Johannes Kepler and the Song of the Earth

Peter Pesic

Dedicated to Curtis Wilson

> The great mathematician and astronomer Kepler (d. 1630), in his "Harmonia Mundi" ... speaks upon the subject of Music like a man who had not only thought of it as a science subservient to the laws of calculation, but studied it as an elegant art, and been truly sensible to its powers. (Charles Burney, A General History of Music, 1776)[1]

Johannes Kepler is often remembered as a unique, idiosyncratic theorist who applied ancient concepts of cosmic harmony to emergent modern astronomy. In many accounts, Kepler's Harmonices mundi libri V (1619) culminates in his so-called Third Law of planetary motion: "the proportion between the periodic times of any two planets is precisely the sesquialterate proportion [i.e., the 3/2 power] of their mean distances."[2] This surprising connection emerged from Kepler's persistent search for harmonic relations between planetary data and became a crucial touchstone for Newtonian celestial mechanics. Accordingly, scholars have tended to depict Kepler as a neo-Platonic thinker mainly concerned with cosmic archetypes rather than earthly matters.[3] Without denying the truth of this view, I wish to consider another, neglected facet of Kepler, his keen interest in practical music and contemporary compositions, not just pure theory.[4] Kepler's strong feeling for what he called the "song of the Earth" illuminates and complements his cosmic concerns.

To be sure, the prevalent view of Kepler as pure theorist accurately reflects the bulk of his writings. The reader of Harmonice mundi encounters lengthy series of geometric-style propositions concerning the ratios of sides of polygons, viewed from the perspective of neo-Platonic philosophy. Indeed, the work concludes with a polemic against the English Rosicrucian Robert Fludd, from whom Kepler distinguishes himself "in the way in which a practitioner does from a theorist."[5] According to Kepler, Fludd "has advice on the composition of figured melody, an art which I do not profess" and "also digresses to various musical instruments, to which I had not even given thought."[6]

Though the moments when Kepler turns to actual musical compositions are few and brief, they give a further insight into his sensibility. In those moments, he characteristically gives examples from compositions by Orlando di Lasso. Kepler does not say much or go deeply into these examples, yet they are still interesting because they figure in an astronomical work. Indeed, in the long tradition linking music and astronomy, Kepler is remarkable for citing specific musical examples, not just theoretical generalizations. I wish to explore what these examples might mean in the context of his whole project.

Such inquiries face many pitfalls. For instance, Erwin Panofsky argued that Galileo Galilei's artistic judgments, particularly his antipathy to manneristic art and its predilection for oval shapes, influenced his scientific views, including his rejection of the elliptical orbits found by Kepler in his First and Second Laws of planetary motion.[7] Such assertions must be carefully balanced, for surely Galileo's artistic views were one factor among many, not simple determinants of his scientific views.[8] I will take a different approach in this paper, not relying on questionable generalizations from sweeping terms like "mannerism" but rather on Kepler's explicit use of musical examples at critical points in his argument. In so doing, I will try to explore how his feeling for this music may have informed his scientific views.

Based on a lecture given at St. John's College in Santa Fe, NM on November 19, 1999. This is the preliminary version of a text to be published in 2004 by the MIT Press.

Kepler's musical background and activities

From early childhood, Kepler was steeped in the musical traditions of Württemberg Protestantism, in school and in church.[9] Beginning in his fifth year, he practiced German psalmody as well as the Latin sequences and hymns that he later cites in Harmonice mundi.[10] This daily singing was supplemented by weekly lessons in theory. The standard of musical cultivation as well as of theoretical instruction in Württemberg was quite high, including also contrapuntal and figured music.[11] Michael Dickreiter concludes that Kepler derived a solid theoretical knowledge and practical skill from his primary schooling, continued and deepened during his theological studies in Tübingen (1589-1594).[12] There, he, like all his fellow students, had musical instruction. The academic ordinances prescribed singing three days a week, so that the students must "always study new motets and good songs, and thus keep the exercise of music in practice."[13] Kepler also participated in performances of church music and private festivities. During those years, he encountered Glarean's musical theories and befriended Lucas Osiander, son of the well-known theologian and sacred composer of the same name.[14]

Kepler's first job was as mathematics teacher in Graz (1594-1600), where he also taught Virgil and rhetoric. This was more than mere necessity; his abiding interest in the practice of rhetoric (and use of Virgilian images) informed his mature writings.[15] The musical life of the school where Kepler taught was many-sided. The organist Erasmus Widmann so favored dance styles in his sacred music that sarcastic critics wondered whether they were in a church or a beer-hall.[16] During Kepler's stay, the Italian organist Annibale Perini brought Venetian musical practice to Graz. Indeed, Andrea Gabrieli had dedicated his Primus Liber Missarum 6 V (1572) to Karl, the Habsburg archduke resident in Graz. Karl had close links to Venice; his wife, Maria had a personal bond to Lasso's family and a strong interest in his music. The archducal library included works by Lasso, Adrian Willaert, Philippe de Monte, and Ludovico Zacconi, among other contemporary composers.[17] It is not clear what part Kepler took in all this, though it seems likely he would have been aware of these musical cross-currents.

His correspondence reflects above all his preoccupation with his first, seminal work, Mysterium Cosmographicum (1596). One of his letters does mention "the excellent music that Italy abounds in" and Kepler's acquaintance with Lasso's music definitely began in Graz, if not before.[18] In 1599, Kepler wrote a friend that he wished that "Orlando, if he lived," could teach him how to tune a clavichord properly.[19] Note that Kepler singles out the great composer as the ultimate authority on tuning.

