, the mean motus of the Moon is

[91] This excludes the two diagrams in the missing section of I.3-4, which was presumably on a leaf, now lost, between ff. 3 and 4.

[92] North (1976), II. 180.



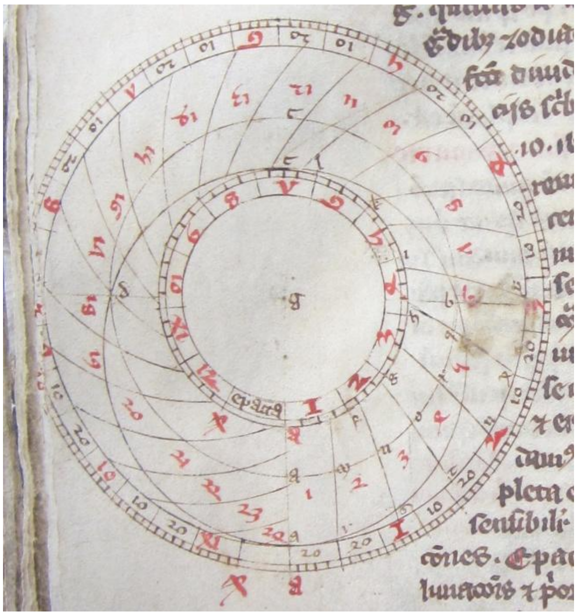
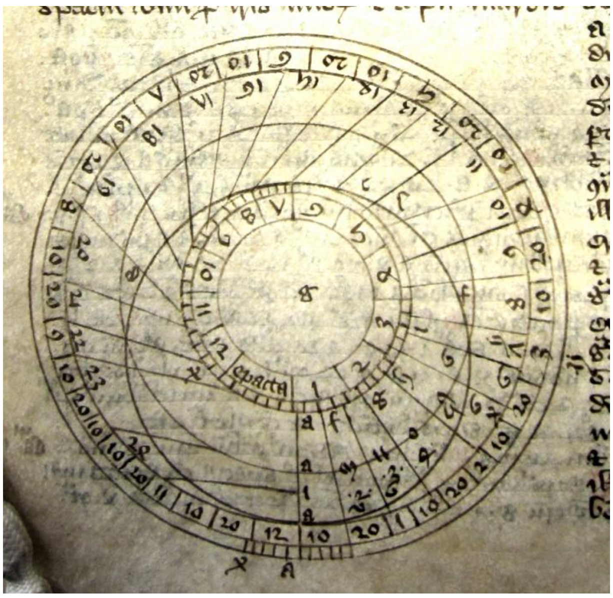
Figs. 4 and 5: The spiral on the first face of the second disc of Richard of Wallingford's Albion. Oxford, Corpus Christi College MS 144, f. 59v; Bodleian Library MS Laud Misc. 657, f. 17r. By permission of the President and Fellows of Corpus Christi College, Oxford, and the Bodleian Libraries, University of Oxford.

produced, if this is desired.'[93] The comment was most likely written by Simon Tunsted since, as we shall see, John Westwyk later ascribes such a change in the design of the spiral to the Oxford master. However, the fact that the change is not accompanied by corresponding changes in part II, where the inscription of the spiral is explained, makes it possible that the comment arose from observation of a real albion. Either way, it may have caused Westwyk enough confusion to make him abandon his diagram.

A final, and perhaps most probable, explanation for the incomplete diagram is simply that Westwyk did not feel confident rendering the spiral. Close examination of his other diagrams suggests that, while he was able to copy simpler figures with care and a reasonable level of accuracy, more complex diagrams caused him greater difficulty. We see this, for example, in his copy of the diagram illustrating the hour lines of lunation on the first face of the first disc. The explanation in section II.17 is quite explicit, but a comparison (figures 6 and 7) with the best extant version of this diagram, again from Corpus Christi 144, shows that Westwyk did not follow it effectively – if indeed he was following the written explanation at all.[94] The instructions state that, after completing the inner and outer graduated rings, an eccentric circle is to be drawn touching the outside of the inner graduated ring in direction C, and the inside of the outer graduated ring in direction A; a further concentric circle is then to be drawn, of a medium size such that it intersects the eccentric circle on the horizontal diameter DGB. This was

[93] MS Laud Misc. 657, f. 22v.

[94] Other decent versions are in British Library MSS Harley 80 (f. 40r) and 625 (f. 148v), and Bodleian Library MS Ashmole 1796, f. 135v.

Figs. 6 and 7: The hour lines of lunation on the first face of the first disc of Richard of Wallingford's Albion. Oxford, Corpus Christi College MS 144, f. 58v; Bodleian Library MS Laud Misc. 657, f. 15v. By permission of the President and Fellows of Corpus Christi College, Oxford, and the Bodleian Libraries, University of Oxford.

accomplished successfully in Corpus Christi 144, but Westwyk drew the medium-sized circle rather too large, so it clearly does not intersect the eccentric circle in the correct place. Moreover, the inner, middle and outer circles were to be divided into 20, 22 and 24 parts respectively; Westwyk divided them rather unevenly into 23, 24 and 25 (comparison of the lower-left quadrants of figures 6 and 7 should make the difference clear). It seems that Westwyk replicated an existing diagram, making a superficially faithful copy of the image, without representing – or perhaps without attempting to represent – the detail of the instructions in the treatise.[95]

It is worth exploring those areas where Westwyk is most explicit about the extent of his abilities, in order to understand the way he went about compiling his copy. Perhaps the most significant examples come after the treatise proper, where in the final folios (44r-45r) before commencing his copy of the *Rectangulus* he makes good some omissions and inconsistencies in the *Albion*. First he writes 'This whole passage should be put before the beginning of this book, that is before the conclusions. From the collection of Simon Tunsted, professor of sacred theology.'[96] He then writes out the prologue to the treatise, which was missing from the beginning of the manuscript. This is followed by a table of lunar elongations (see appendix C.7 and figure 44), with the following five observations:

[95] The diagram on f. 19r is very similar in this regard.

[96] MS Laud Misc. 657, f. 44r. This remark is highlighted with a red *signe-de-renvoi* in the form of a swastika (there is no corresponding symbol on f. 2r, where the treatise begins).

> ¶ 'This table should be placed after the table of the mean motus of the Moon, at this sign: ✧, because the lord abbot put the mean motus of the Moon on his spiral, but Master Simon put the elongation of the Moon from the Sun on his spiral, as is found in the 4th use; and so I wrote this table so that anyone can do it this way if he pleases.
> ¶ Also, the abbot works with the circle of Iomyn for the equation of days. But Simon works in another way, as is taught in the 18th use; and also in many other places which can be seen to be inconsistent, as is easily found in the uses.
>
> ¶ Note: if the mean motus of the Sun is subtracted from the mean motus of the Moon, the elongation of the Moon from the Sun is produced.
> ¶ Also, if the mean motus of the Sun is added to the elongation of the Moon from the Sun, the mean motus of the Moon is produced.
> ¶ Also, add the argument of the Moon to the mean motus of Caput and you will have the argument of latitude of the Moon.[97]

It has already been observed that the diagram of the spiral is one of only two incomplete in this copy, perhaps because John Westwyk was troubled by the changes Simon Tunsted made to that aspect of the design (but not to the corresponding sections in part II of the treatise), which were described in section III.4. Here we see that Westwyk did not give up on this issue. The title of his new lunar elongation table is based on that of the table of mean motus of the Moon on folio 39v, where Westwyk also added a *signe-de-renvoi* matching the diamond on folio 45r. The presence in the table of obvious copying errors demonstrates that Westwyk did not compute it himself, but transcribed it from another source. The large number of these errors (20 in a table with 366 values in signs, degrees and minutes) could be deemed a stain on Westwyk's otherwise impressive copying record, but it is quite possible that he made a an accurate copy of a corrupt exemplar. The twenty errors do include some that are more likely to be computational, such as 20° instead of 19°; the nature of these, and the fact that the table does not follow a consistent arithmetical progression, suggest that it was computed by subtracting values for solar mean motion from an existing table of lunar mean motions.

John Westwyk's last three notes summarise basic features of the Ptolemaic lunar theory, simple points that Richard of Wallingford did not consider worthy of mention. The fact that Westwyk felt it necessary to rearrange the rudimentary lunar arithmetic in the first two points suggests something about his expertise – or perhaps that of his intended reader. In addition, the third point may be wrong: the argument of lunar latitude was defined by the distance of the (uniform) motus of Caput Draconis from the Moon, that is from its true place.[98] Perhaps that is what Westwyk meant by 'argumentum lune' – *argumentum* was used in a variety of senses in planetary theory – but the statement is, at best, unclear.

The second of John Westwyk's five observations represents his moment of greatest frankness about his editorial task. The implication is clear: he has noted multiple differences between the work of Richard of Wallingford and Simon Tunsted, but he is not always able to

[97] MS Laud Misc. 657, f. 45r.
[98] Since Caput Draconis was thought to maintain a constant velocity, its mean and true motuses were identical.

untangle their implications or decide which is better. Here we have the impression of a copyist who saw himself as an editor in something like the modern sense: reading with a care for presentation and consistency, if not always with full understanding of the material, especially where inconsistencies did arise. In fairness, it might be noted that his occasional inability to understand Tunsted's changes was not always his fault: when Wallingford's modern editor John North came to that section III.18, he deduced that Tunsted must have omitted certain scales on his instrument, but lamented that 'since his list in III.1-2 is rather carelessly made, it is difficult to say which these were.'[99]

One scale that was certainly omitted from Simon Tunsted's instrument was the secondary scale of oblique ascensions. The design of the Albion called for at least one scale of oblique ascensions, in order to help find the ascendant and the divisions of the houses.[100] This was to be inscribed at least once, in the innermost (third) circle on the limb of the second face of the mater, for the latitude of a place 'where we intend to stay for a long time and make many observations.'[101] Additional scales of oblique ascensions could also be inscribed on the plates for other latitudes; Richard of Wallingford generally refers to these secondary scales as being on the 'second limb' (on the plates), as opposed to the 'first limb' on the mater. When it came to the description of the use of these secondary scales, John Westwyk's copy of section III.40 includes the following note: 'this chapter assumes that the oblique circle is inscribed on the limb of the second disc, but it is not so on our instrument, and hence [this chapter] is void.'[102] The whole chapter is bracketed. North mused: 'are we to conclude that Simon Tunsted did not anticipate much travelling?' and Rand suggested that it was in fact John Westwyk who had made this change, and did not anticipate travel to other latitudes.[103] However, if we examine changes that appear in related sections of the treatise, the situation becomes more complicated. We should first note that Westwyk may have been using Simon Tunsted's altered terminology to refer to certain parts of the instrument: in his description in section III.2, Tunsted refers to the zodiac scale on the limb of the second face as 'zodiacus secundi limbi,' where Richard of Wallingford had called it 'zodiacus primi limbi', and when he explained the inscription of the primary scale of oblique ascensions, this is on 'limbo secundo' rather than 'limbo primo.'[104] The scale(s) of oblique ascensions are inscribed using information from a table of oblique ascensions; as we have

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[99] North (1976), II. 209. North does not mention Westwyk's editorial comments, but in any case, as we have already seen, assumed that he was essentially copying verbatim from an earlier exemplar.
[100] The scale of oblique ascensions gave right ascensions at the desired latitude, corresponding to the zodiac degrees inscribed on the outermost scale on the limb (North (1976), II. 177-178).
[101] Richard of Wallingford, 'Tractatus albionis', in North (1976), I. 324-325 (North's translation).
[102] MS Laud Misc. 657, f. 30v.
[103] North (1976), II. 235; Rand (2015), 13.
[104] MS Laud Misc. 657, ff. 21v, 16v.

seen, Westwyk included two, for latitudes 51° 50' (Oxford – or perhaps St Albans) and 55° (Tynemouth).[105] The heading of the latter reads:

> Table of ascensions of signs on the oblique circle at latitude 55°. It was calculated and composed as explained in the canons in the second book of the Almagest; and with it the second circle on the second limb of the second face of the instrument should be divided, as is explained in chapter 18 of the second part of this [treatise]. // Tynemouth.[106]

The table for Oxford contains a slightly different heading, which instructs the reader to divide 'the *third* circle on the second limb of the second face of this instrument.'[107] The reference to 'limbo secundo' in both headings, where all copies of these tables in other manuscripts refer to 'limbo primo', seems to be Tunsted's revised terminology rather than a redesign of the instrument. On the other hand, the renumbered circle could be a deliberate change. Although Westwyk's primary concern was clearly compilation rather than the construction of a physical albion, it nonetheless seems plausible that he intended both of the tables he copied to be of use on any instrument that might later be made, so that it could be used either in the mother monastery or its northern cell. If so, it is curious that he should have rejected Richard of Wallingford's method of accommodating secondary latitudes on plates. Moreover, his numbering is somewhat confusing. As section II.18 explains, there were already three scales on the limb of the mater: the zodiac, right ascensions and oblique ascensions. If Westwyk did mean for there to be a second oblique ascension scale, it should have been the fourth on the limb. However, he may simply be following the headings in other copies of the *Albion*, which all contain similar confusion: most call the scale of oblique ascensions the second circle, while in the best copy, Corpus Christi MS 144, the word 'secundus' has clearly been erased.[108] Still, it remains possible that Westwyk's renumbering was a mistake, and he intended the new oblique ascensions to supply a secondary scale on a plate, as Richard of Wallingford suggested. If so, the 'vacat' note in section III.40 represents an inconsistency. This could be explained in two ways. First, it may be the work of Simon Tunsted, maintained by John Westwyk to the point of bracketing the chapter. Or second, Westwyk may, as appears to be the case elsewhere, be describing a real instrument in his possession (made by someone, perhaps Tunsted himself, who did not anticipate travelling). That instrument had a perceived deficiency that he hoped to rectify by providing tables for two latitudes in his compilation.

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105 Curiously, the St Albans Richard of Wallingford compilation gives a different latitude for Tynemouth in its table of latitudes: 54° 20' (MS Ashmole 1796, f. 59r).

106 MS Laud Misc. 657, f. 42v. 'tynemuth' is added as a gloss beneath the heading.

107 MS Laud Misc. 657, f. 42r; my emphasis. 'This' [huius] is a marginal insertion marked with a caret, perhaps intended to draw attention to a particular physical albion.

108 Corpus Christi, Oxford MS 144, f. 78v; British Library MSS Harley 80, f. 54r; Harley 625, f. 164r. The tables in Bodleian MS Ashmole 1796 lack headings.

The two tables of oblique ascensions are the most obvious work of compilation in the Laudian manuscript. John Westwyk did not substitute a Tynemouth table for the existing one for Oxford, but added it as a supplement to the one he had copied from his exemplar. This is despite the fact that, as the heading states, the table was only to be used once, as a reference for the inscription of that scale on the limb of the instrument. Yet copying the 360 values of degrees and minutes (with perfect precision, as we have seen) for the ascensions of signs at latitude 51° 50' was nothing compared to the task of computing them from scratch for latitude 55°. This was almost certainly done at the time this copy was made, whether by Westwyk or a collaborator, since tables were not routinely computed for that latitude. Moreover, the errors that can be identified in this table seem to be mistakes in calculation, rather than copying.

I have evaluated the accuracy of the table by recomputing it in a spreadsheet program, using modern equivalents of medieval formulae (see appendix C). It must be noted that this does not produce identical results to those in medieval tables, which were computed by reference to tables of chords, interpolating and rounding where necessary. The reference tables rarely survive and the methods of calculation and rounding remain opaque to us; in this situation, electronic recomputation cannot usually reveal the details of astronomers' methodologies (a rare exception will be discussed in chapter 5). What it can do is identify calculation errors and certain parameters used to draw up the tables; it can also allow different tables to be compared.

In his discussion of the table of oblique ascensions for Oxford, John North noted that astronomers computed tables with reference to existing tables that they had to hand; these tables might not always incorporate the same underlying values for parameters such as the obliquity of the ecliptic.[109] Various values for the obliquity were used in the medieval period, and identifying the particular value underlying a table can reveal something about its sources.[110] Since the oblique ascension ($\varrho$) at a given latitude ($\varphi$) could be computed for a range of different celestial longitudes ($\lambda$) via the right ascension ($\alpha$), by a process equivalent to the modern formulae

(1) $\alpha = \arctan(\tan\lambda \,.\, \cos\varepsilon)$
(2) $\sin(\alpha - \varrho) = \tan\varepsilon \,.\, \tan\varphi \,.\, \sin\alpha$,

North pointed out that an astronomer computing a table of oblique ascensions might well have used a different value for the obliquity ($\varepsilon$) from that incorporated into his reference table of right ascensions. North regretted that 'there are too many possibilities for it to be profitable to investigate them all,' but tested some values using $\lambda = 45°$, and suggested that the table for 51° 50' had been made using a table of right ascensions that incorporated an obliquity of 23° 35', and

[109] North (1976), II. 247.
[110] Chabás and Goldstein (2012), 23.

then an obliquity of 23° 33' 30" in stage (2).[111] The former value is attributed to al-Battānī, whose table of right ascensions was included in the Toledan Tables; the latter is the value more generally used in the Toledan Tables.[112]

What was not profitable for North is easier for us forty years on. I constructed a spreadsheet to automatically recompute values across the entire table as different values for the obliquity were inputted. Although, for the reasons just explained, it was impossible to compute a table that matched the medieval exemplar perfectly, an iterative process could give a close reproduction and thereby an optimal value for the obliquity. This revealed that across the full range of longitudes, the obliquity values North suggested do indeed produce a close match to the table of oblique ascensions for 51° 50' in the St Albans manuscripts (see table 1 below).[113] It should be noted that these spreadsheet techniques can produce a spurious precision. For example, the fact that the closest match with the manuscripts occurred with a stage (2) obliquity of 23° 33' 22" is not sufficient grounds to claim that this was in fact the parameter used by the medieval astronomers. Rather, these techniques allow us to compare and choose from a limited range of discrete values attested in surviving manuscripts. The match will inevitably be imperfect, owing to the vagaries of calculation techniques and the imperfections of medieval reference tables, but the use of a consistent (if anachronistic) technique allows the degree of closeness to be measured so that different values for the obliquity can be compared. The measure of closeness used was a least-squares fit: the sum (Σ) of the squares of the differences between the manuscript and spreadsheet tables. The closer the match between the original and recomputed table, the smaller the sum of squared residuals. This is a fairly crude method of statistical analysis, but uncertainties over medieval calculation techniques, particularly rounding, mean that more sophisticated statistical techniques are unhelpful. A rough measure allows our attention to be drawn to the larger trends, so that different parameters can be compared. Whatever the results obtained by such techniques of recomputation and statistical analysis, they can only ever be an adjunct to the examination of tangible manuscript evidence.[114]

[111] North (1976), II. 247-248.
[112] Toomer (1968), 34-35; Chabás and Goldstein (2012), 23.
[113] North did use some computer power to test his theories in later studies such as *Horoscopes and History* (1986).
[114] A range of statistical methods, including determining confidence intervals by a method on similar principles to (albeit more complex than) the one used here, are described in van Dalen (1989). For the use of more advanced statistical techniques in history of astronomy, see Van Brummelen and Butler (1997).

Table 1: Test of obliquities (ε) used in table of oblique ascensions for 51° 50', MS Laud Misc. 657, f. 42r.

| ε (1) | ε (2) | Σ | Notes |
|---|---|---|---|
| 23° 33' 30" | 23° 33' 30" | 188 | Values suggested by North (1976), II. 247-248 |
| 23° 33' 30" | 23° 35' | 1680 | |
| **23° 35'** | **23° 33' 30"** | **128** | |
| 23° 35' | 23° 35' | 1528 | |
| 23° 51' 20" | 23° 51' 20" | 158788 | Value of ε used in *Almagest* |
| 23° 35' | 23° 51' | 161560 | Attested values of ε producing lowest Σ for 55° (Tynemouth) table (see Table 2 below) |
| 23° 35' | 23° 33' 22" | 110 | Non-attested values of ε producing lowest Σ |

With this in mind, we should examine the table of oblique ascensions specially computed for Tynemouth.[115] The heading (quoted above, p. 29) notes that the table was computed as explained in book II of the *Almagest*.[116] This was copied directly from the previous *Albion* oblique ascension tables. Regardless of their citation, those older tables, as we have just seen, did not use a Ptolemaic value for the obliquity of the ecliptic. But John Westwyk's table did: the spreadsheet-generated table matched best with the same value of 23° 35' for the right ascension, but Ptolemy's 23° 51' for the oblique ascension (see table 2 below).[117]

Table 2: Test of obliquities (ε) used in table of oblique ascensions for 55°, MS Laud Misc. 657, f. 42v.

| ε (1) | ε (2) | Σ | Notes |
|---|---|---|---|
| 23° 33' 30" | 23° 33' 30" | 196229 | Values suggested by North (1976), II. 247-248 |
| 23° 33' 30" | 23° 35' | 162882 | |
| 23° 35' | 23° 33' 30" | 196995 | |
| 23° 35' | 23° 35' | 163932 | |
| 23° 51' 20" | 23° 51' 20" | 2667 | Value of ε used in *Almagest* |
| 23° 51' | 23° 51' | 2422 | Value of ε used in *Handy Tables* |
| 23° 35' | 23° 51' 20" | 1370 | Combination of *Almagest* and al-Battānī values |
| **23° 35'** | **23° 51'** | **939** | **Attested values of ε producing lowest value of Σ** |
| 23° 35' | 23° 50' 10" | 434 | Non-attested values of ε producing lowest Σ |

This does not necessarily mean that Westwyk followed the suggestion of the table heading and used the *Almagest* as his manual. But whatever his precise computation method, it was not the same as that of Richard of Wallingford. We can see this by comparing the differences between the manuscript and spreadsheet tables. As already explained, the sum (Σ) of squared residuals is

[115] The table is transcribed and analysed in appendix C.4 and C.5.
[116] Ptolemy (1984), 95-99 (II.7).
[117] The *Almagest* (I.15) has a declination table with the more precise value of 23° 51' 20"; this was rounded to 23° 51' in the *Handy Tables*.

a crude measure of the accuracy of recomputation and the consequent likelihood that a particular obliquity was used, but the tables above demonstrate that it can yield clear enough results to choose between two discrete variables (see appendix C for further explanation). When the original *Albion* table was recomputed, the optimum attested values of 23° 35' and 23° 33' 30" produced a Σ (once copying and other errors were eliminated) of 128'.[118] But in Westwyk's new table the optimum attested values of 23° 35' and 23° 51' produced a total difference (after the elimination of four computation errors) of 939'.[119] This was the result of an accumulation of very small discrepancies, and is still far smaller than when other obliquities are used; for example, when 23° 33' 30" is used instead of 23° 51', much larger discrepancies appear, totalling 196995'. But it does indicate that John Westwyk's computation method differed from that of Richard of Wallingford in some way. In such a complex calculation there are many possible causes of small differences, whether interpolation of reference values, arithmetical procedures, rounding or presentation, and it is impossible to be certain what methods John Westwyk followed. Analysis of the patterns of differences (see appendix C) suggests that they may have arisen in part from Westwyk's use of a table of chords; but with many possible causes, we cannot be sure. What we can conclude is that, with only four computation errors, his methods were quite successful.

## Ascensions and houses

It is worth noting that the one table which John Westwyk went to the trouble of computing from scratch had an astrological function. The scales of oblique ascensions on the Albion were intended by Richard of Wallingford to facilitate finding the ascendant, which was then used to determine the twelve astrological houses (III.38-39). And it is clear from Westwyk's copy of III.39, the only explicitly astrological section of the *Tractatus albionis*, that he was particularly interested in this function. His copy of this section is initially quite close, though it does systematically reverse the references to the ascendant and nadir of the ascendant, a change which, as North noted, went some way towards remedying an error in Richard of Wallingford's original description of the use of the Albion's astrolabe plate to divide the houses.[120] This modification was most likely the work of Simon Tunsted, but a more significant change, an

[118] One apparent error that appears in several (but not all) copies of the *Albion*, including both of John Westwyk's oblique ascensions tables (see example in appendix C.4), is the loss of a degree where the sign changes. Since the tables are commonly tabulated in degrees (up to 30) and minutes, each time the degrees exceed 30 the number of signs is given in the degrees column (often decorated: in MS 657 Westwyk enclosed the number in a red box). However, this often caused the scribe to omit the number of degrees in the first cell of the new sign; this was often, but not always, 0. It is fairly easy to tell whether the hidden number of degrees is 0 or 1 by a rough interpolation between the cells above and below, but it is not clear whether medieval table users were aware of the situation.
[119] The supposed computation errors were of 1°, 1°, 30' and c. 8'. In all other cases the difference was 4' or less (usually just 1' or 2').
[120] MS Laud Misc. 657, f. 30r; North (1976), II. 234.

addition of 114 words that almost doubles the length of the section, may well have been made by John Westwyk. North read the beginning of this as 'In astrolabio nostro' and implied that here Tunsted was giving more details of his adjustments to the Albion's astrolabe plate. In fact the section begins 'In astrolabio vero', and it is clear that this section is not giving further details of a (modified) function of the Albion, but comparing the Albion's function with that of an astrolabe. This kind of digression was not Tunsted's habit, but it does fit with a passage that Westwyk added after the end of the *Albion* treatise, describing the parts of the astrolabe.[121] The new section in III.39 describes how to use an astrolabe to find the limits of the houses.[122] The method is exactly that described in (pseudo-)Māshā'allāh's astrolabe treatise (in a passage later translated with little modification by Geoffrey Chaucer).[123] Westwyk's addition begins thus:

> primo ponitur gradus ascendentis super lineam medie noctis et secundo transfertur gradus iste usque ad lineam 8e hore. Quia posito gradu ascendentis super lineam 8e hore habetur inicium secunde domus in linea medie noctis.[124]

This appears to be a slightly expanded paraphrase of Māshā'allāh's instruction to

> gradum ascendentem super lineam .8. hore pone. Tunc gradus qui ceciderit super lineam medie noctis est inicium secunde domus.[125]

That astrolabe treatise was certainly present at St Albans: in the mid-fourteenth century it was collated with Richard of Wallingford's collected works in MS Ashmole 1796.[126] The similarities between Westwyk's additions to MS 657 and Māshā'allāh's popular treatise strongly suggest that Westwyk studied that manuscript before – or while – composing his commentary on finding the houses with an astrolabe.

The divisions of the houses are the subject of the tables that were added to MS 657, probably very soon after Westwyk's compilation.[127] It is worth considering these briefly, as they are relevant to the astronomical and astrological interests of monks. Starting from the tenth house (midheaven), they give the longitudes of houses 11, 12, 1, 2 and 3, from which the remainder can easily be derived. Thus far the approach is similar to that of John Walter, who

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121 MS Laud Misc. 657, f. 43r-v.

122 North (1976, II. 234) suggests that the author 'has carelessly made his houses out of phase by one house'. This is not the case: the method is exactly the same as the one North himself explains in *Chaucer's Universe* (1988, 84).

123 Māshā'allāh (tr. anon.), 'De operatione vel utilitate astrolabii', II.37, in Gunther (1929), 227-228; 'A Treatise on the Astrolabe', II.36, in Chaucer (1988), 679. On the ascription to Māshā'allāh ibn Atharī (c. 740–815) of the widely circulating compilation on the construction and use of the astrolabe, see Kunitzsch (1981).

124 MS Laud Misc. 657, f. 30r. 'First the degree of the ascendant is placed on the midnight line; and secondly the same degree is transferred to the line of the 8th hour. For when the degree of the ascendant is placed on the line of the 8th hour, the start of the second house is found on the midnight line.'

125 Māshā'allāh (tr. anon.), 'De operatione vel utilitate astrolabii', II.37, in Gunther (1929), 227. 'Place the degree of the ascendant on the line of the 8th hour. Then the degree which falls on the midnight line is the start of the second house.'

126 MS Ashmole 1796, ff. 40v-55v.

127 MS Laud Misc. 657, ff. 53v-56v.

Fig. 8: Page from a table giving the limits of the astrological houses (time column at left). Bodleian Library MS Laud Misc. 657, f. 56v. This page is particularly badly copied: note the blank row at the top where signs should be given for each column, the partially repeated row ($\lambda_{10}$ = Sco 12), and the compounded errors in values for $\lambda_1$ (the copyist apparently realised his error and rushed to catch up in the final three rows). Reproduced by permission of the Bodleian Libraries, University of Oxford.

devised a set of tables based on midheaven at Oxford in the late 1380s.[128] Unlike Walter's, however, these tables incorporate a time column, allowing the user to adjust the values given for noon to define the houses at any time of day. This presentation seems to be unique to MS 657, and the computation necessary to produce it was highly complex (see appendix C.6).[129] However, it is unlikely that this manuscript represents original work, as the tables are quite poorly copied, omitting some hours in the time column and signs at the heads of the columns of houses; the first page was abandoned and the tables begun again on the next, and on the final page (figure 8) a row is repeated and an error accumulates over ten cells, probably owing to miscopying from the wrong column in the exemplar. The values in the table accord best with an obliquity of 23° 33' 30" and latitude of 51° 50', but of course this does not preclude their having been copied at Tynemouth, since tables for the Oxford latitude were widespread.[130]

Apart from the question of whether the tables were usable at the latitude where the manuscript was located, it could be pointed out that they were unnecessary in this compilation, since the astrological houses could be defined with a similar level of precision by the methods described in the *Albion* – or indeed, as we have just seen, by using a common astrolabe. The fact that these tables were nonetheless copied into MS 657 suggests that early readers of Richard of Wallingford's work, including those in a monastic setting, were particularly interested in its astrological uses (as can also be seen from the copying and translation of his *Exafrenon* treatise).[131] It is also a reminder that immediate necessity was seldom the sole (or even principal) motivation for computing tables: devotional labour, or the satisfaction of devising a new, perhaps more user-friendly, presentation, were often factors in the production of complex new tables.[132] We can see these concerns in the mind of the scribe, who apparently decided, after copying the first four signs, to colour-code the remaining eight, making values for midheaven and the ascendant stand out by writing them in red. However, the overall impression is rather messy, and the errors in this table serve to highlight the impressive performance of John Westwyk in making his copy of the *Tractatus albionis*.

128 North (1986), 126-130.
129 Chabás and Goldstein (2012, 207-11) describe a set of tables of houses with a similar time correction, produced by Abraham Zacut (1452-1515), but these are laid out according to the ascendant rather than midheaven; see also Chabás and Goldstein (2000).
130 Since the tables give only degrees, not minutes, we cannot be certain about this obliquity, and an obliquity of 23° 35' may well have been used at some stage in their production.
131 Richard of Wallingford, 'Exafrenon pronosticacionum temporis', in North (1976), 179-243.
132 On changing presentations, see Chabás (2012).

## Saphea, astrolabe, Albion

While astrology and the houses were certainly important to John Westwyk and at least one later user of the manuscript, it was clearly not his sole or indeed primary concern. Given his later work on the equatorium, we should not be surprised that the aspect of the Albion that appears to have interested him most was its relationship with other instruments. This is suggested by the folio that immediately follows the *Tractatus albionis*. Before copying out the missing prologue, Westwyk wrote a little over two pages of commentary, starting with a description of the saphea and astrolabe.[133] These instruments were both part of Richard of Wallingford's multifunctional invention, but of course they were also separate instruments in their own right, and Westwyk seems concerned to explore the implications of this. In doing so, he draws on the relevant sections of Richard's treatise, as well as the canonical texts of al-Zarqālī (Arzachel) on the saphea and Māshā'allāh on the astrolabe.[134] North suggested that Westwyk's addition was 'nothing more than a revised version of the Latin translation of the opening chapters of Arzachel's text', but this ignores the section on the astrolabe and the numerous cross-references to parts of the Albion; even the first part which is obviously based on al-Zarqālī's ṣafīḥā al-shakkāziyya reads more like interpretation than paraphrase.[135] Richard of Wallingford had deliberately not given full details of the saphea since 'it has its own treatise';[136] it appears John Westwyk was hoping to mitigate Richard's omission with some helpful detail from that treatise. He was not alone in this: one medieval compiler began a hybrid copy of William the Englishman's (1231) and Profatius's (1263) translations of the saphea on the verso of the final folio of the *Tractatus albionis*. That mid-fourteenth-century manuscript, now British Library MS Harley 625, formed part of an astronomical compilation bequeathed to Merton College by Simon Bredon, who probably owned and may well have designed the Merton College equatorium.[137] Like that compiler, and like all medieval readers, John Westwyk did not see texts in isolation.[138]

Westwyk's new pages (transcribed and translated in appendix B) are separate in position, style and content from the rest of the *Albion*, and they may well constitute original writing by

133 MS Laud Misc. 657, ff. 43r-44r.

134 (Pseudo-) Māshā'allāh's astrolabe treatise was certainly in the library at St Albans, as we have seen. Arzachel's tables and canons were also there (now Trinity College Dublin MS 444); his saphea treatise is not represented in surviving manuscripts or catalogues from the monastery, but it may well have been there, since it was a popular companion work for the sorts of instrument treatises that interested the St Albans monks.

135 North (1976), II. 191. North juxtaposes the first few lines of Westwyk's addition (f. 43r) with the opening chapters of al-Zarqālī's treatise, translated by Profatius (Jacob ben Machir ibn Tibbon), in the edition by José María Millás Vallicrosa (al-Zarqālī, 1933, 114).

136 Richard of Wallingford, 'Tractatus albionis', III.36, in North (1976), I. 380.

137 British Library MS Harley 625, f. 164; Watson (1976); Millás Vallicrosa (1943), 433-437. The Merton College equatorium, which is on the back of an astrolabe, will be discussed in the next chapter. For Bredon's will, see Powicke (1931), 82-86.

138 A good example of the way that compilers and readers made links between diverse texts is described in Kurtz and Voigts (2011).

John Westwyk. If so, they represent his most extended contribution to MS 657, and can tell us a great deal about his interests and abilities. Much of the writing is descriptive, focusing on the parts of the instruments and their functions, giving details of precisely how and where they are graduated and labelled. It seems quite likely that here he was not only interpreting his reading, but describing a physical instrument. So, for example, he notes that the circumference of the saphea is divided by degrees, but labelled at every fifth degree. When it comes to the astrolabe, he begins by describing features that are common to all astrolabes, noting details that suggest he was working from an individual exemplar: almucantars labelled in three places, and azimuth arcs marked by numbers written at the horizon line. Yet almost immediately he moves on to more distinctive features, making clear that his instrument was no ordinary astrolabe: the Albion's astrolabe plate is adorned with an ecliptic, with six latitude circles marked on each side of it; he notices that the names of signs are written in such a way that each sign begins at the end of its name; and he concludes that this is because 'this zodiac goes in the opposite direction to what is usual on other instruments.'[139]

Westwyk begins the two main paragraphs on folio 43r with the parallelism 'Quantum ad saphea' and 'Quantum ad astrolabium', emphasised with red two-line initial Qs, whose tails extend down five or six lines of the margin. However, he appears to have abandoned any intention of signalling the content of his commentary on the parts of the Albion, as without warning, after a 109-word description of the astrolabe plate, he begins to describe striking features of other parts of the instrument, focusing in particular on the rather complex plate for lunar and solar eclipses. This is his longest and most original section of commentary, which draws on parts II and III of the *Albion* treatise (on construction and use of the instrument) in both Richard of Wallingford's and Simon Tunsted's versions,[140] as well as introducing some theoretical content which demonstrates that he was supplementing his reading with material from other sources. So, for example, he notes that the two diameters of the eclipse plate are divided into scales of 60 and 64 parts, and observes that those divisions are marked faintly and numbers written to one side; to justify this, he draws on Richard of Wallingford's warning that the circles of eclipses should not be allowed to confuse the scales. He then points out that the 64-part scale is used to find the quantity of a lunar eclipse, as explained in Richard's section III.23, before digressing to explain something not found in the *Albion*, namely three reasons why this quantity should vary:

> the first is if the Sun is at the aux of its eccentric, so that its shadow is larger; secondly by the descent of the Moon from the aux of its epicycle, so that it approaches the widest part of the shadow; and

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[139] MS Laud Misc. 657, f. 43r. This is as described by Richard of Wallingford, 'Tractatus albionis', II.22, in North (1976), I. 328.
[140] The principal relevant sections are II.25-28, and III.23-25 and 33.

> thirdly is its latitude from the ecliptic, since when this is greater it moves more laterally, and the smaller it [the latitude] is the more it is overshadowed for this reason.[141]

This explanation most closely resembles that of al-Battānī (Albategni), the ninth-century Syrian astronomer whose zīj (much more than the collection of tables the name suggests) was translated into Latin twice in the twelfth century, by Robert of Chester and Plato of Tivoli.[142] There is no record of al-Battānī's work at St Albans, but he is cited in the *Albion*, where Richard of Wallingford gave an indication of his reputation by placing him alongside Ptolemy. Richard's reference comes at the end of his chapter about the quantities of lunar eclipses, but he did not note that between 'demonstracionibus Ptolomei et Albategni' there are significant differences.[143] Perhaps most notable is the fact that al-Battānī explicitly contradicted Ptolemy's assertion that the Sun's movement on its eccentric makes no observable difference to eclipses; it is al-Battānī's view, of course, that is reflected in the first of John Westwyk's explanations quoted above.[144] We cannot be sure that Westwyk obtained his knowledge directly from al-Battānī, but it does give an indication of the breadth of his reading.

In the final part of his commentary, John Westwyk returns to more descriptive material, commenting on the tools for the solar eclipse and lunar latitude on the same eclipse plate. We get a sense of his patterns of thought as, immediately after noting that the eclipse plate is divided in two directions, he digresses to point out that the direction of divisions on the spiral is in succession of signs, but the circles of right and oblique ascensions (to which, as we have seen, he has had to pay particular attention) are graduated in the opposite direction. On the other hand, he goes on, the zodiac on that limb of the second face is graduated directly, in fives; and the right and oblique ascensions are also graduated in fives; and all three of these circles start at the suspension-ring. There is a strong sense that he is writing down these notes as they occur to him: observations on the treatise and instrument leading one into another in a stream of connected but disorganised thoughts. In the last of these he returns to the spiral, explaining how many turns of the spiral were necessary to accommodate the mean argument of Mercury.[145] Richard of Wallingford's spiral also incorporated values for the mean motus and mean argument of the Moon, and Westwyk began to explain this, writing 'Medius motus lune' before apparently remembering that Simon Tunsted had adapted the design, placing the lunar elongation on the spiral instead of the mean motus. Without correcting his mistake, Westwyk began a new

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141 MS Laud Misc. 657, f. 43r.
142 al-Battānī (1899), 57-58. On his translation and influence, see Nallino, in al-Battānī (1899), xlix-l; North (2008), 197-199. On the confusion between the translators Robert of Ketton and Robert of Chester, see Burnett (2004).
143 Richard of Wallingford, 'Tractatus albionis', III.24, in North (1976), I. 368.
144 Ptolemy (1984), 252 (V.14); al-Battānī (1899), xlii, 58.
145 MS Laud Misc. 657, f. 44r. His discussion is confused but broadly correct; this aspect of the instrument design is discussed by North (1976), II. 180-182.

paragraph and explained how much space the elongation and mean argument of the Moon occupy on the spiral. With that, and without any *explicit*, John Westwyk stopped his commentary. He may have intended to write more, since he left the middle third of that folio blank, before commencing his copy of the missing *Albion* prologue.

## CONCLUSION

It is clear that John Westwyk made some significant additions to his copy of Richard of Wallingford's *Tractatus albionis*: significant not only in terms of the content of the manuscript, but also in terms of what they can tell us about him. We cannot be certain that Westwyk made all of the changes noted in this chapter, but we know enough about his work to make this possible. The expertise necessary for some of those changes which can be ascribed to him with confidence – the unusual table for Tynemouth and the table of lunar elongations where he refers to himself and Simon Tunsted as separate individuals – surpasses that necessary for the other changes which I have suggested with less certainty could be his. Some of these arise from compilation of two versions of Wallingford's work, which would have been easily possible given how many copies were made at St Albans; some would have required reference to other works, by Ptolemy and Māshā'allāh, that were certainly present there. Others of the works I have suggested that Westwyk consulted, by al-Battānī and al-Zarqālī, cannot be proven to have been at the monastery, but given the lacunae in catalogues and manuscripts, and the complex astronomy present in manuscripts that have survived from that monastery, it is likely enough that they were there. The references to the work of al-Battānī and al-Zarqālī come in the final folios that Westwyk appended to the *Albion*, in sections which, as we have seen, contrast with the careful compilation apparent in the main part of his copy. The disorganised style of these additions, and the way they range over various parts of the instrument, focusing on its physical features, makes them more likely to be original reflections. The fact that Westwyk was later to cite al-Zarqālī (among several other astronomers) in a marginal annotation in his *Equatorie of the Planetis* suggests strongly that he had read him; this is most likely to have been early in his career, when he perhaps had the easiest access to such sources. And our knowledge that he was later to write his own original treatise on a planetary instrument makes it easier for us to assert that he was more than just the copyist of this one.

Thus, even if the additions to the *Tractatus albionis* analysed in this chapter were not all the work of John Westwyk, it seems clear that they were not blindly copied from Simon Tunsted either. We do not have to go as far as Clark does in asserting that Laud MS 657 was 'more advanced than Tunstede's work' and that Westwyk 'advanced [his] knowledge further than

Richard himself';[146] it is enough to state that John Westwyk's writing displayed substantial astronomical knowledge, attention to detail in copying and compilation, computational skills and interest in instruments. And even if this manuscript did not contain a single word of original writing by Westwyk, the act of careful *compilatio* would still be an impressive demonstration of his abilities as one of those 'conservators and transmitters of authoritative knowledge' who personified medieval scholarship.[147] In the absence of evidence, it is impossible to state that he acquired his abilities through study at the University of Oxford. But what is certain is that they would serve him well when he came to compose the *Equatorie of the Planetis* a decade later.

More widely, MS 657 reveals much about the activities of copying and compilation in monasteries. They are shown to be complex activities which may entail careful methodical reading and sometimes even improvement of texts, an important corrective to the notion that hand-copied books necessarily degenerated over time.[148] Reading was constantly accompanied by responsive action, not only writing but probably also the use of the instruments described in such texts. And religious motivations and responses, if not explicit, were seldom far below the surface. Richard of Wallingford may have been following a familiar formula when he prayed in the *Tractatus albionis* that Christ would 'forgive the presumptuous curiosity, inasmuch as we have turned aside to these things from the study of piety.'[149] But it is clear that careful copying and compilation could themselves be pious activities for monks, fully compatible with the strictures of St Benedict and his successors. Whether John Westwyk and his contemporaries who left their names and comments in the works of Richard of Wallingford were doing so to honour their forebear's illustrious memory, to glorify God through the study of creation, or simply fulfilling their duty of quiet contemplation – and satisfying their intellectual curiosity – through the study of astronomy, they were certainly not handicapped from that study by their position as monks. These monks, alongside university scholars and growing groups in secular settings, formed part of vibrant, interactive astronomical communities at the end of the fourteenth century.

[146] Clark (1997), 142-143.
[147] Hathaway (1989), 44.
[148] See, for example, Eisenstein (1983), 218.
[149] Richard of Wallingford, *Tractatus albionis*, III.42, in North (1976), I. 389 (North's translation).

## CHAPTER TWO

# Never fixed, never finished: astrolabes as supports for planetary calculators

We saw in chapter 1 that John Westwyk made reference to a physical instrument in the process of compiling his copy of Richard of Wallingford's *Tractatus albionis*, and considered the possible scales at which it could be constructed. Richard himself had alluded to the relationship between scale and precision, when he wrote that his oval construction for the eccentric of Mercury 'does not contain an error perceptible on an instrument whose diameter is 60 cubits.'[1] By the time Westwyk came to draft his own instrument treatise, he had also read Chaucer's admonition that 'smallist fraccions ne wol not be shewid in so small an instrument as in subtile tables calculed for a cause.'[2] Their influence is apparent in the opening statement of Westwyk's *Equatorie of the Planetis*:

> the largere that thow makest this instrument, the largere ben thi devisiouns; the largere that ben tho devisiouns, in hem may ben mo smale fracciouns; and evere the mo of smale fracciouns, the ner the trowthe of thy conclusiouns.[3]

The prominence of this statement suggests that Westwyk saw his equatorium ('myn equatorie, that was compowned the yer of Crist 1392 complet, the last meridie of decembre') as a tangible calculating tool, whose construction in different sizes would yield more or less precise measurements.[4] He was not making a purely theoretical point: in the very next sentence he specified its size as '72 large enches or elles 6 fote of mesure'. And, as we shall see in subsequent chapters, he had apparently already made the equatorie himself at a reduced size, with which he was somewhat unsatisfied.[5] The fact that the size of the instrument, unlimited in theory, was immediately limited to specific dimensions indicates that precision was not its composer's sole priority. There were obvious limitations to the size of an instrument that was intended to be made and used. Availability of materials was one concern; another was portability. Jean of Lignières had complained that Campanus of Novara's equatorium design was 'very tiresome . . . because of the size of this instrument, it cannot easily be moved from place to place;'[6] he was not alone in his concerns, as this complaint was copied verbatim by at least one other equatorium

[1] Richard of Wallingford, 'Tractatus albionis', II.9, in North (1976), I. 312.
[2] 'A Treatise on the Astrolabe, Prologue, lines. 73-76, in Chaucer (1988), 663.
[3] Peterhouse MS 75.I, f. 71v. In order to make Middle English quotations more readable, *th* has been substituted for *þ*, *z* for *ȝ*, and *v* for *u*, where appropriate; abbreviations (including '&') have been expanded; some punctuation and capitalisation have also been changed. A full diplomatic transcription, with images of the manuscript, can be found in Rand Schmidt (1993), 116-149, and online at http://cudl.lib.cam.ac.uk/view/MS-PETERHOUSE-00075-00001/144.
[4] Peterhouse MS 75.I, f. 71v.
[5] Peterhouse MS 75.I, f. 76r.
[6] Lignières (1955), f. 142v, p. 188.

designer in the preamble to his own treatise.[7] This chapter will examine the ways that such concerns and priorities shaped the manufacture of astronomical instruments.

Of the few equatoria surviving from the medieval period, most are combined with other instruments.[8] This is surely not an accident of survival: it is not simply that such compendia were particularly precious and so were carefully conserved, or at least had greater value in that form than melted down or used as firewood. An astronomer designing a new instrument had good reason to instruct his reader to make it on the back of an existing one. Apart from saving expense on materials, it also saved time and effort in construction (another thing that, in the case of Campanus's design, Jean of Lignières found 'magis tediosa'). And it also provided the benefit of associating a new, perhaps unproven design with the prestige of an established instrument, something that would be particularly useful if a craftsman sought to sell his products.

Equatoria and other planetary instruments could exist in a variety of sizes and materials, as individual devices or as part of a multi-functional compendium. This chapter will consider the basis for the choices made by their creators. Just as an important feature of manuscript studies is consideration of the materials used by the scribe – parchment or paper, iron or oak gall – so, it will be argued, we should give more attention to the *supports* used for equatoria. It will also approach the issue from the opposite direction: since the support for an equatorium was often the "back" of an astrolabe, the question of what astrolabe-makers chose to include in their instruments will also be discussed. The question of supports for equatoria is often ignored, perhaps because so many survive only as designs or descriptions, and in any case the fact that they were often little more than physical diagrams makes it easy to forget that they are three-dimensional.[9] This chapter will focus on a number of examples of planetary instruments on the back of astrolabes. It will consider some surviving objects, and some that were perhaps only imagined; it will thus address the problematic boundaries of practice and theory, science and craft, text and object.

In this context, it is important to question the notion of a "complete" or "finished" instrument. The popularity of object biographies in recent years has highlighted that objects are not immutable, and that we can learn a great deal from the changes that are made after they are first produced; if we are 'attentive auditors' to objects, they will tell us about the ways that they were made, used, collected, displayed and discarded.[10] But even the notion of a 'wounded

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[7] Cambridge University Library, MS Gg.6.3, f. 217v. This treatise will be discussed in detail below.
[8] Poulle (1980). A notable exception is the early-fifteenth-century wooden equatorium now at the monastery of Stams (Austria), described by Poulle (1980), 279-294. See also Kremer (2012) on a late-fifteenth-century astronomical polyptych.
[9] North (1976), II. 261.
[10] Daston (2004), 12. Daston rejects the notion of 'the objectivity of the artifact' (16).

artefact',[11] while helpful in reminding us that objects can tell us much when they are damaged, and that objects were not always used in the way their creator intended, may also promote the impression that there is necessarily a perfect, "healthy" artefact. This obscures the fact that astronomical instruments were frequently altered or customised by their owners. Such customisations are problematic for historians and curators: we may aim to study all features of an object without prejudice, but the temptation to deem a modern mark made by a museum or collector – compared with an inscription made by the object's original creator – as not an integral part of an instrument is often irresistible – and perhaps justifiable. Drawing a line on a spectrum of inscriptions and customisations is invidious, but it is commonplace and sometimes contradictory: a twentieth-century alidade on a medieval astrolabe may be considered "part" of the instrument if it is thought to be a replacement for a lost, presumably similar, original, while an engraving that is almost contemporaneous with the instrument's creation may be considered vandalism if it is significantly different from the rest of the object. In this tacit categorisation of instrumental interventions, a mental image of a standard "complete" astrolabe is implicit. Any divergence from norms is assessed according to criteria that may include astronomical precision or accuracy, congruence with the rest of the object, and even craftsmanship or perceived artistic quality.

This prejudiced analysis of instruments like astrolabes partly stems from the way that they are so often displayed in museums as art objects, divorced from their instrumental function.[12] The underlying cause, though, is that these instruments are now obsolete. The fact that they are no longer evolving allows them to be presented as if they never underwent a process of evolution. But of course they did undergo such a process, which was shaped by the choices of their makers. For this reason, I believe, Bill Brown is right to endorse Arjun Appadurai's focus on 'the things-in-motion that illuminate their human and social context.'[13] Brown argues that we should pose 'questions that ask not whether things are but what work they perform – questions, in fact, not about things themselves but about the subject-object relation in particular temporal and spatial contexts.'[14] The contexts are crucial in order to avoid oversimplification to what Bruno Latour has justly criticised as an artificial distinction between passive objects and active human subjects.[15]

[11] Greenblatt (1990), 22. See also Schaffer (2011).
[12] Maas (2010); Maas (2013).
[13] Arjun Appadurai, 'Introduction: Commodities and the Politics of Value,' in *The Social Life of Things: Commodities in Cultural Perspective*, ed. Appadurai (Cambridge, 1986), 5, quoted in Brown (2001), 6.
[14] Brown (2001), 7.
[15] Latour (2005), 70-82.

Although the focus of this thesis is the work of John Westwyk, and particularly his equatorium, by giving some attention to the contexts of other similar instruments that appear on the backs of astrolabes, we can understand more about the motivations and methods of their production. Equatoria did not need to be stand-alone instruments, but equally, they were not the only thing that might be placed on the back of astrolabes; their inclusion would inevitably entail the displacement of some feature or features. This chapter will therefore examine a treatise and instrument that incorporate an equatorium into an astrolabe. It will then use examples of other instruments and features on the back of astrolabes, to draw attention to the range of options exercised by ingenious instrument designers. Such attention to the choices of people who made and modified astronomical instruments can do more than simply answer the question why Westwyk's equatorium was six feet in diameter and made of brass and wood. It can also enable us to gain a better understanding of the practices, and thereby the concerns, of medieval astronomers and instrument-makers, and can make us think again about how we view, curate and display objects.

## WHY THE BACKS OF ASTROLABES?

The astrolabe was at the heart of late medieval astronomy.[16] It is not surprising that Chaucer included an astrolabe among the possessions of the Miller's Tale's 'poor scholar' Nicholas, on whose bedside shelves it sat alongside a copy of the *Almagest*; nor that an early-fourteenth-century artist should use it to decorate the first folio of a copy of Ptolemy's masterwork (see figure 9), even though the planispheric astrolabe is not included among the instruments described therein.[17] The audience of the Canterbury Tales may not have been aware that the poet whose work they enjoyed had also written (or was soon to write) *A Treatise on the Astrolabe*, but they would certainly have been familiar with that instrument.[18] It had even been used by Peter Abelard and Héloïse for the name of the son born from their ill-starred relationship.[19]

[16] Neugebauer (1949), 240; Pedersen and Pihl (1974, 248-251), for example, entitle a section 'The Astrolabe and the Awakening of Astronomy', and credit it with sparking 'a minor revolution in Mediaeval astronomy.'

[17] The Miller's Tale', in Chaucer (1988), 68 (I. 3208-3209); British Library MS Burney 275 (probably made for Francis Caracciolo, Chancellor of the University of Paris, around 1310), f. 370v.

[18] The dating of the Canterbury Tales is uncertain, but the first fragment, which includes the Miller's Tale, is generally thought to have been written in 1388-92 (Benson (1988), xxv). The *Treatise on the Astrolabe* was most probably written in 1391 (that dating is discussed in Chapter 3 of this thesis, pp. 82-83). One source Chaucer cites in the *Astrolabe* is the Carmelite friar Nicholas of Lynn – perhaps the inspiration for the fictional Oxford scholar.

[19] Astralabe [sic], or (Petrus) Astralabius, was born to the famous lovers c. 1117-18 (Abelard (1962), 74; Abelard and Héloïse (1974), 69, 285-287).

Fig. 9: Detail from *The Almagest*, British Library MS Burney 275, f. 390v. © The British Library Board

The production of planispheric astrolabes in western Christendom was to peak in the second half of the sixteenth century, but already by our period they were being made in large numbers and, importantly, in varied sizes and designs.[20] It is true that the variety in fourteenth- and fifteenth-century astrolabes paled in comparison with what was to come later, and that what variety there was by 1400 was largely decorative.[21] Nevertheless, the astrolabe was always a synthesis of pre-existing instruments, and it seems makers were quite well aware that certain features could be altered while maintaining the instrument's core observational and computational functions.[22] Since the stereographic projection described in Ptolemy's *Planisphaerium*,[23] with its superimposed star map, only occupied one side of the instrument, the maker was left considerable freedom to exercise his personal choice on the other side.[24]

[20] Gibbs, Henderson and Price (1973); de Soysa (2000). De Soysa suggests that astrolabes were relatively homogeneous before the fifteenth century, but his point of contrast is the great diversification that took place from the mid-sixteenth century. There was already plenty of diversity before 1450, as we shall see. See also Schechner Genuth (1998).

[21] Gingerich (1987).

[22] Although the evolution of the planispheric astrolabe and its continued relationship with other instruments has been well documented, this has often been ignored in studies focusing on one particular type of instrument (see, for example, Lorch's (1976) discussion of the torquetum). Such narrow studies misrepresent the complex cross-fertilisation in medieval instrument design. For discussion of the historiographical issues, see Falk (2012), 12-13.

[23] The 'astrolabe' described in Book V of the *Almagest* is closer to an armillary sphere (Ptolemy (1984), 217 ff.). The less well known *Planisphaerium* was translated by Hermann of Carinthia in the twelfth century; that translation was used by Federico Commandino for his sixteenth-century edition (Ptolemy (1558)). An Arabic version of the treatise has recently been edited and translated by Sidoli and Berggren (2007). Sidoli and Berggren note that 'Ptolemy's project is not to describe the construction of a particular instrument, but rather to develop a body of mathematical techniques, many of which he knows will be of interest to instrument makers' (127); the stress in their commentary is on the mathematics but, as they imply, the treatise could be read for more practical purposes too.

[24] The layout of Ptolemy's planisphere was effectively the reverse of a conventional medieval astrolabe: the stars could be engraved directly onto the plate, while the 'spider' probably carried the local coordinates. Thus the horizon could move against the fixed stars, unlike on a medieval astrolabe where the stars move against a fixed horizon. The interpretation of the 'spider' in this context is disputed: cf. Neugebauer (1975), II. 866.

Although astrolabes have received a great deal of attention from historians, mathematicians, antiquarians and craftsmen, a comparatively small proportion of that attention has been dedicated to their backs. Scholars seem to have found little worthy of note on that side, and often give the impression that they are all alike. It is probably fair to say that the backs of Western astrolabes seem homogeneous by comparison with either their fronts or the backs of Eastern astrolabes,[25] but even so, there is some variety that is both interesting in terms of the development of the instrument, and historiographically noteworthy. It is therefore worth examining certain issues briefly, in order to fully understand the options available to an instrument-maker who might be seeking a support for an equatorium. We shall look at one small group of astrolabes, those often termed "Chaucerian", both because of the synchronicity and obvious relevance to Peterhouse MS 75.I, but also because they raise a number of unanswered historiographical questions.

David King wrote in 2011 that 'failing a catalogue of the entire corpus of medieval astronomical instruments, what needs to be done by future investigators is to prepare comparative studies of related groups of instruments.'[26] He presented what he called 'an ordered list of European astrolabes to *ca.* 1500' in order 'to facilitate such undertakings.'[27] This useful list contains 150 instruments (or significant remnants of them), sorted into nine groups according to geographical and temporal provenance. One of these groups, containing ten instruments, is 'English astrolabes with a Y-shaped frame on the rete in the tradition of Geoffrey Chaucer.' The list, whose membership is potentially fluid,[28] is as follows (the name of the astrolabe is followed by its #number in the *International Checklist of Astrolabes* first compiled by Derek Price in 1955).[29]

1. Cambridge, Gonville and Caius College Astrolabe B, #301 (ø 88 mm)
2. Astrolabe dated 1326, London, British Museum 1909,0617.1, #291 (ø 132 mm)
3. 'The Painswick Astrolabe', Oxford, Museum of the History of Science 47869, #299 (ø 122 mm)
4. Astrolabe with equatorium, Oxford, Merton College SC/OB/AST/2, #297 (ø 362 mm)
5. Oriel College astrolabe with horary quadrant, Oxford MHS 47901, #296 (ø 340 mm)
6. British Museum astrolabe 1914,0219.1, #298 (ø 123 mm)
7. 'Parnel's astrolabe', Washington DC, Smithsonian National Museum of American History, #304 (ø 145 mm)
8. Astrolabe presented by R. T. Gunther, Oxford MHS 49359, #4755 (ø 155 mm)

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[25] See, for example, Ackermann (2005).
[26] King (2011), xv.
[27] King (2011), xv. This was based on research carried out in the 1990s (1).
[28] Eagleton (2007), for example, includes a different astrolabe in a private collection in Belgium in comparison with nos. 3, 6, 8 and 9. In a previous dissertation (Falk (2012); see especially appendix B) I compared the saints' days on the back of nos. 1, 2, 3 and 6 with those on three other astrolabes.
[29] King (2011), 7; Price (1955a). I have supplied the museum inventory number (where applicable) and diameter.

9. Tomba-Koelliker astrolabe, Florence, Museo Galileo: Istituto e Museo di Storia della Scienza, inv. 3931, #4521 (ø 146 mm)
10. Astrolabe at Smithsonian NMAH, #2006 (ø 128 mm).

Regarding the title King gave to this group, it might immediately be remarked that to assign astrolabes to countries can be very problematic.[30] But it is more important for our current discussion to note that his Chaucerian criterion is the shape of the rete. King's approach is far from unusual: discussion of this group of astrolabes has focused on the iconography and celestial data on the front of the instruments. In their recent reassessment of no. 9, comparing it with nos. 2, 3, 6, 7 and 8, Jim Bennett and Giorgio Strano dedicated just one paragraph to the backs of the instruments in a six-page comparison section. So it is perhaps not surprising to read the authors' conclusion that

> we might return to the affirmation that the Y design of rete is the most conspicuous feature of the group. While bearing in mind the dangers of giving a historical significance to groupings we may create for convenience in identifying and cataloguing, the Y pattern remains a useful indication of tradition and location.[31]

Their caveat, it should be stressed, is a vital one. There is no certainty that instrument-makers would have recognised the category "Chaucerian" or grouped astrolabes using the same criteria that seem obvious to us. That said, given the apparent renown of Chaucer and his much-copied astrolabe treatise, it remains a possibility, one that is implicit in Catherine Eagleton's argument that some of the astrolabes in this group were made in imitation of the drawings in the *Treatise on the Astrolabe*.[32]

Of course the reason why these astrolabes have been associated with Chaucer is the obvious similarities, most notably in the designs of the retes, to the images in several manuscripts of the *Treatise on the Astrolabe*. The relationship between the various copies of the manuscript, and between the images and the retes of Chaucerian instruments, has been discussed in detail and will not be rehearsed here.[33] However, the backs of these instruments, and their depiction in the manuscripts, do merit further attention. The first point to make is that the backs vary widely. Chaucer's description of the 'bakhalf' of the astrolabe he had given to his son Lowys provides perfect step-by-step clarity for the ten-year-old novice astronomer. The poet explains that the back is crossed by two diameters that divide the circle into quadrants, with south at the top, and

[30] Although instruments were often made for particular latitudes, medieval astronomers were highly mobile, and were remarkably uninterested in the national origins of the authorities they cited. See discussion in Falk (2012), 11-12.
[31] Bennett and Strano (2014), 205. See also Davis and Lowne (2015) on no. 1 in King's list.
[32] Eagleton (2007). This article provides a good introduction to the historiographical question of Chaucer's "own" astrolabe.
[33] Eagleton and Spencer (2006) argue, in a thorough analysis of the relationships between the different manuscripts, that the similarities between diagrams in manuscripts not directly descended from one another indicates that Chaucer's original version of the manuscript had diagrams, and the diagrams in the surviving manuscripts were based on these. For further discussion of the diagrams vs. instruments issue, see Eagleton (2007); Bennett and Strano (2014).

circles for degrees and zodiacal signs. It also had circles of days, months, and holy days. It had a scale of *umbra recta* and *umbra versa* (shadow square), divided on each side into twelve. And it was surmounted by a rule equipped with sights, 'to resceyve the stremes of the sonne by day, and eke [also] by mediacioun of thin eye to knowe the altitude of sterres by night.'[34] These are features that are common to the vast majority of medieval astrolabes, but they are not absolutely necessary. Neugebauer argued that the observation function was essential, writing in his discussion of the *Planisphaerium* that 'only when the central pivot which is needed for the spider is utilized to carry on the other side of the disk a diagonal ruler equipped with sighting holes the instrument becomes an astrolabe.'[35] His general point seems reasonable enough, but there is no reason (except an understandable desire to de-clutter the front) why the sighting alidade should be on the back, especially since the rim of the front must be graduated into 360 divisions in any case. Indeed, for example, no. 10 in King's list has the sighting alidade on the front, while no. 4 (which will be discussed in detail below) uses sighting pinnules at the top of the instrument that would have been combined with a plumb-line for measuring altitudes. It must be stressed that we should be careful drawing conclusions from these parts of surviving instruments, since the extant rules and alidades are frequently replacements for missing pieces. The replacement is not always as obvious as it is in the case of no. 6, where these parts were helpfully marked '1888' when they were added by R. S. Ferguson in that year.[36] But new studies by John Davis, using X-ray fluorescence spectrometry to analyse the metal content of the different parts of instruments, are starting to show that the replacement of these parts may have been more widespread than has hitherto been assumed.[37] Nevertheless, we can be confident that there were never sighting alidades on the back of nos. 5 and 10, simply because they do not have the scales of degrees necessary for their use.

The shadow square mentioned by Chaucer, while useful, is certainly a supplementary feature: altitudes could obviously be measured on the larger scale on the rim of the instrument, and the scale of twelfths only works in shortcutting tangent calculations if it is precisely graduated, which to judge by extant instruments was far from guaranteed. Nonetheless, a shadow square is included on seven of the ten instruments in King's list;[38] that is, on all of the instruments that have the circles of days, months, etc., as described by Chaucer.

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[34] 'A Treatise on the Astrolabe', I.4-13, in Chaucer (1988), 663-665.
[35] Neugebauer (1975), II. 871.
[36] Ferguson (1890). This is the same person as the C. Ferguson cited by Eagleton (2007, 308); Carlyle (2004).
[37] For example, while most components of no. 1 are 81-84% copper and 11-12% zinc, Davis obtained results of up to 65% gold when he scanned the surface of its rule, suggesting that it is a modern, gold-plated, replacement (private correspondence, 22/10/2014, 26/01/2015; see also Davis and Lowne (2015), 279-280). On the use of such methods, see Newbury et al. (2006); Stephenson, Stephenson and Haeffner (2001).
[38] Nos. 1, 2, 3, 6, 7, 8 and 9.

