An Alfonsine Universe: Nicolò Conti and Georg Peurbach on the Threefold Motion of the Fixed Stars

Alfonsine astronomy and the ten-sphere model of the 'medieval cosmos'

Few, if any, diagrammatic representations of the pre-modern view of the cosmos have been replicated and commented on as frequently as the celestial spheres in Peter Apian's *Cosmographicus liber*, first printed in 1524 in the Bavarian town of Landshut. In Apian's presentation of the heavens, there are three mobile spheres (or orbs) located between the sphere of Saturn and the immobile empyrean heaven. These are (i) the eighth sphere, which represents the visible firmament or sphere of the fixed stars; (ii) the ninth sphere or crystalline heaven above the firmament; and (iii) the tenth sphere or *primum mobile*. Of these three spheres, the one that poses the biggest challenge to the modern interpreter is the crystalline ninth sphere, the purpose of which is not spelled out too clearly in the diagram.

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Fig. 1: Peter Apian, *Cosmographicus liber* (Landshut, 1524), p. 6

The general idea of a crystalline orb was rooted in medieval biblical exegesis. As a clever way of handling Scripture's allusion to waters located above the firmament (Genesis 1:6–7), some Christian authors had imagined these waters to exist in a stable, crystalline state, which made it possible to integrate them in a cosmos composed of solid (though not necessarily 'hard') spheres.[1] Yet Apian also hinted at another function of the ninth sphere, by endowing it with zodiacal signs whose boundaries are displaced in relation to the signs depicted on the *primum mobile*. The obvious explanation for this displacement would be that the ninth sphere is subject to precession—a slow and steady revolution from west to east about the poles of

[1] Grant, 1987, pp. 160–164; Grant, 1994, pp. 320–323.

the ecliptic that accounts for observed changes in stellar longitude and declination. Another important clue comes from two small circles featured next to the beginnings of the signs of Aries and Libra in the same crystalline ninth sphere. According to Apian's own words, these circles were meant to represent the "motion of access and recess of the fixed stars" located below in the eighth sphere.[2] The famous diagram hence made provisions for a widely debated (and occasionally maligned) theory of the motion of the fixed stars that Latin Christian authors regarded as the invention of Thābit ibn Qurra, the ninth-century Sabian mathematician.[3]

Rather than having the sphere of fixed stars undergo regular precession, as proposed by Ptolemy in antiquity, the access-and-recess model located its centres of motion on the celestial equator, more specifically at two points where the equator intersects with a fixed mean ecliptic projected onto the ninth sphere. Each of these points was imagined to serve as a centre for the slow circular motion of a reference star (defined as 0° Aries and 0° Libra) located on the mobile ecliptic of the eighth sphere, with the result that the mobile ecliptic continuously shifted its obliquity and position relative to the fixed ecliptic. One consequence of these shifts was that the increase of stellar ecliptic longitude varied over time, making it possible to reconcile the stellar observations recorded by Ptolemy, which seemed to document a precession rate of 1°/100y, with those made later by Arabic astronomers such as

[2] Apian, 1524, pp. 4–5: "Mox sequitur firmamentum: et quod stellifera sphera est: quaeque in duobus parvis circulis circa principia arietis et librae nonae sphaerae trepidat: et iste motus apud astro<nomos>: motus accessus et recessus stellarum fixarum appellatur."

[3] In reality, the origins of this theory appear to lie in eleventh-century al-Andalus. See Samsó, 1992, pp. 220–222, 225, 239–240; Ragep, 1993, II, pp. 400–408; Samsó and Berrani, 1999, p. 297; Comes, 2001, pp. 293–296; Forcada, 2017, pp. 275–281.

al-Battānī, who assumed a much swifter rate of 1°/66y.[4] In Apian's arrangement of the heavenly spheres, this access-and-recess motion is a motion proper to the sphere of fixed stars, whereas the ninth sphere above it accounts for Ptolemy's linear motion of precession, which is capable of making the constellations go full circle relative to the equinoxes.[5] Finally, the tenth sphere imparts to both these spheres and all others below it a swift westward motion around the north and south celestial poles, which accounts for the diurnal revolution of the heavens.

In light of the post-Ptolemaic origin of the access-and-recess theory, assertions that Apian's woodcut confronts us with the 'Ptolemaic universe', or even with the 'medieval cosmos' *tout court*, must obviously be taken with a pinch of salt.[6] Far from representing a doctrine espoused by scholars throughout the Middle Ages, the specific interplay of spheres assumed in the *Cosmographicus liber* can be traced back to Georg Peurbach's *Theoricae novae planetarum*, which Apian himself was to edit and print in 1528.[7] According to the evidence of the earliest manuscripts,[8] this massively influential astronomical textbook was completed on 30 August 1454 at Vienna's *Bürgerschule*, where it presumably served as the basis for public lectures. It concluded with a section on precession, in which Peurbach

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[4] The model has been described numerous times in the literature. See, e.g., Dobrzycki, 1965, pp. 22–30; Evans, 1998, pp. 274–279; Nothaft, 2017, pp. 213–216.

[5] This was already recognized by Evans, 1998, p. 280.

[6] Contrary to the labels used in Dick, 1982, p. 15; Dekker, 2007, p. 137; Grant, 1996, p. 365; Grant, 2010, pp. 141–145.

[7] Peurbach, 1528. According to Zinner, 1990, p. 22, the text went through a total of 56 printed editions between 1472 and 1653.

[8] See Malpangotto, 2012, pp. 344–357, discussing MSS Vienna, Österreichische Nationalbibliothek, 5203, fols. 2r–24r; Vienna, Österreichische Nationalbibliothek, 5245, fols. 1r–26v; Heiligenkreuz, Stiftsbibliothek, 302, fols. 40r–60v.

postulated that the heads of Aries and Libra on the eighth sphere not only traced out small circles on the concave surface of ninth sphere, but that the centres of these circles were themselves mobile, as the ninth sphere underwent precession relative to the tenth sphere or *primum mobile*.[9]

Although Peurbach did not expressly say so, there can be no doubt that this model of precession was rooted in an attempt to make physical and kinematic sense of the Alfonsine Tables, which had been the principal supplier of parameters for European astronomers since the 1320s. One peculiar and notorious feature of these tables was their inclusion of a "mean motion of the apogees and fixed stars" (*medius motus augium et stellarum fixarum*) in addition to a set of tables for the access and recess of the eighth sphere (*motus accessus et recessus octave sphere*). By implication, the fixed stars were assumed to undergo a double motion that combined linear precession as envisioned by Ptolemy with the variable motion traditionally ascribed to Thābit ibn Qurra.[10] The earliest known author to refer to this two-pronged model as a feature of the Alfonsine Tables is Taddeo da Parma, who mentioned the doctrine of "those who composed the tables of King Alfonso" in his *Expositio* of the old pre-Peurbachian *Theorica planetarum* completed at the University of Bologna on 12 July 1318.[11]

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[9] See MS Vienna, Österreichische Nationalbibliothek, 5203, fols. 21v–24r. For an English translation of the chapter on the eighth sphere, see Aiton, 1987, pp. 36–40. For a German paraphrase, see Gerl, 1989, pp. 276–280.

[10] See the relevant tables in Poulle, 1984, pp. 131–133, and the discussions in Dobrzycki, 1965, pp. 34–39; Samsó, 1984, pp. 87–109; North, 1996, pp. 462–469.

[11] MS Venice, Biblioteca Nazionale Marciana, Fondo antico lat. Z. 340, fol. 78v: "Alii vero, sicut fuerunt compositores tabularum regis Alfunsi, tenuerunt viam mediam dicentes auges dupliciter moveri, uno modo ad motum octave spere et ut sic moventur continue ab oriente in occidentem, alio modo moveri ipsas dicuntur motu proprio; et ut sic moventur motu accessionis et recessus, aliquando versus orientem, aliquando versus occidentem."