After Kepler moved to Prague in 1600, he entered the service of the Emperor Rudolf II, famous for his patronage of occult arts. Unmarried, distancing himself ever further from political realities, Rudolf fostered "exact science next to the deepest superstition, religious freedom next to zealotry, a tendency to display the utmost pomp next to diseased manifestations of self-love and eccentricity, refined taste next to brutal sensuality."[20]

In Rudolf's court, both practical and theoretical music were important, including some novel developments.[21] For instance, the court alchemist Michael Maier wrote fifty canons in Atalanta fugiens (1618) whose settings of alchemical texts would complement the manipulations of the "great art."[22] Such a synthesis would have deeply interested the alchemist-emperor. So also did the "perspective lute," which tried to relate musical tones to colors, or the court composer and organist Hans Leo Hassler's experiments with new automatic instruments.[23] As R. J. W. Evans points out, in such activities music was "practical, yet offered immediate contact with cosmic forces."[24] As such, the practice of music aspired to realize the Renaissance dream of mobilizing magic powers through the influence of sound.[25]

Kepler did not record his precise reaction to these developments but did write to a friend a stark disclaimer: "I hate all kabbalists."[26] To be sure, Kepler gave voice to mystic sentiments of his own: "For there is nothing which I examine with more scruple, and which I desire to know so much as this: whether perhaps the God whom I as it were touch by hands when I contemplate the whole universe, can also be

found by me inside myself."[27] However, Kepler noted in Harmonice mundi that "whoever wants to nourish his mind on the mystical philosophy ... will not find in my book what he is looking for."[28] He detested esotericism in all its forms, manifested in his polemic against Fludd mentioned earlier.[29] Nevertheless, Kepler was deeply interested in the larger question of how the practice and theory of music might impinge on cosmic structure. His antipathy to the esoteric strain in Rudolf's court may have indicated his anger at what he considered the bungling of his own favorite idea that music mirrors the cosmos.

Kepler's letters of the period turned to more practical concerns. He corresponded about problems of interval tuning in Andreas Reinhard's Monochordium (1604).[30] Such questions also related to the "Clavicymbalum Vniversale, seu perfectum," a keyboard instrument much admired at court, whose octaves were divided into nineteen steps.[31] He likely attended the services of the court chapel, in which one hundred musicians (including sixty-five singers) performed music by court composers such as Philippe de Monte and Hans Leo and Jacob Hassler, as well as Venetian polychoral music and early monody. He could scarcely have missed the six "Geiger oder Musici" or the eighteen trumpeters and timpanists that were part of the imperial household.

Kepler did record a fragment of the prayers sung by the "Turkish priest" who accompanied the Turkish ambassador to court. According to Dickreiter, this was "the first known ethnological investigation of this sort," perhaps the first foray ever made into ethnomusicology.[32] Kepler was fascinated by what he described as the priest's "practiced and fluent manner, for he did not hesitate at all; but he used remarkable, unusual, truncated, abhorrent intervals, so that it seems that nobody could with proper guidance from nature and voluntarily of his own accord ever regularly contemplate anything like it. I shall try to express something close to it by our musical notation." (Figure 1)[33] I shall return later to the significance of Kepler's attempt to notate the exotic strains of Muslim cantillation. For now, it is an apt image of his alert curiosity about the possibilities of music in practice, not only in theory.

Finally, the archduke Matthias seized power from his Prospero-like brother Rudolf, who died not long after, in 1612. Kepler did not remain in Prague but spent his last years in Linz (1612-1626) as a teacher, though retaining the title of Imperial Mathematician. There, he completed the Harmonice mundi, the apex of his theoretical activities, in a school that was reputed "the undisputed center of musical cultivation to support the renewal of faith" and that gave the highest priority to "musica practica."[34] Lasso had pride of place in their library, followed by other masters of the Renaissance. Dickreiter thinks it probable that Kepler, following the customary academic regulations, would have taken an active part in the choir and also in the house-music of the regional nobility, among whom he had many friends and patrons.[35]

The influence of practical music on Kepler

Thus, although Kepler claimed no skill as composer or performer, he had been surrounded with musical performance all his life and had been personally involved on many occasions. Here, more recent distinctions of professionalism are misleading. The musical experience of an amateur can be no less deep than that of a professional and, in Kepler's time, amateurs did a great deal of serious music-making. It might even be argued playfully that his exposure to musical practice was more sustained and thorough than his knowledge of theoretical writings, which Dickreiter judges as "not very many-sided."[36]

Beyond the traditional school readings in the quadrivium, Kepler was largely self-educated, but with the gusto that characterized his idiosyncratic genius. One thinks of him travelling in October, 1617 to save his aged mother from prosecution as a witch, taking Vincenzo Galilei's Dialogo della musica antica et della moderna (1582) as reading for the journey and reading it "with the greatest pleasure" ("summa cum voluptate").[37] This shows that only two years before Kepler published his own treatise he needed to catch up with contemporary theory. (Indeed, Kepler manuscripts in the Pulkowa library reveal that he only read three-quarters of Galilei's book).[38] To gauge the state of such studies at the time, Kepler was able to

acquire a Greek text of Ptolemy's Harmonia only in 1607.[39] Thus, Kepler essentially reinvented and then rediscovered this important ancient source in the course of pursuing his own vision.