These circular calendars raise complex issues. They represent a solar equatorium: a device to show the Sun's irregular progress around the zodiac. As we shall see in chapter 5 (and as Chaucer was well aware), the functions of an equatorium could be performed by tables, though the convenience of having the information available for instant reference should not be underestimated. If the solar equatorium were included on the back of the astrolabe, as it is on seven of the ten instruments listed above, there were two ways to present it so that it could model the solar equation (the difference between mean and true Sun) effectively: either using concentric circles, in which case one (the inner one, if the outer were to be used for measuring altitudes) would have to be graduated at irregular intervals; or using eccentric circles. Chaucer does not specify which model Lowys's instrument followed; the most recent editor of the *Treatise on the Astrolabe*, Sigmund Eisner, states in his general introduction to the instrument that 'engraved on the back of the mother [of any astrolabe] is a series of concentric circular bands', but Eisner does not present evidence or discuss the matter further, though his illustrations are consistent with this statement.[39] Those illustrations are based on the Painswick astrolabe (no. 3), which indeed has concentric calendar circles.[40] Of the seven astrolabes in King's list that have any sort of calendar on their back, four (nos. 3, 6, 8 and 9) have concentric circles; and three (nos. 1, 2 and 7) have eccentric circles.[41]

We should note that, where the calendars are concentric, the irregular graduation has been carried out with mixed success. This is hardly surprising: while eccentric calendars reproduced Hipparchus's highly effective model of the solar anomaly,[42] the constantly changing apparent speed of the Sun meant that in theory a concentric calendar would have to have every day a slightly different length from the one before or after. Of course, on an astrolabe with a diameter between 12 and 16 centimetres, these differences would be practically invisible. It is quite probable that many instrument-makers simply placed the two equinoxes as accurately as possible at either ends of the horizontal diameter, and divided the days equally on either side, leaving perhaps 187 summer days in the top half, and 178 winter days below. Yet even this could be done better or worse. An example of the latter is the Gunther astrolabe (no. 8). As we can see in figures 10 and 11, the maker apparently divided the days first in months, then in fives, finally in days. As a result, when a month has 31 days, the final six are squeezed into a space meant for five (e.g. October in figure 10). On the other hand, February, which is labelled with 28 days,

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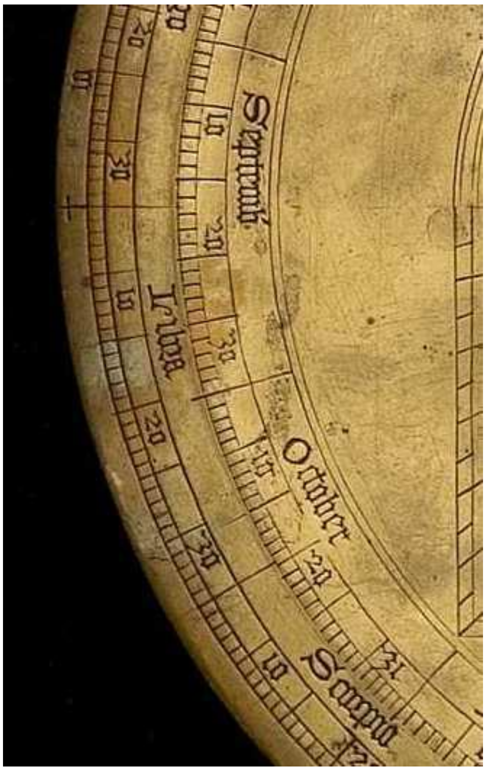
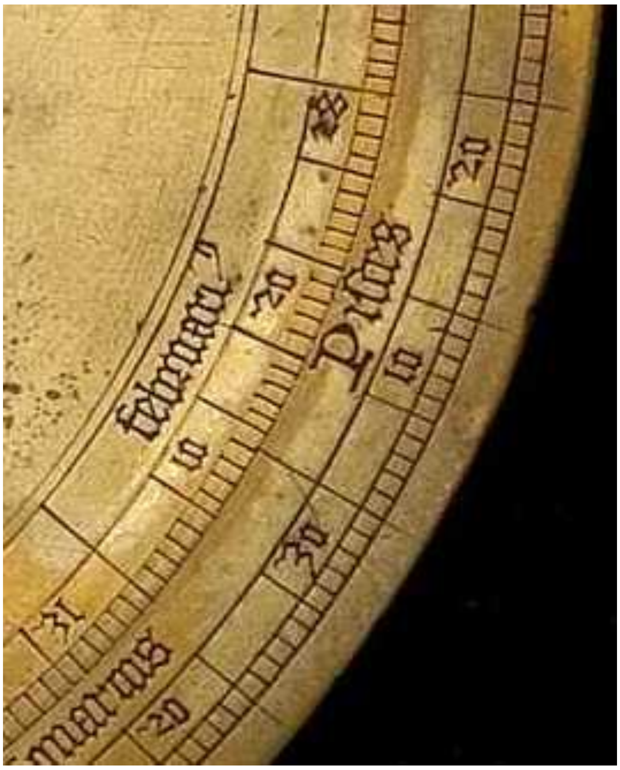
[39] Eisner (2002), 3.
[40] Eisner (2002), 10.
[41] We should also highlight another astrolabe, in a private collection in Belgium (Baptiste (1984), 37; ø = 118 mm). The quatrefoil (rather than Y-shaped) decoration on its rete might exclude it from the "Chaucerian" category, but its back is very similar to the Painswick astrolabe, including concentric calendar circles. It is not included anywhere in King's 'Ordered List'.
[42] As described in *Almagest* III.4, in Ptolemy (1984), 153.

Figs. 10 and 11: Details of calendar scales on astrolabe no. 8 ("Gunther astrolabe"). Reproduced by permission of the Museum of the History of Science, Oxford, inv. 49359.





actually has markings for 29 (figure 11); perhaps 28 would have been too noticeable. Yet this is not the most flagrant error in the calendar marking. Close examination of the month of September (figure 10) reveals that it only has 25 days. It is unclear how this would have satisfied any user (though before we are too critical, it may be worth noting that this defect has escaped historians' attention until now, despite this being one of the most intensively studied of all astrolabes), but it should make us think carefully about how accurate astrolabe calendars needed to be, and the purposes they served.

Given the greater technical difficulty of accurately graduating the concentric circles, the fact that four out of seven possible astrolabes have that configuration may seem surprising. It is also unusual. Of the 92 comparable astrolabes in King's wider 'Ordered List', I have examined 32 (the number would be greater but for the lamentable tendency of cataloguers to picture only the front of astrolabes).[43] Of these, just five have concentric calendars.[44] Each of these is interesting in its own way. For example, Museo Galileo 1107 is unusually small, just 98 mm in diameter;

[43] I have excluded King's last two categories: the 15th-century French 'Fusoris-type astrolabes; and the 15th-century German astrolabes in the tradition of Regiomontanus and Hans Dorn. The former group are so alike as to practically preclude independent choice by their maker, and I felt this would skew the sample (they invariably have eccentric calendars). In contrast, the latter group vary perhaps too widely, including a number of instruments that do not really resemble astrolabes at all, so that their inclusion for comparison might be misleading.

[44] British Museum, London 1961,1201.1 (ICA #161); Merton College, Oxford c. 1390 astrolabe (#303); Museo Galileo, Florence inv. 1107 (#493); British Museum 1853,1104.1 "Blakene Astrolabe" (#292); Victoria and Albert Museum, London M.128-1923 (#190? It may also be listed as #577).

perhaps its maker decided that the difficulty of marking the solar eccentricity on such a small instrument made concentric calendars, however imprecisely graduated, preferable.[45] Meanwhile another of the five, British Museum 1961,1201.1, is also rather small and has had the shadow square and some unequal hour markings added later, reminding us that such instruments are never finished, but always subject to later modification. However, the more pressing issue is the unusual predominance of concentric calendars among the so-called "Chaucerian" astrolabes. The simplest explanation for this is that they influenced each other, or were all influenced by a common ancestor. However, the influence of the *Treatise on the Astrolabe* should not be discounted.

Eagleton's argument that some "Chaucerian" astrolabes were based on the diagrams in manuscripts of the *Astrolabe* has already been mentioned. Some aspects of this argument have been rebutted by Bennett and Strano, and one must stress at the outset that, however strong the relationship indicated by similarities between manuscripts and instruments, the direction of influence is very hard to ascertain. On this point Eagleton's argument hangs on the shape of the shackle attaching the ring to the throne on three instruments (nos. 3, 6 and 8), which she argues is unnatural by comparison with the more common "T-H' bracket', and may be influenced by an apparent attempt by the illustrator of Cambridge University MS Dd.3.53 to show the shackle from two viewpoints simultaneously.[46] Bennett and Strano rejoinder that it could just as easily be an attempt by the illustrator to render an actually existing feature of a real astrolabe.[47] Still, it is noteworthy that the three instruments Eagleton identifies, and a fourth which she also argues is based on the diagrams in Chaucer's treatise (no. 9, which has no throne or shackle), are precisely the four astrolabes that have concentric calendars.

We should therefore turn to examine the manuscript diagrams. Although the earliest surviving manuscripts of the *Treatise on the Astrolabe* are from the first quarter of the fifteenth century, after Chaucer's death, the illustrations in these manuscripts are generally assumed to be reliable copies of those to which Chaucer makes direct reference in his writing.[48] As with the astrolabe(s) they depict, the accuracy of these illustrations has sometimes been evaluated, but

45 It is true that no. 1 in King's list, which does have an eccentric calendar, is even smaller. However this is very inaccurate, not so much because of the difficulty in marking the extent of the solar eccentricity, as because the eccentricity has been marked in the wrong direction. See Davis and Lowne (2015), 268-271.

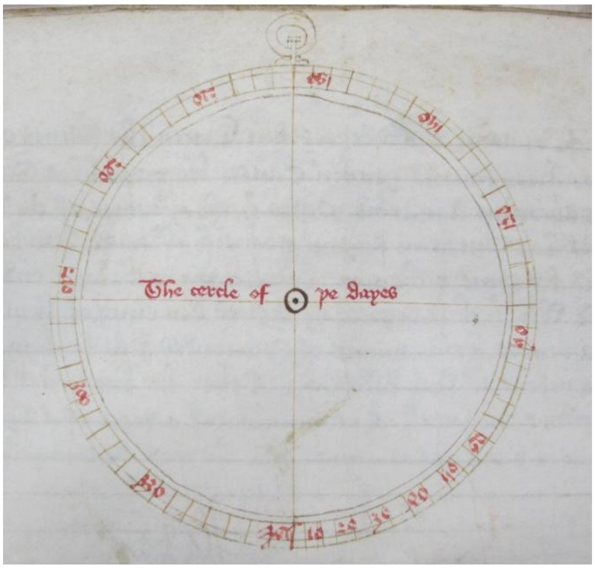
46 Eagleton (2007), 312. Her argument is perhaps weakened by the fact that that Cubist-style illustration only appears once, in one manuscript (Cambridge University Library MS Dd.3.53, f. 2r). On the other hand, the fact that the shackle is shown as a T shape on f. 4v of the same manuscript could be taken as support for her suggestion that the illustrator was trying to provide different perspectives.

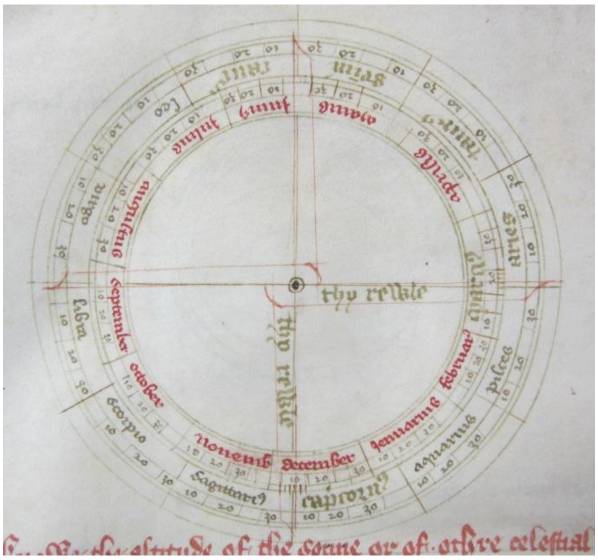
47 Bennett and Strano (2014), 225n56. They do not directly address the point that the unusual shackle looks like an unnecessary complication of the utilitarian T-H design, but they do describe the feature as 'decorative'; perhaps that is explanation enough.

48 Some, but not all, of the manuscripts have the phrase 'for the more declaracioun lo here the figure' linking sections of the treatise to diagrams. See Eisner (2002), 96.

scholars have tended to focus on images of the front of the astrolabe, checking the projection to see if the latitude matches Chaucer's Oxford-based instrument, and seeing how closely the star pointers correspond to contemporary lists.[49] Attention to the illustrations of the back of the astrolabe is long overdue, and may cause us to question their reliability as evidence of the real astrolabe of Chaucer that they are assumed to depict.

The examples that follow are taken from Cambridge University Library MS Dd.3.53, the manuscript with the clearest illustrations,[50] which is also thought to be one of the first and most reliable copies of Chaucer's archetype.[51] As Chaucer describes the different parts of the back of the astrolabe, each is depicted in turn: the diameters creating cardinal points; the degrees and signs on the rim; days, months and holy days; and the shadow square. The illustrations depict each feature of the back individually, and are broadly uniform in size and thus at different scales. So, for example, the shadow square is drawn within a circle, but without the outer calendrical circles. Yet when the illustrator drew the circle of days, he included the ring and throne by which the astrolabe was held; their inclusion (figure 12) suggests that he thought the circle of days was the outermost scale on the instrument. This may have been a lapse of attention, but it does suggest that he was not entirely comfortable with the layout of the calendars, and should make us cautious before treating his subsequent illustration of the two scales together (figure 13) as reliable evidence for the system used for the solar equation. Just because the illustration shows





Figs. 12 and 13: Calendar scales in Chaucer's *Treatise on the Astrolabe.* Cambridge University Library MS Dd.3.53 (*s.* xv *in.*), ff. 4v, 9v. Reproduced by permission of the Syndics of Cambridge University Library.

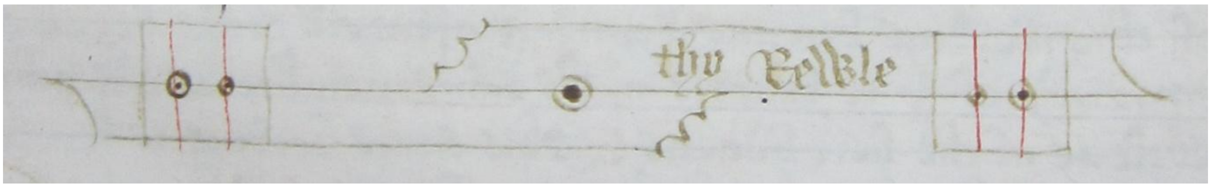
[49] See, for example, Eisner's edition of the *Astrolabe* (Chaucer (2002)) for a typical discussion of the diagrams. In an unfortunate but perhaps telling accident, the list of plates in that edition promises photographs of the front and back of the Painswick Astrolabe (as the frontispiece and on p. 102 respectively), but the front of that astrolabe is pictured in both places.

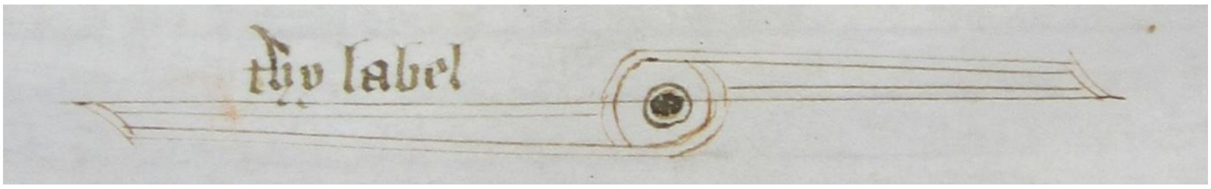
[50] See the list in Bennett and Strano (2014), 187.

[51] See the discussion in Eagleton and Spencer (2006); critical confidence in this manuscript is particularly strong regarding the early sections, including the description and illustrations of the instrument.

concentric calendars, and calendars could be laid out concentrically, we should not assume that it is an accurate representation of Chaucer's astrolabe.

Moreover, in figure 13 the component marked as "thy rewle", the alidade used for observation, looks nothing like the "rewle" drawn when that component was introduced (figure 14), but is identical to the "label" that features on the front of the astrolabe (figure 15), lacking sights and featuring more sharply angled cusps on the bevelled pointers, and a simple, more circular counterchanged form at its centre rather than a wider, more jagged-edged shape between the outer and fiducial edges. We might at this point note that of King's ten "Chaucerian" astrolabes, only no. 9 has jagged edges at the centre of the alidade (though we should recall the caveat that many alidades have been replaced over the years).




Figs. 14 and 15: Chaucer's *Treatise on the Astrolabe*, in Cambridge University Library MS Dd.3.53 (*s.* xv *in.*), ff. 5r, 8v. Reproduced by permission of the Syndics of Cambridge University Library.

To summarise: although King identified ten 'English astrolabes . . . in the tradition of Geoffrey Chaucer' on the basis of the similarity of their Y-shaped rete to that pictured in manuscripts of the *Treaise on the Astrolabe*, attention to the backs of those ten instruments reveals that only four are particularly close to the illustrations of that side. Those four are the same four whose authenticity has been questioned by Eagleton, and, we may note, match precisely the grouping suggested by Bennett and Strano on the basis of their star pointers.[52] We might take all this as further evidence for Eagleton's thesis that the astrolabes were copied from the diagrams, but if one remains unconvinced by her argument regarding the direction of influence, all we can say is that concentric calendars, like Y-shaped retes, are a feature that is rare among astrolabes in general but common to a small group that have a shared, as yet unidentified, origin. Greater attention to those calendars may, in cases such as no. 8 where they turn out to be poorly graduated, allow us to make a stronger claim that these astrolabes were made more for decorative than astronomical purposes, perhaps in imitation of Chaucerian diagrams. We should not rush to mark a firm boundary between the display and use of astrolabes, since an inaccurate calendar

[52] Bennett and Strano (2014), 220.

could still serve to teach their functions and underlying astronomical concepts; but at least in some cases it seems reasonable to suggest that a narrow definition of practical use does not fit particular objects.[53] In other cases, there may be more scope to argue that astrolabe-makers were aware of, but unperturbed by, the problems with their calendars. It was certainly an issue which the great early-fifteenth-century astrolabist Jean Fusoris considered and addressed explicitly in his writings, as we shall see below; it may be significant that his many astrolabes always had eccentric calendars.

More generally, one could make a case for categorisation and analysis of astrolabes that does not place such disproportionate weight on the form of their retes. Such an analysis, for example, might see nos. 4, 5 and 10 – which do not have calendars or shadow squares of any sort on their backs – removed from the "Chaucerian" category, and the 'Blakene Astrolabe',[54] which was made for latitude 52° in 1342 and has concentric calendars, a shadow square and a jagged-edged alidade, added to the group. But this is as open to challenge as any other categorisation: quite apart from its quatrefoil rete, the Blakene Astrolabe also has a reference guide to the solar cycle engraved at the centre of its back. So we may conclude this section by stressing the oft-ignored diversity of astrolabes: even among those made in similar places at similar times we may find significant variety among all the continuity.[55] Such variety is evidence of the significant freedom maintained by the makers and subsequent owners of astrolabes. This was sometimes exercised decoratively, or by the addition of otiose instruments such as the unequal-hour lines discussed by North.[56] And sometimes makers went as far as to change the configuration of the back completely, as happened to three of the "Chaucerian" instruments in King's list.[57] Nos. 5 and 10 were engraved with horary quadrants. And the maker of no. 4, now at Merton College, Oxford, apparently knew what we have already discussed: that the calendars represent a solar equatorium; and, as John Westwyk also realised, where there is a solar equatorium, there may be

[53] See the discussion in the introduction to this thesis. Leopold (1995, 151) has argued that 'instruments as objects for display (rather than as implements for practical use) are first found in German *Kunstkammer* collections of the sixteenth century', but certain instruments before then, such as the enormous, ornate Sloane Astrolabe (British Museum SLMathInstr.54, c. 1300), may well have been made primarily for display.
[54] British Museum 1853,1104.1 (ICA #292).
[55] One historian who has not ignored the calendars is Roderick Webster, who showed an eccentric calendar in his illustrations of a 'classic astrolabe' (1984, 11); however, when he and Marjorie Webster came to compile *Western Astrolabes* (1998), they reused the diagram (fig. 15, p. 35) but added examples of the concentric and eccentric scales from Johann Stöffler's 1513 *Elucidatio fabricae ususque astrolabii* (figs. 7 and 8, p. 33). Stöffler noted 'we have learnt two ways of inscribing the circles of the year, the first of which is by concentric circles, and the second completes the work of inscription by eccentric [circles]', attributing the former method to Messahalla (Stöffler (1553), 44v-45r). In his introduction to the instrument, John North (1974, 212) wrote that the calendars were 'usually concentric', but by 1988 he was more circumspect (48).
[56] North (1981). North may have underestimated the number of alidades that have been replaced (the originals could have made the unequal-hour lines usable), but his overall point is compelling.
[57] It should be emphasised that the options varied widely. Lunar mansions, for example, appear frequently on Islamic astrolabes but also appear on some Western astrolabes, such as Oxford, MHS 46769.

plenty of room for other kinds of equatoria too. It is to this astrolabe-equatorium that we must now turn.

## EQUATORIA ON THE BACKS OF ASTROLABES

Merton College, Oxford, is fortunate to possess two fourteenth-century astrolabes. The later of these has already been mentioned for its rare concentric calendars, and is also noteworthy as another example of modification, in this case the addition of a lunar dial on the back.[58] The earlier is an instrument that has long interested historians. In 1887 Robert Taylor described it as 'the most curious instrument it has been my fortune to see,'[59] and subsequent assessments have expressed similar fascination. Price noted its similarity to the Peterhouse equatorie, and exhibited it alongside his full-scale replica equatorie at a conversazione at the Royal Society in 1952;[60] he also used a picture of it as the frontispiece of his edition of the *Equatorie*, and suggested that it was the 'astrolabium majus' left by Simon Bredon to Merton College in 1372.[61] Its technical features have been discussed in some detail by Emmanuel Poulle, and we shall consider its similarities to John Westwyk's equatorium in chapter 5.[62] So at this point we shall not delve too deeply into aspects of the design of the equatorium, except to address some of the points Poulle raises. What is pertinent here is the way that the technical design has been materialised within the practical constraints of the back of an astrolabe.

The front of the Merton astrolabe-equatorium conforms somewhat to the "Chaucerian" category in terms of the choice and spelling of its star names, and superficially in terms of its roughly Y-shaped rete.[63] However, the most important feature of the front, aside perhaps from the fact that it is for a single latitude (having no separable plates or womb to hold them), is that the maker has placed the usual contents of an astrolabe back on the limb of the front (see figure

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58 It was dated to c. 1390 by R. T. Gunther (1923, 210-212), on the grounds of its similarity to British Museum 1914,0219.1 (no. 6 in King's list), which had been identified as late fourteenth-century on the basis of precession data by Ferguson (1890). The dating has not been challenged, though Gunther suggested that it might be earlier.
59 Taylor (1888), 20.
60 For the circumstances of this event, see Falk (2014).
61 Price (1955b), 129, 155. Bredon's will is printed in Powicke (1931), 82-86; its contents are listed (with some errors) in Gunther (1923), 53-55. It is curious that Gunther, despite noting that Bredon left the largest portion of his library of books and instruments to Merton, did not make this connection; on the other hand, he did suggest that the Oriel astrolabe (no. 5 in King's list), which he 'consider[ed] to be the prototype of the Merton instrument,' 'must have been' 'a part of [Bredon's] bequest,' (p. 208) though Bredon did not leave any instruments to Oriel. For astronomy and astrology at Merton, see Carey (1992), 58-78.
62 Poulle (1980), 200-205.
63 See the table in Gingerich (1987), 98-100. There is some evidence that this instrument was used by the scribe of an early copy of Chaucer's *Astrolabe* (Bodleian Library MS Bodley 619); see Horobin (2009), 111-112; cf. North (1988), 39n2. The rete is actually quite different from the more common Y-shape, as the arms of the Y join above the pole; below the pole there are two strokes that meet the ecliptic at the heads of Virgo and Taurus, whereas the more common Y-shape rete has a single stroke running from the pole to the summer solstice.

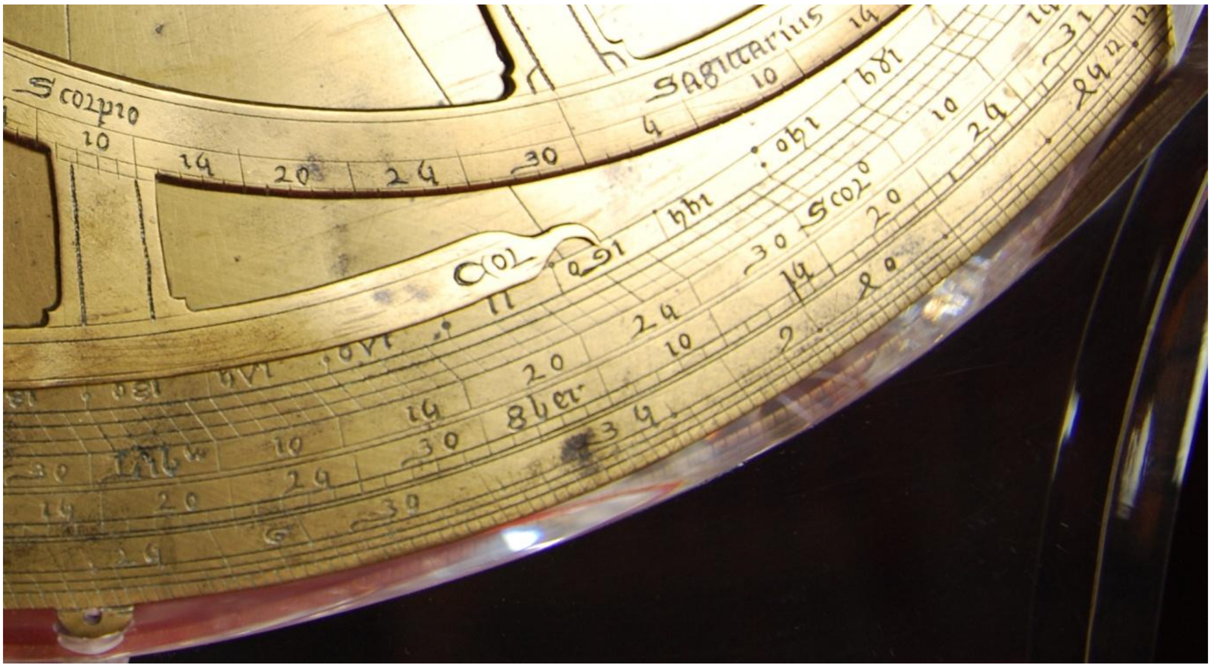

Fig. 16: Detail of limb of Merton astrolabe-equatorium, c. 1350 (Merton SC/OB/AST/2). By permission of the Warden and Fellows of Merton College, Oxford.

16). Working from the outside inwards, they consist of a scale numbered both for measuring altitudes and for shadow-square computation (this was also marked by a later user with some hours in Roman numerals); a concentric calendar of months and days; a scale of zodiac signs and degrees; four circles for use in different years of the leap cycle (a note on the outer limb explains its usage); and an inner scale of 360°, with hour markings every 15°. The outer scale contains 720 divisions but, since angles are measured at the limb using protruding sighting pinnules and a plumb line, they are halved and the scale thus has a precision of quarter-degrees;[64] the numbering reflects this.

The use of sighting pinnules and a plumb-line mirrors the arrangement on Richard of Wallingford's Albion (1326).[65] It is thus not surprising to find that the Albion is one of four instruments cited in a treatise, written in Oxford around 1349, which appears to describe the Merton equatorium, or an instrument much like it.[66] John North described this treatise as 'an outline account of the theory of planetary motion, leading to a barely adequate canon' for the use of three equatoria, attributed to Campanus of Novara (c. 1220-1296), Jean of Lignières (fl. c. 1320), and Profatius Judaeus (Jacob ben Machir ibn Tibbon, c. 1236-c. 1304).[67] North, who was mainly interested in the treatise's allusions to the Albion, did not make the connection between

[64] Not half-degrees, as Gunther (1923, 209) thought.
[65] Richard of Wallingford, 'Tractatus albionis', in North (1976), I. 296, 338-340.
[66] Cambridge University Library Gg.VI.3, ff. 217v-220v (c. 1349); Oxford, Bodleian Library, MS Digby 57 ff. 130r-132v (c. 1375).
[67] North (1976), II. 272. North quotes from the treatise, but his reading of MS Digby 57 is mistaken in a few places.

the text and the Merton equatorium.[68] In contrast, Poulle wrote that the Merton instrument's 'face planétaire correspond parfaitement à un traité d'usages anonyme,' suggesting that the anonymous author may have been William Rede.[69] Both descriptions are useful but insufficient. It is thus worth our pausing to consider some aspects of the text; because it has never been edited, it is transcribed as appendix D.

The text commences with a historical introduction taken (with some changes) from the *Equatorium* of Jean of Lignières; the two treatises share the incipit *Quia nobilissima scientia astronomie*.[70] After this, the treatise is divided into two sections: the first is ostensibly theoretical, while the second part seems more practical. To this extent North's description is correct. However, this dichotomy is highly misleading and overlooks the striking symbiosis between theory and practice represented by the treatise and instrument. The theory is instrumental, in both senses of the word: it is the minimum necessary theory for successful operation of the instrument, directed towards that practical purpose. We see this in the style of explanation; for example, the mean centre of any planet is defined as 'the distance between the apogee of the equant and *a thread* stretched from the equant centre to the epicycle centre.'[71] The author appears quite conscious of this striking blurring of boundaries between Ptolemaic theoretical model and physical instrument, and seems to understand how both work towards increasing understanding. In the final sentence of his introduction, he states that 'through use of the instrument of Campanus, Lignières or [Profatius] Judaeus, the *theorica* may be put forth so that its effect may be sufficiently plain.'[72] The Latin word *theorica* refers to a geometrical model, something already very close to the equatoria that were devised as three-dimensional representations of it. So for the author, the use of the instrument was a vital part of expounding the astronomical theory. Whether 'effect' refers to the instrument's functions or the theory's effects becoming clear is delightfully, perhaps deliberately, ambiguous in that passage. The whole treatise is quite revealing of the role that instruments played in elucidating theories; the very physical description of planetary stations and retrogradations must surely have been written by someone who had an equatorium in front of him. Of course, instruments could perform this function while also providing numerical results for practical purposes.[73]

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68 North (1976, II. 255-256) does discuss similarities between the Merton equatorium and the Albion; see also, with different emphases, North (2005), 357-359.
69 Poulle (1980), 200-201.
70 It was probably for this reason that the Gg.VI.3 scribe identified the text as the *Equatorium* of Jean of Lignières.
71 Gg.VI.3, f. 218r (see appendix D); my emphasis.
72 Gg.VI.3, f. 217v.
73 On this distinction, see Bennett (2003); on its artificiality, see Mosley (2006a); on the potential range of 'practical' purposes, see Maddison (1969), 7-8, 20.

The final introductory sentence (quoted in the previous paragraph) is obviously the source of North's statement that the canons were for the use of the instruments devised by the three named astronomers. The author is concerned to stress the similarity of those instruments, using the singular 'instrumento' in the passage quoted above and, later, writing that 'there is little difference in the method of using them.'[74] However, that was something of an overstatement. The Campanus equatorium was nothing like the others, consisting of a separate instrument for each planet;[75] this was the cause of its great bulk, severely criticised by Jean of Lignières, as we saw earlier, in an introductory passage that our present author copied. Lignières's own equatorium also does not match the description particularly closely, since it does not use equant circles and instead incorporates a separate deferent circle for each planet on its one main plate.[76] Concerning the third instrument, our author's remark that 'Profatius Judaeus, in Montpellier, cleverly composed another equatorium, similar in operation, which is called *semissas*' represents an incorrect attribution: the true author of the *Semissa* was not Profatius, but rather Peter of Saint-Omer (fl. 1289-1308).[77] The attribution to Profatius occurs in several British copies of the *Semissa*, including one in the same codex as the earlier copy of the *Quia nobilissima scientia astronomie*.[78] The semissa is the closest of the three instruments to the description in the *Quia nobilissima scientia astronomie*.[79] However, it differs in having the equant circles on two sides of its main disc ('semissa sphaerarum'). If our author is describing any particular instrument, perhaps it is a fourth, 'the other, newly composed, equatorium,' which he mentions in his conclusion.[80] If so, one wonders why he did not mention it before the final folio, but it may have been because it could not be attributed to a famous inventor, something that was clearly a concern for this and other writers.[81] In any case, the closeness of his description to the Merton equatorium makes it tempting to identify this extant instrument as the new design.[82]

The treatise and instrument were not only close in design, but in time and space. A ready reckoner for precession engraved on the back (figure 17) suggests that the equatorium was made

[74] Gg.VI.3, f. 220v. The two copies of the treatise differ slightly in this respect: in CUL Gg.VI.3, which is probably the earlier copy, a section is headed 'Vera loca omni planetarum . . . per datum instrumentum cognoscere'; but the scribe of Digby 57 changed 'datum instrumentum' to 'instrumenta prius dicta.'
[75] Benjamin and Toomer (1971).
[76] Price (1955b), 125-127, 188-196.
[77] Gg.VI.3, f. 217v; Pedersen (1983), 43. Pedersen has edited the treatise from 22 surviving manuscripts.
[78] Gg.VI.3, ff. 322r-330r. This copy of the *Semissa*, which is incomplete but well illustrated, has been updated for Oxford (f. 324r); the attribution to Profatius (f. 322r) is in a different but contemporary hand to the main text (which is itself different from that of the *Quia nobilissima scientia astronomie*). Cf. Pedersen (1983), 690.
[79] The workings of the *semissa* are explained by Poulle (1980), 205-210.
[80] Gg.VI.3, f. 220v.
[81] We shall note John Westwyk's assiduous citation in chapters 3 and 5 (pp. 84 and 150-152).
[82] It should be admitted that the treatise does not mention the instrument's being constructed on the back of an astrolabe (though it does refer to an astrolabe in two places).

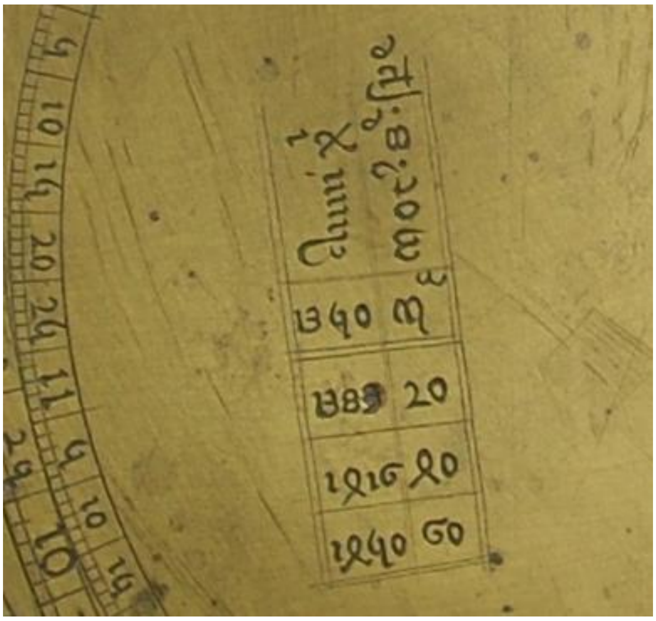

Fig. 17: Ready reckoner for motus of the eighth sphere. Detail from back of Merton astrolabe-equatorium (see also figure 19), c. 1350 (Merton SC/OB/AST/2). By permission of the Warden and Fellows of Merton College, Oxford.

c. 1350; on the front we find 'Lat' 52. 6m. Oxonia'.[83] Meanwhile the two copies of the treatise mention radices and tables computed for 1348 and 1350, at Oxford.[84] It explains the use of these radices and tables, with appropriate techniques for adjustment to different longitudes and interpolation between tabulated values, as a crucial preliminary step before the instrument itself was brought into play.

The first step in its use was to place it on a large, flat table. Here we encounter a further advantage of the use of sighting pinnules on the front. The equatorium clearly had to be horizontal in order for the threads to be carefully moved into position to give the longitudes of the planets, but this meant that when the instrument-maker transferred the features of the back onto the front, he could not incorporate an alidade, as the sights would have prevented its lying flat.[85] The use of pinnules was a neat solution to this problem.

The treatise explains briefly how to use the instrument to compute the longitudes of Saturn, Jupiter, Mars and Venus, before going into greater depth on the more complex procedures for Mercury and the Moon. The instrument included a common epicycle for use with all the planets, a solution also employed on the Peterhouse equatorium. (A comparison of the two designs can be found in chapter 5.) The common epicycle does not survive, but its workings can be reconstructed from the treatise, and numerous scratches on the face of the instrument are testament to its use. The epicycle was connected to the face of the instrument by a common

[83] The more generally accepted latitude of Oxford was 51° 50'.
[84] The earlier copy states that the longitude of Oxford is 18° 'fere ab occidente habitabili', explaining that longitude is 'distantia civitatum a Gadibus Herculis' (Gg.VI.3, f. 218v-219r); the later omits the explanation and the uncertain 'fere', gives a longitude of 15°, and adds a latitude of 51° 56' for Oxford (Digby 57, f. 131r).
[85] That was an option taken by the maker of one "Chaucerian" astrolabe (no. 10 in King's list), as noted above.

deferent radius (see figure 18).[86] One end of this was fixed to the centre of the common epicycle, while the other end was to be pinned to the deferent centre of the desired planet.[87] In the case of Mercury, whose deferent centre moved on a small circle, the treatise describes a circle of 36 small holes, in one of which the nail was placed; this circle of holes survives on the Merton instrument (see figure 19).[88] The common epicycle almost certainly took the form of a ring rather than a disc, so as not to obscure too much of the face of the instrument (not to mention saving materials). The part on which the planets' epicycle radii must have been marked is described simply as the 'true epicycle' (*epiciclus verus*); this might lead one to suppose that the common epicycle could have been a disc with concentric circles for the planets' epicycles, but the way the treatise describes the use of this part makes it more probable that it took the form of a rule.[89] If so, 'true epicycle' is a description of the object's function, rather than its form. Here, too, the boundaries are blurred between description of the constituent parts of the instrument and their roles as symbols in planetary models.

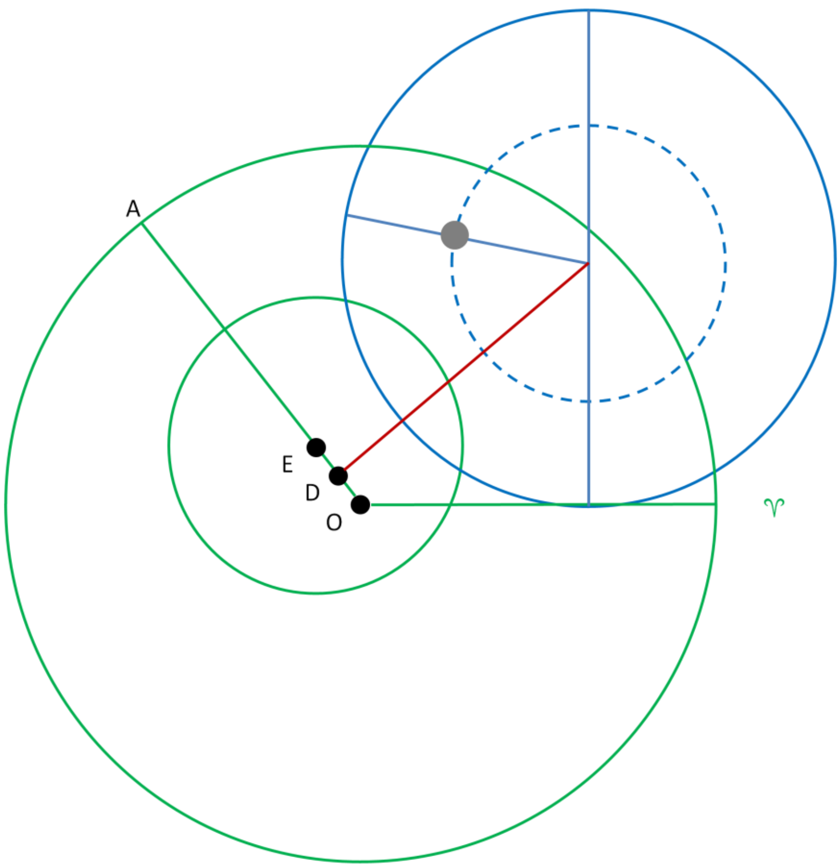


Fig. 18: Diagram of Merton equatorium, showing probable workings of epicycle and common deferent radius (red line).

[86] Gg.VI.3, f. 219v; Poulle (1980, 202) discusses what the length of this must have been, deducing from the deferent centres marked on the face that the maker used some unorthodox parameters.
[87] Gg.VI.3, f. 219v.
[88] Gg.VI.3, f. 219v.
[89] Gg.VI.3, f. 220r.

Fig. 19: Back of Merton astrolabe-equatorium, c. 1350 (Merton SC/OB/AST/2). By permission of the Warden and Fellows of Merton College, Oxford.

As well as the common epicycle, the Merton equatorium is also missing a disc for the more complex model of the Moon. The extant equatorium has holes that might have been used to attach such a disc,[90] and the treatise describes its use. The phrasing of this description, with statements such as 'the plate is fixed to the rule by its wedge,' strongly suggests that the author was describing a particular physical object.[91] This undermines his claim to be writing canons for various different instruments; perhaps we should assume that he added that introductory claim to widen the usefulness of his treatise, without really modifying its main content.

[90] Poulle (1980, 205) suggests that these were placed in error.
[91] Gg.VI.3, f. 220r.

In order to place the common epicycle in the correct position on the face of the equatorium, the Merton design uses the mean centre for each planet. Because these are measured from the planets' apogees, each planet needed a separate graduated equant circle.[92] These circles created problems for the maker and user of the instrument. For the maker, the graduation of eight eccentric circles (for the ecliptic, the eccentric of the Sun, the equants of Mercury, Venus, Mars, Jupiter and Saturn, and the little circle of Mercury) would have been a laborious and error-prone process. Meanwhile for the user of these circles, their visibility would have been reduced when the common epicycle was laid over the face, making the operation of the threads somewhat tricky. Nevertheless, the maker apparently took steps to make the equant circles as readable as possible. First, because their radii are irrelevant to the model, he was able to nest them, making the best possible use of the space on the face of the instrument. Secondly, in order to minimise confusion in the use of the circles and closely clustered deferent centres (where the common deferent radius had to be attached), he labelled each circle with the name of the planet at its apogee. This allowed the apogee, the starting point for laying out the mean centre, to be found quickly. He then ingeniously engraved the labels marking each deferent centre the same way up as the name of each corresponding planet, thus eliminating the possibility of using the wrong deferent centre. Finally, despite their varied sizes, the equant circles are all graduated in 360 degrees and numbered in fives in this way: 5, 10, 15, 20, 25, 1, 5, 10 ,15, 20, 25, 2... This allows numbers of signs to be found easily.

One curious feature of the equant circles is that the instrument has separate circles for the Sun and Venus, and separate holes for the deferent centre of the former and equant centre of the latter, when most readings of the Ptolemaic theory would make them identical. Poulle considered this a weakness of the design, calling it 'hérétique.'[93] But it is quite understandable if we consider that the position of the Sun could be found without the common epicycle (as the treatise explains), so its eccentricity did not need to be scaled to conform to the common deferent radius. If the maker wished to have separate circles to emphasise the separation of the Sun and Venus, he was free to do so; the consequent separation of their centres was surely a small price to pay.[94]

The circles and apogees are of course oriented with respect to the zodiac. But the zodiac

[92] An alternative approach is to use the mean longitude, which is measured from the vernal point. This allowed instrument makers (including John Westwyk, as we shall see in chapter 5) to avoid engraving equant circles, but did require users to translate longitudes measured at the Earth to the appropriate equant centre using parallel threads, which was a potential source of error.
[93] Poulle (1980), 202.
[94] A similar approach was taken for the Peterhouse equatorium: the reader is instructed to lay out the Sun's eccentric with a radius of 30/32 of the common deferent radius used for Venus and the other planets. The centre of the eccentric is displaced from earth by 1/30th of its radius; meanwhile the reader is instructed to find the earth-equant distance for Venus from a set of tables.

could be oriented in any way. The instrument, it should be stressed, was a calculating device, not an observational one, so its orientation was unimportant. And since the corresponding part of the front of the astrolabe was the rete, which turns, there was no obviously symmetrical solution. The invariable practice on astrolabes with eccentric calendars (which, as we have seen, represent a solar equatorium) was to place the Sun's apogee at (or near) the top of the instrument, making an implicit connection between the apogee and the meridian. Since, according to the data in the Alfonsine Tables, the Sun's aux was within 1° of the head of Cancer between 1278 and 1478, this would leave the vernal point (head of Aries), where most calculations began, almost exactly at the "west" point on the right hand side. Most equatorium designers followed this convention.[95] However, the Merton maker chose to place the vernal equinox at the top of the instrument. This divergence from the more common practice suggests two things about his priorities. First, the roughly 18' difference between the aux and the head of Cancer in 1350 was not negligible to him. On the instrument (and in figure 20) we can clearly see that the apogee of the Sun and Venus, where the numbering of their equant circles begins, does not line up with the head of Cancer on the ecliptic scale. Although the ecliptic was only graduated in degrees, a fraction amounting to almost a third of a degree was clearly considered significant by the maker. His awareness of precession is further attested by the presence of the small table engraved on the disc (figure 17), showing the motion of the eighth sphere in increments of 20' at 33-year intervals from 1350 to 1450; the same value is given in the *Quia nobilissima scientia astronomie* treatise, which states that 'the motion of the eighth sphere is almost exactly 1° in 100 years.'[96]

Secondly, taking the focus away from the Sun broke the link between the equatorium and astrolabe: the maker appears to have seen his creation as two quite separate instruments. He

Fig. 20: Detail of limb of Merton astrolabe-equatorium, c. 1350 (Merton SC/OB/AST/2). By permission of the Warden and Fellows of Merton College, Oxford.

[95] See, for example, Museum of the History of Science, Oxford 49847, as well as the Peterhouse equatorie.
[96] Gg.VI.3, f. 220r.

thus rejected any temptation to draw an analogy between the astrolabe's planispheric map of the heavens and the chart in the plane of the ecliptic represented by the equatorium. It seems he saw the equatorium not as a planetarium, but simply as a calculating device. By putting the vernal point at the top of his instrument, the Merton maker ensured that the numbering would start in the same place on both sides.[97] This focus on numbering, rather than the Sun, allows the Merton equatorium to convey a numerical more than spatial understanding of astronomy. This was an instrument that had little to do with stellar observation, and far more to do with computation using data from tables.

The Merton astrolabe-equatorium may have contained two quite separate instruments, but nonetheless it was part of a cohesive, carefully planned whole. The transposition of the scales usually on the back of the instrument to the front, and the use of pinnules rather than an alidade with sights, freed that back to contain a clear, user-friendly calculating device. There were some drawbacks to such a compendium: apart from the limited visibility of the equant circles already mentioned, the holes at the deferent and equant centres, to which the threads and common deferent radius were attached, are pierced right through the instrument; but this is hardly noticeable and does not prevent measurement of altitude and azimuth on the astrolabe. The critical compromise, of course, was in size: at 362 mm in diameter, this instrument is as large as it can possibly be while the astrolabe remains viable for observation; its small throne and the arrangement of the pinnules mean that two people were needed for easy sighting; but as the bear and ram in figure 9 remind us, it was not uncommon for observation to be a collaborative activity. Thus, notwithstanding its current incomplete state, the Merton compendium and treatise are perhaps our best evidence for how the back of an astrolabe could be used as a support for an entirely brass equatorium. The compromise on scale it represents might have been unconscionable for John Westwyk, who demonstrated his priorities by beginning his treatise with an explanation of why size matters. But if he had wanted to save material and increase usability by placing his invention on the back of an astrolabe, the Merton compendium would have served as an excellent model.

### What else might be on the back of an astrolabe?

The author of the canons for the Merton equatorium, apparently concerned to stress the similarities between the instrument he describes and designs attributed to Campanus of Novara, Jean of Lignières and Profatius Judaeus, does not mention that it was on the back of an astrolabe.

[97] The degrees of the zodiac are numbered 1-30 and supplemented by names of signs, but the head of Aries, the vernal equinox, was the conventional start of numbering.

However, one treatise that describes a planetary calculator and does explicitly place it on the back of an astrolabe is the anonymous text with incipit *Motus medii planetarum*. This treatise, which was thought to survive in four copies,[98] has not been satisfactorily dated or attributed. However, I have identified a fifth copy (perhaps unnoticed before now simply because the first two words are transposed), that may allow us to connect it with the early-fifteenth-century French instrument-maker Jean Fusoris. It is transcribed in appendix E.

University of Salamanca Ms. 2621 consists of 175 paper folios (plus three of parchment, added after the codex was foliated), filled with astronomical treatises written in a single fifteenth-century hand.[99] Its scribe clearly had an interest in instruments, since he made copies of several treatises on their construction and use, including the equatorium of Campanus of Novara, the quadrant of Profatius Judaeus, and two anonymous treatises on astrolabes.[100] The inclusion of tables for latitudes 51° and 51° 50' might tempt us to associate it with Oxford, but the presence of two treatises in a mixture of Latin and Dutch, and notes on the difference in longitude between Utrecht and Toledo (and Paris), mean that it was more probably produced in the Low Countries.[101] Guy Beaujouan, who studied the development of Salamanca University (noting the particular influence of English scholars such as Robert Grosseteste) and tracked the tribulations of its manuscripts, speculated that Ms. 2621 was brought to the Colegio de San Bartolomé from Flanders around 1522, but he did not give a reason for that date.[102] The treatise that concerns us now is found on folios 10v-11v. It appears immediately after a table listing stars 'which should be put on an astrolabe.' A note beneath the table states that 'these are the true places of stars in longitude and latitude, computed by Master Jean Fusoris in the year 1428.'[103]

Jean Fusoris is known as a prolific and highly influential astrolabe-maker: 29 of the 150 instruments in David King's 'Ordered List' of pre-1500 Western astrolabes were either made by him or directly influenced by his designs.[104] At the height of his success in the years around 1410 he made instruments for the kings of England and Aragon, and even the Pope, at his workshop

[98] The known copies are Leipzig University MS 1469 ff. 237r-240r; Munich Clm 19689, ff. 162v-164v; Oxford, Corpus Christi College 152, ff. 276v-279r; Wolfenbüttel 2816 ff. 140v-141v. Of these, the last two share an *explicit* with the version in Salamanca Ms. 2621, ff. 10v-11v; the others appear to end one (long) sentence earlier.
[99] Ff. 77-79 are written in a different hand. Lilao Franca and Castrillo González (1997) is a good recent catalogue.
[100] He also copied Qusta ibn Luqa's treatise on the solid sphere, which may be worth noting since Qusta has been suggested as a candidate for the unidentified "Leyk" who seems to be quoted in the first line of the *Equatorie of the Planetis*. But Qusta, who lived in the late ninth century, was surely too early to have written on equatoria (Price (1955b), 165-166). An alternative identification of Leyk will be suggested in chapter 5 (pp. 151-152).
[101] A table of latitudes and longitudes on f. 95v has two entries for Utrecht (the latitudes are 51° 30' and 51° 52'), suggesting that the scribe was particularly concerned for accuracy in this matter. The longitudes are set relative to 'Arim', whose latitude and longitude are given as 0° 0' and 90° 0'.
[102] Beaujouan (1961), 259; Beaujouan (1962), 60.
[103] Universidad de Salamanca Ms. 2621, f. 10r.
[104] King (2011).

in Paris.[105] But far from restricting himself to astrolabes, he was an innovative craftsman who constantly sought to improve his designs and incorporate new devices. This may indeed have been a cause of his great success, as he built a reputation for the unmatched complexity of his productions. Such was his fame that Richard Courtenay, the bishop of Norwich and former chancellor of Oxford University, visited him in 1414 while on a diplomatic mission from Henry V.[106] (The failure of the mission and resumption of hostilities the following year brought Fusoris's English associations under suspicion, and it was from the detailed documentation of his 1416 trial for treason that Emmanuel Poulle was able to reconstruct his career.)[107] Courtenay first came to Paris just after Fusoris had completed an innovative equatorium, and the bishop agreed to purchase it for 400 écus, paying half upfront.[108] The following year Fusoris visited England in search of the balance of the purchase price, perhaps taking with him two astrolabes made for English patrons.[109] Koenraad van Cleempoel has questioned whether Fusoris actually made those astrolabes himself, but they were certainly influenced by his style; what is interesting for us here is that they incorporate an unusual set of equal-hours curves on the back: further evidence of Fusoris's drive to innovate.[110]

Crucially for our understanding of Fusoris, and of astronomy more generally in this period, he not only made instruments, but also wrote about their production and use, critiquing established practices and suggesting refinements. We may first highlight a treatise in French on the construction of the astrolabe which survives in two manuscripts.[111] The treatise does not name Fusoris, but Poulle linked it to him because it contains a table of stars similar to that in Salamanca Ms. 2621. Discussing the back, it explains how to divide the circle of degrees into 360, how to draw an eccentric circle for the calendar scale (it makes the solar eccentricity 1/12$^{th}$ of the radius, surely a copyist's error), and how to produce the shadow square. It gives a partial description of the unequal-hour lines, but does not mention the alidade, so the reader is denied an explanation of how that is to be graduated to make the unequal hours readable. Still, if we accept the attribution to Fusoris, this treatise gives an overview of how a craftsman went about

105 Poulle (1963), 2-5.
106 Poulle, (1963), 3. Poulle calls the bishop "Robert de Courtenay". Davies (2004).
107 Poulle, (1963). The trial documentation was published by Mirot (1900), from Archives Nationales, Paris, LL/85.
108 Mirot (1900), 174, 232. As an indication of how expensive this was, we may note that Fusoris sold four astrolabes, made before his trip to England, for between 24 and 30 écus each (ibid., 245).
109 Courtenay introduced him to Henry V, and he gave the king an astrolabe (Mirot (1900), 174). Carey (1992, 128-137) has discussed this meeting, and the possibility that Fusoris is the author of the treatise on Henry's nativity *Nativitas nocturna*.
110 The astrolabes are National Maritime Museum AST0565 ("the Thornoe Astrolabe"; ICA #337), and Oxford MHS 47674 (#163). See Gunther (1932), 309-311 and addenda; Cleempoel (2005), 138-142. Poulle (1963, 22-25) discusses the Thornoe Astrolabe, but appears to have been unaware of its close relative in Oxford.
111 Vatican Regin. lat. 1337, ff. 121v-135v; Paris BN fr. 1339 ff. 128v-139. It was edited by Poulle (1963, Texte 1).

the process of making an astrolabe in what was probably the first workshop to undertake anything like mass-production of those instruments.

However, a far more interesting treatise is the one in which Fusoris explained the construction and use of his most complex technical challenge: the equatorium.[112] The difficulty of producing what amounted to seven separate brass instruments, which could operate entirely independently of any supporting tables, and which used rules instead of threads, was such that it had taken five years; Fusoris had no intention of repeating the feat.[113] It took him a month to describe the construction process; to this he hurriedly added, at Courtenay's request, a shorter explanation of the uses of the compendium.[114] The treatise is important to our discussion of the backs of astrolabes, because it reveals much about the ways that Fusoris related the different instruments. A particularly severe critique of the astrolabe's standard calendar scales appears when he discusses methods of modelling the Sun's motion:

> The instrument of the Sun can be made in many different ways. The first is the crude method by which it is commonly made on the back of an astrolabe; but it is true that this method suffers from many shortcomings. The first is because the deferent of the Sun and its centre are not moved by the motion of the eighth sphere, but always remain aligned with the same part of the zodiac. The second and larger shortcoming is because that method assumes that the Sun on its deferent traces out the whole zodiac in precisely 365 days, which is not the case.[115]

He goes on to explain that the usual astrolabist's approach of making the instrument for the second year following a leap year is an unsatisfactory approximation, and proposes the addition of marks to the alidade to allow the user to adjust his reading of the calendar for different years in the leap cycle (an approach comparable to the provision of four circles on the limb of the Merton astrolabe-equatorium). However, even this measure is unsatisfactory for Fusoris, since, as he notes, the addition of one intercalary day every four years is excessive (by 1' 46" every four years). To compensate for this, he proposes that the fiducial line of the alidade be filed down, 'just as the zodiac of an astrolabe rete is commonly filed down.'[116] He then goes on to describe a preferable solution, in which the Sun's eccentric is carried on a mobile disc, but here he has tacitly reverted to discussing his equatorium rather than astrolabes. This discussion reveals not only the ways that the boundaries between instruments were blurred in the mind of the craftsman – a useful corrective for historians who too often have considered equatoria as quite separate from astrolabes.[117] It also shows how he saw astrolabes not as fixed or finished, but subject to

[112] This treatise survives in two manuscripts, Paris BN lat. 7295, ff. 22-44v, and 7300A ff. 45v-74v. It was edited by Poulle (1963, Texte 3).
[113] He vowed that he would not make it again for five hundred écus. Mirot (1900), 234.
[114] Poulle (1963), 41-2.
[115] Jean Fusoris, 'Liber primus de motibus planetarum per instrumenta manualiter mota', in Poulle (1963), 150. Cf. the comparisons made by Richard of Wallingford between his Albion instrument and the astrolabe (North 1976), I. 331).
[116] Fusoris, 'Liber primus', in Poulle (1963), 152.
[117] See, for example, the discussion in Arch (2005), 61-64.

adjustment and recalibration; his remark about the common practice of filing down the rete shows that he was not alone in this. And it indicates that he, like others, was aware of the inevitable limitations of some of their traditional features, leaving the way open to experimentation with alternative uses of the back.

The fact that Fusoris critiqued the standard features of the back of the astrolabe and proposed innovative solutions to their deficiencies, and that an instrument providing alternative employment for the back of an astrolabe appears in a manuscript immediately after a table attributed to Fusoris, does not in any way prove that Fusoris created that instrument.[118] But it has been important to give some idea of the creativity of instrument-makers in this period, and an example of the sort of craftsman who might have written the *Medii motus planetarum* treatise. We may now proceed to examine the content of that treatise in more detail, with the aim of further elucidating the purposes which instruments served and, particularly in this case, their relationship with tables.

It was noted above that the *Quia nobilissima scientia astronomie* treatise describes the use of the Merton equatorium with radices and tables of motions, which provided the basic data for computation via the instrument. But as that treatise explained, computation was necessary with the tables too. Readers are instructed how to find the radices of mean motions and adapt them for different longitudes, and then how to use tables of motions in collected (groups of twenty) and expanded (single) years, months, days and hours, taking due account of whether it is a leap year, and interpolating for numbers of minutes that are not explicitly tabulated. We are also instructed how to add these values to each other and to the radix, or to subtract if we are interested in some time in the past. And we are instructed to perform these calculations for the mean centre and mean argument of each planet, taking due account of the motion of the eighth sphere. All in all, the explanation of these preliminary calculations in *Quia nobilissima scientia astronomie* is more than double the length of the explanations of how to compute the true places of the Sun, Venus, Mars, Jupiter and Saturn. And the calculation process described was similarly more time-consuming and more error-prone than the use of the instrument. It is not surprising that contemporaries bemoaned this situation. Even the author of the *Quia nobilissima scientia astronomie*, in an original addition to the introduction he mostly took from Jean of Lignières, bemoaned 'the difficulty, lengthiness and tedium of calculation with tables.'[119]

As we have seen, the Merton equatorium does nothing to ease that time-consuming tedium of tables. But the instrument described in the *Medii motus planetarum* treatise (appendix E) does.

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118 An alternative candidate is John Simonis of Selandia, whose equatorium treatise *Speculum planetarum*, written at Vienne in 1417, appears in the same codex as four of the five copies of *Medii motus planetarum*. For the *Speculum planetarum*, see Poulle (1980), 169-78; on John Simonis, see Pedersen (2008).

119 Gg.VI.3, f. 217v.

The treatise is short, but creative and clear, covering both the construction and use of what is a relatively simple device.[120] As so often, Poulle has explained its workings, leaving us to focus on its significance.[121] It was a device which condensed the tables of daily and annual mean motions of the Sun, Moon, planets and Caput Draconis into a handy dial, which was easy to use and could be placed on the back of an astrolabe. Briefly put, the dial contained a series of concentric circles. Each space between two concentric circles was graduated for the annual or daily mean motion or mean argument of a planet; the graduations all started in the same place but, as each parameter takes a different amount of time to complete one revolution, so each circular graduation was equivalent to a different duration. The whole device was intended to rotate freely on the back of an astrolabe, so that it could be zeroed at the appropriate place on the astrolabe's scale of degrees (which thus functioned as an ecliptic scale); it was read by stretching a thread over the mark for the desired time on each circle, and reading off the corresponding motion on the scale. All in all, the device was an intriguing fusion of tables and instruments. It contained data from tables, arranged spatially in a way that made it something of a diagrammatic planisphere of the Ptolemaic heavens. It was a substitute for tables, yet had something of the durability of an instrument, with its layout representing the eternal circularity of planetary motions.[122] And although it was essentially only strips of data cells arranged around a central point, still perhaps considered a table by its author (his word *tabula* is delightfully ambiguous, able to signify any or all of a board, flat surface or arrangement of data),[123] it also edged from astronomy into cosmology: the circles were arranged from Saturn on the outside to the Moon within, and inside the circle of daily mean lunar motion the author placed the spheres of fire, air, earth and water, perhaps indicating a wider didactic or illustrative intent.[124]

Even if the author considered his creation to be a table, it was not, unlike the Merton equatorium, divorced from the astrolabe that functioned as its support. It not only made use of the astrolabe's 360° scale for both its construction and use; it was laid out with reference to an astrolabe, quartered by diameters whose ends were described as 'meridional', 'midnight', 'western' and 'eastern'.[125] These terms were meaningless in the context of the mean motion dial, but the

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[120] A similar instrument was incorporated into the Albion; see Richard of Wallingford, 'Tractatus albionis', III.4, in North (1976), I. 346-348.
[121] Poulle (1980), 106-110.
[122] If, as the author suggests, the radices were engraved in some spare space on the back of the astrolabe, the need for separate tables could be completely eliminated.
[123] *Dictionary of Medieval Latin from British Sources* (3356-3357). All three senses appear in the longer *Quia nobilissima scientia astronomie* treatise (appendix D).
[124] Curiously, they were placed in that order. Perhaps when the author wrote 'residuum spacium quod est ab intra potes dividere in speram ignis, deinde aeris, deinde terre et quidem spera aquae', the 'quidem' betrayed his realisation that he had accidentally written 'terre' too early, but did not want to emend it (Universidad de Salamanca Ms 2621, f. 11r).
[125] The use of these terms apparently out of context was not uncommon.

author apparently found them useful in thinking about its design. In the same way, he introduced the possible scale of the instrument in the first sentence of the treatise by stating that 'it may also be the same size as a board with almucantars', thus drawing an analogy between the concentric circles on an astrolabe plate and those on his device.[126] More generally, the author highlights his conformity to the conventions of an established genre of instrument treatises, by remarking, for example, that ABCD, which designated the diameter ends, were 'letters often used'.[127] And he expected his reader to be equally familiar with the genre: his injunction that 'the circle of signs is not required on this *tabula*, since it is unnecessary for its use' is clearly aimed at fellow makers who might automatically divide the rim of a circle into 360 degrees because they had not realised that the co-opting of the astrolabe's scale made it unnecessary.[128]

The usefulness and flexibility of the device described in the *Medii motus planetarum* treatise must be what led the treatise to be copied, and its instructions followed, until at least the sixteenth century.[129] Peter Apian was later to incorporate a calendar of mean motions into his lavish *Astronomicum Caesareum* (1540); Fusoris himself had already included such a device in the design of his equatorium compendium. Nevertheless, it should be stressed that the *Medii motus planetarum* treatise does not itself yet describe an equatorium. It did not compute the positions of the planets, but rather was a handy source of the basic data necessary for such computation. Some of this data is already simplified: the device has no scale of annual motion for the Sun's mean argument, which implies that the Sun starts from the same point each year. This disregard of variations in the leap-year cycle would not have satisfied all astronomers, including the maker of the Merton astrolabe-equatorium: as we have seen, that instrument did account for those variations. And the fact that Jean Fusoris discussed the problems of the leap cycle with reference to astrolabe calendars might be taken as evidence against his authorship of this treatise. But his output was highly varied: his critique of astrolabe calendars did not stop him producing dozens of them. Both master of medicine and master craftsman, he was surely more aware than most astronomers of the equilibrium to be found between precision and economy of time and material.

The range of ways in which planetary devices could be presented on the backs of astrolabes should, by now, have given the impression that astronomers and craftsmen had an array of

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126 Ms. 2621, f. 10v (see appendix E).
127 Ms. 2621, f. 10v.
128 Ms. 2621, f. 10v.
129 Oxford, Corpus Christi College MS 152, f. 276v-279r, copied by the court astronomer Nicolaus Kratzer c. 1523. See Thomson (2011). On Kratzer, see North (1978). A device operating on similar lines survives on the back of a sinecal quadrant (made c. 1500) at the Museum of the History of Science, Oxford, inv. 16856.

options when designing and making instruments. Yet although the range of output from a single craftsman such as Jean Fusoris is telling, extant instruments and treatises describing a single device rarely present explicit evidence of choices being made in the design process. It is a paradox of this genre that, while it was common practice to modify existing instruments, treatises always present them as finished. Nevertheless, careful reading does indicate that instrument-makers were aware of the variety of options at their disposal. We see the author of *Medii motus planetarum* catering for the abilities and preferences of his readers when he instructs them to 'make a widely spaced circle, in which you can write the names of months and of whichever feast days you wish.'[130] The choice of which religious feast days to include in the calendar was one way in which the makers of otherwise conventional astrolabes could personalise their creations; a number of surviving instruments feature the days of unusual, regionally specific saints alongside those that appeared in the standard Sarum calendar.[131] Still greater flexibility is offered by the final sentence that appears in three of the five copies of the treatise.[132] Here the author envisages an alternative instrument with two figures (*figurae*) which 'can be made on one *tabula*.'[133] The first of these would be the planetary device described in the treatise; the second an equivalent instrument to give the locations and relative positions of places on earth. The astrolabe has disappeared, yet its conventional layout is referenced in the way the two instruments are summarised: 'according to convention, since just as one [side] measures the heavens, the other measures the earth.'[134] In exactly the same way, the front of an astrolabe with its net of stars looked towards the heavens, while the back, with its calendar of feast days and surveyor's shadow square, represented terrestrial things. The interrelationship of different instruments was such that mental vestiges seem to persist even after all physical traces were removed.

