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MUSICA MUNDANA, ARISTOTELIAN NATURAL PHILOSOPHY AND PTOLEMAIC ASTRONOMY

Emanating from a cosmos ordered according to Pythagorean and Neoplatonic principles, the Boethian *musica mundana* is the type of music that 'is discernible especially in those things which are observed in heaven itself or in the combination of elements or the diversity of seasons'.[1] At the core of this recurring medieval topos stands 'a fixed sequence of modulation [that] cannot be separated from this celestial revolution', one most often rendered in medieval writings as the 'music of the spheres' (*musica spherarum*).[2] In the Pythagorean and Neoplatonic cosmological traditions, long established by the time Boethius wrote his *De institutione musica*, the music of the spheres is just one possible manifestation of the concept of world harmony. It pertains to a universe in which musical and cosmic structures express the same mathematical ratios, each of the planets produces a distinctive sound in its revolution and the combination of these sounds themselves most often forms a well-defined musical scale. Although the Neoplatonic world harmony continued to function in medieval cosmology as the fundamental conceptual premise, the notion of the music of the spheres, despite its popularity among medieval writers, was generally treated neither at any significant length nor in an innovative

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1 'Et primum ea, quae est mundana, in his maxime perspicienda est, quae in ipso caelo vel compage elementorum vel temporum varietate visuntur.' Boethius, *De institutione musica libri quinque*, ed. G. Friedlein (Leipzig, 1867), I.2, p. 187.23–6. English translation in C. Bower, *Fundamentals of Music* (New Haven and London, 1989), p. 9.

2 'Unde non potest ab hac caelesti vertigine ratus ordo modulationis absistere.' *De institutione musica* I.2, p. 188.6–7; *Fundamentals*, p. 9.

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fashion. Quite exceptional in this respect is the treatise that forms the subject of the present study, a text beginning *Desiderio tuo fili carissime gratuito condescenderem* and attributed to an anonymous bishop in the late thirteenth-century manuscript miscellany now in the Biblioteca Apostolica Vaticana (Barb. lat. 283, fols. 37^{r}–42^{v}) but probably coming from a Franciscan convent in Siena. This seldom considered work affords a remarkable and special insight into the ways in which old and new ideas converged, intermingled and coexisted in the dynamic and sometimes volatile cross-currents of medieval scholarship.

In his edition of the treatise, Joseph Smits van Waesberghe considered it to be the work of Adalbold, bishop of Utrecht between 1010 and 1026.[3] His attribution relied primarily upon what he perceived to be conceptual and stylistic similarities between the text of the treatise and other works that can be attributed to Adalbold with a much higher degree of certitude, and among which Adalbold's commentary on Boethius' *O qui perpetua* occupied a central position.[4] Given the extent to which matters of style can become a subject for debate, I suggest that, for the time being and for dating purposes alone, we should look elsewhere for somewhat firmer grounds.

Evidence of a music-theoretical nature, for example, supports a date for the composition of the Barberini treatise later than 1026, the year of Adalbold of Utrecht's death. The author of the text refers to a gamut of nineteen pitches that are in turn divided into eight *graves*, seven *acutae* and four *superacutae*; the terseness of his statement and the lack of any surrounding explicatory material suggests that he must have been under the assumption that such a gamut was familiar to his readers.[5] To my knowledge, a nine-

[3] *Adalboldi Episcopi Ultraiectensis Epistola cum tractatu de musica instrumentali humanaque ac mundana*, ed. J. Smits van Waesberghe (Divitiae Musicae Artis A.II; Buren, 1981). In his review of the edition, Roger Bragard provides useful French translations of numerous passages in the treatise and a good summary of its contents; he does not contest, however, Smits van Waesberghe's attribution, dating or analysis of the text; see R. Bragard, 'Joseph Smits van Waesberghe et les *Divitiae musicae artis*', *Revue belge de musicologie*, 41 (1987), pp. 9–16. No other studies are dedicated to this treatise.

[4] The most recent edition of this commentary on *O qui perpetua*, which accepts Adalbold's authorship, appears in *Serta mediaevalia: Textus varii saeculorum X–XIII in unum collecti*, ed. R. B. C. Huygens (Corpus Christianorum, Continuatio Mediaevalis 171; Turnhout, 2000), pp. 121–40.

[5] *Epistola cum tractatu*, p. 22.1.

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teen-pitch gamut with such a division does not appear in any other music-theoretical work prior to Guido of Arezzo's *Micrologus*, composed after 1026, and does not enter the mainstream of music-theoretical discourse until the twelfth century.[6] In addition, the Barberini author does not obtain the pitches of the gamut by means of ratios alone. While the 'primary consonances' (diapason, diapente and diatessaron) emerge from the usual duple, sesquialtera and sesquitertia ratios alone, the 'secondary consonances' (the tonus, ditonus, semitonus and semiditonus) are expressed by a combination of integrals and fractions that are the mathematical equivalent of the standard Pythagorean ratios. For example, the ditone is calculated thus: 'let two strings of equal dimensions and material be stretched, one by an eight-pound, the other by a nine-pound weight: there results the tone. Let a third string be added and stretched by ten pounds and one eighth: thus there emerges another tone. Between the first and the third string, therefore, there is a ditone.'[7] The Barberini author's use of a mixed

[6] For the most recent discussion pertaining to the dating of Guido's *Micrologus* see *Guido d'Arezzo's Regulae rithmice, Prologus in Antiphonarium, and Epistola ad Michahelem: A Critical Text and Translation*, ed. Dolores Pesce (Musicological Studies, 73; Ottawa, 1999), p. 1. The *graves*, *acutae* and *superacutae* are the division of the gamut from Γ to *aa* as it appears in the *Dialogus in musica* (ed. Martin Gerbert in *Scriptores ecclesiastici de musica sacra* (Saint-Blaise, 1784), i, pp. 253b–254a and 265b); the divisions are maintained but the gamut was expanded by Guido in the *Micrologus* to *dd* (ed. J. Smits van Waesberghe (Corpus scriptorum de musica, 4; Rome, 1955), pp. 93–5); see K.-J. Sachs, 'Musikalische Elementarlehre', in *Rezeption des antiken Fachs im Mittelalter* (Geschichte der Musiktheorie, 3, ed. F. Zaminer; Darmstadt, 1990), pp. 143–4. The Barberini author further associates the nineteen-pitch gamut with the 'sescupla' ratio (6:1), where 6 is the first perfect number: '. . . quod pondus chordae primae per senarium multiplicatum facit pondus chordae postremae, cum senarius numerum perfectorum numerorum primus occurat'. *Epistola cum tractatu*, p. 20.24. A perfect number is one whose sum of factors is equal to it; 6 = 1 + 2 + 3. A search in the TML database indicates that such associations are rather rare and do not occur in other works until the thirteenth and fourteenth centuries, more specifically in the works of Johannes de Grocheio and Johannes de Muris, among others. The entire segment on the *musica instrumentalis* in the Barberini text rightly awaits an in-depth study.

[7] 'Exemplum: tendantur duae chordae aequales et similes, una octo libris, alia novem: proveniet tonus. Addatur tertia chorda, et tendatur decem libris et earum octava unius; sic proveniet iterum tonus. Igitur inter primam chordam et tertiam fiet ditonus.' *Epistola cum tractatu*, p. 18.11–12. The Barberini author also provides the equivalent in ratios; see p. 19.13–14. The whole first octave is expressed by the following series: 8 . 9 . 10⅛ . 10 . 12 . 13½ . 14³⁄₁₆. 16; to obtain the pitches in the second octave, just double the weight associated with each one of the first initial strings, for all intents and purposes, ad infinitum; the nineteenth string is represented by 48 and, therefore, the ratio between the first and the nineteenth pitch of the gamut is 6:1. It should be noted, however, that the arabic numerals do not appear in the main text, but as marginalia in a later hand; the text, nevertheless, explicates the numbers and fractions in words.

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combination of integers and fractions as an alternative to the Pythagorean ratios is quite unusual, certainly for the beginning of the eleventh century. This procedure, however, seems to have had some currency in the early fourteenth century, at the time that Jacques of Liège wrote his *Speculum musicae*.[8]

The present essay will put forth evidence that pertains to the cosmological and philosophical foundations of the Barberini author's treatment of the Boethian *musica mundana* and suggests that the treatise originated not in the intellectual environment of the eleventh century but rather in that of the thirteenth. For the time being, the author remains a bishop: the attribution 'Anonymi Ep[iscop]i tractatus de Musica' appears in the manuscript, albeit in a later hand, and was probably prompted by one of the author's own remarks: 'summoned away from study and prevented by pastoral duties'.[9] For all intents and purposes, however, the bishop remains anonymous.

The treatise as a whole is concerned with the three Boethian categories of *musica*: *instrumentalis*, *humana* and *mundana*.[10] According to the bishop, the study of this threefold *musica* in its quadrivial context prepares us 'to comprehend the incomprehensible'; it is in itself an epistemological continuum, a journey that takes us from *musica instrumentalis* to *musica humana* – which teach us how to obtain agreeable (instrumental) sounds and concordant (vocal) pitches, respectively – and ultimately to *musica mundana*, which 'surpasses by far all [other] disciplines', is the 'glory of philosophers' and makes one 'familiar with, and cognisant of, the divine plan'.[11]

The present essay concerns primarily the section dealing with *musica mundana*. In this part of the treatise, the bishop discusses three topics that are by and large standard in the Neoplatonic literature on the subject: the production of sound by the moving

[8] *Speculum musicae*, ed. R. Bragard (Corpus scriptorum de musica, 3; Rome, 1961), ii, p. 144.

[9] *Epistola cum tractatu*, p. 13.12.

[10] Boethius, *De institutione musica* I.2, pp. 187–9.

[11] 'Musica vero docet secundum proportionem ponderum comprehendere incomprehensibilia. Sunt enim tres species musicae: mundana, humana, instrumentalis. Instrumentalis docet invenire sonos delectabiles; humana: voces concordes. Mundana musica longe supereminet omnibus scientiis. Haec enim est deliciosa scientia. Haec: philosophorum gloria. Haec facit familiarem et conscium divini consilii.' *Epistola cum tractatu*, p. 14.3–5.

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celestial bodies, the methods for calculating the specific pitches produced by the planets in their revolution, and the cosmic and musical proportions of those sounds. His treatment of each topic is unusual, however. As we shall see, his text manifests a broad spectrum of philosophical dispositions that inform not a static but a thoroughly dynamic model of the harmony of the spheres that is quite exceptional in musical cosmology prior to the Renaissance. His firm adherence to a Neoplatonic sounding universe notwithstanding, the bishop is dependent on Aristotelian natural philosophy, and he weaves into his discussion notions stemming from Aristotle's *De anima*, *Physica* and *Meteorologica*. Furthermore, his interpretation of the Boethian *musica mundana* develops on cosmological grounds derived not from theories advocating a concentric universe, but instead from the Ptolemaic system of eccentrics and epicycles current in the thirteenth century. The author thus reconciles traditions that on the surface appear to be conceptually contradictory: the Neoplatonic notion of the harmony of the spheres, Aristotelian natural philosophy and Ptolemaic cosmological models.

I. THE NEOPLATONIC FRAMEWORK

Written in epistolary form and style, the beginning of the Barberini treatise provides some insight into the author's disposition towards the subject of celestial music. The general narrative is internally consistent overall, and some of the personal details it includes appear to ring true rather than being mere rhetorical devices. The bishop warns his addressee that embarking on an investigation into *musica mundana* is a difficult enterprise, and that in his particular case this difficulty arises from both objective and subjective factors. He maintains that knowledge of the subject is fragmentary, since none of the earlier philosophers undertook the task of writing a treatise entirely devoted to *musica mundana.* Some even confessed their lack of competence in the subject, and most quoted from each other's works.[12] Furthermore, in a passage heavy

[12] 'De dulcedine mundanae musicae libemus aliquid modicum, exempli causa tantummodo, quandoquidem de ea nihil perfectum habemus. De ea namque tractatum facere nullus adhuc philosophorum praesumpsit. Fatebantur enim se nescire; sed singuli passim per diversos tractatus quippiam modicum mutue coronati sunt'. *Ibid.*, p. 23.1.

