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‘The Service of Astronomy’: European star-gazing and its implications in the Middle Ages

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Abstract. What follows is an exploration of medieval European astronomy focussing on the twelfth and thirteenth centuries as a period of significant change in terms of technologies and learning largely via the inheritance from Greek and Islamicate astronomical thought through translation into Latin. Robert Grosseteste (c. 1170-1253) is used as a particular focal point for discussion, setting his treatise on astronomy *On the Sphere* in the context of his writing on related topics and those of his contemporaries. Why contemporaries should claim astronomy as the highest of the liberal arts is understood and appreciated through the use of case study and more general reflection - and so too the limits of the discipline.

> *Natural Philosophy needs the service of astronomy more than [it needs] any of the other [arts]; for there are no works belonging to nature and to us – as for instance the planting of plants, the transmutation of minerals, the healing of illness – that may be excluded from the service of astronomy* [1].

The high claim made here for astronomy comes from Robert Grosseteste’s treatise *On the Liberal Arts*, written at the very end of the twelfth century or the very beginning of the thirteenth century. In it Grosseteste explored the importance of the subjects that make up the liberal arts (those of persuasion: grammar, dialectic and rhetoric, and the mathematical: arithmetic, geometry, music and astronomy) to the correction of human error. Music, the science of proportion, was essential for thinking about body (from the human body to the body of the cosmos), but pride of place lay with astronomy, treated last and at greatest length, showing its integration with medicine, alchemy and astrology. Grosseteste, born about 1170, became a reforming Bishop of Lincoln in 1235, a spiritual advisor to Simon de Montfort, a well-known author of works on pastoral care and one of the first generation of Latin western scholars to engage with, absorb and criticise Aristotle’s natural philosophy [2]-[5]. The texts of this corpus were translated to Latin from Greek and from Arabic together with interpretation and commentary from Islamicate thinkers over the course of the twelfth and thirteenth centuries. Most unusually for his period Grosseteste learnt Greek and enjoyed fame as a translator of theological and philosophical works. Later in life he translated from Greek Aristotle’s *On the Heavens* [6], [7].

This paper will return to Grosseteste for a more detailed exposition of medieval astronomy. To contextualise and understand his focus on the subject requires a broader consideration of key developments from preceding generations of scholars and the longer lines of learning crossing cultures from India to Iberia. A useful start can be made with Petrus Alfonsi, born in Aragon, modern-day eastern Spain in about 1062 and brought up in the rich traditions of Islamicate learning. He converted around 1106 from Judaism to Christianity, his godfather being Alfonso I of Aragon [8]-[10]. Petrus Alfonsi moved to northern France, writing energetically to scholars at Paris in about 1106 condemning their preference for older books for astronomical study from Late Antiquity:

This art may only be understood firstly through practice, and similarly no one can master the art without practice. Others, indeed, after they have read Macrobius and others who seem to have laboured in this art, suppose that they may be satisfied with themselves and that they have obtained a full knowledge of this art [11].

Rather than continue in this state of affairs scholars of astronomy should be using more recent Islamicate learning including tables of astronomical data to assist, for example, the calculation of planetary position and sometimes with notes on astronomical instruments. Petrus translated the table of al-Khwarizimi into Latin [8]. During the reign of King Henry I of England Petrus was active as a teacher in the southwest of England in and around Bath. He, his methods and his translated tables held strong influence on a group of scholars in the first quarter of the twelfth century in the Wye and Severn Valley regions. Petrus's career coincided with the beginning of the movement that transformed the practice and theory of medieval astronomy fuelled by major translations made for the most part on the frontiers of Latin Christendom [12]. Within this process there were two principal lines of inheritance for the scholars of Latin Christendom in addition to the existing learning from Late Antiquity. Firstly, ancient Greek astronomy and astrology translated directly to Latin mostly in Constantinople and secondly, the works in these and other subject areas of Islamicate thinkers translated into Latin from Arabic, mostly in the Iberian Peninsula centred around Toledo. The works in Arabic brought not only new conceptual frameworks but also a complex of ideas drawn from ancient Greek thinking although also from India.