Still, even if we accept both that instrument-makers had a range of options and were fully aware of those options, there remains the question of how they made their choices. This is an issue on which the surviving texts and objects are silent; they are likewise silent on the related issue of how or by whom the diversification of instrument design was driven. Detailed consideration of these issues is outside the scope of this chapter, but the astronomers and designs we have examined permit some brief speculation. The constraints of materials and space were clearly a decision-making factor, as the Merton astrolabe-equatorium testifies. As we have seen, every aspect of it speaks of careful choices to create space on the back and make the best possible use of it. And the accompanying *Quia nobilissima scientia astronomie* treatise highlights an

130 Ms 2621, f. 10v.
131 Davis and Lowne (2015); Falk (2012), 29-35 and appendix B.
132 Oxford, Corpus Christi College MS 152; Wolfenbüttel 2816; Salamanca Ms. 2621.
133 Ms. 2621, f. 11v.
134 Ms. 2621, f. 11v.

oft-ignored motivation for this: the desire to represent, elucidate and perhaps teach astronomical theories. Of course practical concerns must also have played their part, as the time-saving potential of the planetary calendar described in *Medii motus planetarum* amply illustrates. Such practical concerns of use were balanced by the practical concerns of sale; we must not forget that at least some of these designs were made and sold, or were intended to be. The saints' days on Gonville and Caius Astrolabe B (no. 1 in David King's list) can be linked with the particular religious and geographical interests of the college founder Edmund Gonville (d. 1351), suggesting that it was made to that purchaser's specifications.[135] On the other hand, the writings of Jean Fusoris show his pursuit of both improved design and money; surely where there was a potential for competitive advantage, innovation could be supplier-driven. Yet if we accept Fusoris's account of his dealings with the bishop of Norwich, and his unwillingness to make a second equatorium even for five hundred écus, we must believe that money was not his sole concern.[136] Rather, his writings suggest the pursuit of innovation for its own sake. This tendency can be seen across mathematical disciplines; for example, hand diagrams used in manuscripts to illustrate finger-calculating methods show constant innovation across the Middle Ages, as each scholar tried to invent his own method or improve existing ones.[137] It could be argued that the variety in the surviving astrolabes from this period, which has become clear through our examination of their backs, indicates the same drive towards innovation for its own sake.

## Conclusion

The innovation we have identified in medieval instrument design was to continue, and indeed accelerate, in the early modern period. Western astrolabes from the sixteenth century show striking diversity, and publications on the astrolabe peaked in the years 1510-60.[138] There was a later peak in the 1590s, perhaps reflecting renewed interest in time-telling devices as a result of the Gregorian calendar reform. The seventeenth century was to see a marked decline in astrolabe production, but this was accompanied by maximal innovation,[139] as makers strove to adapt to the increasingly accepted Copernican cosmology,[140] or to affect a somewhat neutral stance by including a universal projection on the back. Even as makers moved away from astrolabes, their legacy persisted: it is apparent, for example, in the design of John Holland's brass

[135] Davis and Lowne (2015), 271-276.
[136] Mirot (1900), 234.
[137] Murdoch (1984), 79-80.
[138] Turner (2005), 31.
[139] For quantitative analysis of these trends, see de Soysa (2000), 8-10.
[140] See, for example, John Blagrave's *Astrolabium Uranicum generale* (1596).

logarithmic scale and horizontal instrument, made in 1650.[141]

This chapter's analysis of the backs of astrolabes, whether used as supports for planetary instruments or for other purposes, has wider implications for the way we view instruments. Those we have examined blur the boundaries between presentation and computation of data, between demonstration of theories and practical observation, between astronomy and cosmology. This should encourage us to reconsider the sometimes narrow categories which have been imposed to help historians understand the nature and purpose of texts and objects, but which can end up hindering our understanding. Mosley has stressed 'how much interpretation of a single instrument depends upon the construction of a history of the class of objects of which it is an example.'[142] By examining a selection of instruments, both physical and described, this chapter has sought to examine and question the classes of astrolabes and equatoria.

More generally, identification of instruments that function as tables or guides to theories blurs the text-instrument boundary. A text can be an instrument; a *theorica* can sometimes seem as tactile as a physical model; a brass or wood object might be little different from a diagram.[143] This is important not so much for our definitions as for our understanding of how medieval astronomers saw texts and objects.[144] For example, the question of why so few physical equatoria survive, in contrast to the many surviving treatises describing them, is complicated if blurring of categories makes that contrast invalid. Likewise, the question of whether or how accurately the diagrams in *A Treatise on the Astrolabe* depict a single instrument, or which came first: diagrams or instrument, is complicated if the diagrams are themselves in some way an instrument. The fact that Campanus of Novara's description of his equatorium was known simply as a *Theorica planetarum* highlights immediately the mixed meaning of the first word, and the fact that texts may not be all they seem: some that appear theoretical have a great deal to tell us about instruments, while others that describe instruments in very specific terms could have had a predominantly theoretical, pedagogical purpose.

These insights have implications for museum practices. The separation of text from object is perhaps an inevitable consequence of the way that museums build and display their collections, but its effects on our understanding should be acknowledged. In this case, the tendency to treat astrolabes as, in Jordanova's words, 'decontextualised commodities' hides both the variety of

141 Whipple Museum of the History of Science, Cambridge, Wh.1029.
142 Mosley (2006b), 317.
143 I have previously discussed the text-instrument relationship with reference to astrolabes in Falk (2012), 6-7.
144 The problematic status of an instrument may have been a factor in the increasing use of the word *organum* instead of *instrumentum* to describe a man-made scientific object from the late sixteenth century onwards (see, for example, Galileo's description of his telescope in *Sidereus Nuncius*). Other explanations include the intellectual appeal of Greek. For a brief historical overview of uses of the two words in this context, see Golvers (2003), 106-108.

ways that they were used, and their mutability.[145] These instruments might also be called 'detextualised commodities', and the impact of this detextualisation is again to conceal the choices made at every stage of their existence by their designers, makers and modifiers. Understanding these points allows us to re-examine categories such as "Chaucerian" astrolabes, and to consider that in a context of (hitherto underestimated) flexibility and innovation, rather than highlighting differences between instruments, we should be surprised to find any similarities at all.

Such considerations bring us back to the point that began this chapter: that in this area of material culture, it might be helpful to adopt an insight that manuscript studies itself took from material culture – the importance of supports. Here, finally, we may begin to approach the question that has been implicit throughout this chapter: why did John Westwyk choose not to place his equatorium on the back of an astrolabe? The analysis above suggests several answers. If, as the practical nature of the treatise suggests, Westwyk intended the equatorie to be made, he must have considered the possible supports that could be used.[146] This is not purely a craft question, but goes to the heart of the purpose of any planetary calculator. The practical benefits of saving time, effort and material by using the back of a portable astrolabe must have been balanced against the precision achievable with a larger, less portable instrument. Theoretical or pedagogical considerations, including the link between the two instruments, must have been considered. The same design could serve multiple purposes, but one or more of those purposes could be prioritised by the mode of presentation. We saw at the start of this chapter that Westwyk began his treatise by foregrounding the link between size and precision, and in later chapters we shall see further evidence that he envisaged the equatorie as an instrument of practical calculation: the larger, the better. The same design could serve multiple purposes, but one or more of those purposes could be prioritised by the mode of presentation. Thinking through these complex relationships should bring us to a deeper understanding of what was in the minds – and hands – of medieval astronomers when they designed, described, made, modified and used instruments.

145 Jordanova (1989), 25.
146 Evidence of the practical nature of the treatise will be presented in the following chapter.

# CHAPTER THREE

## Late medieval language choice: the scientific vernacular and John Westwyk

The *Equatorie of the Planetis* was, according to Larry D. Benson, 'the most important work to be proposed for inclusion in the [Chaucer] canon in recent years.'[1] That proposal was made by Derek Price, whose attention was first arrested by the fact that, despite the Latin incipit cited in the library catalogue, 'nearly every page was dated 1392 and written in Middle English instead of Latin . . . The conclusion was inescapable that this text must have had something to do with Chaucer.'[2] Yet research since Price's time has shown that he should not have been surprised to find an instrument treatise in the vernacular, even in a codex that began in Latin. By the time the *Equatorie* manuscript was composed in the early 1390s, writing in English was neither new nor unusual: the vernacular was used and accepted for many purposes in varied contexts.[3] These included scientific writing.[4] That was not a monolithic genre, and it is plain that some sciences were more susceptible to vernacularisation than others.[5] But a number of studies have now shown that astronomical and technical writing were among the areas in which the use of English was coming into full flower in the time of John Westwyk.[6]

This does not, of course, mean that English supplanted Latin. Historians once wrote of the 'triumph of English': the expansion of vernacular usage in all written contexts as an inevitable part of the construction of a national self-identity in the century of the Hundred Years' War.[7] But, as the *Equatorie* manuscript itself exemplifies, Latin and English coexisted within manuscripts and genres, often in ways which demonstrate that code-mixing and code-switching were deliberate and effective discourse strategies.[8] The interaction and cross-fertilisation of languages was not restricted to English and Latin, but also involved French, Hebrew and others.[9]

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[1] Benson (1988), xxiii. Benson, like F. N. Robinson (1957, viii-ix) before him, remained reluctant to accept the *Equatorie* into the canon.
[2] Price (1975), 27. Price was presumably using M. R. James's *Descriptive Catalogue of the Manuscripts in the Library of Peterhouse* (1899); this gives the Latin incipit to the codex, but does also note that the treatise beginning on f. 71v is in English.
[3] A sense of the range of the vernacular by this period is given in *The Idea of the Vernacular: An Anthology of Middle English Literary Theory, 1280-1520*, ed. Jocelyn Wogan-Browne et al. (1999); the subtitle of this anthology belies the variety of its contents.
[4] This has been amply shown by the many manuscripts assembled by Linda Ehrsam Voigts and Patricia Deery Kurtz for their database of *Scientific and Medical Writings in Old and Middle English* (eVK2), accessible at http://cctr1.umkc.edu/search. The project is explained in Voigts (1995b).
[5] Pahta and Taavitsainen (2004).
[6] Voigts (1989); Voigts (2004). John Hagge (1990) addresses particular attention to the genre of technical writing, critiquing a number of recent historians who have accepted uncritically R. T. Gunther's (1929, v) assertion that Chaucer's Astrolabe was 'the oldest work written in English upon an elaborate scientific instrument.'
[7] Cottle (1969); Trevelyan (1963), I. 1-3.
[8] Voigts (1996); Pahta (2004).
[9] On the variety of languages used in medieval England, see Clanchy (1993), 200-206.

Language choice was clearly contingent on subject matter, at least in part.[10] Since Price's remark that 'vernacular writers on science in England during the fourteenth century seem to have been preoccupied with instrumental tracts', the assumption that vernacular writers existed as a separate category has been exploded.[11] Instead, we may reverse Price's formulation and ask why scholars writing about instruments frequently chose to do so in the vernacular. In order to answer this question, it will be necessary to examine the precise nature of the technical and scientific texts that are frequently lumped together by historians who pay little or no attention to the subtle differences in their content and the aims of their writers. Likewise, it will also be necessary to critically examine even the basic statement that such texts are in English, paying attention not only to their macaronic mixture of languages, but to the liminal linguistic status of much of the technical vocabulary used at a time when English was developing rapidly to meet the needs of its users.

Against this changed historiographical background, it is worth examining the question of why John Westwyk composed his *Equatorie of the Planetis* – mostly – in English. Study of this treatise's language has hitherto almost always approached it through the question of authorship, drawing comparisons and contrasts with Chaucer's *Treatise on the Astrolabe*.[12] Now that we know the *Equatorie* is not by Chaucer, we may assess its author's linguistic choices in their own right. Now we know that author's biographical details, the treatise has much broader value as evidence of the contexts and purposes of the use of the vernacular. Since Westwyk does not justify his choice of language, conclusions must be tentative, but can be supported by reference to other, similar, documents written in English and Latin (a language in which he was plainly proficient). Those documents will, because of its multiple ties to the *Equatorie*, include the *Treatise on the Astrolabe*, but this chapter will look beyond the *Astrolabe* and its well-known justifications for the use of English. In fact, it is important to provide a corrective to any assumption that the *Astrolabe* is alone in justifying its use of English, or that the reasons Chaucer gives are the only possible ones.[13] It will be shown in this chapter that the motivations for writing in English were more complex than has sometimes been thought, as is the supposed genre of technical writing into which the *Equatorie* falls.

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[10] Voigts (1989). It is worthwhile to compare language choice in other genres; see, for example, Dodd (2011).
[11] Price (1960), 401.
[12] See, for example, Benson (1992); Partridge (1992).
[13] As the editors of the anthology *The Idea of the Vernacular* argue in justifying placing the focus of their excerpts away from Chaucer, 'the internationalist high-culture tradition he represents is less pivotal to the development of written English and of *theorizing* in and about English than is often thought.' Wogan-Browne et al. (1999), xvi (their emphasis).

## WESTWYK'S NAKED WORDES: SITUATING THE AUTHOR

In order to assess the motivations of the monk John Westwyk for writing the *Equatorie of the Planetis* in English, we must first be sure that the act of language choice was his, and not that of some previous writer whose text he was copying. The notion that the *Equatorie* is a holograph has been questioned by some scholars, but the arguments in its favour are overwhelming.[14] The appearance of the treatise in a single scribal hand, free of copying errors and with multiple emendations and additions suggestive of an editing process, makes it highly likely that the unique exemplar in Peterhouse MS 75.I is in the hand of the person who composed it. This does not mean that it was an entirely original composition: technical texts like this one rarely were wholly original, and when they appear in English it is prudent to assume that non-English sources underlie them.[15] The Latin additions and glosses John Westwyk inserted in his draft text suggest that it may be at least a partial translation, but that is immaterial to the question at hand, which is, independently of any sources, why he chose to write it in English.

The *Equatorie*'s long association with Geoffrey Chaucer meant that this question was, until recently, rarely asked: writing in English was just what Chaucer did. And scholars seeking concrete reasons could simply refer to the fluent justification he gave in the prologue to the *Treatise on the Astrolabe*. But where doubt has arisen as to Chaucer's authorship of the *Equatorie*, so has the question of language choice. It has hitherto been asked most explicitly by A. S. G. Edwards and Linne Mooney, who wondered 'who, with the wealth to possess such an instrument – and such a book of instructions to explain it – would require that those instructions be written in English? (As he explained in the prologue, Chaucer Englished the instructions on the astrolabe only in deference to Lewis's age: 'for Latyn canst thou yit but small, my litel sone.')'[16] Edwards and Mooney, like all other scholars, do not give any detailed answer to the question, suggesting merely that 'it was made for private use by the scribe rather than for any systematic dissemination.'[17] This suggestion will be challenged below (as will their assumption that the *Astrolabe* really was written for an audience of one). But first it is important to cement the principle that a choice of languages did exist. Whether or not the *Equatorie* is translated from Latin, its author could certainly read and write fluently in that language. This is evident both in Peterhouse MS 75.I, which apart from the Latin glosses interspersed within the treatise also

[14] The arguments on both sides are summarised by Rand Schmidt (1993), 15-27. Perhaps the strongest opposition is in Edwards and Mooney (1991), but their arguments are convincingly rebutted by Rand Schmidt.
[15] Jones (1990).
[16] Edwards and Mooney (1991), 37. Their quotation is from 'A Treatise on the Astrolabe', Prologue, lines 27-28, in Chaucer (1988), 662.
[17] Edwards and Mooney (1991), 37. Mooney (1999, 145) later suggested that it must have been written by or for a member of the court circle.

contains longer canons amongst the tables, and, of course, in Westwyk's compilation of Richard of Wallingford's *Albion* and *Rectangulus* treatises, discussed in chapter 1 of this thesis.[18]

Recent scholarship has demonstrated that writers in this period had the authorial self-awareness to make a conscious choice of language, and exercised that choice in ways that took full advantage of its political, cultural and symbolic significance.[19] Such significances of course varied, but some of the associations of English included its status as a syntactically straightforward, easily intelligible language that, notwithstanding its relative crudity, was less susceptible to trickery than Latin; its immediacy and naturalness as the spoken 'mother tongue' of the people; and its flexibility as a melting pot in which words and their cultural associations could be co-opted wholesale from other languages. Ruth Evans et al. argue that for many writers in this period, besides its important implications for accessibility to readers, 'the vernacular [was] a sign of the natural, of truth, plainness, and emotional directness, of the physical or embodied and the socially situated itself, and can function as such even in texts whose use of English is technical, abstract, and far from plain.'[20] It could be argued further that such a function of the vernacular was especially useful in technical texts such as the *Equatorie*, where a display of clarity and openness might be particularly attractive for an author seeking to defend himself against any accusation that the text is inaccessible. Thus Chaucer announces his intention to explain the astrolabe 'under full light reules and naked wordes in Englissh.'[21] 'Naked' here may have some negative connotations, conveying the suggestion that English might be thought incapable of communicating the full complexities of a scientific treatise, by contrast with the 'subtile conclusiouns' expressible in Latin,[22] but Chaucer was almost certainly being ironically self-deprecating: apologies for the roughness of the language were a popular trend in vernacular writing of this period, and should not be taken at face value.[23] The same self-deprecation is employed by John Westwyk when he excuses a perfectly serviceable diagram of his instrument (figure 21) with 'I wot wel it is figured boistosly.'[24] ['I know it is roughly drawn.']

The complex potential readings of 'naked wordes' are explored by Andrew Cole, who uses the phrase to support his contention that Chaucer's work exhibits the influence of Wycliffite texts.[25] As Cole explains, while Wyclif used the word 'naked' in one positive sense, denoting preaching that did not distract the listeners with extraneous fables (a metaphor that, as 'nudis

[18] See, for example, Peterhouse MS 75.I, ff. 3v and 7r.
[19] Evans et al. (1999).
[20] Evans et al. (1999), 330.
[21] 'A Treatise on the Astrolabe', Prologue, lines 26-27, in Chaucer (1988), 662.
[22] 'A Treatise on the Astrolabe', Prologue, line 53, in Chaucer (1988), 662.
[23] Taylor (1999).
[24] Peterhouse MS 75.I, f. 73v.
[25] Cole (2002). See also Cole (2008).

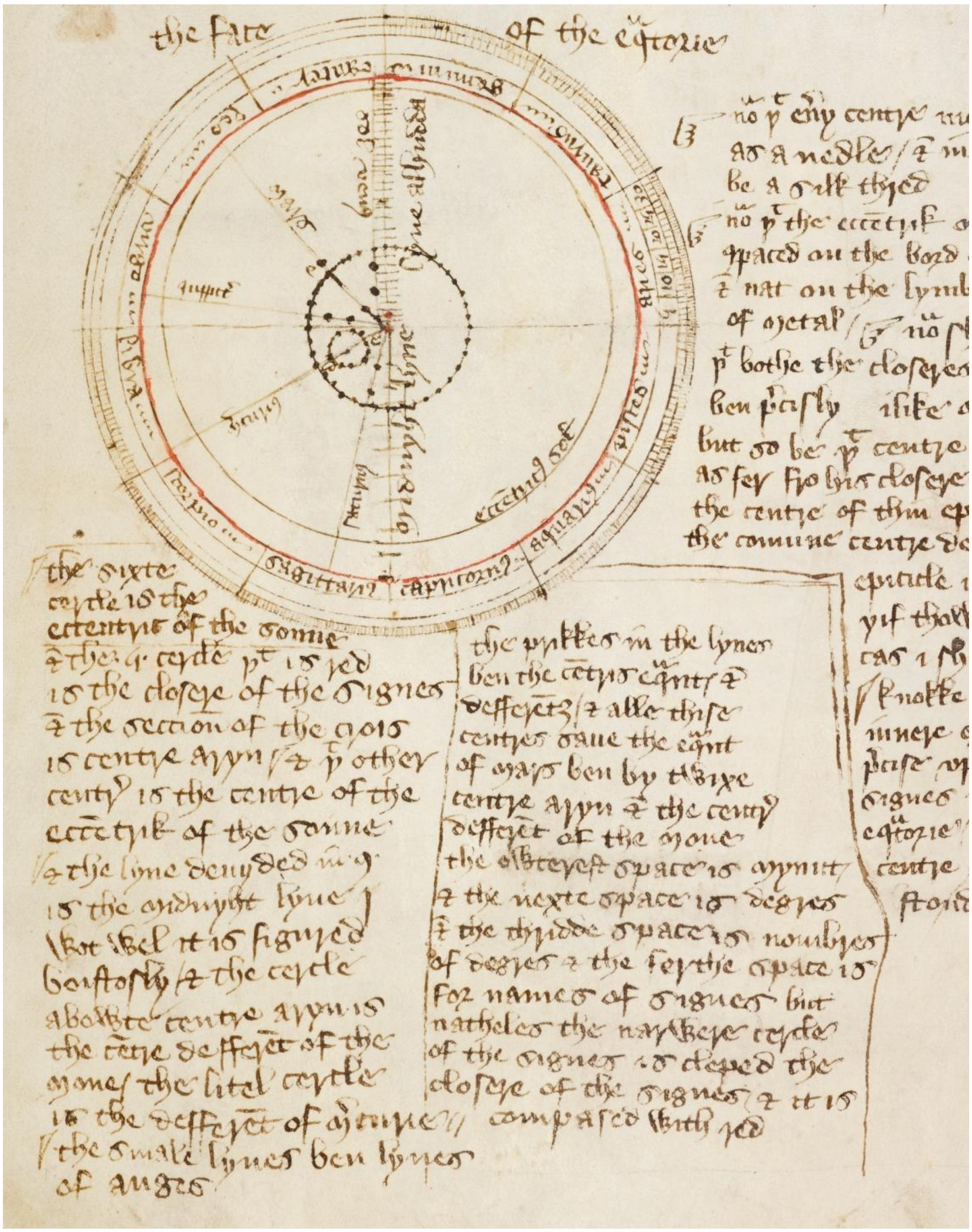

Fig. 21: The face of the equatorie. Peterhouse, Cambridge MS 75.I, f. 73v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

verbis', had a long pedigree), in general the Wycliffites used the phrase 'naked wordes' to condemn arguments that were not based on scripture or experience or, at the other extreme, that employed an excessively literal reading of scripture; words could also be 'naked' if they were unaccompanied by actions. Meanwhile the image of nakedness was also used to condemn the Wycliffites for disregarding established authorities.[26] Cole convincingly argues that a writer in any educated setting – whether at court like Chaucer or, for our purposes, in the monastic environment where John Westwyk spent most of his life – could not have been unaware of the import of a phrase like 'naked wordes', as well as others that echo Wycliffite writings in similar

[26] Cole (2002), 1141-1148.

ways. The significance of this for understanding of the *Equatorie* and other technical treatises is that, even for material apparently unrelated in subject matter, we must consider that the choice to write in English had inescapable religious associations.[27] This is particularly likely in the claustral setting occupied by Westwyk: as we saw in chapter 1, scholarly activities like glossing and copying were papally promoted as pious labour; by extension, the act of translation or adaptation may well have represented a pastoral, charitable service of dissemination.[28]

It must be noted that Cole's argument for the direct influence of the Wycliffite General Prologue on the composition of the *Treatise on the Astrolabe* is weakened by the fact that the former is usually dated to 1395-97, the latter to 1391.[29] Cole suggests that the echoes of the Wycliffite General Prologue audible in Chaucer's Prologue may be sufficient evidence for redating the latter to the mid-1390s, but he does not take full account of the astronomical data inserted by an author who was clearly proficient in that art.[30] It is fair to point out, as Cole does, that the Prologue was probably written last, and that references to 12 March 1391 in the *Astrolabe* are merely examples and do not indicate the precise date when the author completed his work.[31] But an astronomer who took pride in his ability would not use an antiquated example when a more up-to-date one was just as easy to obtain.[32] John North, seeking to propose that the *Astrolabe* and *Equatorie* were drafted at around the same time in 1393, emphasised that the cycle of leap years meant that the 1391 examples remained useful until early 1395, but even if we use North's *terminus ante quem*, that would probably not be late enough for Cole's argument of direct influence.[33] Moreover, stronger evidence for an earlier dating of the *Astrolabe* is supplied by the comment in the *Equatorie* that a line on the equatorium 'is cleped [called] in the tretis of the astrelabie the midnyht line.'[34] There were, of course, other treatises on the astrolabe, but none that we know of in English, and the fact that Chaucer's *Astrolabe* indeed uses that English phrase, and that elsewhere in the manuscript John Westwyk cites Chaucer explicitly, suggests that the *Treatise on the Astrolabe* was composed before the *Equatorie*, for which a plausible date of

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27 This is not to suggest that writing in English was necessarily a marker of heterodoxy. In fact, even in devotional writing matters were more complicated, as Amanda Moss (2011) has shown. But the potential connotations were certainly there.
28 Getz (1990). Park (2011) explores the linguistic and theological relationship between diligent observation and devout observance.
29 Hudson (1978), 173-74; Dove (2007), 110-112; Reidy (1988), 1092.
30 Cole (2002), 1154-1155.
31 'A Treatise on the Astrolabe', II.1, II.3, in Chaucer (1988), 669-670. It should be noted that the dates of examples do vary slightly between manuscript copies of the *Astrolabe*. See Chaucer (2002), 169-181.
32 Many descriptive treatises of this kind update their examples even where little else is changed. Westwyk did this himself in his copy of Richard of Wallingford's *Tractatus albionis* (Laud Misc. 657, discussed in chapter 1); see also the two copies of the equatorium treatise *Quia nobilissima scientia astronomie* in Cambridge University Library MS Gg.VI.3, ff. 217v-220v, and Bodleian Library MS Digby 57, ff. 130r-132v (appendix D, discussed in chapter 2 of this thesis).
33 North (1988), 63, 175-176.
34 Peterhouse MS 75.I, f. 72v.

composition is sometime in the first nine months of 1393.[35] Cole's argument may thus be weakened, but this actually makes it more relevant to our discussion of the *Equatorie*. The Wycliffite General Prologue may have come too late to influence either that treatise or the *Astrolabe*, but the exegetical turns of phrase it incorporates were already in the air in the early 1390s.[36]

It would be something of a leap to conclude that Westwyk was motivated to write in English solely by spiritual concerns, but it does seem likely that he was aware of the religious connotations of his choice of language. Moreover, English had other implications. For example, Chaucer dedicated the *Astrolabe* to 'the king, that is lord of this langage', thus explicitly making his act of translation a statement of national identity and pledge of fealty.[37] It is not valid to conclude, from the fact that Chaucer was almost certainly making a political statement by his use of English, that the language of the *Equatorie* reflects similar political concerns. However, one might note that Westwyk had been at St Albans, where many monks made royal connections; that his whereabouts after a disastrous crusading expedition to Flanders in 1383 are unknown; and that ten years later he was writing astronomical tables for London on unusually large sheets of parchment; and one might therefore speculate that he had some association with the royal court.[38] Be that as it may, it is reasonable to assume that Westwyk was conscious of the multifaceted implications of his choice of language, and of how it reflected on him as its author.

Moreover, the association between John Westwyk's *Equatorie* and Geoffrey Chaucer's *Astrolabe* is more than merely circumstantial. It has already been mentioned that Westwyk quotes from 'the tretis of the astrelabie', and refers to Chaucer by name. The presence of Chaucer's name was long considered the strongest evidence for his authorship of the manuscript; it was what convinced North to reverse his earlier verdict on the issue.[39] The name appears in a note on folio 5v (see figure 1), amongst the tables that comprise the bulk of the manuscript, which gives in sexagesimal notation the number of days in 1392 (Julian) years, with the label 'deffe[a] xpi & R[x]a chaucer' – the difference between [the era of] Christ and the radix of Chaucer. North argued that since the computation of such radices was 'a trifling matter', it would have been nonsensical to cite a source for this datum, and thence that this note, which is in the same hand

[35] 'A Treatise on the Astrolabe', I.4, in Chaucer (1988), 664. *The Riverside Chaucer* uses the spelling 'midnyght', but a variety of forms (including 'midnyht') are used in early-fifteenth-century copies of the treatise. Peterhouse MS 75.I, f. 5v; North (1988), 171, drew attention to a note on f. 5v of Peterhouse MS 75.I indicating that the entry of the Sun into Libra in 1393 (14 September) was in the future.

[36] Dove (2007, 32) considers Cole's suggestion 'an interesting possibility, [but] Chaucer's prologue is so allusive that it is hard to be sure of anything except that he is showing awareness of the Bible debate.'

[37] 'A Treatise on the Astrolabe', Prologue, lines 56-57, in Chaucer (1988), 662; Lerer (2004).

[38] Rand (2015), 10-11; Clark (2004), 23. Most of the tables in Peterhouse MS 75.I are in Westwyk's hand, and almost all of those are for the latitude and/or meridian of London.

[39] North (1969), 433-436; North (1988), 169-181.

as the *Equatorie* treatise, must have been written by Chaucer himself.[40] However, as we shall see in chapter 5, closer attention to Westwyk's radices suggests that perhaps for him they were not so trifling as North supposed. More importantly, Peterhouse MS 75.I as a whole reveals that Westwyk was in the habit of citing authorities for his data. These include Arzachel (al-Zarqālī), the eleventh-century Toledan inventor of the *saphea*, on whose writings Westwyk had drawn in his commentary on the *Tractatus albionis*;[41] Profatius, who, as we saw in chapter 2, was also cited (incorrectly) in the *Quia nobilissima scientia astronomie* treatise;[42] and 'R. B.', possibly Roger Bacon, who was known to have drawn up astronomical tables, and is cited in identical terms in other scientific manuscripts of this period.[43] Perhaps most striking is Westwyk's attribution of a small table of planetary positions to 'J. Somer, oxonia' (figure 22), undoubtedly the same 'reverent clerk' John Somer cited by Chaucer as a source for his own tables.[44] That Chaucer joined this list of illustrious instrument- and table-makers is testament to the respect with which Westwyk must have viewed him.[45] This being the case, it may be argued that not only was John Westwyk subject to the same intellectual influences as Chaucer, as suggested above; Westwyk may well also have been directly influenced by Chaucer in his choice of language. If so, the reference quoted above becomes more than just a passing allusion. Rather, by explicitly using the same terminology –

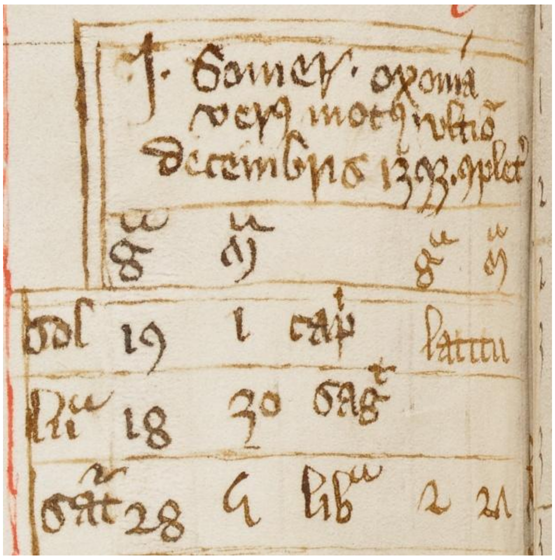

Fig. 22: Heading of table of planetary positions attributed to John Somer. Peterhouse, Cambridge MS 75.I, f. 63v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

[40] North (1988), 173.
[41] Peterhouse MS 75.I, f. 64r; Millás Vallicrosa (1943).
[42] Peterhouse MS 75.I, f. 70r.
[43] Peterhouse MS 75.I, f. 64r; Bacon (1897), 208-210. Voigts (1990) examines use of the initials 'R. B.' in three related scientific manuscripts, and suggests that they most likely refer to Roger Bacon.
[44] Peterhouse MS 75.I, f. 63v; 'A Treatise on the Astrolabe', Prologue, line 85, in Chaucer (1988), 663; Somer (1998); O'Boyle (2005) assesses the widespread influence of Somer's tables. Somer is also cited several times in Bodleian Library MS Laud Misc 674; Voigts (2010) discussed this manuscript and places Somer in his Franciscan context.
[45] Westwyk's placement of this little table on a page facing a table of solar declinations, and Chaucer's promise that the third part – probably never written – of his *Treatise on the Astrolabe* would contain 'tables of the declinacions of the sonne, . . . and many anothir notable conclusioun after the kalenders of the reverent clerkes, Frere J. Somer and Frere N. Lenne' (663), makes it tempting to suggest that Westwyk set out to complete Chaucer's project, but at this stage there is insufficient evidence to support such an argument.

'the midnyht line' – as the *Astrolabe*, John Westwyk was situating himself within a new tradition, drawing on the burgeoning authority of Chaucer's vernacular astronomy.[46] Westwyk makes no apology for his use of English, but only for the roughness of his diagrams; this does not mean that he felt no qualms about it – indeed, there is some evidence to suggest that expressions of anxiety about English became *topoi*, increasing in proportion to the language's acceptability – but the fact remains that, unlike Chaucer, he made no attempt to justify it.[47] If the *Astrolabe* motivated not only Westwyk's choice of language but also his self-presentation as an author, that is an important point about Chaucer's influence that has not hitherto been sufficiently recognised.

## TIME AND PLACE: JOHN WESTWYK'S NAMELESS SELF-IDENTIFICATION

So how did John Westwyk want to be viewed? And what does it mean to call him the author of a treatise that he may have at least partly translated? Authorship is sometimes thought to be synonymous with ownership: taking (or being assigned) responsibility for a work, generally by stating the author's name.[48] Even if we accept this equivalence, responsibility was a subtle assignment in medieval writing, and could be assumed by someone undertaking a range of different activities.[49] Chaucer, of course, had avoided it in the *Astrolabe*, casting himself as 'a lewd compilator,' ostensibly in order to slay envy.[50] John Gower, on the other hand, might be seen as claiming it by commissioning presentation copies of his works, making an effort to ensure they were copied accurately.[51] On other occasions Gower was more circumspect, conscious of the association between *auctor* and *auctoritas*: a claim to authorship might be read as placing oneself alongside the fathers, or even the ultimate *auctoritas*: God.[52] This is why he closes the *Vox clamantis* with the disclaimer 'but I did not write these verses in a book as an author[ity]; but am merely transmitting what I have heard for you to read.'[53] The definition of an author as an Aristotelian efficient cause was a popular one in late medieval scholastic commentaries, which

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46 Peterhouse MS 75.I, f. 72v. It should be noted that the popular astrolabe treatise attributed to Māshā'allāh ibn Atharī, which was (in Latin translation) Chaucer's main source, refers to 'linea . . . dicitur angulus terre et medie noctis.' Māshā'allāh (tr. anon.), 'De operatione vel utilitate astrolabii', II, in Gunther (1929), 217. It is possible that Westwyk (or his Latin source) adapted the phrase from Māshā'allāh, but given Westwyk's reference to Chaucer and use of identical phraseology, Chaucer's treatise seems the more likely source.

47 Taylor (1999).

48 See, for example, Foucault (1979).

49 See Taylor (1999), 4-5; Finkelstein and McCleery (2013), 67-70. Conti (2012, 270-272), notes that autonomous authorship also assumes a level of control over the way a written work is read and interpreted.

50 'A Treatise on the Astrolabe', Prologue, lines 66-64, in Chaucer (1988), 662. This contrasts with his attitude elsewhere; he famously acted with the authority of an author in rebuking his copyist Adam. See 'Chaucers wordes unto Adam, his owne scriveyn', in Chaucer (1988), 650; see also Mooney (2006).

51 Taylor (1999), 15.

52 Minnis (1984), 94-117, 181-186.

53 'Vox clamantis', VII.1445-1446, in Gower (1902), 312.

often divided that efficient cause into two or more levels, and here Gower appears to identify himself as an instrumental efficient cause, suggesting that God remains the primary efficient cause.[54]

Perhaps the clearest explanation of the efficient causes of a written work was that of the Franciscan St Bonaventure (c. 1250). Asking in his commentary on Peter Lombard's *Sentences* 'What is the efficient cause or author of this book?', Bonaventure concludes:

> There are four ways of making a book. Sometimes a man writes the materials of others, neither adding nor changing anything; and this person is said to be merely a scribe [*scriptor*]. Sometimes a man writes the materials of others, adding, but not his own material; and this person is called a compiler [*compilator*]. Sometimes a man writes both the materials of others, and his own, but those of others are primary, with his own added for clarification, and this person is called a commentator [*commentator*], not an author. Sometimes a man writes both the materials of others and his own, but his own are primary, and the materials of others are added for confirmation; and such a man must be called an author [*auctor*].[55]

We should immediately note that, by Bonaventure's definition, even an author does not write solely his own materials, but always incorporates the work of earlier scholars; a book was necessarily a collaborative enterprise. And the passage as a whole reveals that medieval ways of thinking about the responsibility for making books were utterly unlike modern notions of authorship. All four of the categories in Bonaventure's scheme are making books; all are responsible.[56] Nevertheless, there are clearly differences between the categories, and John Westwyk can be placed in various roles in his two known works. As we saw in chapter 1, in Bodleian Library MS Laud Misc. 657, he was a straightforward *scriptor* of Richard of Wallingford's *Rectangulus* treatise, but a *commentator* of the *Tractatus albionis*. In the latter, and in the manuscript as a whole, he was also a *compilator*. But he claims no responsibility or ownership of the text: his name appears on the first folio, but only as the donor of the manuscript.[57]

In Peterhouse MS 75.I, on the other hand, Westwyk positions himself as *auctor*. He may not have given his name, but he certainly makes his authorial presence felt throughout the manuscript.[58] The *Equatorie* is probably a partial translation, as we shall see, but it is perhaps noteworthy that Bonaventure's scheme does not define a *translator*: medieval translation was an activity that often involved substantial originality or adaptation.[59] And the creative process involved in translation into English undoubtedly allowed him to assert a degree of authorial

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[54] Minnis (1984), 173-174.
[55] St Bonaventure, 'In librum primum sententiarum', Proemium, Quaestio iv, in Bonaventure (1882), I. 14-15. On these categories and their interpretation, see Burrow (1982), 29-31; Minnis (1984), 94; Taavitsainen (2004).
[56] Matters were indeed often more complicated, as scribes often made deliberate changes in the process of copying. See Burrow (1982), 30-31; Conti (2012), 276-288.
[57] MS Laud Misc. 657, f. 1v.
[58] It is possible, of course, that Westwyk was identified as author or compiler on a folio or folios now lost from Peterhouse MS 75.I. There is some evidence of missing leaves in the manuscript (see Rand Schmidt (1993), 103-107), but the location of these gives no reason to suspect that Westwyk identified himself on those.
[59] On the variability of translations and the unhelpful concept of "faithfulness", see Wellendorf (2012), 303-308.

independence. As no source text for the *Equatorie* is known to be extant, we cannot know precisely how many changes Westwyk made, but some idea of the freedom felt by translators can be gleaned from a glance at the *Treatise on the Astrolabe*. Chaucer, too, does not name his sources, but the principal one was certainly (pseudo-) Māshā'allāh; however, Chaucer followed the well-worn path of St Jerome in translating *sensum de sensu*.[60] Eisner remarks that 'Chaucer gently refines his source when he translates . . . adapt[ing] his material to a purpose that includes explication, clarity of exposition, and foremost attention to the requirements of the listener or reader.'[61] The possible listeners or readers of the *Equatorie* will be discussed below, but for now we should note that Eisner might have added the purpose of asserting himself as the work's author, a purpose that is clear from the *Astrolabe*'s Prologue. Translation into a new language undoubtedly facilitated this.[62]

John Westwyk identifies himself not by name, but by time and place. Such parameters are integral to the tables that comprise the bulk of the manuscript, but they were not essential in the equatorium treatise. Yet on its first page the author declares that 'myn equatorie ... was compowned the yer of Crist 1392 complet, the laste meridie of decembre', and on the facing page he cites the apogee of Saturn at London at the same date, thus locating himself in (or near) the city at that time.[63] We do not need to read this as a literal description of a craftsman engraving the final mark of a planet's epicycle at noon on new year's eve to see that the author is here stamping his own imprint on the work he is translating. This practice of emphasizing one's own historical situation while transmitting a timeless work was common practice among medieval translators; as with Chaucer's examples from 1391, we cannot assume that dates were inserted thoughtlessly.[64] Westwyk was perhaps not making a deliberate political point through his use of the vernacular, but the process of translation and compilation, bringing together a personal selection of texts and tables in this manuscript, was a concrete statement of authorship.[65] Writing in the vernacular was integral to this.

60 St Jerome, letter to Pammachius, quoted in Bellos (2012), 104. Bellos uses Jerome's famous self-justification as the starting-point for a fierce critique of the 'lop-sided dispute' between "literal" and "free" translation.
61 Eisner (1985), 198. It should be noted that some of the additions Eisner claims that Chaucer made to Sacrobosco's *De sphaera*, another source text for the *Astrolabe*, are in fact in Sacrobosco's original; Eisner may have been misled by using Lynn Thorndike's terse translation (see Thorndike (1949), 91, 126, cited in Eisner (1985, 197-198).
62 Andrew Butcher (2011) has explored how translation allowed multiple authors to assert themselves in a range of registers within a single text. See also Pahta (2004).
63 Peterhouse MS 75.I, ff. 71v, 72r.
64 Evans (1999b) suggests that language choice gave authors an opportunity to expose power relations and reveal historical discontinuities.
65 Butcher (2011, 306) argues that composite texts could become 'potential source[s] of change and even resistance.'

'NOTA: I CONSEILE THE...': THE AUDIENCE FOR ENGLISH

Nonetheless, few scholars would dispute that, in making a choice of language, concerns about the potential audience for a text outweighed any statements the author might wish to make for or about himself. And the *Equatorie of the Planetis* certainly was written for an audience other than the author himself. When Westwyk writes 'Note: I advise you not to write in the names of the Signs until you have checked that your common deferent centre is correctly and accurately placed on the Encloser of Signs on your equatorium', this can only be read as a word of advice from someone who has had the experience of constructing this equatorium and wants his reader(s) to learn from his mistakes.[66] The didactic intent displayed in the treatise will be discussed below, but for now it must be stressed that the *Equatorie* was written in English to be read in English.

It has been suggested that the *Treatise on the Astrolabe* is unique among technical treatises in providing for both students and non-academic practitioners.[67] But I would argue that this was precisely John Westwyk's intention too. The ways in which these dual audiences were catered for will be explored below, but the point here is that English was the language in which they could best be addressed. And it was a language with a broad base: recent scholarship has shown that by the fourteenth century there was an established literate public, keen to engage with texts on subjects ranging from chivalry to gynaecology, in the vernacular as well as Latin.[68] That public included laypeople in the extended communities of the monasteries of St Albans and Tynemouth, where Westwyk spent most of his life; it also included some people within such communities who perhaps should have known Latin but did not.[69] There is ample evidence of clerks and monks struggling with the language, including at St Albans, and even the theologian and bishop of Chichester Reginald Pecock composed in English for later translation into Latin.[70] We have seen that John Westwyk was perfectly able to read and write in Latin, but it is quite possible that he translated or composed the *Equatorie* as an act of Christian charity for readers who could not. Perhaps he had a specific person or people in mind: friendship was frequently invoked as a reason for composing treatises, including by Chaucer himself.[71] The direct address to the reader that occurs throughout the *Equatorie* certainly gives the impression that the author could picture his reader and knew where he might make mistakes. And it was almost certainly "he". Works were often translated into the vernacular for women religious, who were equated with the laity as

[66] Peterhouse MS 75.I, f. 74r (see appendix A for original Middle English).
[67] Mead (2006).
[68] Clanchy (1993), 1, 15, 201; Havely (2000), 260-262; Watson (1999), 350.
[69] Clark (2004), 72-78; North (1976), II. 95. It should be noted that the extended communities of St Albans and Tynemouth must have been very different in size and nature. Texts produced at the latter, rather isolated, community were very probably for internal use only. On Tynemouth, see Rand (2015), 7-9; Craster (1907).
[70] Walsingham (1867), II. 114 (written in the early 1390s); James (2011).
[71] 'A Treatise on the Astrolabe', Prologue, lines 6-8, in Chaucer (1988), 662; Laird (2007).

target audiences; the vernacular was sometimes seen as symbolically female as a result.[72] But the physical requirements of this craft text make a male reader far more likely.

But just as Chaucer's *Astrolabe* is now widely accepted to have been written for an audience beyond Litel Lowis, so the *Equatorie*'s author may well have had a wider readership in mind. There is a sense in which a readership for astronomical texts in the vernacular could be called into being by the production of such texts.[73] Writing in what Pecock called 'the comoun peplis langage' would not only make the text accessible to a great number of readers, especially in secular settings such as the court;[74] it would also make it accessible to an even greater number of listeners, for whom literacy was a collective attribute.[75] Writings in this period were often read aloud; even many literate people had works read to them as a matter of preference. Granted, such aloud reading was more likely to consist of romances than technical works containing diagrams, but the fact that the *Equatorie* was in English would have made it possible for an illiterate craftsman to follow its instructions by having it read to him; he could still glance at the diagrams, to which Westwyk explicitly draws his attention in the text.[76]

It might be objected that the less educated groups described above could not be expected to understand what has been described as 'a technical treatise on a rare, complex instrument', of interest only to 'professional astronomers, university academics, or medical astrologers.'[77] The supposed difficulty of the astronomical theories, and the challenges involved in the construction and use of such instruments, are popular themes among the Chaucer scholars who have ventured into this area.[78] But needless to say it is quite wrong for such scholars to project their own scientific frailties onto medieval readers.[79] In consigning the *Astrolabe* to a readership made up of 'the "Merton school" of scientists' and 'scientifically minded amateurs', Derek Pearsall is placing

72 Watson (1999), 343.
73 Ruth Evans (1999a, 111), employs Louis Althusser's concept of 'interpellation'. Brian Stock (1983, 522) observes that 'where there are texts, there are also presumably groups to study them.'
74 On Pecock's use of that term and 'modiris langage', see James (2011), 110-117.
75 Evans (1999a), 113.
76 Peterhouse MS 75.I, ff. 73v, 74r. The same link between image and text is found in many early copies of the *Astrolabe*. Nevertheless, it should be remembered that such diagrams were understood quite differently from the way images in textbooks are used today. On the complex functions of visual representations of instruments in a slightly later period, see the essays in Jardine and Fay (2014), especially the contribution by Higton.
77 Arch (2005), 62-63.
78 See, for example, Pearsall (1992), who describes the *Equatorie* as 'alarmingly technical' (219); Laird (2007), 441-442. Laird suggests that it was in the hope of expanding the select group of astronomical savants that Chaucer wrote the *Treatise on the Astrolabe*.
79 It must be noted that the technical misunderstandings of some Chaucer scholars make anyone familiar with the basic features of an astrolabe doubtful of their ability to judge his *Treatise*. George Ovitt (1987), for example, having mis-placed the womb on the back of the instrument and erroneously described the rete as one of the 'thynne plates compowned for diverse clymates' ('A Treatise on the Astrolabe', I.3), goes on to critique Chaucer's definition of the equinoxes as 'somewhat ambiguous' (42, 45). It is not: Ovitt has confused the Heads of Aries and Libra with the entire Signs.

readers into anachronistic categories.[80] Astronomy and astrology were popular and widely understood throughout this period; there is good reason to believe that the *Equatorie* would have been within the technical capabilities of a large number of readers.[81] And these could certainly have included members of monastic communities: the large number of copies of the *Astrolabe* associated with religious houses is testament to interest in that text in such settings.[82] We might also note that there were many other apparently more complex texts in monasteries (as we saw in chapter 1), but here we should be chary of judging complexity. For example, almost a quarter of the *Equatorie* treatise is dedicated to explaining the method for computing the latitude of the Moon, a method which to modern readers seems very simple in comparison with other parts of the treatise.[83] It is perfectly possible that scientific content which strikes us as troublesome might have been straightforward for a medieval reader, and vice versa. We should therefore not leap to conclusions about how educated a reader of the *Equatorie of the Planetis* would have to have been.

## WHAT WAS ENGLISH FOR? THE DOMAINS OF THE *EQUATORIE OF THE PLANETIS*

It should be clear, then, that there are likely to have been readers who could understand the astronomical content of the *Equatorie of the Planetis* but who would appreciate its being composed in English. Yet historians who would continue to argue for some medieval version of "two cultures" might quite reasonably point to the fact that the vernacular was slower to be adopted for writing with a broadly astronomical content, at least in comparison with other subjects.[84] If John Westwyk bucked this trend, it must have been because the advantages of writing in English – its accessibility for both author and audience, its suitability for particular purposes or contexts, and any ideological or religious motivations – outweighed the advantages of writing in Latin.

We can discern four such potential advantages. In the first place, Latin was the language of the universities.[85] These were the main sites for astronomical study and the production of astronomical treatises. In the century when the *Equatorie* was written, the outstanding setting within England for this work was Merton College, Oxford, and astronomers of the "Merton school" such as John Maudith, William Rede and Richard of Wallingford worked in Latin.[86] Secondly, the work of such men, which invariably had their names attached to it as testament to

[80] Pearsall (1992), 217-218.
[81] Carey (1992, 3-17) discusses the wide appeal of astrology.
[82] Horobin (2009), 121-124. Horobin tracks Bodleian Library MS Bodley 619 between Oxford and the Benedictine priory of Great Malvern, showing how popular texts could travel between different settings. See also Eagleton (2003).
[83] Peterhouse MS 75.I, ff. 77r-78v; North (1988), 168.
[84] Pahta and Taavitsainen (2004).
[85] Verger (2000).
[86] Gunther (1923), 42-65. Richard of Wallingford was claimed by Merton but, as a Benedictine monk from the south of England, must have attended Gloucester College (North (2005), 38-39).

the authoritative quality of the tables they produced, helped lend cultural authority to the language they used. Latin was the language of authoritative astronomical work in a way that went beyond university habit; it was the language of scholastic thought.[87] Thirdly, the use of Latin eliminated cultural differences: very useful in a field with pretensions to universal appeal and applicability. The use of Latin made astronomical works more likely to be transmitted across national boundaries. In an era when all western Christian astronomers doffed their caps to the authority of Toledo, in the form of the Alfonsine Tables that had been filtered through Paris, the possibilities for dissemination of their work must have occurred to every astronomer; even tables produced for specific locations could have a wider influence, if they incorporated new methods of computation or presentation. An astronomer who invented or refined an instrument would have even more reason to consider this possibility. And finally, all these reasons to an extent negated one of the advantages of the vernacular: its supposed comprehensibility. While in many genres the potential utility or audience of a work could be widened by writing in English, in the world of international astronomy that function was performed by Latin. While in some circumstances, such as the world of craftsmen, the wealth of technical terminology in English made it more comprehensible than Latin, in astronomy, with its Greco-Latin vocabulary, the situation was reversed. Why did John Westwyk reject such advantages?

Even if Westwyk had at one time studied at Oxford, he was probably not there when the *Equatorie of the Planetis* was written.[88] As for the potential for transmission for his text, this surely depended on authorial ambition; we shall see shortly what appear to have been John Westwyk's purposes in writing. For now, we may challenge the applicability of the (undoubtedly correct) assertion that Latin was the authoritative and comprehensible language of astronomy, by questioning to what extent works like the *Equatorie* and *Astrolabe were* astronomy. Again, we must take issue with the simplistic categories imposed by some historians and Chaucer scholars who assume that these technical treatises are monolithic in their content; rather, several domains often cohabit the same text.[89] Although Peterhouse MS 75.I is clearly the work of a single man – every section is either wholly in Westwyk's hand, or was annotated by him – it is not easily assigned to a single genre or domain. Part of it – the tables of planetary motions computed according to Ptolemaic models – is undoubtedly astronomical. Meanwhile, the horoscope and accompanying commentary Westwyk copied from a text by Māshā'allāh might be better called astrological, while Westwyk's tables of ascensions, houses and the like might be somewhere between the two.[90] The

[87] Evans (1999b), 366.
[88] See discussion in chapter 1 (p. 21 and n74).
[89] Voigts (1996) discusses the use of the linguistic concept of "domains" to analyse language mixing in medieval contexts.
[90] For details of the horoscope and its source, the *Liber Messahale de receptione*, see Kennedy (1959).

guidance on the use of the table of proportions is perhaps mainly mathematical, while the painstakingly precise worked examples for the latitude of the Moon might be better categorised apart from their subject matter as examples of pedagogical writing. Finally, of course, the instructions for the assembly of a large wood and brass object must be called craft writing.

That, surely, is why Westwyk wrote canons to the tables in Latin: this was indisputably the language of pure astronomy. (The ciphered text that also occurs amongst the tables is perhaps a genre unto itself.) The tables have various sources, but many of them are linked with Oxford and with the '1348' tables that were compiled there, perhaps by the Merton astronomer Simon Bredon.[91] Such tables formed the bulk of the (extant) output of astronomers such as Maudith and Rede, and it is hardly surprising that what few words they contained were in Latin. But Westwyk faced a different choice when he came to write his equatorium treatise. This bears striking features of two domains – pedagogy and craft writing – in which English was ideally suited to the communication of ideas and information to Westwyk's chosen audience.

## PRACTICAL AND PEDAGOGICAL PURPOSES

The fact that the *Equatorie* treatise discusses the construction and use of an astronomical instrument does not in itself make the treatise practical. As we saw in the last chapter, instrument treatises could be theoretical, especially where they were little more than explanations of how to reproduce Ptolemaic diagrams with movable parts.[92] The blurred boundaries between texts and instruments, between *theoricae* as theories and as geometrical or physical models, between instruments for illustration or for practice, help explain why, as Chaucer recognised, Latin was still the default choice of language for 'eny commune tretys of the astrelabie' – or other instrument.[93] Yet sometimes the contents of treatises can allow their purpose to be defined with more confidence. They were practical when they dealt more with concrete measurements than geometrical ratios, and included apparatus that was more functional than abstract: fewer majuscule letters denoting points in a diagram; more nails.

This was certainly the case with the *Equatorie of the Planetis*. Unlike many instrument treatises, in which sparse Euclidian descriptions of construction methods read like thought experiments, and which devote little attention to the practicalities of manufacture, the *Equatorie* is

[91] North (1988), 187-191; North (1977), 269–301. North believes the most likely author of the 1348 tables was the Oxford astronomer William Batecombe, about whom little is known. The tables are discussed in chapter 5 of this thesis.
[92] North (1976), II. 261.
[93] 'A Treatise on the Astrolabe', Prologue, lines 54-55, in Chaucer (1988), 662.

an intensely practically focused work.[94] John Westwyk not only listed appropriate (if somewhat ambitious) dimensions for the parts of his equatorium; he gave thought to how they could best be explained. For example, presumably realising that his instruction to 'tak thanne a cercle of metal that be 2 enche of brede, and that the hole dyametre contene the forseide 72 enches or 6 fote', could refer either to a ring two inches wide, or a cylinder two inches high, he corrected it to read 'tak thanne a cercle of metal that be 2 enche of brede, and that the hole dyametre with in this cercle shal contene 68 enches or 5 fote and 8 enches,' thus making his meaning unambiguous (see figure 23).[95] In the same way, while other authors could be thought to refer to materials merely in passing, or perhaps to help readers imagine their instrument more easily, Westwyk discusses them with the functional detail of a craftsman. His first instruction is to make a wooden disc 72 inches in diameter, and he shows his awareness of the potential difficulties of making and using such a large board by adding 'the whiche rownde bord for it shal nat werpe ne krooke, the egge of the circumference shal be bownde with a plate of yren in maner of a karte whel. This bord yif the likith may be vernissed or elles glewed with perchemyn for honestye.'[96] It is clear that he had already made the instrument himself at a smaller scale, as he laments that 'the centre defferent of mercurie hath but 24 holes as in myn instrment'; he had earlier suggested with practical flexibility that this circle of Mercury's mobile deferent centre should be pierced 'in 360 holes yif it be possible or in 180 or in 90 atte leste.'[97] The treatise is full of practical suggestions for a reader who will use the instructions to make the equatorium. We have already observed Westwyk warning the reader not to engrave the names of the Signs before one has confirmed that the basic frame of the instrument is correctly shaped. And Westwyk was even able to anticipate and mend his reader's mistakes, writing 'yif thow myshappe in this cas i shal teche the aremedie: knokke thi centre defferent innere or owtre til it stonde precise up on the closere of the signes in the lymbe of thin equatorie.'[98]

That is far from the only place where John Westwyk is explicitly teaching his reader. It is

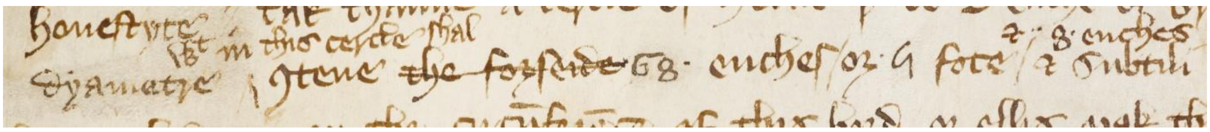

Fig. 23: Corrections made by John Westwyk to his instructions. Peterhouse, Cambridge MS 75.I, f. 71v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

[94] Compare, for example, the equatorium (*Theorica planetarum*) of Campanus of Novara, in Benjamin and Toomer (1971). Campanus's contemporaries were well aware that the construction of his equatorium was impracticable, as we saw in chapter 2.
[95] Peterhouse MS 75.I, f. 71v.
[96] Peterhouse MS 75.I, f. 71v.
[97] Peterhouse MS 75.I, ff. 76r, 72v.
[98] Peterhouse MS 75.I, f. 73v. 'if you make this mistake, I shall teach you a remedy: knock your [common] deferent centre further in or further out until it stands exactly on the Encloser of Signs on the limb of your equatorium'.

all too easy to ascribe pedagogical intent to technical treatises, since a well written technical text must by nature be somewhat didactic: it must have a clear meaning, invulnerable to alternative readings, important or unfamiliar terms should be defined, and so on.[99] But for a text to be truly pedagogical, rather than merely instructive, it should go beyond allowing the reader to reach a practical result (successfully producing an instrument, for example): there must be the further aim to allow the reader to truly understand what he is doing, enabling him to see why each part of the assemblage under construction takes the form that it does, and giving him the potential to make adjustments to the design. Although Chaucer's *Treatise on the Astrolabe* does not deal with the construction of an astrolabe (a task considerably more difficult than making an equatorium, despite the planetary instrument's greater theoretical complexity), it is still a practical treatise, and its pedagogical intent is undeniable. Likewise, when in its opening sentence the *Equatorie* informs the reader that 'the largere that thow makest this instrument, the largere ben thi devisiouns; the largere that ben tho devisiouns, in hem may ben mo smale fracciouns; and evere the mo of smale fracciouns, the ner the trowthe of thy conclusiouns,' the didactic intent is made plain.[100] It is not enough for John Westwyk that his reader make the equatorium 72 inches in diameter: he wants him to understand why. Throughout the treatise the reader is addressed directly in this way; the examples we have already seen demonstrate how Westwyk methodically builds a personal rapport with his reader. In the next chapter we shall see further examples that demonstrate how Westwyk's vernacular behaviour facilitated this outcome.

Such practical and pedagogical intent is unusual in vernacular treatises; it is almost unheard-of in Latin. As an illustration, let us examine an item common to the majority of instrument treatises: the instruction to draw and divide a circle into four quadrants. Among the countless manuscripts in which that instruction appears, parallel Latin and English versions survive in an early-fifteenth-century sundial text in University of Aberdeen MS 123. The translator of this text took the original instruction 'Describe circulum diametris eius ortogonaliter se intersecantibus supra centrum E. Et sint diametri AB & CD' and rendered it in English as follows: 'Fyrst make acercle with a cumpas of what quantyte ye lyk and devyde ye forsayd cercle eviyn in to 4 quarters wyth 2 lynys crossand tham self in the centre of the forsayd cercle and calle the ton lyne AB and the tother lyne CD.'[101] This translation is noticeably more wordy than the original, incorporating the practical advice to use a compass and noting that the size does not matter, while omitting to

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[99] Eisner (1985), 179-180. Bernard and Proust (2014) critique historians' assumptions of pedagogical purposes in texts.
[100] Peterhouse MS 75.I, f. 71v.
[101] University of Aberdeen MS 123, f. 66v. Orthography has been edited in the same way as with Peterhouse MS 75.I. A full diplomatic transcription can be found in appendix F.

designate the centre of the circle as E.[102] But it maintains many of the same details, including the rest of the initial letters that were so popular in Latin treatises. The *Equatorie*, by contrast, evinces a quite different approach:

> tak thanne a cercle of metal that be 2 enche of brede . . . and subtili lat this cercle be nayle up on the circumference of this bord or ellis mak this cercle of glewed perchemyn. This cercle wole I clepe the lymbe of myn equatorie . . . this lymbe shaltow devyde in 4 quarters by 2 diametral lynes in maner of the lymbe of a comune astrelabye and lok thy croys be trewe proved by geometrical conclusioun.'[103]

This is a practical rather than geometrical treatise: initial letters are eschewed in favour of examples of possible materials and explicit instructions about size. Technical terms are defined using the personal, oral phrase 'I clepe' [call], explained by analogy with objects already familiar to the reader, and repeated so that they stick in the mind of the student. Here, as is most common in the treatise, the explicatory simile is to an astrolabe, but in other places homely objects like a cartwheel or needle are referenced. And we are given a useful tip to ensure that our two diameters are perpendicular. This is a model of practical, pedagogical prose.

Of course many of the features just noted stem at least in part from the author's personal style and purposes, and are somewhat independent of the language used. But there were ways in which Westwyk's style was facilitated by his use of English. A more practical approach, and use of craft terminology, was often easier, or even unavoidable, in the vernacular. For example, the Latin word "ortogonaliter" had no vernacular equivalent (the words "orthogonal" and "orthogonally" did not appear in English until the sixteenth century), which may explain why, in the passage quoted above, the Aberdeen translator replaced that one word with the explanation that the diameters should divide the circle evenly into four quarters.[104] A little later in the same treatise, the translator renders the instruction 'protrahe lineam . . . ortogonaliter' by 'drawe a lyne streght up and down.'[105] This circumlocution gives a less geometrical, more practical sense. Similarly, direct address to the reader, which helps Westwyk build a personal rapport with his audience, is facilitated by the explicit subject pronouns used in English. Since Latin is a null-subject language; the subject of the verb is only indicated by the conjugation of the verb.[106] The variety in Latin conjugation means that the subject is almost always identifiable, but nonetheless it does draw attention away from the actor. The use of the vernacular creates a more personal effect and, in particular, allows the author to emphasise his presence in the text.

[102] A similar freedom is apparent in the translated canons analysed by Boudet and Husson (2012).
[103] Peterhouse MS 75.I, f. 71v.
[104] "Orthogonal" and "orthogonally" are not listed in the *Middle English Dictionary* (McSparran (2001)); the first reference for both in the *Oxford English Dictionary* is Leonard Digges's *Geometrical Practise, named Pantometria* (1571) ('orthogonally, adv.', *OED Online,* http://www.oed.com/view/Entry/132823).
[105] Aberdeen MS 123, ff. 66r, 67v.
[106] Camacho (2013).

