'I found this written in the other book': Learning Astronomy in Late Medieval Monasteries

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Recent histories have challenged narratives of a late medieval decline in monastic scholarship. This article extends that work to the natural sciences, showing how monks could learn astronomy and mathematics through their scholarly labour of reading, copying and glossing. Although the processes of learning are often poorly documented, and are often conflated with teaching, it is possible, through close reading of annotations and reconstruction of mathematical processes, to get a glimpse of an individual in the moment of acquiring scientific skills. Focusing on a piece of adaptive copying carried out by an English Benedictine monk c.*1380, this article explores the devotional motivations underlying his work, and argues that it was through such copying and compilation that he acquired the expertise necessary to invent an astronomical instrument some years later.*

Medieval learning can be hard to trace. We certainly have good evidence of medieval teaching: one celebrated teaching text from the science of astronomy is Geoffrey Chaucer's guide to the astrolabe, ostensibly written for his ten-year-old son, through which, he writes, 'I purpose to teche the a certein nombre of conclusions aperteynyng to the same instrument'.[1] Much, too, is known about techniques of memorization.[2] Yet we do not know how 'little Lewis' read his father's instructions, or how he came to understand the instrument in his hands. This is a common problem, since documents of learning contexts, generally produced by teachers, tend to reflect the transmission of didactic material rather than its reception.[3] Thus when

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[1] Geoffrey Chaucer, *A Treatise on the Astrolabe*, Prologue 11–13, in *The Riverside Chaucer*, ed. Larry Benson (Oxford, 1987), 662.
[2] Mary Carruthers, *The Book of Memory: A Study of Memory in Medieval Culture*, 2nd edn (Cambridge, 2008).
[3] Alain Bernard and Christine Proust, eds, *Scientific Sources and Teaching Contexts throughout History: Problems and Perspectives* (Dordrecht, 2014), 1–15.

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historians discuss 'medieval learning' they are often referring to the delivery of knowledge – or, worse, simply knowledge itself – rather than the processes by which it was absorbed.[4]

Recent historical work has, however, begun to trace learning processes. Research within the field of history of science has focused on the practices of scientists, including learning practices, though this 'practice turn' is less popular for pre-modern science and rarely extends to the poorly documented practices of scientific non-elites.[5] Meanwhile, historians of monasticism, seeking to challenge assumptions about a late medieval decline in monastic scholarship, have begun to uncover the opportunities monks had to learn in almonry schools, at university and within the cloister itself.[6] This article brings the two fields together through its exploration of the astronomical study of a monk who, although he was immersed in the scholarly practices of well-resourced Benedictine houses, may not have attended university, and never attained either prominence within scientific circles or a position of authority within the cloister.

The 'monastic renaissance' we find in at least some wealthier and better-connected monasteries extended to the sciences, which were not just practised by experts in universities.[7] In particular, astronomy was an important subject of study, enshrined in the *quadrivium* of mathematical sciences and central to monastic concerns such as timekeeping and healthcare. It was studied through a range of Christian and non-Christian sources, including some texts that were explicitly intended as beginners' primers. However, such textbooks were not indispensable to learning, and this article will show how monastic scholarly practices could facilitate learning (and indeed may have been implicitly intended to do so) in ways that obviated the need for the guidance of a teacher. Close reading of the texts and objects

[4] See, for example, John Murdoch and Edith Sylla, eds, *The Cultural Context of Medieval Learning* (Dordrecht, 1975), 1–30.

[5] Karine Chemla, 'Observing Mathematical Practices as a Key to Mining our Sources and Conducting Conceptual History', in Lena Soler et al., eds, *Science after the Practice Turn in the Philosophy, History, and Social Studies of Science* (New York, 2014), 238–68.

[6] See, for example, James Clark, *The Benedictines in the Middle Ages* (Woodbridge, 2011), who sets himself against the views of David Knowles, *The Religious Orders in England* (Cambridge, 1957).

[7] James Clark, *A Monastic Renaissance at St Albans: Thomas Walsingham and his Circle, c.1350–1440* (Oxford, 2004).

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produced in monasteries can reveal the processes by which those sciences were learned and in turn developed and disseminated.