1. Transmission, translation and models

It is into this context that the tables of al-Khwarizmi fit alongside a wide variety of other thinkers: al-Farghani and his treatise on the astrolabe, the astrological works of Abu Ma'shar, and Thābit ibn Qurra's extensive reform of the rather complicated mathematical modelling for astronomy of Ptolemy from Roman Egypt (100 – c. 170 CE), one of the foundational figures of ancient and medieval astronomy. This critical reform was continued by Ibn al-Haytham, another figure central to medieval astronomy whose works were mostly received in the West in the thirteenth century. To these should be added perhaps the two best known Islamic philosophers: the Persian Ibn Sīnā (Latinised as Avicenna), notable in this context for his separation of astronomy and astrology, and Ibn Rushd (Latinised as Averroes) from Islamic Spain, whose articulation of the concentric model of the Universe proved popular. Ibn Rushd died only in 1198 CE, whilst his compatriot and fellow-astronomy al-Bitruji died in 1204. Islamicate astronomy and its influence on the Latin West was from a living tradition. Latin astronomy could certainly be seen as a branch of its Islamic inheritance [5].

Common to all ancient and medieval astronomical thinking was a basic understanding that the Universe was divided into two regions: the sub-lunary below the Moon subject to change and corruption, and the super-lunary above the Moon, eternal and subject only to diurnal motion [13] (see figures 1 and 2 for medieval illustrations of this schema). The super-lunary region was composed of spheres related for the most part to the planets and their motions. There were some divergences on how the spheres were to be described. While Plato simply stated that there was an axis of light that supported the super-lunary and sub-lunary when analysing the myth of air in *Timaeus*, Eudoxus (390-340 BCE) conceived twenty seven concentric spheres, building out from the Earth at the centre to the planets on the outside. Aristotle's model, depending on which of his works are used, has forty seven or fifty five spheres; Ptolemy reduced the number further, to forty one. A feature of medieval astronomy was a simplification of these models. Ibn Sīnā preferred nine spheres and although Ibn Rushd insisted on only eight to conform to the number of planets visible, the nine celestial spheres of Dante's *Paradise,* written at the beginning of the fourteenth century, shows the extent to which this model had become standard in Latin Christendom and as figure 1 indicates, a common illustration. A century earlier Grosseteste operated with a system of nine super-lunar spheres associated to Quintessence, Aristotle's Fifth Element (the Firmament, the Primum mobile - the fixed stars, Saturn, Jupiter, Mars, Sun, Venus, Mercury and the

Moon) and then sub-spheres for that below the Moon associated to the elements (Fire, Air, Water and Earth - the last two spheres mingled together).

Figure 1. An image of the cosmos from L'image du monde by Goussouin de Metz-mid 13th century, BN Paris MS Fr. 14964 f. 117. (Used with permission.)

Figure 2. The Earth and planets from a mid-13th century manuscript, probably illustrated in France. Scan by NYPL, Public domain via Wikimedia Commons.

2. Astrolabes and astrology

The transmission of astronomical learning extended to its practical tools as well. Although there was a heavy emphasis on the theoretical and the discussion and testing of older authoritative sources, medieval astronomy did proceed by observation as well. The expansion in capacity to map and measure the heavens physically went hand in glove with the enlargement of astronomical learning from the twelfth century onwards [5]. Most observation prior to the thirteenth century was by the naked eye. Instruments like the planispheric astrolabe (figure 3), the armillary astrolabe and the horary quadrant had entered wider use over the twelfth century from their Islamicate development. With tools like the astrolabe the altitude of celestial bodies could be measured and the latitude and longitude of the stars. Its operation and implications were discussed more systematically in Latin Christendom, from the twelfth century including at the end of the fourteenth century by Geoffrey Chaucer [14]. Astronomical measurement was important in a number of ways. It lay behind the science of the calendar, a discipline known as compotus in the period, especially important to a Christian society where the calculation of the date of Easter was complicated, involving both solar and lunar cycles. Reform of the calendar remained of widespread concern across the Middle Ages and was ultimately unresolved until much later [15].