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with autobiographical overtones, the bishop accuses some of his contemporaries of having hindered a genuine dialogue on the subject. His specific targets would seem to be the radical empiricists of the day, those thinkers adhering to philosophical positions that condoned only the kind of knowledge grounded in sensory experience, and then only in so far as it pertained to the terrestrial realm:

I lectured not upon *musica*, as you say, but upon that raw and formless material for music, which formerly, as it were a kind of theme for debate on [celestial] motions, I meant – for me and not the others – to condemn to silence. I did so lest I should appear to undertake with boasting arrogance that which seems altogether impossible to those who are less subtle in their considerations [and] who deem probable only that which their bleary sight can contemplate up close. They marvel, they even mock with laughing declamations (the notion) that anyone should venture to measure the course of the planets, the magnitude of the [celestial] orbs and their distances from earth. Since they doubt whether, with the keenness of a sharper intellect, one can investigate those things subject to the senses [i.e. the planetary measurements], with what stupid guffaws they will laugh at the inquiry into those that escape the senses, especially the celestial music, or at anyone willing to undertake it.[13]

Summoned away from his studies and prevented by his pastoral duties from completing what he had started,[14] it is only now, in his old age and at the request of his younger disciple, that he finds the opportunity to write down some of his thoughts on the heavenly music. The culmination of long musing on the subject, his enterprise accords with the non-empirical philosophical approach, for it aims to 'serve the common good of others, whose finer insight unravels that which holds the heavenly bodies together and, with a kind of divinely acute ability, measures the high heavens, and deems those things that are subject to the senses to be relatively unworthy of study'.[15]

[13] 'Praelegi itaque non musicam, ut dicis, sed rudem illam et informem musicae materiam, quam olim mihi non aliis quasi quoddam thema proposui de motibus disputandi silentio damnare, ne viderer aliquid ex iactantiae supercilio promittere, quod quibusdam minus subtiliter intuentibus, omnino videtur impossibile, qui hoc solum probabile iudicant, quod sua potest lippitudo com(m)inus intueri. Mirantur enim, immo subsan(n)ant, et ridiculose declamant, quempiam planetarum cursus orbesque quantitates et a terra distantias audere metiri. Si igitur ea quae sensui subiecta sunt, acutioris ingenii subtilitate perpendi posse diffidunt: quo stupore, quo cachinno de his quae sensus effugiunt et maxime de musicae caelestis inquisitione vel aliquem agere velle ridebunt?' *Ibid*., p. 12.5–7.

[14] 'A studiis etenim evocatus et pastorali cura praeventus, ut nosti, quod inceperam complere non potui.' *Ibid*., p. 13.12.

[15] 'Sed ne tamen illorum qui terrena tantum sapiunt, videar magis sales effugere quam communi aliorum utilitati deservire, quorum subtilior acies superum conexa penetrat et divinae quodam subtilitatis ingenio caeli metitur ardua et subiacentia sensui, quasi suo reputat indigna studio.' *Ibid*., p. 12.8 (punctuation altered).

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The bishop's general rhetoric may very well derive from a desire to heighten the significance of his own work, and some of his autobiographical reminiscences may prove to be too generic to serve as evidence for a precise positioning of the treatise in the larger intellectual currents of the time. This cautionary note notwithstanding, there emerge from his remarks manifestations of two opposing contemporaneous epistemological stances, one relying exclusively upon sensory perception, the other minimising its relevance.[16] As far as the subject of *musica mundana* is concerned, they can be summarised as follows: (1) the impossibility of being experienced by the senses renders the notion of *musica mundana* preposterous and its investigation foolish; and (2) the sensory implications are immaterial, for the subtleties of *musica mundana* are conceptual and of a divine nature, and only an investigation into the cosmic order and its underlying principles can account for it.

The presence in one text of two contemporaneous philosophical camps of unlike mind regarding the music of the spheres suggests that the bishop wrote his treatise at a time when the unconditional acceptance of the Neoplatonic notion of the music of the spheres had begun to wane. It was not until the emergence of new philosophical and scientific paradigms in the thirteenth and fourteenth centuries, however, that medieval scholars began to question this particular understanding of the Boethian *musica humana*. Even though the notion of world harmony remained unchallenged as a philosophical and theological concept, the gradual assimilation during the thirteenth century of Aristotelian natural philosophy and of Greco-Arabic astronomy into Latin cosmological models made it increasingly hard for the literal interpretation of the *musica spherarum* to maintain itself.

As is well known, the most authoritative challenge came with the introduction to the West of the Latin translation of Aristotle's *De caelo* sometime in the late twelfth century. *De caelo*, the only cosmological treatise Aristotle wrote, was a powerful influence in

[16] In general terms, the situation appears to be similar to the late twelfth-century controversy between *medici* and *astrologi* to which Hermann of Carinthia bears witness, the *medici* restricting their inquiries to qualitative and perceptible events, the *astrologi* attempting to explain the physical facts in reference to the whole cosmos. Summarised in Hermann of Carinthia, *De essentiis: A Critical Edition with Translation and Commentary*, ed. C. Burnett (Texte zur Geistgeschichte des Mittelalters, 15; Leiden, 1982), pp. 22–5.

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cosmological thought well into the seventeenth century, as witnessed by the number of commentaries and questions that it elicited. It also became the most authoritative refutation of the Pythagorean and Neoplatonic claim that the planets produce actual sound in their movements. After a brief summary of the Pythagorean claim, Aristotle maintains that:

melodious and poetical as the [Pythagorean] theory is, it cannot be true on account of the facts. There is not only the absurdity of our hearing nothing, the grounds of which they try to remove, but also the fact that no effect other than sensitive is produced upon us. Excessive noises, we know, shatter the solid bodies even of inanimate things; the noise of thunder, for instance, splits rocks and the strongest of bodies. But if the moving bodies are so great, and the sound which penetrates to us is proportionate to their size, that sound must need reach us in an intensity many times that of thunder, and the force of its action must be immense. Indeed the reason why we do not hear and show in our bodies none of the effects of violent force is easily given: it is that there is no noise.[17]

The authority of Boethius and his Neoplatonic *musica mundana* and the authority of the soundless cosmos of the Philosopher were coming face to face, and from the thirteenth century onwards scholars had to chose sides, negotiate between two contradictory views, or find suitable (or at least acceptable) compromises. The consequences this fascinating encounter had on the development of speculative musical thought of the later Middle Ages in general and on the treatment of *musica mundana* in particular are yet to be adequately examined. In the most comprehensive study to date on the fortunes of the Boethian *musica mundana* in the Middle Ages and Renaissance, James Haar suggested that by the mid-thirteenth century the Philosopher's stance was already at the root of some radical views.[18] Vincent of Beauvais maintained in his *Speculum naturale* that *musica mundana* must be taken in a metaphorical sense lest it perpetuate dangerous astrological tendencies.[19] In *Opus ter-*

[17] Aristotle, *On the Heavens*, trans. J. L. Stocks, in *The Complete Works of Aristotle: The Revised Oxford Translation*, ed. J. Barnes (Princeton, 1984), II.9 (290^{b}30–291^{a}6), p. 479. All other references are taken from Barnes's edition unless otherwise noted.

[18] J. Haar, '*Musica mundana*: Variations on a Pythagorean Theme' (Ph.D. diss., Harvard University, 1960), pp. 299–313.

[19] 'The above opinion on the harmony of the heavens is to be rejected, lest that ancient error of superstition concerning the cult of the celestial stars . . . having not only life, sense and motion, but even something of divinity in them seem to have a place even among us' ('Ob hoc autem praecipue praedicta sententia de coelorum concentu respuitur, ne antiquus ille superstitionis error de cultu coelestium syderum, . . . tamquam non solum vitam et sensum ac motum, sed etiam numinis aliquid in se habentium, apud nos etiam locum habere videatur'). Vincent of Beauvais, *Speculum naturale* XV, xxxii, in

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tium, Roger Bacon pointed out that the theory persisted among the unlearned, and that Boethius, who merely recounted it, did not approve of it; Bacon himself rejected it altogether and declared that 'nulla est musica mundana'.[20] Furthermore, a significant number of music treatises from the thirteenth and fourteenth centuries wholly or partially embraced the Aristotelian refutation, in spite of their traditional dependence on Boethius.[21]

The anonymous bishop positions himself strongly in the Neoplatonic camp. As we have seen, he wrote his treatise despite possible ridicule from radical empiricists, who rejected the music of the spheres based upon the lack of sensory experience, a type of argument very much indebted to the Aristotelian position on the subject. Moreover, the bishop openly embraces the Neoplatonic perspective by accepting its basic premises as true: the celestial spheres produce sound in their movement, and those sounds effect musical harmony.[22]

A committed Aristotelian would argue that the bishop, like other Neoplatonists, offers no systematic demonstration of the presence of sound in the cosmos, and that the only rationales that he provides stem from empirical analogies with the sublunar world. He claims that it is obvious that planets must produce sound in their movement, as long as much smaller bodies in the sublunar world, such as birds, arrows, stones and rods, produce sound while moving through the air. At first, the source of this statement seems to be Macrobius' commentary on *Somnium Scipionis*.[23] Like Macrobius, the bishop maintains that planets produce sound in their rapid orbital movement in a manner similar to that of a rod

Bibliotheca mundi seu venerabilis viri Vincentii Burgundi ex Ordine Praedicatorum, episcopi Bellovacensis, Speculum Quadruplex: naturale, doctrinale, morale, historiale (Douai, 1624), i, p. 1112, col. 2. English translation in Haar, '*Musica mundana*', p. 306.

20 '. . . nulla est musica mundana, licet secundum opinionem antiquorum Pythagoricorum duravit haec opinio apud vulgum . . . Et ideo, quia Boetius fecit mentionem de ea in sua Musica, hoc non est nisi secundum opinionem vulgi recitando.' Roger Bacon, *Opera quaedam hactenus inedita*, ed. J. S. Brewer (London, 1859; repr. London, 1965), i, *Opus tertium*, p. 230.

21 Haar, '*Musica mundana*', pp. 309–13.

22 'It came to mind what the philosophers said that the celestial bodies render sound in their motion and, even more importantly, that they produce musical harmony. This sounds convincing . . .'. ('Subiit namque, quod dixerunt philosophi, superiora corpora suis motibus sonum reddere et, quod maius est, musicam harmoniam efficere. Hoc mihi persuadet . . .'.). *Epistola cum tractatu*, p. 24.15.

23 *Commentarii in Somnium Scipionis*, ed. J. Willis (Bibliotheca scriptorum Graecorum et Romanorum teubneriana; Leipzig, 1970), 2.4.2–5, pp. 107–8.

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whisked through the air: the faster they move the higher the pitch and vice versa. The bishop omits, however, the other two modes of sound production to which Macrobius refers in the same passage, vibrating strings and air columns in pipes. Instead, he generates a set of variants of the 'whisked rod' example, bringing in birds, arrows and stones that move through the air.

Upon more careful examination, however, the bishop's examples more likely relate to later medieval accounts of the Aristotelian modes of sound production, particularly as they appear in commentaries on Aristotle's *De anima* II.8, than to the passage in Macrobius.[24] Aristotle's text is devoted to a whole range of issues pertaining to sound production as well as to perception. Sound is produced when two bodies strike each other or when one body strikes another with a sudden sharp blow and air is violently expelled from between them.[25] A modification of the standard Aristotelian model appears in Averroes' commentary on *De anima*, where he maintains that when air is struck by a whip it acts both as the struck body and the expelled air, an example that was subsequently adopted by several Latin commentators, Albertus Magnus among them.[26] In theory, this modified model can be extended to cover other kinds of objects as well, for regardless of the nature of the object that moves through the air, the whiplash effect remains the same. The bishop may have ultimately con-

[24] The best study to date on the impact of Aristotle's *De anima* on medieval concepts of sound is M. Wittman, *Vox atque sonus: Studien zur Rezeption der Aristotelische Schrift 'De Anima' und ihre Bedeutung für die Musiktheorie*, 2 vols. (Pfaffenweiler, 1987); the second volume contains an edition of twelve commentaries on *De anima* II.8 from the mid-thirteenth to the mid-sixteenth century. For the role that Aristotelian natural philosophy had in general on the development of music-theoretical discourse and on the notational procedures of the later Middle Ages, see Dorit Esther Tanay, *Noting Music, Making Culture: The Intellectual Context of Rhythmic Notation, 1250–1400* (Neuhausen–Stuttgart, 1999).