Monasteries had been centres of astronomical scholarship before the foundation of universities and continued to be so, if in a reduced capacity, thereafter. Such scholarship went well beyond the practical timekeeping and calendrical calculation developed by Bede (*c.*673–735): 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.[8] Moreover, Benedictine abbeys in Catalonia, France and southern Germany had been at the forefront of the reception of mathematical knowledge from the Islamic world, producing some of the earliest Latin translations of texts on instruments such as the astrolabe.[9] Such scholarly commitment was underpinned by a range of motivations. Precise timekeeping symbolized order and authority, and had the practical benefit of regulating monastic routines; it is not surprising that monasteries possessed a range of time-telling devices.[10] A second practical driver could have been the use of 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 the biblical verses to be intoned when carrying out surgical procedures such as phlebotomy.[11] Monks were also, it seems, attracted to astronomy by devotional motivation – the desire to approach the mind of God by learning about his creation – as well, perhaps, as simple intellectual curiosity.[12]

[8] Bede, *The Reckoning of Time*, ed. Faith Wallis, TTH 29 (Liverpool, 1999); Stephen McCluskey, *Astronomies and Cultures in Early Medieval Europe* (Cambridge, 1998), 180–4.

[9] Charles Burnett, 'King Ptolemy and Alchandreus the Philosopher: The earliest Texts on the Astrolabe and Arabic Astrology at Fleury, Micy and Chartres', *Annals of Science* 55 (1998), 329–68.

[10] Catherine Eagleton, 'John Whethamsteade, Abbot of St Albans, on the Discovery of the Liberal Arts and their Tools: Or, Why were Astronomical Instruments in Late Medieval Libraries?', *Mediaevalia* 29 (2008), 109–36, at 122.

[11] Hilary Carey, *Courting Disaster: Astrology at the English Court and University in the Later Middle Ages* (Basingstoke, 1992), 41–2; Cornelius O'Boyle, 'Astrology and Medicine in Later Medieval England: The Calendars of John Somer and Nicholas of Lynn', *Sudhoffs Archiv* 89 (2005), 1–22, at 14–15.

[12] On this issue, see Andrew Cunningham, 'The Identity of Natural Philosophy: A Response to Edward Grant', *Early Science and Medicine* 5 (2000), 258–78; Edward Grant, 'God and Natural Philosophy: The Late Middle Ages and Sir Isaac Newton', ibid. 279–98; Andrew Cunningham, 'A Last Word', ibid. 299–300.

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With the rise of the European universities in the twelfth century, monasteries lost some of their importance as centres of scholarship, but they remained significant intellectual institutions. Several recent histories have argued against earlier accounts of late medieval monastic stagnation. Historians have naturally focused on traditional monastic interests such as theology, history and canon law, but the point applies equally, and in some cases with even greater force, to the mathematical sciences. From the late thirteenth century, the chapters of English Benedictines enacted statutes to promote study, and in 1336 the papal bull *Summi magistri* ordered Benedictine houses to send one monk in every twenty to university; although some were later reprimanded for not doing so, others, like Westminster and St Albans, sent far more than required.[13] Few monks stayed long enough to graduate, and they were required to focus on theology and canon law, but they would have studied the introductory arts course, unless they had already done so at their monastery.[14] That meant at least some of the mathematical sciences: arithmetic, geometry, astronomy and music. On their return to the cloister, some monks brought their scientific interests, or at least their scientific books, with them. Many astronomical texts surviving from monastic libraries were produced at universities. Even if the monks who brought them back deposited them in the monastic library and never looked at them again, they were available for other monks to study.[15] They include the most widespread primers such as John of Sacrobosco's *On the Sphere*, as well as a range of more recondite texts. These fed into an active internal network of learning, in which monks were encouraged to busy themselves with the gamut of scholarly tasks: 'studying, reading, and writing books; glossing, correcting, illuminating, and also binding', as the 1351 constitutions of Thomas de la Mare (abbot of St Albans 1349–96) put it.[16] The abbots of St Albans were clearly aware of the advantages of university

[13] David Wilkins, ed., *Concilia Magnae Britanniae et Hiberniae* (London, 1737), 595; Alban Léotaud, 'The Benedictines at Oxford, 1283–1539', in Henry Wansbrough and Anthony Marett-Crosby, eds, *Benedictines in Oxford* (London, 1997), 20–36, at 25–6.
[14] Joan Greatrex, 'From Cathedral Cloister to Gloucester College', in Wansbrough and Marett-Crosby, eds, *Benedictines in Oxford*, 48–60, at 54–6.
[15] Wilbur R. Knorr, 'Two Medieval Monks and their Astronomy Books: MSS. Bodley 464 and Rawlinson C.117', *Bodleian Library Record* 14 (1993), 269–84.
[16] Thomas Walsingham, *Gesta abbatum monasterii Sancti Albani*, ed. Henry T. Riley, 3 vols, RS 28 (London, 1867–9), 2: 433 (my translation).