It is clear that the capacities of languages were closely aligned to their uses: words might not be coined unless there was a need for them. Although English was the most commonly spoken language throughout this period, its written uses were only gradually expanding; these started, as one might expect, with those related to speech: the recording of what people said, for example in legal proceedings, and the dissemination of texts to be read aloud. Andrew Butcher has shown how the fifteenth-century estates account book of Canterbury Cathedral Priory, which generally followed a traditional format in Latin, used English in particular cultural contexts, particularly where subject-specific vocabulary was required; this included occupational names, building materials, and technical processes.[107] Anyone who has translated an extended piece of explicatory prose can confirm that there are many concepts that are easier to express in one language than another; translators are often forced either into clumsy circumlocutions or into leaving foreignisms that are as much transliteration as translation.[108] Perhaps the reason why Chaucer's prose in the *Astrolabe* 'flows artlessly through uncomplicated sentences,' as Ralph Elliott thought, is that the vernacular was well suited to the author's expository purposes.[109] *The Equatorie of the Planetis* evidences a range of techniques used to make it admirably clear – that its instructions can still be successfully followed today without the need for guesswork or peripheral research is an attribute rare among medieval treatises – but surely the choice of language was the first step in making it so.[110]

It is perhaps worth emphasising that English was not in direct competition with Latin. Where English did compete with another language in this period, that language was mainly French; in the contexts where Latin ruled, it largely remained unchallenged.[111] Indeed in some contexts in the early fifteenth century, the use of Latin actually increased, as French fell out of favour while English did not yet command full acceptance.[112] But since the use of languages was heavily context-dependent, perhaps the most significant driver of a change in language use was a change in the nature of those contexts: a change in the uses of writing. If we see the *Equatorie* as being in a new domain of instrument craft, the use of the vernacular does not result from rejection of Latin, but from the opening up of a new context for writing. It clearly differed from other late medieval equatorium treatises, such as the much-copied design of Jean of Lignières or

[107] Butcher (2011), 300.
[108] On this problem, see Bellos (2012), 50-52, 108-109.
[109] Elliott (1974), 142. Hagge (1990, 280-281) disputes the simplicity of Chaucer's prose, as a part of his argument for greater continuity between 'Old English and the beginnings of vernacular technical prose'.
[110] Westwyk's instructions were followed in the construction of the interactive virtual equatorium accessible alongside the digitised manuscript, at http://cudl.lib.cam.ac.uk/view/MS-PETERHOUSE-00075-00001. For Price's reconstruction of the equatorie according to Westwyk's instructions, see Falk (2014).
[111] Dodd (2011), 228.
[112] Dodd (2011), 264-266.

the complex *Albion* of Richard of Wallingford, in its practical and pedagogical focus.[113] While Jean's and Richard's treatises do describe certain practical steps involved in the construction of their instruments, such as selecting suitable materials or dividing a circle accurately, they still tend towards the theoretical, for example in the designation of points by letters of the alphabet. John Westwyk eschewed these in favour of practical tips for making holes, soldering metal and filing brass, which were more easily explained in the vernacular. Nevertheless, as we have seen, he still used Latin where he felt it was appropriate, and drew on it as he coined new terminology in English. Thus the two languages interacted in ways that were much more complex than simple displacement of one by another.

## Conclusion

By the late fourteenth century writing in English was relatively ordinary, even for technical purposes. Yet, as this chapter has demonstrated, it can still be productive to ask why the vernacular was used in particular contexts and for particular purposes. Of course, with the use of Latin no longer invariable, the opposite question could have been asked: *why not* write astronomy in the vernacular? There was a long tradition of vernacular astronomical writing in Spain, as well as more recent ones in France and Ireland.[114] The answer is that what we see in the *Equatorie of the Planetis*, and in other works of this period, is not so much the hard-fought triumph of English over its opponent Latin, as the inevitable exercise of a pragmatic personal choice between two closely related and mutually influential languages. Thus, on one level, John Westwyk's decision was as inconsequential as that of the Aberdeen manuscript translator to use Roman rather than Arabic numerals for the hours of the clock. Nevertheless, the choice of language to an extent always reflected the type of document being written, not least because of the inherent capabilities of the language; in this sense Chaucer was wrong to claim that 'diverse pathes leden diverse folk the righte way to Rome.'[115] Moreover, wider religious and political influences may have been involved, while for individual scholars the opportunity to translate was a chance to emphasise their own historical situation within a theoretically timeless work. But although a choice of language had to be made, in the *Equatorie* it seems to have been quite a natural one, not needing justification. Such a choice was a matter for the author and his relationship with his audience. And the use of language in the *Equatorie* tells us much about that audience. Whether the treatise was written for laymen, for young religious who had not learned Latin, to be read aloud to a craftsman, or for the author's own personal translation practice, we cannot be certain, but it

113 Lignières (1955); Richard of Wallingford, 'Tractatus albionis', in North (1976).
114 See, for example, Rico y Sinobas (1863); Boudet and Husson (2012); Williams (2002).
115 'A Treatise on the Astrolabe', Prologue, lines 39-40, in Chaucer (1988), 662.

seems most likely that John Westwyk had a single initial reader in mind, towards whom he had clear pedagogical aims.

It was inevitable that pedagogy in this period should have made scholars think of Chaucer. But it is absurd to suppose that Chaucer was the only person in England with the capacity and inclination to write didactic prose. The publication and analysis of more and more manuscripts that display varying levels of scientific understanding has contributed to an impression of a vibrant astronomical community in this period. The way in which the *Equatorie* is written, with its blend of invention and imitation, explanation and personal communication, confirms that impression. We may never know the nature of the relationship that caused Westwyk to cite Chaucer, or be sure who 'R. B.' was, but the fact that such scholars existed is indisputable. Examination of the linguistic context in which the *Equatorie* was written has allowed us to view them not as individuals, but as a community that taught each other new ideas and communicated their methods. They had a common language: an English that incorporated a significant number of terms adopted from Latin, familiar enough to make definition unnecessary. Where definitions were required, they were cobbled together using whatever objects felt most familiar, whether cartwheels or parts of an astrolabe.

In the next chapter we shall see how Westwyk worked within this linguistic environment, moulding this English to suit his precise pedagogical and technical needs. For now, though, we can say that the *Equatorie* exemplifies a thoroughly pragmatic language choice. Its use of the vernacular reflects the register in which its author sought to communicate, and although communities of astronomers crossed institutional and geographic boundaries, the *Equatorie's* plain, oral English is indicative of a specific setting, and perhaps even a specific relationship.[116] It represents a dialogue between a scholar and a craftsman – who may indeed be the same person. Edgar Zilsel wrote that 'the separation of liberal and mechanical arts manifested itself clearly in the literature of the [medieval] period;' he argued that Latin scholarship and vernacular craftsmanship were different activities practised by different people.[117] Zilsel's thesis has been critiqued over the years, especially insofar as it posits the interaction between artisans and scholars as a cause of the Scientific Revolution, but his medieval dichotomy has remained stubbornly intact.[118] Yet the kinds of astronomical communities epitomised by the *Equatorie of the Planetis* present a challenge to that dichotomy, as it blends scholarship and craftsmanship both in

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[116] On the relationship between language and register in medieval scientific contexts, see Jones (2015).
[117] Zilsel (1942), 942. See also Hall (1959), 21.
[118] Roberts, Schaffer, and Dear (2007) represents a sustained recent critique of Zilsel's thesis. It is partially defended and updated in Long (2011), but Long (2009, 218) maintains the position that 'there was an explicit and obvious divide between the learned Latin culture of the medieval universities and the vernacular, skill-based craft cultures of artisanal production in urban centers.'

the instrument itself, and in the way it was communicated by John Westwyk. The practical nature of the treatise is what first strikes a reader, but closer examination reveals a deeper intent. The treatise informs, educates, warns, tells a story, recommends and motivates; in short, it teaches. And the flexible, developing language perfectly suited to this experiment in pedagogy was English.

## CHAPTER FOUR

## 'I shal teche the aremedie': crafting the vernacular

The previous chapter's examination of the linguistic context in which John Westwyk came to write the *Equatorie of the Planetis* sought to reveal a range of reasons why this Benedictine monk chose to write in Middle English. In turn, this chapter will address the question of *how* Westwyk worked in, and with, that language. In the last chapter, it was argued that the use of the vernacular enabled Westwyk to write practical, pedagogical prose, in which he asserted his authorship and, perhaps, acknowledged his debt to Geoffrey Chaucer. In this one, Westwyk's own English will be analysed, in order to show how he employed and sometimes moulded the language to suit his purposes.

Vernacular practices have received little attention from historians of astronomy. In part, perhaps, this is because until recently many historians of science have been less interested in practices than ideas; in part it stems from the tendency of many scholars, until recently, to focus attention on the leading edge of scientific achievement.[1] John North, for example, wrote that

> No one, so far as I know, has made a detailed study of scientific writings as a whole in Middle English. There is little incentive to make even a conspectus of works which, written as they usually were by men of something less than the best academic training, tend to be intrinsically uninteresting except from a social or linguistic point of view.[2]

Chapter 5 of this thesis will, I hope, challenge the notion that scientific work that is anything less than cutting-edge is uninteresting; the imperfections identifiable in the *Equatorie of the Planetis* are surely what make it particularly worthy of detailed study. For now let us take up North's intimation that linguistic study is irrelevant to history of science. In the last chapter I showed how Westwyk's presentation of astronomical content was contingent on his choice of language. In this chapter, I will develop that point, examining the complex interplay between the form and content of the *Equatorie* and demonstrating what a linguistic approach can add to study of historic scientific texts.

North was not alone in largely ignoring vernacular astronomy: a glance at the bibliography of this thesis will reveal that Peterhouse MS 75.I has been studied most often by Middle English scholars. It has been subjected to a wide variety of linguistic analyses: categorisation of individual vocabulary items; statistical survey of collocations of frequent words; studies of spelling, and so on.[3] But those analyses, focused on the authorship debate, almost always took the form of

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[1] For discussion of the 'practice turn', see Soler et al. (2014); for its application to (early modern) knowledge production through scholarship and craft, see Roberts, Schaffer and Dear (2007).
[2] North (1976), II. 94.
[3] See, for example, Wilson (1955); Rand Schmidt (1993), 74-84; Benson (1992).

comparison between the *Equatorie* and the *Treatise on the Astrolabe*. Other Middle English texts were drawn on, but only to inform judgements about whether Westwyk's work could be ascribed to Chaucer.[4] Previous scholars have not used linguistic analysis to elucidate the treatise's astronomical content and process of composition. This chapter will attempt to remedy that situation.

Comparison with Chaucer remains useful, but – now that it no longer seems tenable to ascribe the *Equatorie of the Planetis* to him – for different reasons. In the first place, as I have demonstrated, his popular *Astrolabe* treatise had a significant influence on John Westwyk. More importantly, the similarities and differences in forms of expression between treatises on similar subjects can tell us much about the characteristics of technical English in this period.[5] Where previous scholars analysed the regional dialect and even personal idiolect in the *Equatorie* in order to inform the authorship debate, now we may employ such analyses to identify characteristic features of astronomical and craft writing in this period. It was perhaps natural for Derek Price to take similarities between the *Equatorie* and *Astrolabe* as evidence of Chaucer's authorship, but in the half-century since Price discovered Peterhouse MS 75.I it has become clear that there were many more people interested in and writing about astronomy in this period than he supposed; some have even been identified by name. Now those similarities indicate popular forms of expression, and act as an important counter to the myth of Chaucerian exceptionalism, offering the potential to correct the persistent assumption that science was carried out by a few great men.[6]

Apart from other Middle English writings, it will also be necessary to make reference to treatises in Latin, not only because the texts whose content is most comparable to that of the *Equatorie* were written in that language, but also because drawing contrasts with those texts should allow us to identify features of Westwyk's writing that stem from his use of the vernacular. For those reasons, further reference will be made in this chapter to the parallel English and Latin sundial texts in University of Aberdeen MS 123 (transcribed in full in appendix F), composed in the early fifteenth century, as well as to the equatorium treatise of Jean of Lignières and *Albion* of Richard of Wallingford, which both date from the second quarter of the fourteenth century.[7]

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[4] Rand Schmidt (1993) used the navicula text *The Shippe of Venyse*, and the anonymous translation of Andalò di Negro's *Theorica planetarium*, both in Trinity College, Cambridge MS O.5.26, as 'non-Chaucerian controls' (61). On the former, see Eagleton (2010).
[5] Partridge (1992), 31.
[6] The inclusion of Chaucer among the 'great men of science' owes much to the work of Robert T. Gunther. For clear statements of his views, see Gunther (1937), v, and (1929), v.
[7] Lignières (1955); Richard of Wallingford, 'Tractatus albionis', in North (1976).

Comparisons between "English" and "Latin" texts are problematic: it should immediately be remembered that technical texts are rarely found entirely in English, but almost always contain words in Latin and sometimes other languages too.[8] More fundamentally, this was a period when English was rapidly developing as a language, changing its vocabulary, spelling and syntax. This has a number of consequences for the linguistic study of a text like the *Equatorie*. In the first place, historians' attention is inevitably drawn to words whose first appearance within an English text comes in Peterhouse MS 75.I. If we are to assert that this is their first appearance "in English", it must be bearing in mind that it is only their subsequent acceptance into the language that makes them English, rather than anything John Westwyk did. It is only this that distinguishes words like *eccentrik* and *withdraw* from *motus* and *aux*, which may now seem to the modern reader like loan words used by the author for lack of a better alternative in English; little different from the authorial Latin glosses that appear frequently throughout the manuscript.

Nonetheless, John Westwyk's choice to write in English did necessitate some linguistic innovation, and this chapter will examine how he went about that process. More broadly, it will demonstrate the complex interplay between the form and content of Middle English scientific treatises. We shall assess how the subject matter and aims of the *Equatorie* influenced its style; in other words, the way that the vernacular was used, and sometimes moulded, to suit the practical and pedagogical purposes of its author. The first four chapters of this thesis address Westwyk's experience and environment; his motivations and, now, his methodologies. After this we shall be prepared, finally, to examine the content of his manuscript.

## DIDACTIC DEFINITIONS

In any instructional treatise one would expect to find certain key terms defined near the beginning, and the *Equatorie* does not disappoint in this respect. The definition of terms is not unique either to treatises in English, nor to those that appear didactic, but certain features of the way John Westwyk defines his terms are particularly noteworthy. First, not every term is defined: "lymbe", "aryn", and "alhudda", for example, are, while some potentially problematic words like "aux" and "motus" are not. This suggests two possibilities: first, that Westwyk had a particular reader, or general type of reader, in mind, and set out to provide them with information that would be useful to them. Terms specific to the equatorium are generally defined, while those that have applications elsewhere in astronomy tend not to be, suggesting that the intended reader of this treatise had some knowledge of the subject but not of this particular instrument. The second possibility relates more directly to language, since those terms not defined seem to be

[8] Voigts (1996).

those that are transliterated from Latin; this suggests that the reader might have been familiar with key astronomical terms in Latin but not in English.

A second noteworthy feature of the way Westwyk defines his terms is that he does so explicitly, and often by identifying himself as the inventor of that term. Nine terms are explicitly defined in this way: "degres of the semydiametre", "lyne alhudda", "commune centre defferent", "equacion of his centre", "equacioun of his argument", "lymbe", remenaunt", "centre aryn", and "closere of the signes".[9] Of these, the first five definitions are signalled with the phrase "is [or shal be] cleped". Meanwhile, the other four follow the phrase "wole I clepe" or "wole I calle". In contrast, Jean of Lignières never explicitly defines any terms; where a user might learn new words by studying his treatise, the definitions are implicit, as for example when the word "limbus" is introduced by saying 'ex utraque parte eleventur limbi aliquantulum ad modum membris astrolabii.'[10] Richard of Wallingford, meanwhile, does define terms using the word "dicitur", and sometimes disambiguates a certain part of his Albion by saying that it 'est illa que...'[11] But, unlike John Westwyk, he never claims ownership of the term he is defining. Moreover, aside from the personal note that often appears in Westwyk's definitions, there is an oral quality to the words "calle" and "clepe". He does not explain the "name" (a word whose use in both its nominal and verbal forms is recorded before the date of composition of the *Equatorie*) of any parts of his instrument; he always tells us how he speaks about it.

Thirdly, those terms that are defined in this way are always repeated immediately. This is the sign of a true teacher: one who knows that in order for a lesson to stick in the mind of his student, it must first be clear precisely what is being taught, and then must be practised. So, for example, having instructed the reader to carefully nail a circle of metal on the outer two inches of the main disc of the instrument, Westwyk writes 'this cercle wole I clepe the lymbe of myn equatorie.'[12] Then, in the remaining nineteen lines of that first page of the treatise, he repeats the word six more times: 'this lymbe', 'thy lymbe', 'the same lymbe,' in such a way that the message cannot fail to stick in the mind of his reader.

Thus, again, Westwyk's writing goes beyond being merely instructive, to being firmly didactic. And this didactic spirit suffuses even the most coldly practical parts of the treatise. The most obvious and attractive way in which this is achieved, heightening the text's readability, is Westwyk's personal touch. The word "I" appears a full 48 times (and "my" a further thirteen) on

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[9] See appendix G. One might add to this list "midnyht line", which is defined by reference to the *Treatise on the Astrolabe*. See the discussion of this phrase in chapter 3, pp. 82-83.
[10] Lignières (1955), 188. 'Let the edges [limbi] on each side be raised up a little, like the limbs [membris] of an astrolabe.'
[11] See, for example, Richard of Wallingford, 'Tractatus albionis', III.1-2, in North (1976), I. 340-346.
[12] Peterhouse MS 75.I, f. 71v.

the fourteen pages of the treatise, constantly reminding the reader that the document he is reading is a proxy for the author and cannot be independent of him.[13] The English subject pronouns make this personal nature of the treatise far clearer than it could be in Latin since, as was explained in chapter 3, the latter is a null-subject language, in which it is harder for the author to emphasise his presence.[14] References to the reader are even more numerous: the word "thy" appears 158 times[15] – surpassed only by "and", "in", "of" and "the" – and "thow" another nineteen. What is particularly noteworthy about this is that the possessive adjective "thy" is frequently used in situations where a user of modern English would more typically employ the definite article "the": while in the early part of the treatise, where construction is discussed, it most commonly attaches to the reader's compass, later it is more likely to attach to a part of the instrument such as the black or white thread, or even to a planet, as on folio 74r where a diagram is labelled 'thus lith thin instrument whan thow makest equacioun of thy mone.' The same usage appears in The *Treatise on the Astrolabe*, where "thy" refers both to parts of the instrument and to the object of the investigation, such as the Sun.[16] But I know of no Latin treatises in which the possessive adjective is employed in this way. This may, in part, be because it would require the scribe to write an extra word (Latin has no definite article, though the demonstrative adjective "ille" was in rare instances employed). But it also reveals the distinctive didactic approach that Westwyk used, perhaps influenced by his reading of Chaucer.

The above statistics do have the merit of being unarguable data, but they are poor indicators of the truly personal nature of the treatise. On every folio Westwyk makes direct contact with his reader, in phrases such as 'I conseile the[e]', 'I seye considere', 'wyrk with Cauda as I tawhte the[e]'. The oral language in which these lessons are presented creates a clear image of a master coaching a pupil; in places the *Equatorie* could be the verbatim recording of an astronomy class.[17] One gets the sense of a author and reader who enjoyed a genuine personal relationship, every bit as believable as that between Chaucer and his supposed son Lewis. And if the *Astrolabe* contains moral as well as astronomical lessons, as Lerer believes – the reader and instrument user locating himself in the world in more ways than one – this is equally if not more true of the *Equatorie*, pertaining as it does to an instrument whose potential astronomical and astrological functions have clear moral implications for the person using it.[18]

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[13] The word counts in this chapter are taken from J. L. Dawson's 'Concordance to *The Equatorie of the Planetis*', in Rand Schmidt (1993), 283-407.
[14] Camacho (2013).
[15] This includes sixteen instances of "thi", twenty-two of "thin" and fifteen of "thyn".
[16] See, for example, 'A Treatise on the Astrolabe', II.1, in Chaucer (1988), 669.
[17] On such forms of address, see Taavitsainen (1994).
[18] Lerer (2004), 912. On the moral implications of astrology, see Carey (1992), 8-20.

## LEARNING OPPORTUNITIES

Nonetheless, the principal lessons of the *Equatorie* are still astronomical. The didactic nature of the treatise is most apparent where Westwyk digresses from information that is absolutely necessary to the practical construction of the instrument, providing information that, while strictly superfluous, might still be interesting or educational for his reader. He does not deviate as far as Chaucer, for example, does when explaining the etymologies of the names of the months to Lewis;[19] indeed, the digressions in the *Equatorie* treatise only become apparent when one follows its steps and can identify those that are extraneous to the construction and most basic use of the instrument. For instance, in the process of explaining how to use the completed equatorium to compute the longitude of a superior planet, Westwyk instructs his reader to move the black thread, from where it was laid to mark the planet's mean longitude, to lie over the centre of the epicycle. This does not help the reader find the true longitude but, as Westwyk explains,

> than shal this blake thred shewe bothe the verrey [true] motus (*locum*) of the epicicle in the grete lymbe and ek [also] the verrey aux of the planete in the epicicle; and thanne the ark by twixe [between] medios motus of the planete and the verrey motus of the epicicle is cleped the equacion of his centre in the lymbe (z*odiacus*) to whom is lik the equacion of his argument in his epicicle; that is to sein [say] the ark by twixe his mene aux and his verrey aux.[20]

Having thus outlined how this relocation of the black thread can be used to show the planet's equation of centre, which is identical with the equation of its anomaly on the epicycle, Westwyk continues, explaining the difference between the mean and true apogees on the epicycle quite thoroughly.[21] It is not necessary to know any of this to be able to use the instrument, but it is clear that Westwyk wants his readers to go beyond a basic working knowledge towards true understanding of the underlying theory. It is likewise understanding that is being pursued when he goes beyond instructing his pupil(s) to maintain the position of the common deferent centre, taking the trouble to give a reason for his instructions. He explains that 'yif thy commune centre different [sic] stirte fro the centre defferent on thy plate al thin equacion of thy planete desired is lorn.'[22] This explanation was sufficiently important to be marked with a pointing *manicula*; the similarity of pen and ink to the text of the treatise make this very likely to be authorial (see figure 24).

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[19] 'A Treatise on the Astrolabe', I.10, in Chaucer (1988), 665.
[20] Peterhouse MS 75.I, f. 75r. *Locum* and *zodiacus* are Westwyk's own interlinear additions.
[21] He is perhaps at particular pains to do so at this point because the terminology is particularly confusing: the mean and true apogees on the epicycle are quite different from the planet's apogee on the ecliptic, and the equation of its anomaly on the epicycle is different from the equation of anomaly measured at the centre of the equatorium (Earth). (This repetition of terms was confusing enough to cause problems for the normally dependable Price, who mislabelled a diagram in his edition of the manuscript (Price (1955b), 108).)
[22] Peterhouse MS 75.I, f. 76r.

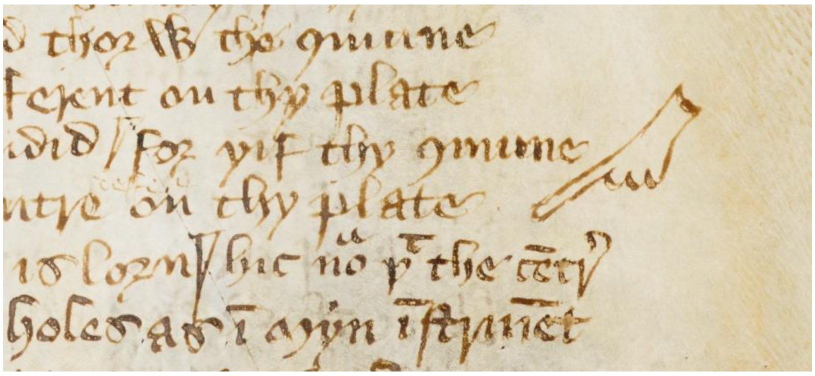

Fig. 24: Manicula. Peterhouse, Cambridge MS 75.I, f. 76r. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

That hand is not the only indication of Westwyk’s concern to emphasise important information in places where it is most needed. Almost every folio in the treatise includes the admonition ‘nota that . . .’, followed by a reminder of some vital feature of the instrument (see figure 25). Such notes were typically added as marginalia by later readers, in order to highlight sections that particularly interested them; but here Westwyk himself has included them in the body of the treatise, as if to guide readers and emphasise what they most need to know.

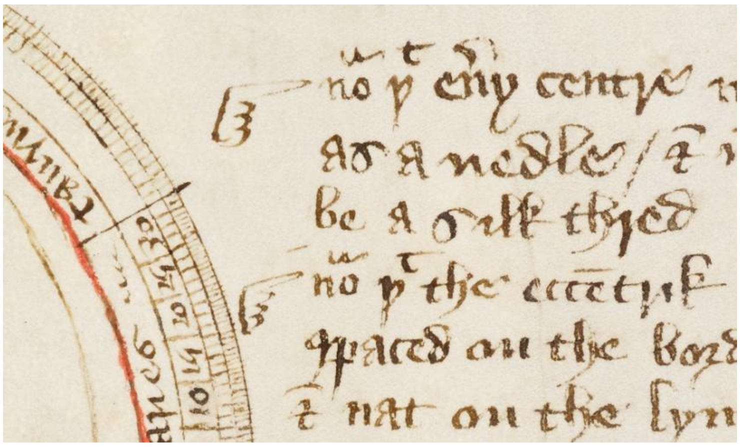

Fig. 25: Maniculae and ‘nota þat’ marks. Peterhouse, Cambridge MS 75.I, f. 73v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

It should be acknowledged that, outside the treatise, these authorial admonitions do not always occur in plain English. Where Westwyk added advisory canons to the tables that form the bulk of the manuscript, these notes were more often either in Latin or, if they were in English, it was usually disguised by the use of ciphered text.[23] The content of these canons will be discussed further in chapter 5, but it is not clear why he should have used different languages in this way. It might be noted that the Latin canons are not strictly necessary for the equatorium, and therefore that the more complex calculations they address would be of lesser interest to the audience for whom Westwyk was writing the treatise. Alternatively, it could be suggested that Westwyk saw these points as more astronomical and less practical, and felt that Latin would be more appropriate for the explanations.[24] Further, the cipher passages, which encode relatively simple instructions and certainly nothing worth keeping secret, could have resulted from Westwyk’s

[23] The simple substitution cipher was decoded by Price (1955b), 182-187.
[24] This might suggest that he was writing for a bilingual audience, but there is insufficient evidence to speculate on this point.

desire to practise his skills, or perhaps to test those of his readers. However, taken together, it seems most likely that Westwyk's annotations and commentaries among the tables were for his own reference; I would argue that we should read Latin and ciphered remarks separately from the (mostly) Middle English treatise.

Nevertheless, it is English that Westwyk chose for the majority of the *Equatorie* manuscript, and the choice of language had a significant impact on his didactic phraseology. His use of oral language has already been mentioned; it is most apparent in the way he used repetition for emphasis. Such emphatic repetition is, of course, not exclusive to English, but it was facilitated and made more common by the oral nature of the language at the time when the *Equatorie* was written. To take an example from the core function of the equatorium, the computation of the latitude of a superior planet; the author tells his reader to

> put the commune centre defferent of thyn Epicicle up on the centre different in thy plate of thilke planete that thow desirest to have equacioun. I sey that with a nedle thow shalt stike the comune centre defferent of thin epicicle up on the centre defferent that is perced on thy plate for swich a planete a the list [which you want] to have of equacoun.

The common epicycle thus fixed in place, the white thread is brought into play:

> under whiche white thred ley the pool [pole] of thyn epicicle and stondinge thyn epicicle stille in this maner – I seye stondinge the pool of thin epicicle undir thy white thred stille – and the commune centre different fix with thy nedle to the forseide centre defferent of the planete desired . . .[25]

We are thus told no less than three times that the common deferent centre is to be fixed to the deferent centre of the desired planet, and again thrice that the common epicycle is to be laid under the white thread; the reminder is rendered more forceful by the oral phraseology 'I sey' and 'forseide', suggesting that the author is there looking over the reader's shoulder as we follow his instructions.

Such emphatic repetition is entirely absent from the instructions of Jean of Lignières and Richard of Wallingford, who, while explaining the use of their instruments perfectly clearly, nonetheless both describe each step only once. Perhaps Middle English was particularly well suited to didactic repetition, or at least such repetition was more widely acceptable within the conventions of its use. Such a supposition is supported by the parallel sundial texts in Aberdeen MS 123. An early passage instructs readers to draw a circle, divide it into quarters with two diameters, and then to mark the latitude for which the sundial is to be made within a quadrant of ninety degrees:

> Postea diuide 4 unam istius circuli in 90 g$^{a}$. Et tunc in 4$^{a}$ ad postremo computa latitudinem regionis ad quam vis instrumentum componere incipiendo ab A versus D & vbi terminatur pone signum F.[26]

In English, this passage was significantly expanded:

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[25] Peterhouse MS 75.I, f. 75r.
[26] Aberdeen MS 123, f. 66r.

> then devyde awharter of that cercle **fro A to D** in to 90 partes or degres, and take the latitude of the region or contre for whylk thou makys thyn instrument to serve in, and counte **fro A toward D**. As for the cyte of York, take the latitude therof that is 52 degres, whilk is the latitude of the forsayd cyte, and contre **fro A toward D**, and merke wele with a pryk wher 52 degres endes **toward D**, and set ther F.[27]

Readers may first be struck by the insertion of a concrete example, or by the practical tip to mark point F well with a prick, but here I wish to highlight the quadrupling of the instruction to count the latitude towards D. The translator does not deliberately draw attention to the fact he is repeating it in the way Westwyk does, but nonetheless he clearly wishes to stress this point.

A further striking feature of the Aberdeen text is the insistent use of the word 'then' marking successive steps in the construction process. The Latin source text already contained many of these structural markers: most commonly 'tunc' at the beginning of a sentence, but also a variety of other adverbs such as 'postea', 'postmodum' and 'quo facto'; eight different connectors are used a total of twelve times in this relatively short set of instructions. In translation, these are multiplied but also homogenised: of the seventeen instances where successive steps are signalled, twelve use 'then', and only four other words are used. Thus the translator has altered his source text to emphasize how the construction progresses, keeping the language simple and clear at every stage. John Westwyk used the same technique to add structure to his treatise, including the marker 'than(ne)' a total of 53 times.

Such simplification should not be taken as a sign of the author's simplistic understanding. The assumption has tended to be made by historians that scholars always wrote at the limit of their own abilities, as North implied in the remarks quoted above, but there is no *a priori* reason why this should be the case. In the case of the *Treatise on the Astrolabe*, it is accepted that Chaucer was writing well within his scientific limits because his childish audience is explicitly named, and he makes it clear that he is adapting his style and content to that audience. But such accommodations could also be made where the audience and methodology are not made explicit. It has already been noted that the use of English might imply a less educated audience; it therefore seems plausible that, notwithstanding areas in which Westwyk was learning as he wrote (which will be explored in chapter 5), there were other areas in which he was displaying pedagogic sophistication in simplifying the content of his treatise for his less educated, English-speaking audience. Recognising that the author tailored his treatise to his audience in important respects – not only the prose used, but also the way that diagrams are included, labelled and referenced in the text – is important to our understanding of this manuscript. As a piece of pedagogic prose, ranging from instructions through explanation to worked examples, it was

[27] Aberdeen MS 123, ff. 66v-67r (orthography edited). See appendix F for diplomatic transcription.

structured and composed in the way that best suited Westwyk's didactic purposes. This included his use of English.

Nonetheless, the purpose of producing Peterhouse MS 75.I was not purely pedagogic. As with so many medieval manuscripts, in part the reason for producing a new written document from existing material, whether the process involved making a facsimile, compilation, translation, the addition of new material, or free adaptation, was *translatio studii* – the transmission of learning.[28] Often, as intimated in the previous chapter, this was a politically charged process involving reflection on the relationship between past and present cultures, but the fact remains that the product that was being transferred between cultural settings had astronomical content. While the knowledge content of astronomical treatises could be developed, reformulated and supplemented in the process of transmission, the core content had still to be passed on. The *Equatorie* treatise is no exception to this; the text is at least partly adapted from a Latin original. Whether that Latin original was itself translated from Arabic is less clear. Price argued that 'the *Equatorie* is clearly derived from a Latin version of some Arabic treatise' but, as we shall see in the next section, the few Arabisms in the treatise could have been part of the language of an astronomer writing in Latin or English.[29] The opening phrase 'in the name of god pitos & merciable' is certainly influenced by the Arabic 'bismillāhi r-raḥmāni r-raḥīm', the invocation used by Muslims before any Qur'an reading, prayer or other action requiring God's blessing, but by the time Westwyk was writing this invocation had become common, and was certainly being used in texts composed in Latin.[30]

If the original source text for the *Equatorie* was not in Arabic but rather in Latin, the possibility arises that Westwyk himself wrote the treatise in Latin first, before translating it into English. The evidence concerning any source text or texts is scanty. Since references in such texts to specific locations and times were frequently changed in the process of copying or translation, we cannot infer anything about the age of the source from the dates and places cited in the *Equatorie*. But the glosses in Latin interspersed throughout the extant treatise raise questions about Westwyk's relationship with his source text. It could be suggested that he doubted his ability to communicate the technical content clearly in pure English; or that, if he had written it in Latin himself, he felt no need to hide traces of the precursor text. The Latin additions might be taken as further evidence that Westwyk was writing for a bilingual audience; or he might simply have been showing off his linguistic abilities. But perhaps the most likely

[28] Campbell and Mills (2012).
[29] Price (1955b), 4.
[30] North (1988), 158.

explanation is that he was taking extra care to ensure that his technical translation would be clear, particularly because the use of English for this purpose was so unusual. Westwyk was not the only writer on instruments to take such precautions: for example, the roughly contemporaneous scribe who translated the collection of astronomical and astrological texts into English preserved as Trinity College Cambridge MS O.5.26, which include a text on the navicula, added glosses throughout the manuscript where he presumably considered that the meaning might not be clear. This was usually because he was using a Latinate word that might not be familiar to readers who only spoke English, or a technical term that might require explanation. These glosses were always underlined and always introduced simply with the word 'or', as for example when the scribe writes 'Whan thou wolt compowne or make the schippe.'[31] Eagleton argues that 'the underlining of "or make" enables the sense to be clear in English even though that language was lacking a rich technical vocabulary for this kind of text.'[32] But if the only purpose was to make the meaning clear, the scribe could simply have used the second word. It seems, therefore, that this scribe was balancing two competing priorities: taking advantage of the utility and intelligibility of English, which had a perfectly adequate vocabulary for such practical texts; and keeping close to his source text in order to co-opt the scientific prestige of Latin. The glosses that result could be seen as the result of indecision, but offer didactic clarity.

However, the glosses in the *Equatorie* are different: they are usually in Latin and usually interlinear, suggesting that Westwyk added them later. Although he did use some individual Latin words in his treatise, as will be discussed below, and in one case concludes a section with the formulaic phrase 'laus deo vero', the vast majority of the Latin that appears in the treatise (as opposed to the tables, which contain many Latin headings) is interlinear. Krochalis has suggested that these interlinear glosses appear to be the work of a translator looking back through his work and making additions to ensure greater clarity.[33] (Although I would not describe Westwyk straightforwardly as 'a translator', that is not as important a disagreement as it might seem, since translation, adaptation and original writing could not be easily separated in the work of an *auctor*.[34]) The glosses usually occur on technical points, as when, in discussing the method for computing the latitude of the Moon, Westwyk writes 'withdraw the verrey motus of caput owt of the verey motus of the mone & writ that difference (*id est verum argumentum latitudinis lune*) for that

[31] Trinity College MS O.5.26, f. 122r, published in Price (1960), 405. In some cases the scribe even maintained the original Latin, as when he wrote 'anni expansi or of þe ȝere strauȝt out' (MS O.5.26, f. 120r). Jones (1989) discusses the use of such doublets as a translation strategy.
[32] Eagleton (2004), 105.
[33] Krochalis (1991). Jones (1990) discusses a case where both a source text and a translation in the translator's hand are extant.
[34] Jones (1989), 89.

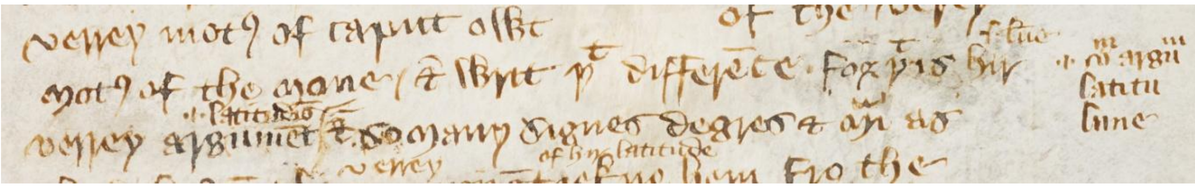

Fig. 26: Interlinear and marginal additions. Peterhouse, Cambridge MS 75.I, f. 77r. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

is hir (*scilicet lune*) verrey argument (*id est latitudinis*)' (see figure 26).[35] Westwyk explains this method at some length, and it appears to have caused him some confusion (as we shall see in chapter 5), so it is hardly surprising if, when reading through his explanation, he decided to add some clarifying glosses.

Krochalis suggested that the reason why some glosses were in Latin, rather than English, is explained by the fact that the author was 'perhaps hurrying to get through' the task; leaving some Latin, she implies, saved Westwyk time and effort.[36] But since both Latin and English additions occur throughout the treatise, with no greater occurrence of Latin later, this seems implausible. An alternative explanation is that the two languages serve different purposes. Reading through his manuscript, Westwyk perhaps spotted instances where he was dissatisfied with his own translation, as for example on folio 73r, where we find the instruction 'in the cercle that is closere of the signes make a litel hole'. Westwyk modified the verb 'make' by adding 'thow shalt' at the beginning of the phrase, and the word 'perce' above the verb itself. The original Latin verb would have incorporated the person and tense, and Westwyk perhaps decided that the English word 'make' was too general . Such instances are mostly corrected with additions in English. On the other hand, Latin additions such as the one quoted in the last paragraph may stem from Westwyk's desire to supplement the text with further explanation, probably for his own reference (or perhaps for a bilingual reader).[37] In other words, where English glosses are used it may be because Westwyk felt that his first translation was insufficiently effective at reproducing the original Latin source; conversely, where Latin glosses are used, it may be that he decided he had been too faithful to the source, which needed expansion. Perhaps in subsequent drafts these additions too would have been rendered in English, but it is clear that what is extant in Peterhouse MS 75.I is a work in progress.

[35] Peterhouse MS 75.I, f. 77r. Phrases in parentheses are interlinear or marginal additions.
[36] Krochalis (1991), 46.
[37] It might be suggested that Westwyk simply realised he had omitted part of his source text, but the consistently explicatory (and Latin) nature of the additions makes this implausible.

## VOCABULARY AND STYLISTIC INNOVATION

Glosses, then, were a way for John Westwyk to ensure the clarity of his writing. And he would have been particularly concerned on this score when using vocabulary that was potentially unfamiliar to his readers. To a certain extent, of course, use of new vocabulary must follow rather than precede its acceptance: a writer must be able to assume his readers will understand the terms he uses.[38] But this was not always possible; in that case, the writer needed to provide some form of explanation. Westwyk was assisted by the fact that many of the terms he used had already appeared in the *Treatise on the Astrolabe*, a text with which he knew (or assumed) that his reader(s) had some familiarity. As we have already seen, the 'midnyht line' on the equatorium was defined by explicit reference to the *Treatise on the Astrolabe*; another term, label, was implicitly defined by taking advantage of his reader's familiarity with the more common instrument.[39] This was done in a subtle but effective manner. Westwyk instructs his reader to

> tak thanne **a rewle** of latoun [...] **this rewle** mot [must] be shape in maner of **a label** on an astrelabie. The centre of **this rewle** shal be nayled to the centre of the forseide barre in swich a manere that **this label** may torne abowte as doth the **label** of an astrelabie. In middes of this nayl that fastnyth the barre and the **label** togidere ther mot be a smal prikke.[40]

The word "rewle" is used in two other senses in the treatise: a principle or norm of practice; and a straight edge used to draw lines. Neither use was new at that time. On the other hand, the word "label", in the sense of a metal pointer, does not appear in any other extant source prior to the *Equatorie* apart from the *Treatise on the Astrolabe*.[41] Thus Westwyk exploited his reader's greater familiarity with the word "rewle" to help redefine the word "label", a word with which the reader would have been a little acquainted. In the passage above we see him subtly introduce the new word by a gradual process of interwoven replacement. After this passage, "rewle" is no longer used to describe that part of the instrument; it is only described (and a diagram is captioned; see frontispiece) with the new word "label", which appears a further twelve times in the treatise.

However, the *Equatorie* does contain several words or phrases that may appear in English for the first time here. They are listed in appendix G, together with some comparisons with other texts and languages. We noted earlier that in nine cases Westwyk drew attention to his use of these words with phrases such as "wole I clepe"; as the examples already cited show, this was generally where he had taken a multi-word technical term and translated it into a new phrase that his reader might not immediately recognise, such as "comune centre defferent". More common,

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38 Dodd (2011, 250-251) has discussed how the standardisation of English may have been a necessary precursor to its use in government documents.

39 Authors of equatorium treatises invariably assumed their readers would have some familiarity with the astrolabe, referring to it in their explanations. See, for example, Campanus of Novara, 'Theorica planetarum', II.77, in Benjamin and Toomer (1971), 142; Lignières (1955), 188.

40 Peterhouse MS 75.I, f. 73r.

41 The data on usage and appearance is taken from the *Middle English Dictionary* (McSparran (2001)).

though, is the use of terms that were already established in Latin, which he adopted with few changes.[42] When he did this, he did not define the adopted words, which suggests that he might have expected his reader to have some familiarity with Latin terms such as *motus*, *aux* and *eccentrik*, all of which probably have their first appearance in English in Peterhouse MS 75.I.[43] Of those three terms, *aux* (and its plural *auges*) are simply transferred intact from Latin, while the seven appearances of "eccentrik" demonstrate consistent adaptation of the Latin term "eccentricus".[44] The case of *motus* is more complex. In eight cases Westwyk used the anglicised "mot", but in a further 49 he retained the Latin term (always abbreviated as "mot9").[45] The cause of such inconsistency is unclear. The frequency with which the shorter version appears makes it unlikely that he simply omitted the "9" character accidentally, and inadvertent confusion with "mot" meaning "must" seems implausible for the same reason. It seems more likely that he was simply undecided about whether or not to translate the word. The fact that the translated version is concentrated on four consecutive pages in the middle of the treatise (ff. 76r-77v) suggests that he decided anglicisation would be appropriate, but later changed his mind.

A similar sort of bilingualism occurs with the word "degre", a word that would have been familiar to any reader of the *Treatise on the Astrolabe*. Westwyk's handling of this is consistent: where he writes it out in full, he translates it (31 times in the treatise); where he abbreviates it, he uses the Latin abbreviation *g*[a] (32 times).[46] The abbreviation tends to occur after a number, while the full version is more likely to be used in a passage of explanation, but that is not an absolute rule. Still, it seems plausible that Westwyk was used to using the Latin abbreviation in calculations and tended to maintain that when writing numbers, whereas in a passage of prose it perhaps felt more natural to use the established English form (itself taken from French).

Another established word, but one employed by Westwyk in a novel context, was "mene". Its use to mean "intermediate", again with a root in Norman French, went back at least to the middle of the fourteenth century, but Westwyk was the first to use it in a strictly astronomical (or

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42 A striking comparison may be made with the roughly contemporary Irish astronomical tract *Da Cailibh na Firmaminnti & na Ceithre Dula*, which was in part a translation of (pseudo-) Māshā'allāh's *De scientia motus orbis*. In this case the translator created many more new astronomical terms in Irish instead of simply adopting Latin terms. See Williams (2002). On the attribution of this and other works to Māshā'allāh, see Mimura (2015).
43 "Mote" appears in the Supplementary Propositions to the *Treatise on the Astrolabe* (II.44), but these were probably written in 1397 (Reidy (1988), 1093).
44 It is on one occasion spelt "eccentric". Another example is provided by the two instances of "meridie", which was not an entirely new word. These could be thought to be a faithful rendering of the Latin ablative, which would be appropriate in the context, but Westwyk did not decline any other Latin loan word in the treatise so that seems unlikely. (One Latin loan word is declined among the tables (f. 38v), where the word *retrogradorum* (referring to the planets) appears in a ciphered passage. North (1988, 188) calls attention to the use of this word in a Latin canon on f. 45r, suggesting that this unusual usage might be evidence of a link to John Somer.
45 The spelling "mote", preferred by Chaucer in the Supplementary Propositions, is never used.
46 There is one exception to this: *g*[a]*d* on f. 78v.

mathematical) sense.[47] It seems likely that he felt that the pre-existing general sense of the word was sufficiently close to the new technical sense to obviate the need to use the Latin adjective *medius*, or to provide a definition or explanation.

Three words in the treatise are apparently of Arabic origin: *almenak*, *aryn* and *alhudda*.[48] The first was well established in English (though its meaning varied, sometimes denoting a perpetually valid, flexible set of tables, at other times something more fixed and temporary), having passed into contemporary French and Spanish by the twelfth century;[49] it appears in the *Treatise on the Astrolabe*, as well as a translation of the *Exafrenon* of Richard of Wallingford made in the late 1380s.[50] The second, which Westwyk uses to refer to the centre of his instrument, is a little more unusual. The name *Aryn* (or *Arim*) was fairly commonly used in medieval geography to refer to the centre of the habitable earth, resulting from a corruption of the Indian city of Ujjain.[51] For geographers, this usually meant zero or 90° longitude, but zero latitude could also be assigned to that place.[52] In considering how such a global reference point came to be identified with the middle of an astronomical instrument, it is worth noting an intermediate use in the astrolabe treatise of Rudolf of Bruges (*fl. c.* 1144). In a fairly brief section concerning the uses of the astrolabe, Rudolf notes that at Arin, which is 'sub circulo recto' [i.e. on the equator], the days are of equal length throughout the year and therefore equal hours can always be used; the further one is from this, the greater the variation in unequal hours.[53] It is easy to see how the use of this explanatory detail in instrument treatises may have given rise to the application of the name *Aryn* to the centre of the instrument, which in the case of the equatorium is analogous to the centre of the Earth.[54]

Westwyk defines both *aryn* and *alhudda* explicitly. For the latter, he writes that 'thilke lyne that goth fro centre aryn un to the cercle closere of the sygnes ... shal be cleped lyne alhudda.'[55] *Alhudda* seems likely to be a transliteration of the Arabic aḥuḍḍa (meaning depths), which in its

[47] This word also appears in the Supplementary Propositions to the *Treatise on the Astrolabe* (II.44), but these probably postdate the *Equatorie*, as already mentioned.
[48] There is also a list of stars, including many Arabic names, on f. 71r; although the presence of meridian altitudes for some stars at London, which Westwyk seems to claim to have measured himself (he writes 'cuius rei expertus sum'), is noteworthy, the list itself is fairly conventional; see, for example, Cambridge University MS Ii.3.3, f. 70r.
[49] Its roots in Arabic are unclear. On its etymology and variant meanings, see Benjamin and Toomer (1971), 374-375. See also Chabás (1996).
[50] In that translation the word is spelt "Armanac", not "Almanac" as in Price's partial edition; Oxford, Bodleian Library MS Digby 67, f. 6ra; Price (1955b), 204.
[51] Price (1955b), 64.
[52] It is used for the prime meridian in a table of latitudes and longitudes in the instrument compilation Salamanca Ms. 2621 (f. 95v), discussed in chapter 2 of this thesis. See also Bodleian Library MS Laud Misc 674, f. 73r, which cites Arzachel on the difference in longitude between Arim and Toledo.
[53] Rudolf of Bruges (1999), 75.
[54] I am not suggesting that John Westwyk read Rudolf's treatise, or that Rudolf's treatise is the treatise on the astrolabe referred to in the *Equatorie* (that would be extremely unlikely, as Rudolf does not use the phrase "midnight line" or anything similar; he always refers to it as 'linea septentrionalis').
[55] Peterhouse MS 75.I, f. 72r.

singular form ḥaḍīḍ referred to the perigee. But this should not be taken as evidence that Westwyk was translating a work originally written in Arabic, since 'lyne alhudda' describes the radius of the equatorium on which lies the solar apogee, rather than its perigee. Given this opposite meaning, one might suppose that Westwyk had seen the word in a treatise on a similar subject and, misunderstanding its sense, chosen to use it for a part of his instrument that had thitherto lacked a name. However, Westwyk may not have been the first person to make this association. A manuscript produced in Germany in the mid-fifteenth century, which contains a number of astrological treatises, incorporates a text headed 'Note [on] the foreign names which are found in authoritative works.'[56] Among various familiar and unfamiliar Arabic terms is the following definition: 'Alucha id est linea medij celi.'[57] The line of midheaven, or meridional line, was the line running from the centre to the top of an astrolabe plate, just as 'lyne alhudda' runs on the equatorie (see figure 20 and frontispiece); and Westwyk himself uses the term 'meridional lyne' in preference to 'lyne alhudda' in the latter part of his treatise.[58] (This may suggest that Westwyk was using a different source text for that part, but we would need more evidence to be sure of that.) The obvious difference between *alhudda* and *alucha* should make us cautious, but since they share a definition (and no meaning or source can be found for the latter word), we might tentatively suggest that Westwyk was using a term that was circulating in some Latin texts at this time.[59]

Taken together, the Arabic words found in the *Equatorie of the Planetis* seem to be evidence not of a single underlying Arabic source text, but rather of individual Arabic words filtered through Latin. Of the four instances of Arabic words or phrases we have discussed (including the *bismillah* mentioned earlier) two are certainly somewhat commonplace or conventional, while the other two are both found in at least one Latin treatise, and in the *Equatorie* are probably used out of what in Arabic would be their correct astronomical context. It thus seems most likely that the *Equatorie* treatise only contains these few Arabisms because Westwyk had adopted them from other texts he had read.

The foregoing discussion may have conveyed the impression that the *Equatorie* treatise is relatively free from neologisms. Such an impression would probably be an accurate one. Although the *Middle English Dictionary* cites Peterhouse MS 75.I as the earliest source for dozens

[56] Vienna, Österreichische Nationalbibliothek, Cod. 5438, ff. 168r-171r. It is edited in Kunitzsch (1977).
[57] Cod. 5438, f. 168r, in Kunitzsch (1977), 13.
[58] Peterhouse MS 75.I. *Lyne alhudda* appears (13 times) only on ff. 72r-73r; *meridional lyne* (12 times) only on ff. 77r-78v.
[59] Kunitzsch (1977), 23. Kunitzsch notes that the usual Arabic equivalent to *linea medii celi* was *khaṭṭ wasaṭ as-samā'*. He suggested that the mystery word could also be read as *alruha* or *aliuha*, but was equally unable to identify them.

of words, in many cases, such as "difference", "marke" or "crois", the meaning intended by the author was so close to a pre-existing usage as to be almost indistinguishable.[60] Other cases, such as "boydekyn" or "karte whel", concern everyday items whose names surely cannot have been invented by a Benedictine monk for use in an astronomical treatise. As appendix G shows, the list of genuine coinages in the manuscript is quite short, and they are invariably signalled by the writer.

There is a further group of words whose only prior appearance is in the *Treatise on the Astrolabe* or some other work by Chaucer. R. M. Wilson, in the 'Linguistic Analysis' he undertook for Price's 1955 edition of the *Equatorie*, numbered these at 35, but Stephen Partridge, taking account of appearances in Trinity College MS O.5.26 and supposed differences in usage between the *Astrolabe* and *Equatorie*, reduced this to seven.[61] Partridge was very strict on the question of usage because the purpose of his analysis was to see if common words between the two treatises could be used to argue for Chaucer's authorship of Peterhouse MS 75.I, but the thrust of his analysis is relevant here: the more manuscripts from this period we examine, the less exceptional the vocabulary of the *Equatorie* turns out to be. It could hardly be otherwise, if Westwyk wanted his readers to understand his treatise. Partridge dismisses the significance of the seven words that are shared by the *Equatorie* and *Astrolabe*, stating simply that the shared unusual vocabulary 'can be explained [...] by the fact that they are two of the earliest Middle English treatises on scientific instruments.'[62] That is, no doubt, true. But in that case it is particularly noteworthy that Westwyk needed to define so few words. Instead, he took advantage of his audience's familiarity with the *Treatise on the Astrolabe*, as well as with a few Latin terms that he brought into English perhaps for the first time. Where he may have been unsure that his audience would understand the Latin term, he modified the sense of existing English words such as "drawe out" (to mean "subtract"), or created new derivative forms such as "[en]closer".

This is typical of what Butcher has termed 'vernacular behaviour' in this period.[63] The fluid use of language, allowing the construction of new vocabularies and identities, was a symptom of the increased use of English in many settings. The permeable boundaries between Latin, French (whose influence is particularly apparent where adjectives follow nouns) and English, and between oral and written uses of the language, gave Westwyk great flexibility for the adaptation of his Latin source text (or texts). It has long been accepted that the process of translation afforded significant scope for self-expression, but what the *Equatorie* and related manuscripts show is that this applied to astronomical material too. When we see a scribe in Aberdeen MS 123

[60] McSparran (2001).
[61] Wilson (1955); Partridge (1992).
[62] Partridge (1992), 31.
[63] Butcher (2011), 296.

practising writing in English and perhaps trying out different spellings (figure 27), or translating Indo-Arabic numerals in a Latin text back into their Roman equivalents in the English version (see appendix F), we are witnessing processes of learning and experimentation that helped shape Middle English scholarship.

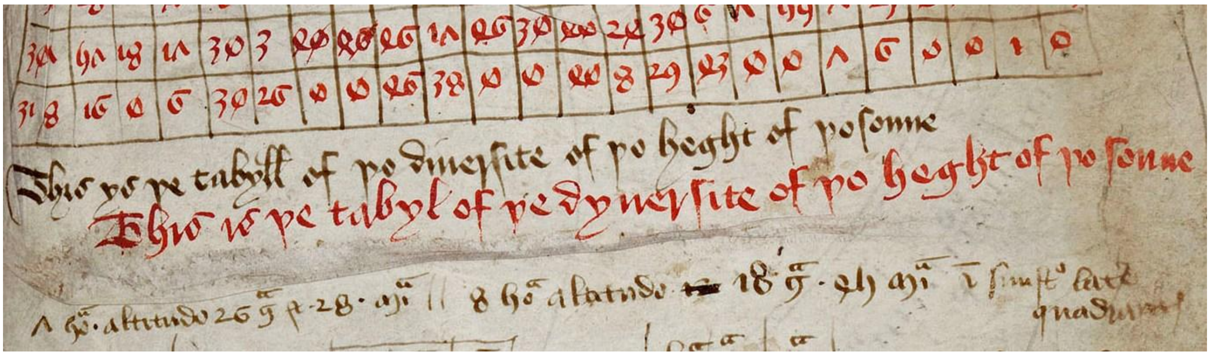

Fig. 27: Practice writing a table heading in English with alternative spellings. University of Aberdeen MS 123, f. 44r. Reproduced by permission of the University of Aberdeen.

## Conclusion

Such 'vernacular behaviour', it is clear, was characteristic of the vibrant, multilingual, astronomical community within which John Westwyk worked. The previous chapter employed an analysis of Westwyk's language choice, in order to situate him firmly within that community. This chapter has examined how he used the linguistic tools at his disposal to compose a fluent, cohesive piece of craft writing. We have seen how Westwyk established an intimate didactic relationship with his reader, making the objectives of his teaching clear at every stage. Whereas in the last chapter we saw how he used his own languages purposefully, in this chapter we saw how he exploited and expanded the linguistic range of his reader. But of course he was not just teaching language: he used his Middle English – and occasionally Latin too – carefully as a tool to clearly convey the technical and practical information necessary for the construction and use of his equatorium. In turn, the equatorium itself would be a tool for learning astronomical concepts (as well as simply finding planetary positions); but Westwyk's didactic language was an indispensable instrument in the first instance.

A close reading of the *Equatorie of the Planetis*, in conjunction and comparison with other texts, has enabled us to reconstruct these teaching and learning processes, as well as the environment in which they took place. Westwyk may cite Roger Bacon, but his plain, oral diction is a world away from the academic milieu Bacon describes, where scholars were equally at home in English, French or Latin.[64] His clarity is perfect for this dialogue between scholar and craftsman. His language use is equally as pragmatic as his language choice. He minimised neologisms and where they were required he modified the sense of existing words, or borrowed words from his reading in Arabic-influenced Latin sources. As we have seen, the *Equatorie*'s Arabic-derived words and phrases are most likely to have come not from a single Arabic treatise that underlies Westwyk's, but rather from Latin texts which may have had entirely different subjects.

Thus our close reading has been able to tell us more than we might have expected about this manuscript. Contrary to Price's suggestion, we should not hope to find a single Arabic source for Westwyk's treatise.[65] Instead, we should widen our view of the Latin – and perhaps vernacular – sources which underlie his astronomical understanding and linguistic capabilities. This chapter has demonstrated the benefits of close literary analysis for our understanding not only of a single text, but of scholarly practices in the astronomical community from which that text arises. Westwyk was certainly not alone in his pragmatic approach to composition and translation. We see it too in Aberdeen MS 123, where the translator ignored sentences that dealt with purely theoretical matters and perhaps also those he could not understand. These approaches allowed writers to find a voice appropriate to the material they wished to communicate. In this chapter we have seen how John Westwyk blended scholarship and craftsmanship in his use of the vernacular. In the final chapter of this thesis we shall see how they were blended in the instrument and tables that he compiled.

[64] Bacon (1859), 433.
[65] Price (1955b), 4.

## CHAPTER FIVE

# Learning through instrument and tables: the content of the *Equatorie of the Planetis*

> The fifthe partie shal be an introductorie, after the statutes of oure doctours, in which thou maist lerne a gret part of the generall rewles of theorik in astrologie. In which fifthe partie shalt thou fynden tables of equaciouns of houses after the latitude of Oxenforde; and tables of dignitees of planetes, and othere notefull thinges.
>
> Geoffrey Chaucer[1]

Chaucer's desire to help his son Lewis – and perhaps other readers – 'lerne sciences touching nombres and proporciouns' is familiar to readers of his *Treatise on the Astrolabe*.[2] But while the potential for learning through the use of an instrument has been accepted and widely discussed since Chaucer's time, little has been written about the connection between tables and learning practices in astronomy; or about how tables and instruments were used together by astronomers. The abundance of tables in medieval scientific manuscripts is testament to their popularity, but it is difficult to identify how they were used, with or without instruments, since evidence of such use is scarce. Assessing how astronomers learnt to use both instruments and tables, or learnt theories and techniques through them, is difficult; this is especially true for tables, which are rarely accompanied by didactic text in surviving manuscripts; explicatory canons which do sometimes direct their users are invariably written in spare instructional prose, and there are few clues as to how, or by whom, such canons were followed.

Nevertheless, both descriptions of instruments and unadorned tables can be rich sources of evidence about the practices of the astronomers who used them. And where those astronomers lacked expertise, we can draw conclusions about the ways that they learnt and practised the techniques of their art through such use. This is why the work of John Westwyk is such a valuable case to study. Derek Price suggested that his *Equatorie of the Planetis* was 'obviously intended for the amateur rather than the professional' reader.[3] Price's implication, supporting his contention that the *Equatorie* represented Chaucer's completion of his *Treatise on the Astrolabe* (it incorporates much of the content Chaucer had promised for the *Astrolabe*'s third, fourth and fifth parts), was that its author was a competent astronomer writing for a less learned pupil. But Price, concerned above all to prove Chaucer's authorship of the treatise, did not consider it in its

[1] 'A Treatise on the Astrolabe', Prologue, lines 100-107, in Chaucer (1988), 663.
[2] 'A Treatise on the Astrolabe', Prologue, lines 2-3, in Chaucer (1988), 662. The explicit and potential audiences of the *Astrolabe* have been discussed by many scholars: see, for example, Laird (2007); Mead (2006).
[3] Price (1955b), 159.

codicological context. He dismissed the tables that comprise the bulk of the manuscript as 'of comparatively slight interest since they are a simple modification of the well-known Alfonsine tables,' and thought it 'only necessary to indicate their content and the manner in which they have been modified.'[4] Similarly, John North, despite stating that 'the sheer aptness of *all* the tables in the codex for use with the equatorium cannot be too strongly emphasized', gave almost no explanation of that use.[5] When one examines the tables closely and considers their use both with and without the instrument, their heterogeneity stands out, and the conclusions of Price and North begin to seem rather bold.

The first four chapters of this thesis have, I hope, gone some way towards reconstructing the intellectual and institutional environment in which John Westwyk came to produce Peterhouse MS 75.I. This chapter will analyse the content of the manuscript, assessing how Westwyk compiled, computed and composed his unique compendium, and suggesting what he learned in the process. Whereas scholars such as Price, North and Emmanuel Poulle, influenced by the seminal mathematical histories of Otto Neugebauer, have – rightly – seen the *Equatorie* within a wide-ranging, enduring network that communicated astronomical theories and instruments across the medieval world, I take a different approach.[6] Rather than emphasising the continuity visible through this manuscript, this chapter will emphasise the individuality of its production, the specific historical context of its use. I take Westwyk's seventy-eight folios together as a personal compilation that reveals much about his priorities, learning processes, and level of expertise. I do not give a full description of the equatorium's functions, since that has been done by previous scholars.[7] Instead, I call attention to features of the design and description – many not mentioned in earlier studies – which reveal the nature and qualities of the instrument. In addition, this chapter has a mathematical focus, exploring what we can learn through a reconstruction of Westwyk's practices in compiling, computing and using tables that required and enabled a range of astronomical techniques. Together, these parallel technical analyses provide new insights into these astronomical tables and instrument, as well as the man and environment that produced them. They will be seen to display a lower level of astronomical understanding than has hitherto been assumed, but a high level of conceptual ingenuity.

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[4] Price (1955b), 75.
[5] North (1988), 176 (his emphasis).
[6] Poulle (1980, 161-165) analysed the equatorie design as part of his monumental study of planetary instruments, but did not discuss the tables or the wider context of this manuscript. Neugebauer's approach was most clearly expressed in his *History of Ancient Mathematical Astronomy* (1975), but his influence began much earlier; Price thanked him in the preface to his work on the *Equatorie* (1955b, xvi).
[7] The most thorough description remains that of Price (1955b), 93-118. For its place among the evolving designs of medieval equatoria, Poulle's (1980) exhaustive survey is invaluable.

Readers may be wondering how, given that the previous two chapters analysed Westwyk's pedagogical purposes and practices in writing the *Equatorie*, he can also have been learning the arts of astronomy. Can he have been both student and teacher? In response, it might first be pointed out that it is quite possible for Westwyk to have wanted to pass on what he had already learned of astronomical theory and, especially, practical instrument-making, while he was still learning more complex theories, uses of the equatorium, and especially the techniques of computing and using mathematical tables. More fundamentally, it may well have been through teaching that Westwyk learnt most successfully. The principle that teaching and learning go hand in hand is popular in modern pedagogy, but has an ancient pedigree, and may well have been familiar to Westwyk in the form of Seneca's dictum 'homines dum docent discunt'.[8] Close study of the contents of the *Equatorie* will reveal how Westwyk's practices represent a balance of competing – and often complementary – priorities: learning and teaching; instruments and tables; production and use; scholarship and craftsmanship.

## THE *EQUATORIE*: INSTRUMENT AND TABLES

John Westwyk's equatorium was, he tells us early in his treatise, 'compowned the yer of Crist 1392 complet, the laste meridie of decembre.'[9] Like other equatoria, this instrument requires an input of mean motion data in order to compute the longitudes of the planets (including the Sun and Moon); the necessary tables, with radices for 1392, are found, written in Westwyk's hand, in the first folios of the manuscript. The fact that in his very first sentence Westwyk tells his reader how size might affect 'the trowthe of thy conclusiouns', and provides all the necessary reference material, calibrated to the correct date and meridian, suggests that his priority is the use of the instrument with tables to compute data. It will be seen throughout this chapter that his practices were by no means so straightforward: he used the tables alone, and he used the instrument to highlight theoretical points. Nevertheless, let us first evaluate the equatorie as a computational aid. We cannot be sure that it was Westwyk's invention, and we have seen in previous chapters that the *Equatorie* is likely to be at least partly translated from Latin, but there are several signs of original composition, so our evaluation of the instrument will also be to some extent an evaluation of Westwyk himself.

Price, in a trenchant essay quoted in the introduction of this thesis, argued that equatoria were 'tangible models . . . planetary simulations.'[10] Yet, as North points out, they 'did not

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[8] 'While men teach, they learn.' *On Crowds*, VII.8, in Seneca (1917), 34. Seneca's writings were very popular in this period, and his influence on Chaucer has been discussed by Wilson (1993).
[9] Peterhouse MS 75.I, f. 71v. 'complet' refers to completed years.
[10] Price (1980), 76.

necessarily resemble the *physical* model at which the maker of a mechanical planetarium must needs aim.'[11] In fact, as North notes, they seem much closer to the diagrams of Ptolemy's *Almagest*. The striking similarities between equatoria and theoretical diagrams suggest that, for men who wrote about them, the boundaries were blurred: the instruments sometimes acted as explicatory diagrams with moving parts, as we saw in chapter 2.[12] On the other hand, their diagrammatic nature perhaps made it easier for someone seeking a computational tool; the challenge for the designer was to simplify those theories into a form that was as easy as possible to construct and use, while still computing the positions of the planets to an optimal degree of precision. As a computational aid, the success of an equatorium may be evaluated based on how much time it saved its user in the task of finding planetary positions, and at what cost in terms of accuracy, compared with the alternative method: calculation using tables alone. Judged by this standard, the Peterhouse equatorie is remarkably successful.