[25] '. . . sed oportet firmorum fieri percussionem ad invicem et ad aera. Hoc autem fit, cum permaneat percussus aer et non solvatur. Unde si velociter et fortiter percutiatur, sonat; oportet enim pertingere motum rapientis fracturam aeris . . .'. I follow here the Latin translation of James of Venice printed at the bottom of the page in *De anima*, ed. C. Stroick, in Albertus Magnus, *Opera omnia*, ed. B. Greyer, vol. 7, pt. 1 (Aschendorf, 1968), p. 125.

[26] '. . . accidit quod ea que sunt velocis motus faciunt in aere sonum licet non percutiant aliud, ut motus corrigie in aere'. Averroes, *Commentarium magnum in Aristotelis De anima libros* II.9, ed. F. S. Crawford (Cambridge, Mass., 1953), p. 250. See also Albertus Magnus, *De anima*, 2.3.18, p. 125. A detailed discussion of Aristotelian modes of sound production and perception appears in C. Burnett, 'Sound and its Perception in the Middle Ages', in C. Burnett, M. Fend and P. Gouk (eds), *The Second Sense: Studies in Hearing and Musical Judgement from Antiquity to the Seventeenth Century* (London, 1991), pp. 43–69; both Averroes and Albertus Magnus are mentioned on p. 52.

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ceived of birds, stones and arrows producing sound in their movement through the air for reasons that are as Aristotelian as those of Averroes's whip.

Therefore, even when considered separately, outside the larger context of the bishop's treatise these sublunar sounds are likely to reflect Aristotelian models of sound production. When taken in conjunction with information the bishop provides in another passage in the treatise, this likelihood increases significantly. The passage in question occurs in the section devoted to the *musica instrumentalis*. Here, the bishop states:

> It should be noted too that a less malleable metal produces a more powerful sound; tin is thus more sonorous than lead; silver and gold more so than tin; copper is the more sonorous of them, the red copper more so than the white; glass is more sonorous than copper. In the case of metals, the closer they are to average solidity, the more agreeably they sound. Glass also sounds sweeter than silver because it is more solid. Glass actually sounds sweeter than any metal because, although less malleable, it is more solid; it cannot be hit very strongly, for it would render an intolerably high pitch.[27]

The sonority of metals is directly proportional to their malleability: the 'harder' a metal is, the more sonorous and vice versa. The scale of potential sonority resulting from the bishop's remarks is that of lead–tin–silver–gold–copper. The sound itself, once produced, possesses a tone that is contingent upon the solidity of the metal as well. In this case, however, it is the median degree of malleability that conditions the most pleasing sound in metals, which is manifest most perfectly in silver. Nevertheless, glass surpasses all metals because it is most sonorous, more so than copper, and produces the sweetest sound, more so than silver.

The distinction the bishop draws between the sonority of a metal and the quality of the sound that metal produces parallels the Aristotelian concept as expressed in the first statement in *De anima* II.8: that sound exists either in potentiality or in actuality. According to Aristotle, sound in potentiality is the sonorous quality of an object prior to its being struck, and 'soft' materials such

[27] 'Etiam notandum quod metallum inflexibilius violentiorem facit sonum et ideo stagnum fortius sonat quam plumbum; argentum et aurum quam stagnum. Aes vero violentius omnibus; rubeum (aes) autem violentius albo. Vitrum vero fortius aere. In metallis vero quae magis accedunt ad mediocritatem fortitudinis, amicabiliorem sonum faciunt. Vitrum quoque dulcius sonat argento, quia solidius est. Item vitrum dulcius sonat omni metallo quia solidius est, licet sit inflexibilius; non enim grandem recipit percussionem; quodsi reciperet, sonum intolerabiliter acutum redderet.' *Epistola cum tractatu*, p. 16.14.

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as wool or sponge are not sonorous, while solid materials such as bronze are sonorous. The latter category alone can produce an actual sound. Aristotle himself does not go into the tone qualities of the actual sounds, but the topic had some currency in Latin commentaries on *De anima*. Albertus Magnus, for example, maintains that gold, silver and copper are more sonorous than tin and lead; this remark in effect provides a scale similar to that of the bishop. The tone of the actual sounds ranges from the dullest to the sharpest, produced by lead and copper, respectively; implicitly, silver is in the middle position and, therefore, produces the most balanced tone. Moreover, in order to temper the sharpness of the sound produced by copper, one has to mix copper with tin when making bells or organs.[28]

The evidence just presented suggests that the theories of sound production underlying the bishop's treatment of *musica mundana* are contingent upon Aristotelian models current in the thirteenth century. His philosophical position thus becomes almost paradoxical: in referring to birds and rods, he introduces sublunar sounds that are produced in Aristotelian fashion in support of a thoroughly Neoplatonic notion of planetary sounds, which in turn the Aristotelians completely rejected. It is an intellectual strategy that the bishop adopts throughout his treatise and that consistently helps him elegantly to circumvent and rather conveniently to overlook any dialectical friction that might emerge between a Neoplatonic conceptual framework and Aristotelian rationales.

The question Neoplatonists most often asked was, why can human ears not hear the harmony of the cosmos if the planets indeed produce sound in their movement? To account for this human limitation, the bishop offers two justifications: (1) the sound is not audible on account of the great distances separating the planets from earth; and (2) the sound is not actually heard because it is so loud that it deafens human ears.[29] Both explanations are Neoplatonic in character, yet the examples he invokes in support for each justification are, once again, indicative of his

[28] Albertus Magnus, *De anima* 2.3.17, p. 124.

[29] The latter is the standard justification derived from Cicero's *Somnium Scipionis* and adopted by all medieval thinkers who upheld the actuality of a music of the spheres; cf. Macrobius, *Commentarii* 2.4.14, p. 109. Aristotle also mentions it in *De caelo* II.9 in the context of his refutation of celestial harmony.

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general intellectual strategy. In other words, although his reasoning is slightly challenging and at times quite muddy, his propensity to employ supporting arguments imbued with Aristotelian rather than Neoplatonic imagery comes again to the fore. At this juncture, however, his arguments develop from somewhat ambiguous analogies between visual and auditory perceptions. I suspect that these analogies reflect a mixture of details pertaining to propagation of sound and light most probably picked up from writings on optics and sources dependent on Aristotle's treatment of sight in *De anima* II.7.

For example, the bishop maintains that 'we see the flying birds, but we do not hear them, for hearing is more sluggish than sight', very much in a vein similar to that expressed by Roger Bacon in his *Opus maius*: 'We note in the case of one at a distance striking with the hammer or a staff that we see the stroke delivered before we hear the sound produced.'[30] The bishop also asserts that, just as the ear is continuously enveloped by the sound of the celestial bodies, the eye is continuously enveloped by air; both dull the perceptive capacity of their respective organs.[31] Consequently, 'the eye can not see the sun's ray, which is air illuminated by the sun, unless it moves out of its direct path'.[32] When the enveloping medium changes, the eye behaves differently: submerged in water, although it still cannot see the water itself, it can see the objects

[30] '. . . sic enim procul aves volantes videmus, sed non audivimus, eo quod auditus hebetior est visu'. *Epistola cum tractatu*, p. 25.19. Cf. R. Bacon, *The 'Opus maius' of Roger Bacon*, ed. J. H. Bridges (London, 1900), ii, at v.i.ix.4, pp. 72–3; English translation in A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science, 1100–1700* (Oxford, 1962), p. 147. Crombie maintains that for Bacon, light was analogous to sound in that the multiplication of its species through a medium was a kind of pulse propagated from part to part similar to the propagation of sound (p. 146). For a similar position see also Grosseteste's analogy between the cause of repercussion in light and in sound that appears in his commentary on *Analytica Posteriora* and cited in Crombie, pp. 113–15.

[31] Cf. Aristotle, *De anima* (419^{a}25–34), p. 667.

[32] '. . . sed et radius solis, id est aer illuminatus a sole, non videtur, nisi oculus sit extra radium'. *Epistola cum tractatu*, p. 25.20. This passage vaguely relates to Roger Bacon's discussion of the species of light in *De multiplicatione specierum*, probably written in the early 1260s: 'for an eye situated in a corner of the house does not see the sun, but the ray entering through a hole or window or other aperture, whereas if it is exposed to the principal ray, it will see the sun' ('quoniam oculus in angulo domus non videt solem, sed radium cadentem per foramen vel fenestram vel aliam aperturam; quod si ponatur ad radium principalem, videbit solem'), in *Roger Bacon's Philosophy of Nature: A Critical Edition, with English Translation, Introduction and Notes, of 'De multiplicatione specierum' and 'De speculis comburentibus'*, ed. and trans. D.C. Lindberg (Oxford, 1983), II.2.127–9, pp. 102–5. For 'illuminatus a sole', see II.2.28–30, p. 96.

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in the water and, by implication, possibly the sun's rays.[33] Analogously, the bishop maintains that, although we are incapable of hearing the continuous sound of the planets under normal atmospheric circumstances, when the medium that enfolds our ears changes either through having the ears covered with our palms or placed in water, or on account of curtailing internal liquid, we can indeed catch hold of the sun's path and, by implication, of the celestial sounds.[34] Ambiguous details and shaky argumentation notwithstanding, the notion at the core of the bishop's discussion is Aristotelian and dependent upon the reception of *De anima*: the phenomena pertaining to visual and sound perception are analogous.

II. THE MODEL OF THE COSMOS

I have argued so far that the philosophical premises at the core of our bishop's discussion are unquestionably Neoplatonic, and that some of his arguments draw upon examples borrowed from the Aristotelian natural philosophy current in the thirteenth century. In so far as the cosmological framework is concerned, however, there is clear evidence that the bishop worked out neither a Neoplatonic nor a strictly Aristotelian model, but instead one heavily indebted to Ptolemaic astronomy. Instrumental in bringing Ptolemy's system to the scientific fore and providing a fuller and more precise measurement for the planetary motions were the translations of a variety of Arabic astronomical works in the twelfth century and that of Ptolemy's *Almagest* by Gerard of Cremona around 1175. As such, although described by several authors of the late antique period – Calcidius among them – the

[33] *Epistola cum tractatu*, p. 25.21–2. Possibly this would happen through multiple refractions. The imagery and in part the vocabulary (but not the tight argumentation) are reminiscent of yet another passage from *De multiplicatione* where Bacon discusses principles of refraction in media of different transparency; see Bacon, *De multiplicatione* II.2.36–84, pp. 98–101.

[34] I suggest a possible yet tenuous connection between this passage and Avicenna's revision of Aristotle's second mode of sound production (see above) in his commentary on *De anima*: 'Sound therefore happens as a result of the disturbance of a soft and fluid body squeezed between two bodies resisting it' ('Ergo sonus accidit ex commotione mollis corporis impetuosi, constricti inter duo corpora contraria sibi resistentia'), in *Avicenna Latinus. Liber de anima*, ed. S. Van Riet, 2 vols (Leiden, 1968–72), p. 164.83–5. Aristotle himself suggests in *De anima* II.7 (419^b18) that water, though less efficient than air, is a possible medium for the propagation of sound.