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education, as they were consistently generous benefactors to Gloucester College, Oxford.[17] As well as the benefits of learning which monk-students brought back to St Albans and which trickled down through the monastery, such munificence must have contributed to the abbey's reputation for scholarship at this time; and this in turn may have attracted new monks to the house, sometimes directly from Oxford.[18]

One monk who made that move 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 for a further nine years, during which he completed his most important work.[19] He had been back in the monastery for only a few weeks in autumn 1327 when abbot Hugh of Eversden died, and following some energetic lobbying Richard was elected to succeed him.[20] Succeeding generations of monks recalled his efforts to restore the abbey finances neglected by previous abbots, and the leprosy that cut short his tenure, but above all they celebrated his achievements as an astronomer. Both the surviving images of him (in the abbey chronicle and book of benefactors) show him with astronomical instruments of his own invention.[21] In his most important and celebrated work, the *Treatise on the Albion* (1326), he prayed of his Albion instrument, a multifunctional planetary computer of unprecedented refinement and complexity, that 'its place among other instruments will not be undistinguished, especially since its design could direct the minds of many people to higher things'.[22] The Albion was certainly distinguished in its capacity to simplify and speed up the difficult calculations involved in astronomy and astrology, such as predicting eclipses and the positions of celestial bodies, as well as timekeeping and calendrical computation; in addition, any student who worked through the treatise, which comprised geometrical proofs as well as explanation of the instrument's construction

[17] Léotaud, 'Benedictines at Oxford', 27–8.
[18] Walsingham, *Gesta abbatum*, ed. Riley, 3: 410–11; Clark, *Monastic Renaissance*, 15.
[19] Walsingham, *Gesta abbatum*, ed. Riley, 2: 182.
[20] John North, *God's Clockmaker: Richard of Wallingford and the Invention of Time* (London, 2005), 77–9.
[21] London, BL, Cotton MSS Claudius E.IV, 'Deeds of the Abbots of St Albans', fol. 201^{r}; Nero D.VII, 'Book of Benefactors', fol. 20^{r}.
[22] Richard of Wallingford, 'Tractatus albionis', in J. D. North, ed., *Richard of Wallingford: An Edition of his Writings*, 3 vols (Oxford, 1976), 1: 340 (my translation).

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and uses, would learn a great deal about the heavens. There is no sense in monastic accounts that Richard's scientific interests detracted from his piety; rather, the monks took pride in his contribution to the abbey's reputation for learning.[23] It was surely to preserve and perhaps enhance this reputation, as well as to honour his memory, that fresh copies were made of Richard's most significant work: at least three of the nine more-or-less faithful copies of the *Albion* (that is, those not following John of Gmunden's popular fifteenth-century edition) were produced at St Albans.[24] It is clear that his successors valued his achievements in advancing learning at the monastery and promoting its reputation as a centre of scholarship. The abbey chronicle stresses Richard's 'many books and instruments of Astronomy, and Geometry, and other particular sciences, in which he excelled beyond all his contemporaries'; his fifteenth-century successor abbot John Whethamsted (himself a great supporter of monastic learning, who built and stocked the library at Gloucester College) wrote that 'the albion contains in itself the functions of all the other instruments. Richard of Wallingford, formerly abbot of the monastery of Alban, first discovered it – a man so learned in the art of astronomy that, from his time to the present, there has been no Englishman like him.'[25]

Reverence for Richard of Wallingford was undoubtedly a motivating factor in the production of the manuscript that is the principal subject of this article, Bodleian Library MS Laud Misc. 657. The codex comprises eighty leaves, still in their medieval binding, of which twenty-six were initially left blank (four of these were filled by a slightly later hand). In the first two-thirds of the book, a single hand copied two of Wallingford's works: the *Albion* and another instrument treatise, the *Rectangulus*, also written in 1326. This copy of the *Rectangulus* has little to distinguish it from others. *Albion*, however, presents a different case, as its scribe explained on the first page:

[23] BL, MS Cotton Nero C.VI, fol. 149^{r}; Walsingham, *Gesta abbatum*, ed. Riley, 2: 207.
[24] Oxford, Bodl., MS Laud Misc. 657, fols 2^{r}–45^{r}; MS Ashmole 1796, fols 118^{r}–159^{v}; Oxford, Corpus Christi College, MS 144, fols 44^{r}–78^{v}; North, ed., *Richard of Wallingford*, 2: 127–30.
[25] Walsingham, *Gesta abbatum*, ed. Riley, 2: 207 (my translation); BL, MS Cotton Nero C.VI, fol. 149^{r} (my translation). On Gloucester College and John Whethamsted, see Léotaud, 'Benedictines at Oxford', 28.

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> 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.
>
> 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. May the soul of the said John and the souls of all the faithful, through the mercy of God, rest in peace. Amen.[26]

The life of this John Westwyk has been partially reconstructed in a recent article by Kari Anne Rand: he was evidently first a monk of St Albans before moving to Tynemouth around 1380.[27] He was there for no more than three years before leaving to take part in the 1383 crusade to Flanders led by Bishop Henry le Despenser. Later he returned to St Albans, where he probably died soon after 1397; it was there or perhaps in London that he wrote the Middle English instrument treatise known as *The Equatorie of the Planetis*, long attributed to Chaucer.[28] There is no evidence that Westwyk studied at university. Yet his composition of the *Equatorie* in 1393 demanded no little scientific expertise. Assuming that he acquired this expertise within the monastery, his learning processes can be observed in his production, shortly before his move north to Tynemouth, of MS Laud Misc. 657.

Westwyk's prefatory note, quoted above, makes it quite explicit that he is collating two versions of the treatise, those of Richard of Wallingford and Simon Tunsted (a Franciscan active at Oxford in the 1350s and 1360s), and that he is studying them alongside an actual Albion instrument. For the most part his copy is identical to other early copies of Richard of Wallingford's treatise. Where it differs, it is not always immediately clear how much is copied directly from Tunsted, since no other copy survives of his version.

[26] Bodl., MS Laud Misc. 657, fol. 1^{v} (my translation).
[27] Kari Anne Rand, 'The Authorship of *The Equatorie of the Planetis* revisited', *Studia Neophilologica* 87 (2015), 15–35.
[28] Cambridge, Peterhouse, MS 75.I. The attribution was proposed by Derek Price, ed., *The Equatorie of the Planetis* (Cambridge, 1955); see also Kari Anne Rand Schmidt, *The Authorship of the Equatorie of the Planetis*, Chaucer Studies 19 (Woodbridge, 1993); eadem, 'Authorship revisited'.

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Wallingford's editor John North suggested that all substantive changes were Tunsted's; conversely, James Clark argued that Westwyk had produced a 'more advanced' version of Tunsted's text.[29] Careful reading, however, makes it clear that while most changes were probably made by Tunsted, some represent original writing by Westwyk.[30]

Throughout the text Westwyk is clear about his elucidatory editorial task. For example, where he writes out two versions of the same description of a part of the instrument, he interposes himself: 'Concerning the circle on the first face of the first disc, I found this written in the other book.'[31] Elsewhere he makes his use of a physical Albion instrument explicit, noting 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.'[32] Collating rather than editing, he bracketed the void conclusion, but did not delete it.

In his later *Equatorie of the Planetis* treatise, Westwyk was to show himself attentive to the relationship between the size and accuracy of instruments: the treatise begins by advising the reader that 'the largere that thow makest this instrument … the ner the trowthe of thy conclusiouns'.[33] In his collation of the *Albion* we see him learning the importance of size. 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 he then drew a caret, with the marginal addition 'or 12'.[34] A marginal gloss in an early fifteenth-century hand in another St Albans copy of the *Albion*, which refers in the present tense to 656 divisions in the margin of the spiral disc of 'the abbot's Albion', suggests that the writer had seen Richard of Wallingford's own instrument; the number of divisions suggests that it was probably around 15 inches in diameter.[35] It could well be the same