Another early reference appears in Jean des Murs's *Expositio intentionis regis Alfonsii circa tabulas eius* (1321), where we are told that Alfonso X, King of Castile and León

> conceived of a twofold motion in the eighth sphere, one being a continuous mean motion in the direction of the signs, which he attributed to the fixed stars in the eighth [sphere] and the apogees of the eccentric planets, the second being through an access and recess at the intersection of the zodiac and the celestial equator. [...] The reason Alfonso calls [the latter] motion the "motion of the eighth sphere" is not because the stars are outside the eighth sphere, but in order to distinguish and differentiate between the aforementioned motions.[12]

On the evidence of this passage, Jean des Murs thought of both motions as intrinsic features of the eighth sphere, which explains why there is no talk anywhere in his *Expositio* of raising the total number of spheres from nine to ten. Generally speaking, late medieval astronomers had good reasons to eschew drawing any physical conclusions from the tables in front of them, which apparently had not been cast with any coherent underlying model in mind.[13] The resulting problems come to the surface in the account provided in 1454 by Peurbach, who had to admit that the assumed precessional shift of the centres of the small circles governing the access-and-recess entailed a disjunction between the equinox calculated on the basis of the Alfonsine Tables, on the one hand, and what might be called the 'physical' equinox, on the

[12] Poulle, 1980, p. 258: "Ymaginatur Alfonsius motum duplicem in 8ª spera, unum continuum equalem secundum successionem signorum quem attribuit stellis fixis in 8ª et augibus ecentricorum planetarum, secundum per accessum et recessum ad intersectionem zodiaci et equinoctialis [...]; igitur hunc motum vocat Alfonsius motum 8ᵉ spere non quod stelle fixe sunt extra 8am speram sed ratione distinctionis et diversitatis motuum predictorum".

[13] For late medieval criticisms of the Alfonsine 'model', see Nothaft, 2017, pp. 227–235.

other. Simply put, the Sun in Peurbach's model was capable of crossing the celestial equator several days before or after it arrived at 0° Aries or 0° Libra of the tenth sphere or *primum mobile*. The available tables only accounted for the latter type of longitude, leaving contemporary astronomers with a number of unanswered questions as to how Peurbach's model could made computationally viable.[14]

The problems raised by the *Theoricae novae* are not without historical significance considering that a satisfactory solution to them became available only when Nicholas Copernicus transferred the multiple motions of the eighth sphere to the axis of the Earth. For this reason alone, fifteenth-century attempts at interpreting the Alfonsine Tables in physical terms deserve to be included in the larger story leading from ancient and medieval geocentrism to the geokinetic paradigm of modern astronomy.[15] The purpose of this article is to offer new insights into the origins of Peurbach's take on Alfonsine precession, which may be regarded as the most influential physical precession model of the century prior to the publication of Copernicus's *De revolutionibus orbium coelestium* (1534). I shall argue below that this model was not an original invention on Georg Peurbach's part. Instead, he owed its essential features to a work by the Paduan astrologer and nobleman Nicolò Conti (*Nicolaus Comes de Comitibus*, d. 1468),[16] whom he had met on a trip to Italy. Conti's work, a short treatise *De triplici motu octave spere* written in 1450, has not received much attention from historians of science since the brief summary Lynn Thorndike devoted to it in 1934.[17] In what

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[14] For the relevant passage in the *Theoricae novae* see MS Vienna, Österreichische Nationalbibliothek, 5203, fol. 23r–v, and the translation in Aiton, 1987, pp. 38–39. See also the discussions of Peurbach's model in Dobrzycki, 1965, pp. 40–42; Dobrzycki, 1983, pp. 64–66; Swerdlow, 1990, pp. 179–183.

[15] The debate triggered by the *Theoricae novae*'s precession model in the first half of the sixteenth century is sketched in Dobrzycki, 1965, pp. 42–56; Lerner & Segonds, 2015, pp. 110–120.

[16] For biographical data, see de Ferrari, 1983.

[17] Thorndike, 1923–58, IV, pp. 250–252.

follows, I shall attempt a fresh analysis of Conti's text, focussing in particular on its presentation of the motion of the eighth sphere in the shape of two original diagrams. The appearance of nearly identical diagrams in the *Theoricae novae* provides good grounds for arguing that Peurbach drew the outlines of his model from Conti. Besides highlighting similarities between the two texts, I shall adduce evidence of personal ties between Conti and Peurbach, which help explain how the model in question was transmitted from Padua to Vienna. In a separate section of this article, I shall draw attention to passages in Conti's treatise that point to an astrological impetus behind his attempt to endow the standard astronomical tables with a sound physical model. As we shall see, Conti here followed a line of thought previously explored by two influential Italian astronomer-astrologers, Pietro d'Abano and Giovanni Bianchini, who both had regarded the motion of the eighth sphere as an agent and regulator of historical change.

An Italian prelude to Peurbach's "Theoricae novae"

Nicolò Conti's *De triplici motu octave spere*[18] is a short treatise of approximately 2900 words. It survives in at least five manuscripts ranging from *c.*1463 to the early sixteenth century, to which I shall refer by the following sigla:

A Arras, Bibliothèque municipale, 688 (748), fols. 66r–69r. From the library of Saint-Vaast Abbey (Arras). Copied by Conrad Schoulter of Rotenburg *c.*1463 (fol. 55v).[19]

[18] This is the title used in the heading of *Vβ*, a copy made by Lorenzo Bonincontri. The only other manuscripts to furnish the text with a title are *F* (*De motu accessu et recessu* and *Tractatus de accessu et recessu motus octave spere*) and *Vi* (*Opusculum de motu accessu et recessu*).

[19] *Catalogue général*, 1872, pp. 274–275; Thorndike, 1950b, p. 325.

F Florence, Biblioteca Medicea Laurenziana, Ashburnham 208 (134, 140), pp. 407–417. Unidentified Italian hand, s. $XV^{2/2}$. Previous owners: Bartholomeus Cherubinus; Federico Delfino (1477–1547, professor of mathematics in Padua).[20]

Vα Vatican City, Biblioteca Apostolica Vaticana, Barb. lat. 256, fols. 90r–95v. Unidentified Italian hand, s. XV/XVI. Previous owner: Carlo di Tommaso Strozzi (1587–1670).[21]

Vβ Vatican City, Biblioteca Apostolica Vaticana, lat. 3379, fols. 1r–4v. Copied by Lorenzo Bonincontri of San Miniato (1410–*c.*1491), s. $XV^{2/2}$.[22]

Vi Vicenza, Biblioteca Civica Bertoliana, 208 (132), fols. 258r–265v. Copied by Bartolomeo da Valdezocco of Padua *c.*1470 (fol. 256r).[23]

Copies *AFVαVi* preface the main text with a letter of dedication signed on 9 November 1450 in the town of Monselice, 12 miles south of Padua, where Conti lived and died in 1468. The letter addresses, in a heavily adulatory fashion, the famous condottiere Domenico Malatesta (also known as Malatesta Novello, 1418–1465), who was then ruler of Cesena and soon-to-be founder of the Biblioteca Malatestiana (erected 1447–1452). We learn from it that the work had been occasioned by a learned dispute in Malatesta's presence between Conti and a certain Abbot John from England, who rejected Conti's claim that one needed to postulate the existence of a ninth and tenth sphere above the sphere of fixed stars. At the time of the

[20] Paoli, 1891, pp. 221–223.

[21] Silverstein, 1957, pp. 71–72; Federici Vescovini, 1998, p. 294.

[22] Heilen, 1999, pp. 23–31, 43–46, 157–159; Juste, 2018b. This manuscript is available online at https://digi.vatlib.it/view/MSS_Vat.lat.3379 [accessed 26 October 2018].

[23] Pesenti Marangon, 1978, pp. 88–93; Giovè Marchioli, Granata, & Pantarotto, 2007, pp. 59–60; Juste, 2018a.

discussion, Conti had considered it wise to concede rhetorical ground to his opponent, but now he felt at liberty to reveal to Malatesta the details and rationale behind his stance, by sending him a little treatise he had put together over the course of several nights.[24] The treatise that follows this pronouncement was at its most fundamental level an attempt to add a physical dimension to the computational rules of the Alfonsine Tables, which to Conti's mind were a faithful reflection of observable reality. This much is clear from his opening statement, which treats the precession and access-and-recess components employed in the standard tables as if they were separate motions actually discernible in the heavens.

> That there are three spheres above the seven planetary spheres is something I detect as follows. For it appears to me [*video namque*] that the sphere of fixed stars moves with a threefold motion: one is a diurnal motion going at a uniform speed from east to west; another is an oblique motion of return that goes in the opposite direction, from west to east; the third is a motion of access and recess that wavers now eastward, now southward, now westward, now northward.[25]

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[24] *Vα*, fol. 90r: "Cum autem, uti nosci, ultra octavam speram nonam et decimam ponendas assererem quibusdamque approbarem rationibus, visum est mihi excellenti humanitati tue sermo ille pergratus reddi, quamquam reverendissimus in Christo pater, dominus Iohannes, abbas Anglicus non minus scientia quam religione et morum gravitate venerandus, id negandum diiudicaret. Visum est mihi pro illo tunc aliqualiter cedendum sermonibus suis fore, quoniam sub dubio sepius respondent periti [...]. Item tamen itemque considerans virtutem esse veritatem elucidare hoc opusculum continuis vigiliis confectum si [*ms.* sed] quando mihi otii pars aliquanta fuit tue excelse dominationi dicare proposui."