Following the models set out in Ptolemy's *Almagest*, it maps the motion of the planets in the plane of the ecliptic. Like almost all medieval instruments, it ignores motion in latitude (with the exception of the Moon), meaning that the instrument can effectively be two-dimensional.[13]

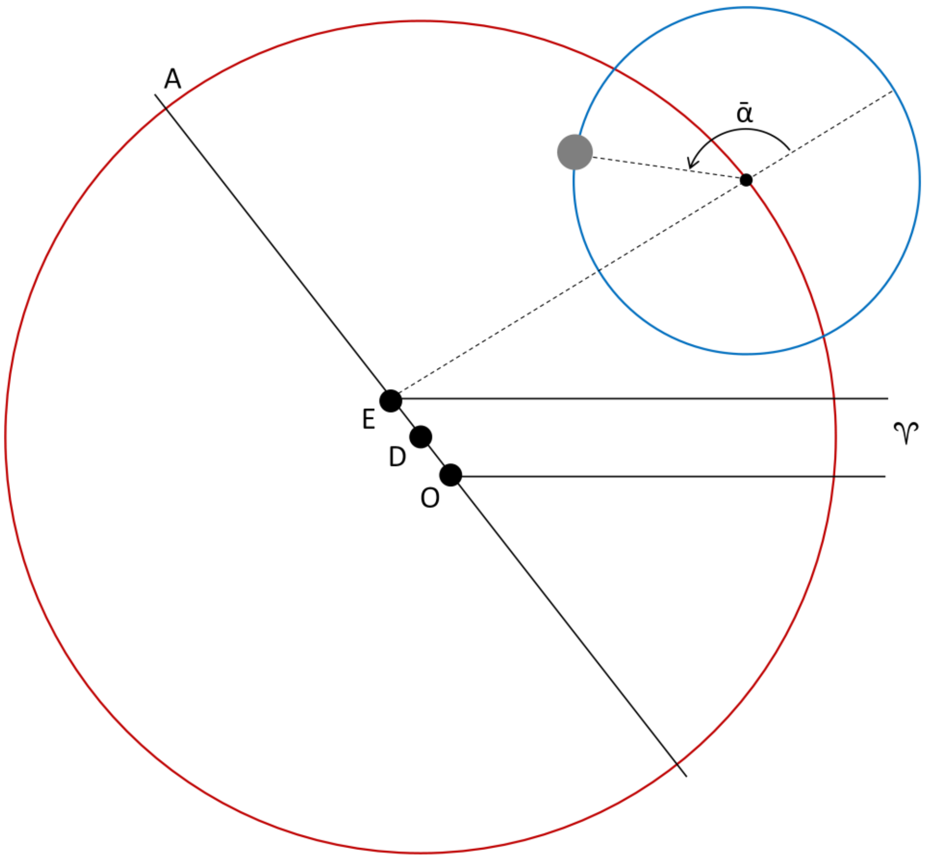


Fig. 28: Basic Ptolemaic theory for an outer planet, showing the position of the observer (O), the equant (E) and deferent (D) centres, the planetary apogee (A), the epicycle (blue) and deferent (red), and the mean anomaly (ᾱ).

[11] North (1976), II. 261 (his emphasis).
[12] Some of the earliest printed equatoria, such as those of Johannes Schöner (1521) or Peter Apian (1540), seem to fit this description rather well.
[13] Richard of Wallingford's Albion is a rare medieval example of an instrument that does deal with planetary latitudes ('Tractatus albionis', III.41, in North (1976), I. 386).

Ptolemy's theory (see figure 28) permits a planet's position in longitude to be found from constantly changing mean motions.[14] Five pieces of information are required to ascertain a planet's longitude in this model: the relative sizes of the deferent and epicycle; the eccentricity of the deferent (i.e. the distance of D and E from O); the direction of the line of apsides (i.e. of D and E from O); the location of the epicycle centre in longitude; and the arc of the motion of the planet around the epicycle. Of those five, the first two were not thought to change over time (though accepted values varied); the other three were commonly tabulated in the collections of tables that circulated widely across Europe in the fourteenth century, invariably based on those adapted at Paris c. 1320 from the tables compiled for Alfonso X of Castile and León (1252-84).[15] The line of apsides moved slowly and irregularly, as we shall see shortly, but the remaining two parameters in the theory moved at a constant speed, and could thus be tabulated in daily and annual increments, which could be added to the radix (the value at some epoch, such as the Incarnation of Christ) to give the mean motions at the desired date. The position of the epicycle centre on its path around the deferent circle was measured as an arc at E, either from the vernal point ♈ (mean longitude $\bar{\lambda}$, also known as mean motus) or from the apogee A (mean centre $\bar{\kappa}$), while the position of the planet on its epicycle was given by the mean anomaly $\bar{\alpha}$ (also known as mean argument), measured from the mean epicyclic apogee (a point on the epicycle diametrically opposite to E).[16]

In order to evaluate the success of the Peterhouse equatorium in representing and simplifying this model, a comparison with the 1350 Merton astrolabe-equatorium (discussed in chapter 2) will be instructive. Of all medieval equatoria it is perhaps the most similar in design to the Peterhouse equatorium.[17] However, some significant differences allow us to highlight the further simplifications that are unique to the equatorie. The essential features of the Merton design (figure 29; and see also the photograph in figure 19) are, simply stated, as follows: first, all the planets are shown on a single disc (in contrast to earlier designs, such as that of Campanus of Novara (c. 1260), which effectively consisted of seven separate instruments).[18] Second, that disc represented the ecliptic, and featured graduated circles representing the equant circles of each planet (one is shown in figure 29). Such an ecliptic disc could not be graduated to show the direction of ♈ from every planet's equant centre, but the graduated equant circles allowed the user to locate the centre of the epicycle directly, using the mean centre ($\bar{\kappa}$). Third, it used what

[14] The theory is explained in historical perspective by Evans (1998), 355-384.
[15] Chabás and Goldstein (2012).
[16] Because the vernal point (♈) is deemed to be infinitely far away, the angle from E and O will be the same.
[17] This similarity does not arise in Poulle's (1980) analysis, because he grouped equatoria that use mean centres separately from those that use mean longitudes.
[18] Benjamin and Toomer (1971), 30.

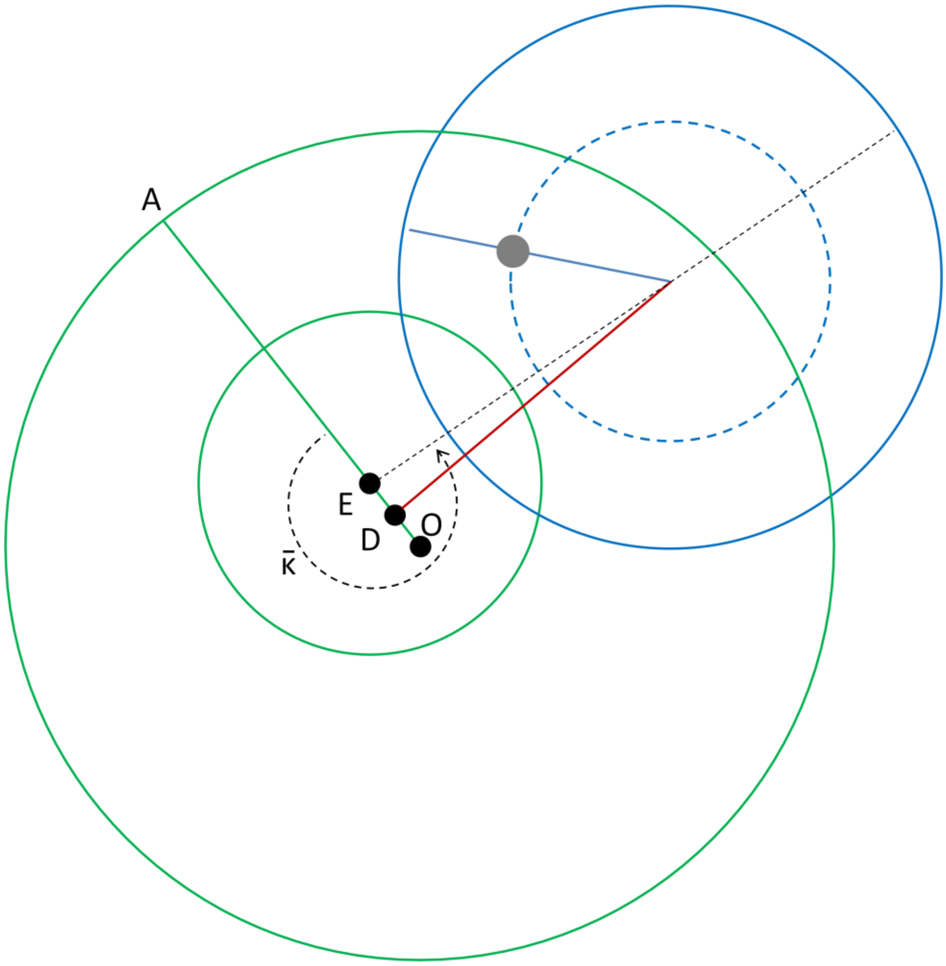


Fig. 29: Workings of the Merton equatorium, showing the ecliptic disc (large green circle), graduated equant circle (small green circle), deferent radius (red) and common epicycle (blue), whose centre is located using the mean centre ($\bar{\kappa}$) measured from the apogee.

Campanus had called a common epicycle: a graduated circle sized to accommodate the epicycles of all the planets, whose different radii were marked on a rule that rotated about the centre of the common epicycle and thus traced out the epicycles of all the planets at once. Fourth, the deferent circle was reduced to a radial bar (evocatively described as *cauda epicicli* – epicycle tail – in a number of fifteenth-century manuscripts),[19] fixed permanently to the centre of the common epicycle; its other end could be attached to the deferent centre for any desired planet (these are all marked on the disc). This single deferent radius could be used for all planets if their epicycle radii on the rotating rule were sized in proportion to it.

Figure 30 shows the essential features of the Peterhouse equatorium. Its similarities to the Merton design are obvious, but some important simplifications should be noted. First, it dispenses with the graduated equant circles. This prevents the placing of the epicycle directly using the mean centre; instead, the mean longitude ($\bar{\lambda}$) can be laid out at O, and the angle translated to E using parallel threads. This rather fiddly technique will be discussed further below, but it will be noted immediately that the removal of the equant circles greatly simplifies the instrument's production. That first difference is not unique to the Peterhouse equatorium: a

[19] Poulle (1980), 158.

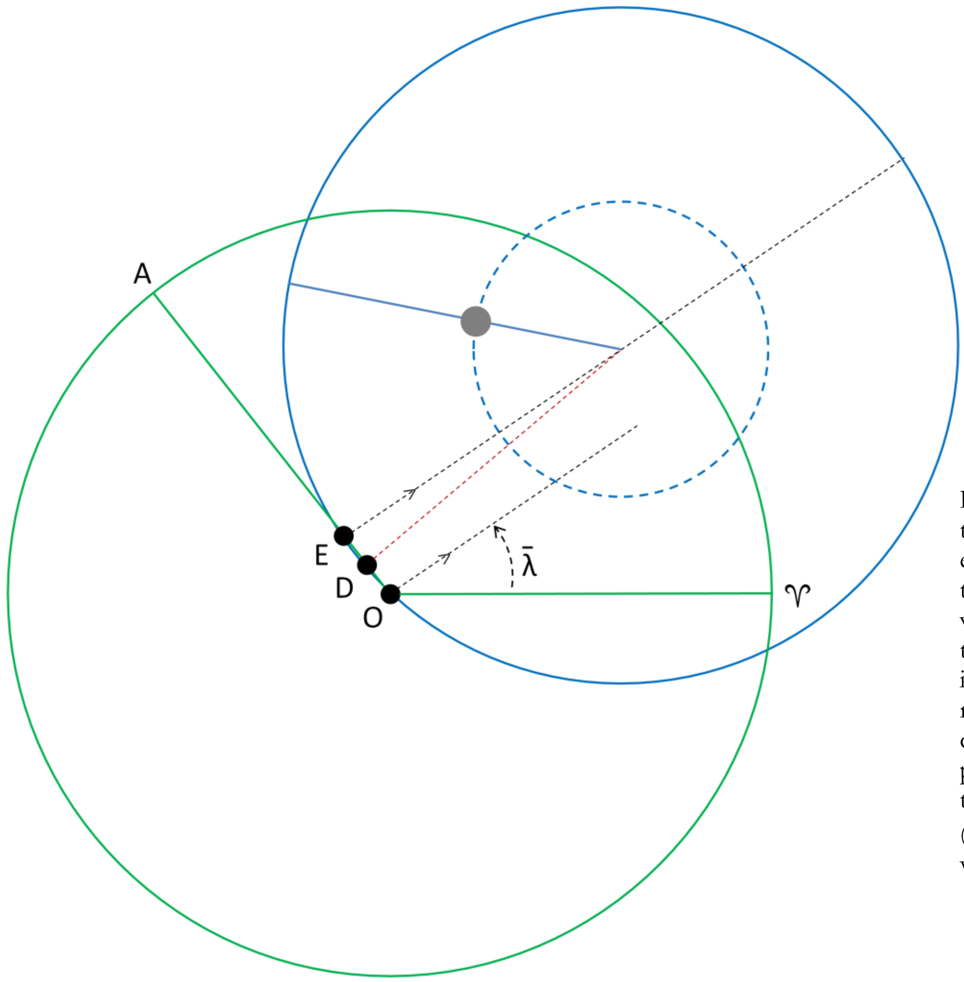


Fig. 30: Workings of the Peterhouse equatorium, showing the common epicycle with radius equal to the (now merely imaginary) deferent radius. The epicycle centre is located via parallel threads, using the mean longitude ($\bar{\lambda}$) measured from the vernal point.

number of manuscripts from this period contain the same simplification, accepting as a consequence that the mean longitude would have to be used to locate the epicycle centre.[20] However, the second simplification does not occur in any other surviving manuscript. The equatorie designer realised that the common epicycle could do the work of both deferent radius and epicycle, if its radius were made equal to the deferent radius. The rim of the common epicycle could be fixed in place over the deferent centre of the desired planet, thus obviating the need for the "epicycle tail" of the Merton design.

This represents a clear simplification in design. The advantages (and one disadvantage) for its construction will be discussed below, but for now it is worth discussing a disadvantage of this simplification which was raised by Poulle. He pointed out that if a reference point on the rim of the common epicycle was to be held in place over D on the face of the instrument, the common epicycle could not be rotated to enable the mean anomaly to be counted out from a mean epicyclic apogee marked on the common epicycle. Thus the use of such a reference point, which John Westwyk calls a 'comune centre defferent', is incompatible with the use of a mean epicyclic

[20] Poulle (1980), 150-192.

apogee marked 0 on a graduated common epicycle.[21] While Poulle is right about this disadvantage, it is by no means so serious as he implies in dismissing the equatorium's 'médiocre performance.'[22] The common epicycle can still be graduated and numbered and the mean anomaly counted out; the user only has to take account of the fact that they may not be counting from 0. This minor inconvenience is clearly outweighed by the advantage of dispensing with a separate deferent circle or radius.

While the design can thus be shown to represent an improvement on earlier equatoria, the full ingenuity and user-friendliness of the Peterhouse equatorium only begin to become apparent when we consider the practicalities of its construction, as described by John Westwyk.[23] As a result of the simplifications noted above, the instrument consists simply of a disc, a ring and a rule ('label'); Westwyk directs their construction and calibration step by step. In chapter 3 we saw the practical usability of his instructions to the reader, as when he explains how to correct any error in the radius of the common epicycle.[24] Here let us focus on his description of its design, which is thorough enough that it can still be used to construct a working instrument today (see figure 31). His comments, corrections and modifications paint a vivid picture of a craftsman learning from the experience of making his own instrument.

Westwyk's constant commentary on what is practically feasible renders untenable any doubts about whether the equatorie is a real, physical object. Such doubts have been raised by its extravagant size: North remarks cautiously that 'an instrument as large as this would have been very unusual',[25] while Poulle is somewhat more optimistic, writing that 'si cet instrument a été effectivement exécuté, comme certaines allusions le laissent à penser, ce devait être un monument impressionnant.'[26] The implication of these discussions is that it was all or nothing: either the author intended his instructions to be taken literally and followed to the letter, or we can assume that the whole project was a thought-experiment and the instrument was never constructed in anything like the form described. But as we have already seen, Westwyk had himself made the equatorium at a size smaller than he prescribes;[27] and he offers his reader the same practical

21 Peterhouse MS 75.I, f. 73r. Westwyk here states that the common deferent centre, which incorporates a hole so that it can be pinned to a planet's deferent centre, is to be located at the head of Cancer. Since the epicycle will be fixed in place, the names of signs merely denote groups of 30 degrees, but Westwyk seems perfectly comfortable with that.
22 Poulle (1980), 163.
23 "User-friendliness" may be a modern term, but it is an idea familiar to medieval instrument- and table-makers, as Chabás and Goldstein (2013) have shown.
24 Peterhouse MS 75.I, f. 73v. See also Price (1955b), 68-69; North (1988), 164.
25 North (1988), 159.
26 Poulle (1980), 164. Poulle goes on to argue that in order to be able to attach the common deferent centre to the deferent centre of Venus (the planet with the smallest eccentricity) while leaving room for a thread at the Earth, those dimensions would be necessary. Any smaller and the resulting reduction in the width of the metal ring of the common epicycle would render it unsustainably fragile.
27 Peterhouse MS 75.I, f. 73r. See discussion in chapter 3, p. 93.

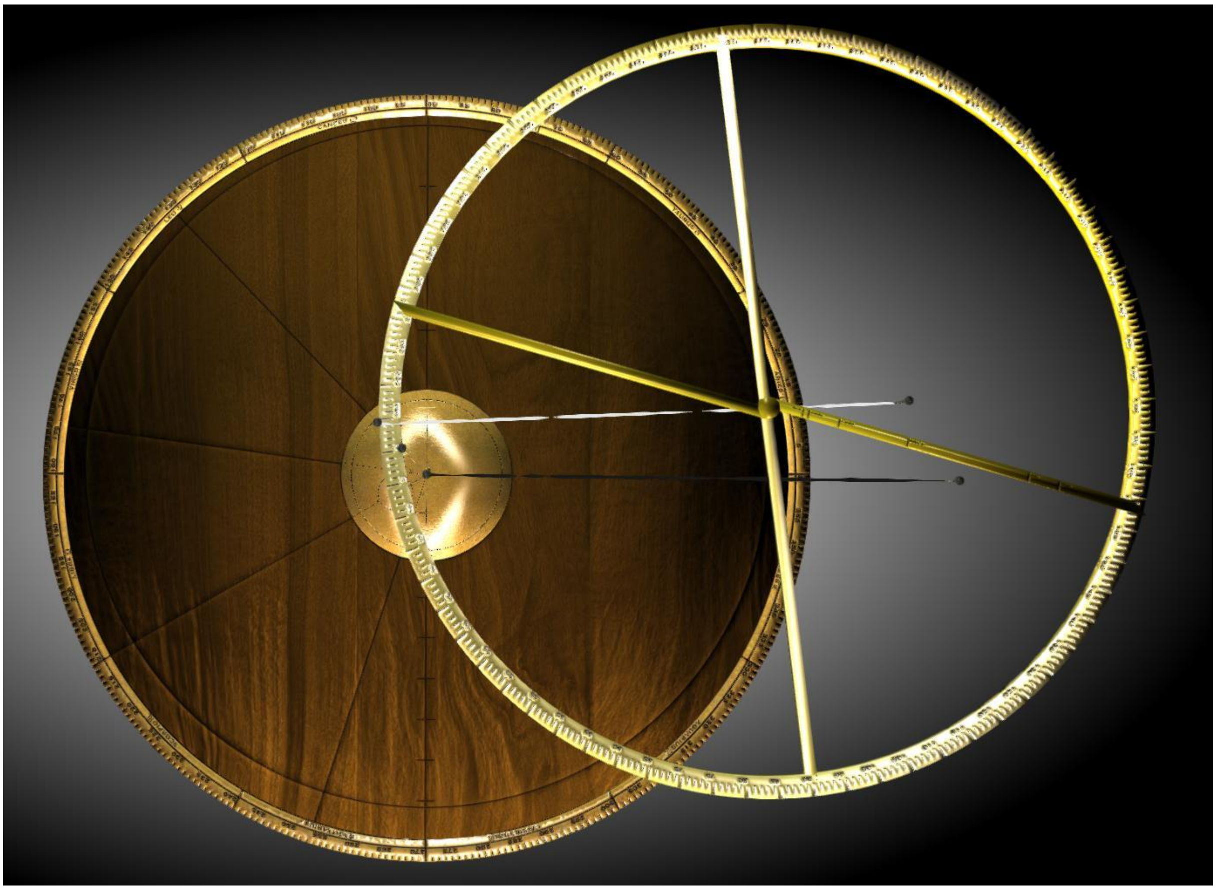

Fig. 31: Virtual model made according to the instructions in Peterhouse MS 75.I, by Ben Blundell and Seb Falk for the Cambridge Digital Library (http://cudl.lib.cam.ac.uk/view/MS-PETERHOUSE-00075-00001). Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

leeway, for example when he advises that the circle of Mercury's movable deferent should be pierced with 360 holes 'yif it be possible or in 180 or in 90 atte leste', advice that may well be taken directly from Richard of Wallingford's instruction to divide the little circle of Mercury on his Albion into '360 partes equales . . . vel in quot eorum fuerit possibile.'[28] Since Westwyk seems to be translating and composing or modifying his draft as he worked through the construction and use of the equatorium, it is quite possible that he was being literal and practical on some points, and idealistic or unrealistic on others. We have a hint of this when he explains the material to be used for the disc. After writing on the first folio that it could be either 'a plate of metal or elles a bord that be smothe shave by level and evene polised', the 'bord' is repeated a further five times in discussions of the preparation of the face of the instrument, while the idea that the whole face could be made from metal is never again mentioned.[29] This suggests that an idealistic vision is being rapidly tempered by an awareness of what is practically feasible.

This revision in favour of more modest aspirations is completed by the almost immediate recommendation of a metal plate, 16 inches in diameter, to be nailed over the middle of the

[28] Peterhouse MS 75.I, f. 72v; Richard of Wallingford, 'Tractatus albionis' II.6, in North (1976), I. 304.
[29] Peterhouse MS 75.I, f. 71v.

board.[30] This plate displays an admirable balance of practicalities. It is to be pierced with holes to mark the deferent and equant centres for each planet and the Moon, making it easier to fix in place the 'comune centre defferent' and the threads that are to be used for measurement. Secondly, it can be turned to account for the movement of the apogees due to precession. If the markings were made directly onto the face, the equatorium would eventually become out of date through these movements; the plate can be turned, and 'thus may thin instrument laste perpetuel.'[31] Actually the instrument is not quite perpetual, but this raises a third point of practicality. The eccentric circle of the Sun does not fit on the 16-inch plate, so cannot be turned and will have to be redrawn if the instrument is to be updated. But in order to include the Sun, whose eccentric has a radius of fifteen-sixteenths of the face (excluding the two-inch limb of the disc), almost the entire face would have to be covered with a metal plate. It seems that Westwyk had weighed up these practicalities when he wrote that 'the eccentrik of the sonne is compaced [drawn] on the bord of the instrument and nat on the lymbe for sparing of metal.'[32]

Of course metal should be spared as much for reasons of cost as for ease of construction. But another aspect of the design suggests that, where those two priorities are in conflict, the latter comes first. This is the removal of the radial bar of the deferent and its replacement by a larger common epicycle to serve as both epicycle and deferent radius. As we have seen, on the Merton equatorium the common epicycle only needed to be as big as the largest planetary epicycle (relative to the size of their deferents), which is that of Venus. But in the Peterhouse design, the size is dictated by the radius of the common deferent. This must be in proportion to the planets' eccentricities which, in turn, are based on a unit equal to the interior radius of the face, from the centre to 'the [en]closere of the signes' (where the face joins the limb), which measures 34 inches. Because the common deferent centre is located on the interior rim of the common epicycle and the ring of the epicycle has the same width – 2 inches – as the limb of the disc, the result is that the epicycle and disc are exactly the same size. Westwyk gives no sign of concern over the consequent increase in material and cost, though the common epicycle has a diameter about one-third greater than it otherwise would. Of greater importance, it seems, was the fact that this modification not only made the instrument overall more streamlined and easier to use, and allowed the mean anomaly to be laid out with a high degree of precision but, perhaps most importantly, greatly simplified the most difficult task in its construction: dividing the graduated circles of the limb and epicycle.

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30 Peterhouse MS 75.I, f. 71v.
31 Peterhouse MS 75.I, f. 71v.
32 Peterhouse MS 75.I, f. 73v. It is not clear how the Sun's eccentric circle could be drawn on the limb; this is perhaps a mistake.

Accurately dividing a circle was a notoriously difficult problem for instrument-makers. Westwyk does not specify how he wanted the limb and epicycle to be divided, but elsewhere he instructs his reader to make 360 small holes in the circle that carries the Moon's movable deferent and equant centres, the spaces between the holes being 'devyded owt of the degres of the lymbe.'[33] This presumably meant drawing lines inwards from the degrees on the limb, which was a viable solution because the circle to be divided was centred on the Earth. The same was not true of the circle of Mercury's movable deferent, so in this case 'the spaces by twixe [between] the holes shal nat be devided owt of the grete lymbe of the instrument, as is the centre defferent of the mone, but owt of the circumference of the same litel cercle it shal be devided by thy compas.'[34] It is not entirely clear what this means: a compass could be used to divide a circle geometrically, but Price thought that the circle was to be divided using a protractor.[35] Even if that is the case, it was hardly a technique that could be used to divide the limb, as any small error in the placement of the protractor would be greatly magnified when the lines were extended all the way to the limb. Thus these examples do not give us a completely clear picture of Westwyk's construction techniques, but his discussion certainly demonstrates that he was grappling with a genuine practical problem and perhaps hoped to provide his reader with sufficient instruction to overcome it.

In this he was not always successful: there are some occasions when idealism perhaps trumps user-friendliness in the construction of the equatorium. For example, Westwyk specifies explicitly that on the limb 'everi degre shal ben devided in 60 mi[nutes]',[36] which was impossible even if the disc was six feet in diameter, since that would require 95 minute-marks to be engraved on every inch of the instrument's circumference; marks every four or five minutes is perhaps the most a medieval craftsman could have accomplished at that scale. Moreover, when the treatise gives instructions for marking the face with signs, numbers and the line of apsides for each planet, a certain amount of expertise is assumed. Westwyk notes that the names of the twelve signs are to be written on the limb, but does not specify where these or the numbering of degrees should begin. The first reference to the position of any of the signs is an interlinear addition on the second folio, in Latin: 'versus finem geminorum', indicating that the radius he is about to call *lyne alhudda* points to the cusp of Gemini and Cancer.[37] This reference comes immediately before we are instructed to draw the Sun's deferent, with its centre on this radius. This would place the

33 Peterhouse MS 75.I, f. 72r.
34 Peterhouse MS 75.I, f. 72v.
35 Price (1955b), 67. Price gave no justification for this assertion, but it is perhaps supported by the fact that the thick vellum sheet which is now an endleaf in the codex, and which was perhaps part of the original limp parchment binding, appears to have been divided in this way.
36 Peterhouse MS 75.I, f. 72r.
37 Peterhouse MS 75.I, f. 72r.

Sun's apogee at 0° Cancer, which is not far from its position, as indicated by the tables in the manuscript, at almost 0° 9' in December 1392.[38] However, it is surprising that Westwyk is so vague about this, and it may be remarked that he was fortunate that the Sun's apogee was so near to the beginning of a sign at the time he was writing.

As well as a certain expertise required to follow Westwyk's instructions, it should be noted that the reader would need to be adequately equipped. Aside from the materials comprising the equatorium itself, the need for a compass has already been noted. To this should be added a set of planetary tables. Westwyk instructs us to mark the lines of apsides according to 'the table of auges [apogees] folwynge'; this can duly be found on folio 6v of the manuscript.[39] The next step is to mark the deferent and equant centres on the lines of apsides; a little later, the radii of the planets' epicycles are to be marked on the rotating label. For both these steps Westwyk includes the values for Saturn, as examples within an admirably clear explanation, but we are not to have our hand held all the way: 'this ensample of saturne techith how to maken in the label alle the semydiametres of epicycles of alle the planetis.'[40] These semidiameters, we are told, can be found along with the eccentricities 'in thi table of centris.'[41] The manuscript does not include a table giving the eccentricities or epicycle radii of the planets, so 'thi table' could be read literally as an assumption that the reader – perhaps a particular individual of whose resources Westwyk was aware – was expected to have these planetary constants already.[42]

A final point to be made against the usability of Westwyk's construction directions concerns the order of the steps in the process. The *alhudda* line (which Westwyk implicitly equates to the meridian line on an astrolabe) is used as a reference measure for the instrument.[43] It is first divided into 32 parts, to allow the Sun's eccentric circle to be accurately drawn; then it is divided into 60, so that the eccentricities of the planets, defined as fractions of 60°, can be correctly marked on the face. Finally, the 60 divisions are erased and the line is divided into five parts, so that it can be used to compute the latitude of the Moon. 'thise divisiouns,' we are told, 'ne shal nat be scraped awey.'[44] But we have not yet marked the label with the planets' epicycle radii, which are to be sized relative to the same 60° deferent radius. So Westwyk gives us a new instruction:

[38] Peterhouse MS 75.I, f. 6v.
[39] Peterhouse MS 75.I, f. 72r.
[40] Peterhouse MS 75.I, f. 73v.
[41] Peterhouse MS 75.I, f. 72v.
[42] Apart from the values given for Saturn, we cannot be sure what constants were used. The ones for Saturn accord with Ptolemaic values, but the diagrams on ff. 73v and 74r show the equant centre of Mars outside the Moon's circle of holes, making the distance of Mars's equant greater than 12° 28' (as a fraction of a deferent radius of 60°); Ptolemy's value is 12°. Price (1955b, 69, 115) took this as evidence of a possible link with the equatorium treatise (or at least the tables) of Jean of Lignières, who gives an equant distance of 13° for Mars.
[43] Peterhouse MS 75.I, f. 72v. Cf. the discussion of the orientation of the Merton equatorium in chapter 2 (p. 65).
[44] Peterhouse MS 75.I, f. 72v.

> tak thanne by thy large compas the distaunce by twixe centre aryn and the closere of the signes, which distaunce is the lengthe of lyne alhudda; and be it on a long rewle or elles be it on a long percemyn marke with thy compas the forseide distaunce, & devyde it in 60 parties equals and than hastow a newe lyne alhudda.[45]

Thus, because Westwyk was hasty in instructing us to erase the 60 divisions, we are forced to make them again on a rule or piece of parchment. Price is perhaps right to criticise his 'bad planning or lack of foresight' at this point, but it does give us an insight into the composition process.[46] Even if the design of the instrument was worked out in full beforehand, it seems clear that the steps in its construction were still being delineated as this manuscript was being drafted. Here again, therefore, we see Westwyk working thoughtfully to translate an ingenious design into user-friendly instructions for construction.

## THE EQUATORIUM AND TABLES: APT TO BE USED TOGETHER

The same attention to practical usability, alongside pedagogical clarity, is apparent as we turn to see how Westwyk described the use of the equatorie with its accompanying tables. The two parts of figure 32 show the stages (numbered step by step) in the use of the equatorium. It should be stressed that, since stages 1 and 4 involved laying out the mean longitude ($\bar{\lambda}$) and mean anomaly ($\bar{\alpha}$) according to values found in the tables, the equatorie by itself is useless. Nevertheless, the first set of tables in Westwyk's hand (folios 1r-13v) is perfectly sufficient; of them it would be correct to say, as North rather exaggeratedly said of the whole codex, that they are entirely apt for use with the equatorium, and it seems likely that Westwyk compiled them for that purpose. They are broadly standard tables in the Parisian Alfonsine tradition, supplying daily and annual changes in the mean planetary longitudes and anomalies, together with radices for 1392 at London.[47] Once the mean longitude and mean anomaly for the desired date were known, the process of computing the true longitude was remarkably simple. First, a black thread attached to the centre of the disc (*centre aryn*) was drawn out to the limb, to the point corresponding to the mean longitude of the desired planet. Next, the mean longitude was transferred to the equant by means of a white thread stretched parallel to the black thread. This step is a consequence of a substantial simplification in the design of the instrument, but it is, as already mentioned, a little fiddly. Westwyk demonstrates his awareness that this was a possible source of error with the advice to 'proeve by a compas that thy thredes lyen equedistant'.[48] Thirdly, the common epicycle, whose common deferent centre had already been fixed to the planet's deferent centre, was turned so that its centre (or *pole*) lay under the white thread. In the fourth step the label could then be

[45] Peterhouse MS 75.I, f. 73r.
[46] Price (1955b), 68.
[47] On the forms and contents of the Parisian Alfonsine Tables, see Chabás and Goldstein (2012), 53-61.
[48] Peterhouse MS 75.I, f. 75r.

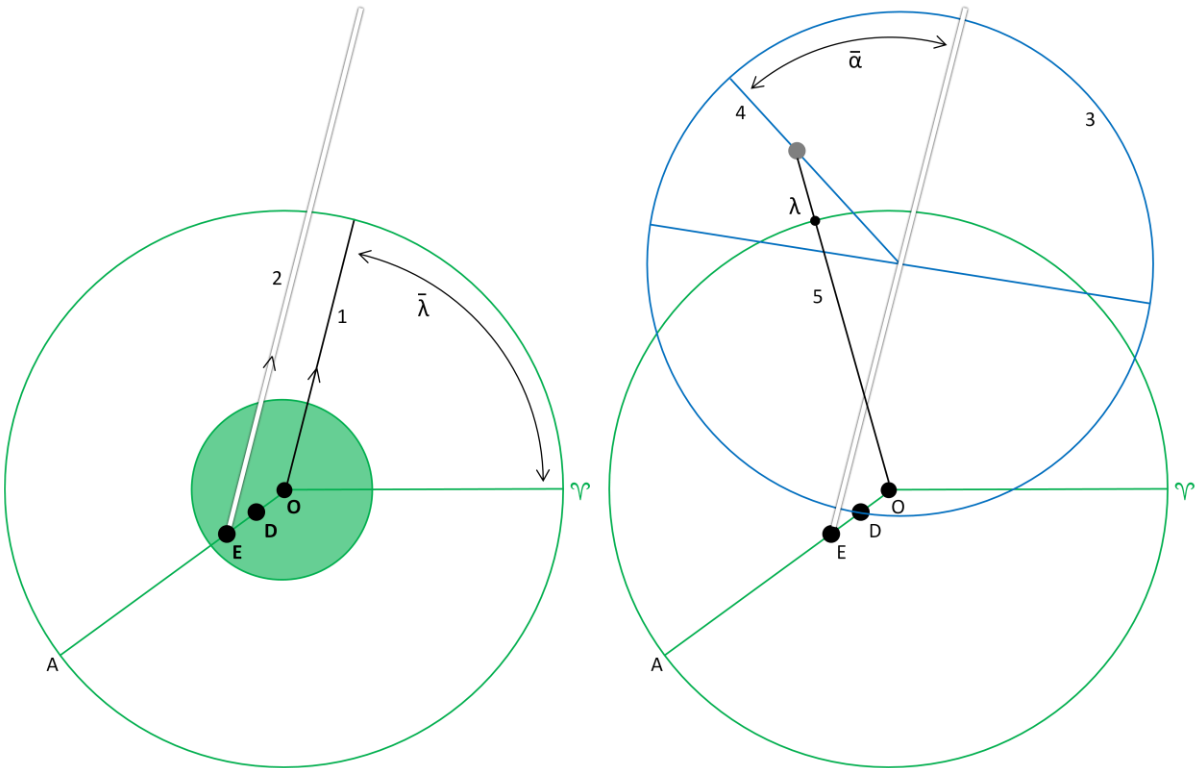


Fig. 32: Steps (numbered) in the use of the Peterhouse equatorium to find the true ecliptic longitude (λ) of a superior planet.

turned, starting from the white thread (which now marks the mean epicyclic apogee), through an arc corresponding to the mean anomaly. Finally, the black thread could be moved to the planet's mark on the label; the planet's ecliptic longitude could be read off where the black thread crossed the scale on the limb. Even including the work of computing the mean longitude and mean anomaly, the whole process can be accomplished within five minutes, giving the longitude of a planet to a high level of accuracy and a precision of around 2' of arc.[49]

Thus, as a tool for quickly computing the longitudes of those planets, for an astronomer working at London soon after 1392, the equatorium treatise and those planetary tables that directly accompany it display impressive ingenuity and user-friendliness. However, it should be noted that the explanation in the manuscript is not quite as straightforward as that given above. For example, as we saw in chapter 4, Westwyk incorporated an extra educational step, in which the black thread was stretched over the centre of the epicycle to reveal the longitude of the epicycle centre, the true epicyclic apogee and – in the angle between the black thread here and its

[49] Tests using the virtual equatorie at http://cudl.lib.cam.ac.uk/view/MS-PETERHOUSE-00075-00001 have demonstrated that (as with any model that replicates the Ptolemaic theories but ignores variations in latitude and treats the deferent and epicycle as if they are in the plane of the ecliptic) it gives results usually within 2° of those produced by modern methods, and often much closer. A precision of 2' is based on the estimate (mentioned above) that the disc was large enough for divisions every 4 or 5 minutes on the limb; a user could probably interpolate by eye between those divisions.

first position at the mean longitude – the equation of centre.[50] And his account becomes more confused when he explains the use of the equatorie to represent more complex – and simpler – Ptolemaic theories than the one for the motions of Venus, Mars, Jupiter and Saturn. But let us first consider a more immediate – and revealing – complication: the changing planetary apogees.

## CALCULATION AND COPYING; PRECISION AND ACCURACY

Before the mean longitude and mean anomaly of a planet were laid out to find its true longitude, the equatorie could be calibrated using the sixteen-inch plate at its centre, so that the lines marking the planetary apogees, on which lay the deferent centre and equant, were up to date. This task was not particularly important for a user soon after the equatorium's production, and it did not have to be done every time it was used, but it is clear that Westwyk attached some importance to it. The parts of the tables and treatise pertaining to this task shed important light on his methods and priorities in composing and compiling his manuscript.

The Alfonsine apogees were thought to move in two ways: a linear precession, increasing in longitude by one revolution every 49,000 years, also known as the mean motus of apogees and fixed stars; and accession and recession of the eighth sphere, an oscillating motion of up to 9° in each direction, with the period of oscillation being 7000 years.[51] The relevant tables are on folios 5r-7r and 13v. Radices are given for *auges medie* (the apogees incorporating only linear precession) and *auges vere* (apogees fully corrected to include accession and recession of the eighth sphere). To find the apogee for the desired date, the radices were to be corrected first by the addition of the linear component. This was provided in tables of annual and daily motion; the former was laid out with 1-3 years of 365 days, followed by 4, 8, 12... 56 years of 365¼ days, and then 1-3 years of 365¼ days. The linear movement of the apogee in the time since the date of the radix could be added to the radix value to give the "mean apogee".

Calculating the "true apogee" was slightly more complicated, as none of the tables in Westwyk's hand gives the oscillating component directly. Instead, he wrote out daily and annual tables of what is called *argumentum medium vel accessus et recessus 8^e^ spere*.[52] These tables, which are laid out in the same way as those just mentioned, give daily and annual fractions of a complete revolution in 7000 years. The values are therefore seven times those in the tables of linear precession. To convert these fractions of a complete revolution into the correct fractions of a complete oscillation of ±9°, Westwyk initially intended to use his equatorium. He instructs his

50 Peterhouse MS 75.I, f. 75r.
51 Dobrzycki (2010).
52 Peterhouse MS 75.I, ff. 6r, 7r.

Table 3: Contents of Peterhouse MS 75.I.

| | |
|---|---|
| **ff. 1r-13v in John Westwyk's hand** | |
| 1r | Note with sexagesimal equivalent of 1392, 1393 years; table to convert years to days<br>Radices of mean longitude and mean anomaly of planets for 31/12/1393<br>Table of annual motion of deferent centre of Moon (radix for Incarnation, London) |
| 1v-3r | Annual motion of mean longitude and mean anomaly of Moon, Caput Draconis and planets, with radices for Incarnation, London |
| 3v | Annual values for mean motus of ascendant for latitude 51° 34'; radix for 28/2/1393 |
| 4r-4v | Ascensions of signs for latitude 51° 50'<br>Tables to convert between hours and sexagesimal fractions of day |
| 5r | Radices of mean longitudes and anomalies, 31/12/1392 and Incarnation, London<br>Radices of mean apogees, Incarnation, London |
| 5v | 'Radix chaucer' note giving number of days in 1392 years; note with days in 1395 years<br>Multiplication table for orders of sexagesimals; table to convert between years and days |
| 6r | Daily motion of mean argument of 8th sphere |
| 6v | Apogees of planets for Incarnation, 1392, 1400<br>Radix for mean elongation of Moon, Incarnation, Toledo |
| 7r-13r | Annual and daily motions of mean longitudes and mean anomalies of Sun, Moon, Caput Draconis and planets. Radices for 13/12/1392, London |
| 13v | Daily motion of apogees (linear precession) |
| **ff. 14r-62r in "Hand S", with annotations by "Hand A" and Westwyk[53]** | |
| 14r-16v | Calendar for motions of apogees; table of equation of the 8th sphere |
| 16v-30r | Calendars for mean longitudes and mean anomalies of Sun, Moon, Caput Draconis and planets, and for motion of deferent centre of Moon |
| 30v-31v | Calendar for mean centre of Moon; radix for 28/2/1392 |
| 32r-38r | Tables for latitudes of Moon and planets |
| 38v-44v | Tables of proportion for multiplication of sexagesimal numbers |
| 45r-61r | Tables of equations for planets |
| 61v | Table of ascensions of signs and houses for latitude 50° 50' |
| 62r | Ready reckoner table of precession for 1349-1468, at rate of 1° in 98-99 years |
| **ff. 62v-78v in John Westwyk's hand** | |
| 62v | Hourly values (excess degrees) for motion of Moon, 1-12 hours[54] |
| 63v | Difference in length of half of longest day over equinoctial day, for latitudes 0-60°<br>Planetary longitudes and latitudes for 31/12/1393 (attributed to J. Somer, Oxford) |
| 64r | Solar declination and differences in ascensions of signs for latitudes 0-60°<br>Radices (including mean centre), 28 Feb 1394, London |
| 64v | Horoscope with accompanying Latin text |
| 65r-70v | Ascensions of signs for latitude of Oxford, 51° 50' (John Walter's tables)[55] |
| 71r | Incomplete star table, with altitudes at Oxford (partial) and London |
| 71v-78v | *The Equatorie of the Planetis* |

[53] Price (1955b), 75, designated the two main hands of the manuscript as Hand C and Hand S. Subsequent scholars have followed this usage, but Hand C has now been identified as that of John Westwyk. 'Hand A', a hand roughly contemporary with Hand S, added canons on two folios; Westwyk subsequently annotated one of those. See Rand Schmidt (1993), 111-112.
[54] The fact that 63r is blank may suggest that the table on 62v is incomplete: it does not contain values for 13-24 hours. However, the canon on 62v explains how to use the table as it stands to find the motion in 13-24 hours.
[55] North (1988), 191.

reader to divide 'the line that goth fro centre aryn to the hed of capricone, which lyne is cleped in the tretis of the astrelabie the midnyht line', into nine: 'thise last seid 9 divisiouns in the midnyht lyne shollen serven for equacioun of the 8$^{e}$ spere.'[56] However, he does not explain the technique for using these divisions to compute the equation of the eighth sphere from the mean argument of the eighth sphere.

Why might he have left the treatise unfinished in this way? Beyond lack of opportunity or lack of knowledge, there are several reasons why Westwyk may have chosen not to explain this technique in full. First, although it is important for the long-term maintenance of the equatorium's capabilities, the effects of precession would only be noticed after some years; the explanation of this function was thus hardly likely to be a priority. Secondly, the technique would have been analogous to that of computing the latitude of the Moon on the *alhudda* line (the opposite radius), which Westwyk explains at great length; he may have felt it unnecessary to explain a similar principle again, presuming that a reader could infer the analogy. It should be noted that the function of accession and recession of the eighth sphere was not as simple as that for the latitude of the Moon, so a third – somewhat remote – possibility is that Westwyk realised that the same technique would not work so well for the latter function, and abandoned his attempt to use the equatorium in this way.[57] However, a more likely explanation is that he found a simpler method of obtaining the necessary data. The large set of tables that are not in Westwyk's hand (ff. 14r-62r; see table 3) contain a table of the equation of the eighth sphere, as well as a ready reckoner of additions to be made to the apogees for each year for 1349-1468.[58] That set of tables is evidently older than those which Westwyk drew up for use with the equatorium, but his annotations on them, and the repetition of some material, suggest that he began to use them after he had made his own set.[59] The fact that he instructed his readers to mark the tool for the equation of the eighth sphere on the face of the equatorium, but did not explain how to use it, suggests that he may have obtained the larger set of tables before he completed the treatise, and realised that they obviated the need for that tool. Nevertheless, a reader who could work out its use (with or without reference to the explanation of lunar latitude), could still use it; Westwyk may have been presenting his reader the same choice of techniques that he enjoyed.

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[56] Peterhouse MS 75.I, f. 72v.
[57] The Moon's latitude ($\beta$) can be computed from the Moon's distance in longitude (L) from its node, where its orbit crosses the ecliptic, by the relationship $\beta = 5\sin L$ (North (1988), 165-8), which was easily modelled on the face of the equatorium. The relationship between the equation of accession and recession of the eighth sphere ($\psi$) and the mean argument of the eighth sphere ($\theta$) was of the form $\sin\psi = \sin 9.\sin\theta$ (Chabás and Goldstein (2012), 51). Nevertheless, an astronomer working to a precision of minutes could use the approximation $\psi = 9\sin\theta$ to satisfactory effect.
[58] Peterhouse MS 75.I, ff. 16r-16v, 62r.
[59] North (1988), 176.

The tables of linear precession that appear in both Westwyk's own set of tables and those in "Hand S" raise some important questions. In the first place, it may reasonably be wondered what the purpose was of tabulating daily values for an astronomical variable that changed by less than half a minute of arc in a whole year, an amount that could not be read on an equatorium even if it were constructed at the scale Westwyk recommends. More striking still is the fact that those daily values – and indeed many others in the codex – are given to a precision of sexagesimal ninths. The 37 that appears in the column of ninths for one day's motion of the apogees (f. 13v) is equal to one 98,000,000,000,000,000$^{\text{th}}$ part of a complete circle; an equatorium capable of displaying such precision would have to be around nine trillion times the size specified in Westwyk's description. Such precision clearly does not reflect observational accuracy, but arising from calculations carried out by standard methods in accordance with Ptolemaic theory, it was difficult to discard. And the same principle gives us the reason for the table of days: smaller divisions of the basic unit of one revolution in 7000 years simply seemed more precise.

This greater precision is a paradoxical indicator of an amateur compilation: perhaps partially motivated by the satisfaction of correct – albeit observationally meaningless – calculation, but lacking the sophistication necessary for purposeful rounding.[60] For historians, on the other hand, it is highly valuable, as it may indicate how the tables were adapted from earlier, more rounded versions, and the order in which they were produced. We can see this in the example of annual and daily motions of the mean motus of apogees. In Westwyk's table on f. 7r we find the motion in one year as 0;0,26,26,56,20,0,0,1,44,15°. It can immediately be seen, in the middle row of figure 33, that the final 15 was added after the rest of the table was written. The two columns of zeroes in the middle of the figure also attract attention, suggesting that the number was rounded at an intermediate stage. A full revolution divided by 49,000 years is approximately 0;0,26,26,56,19,35,30°; it is clear that this was at first rounded to 0;0,26,26,56,20°.

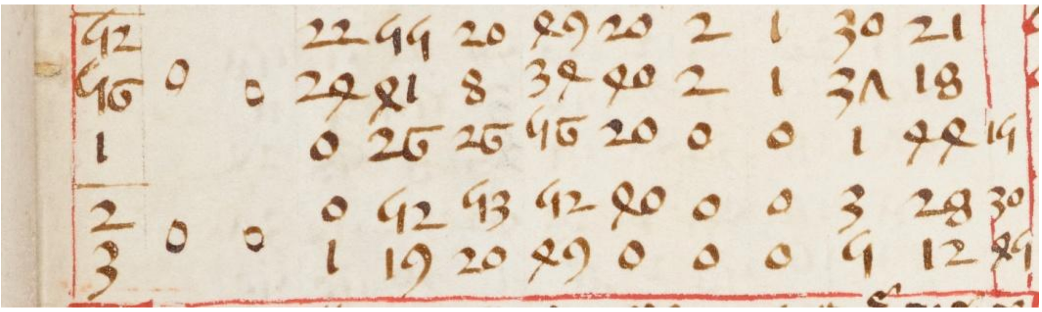

Fig. 33: Last five rows of table of annual motion of mean motus of apogees. (The left-hand column shows number of years.) Peterhouse, Cambridge MS 75.I, f. 7r. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

[60] The word 'amateur', although sometimes used by historians of medieval science (quoted, for example, in the introduction to this chapter), is problematic. Here I am using it to denote lesser expertise, along with the freedom to pursue personal interests and satisfaction. See the discussion in my introduction to this thesis (p. 3).

We may identify the source of the extra 1,44 by comparing the values in Westwyk's table of daily motions (f. 13v). The value for one day found there (0;0,0,4,20,41,17,12,26,37°) is exactly equal to 0;0,26,26,56,20° ÷ 365¼ (or 6,5;15, as it would have been rendered), to the precision of sexagesimal ninths that seems to have been preferred by the creator of these tables. If that daily figure is multiplied by 365¼, again using nine sexagesimal places, we obtain 0;0,26,26,56,20,0,0,1,44°, which was the figure Westwyk first wrote. It seems most likely, then, that the table of annual linear precession was produced from a table of daily motions, which itself had been based on a rounded value for the annual motion. That may not have been done by Westwyk (though I know of no other extant tables, from which he could have copied, with as many sexagesimal places as his). But the last step is clearly Westwyk's own. He apparently noticed – perhaps as he was rubricating the table – that the figure for 4 years (0;1,45,47,45,20,0,0,6,57°) does not match the figure for a single year: the figure ending in 44, multiplied by 4, could not result in a number ending in 57. It was a simple exercise for Westwyk to split the difference, squeezing an extra column into the final three rows of the table and writing 15, 30 and 45. He thus made the table appear internally consistent – and gave it a precision of sexagesimal tenths.

Examination of such precise tables can also reveal how carefully they were computed. Here a useful source are the radices of planetary mean longitudes and mean anomalies for *era Christi* (noon, 31 December preceding AD 1), whose values were consistent across manuscripts based on the Parisian Alfonsine Tables.[61] These were generally given for the meridian of Toledo, but in the tables Westwyk wrote out for use with his equatorium, they are recomputed for the meridian of London. This was achieved by subtracting an arc equal to 8° 26' of time (0;33,44h), which was thought to be the difference in longitude between London and Toledo.[62] It is hardly surprising that this calculation, which required daily motions to be multiplied by 8° 26'/360° (0;1,24,20°), was carried out imperfectly. In table 4 Westwyk's radices for *era Christi* are shown alongside Toledo values at the same epoch.[63] They should differ by an amount corresponding to the correction for longitude, but this is not always the case: there are small scribal errors in six of the ten radices for the era of Christ.

[61] Chabás and Goldstein (2012), 59-61.
[62] Price (1955b), 80-82.
[63] These are taken from the first printed edition of the Alfonsine Tables (Alfonso (1483)). It is highly likely that these very common Toledo values were used, but even if not, it would not make any difference to most of the results, as most columns in the table were evidently subtracted from zero (because the correction was carried out to a greater number of sexagesimal places than the initial Toledo radix).

Table 4: Radices of mean longitude and mean argument 'ad eram Christi', adapted from Toledo values (f. 5r).

| | Toledo values (°) | Westwyk's radix (f. 5r) (°) | Value recomputed for meridian of 8°26' (°) |
|---|---|---|---|
| Argument of the 8th sphere | 5,59;12;34 | 5,59;12,33,59,17,15,7,7,40 | (as left) |
| Mean longitude of the Sun, Venus, Mercury | 4,38;21,0,30,28 | 4,38;19,37,23,**6**,45,12,**37**,4,39 | 4,38;19,37,23,**5**,45,12,**38**,4,39 |
| Mean longitude of the Moon | 2,2;46,50,16,40 | 2,2;28,19,4,**8**,34,**9**,25,53,28 | 2,2;28,19,4,**6**,34,**19**,25,53,28 |
| Mean anomaly of the Moon | 3,19;0,14,31,17 | 3,18;41,52,42,26,30,20,23,4,24 | (as left) |
| Mean longitude of Caput Draconis | 1,31;55,52,41 | 1,31;55,48,**12**,3,5,8,50,13,37 | 1,31;55,48,**13**,3,5,8,50,13,37 |
| Mean longitude of Saturn | 1,14;5,20,12 | 1,14;5,17,22,30,23,29,37,9 | (as left) |
| Mean longitude of Jupiter | 3,0;37,20,44 | 3,0;37,13,43,22,36,52,36,10,3,20 | (as left) |
| Mean longitude of Mars | 0,41;25,29,43 | 0,41;24,45,31,12,**48**,59,38,20 | 0,41;24,45,31,12,**58**,59,38,20 |
| Mean anomaly of Venus | 2,9;22,2,36 | 2,9;21,10,**56**,**45**,49,16,40,45,40 | 2,9;21,10,**36**,**25**,49,16,40,45,40 |
| Mean anomaly of Mercury | 0,45;23,58,0 | 0,45;19,**32**,0,5,9,40,33,34,40 | 0,45;19,**36**,0,5,9,40,33,34,40 |

The quantity of these errors is not unusual for a table of this kind; any theory as to their origin must be speculative, so the following remarks are offered merely as tentative suggestions. Few of the errors seem to have arisen in a direct copying process: most of the numbers are correct, so eyeskip in the source text can be ruled out, and the fact that in most cases the erroneous and correct digits look very different make errors unlikely to be the result of misreading of individual digits (the confusion of 12 for 13 in the mean longitude of Caput Draconis is a possible exception). Moreover, Westwyk was a very careful copyist, as we saw in chapter 1, and every table except one in Westwyk's first set (ff. 1r-13v) is marked 'examinatur', suggesting that he double-checked them. Rather, the source of most errors looks to have been transcription from an abacus or set of counting stones. It would have been very easy to miscount 7 for 8, as in the mean longitude of the Sun, Venus and Mercury, or to overlook a single stone in the column of tens, as in the mean longitude of the Moon. The possibility thus remains that these calculations were an exercise for Westwyk himself, and not merely copied from a pre-existing table.

On the other hand, another table adjusted for the longitude of London reveals how easily copying errors could slip in, even for a copyist as diligent as Westwyk. Figure 34 shows a small table of the radices of the mean apogees of the planets. Since the apogees moved at a the same rate owing to precession, each radix was adjusted by the same amount: 8° 26'/360° multiplied by the daily motion of 0;0,0,4,20,41,17,12,26,37°, which is given in a table on the same folio. Because they were adjusted to a greater level of precision than the original Toledo radices, the final seven columns in the table are the same for each planet. Yet in the penultimate column the final two rows show 4 instead of 8, which must have arisen from a lapse in concentration when copying. (An identical table on folio 5v repeats this error.) Such a copying error does not prove that the recomputation was not the work of John Westwyk: he could have miscopied from his own earlier calculations. But it does remind us how great was the potential for mistakes to be

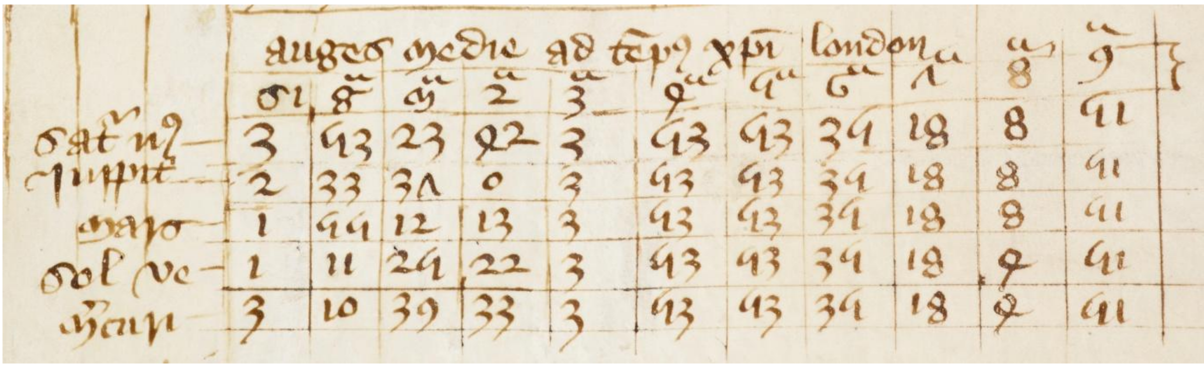

Fig. 34: Table of mean apogees 'ad tempus Christi', adapted from Toledo values. Peterhouse, Cambridge MS 75.I, f. 13v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

made. In addition, the fact that such a noticeable error was not corrected suggests that Westwyk made little further use of this table.

### 'THIS CANON IS FALS': LONGITUDE PROBLEMS

If Westwyk was learning as he composed and compiled his instrument and tables, he was learning even more as he used them. From his earliest remarks on size, which seem to allude to Chaucer's observation that 'smallist fraccions ne wol not be shewid in so small an instrument as in subtile tables calculed for a cause,' Westwyk shows awareness that instruments and tables represented competing (and complementary) methods of computing planetary positions; these methods had to balance speed and convenience against precision.[64] It may also be suggested that learning different techniques was an objective in itself, separate from the ultimate outcome of finding positions. Peterhouse MS 75.I reveals how Westwyk tried two alternative techniques: the use of an equatorium with tables, and the use of tables alone. In explaining these, he showed insight but also made a number of revealing mistakes, most not noted by previous historians. Taken together, these mistakes provide a more nuanced picture of his astronomical practices, interests and expertise. In this section we shall discuss those that arise in his discussions of longitudes.

The first and most minor pair of mistakes in the treatise concern the method for computing the longitude of Mercury. These were noted by Price, and possibly also by Westwyk himself, who wrote 'this canon is fals' at the top of the page and drew a series of lines across the text (see figure 35).[65] As Price pointed out, these mistakes, which consist in an instruction to count the mean centre of Mercury anticlockwise around the small circle of holes to find its deferent centre (it should be clockwise), and the implicit suggestion that the equant centre also moves round the circle (it does not), hardly warrant the cancellation of the whole of folio 76r.

[64] 'A Treatise on the Astrolabe, Prologue, lines. 73-76, in Chaucer (1988), 663. On the importance of convenience to table-makers, see Chabás and Goldstein (2013).
[65] Price (1955b), 70-71; Peterhouse MS 75.I, f. 76r.

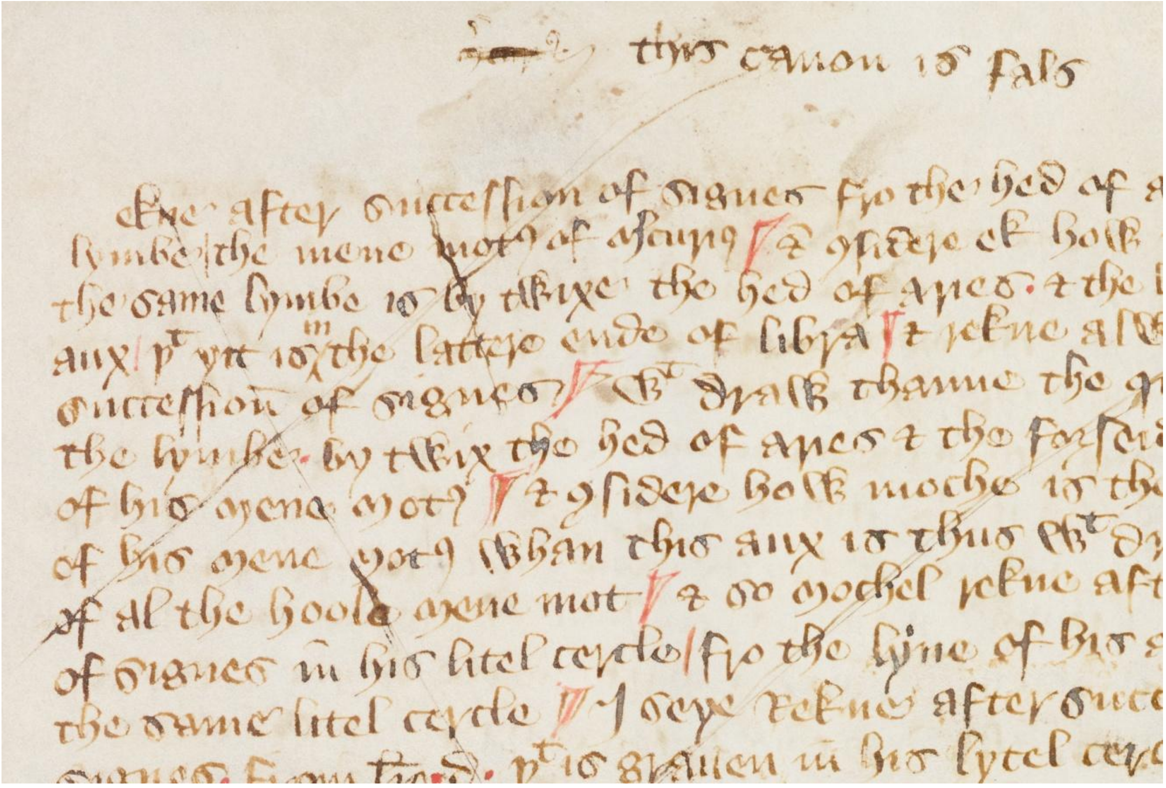


Fig. 35: 'This canon is fals'. Peterhouse, Cambridge MS 75.I, f. 76r. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

However, it is possible that Westwyk did not himself realise what the specific error was, only noting that his calculations of Mercury did not match observed positions, without realising why.

Somewhat greater confusion is discernible where Westwyk once again wrote an exasperated 'þis canon is fals' at the head of folio 77r, drawing another series of diagonal lines across the top half of the folio. Price felt that there was 'no serious error in this section,' and indeed there is nothing that can be simply dismissed as wrong.[66] But there is a passage, not noted by Price, which is worthy of discussion. At the end of his instructions for using the equatorium to find the longitude of the Moon, Westwyk writes: 'the centre of hir (*lune*) epicicle (*in volvella*) moevyth equaly aboute the centre of the zodiac, that is to sein [say], aboute the pol[e] of the epicicle that is thy riet.'[67] The analogy at the end between the common epicycle and the rete of an astrolabe is clear enough, but his identification of the pole (centre) of the epicycle with the centre of the zodiac cannot be correct, and how the centre of the Moon's epicycle is supposed to move uniformly around this pole is unclear, since the centre of the Moon's epicycle is surely itself at the centre of the (common) epicycle! However, in the Ptolemaic model, the Moon's epicycle centre does move with uniform velocity with respect to the Earth, at the centre of the equatorium; this explains the first part of Westwyk's statement, and suggests that the 'volvelle' mentioned does

[66] Price (1955b), 71.
[67] Peterhouse MS 75.I, f. 77r. The words in parentheses are interlinear additions.

not refer, as Price thought, to the epicycle, but rather to the sixteen-inch metal plate on which are inscribed the centres for each planet and which was intended to be rotated to account for equinoctial precession.  It remains unclear how the centre of the zodiac has been identified with the pole of the epicycle, but perhaps this is the error that caused Westwyk's exasperation.