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Ptolemaic system of eccentrics and epicycles did not enter the mainstream of Latin astronomical thought until the thirteenth century. Furthermore, the bishop's model of the cosmos manifests Ptolemaic characteristics that during the thirteenth century were transmitted in such widely popular works as Sacrobosco's *Treatise on the Sphere* and the anonymous *Theorica planetarum*, two prime astronomical texts in the Faculty of Arts curriculum at Oxford and, by 1255, Paris.[35]

The bishop conceives of a nine-sphere cosmos. The ether extends from the circle of fixed stars (*aplanes*) to that of the moon; this cosmos moves uniformly from east to west under the impetus of the starless ninth sphere (*anastros*), which thus functions as the Aristotelian *primum mobile*.[36] As Smits van Waesberghe remarked, the term *aplanes* appears several times in Macrobius' commentary on *Somnium Scipionis* and a host of Carolingian and post-Carolingian treatises in reference to the sphere of the fixed stars; *anastros,* on the other hand, is found in Martianus Capella's *De nuptiis* and some of its Carolingian commentaries referring to the 'outermost circle'.[37] The specific association of *anastros* with the ninth sphere conceived as the *primum mobile* seems to be peculiar to the bishop, however, and the context in which it appears echoes Robertus Anglicus' commentary on Sacrobosco's *Sphere*.[38]

35 The popularity of Sacrobosco is also witnessed by a significant number of commentaries on *De sphera* that come from the thirteenth as well as the fourteenth century. For the Latin text and an English translation of Sacrobosco's *De sphera* and of the commentaries on *De sphera* by Robertus Anglicus, Michael Scot and Cecco d'Ascoli, see L. Thorndike, *The 'Sphere of Sacrobosco' and its Commentators* (Chicago, 1949). The anonymous *Theorica planetarum* has not been edited, but an English translation by Olaf Pedersen appears in E. Grant (ed.), *A Source Book in Medieval Science* (Cambridge, Mass., 1974), pp. 451–65.

36 'Certum est, quoniam totus aether ab applano usque ad lunam rotatur impetu nonae sphaerae, quae dicitur anastron, ab oriente in occidente(m) uniformiter.' *Epistola cum tractatu*, p. 25.17. The passage from Adalbold's commentary on *O qui perpetua* that Smits van Waesberghe mentions at this point in his edition features a different cosmic model. It lacks both the ninth sphere and the unidirectional motion of the whole cosmos. Adalbold's sphere of fixed stars moves from east to west while the planets have their own movement from west to east; as such the *aplanes* slow down the movement of the planets: 'dum speram applanetis ab Oriente in Occidentem, planetarum autem orbes ab Occidente convertit in Orientem. Applanetis enim festinationem sic obrotatio planetarum retardando temperat.' *Serta mediaevalia*, ed. Huygens, p. 129.

37 *Epistola cum tractatu*, pp. 60–1.

38 '. . . while there are nine celestial orbs, in the first orb there is no star, in the next orb beneath it are those stars which . . . are called "fixed"' ('cum novem sint orbes celestes, in primo orbe non est aliqua stella, in alio orbe sub illo sunt ille stelle . . . que dicuntur fixe'; Robertus Anglicus, *Commentary on the Sphere* (*c.*1271), in *The Sphere of Sacrobosco*, ed. Thorndike, p. 201 (English) and p. 145 (Latin); 'by this movement all nine spheres

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In addition to this astronomical nine-sphere cosmos, the bishop alludes to a 'highest heaven' where the souls of the blessed sing.[39] This is most likely a reference to the *caelum empyraeum*, which emerged as the ultimate heaven and the abode of the blessed in the twelfth century. Like some thirteenth-century thinkers, such as Thomas Aquinas, Campanus of Novara and Robert Grosseteste, the bishop deems the *empyraeum* to be beyond the reach of rational investigation and in the domain of faith alone: 'To which one must ascend through humility of faith and not through the enjoyment of reason or violence of demonstration.'[40]

are moved in uniform and continuous motion by the force of the first sphere' ('isto motu moventur omnes novem spere motu uniformi et continuo raptu prime'), *ibid*., p. 207 (English) and p. 153 (Latin).

[39] '. . . to seek the highest heaven, where not the planets but the fixed stars sing, not the ones in error but the saints' ('altius caelum appetere, ubi canunt non planetae, sed applani, non errantes, sed sancti'). *Epistola cum tractatu*, p. 27.2. This passage builds upon the two meanings of the term *errans*, astronomical and theological: the planets (*stellae errantes*) and the ones in error are placed in opposition to the fixed stars (*aplanes*) and the saints. In his commentary on the *Somnium Scipionis*, Favonius presents a slightly similar notion: 'The first circle, that which is above all the others, is the circles of the aplanes; since a uniform and continuous movement never ceases to act upon it, it is the subject of no error' ('Nam primus ac summus est aplanes, qui, quia semper uno ac iugi continuatus agitur motu, nulli videtur errori esse subiectus'); *Disputatio de Somnio Scipionis*, ed. and trans. R.-E van Weddingen (Collection Latomus, 27; Brussels, 1957), p. 33.16–17.

[40] 'Ad quod per fidei humilitatem, non per rationis elationem aut demonstrationis violentiam est ascendendum.' *Epistola cum tractatu*, p. 27.2. Bartholomeus Anglicus (fl. *c*.1230): 'The empyrean heaven is the first and highest heaven, the place of angels, the region and dwelling place of blessed men' ('coelum empyroeum est primum et summum coelum, locus angelorum, regio et habitaculum hominum beatorum'); *De genuinis rerum coelestium, terrestrium et inferarum proprietatibus* (Frankfurt, 1601; facs., with title *De rerum proprietatibus*, Frankfurt, 1964), pp. 379–80. Thomas Aquinas: 'the empyrean heaven cannot be investigated by reason because we know about the heavens either by sight or by motion. The empyrean heaven, however, is subject to neither motion nor sight . . . but is held by authority' ('quod caelum empyreum ratione investigari non potest: quia quidquid de caelis cognoscimus hoc est per visum aut per motum. Caelum autem empyreum nec motui subjacet nec visui . . .; sed per autoritatem est habitum'). *Scriptum super libros Sententiarum Magistri Petri Lombardi Episcopi Parisiensis*, ed. R. P. Mandonnet (Paris, 1929), ii, p. 71. Translation in E. Grant, *Planets, Stars, and Orbs: The Medieval Cosmos 1200–1687* (Cambridge, 1996), p. 377. Campanus of Novara (*c*.1205–96): 'Whether there is anything, such as another sphere, beyond the convex surface of this [ninth] sphere, we cannot know by the compulsion of rational argument. However, we are informed by faith, and in agreement with the holy teachers of the church we reverently confess that beyond it is the empyrean heaven in which is the dwelling place of good spirits'. ('Extra autem huius orbis convexam superficiem utrum sit aliquid utpote alia spera necessitate rationis non cognoscimus. Fidei vero informatione sanctis ecclesie doctoribus assentientes reverentur confitemur extra ipsam celum esse empireum in quo est bonorum spirituum mansio'). *Campanus of Novara and Medieval Planetary Theory: Theorica planetarum*, ed. and trans. F. S. Benjamin, Jr., and G. J. Toomer (Madison, 1971), p. 182. I have opted here for the English translation in Grant, *Planets, Stars, and Orbs*, p. 377.

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Down below, in the astronomical realm, the impetus of the ninth sphere effects not only the motion of the planets but also that of the comets, or shooting stars, below, which, as in Aristotle's *Meteorologica*, inhabit the space between the region of the upper air and the moon.[41] In addition to being carried along in the constant east to west motion of the zodiac, the planets themselves exhibit other types of motion as well. Both restlessly and at inestimable speeds, they move by longitude (*ante et retro*), that is, around the zodiac; by latitude (*dextrorsum, sinistrorsum*), that is, between the tropics; and by altitude (*sursum, deorsum*), that is towards and away from the earth.[42] The longitudinal motion itself can be broken down into the direct motion (*progressio)*, station (*statio*) and retrograde motion (*retrogradatio)* of a planet, and, like all the other planetary movements, it is continuous. The station represents the point common to the direct and retrograde motions. The bishop conceives of it as the analogue of the 'instant' in the continuum of time, an analogy of motion and time that is lifted almost verbatim from Aristotle's *Physica*.[43]

Before the Ptolemaic cosmological system established itself in the Western astronomical mainstream, the regularly periodic longitudinal motion of the planets was sometimes explained as being caused by the force of solar rays, while the variations in planetary altitude were believed to be contingent upon planetary absides.[44]

[41] '. . . moreover, [the movement of the ninth sphere] carries in its impetus the upper part of the region of the air, in which comets, that is shooting stars, move in the manner of the stars [i.e., from east to west]' ('immo etiam conrotatur eius impetu pars aeris superior, in qua cometae et stellae crinitae moventur ad modum stellarum'). *Epistola cum tractatu*, p. 25.17. Cf. Aristotle, *Meteorology* I.4–7.

[42] 'The planets themselves move in this ether both forwards and backwards, rightwards and leftwards, upwards and downwards, as restless as they are of unfathomable speed' ('In ipso autem aethere moventur superiora corpora ante et retro, dextrorsum, sinistrorsum, sursum, deorsum, tam irrequieta quam inaestimabili velocitate'). *Epistola cum tractatu*, p. 25.17. Rather than on physical orbs, the bishop's planets seem to move freely through a type of fluid heaven similar to that of Ptolemy's *Almagest*.

[43] 'Now, since time cannot exist and is unthinkable apart from the now, and the *now is a kind of middle-point, uniting as it does in itself both a beginning and an end, a beginning of future time and an end of past* time . . . but if time exists, it is evident that motion must too, time being a kind of affection of motion' ('Si igitur inpossibile est esse et intelligere tempus sine ipso nunc, *nunc autem est medietas quedam, et principium et finem habens simul, principium quidem futuri temporis, finem autem preteriti* . . . At vero si tempus, manifestum est quia necesse est esse et motum, si quidem tempus est passio quedam motus'). Latin text from *Physica. Translatio vetus*, ed. F. Bossier and J. Brams, in *Aristoteles Latinus* VII 1.2 (Leiden and New York, 1990), p. 281 (251^{b}20–8). Emphasis mine.

[44] According to Bruce Eastwood, the explanation that the direct and retrograde motions of the planets were determined by the Sun are based on Plinian astronomical theories;

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The bishop offers no specific astronomical explanation for the longitudinal motions of the planets. This comes as no surprise, for in general his discourse lacks systematic explanations and develops in a rather axiomatic mode. More often than not, he seems to expect of the reader a familiarity with the philosophical and cosmological content of his arguments, no matter how sketchy his presentation of that content is. For that familiarity to function correctly, however, one must assume that the conceptual models behind his discourse are relatively consistent and widespread. It is, therefore, reasonable to conjecture that the astronomical circumstances behind all three types of planetary motion, including the longitudinal, develop from one and the same model of the cosmos. And the bishop is definitely more generous in providing details about that cosmic model when he discusses altitudinal planetary motion:

. . . each of the six planets, the farther away it is from earth according to whatever circle, the more efficacious it is; not because it is further, I say, but because it is faster and indeed more sonorous. Only the moon, the lower it is on its epicycle, the more efficacious it is, because there it is faster and more sonorous. On the eccentric, the farther it is from earth, the more efficacious, the faster and more sonorous it is.[45]

He unambiguously states that altitudinal motion is contingent upon a system of eccentrics and epicycles. By implication, both the longitudinal and the latitudinal planetary movements mentioned by him earlier in the treatise should be contingent on the same system. Moreover, he gives a rather detailed account of the eccen-

see B. Eastwood, 'Plinian Astronomical Diagrams in the Early Middle Ages', in E. Grant and J. E. Murdoch (eds), *Mathematics and its Applications to Science and Natural Philosophy in the Middle Ages: Essays in Honour of Marshall Clagett* (Cambridge, 1987), p. 148. However, the explanation also appears in Macrobius' *Commentarii* 1.20.5; several centuries later, Bartholomaeus Anglicus continues to elaborate on the same theory; see *De rerum proprietatibus* (1964 edn, p. 399, cited in Grant, *Planets, Stars, and Orbs*, pp. 453–4).