[25] Ibid., fol. 90v: "Tres esse speras supra speras septem planetarum taliter deprehendo. Video namque speram stellarum fixarum triplici motu moveri, uno scilicet motu diurno ab oriente sumente cursum suum semper uniformem in occidentem; alio scilicet motu reversionis per obliquum huic opposito, que tendit ab occidente in orientem; tertio motu accessus et recessus quo trepidat nunc in orientem, nunc in meridiem, nunc in occidentem, nunc in septemtrionem."

Astronomical observation in a stricter sense entered his treatise only briefly, in a passage comparing the longitude of Regulus (αLeo) as recorded in Ptolemy's star catalogue (122;30°) with the longitude (141;42°) supposedly found in the here and now with the aid of an armillary sphere.[26] The stated longitudinal increase of 19;12° comes suspiciously close to the result a contemporary astronomer could obtain if he took the combined precession and access-and-recess equation for the 198 years from the *radix* of the Alfonsine Tables (AD 1252) to the present year 1450 (2;2°) and added it to the Alfonsine version of Ptolemy's catalogue, which increased all stellar longitudes in the original catalogue by +17;8°.[27] This method would have given Regulus's current longitude as 122;30° + 17;8° + 2;2° = 141;40°, just 2 arc minutes below Conti's result.[28] By contrast, an accurate observation for January 1450 would have placed Regulus at 142;11°.

In his effort to match a physical model to the Alfonsine Tables, Conti based himself on the well-established assumption that any sphere could by nature only be endowed with a

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[26] *Vα*, fol. 92r: "Hoc idem etiam experientia manifestatur antiquis observationibus suppositis esse veris. Nam cor Leonis tempore Ptolomei erat in 2 gr. 30 min. Leonis. Nunc autem ipsum armillis reperimus in 21 gr. 42 min. Leonis. Videtur ergo a tempore Ptolomei hucusque motum esse secundum successionem zodiaci gr. 19 et 12 min." Conti treats the size of this elongation as evidence that the fixed stars are subject to precession in addition to access and recess.

[27] The star catalogue in question would have been available to Conti as part of an adaptation of the Alfonsine Tables made by his Paduan predecessor Prosdocimo de' Beldomandi. See Chabás, 2007, pp. 276–279.

[28] One may compare the star catalogue in MS *A*, fol. 20r–v, which is dated 1455 and places Regulus at 4s 21;43°, using a constant of +19;13° relative to Ptolemy's catalogue.

single mover and, hence, a single motion around a single set of poles.[29] If a sphere exhibited several motions, the conclusion to draw from this was that all motions but one accrued to it from the spheres above it. Once it was accepted that the diurnal motion was transmitted downwards from the uppermost sphere, the only remaining task was to decide which of the other two motions inherent in the fixed stars—i.e., precession and access-and-recess—was proper to the eighth sphere, where the stars resided. The other one was then automatically attributable to the ninth sphere separating the fixed stars from the *primum mobile*. An informative testimony to the currency of this general view in the first half of the fifteenth century can be gleaned from an anonymous *Tractatus introductorius in totam astronomiam speculativam* datable to 1414, the only known copy of which is kept at the National Library in Vienna. In addressing the motion of the fixed stars, the author of this treatise offers some brief comments on the changes that had affected astronomical theory over the centuries. According to his potted history, Ptolemy and his Arabic populariser al-Farghānī had both attributed to the eighth sphere an eastward motion of 1° per century, adding above it the ninth sphere as *primum mobile*.[30] He also knew about the access-and-recess model attributed to Thābit, but was unaware that it had originally been there to replace, rather than to supplement Ptolemy's theory of precession. To modern astronomers and natural philosophers he attributed the opinion

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[29] *Vα*, fol. 90v: "Cum ergo non videatur conveniens eandem speram super diversis polis eque primo posse moveri diversis motibus ab uno vel pluribus motoribus eque immediate appropriatis, relinquitur duos illorum motuum inesse sibi tamquam accidentes."

[30] See the anonymous *Tractatus introductorius in totam astronomiam speculativam* in MS Vienna, Österreichische Nationalbibliothek, 5247, fols. 1r–47v, at fol. 5v. The surviving copy only contains the first five of what were originally eighteen chapters. The present year is given as 1414 on fol. 43v.

> that the ninth sphere is not the first mobile, but that there is a tenth sphere above it, which is the first mobile. And they hypothesize that the tenth sphere moves with a single motion from east to west about the poles of the world and that this motion moves with it all the lower spheres. The ninth sphere, by contrast, moves with the motion of access and recess as its proper motion and transmits an analogous motion down to the eighth sphere, whereas the eighth sphere moves from west to east about the poles of the zodiac, by one degree every 100 years, and transmits an analogous motion down to the spheres of the planets.[31]

The mentioned arrangement of spheres, where access-and-recess motion is an intrinsic feature of the ninth sphere, owed some of its popularity to Albert of Saxony, who endorsed it in his *Quaestiones* on Aristotle's *De caelo* written during his time as an Arts master at the University of Paris in the 1350s.[32] One of Albert's successors at the Arts faculty was Pierre d'Ailly, who not only taught the same view, but already classified it as the *communis opinio*

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[31] Vienna, Österreichische Nationalbibliothek, 5247, fol. 6r: "Posteriores vero astronomi, scilicet Thebit et plures alii experti sunt speram octavam preter predictos duo motus adhuc moveri tertio, qui vocatur 'motus accessus et recessus' [...]. Et propter hoc plures moderni astronomi et philosophi naturales dicunt nonam speram non esse primum mobile, sed quod ultra eam sit decima spera, que sit primum mobile. Et ymaginantur quod decima spera moveatur uno motu ab oriente in occidentem super polis mundi et quod isto motu movet secum omnes speras inferiores. Nona autem spera movetur motu accessus et recessus tamquam motu sibi proprio et consimilem motum producit in octavam speram, sed octava spera movetur ab occidente in orientem super polis zodiaci in 100 annis uno gradu et consimilem motum producit in speris planetarum, que eciam omnes moventur propriis motibus ab occidente in orientem, licet non omnes equali velocitate, ut dictum est."

[32] Albert of Saxony, *Quaestiones in Aristotelis de caelo*, bk. 2, q. 6 (ed. Patar, 2008, pp. 271–276). Albert's opinion according to which the sphere of fixed stars is moved by three separate motions can be traced back further to Albertus Magnus, *De caelo et mundo*, bk. 2, tr. 3, c. 11 (ed. Hossfeld, 1971, pp. 166–167). See Duhem, 1913–1959, III, pp. 337–344, 382; Price, 2012, pp. 424–429.

among contemporary astronomers.[33] Pierre's colleague Marsilius of Inghen later carried the doctrine in question from Paris to the University of Heidelberg, whose co-founder he became in 1386.[34] Given Albert of Saxony's role in founding the University of Vienna (he became its first rector in 1365), it is not surprising to find traces of the same doctrine in the aforementioned *Tractatus* of 1414, which presumably originated in a Viennese context.

That these various scholastic writers all felt the need to accept the simultaneous reality of Ptolemy's precession and pseudo-Thābit's access-and-recess theory can almost certainly be viewed as a reflection of the dominant role that the Alfonsine Tables played in contemporary astronomy. At the same time, however, one is struck by the fact that neither Albert of Saxony nor his aforementioned successors took any explicit recourse to these tables in their argument. In line with this neglect they all treat Ptolemy's linear precession as a motion proper to the eighth rather than the ninth sphere and give its rate as 1° per century instead of the Alfonsine value of 1° in *c.*136 years. Things are different in the case of Nicolò Conti, who made a visible effort to create a model that would fit the specific indications given by the tables of King Alfonso, even as he retained the Ptolemaic rate of precession for the sake of simplicity.[35] As Conti himself repeatedly indicates, his goal was to provide a

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[33] See question no. 2 in d'Ailly, 1531, fol. 149r–v. The text is likely to have written between 1368, when d'Ailly became an Arts master, and 1376, when he wrote his Sentences commentary, indicating that he had moved on to theology.

[34] Marsilius of Inghen, 1501, I, fol. 242v (bk. 2, q. 10). See Duhem, 1913–59, IV, pp. 166–167.

[35] *Vα*, fol. 92r–v: "Oportet igitur hos duos circulos parvos, in quorum circumferentiis capita Arietis et Libre spere stellate circumvolvunt, in concavitate none spere locatos ymaginari circa duo puncta dyametraliter opposita, que puncta continue et semper directe sub ecliptica decime spere ab occidente in orientem uniformiter moveantur, que erit motus augium et stellarum fixarum in centum annis uno gradu fere." Peurbach later made sure to work with nothing but Alfonsine parameters, stating that the ninth sphere moved at a rate of 1;28° every 200 years, with a total period of revolution of 49,000 years. See Aiton, 1987, pp. 37–38.

physical model capable of saving “the calculations and operational method of the tables of the eighth sphere” or, indeed, “the rationale behind the calculations involving the tables for the motion of the eighth sphere.”[36] If this stance was taken seriously, the roles of the eighth and ninth spheres had to be reversed. After all, the Alfonsine Tables referred to the access-and-recess motion as a feature of the eighth sphere, which contradicted the philosophers’ habit of placing it in the ninth sphere.