A more serious mistake in the method for the Moon's longitude appears on the previous folio, though this was not noted or corrected by Westwyk or subsequent readers (or historians). We have seen that for the planets, the use of a black thread to mark the mean longitude on the limb is followed by the stretching of a parallel white thread from the equant centre, and the placing of the epicycle centre under the white thread (see figure 32).  However, in the case of the Moon (figure 36), which has a quite different model involving moving deferent and equant centres, the epicycle centre is moved under the black thread that marks the mean longitude; then the white thread, one end of which is fixed to a point diametrically opposite the deferent centre on the Moon's small circle of holes, is stretched over the centre of the epicycle in order to mark

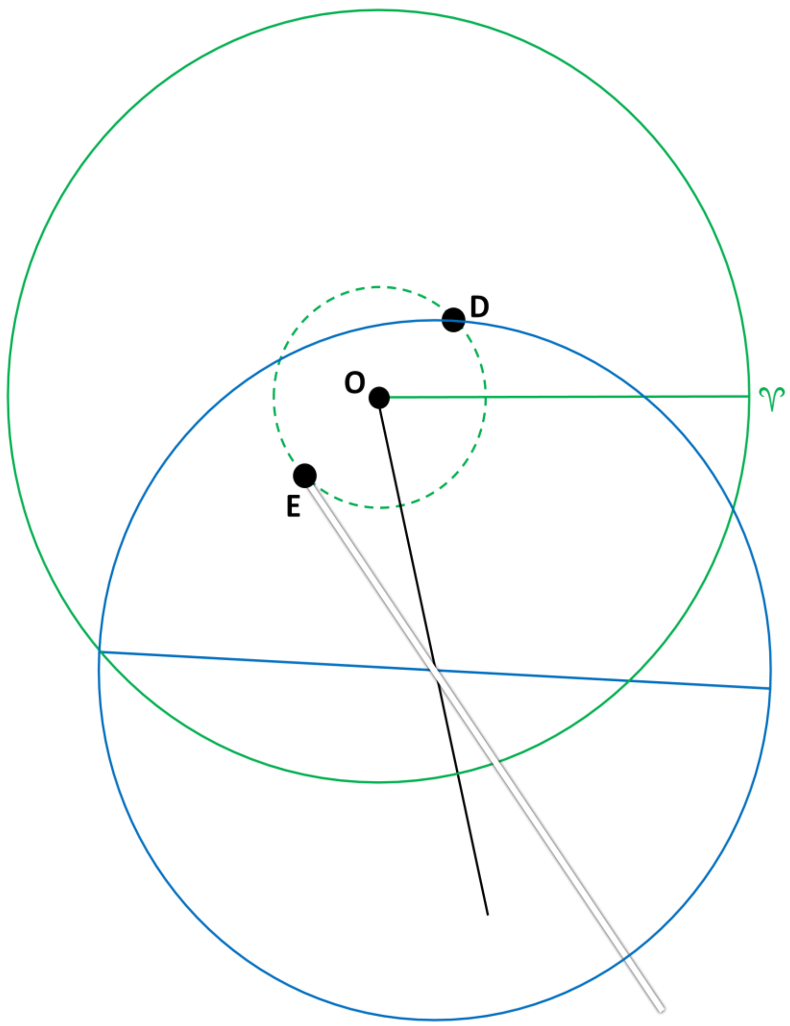


Fig. 36: Setting the black and white threads for the longitude of the Moon.

the mean epicyclic apogee (just as it does for the planets).[68] It therefore makes no sense for Westwyk to instruct users, after marking the mean longitude with the black thread, to 'ley thy white thred equedistant by [parallel to] the blake thred in the lymbe.'[69] It is perhaps an understandable mistake, as it represents the carrying over of one step too many of the procedure for the planets. Westwyk may have come some way to realising his mistake as, two lines below, he added the interlinear instruction 'tak thanne thy white thred and ley it over the pol of the epicicle', but he did not cross out the previous instruction, and this passage is rendered rather confused as a result.[70]

A final and most serious mistake in Westwyk's treatment of longitudes appears in his explanation of the simplest Ptolemaic model: that of the Sun. There are two ways in which an equatorium such as this could represent the Sun's motion: either by a simple eccentric model, or by an epicyclic model analogous to that used for the planets.[71] These are shown in figure 37.[72] In the former (left), the Sun's mean longitude is translated from the earth to the centre of its

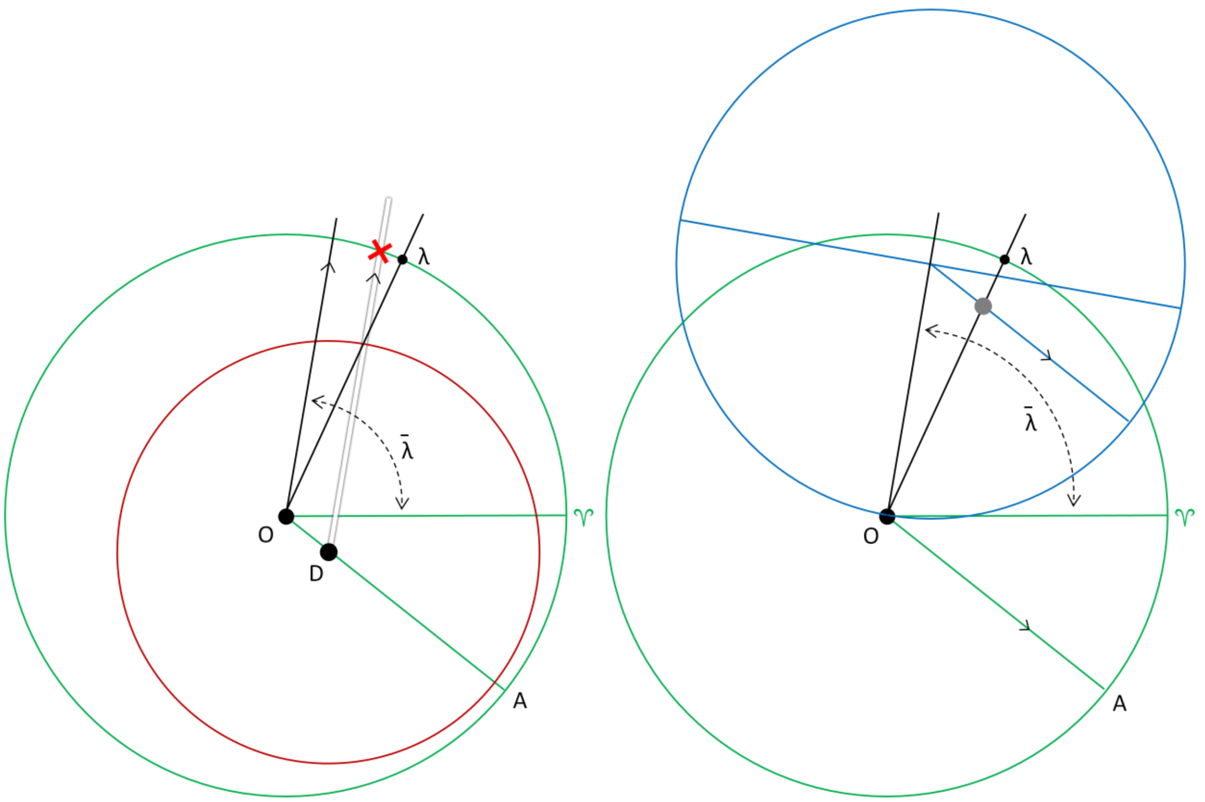


Fig. 37: Two possible (and one incorrect) methods for finding the Sun's longitude using the equatorium.

[68] Westwyk does refer to a 'centre equant' in his explanation of the lunar model, but it does not fulfil quite the same function as the planets' equant centres, and is more often called *centrum oppositum* in Latin treatises. Benjamin and Toomer (1971, 42-47) give an excellent explanation of the lunar model.
[69] Peterhouse MS 75.I, f. 76v.
[70] Edwards and Mooney (1991, 34) asserted that this insertion, without which they thought the passage as a whole would make no sense, must have been a remedy for a copyist's error; for them it was therefore evidence against the treatise's status as an authorial draft. However, it seems more likely to be the result of authorial confusion.
[71] Benjamin and Toomer (1971, 40-42), succinctly explain the equivalence of these two methods.
[72] The eccentricity of the Sun is greatly exaggerated for the sake of clarity in this figure.

eccentric circle (red), before the true longitude is read off at the limb using a thread through the eccentric circle; the common epicycle is not used. In the latter (right), the pole of the epicycle is placed over the black thread marking the mean longitude, the label is aligned with the Sun's apogee, and the black thread is drawn to a mark on the label corresponding to the Sun's eccentricity, in order for the longitude to be read at the limb in the usual way; the white thread is not used. Unfortunately Westwyk appears to have confused these two methods, arriving at an explanation that accurately conveys neither.[73] He appears to favour the eccentric method for calculating the Sun's true longitude: he instructs his reader to draw the eccentric circle of the Sun on the face of the equatorium, stresses that 'the sonne ne hath non epicicle' and that the 'eccentrik of the sonne shal nat be compassed in this epicicle',[74] and does not mark the Sun's eccentricity on the label in his diagram on folio 74r (see frontispiece). Yet when he turns to explaining how to find the Sun's longitude, he instructs us to use the common epicycle, which is redundant in the eccentric method. He correctly explains how to use the black thread to mark the mean longitude before laying the white thread parallel from the centre of the Sun's eccentricity; however, he then writes that 'wher as the white thred kervyth the grete lymbe tak ther the verrey place of the sonne' [i.e. the true longitude is where the white thread crosses the limb], when in fact the black thread should be moved to cross where the white thread cuts the Sun's eccentric circle before the reading is taken on the limb where the black thread, not the white, crosses it.[75] (The red cross in figure 37 indicates where we would read the Sun's true longitude if we were to follow the instructions as they stand.) Westwyk asks us to use the epicycle in a way that almost replaces that second position of the black thread, but he does not mention the Sun's eccentric circle and it is quite incorrect to say that the longitude of the Sun can be found where the white thread crosses the limb. The inclusion of the epicycle may suggest that Westwyk was intending to explain how the epicyclic model could be used without having marked the Sun's eccentricity on the label. But this would be no simple matter. The eccentricity could not be straightforwardly transferred from the disc to the label by, for example, using a compass, because the eccentricity on the disc is marked relative to the size of the Sun's eccentric circle that is drawn on the disc with a radius 30/32 of the radius of the common deferent.[76] So if the common epicycle, whose radius is equal to the common deferent, were to be used, the eccentricity would have to be scaled up accordingly.

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[73] Although Price (1955b, 98, 68) explained the eccentric method and noted that 'two quite independent schemes are given for calculating the position of the Sun', he did not note that neither scheme is correctly explained in the manuscript: they appear to have been confusingly conflated.

[74] Peterhouse MS 75.I, f. 73v.

[75] Peterhouse MS 75.I, f. 75v.

[76] The construction method explained in the treatise makes the Sun's eccentricity 1/30th of its radius. This differs from the Ptolemaic value of 1/24th (Ptolemy (1984), III.4, at 155).

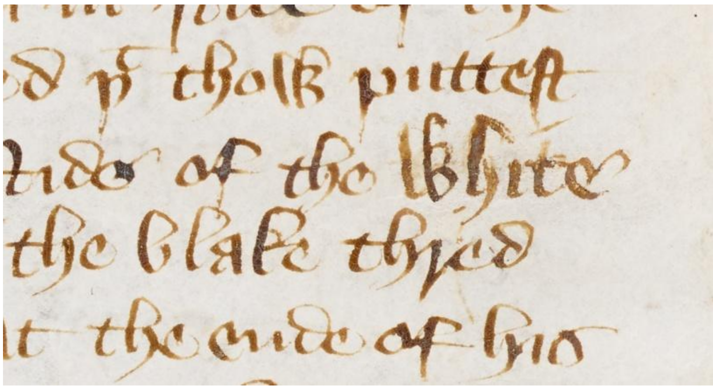

Fig. 38: 'white' almost certainly written over 'black'. Peterhouse, Cambridge MS 75.I, f. 75v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

Some sense that Westwyk was struggling with the solar theory, perhaps attempting to separate and accurately represent models from more than one different source text, is suggested by the fact that twice in this passage the word 'white' has been written over a previously erased word. Edwards and Mooney state, probably correctly, that the erased word in both cases was 'black', though it is hard to be certain (the emendation is much clearer in figure 38 than figure 39). They argue that these changes 'seem more likely scribal than authorial in nature, since the sense of the passage would be garbled by the initial error,' and are thus evidence for their thesis that the treatise is not an author's draft.[77] However, while 'white' does fit better than 'black' in those two instances, the corrections were by no means so straightforward as Edwards and Mooney suggest. Indeed, immediately below the second emended 'white', the same word appears again, in the sentence quoted in the last paragraph (see figure 39). Here, it could be argued, its replacement by 'black' would be a distinct improvement: much of the confusion in the passage would be unravelled, though it would still leave the explanation somewhat incomplete. What this discussion should demonstrate is that, when we examine such "corrections" in the context of their content and their author's learning practices, it becomes less reasonable to assume they are the work of a scribe simply copying the text.

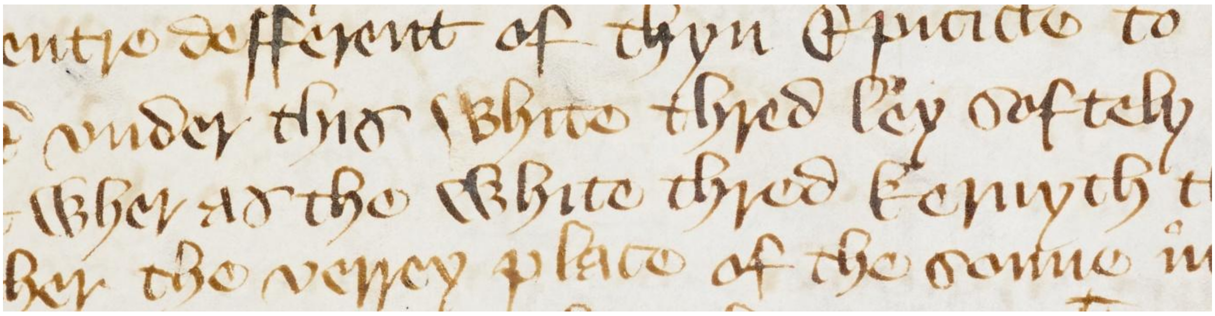

Fig. 39: Two instances of the word 'white', one of them written over a previously erased word. Peterhouse, Cambridge MS 75.I, f. 75v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

[77] Edwards and Mooney (1991), 35.

## Experimentation for learning

Westwyk's learning was not confined to his construction and use of the equatorie. Peterhouse MS 75.I provides rich evidence of his experimentation with a range of instrumental and computational techniques for obtaining astronomical answers at different levels of precision.[78] We have already seen that the set of tables he collected for his manuscript included not only precise tables of the linear and oscillating components of precession, but also a ready reckoner to adjust the apogees. Westwyk clearly used both. Above the ready reckoner on folio 62r we find a signe-de-renvoi (the geomantic figure for Fortuna Major);[79] the same sign appears eighteen folios earlier, together with a note in Westwyk's hand instructing the reader to use the ready table of additions. (As figure 40 shows, the reference to the eighteenth folio following has been emended in a different hand, suggesting that the tables may not have been in their current order when Westwyk wrote the canon.) Westwyk's canon describes the adjustment of the apogees as the final stage in a computation of planetary positions that was a complete alternative to the use of his equatorium. Instead, this technique used the tables on folios 45r-61r, written in "Hand S". Entitled 'Equatio [name of planet]', they are double-argument tables at intervals of 6°, allowing the user to find the longitude directly from the mean centre (down the left hand side of the table) and the mean anomaly (along the top). The longitude is given in degrees and minutes, with the names of the signs written down the right hand side and demarcated by lines across the table; annotations underneath indicate phases of direct and retrograde motion, stations, and conjunctions. The tables are in the style of the "1348" tables associated with Oxford;[80] the only significant difference is that the Oxford tables, following Jean of Lignières, were given with signs of 30°, whereas Westwyk's tables use signs of 60° for the mean centre and mean anomaly.[81]

Although Westwyk's canon details the procedure for use of these tables, he does not

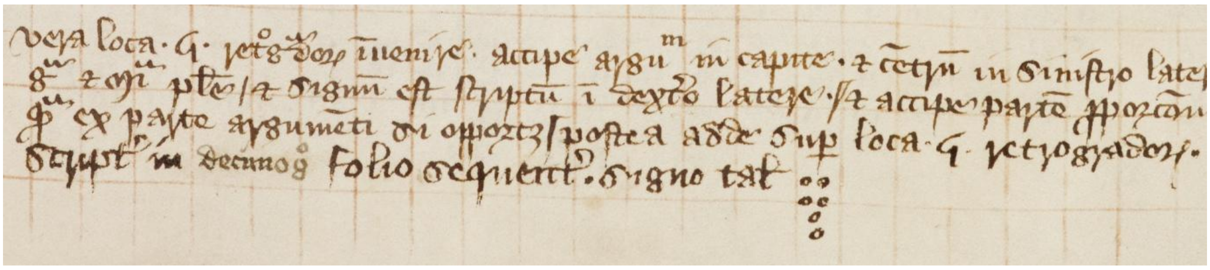

Fig. 40: Part of a canon explaining the use of a table of equations, with signe-de-renvoi and corrected folio reference. Peterhouse, Cambridge MS 75.I, f. 45r. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

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[78] 'Experimentation' here is not intended to suggest any systematic comparison of methods; rather, it has its true medieval sense of experiencing, and perhaps learning from that experience.

[79] North (1988), 188.

[80] North (1988), 188; North (1977), 279-284.

[81] An example of the more usual 30° presentation is in Cambridge University Library MS Ii.1.27, ff. 23r-33v. This manuscript (dated 1424) also contains canons ascribed to Lignières.

explain how the mean centre, which is not tabulated anywhere in the codex, was to be found. Although it could be calculated simply by subtracting the apogee from the mean longitude, it represents an added step in the process and an inconsistency in the tables: the mean longitudes provided elsewhere in the codex are perfect for use with his equatorium design, as we have seen, but are not ideally suited for the use of these Oxford-style tables of equations. However, once the mean centre was obtained, the tables of equations could be used to give an approximation of the longitude of the planets in a single step. However, that would only be a very rough approximation, since the tables, like the Oxford tables from which they were presumably copied, give mean centres and mean anomalies in 6° increments. Westwyk does not specify how or when he thought interpolation should be used to obtain more precise results: his canon merely advises the reader to 'take the proportional part corresponding to the centre or corresponding to the argument if necessary [*si oportet*]'; a suitable table of proportions appears on the preceding few folios (38v-44v).[82] We cannot be certain how often Westwyk would have deemed it necessary to use the table of proportions, but its use had the potential to add significant labour to the procedure of computing the longitude. If, as is most likely, both the mean centre and mean anomaly fell between 6° values, the table of proportions would have had to be used for two sets of sexagesimal multiplication; for each, the table would have to be consulted four times and the resulting four figures added together, taking care to ensure that they were kept in the correct sexagesimal column. Including the addition of the final interpolated figure to the rounded value drawn from the table of equations, interpolation could involve up to eight multiplications using the tables of proportion and three additions: a time-consuming and error-prone process. There is ample evidence in the manuscript that Westwyk attempted, and experienced difficulties with, these interpolations: a note in ciphered Middle English on the first page of the table of proportions emphasizes that for the planets, the proportions of 6° should be used (the table also permits working with proportions of 3°). On the same page Westwyk corrected a note made (in Latin) by an earlier user of the "Hand S" tables, reminding the user that degrees multiplied by degrees yield degrees (rather than minutes as originally stated), minutes multiplied by minutes yield seconds, and so on.[83] A similar reminder is conveyed by the small multiplication tables that Westwyk added to ff. 1v, 5v and 7r. A note on the last of these folios, concerning the adaptation of planetary longitudes to account for the equation of days, refers to the tables of equations, suggesting that Westwyk used the tables he had compiled and those in "Hand S" together.

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[82] Peterhouse MS 75.I, f. 45r. The table allows the user to multiply two numbers from 1 to 60, with the results given as a proportion of 6°. For example, 5 x 5 gives the result 4,10.
[83] Peterhouse MS 75.I, f. 38v.

It is clear, then, that even if Westwyk originally obtained the "Hand S" tables to facilitate calculation with his equatorium – and his note 'pro instrumento equatorii' on a calendar of the daily motion of the Moon's deferent centre is evidence that he did use them in that way – he also took advantage of the opportunity they provided to compute positions without the equatorium, using interpolation techniques on some occasions to obtain more precise results.[84] The fact that Westwyk used both methods indicates that he was learning, or trying out, different techniques, perhaps at different times or for different purposes. For a very rough approximation the tables could be used more quickly than the instrument, and were more portable; on the other hand, they could perhaps give greater precision, but only via complex and time-consuming calculations. As we have seen, the equatorium provided for a good balance of speed and precision, and although it needed instructions for use, so did the tables of equations, as demonstrated by the canons that Westwyk added to them. And of course they could be used to learn different techniques, or to emphasise different theoretical points.

The diversity of methods and content is most obvious in the manuscript's final set of tables, written in Westwyk's own hand. Few of these tables are closely related to the equatorium, because they are not planetary; some, indeed, are more suited to use with an astrolabe, an instrument with which Westwyk was clearly familiar. They are, however, squarely astrological and are thus related to the planetary tables. Most obvious in this regard is the horoscope of Māshā'allāh that appears on folio 64v, but the tables of right and oblique ascensions on folios 65r-70v should also be noted.[85] The latter are based on John Walter's tables of astrological houses, and this set of tables gives the strong impression of having been compiled from a wide variety of sources that caught Westwyk's eye.[86] Their variety, and discrepancy with tables earlier in the manuscript, is striking. Most obvious is the fact that the majority of this set were explicitly produced for Oxford, in contrast with Westwyk's first set of tables where it is stated that the radices are for London. Yet this discrepancy is not new: it exists even within the first set, where on folio 3v we see that the table of revolutions of years is for latitude 51° 34' (suitable for London), while the facing page has a table of ascensions of signs for latitude 51° 50', which was probably Oxford. (St Albans, Westwyk's sometime home, was ascribed a latitude of 51° 38'.[87]) But other inconsistencies are new. The table on folio 63v, which gives the differences in half the length of the day between the equinox and solstice for latitudes from 0 to 60°, incorporates an ecliptic obliquity of 23;35°, which contrasts with the figure that appears directly on folio 64r,

84 Peterhouse MS 75.I, f. 20r.
85 Kennedy (1959).
86 North (1988), 191; North (1986), 128-130.
87 Bodleian Library MS Laud Misc. 674, f. 74r.

which is 23;33,30°.[88] Finally, a list of radices on folio 64r, computed for 28 February 1394, at London, incorporates a longitude of 8° east of Toledo. This contrasts with Westwyk's first set of tables which, as we saw, were adapted from Toledo tables by the subtraction of an arc equivalent to 8° 26' of time. It is likely, therefore, that rather than updating his own radices by the addition of a year's (or in this case a year and two months') motion to previous radices, Westwyk took these radices ready-prepared from another source.

The source of Westwyk's radices is significant because the (now settled) arguments about Chaucer's possible authorship of the manuscript pivoted around the 'Radix Chaucer' note on folio 5v. That note expresses 1392 years sexagesimally and remarks that it is 'deffe[a] xpi & R[x]a chaucer' – the difference between [the era of] Christ and the radix of Chaucer. As we saw in chapter 3, North argued that this was Chaucer writing his own name, because no astronomer would cite another for such a simple radix; it was, North stated, 'a trifling matter for anyone who was capable of calculating with such a set of tables as we have here, to produce fresh radices for each year's end.'[89] But the evidence we have already seen suggests that, for an amateur astronomer such as John Westwyk, that was not the case. Westwyk was not as capable as North supposed; on the other hand, he was keen to draw on a wide range of material, and to cite his sources. In chapter 3 we dwelt on his references to Chaucer and to John Somer and their significance for his motivation and self-positioning; here let us highlight some others, which cast light on his mathematical sources and expertise. On the folio facing the small table attributed to Somer (figure 22) is a table of declinations; above it Westwyk commented that 'these are the declinations of Arzachel, I believe. Correct, according to R.B.'[90] We have already seen that Westwyk drew on Arzachel's writing on the *saphea* in his commentary on the *Tractatus albionis*; but Arzachel was also a leading contributor to the Toledan Tables.[91] Here Westwyk seems to be cross-referencing the table he has copied with two other sources, the other perhaps being Roger Bacon.[92] A further cross-reference appears on the penultimate page of the table of ascensions, itself the penultimate table of the codex, where we find a note referring to the Jewish astronomer Jacob ben Makhir Ibn Tibbon (c. 1236-c. 1304), known to Westwyk as Profatius.[93] The note (shown in figure 41) gives the maximum and minimum values for the equation of days, which is related to the modern equation of time.[94] The maximum equation is stated to be when the Sun is at Scorpio 8-9°, and it cannot be coincidental that the note appears beneath the section of the

88 North (1986, 128-130) discusses the table of differences in half-day length.
89 North (1988), 173.
90 Peterhouse MS 75.I, f. 64r. Price (1955b, 87) read the initials as 'E.B.'.
91 Millás Vallicrosa (1943).
92 See discussion in chapter 3, p. 84.
93 Peterhouse MS 75.I, f. 70r.
94 North (1986), 128-129.

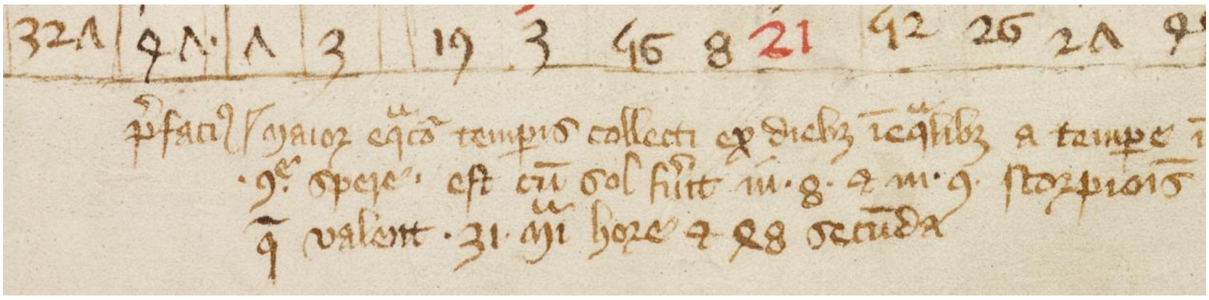

Fig: 41: Reference to Profatius below table of ascensions. Peterhouse, Cambridge MS 75.I, f. 70r. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

table for an ascendant in Scorpio, where the maximum value is indeed at 8-9°. However, the two maximal values for the equation are different: the note says 7° 57', while the table gives 7° 54'.[95] Judging by its appearance before a wedge paragraphus and to the left of an otherwise aligned body of text, the reference to Profatius as an authority appears to have been added later. It is possible that Westwyk computed his own value and called upon Profatius as an authority, but this seems unlikely to have been within his astronomical capabilities.[96] What is more likely is that, as a diligent student and copyist, he had spotted a discrepancy in two sources he was using. He maintained the value he found in John Walter's tables, but noted (correctly) that Profatius had used a different value.

The attention we have given to Westwyk's citations from different angles in this and previous chapters puts us in a position to reconsider the most mysterious citation in the manuscript: the erased reference to 'Leyk' in the first line of the treatise (figure 42). Westwyk names this person as the source of his remarks about the size of the equatorie, which has led to some speculation. J. A. W. Bennett suggested it referred to Nicholas of Lynn (or de Leuka), the 'reverent clerk' cited by Chaucer alongside John Somer, while North thought it might represent the Franciscan chronologist Robert of Leicester (c. 1266-c. 1330).[97] Both of those are arguable readings of the scraped-away word, but neither of those figures is known to have written on the

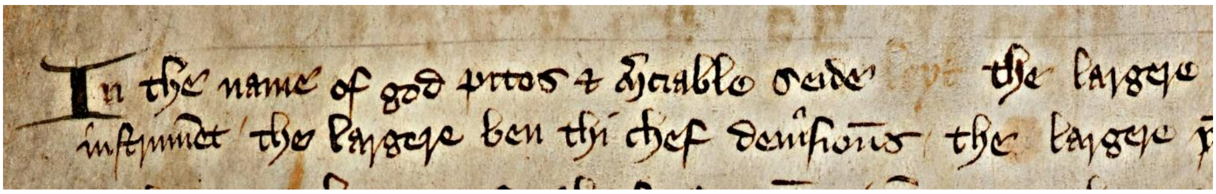

Fig: 42: Opening of the *Equatorie*, featuring "leyk" (contrast enhanced). Peterhouse, Cambridge MS 75.I, f. 71v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

[95] A maximal value of 7;57 does indeed appear in work commonly attributed by medieval astronomers to Profatius (in fact it is by Peter of St Omer (fl. 1289-1308), as mentioned in chapter 2, p. 60); it also appears in the work of Jean of Lignières. 7;54 is the figure used by al-Battānī, the Toledan Tables and Parisian Alfonsine Tables. See Chabás and Goldstein (2012), 40.

[96] In order to check his result, we would need to know what value he was using for the solar eccentricity, which is not certain; the value incorporated into the equatorium design was 1/30th of the solar radius, but this was quite different from the value common to authorities in this period (see Chabás and Goldstein (2012), 66).

[97] Bennett (1974), 77-78; North (1988), 158n27; Jotischky (2004a).

subject of instruments.[98] Meanwhile Price made two suggestions: that 'leyk' may be an error for 'lyners', i.e. Jean of Lignières; or, assuming that the *Equatorie* was based on an Arabic source, it may arise from a backward transliteration of the word qīla, meaning "it is said".[99] The former seems perhaps a misreading too far, while the latter suggestion is weakened by the doubt we cast on the apparent Arabic origins of the treatise in chapter 4 of this thesis. However, the attribution of Peterhouse MS 75.I to John Westwyk, and our analysis of Westwyk's reading of Richard of Wallingford, permits us to make another suggestion here: that 'leyk' refers to John Loukyn, sub-sacrist of St Albans in the late fourteenth century.[100] As sub-sacrist he would have had some responsibility for maintaining Richard's abbey clock, and he appears to have pursued his interests beyond merely mechanical issues, as he owned a book containing almost all of Richard's works, including the *Albion* and *Rectangulus* treatises, as well as fragmentary drawings and descriptions of the clock.[101] That book, Bodleian Library MS Ashmole 1796, was mentioned in chapter 1 of this thesis, where we noted that it also contained a copy of (pseudo-) Māshā'allāh's astrolabe treatise, to which Westwyk probably referred in his commentary on the *Albion*. Westwyk would almost certainly have known Loukyn, and if he consulted Loukyn's copy of Māshā'allāh, he may also have discussed instrument-making with him. Loukyn's position, reading, and probable relationship with John Westwyk make him a plausible candidate to be the mystery 'Leyk'.

It should by now be evident that Westwyk was both a diligent copyist and table-maker, respectful of the methods and results of his predecessors; and willing to experiment with different techniques and forms of presentation. This is further demonstrated by the way his treatise and tables address the Moon. First, on f. 62v, we find a table strikingly duplicated. This is the first table of Westwyk's latter set, and the only one of this group that could be used – albeit indirectly – with the equatorium: it is a division table allowing the user to interpolate hourly values for the longitude of the Moon. This table, which was useful for the prediction of eclipses, has no equivalent in Westwyk's first set of tables, and it seems that he may have chosen to add it later. A note in Latin instructs the user to first calculate the daily motion of the Moon from two successive noon positions 'in almenac'. The user then looks for this 24-hour difference (in degrees and minutes) on the far right of the table, and can then interpolate the motion in 1-12 hours within the table. Although it is unusual to find a table whose entry is on the right, its content is straightforward; however, what is strange is that the table appears to be missing every

[98] Rand Schmidt (1993, 144) discusses the palaeography of this word.
[99] Price (1955b), 165-166.
[100] John Loukyn is listed as a *conversus* (lay brother) in the St Albans Benefactors Book (London, British Library MS Cotton Nero D.vii, f. 81v, transcribed in Dugdale (1819), II. 209-210). He is recorded in the *Gesta abbatum* as being at St Albans during the abbacy of Thomas de la Mare (1349-96); see Walsingham (1867), III. 68.
[101] North (2005), 174; Bodleian Library MS Ashmole 1796; it is here that Loukyn is identified as sub-sacrist. His name appears in four places: ff. 22v, 119v, 130r, 160r.

fourth row.[102] Such regular omissions are unlikely to be inadvertent; nonetheless it was probably dissatisfaction with those gaps that motivated Westwyk to redraw the table immediately beneath, identical but for the insertion of the missing rows, and a slightly different range.[103]

It is clear from this table, as well as from the radix Westwyk added to the "Hand S" calendar of the double elongation of the Moon (f. 30v), that he was particularly interested in lunar positions and eclipses. We should not be surprised, therefore, that his equatorium included a tool to compute the latitude of the Moon. He explained this tool in staggering detail, covering three-and-a-half pages of the manuscript, with emphatic repetitions and three worked examples (ff. 77r-78v, for 17 December and 19 and 23 February 1391). The level of worked detail indicates that Westwyk lacked confidence with these techniques, and this is supported by some errors in his explanation. He states that Caput and Cauda Draconis are each confined to one half of the zodiac, when in fact they both rotate through the zodiac, always opposite each other. There is also a mistake in the last of his three worked examples: he gives the latitude as 1° 22' N, when it was in fact southerly. This is an understandable error caused, perhaps, by the fact that northerly and southerly latitudes were read on the same ±0-5° scale on the equatorium.[104] Overall, it is hard to escape the conclusion that Westwyk was himself learning these methods as he was carefully teaching them to his reader.

The sense of learning through experimentation, at the same time as providing instruction for future readers, is perhaps most apparent in the comments in cipher that appear in five places within the later sets of tables.[105] Not only is the fairly basic substitution cipher itself evidence of experimentation with different techniques and ideas; the contents of the ciphered passages suggest incipient understanding of the tables being copied and commented on. For example, the ciphered comment on the table of half-day lengths on folio 63v (figure 43) reads 'this is how mochel the half ark of the lengest dai is more than six houris', which is a straightforward description of a fairly simple table.[106] Perhaps this was intended to whet the appetites of future

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[102] The leftmost column gives 24 hours' motion in minutes; since the maximum value given is 1080', there may be some relation with the common division of one hour into 1080 points (*ḥelaqim*); see Chabás and Goldstein (2012), 141.

[103] The rows are at intervals of 24'. The range of the first table is 10;0-17;12°/day; the second is 11;12-18;0. Both ranges exceed anything possible according to Ptolemaic lunar theory. Values for maximum and minimum daily lunar motion varied, but on the equatorium the range of achievable values was certainly no greater than 11;36-14;48°/day, so in that sense either table would have been quite sufficient. See Goldstein (1992).

[104] In Westwyk's defence, we may note that errors which Price claimed to have identified in his explanation were, in fact, correct; Price mixed up figures for the retrograde motion of Caput Draconis and the resulting position, which was obtained by subtracting the motion from 360°. We may therefore reasonably conclude that no scholar is immune to such errors, and we should not judge Westwyk's performance too harshly. It is also worth noting that Westwyk had almost certainly not computed these exceptionally accurate (barring his one cardinal error) positions on the equatorium, but rather taken them from tables for use in his worked examples. See arguments in Price (1955b), 72-73; North (1988), 168-169.

[105] Peterhouse MS 75.I, ff. 14r, 30v, 38v, 62v and 63v. Price (1955b, 182-187) explains the cipher.

[106] 'This is the amount by which the half-arc [half the daylight hours] of the longest day is more than six hours.'

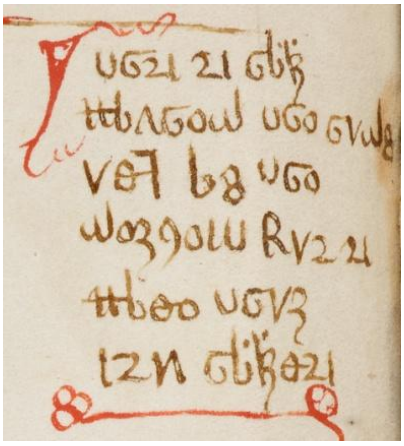

Fig. 43: Ciphered Middle English text. Peterhouse, Cambridge MS 75.I, f. 63v. Reproduced by permission of the Master and Fellows of Peterhouse, Cambridge.

readers, or make the material appear more complex. Either way, we have a glimpse of Westwyk's enjoyment of the parallel challenge of learning the use of the tables and of cipher. In cipher, in Latin and in plain English he makes notes on what he sees and copies, cites authorities whose achievements he respects, and comments on the results of his computations.

## Conclusion

Peterhouse MS 75.I is not an astronomer's rough workbook. Although his equatorium treatise is a draft, and some of his calculations contain errors, John Westwyk clearly took pride in his compilation. His diagrams are carefully drawn, and the radices he compiled (apparently at the same time) for 1392 and 1400 demonstrate his intention to continue using the tables for years into the future.[107] He surely realised that he still had techniques to learn; the absence of his annotations on some of the more complex "Hand S" tables, such as the double-argument tables of latitudes, suggest the limitations of his abilities or interests.[108] And although he perhaps lacked the sophistication to realise that great precision did not equate to 'the trowthe of conclusiouns', he was far from incompetent, capable of explaining the construction and use of an equatorium in clear prose.

More significant than his mistakes is his malleability. He was willing to try different forms of presentation such as signs of 60° and 30°, and years ending on 31 December and 28 February; different layouts such as tables of numbered days and calendars grouped by months; even entirely different calculation techniques, using tables as well as the equatorium he had designed or adapted. Such variety in presentation, parameters and authorities is not, perhaps, unusual within

[107] Peterhouse MS 75.I, f. 6v.
[108] Peterhouse MS 75.I, ff. 32r-38r. Like the double-argument tables of longitudes on ff. 45r-61r, these are identifiably within the 'Oxford tables' tradition (cf. Cambridge University Library MS Ii.1.27, ff. 34r-38v), with the same exception that they use signs of 60° instead of 30°.

compilations of tables; but it has not hitherto been appreciated of the *Equatorie* manuscript.[109] Granted, it was surely forced on Westwyk by the sources available to him, but he was quite willing to use, and perhaps learn from, them. His suggestibility extends to language, where he adopts Latin and Arabic terms from his source texts and incorporates them into his own Middle English (whether plain or ciphered). Sometimes this was for lack of an existing term in the vernacular; but in other cases, such as his use of 'retrogradorum' when he could easily have written 'planetis', we again have the sense of a keen learner trying out new ideas and techniques as he computes, compiles and composes a new treatise.[110]

This willingness to experiment was not, perhaps, common to university-educated scholars in the heyday of scholasticism. Rather, it is the hallmark of the amateur: a monk producing an idiosyncratic compilation, perhaps for use in his community. And it shows the practical eye of a craftsman. With great clarity, Westwyk describes a device whose ease of construction and use would more than compensate for its deficiencies in representing Ptolemaic diagrams. The equatorie evinces impressive practical ingenuity: if this instrument was never made according to the instructions in the treatise, it certainly deserved to be. To be sure, making simplicity a priority almost inevitably leads to omissions, and it could be argued that the equatorie is the poorer for not taking account of planetary latitudes, nor including a completely explained tool for the accession and recession of the eighth sphere. But the result of narrowing down its possible functions is that those functions with which it is left become clearer and more user-friendly. We are left with a workable alternative to the use of tables on their own; desire for a more complex instrument might only have given us an alternative that sacrificed accuracy for no great saving in time. It is thus argued that the omissions and inconsistencies identified in this chapter diminish the astronomical value of the treatise and tables only very slightly.

And their historical value is not diminished at all; in fact it is enhanced. Westwyk's imperfections, as is often the case, tell us far more than a faultless document or object would do.[111] In the first place, they remind us of the humanity and individuality of their author. We still do not know the precise circumstances in which John Westwyk produced Peterhouse MS 75.I. But an analysis of this manuscript has told us much about his abilities, interests and the methods through which he learned the science of astronomy. More broadly, technical study of Westwyk's work has revealed important details of the processes of transmission, compilation and computation that went into this manuscript and others like it. Westwyk was an individual monk,

[109] North (1988, 184), noted its variety, but there is much that can be added to his account, as this chapter has shown.
[110] Peterhouse MS 75.I, f. 38v. On this use of 'retrogradorum', which may be influenced by John Somer, see North (1988), 188.
[111] See the discussion of 'wounded artefacts' in chapter 2, pp. 10-11.

but one learning the tools and techniques of a mathematical astronomy that extended across medieval Christendom, and beyond.

# Conclusion

> The science of Astronomie
> I thinke for to specefie,
> Withoute which, to telle plein,
> Alle othre science is in vein.
>
> John Gower, *Confessio Amantis* (c. 1390)[1]

> No one should pursue what he thinks will benefit himself but rather what benefits someone else.
>
> *The Rule of Benedict* (c. 540)[2]

John of Westwyk was a monk of his time. He travelled and studied; watched the stars; read, copied, compiled and calculated; invoked and praised God; described, drew, made and used instruments; read and wrote in multiple languages; compared and cited; learned and taught; checked, erased, edited. This thesis has reconstructed the astronomical practices of this late-fourteenth-century English Benedictine. It has analysed his computation and use of tables, his respectful reading of his monastic and scientific ancestors, the craft context of his instrument study. Above all, it has considered the charitable act of communication that is Peterhouse MS 75.I. It has examined this document of amateur astronomy from inside and out, showing what content and context can together contribute to our understanding of medieval science.

Before concluding, it is perhaps desirable to note a few things that this thesis has not been about. In the first place, I have not attempted a systematic analysis of equatoria, nor evaluated the place of the *Equatorie* in the long history of planetary instruments. Readers seeking the former are advised to consult Emmanuel Poulle's magisterial survey; for the latter, while there is now much to add to Derek Price's excellent – but sixty-year-old – account, this has not been the occasion to do so.[3] I have preferred to concentrate on the astronomical achievements of one man in his specific context. Even here though, there are some answers my research has not provided. I have cast little new light on the events of John Westwyk's life between his return from crusade in Flanders late in 1383 and his death, probably in 1397 or soon after.[4] When he came to compile Peterhouse MS 75.I he had access to unusually large sheets of parchment, many of them already filled with tables of mean motions, equations and ascensions, but we still do not know whether this access was within a monastery; nor do we know the nature of his connection with London, which led him to draw up radices for that location. It is tempting to speculate that

[1] Book VII, lines 625-628, in Gower (2004), 279.
[2] ch. 72, in Benedict (2008), 103.
[3] Poulle (1980); Price (1955b), 119-133. See also North (1986), 249-286, on 'The place of *Albion* in the history of the equatorium.'
[4] Rand (2015), 10-11.

he was exploiting the strong connections between St Albans and the royal court, or the monastery's wider confraternity which included merchant elites in the capital, but there is insufficient evidence to support such a claim.[5] We can take only the salutary reminder that astronomy was produced and practised in more settings, and by more individuals, than will ever be found in written sources.

Not yet found among the written sources is any parent text for the *Equatorie*. I have identified a number of important influences in the work of Westwyk, some of which he himself names, but I have not been able to recover a discrete treatise of which the *Equatorie* might represent a translation. The possibility remains that no such treatise ever existed: that Westwyk was composing his text simultaneously in Latin and Middle English, or was translating his own Latin draft; perhaps more likely is that he was working from one or more Latin treatises that no longer survive. But it seems counter-productive to guess at the identity or nature of such treatise(s). Previous historians have attempted to link the *Equatorie* to known figures at more than one level: John North, for example, while arguing that Chaucer had composed Peterhouse MS 75.I, also suggested that his source might be a treatise by William Batecombe, probable author of the 'Oxford tables', since the library of Austin Friars at York had contained a manuscript entitled *Equatorium abbreviatum cum canonibus Badcomb*, and the Peterhouse equatorie certainly is 'abbreviatum'.[6] One might struggle to imagine its drastically simplified design as the work of the same man who drew up complex double-argument tables of planetary latitudes, or might wonder why Westwyk did not cite this among all his other sources. More fundamentally, though, an important lesson of this thesis – and the authorship debate that preceded it – is that, without strong evidence, we should be chary of allocating a text to a particular name on the list of known fourteenth-century astronomers: a list which, while growing, still surely remains only a fraction of the astronomical community at that time. Furthermore, in the absence of anything but circumstantial evidence linking the *Equatorie* to any other treatise or author, I have been equally unwilling to speculate about how much of the manuscript can be categorised according to the (often misleading) modern terms *translation*, *adaptation*, or *original*. As I have shown, evidence can be adduced for all three, but the complexity and fluidity of the relationships between language, content and ideas of authorship make pithy conclusions untenable.

Nevertheless, this thesis has made much of the language of the *Equatorie of the Planetis*. In part, of course, this is because the changing natures and purposes of languages in late medieval England are themselves worthy of study. And my research has included an in-depth study of the

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5 Clark (2004, 34-37), discusses the close ties between the Abbey and the royal family, lay patrons and merchant elites.

6 North (1988), 187-188; James (1909), 56. On Batecombe, see North (1977), 279-280.

pioneering use of the vernacular at the boundary of science and craft. Yet this also informs the rest of the thesis, and future research, since, as Quentin Skinner points out, linguistic study must be at the heart of any attempt to understand the content of a written source in its correct historical context.[7] The case-study approach of this thesis has allowed us to situate Peterhouse MS 75.I in its own particular setting, so that it can stand as specific evidence of local, contingent astronomical practices.[8]

This is not to deny the broad popularity and transferability of astronomy and its instruments across diverse late medieval settings. The transmission and application of knowledge between university and monastic contexts; the interconnections of texts, instruments, parameters and inventions; and the wide range of uses to which these were put, are all revealed through my research. And it has been clear in each chapter how astronomical knowledge was developed in the process of transmission. James Secord's description of 'knowledge in transit' is applicable here in a variety of ways.[9] The blurred boundaries between medieval forms of communication, so problematic for modern scholars wishing to categorise texts such as the *Equatorie of the Planetis*, were ideally suited for the development of astronomical ideas through the processes of transmission by contemporaries. One of those processes was, of course, translation, and this thesis has shown how Westwyk developed knowledge both through what might be seen as typical medieval *translatio studii*, and through his own local, contingent, craft-focused translation.[10] In each of these he pioneered new modes of communication, whether at the level of individual lexical items or communicative strategies. Yet another process was learning, and we have seen how, as Westwyk grappled with the techniques of tables and instruments, he revealed, and perhaps refined, mathematical methods and productive practices.

The paradox at the heart of this thesis remains that of Westwyk's dual role as student and teacher. Peterhouse MS 75.I never shows a perfect state of understanding fit for one-way transmission, but rather the vibrant reception and development of ideas. This, it seems, is the perennial position of the go-between in knowledge production.[11] The *Equatorie of the Planetis* appears to broker an instrumental relationship between scholarship and craft. In doing so, it reveals creativity not often associated with medieval ideas, particularly in institutional settings. David Knowles saw in late medieval England 'an academic society which lacked . . . the impulse

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7 Skinner (1969), 49.

8 Here I have drawn on the 'situated knowledge' of the sociology of scientific knowledge; see, for example, Shapin (1995), 304-307.

9 Secord (2004).

10 See also Jones (1989, 89), on the significance of translation in the 'process of adaptation and diffusion' of medieval science and medicine.

11 Schaffer et al. (2009); Gretchen Mieszkowski (2006) has surveyed the figure of the (romantic) go-between in medieval literature, including the character of Pandarus in Chaucer's *Troilus and Criseyde*.

of creative thought.'[12] Knowles was disappointed at the lack of new ideas and arguments in writings of the period but, as I have shown, creativity bloomed in varied settings and practices. The engine of improvement did not have to be ideas; the 'mindful hand' of the craftsman had an important role to play.[13] These craftsmen, it has been shown, worked with instruments much as textual scholars worked with their treatises: copying, compiling, adapting, translating; occasionally inventing *de novo*.

Did they thereby further the cause of scientific progress in the medieval period? Most historians have thought not. The pioneering historian of technology Maurice Daumas wrote scathingly of how, before the sixteenth century, instruments 'ont très peu évolué pendant des siècles, malgré leur apparente diversité.'[14] He blamed this on the stagnation of theories, as well as 'l'extrême lenteur avec laquelle progressaient les techniques de fabrication.' Derek de Solla Price, while taking an opposite view of the appeal of medieval instruments, seemed to agree about their lack of importance, writing that:

> Our civilization has produced not merely a high intellectual grasp of science but also a high scientific technology. [This] seems to be based upon the artifacts produced by and for scientists, primarily for their own scientific purposes . . . Curiously enough, this movement does not seem to have sprung into being in response to any need or desire on the part of the scientists for devices they might use to make experiments and perform measurements . . . On the contrary, it seems clear that in the sixteenth and earlier centuries the world was already full of ingenious artisans who made scientific devices that were more wondrous and beautiful than directly useful.[15]

We have seen in this thesis that a medieval instrument could be both model and tool; a device for teaching and learning; a three-dimensional diagram and a user-friendly computer. Innovation was more than decorative; usefulness was more than the achievement of a practical outcome. Makers, as we have seen, created inspiring and didactic models but also solved technical, representational and material problems. John Westwyk's equatorie may not have contributed to, or even reflected, the development of astronomical knowledge; but an overview of his work has revealed the diverse textures of scientific practices in this period. Craft, mathematics, astronomy and astrology are all evident, underpinned by the cosmology through which a monk sought to approach the mind of God.[16]

It is only through an in-depth study that we have been able to understand the complexity of astronomical practices in this period. To be sure, there is no guarantee that the reading, thinking, making and writing habits of John Westwyk were replicated in other members of his astronomical community. The depiction of that community is necessarily a pointillist enterprise.

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[12] Knowles (1957), II. 83.

[13] Roberts, Schaffer, and Dear (2007).

[14] Daumas (1953), 1-2.

[15] Price (1975), 29.

[16] Westwyk writes nothing that is explicitly cosmological but, as I have argued elsewhere (Falk (2012), 4-5), astronomers could hardly escape the cosmological implications of their work. (The planetary calculator analysed in chapter 2 gave a hint of this.)

This is why further studies are needed which, whether focussing on individuals, groups or institutions, engage with the full spectrum of their intellectual endeavours: instruments and tables; astronomy and theology; cosmology and mathematics. This thesis covered the content of the *Equatorie* last because it is less important than the attitudes that produced it. It is to be hoped that future work will be able to address monastic science more broadly, giving astronomical practices their proper place among monks' habits of mind. Did an obsession with the precision of calculations have its counterpart in approaches to doctrinal issues? Would Westwyk's reading of Wyclif parallel the way he read Wallingford? These are the sort of questions we should now be addressing.

This thesis has rejoiced in its treatment of an inexpert astronomer, and has sought to show that amateur practices are as worthy of study as those of intellectual elites. It is a story far from the foundations of instrument studies a hundred years ago, in which R. T. Gunther suggested that 'the history of the evolution of astronomical instruments is that of all scientific research, and shows a continual process of development . . .'[17] The scientific concerns of monks were surely shaped less by a drive to advance theories than by their own practical, pedagogical, communicative priorities, that were both local – whether at windswept Tynemouth or gilded St Albans – and personal. And yet as they developed and communicated their own understanding, through the practices we have examined in this thesis, they amply shared in Gunther's vision of 'the ever-widening, combining and co-ordinating activity of the mind of man.'[18]

[17] Gunther (1923), 5.
[18] Idem.

## APPENDIX A

### Original Latin and Middle English passages quoted in translation in this thesis

Where I have translated quotations for the convenience of readers, they will be found in their original languages in this appendix. (In some cases I have quoted from previously published translations; the original versions of these quotations are not included here.)

| Page | | |
|---|---|---|
| 1 | Richard of Wallingford, 'Tractatus albionis', III, in North (1976), I. 340 | Hoc autem unicum instrumentum, si omnium et singulorum commoditates corpore tam brevi contineat, et quedam alia forsitan superaddat, inter cetera non erit abiectum, maxime cum eius invencio multorum ingenia excitare poterit ad maiora. |
| 1 | British Library MS Cotton Nero C.vi, f. 149r | Albeonam utique, que in se unica omnium aliorum instrumentorum commoditates legitur continere |
| 13 | Oxford, Bodleian Library, MS Laud Misc. 657, f. 1v | Hunc librum dedit Dompnus Iohannes de Westwyke deo & beate marie & sancto Oswyno regi et martiri de tynemuth. Et monachis ibidem deo seruientibus |
| 15 | Richard of Wallingford, 'Rectangulus', in North (1976), I. 406 | eodem tempore |
| 15 | MS Laud Misc. 657, f. 1v | Sciendum est quod Dominus Ricardus Abbas monasterii sancti Albani primo composuit istum librum; Et per eum excogitauit & fecit instrumentum illud mirificum quod dicitur Albeon. Sed postea quidam Symon tounstede sacre theologie professor quedam mutauit tam in libro quam in instrumento, sicut patet studentibus in libro isto. Quedam eciam superaddidit. |
| 16 | *Summi magistri*, in Wilkins (1737), II. 594 | per exercitium lectionis adquiritur scientiae margarita |
| 16 | *Gesta abbatum*, in Walsingham (1867), II. 433 | studendo, legendo, librosque scribendo, notando, corrigendo, illuminando, pariter et ligando |
| 22 | MS Laud Misc. 657, f. 1v | quedam mutauit tam in libro quam in instrumento, sicut patet studentibus in libro isto |
| 22 | MS Laud Misc. 657, f. 21r | de circulus in prima facie rote prime in alio libro sic scriptum inveni |
| 23 | MS Laud Misc. 657, f. 22v | haec clausula vacat, quia hoc dictum supponit circulum anni solis cum diebus mensibus esse descriptum in limbo secundo sicut in primo, quod non accidit in instrumento nostro, nec requiritur et ideo bene omittitur |
| 23 | MS Laud Misc. 657, f. 11r | Nota quod in hoc spacio debet esse figura circulorum primi limbi prime faciei, sed in instrumento planissime describitur ideo hic omittitur. |

| | | |
|---|---|---|
| 24-25 | MS Laud Misc. 657, f. 22v | abbas in suo circulo involuto posuit medium motum lune, sed in nostro instrumento ponitur in circulo involuto elongacio lune a sole, quia si sibi addatur medius motus solis provenit medius motus lune si ipsum placuerit habere |
| 26 | MS Laud Misc. 657, f. 44r | Tota ista clausula debet poni ante principium istius libri, scilicet ante conclusiones. Ex collectis Symonis Tounstede sacre theologie professoris. |
| 27 | MS Laud Misc. 657, f. 45r (see figure 44) | ¶ Ista tabula deberet poni post tabulam medii motus lune ad tale signum ✧, quia dominus abbas posuit in suo circulo involuto medium motum lune, sed magister Symon posuit in suo circulo involuto elongacionem lune a sole sicut habetur in utilitate 4a; et ideo scripsi istam tabulam ut si cui melius placuerit ita faciat.<br>¶ Item abbas operatur cum circulo Iomyn pro equacione dierum. Sed Symon operatur alio modo, sicut docetur utilitate 18a; et etiam in aliis locis quae plurimis videntur disconvenire, prout in utilitatibus planius invenitur.<br><br>¶ Nota si subtrahatur medius motus solis a medio motu lune proveniet elongacio lune a sole.<br>¶ Item si addatur medius motus solis elongacioni lune a sole provenit medius motus lune.<br>¶ Item adde super argumentum lune medium motum capitis et habebis argumentum latitudinis lune. |
| 28 | MS Laud Misc. 657, f. 30v | istud capitulum supponit quod circulus obliquus describitur in limbo rote secunde, sed sic non est in nostro instrumento et immo vacat |
| 29 | MS Laud Misc. 657, f. 42v | Tabula ascencionum signorum in circulo obliquo in latitudine .55. gra. calculata est et composita sicut docent canones in secundo libro Almagesti; et debet per eam dividi circulus secundus in limbo secundo secunde faciei instrumenti sicut docetur capitulo 18$^{o}$ secunde partis huius // tynemuth |
| 29 | MS Laud Misc. 657, f. 42r | circulus 3$^{us}$ in limbo secundo secunde faciei (^huius) instrumenti |
| 37 | Richard of Wallingford, 'Tractatus albionis', in North (1976), I. 380 | operacio autem que sit per sapheam habet suum tractatum |
| 38 | MS Laud Misc. 657, f. 43r | zodiacus hic transit contrario modo usitato in aliis instrumentis |
| 39 | MS Laud Misc. 657, f. 43r | prima est si sol fuerit in auge ecentrici, ex hoc enim fit umbra maior; secunda ex descensu lune ab auge epicicli sui, ex hoc enim appropinquat ad grossiorem partem umbre; et tercia est latitudo eius ab ecliptica, quia cum fuerit maior latitudo transit magis lateraliter, et quanto minor tanto magis obumbratur ex hac causa. |

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| 43 | Richard of Wallingford, 'Tractatus albionis', II.9, in North (1976), I. 312 | iste circulus ecentricus non habet errorem sensibilem in instrumento cuius diameter est 60 cubitorum |
| 43 | Brussels, Royal Library, MS 10124, f. 142v, in Price (1955b), 188. | magis tediosa . . . propter magnitudinem huius instrumenti eo quo de levi non potest deferri de loco ad locum sive de regione ad regionum |
| 56 n55 | Stöffler (1553), 44v-45r | Duos inscribendorum circulorum anni accepimus modos, quorum primus per circulos concentricos, secundus vero per eccentricos inscriptionis operationem absoluit. |
| 59 | Cambridge University Library MS Gg.VI.3, f. 218r (see appendix D) | distantia inter augem equantis et filum pertensum a centro equantis ad centrum epicicli |
| 59 | Gg.VI.3, f. 217v | per operationem cum instrumento Campani Lyners vel Judei proponenda est theorica ut effectus pateat satis planus |
| 60 | Gg.VI.3, f. 220v | in modo operandi cum eis parva sit diversitas |
| 60 | Gg.VI.3, f. 217v | Prefatius Judeus in Monte Pessulano aliud equatorium consimilis operationis prudenter composuit quod vocant semissas |
| 60 | Gg.VI.3, f. 220v | aliud equatorium de novo componitum |
| 62 | Gg.VI.3, f. 220r | figatur tabula super asserem per suam lingulam |
| 65 | Gg.VI.3, f. 219v | motus aut 8 sphaerae vix est 1 gradus in 100 annis futuris |
| 67 | Universidad de Salamanca Ms. 2621, f. 10r | Tabula stellarum fixarum prout poni debent in astrolabio |
| 67 | Ms. 2621, f. 10r | Ista sunt vera loca stellarum secundum longitudinem et latitudinem equata per magistrum Johannem Fusoris anno 1428 |
| 69 | Jean Fusoris, 'Liber primus de motibus planetarum per instrumenta manualiter mota', in Poulle (1963), 125-180, at 150. | Solis instrumentum multipliciter potest componi. Primo grossomodo quemadmodum communiter fit in dorso astrolabii; sed verum est quod modus iste multos patitur defectus. Primus est quia deferens solis et centrum ipsius non moventur motu 8e spere, ymmo manent semper in directo ejusdem partis zodiaci. 2us et major defectus est quia in illo modo supponitur quod Sol describat in deferente suo totum zodiacum prescise in 365 diebus, quod non est verum. |
| 69 | Fusoris, 'Liber primus', 152 | extremitas allidade rotundanda posset limari sicut communiter limatur zodiacus rethis astrolabii |
| 71 | CUL Gg.VI.3, f. 217v (see Appendix D) | difficultatem prolixitatem et tedium calculationis per tabulas |
| 72 | Universidad de Salamanca Ms. 2621, f. 10v (see Appendix E) | si placet etiam sit tanta sicut una tabula cum almucantharat |
| 72 | Ms. 2621, f. 10v | litteris saepe dictis |

| | | |
|---|---|---|
| 72 | Ms. 2621, f. 10v | in ista tabula non debet stare circulus signorum cum non valeat pro practica quod in ea staret |
| 73 | Ms. 2621, f. 10v | fac circulum late distante quod in ea posses scribere nominam mensium et quorum datam festorum quae tibi placent |
| 73 | Ms. 2621, f. 11v | possunt fieri in una tabula |
| 73 | Ms. 2621, f. 11v | propter convenienciam quam habent, quia sicut una mensurat celum sic per aliam mensuratur terra |
| 85 | 'Vox clamantis', VII.1445-6, in Gower (1902), 312 | hec set ut auctor ego non scripsi metra libello / Que tamen audivi trado legenda tibi |
| 86 | St Bonaventure, 'In librum primum sententiarum', Proemium, Quaestio iv, in Bonaventure (1882), I. 14-15 | Quae sit causa efficiens sive auctor huius libri.<br>quadruplex est modus faciendi librum. Aliquis enim scribit aliena, nihil addendo vel mutando; et iste mere dicitur scriptor. Aliquis scribit aliena, addendo, sed non de suo; et iste compilator dicitur. Aliquis scribit et aliena et sua, sed aliena tamquam principalia, et sua tamquam annexa ad evidentiam; et iste dicitur commentator, non auctor. Aliquis scribit et sua et aliena, sed sua tanquam principalia, aliena tamquam annexa ad confirmationem; et talis debet dici auctor. |
| 88 | Peterhouse MS 75.I, f. 74r | nota I conseile the ne write no names of signes til þat thow has proued þat thi comune centre defferent is treweli & justli set in direct of the closere of the signes of thin equatorie |
| 116 | Vienna, Österreichische Nationalbibliothek, Cod. 5438, ff. 168r-171r, in Kunitzsch (1977), 12. | Nota nomina extranea que reperiuntur in libris autorum |
| 148 | Peterhouse MS 75.I, f. 45r | accipe partem proporcionalem tam ex parte centri quam ex parte argumenti si oportet. |
| 150 | Peterhouse MS 75.I, f. 64r | istae sunt declinationes arsachelis ut estimo // verum est quod R.B. |

## APPENDIX B

## Excerpt from MS Laud Misc. 657

This appendix is a transcription and translation of folios 43r-44r of Oxford, Bodleian Library MS Laud Misc. 657. These folios contain additions to the text of the *Tractatus albionis* of Richard of Wallingford. The canonical version of the treatise is edited in J. D. North, *Richard of Wallingford: an Edition of his Writings* (1976); this includes the prologue, which appears on the lower part of folio 44r of MS 657.

Other significant but shorter additions to the treatise are quoted in chapter 1 of this thesis.

Some changes have been made for clarity: paragraph marks (¶ and //) have been removed, and line breaks and appropriate punctuation added. All abbreviations have been expanded. Dots around numbers and letters have been removed. The beginnings of sentences, and proper nouns, have been capitalised. The letters 'u' and 'v' have sometimes been changed. Digits have been expanded where they function as an abbreviation of a non-numerical word (e.g. *secundum*), but have otherwise been left unchanged.

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| | |
|---|---|
| **[43r] Quantum** ad sapheam, sciendum quod linea recta transiens ab armilla in partem opponitam dicitur axis mundi. Linea ipsam secans orthogonaliter in medio est equinoctialis. Omnes vero arcus secantes directe diametrum mundi, utrimque versus utrumque polum sunt circuli latitudinum ab equinoctiali et signant paralellos equidistantes equinoctiali, et eorum divisio procedit per 5 usque ad 90. Et sunt arcus ex utraque parte 18, quorum quilibet continet 5 et similiter 90 quod patet per numeros quibus intitulantur. Consimiliter dividitur equinoctialis per arcus secantes eam directe, et eorum divisio est similis priori, et omnes terminantur in polis ex utraque parte et sic dividitur in signa, et gradus et ita intitulatur ipsa equinoctialis tam ordine recto quam retrogado. Consimiliter per omnia dividitur zodiacus secundum suos polos et ecliptica. Et est zodiacus linea recta ut equinoctialis et eius polus declinat ad partem fili limbi, per quantitatem declinationis. Dividitur etiam emisperium apparens simili modo sicut altera medietas equinoctialis, ita quod continet 6 lineas rectas: equinoctialem, zodiacum, vel eclipticam, orizontem, diametrum mundi, diametrum | Concerning the saphea, know that the straight line crossing from the ring towards the opposite side is called the axis of the world. The line cutting this orthogonally in the middle is the equator. All the arcs cutting the diameter [axis] of the world at right angles, from one pole to the other, are circles of latitude from the equator, and are marked by equidistant lines parallel to the equator, and they are divided in 5s up to 90. And there are 18 arcs on each side, each of which contains 5, up to 90, which is shown by the numbers marked there. Similarly the equator is divided by arcs cutting it at right angles, and their division is similar to the previous one, and they all meet at the poles at each end, and are thus divided into signs and degrees and so this equator is labelled both clockwise and anticlockwise. Similarly [running] through everything are the zodiac, divided according to its poles, and the ecliptic. And the zodiac is a straight line like the equator, and its pole declines to the part of the thread on the limb, according to the amount of declination. Also, the visible hemisphere is divided in the same way as the other half of the equator, so that it contains 6 straight lines: equator, zodiac or ecliptic, horizon, axis of the world, axis of the zodiac, |

zodiaci, et semidiametrum orizontis cuius polus est prope opponitum augium.

and semidiameter of the horizon, whose pole is near the opposite aux.

Circumferencia vero eius est circulus meridionalis qui dividitur in singulos gradus et intitulantur per 5 et 5 incipiendo ab equinoctiali et procedendo ad polos utriumque. Incipit enim ex una parte a capite cancri, et ex alia a capite capricorni, et sic regula cuiuscunque poli fuerit consimiles divisiones et intitulaciones.

The circumference of this [saphea] is the southern circle which is divided into individual degrees and labelled in 5s, starting from the equator and proceeding to each of the poles. So on one side it starts from the head of Cancer, and on the other from the head of Capricorn, and thus the straight line of each pole has similar divisions and labels.

Nota quod aries et libra incipiunt a centro. Nota quod principio capricorni existente in linea meridiana quicquid apparet super orizontem per istud instrumentum innotescit tam regula ecliptice quam regula equinoctialis. Nota etiam quod capta elevacione solis meridiana scire potes locum solis: nam vide quis arcus secans diametrum mundi illam elevacionem tangit, et vide ubi secat eclipticam et ibi est gradus solis verus. Set considera in qua medietate zodiaci fuerit et cetera.

Note that Aries and Libra start from the centre. Note that the start of Capricorn is located on the meridian line which appears on the horizon and is shown on this instrument both by the ecliptic and equator. Note also that if the meridian altitude of the Sun is found, you can also know the place of the Sun: for see which arc cutting the axis of the world touches this altitude, and see where it cuts the ecliptic and there is the true degree of the Sun. But consider which half of the zodiac it is in, etc.