45 '. . . quilibet sex planetarum quanto remotior est a terra secundum quemcumque circulum, efficacior est; non quia remotior, inquam, sed quia velocior, immo quia sonorior. Sola luna, quanto inferior est in epicyclo, tanto efficacior est, quia illic velocior et sonorior. Nam in excentri, quanto elongatior est a terra, tanto efficacior, tanto velocior, tanto sonorior.' *Epistola cum tractatu*, p. 29.9. An eccentric circle is 'a circle whose center is not at the center of the world, . . . or a circle with a displaced cusp, or an outgoing center'. *Theorica planetarum*, trans. Pedersen, par. 1. An epicycle is 'a small circle on whose circumference is carried the body of the planet, and the center of the epicycle is always carried along the circumference of the deferent' ('circulus parvus per cuius circumferentiam defertur corpus planete, et centrum epicicli semper defertur in circumferentia deferentis'). Sacrobosco, *Sphere*, p. 141 (English), p. 114 (Latin). For a discussion of this passage in the context of the bishop's *musica mundana* see below, p. 62.

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tric and epicyclical lunar motions. To my knowledge, eccentrics and epicycles came to explain the observed planetary motions to the level of detail witnessed in the Barberini text only in the early thirteenth century, and as a direct result of the gradual integration of Ptolemaic astronomical theories in writings by Sacrobosco, Bartholomeus Anglicus and Robertus Anglicus, and in the anonymous *Theorica planetarum*, among other texts.[46] The bishop's reliance upon precisely those theories in order to frame his account of the celestial production of sound emerges as the strongest piece of evidence thus far in support for a thirteenth-century dating of his treatise. It also helps bring about his remarkably original interpretation of the celestial sounds.

III. THE PLANETARY PITCHES

If planets make sound in their various celestial motions, any Neoplatonist would ask, what are the exact pitches that produce the harmony of the spheres? The often-favoured solutions feature a combination of planetary pitches or intervals that produce a well-defined musical scale, albeit one that could be configured in any of several possible ways. Instrumental in the transmission of these cosmic configurations, in addition to Boethius, were a number of other late antique or early medieval writers, such as Pliny, Hyginus, Censorinus, Favonius and Martianus Capella.[47] Boethius accounts for two possible scales in his *De institutione*, one adopted from Nicomachus and the other from Cicero's *Somnium Scipionis*. The other writers offer scalar versions that reflect three slightly different yet related traditions going back to an alleged Varronian prototype.[48] Although all of them, including Boethius, adopted

[46] See Sacrobosco, *Sphere*, pp. 113–14 (Latin), pp. 140–1 (English); Robertus Anglicus, *Commentary on the Sphere*, pp. 193–5 (Latin), pp. 242–3 (English); Bartholomaeus Anglicus, *De rerum proprietatibus*, pp. 398–9.

[47] Pliny, *Naturalis historiae*, ed. C. Mayhoff (Stuttgart, 1967–96), II.22, p. 154; Hyginus, *De astronomia*, ed. B. Bunte (Lepzig, 1875), pp. 117–18; Censorinus, *De die natali liber,* ed. N. Sallman (Leipzig, 1983), 13.2–6; Favonius, *Disputatio de Somnio Scipionis*, pp. 42–3; Martianus Capella, *De nuptiis Philologiae et Mercurii*, ed. J. Willis (Leipzig, 1983), II.169–99, pp. 49–54; Boethius, *De institutione musica* I.27, p. 219.

[48] As one possible actualisation of the music of the spheres, the concept of the cosmic musical scale seems to have been adopted in the Latin tradition by Varro and disseminated by Varronian followers; see P. Tannery, *Recherches sur l'histoire de l'astronomie ancienne* (Paris, 1893), p. 330.

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what Macrobius identified as the 'Chaldean' order of planets, their cosmic scales vary in terms of their ambitus, planetary intervals and, in the case of the two versions in Boethius, direction.[49] Most important, only Boethius assigns a specific pitch to each planet, and does so in both the Nicomachean and Ciceronian versions. All other authors speak not of pitches as such but of intervals that occur between two successive planets. Each of their planetary scales develops not as a succession of pitches but of three possible intervals: the semitone, the tone and the semiditone (tone and a half). The sequences of pitches – the musical scales – that can be generated from the various combinations of these standard planetary intervals are somewhat difficult to position in the standard Greater or Lesser Perfect Systems (see Table 1, where the starting pitch [D] has been chosen for convenience).

Widely disseminated during the Middle Ages, most of these planetary musical scales considered the distance of a planet from the eighth sphere, the primary mover, to be the principal factor in determining the musical pitch the planet produces: since the moon is the farthest from the sphere, it is therefore the slowest and thus produces the lowest sound; Saturn is the closest, therefore the fastest and produces the highest pitch. Nicomachus' scale was exceptional in prescribing the reverse: the moon produces the highest pitch and Saturn the lowest. In Nicomachus' case, the velocity of the planet, while still directly proportional to its pitch, is deemed to be directly proportional to the planet's distance from the eighth sphere: because the moon, for example, is the farthest planet from the eighth sphere, it is also the fastest and, therefore, produces the highest pitch. Both of these sets of criteria were entertained during the Middle Ages, with a clear preference for the former. A complementary factor was occasionally brought into the discussions, though rarely, if ever, systematically explored: the

[49] According to Macrobius, the disagreement between the Platonic and the Ciceronian order of planets comes from them having adopted the 'Egyptian' and the 'Chaldean' orders, respectively; see Macrobius, *Commentarii in Somnium* I.19.1–2, p. 73. The 'Egyptian' order has the Sun in the second position, following the Moon (i.e., Earth, Moon, Sun, Venus, Mercury, Mars, Jupiter, Saturn, Fixed Stars); the 'Chaldean' order has the Sun in the middle position between Earth and the starry sphere (i.e., Earth, Moon, Venus, Mercury, Sun, Mars, Jupiter, Saturn, Fixed Stars). In addition, Venus and Mercury can exchange positions in both systems. For a list and a brief discussion of authors who subscribed to one or the other orders see Jacques Flamant, *Macrobe et le néo-platonisme latin, à la fin du IV^e^ siècle* (Leiden, 1977), pp. 421–4.

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Table 1 *Planetary scales*

Pliny	Martianus Capella	Favonius/ Censorinus	Hyginus	Boethius (Cicero)	Boethius (Nicomachus)
[*e*] Fixed stars					
	[*e*♭] Fixed stars				
		[*d*] Fixed stars	[*d*] Fixed stars		*d* Moon
[*c*♯] Saturn		[*c*♯] Saturn			
[*c*] Jupiter	[*c*] Saturn	[*c*] Jupiter			*c* Venus
[*b*] Mars	[*b*] Jupiter	[*b*] Mars	[*b*] Saturn		
	[*b*♭] Mars				*b*♭ Mercury
[*a*] SUN	[*a*] SUN	[*a*] SUN	[*a*] Jupiter	*a* Fixed stars	*a* SUN
			[*G*♯] Mars		
			[*G*] SUN	*G* Saturn	*G* Mars
[*F*♯] Venus	[*F*♯] Venus	[*F*♯] Venus	[*F*♯] Venus		
[*F*] Mercury	[*F*] Mercury	[*F*] Mercury	[*F*] Mercury	*F* Jupiter	*F* Jupiter
[*E*] Moon	[*E*] Moon	[*E*] Moon	[*E*] Moon	*E* Mars	*E* Saturn
[*D*] Earth	[*D*] Earth	[*D*] Earth	[*D*] Earth	*D* SUN	
				C Venus	
				B Mercury	
				A Moon	

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size of the planet. It was generally assumed that the larger the planet, the more powerful the sound.

The bishop's approach is not only extremely idiosyncratic but methodologically very intricate. The harmony of the spheres that results from his speculations does not conform to either the Boethian or to the more general Neoplatonic prototypes outlined above. Unlike Boethius, he assigns no specific pitches to each planet. Unlike the other Neoplatonic writers, he asserts that not one, not two, but all three planetary factors determine the cosmic harmony, and that they do so not individually but in combination. Because of this there emerge ratios among the various planetary pitches that become contingent upon compound ratios of the size of the planet, its distance from earth and its *motus*.[50] Furthermore, we shall see that while the size of the planet remains constant, the two other parameters become variable under the influence of the Ptolemaic system adopted by the bishop. Most of this information as well as the bishop's guidelines for calculating the musical intervals among the planets appears at the end of the treatise, almost like an afterthought, the *Corollarium* in the modern edition. I believe, however, that the so-called *Corollarium* represents more than just an afterthought. In the main body of the text, the bishop comments: 'For the sizes of the planets are known and so are the variation of their motions and their distances from earth. These

[50] The bishop seems to use the term *motus* in two ways. When used 'properly', it signifies the 'motion' of a planet: 'The term "proportion of the movements" is properly used for the proportion of the spaces that the things moved traverse in equal segments of time' ('Proportio motu(u)m proprie dicitur: proportio spatiorum, quae mota transcurrunt in aequis temporibus'). *Epistola cum tractatu*, p. 28.4. In the 'improper' sense, left here untranslated, it relates to the arc of the zodiac that a planet traverses in its revolution in a given time; he also makes sure to point out that it is not a proportion of the actual space that the planets traverse, but a proportion of the minutes of arc: 'The proportion of a planet's *motus* to its own or to that of another is called – albeit improperly – the proportion of the minutes (of arc) that one planet advances in a short time to the minutes that it or another advances in the same length of time, not the proportion of distance to distance. For the further a minute of arc is from earth, the more space it occupies, even if the eye judges otherwise' ('Proportio motus unius planetae ad motum eiusdem vel alterius dicitur – quamvis improprie – proportio minutorum, quae progreditur unus planeta in aliquantulo tempore ad minuta, quae ipse vel alius progreditur in tanto tempore; non proportio spatii ad spatium. Nam unum minutum quanto remotius a terra, tanto maius spatium occupat, licet visus aliter iudicet'). *Ibid*., p. 28.8. Simply put, this latter use of *motus* expresses the concept of angular velocity and thus relates to the technical term *motus* that in astronomical works indicates the angular distance of a planet from the first point of Aries; see, for example, *Theorica planetarum*, par 3, 17 and 41.

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things in place, to find the harmonies one can resort to the two diagrams written below and supported on this side and that by some axioms that my insomnia of tonight has brought together.'[51] The diagrams have not survived, but the *Corollarium* delivers the information in such a terse mode that it is hard to see it as representing anything other than the axioms of the insomniac bishop. He creates here a methodological blueprint that will eventually yield a mathematically derived set of formulae for calculating the ratios between the planetary pitches.

The axioms in his first main line of argument, tabulated in Table 2, are as follows:[52]

1. In general terms, the motion of a planet is directly proportional to its pitch; that is, the ratio between the higher and the lower pitch is same as that between the greater and the lesser motion.

2. In the case of two planets that are of unequal size but that manifest the same motion, the size of each planet is inversely proportional to its pitch – that is, the larger the size the lower the pitch, and vice versa.

3. When both motion and size are variable, when we are therefore dealing with two planets of different sizes and covering unequal arcs of the zodiac, there emerges a compound ratio of the greater to the lesser motion and the lesser to the greater size; the ratio of two pitches thus produced depends upon this compound ratio.

Table 2 *Axioms: planetary pitch (P), size (S) and motion (M)*

Constant	Variable	Ratio
size	motion	$P_1/P_2 = M_1/M_2$
motion	size	$P_1/P_2 = S_2/S_1$
—	motion and size	$P_1/P_2 = M_1/M_2 \cdot S_2/S_1$

[51] 'Si ergo motus superiorum corporum, ut persuadent philosophi, sine sono non est, mihi videtur ostendi posse: . . . Quantitates enim planetarum sciuntur et variationes motuum et elongationes a terra. Quibus positis, ad has harmonias inveniendas, duo subscripta faciunt theoremata, quibusdam velut axiomatibus, hinc (et) inde circumfulta, quae illius noctis mihi congessit insomnitas.' *Epistola cum tractatu*, p. 26.23–4.

[52] *Ibid*., p. 28.2–4.

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So far, the principles that the bishop has put forth can work perfectly well in the concentric system of planetary spheres, and are, therefore, unexceptional in the context of traditional Neoplatonic speculation on the music of the spheres. A drastic departure from the customary line of Neoplatonic reasoning occurs, however, once he introduces into the equation the parameter of planetary elongation – that is, the distance of the planet from earth. The entire picture changes significantly and there is a manifold increase in the complexities involved in the production of various pitches. This is due to the fact that for him the concept of elongation represents not only the distance to earth of each one of the planets at a single given time, but also the distance to earth of one and the same planet at two different moments in time.