Though he was engaged in reviving the ancient vision of cosmic harmony, Kepler's awareness of contemporary music informed crucial departures from the ancients. To begin with fundamental issues of interval construction, Kepler parted company with the Pythagorean tuning as transmitted by Boethius, the author of De institutione musica (early sixth century) and the most influential authority on music in the early Middle Ages. Boethius and also Macrobius defined the major third as 81:64 and the minor third as 32:27. Instead, Kepler advocated just intonation (5:4 and 6:5, for the major and minor thirds, respectively). In justification, Kepler asserts that the Pythagoreans "were so much given over to this form of philosophizing through numbers that they did not even stand by the judgment of their ears, though it was by their evidence that they had originally gained entry to philosophy; but they marked out what was melodic and what was unmelodic, what was consonant and what was dissonant, from their numbers alone, doing violence to the natural prompting of hearing."[40] Though Kepler praises Ptolemy for including just intonation among his tunings, Kepler considers that Ptolemy still erred by denying that thirds and sixths were consonances, so that "the man who restored the judgment of the ears to its rightful place in words and doctrine nevertheless deserted it again."[41]

To be sure, Kepler may be echoing the ancient Greek theorist Aristoxenus in praising practical judgment over pure theory, a old commonplace of anti-Pythagorean teachings. More recently, Gioseffo Zarlino had already given a classic and widely-known exposition of just intonation in Le Istitutioni Harmoniche (1558), which Kepler probably knew, since he refers to Zarlino elsewhere.[42] However, Kepler presents his own views without reference to Aristoxenus or Zarlino, using arguments based on ratios between sides of regular polygons as well as through the long-standing practice of musicians, who needed just thirds and sixths as consonances for their polyphonic music.[43]

In D. P. Walker's view, "though modern music reveals the archetypical structures of the heavens, it is not an imitation of the celestial music, nor derived from it; but both are likenesses of the same archetypes, the geometric beauties coeternal with the Creator; and modern music, as we shall see, thereby even allows us to experience something of God's satisfaction in His own handiwork."[44] Yet here Walker may not have gone far enough, for a careful examination of Kepler's reasoning shows not merely that he treated pure mathematics and musical practice as parallels that never meet, but rather that his musical judgments informed his mathematical choices.

As I have discussed in detail elsewhere, Kepler could have included as "consonances" such discordant ratios as 3:7 if he had included the sides of a regular heptagon following the same reasoning through which his treatment of the pentagon led to the major sixth, 3:5.[45] Here he relied on geometry to exclude the heptagon, which cannot be constructed with ruler and compass, unlike the pentagon. Yet just at this juncture he pauses to acknowledge that the nascent art of algebra would allow a calculation of the heptagon's side that, if accepted, would give the heptagon as much a claim to validity as the pentagon.

In the end, he does not allow algebra equal legitimacy, for which his ultimate reason is an appeal to musical practice. Algebra would allow intervals like 3:7 that are "utterly abhorrent to the ears of all men and the usages of singing, even though it may be possible for strings to be tuned in that way, seeing that as they are inanimate they do not interpose their own judgment but follow the hand of the foolish theorist without the least resistance."[46] "Foolish theory" is here corrected by the touchstone of practice. To be sure, Kepler also brings forward purely mathematical arguments to justify his rejection of algebra in this case. These arguments concern the comparative intelligibility of geometric and algebraic solutions. Yet his discussion of algebra reveals also his admiration of this new mathematical art, which he sometimes used in astronomical calculations. Musical practice resolves his doubts and guides his philosophical search.

Kepler applies this touchstone not just to these elements but also in the highest flights of his cosmic vision. Consider first Kepler's treatment of melody in monophonic chant in Book III of Harmonice mundi, chapter XIII, entitled "What Naturally Tuneful and Suitable Melody Is." Here he goes beyond the theoretical commonplaces that go back to the medieval theorist Hucbald, which restricted "tuneful and

suitable melody" to a few allowed intervals. Kepler attempts a rhetorical analysis that encompasses fine details of the melodic "foregrounds" of two very different melodies. He begins with the Turkish chant mentioned earlier (Figure 1, top), though he treats it as a kind of anti-music, "that grating [stridulo] style of song which the Turks and Hungarians customarily use as their signal for battle, imitating the uncouth voices of brute beasts rather than human nature."[47] Kepler notices that the Hungarians also use such "grating" songs, which are thus not only the province of infidels or aliens but of nearby fellow-subjects of the emperor. Indeed, they are used as signals for battle, making their rudeness more intelligible. He even hazards a theory for how such songs arose; their "original author absorbed uncouth melody of this kind from an instrument which was rather unsuitably shaped, and from long familiarity with the construction of the instrument transmitted such melody to his descendants and to his whole nation." The problem is not a barbaric soul but an instrument's disproportionate body. Here again Kepler asserts that the physical shape is prior to the sound that comes from it.

Examined more closely, his transcription is a recognizable attempt to capture the ululation of Muslim cantillation, as of a muezzin's call to prayer. Here he confronted complex melos and glissandi that are an essential part of middle Eastern music. Kepler took some pains to be faithful to what he heard, though his notation and musical preconceptions were of little help. The passage begins and ends on g-G, indicating the presence of the octave even in this strange style.

For comparison, Kepler cites a famous Gregorian chant, the Easter sequence Victimae paschali laudes (Figure 1, middle). Perhaps not coincidentally, it too begins and ends on G, its highest note also g; Christians and Muslims both acknowledge the overarching octave G as they worship the same God. In his commentary on the Gregorian chant, Kepler notes that the Gregorian chant "rings out chiefly on the positions of B[-flat], D, and G, exhibiting them as the skeleton of the octave, most frequently returning to D, and next to it B[-flat], but from time to time reaching up to g above, and to all those positions significantly, but not in that way to A or to f, positions which are primarily dissonant; and at length it returns to G and ends there."[48] Kepler use of the term "skeleton" (used earlier by Pietro Aron, Glarean, and Zarlino) shows his effort to understand the inner construction of melody, not merely its constituent intervals. He goes so far as to write down this skeleton explicitly (Figure 1, bottom), emphasizing its triadic shape while leaving the Gregorian melody far behind. However, by rewriting it thus in the F clef, the reader is immediately reminded of the Turkish chant, written on the same page in the same clef (Figure 1), as if to show that, in skeletal form, the Turkish chant and Victimae paschali have some relation. However, Kepler's text mainly points to their differences. Where the Turkish chant jumbles dissonance and consonance, Victimae paschali carefully observes their skeletal relations.[49]