Accurate astronomy was also important for astrology, a much debated and popular subject in Latin Christendom. While churchmen on the whole took the position of Augustine of Hippo that anything approaching a contradiction of the doctrine of free will was to be condemned and that Christian scholars should not be engage in the practice at all, it is clear that others held different views. In twelfth-century England, for example, astrological prediction was popular as the number of surviving horoscopes demonstrate. Moreover, a concomitant principle of the ancient and medieval universe of the spheres

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with the Earth at the centre was that things above affected things below. The notion that the influence of the celestial spheres was to be felt on Earth and amongst humans was then perfectly rational in its own terms. Astrology and astronomy were to that extent two aspects of the same subject. Ptolemy's treatise on astrology, *Tetrabiblios* or *Quadripartitus* in its Latin translation was equally as consulted as his *Almagest* [4], [16]-[18]. Astrology for natural purposes was acceptable, for the best moment to plant crops, for example or for medical intervention, as Grosseteste's remarks on the service of astronomy quoted earlier underline. Nevertheless, concerns remained about astrology and in the realm of the practical as well as doctrinal. One of the arguments raised by Grosseteste against predictive astrology was that alongside the contradiction of free will it was also an impossible task given the inaccuracy of the tools for observation [5].

Figure 3. An Astrolabe from c.1221 Oxford Museum of the History of Science (Picture: Giles E. M. Gasper).

3. Teaching astronomy

Astronomy, as noted above, was part of the liberal arts, the framework of learning whose articulation in Christendom developed evolved from Roman authorities from Quintilian to Macrobius [4]. The liberal arts did not form a fixed curriculum and different ways of organising the schema were adopted, but as Grosseteste's treatise on the value of the arts shows, pride of place was given to astronomy over the course of the twelfth century. Other and more extensive changes to the organisation of learning were afoot across the same period, for example a shift in some of the quadrivial arts to a distinction between practice and theory as separate areas of study. The sharper focus on Aristotle's natural philosophy from the thirteenth century onwards changed pedagogic priorities again, which took place at the same time as and within newer institutions of higher learning and the emergence of the university. The production of textbooks for the study of astronomy from the same period show its continued importance to learned society. The treatise *On the Sphere* by John Sacrobosco (c.1195-c.1256) is one of the best examples, used well into the seventeenth century and surviving in hundreds of manuscript copies [19]. Grosseteste wrote his own treatise *On the Sphere*, probably between 1216 and 1221 [5]. It is of a more advanced nature than Sacrobosco's but operates with a broadly similar structure. While its immediate audience is difficult to identify it was also popular, surviving in over fifty manuscript copies including some with short diagrammatic sequences. Unlike for Sacrobosco, a much wider range of Grosseteste's other writings survive, allowing a much fuller exploration of this thinking on the place and purpose of astronomy. This wider material includes astrological diagrams, dated to 1215, the reflections on astronomy in his treatise *On the Liberal Arts*, and his majestic discussion of the creation of the Universe in his treatise *On Light* [20].

Grosseteste’s career is not entirely straightforward to map but reveals an active clerical career [2]-[5]. His first entry in the historical record was as a witness to a charter of Hugh, Bishop of Lincoln in the very late 1180s or early 1190s, which implies a birth year of about 1170. His first verifiable position was in the household of William de Vere, Bishop of Hereford from 1195-1199 and thereafter his occasional appearance in charters and legal cases connected to that diocese and Hugh Foliot, Archdeacon and from 1219 Bishop, suggest that Grosseteste was in some way supported by Hugh. Grosseteste’s first benefice came in 1225 at Abbotsley in the diocese of Lincoln, he was appointed as Archdeacon of Leicester in 1229, an office he resigned in 1232, before becoming Bishop of Lincoln in 1235. His connection to university learning is also not entirely clear. He early training in the arts may well have been at Lincoln Cathedral. A connection to Oxford though often assumed and not unlikely is, strictly speaking not demonstrable until the late 1220s and while he may have visited Paris, whose university was the first in medieval Europe, there is no evidence that he taught there or was formally associated with the place. From about 1229 to 1235 he was lector to the Oxford Franciscan house and it is in this capacity that his association with the University can be more firmly suggested [21]. An active and reforming Bishop he embodied the values of two major events in 1215: the decrees of the Fourth Lateran Council and its transformation of pastoral care, and the Magna Carta with its emphasis on good governance, including in its first clause the freedom of the Church. He died in 1253, an important figure in both secular and ecclesiastical political life.