Conti was well aware that this re-arrangement of the celestial spheres made it necessary to abandon a crucial element of the traditional access-and-recess theory, according to which the heads of Aries and Libra in the eighth sphere (♈$_8$ and ♎$_8$) always revolved around the equivalent points of the zodiac of the *primum mobile*, which were located on the celestial equator. In Conti’s system, the points in question were no longer fixed. Instead, they moved along with the ninth sphere, meaning that they could take on any longitude relative to the fixed ecliptic. This displacement had a number of theoretical consequences, one of which concerned the definition of the so-called “equation of the eighth sphere.” In classical access-and-recess theory (as associated with pseudo-Thābit), this “equation” was equal to the distance τ on the mobile ecliptic of the eighth sphere between ♈$_8$ and the vernal point (or ♎$_8$ and the autumn equinox). The standard way of calculating τ was to use a table based on the relation $\sin \tau = \sin \tau_{max} \times \sin \theta$, where θ is the arc of motion of ♈$_8$ on the small circle and $\tau_{max} = \pm 10;45°$. The Alfonsine Tables maintained the structure of these tables, but lowered τ_{max} from ±10;45° to ±9°.

<insert Fig. 2 here>

[36] *Vα*, fol. 92v: “Nam tantum secundum hanc ymaginationem et secundum nullam aliam, quamvis multe alie et diverse sint, possumus calculationes et modum operis tabularum octave spere salvare.” Ibid., fol. 95r: “Patet igitur quomodo secundum hanc ymaginationem contra philosophiam naturalem inconvenientia nulla sequuntur et quod tabularum de motu octave spere rationes calculationum salvantur.”

Fig. 2: Conti's diagram for the equation of the eighth sphere

Conti realized that the equation had to be reinterpreted in order to make it fit a model where the centre of the small circle moved along the ecliptic of the ninth sphere. He expressed this reinterpretation in the form of a diagram placed at the end of his treatise (Fig. 2),[37] which depicts the fixed ecliptic of the ninth sphere as an arc ACB, where point A indicates the fixed location of ♈$_{10}$ (i.e., the point where the fixed ecliptic intersects with the celestial equator) and C the current location of ♈$_{9}$. The latter point is also the centre of the small circle describing the path of ♈$_{8}$. It intersects the fixed ecliptic at K and M. In calculating the longitudes of the fixed stars and apogees relative to this fixed ecliptic, astronomers working with the Alfonsine Tables had to combine two components. One was a linear term represented in the diagram by arc AC, while the other corresponded to τ. According to Conti's model, τ was going to be 0° whenever ♈$_{8}$ was at L or D, in which case ♈$_{8}$ came to lie on a great circle passing from the ecliptic pole, E, through C. In his treatise, Conti argued that this had been the situation close to the time of Christ's birth, whereas by the present year 1450 ♈$_{8}$ had advanced from D to F. A great circle drawn from E through F intersected the fixed ecliptic at G, such that CG was equal to τ. Conti hence ended up defining τ as an arc on the ecliptic determined by two great circles through the poles of the fixed zodiac, of which one went through ♈$_{9}$ and the other through ♈$_{8}$.[38]

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[37] *A*, fol. 69r (diagram turned on its head); *F*, p. 417; *Vα*, fol. 94v (diagram turned on its head); *Vβ*, fol. 3v; *Vi*, fol. 265v.

[38] *Vα*, fols. 94v–95r: "Nunc ergo nostris temporibus ivit in medietatem circuli orientalem. Ponamus itaque quod sit supra F. Duco circulum magnum per polos zodiaci et F secantem eclipticam primi mobilis in G. Dico quod arcus DF est motus accessus et recessus et est arcus circuli parvi interceptus inter duos circulos magnos ductos per polos zodiaci, quorum unus transit per centrum circuli et alter per principium Arietis octave spere. Arcus

One consequence of this newly formed understanding of τ was that its maximum value ended up being identical with the radius of the small circle. This conclusion did not harmonize with the classical access-and-recess theory, where $\tau_{max} = \pm 10;45°$ whereas the radius of the small circle was defined as 4;18,43°. However, since the Alfonsine Tables only provided tables for τ without specifying the underlying model, it was perfectly possible to apply the Alfonsine value for τ_{max} (±9°) to the radius of the circle without overt contradiction of the source material. That said, Conti dropped no hint that his re-interpretation of τ also changed the mathematical relation involved in computing it, as was later noticed by Johannes Regiomontanus.[39]

Conti's claim that τ = 0° at or close to the time of Christ's birth is in agreement with the Alfonsine Tables, where the mean motion of the eighth sphere reaches the appropriate point in its cycle in May of AD 16.[40] It appears that he owed his knowledge of this esoteric fact to his colleague and contemporary Giovanni Bianchini (d. 1469), whom he referred to as "the most erudite among mathematicians."[41] In *c.*1442 Bianchini had completed a new set of astronomical tables dedicated to his patron Leonello d'Este, Marquis of Ferrara, which maintained the basic parameters of the Alfonsine Tables while making a number of significant changes to their format and layout. Examples of these changes include Bianchini's *Tabula motus augium communium*, which combined the two motions of the apogees and

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autem CG dicitur 'equatio octave spere' et est arcus ecliptice interceptus inter duos circulos magnos iam dictos, que equatio nulla est dum fuerit caput Arietis aut in D aut in L, maxima autem cum fuerit in K vel in M".

[39] See Regiomontanus, 1557, sig. F5r–v (no. 54), and Gerl, 1989, pp. 275–276. According to Dobrzycki, 1965, p. 41, the correct relation in the Conti-Peurbach model is $\tan \tau = \tan 9° \sin \vartheta$ (as opposed to $\sin \tau = \sin 9° \sin \vartheta$).

[40] Mercier, 1977, pp. 58–59.

[41] *Vα*, fol. 94v: "Modicum autem post nativitatem Christi erat caput Arietis octave spere in D secundum quod etiam ille eruditissimus mathematicorum Iohannes Blanchinus in ratione compositionum suarum tabularum determinavit."

fixed stars into a single term tracking the increase in apogeal longitude over a period of 49,000 years.[42] As Bianchini noted in the accompanying set of canons, the *radix* for this table was 17 May AD 16, at which $\tau = 0°$ in the Alfonsine access-and-recess tables.[43] From the way Bianchini turned this date into the starting point not just for a period of access and recess (7000 years), but for the entire 49,000-year period it took for $♈_9$ to go full circle in relation to $♈_{10}$, a user such as Conti could draw the additional inference that 17 May AD 16 had also been the moment when $♈_9$ and $♈_{10}$ occupied one and the same place. He accordingly wrote that $♈_9$ had been found at point A of his diagram near the birth of Christ.[44] Though important from the vantage point of his proposed model, this conclusion was not supported by the Alfonsine Tables in their standard form, in which the *motus augium et stellarum fixarum* was no more than a measure of the increase of the elongation between $♈_9$ and $♈_{10}$ over time, without any indication as to when this elongation reached 0°. Conti's evident familiarity with Bianchini's tables enabled him to close this knowledge gap and complete the physical model in this regard.

When Peurbach finished his *Theoricae novae planetarum* in 1454, he presented a theory of the motion of the eighth sphere and its concomitant equation that was in all essential details the same as that found in *De triplici motu octave spere*. That this doctrinal resemblance was not a matter of serendipity can be seen rather clearly from the diagram Peurbach included to elucidate this particular aspect of his model (Fig. 3), which replicates the structural outlines of Conti's diagram. Peurbach's version merely added a line from Conti's point A representing $♈_{10}$ to the centre of the world (*centrum mundi*), which was a

[42] Bianchini, 1495, sigs. a2r–a6v. For discussion see Chabás & Goldstein, 2009, pp. 28–35.

[43] Bianchini, 1495, sig. A4v.

[44] *Vα*, fol. 94v: "Tempore igitur Christi punctus C erat sub A, sed nunc nostris temporibus recessit C ab A secundum continuitatem signorum."

simple way of highlighting the fact that the corresponding point on the ecliptic intersected with the celestial equator. Since Peurbach did not include any description of this diagram in the main text of the *Theoricae novae*, he could omit the point labels that had characterized Conti's version.