The axioms in his second line of argument, tabulated in Table 3, are as follows:[53]

1. When all three parameters are considered, the greater the elongation, the greater the motion and the lesser the size are, the higher is the pitch.

2. In the case of one single planet, the ratio between the pitch that planet produces in one position and the pitch it produces in another position consists of the compound ratio among its two motions and two elongations.

3. In the case of two different planets, the ratio between the pitch of the superior planet and that of the inferior planet derives from the compound ratio of the greater motion to the lesser, of the greater elongation to the lesser and of the lesser size to the greater.

Table 3 *Axioms: Planetary pitch (P), size (S), motion (M) and elongation (E)*

general	$P_1/P_2 = M_1/M_2$ $P_1/P_2 = S_2/S_1$ $P_1/P_2 = E_1/E_2$
one planet	$P_1/P_2 = M_1/M_2 \cdot E_1/E_2$
two planets	$P_1/P_2 = M_1/M_2 \cdot E_1/E_2 \cdot S_2/S_1$

[53] *Ibid.*, p. 28.5–7.

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In the second axiom, the bishop introduces a temporal parameter in order to accommodate a situation not encountered in standard Neoplatonic speculations: that one single planet can actually produce different pitches at different moments in time. He maintains that the ratio between two of these pitches becomes dependent upon the compound ratios of that planet's motions and elongations at the two moments in time. For such compound ratios even to exist, however, the elongation and the motion of each planet must vary during the planetary revolution.

The concentric orbits and uniform planetary speed espoused in the standard Neoplatonic cosmology can neither generate nor accommodate variations such as these. The Ptolemaic system of eccentrics and epicycles, on the other hand, can account for both. As shown in Figure 1, in this cosmic model the elongation of each planet does indeed vary on account of either the eccentric or the epicycle, or both. It does so within the limits established by the combined eccentric and epicyclical apogees and their combined perigees. Moreover, in the Ptolemaic system, the velocity of a planet does indeed vary as well, for it is contingent upon the position of the planet on its epicycle. As the centre of the epicycle moves eastward on the eccentric deferent, a planet at the apogee of its epicycle is said to be quickest because the direction of its motion is the same as that of its orbital rotation (i.e., clockwise); a planet at the perigee of its epicycle is said to be slowest because it moves in a direction opposite to that of its orbital rotation. In

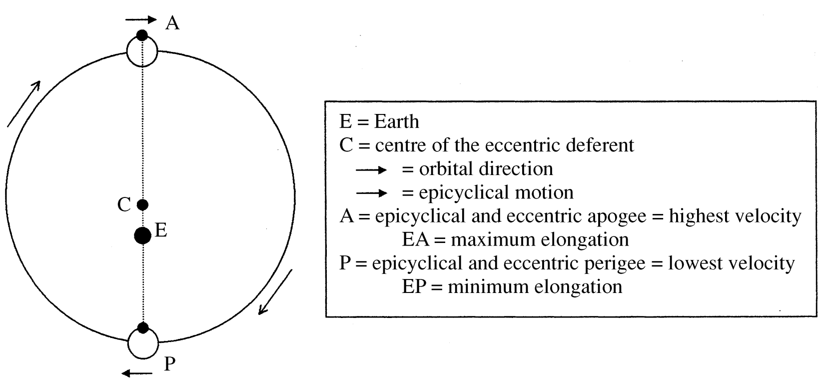

Figure 1 Planetary velocity and elongation

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the case of the moon, however, the situation is reversed: because the rotation of its epicycle is in an anticlockwise direction, the moon at the apogee of its epicycle is said to be slowest and at the perigee, fastest.[54]

These parameters are only implied in the bishop's second axiom, but they are clearly explained several paragraphs later. He specifies here that the sounds the celestial bodies emit in their revolution are also contingent on the position of the planets on their respective epicycles: the higher a planet is on its epicycle, the faster and more sonorous it is (the opposite is true in the case of the moon).[55] The cosmic parameters, therefore, have a definite impact upon the pitches that the planets emit in their revolutions. On the one hand, both the elongation and the speed of a planet are each directly proportional with its pitch. On the other hand, when elongation and speed participate in a compound ratio, a given planet would emit the highest pitch at the combined apogees of both its eccentric deferent and its epicycle where it is the quickest; it would emit the lowest pitch at their combined perigees where the planet is the slowest. Larger orbital cycles notwithstanding, the situation can be mathematically formulated as follows: because both the elongation and the speed of a planet constantly change, the compound ratio of these two factors changes as well; consequently, the ratio of two pitches emitted by the same planet at two different moments in time is always different from 1.

The implications these details have on the kind of planetary music the bishop envisages are immense, for although he fully embraces the Neoplatonic doctrines in spirit, so to speak, he does not follow them to the letter. Standard Neoplatonism stipulates a never-changing planetary music, either by having each planet generate a continuous sound of invariable pitch or by assigning a fixed

[54] For the orbital direction on the eccentric see *Theorica planetarum* pars 11 (Moon), 32 (superior planets), 59 (Mercury) and 77 (Venus); see also Robertus Anglicus, *Commentary on the Sphere*, pp. 242–3. Although Robertus Anglicus mentions the speeds of the planets on their epicycles only in passing and in an astrological context elsewhere in the commentary, they appear in a more precise fashion in *Theorica planetarum* par. 15: 'When the moon is in the upper part of the circumference of the epicycle it moves from east to west and therefore has a slow motion. In the lower part the motion is in the opposite direction and therefore fast. The other planets behave in the opposite manner.'

[55] *Epistola cum tractatu*, p. 29.9. See above, n. 45.

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interval between two successive planets. In the bishop's rendition of the planetary music, we can no longer conceive of a single constant pitch per planet. What he envisages, therefore, is that each planet emits a sound of varying pitch that rises and falls within a continuous field of pitches, and that the limits of this field are contingent upon the limits established by the planet's eccentric and epicyclical motion. Not until the early fifteenth century will another music theorist, in this case Giorgio Anselmi, assume that a single planet produces more than one pitch by reason of its epicyclical motion.[56]

Allowing for variable planetary distance and velocity – allowing, therefore, for planets to emit sounds of continuously varying pitch – negates the possibility of a single, fixed and continuously sounding celestial musical scale. Although the planetary alignment produces one particular scale at any given instant, at every other instant the changes in the orbital parameters will result in proportional changes in the pitch and, therefore, in the intervallic content of that scale. By adopting the dynamic Ptolemaic cosmological system, which causes each planet to emit a spectrum of pitches and together to generate a fluid type of celestial music, the bishop offers a reinterpretation of the Neoplatonic *musica mundana* that is, however, strikingly similar to that espoused by Hermann of Carinthia in his *De essentiis*. Hermann draws on notions found in Abu Ma'shar's *Introductorium*, a work that he had translated into Latin several years earlier.[57] Hermann's celestial

[56] Giorgio Anselmi, *De musica: dieta prima de celesti harmonia, dieta secunda de instrumentali harmonia, dieta tertia de cantabili harmonia*, ed. G. Massera ('Historiae Musicae Cultores' Biblioteca, 14; Florence, 1961), pp. 101–2. It is not the dynamic aspect, i.e. the multiplicity of sounds emitted by one single planet that is at issue here, but its relation to a specifically Ptolemaic system of eccentrics and epicycles. Several centuries earlier, commenting on Martianus' *De nuptiis*, Eriugena had described a dynamic music of the spheres as well; see, for example, B. Münxelhaus, 'Aspekte der Musica Disciplina bei Eriugena', in *Jean Scot Erigène et l'histoire de la philosophie. Colloque International du C.N.R.S.* (Paris, 1977), pp. 253–62. As I have shown elsewhere, Eriugena's dynamic music of the spheres was a direct outcome of the Plinian absidal cosmos he adopted (absides are circumterrestrial but not geocentric planetary circles, each *absis* having its own centre, path, length and motion); G. Ilnitchi, 'Celestial Harmony and Plinian Astronomy in the Eriugenian Commentaries on Martianus Capella's *De nuptiis*', paper read in 2000 at the Medieval and Renaissance Music Conference held in Oxford.

[57] Among the Arabic scholars, Abu Ma'shar Ja'far ben Muhammad ben 'Umar al-Balkhi, known in the Latin Middle Ages as Albumasar, was probably most influential. Heavily astrological and drawing on Aristotle's natural philosophy, his *Introductorium in astronomiam* was translated twice during the twelfth century: in 1133 by John of Seville and in 1140 by Hermann of Carinthia. In his controversial but stimulating book, Lemay argues

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modulation consists of 'the sounds responding to the distance of the intervals, the single changes varying with harmonic modulation according to the ascent and descent of the planets';[58] the pitch, therefore, varies with the 'ascent and descent' of the planet, which is nothing else than the planet's movement on its eccentric and epicycle.[59] Hermann's account may be less specific, but his music of the spheres shares in common with that of our bishop both the cosmic framework and the ever-changing planetary sounds.

IV. THE ZODIAC AND CELESTIAL INFLUENCE

In his preoccupation with the methods through which mathematical ratios among the pitches are to be derived, the bishop provides little, if any, factual information regarding the pitches themselves. Although his reasoning process is not only cogent but also detailed and his mathematical formulas relatively easy to reconstruct, it is clear that, given the right astronomical tables, the reader may be expected to work out the types of ratios the bishop puts forth and to come up with concrete solutions on his own. After all, he claims that the sizes of the planets, their motions and their distances from earth are known, and, indeed, all this information was available in one form or another in the astronomical treatises of the day.[60] As far as I can tell, however, none

that many authors of the twelfth century came for the first time in contact with Aristotle's natural philosophy in Albumasar's *Introductorium*; see R. Lemay, *Abu Ma'shar and Latin Aristotelianism in the Twelfth Century: The Recovery of Aristotle's Natural Philosophy through Arabic Astrology* (Beirut, 1962). It is worth noting that, translated into Latin several decades earlier than Ptolemy's *Almagest*, Albumasar's *Introductorium* contains one of the earliest treatments of the Ptolemaic planetary motions according to the system of eccentrics and epicycles available in the Latin world; *ibid*., p. 97.

[58] Hermann of Carinthia, *De essentiis* 68rG, and Burnett's commentary on pp. 292–4.

[59] *Ibid*. 68rE, and Burnett's commentary on pp. 291–2.

[60] In the *Almagest* Ptolemy establishes the absolute distances only for the sun and the moon, while in his *Hypotheses of the Planets* he calculates both the absolute distances for all the planets and the absolute size of their bodies. Although the *Hypotheses* was not available in Latin translation during the Middle Ages, its main concepts reached the Latin world through a host of Arabic sources in a manner that remains largely unknown; see Grant, *Planets, Stars, and Orbs*, p. 17. The first Latin writer to exploit the Ptolemaic technique for calculating the exact sizes and distances of the planets was Campanus of Novara in his *Theorica planetarum,* written most likely in the 1260s. For a more detailed discussion of these issues and of Campanus' dependence upon the Arabic tradition and especially Alfraganus, see *Campanus of Novara and Medieval Planetary Theory*, pp. 53–5. See also Robertus Anglicus' discussion based upon the data found in *Almagest* and elsewhere in his *Commentary on the Sphere*, pp. 194–5 (Latin) and p. 243 (English).

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of the ratios he develops can be reduced to the traditional Neoplatonic ratios that express the musical consonances. In other words, there are no evident 2:1, 3:2 or 4:3 ratios that seem to emerge from these planetary relations and that would correspond to diapason, diapente or diatessaron and their compounds. Paradoxically, therefore, although his objective is to advance a systematic method of calculation of pitches that eventually develop among the planets in their celestial movement, he does not specify their nature in terms of common Pythagorean musical ratios. The bishop would thus seem to be inadvertently undermining the very foundations of *musica mundana*.