[29] North, ed., *Richard of Wallingford*, 2: 130; James Clark, 'Intellectual Life at the Abbey of St Albans and the Nature of Monastic Learning in England, *c*.1350–*c*.1440: The Work of Thomas Walsingham in Context' (DPhil thesis, University of Oxford, 1997), 142.
[30] This is also more or less the conclusion drawn by Rand, 'Authorship revisited', 12–13.
[31] Bodl., MS Laud Misc. 657, fol. 21^{r} (my translation).
[32] Ibid., fol. 22^{v} (my translation).
[33] Peterhouse, MS 75.I, fol. 71^{v}.
[34] Bodl., MS Laud Misc. 657, fol. 10^{v}.
[35] Corpus Christi, MS 144, fol. 59^{v}; North, *Richard of Wallingford*, 2: 181.

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instrument studied by Westwyk, who perhaps revised the text to reflect the size of the instrument he was using, before deciding to reinsert Wallingford's original specification. Certainly on the following page access to the instrument made a difference to Westwyk's scribal practice, as he wrote: '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'.[36] Following this is a partially complete diagram; the circles have been traced out, but the scales have not been filled in (Fig. 2; cf. Fig. 1). Manuscripts of the *Albion*, particularly those from St Albans, generally include a high proportion of Richard of Wallingford's diagrams (perhaps reflecting a devotional motivation for their production), unlike many medieval treatises, where copyists were often reluctant to do the geometry, so Westwyk's omission is more significant than it might appear.

On occasions Westwyk's collation of the two versions of the *Albion* tested the limits of his abilities. In one remarkably frank note, he wrote: '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 seem inconsistent.'[37] 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 disentangle their implications or decide which is better.

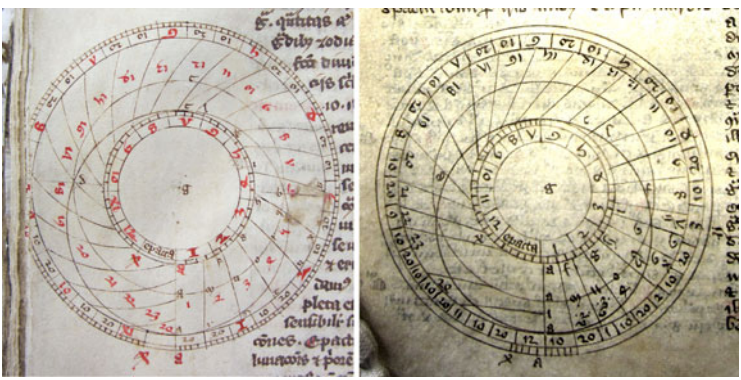
Westwyk's attempts to work out the treatise as he collates it are in general quite successful. However, some mistakes are apparent. Close examination of his diagrams suggests that while he was able to copy simple figures with care and a reasonable level of accuracy, more complex constructions caused 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 the treatise is quite explicit, but a comparison (Figs 3–4) with the best extant version of this diagram, in Corpus Christi MS 144, shows that Westwyk did not follow it effectively. The instructions require that, after completing the inner and outer graduated rings, an eccentric circle is to be drawn touching the outside of the inner graduated ring at the top, and the inside of the outer graduated ring at the bottom; a further concentric circle is then to be drawn, of a medium size such that it

[36] Bodl., MS Laud Misc. 657, fol. 11^{r} (my translation).
[37] Ibid., fol. 45^{r} (my translation). The circle of iomyn (from the Arabic for 'day') was a part of the Albion used to convert between mean and true time.

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Figs 1–2: The first limb of the first face of Richard of Wallingford's Albion. Fig. 1 is a complete diagram of that part of the instrument; John Westwyk explained his choice not to complete this diagram in his copy (Fig. 2). Oxford, Corpus Christi College, MS 144, fol 55^{r}; Bodl., MS Laud Misc. 657, fol 11^{v}. Reproduced by permission of the President and Fellows of Corpus Christi College, Oxford, and the Bodleian Libraries, University of Oxford.



Figs 3–4: The hour lines of lunation on the first face of the first disc of Richard of Wallingford's Albion. The two medium-sized circles should intersect on the horizontal diameter DGB; this has been done successfully in Fig. 3 (left), but in Fig. 4 (John Westwyk's copy) the intersection is clearly too low. Westwyk also did not divide the inner, middle and outer circles evenly into the correct number of parts. Oxford, Corpus Christi College, MS 144, fol 58^{v}; Bodl., MS Laud Misc. 657, fol 15^{v}. Reproduced by permission of the President and Fellows of Corpus Christi College, Oxford, and the Bodleian Libraries, University of Oxford.