<insert Fig. 3 here>

Fig. 3: Diagram for the equation of the eighth sphere in Peurbach's *Theoricae novae planetarum*, MS Vienna, Österreichische Nationalbibliothek, 5203, fol. 23v

A similarly revealing comparison can be gleaned from the other diagram Nicolò Conti included and described in his *De triplici motu octave spere*. In it he depicted the relation between the motions of ♈$_8$ and ♎$_8$ on their small circles and the concomitant shifts that the heads of Cancer and Capricorn (♋$_8$ and ♑$_8$) undergo in relation to the ninth sphere. In Fig. 4 below,[45] the small circles FHKM and EIGL must be imagined to lie in a plane perpendicular to the drawing itself, while lines HTG, BTA, and MTL all represent great circles on the surface of a hemisphere. Of these lines, BTA coincides with the fixed ecliptic, whereas HTG and MTL indicate the maximum deviations the ecliptic of the eighth sphere will reach relative to this mean position during a full cycle of access and recess. Now, if circle FHKM is travelled by ♎$_8$ and EGIL by ♈$_8$, such that ♈$_8$ is at 0° whenever ♎$_8$ is at 180° and *vice versa*, then ♋$_8$, which is 90° removed from either point, will necessarily oscillate between points O and N. The point marked by T indicates a mean position where ♋$_8$ = ♋$_9$, which is reached whenever ♈$_8$ arrives at L or G, such that the corresponding position of ♎$_8$ will be at M or H and ♋$_8$ comes to lie in the middle of the great circle BTA.

<insert Fig. 4 here>

Fig. 4: Conti's diagram for the motion of ♋$_8$

[45] See the drawings of this diagram in *A*, fol. 68r; *F*, p. 414; *Vα*, fol. 94r; *Vβ*, fol. 2v; *Vi*, fol. 263v.

Peurbach's *Theoricae novae* offer a diagram that is structurally identical to the one just described, although it again features no letters of the alphabet to serve as point labels. As seen from Fig. 5, Peurbach made one important addition in the shape of a figure-eight drawn around the centre of the diagram (point T in Conti's version), whose contours are bounded by the diagonal lines HTM and LTG. This shape describes the path taken by ♋$_8$ over a complete cycle of access and recess, thereby highlighting the fact that in between the extremes indicated in Conti's diagram—when ♈$_8$ and ♎$_8$ reach 0°, 90°, 180° or 270°—♋$_8$ will stray outside line BTA. Peurbach draws attention to this point by writing that it was necessary for "the heads of Cancer and Capricorn of the eighth sphere to traverse sort of conical figures having for a base curved lines on both sides of the heads of Cancer and Capricorn of the ninth."[46] This remark follows the logic of Conti's diagram, which differs from pseudo-Thābit's access-and-recess model in the way it defines the position of ♋$_8$. In the classical model ♋$_8$ and ♑$_8$ (which is not shown here) are by definition the two points where the mobile ecliptic of the eighth and the fixed ecliptic of the ninth sphere intersect.[47] This definition entails that ♋$_8$ will always slide along the fixed ecliptic without incurring any changes in latitude. Conti makes this assumption explicit when writing that "the heads of Cancer and Capricorn of the eighth sphere are never separated from the surface of the ecliptic of the ninth, but adhere to it inseparably in perpetuity."[48] Yet his diagram told a different

[46] MS Vienna, Österreichische Nationalbibliothek, 5203, fol. 22v: "Capita vera Cancri et Capricorni octave spere quasi figuras conoidales habentes pro basi lineas curvas utrinque a capitibus Cancri et Capricorni none recedendo peragere necesse est." I here follow an unpublished English translation of the text by Noel Swerdlow.

[47] ps.-Thābit, *De motu octave spere*, ed. Carmody, 1960, pp. 104–105 (§27–29). See also the English translation in Neugebauer, 1962, pp. 294–295.

[48] *Vα*, fol. 94r: "Et quomodo capita Cancri et Capricorni octave spere numquam separantur a superficie ecliptice none, sed sibi inseparabiliter continue adherent."

story, insofar as its geometry suggested that ♋$_8$ was on the ecliptic of the ninth sphere only at the mentioned points O, T, and N. Peurbach noticed the discrepancy and modified Conti's diagram by drawing the figure-eight that resulted for the position of ♋$_8$ from the intermediary positions of ♈$_8$ and ♎$_8$.

<insert Fig. 5 here>

Fig. 5: Conti's first diagram in Peurbach's *Theoricae novae planetarum*, MS Vienna, Österreichische Nationalbibliothek, 5203, fol. 22r

There is, as far as I am aware, no precedent for either of these diagrams in earlier Latin works discussing the access and recess of the eighth sphere, whether they be the widely copied treatise *De motu octave spere* attributed to Thābit ibn Qurra or alternative sources such as the detailed account of the same theory in Campanus of Novara's *Compotus maior* (1269).[49] In striking contrast to these and other works, Conti and Peurbach both offered an interpretation of the access and recess of the eighth sphere in which the centres of the small circles carrying ♈$_8$ and ♎$_8$ precess along the ecliptic of the ninth sphere, while the maximum equation of the eighth sphere (τ_{max}) is regarded as being equal to the radius of these circles. Simple as the two diagrams may look, the originality of the underlying model hence leaves no viable alternative to assuming that Conti's *De triplici motu* and Peurbach's *Theoricae novae* are somehow closely connected. Personal ties between the two astronomers are indeed documented by the owner's note on the final page of a northern Italian manuscript of Haly Abenragel's *De iudiciis astrorum* written in the first half of the fifteenth century, which informs us that Georg Ulrich of Peurbach received the book as a gift "from the eminent and

[49] Campanus of Novara, 1518, fols. 162rb–164va (ch. 10). The printed edition omits the diagram that belonged to this chapter. See, e.g., MSS Florence, Biblioteca Riccardiana, 885, fol. 265v; Oxford, Bodleian Library, Digby 215, fol. 74v; Oxford, Bodleian Library, Rawlinson C.117, fol. 14v.

noble Lord Nicolò Conti of the Contis."[50] The Latin form of Conti's name used here is *Nicolaus comes de comitibus*, which is the way it also appears in the colophon of witness *F* to *De triplici motu*.

A possible explanation for how Conti and Peurbach first became acquainted with each other is provided by Johannes Regiomontanus's famous oration in praise of mathematics and astronomy, which he delivered at the University of Padua in 1464.[51] In the course of his encomium, Regiomontanus briefly mentioned Nicolò Conti as one of astronomy's most recent luminaries,[52] presumably because he was a famous son of Padua. Prior to this reference he had already reminded his audience that Georg Peurbach once "publicly taught astronomy in this highly celebrated city."[53] Our timeline of Peurbach's career is not detailed enough to allow us to date this Paduan sojourn with any confidence. The idea that he departed for Italy as early as 1448, as voiced in some of the literature,[54] rests on the unsubstantiated claim that Martin Król, an astronomer from Kraków, made Peurbach's acquaintance when travelling in Italy at that approximate time.[55] A significantly later date

[50] MS Vienna, Österreichische Nationalbibliothek, 2429, fol. 93r: "Iste liber est mei, Georgii Udalrici de Peurbach, donatus michi per magnificum et nobilem dominum Nicolaum comitem de comitibus." See on this manuscript and Peurbach's ownership of it: Pfändtner, 2007, pp. 123, 133.

[51] On the background to this lecture, see Swerdlow, 1993; Byrne, 2006.

[52] See the critical edition in Malpangotto, 2008, p. 144, ll. 463–465: "Fama postremo clarissima Domini Nicolai de Comitibus et aliorum secularium virorum dignitatem studii nostri comprobare solet."

[53] Malpangotto, 2008, p. 139, ll. 244–246, 250–251: "Quocirca post plurimos nationis nostrae insignissimos astrorum contemplatores, te tandem Georgi de Peurbach, Germanorum perenne decus appellare iubeor, [...] qui olim in urbe hac praeclarissima astronomiam publice docuisti".

[54] Großmann, 1929, pp. 235–236; Grössing, 1983, p. 80; Samhaber, 2000, pp. 9, 43.