Explicit analogies between Pythagorean cosmic and musical ratios appear, however, at the onset of his discussion of *musica mundana*:

> In the heavens there are four principal aspects: sextile, quartile, trine and opposition. The sextile consists of one-sixth of the path of the zodiac (*caelum*), that is 60°, compared with which the whole circle is six times as great; for example the weight (*pondus*) of the nineteenth string to that of the first. The quartile aspect occupies a fourth of the zodiac, that is 90°; it is in a 3:2 ratio to the 60° segment, which in music is called diapente. The trine aspect occupies a third of the zodiac, that is 120°; it is in a 4:3 ratio to the 90° segment, which in music is called diatessaron.
>
> Thus, the ratio between the degrees of the trine aspect to those of the quartile produces the diatessaron, between the degrees of the quartile to those of the sextile aspect produces the diapente and between those of the trine and of the sextile aspect, the diapason. Similarly, the opposition makes the diapason to the quartile, the diapente to the trine, while the trine in ratio to the quartile is said to produce the diatessaron.[61]

What this passage reveals is that mathematical ratios characteristic of musical consonances do have a place in the bishop's model of the music of the spheres after all, but they occur not among the planets, as one would expect in standard Neoplatonic

[61] 'In caelo quattuor dicuntur esse aspectus principaliter: sextilis, quartus, trinus et oppositio. Sextilis: sextam partem caeli tenet, scilicet .LX. gradus, ad quos totus circulus sescuplus est, sicut et pondus ultimae undeviginti chordarum ad pondus primae. Quartus aspectus quartam partem caeli tenet, scilicet .XC. gradus, quorum proportio ad .LX. sesqualtera est, quae dicitur in musica diapente. Trinus aspectus tertiam partem caeli tenet, scilicet .CXX. gradus, quorum proportio ad .XC. gradus est sesquitertia, quae dicitur in musica diatessaron. Igitur gradus trini aspectus ad gradum quarti aspectus diatessaron faciunt; gradus quarti aspectus ad gradum sextilis aspectus diapente; gradus trini aspectus ad gradum sextilis diapason. Item oppositio ad quartum aspectum diapason facit, ad trinum diapente, et trinus ad quartum diatessaron facere dictus est.' *Epistola cum tractatu*, p. 23.2–7.

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practice, but among the four aspects of the zodiac: the sextile, quartile, trine and opposition. The diagram in Figure 2 lays out the relationship between various segments on the circle of the zodiac, the ratios between the numerical degrees of the zodiacal *aspects*, and the musical consonances these ratios express. Not all possible zodiacal (or for that matter musical) ratios are accounted for. The bishop calculates only the ratios of 2:1, 3:2, 4:3 and 6:1 that correspond to the diapason, the diapente, the diatessaron and the interval of a *bisdiapason cum diapente*.

Treated as a proportional consonance with the ratio of 6:1, the latter interval of a nineteenth is very unusual in the general context of Pythagorean speculations.[62] Regardless, we have seen that the bishop seems to be particularly fond of it, and employs it not only in the context of *musica mundana* but also in his discussion of *musica instrumentalis* and *humana*. In the segment on *musica instrumentalis*, nineteen is the maximum number of strings that can enter proportional relationships 'because the weight (*pondus*) of the first string multiplied by six generates the weight of the hind-

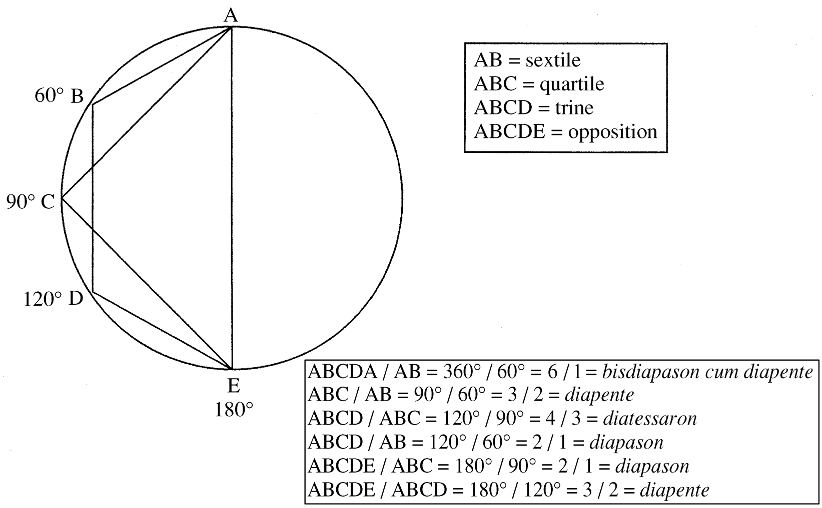

Figure 2 Planetary aspects and musical ratios

[62] It does not appear, for example, in the table of intervals compiled by Klaus-Jürgen Sachs for his article 'Musikalische Elementarlehre', pp. 129–30.

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most (highest?) string, since six is the first perfect number'. Together, these strings generate a nineteen-pitch gamut that the bishop maintains is characteristic of the *musica humana* as well. Here, the pitches are further arranged according to eight *graves*, seven *acutae* and four *superacutae*, which together form none other than the standard nineteen-pitch gamut as laid out by Guido of Arezzo in his *Micrologus*, chapter 2.[63] What is relevant to the present discussion is that the zodiacal *bisdiapason cum diapente* ratio of 6:1 in the context of *musica mundana* provides the mathematical and to some extent the ultimate cosmological endorsement for the gamut common to the other two Boethian types of *musica*, *instrumentalis* and *humana*.

The link between zodiacal aspects and musical consonances is extremely idiosyncratic, and no other medieval Latin treatise I have encountered features this association in an explicit manner. We do find it, however, in two Hellenistic works by Ptolemy: the *Tetrabiblos* and the *Harmonics*. Ptolemy provides the more detailed account of the relation between the zodiac and musical consonances in his *Harmonics*.[64] Knowledge of this treatise, however, entered the Latin world at the earliest towards the mid or late fourteenth century, and it is therefore very unlikely to have been the source for our treatise. On the other hand, the *Tetrabiblos* (or the *Quadripartitum*, as it was known during the Latin Middle Ages), where Ptolemy briefly yet specifically associates the zodiacal aspects with the consonant ratios 3:2 and 4:3,[65] was translated by Plato of Tivoli sometime around 1140, and soon after it became a standard text in the Latin West. If our treatise was composed in the thirteenth century, as its dependence upon Aristotelian natural philosophy and Ptolemaic astronomy suggests, Ptolemy's remarks in the *Tetrabiblos* may very well have provided the source of our author's zodiacal musical speculation.[66] Furthermore, the

[63] *Epistola cum tractatu*, p. 22.1. See above, n. 6.

[64] See T. J. Mathiesen, *Apollo's Lyre: Greek Music and Music Theory in Antiquity and the Middle Ages* (Lincoln, Nebr., and London, 1999), pp. 484–93.

[65] Ptolemy, *Tetrabiblos*, ed. and trans. F. E. Robbins (Loeb Classical Library, 435; Cambridge Mass., 1948), I.13, pp. 73–4.

[66] A similar relationship between planetary sounds and zodiacal aspects appears in Michael Scot, *Liber introductorius*, as mentioned in F. A. Gallo, "Astronomy and Music in the Middle Ages: The *Liber Introductorius* by Michael Scot', *Musica disciplina*, 27 (1973), pp. 5–9, at p. 8, n. 22.

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similarities go even further, albeit in very general terms. Both writers position their remarks amidst accounts of the various positive and negative planetary influences on terrestrial things, and as such they make the proportions participate in the larger phenomenon of celestial causation. The bishop states:

In accordance with these aspects, the ray of the sun, refracted by the moon and reverberating in sublunar objects, has now one, now another effect: in the brain and the bone marrow, which concern physicians; in seas and shells and even in the varieties of wind, which concern seafarers; in herbs, arbours, infirmities and many other matters, which concern the unlearned and the common people.[67]

Although widely accepted during the Middle Ages, during the thirteenth century the medieval belief that celestial bodies have a controlling influence over the terrestrial region derived additional authority from Ptolemy's *Tetrabiblos*, as well as from Aristotle's *De caelo* and his writings on natural philosophy. They provided the intellectual basis for the notion that the incorruptible celestial substance excelled and, therefore, should influence the behaviour of corruptible bodies in the sublunar realm.[68] Further reinforcement came from a variety of Greek and Arabic works that became available in western Europe by the end of the twelfth century, among which probably the most influential was, once again, Abu Ma'shar's *Introductorium*. The bishop's remarks, however, are so terse and the information therein so meagre and of such general nature, that an attempt to determine whether they depend on a specific astrological tradition is bound to fail – with one possible exception: the 'doctrine of rays' as transmitted in al-Kindi's treatise, known in its late twelfth-century Latin

[67] 'Secundum hos aspectus radius solis, refractus in luna, et inferiora reverberans, alios et alios habet effectus; in cerebro et medullis, quod patet physicis; in mari et conchyliis, immo etiam in aeris varietatibus, quod patet marinariis; in herbis et arboribus et infirmitatibus, in rebus quampluribus, quod patet etiam idiotis et simplicibus.' *Epistola cum tractatu*, p. 24.11–12. While the general tone is similar to that in *Tetrabiblos* I.3, esp. pp. 25–30, and so is the order of the examples, the passage also echoes a segment from Abu Ma'shar's *Liber introductorii*: 'Nam et marinarii et illi qui volunt scire nubilum aspiciunt applicationem Lune ex eodem tempore ad hos dies et loca nota que nominavimus, sciuntque ex eis esse ventorum et nubilorum atque pluviarum et rorum . . .'; see *Liber introductorii maioris ad scientiam judiciorum astrorum*, ed. R. Lemay (Naples, 1995–6), pp. 132–3. See also Robertus Anglicus' comments on astrological medicine in his *Commentary on the Sphere*, pp. 228–9.

[68] For a discussion of the theories of celestial causation in the Middle Ages and beyond, see Grant, *Planets, Stars, and Orbs*, pp. 569–617, and J. North, 'Medieval Concepts of Celestial Influence: A Survey', in P. Curry (ed.), *Astrology, Science and Society: Historical Essays* (Woodbridge, 1987), pp. 5–17.

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translation as *De radiis*.[69] I will concern myself here not with the whole complex of al-Kindi's astrological doctrines in *De radiis*, but only with those aspects that I believe to have found their way, directly or indirectly, into the bishop's assessment of the kind of relationship manifest between the planetary rays and celestial harmony.

Al-Kindi begins with the fundamental claim that 'the world of the elements and everything composed of them depends on the disposition of the stars'; the reason for this, he argues, is that the stars send their rays into the world.[70] The radiation varies with the nature of the star, its position in the *machina mundana* and the combination of rays from different stars, so that when the diverse rays coalesce into a single one, 'in every different place there is a different tenor of rays derived from the total harmony of the stars'.[71] If someone were granted a full understanding of the celestial harmony, he would also fully understand the elementary world and everything it contains, anywhere, anytime; for any thing in the elementary world is an effect of the whole celestial harmony.[72] The two notions that seem to have some bearing upon our discussion can be summarised as follows: the celestial harmony emerges as the ultimate cause of changes in the sublunar world through the agency of rays, and provides the ultimate knowledge. Similarly, the bishop maintains that the planets emit rays whose compound refraction fosters sublunar changes, and that knowledge of this very harmony will ultimately reveal the full extent of celestial causality.[73] His celestial harmony, although permeated

[69] The Latin text has been edited and briefly discussed by M.-Th. d'Alverny and F. Hudry, in 'Al-Kindi, *De radiis*', *Archives d'histoire doctrinale et littéraire du moyen âge*, 41 (1974), pp. 139–260. For a brief summary of its contents see L. Thorndike, *A History of Magic and Experimental Science*, i (New York, 1923), pp. 642–6, and the recent study by P. Travaglia, *Magic, Causality and Intentionality: The Doctrine of Rays in al-Kindi* (Florence, 1999), pp. 17–48.

[70] Al-Kindi, *De radiis*, p. 218.

[71] *Ibid*., pp. 219–20.