Yet Kepler never disclaims the odd resemblance between them, at least at the skeletal level. This implicit relation remains open because Kepler continues to discuss the melodic structures of both the Turkish and the Christian chant simultaneously. Here he refers to "Euclid" for a vocabulary of melodic devices, by which he means the Introductio harmonica now attributed to Cleonides, a student of Aristoxenus.[50] Ancient writers gave the terms that Kepler takes up: ἀγωγὴ (literally "approach," passage from one consonance directly to another), τονὴ ("emphasis," dwelling on a consonance), πεττεία ("gaming," a species of ἀγωγὴ involving playful "tiny motions"), and πλοκὴ ("twisting," a species of τονὴ that entwines or "wanders in its passage around the ἀγωγὴ, as a dog does around a passerby."). Having no examples of ancient Greek music, Kepler interprets these terms in light of the music he knows. He applies the same vocabulary to the Gregorian chant as he does to the Turkish.[51] Throughout, he reinterprets the ancient terminology to fit the musical realities of his examples.

He must go further still in order to encompass what he considers the moderns' decisive innovation. As Walker notes, Kepler's insistence on cosmic polyphony decisively separates him from the ancients, whose "music of the spheres" (musica mundana) and "instrumental music" (musica instrumentalis) were alike monophonic.[52] Here, no mathematical argument enters in. Only Kepler's profound feeling for polyphonic music inspires his search for the cosmic polyphony. Accordingly, we should carefully consider the examples of polyphony that he holds up, the most notable being Lasso's

motet In me transierunt (from his Sacrae cantiones quinque vocem, 1562).[53] Kepler cites it or draws examples from it a few times in Harmonice mundi, although he does mention several other motets by Lasso in passing.[54]

Indeed, this particular motet was already famous in Kepler's time, even beyond the general measure of Lasso's renown. Werner Braun treats it as the exemplar of the Phrygian mode that is cited in the late fifteenth and sixteenth centuries.[55] Given the scope of his reading in contemporary German theorists and especially his extensive correspondence with the learned Leipzig Thomascantor Seth Calvisius, Kepler may well have known the rhetorical analysis that Joachim Burmeister (ca. 1564-1629) made of this motet in his Musica αὐτοσχεδιαστικῆ (1601), expanded in his Musica poetica (1606).[56] That we possess no specific reference might be explained by the disappearance of some of Kepler's letters to Calvisius in which Burmeister might well have been discussed.[57] However, Burmeister use thirty-two different works by Lasso as examples, devoting only two paragraphs to In me transierunt.[58] Indeed, other Phygian motets by Lasso might have been even better examples.[59] Thus, Kepler's choice of this particular motet reflects his particular feeling for it. His comments, few as they are, stand on their own and show a certain coherence when they are assembled in three closely successive stages.

Immediately after his discussion of the Turkish and Gregorian chants, Kepler cites the opening gesture of In me transierunt, a rising minor sixth that then descends by steps (Figure 2), juxtaposed with the observation that "we rather rarely admit sixths, although they are consonances, and only minor sixths."[60] Lasso's opening illustrates this "rather rare" interval. Interestingly, Kepler writes the same, somewhat incorrect rhythm, both times he cites this incipit in his text, probably showing that he is quoting from memory.[61] This would indicate how familiar this motet is to him and perhaps how dear. Even his mistake is revealing; by incorrectly citing the opening e' as dotted, Kepler places the expressive minor sixth e'-c' to arrive on the downbeat in the cantus, as an appoggiatura, an accented dissonance, whereas the authentic text lacks his dot and consequently arrives on the offbeat, resolving by suspension. Thus, Kepler's rhythmic mistake throws the expressive semitonal descent c'-b'-a' into higher relief.

In the next chapter, Kepler cites this incipit as an illustration of the "common Phrygian" mode.[62] Finally, in the next chapter Kepler comments in more detail on this melodic shape. Trying to clarify the significance of leaps, he adverts to the analytic terminology he had applied to the Gregorian and Turkish chants:

> The force of a leap is also great, as it is like a potential Agoge; for it has rashness, movement, boldness, it is warlike, manly, brash, if it is frequent, especially over a diapente. Its figure, the triangle, consists of acute angles, and covers the whole circle in three lines. On the contrary, a single ascending leap over a soft sixth, with a downward Agoge following, expresses the magnitude of grief, and is suitable for wailing, on account of the similarity of the note, as in Orlando's "In me transierunt."