[55] See Morawski, 1900, 2:297; Barycz, 1953, p. 723, and the scepticism rightly expressed by Knoll, 2016, p. 382.

emerges from Peurbach's correspondence with the Viennese court astrologer Johann Nihil. In a letter its nineteenth-century editor tentatively dated to 1454, Nihil alludes to Peurbach's financial difficulties and announces his intention to write to a certain Count Nicholas "so that he sends a messenger with money, because I do not see that the matter can be expedited any other way, or that he deposits money in Venice with the agent of some merchant."[56] The passage might indicate that Peurbach was staying in the Veneto at the time, yet the identification of Count Nicholas with Nicolò Conti is as uncertain as Ernst Zinner's suggestion that it was Conti who invited the Viennese astronomer to come to Padua.[57] What may speak in favour of this identification is a letter Peurbach wrote to Nihil in 1456. In it he alludes to an astrological judgment a certain *dominus Nicolaus* had written for the comet seen that year.[58] Although no such judgment seems to survive under Nicolò Conti's name, the comet itself would receive repeated mentions in an astro-meteorological work he composed in 1466 for his son Naimerio.[59] There is, then, good reason to conclude that Peurbach

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[56] Czerny, 1888, p. 293: "Pro domino Nicolao in dies diligenciam faciam exactam, sed ingratas facit moras protonotarius ille. [...] Dum videro expedicionem literarum, evestigio sibi scribam, ut nunccium mittat cum pecunia, quia non video per alium modum posse rem expediri, vel quod deponat pecuniam in Veneciis circa famulum alicujus mercatoris etc." In a previous letter (Czerny, 1888, p. 291), Nihil writes about his intention to send an almanac to *dominus comes Nicolaus*, who appears to be the same individual.

[57] Zinner, 1990, p. 21; Samhaber, 2000, p. 74.

[58] Czerny, 1888, pp. 302–303: "Judicium cometis domini Nicolai nondum habeo, id tamen habiturus prope diem sum, quod ad vos mittam."

[59] Thorndike, 1923–58, IV, p. 254. The work in question survives in MSS London, University College, lat. 16, fols. 43ra–69va; Oxford, Bodleian Library, Laud. Misc. 535, fols. 1r–67r; Paris, Bibliothèque nationale de France, n.a.l. 901, fols. 177r–305v; Venice, Biblioteca Nazionale Marciana, VIII.78 (a. 229, l. 168) (96 fols.); Vienna, Österreichische Nationalbibliothek, 5215 (63 fols.).

remained in contact with his Italian colleague after returning from his stint in Padua, which likely ended after 1450 and hence after Conti composed *De triplici motu*.

It remains to discuss the direction of the flow of information between Conti and Peurbach: who originated the precession model depicted in the two diagrams and who merely adopted it from his colleague? From a chronological point of view, the answer may seem clear: *De triplici motu* was completed no later than 9 November 1450 and hence close to four years before Peurbach finished his *Theoricae novae*, the earliest version of which is dated to the end of August 1454. Yet this state of affairs still leaves us with the possibility that Peurbach had developed the model describing the eighth and ninth spheres several years in advance of his *Theoricae novae* and that it was him who communicated these ideas to Conti, presumably on the aforementioned visit to Italy. This scenario, if true, would turn Conti's work into a rather odd case of literary camouflage. After all, it is the latter who in the preface and the opening paragraphs of *De triplici motu* presents the model he is about to discuss as a novelty, one that requires detailed exposition and justification. Nowhere in his treatise does he drop any hint that this exposition depended on somebody else's work, even though he is otherwise happy to credit Giovanni Bianchini for specifying the last date at which $\tau = 0°$.[60] In striking contrast to the terse matter-of-fact treatment the model would receive four years later in Peurbach's *Theoricae novae*, Conti built the case for his understanding of Alfonsine precession from the ground up, starting with the necessary order of the three spheres responsible for the composite motion of the fixed stars before specifying the relevant geometrical and computational aspects with the aid of two diagrams. The more original of the two was no doubt that represented by Fig. 2, which effectively established a new definition of the equation of the eighth sphere compared to that in the classical model of pseudo-Thābit.

[60] See n. 41.

Conti introduced the concomitant diagram with the confidence of someone who regarded himself as its inventor:

> Now, in order to ensure we grasp this more easily based on the operational principles of the tables for the motion of the eighth sphere, and in order to declare their principles in the manner of those who comment on the tables, I draw myself [*facio michi*] the ecliptic of the first mobile as a line from A to B.[61]

Peurbach's account carried no such pretensions to originality, whether overt or implicit. Although the *Theoricae novae*'s earliest manuscripts place four different diagrams in the margins of this account, none of them receive any mention or explanation in the main text. In one particularly revealing instance, Peurbach appears to be following the exposition of Fig. 2 in *De triplici motu,* but where the latter text speaks of points on the surface of the small circle LMDK, the *Theoricae novae* replaces them with the equivalent degree positions. Similar to Conti, Peurbach notes that τ is zero when the mean motion of access and recess (i.e., the position of $♈_8$ on the small circle) is at 0° or 180° (points D and L) and that it reaches its maximum of 9° when the mean motion is at 90° or 270° (points K and M). His words overlap briefly with those in *De triplici motu* when he goes on to add that τ is positive as long as the mean motion of access and recess is < 180° and negative where it is > 180°.

Conti, *De triplici motu octave spere*:[62]	Peurbach, *Theoricae novae planetarum*:[63]

[61] *Vα*, fol. 94v: "Ut autem per rationes operum tabularum motum octave spere id facilius comprehendamus et ipsarum rationes more tabularum expositorum assignemus [*ms.* assignamus], facio michi eclipticam primi mobilis lineam AB".

[62] Ibid., fols. 94v–95r.

[63] MS Vienna, Österreichische Nationalbibliothek, 5203, fol. 24r.

Arcus autem CG dicitur “equatio octave spere” et est arcus ecliptice interceptus inter duos circulos magnos iam dictos, que equatio nulla est dum fuerit caput Arietis aut in D aut in L, maxima autem cum fuerit in K vel in M, addenda quidem in K, minuenda in M, et ipsa addenda continue crescit capite Arietis transeunte per quartam DK, deinde per quartam KL decrescit. Post vero minuenda per quartam LM continue crescit, deinde per quartam MD decrescit. Propterea dicunt tabuliste si *motus accessus et recessus fuerit minor semicirculo addenda est equatio octave spere* cum motu augium et stellarum fixarum, si vero *maior*, *minuenda* est, et quod exit addendum super radices augium.	Equatio autem octave spere est arcus ecliptice none spere centrum parvi circuli et circulum magnum a polos ecliptice none per caput Arietis octave transeuntem interiacens. Cum igitur medius motus accessus et recessus nichil fuerit aut semicirculus, nulla sit dicta equatio, sed si 90 gradus aut 270 fuerit, ipsa erit maxima. Cum autem talis *motus accessus et recessus fuerit semicirculo minor*, *equatio* erit semper *addenda*, sed cum *maior* fuerit, erit *minuenda*.

Here and elsewhere, Peurbach’s verbal depiction of the motions of the eighth sphere offered no more than the basic outlines of the model described in *De triplici motu*, although he did make sure to spell out certain consequences that had received no attention in Conti’s work. Besides noting the conical figures traced out by ♋$_{8}$ and ♑$_{8}$,[64] he also drew attention to the fundamental theoretical disconnect between the equinoxes and solstices predicted by this

[64] See n. 46.

model and those one could actually obtain from the Alfonsine Tables.[65] There is no reason, however, why Peurbach could not have come to these conclusions from reading somebody else's account of the same model. Perhaps the best evidence that Peurbach had such an account before him and that it was none other than Nicolò Conti's *De triplici motu* is contained in his statement that the proper motion of the eighth sphere "is called the motion of trepidation [*motus trepidationis*] or access and recess [*accessus et recessus*] of the eighth sphere."[66] Peurbach's use of the verb *vocatur* ("is called") here seems to imply that the expression *motus trepidationis* as a synonym for *accessus et recessus* had already been introduced by others before him. As far as I am aware, the only text prior to the *Theoricae novae* to use *trepidatio* ("trembling" or "wavering") in this particular way is *De triplici motu*, where terms such as *trepidare*, *trepidatio*, and *motus trepidationis* are deployed to describe the unsteady, multidirectional motion performed by the eighth sphere.[67] Given the absence of this term from earlier works such as pseudo-Thābit's *De motu octave spere*, it seems reasonable to conclude that, when modern scholars speak of the "theory of trepidation" in their writings, they are using a neologism first coined by Nicolò Conti in 1450 and popularized a few years later by Peurbach in his *Theoricae novae planetarum*.

[65] See n. 14.

[66] MS Vienna, Österreichische Nationalbibliothek, 5203, fols. 22r: "Tercius autem est sibi proprius qui motus trepidationis vocatur sive accessus et recessus octave spere."

[67] See, e.g., *Va*, fols. 92v: "Ut autem facilius motus huiusmodi trepidationis intelligi queat, describam circulum orizontis" etc. Ibid., fol. 93v: "Ex hac ergo descriptione satis apparet modus trepidationis accessus et recessus octave spere et quomodo principia Arietis, Cancri, Libre et Capricorni octave spere nunc antecedunt ea none spere, nunc subsequuntur." See also n. 25 above and n. 68 below.