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intersects the eccentric circle on the horizontal diameter DGB. This was 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 3 and 4 should make the difference clear).

Westwyk's attempts to learn from the treatise are clearest in the long section he added to the end of it, which draws on a range of diverse sources in Islamic and Jewish astronomy. Wallingford advertised his invention as bringing together the functions of several other instruments, and Westwyk appended a two-page summary of the relationship between those instruments.[38] This is separated from the main treatise and is somewhat disjointed in style, quite different from the earlier text, so it is very likely to be an original addition by Westwyk himself. He first compares the Albion with the saphea of the eleventh-century Andalusian astronomer al-Zarqālī, whom he knew as Arzachel; Wallingford had deliberately not given full details of the saphea since 'it has its own treatise', and it appears Westwyk was hoping to mitigate Richard's omission with some helpful detail from that treatise.[39] He then moves on to the astrolabe, noting a few features common to all astrolabes before exploring some distinctive attributes of the Albion's astrolabe plate. Here his discussion draws on the canonical text attributed to the eighth-century Persian Jewish astronomer Māshā'allāh, which was in the library at St Albans.[40] Finally, after the astrolabe plate, Westwyk focuses his attention on the Albion's rather complex plate for lunar and solar eclipses. Here, too, he draws on his reading of other sources to supplement the *Albion*'s theoretical content. Richard of Wallingford had cited Albategni, the tenth-century Syrian al-Battānī, and Westwyk apparently followed up this citation in order to expand on Wallingford's

[38] Ibid., fols 43^{r}–44^{r}.

[39] Richard of Wallingford, 'Tractatus albionis' 3.36, in North, ed., *Richard of Wallingford*, 1: 380 (my translation).

[40] Collated with Richard of Wallingford's collected works in Bodl., MS Ashmole 1796, fols 40^{v}–55^{v}. Arzachel's tables and canons were also there (now Dublin, Trinity College, 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.

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discussion of lunar eclipses with al-Battānī's explanation of three reasons why the quantity of eclipse varies.[41]

The learning process visible through MS Laud Misc. 657 extends to its mathematical tables. It was unusual for medieval astronomical treatises, especially instrument treatises, to include tables; although tables circulated in enormous quantities and variety, they were normally somewhat independent from texts, and astronomers tended to compile their own sets to suit their individual purposes. The *Albion*, however, did have its own tables, which Richard of Wallingford had drawn up specifically to aid in the construction of the instrument.[42] John Westwyk copied the complete set, with great accuracy: a comparison of a sample table (4.17) in five copies of the *Albion* shows that Westwyk's copy has no scribal errors at all, whereas three of the other four have rather more.[43] His accuracy is remarkable, particularly since the opaque content of tables normally leads to a higher incidence of scribal errors than is found in texts.

Apart from copying them, Westwyk made two important additions to the *Albion* tables. First, he added a table of lunar elongations at the end of the treatise, because, as he explained, 'the Lord Abbot put the mean longitude of the Moon on his spiral; but Master Simon put the elongation of the Moon from the Sun on his spiral … so I wrote this table, so that anyone can make it that way if he likes'.[44] Tunsted's redesign had made Wallingford's original table useless; Westwyk, in contrast, is at pains to make his copy useful, adding a *signe-de-renvoi* so that the new table can be read alongside the original one (where he marked a corresponding sign).[45] Westwyk's statement that 'I wrote' (*scripsi*) the table does not mean that he computed it personally; its inconsistent values suggest that it was derived from

[41] Bodl., MS Laud Misc. 657, fol. 43^{r}. Al-Battānī's *zīj* was translated into Latin twice in the twelfth century; there is no record of his 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: Al-Battānī, *Opus astronomicum*, ed. Carlo Nallino (Milan, 1899), 57–8; Richard of Wallingford, 'Tractatus albionis' 3.24.

[42] Richard of Wallingford, 'Tractatus albionis' 2.10.