It is from the period between 1195 and 1229 or so that Grosseteste’s sustained engagement with the natural philosophy of Aristotle and its legacy in the Latin, Greek and Islamicate traditions dates. Astronomy was never far from his mind in this context. *On the Sphere* highlights not only the major themes involved in the study of the subject but sets them in a larger conceptual frame with two foundation points in Euclidean geometry and Aristotelian astronomy [5, pp242–78]. Grosseteste was keen to explore the *why* as well as the *how* of the Universe and in this sense is indicative of the ways in which the new learning stimulated Latin scholars. Although it was not to Grosseteste’s purpose in the course of his exploration of these authorities to reconcile divergent views amongst his sources he revealed not only that he knew that Ptolemy's mathematical solutions were not totally reconcilable with Aristotle's physical universe, but also that Thebit had criticised Ptolemy firmly.

As noted, Grosseteste’s *On the Sphere* is not a basic text on astronomy. It includes none of the teaching aids, for example, easily memorable poetic verses, that are to be found in the work of Sacrobosco. The structure of Grosseteste’s treatise moves from a simple question on the sphericity of the Heaven and Earth and demonstrations of how to prove that the Earth is a sphere, to celestial and terrestrial coordinates and thought about the duration of the day with respect to the passage of the Sun. Lest modern readers should forget, in the classical and medieval the Earth lies at the centre of the Universe and is still with the super-lunary spheres rotating around at different speeds. Grosseteste’s *On the Sphere* tackles next the Zodiac, the effects of solar eccentricity, for example on the geography and habitability of the Earth, before moving to a particularly contested question on the trepidation of the equinoxes. The final discussion addresses the issue of the Moon and solar and lunar eclipses, and the treatise ends, somewhat abruptly, at this point.

That a treatise on astronomy should deal with understanding of the climate on Earth illustrates the encompassing nature of the discipline within the medieval period. In addition, in this context the axiom that everything above affects that which is below, that is to say that what occurs in the heavens will have effect on the Earth, plays its part too alongside the notion of the intrinsic wholeness of the Universe. What is experienced on Earth can be used to explore how things happen in the super-lunary realm, a mode of explanation that Grosseteste used in his discussion of comets. The habitability of the Earth is a regular feature of astronomical writing; in this sense Grosseteste’s *On the Sphere* is, once more, exemplary of more general interests, as well as the arena for his own particular thinking. Medieval scholars followed their authoritative sources that the northern and southern hemispheres were best conceived as consisting of climes or climates, seven according to Ptolemy, from the frozen polar regions to the heat of the equator. There was general agreement too that only the northern hemisphere of the Earth was habitable, a subject to which Grosseteste devoted some considerable time.

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Medieval astronomical treatises were often illustrated and in quite particular ways. A very common image was a representation of the spheres of the Universe in hemispherical form. Diagrams of a more technical nature were also included. This is the case for Sacrobosco's text and also in a more limited way for Grosseteste's *On the Sphere*. There are four well illustrated versions of the treatise with illustrations inserted at key points for explanation [5]. A good example is to be found in the discussion of the Sun and the Moon, their qualities (the Moon is a shadowy body which has no light except from the Sun), and their movements and eclipses. Whether the diagrams were part of the original authorial conception or whether added in later copies, perhaps to explain difficult parts of the text and their visualisation, is an interesting though largely unanswerable question. As in figure 4, similar sets of illustrations are common across the medieval period.