The fixed stars as agents of historical change

Nicolò Conti's declared attempt to save the appearances with regard to the computational method of the Alfonsine Tables was limited to the motions of the apogees and fixed stars and accordingly paid no particular attention to the planetary spheres below the fixed stars, even though the latter were normally imagined to move along with the eighth sphere. One important theoretical consequence of the transmission of the eight sphere's irregular access-and-recess motion down to the sphere of the Sun would have been noticeable variations in the length of the tropical year, which remained unaddressed in Conti's treatise, presumably because they were not reflected in the computational rules of the Alfonsine Tables. Another consequence were rather large variations in the obliquity of the mobile ecliptic of the eighth sphere (with a maximum equal to $\tau_{max} = 9°$), which again were not part of the framework of Alfonsine astronomy. Conti introduced the issue as follows:

> There is nevertheless one thing about this model that strikes some people as unsuitable, namely that the fixed stars change their latitudes from the ecliptic of the first mobile. This is indeed a consequence [of the model], as is obvious to anyone who understands the aforementioned motion, and I do not consider it to be unsuitable in the sense that it goes against Ptolemy's position. For if one accepts the motion of trepidation, which Ptolemy did not know about, a change in latitudes follows by necessity. For there does not appear to be any way by which we can save the principles of the tables and assume a motion of access and recess such that the latitudes would perpetually remain the same without variation. For if there were such a way, I believe human ingenuity would have committed something about it in writing. It is nevertheless true that the stars according to this model change their

> latitudes in different ways, for those closer to the heads of Aries and Libra do so more, whereas those [closer to] the beginnings of Cancer and Capricorn do so less.[68]

Although Conti does not mention any of the critics he is responding to by name, it is possible to identify at least a few astronomers who had singled out changes in stellar latitude as a reason to reject the idea that the eighth sphere moved in accordance with the theory of access and recess. The known examples range from Jean de Lignères's *Theorica planetarum*, which originated in 1335, presumably at the University of Paris,[69] to Heinrich Selder's *Canones* on the Alfonsine Tables written in 1365.[70] Selder's assertions that the stars maintained a constant ecliptic latitude and that the theory of access and recess had to be rejected were excerpted into a *Correctio tabularum Alphonsi* that appears in two sixteenth-century printed

[68] *Vα*, fol. 95r–v: "Unum tamen quibusdam videtur hec ymaginatio inconveniens adducere, scilicet stellas fixas suas latitudines ab ecliptica primi mobilis permutare, quod revera sequitur, ut manifeste quilibet intelligens motum predictum perpendit, nec ipsum inconveniens esse reputo, eo quod sit contra positionem Ptolomei. Nam posito motu trepidationis quem Ptolomeus ignorabat necesse est sequi latitudinum variationem. Nullus enim apparet esse modus quo salvaremus rationes tabularum et quod posito motum accessus et recessus latitudines invariabiliter eedem in sempiternum permanerent. Si enim modus talis esset, credo quod humanum ingenium aliquid eius scriptitiasset. Verum tamen est quod differenter stelle suas latitudines secundum hanc ymaginationem mutant, nam plus hee que capitibus Arietis et Libre magis appropinquant, minus vero que principiis Cancri et Capricorni."

[69] MS Paris, Bibliothèque nationale de France, lat. 7281, fols. 163r–172r, at fol. 166v. See Nothaft, 2017, pp. 228, 230.

[70] MS Erfurt, Universitäts- und Forschungsbibliothek, Amplon. fol. 37, fol. 76vb (3.15): "Sed latitudo earundem est arcus eiusdem circuli interceptus inter eclipticam et corporis ipsius stelle, que latitudo est sempiterne invariabilitatis, quia motus accessus et recessus salva reverentia ponentium eum prorsus est negandus." Ibid., fol. 77r (3.16): "Et ponam ibidem motum octave spere secundum modum quem hic teneo cum reprobatione Thebith et omnium aliorum ponentium motum accessus et recessus." See Nothaft, 2017, p. 234.

editions of the collected works of Nicholas of Cusa.[71] What makes this *Correctio* particularly intriguing is its inclusion, in the part immediately preceding Selder's critique, of references to dates in the 1420s. This raises the possibility that the excerpts constituting the text were made by Nicholas of Cusa himself during his years of studying canon law at the University of Padua (1417/18–1423).[72]

On a conventional understanding of the access-and-recess theory, the predicted changes in stellar latitude were unobservable, as they only concerned the relation between the fixed stars and the fixed ecliptic of the ninth and tenth spheres, which did not correspond to the actual path of the Sun. Conti recognized this when writing that the objection concerned changes in latitude "from the ecliptic of the first mobile" (*ab ecliptica primi mobilis*). Not only did he regard the notion that the fixed stars changed their latitude relative to this fixed ecliptic as unproblematic but he saw in it one of the chief virtues of the entire model. Far from invalidating the model implicit in the Alfonsine Tables and the tables of Giovanni Bianchini, he argued these changes played a valid and important in the world machine. Concluding his treatise, Conti wrote:

> I, however, consider this to be suitable rather than unsuitable. For who is in doubt that the regulation of things below requires a variation of latitudes, so that they receive the influences coming from the stars sometimes more orthogonally and sometimes more obliquely? The same opinion seems to have been held by Peter of Padua, according to

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[71] Nicholas of Cusa, 1565, 2:1173, where the two statements cited in n. 70 are reproduced back to back. The same text was already printed in Nicholas of Cusa, 1514, II, fols. 29v–32v, but no manuscript has been identified to date. It primarily consists of excerpts from a critique of the Alfonsine Tables written in Paris in 1347. See Nothaft, 2015.

[72] See on this point North, 1977, p. 289. On Nicholas of Cusa's Paduan sojourn, see Federici Vescovini, 2002; Müller, 2013, pp. 60–77.

> whose theory the zodiac of the eighth sphere will at one point be 48 degrees removed from the zodiac of the first mobile, such that according to him the stars also change their latitudes relative to the ecliptic by about 48 degrees. Yet what his theory [predicts] has not yet been experienced, nor is it in tune with our tables for the motions of the eighth sphere. It hence appears that one will have to leave it behind rather than follow it.[73]

What Conti had in mind here were the extensive comments on the motion of the eighth sphere his Paduan compatriot Pietro d'Abano (d. 1315/16) had recorded in 1310 in a separate *Tractatus de motu octavae spherae* as well as in some parts of his *Lucidator dubitabilium astronomiae*.[74] His understanding of d'Abano's sometimes rather obscurely worded thoughts

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[73] *Vα*, fol. 95v: "Ego autem istud magis conveniens quam inconveniens puto. Inferiorum enim ordinationem talem requirere latitudinum variationem quis ambigit, ut influentias a stellis quandoque rectius incidentes, quandoque plus oblique suscipiant, prout etiam velle videtur Petrus Paduanensis, secundum cuius ymaginationem zodiacus octave spere aliquando a zodiaco primi mobilis quasi 48 gradus distabit, unde stelle secundum eum latitudines suas respectu ecliptice diurne quasi 48 gradus etiam permutabunt? De eius tamen ymaginatione nondum aliquid expertum est nec consona nostria tabulis motuum octave spere. Idoe nobis relinquenda magis quam insequenda fore videtur." See also ibid., fols. 91v–92r: "Et ille zodiacus stellatus maneat in eadem maxima declinatione ab equatore motus primi determinata a natura secundum exigentiam dispositionum inferiorum, aliis tamen partibus zodiaci stellati secundum magis et minus declinationibus, ut talium ymaginum radii influentiales quandoque magis perpendiculares, quandoque minus perpendiculares sint super regionem habitabilem secundum inferiorum ordinationem et necessitatem."

[74] Pietro d'Abano, *Lucidator dubitabilium astronomiae* (2.2–3) and *Tractatus de motu octavae spherae*, ed. Federici Vescovini, 1992, pp. 173–191, 347–365. The *Tractatus de motu octavae spherae* precedes Conti's work in *A* (fols. 60r–65v) and follows it in *Vα* (fols. 103r–114v). For further discussion of d'Abano's views on the motion of the eighth sphere, see Paschetto, 1984, pp. 287–294; de Callataÿ, 1996, pp. 174–181; Seller, 2009, pp. 142–195.

on the matter was not perfect, as seen from his criticizing d'Abano for claiming that the eighth sphere could move up to 48° in latitude relative to the ninth sphere. When d'Abano spoke of a motion in latitude in his *Tractatus* he was really referring to changes in declination relative to the celestial equator, which were a necessary and observable result of precession. The amplitude of this motion was of course twice the maximum declination of the Sun, which is why d'Abano claimed that it was 47;42° according to Ptolemy (2 × 23;51°) and 47;6° according to more recent astronomers (2 × 23;33°).[75] Conti simplified this value to 48° and mistakenly related it to the changes in ecliptic latitude implied by the theory of access and recess.