[72] 'Si enim alicui datum esset totam condicionem celestis armonie comprehendere, mundum elementorum cum omnibus suis contentis in quocumque loco et quocumque tempore plene cognosceret . . . Omnis enim res, quam modica in mundo elementorum agens, totius celestis armonie est effectus.' *Ibid*., p. 223. Al-Kindi argues also that through a knowledge of things in the elementary world it is possible to arrive at an understanding of the celestial harmony; in other words, one may come to know the effect by knowing its cause, or the cause by knowing its effect.

[73] 'Moreover, those very projections of rays, as said above, borrow their strength from music [i.e., the musical ratios in the zodiac]. Therefore, if philosophers establish that these

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by al-Kindi's radiation, has a unequivocal musical component, however: the planets make sound, albeit it cannot be heard, and the compound refraction of their rays is contingent not only upon their eccentric and epicyclical motion but also upon the zodiacal aspects, which in turn relate to each other according to musical ratios.

One fundamental question comes to the fore. If the musical consonances pertain to planetary aspects that foster terrestrial changes, rather than to the Neoplatonic sounds that planets emit in their revolutions, how can one reconcile the notions of the music of the spheres and celestial causation, and integrate them in a harmonious conceptual whole? If there were such a relationship, it could not be simply explained by the influence of the heavens making itself felt in the sublunar world by means of conventional sound, for the harmony of the spheres cannot be heard and the ratios of the planetary aspects are by their very nature silent. I suspect that possible answers may emerge from considering the bishop's understanding of the term 'ray'. In the treatise, 'ray' appears in two contexts: in the passage, quoted above, in which he discusses celestial influences, and in the last paragraph of the treatise. Both times, as a primary vehicle for celestial influence on the terrestrial realm, the ray has a musical component.

From the thirteenth century onwards, the three agents of celestial causation most often identified and discussed by Latin scholars were motion (*motus*), light (*lumen*) and influence (*influentia*).[74] Not always, however, did writers clearly distinguish among these agents or their effects. Nor did they always consider the potency of celestial influence to be contingent upon the zodiacal aspects of the planets alone. Robertus Anglicus, for example, seems to combine light and influence into one type of ray, expressed as a single entity with a twofold action: 'a planet produces heat by the reflection of rays on the surface of the solid body and it also

musical projections of the rays, which are known as aspects, constitute the effects of the planets, far more the celestial harmony, once it has become known, fully will reveal the secret councils (of these effects)' ('Sed et ipsae proiectiones radiorum, ut supradictum est, vim suam mutuantur ex musica. Si igitur musicae proiectiones radiorum, quae dicuntur aspectus, effectus planetarum philosophis ostendunt, longe plenius harmonia caelestium, cum cognita fuerit, eorum arcana consilia revelabunt'). *Epistola cum tractatu*, p. 29.15.

[74] Discussed in some detail in Grant, *Planets, Stars, and Orbs*, pp. 586–615.

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produces virtue by the same ray'.[75] He further argues that, in addition to being conditioned by the zodiacal aspects, the influences of motion and ray are intricately linked with the Ptolemaic astronomical system, for 'the moon and other planets have stronger dominion over inferior things when they are in their apogee than when they are in their perigee' because at the apogee they move faster, whereas the influence of the ray is stronger when the star is in the lower part (of the orbit) because then the ray is shorter.[76]

The ray, as celestial *influentia,* was most akin to light; yet *influentiae* were invisible and could penetrate solid opaque bodies, which light could not do. In his *De fluxu et refluxu maris*, written very likely between 1220 and 1230, Robert Grosseteste criticises and rejects the explanation of the tides offered by Alpetragius in *De motibus caelestibus*:[77] 'the other high and low tides take place when the moon is in the two quarters below the horizon, and its light cannot act on the sea. Since heavenly bodies can only act on lower bodies by their light, it is doubtful how the moon can be the cause of the motion of the sea'.[78] In the second half of the thirteenth century, however, Richard of Middleton argues that the same substantial forms of the celestial bodies that emit light rays radiate the influ-

[75] The whole passage reads: 'Also note that a star exerts influence in two ways, by motion and by ray. By motion it produces heat; by ray it produces heat and virtue. For it produces heat by the reflection of the rays on the surface of a solid body, and it also produces virtue by the same ray' ('Item nota quod stella influit dupliciter, per motum et per radium. Per motum influit calorem, per radium influit calorem et virtutem. Influit enim calorem per reflexionem radiorum ad superficiem corporis solidi. Influit etiam virtutem per eundem radium'). Robertus Anglicus, *Commentary on the Sphere*, p. 154 (Latin) and p. 209 (English).

[76] '. . . luna et alii planete habent dominium fortius super res inferiores quando sunt in auge sui circuli quam quando sunt in opposito sue augis . . . quia quando stella est in auge sui circuli, velocius movetur, et quanto velocius movetur, fortius influit in hec inferiora. Et forte, si loquamur de influentia que fit per radium, tunc fortior est influentia quando stella est in parte inferiori eo quod tunc radius est brevior.' *Ibid.*, p. 162 (Latin) and pp. 214–15 (English).

[77] That is al-Bitruji (fl. 1185), a Spanish Muslim scholar; his treatise was translated into Latin by Michael Scot in 1217 under the title *De motibus caelorum* and edited by F. J. Carmody, *De motibus caelorum: Critical Edition of the Latin Translation of Michael Scot* (Berkeley, 1952).

[78] R. Grosseteste, *On the Causes of the Tides*, in Grant, *Source Book*, p. 642; reprinted from R. C. Dales, 'The Text of Robert Grosseteste's *Questio de fluxu et refluxu maris* with an English Translation', *Isis*, 57 (1966), p. 461. Grosseteste's authorship has been hotly debated; see J. McEvoy, 'The Chronology of Robert Grosseteste's Writings on Nature and Natural Philosophy', *Speculum*, 58 (1983), pp. 629–30.

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ence (*influentia*) as well, and that it is the *influentia* that causes the ocean tides.[79]

For Grosseteste, because light is the only causal agent and it cannot traverse the solid body of the earth, the action of the moon on the ocean tides is difficult to explain. For Richard of Middleton, the problem is non-existent, because to him it is not the light but the *influentia* of the moon that causes the tides. The bishop subscribes to this later interpretation of Alpetragius' theory. In the last paragraph of his treatise he states:

> Although the potency of rays is great, it is made far more powerful by *musica*. The planets do not operate less where [when?] they illuminate than where they do not illuminate. The moon rising at 90° longitude equally raises the ocean in India and in Britain, granted that it illuminates the former while it does not illuminate the latter. Sound can penetrate even the most solid objects; the ray [of light] cannot.[80]

Lunar rays cause the tides in Britain as those in India. Nevertheless, light cannot be the cause of the tides in Britain because it cannot penetrate solid objects. Since sound can penetrate solid objects (as long as they are porous, Aristotelians would argue), it is sound, therefore, that must be effecting the tides. Like Robertus Anglicus' rays, the bishop's rays seem to have a composite spectrum. He suggests that in addition to light there is some kind of sound that acts upon the terrestrial realm as a form of celestial *influentia*. The strength of these rays depends upon the musical ratios in the zodiac and, as mentioned above, understanding the general *modus operandi* of celestial causation is contingent upon understanding cosmic harmony, and vice versa.

There is reason to suspect that the anonymous author's views had a wider currency in thirteenth-century speculation on *musica mundana* than the survival of his treatise in one manuscript might imply. As mentioned earlier in this essay, around 1267, Roger

[79] 'Ad quintum dicendum quod corpora superiora non alterant ista inferiora per influentiam luminis tantum, sed etiam per motum et per influentia immissas a suis formis substantialibus cum radiis luminosis per quam influentiam causat luna mirabiles aestus oceani, hoc est fluxum eius et refluxum'. *Clarissimi theologi magistri Ricardi de Media Villa . . . Super quatuor libros Sententiarum Petri Lombardi questiones subtilissimae* (Brescia, 1591; facs., Frankfurt, 1963), p. 189, col. I.

[80] 'Verumtamen licet radiorum sit multa potentia, revera longe fortior est musica. Nam planetae non minus operantur, ubi radiant, quam ubi non radiant. Luna oriens existentibus in longitudine nonaginta graduum, et apud Indos et apud Brittanos, aequaliter extollit oceanum, licet illis radiet, istis non radiet. Sonus omnia solidissima penetrare potest; radius vero non potest.' *Epistola cum tractatu*, p. 29.12–13.

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Bacon rejected the existence of *musica mundana* and maintained that Boethius only recounted an opinion of the unlearned. In the same passage from *Opus tertium*, Bacon reports that 'Other philosophers have said that *musica mundana* comes not from the sound of celestial bodies but from sound generated by the rays of those bodies, saying that [in the case of *musica mundana*] sound is generated . . . from beams rarefying the air.'[81] He further argues that not all the rarefactions of the air can generate sound, but only those caused by percussion according to Aristotle; and since the ray does not percuss, but is generated by the potentiality of matter, celestial rays cannot generate sound. Bacon's relatively lengthy argumentation suggests that the 'sounding beam' theory he was rejecting had some advocates. However, as far as I know, these advocates have never been identified; the anonymous bishop may very well have been one of them.[82]

None of the bishop's statements can be traced to a specific source. His musings are very much informed by an internalised and sometimes imprecise awareness of a host of doctrines pertaining to Aristotelian production and propagation of sound, Ptolemaic astronomy and astrological speculations current about the mid-thirteenth century. In his treatise, rather than cancelling each other out, all these doctrines coalesce to form a relatively cogent conceptual system to support a notion of *musica mundana* that can be summarised as follows: (1) the continuous spectrum of pitches that each planet produces in its revolution depends upon

[81] 'Propter quod alii subtilius philosophantes dixerunt quod musica mundana non est ex sono coelestium corporum, sed ex sono generato ex radiis corporum illorum, dicentes sonum . . . generari . . . ex radiis rarefacientibus aerem.' R. Bacon, *Opus tertium*, p. 229.

[82] One other strong candidate is the anonymous author of the glosses on Boethius' *De institutione musica* found in Oxford, Bodleian Library, Ashmole 1524 and Milan, Biblioteca Ambrosiana Q.9.Sup., discussed in C. Panti's article 'Grosseteste's Theory of Sound', in F. Hentschel (ed.), *Musik — und die Geschichte der Philosophie und Naturwissenschaften im Mittelalter* (Leiden, 1998), pp. 14–16. As Panti points out, the glossator's theory of sound as incorporated light is similar to that espoused by Grosseteste and Albertus Magnus, among others. He applies this theory in order to solve the problem of how the music of the spheres is produced: the sound is produced by the light (*lux*) emitted by the celestial bodies; part of the *lux* that reaches us is visible, while the part that is incorporated in the most subtle air is perceived as sound; its composition is less dense than that of our hearing and, therefore, celestial sound is not audible to us ('Sed a corporibus celestibus continue lux diffunditur et penetrat partes huius aeris, et quod illius lucis absque incorporatione in subtili aeris venit ad nos visibile est; quod vero in aeris subtilissimo de illa luce incorporatur, et sic pervenit ad nos quantum est de natura sua audibile, est et sonus. Nobis tamen audibile non est, quia compositio nostri audibilis grossior est quam sit illius soni compositio'). *Ibid.*, p. 16.

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compound ratios between the planetary sizes, elongations and motion at any given time; (2) in their course through the heavens planets reach certain 'zodiacal nodes', when their aspects form ratios analogous to those of musical consonances; (3) at these 'nodes', the pitches that the planets emit at that exact moment coalesce into 'sounding rays' of maximum strength and manifest themselves as *influentiae* upon the sublunar world. The bishop envisions a music of the spheres that cannot be heard but that nevertheless participates in the celestial influence on the sublunar world. He thus succeeds in neutralising one of the most powerful arguments that Aristotle offered in *De caelo*: that there is no noise in the heavens not only because we do not hear it, but also because 'no effect other than the sensitive is produced upon us' and we 'show in our bodies none of the effects of the violent force'.[83]

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[83] Aristotle, *On the Heavens* II.9 (290^{b}30–291^{a}6), p. 479.

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