**Quantum** ad astrolabium, nota quod ibi sunt circuli altitudinum qui dicuntur almicantarath et patent per suos numeros in tribus locis. Sunt etiam circuli azimuth descendentes a cenith ad orizontem et patent per numeros scriptos in orizonte. Sub orizonte sunt arcus horarum 12. Praeterea ibi est zodiacus in cuius medio est ecliptica et ex utroque latere habet 6 circulos qui designant latitudinem et dividitur etiam transversaliter secundum longitudinem ut patet. Nota etiam quod nomina signorum sic scribuntur quod a fine dictionis incipit signum et hoc ut appareat legenti et causa est quia zodiacus hic transit contrario modo usitato in aliis instrumentis. Cohaeret vero extimus dividitur in signa et gradus equales.

Concerning the astrolabe, note that there are the circles of altitude which are called almucantars, and are identifiable by their numbers in three places. There are also the circles of azimuth descending from the zenith to the horizon, and they are identifiable by numbers written at the horizon. Below the horizon are 12 [unequal] hour arcs. In addition there is the zodiac, in the middle of which is the ecliptic, which on each side has 6 circles designating latitude; and they are also divided cross-wise according to longitude, as can be seen. Note also that the names of the signs are written in such a way that each sign starts at the end of the name, so that they are easy to read, and the reason is that this zodiac goes in the opposite direction to what is usual on other instruments. Next there is the outer [scale] divided evenly into signs and degrees.

Nota quod linea corde recte et verse dividitur in 60, sed utrimque procedit ultra laminam ad circulum altitudinis et ibi terminatur ita quod utraque linea capitis limbi et eius opponiti est pars **[43v]** linee predicte, et divisiones sunt ibi subtiles etiam numeri ibi scribuntur a latere si

Note that the line of direct and versed chords is divided into 60, but at both ends it continues beyond the plate to the circle of altitude, ending there, so that both the line of Caput [Draconis] on the limb, and its nadir, are part of the aforementioned line, and there the divisions are advertantur, quia propter confusionem orbium non possunt aliter fieri, linea continens minuta casus et more utriusque scilicet eclipsis dividitur in (minuta fere) 64 partes que incipiunt a centro et procedunt crescendo usque ad limbum et signant maximam quantitatem eclipsium lune; que quantitas fit maiorem ex tribus causis, quarum: prima est si sol fuerit in auge ecentrici, ex hoc enim fit umbra maior; secunda ex descensu lune ab auge epicicli sui, ex hoc enim appropinquat ad grossiorem partem umbre; et tercia est latitudo eius ab ecliptica, quia cum fuerit maior latitudo transit magis lateraliter, et quanto minor tanto magis obumbratur ex hac causa. Linea semidiametralis que continet puncta eclipsis lunaris est in parte qua scribitur luna et eius margo dividitur in puncta eclipsis lunaris incipiendo a centro et sunt 22 puncta. In linea vero supra marginem versus lunam sunt divisiones 12 que signant excessum punctorum eclipsium in opponito augis ad puncta eclipsis in auge.

faint, and also numbers can be seen written at the side, since to avoid confusing the circles they cannot be made any other way; the line containing the minutes of both partial and total eclipse is divided on each side into 64 parts which begin from the centre and increase toward the limb, and denote the maximum quantity [duration] of the eclipse of the Moon; which quantity is made greater by three causes, of which the first is if the Sun is at the aux of its eccentric, so that its shadow is larger; secondly by the descent of the Moon from the aux of its epicycle, so that it approaches the widest part of the shadow; and thirdly is its latitude from the ecliptic, since when this is greater it moves more laterally, and the smaller it [the latitude] is the more it is overshadowed for this reason. The semidiametral line which contains the points of lunar eclipse is in the part which is labelled "Moon" and its margin is divided into points of lunar eclipse, starting from the centre, and there are 22 points. On the line on the margin, next to the Moon, are 12 divisions which denote points outside eclipses, from the opposite aux to the points of eclipse at the aux.

Ex alia parte que deservit soli est equalis margo pro sole et dividitur ad puncta eclipsis solaris incipiendo a centro et procedendo ad 12 puncta, sed non protenditur secundum longum ad limbum sed terminatur in tropico eclipsis solaris. Nota quod aux solis est linea minutorum casus aux lune in parte opponita, et hic intelligitur aux pro inicio tropici eclipsis solaris vel in inicio tropici lunaris. Circulus latitudinis lune est primus semicirculus ex parte solis et dividitur in 10 partes equales que sunt gradus latitudinis lune ab ecliptica et quilibet gradus dividitur in 60 minuta. Nota tamen quod latitudo lune maxima non excedit 5 gradus sed scribuntur ibi bis, semel crescendo et $2^{o}$ dividendo ut fiant coniuncia cum argumento latitudinis et equacio. Duo semicirculi proximo sequentes sunt argumentum latitudinis lune et dividitur per signa et gradus ita quod exterior et maior designat omnem distanciam a capite usque ad caudam unde finitur ad 6 signa. Alius revertitur a cauda usque ad caput per alia 6 signa divisus unum illi $2^{o}$ simul dicuntur semicirculus capitis draconis. Tropicus solaris

On the other part which serves for the Sun is likewise a margin for the Sun, and it is divided into points of solar eclipse starting from the centre and amounting to 12 points, but it does not extend as far as the limb but ends at the tropic of eclipse of the Sun. Note that the aux of the Sun is the line of minutes of partial eclipse at lunar aux on the other side, and this means the aux for the start of the tropic of solar eclipse or the start of the tropic of lunar eclipse. The circle of latitude of the Moon is the first semicircle on the side of the Sun, and it is divided into ten equal parts which are the degrees of latitude of the Moon from the ecliptic, and each degree is divided into 60 minutes. But note that the maximum latitude of the Moon does not exceed 5 degrees but they are written there twice, first rising and second dividing to join up with the argument of latitude and the equation. The next two semicircles are the argument of latitude of the Moon, and it is divided by sign and degree, so that the outer and larger denotes the whole distance from Caput [Draconis] to Cauda, whence it finishes at 6 signs. The other returns from Cauda towards qui sequitur ex parte solis.

Caput, through another 6 signs, one divided like the second, so they are called semicircle of Caput Draconis. The tropic of the Sun is what follows on the side of the Sun.

Nota quod signa et eorum (numeri) scribuntur secundum successionem signorum usque sinistram et totum infra circulum involutum, sed duo circuli rectus et obliquus et eorum numeri contrarie et etiam numerus contrarius infra signa. Primus circulus scribitur directe 5 10 15 cum signis et habet numeros quatenus 90 incipienter a 4 punctis principalis scilicet a capricorinio aut et retro id est usque ad arietem et usque ad libram. Item circulus rectus scribitur contra successionem signorum, aries 5 10 15. Item circulus obliqus scribitur contra successionem signorum aries talis 5 10 15. Item isti tres circuli incipiunt in ar- **[44r]** milla. Argumentum medium mercurii continet 3 revoluciones et ultra 7: 20 fere die decembris usque ad finem et est finis super 18 die Januarii fere.

Note that signs and their numbers are written in succession of signs towards the left, and everything is [thus] within the spiral circle, but the two right and oblique circles and their numbers are contrary, and also the number[s] within the signs are contrary. The first circle is written directly 5 10 15 with signs, and has four sets of 90 numbers, beginning from the four main points, that is from Capricorn or [Cancer] and back, that is up to Aries and up to Libra. Also, the direct circle is inscribed against succession of signs: Aries 5 10 15. Also the oblique circle is inscribed against succession of signs: such as Aries 5 10 15. Also, these three circles start at the ring. The mean argument of Mercury [on the spiral] contains 3 revolutions and 7 over: around the 20th day of December up to the end, and the end is on about the 18th day of January.

Medius motus lune
Elongacio lune a sole continet ultra mercurium 13 revoluciones et plus scilicet post festum thome apostoli usque ad finem anni
Argumentum medium lune continet 14 revoluciones et plus nec est circa ubi incipiunt ista 4 puncta

The mean motus of the Moon
The elongation of the Moon from the Sun contains, after Mercury, 13 revolutions and some more, that is after the feast of Thomas the Apostle up to the end of the year.
The mean argument of the Moon contains 14 revolutions and some more, nor is it near where these 4 points begin.

# APPENDIX C

## Tables and formulae

### C.1 TABLES IN OXFORD, BODLEIAN LIBRARY MS LAUD MISC. 657

The chapter numbers in brackets correspond to those used in some manuscript copies of the *Tractatus albionis* (though not in this manuscript), and adopted by John North for his edition of the treatise. The numbered tables, and the table of versed chords in the *Rectangulus*, were transcribed by North. The two tables added by John Westwyk are transcribed in this appendix.

| **Tables from Richard of Wallingford's *Tractatus albionis* (1326)** | |
|---|---|
| 32r | True motus of the sphere of Saturn (IV.1) |
| 32v | True motus of the sphere of Jupiter (IV.2) |
| 33r | True motus of the sphere of Mars (IV.3) |
| 33v | True motus of the sphere of the Sun and Venus (IV.4) |
| 34r | True motus of the sphere of Mercury (IV.5) |
| 34v | True motus of the sphere of the Moon (IV.6) |
| 35r-35v | True motus of the Moon and of the equation of the argument for the hour of conjunction (IV.7) |
| 36r | "Table of Iomyn" or of the equant of the daily motion (IV.8) |
| 36v | Latitude of the Moon (IV.9)<br>Table of longitude with its twelfth part; table of twelve conjunctions (IV.10) |
| 37r | Motion of Moon in hours at aux, mean distance, and opposite aux (IV.11) |
| 37v | Table of fixed stars (IV.12) |
| 38r-38v | Mean motus of Mercury (IV.13) |
| 39r-39v | Mean motus of the Moon (IV.14) |
| 40r-40v | Argument of the Moon (IV.15) |
| 41r | Right ascensions (starting at Capricorn) (IV.16) |
| 41v | Right ascensions (starting at vernal equinox) (IV.16) |
| 42r | Oblique ascensions at latitude 51° 50' (Oxford) (IV.17) |
| 42v | Oblique ascensions at latitude 55° (Tynemouth) |
| 44v-45r | Lunar elongations (to be inserted after table of mean motus of the Moon (39v)) |

| | |
|---|---|
| 51v-52r | (*Rectangulus* treatise) Table of versed chords |

| | |
|---|---|
| 53v-56v | Table of astrological houses |

## C.2 Differing values in tables of oblique ascensions for 51° 50' (minutes column)

The table below shows those values in the table of oblique ascensions where the table in MS Laud Misc. 657 does not match the tables edited by John North. In all other cases the table in this manuscript matches both North's edition and the vast majority of other manuscripts, showing it to be an excellent copy.

| | | Albion manuscripts | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| S | ° | L | C | H1 | H2 | A | M | JN | SF |
| 0 | 19 | 59 | 59 | 59 | 59 | 59 | 55 | 55 | 54 |
| 2 | 8 | 45 | 45 | 45 | 45 | 45 | 43 | 43 | 43 |
| 2 | 29 | 14 | 14 | 14 | 14 | 14 | 13 | 13 | 14 |
| 4 | 18 | 38 | 38 | 38 | 38 | 38 | 48 | 48 | 47 |
| 6 | 2 | 21 | 21 | 31 | 21 | 21 | 51 | 51 | 51 |
| 6 | 18 | 51 | 51 | 51 | 51 | 51 | 41 | 41 | 42 |
| 7 | 3 | 18 | 18 | 18 | 18 | 18 | 15 | 15 | 15 |
| 7 | 6 | 32 | 32 | 32 | 32 | 32 | 34 | 34 | 33 |
| 7 | 29 | 22 | 22 | 22 | 22 | 22 | 23 | 23 | 23 |
| 7 | 30 | 4 | 4 | 46 | 4 | 4 | 46 | 46 | 46 |
| 9 | 12 | 44 | 44 | 44 | 44 | 44 | 46 | 46 | 46 |
| 10 | 29 | 42 | 42 | 43 | 42 | 42 | 41 | 41 | 41 |
| 11 | 12 | 31 | 31 | 31 | 31 | 21 | 31[a] | 31 | 32 |
| 11 | 28 | 2 | 2 | 2 | 4 | 2 | 11[b] | 11 | 11 |

**L** = Oxford, Bodleian Library MS Laud Misc. 657, f. 42r
**C** = Oxford, Corpus Christi College MS 144, f. 78v
**H1** = British Library MS Harley 80 f. 54r
**H2** = British Library MS Harley 625 f. 164r
**A** = Oxford, Bodleian Library MS Ashmole 1796, f. 159r

**M =** Oxford, Bodleian Library MS Laud Misc. 674, f. 72r-v (John Maudith's tables)
**JN** = J. D. North, *Richard of Wallingford*, III. 96-7. Values following all amendments.
**SF** = Tables computed using formulae in C.5 below; ε = 23° 35' (stage 1) and 23 33' 30" (2)

[a] North's edition transcribes this as 39
[b] North's edition transcribes this as 3

**Notes**

1. For his edition, John North examined the tables in C, A, H1 and L. He corrected these using values from John Maudith's tables in M (and another copy in Oxford, Corpus Christi College MS 144, f. 122r). See explanations on II. 238-239 and 247-248.
2. North corrected 14 values that he stated he had found in 'MSS. read', 12 of which are listed above. The remaining two values he corrected (in $3^s$ 3° and $10^s$ 27°) do not appear in any of the four manuscripts North used.
3. North gave the number of degrees of ascension corresponding to $8^s$ 15° of longitude as 16°; the correct value, which appears in all manuscripts, is 15°. This was presumably a typographical error.

## C.3 ANALYSIS OF OBLIQUITIES USED TO COMPUTE TABLES OF OBLIQUE ASCENSIONS

I set out to identify the values used for the obliquity of the ecliptic (ε) in the tables of oblique ascensions at 51° 50'. To do this, I constructed a spreadsheet using formulae equivalent to those used by medieval astronomers. In imitation of their methods, the spreadsheet allowed two different values of ε to be used at different stages in the process (formulae in C.5 below).

The spreadsheet produced multiple versions of the table of oblique ascensions, via a range of values for ε. The values I used were initially those suggested by John North, which he had not been able to test fully at the time he was writing. In addition, I tested other values of ε (mostly those attested in contemporary manuscripts).

I compared the recomputed tables with the table for 51° 50' in surviving manuscripts of the *Tractatus albionis* (incorporating suggestions made by North, as in section C.2 above). To assess the closeness of the recomputed version, a least-squares fit was used. This calculated the sum (Σ) of the squares of the differences between each cell of the table; a smaller Σ represents a closer match.

The least-squares fit accommodates positive and negative differences, and accentuates the weight given to greater differences. This is appropriate, since small differences (of 1' or 2') are likely to be caused by rounding and other calculation techniques; larger differences (4' and above) may be more significant, indicating discrepancies between the parameters used in the tables being compared.

Below is a sample of the results produced (this table reproduces table 1 in chapter 1, p.32). The lower the sum (Σ) of the squared residuals, the better the fit.

| ε (1) | ε (2) | Σ | Notes |
|---|---|---|---|
| 23° 33' 30" | 23° 33' 30" | 188 | Values suggested by North<br>Richard of Wallingford (1976), ii. 247-8 |
| 23° 33' 30" | 23° 35' | 1680 | |
| 23° 35' | 23° 33' 30" | 128 | |
| 23° 35' | 23° 35' | 1528 | |
| 23° 35' | 23° 51' | 161560 | Attested values of ε producing lowest Σ for 55° (Tynemouth) table (see section C.5 below) |
| 23° 51' 20" | 23° 51' 20" | 158788 | Value of ε used in Almagest |
| 23° 35' | 23° 33' 22" | 110 | Non-attested values of ε producing lowest Σ |

From the above table it can be seen that of all values of ε attested in medieval manuscripts, those suggested by North (in bold) do indeed provide the closest match to the table of oblique ascensions for 51° 50' in *Tractatus albionis*.

## C.4 Transcription of MS Laud Misc. 657, f. 42v

Tabula ascencionum signorum in circulo obliquo in latitudine .55. gra. calculata est et composita sicut docent canones in secundo libro Almagesti; et debet per eam dividi circulus secundus in limbo secundo secunde faciei instrumenti sicut docetur capitulo 18º secunde partis huius.

// tynemuth

Tabula ascensionum signorum in circulo obliquo in latitudo .55. gra.

| gradus zodiaci | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | | 11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | g | m | g | m | g | m | g | m | g | m | g | m | g | m | g | m | g | m | g | m | g | m | g | m |
| 1 | 0 | 20 | 11 | 8 | 26 | 10 | 21 | 58 | **3** | 24 | 16 | 29 | 1 | 30 | 16 | 32 | 1 | 30 | 10 | 14 | 5 | 6 | 19 | 39 |
| 2 | 0 | 41 | 11 | 33 | 26 | 49 | 23 | 5 | 2 | 52 | 17 | 59 | 2 | 59 | 18 | 3 | 2 | 57 | 11 | 18 | 5 | 42 | 20 | 3 |
| 3 | 1 | 1 | 11 | 57 | 27 | 28 | 24 | 13 | 4 | 21 | 19 | 30 | 4 | 29 | 19 | 35 | 4 | 24 | 12 | 20 | 6 | 17 | 20 | 26 |
| 4 | 1 | 22 | 12 | 23 | 28 | 8 | 25 | 21 | 5 | 49 | 21 | 1 | 5 | 58 | 21 | 5 | 5 | 50 | 13 | 23 | 6 | 54 | 20 | 49 |
| 5 | 1 | 42 | 12 | 48 | 28 | 49 | 26 | 32 | 7 | 18 | 22 | 32 | 7 | 28 | 22 | 36 | 7 | 15 | 14 | 24 | 7 | 28 | 21 | 12 |
| 6 | 2 | 2 | 13 | 13 | 29 | 30 | 27 | 42 | 8 | 47 | 24 | 1 | 8 | 58 | 24 | 7 | 8 | 40 | 15 | 24 | 8 | 1 | 21 | 35 |
| 7 | 2 | 23 | 13 | 39 | **1** | 13 | 28 | 54 | 10 | 17 | 25 | 33 | 10 | 27 | 25 | 37 | 10 | 5 | 16 | 22 | 8 | 35 | 21 | 57 |
| 8 | 2 | 43 | 14 | 4 | 1 | 57 | **2** | 6 | 11 | 46 | 27 | 3 | 11 | 57 | 27 | 8 | 11 | 29 | 17 | 20 | 9 | 8 | 22 | 19 |
| 9 | 3 | 4 | 14 | 31 | 1 | 41 | 1 | 20 | 13 | 16 | 28 | 33 | 13 | 28 | 28 | 39 | 12 | 53 | 18 | 16 | 9 | 40 | 22 | 41 |
| 10 | 3 | 25 | 14 | 58 | 2 | 26 | 2 | 34 | 14 | 46 | **5** | 3 | 14 | 57 | **8** | 10 | 14 | 16 | 19 | 12 | 10 | 12 | 23 | 2 |
| 11 | 3 | 45 | 15 | 25 | 3 | 12 | 3 | 50 | 16 | 15 | 1 | 33 | 16 | 27 | 1 | 41 | 15 | 38 | 20 | 6 | 10 | 43 | 23 | 25 |
| 12 | 4 | 6 | 15 | 53 | 3 | 59 | 5 | 6 | 17 | 46 | 3 | 4 | 17 | 55 | 3 | 11 | 16 | 59 | 20 | 0 | 11 | 14 | 23 | 46 |
| 13 | 4 | 27 | 16 | 20 | 4 | 46 | 6 | 23 | 19 | 16 | 4 | 34 | 19 | 27 | 4 | 42 | 18 | 20 | 21 | 53 | 11 | 44 | 24 | 8 |
| 14 | 4 | 48 | 16 | 48 | 5 | 35 | 7 | 42 | 20 | 48 | 6 | 4 | 20 | 56 | 6 | 12 | 19 | 39 | 22 | 44 | 12 | 12 | 24 | 30 |
| 15 | 5 | 8 | 17 | 17 | 6 | 25 | 9 | 1 | 22 | 17 | 7 | 33 | 22 | 26 | 7 | 43 | 20 | 59 | 23 | 35 | 12 | 43 | 24 | 51 |
| 16 | 5 | 30 | 17 | 48 | 7 | 16 | 10 | 21 | 23 | 47 | 9 | 4 | 23 | 56 | 9 | 12 | 22 | 18 | 24 | 25 | 13 | 12 | 25 | 12 |
| 17 | 5 | 52 | 18 | 16 | 8 | 7 | 11 | 40 | 25 | 17 | 10 | 33 | 25 | 26 | 10 | 44 | 23 | 37 | 25 | 14 | 13 | 40 | 25 | 33 |
| 18 | 6 | 14 | 18 | 46 | 9 | 0 | 13 | 1 | 26 | 49 | 12 | 4 | 26 | 56 | 12 | 14 | 24 | 54 | 26 | 1 | 14 | 17 | 25 | 54 |
| 19 | 6 | 35 | 19 | 17 | 9 | 54 | 14 | 22 | 28 | 19 | 13 | 34 | 28 | 27 | 13 | 45 | 26 | 10 | 26 | 48 | 14 | 35 | 26 | 15 |
| 20 | 6 | 57 | 19 | 47 | 10 | 48 | 15 | 44 | 29 | 50 | 15 | 3 | 29 | 57 | 15 | 14 | 27 | 26 | 27 | 34 | 15 | 2 | 26 | 35 |
| 21 | 7 | 19 | 20 | 20 | 11 | 44 | 17 | 7 | **4** | 21 | 16 | 32 | **7** | 27 | 16 | 44 | 28 | 40 | 28 | 19 | 15 | 29 | 26 | 56 |
| 22 | 7 | 41 | 20 | 52 | 12 | 40 | 18 | 31 | 2 | 52 | 18 | 3 | 2 | 57 | 18 | 14 | 29 | 54 | 29 | 3 | 15 | 56 | 27 | 17 |
| 23 | 8 | 3 | 21 | 25 | 13 | 38 | 19 | 55 | 4 | 23 | 19 | 33 | 4 | 27 | 19 | 43 | **10** | 6 | 29 | 47 | 16 | 21 | 27 | 37 |
| 24 | 8 | 25 | 21 | 59 | 14 | 36 | 21 | 20 | 5 | 53 | 21 | 2 | 5 | 59 | 21 | 13 | 2 | 18 | **11** | 30 | 16 | 47 | 27 | 58 |
| 25 | 8 | 48 | 22 | 32 | 15 | 37 | 22 | 45 | 7 | 24 | 22 | 32 | 7 | 28 | 22 | 42 | 3 | 28 | 1 | 11 | 17 | 13 | 28 | 18 |
| 26 | 9 | 11 | 23 | 7 | 16 | 37 | 24 | 10 | 8 | 55 | 24 | 2 | 8 | 59 | 24 | 11 | 4 | 39 | 1 | 52 | 17 | 38 | 28 | 38 |
| 27 | 9 | 34 | 23 | 43 | 17 | 39 | 25 | 36 | 10 | 25 | 25 | 31 | 10 | 0 | 25 | 39 | 5 | 47 | 2 | 32 | 18 | 3 | 28 | 59 |
| 28 | 9 | 57 | 24 | 18 | 18 | 42 | 27 | 3 | 11 | 57 | 27 | 1 | 12 | 1 | 27 | 8 | 6 | 56 | 3 | 11 | 18 | 27 | 29 | 19 |
| 29 | 10 | 21 | 24 | 54 | 19 | 46 | 28 | 30 | 13 | 28 | 28 | 30 | 13 | 31 | 28 | 36 | 8 | 2 | 3 | 50 | 18 | 52 | 29 | 40 |
| 30 | 10 | 45 | 25 | 31 | 20 | 51 | 29 | 57 | 14 | 59 | **6** | 0 | 15 | 1 | **9** | 3 | 9 | 9 | 4 | 29 | 19 | 15 | **12** | 0 |

**Note**: the numbers in bold are signs: each time the degrees exceed 30, John Westwyk gives the number of the new sign, and highlights it with a red box around the number. He does not give the number of degrees, or note that in four cases (3, 4, 7 and 10 signs) that number was not 0, but 1. This was a common omission in such tables, and it is not clear whether their users were aware of the situation.

## C.5 ANALYSIS OF TABLE OF OBLIQUE ASCENSIONS FOR 55° (TYNEMOUTH)

In order to analyse the table of oblique ascensions transcribed in C.4 above, it was recomputed using the following formulae (adapted from North, *Richard of Wallingford*, II. 247):

(1) $\alpha = \arctan(\tan\lambda \,.\, \cos\varepsilon)$
(2) $\sin(\alpha - \varrho) = \tan\varepsilon \,.\, \tan\varphi \,.\, \sin\alpha$

where $\alpha$ = right ascension, $\varrho$ = oblique ascension, $\varphi$ = latitude of observer, $\lambda$ = celestial longitude, $\varepsilon$ = ecliptic obliquity.

The table was recomputed in Microsoft Excel. The following apparent errors were ignored in the process of analysis:

| S | ° | MS 657 f. 42v | Computed value |
|---|---|---|---|
| 2 | 8 | 1 57 | 0 57 |
| 6 | 27 | 10 0 | 10 31 |
| 9 | 12 | 20 0 | 20 59 |
| 10 | 18 | 14 17 | 14 9 |

Values in MS 657 (f. 42v) were ignored where they differed from the computed value by more than 4'

These computed values used $\varepsilon$ = 23° 35' in (1)
$\varepsilon$ = 23° 50' 10" in (2)
The latter value of $\varepsilon$, although not attested in any contemporary source, produced the best overall match with the table in the manuscript, and so is useful for comparison purposes.

A least-squares fit (explained in C.2 above) was used to compare the values in MS 657 with those produced by spreadsheet recomputation, using various values of $\varepsilon$.

Below is a sample of results produced for the table of oblique ascensions for 55° (Tynemouth). (This table reproduces table 2 in chapter 1, p.32.) A smaller $\Sigma$ represents a closer match.

| $\varepsilon$ (1) | $\varepsilon$ (2) | $\Sigma$ | Notes |
|---|---|---|---|
| 23° 33' 30" | 23° 33' 30" | 196229 | Values suggested by North Richard of Wallingford (1976), ii. 247-8 |
| 23° 33' 30" | 23° 35' | 162882 | |
| 23° 35' | 23° 33' 30" | 196995 | |
| 23° 35' | 23° 35' | 163932 | |
| 23° 51' 20" | 23° 51' 20" | 2667 | Value of $\varepsilon$ used in Almagest |
| 23° 51' | 23° 51' | 2422 | Value of $\varepsilon$ used in Handy Tables |
| 23° 35' | 23° 51' 20" | 1370 | Combination of Almagest and al-Battānī values |
| 23° 35' | 23° 51' | 939 | Attested values of $\varepsilon$ producing lowest value of $\Sigma$ |
| 23° 35' | 23° 50' 10" | 434 | Non-attested values of $\varepsilon$ producing lowest $\Sigma$ |

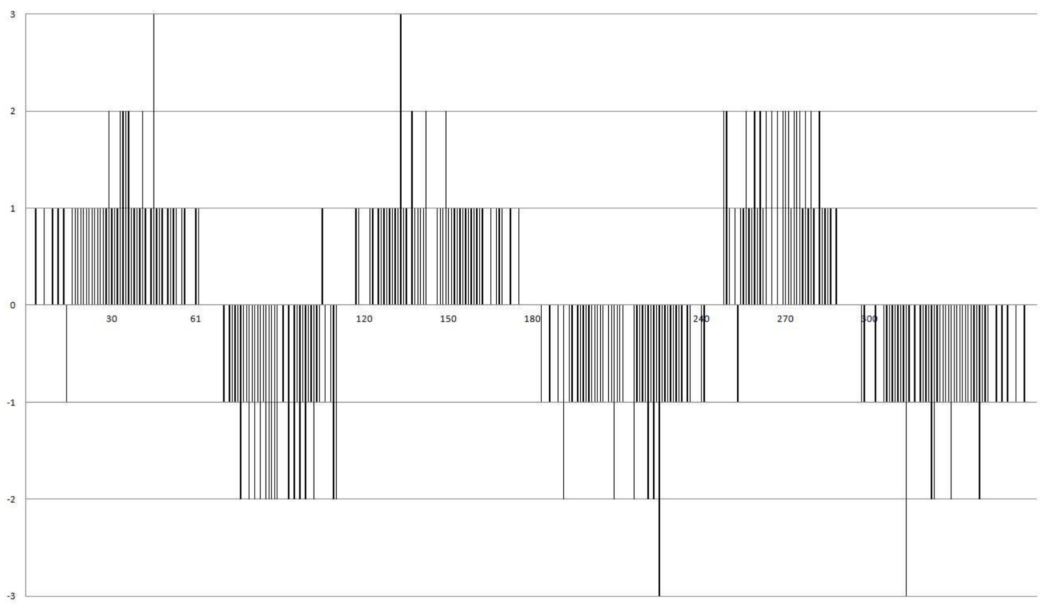
The evidence presented here is sufficient to demonstrate that this table was computed using parameters different from those of Richard of Wallingford. The table and graph on the following page represent a tentative attempt to explain why the lowest $\Sigma$ value is still higher than for Richard's table.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 4 | 0 | 1 |
| 2 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 4 | 0 | 1 |
| 3 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 4 | 1 | 4 | 0 | 4 | 1 | 1 | 1 | 0 | 0 | 4 | 0 | 1 |
| 5 | 0 | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 1 |
| 6 | 0 | 4 | 0 | 4 | 1 | 1 | 0 | 0 | 0 | 4 | 1 | 1 |
| 7 | 1 | 4 | 0 | 1 | 1 | 1 | 1 | 4 | 0 | 1 | 1 | 1 |
| 8 | 0 | 1 | X | 4 | 1 | 1 | 0 | 1 | 0 | 4 | 1 | 1 |
| 9 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 4 | 1 | 1 | 1 |
| 10 | 1 | 1 | 0 | 4 | 1 | 1 | 1 | 1 | 4 | 4 | 1 | 4 |
| 11 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 12 | 1 | 4 | 0 | 1 | 1 | 1 | 4 | 4 | 0 | X | 1 | 1 |
| 13 | 0 | 1 | 1 | 4 | 1 | 1 | 0 | 1 | 1 | 4 | 1 | 1 |
| 14 | 1 | 0 | 1 | 1 | 9 | 0 | 1 | 4 | 1 | 1 | 9 | 0 |
| 15 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 16 | 0 | 9 | 1 | 1 | 1 | 1 | 0 | 9 | 1 | 1 | 0 | 1 |
| 17 | 1 | 1 | 4 | 1 | 0 | 0 | 1 | 1 | 4 | 1 | 1 | 0 |
| 18 | 1 | 1 | 1 | 0 | 4 | 1 | 1 | 1 | 1 | 0 | X | 1 |
| 19 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 20 | 1 | 0 | 4 | 4 | 1 | 1 | 1 | 1 | 4 | 0 | 1 | 1 |
| 21 | 1 | 1 | 1 | 4 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| 22 | 1 | 1 | 4 | 0 | 1 | 0 | 1 | 1 | 4 | 0 | 1 | 0 |
| 23 | 1 | 1 | 1 | 0 | 4 | 1 | 1 | 1 | 1 | 0 | 4 | 1 |
| 24 | 1 | 1 | 4 | 0 | 0 | 0 | 1 | 1 | 4 | 0 | 4 | 0 |
| 25 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 26 | 1 | 1 | 4 | 0 | 0 | 1 | 1 | 1 | 4 | 0 | 1 | 1 |
| 27 | 1 | 1 | 4 | 0 | 1 | 0 | X | 1 | 0 | 0 | 1 | 0 |
| 28 | 1 | 0 | 4 | 1 | 1 | 0 | 1 | 0 | 4 | 1 | 1 | 0 |
| 29 | 1 | 0 | 4 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 30 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 |
| Totals: | **23** | **47** | **48** | **40** | **40** | **19** | **25** | **40** | **47** | **43** | **41** | **21** |

## Table of squared residuals

This table shows squared differences between the table of oblique ascensions for 55° (MS Laud Misc. 657, f. 42v) and a table recomputed using the optimum (non-attested) values for the obliquity of the ecliptic: ε (1) = 23° 35', ε (2) = 23° 50' 10''. Σ = 434.

Cells with black writing on a white background represent positive differences; those with white writing on a back background represent negative differences. Xs represent supposed errors in the manuscript (see above). The pattern of positive and negative differences is graphically represented below (using unsquared residuals, which range from -3 to +3). The trigonometric shape of the graph suggests that the differences arise from the way John Westwyk used a table of chords.



## C.6 EQUATIONS USED TO COMPUTE HOUSES, GIVEN LONGITUDE OF MIDHEAVEN ($\lambda_{10}$)

$\alpha_{10}$ = arctan (tan $\lambda_{10}$ . cos $\varepsilon$)
$\varrho = \alpha_{10} + 90$

To find $\alpha$ (i.e. $\alpha_1$) from $\varrho$, rearrange equation (2) from section C.5 above:

$$\sin(\alpha - \varrho) = \tan\varepsilon \,.\, \tan\varphi \,.\, \sin\alpha$$

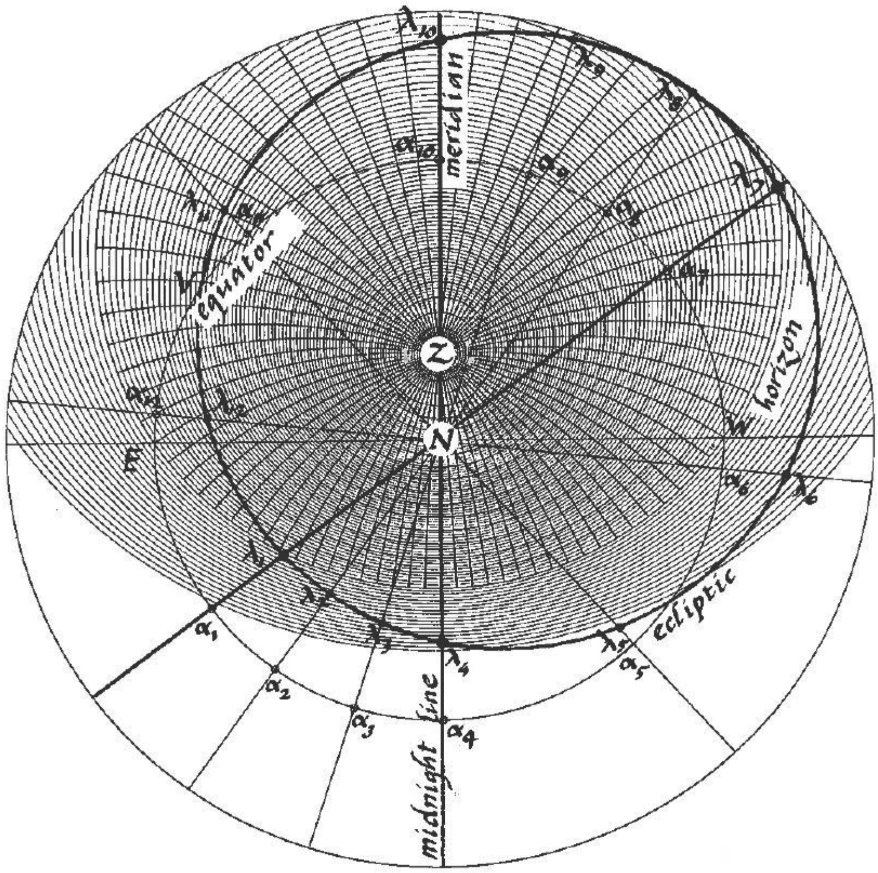
becomes

$$\tan\alpha = \frac{\sin\varrho}{(\cos\varrho - \tan\varepsilon \,.\, \tan\varphi)}$$

To find cusps of remaining houses from longitude of ascendant ($\alpha_1$):[1]

$\alpha_{11} = \alpha_1 - 2(90 - \alpha_0 + \alpha_1)/3$
$\alpha_{12} = \alpha_1 - (90 - \alpha_0 + \alpha_1)/3$
$\alpha_2 = \alpha_1 + (90 + \alpha_0 - \alpha_1)/3$
$\alpha_3 = \alpha_1 + 2(90 + \alpha_0 - \alpha_1)/3$

$$\lambda_n = \arctan\left(\frac{\tan\alpha_n}{\cos\varepsilon}\right)$$




North (1986), 4

[1] The method is described in North (1986), 5-9.

## C.7 TRANSCRIPTION OF MS LAUD MISC. 657, FF. 44V-45R

Tabula medii motus elongationis lune a sole calculata et composita est modo communi calculandi tabulas mediorum motuum planetarum ad singulos dies anni solaris; et per eam debet dividi circulus involutus sicut docetur capitulo 20$^{o}$ secunde partis huius.

| Dies | Tabula Elongacionis Lune a Sole | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Martius | | | Aprilis | | | Mayus | | | Junius | | | Julius | | | Augustus | | | September | | | October | | |
| | sig | g | m | sig | g | m | sig | g | m | sig | g | m | sig | g | m | sig | g | m | sig | g | m | sig | g | m |
| 1 | 0 | 12 | 11 | 1 | 0 | 6 | 1 | 5 | 50 | 1 | 23 | 24 | 1 | 29 | 28 | 2 | 17 | 22 | 3 | 5 | 17 | 3 | 11 | 1 |
| 2 | 0 | 24 | 23 | 1 | 12 | 18 | 1 | 18 | 1 | 2 | 5 | 56 | 2 | 11 | 39 | 2 | 29 | 34 | 3 | 17 | 29 | 3 | 23 | 12 |
| 3 | 1 | 6 | 34 | 1 | 24 | 29 | 2 | 0 | 12 | 2 | 18 | 7 | 2 | 23 | 51 | 3 | 11 | 45 | 3 | 29 | 40 | 4 | 5 | 24 |
| 4 | 1 | 18 | 45 | 2 | 6 | 41 | 2 | 12 | 24 | 3 | 0 | 19 | 3 | 6 | 2 | 3 | 23 | 57 | 4 | 11 | 52 | 4 | 17 | 35 |
| 5 | 2 | 0 | 57 | 2 | 18 | 52 | 2 | 24 | 35 | 3 | 12 | 30 | 3 | 18 | 13 | 4 | 6 | 8 | 4 | 24 | 3 | 4 | 29 | 46 |
| 6 | 2 | 13 | 9 | 3 | 1 | 3 | 3 | 6 | 47 | 3 | 24 | 42 | 4 | 0 | 25 | 4 | 18 | 20 | 5 | 6 | 15 | 5 | 11 | 58 |
| 7 | 2 | 25 | 20 | 3 | 13 | 15 | 3 | 18 | 58 | 4 | 6 | 53 | 4 | 12 | 36 | 5 | 0 | 31 | 5 | 18 | 26 | 5 | 24 | 9 |
| 8 | 3 | 9 | 32 | 3 | 25 | 26 | 4 | 1 | 10 | 4 | 19 | 4 | 4 | 24 | 48 | 5 | 12 | 43 | 6 | 0 | 37 | 6 | 6 | 21 |
| 9 | 3 | 19 | 43 | 4 | 7 | 38 | 4 | 13 | 21 | 5 | 1 | 16 | 5 | 6 | 49 | 5 | 24 | 54 | 6 | 12 | 49 | 6 | 18 | 32 |
| 10 | 4 | 1 | 54 | 4 | 19 | 49 | 4 | 25 | 33 | 5 | 13 | 27 | 5 | 19 | 11 | 6 | 7 | 6 | 6 | 25 | 0 | 7 | 0 | 44 |
| 11 | 4 | 14 | 6 | 5 | 2 | 1 | 5 | 7 | 44 | 5 | 25 | 39 | 6 | 1 | 22 | 6 | 19 | 17 | 7 | 7 | 11 | 7 | 12 | 55 |
| 12 | 4 | 26 | 17 | 5 | 14 | 12 | 5 | 20 | 55 | 6 | 7 | 50 | 6 | 13 | 34 | 7 | 1 | 28 | 7 | 19 | 23 | 7 | 25 | 7 |
| 13 | 5 | 8 | 29 | 5 | 26 | 24 | 6 | 2 | 7 | 6 | 20 | 2 | 6 | 25 | 45 | 7 | 13 | 40 | 8 | 1 | 35 | 8 | 11 | 18 |
| 14 | 5 | 20 | 40 | 6 | 8 | 35 | 6 | 14 | 18 | 7 | 2 | 13 | 7 | 7 | 56 | 7 | 25 | 51 | 8 | 13 | 46 | 8 | 19 | 29 |
| 15 | 6 | 2 | 52 | 6 | 20 | 46 | 6 | 26 | 30 | 7 | 14 | 25 | 7 | 20 | 7 | 8 | 4 | 24 | 8 | 25 | 58 | 9 | 11 | 41 |
| 16 | 6 | 15 | 3 | 7 | 2 | 58 | 7 | 8 | 41 | 7 | 26 | 36 | 8 | 2 | 19 | 8 | 20 | 14 | 9 | 8 | 9 | 9 | 13 | 52 |
| 17 | 6 | 27 | 15 | 7 | 15 | 9 | 7 | 20 | 53 | 8 | 8 | 47 | 8 | 14 | 31 | 9 | 2 | 26 | 9 | 20 | 20 | 9 | 26 | 4 |
| 18 | 7 | 9 | 26 | 7 | 27 | 21 | 8 | 3 | 4 | 8 | 20 | 59 | 8 | 26 | 42 | 9 | 14 | 37 | 10 | 2 | 32 | 10 | 8 | 15 |
| 19 | 7 | 21 | 37 | 8 | 9 | 32 | 8 | 15 | 16 | 9 | 3 | 10 | 9 | 8 | 54 | 9 | 28 | 49 | 10 | 14 | 43 | 10 | 20 | 27 |
| 20 | 8 | 3 | 49 | 8 | 21 | 44 | 8 | 27 | 27 | 9 | 15 | 22 | 9 | 21 | 5 | 10 | 9 | 0 | 10 | 26 | 55 | 11 | 2 | 38 |
| 21 | 8 | 16 | 0 | 9 | 3 | 55 | 9 | 9 | 38 | 9 | 27 | 33 | 10 | 3 | 17 | 10 | 21 | 11 | 11 | 9 | 6 | 11 | 14 | 50 |
| 22 | 8 | 28 | 12 | 9 | 16 | 7 | 9 | 21 | 50 | 10 | 9 | 45 | 10 | 15 | 28 | 11 | 3 | 23 | 11 | 21 | 18 | 11 | 27 | 1 |
| 23 | 9 | 10 | 23 | 9 | 28 | 18 | 10 | 4 | 1 | 10 | 21 | 56 | 10 | 27 | 39 | 11 | 15 | 34 | 0 | 3 | 29 | 0 | 9 | 12 |
| 24 | 9 | 22 | 35 | 10 | 10 | 29 | 10 | 16 | 13 | 11 | 4 | 8 | 11 | 9 | 51 | 11 | 27 | 46 | 0 | 15 | 41 | 0 | 21 | 24 |
| 25 | 10 | 5 | 4 | 10 | 22 | 41 | 10 | 28 | 24 | 11 | 16 | 18 | 11 | 22 | 2 | 0 | 9 | 57 | 0 | 27 | 52 | 1 | 3 | 35 |
| 26 | 10 | 16 | 58 | 11 | 4 | 52 | 11 | 10 | 36 | 11 | 28 | 30 | 0 | 4 | 14 | 0 | 22 | 9 | 1 | 10 | 3 | 1 | 15 | 47 |
| 27 | 10 | 29 | 9 | 11 | 17 | 4 | 11 | 22 | 47 | 0 | 10 | 42 | 0 | 16 | 25 | 1 | 4 | 20 | 1 | 22 | 15 | 1 | 27 | 58 |
| 28 | 11 | 11 | 20 | 11 | 29 | 15 | 0 | 4 | 59 | 0 | 22 | 53 | 0 | 28 | 37 | 1 | 16 | 32 | 2 | 4 | 26 | 2 | 10 | 10 |
| 29 | 11 | 23 | 32 | 0 | 11 | 27 | 0 | 17 | 10 | 1 | 3 | 5 | 1 | 10 | 48 | 1 | 28 | 43 | 2 | 16 | 38 | 2 | 22 | 21 |
| 30 | 0 | 5 | 43 | 0 | 23 | 38 | 0 | 29 | 21 | 1 | 17 | 16 | 1 | 23 | 0 | 2 | 10 | 54 | 2 | 28 | 49 | 3 | 4 | 33 |
| 31 | 0 | 17 | 55 | **0** | **0** | **0** | 1 | 11 | 33 | **0** | **0** | **0** | 2 | 5 | 11 | 2 | 23 | 6 | **0** | **0** | **0** | 3 | 16 | 44 |

**Errors noted**

| Entry | MS reads | Correct |
|---|---|---|
| Mar. 8 | 9° | 7° |
| Mar. 25 | 5° 4' | 4° 46' |
| May 12 | 20° | 19° |
| June 1 | 24' | 44' |
| June 25 | 18' | 19' |
| June 29 | 3° | 5° |

| Entry | MS reads | Correct |
|---|---|---|
| July 9 | 49' | 59' |
| Aug. 15 | 4° 24' | 8° 3' |
| Aug. 19 | 28° | 26° |
| Oct. 13 | 11° | 7° |
| Oct. 15 | 11° | 1° |
| Nov. 1 | 29° | 28° |

| Entry | MS reads | Correct |
|---|---|---|
| Nov. 3 | 17' | 19' |
| Nov. 14 | 4' | 24' |
| Nov. 16 | 38' | 48' |
| Dec. 27 | 46' | 36' |
| Jan. 5 | 10° 33' | 11° 20' |
| Feb. 4 | 13' | 3' |
| Feb. 12 | 22° | 24° |

| Dies | Tabula Elongacionis Lune a Sole | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | November | | | December | | | Januarius | | | Februarius | | |
| | sig | g | m | sig | g | m | sig | g | m | sig | g | m |
| 1 | 3 | 29 | 55 | 4 | 4 | 39 | 4 | 22 | 34 | 5 | 10 | 28 |
| 2 | 4 | 11 | 7 | 4 | 16 | 50 | 5 | 4 | 45 | 5 | 22 | 40 |
| 3 | 4 | 23 | 17 | 4 | 29 | 2 | 5 | 16 | 56 | 6 | 4 | 51 |
| 4 | 5 | 5 | 30 | 5 | 11 | 13 | 5 | 29 | 8 | 6 | 17 | 13 |
| 5 | 5 | 17 | 41 | 5 | 23 | 25 | 6 | 10 | 33 | 6 | 29 | 14 |
| 6 | 5 | 29 | 53 | 6 | 5 | 36 | 6 | 23 | 31 | 7 | 11 | 26 |
| 7 | 6 | 12 | 4 | 6 | 17 | 47 | 7 | 5 | 42 | 7 | 23 | 37 |
| 8 | 6 | 24 | 16 | 6 | 29 | 59 | 7 | 17 | 54 | 8 | 5 | 48 |
| 9 | 7 | 6 | 27 | 7 | 12 | 10 | 8 | 0 | 5 | 8 | 18 | 0 |
| 10 | 7 | 18 | 38 | 7 | 24 | 22 | 8 | 12 | 17 | 9 | 0 | 11 |
| 11 | 8 | 0 | 50 | 8 | 6 | 34 | 8 | 24 | 28 | 9 | 12 | 23 |
| 12 | 8 | 13 | 1 | 8 | 18 | 45 | 9 | 6 | 39 | 9 | 22 | 34 |
| 13 | 8 | 25 | 13 | 9 | 0 | 56 | 9 | 18 | 51 | 10 | 6 | 46 |
| 14 | 9 | 7 | 4 | 9 | 13 | 8 | 10 | 1 | 2 | 10 | 18 | 57 |
| 15 | 9 | 19 | 36 | 9 | 25 | 19 | 10 | 13 | 14 | 11 | 1 | 9 |
| 16 | 10 | 1 | 38 | 10 | 7 | 30 | 10 | 25 | 25 | 11 | 13 | 20 |
| 17 | 10 | 13 | 59 | 10 | 19 | 41 | 11 | 7 | 37 | 11 | 25 | 31 |
| 18 | 10 | 26 | 10 | 11 | 1 | 53 | 11 | 19 | 48 | 0 | 7 | 43 |
| 19 | 11 | 8 | 21 | 11 | 14 | 5 | 0 | 2 | 0 | 0 | 19 | 54 |
| 20 | 11 | 20 | 33 | 11 | 26 | 16 | 0 | 14 | 11 | 1 | 2 | 6 |
| 21 | 0 | 2 | 44 | 0 | 8 | 28 | 0 | 26 | 22 | 1 | 14 | 17 |
| 22 | 0 | 14 | 56 | 0 | 20 | 39 | 1 | 8 | 34 | 1 | 26 | 29 |
| 23 | 0 | 27 | 7 | 1 | 2 | 51 | 1 | 20 | 45 | 2 | 8 | 40 |
| 24 | 1 | 9 | 19 | 1 | 15 | 2 | 2 | 2 | 57 | 2 | 20 | 52 |
| 25 | 1 | 21 | 30 | 1 | 27 | 13 | 2 | 15 | 8 | 3 | 3 | 3 |
| 26 | 2 | 3 | 42 | 2 | 9 | 25 | 2 | 27 | 20 | 3 | 15 | 14 |
| 27 | 2 | 15 | 53 | 2 | 21 | 46 | 3 | 9 | 31 | 3 | 27 | 26 |
| 28 | 2 | 28 | 4 | 3 | 3 | 48 | 3 | 21 | 43 | 4 | 9 | 37 |
| 29 | 3 | 10 | 16 | 3 | 15 | 59 | 4 | 3 | 54 | addicio motus | | |
| 30 | 3 | 22 | 27 | 3 | 28 | 11 | 4 | 16 | 5 | sex horarum | | |
| 31 | **0** | **0** | **0** | 4 | 10 | 22 | 4 | 28 | 17 | 2 | 2 | 47 |

¶ Ista tabula deberet poni post tabulam medii motus lune ad tale signum ✧, quia dominus abbas posuit in suo circulo involuto medium motum lune, sed magister Symon posuit in suo circulo involuto elongacionem lune a sole sicut habetur in utilitate 4a; et ideo scripsi istam tabulam ut si cui melius placuerit ita faciat.

¶ Item abbas operatur cum circulo Iomyn pro equacione dierum. Sed Symon operatur alio modo, sicut docetur utilitate 18[a]; et etiam in aliis locis quae plurimis videntur disconvenire, prout in utilitatibus planius invenitur.

¶ Nota si subtrahatur medius motus solis a medio motu lune proveniet elongacio lune a sole.

¶ Item si addatur medius motus solis elongacioni lune a sole provenit medius motus lune.

¶ Item adde super argumentum lune medium motum capitis et habebis argumentum latitudinis lune.

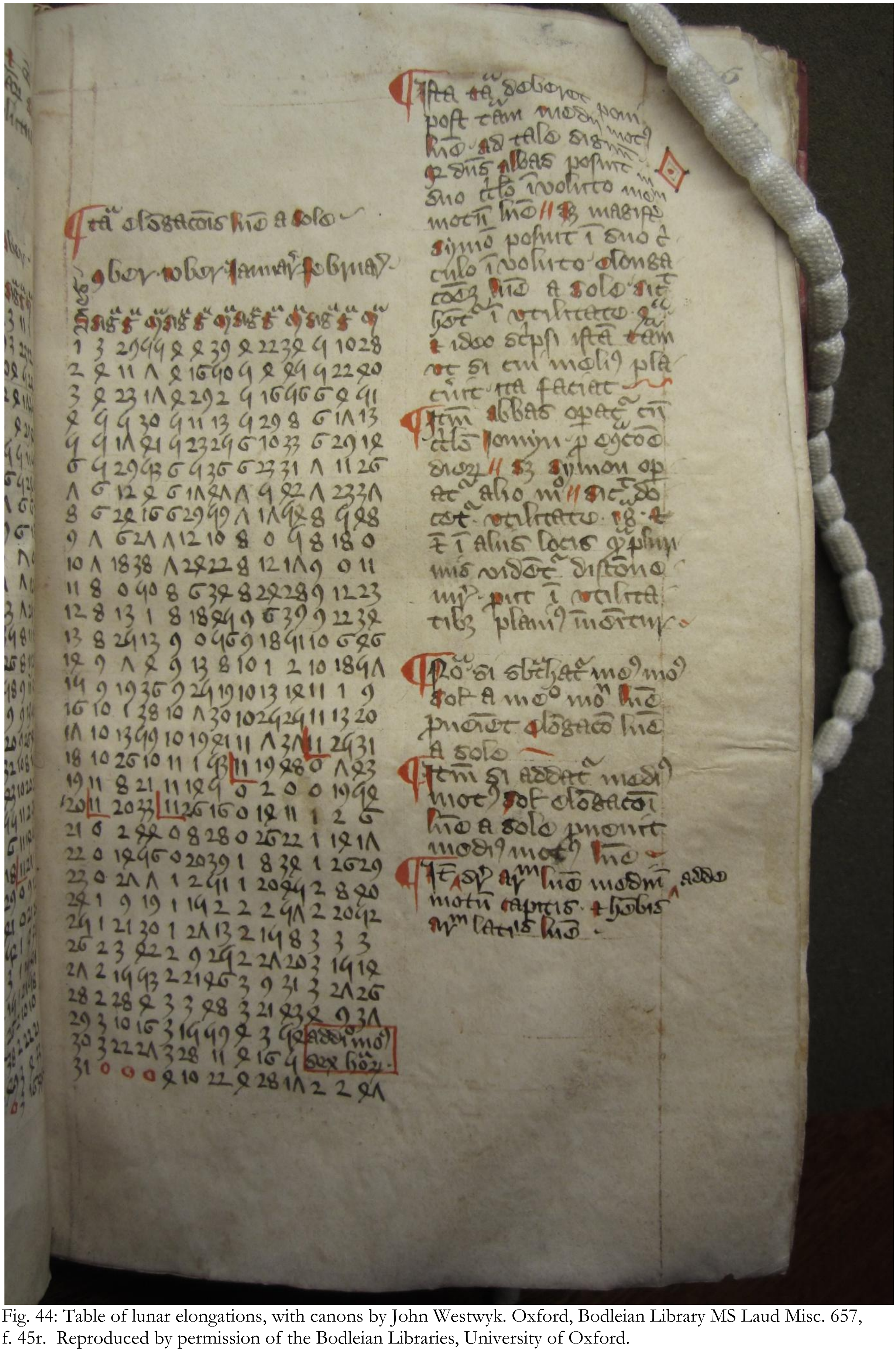


Fig. 44: Table of lunar elongations, with canons by John Westwyk. Oxford, Bodleian Library MS Laud Misc. 657, f. 45r. Reproduced by permission of the Bodleian Libraries, University of Oxford.

# APPENDIX D

## *Quia nobilissima scientia astronomie*

This appendix is a transcription of the *Quia nobilissima scientia astronomie* treatise. It is based on both copies of this treatise:

- Cambridge University Library Gg.VI.3, ff. 217v-220v (C)
- Oxford, Bodleian Library, Digby 57, ff. 130r-132v (D)

Both were written in Oxford; C was produced *c.* 1349,[1] D *c.* 1375.[2]

Since there are significant differences between the two manuscripts, it seemed most appropriate to transcribe the texts side-by-side. Where the texts differ, this has been highlighted in **bold** text. Where the order of paragraphs differs, I have reordered D (and noted this in *italics*) so that the two manuscripts are comparable as far as possible. (Where D moves some individual sentences, I have not reordered these, but have noted it in *italics* opposite.)

Some changes have been made for clarity: paragraph marks (¶ and //) have been removed, and line breaks and appropriate punctuation added. All abbreviations have been expanded. Dots around numbers and letters have been removed. The beginnings of sentences, and proper nouns, have been capitalised. The letters 'u' and 'v' have sometimes been changed. Digits have been expanded where they function as an abbreviation of a non-numerical word (e.g. *secundum*), but have otherwise been left unchanged.

---

| | |
|---|---|
| **[C: 217v]** [Q]uia nobilissima scientia astronomie non potest bene sciri **nec compleri** sine instrumentis debitis, propter quod **fuit necessarium** componere instrumenta in ea. Composuerunt **propterea** antiqui multa diversa instrumenta ut sunt: astrolabium, saphea, cum quibus sciuntur plura tam de tempore quam de motu. **Et ut armille, sphaere solida, triketum et regule cum quibus verificantur loca stellarum tam erraticarum quam fixarum, et chelindrum, et quadrans quibus utebantur antiqui in accipiendo horas. Et umbras et solis altitudinem et hiis similia parva[3]. Potest etiam sphaera multe communis cum pauctis additis taliter componeri quod cum ea sola potest operari qui quidem potest cum omnibus atque singularis instrumentis predictis. In tempore atque in motu. et semisam autem** | **[D: 130r]** Quia nobilissima scientia astronomie non potest bene sciri sine instrumentis debitis, propter quod **necessarium fuit** componere instrumenta in ea. Composuerunt **ea propter** antiqui multa diversa instrumenta ut sunt astrolabium **et** saphea, cum quibus sciuntur plura tam de tempore quam de motu. |

[1] It contains a reference to tables compiled for the end of 1348; the hand matches a mid-fourteenth-century dating.
[2] Although D makes reference to tables produced for 1350 completed years, it is preceded in the manuscript by eclipse tables for 1376-90 in the same hand.
[3] Should perhaps say 'plura'.

**valuerit superaddi.**

**Insuper** illa tarde quidam bonus vir et subtilis Campanus nomine quoddam instrumentum valde necessarium per quod sciuntur **vera** loca omnium planetarum et eorum **direcciones stationes** et retrogradationes **composuit, et primitus adinvenit**.

**Sed** illa tarde quidam bonus vir et subtilis Campanus nomine **composuit, et primitus adinvenit**, quoddam instrumentum valde necessarium per quod sciuntur loca **planetarum vera** omnium planetarum et eorum **stationes direcciones** et retrogradationes.

Sed eius composicione est minus[4] tediosa, propter multitudinem tabularum in eodem instrumento contentarum, cum earum concavitatibus diversis, et **etiam** propter magnitudinem eiusdem instrumenti, eo quod de levi non potest deferri de loco ad locum, seu de regione ad regionem. Quia propter expediens **est** tum propter causas predictas cum propter difficultatem prolixitatem et tedium calculationis per tabulas istud opus sit abbreviare, ut in una superficie unius tabule **tantum** possent omnes planetae leviter et satis veraciter equari. Unde magister Johannis de Lyners instrumentum Campani abbreviavit **modo prius dicto**. Et Prefatius Judeus in Monte Pessulano aliud equatorium consimilis operationis prudenter composuit quod **vocant semissas**. Praeterea quidam abbas de Sancto Albano **quaedam instrumenta composuit et primitus** adinvenit, **quorum unum** vocant tribus nominibus anglicis: .al.**by**.on., similis iunctis albion; **et aliud rectangulum**, **qui omnia instrumenta prius inventa prevalet et excellit**. Sed per operationem **cum** instrumento Campani Lyners vel Judei proponenda est theorica ut effectus pateat satis planus.

Sed eius composicione est minus tediosa, propter multitudinem tabularum in eodem instrumento contentarum, cum earum concavitatibus diversis, et **essiam** propter magnitudinem eiusdem instrumenti, eo quod de levi non potest deferri de loco ad locum, seu de regione ad regionem. Quia propter **multum** expediens **fuit** tum propter causas predictas cum propter difficultatem prolixitatem et tedium calculationis per tabulas istud opus sit abbreviare, ut in una superficie unius tabule possent omnes planetae leviter et satis veraciter equari. Unde magister Johannis de Lyners instrumentum Campani **predictum multum subtiliter** abbreviavit. Et Prefatius Judeus in Monte Pessulano aliud equatorium consimilis operationis prudenter composuit quod **vocatum est semissem**. Praeterea quidam abbas de Sancto Albano **quoddam instrumentum** adinvenit, **omnia instrumenta maiora et minora prius dicta prevalens et excellens**, **quod** vocant tribus nominibus anglicis: .al.**bi**.on., similis iunctis albion. Sed **notandum est quod** per operationem **in** instrumento Campani Lyners vel Judei proponenda est theorica ut effectus pateat satis planus.

**In nomine domini nostri Ihesu Christi sciendum est** quod **quemlibet** planeta praeter solem habet tres circulos, scilicet equantem defferentem et epiciclum. **Sol vero unum habet circulum qui est eccentricus in cuius circumferencia movetur equabiliter centrum solis**. Omnes **aut** equantes et defferentes sunt eccentrici id est **centra eorum sunt** extra centrum mundi praeter equantem lune qui est concentricus et est idem cum ecliptica.

**Scito in nomine dei** quod **quilibet** planeta praeter solem habet tres circulos, scilicet equantem defferentem et epiciclum.

*[This sentence appears later in D]*

**Et** omnes equantes et defferentes sunt eccentrici id est extra centrum mundi praeter equantem lune qui est concentricus et est idem cum ecliptica. **Quia ecliptica equipollet cuiusque circulo descripto super centrum mundi**.

[4] In other versions of John of Lignières, this is 'magis'

Equans vero et defferens **Saturni Jovis Martis vel Veneris** regula eiusdem **partis** celi **elevantur**, ita quod tam centrum equantis quam centrum defferentis **erunt** in eadem linea recta **transeunte** a centro terrae ad punctum predictum in firmamento; **quod centrum defferentis est punctus medius in eadem lineam inter centrum equantis et centrum terrae. Punctus aut uniuscuiusque equantis aut defferentis maxime rotatus a centro terrae** dicitur aux vel longitudo longior. Punctus vero **ei** opponitus dicitur **aut** augis vel longitudo propior. Puncta quidem media inter augem et **eius oppositionem** dicuntur longitudines medie.

*[Some of this appears just above in C]*

Omnes vero auges tam equantium quam deferentium singlorum planetarum sunt inmobiles praeter **auges deferentium** lune et mercurii et[5] praeter motum octave sphere.

Equans vero cuiuscunque planetae est circulus regula cuius centri motus planetae **illius** est equalis, **et** hinc est quod dicitur equans. Deferens aut dicitur **[218r]** quia deferent centrum epicicli quoniam in circumferentia deferentis centrum epicicli situatur **et figitur**. Et nota quod deferens et equans uniuscuiusque planetae sunt equales. Epiciclus vero dicitur circulus parvus in cuius circumferencia centrum corporis planetae **continue situatur**. Centrum planetae medium est distantia inter augem equantis et filum **pertensum** a centro equantis per **terminum motus centri** planetae in suo equante **versus oriens computado**.

Filum **dicto transiens ad firmamentum per centrum epicicli, cuius epicicli superior pars cadens sub filo augem ipsius media** designabit. Sed in luna filum egrediens a puncto opposito centro **ecentrici** deferentis lune **in eadem diametro sito**, qui tantum distat a centro **terrae** quantum centrum

Equans vero et deferens **uniuscuiusque planete** regula eiusdem **puncti** celi **elevatur**, ita quod tam centrum equantis quam centrum defferentis **est** in eadem linea recta a centro terrae **transeunte** ad punctum predictum in firmamento; **qui quidam punctus**

*[Some of this appears just below in D]*

dicitur aux vel longitudo longior. Punctus vero opponitus dicitur **oppositum** augis vel longitudo propior. Puncta quidem media inter augem et **opponitum augis** dicuntur longitudines medie. **Et nota quod in Saturno Jove Marte et Venere habito centro equantis punctus medius inter centrum equantis et centrum terrae est centrum deferentis**. Omnes vero auges tam equantium quam deferentium singlorum planetarum sunt inmobiles praeter **augem deferentis** lune et **augem deferentis** mercurii et praeter motum octave sphere **communi in omnibus motibus veris est semper addendus**.

*[The following two paragraphs are interchanged in D]*

Equans vero cuiuscunque planetae est circulus regula cuius centri motus planetae **medius** est equalis, hinc est quod dicitur equans. Deferens aut dicitur quia deferent centrum epicicli quoniam in circumferentia deferentis centrum epicicli situatur. Et nota quod deferens et equans uniuscuiusque planetae sunt equales. Epiciclus vero dicitur circulus parvus in cuius circumferencia **situatur** centrum corporis planete. Centrum planetae medium est distantia inter augem equantis et filum **egrediens** a centro equantis **ad centrum epicicli** per **locum medium eiusdem** planetae in suo equante.

**Postea notandum est quod** filum **egrediens a centro equantis per centrum epicycli ad superiorem eius partem augem epicicli mediam** designabit. Sed in luna filum egrediens a puncto opposito centro deferentis lune, qui tantum distat a centro **mundi** quantum centrum ecentrici transiens per

[5] C *repeats* et

ecentrici transiens per centrum epicicli ad partem eius superiorem eiusdem, **epicicli** augem mediam **declarabit**.

centrum epicicli ad partem eius superiorem eiusdem, **lune** augem mediam **designabit**. **[130v]**

*[This sentence appears earlier in C]*

**Sol vero unicum habet circulum qui est ecentricus in cuius circumferencia equaliter movetur centrum solis**.

Argumentum **vero** solis est distantia centri corporis solis ab auge **sui equantis**.

Argumentum omnium aliorum planetarum est distantia centri corporis planetae **in epiciclo** ab auge media **ipsius** procedendo **versus orientem**.