Note that the felt rhetorical force of each leap is prior to its interpretation in terms of geometrical figures. Note also that, in the Lasso incipit, the "wailing" results from the minor sixth sinking a semitone, down to a fifth. Kepler does not go further into the details of the motet, recognizing ruefully that he is not adequate to the task. The inquiry into the relation between sounds and affects "is various and manifold, and very nearly infinite. Since it is too much for my muscles, it would be more correctly passed on completely to the practical men, that is, to practicing musicians, seeing that without teaching, guided solely by nature, they emerge time and again as the authors of wonderful tunes."[63] As Kepler acknowledges the limits of his ability, he also confirms explicitly that it is the testimony of "practicing musicians" he considers most important. Though his own harvest of insights is limited to this one small observation, it will turn out to be pregnant. Having already classified this motet into the Phrygian mode, he notes that the prominent semitone in this mode makes it "sound plaintive, broken, and in a sense lamentable."[64]

Though he does not draw our attention to it, this discussion helps illuminate the climax of

Kepler's work, his description of the cosmic music of the planets. At this point, he pauses to make a solemn exordium:

> Now there is need, Urania, of a grander sound, while I ascend by the harmonic stair of the celestial motions to higher things, where the true archetype of the fabric of the world is laid up and preserved. Follow me, modern musicians, and attribute it to your arts, unknown to antiquity: in these last centuries, Nature, always prodigal of herself, has at last brought forth, after an incubation of twice a thousand years, you, the first true offprints of the universal whole. By your harmonizing of various voices, and through your ears, she has whispered of herself, as she is in her innermost bosom, to the human mind, most beloved daughter of God the Creator.[65]

His point is that the planets are "singing" a polyphonic motet à la Lasso and he explicitly directs us to "modern musicians" in order to hear Nature's secret whispering.

In this cosmic motet, Kepler identifies the particular vocal part of each planet: soprano (Mercury), alto (Earth and Venus), tenor (Mars), and bass (Saturn and Jupiter).[66] He also notes that the motions of each planet suit its particular vocal part: Mercury as "the treble is most free," Earth and Venus with "very narrow distances between their motions ... as the alto which is nearly the highest is in a narrow space," Mars as tenor "is free yet proceeds moderately," while Saturn and Jupiter "as the bass make harmonic leaps."[67] The interweaving of their six individual "songs" lead to a complex work of practical polyphony, in which Kepler anticipates "certain syncopations and cadences" and all sorts of passing dissonances as planets pass between rare moments of cosmic consonance, particularly when they reach perihelion or aphelion. We shall return to the problem of reaching such cosmic cadences, moments of complete resolution and consonance.

If "the planets in combination match modern figured music,"[68] as if emerging from the same archetype, we must return to the modern masters with renewed attention. Kepler also clarifies that he does not simply identify this celestial music with any existing composition. In part, this reflects his notable departure from the ancient conception that there is an audible music of the spheres. On the contrary, Kepler asserts that "in fact, no sounds exist in the heaven, and the motion [of the planets] is not so turbulent that a whistling is produced by friction with the heavenly light."[69] His cosmic harmony reflects the relative minimum and maximum angular velocities of the planets, as measured from the sun.

Curiously, this harmony involves certain elements that emerged when considering the Turkish chant. There, we noted that Kepler may well have been trying to notate complex glissandi that are not really expressible in discrete notation, though they are quite regular and customary parts of Turkish music. Indeed, in Western music theory the glissando as such was not explicitly used until the animal and bird imitations in Carlo Farina's Capriccio stravagante (1627). However, the problem of glissando is not confined to the Turkish chant. It emerges as a central feature of the planetary music itself. Since the planets move continuously in their orbits, their distances to the Sun vary smoothly from perihelion to aphelion. As Kepler puts it, "they advance from one extreme to the opposite one not by leaps and intervals, but with a continually changing note, pervading all between (potentially infinite) in reality. I could not express that in any other way but by a continuous series of intermediate notes."[70]

Accordingly, Kepler's cosmic music is really a complex interweaving of glissandi, each confined within certain limits, which Walker compares to the wailing of air-raid sirens.[71] Ironically, the continuous sliding Kepler found so strange and difficult to notate in the Turkish chant turned out to be an all-pervasive feature of the heavenly music. Here, the Turks and Hungarians, with their "grating," "uncouth" singing, were in touch with a dimension of musical practice that Kepler discovers in his cosmic music.

The very soundlessness of the spheres directs him all the more insistently to the modern polyphonic masters, as if their harmonies will guide him in this strangely silent realm. In a playful marginal note, Kepler clarifies his meaning:

> Shall I be committing a crime if I demand some ingenious motet from individual composers of this age for this declaration: The royal psalter and the other sacred books will be able to supply a suitable text for it. Yet take note that no more than six parts are in harmony in the heaven....If anyone expresses more closely the heavenly music described in this work, to him Clio pledges a wreath, Urania pledges Venus as his bride.[72]

Thus, Kepler invites composers to take up the challenge of writing a motet that will incorporate the harmonies that he has discovered in planetary data. Since he accepts Zarlino's system and refers only to Lasso and Artusi, never to Monteverdi, J. V. Field concludes that "Kepler was on the side of orthodoxy rather than standing up to be counted as a partisan of the avant garde."[73] This is confirmed by Kepler's choice of In me transierunt as an exemplar, rather than one of Lasso's rare ventures into chromatic experimentalism, such as the Prophetiae Sibyllarum.[74]

Though he does not mention any composer by name in his challenge to "the composers of this age," Kepler's mention of the royal psalter fits Lasso's In me transierunt, which used psalm texts (Psalms 88:16 and 38:10, 17, 21), but then so did myriad other sacred works of the time. The phrase "more closely" suggests that some polyphonic music already expresses the heavenly sounds closely. Perhaps Lasso's motet fell short of the challenge by having five voices, not the requisite six, an issue that will return. It does contain the chords that Kepler describes as characterizing the planetary harmonies E mollis and C durus in mm. 15, 28, 30, 31, 58 (in anachronistically modern terms, E minor 6/3 and C major 6/4). By itself, this is hardly decisive, for these are common harmonies that appear in many motets. Is In me transierunt then merely a generic exemplar of polyphonic mastery?