[43] Bodl., MS Laud Misc. 657, fol. 42^{r}; Corpus Christi MS 144, fol. 78^{v} (the only other perfect copy); BL, MS Harley 80, fol. 54^{r}; MS Harley 625, fol. 164^{r}; Bodl., MS Ashmole 1796, fol. 159^{r}; see Sebastian L. D. Falk, 'Improving Instruments: Equatoria, Astrolabes, and the Practices of Monastic Astronomy in Late Medieval England' (PhD thesis, University of Cambridge, 2016), 172.

[44] Bodl., MS Laud Misc. 657, fol. 45^{r} (my translation).

[45] Ibid., fol. 39^{v}.

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two pre-existing tables rather than drawn up from scratch. It contains a large number of copying errors, and since, as we have established, Westwyk was normally a very accurate copyist, it was most likely copied from a corrupt exemplar.

However, the second additional table was certainly computed by Westwyk himself. The design of the Albion called for at least one scale of oblique ascensions (the arc of the ecliptic that rises with a given arc of the equator – that is, in a given time), in order to help find the ascendant and divide the astrological houses. The first such scale was to be inscribed in the innermost 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; additional scales could also be inscribed on the plates for other latitudes'.[46] To assist in this, the final table in the *Albion* treatise was a table of oblique ascensions for latitude 51° 50′, the latitude of Oxford. (St Albans was close to the same latitude, which may partially account for the survival of so many books of Oxford astronomy at the abbey.) Westwyk copied that table, but also added another, for latitude 55°; to make his intention clear, he wrote 'tynemuth' [*sic*] just below the table header.[47]

Tynemouth was a dependent house of St Albans. Set on a cliff overlooking the North Sea, and strategically close to the Scottish border, it was in every sense an outpost. Ambitious monks went there to prove themselves (including Thomas de la Mare, who had been prior when elected to the abbacy of the mother house);[48] wayward monks were sent there as punishment.[49] We cannot be sure why Westwyk went, but we know he was there for only three years before joining the ill-fated crusade of the bishop of Norwich to Flanders.[50] In any case, he took MS Laud Misc. 657 with him. Its quality of parchment and (as we have seen) varied sources mean that it was clearly produced at St Albans; but Westwyk's addition of the table for 55° shows that it was intended as a gift for the northern cell: the addition represents an act of charity in distributing the fruits of learning in St Albans to a

[46] Richard of Wallingford, 'Tractatus albionis' 2.18, in North, ed., *Richard of Wallingford*, 1: 324–5.
[47] Bodl., MS Laud Misc. 657, fol. 42^{v}.
[48] Walsingham, *Gesta abbatum*, ed. Riley, 2: 380–1.
[49] Ibid. 1: 258.
[50] Ibid. 2: 416; for the date of Westwyk's arrival at Tynemouth, see Rand, 'Authorship revisited', 7.

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daughter house, but also an act of devotion to the memory and reputation of Richard of Wallingford.

Computing the table required some sophisticated spherical trigonometry. The table header, which Westwyk copied from Wallingford's original, explains that 'it was calculated and composed as explained in the canons in the second book of the *Almagest*'.[51] However, when we deconstruct the tables for 51° 50′ and 55° using modern software, we find that although Wallingford cited Ptolemy's *Almagest*, the most important work of ancient astronomy, as a source, he used a value for the table's crucial underlying parameter – the obliquity of the ecliptic – that was different from Ptolemy's: 23° 33′ 30″, rather than 23° 51′ 20″.[52] Yet Westwyk did use a Ptolemaic value in his calculations. Having no way of knowing what Wallingford had done, he simply followed the lead Wallingford had given in the table header. The great labour of calculation meant that tables like this were far more often copied than computed from scratch; it is therefore rare to find a table for an unusual latitude like Westwyk's. Its production was perhaps in part an act of charity towards the monks of Tynemouth, but it was also undoubtedly an exercise in mathematical learning. His faithfulness to Ptolemy's methods, greater than that of his source, can be seen as a learner's uncertainty about how closely to follow unfamiliar instructions.