More important for Conti's argument, however, was d'Abano's belief that the changing alignment between the eighth and ninth spheres was responsible for large-scale historical changes. At times when the two zodiacs were in close alignment, such that the sign of Aries in the eighth sphere was found below the corresponding sign of the ninth sphere, the result was a surge in prosperity, virtue, and wisdom in the realm below, whereas the increasing separation of the two reference frames experienced in modern times resulted in political, moral, and intellectual decay.[76] The influence of this astrological reading of precession is visible very clearly in the *Tabulae primi mobilis* by Conti's Ferrarese colleague Giovanni Bianchini, which date from between 1446 and 1452.[77] In the introduction to this work Bianchini put forward the view that the signs of the zodiac owed the elemental qualities and influences that astrologers attributed to them solely to those stars that had been found within their boundaries at the time when Ptolemy wrote his *Tetrabiblos*. At that time,

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[75] Pietro d'Abano, *Tractatus de motu octavae spherae* 2.2 (ed. Federici Vescovini, 1992, pp. 353–354).

[76] Ibid. 4.1 (ed. Federici Vescovini, pp. 362–364). See also Pietro d'Abano, *Lucidator* 2.3 (ed. Federici Vescovini, 1992, pp. 184–185).

[77] The date is discussed in Thorndike, 1950a, at p. 8.

Bianchini argued, the eighth and ninth sphere had been in near-perfect alignment. The heads of Aries and Libra in the eighth sphere had then been approximately below the equivalent points of the ninth sphere, such that astrological judgments based on the zodiacal constellations would have yielded the same results as those judgments based on the tropical zodiac of the ninth sphere. Moreover, it was worth noting that

> Jesus Christ was born at that time and then the whole world could be seen to rest in peace under the rule of the Romans. All kings, lords, and princes of the people came together as one and esteemed each other. Afterwards, just as the eighth sphere separated itself through its motion and became elongated from the boundaries of the ninth sphere, so the mutual esteem and friendships of living beings are seen to fall apart and discord, hatred, and enmity [are seen] to grow.[78]

Conti evidently shared some of Bianchini's assumptions about stellar influence, which extended to the idea that even the stars remote from the zodiac "have their special character and nature and exert their own influence on earth according to their location in the

[78] MS Paris, Bibliothèque nationale de France, lat. 7270, fol. 148vb: "Caput Arietis et Libre octave spere tunc fere erant sub capite Arietis et Libre none spere, quare iudicium quod per naturam corporum stellarum fixarum ferebatur erat idem cum iudicio ferendo secundum situm figure none spere erecte per motum quottidianum supra polos mundi, et [...] Hiesus Christus salvator mundi illo tempore natus est et tunc totus mundus in pace videbatur requiescere sub imperio Romanorum. Reges omnes, domini et principes populi in unum conveniebant et ad invicem se diligebant. Postmodum sicut octava spera per motum suum separata est et elongata a terminis none spere ita dilectiones et amicitie animantium videntur separari et discordie crescere odia et inimicitie." Later in the same passage Bianchini explicitly refers to dist. 4 of Pietro d'Abano's *Tractatus de motu octavae spherae*. See Thorndike, 1953, pp. 14–15.

[astrological] chart”.[79] What he took issue with, however, was the opinion of “those who said that at the time of Christ the zodiac of the eighth sphere was directly below the zodiac of the ninth sphere,” which ran afoul of the Alfonsine assumption that ♈$_{8}$ circled ♈$_{9}$ without ever coinciding with it. Conti realized that it was still possible to safeguard the essential thrust of d’Abano’s and Bianchini’s opinion if one re-defined the coincidence ♈$_{8}$ and ♈$_{9}$ as the time when τ was at or near 0°, such that the two points lay on the same great circle passing through the poles of the fixed zodiac. This, as Conti knew from Bianchini’s tables, had been the case close in AD 16, close to the year of Christ’s birth. In the mentioned scenario, “one zodiac would not be below the other one, as they assumed,” yet the basic idea according to which “the influence of both spheres would have come to these lower parts with greater unity because of this conjunction between them” still rang true.[80]

In Conti’s model, of course, this celestial unity was capable of extending not just to two, but to three spheres, since at the aforementioned point in time ♈$_{9}$ coincided with ♈$_{10}$ while ♈$_{8}$ shared the same longitude of the fixed ecliptic as ♈$_{9}$. There was hence every

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[79] MS Paris, Bibliothèque nationale de France, lat. 7270, fol. 149rb: “Que stelle remote habent proprietatem et naturam de per se influentes super terram secundum earum situm in figura respectu ad earum elevationes ab orizonte et commixtiones quas habent cum planetis et cum locis principalibus in figura prout ante dictum est.”

[80] *Vα*, fol. 93r: “In hoc etiam situ caput Arietis octave spere erit cum capite Arietis none super eodem circulo transeunte per polos zodiaci et centra amborum circulorum. Similiter caput Libre cum capite Libre. Unde tunc coniungi dicitur caput Arietis octave spere capiti Arietis none spere. Numquam [*ms.* nunc] enim aliter possunt coniungi, eo quod unum volvitur in circumferentia et aliud est centrum eiusdem circuli. Ex quo manifeste patet quosdam errasse qui dixerunt quod tempore Christi zodiacus octave spere fuerit directe sub zodiaco none [...] nisi intelligerent dictum suum de coniunctione, ut dictum est, per circulum eundem transeuntem per polos zodiaci none. Sed sic unus zodiacus non esset sub alio, ut ipsi putabant. Verum est tamen quod dixerunt cum hoc quod influxus ambarum sperarum venisset in ista inferiora magis unitus propter talem ipsarum coniunctionem.”

reason to believe that Christ's life on earth was accompanied by an especially beneficial state of the heavens.

Conclusion

Nicolò Conti's *De triplici motu octave spere* is of historical significance for offering us the clearest account hitherto available of the reasoning that underpinned Georg Peurbach's physical-kinematic model of the eighth, ninth, and tenth spheres, as presented in his immensely influential *Theoricae novae planetarum*.[81] One of the most important findings in this regard is that this reasoning respected certain astrological considerations, in particular Pietro d'Abano's idea that the precessional motion of the sphere of fixed stars was an agent of historical change. Conti expanded on this notion by suggesting that the access-and-recess component in his model, with its concomitant changes in stellar latitude relative to the fixed ecliptic, was needed to regulate affairs in the lower realm.[82] Noticing this astrological component in Conti's argument throws into sharp relief the physical realism of his three-sphere model, which was clearly more than just a hypothetical attempt at saving the phenomena.

At the same time, it is impossible to overlook that the model of *De triplici motu* was primarily grounded in an exegesis of the Alfonsine Tables, in particular of the way these tables combined an eighth sphere endowed with an access-and-recess motion with a linear

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[81] The influence of Peurbach's presentation of this model on later-fifteenth century and sixteenth-century astronomy is beyond the purview of this article. One phenomenon worth addressing in future studies of this kind would be the existence of armillary spheres adapted to representing the threefold motion of the fixed stars. See Samhaber, 2000, pp. 134–137.

[82] This is similar to the reasoning involved in the access-and-recess component's use in apocalyptic calculations, as seen in the works of Pierre d'Ailly, Jean de Bruges, and Pierre Turrel. See Smoller, 1998.

increase of the fixed stars in ecliptic longitude. Conti's uncritical, even reverential, attitude towards these tables and their computational principles would have appeared excessive at least to some fifteenth-century observers. When Regiomontanus discussed the eighth sphere and its motion in a letter to Giovanni Bianchini in 1464, he saw reason to criticize "the common astronomers of our age who, just as credulous women, receive as something divine and immutable whatever they come upon in books either of tables or their canons, for they believe in writers and make no effort to find the truth".[83] The treatise Conti had written 14 years earlier was certainly vulnerable to this charge and it is tempting to suppose that it was one of the examples Regiomontanus had in mind.

On a more technical level, Conti failed to accomplish what he had set out to do, which was to create a model of the spheres that would respect in the fullest terms the principles of the Alfonsine Tables. Even Conti's friend Peurbach, who based the final part of his *Theoricae novae* on the model and drawings of *De triplici motu*, had to admit that the movement of the eighth sphere he described was not adequately captured by the solar longitudes one could glean from the available tables. Attempts to improve upon the flaws of Peurbach's model would later gave rise to works such as Johann Werner's *De motu octavae spherae* and, ultimately, Book III of Nicholas Copernicus's *De revolutionibus orbium coelestium*. Conti's little treatise deserves to be remembered as an early link in the chain of discussion that ties all these works together.

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[83] See the English translation of Regiomontanus's letter in Swerdlow, 1990, pp. 170–171.

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