There is, I think, one telling aspect of Lasso's motet that recommends it to Kepler as approaching the ideal, unwritten celestial motet. Recall that earlier Kepler had drawn attention to the prominent semitone in the incipit of In me transierunt, which characterizes its "wailing" Phrygian modality and also threads through the whole motet. To be sure, such scalar semitonal motion is common in Lasso's motets, as it is in many other works of the time. Yet this motet has a special significance in the light of Kepler's planetary melodies, for he identifies a special semitonal motion as the song of the Earth (Figure 3). As Kepler notes in the margin at this point,

> The Earth sings MI FA MI, so that even from the syllable you may guess that in this home of ours MIsery and FAmine [MIseria et FAmes] hold sway.[75]

This makes clear that Kepler reads the song of the Earth not as it stands in figure 3, g'-a' flat-g' (extremely rare in the practice of his times), but as MI FA MI. Here it is important to note that modern "solmization," meaning systems that denote degrees of the scale using single syllables (such as do or ut = C, mi = E, fa = F), only began to be used about 1600 in France. Kepler would have learned the more traditional solmization that denotes each pitch by a more complex name that specifies its place in a hexachord (a group of six sequential pitches, beginning either on C, G, or F). In this notation, In me transierunt begins e la mi, c sol fa, b fa mi, bringing MI FA MI to the fore. In contrast, if the motet began with a semitone (as in e-f-e: e la mi, f fa ut, e la mi), the solmization MI FA MI would be less dramatic.[76]

In this sense, the opening of In me transierunt may be the most vivid way to realize Kepler's song of the Earth in the musical practice that he knew. To Earth Kepler also assigns the Phyrgian mode whose final is MI, "because its motions revolve within a semitone [16:15]." Because of all these qualities, In me transierunt may well have struck Kepler as a powerful treatment of the song of the Earth, embedding the earthly semitone in a rich constellation of sonorities that draw the mind to imagine more vividly the full universal harmony.[77]

After all, one of the greatest differences between Kepler's harmonies and the ancients' is that now the Earth too has a voice, no longer consigned to voiceless immobility at the center of the Aristotelian cosmos. The Earth moves and sings, and its song is not neutral and divinely impassive, like the ancient

celestial monophony, but is redolent of human misery. Singing, the Earth prays with the royal psalmist, not expressing alone its desolation but seeking the larger concourse of divine mercy. How appropriate, then, and how moving must Kepler have found Lasso's texts: "Thy wrath has swept over me; thy terrors destroy me. / My heart throbs; my strength fails me; my sorrow is ever before me. / Forsake me not, O Lord; O my God, be not far from me." As a devout Christian, he viewed the semitone of human suffering as a crucial passage in the quest for divine grace. As such, the song of the Earth needs to be understood as part of the larger scheme of suffering and redemption. The semitone in Lasso's motet and in Kepler's song are signs of terrestrial dissonance reconciled in celestial harmony.

Kepler's sexual theory of music

Aware that his discoveries emphasize the primacy of experience and felt response, Kepler articulates a radical and explicitly sexual account of music. Though novel, it draws on certain suggestive passages in the ancient writings, not to speak of the larger connections between ἔρος, ἔθος, and μουσική in Plato.[78] Kepler also used erotic imagery along with images of war and battle in his Astronomia nova (1609), as I have discussed elsewhere.[79] Yet his sexualization of music and astronomy in the Harmonice mundi has not received much attention, despite Walker's excellent treatment, which I will try to reconsider and extend.[80]

Kepler's central idea is that cadential action is fundamentally sexual in character, stemming from the sexuality of numbers themselves. Already in a letter of 12 May 1608 to his friend Joachim Tanckius, a Leipzig physician, Kepler gives a diagram depicting the sexual intercourse of the numbers. He identifies 2 and 10 as male, 3 and 24 as female, noting that "I do not think I can more clearly and explicitly explain this than by saying that you are to see the images here of phalluses, there vulvas."[81] A similar, but slightly less explicit, figure appears in Harmonice mundi (Figure 4).[82] There, he draws attention to the geometric figures he considers the source of musical ratios: "What is surprising then if the progeny of the pentagon, the hard third of 4:5 and the soft 5:6, moves minds, which are the images of God, to emotions which are comparable with the business of generation?"[83]

Accordingly, Kepler specifies that "the major third will turn out manly, the minor feminine," a view which Marin Mersenne repeats in 1636 (though omitting the detailed sexual imagery).[84] Kepler's exposition deserves close reading. Between the major and minor thirds, as male and female, the semitone difference is crucial, "for a semitone following after always invites the voice to climb over it, on account of its small size; for it is like a crest on a slope which gets more gentle."[85] Here Kepler specifies the position of their intercourse. He goes on to describe the successive stages of sexual excitement expressed in the sensitive detail of melodic motion: "And every time a semitone occurs towards the upper part, it is taken as a sort of boundary to the melody, towards which it tends, and then as if the crest has been passed, and when the effort is complete it often begins to turn back to the lower part. Certainly if we sing RE MI, the hearing is not satisfied, but expects that FA should also be added."

The waves of melody parallel the increasingly urgent desire for satisfaction:

> Therefore since a hard third, which has the lowest position in the eighth tone, lacks a semitone, which is only added to make up a diatessaron, it is deservedly considered as active, and full of efforts, having force which is γόνιμος [productive], and ἀκμὴ ἄσχετος [irrepressible vigor], seeking its own end, that is to say a diatessaron, of which the semitone is like an ἔκφυσις [bursting out] for it, sought with its whole effort. But the minor third which stands in the lowest position of the first tone [i.e., mode one], since it has encompassed the semitone, from which it usually falls back when it has climbed over it, as if content with itself, and made by nature to be overcome and to be passive, always like a hen prostrates itself on the ground, ready for the cock to tread it. And there are the causes of the emotions in the kinds, and in the tones of the primary system, which rises up from G.[86]

Kepler uses Greek to veil his explicit meaning, perhaps to avoid the censure of the prurient. His climactic sentence describes the height of sexual ardor leading to ἀκμὴ ἄσχετος, the "highest culmination" of orgasm and ἔκφυσις, bursting out as ejaculation or begetting.[87] The Greek words emphasize the union of the generative and the sexual, but are not exclusively masculine in character, for ἔκφυσις can also meaning bearing, generation.