**Sed** in luna **ab auge versus** occidentem **proceditur**.

Argumentum solis est distantia centri corporis solis ab auge **sua media**, **que distancia in omnibus aliis planetis dicitur centrum planetae**. Argumentum **vero** omnium aliorum planetarum est distantia centri corporis planete ab auge media **sui epicicli** procedendo **sinistrorsum videlicet ab occidente in orientem**. **Praeter** in luna **que movetur ab oriente in** occidentem **cum fuerit in superiori parte sui epicicli. Si centrum epicicli cuiuscunque planetae alterius et centrum corporis solis semper deferuntur ab oriente in occidentem contra motum firmamenti et primi mobilis quod idem est**.

**Medius motus lune est arcus zodiaci cadens inter primum arietis et filum pertensum a centro terrae ad centrum epicicli secundum successionem signorum computatus. Notandum insuper est quod filum a centro terrae perveniens per centrum corporis planetae ad firmamentum progrediens, verum locum vel motum eiusdem planetae in cuiuslibet signorum manifestat**. **Praeterea per luna** sciendum est quod aux deferentis **eius** semper movetur ab oriente in occidentem **fere** undecim gradibus omni die. Et centrum ecentrici describit quidem parvum circulum circa centrum mundi in quo motus centri deferentis motui augis eiusdem **est equalis** et ad eandem partem celi. Centrum quidam epicicli lune movetur omni die **circiter** 13 gradus et sol circiter unum gradum **semper** ab **oriente in occidens**. Quare sequitur quod si centrum solis, aux **deferentis** lune, et centrum epicicli lune fuerint in aliqua hora in aliquo **loco** celi **simul** sicut sunt in omni coniunctione solis et lune et in omni oppositione.

**Istis vero non obstantibus** sciendum est quod aux **ecentrici** deferentis **lune** semper movetur ab oriente in occidentem undecim gradibus **fere** omni die **naturali**. Et centrum ecentrici describit quidem parvum circulum circa centrum mundi in quo motus centri deferentis **equalis est** motum augis eiusdem et ad eandem partem celi. Centrum quidam epicicli lune movetur omni die **naturali per** 13 gradus et sol circiter unum gradum ab **occidente in orientem**. Quare sequitur quod si centrum solis, aux **ecentrici** lune, et centrum epicicli lune fuerint in aliqua hora in aliquo **gradu** celi sicut sunt in omni coniunctione solis et lune et in omni oppositione **sol et lune in crastina die eadem hora et aux ecentrici lune versus occidentem distans a sole per 12 gradu**.

Centrum epicicli **lune et aux ecentrici**

*[The following two paragraphs are interchanged in D]*

Centrum **vero** epicicli **movetur versus**

**eiusdem erunt in gradu oposito soli**,

*[Some of this appears just below in C]*

quod semper sol est in medio inter augem **deferentis** et centrum epicicli aut sol est in opposito illorum aut omnes 3 simul erunt, **quia sint gratia exempli simul omnes 3 motus**.

**Circa in die uno** aux **deferentis transit** versus occidentem 11 **gradibus** et sol unum gradum **versus orientem**. Quare erunt 12 gradus inter **solem et centrum epicicli et totidem sunt inter solem et augem, ex parte altera quare manifestum est quod sol est in medio**.

Sequitur etiam quod centrum epicicli lune bis percurrit **de nocte** in mense lunari quia semel ab auge usque ad oppositum quia tunc iterum centrum epicicli est in auge. Et semel ab opposicione usque ad coniunctionem quia tunc omnes **2** erunt simul **secundum gradum propositum**. Deferens vero mercurii sic describitur pertrahatur linea recta a centro terrae ad augem equantis, in qua linea invento centro equantis capiatur in eadem tantum a centro equantis quantum est inter centrum terrae et centrum equantis et ibi est centrum circuli quod describit centrum deferentis mercurii **[218v]** quod **centrum deferentis ad maius** in duplo plus distabit a centro equantis quam centrum equantis a centro terrae.

Movetur aut centrum deferentis ab orientem in occidentem in suo parvo circulo **representative** tantum quantum movetur sol versus orientem **in suo circulo**. Quare sequitur quod centrum epicicli mercurii bis in anno pertransit **suum differentem**. Sed non est ubi semel[6] in auge **deferentis** eccentrici.

**Quod quidem aux continue vagatur inter 2 lineas exeuntes a centro terrae ad deferentem contingentes primum circulum prius descriptum. Quia linea transiens a centro terrae ad deferentem per centrum eiusdem, intra augem illius demonstrabit, quod linea semper est inter 2 lineas**

**orientem per 13 gradum et sol per 1 gradum sic gradus erunt 12 gradus inter solem et centrum epicicli lune, quare manifestem est quod sol tunc est in medio inter augem ecentrici lune et centrum epicicli eiusdem, unde sequitur cum isti motus sunt uniformes**, quod semper sol est in medio inter augem **ecentrici lune** et centrum epicicli **eiusdem** aut sol est in opposito illorum aut omnes 3 erunt simul.

**Quia** aux **ecentrici movetur** versus occidentem **per** 11 **graduum** et sol **transit versus orientem per** 1 gradum. Quare erunt 12 gradus inter **augem et locum solis tunc**.

*[Some of this appears just above in D]*

Sequitur etiam quod centrum epicicli lune bis percurrit **ecentricum lune** in **omni** mense lunari quia semel ab auge usque ad **eius** oppositum quia tunc iterum centrum epicicli est in auge. Et semel ab opposicione usque ad coniunctionem quia tunc omnes erunt simul **scilicet sol, aux ecentrici et centrum epicicli**. Deferens vero mercurii sic describitur pertrahatur linea recta a centro terrae ad augem equantis, in qua linea invento centro equantis capiatur in eadem tantum a centro equantis quantum est inter centrum terrae et centrum equantis et ibi est centrum circuli quod describit centrum deferentis mercurii quod in duplo plus distabit a centro equantis quam centrum equantis a centro terrae.

Movetur aut centrum deferentis ab orientem in occidentem in suo parvo circulo tantum quantum movetur sol versus orientem. Quare

sequitur quod centrum epicicli mercurii bis in anno pertransit **eccentricum**. Sed non est ubi semel in auge eccentrici.

[6] C *repeats* ubi semel.

**predictas vel eadem est cum altera predictarum patet igitur intentum.** Patet est quod cum centrum epicicli mercurii fuerit in opposito augis **equantis** quod predicto equans et deferens erunt idem circulus. **Et est quod omnes 3 superiores planetae quando coniungentur cum sole sunt in augibus mediis suorum epiciclorum. Ex hiis a dictis plura possit concludi.**

**Sed** pro instrumentis predictis **de theorica** haec dicta sufficiant.

**Unum pro modo operandi cum**

Patet est quod cum centrum epicicli mercurii fuerit in **[131r]** opposito augis **deferentis** quod predicto equans et deferens erunt idem circulus.

**Notandum insuper est quod linea recta a centro terrae ad firmamentum per centrum cuiusvis planetae perducta verum motum et locum quod idem est eiusdem planetae declarat. Pro statione retrogradatione et directione est sciendum quod planeta dicitur directus quando motus eius mutatur motu epicicli contra firmamentum. Retrogradus aut dicitur quando fit econverso. Prima statio est punctus epicicli in quo incipit planeta retrograri. Secunda statio dicitur punctus epicicli in quo incipit planeta dirigi. Luna vero non dicitur habere ista accidentia quamvis habeat epiciclum quia motus centri epicicli lune est maior quam motus lune in suo epiciclo. Dicitur tum in superiori parte epicicli tarda in cursu, in inferiori velox in cursu. Statio prima in prima significatione dicitur arcus epicicli cadens inter augem veram epicicli et punctum stationis prime in prima significatione, que aux vera designatur per lineam exeuntem a centro terrae per centrum epicicli ad superiore eius parte. Statio secunda in secunda significatione dicitur arcus epicicli existens inter augem veram epicicli et punctum stationis secunde in prima significatione arcus dico transiens per prima stationem ad secundam. Arcus vero retrogradationis est arcus epicicli cadens inter primam stationem et secundam, et arcus epicicli inter stationem secundam et primam transeundo per augem epicicli dicitur arcus directionis, et isti duo arcus variantur secundum quam centrum epicicli accedit ad centrum terrae vel recedit ab eo et qua proportione unus eorum augetur alius minuitur** pro instrumentis predictis. Haec dicta sufficiant.

**instrumentis predictis doctrina sequentis communis est.**

Vera loca omni planetarum; **directionem, stacionem** et retrogradationem 5 planetarum retrogradarum ad quodcunque tempus proponitum sive preteritum sive futurum et in qualibet regionem per **datum instrumentum** cognoscere. Cum hoc autem scire **habuerit** a sole quidem incipiendo est, cum inter omnes planetas dignior **a quibusdam** reputatur, et motus aliorum a motu ipsius quodammodo regulantur. Sed in sole argumentum eius et in aliis planetis omnibus tam centrum medium quam argumentum medium cum medio motu lune ad tempus proponitum primitus apertum per tabulas calculari. Unde argumentum solis gratia exempli motuum singlorum pro aliis sic per tabulas calculetur.

Vera loca omni planetarum; **stacionem, directionem**, et retrogradationem 5 planetarum retrogradarum ad quodcunque tempus proponitum sive preteritum sive futurum et in qualibet regionem per **instrumenta prius dicta** cognoscere. Cum hoc autem scire **volueris** a sole quidem incipiendo est, cum inter omnes planetas dignior **ab omnibus** reputatur, et motus aliorum a motu ipsius quodammodo regulantur. Sed in sole argumentum eius et in aliis planetis omnibus tam centrum medium quam argumentum medium cum medio motu lune ad tempus proponitum primitus apertum per tabulas calculari. Unde argumentum solis gratia exempli motuum singlorum pro aliis sic per tabulas calculetur.

**Sumatur igitur primo radix** argumenti solis scriptam in capite tabule motus eius, **extra scribendo ipsam** in tabula calculatora. **Oportet sciendum est** quod radix est motus planetae ad certum tempus videlicet ad principium anni quod est **apud nos** in meridie ultime diei decembris, quia dies incipit in meridie diei preteritis, et finitur in meridie eiusdem diei. Et ad **certum locum** cognite regionis, vero gradu radicis argumentorum et centrorum planetarum in istis tabulis ponite sunt pro fine anni incarnationis Christi **1348** ad longitudinem **18** graduum **fere** ab occidente habitabili videlicet ad **civitatem** Oxoniam in Anglia.

**Cum igitur locum solis certum investigare volueris, sumas radicem** argumenti solis scriptam in capite tabule motus eius, **ipsam scribendo** in tabula **tua** calculatora. **Et scias** quod radix est motus **certi** planetae ad certum tempus videlicet ad principium anni quod est in meridie ultime diei decembris, quia dies incipit in meridie diei preteritis, et finitur in meridie eiusdem diei. Et ad **locum certum** cognite regionis, vero gradu radicis argumentorum et centrorum planetarum in istis tabulis ponite sunt pro fine anni incarnationis **domini nostri Ihesu** Christi **1350 perfectis** ad longitudinem **15** graduum ab occidente habitabili **et ad latitudinem 51 graduum et 56 minutorum** videlicet ad Oxoniam in Anglia.

*This paragraph (up to* 'regionis date'*) is later in D: it precedes the paragraph beginning* '(Nota modum operandi)'

Sed pro locis aliarum regionum quarumcunque **radicis** sic fiet equatio: capiatur longitudo civitatis **vel loci** regionis date inventa per tabulas **in quibus scribitur longitudine, que est [219r] distantia civitatum a Gadibus Herculis, et latitudo que est elevatio poli mundi super orizontem ipsam, dividido per 15, et exibunt hore. Residuum vero si sit vel si est parvo non posset diuidi per 15, multiplicetur per 60 et iterum diuidatur per**

Sed pro locis aliarum regionum quarumcunque sic fiet equatio: capiatur longitudo civitatis regionis date inventa per tabulas

**15 et exibunt minuta hore vel per** quod docetur in tractatu astrolabii **de novo prolato.** Et longitudo prescripta minuatur **illam** minor de maiori et exibit distantia in longitudine inter **illa**, **ratio perfecta quae** reducatur in tempus, capiendo pro quolibet gradu 4 minuta **unius** hore, et pro **qualibet minuta** 4 secunda hore. **Et** quo tempore sic invento quaeratur **medius** motus **cuiuslibet planetae pro ut sunt** [unreadable] **ordine**; qui minuendus **a sua radice comperta** pro locis orientalioribus, addendus pro **locis occidentalioribus**; et exurget **radix equata in** longitudine ad locum **date regionis**.

Postea **significantur** totum tempus preteritum vel futurum in annis, mensibus, diebus, horis et minutis horarum usque ad tempus in quo **placuerit** verum locum solis cognoscere et **istud servetur**. Deinde primo **intretur** cum annis Christi perfectis vel cum minoribus propinquioribus in tabulam annorum **colectorum** et expansorum sub argumento solis. **Motum** ibi inventum extra **scribendo**.

Iterum cum residuo annorum quandum fuerit **intretur tabulam eandem semper extrahendo quodlibet sub suo genere**. Deinde cum mensibus Christi **intretur** in tabulam mensium et cum numero dierum perfectorum tabulam dierum.
**Sed si sit annus bisextilis et transiverit locus bisexti intretur cum uno diei ampliori**.

Similiter cum horis tabulam horarum, et cum minutis horarum **intretur** eandem tabulam horarum. Et si minuta **praecise non** inveniantur **intretur** primo cum maiore, deinde cum minore, et qualibet **fractio ponatur** in una denominacione ulteriori, qua prius **fuerat** quando **intrabatur ad** horas.

**Habens peractis colligentur** omnes motus istorum introituum simil, **incipiendo** ab extremis pro quibuslibet 60 secundis ponendo unum minutum **minutis**, et pro **quolibet** 60 minutis unum gradum[7] **gradibus**. Pro 30 vero gradibus unum signum **signis** abiciendo 12

**secundum** quod docetur in tractatu astrolabii. Et longitudo prescripta **in tabulis tuis. Et** minuatur minor de maiori et exibit distantia in longitudine inter **illas 2as civitates**, **que** reducatur in tempus, capiendo pro quolibet gradu 4 minuta hore, et pro **quolibet minuto gradus** 4 secunda hore. Quo tempore **distancie** invento quaeratur motus **omnium planetarum in eodem et argumentorum eorum**; qui minuendus **est** pro locis orientalioribus, **et** addendus pro **occidentalioribus locis**; et exurget **motus equatus pro** longitudine ad locum **regionis date**.

Postea **capias** totum tempus preteritum vel futurum in annis, mensibus, diebus, horis et minutis horarum usque ad tempus in quo volueris verum locum solis cognoscere et **illud tempus serva**. Deinde primo **intra** cum annis Christi perfectis vel cum minoribus propinquioribus in tabulam annorum **collectorum** et expansorum sub argumento solis. **Et motum** ibi inventum extra **scribe sub radice quodlibet genus sub suo genere**. Iterum cum **[131v]** residuo annorum quandum fuerit **intra eandem tabulam consimili modo operando ut predictum est**. Deinde cum mensibus Christi **perfectis intra** in tabulam mensium et cum numero dierum perfectorum **intra** tabulam dierum.

Similiter cum horis **intra** tabulam horarum, et **iterum** cum minutis horarum **intra** eandem tabulam horarum. Et si minuta **non praecise** inveniantur **intra** primo cum maiore **et propiore numero**, deinde cum minore, et qualibet **fractionem pone** in una denominacione ulteriori, qua prius **fecisti** quando **intrasti** horas.

**Deinde agrega** omnes motus istorum introituum simil, **incipiens** ab extremis pro quibuslibet 60 secundis ponendo unum minutum, et pro **quibuslibet** 60 minutis unum gradum. Pro 30 vero gradibus unum signum abiciendo 12 signa quotiens

[7] C *repeats* et pro quibuslibet 60 minutis unum gradum

signa quotiens excreverint. Nam quod ex tali addicione provenerit est **motus argumenti solis** in tempore dato, **qui** addatur radici pro tempore futuro vel minatur ab ea pro **transacto**, et exibit motus argumenti solis.

excreverint. Nam quod ex tali addicione provenerit est **medius motus illius planete pro quo fit opus** in tempore dato, **quam** addatur radici pro tempore futuro vel minatur ab ea pro **tempore preterito**, et exibit motus argumenti solis **in $9^{a}$ sphaera ad tempus datum et hoc ad meridiem oxonie**.

**Postea quaeratur motus 8 sphaerae cum eodem tempore qui addendus est super verum locum cuiuslibet planetae pro tempore futuro, vel minuendus est a vero loco cuiuslibet pro tempore preterito, et exibit motus equatus ad [219v] 9 sphaeram per $8^{ua}$ per tempore dato et situ oxonum.**

Et **predicto** modo **inveniuntur** tam **centra media** quam **argumenta media** omnium planetarum **cum medio motu** lune. **Sed verus locus** capitis draconis lune **sit invenietur invento eius motu in tempore dato minatur ipse a radice sua pro tempore futuro et addatur per transacto et exibit verus locus eius in 9 sphaera ad tempus propositum cum addicione vel diminutione 8 sphaerae. Motus aut 8 sphaerae vix est 1 gradus in 100 annis futuris.**

Et **isto** modo **invenitur** tam **centrum medium** quam **argumentum medium** omnium planetarum **et medius motus** lune **ad quodcunque tempus**. **Praeter verum locum** capitis draconis lune **qui debet addi radici pro tempore preterito et minui ab eadem pro tempore futuro et praeter motum octave sphaerae qui addendus est omnibus veris motibus pro tempore futuro et minuendus pro tempore preterito in inicium operis**.

**Postea notandum est** quod argumentum solis est centrum veneris pro eodem tempore quia eadem est aux utriusque, et quod motus argumenti solis defuit centro veneris et centro mercurii habita eius radice quia omnium illorum tertium unus et idem est motus.

**Scias postea** quod argumentum solis est centrum veneris pro eodem tempore quia eadem est aux utriusque, et quod motus argumenti solis defuit centro veneris et centro mercurii habita eius radice quia omnium illorum tertium unus et idem est motus.

**Pro vero loco solis habendo**. Invento **eius** argumento ad tempus proponitum, **quaeratur numerus similis argumento eius in suo equante ab auge eius computado, secundum quod signa iacentis, ipso equante in omnibus planetis prius disponito et clavato, vel substantialiter descripto**, et **fiat ibi nota mentalis per** quam **extendatur** filum centri terrae usque ad **firmamentum** et ubi hoc filum ceciderit in orbe signorum ibi est verus locus solis in $9^{a}$ sphaera.

**(Nota modum operandi)**[8] **Omnibus scitis**, invento argumento **solis** ad tempus proponitum **in regione data**, **quaere consimilem numerum in ecentrico equante solis**,

et **fac ibi notam mentalem super** quam **extende** filum centri terrae usque ad **orbem signorum** et ubi hoc filum ceciderit in orbe signorum ibi est verus locus solis in $9^{a}$ sphaera.

Pro veris locis Saturni, Iovis, Martis et Veneris **cognoscendus** quod solum **requirintur**

Pro veris locis Saturni, Iovis, Martis et Veneris **est sciendum** quod solum **requiritur**

8 This is a marginal note in the same hand as the main text.

**centra media** et **argumenta media** eorum, quibus ad tempus proponitum ut predictum est **congregatis instrumento super tabulam planam et largam prius ponito et clavato**.

**Quaeratur numerus similis** centro **medio** planetae cuiusvis eorum in suo equante **ab auge versus oriens computado. Postea capiatur alius numerus** argumento **medio** eiusdem planetae **similis** in epiciclo communi **modo priori**. Et **fiant note** in terminis utriusque mentales.

**Postea capiatur regula** semidiametri deferentis communis, in **quo** uno fine figitur centrum epicicli et in altero clavus parvus **qui ponatur** in centro deferentis planetae equandi circumvoluendo semidiametrum deferentis communis et epiciclum communem quousque centrum epicicli, et aux eiusdem sint sub filo vel supra filum extensum a centro equantis super tabulam multum extra instrumentum per notam **prius** factam in equante **procedens**, **epiciclo communi secundum hanc dispositionem immobili exeunte**, circumvoluatur epiciclus verus ad notam argumenti medii **peractam** in epiciclo communi.

Egrediatur **etiam** filum a centro terrae **ad firmamentum** per centrum corporis planetae in suo epiciclo, cuius fili contactus in orbe signorum est verus locus illius planetae pro quo fuerit opus in 9 sphaera.

Pro **vero loco mercurii congregando**: quaeratur tam centrum medium quam argumentum medium **eodem** ad tempus proponitum **ut dictum est**, et signetur terminus centri **planetae** in suo equante et terminus argumenti in epiciclo communi.

Postea quaeratur similis numerus centro **medio** mercurii ab auge descendendo versus occidentem vel saltem propinquior ad annum vel ad retro in circulo parvo quem describit centrum deferentis qui **circulus** dividitur in **12** signa et quodlibet signum in 3 partes **equales** et in qualibet divisione **modicum est** foramen ponatur igitur clavus semidiametri deferentis

**centrum medium** et **argumentum medium cuiusvis** eorum **in instrumentis predictis**, quibus ad tempus proponitum ut predictum est **per tabulas cognitis**.

**Quaere numerum similem** centro planetae cuiusvis eorum in suo equante **et essiam numerum** argumento eiusdem planetae similem in epiciclo **[132r]** communi.

Et **fac notas** in terminis utriusque mentales.

**Tunc capias regulam** semidiametri deferentis communis, in **cuius** uno fine figitur centrum epicicli et in altero clavus parvus **quem pone** in centro deferentis planetae equandi circumvoluendo semidiametrum deferentis communis et epiciclum communem quousque centrum epicicli, et aux eiusdem sint sub filo vel supra filum extensum a centro equantis super tabulam multum extra instrumentum per notam factam in equante **primitus transiens**, **et**

circumvoluatur epiciclus verus ad notam argumenti medii **prius factam** in epiciclo communi, **epiciclo communi inmobili exeunte secundum dispositionem**. Egrediatur **consequentem** filum a centro terrae **ultra zodiacum** per centrum corporis planetae in suo epiciclo **(nota bene)**[9], cuius fili contactus in orbe signorum est verus locus illius planetae pro quo fuerit opus in 9 sphaera.

Pro **mercurio equando**: quaeratur tam centrum medium quam argumentum medium ad tempus proponitum, et signetur terminus centri in suo equante et terminus argumenti in epiciclo communi **ut predictum est**.

Postea quaeratur similis numerus centro mercurii ab auge descendendo versus occidentem vel saltem propinquior ad annum vel ad retro in circulo parvo quem describit centrum deferentis qui dividitur in signa et quodlibet signum in 3 partes et in qualibet divisione **est modicum** foramen ponatur igitur clavus semidiametri deferentis communis in

[9] This is a marginal note in the same hand as the main text.

communis in foramine correspondente centro mercurii, vel saltem propinquiori si praecise non inveniatur. Circumvoluendo semidiametrum **[220r] predictum** et epiciclum communem quousque centrum epicicli et aux eiusdem sunt sub filo vel supra filum extensum **a centro equantis** per notam centri in equante multum extra instrumentum super tabulam. Epiciclo communi **sic dispositio fixo remanente**, circumvoluatur epiciclus verus ad notam argumenti medii in epiciclo communi, et exeat filum a centro terrae per centrum **corporis** mercurii in suo epiciclo ad firmamentum cuius **fili abcisio** in zodiaco et verus locus **mercurii** in 9ª sphaera. Vel sic ponatur tabula centri deferentis lune et mercurii super centrum circuli parvi et per clavum suum **idem** figatur, et circumvoluatur eadem tabula ab oriente in occidentem quousque consimilis gradus **extimi circuli** in predicta tabula descripti sit super lineam exeuntem a centro terrae ad augem equantis, quotus fuerit centrum mercurii. Qua **tabula** sic disponita et fixa exeunte, ponatur clavus semidiametri deferentis communis in centro deferentis **mercurii** et cetera omnia fiant ut predictum est.

Pro vero loco lune **sciendo**. Primo medius motus, centrum medium, et argumentum medium eiusdem **modo predicto** per tabulas inveniantur. Postea notetur medius motus lune a principio arietis versus **oriens** computando, **per** cuius terminum exeat filum a centro terrae, multum extra **super tabulam**. Et circumvoluatur **parva tabula centri** deferentis lune **versus occidentem circa centrum terrae prius per clavum firmata**, quousque terminus centri medii lune in extimo circulo cadat sub filo extenso. Quo facto figatur tabula **super asserem per suam lingulam**. Deinde ponatur clavus semidiametri **deferentis communis** in centro deferentis lune ipsam circumvoluendo quousque centrum epicicli communis cadat sub vel supra filum **predictum**. Postea circumvoluatur epiciclus communis centro eiusdem exeunte fixo quousque filum egrediens a puncto opposito centro eccentrici lune **transeat** simul per centrum epicicli et augem eiusdem de hinc

foramine correspondente centro mercurii, vel saltem propinquiori si praecise non inveniatur. Circumvoluendo semidiametrum **predictam** et epiciclum communem quousque centrum epicicli et aux eiusdem sunt sub filo vel supra filum extensum per notam centri in equante

multum extra instrumentum super tabulam. Epiciclo communi **secundum hanc dispositionem inmobili exeunte**, circumvoluatur epiciclus verus ad notam argumenti medii in epiciclo communi, et exeat filum a centro terrae per centrum mercurii in suo epiciclo ad firmamentum cuius **abscisio** in zodiaco et verus locus eius in 9ª sphaera. Vel sic ponatur tabula centri deferentis lune et mercurii super centrum circuli parvi et per clavum suum figatur, et circumvoluatur eadem tabula ab oriente in occidentem quousque consimilis gradus **circuli extimi** in predicta tabula descripti sit super lineam exeuntem a centro terrae ad augem equantis, quotus fuerit centrum mercurii. Qua sic disponita et fixa exeunte, ponatur clavus semidiametri deferentis communis in centro deferentis et cetera omnia fiant ut predictum est.

**(Nota de Luna)**[10] Pro vero loco lune **cognoscendo**. Primo medius motus **lune**, centrum medium, et argumentum medium eiusdem per tabulas inveniantur. Postea notetur medius motus lune a principio arietis versus **orientem** computando, **ad** cuius terminum exeat filum a centro terrae, **et** multum extra. Et circumvoluatur **tabula parva** deferentis lune **primitus ponita et fixa per clavum circa centrum terrae**, quousque terminus centri medii lune in extimo circulo cadat sub filo extenso. Quo facto figatur tabula **per lingulam suam super asserem**. Deinde ponatur clavus semidiametri in centro deferentis lune ipsam circumvoluendo quousque centrum epicicli communis cadat sub **filo** vel supra filum. Postea circumvoluatur epiciclus communis centro eiusdem exeunte fixo quousque filum egrediens a puncto opposito centro eccentrici lune transiat simul per centrum epicicli et augem eiusdem de hinc vertatur epiciclus **[132v]** verus, epiciclo communi non amoto, ad

[10] This is a marginal note in the same hand as the main text.

vertatur epiciclus verus, epiciclo communi non amoto, ad medium argumentum lune **contra cursum communem computatum**. Quo facto extendatur filum a centro terrae per centrum **corporis planetae** lune ultra zodiacum, et locus que filum **absciderit** est verus locus lune **ad tempus proponitum** in 9 sphaera.

medium argumentum lune **in epiciclo communi**. Quo facto extendatur filum a centro terrae per centrum lune ultra zodiacum, et locus **eius** que filum **abscinderit** est verus locus lune in 9 sphaera.

Vel sic habitis mediis motibus ut predictum est signetur centrum **lune** in equante et argumentum medium in epiciclo communi. Deinde ponatur clavus semidiametri **deferentis** communis in centro deferentis lune, **ipsum** semidiametrum circumvoluendo, quousque centrum epicicli cadat sub vel supra filum extensum a centro terrae per centrum **medium** lune in **suo equante**, transiens multum extra. Circumvoluatur quia epiciclus communis quousque filum proveniens a puncto opposito centro eccentrici lune **transiat simul** per centrum epicicli et augem eiusdem. Deinde circumvoluatur epiciclus verus ad notam argumenti **medii lune in** epiciclo communi **ipso non amoto, progrediatur** filum a centro terrae per centrum **corporis planetae** lune in suo epiciclo ultra zodiacum et locus zodiaci qui **absciditur** notetur, qui vel est equalis cum centro medio lune, vel **minor**, vel **maior**. Si equalis **autem** medius motus lune et verus **est** idem. Si vero minor fuerit, capiatur excessus **quo subtractus de** medio motu lune; **verus locus ipsius** exurget.

Vel sic habitis mediis motibus ut predictum est signetur centrum **medium** in equante et argumentum medium in epiciclo communi. Deinde ponatur clavus semidiametri communis in centro deferentis lune, **ipsam** semidiametrum circumvoluendo, quousque centrum epicicli cadat sub **filo** vel supra filum extensum a centro terrae per centrum lune in **equante suo notatum**, transiens multum extra **zodiacum**. Circumvoluatur quia epiciclus communis quousque[11] filum proveniens a puncto opposito centro eccentrici lune **transeat** per centrum epicicli **lune** et augem eiusdem. Deinde circumvoluatur epiciclus verus ad notam argumenti epiciclo communi **inmobili exeunte, protendatur quia** filum a centro terrae per centrum lune in suo epiciclo ultra zodiacum et locus zodiaci qui **abscinditur** notetur, qui vel est equalis cum centro medio lune, vel **maior**, vel **minor**. Si equalis **certum est quod** medius motus lune et verus **sunt** idem. Si vero minor fuerit, capiatur excessus **centri super locum inventum sub filo qui minuendus est a** medio motu lune,

**Sed si maior [220v] fuerit additur excessus medio motum lune, et exibit verus locus eiusdem in 9 sphaera. Et haec operatio semissarum in luna sed in aliis planetis omnibus addatur aux in secunda significatione, id est distantia inter arietem et augem equantis ad motum per predicta inventum.** Et exurget verus locus **ipsius pro quo fuerit opus** in 9 sphaera. **Istius varietis et aliarum diversitatum in operando cum instrumentis prius dictis Jovis et Capitis est intelligenti cuilibet manifesta.**

et exurget verus locus **eiusdem** in 9$^a$ sphaera.

Pro direccione, stacione et retrogradacione 5 planetarum **retrogradarum** est notandum quod si aliquis **eorum** per duos dies vel tres vel

Pro direccione, stacione et retrogradacione 5 planetarum **retrogradorum** est notandum quod si aliquis **planeta** per duos dies vel tres

[11] D *repeats* quousque

ebdomadam **vel mensem** in eodem loco **reperiatur** est stacionarius. Si vero per certum tempus post plures gradus habuerit in motu est directus, si pauciores retrogradus. Arcus vero inferior epicicli est locus retrogradacionis, superior directionis. Puncta quidem contactuum harum contingentium epicicli **destram** et sinistram denotant staciones. **Illam** vero a dextris primam, et altera **altera**. Centrum verum, argumentum verum, et aux vera, **medius motus planetae, et medius motus centri epicicli**, et numquid planeta sit ascens vel descendens sive in eccentro sive in epiciclo, et diversitas diametri circuli brevis, ex qua causantur longitudines longiores et propinquiores **et minuta proportionalia** et **hiis** similia per datum instrumentum intelligenti **cuilibet** satis patent.

vel **per** ebdomadam **inveniatur** in eodem loco **vel per mensem** est stacionarius. Si vero per certum tempus post plures gradus habuerit in motu est directus, si pauciores retrogradus. Arcus vero inferior epicicli est locus retrogradacionis, superior directionis. Puncta quidem contactuum harum contingentium epicicli **dextram** et sinistram denotant staciones. **Ille** vero a dextris primam, et altera **secundam**. Centrum verum, argumentum verum, et aux vera, et numquid planeta sit ascens vel descendens sive in eccentro sive in epiciclo, et diversitas diametri circuli brevis, ex qua causantur longitudines longiores et **longitudines** propinquiores et **his** similia per datum instrumentum intelligenti **theorica** satis patent.

**Modo predicto vera loca omnium planetarum in 9 sphaera circa admodum motus 8 sphaerae pro futuro vel diminutione pro preterito ut predictum est per communem prescripto veraciter possunt sciri. Et hoc ad meridiem diei equalis quaesiti vel ad certum tempus post. Pro quo fuerit opus verum quia motus lune qui maximus est vix est propter vel ubi instrumentum fuerit maius inter meridiem cuius equalitatis et differentis, immo de equacione dierum vel ad praesens. Sed quia tam motus quam instrumentum equantur ad tempus praesens immo illa vera fit equatio**.

**Notandum est quod vocatur datum instrumentum** omnia instrumenta Campani simul iuncta, vel equatorium magistri Johannis de Lyners, vel semissas Prefatii Judei, vel aliud equatorium de novo componitum, et pro parte abbreviatum. **Prenominata instrumenta prevalens et excellens, tam in operis facilitate, quam in locorum certitudine**. Sed sciendum est quod **non prescriptus** non tangit modum operandi cum albion, **vel rectangulo**. Sed **solum** cum instrumentis **predictis quamvis in modo operandi cum eis parva sit diversitas tamen pro eisdem haec dicta sufficiant.**

**Explicit equatorium magistri Johannis de**

**Et voco instrumentum datum** omnia instrumenta Campani simul iuncta, vel equatorium magistri Johannis de Lyners, vel semissas Prefatii Judei, vel aliud equatorium de novo componitum, et pro parte abbreviatum. **Omnia predicta excellens in locorum certitudine et operis facilitate**. Sed sciendum est quod **iste canon praecedens** non tangit modum operandi cum albion. Sed cum instrumentis **prius dictis etc.**

**Lyners.**

## APPENDIX E

## *Medii motus planetarum*

This appendix is a transcription of the *Medii motus planetarum* treatise. It is based on two of the five copies of this treatise:

- Universidad de Salamanca Ms. 2621, ff. 10v-11v (S)
- Oxford, Corpus Christi College MS 152, ff. 276v-279r (C)

S is an early-fifteenth-century copy, probably made in the Netherlands. C is in the 'Notebook' of Nicholas Kratzer, made in England c. 1515-23.[1] (The other copies are Leipzig University MS 1469 ff. 237r-240r; Munich Clm 19689, ff. 162v-164v; Wolfenbüttel 2816 ff. 140v-141v.) The transcription has been made from S, with omissions supplied from C where S is clearly defective (this occurs in only two places). The footnotes indicate variant readings in C. Omissions are indicated in footnotes by square brackets.

Some changes have been made for clarity: paragraph marks (¶) have been removed, and line breaks and appropriate punctuation added. Dots around numbers and letters have been removed. The beginnings of sentences, and geometrical letters, have been capitalised. The letters 'u' and 'v' have sometimes been changed. Digits have been expanded where they function as an abbreviation of a non-numerical word (e.g. *secundum*), but have otherwise been left. Words cancelled in S have been included, marked with a ~~strikethrough~~.

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**[S:10va; C: 276v]** Medii motus planetarum scilicet saturni jovis martis solis et lune et veri motus veneris mercurii et capitis draconis in una tabularum quae si placet etiam sit tanta sicut una tabula cum almucantharat[2] illi sic fiunt. Primo oportet[3] habere verissime calculatum ex tabulis alfontii[4] quantum in signis quaslibet planetarum et etiam caput draconis moveatur in uno anno et quantum moveatur in duobus, et quantum in 3 in[5] 4 5 6 7 8 9 10. Et[6] quantum in 20 30 40 50 60 70 80 90 100. Et quantum in 200 300 400 500 600 700 800 900,[7] et quantum in signis gradibus et minutis moveatur in 1000[8] annis, semper intelligendo ab recto[9] revolucionibus.

2º oportet te scire per quanto **[C: 277r]** gradus et minutas moveatur saturnus et simili juppiter caput draconis in[10] 100. 200. 300.[11] diebus et non est necessarium minus capi vel pauciores dies[12] quia sunt tardi motus. De marte vero et venere scias per quanto gradus et signa[13] moveantur in

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1 North (1978).
2 C: *adds* et
3 C: [oportet]
4 C: [ex tabulas alfontii] in
5 C: [duobus, et quantum in 3 in] 2 3
6 C: [Et]
7 C: [100. Et quantum in 200 300 400 500 600 700 800 900]
8 C: *adds* id est mille
9 C: [ab recto] obiectis
10 C: [in]
11 C: et in 200 et in 300
12 C: diffiniciones
13 C: [et signa]

diebus 10 20 30 40 50 60 70 80 90 100 200 300. De sole et mercurio et de luna que sunt velociores scias per quanto gradus et signa et minuta moventur per diem 1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200 300[14] et ultra 300[15] diebus non transitur quia statim essent annus.

Deinde praedictam tabulam quadra duabus dyametris et notentur[16] litteris saepe dictis scilicet[17] A meridionalis B medie noctis ~~B~~ D occidentalis C orientalis quae est versus sinistram.[18] Et ab ista linea incipies[19] imponere motum unius cuiuslibet planete. Et quia in ista tabula **[S: 10vb]** non debet stare circulus signorum cum non valeat pro practica quod in ea staret. Ergo fiat foramen per centrum tabule et ponetur[20] supra dorsum astrolabii affixa cum cera quod maneat inmobilis ita quod C linea orientalis in tabula recte sit[21] supra lineam C[22] in dorso astrolabii et similiter alie linee[23] sint per[24] suas lineas.[25]

Deinde pone pedem circini in centro et describe circa extremitatem tabule 3 circulos qui continent duo spacia. Primum scilicet[26] exterius erit pro motu saturni in annis; aliud in spacium interius erit pro motu saturni[27] in diebus. Deinde pone tabulam supra dorsum astrolabii fixe ita quod linea orientalis sit supra lineam orientalem dorsi recta. Tunc vide quantum de gradibus et minutis saturnus pertranseatur in uno anno transeundo ab ariete secundum successionem ~~annorum~~ signorum et ibi fac notam in spacio exteriori et circa eam[28] scribas istum numerum 1. Deinde vide quantum moveatur in duobus annis a principio arietis et ibi iterum fac notam secundam circa quam scribe 2 etcetera.[29] Consequenter impones omnis[30] alios numeros praedictos tam annorum quam dierum.

Deinde **[C: 277v]** facias circulum parve distante qui sit pro distinctione orbis saturni et jovis sequentis qui similiter habebit duos circulos ut saturnus.[31] Deinde facies iterum parve distante sed procedendo versus intra qui sit pro distinctione orbis jovis et martis sequentis qui similiter habebit duos circulos vt juppiter.[32] Deinde facies iterum circule parve distante semper procedendo ~~versus~~ versus intra qui sit pro distinctione orbi jovis[33] ~~et~~ martis ~~sequentis qui similiter habebit duos circulos~~ et solis. Post hoc[34] fac iterum circulum parvum sed modicum maiorem in

14 S: [De sole ... 200 300]
15 C: [trecenta in]
16 C: vocantur
17 C: [scilicet]
18 C: *adds* maiam
19 C: incipias
20 C: pone
21 C: sicut
22 C: *adds* orientalis
23 C: [linee]
24 C: super
25 S: *repeats this paragraph.*
26 C: patet
27 C: [in annis; aliud in spacium interius erit pro motu saturni]
28 C: [et circa eam] circa quam
29 C: [etcetera] Et sic
30 C: impone omnes
31 C: jupiter
32 C: [facies iterum ... vt juppiter.]
33 S: iovis *should have been cancelled*
34 C: [facies iterum circule ... Post hoc] versus intra fac iterum ut prius circulum parve distante pro distinctione marte et solis.

quo pones[35] anni dividendo eum in 365 partes equales. Dies iste posses distinguere[36] secundum kalendarium per septimanas. Post hoc[37] fac circulum late distante quod in ea posses scribere[38] nominam mensium et quorum datam festorum quae tibi placent, quo insignabis (cum virgulis) ad dies in quibus **[S: 11ra]** veniunt, debet ergo scriptura mensium et festorum esse versa[39] versus centrum.

Deinde fac iterum circulum parve distante pro distinctione orbis solis et veneris sequentis et similiter fac duos circulos pro venere sicut de saturno et similiter[40] fac de mercurio et similiter fac[41] de capite draconis. Deinde semper versus intra fac iterum circulum parve distante ut[42] prius pro distinctionem orbis capitis draconis et lune.[43] Post hoc fac circulum in modico maiorem qui[44] continebit divisiones 29[45] dierum et unius medie diei et tantum est tempus de coniunctione in coniunctionem lune[46] cum sole. Divide ergo eum in tot partes. Post hoc fac alium[47] circulum et eiusdem quantitatem in quo subdiuides quemlibet[48] diem de predictis 29[49] in $4^{or}$ partes equales et[50] dimidium diem in partes duas. Per istos[51] duos circulos scies[52] quo die et in qua $4^{ta}$ diei erit[53] coniunctio solis et lune. Deinde fac duos circulos ut de saturno exteriorem pro motu lune in annis, interiorem pro diebus. Deinde residuum spacium quod est ab intra potes dividere in speram ignis, deinde aeris, deinde terre et quidem spera aquae. In una modica parte circundet speram terre[54] et non circondet eam[55] ex parte linee EB recta.[56] **[C: 278r]**

Deinde scias quod eodem modo sicut inposuisti motum saturni et secundum successionem signorum incipiendo semper a linea CE posita super arietem et quod sit in linea occidentali dorsi[57] rectis, sic etiam impones[58] motum jovis martis veneris[59] mercurii et lune. Primo in annis $2^{o}$ ~~do~~ in diebus prout a[60] quolibet planetarum inferius dicetur in tabulis suis[61], sed caput draconis

35 C: *adds* dies
36 C: [Dies iste posses distinguere] Illos possent distingueri
37 C: [Post hoc] Postea
38 C: posset scribi
39 C: [versa]
40 C: consimilem
41 C: [fac]
42 C: *adds* semper
43 C: [et lune]
44 C: quem
45 C: [divisiones 29] differensiones duorum
46 C: [lune]
47 C: iterum
48 C: quamlibet
49 C: $2^{o}$
50 C: *adds* in
51 C: illos
52 C: scias
53 C: [die et in qua $4^{ta}$ diei erit] puncto aut qua parte diei evenit
54 C: [et quidem spera aquae. In una modica parte circundet speram terre]
55 C: *adds* totum sed circundat eam
56 C: [recta]
57 C: *adds* et
58 C: [eciam impones] imponas
59 C: *adds* et
60 C: de
61 C: [suis]

imponitur procedendo[62] contra successionem signorum incipiendo[63] a linea C transeundo versus pisces aquarium recta et ille erit verus motus[64] eius. Si autem imponeretur[65] secundum successionem signorum tunc fieret motus medius. Motus[66] medius solis erunt dies anni[67] dictum est.

Deinde scribe[68] in linea C parvulos[69] circulos[70] pro corporibus planetarum unumquemque[71] in suo orbe locando. Et sic tabula motuum planetarum facta erit. Iterum in cuiuslibet planete orbe scribe suum motum circa lineam CE et[72] **[S: 11rb]** eius circulus superior ut[73] motus eius in annis et interior in diebus. Deinde quaere[74] ad principium alicuius anni ipsorum omni loca que insignabis cum regula et nomine planete circa eam et hoc in exteriori extremitate sive dorso astrolabii spacio ab[75] hoc dimisso quid scilicet est supra gradus signorum. Scias ergo per predictas radices in quibus signis sint omnis planete uno tempore.

<u>Practica eius</u>.  Operare[76] igitur cum tabula sic: quando vis scire locum alicuius planete ultra predictum tempus scilicet in quo signo[77] gradu et minuta sit pro 2 3 vel 10[78] annos, rectis[79] affige eam cum clavo in centro in dorso astrolabii et alliga filum ad clauum per quid vides si una distinctio vel nota motus sit recte sub aliquo[80] gradu. Sit ergo **[C: 278v]** exempli gratia[81] saturnus: move ergo tabulam donec linea CE recte[82] veniat in locum radicis saturni quam precisitatem probabis per filum[83] supra radicem. Deinde si volueris scire in quo signo gradu vel[84] minuta saturnus sit pro unum annum, tunc stante tabula move filum quousque recte cadat supra[85] notam circa quam stat numerus 1[86] in circulo saturni motus anni et gradus alicuius signi super quem[87] est filum, ipse est in quo est saturnus post annum unum.[88] Si post hoc vis scire quantum moveatur in duobus[89] annis tunc move tabulam quousque tabula veniat cum linea C sub[90] filo. Cum sic

[62] C: transeundo
[63] C: [incipiendo] scilicet in capiendo
[64] C: [recta et ille erit verus motus] et ille evenit motus verus
[65] C: impones
[66] C: Et post
[67] C: *adds* de quibus
[68] C: inscribe
[69] C: parvos
[70] C: *adds* quamque
[71] C: [planetarum unumquemque] semper unum planetarum
[72] C: *adds* que
[73] C: sit
[74] C: [quaere]
[75] C: [dorso astrolabii spacio ab] spacio dorso astrolabii et
[76] C: [Practica eius.  Operare] Oportet
[77] C: *adds* et
[78] C: [vel 10] et
[79] C: [rectis]
[80] C: aquario
[81] C: gratia exempli
[82] C: [CE recte] rectem
[83] C: *adds* tendendo filum
[84] C: [signo gradu vel minuta] gradu et minuta alicuius signi
[85] C: super
[86] C: [1]
[87] C: quam
[88] C: unum annum
[89] C: decem
[90] C: [sub]

steterit[91] super notam[92] unius anni, tunc[93] tabula sic stante pone filum super notam circa quam stat numerus 2[94] et gradus alicuius signi ipsi note[95] correspondens ipse est in quo erit saturnus per duos annos a radice vel per 10 annos ab[96] anno prius computato. Et eodem modo facies[97] ultra annos si motus eius vis[98] habere in aliquot diebus[99]. Sint ergo de luna 15 dies lune. Tunc primo quaeras[100] dies 10 in circulo dierum et pone filum super[101] eius notam et gradu ei correspondens ipse est in grado[102] in quo luna est in 10[103] die. Deinde volue tabulam quousque[104] linea CE veniat sub filo, et tabula sic stante pone filum super notam super quam stat numerus 5.[105] Et gradus huic note correspondens ipse est in quo luna erit post[106] 15 dies. **[S: 11va]** Similiter faceres si velles adhuc vnum duos[107] vel 3 dies superaddere. Et recte idem modus est querenda loca omnium aliorum[108] planetarum.

In luna autem[109] ut predictum est eciam habes subdivisum quantum luna moveatur in quarta[110] partem diei et hoc ut eo precisius inveniatur coniunctio et oppositio recta[111] solis et lune. Potest ergo[112] ille circulus subdivisionis dierum lune situari supra circulum in quo stat **[C: 279r]** motus[113] lune in diebus, ita quod non stet supra circulum in quo stet motus lune[114] in annis, ut predictum est.

Figura de motibus planetarum per quam inveniuntur et mensurantur loca stellarum et celorum[115] et figura regionum pro quam mensurantur et inveniuntur locum regionum et civitatum in terra[116], ille figure possunt fieri ex[117] una tabula ut predictum est; una ex uno latere tabule et alio ex alio latere[118] propter convenienciam quam habent, quia sicut una mensurat celum[119] sic per aliam mensuratur terra et ambe sunt perpetue veritatis sicut et cetere tabule.

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91 C: steterat
92 C: *adds* motus
93 C: et
94 C: decem
95 C: motui
96 C: [saturnus per duos annos a radice vel per 10 annos ab] ipse saturnus a radice ei per decem annos vel
97 C: scias
98 C: [annos si motus eius vis] annum motum eius
99 C: *adds* suis
100 C: quaere
101 C: supra
102 C: [in grado]
103 C: [luna est in 10] est luna in decima
104 C: *adds* iterum
105 C: [filum super notam super quam stat numerus 5.] super tabulam notam circa quam stant quousque.
106 C: [luna erit post] est luna pro
107 C: et duo
108 C: [aliorum]
109 C: aut
110 C: [in quarta] per quartam
111 C: *adds* respectu
112 C: igitur
113 C: [quo stat motus] quantum continet motum
114 S: [in diebus ita quod non stet supra circulum in quo stet motus lune]
115 C: [et celorum] in celo
116 C: [in terra]
117 C: in
118 C: [una ex uno ... ex alio latere] ex uno latere tabule et ex alio latere tabule et alia ex altero latere tabule
119 C: [mensurat celum] mensuratur

## APPENDIX F

## Excerpt from University of Aberdeen MS 123

Folios 66r-67v of this manuscript contain Latin and English versions of a short treatise, composed in the early fifteenth century, describing how to make and use a sundial. The English translation is incomplete, but what there is is revealing.

The transcriptions have been placed side by side for ease of comparison. Contractions have been expanded; the letters supplied are italicised. Letters used as geometrical markers for the instrument, and in the Roman numerals denoting hours of the clock, have been capitalised. [-] indicates where the text is illegible.

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**[66r]** Instrumentum p*er* q*uo*d sciunt*ur* hore diei p*er* vmbram sup*ra* sup*erfici*em plana*m* equed[-] orizont*i* p*ro* quacumq*ue* regione volu*er*is fabricare
Describe circulum diamet*ri*s eius ortogo*nali*ter se int*er*secantib*us* sup*ra* centru*m* E. & sint diamet*ri* AB & CD

Postea diuide 4*am* una*m* istius circuli in 90 g[a].

Et tu*n*c in 4a ad pos*tre*mo co*m*pu*t*a latitu*din*em regio*n*is ad qua*m* vis instrumentu*m* *com*pon*er*e inci*pien*do ab A v*er*sus D & vbi terminatur pone signu*m* F.

duc F li*ne*am F E que rep*re*sentat axem mu*n*di Tu*n*c signa pu*n*ctu*m* ad*vers*o puctu*m* i*n* li*ne*a AE. siue infra circulu*m* siue ex*tr*a non est vis et sit puctus G
duc *igitur* a pu*n*cto G vnam li*ne*am ortogo*naliter* secante*m* axem mu*n*di FE i*n* pu*n*cto H. Et*iam* erit ista li*ne*a GH semidia*meter* equinocci*alis* acci*pe* *igitur* de li*ne*a GE porcione*m* e*qu*alem li*ne*e GH et sit linea GY. Tunc pone pedem circini i*n*mo*bi*le*m* in pu*n*cto Y & describe circulu*m* s*cilicet* quanti*tatem* li*ne*e GY qui quidem circulus rep*re*sent*at* equinocciale*m* Eu*m* *igitur* diuide i*n* 24 p*ar*tes eq*ua*les et sint diuisiones PQRST quo facto p*rot*rahe li*ne*am ex vt*raque* parte in *conti*n*uum* et dire*cta*m li*ne*am di*visi*o *con*ting*it* & ortogo*naliter* secant*ur* diamet*ra*m AB

**[66v]** To make a Instrument to knowe þe ourys of þe day by þe vmbre of a style or standert w*ith* a fane sett streght up apon a playn thyng or a borde or a playn staue Fyrst make acercle w*ith* a cu*m*pas of what quantyte ye lyk & deuyde ye forsayd cercle eviyn in to 4. quarters wyth 2. lynys crossand þam self i*n* þe centr*e* of þe forsayd cercle & calle þe ton lyne AB & þe toþer lyne CD þen deuyde awhart*er* of þ*at* cercle fro A to D in to 90 partes or degres & take þe latitude of þe region or contre for whylk þ*ou* makys thyn instrument to s*er*ue in and covnte fro A **[67r]** toward D. As for þe cyte of ȝork take þe latitude þ*er*of þat is 52 d[egrees] whilk is þe latitude of þe forsayd cyte & contre Fro A toward D & merke wele w*ith* apryk wher 52 degres endes toward D & set þ*er* F drawe þen a streght lyne fro F to þe centre of þe cercle þat is called E. Than note & merke w*ith* in þe ~~lyne~~ sayd cercle in þe lyne þat is callyd AE a lytyl fro þe syde of þe cercle a poynt or pryk & calle it G. drawe þen fro G a lyne to crosse ou*er* þe lyne FE & merk þ*at* poynt & calle it H. Take þen of GE lyne a porcyou*n* or parte evyn as long as GH lyne & calle it GY. Then set þe foote of þe compase fyx i*n* Y poynt / & þe toþ*er* fote i*n* G poynt & make a cercle aft*er* **[67v]** þat quantyte Deviyde þen þis serkyl in to 24 eviyn p*artes* þat is to say þ*i*lk a quarter in to 6 & calle those p*ar*t*es* PQRST þen drawe a lyne streght up & down in puncto G & illa li*ne*a rep*re*sentabit i*n* pla*n*o eq*ui*noci*alem* & ea*m* diuides isto modo pone re*gul*am sup*ra* pu*n*ctu*m* P & sup*ra* cent*rum* Y & nota ubi tangit *contrarietat*e*m* & pone ibi K deinde pone re*gul*am super centrum Y & super pu*n*ctu*m* Q & nota vbi tangit linea*m* *contrarietat*e*m* & sit i*n* pu*n*cto L. Et eode*m* m*odo* fac sup*ra* pu*n*cta R S T & tu*n*c no*ta* i*n* li*ne*a *contrarieta*te M N O

crossand AB in G poynt & calle it XV lyne.

Then lay a rewlar upon Y centre & P poynt / & merke wher it touchis XV lyne þat gose up & downd & kalle þ*at* poynt K ȝet lay þy rewlar upon Y centre & Q poynt & merk wher it touchis XV lyne & set in þ*at* poynt L & þe same way do upon RST po[y]nt*es* & marke i*n* X [-] lyne MNO

Postmodu*m* t*ra*he lineas KE LE ME NE OE & iste linee rep*resentant* ho*ra*s li*ne*a GE rep*resentat* 12 ho*ra*m li*ne*a KE 11 LE 10 ME $9^{am}$ NE $8^{am}$ OE $7^{am}$ CE $6^{am}$ que li*ne*e si ult*ra* centru*m* duca*n*tur *con*si*mi*les rep*resentant* ho*ra*s p*ost* m*er*idiem sicut rep*resentant* an*te* m*er*idie*m* ut li*ne*a OE si ult*ra* ducatur rep*resentat* $7^{am}$ hora*m* post meridiem & NE $8^{am}$ hora*m* &c*etera* Insup*er* duc li*ne*am FE que rep*resentat* axem mu*n*di i*n* *con*ti*nuum* & dir*eccionu*m quosusq*ue* secet li*ne*am *contrarieta*tem & sit pu*n*ct*us* *con*tactus Z. tu*n*c erige stilu*m* ortogo*nal*it*er* sup*ra* pu*n*ctu*m* G ad altitu*dinem* GZ & alliga filu*m* i*n* cent*ro* E & ad su*m*mitate*m* stili p*re*di*c*ti q*uo*d quide*m* filu*m* rep*re*sent*at* axem mu*n*di i*n* altu*m* Et eius vmbra ostendet tibi hora*m* sine defectu du*m* t*ame*n p*re*di*ctu*m instru*mentu*m sit b*e*n*e* situat*um* ut postea dicetur. Et sic*ut* op*er*at*us* es*t* i*n* di*uisi*one $4^{e}$ AC i*ntr*a o*mn*i*n*o eode*m* mo*do* op*er*and*um* est $4^{o}$ AD et erit instru*mentum* *com*pletu*m* veru*m* t*ame*n si loco fili p*re*di*c*ti axe*m* mu*n*di rep*re*sant*at* i*n* altu*m* AB **[66v]** tab*u*lam metallica*m* erig*er*e ut Firmi*us* teneat & diucius maneat expedit p*re*dictam tablam e*qua*l*is* spissitud*in*is e*ss*e & figur*a* triangularis sit *er*go e*qua*le *tri*an*gulo* EG Z & erigatur i*n* altu*m* juxta li*ne*am GE ex p*ar*te D Et q*uia* na*rra*tu*rum* est illa*m* tabulam aliq*ua*nte spissitid*in*is esse ideo no*n* d*ebe*t diuidi $4^{o}$ AD sup*ra* pu*n*ctum E s*ed* d*ebe*t diuidi s*upra* distantem AB C v*er*sus D tantu*m* est qua*n*ta e*st* spissitudo tab*u*le & de*be*t i*st*e pu*n*ctus e*ss*e i*n* li*ne*a D.

Aftyrward draw a lyne streght fro K to E centre & þ*at* lyne betokyns þe XI ho*ur*s befor none. draw þen a lyne fro L to E & þat schal betokyn X of þe clok. drawe [y]et a lyne fro M to E & anoþ*er* fro N to E and fro O to E & these iii lynes betokyns IX VIII & VII of þe clok & CE lyne betokyns VI of þe clok & GE XII ho*ur*s þ*at* is mydday Forþ*er*mor drawe FE lyne owt whilst it touche XV lyne & merke þe poynt þ*er* he touchys & set þ*er* Z. þen make þy style of þe lengh of GZ lyne & set it streght up in G poynt knyt þen a threde fro þe style vp to E centr*e*

Or if þ*ou* wyl make afayne of metal or of borde make it evyn & playn & 3 cornerd of þe quantite of EGZ triangle & þe vmbre of þ*at* schal schewe þe owrys truh &c

**De modo situandi p*red*i*ctu*m instr*umentu*m**

Post composic*ion*em instrume*n*ti debes li*n*eam m*er*idi*anem* querer*e* i*n* instr*umenti*s loco vbi vis instru*mentum* situare [...ia*m*] li*ne*am sic inuenies sup*ra* sup*erficiem* plana*m* i*n*mo*bilem* equed*istantem* orizonti ¦ describe circulu*m* 3$^{m}$ & sup*ra* ei*us* centru*m* stilu*m* erige ortogo*naliter* sic q*uod* cuspis eius e*qua*l*ite*r distet a circu*m*fere*n*cia c*ir*culi & sit stilus altitud*o* tal*is* q*uod* vmbra eius m*er*idia*na* sit minor diamet*ri* circuli Tunc considera an*te* m*er*idiem qu*am* vmbra stili erit e*qua*l*is* se*m*idiamet*ro* circuli & p*re*dicta vmb*r*a ta*n*git circu*m*ferencia*m* pone nota*m* & eod*em* modo fac post m*er*idie*m* & pone nota*m* ut p*rius*. Circu*m*ferencia*m* aute*m* circuli int*er*cept*am* int*er* istas duas notas diuide p*er* mediu*m* & a loco di*uisi*onis duc li*ne*am ad centru*m* circulu*m* que quidem li*ne*a e*rit* m*er*idiana situac*i*o *igitur* instr*umenti* erit tal*is* q*uod* l*in*ea 12 hore d*ebe*t esse sup*ra* ista*m* li*ne*am m*er*idiana*m* *ve*l saltem d*ebe*t e*ss*e equedista*n*s li*ne*e m*er*idie*m* & e*rit* instru*menti* debite situat*um* &c*etera*.

## APPENDIX G

# Some noteworthy technical terms used in Peterhouse MS 75.I

This appendix presents a selection of the technical terms in the *Equatorie of the Planetis* according to three categories: those explicitly explained or defined in the treatise; those that may make their first English appearance in this manuscript;[1] and other terms worthy of note.

The second group is significantly reduced in size by the fact that the *Equatorie* was composed after the *Treatise on the Astrolabe*;[2] several terms are only recorded there prior to their use in Peterhouse MS 75.I . However, many of those are in any case uninteresting since they are direct transliterations from Latin; a few more interesting terms have been included in group G.3.

In each case, the word or phrase from the *Equatorie* is presented in the first column. The second gives the equivalent term used in Latin treatises. The terms in that column have been drawn from a range of sources that describe equatoria and related instruments.[3] The third column contains equivalent terms in Arabic, most of which are taken from studies by Paul Kunitzsch and Jamil Ragep.[4] The fourth column contains any relevant notes.

### G.1 WORDS EXPLICITLY DEFINED BY JOHN WESTWYK (USING THE VERBS *CALLEN* OR *CLEPEN*)

| ***Equatorie*** | **Latin** | **Arabic** | **Notes** |
|---|---|---|---|
| centre aryn | centrum; centrum terrae | al-markaz (centre), al-quṭb (pole, axis) | *Aryn* was thought to be the centre of the habitable earth. It also appears in the astrolabe treatise of Rudolf of Bruges (s. xii med).[5] |
| closere (of the signes) | ~ circulus signorum; firmamentum | ~ falak al-burūj | This is the first recorded use of the word "closer" (meaning an enclosure). Other treatises do not explicitly define this part of their instrument. |
| comune centre defferent | (centrum deferentis, regula semidiametri deferentis communis) | (markaz al-khārij) | This component is unique to the *Equatorie*; the phrases given are the nearest phrases used in other treatises. |
| degres of the semidyametre | partes semidiametri | ajzā' (or daraj) nuṣf al-quṭr | These degrees are divisions of a semidiameter used to mark out the Sun's eccentricity. They are not given a special name in other treatises. |
| equacioun of his argument | equatio argumenti | zāwīya al-'ikhtilāf | Defined by Westwyk as the angle between the true longitude of the epicycle centre and the true longitude of the planet. |
| equacioun of his centre | equatio centri | ta'dīl al-markaz | Defined by Westwyk as the angle between the true longitude of the epicycle centre and the mean longitude of the planet. |

[1] This list has been compiled by comparing entries in the *Oxford English Dictionary* and *Middle English Dictionary*, drawing on the linguistic analysis by R. M. Wilson (1955). It must be considered provisional.
[2] *Pace* Cole (2002). See chapter 3, pp. 82-83, for discussion.
[3] Lignières (1955); Cambridge University Library Gg.VI.3, ff. 217v-220v (see Appendix C); Richard of Wallingford, 'Tractatus albionis', in North (1976); Campanus of Novara, 'Theorica planetarum', in Benjamin and Toomer (1971). See also Beaujouan (1981).
[4] Kunitzsch (1982); Ragep (1993). I have transliterated the Arabic of Ragep's edition of Naṣīr ad-Dīn at-Ṭūsī's *Memoir on Astronomy*, and standardised Kunitzsch's transliterations.
[5] Rudolf of Bruges (1999), 75.

| | | | |
|---|---|---|---|
| lymbe | limbus | al-ḥujra | This is the first recorded use of the word "limb" as the extremity of any object, though its anatomical meaning was well established. Chaucer's *Treatise on the Astrolabe* uses "bordure" for the equivalent part. |
| lyne alhudda | linea medii celi | khaṭṭ wasaṭ as-samā' | The Latin treatises consulted do not explicitly define these components, which are not important to their instruments. The terms 'linea meridiei' and 'linea medie noctis' are common in astrolabe treatises. |
| midnyht line | oppositio | khaṭṭ az-zawāl | |
| remenaunt, remnaunt | quod remanet; quod relinquitur; residuus | baqīya | This word is used in two senses: the rest (e.g. of the planets); and remainder after subtraction. It is only new (and defined) in the second sense in the *Equatorie*. |

## G.2 Words that make their first recorded appearance in Peterhouse MS 75.I

| ***Equatorie*** | **Latin** | **Arabic** | **Notes** |
|---|---|---|---|
| aux, auges | aux, auges | 'awj | This word does not appear in the OED or MED; it is quite likely that Peterhouse MS 75.I represents its first appearance in an English manuscript. |
| bakside | dorso | aẓ-ẓahr | |
| diametral | diametraliter (adv.) | quṭrī | |
| drawe (owt) | subtraho | naqaṣa (min) | This is the first recorded use of this word to mean "subtract", though "withdraw", which was not a new word at that time, is the word generally used in the *Equatorie*. |
| eccentrik | eccentricus | khārij markaz | |
| equant | equans | mu'adil al-masīr | |
| equatorie | equatorium, instrumenti | ~ 'ādil | This word does not appear in the OED or MED; it is quite likely that Peterhouse MS 75.I represents its first appearance in an English manuscript. It is hardly ever used in Latin treatises: of the four consulted, it only appears in the title of Jean of Lignières's treatise, and then only in some manuscripts. |
| equedistant | equedistanter (adv.) | yatawāzā | This adjective is used to mean "parallel" in the *Equatorie* |
| geometrical | geometricus | bil-khuṭūṭ | |
| mot, motus | motus | ḥaraka | This word does not appear in the OED or MED; it is quite likely that Peterhouse MS 75.I represents its first appearance in an English manuscript. |
| precisely, precise (adv) | precise | bitadqīq | |
| seccioun | sectio | (nuqṭa) taqāṭu' | meaning intersection |
| semydiametre | semydyameter, semidiameter | nuṣf al-quṭr | |

## G.3 OTHER NOTEWORTHY TERMS

| ***Equatorie*** | **Latin** | **Arabic** | **Notes** |
|---|---|---|---|
| almenak | tabulae; almanac | taqwīm | Apparently of Arabic origin, though its etymology is debated. See the discussion in Benjamin and Toomer (1971), 374-375. It is not clear whether the almanac referred to by John Westwyk was time-limited or perpetual. |
| label | regula, lingua, lingula | al-ʿiḍāda (alidade) | Westwyk gently calls attention to the meaning of this word, which he has already used for an analogous part of an astrolabe. |
| mene | medius | wasaṭ | This is the first time the word is used in a strict mathematical sense (rather than meaning intermediate). It appears in the Supplementary Propositions to the *Treatise on the Astrolabe*. |
| retrogradorum | planeta | rājiʼ | This word appears in a passage of ciphered English text among the tables. It is rarely used in Latin texts as a noun synonymous with *planeta*, but the adjective *retrogradus* is common. |
| visage | facies, mater | aṣ-ṣāfīḥa (plate) | This is the first time the word is used to mean the front of an instrument. Westwyk also uses the word “face”. |

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