In 1393, some thirteen years after his collation of MS Laud Misc. 657, John Westwyk wrote *The Equatorie of the Planetis*, drafting a

[51] Bodl., MS Laud Misc. 657, fol. 42^{v}. In Book 2 of the *Almagest* Ptolemy provided tables of rising times (equivalent to oblique ascensions) for a range of latitudes. These may be computed from the right ascensions (explained in *Almagest* 1.16), which were found by a method mathematically equivalent to the modern formula: $\sin \alpha = \tan \delta \times \cot \varepsilon$, where α is right ascension, δ is declination and ε is the obliquity of the ecliptic (the formula for declination also incorporated obliquity). The size of the obliquity also underlies the ascensional difference γ, for which Ptolemy outlines a method equivalent to the modern formula: $\sin \gamma = \tan \delta \times \tan \varphi$, where φ is the observer's latitude. The oblique ascension can be found by subtracting γ from α: see Olaf Pedersen, *A Survey of the Almagest*, rev. Alexander Jones (New York, 2011), 96–7, 110–13.

[52] The methods of analysis are explained in Seb Falk, 'Copying and Computing Tables in Late Medieval Monasteries', in Matthieu Husson, Clemency Montelle and Benno van Dalen, eds, *Editing and analysing Numerical Tables: Towards a Digital Information System for the History of Astral Sciences*, Ptolemaeus Arabus et Latinus (Turnhout, forthcoming 2019). They are based on Benno van Dalen, 'Ancient and Mediaeval Astronomical Tables: Mathematical Structure and Parameter Values' (PhD thesis, University of Utrecht, 1993), 67, 185.

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description of a planetary instrument he had apparently designed himself and compiling astronomical tables to aid in its use. The *Equatorie* is a thoroughly pedagogical work. Although Westwyk was still himself learning as he wrote it (Seneca's dictum 'while men teach, they learn' may well have been familiar to him), he writes with the authoritative voice of a teacher.[53] His instructions for the construction of the equatorium make use of many of the techniques Chaucer had pioneered in his *Treatise on the Astrolabe*: direct, informal address to the reader, didactic repetition and anticipating a student's misunderstandings. He warns his reader against a mistake that will make the instrument inaccurate, and immediately gives a tip for undoing such a mistake, writing 'yif thow myshappe in this cas i shal teche the a remedie'.[54] The resulting set of instructions is remarkably easy to follow, and can be used to make a fully functioning instrument; this is rarely true of medieval treatises, which often read more like thought experiments.[55] The act of charity implied by the composition (or perhaps translation) of this text in Middle English is matched by Westwyk's earlier devotion to the brothers of Tynemouth, and to the memory of Richard of Wallingford, expressed through his copying of the *Albion* and *Rectangulus* treatises. Yet his production of MS Laud Misc. 657 was also a learning experience. John had probably come to St Albans abbey from the nearby village of Westwick, and although he may have studied at the grammar school sponsored by the abbey, he is unlikely to have gone to university. Nevertheless, in part because of the learning brought by those monks who did attend university, John could have obtained an astronomical education (with or without supervision) through the monastic labour of 'studying, reading, writing, glossing [and] correcting' enjoined by his abbot Thomas de la Mare.

That scholarly labour could certainly include astronomy, embracing not only texts by English monks but also the great works of Islamic and Jewish astronomy. Although recent research has revealed

[53] Seneca, *On Crowds* 7.8, in *Epistles, vol. 1*, transl. Richard Gummere, LCL 75 (Cambridge, MA, 1917), 34. The popularity of Seneca at that time is discussed by Grace Wilson, '"Amonges Othere Wordes Wyse": The Medieval Seneca and the "Canterbury Tales"', *Chaucer Review* 28 (1993), 135–45.

[54] Peterhouse, MS 75.I, fol. 73^{v}.

[55] A virtual model of the equatorie, created by Ben Blundell and Seb Falk following Westwyk's instructions, can be found online at: <https://cudl.lib.cam.ac.uk/view/MS-PETERHOUSE-00075-00001>.

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the hitherto unappreciated range of monastic scholarship, more remains to be done to gain a fuller understanding of their scientific interests; many manuscripts remain unedited and poorly catalogued. Likewise, the networks, outside elite university circles, through which scientific ideas circulated and developed remain largely unmapped. The loss of so many texts, as well as library catalogues and other supporting documents, makes it hard to catch a glimpse of such networks and their processes of communication and learning. Yet with careful reading we can uncover some of their practices. At any rate, we can be sure, despite Richard of Wallingford's concern that through such practices he had 'strayed from the study of pious things', that the theories and methods he helped develop were valued, and learned with devotion and pride, by late medieval monks.[56]

[56] Richard of Wallingford, 'Tractatus albionis' 3.42, in North, ed., *Richard of Wallingford*, 1: 389 (my translation).

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