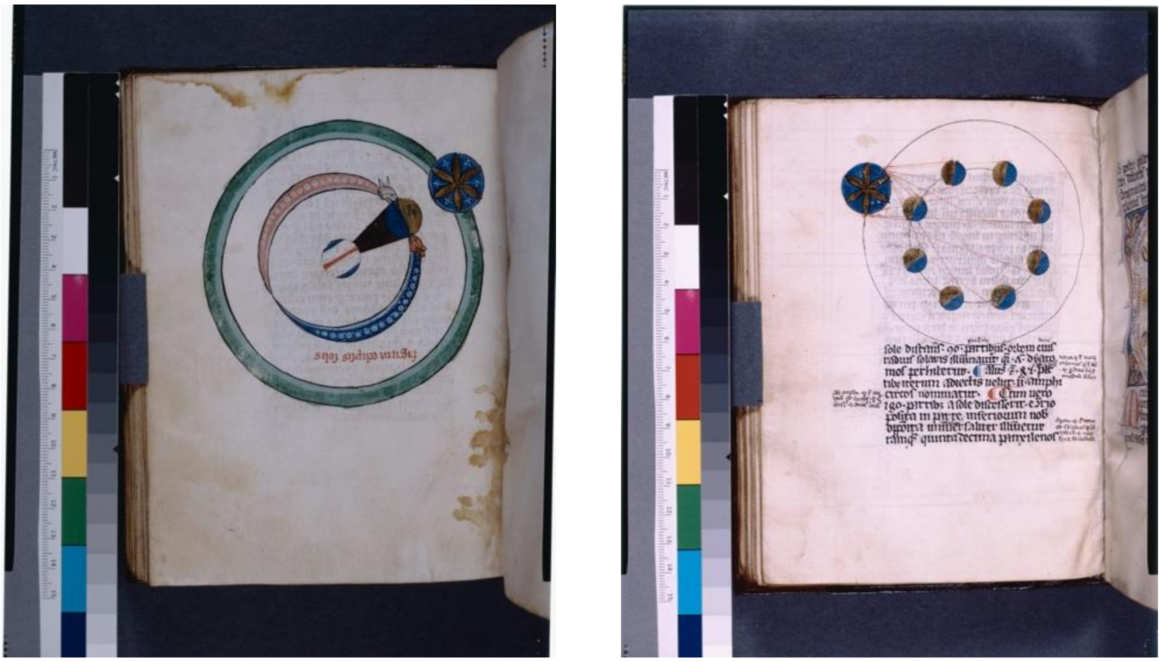

Figure 4. Diagrams of a solar eclipse and the orbit of the Sun from a mid-13th century manuscript, probably illustrated in France. (Scan by NYPL, Public domain via Wikimedia Commons.)

Phenomena that might seem easily identifiable as astronomical to modern understanding were not always so. Comets are such. Within the ancient and medieval periods comets rather than a celestial or wholly celestial occurrence, rather had to be a meteorological one [22]. Since they were by their nature changeable and intermittent, they could not belong to the celestial spheres, in which region there was nothing intermittent or changeable. Therefore, they had to be a phenomenon of the sub-lunary world which was characterised by instability, alteration and decay. Grosseteste devoted a separate treatise to comets and how best they might be conceived, probably written in about 1223 in relation to a reappearance of Halley's Comet (although it is quite difficult sometimes to define whether medieval observation was about supernovae or comets themselves) [23]. Grosseteste first explored notions of longstanding as to the composition, direction and behaviour of comets, pointing out in each case the flaws in the propositions put forward. In his own explanation he argued by analogy from what could be observed on Earth and by extrapolation to what might then be expected in the heavens. Planetary influence was assumed over the material of the comet and extended also to the character of the phenomenon; Grosseteste and his contemporaries attributed to comets distinctively astrological roles, more often than not as the harbingers of disaster especially to rulers, as for example the appearance of Halley's Comet in the build-up to the Norman invasion of England and the death of Harold Godwinson at the Battle of Hastings.