The copulation of numbers is always fruitful. "For just as a father begets a son, and his son another, each like himself, so also in that division, when the larger part is added to the whole, the proportion is continued: the combined sum takes the place of the whole, and what was previously the whole takes the place of the larger part." Kepler here is describing the formation of the well-known Fibonacci series, 1, 1, 2, 3, 5, 8, 13, 21, ... Kepler remarks that this series is closely related to the pentagon, the sides of which are in the "golden proportion" that is the limit of the ratio of successive terms in the Fibonacci series. "God the Creator has shaped the laws of generation in accordance with [this series]," such as "the logic of the seeding of plants" yielding successive generations of 2, 3, 5, 8, ... seeds.

Kepler also describes the "weddings" by which male and female geometric figures marry and produce progeny, remarking that "the study of the sky and music ... must originate from the same fatherland of geometry."[88] As Walker puts it, "polyphonic music, with its thirds and sixths, excites and moves us deeply as does sexual intercourse because God has modeled both on the same geometric archetype."[89]

Yet though geometry is archetypal, it depends upon a sexual response that is mutual. Thus, describing in Book IV the interaction between the Sun and the Earth to make the weather, Kepler, quoting Virgil's Georgics,

> compares the bosom of the Earth to the thighs of a wife, and indeed a joyful wife, that is, one who perceives what is happening to her with pleasure and helps her husband with suitable motions. All these things are signs of life, and suppose a soul in the body which experiences them. For it would not be easy for the Sun, destitute of suitable troops, to invade this citadel of the bowels of the earth, without the co-operation of some kind of soul, seated within, to collude with the enemy and open the gates to him.[90]

This admixture of military imagery of invasion and conquest recalls Kepler's extended erotic "battle" with the planet Mars in his Astronomia nova[91] and opens new possibilities in understanding the cosmic harmonies. Altogether, Kepler considers sexuality an essential aspect of soul, perhaps relying on the biblical notion that knowledge is, most deeply, carnal knowledge, as when "Adam knew Eve, his wife." Such knowledge escapes the sexist vocabulary of subjugation when it reaches full mutuality of intercourse. Indeed, Kepler includes both "hard" and "soft" harmonies of the planets, indicating that both "masculine" and "feminine" must be given equal scope.

Kepler calculated that the universal harmonies "of the hard kind" and "of the soft kind" for six planets are not 5/3 harmonies but rather 6/4 or 6/3 chords (again using quite anachronistic terms that he does not employ).[92] By virtue of their prominent fourths, he considers these intervals as audibly dissonant.[93]

But if the cosmos is harmonious, why are Kepler's planetary chords so dissonant? He ascribes this to marital difficulties between Earth and Venus, as man and wife. As noted earlier, the Earth sings a semitone (16:15), while Venus sings scarcely a diesis (25:24). Thus, "the Earth, on the contrary, and Venus much more, on account of the narrowness of their own intervals, restrict their harmonies not only with the other planets, but most of all their mutual harmonies with each other, to a remarkably small number."[94]

In erotic terms, male and female planets battle for supremacy, the Earth "pressing on with tasks which are worthy of a man, pushing aside and banishing Venus to her perihelion as if to her distaff" or Venus beguiling the Earth "to make love, laying aside for a little while his shield and arms, and those tasks

which are proper for a man; for then the harmony is soft."[95] In either case, the "harmony" of the heavens is shot through with erotic dissonance, for Kepler notes that if "this antagonistic lady, Venus," were silent, the other planets would sound quite consonant major or minor (5/3) chords on G. However, this neglects further harmonic conflicts with Mars at aphelion. As Turkish and Hungarian songs were appropriate to war, though uncouth, it may be that the planetary music, in the throes of cosmic sex and battle, groans unspeakably.

Nevertheless, Kepler does not consider this a failure of his reasoning or of the cosmos. After acknowledging all these problems, he still asserts that "the motions of the heavens are nothing but a kind of perennial harmony (in thought not in sound) through dissonant tunings, like certain syncopations or cadences (by which men imitate those natural dissonances), and tending toward definite and prescribed resolutions, individual to the six terms (as with vocal parts) and marking and distinguishing by those notes the immensity of time."[96] Here he perhaps refers to the practice of "evading the cadence" (fuggir la cadenza), which Zarlino describes as "useful when a composer in the midst of a beautiful passage feels the need for a cadence but cannot write one because the period of the text does not coincide, and it would not be honest to insert one."[97] For example, Lasso's In me transierunt has a beautiful example of cadenza fuggita in mm. 6-7. As Palisca remarks, "Lassus and other masters of the new music depended greatly on the evaded cadence, which permitted them to break up their texts into short phrases for descriptive and affective emphasis, while maintaining harmonic continuity."[98] Though Kepler either does not know or use this precise term, he clearly understands that the cosmic harmony has means to immensely delay its final cadence.