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4. The World Machine: Contextualising astronomy

Medieval astronomy, observational and theoretical, and in its close relation to astrology, medicine and the other mathematical arts of geometry, music and arithmetic, should be seen in the context of the larger conceptual frameworks, cosmological and cosmogonical, on the nature and origin of the Universe and the nature of things. The Christian view on this was uncompromisingly different to the Aristotelian. While for the latter the Universe had no beginning and no end, for the Christian the act of divine creation came *ex nihilo* – out of nothing – and creation will come to a certain end. While authoritative sources were to be respected, they could not contradict Christian truths with the authority of scripture. A fascinating example of how thinking about the physical universe through Plato, Aristotle, Ptolemy and their later commentators and critics could be placed within a Christian framework is Grosseteste's treatise *On Light*, written in about 1225 and so within the period in which astronomy was one of his primary interests. *On Light* deals with the question of body, of matter and form, of shape and dynamic, and Grosseteste focussed on the largest body he could imagine, the Universe or the 'world-machine' in his own terminology. He gave the primary role to light. Light was that which could replicate itself instantaneously.

'*Light… at the beginning of time, extended matter (which it could not leave), drawing it out along with itself into a mass the size of the world-machine*' [20], The World Machine, therefore, has a beginning and it will have an end, and it begins from a single point of light that expands into a sphere reaching its maximum extension. What happens then is that a different form of light compresses matter inside the World Machine to create the celestial spheres which Grosseteste was trying to explain:

…as a necessary consequence of this extension, the outermost parts of matter are more extended and more rarefied than those within, which are closer to the centre. And since the outermost parts will be rarefied to the highest degree, the inner parts will have the possibility of further rarefaction. [20]

This light from the inside of the edge of the Universe pushed matter into the centre until it too reached a point of maximum extension. That created the second sphere and so on until one got to the Moon below which this process broke down. The matter could not be shifted to its end point and this is why there was the unstable realm below the Moon consisting of the four elemental spheres, fire, air and water and earth mingled together, the latter another acknowledgement of the description of the world in the creation story in the first chapter of Genesis. Grosseteste explored arithmetical models, creating finite sequences by dividing two sequences of infinite numbers, to explain the instantaneous propagation of light and created a a homage to ancient cosmology worked through Ptolemaic astronomy. A strong resonance of Plato at the end is accompanied by Aristotelian explanations for the nature of things and all in a fundamentally Christian compass.

Imagination, correctly used, was the key to this exercise for Grosseteste and medieval scholars more widely. Being able to imagine properly involved the capacity to fix something in the mind's eye without letting it become distorted, to make it real and not fantastical. Again, this is an aspect of imagination not always familiar to the modern understanding of the word. It was a mode of thinking that Grosseteste characterised in his first treatise, *On the Liberal Arts* written around 1195 or a little later, *aspectus* - the mind's eye, needing to align to *affectus* – desire. The liberal arts were a primary aid in this context for the correction of human error [4]. Where *aspectus* and *affectus* are not aligned error will occur and in his later commentary on the six days of creation written around 1235 Grosseteste highlighted an astronomical example concerning Aristotle and other ancient astronomers on the issue of the creation of the Universe in a moment of time:

This made them imagine before any given time, another time; just as the fantasy imagines a place outside any given place, and a space outside any given space, and so on to infinity. To cleanse oneself of this error, then, one can only cleanse the affection of one's mind of its love of temporal things, so that the glance of the mind, untouched by images, can go beyond time and grasp the simplicity of eternity, in which there is no extension of before and after, and from which all time and every before and every after proceed [24].

The key to astronomy and for Grosseteste and his contemporaries its challenge was to know exactly what was being seen and this involved the alignment of observation (historic and reported as well as contemporary), learning from the rich and expanding corpus of sources available and experience. The service of astronomy for the thinkers of Latin Christendom was essential, the crucible for calendrical calculation and the construction of the Christian year, and an essential framework for understanding the Universe and the place of the habitable world within.

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