Here again Kepler is deeply informed by compositional practice, in which "Man, aping his Creator, has at last found a method of singing in harmony which was unknown to the ancients, so that he might play, that is to say, the perpetuity of the whole of cosmic time in some brief fraction of an hour, by the artificial concert of several voices, and taste up to a point the satisfaction of God his Maker in His works by a most delightful sense of pleasure felt in this imitator of God, Music."[99] Kepler claims these cosmic dissonances and evaded cadences are really pleasure made excruciating through delayed gratification. Compared to God, we experience the cosmic harmonies immensely dilated and slowed almost beyond intelligibility, but a work like Lasso's motet allows us to taste the ecstasy of cadence evaded that is the divine pleasure.

Cosmic cadence

Of course, this begs the question of whether and when a full resolution might occur. Kepler considers several possibilities. Harmonies between three planets happen rather often, but "harmonies of four planets now begin to be scattered over centuries, and those of five planets over myriads of years. However, an agreement together of all six is hedged about by very long gaps of ages; and I do not know whether it is altogether impossible for it to occur twice, by a precise rotation, and it rather demonstrates that there was some beginning of time, from which every age of the world has descended."[100] He seems to concede that "if there could occur one single sixfold harmony, or one outstanding one among several, that undoubtedly could be taken as characterizing the Creation." Yet his initial if marks this as hypothetical, allowing some doubt whether that initial concord ever really took place. If so, the uniqueness of the instant of creation is somewhat shadowed, opening the unorthodox possibility that there was no such distinct moment.

Without fully resolving this problem, Kepler seems rather to follow the imitative texture used in In me transierunt, common to Lasso and his contemporaries. Kepler considers the planets successively by pairs and then in larger groups, akin to the voices entering one by one in Lasso's motet, without an initial concord of all. Though there is nothing in astronomy that compels him to do so, "for some unknown reason this wonderful agreement with human melody forces me so that I am compelled" to identify planets with soprano, alto, tenor, and bass parts.[101] Throughout, Kepler adverts to musical practice to guide his

steps. He considers "skeletons" of the planetary melodies, recalling the skeleton he constructed for Victimae paschali, and shows how it is possible for those skeletons to line up to form harmonies of all six planets together. After a long series of propositions in Book V, Chapter IX, Kepler concludes that musical and geometric constraints dictated the spacing of the planets as we find them.

In all this, the issue of the final cadence remains open. Just after stating what we now call his Third Law, Kepler had noted that "if we suppose an infinity of time, all the states of the orbit of one planet can coincide at the same moment of time with all the states of the orbit of another planet."[102] This is close to what is presently called the ergodic hypothesis, that eventually the planets will occupy all possible positions vis à vis each other and the fixed stars. Yet this still does not imply that the initial chord will be repeated even after an infinite time has elapsed. Already in the final lines of his first book, Mysterium cosmographicum (1596), Kepler had concluded that "the motions [of the planets] are in irrational proportions to each other, and thus they will never return to the same starting point, even if they were to last for infinite ages."[103] Kepler reaffirms this conclusion in his notes added to the second edition of this work (1621), written after the Harmonice mundi and referring to it directly: "Therefore no exact return of the motions to their starting point is to be found, which can be taken as an end to the motions in accordance with form and reason."[104] Kepler's discovery of the Third Law reinforced this, for the relation between planetary periods and mean distances is irrational, proportional to the 3/2 power (as cubes are to squares), and hence not expressible as any ratio of integers.

If so, there will be no final cadence to the cosmic music. Kepler's 1596 formulation excludes the repetition of any original sonority, while his 1621 addendum goes further to exclude "an end to the motions in accordance with form and reason." Did Kepler not realize this as he wrote the Harmonice mundi in 1619, only reaching the more radical conclusion in 1621? This seems quite unlikely, given that he himself had established the basic result in 1596 and discovered the Third Law in 1618. If, then, he realized that there was no final cadence, he decided to veil this in the Harmonice mundi, for whatever reason. Such a suggestion of the endlessness of the world could have appeared to be dangerously heretical. It is not clear how this might have moved Kepler, who had already been excommunicated by his fellow Württemberg Protestants and driven out of Graz by Catholic edict.[105]

In the end, Kepler hesitates before matters lying beyond human ken. After all, he must bring his own book to its final cadence still aware that he has fallen short of the divine music. On his final pages, he notes how "the human voice in figured melody is almost perpetually out of tune" and hence unequal to grasping the archetypal harmonies.[106] Here the example of figured music again comes to his aid as he contemplates what God nevertheless found "very good" in the harmonies of His creation. Kepler notes that the abstract proportions "must have given way to the harmonies" so that "the geometrical proportions in the figures strive for harmonies," and not the other way around.[107] This is because "life completes the bodies of animate beings," taking them beyond lifeless, static ratios to something that moves and breathes. In his late Epitome of Copernican Astronomy (1618-1621), Kepler likewise emphasizes that "the celestial movements are not the work of mind but of nature; that is, of the natural power of the bodies," which sway their souls away from uniformity and circularity.[108] These deviations are the very signs of life in the cosmic image of its creator.

As with Kepler's sexual imagery, this complex motion is not a flaw but the central beauty of the design, imaging divine potency in cosmic intercourse, in cadential action, and in the endless ebb and flow of human desire. For Kepler, the climactic moment may be the realization of a cadence that never ceases, "finite and yet similar to the infinite,"[109] signing the finite cosmos with the hidden signature of the infinite.

Acknowledgments

I wish to thank H. Floris Cohen, Marie Louise Göllner, James Haar, and Curtis Wilson for their valuable criticisms, suggestions, and encouragement.

[1] Charles Burney, A General History of Music from the Earliest Ages to the Present Period (London, 1776-1789; new edition, ed. F. Mercer, 2 vols, London, 1939), 2:459.

[2] The standard modern edition is Johannes Kepler, Gesammelte Werke, ed. Walther von Dyck, Max Caspar, Franz Hammer, Martha List, and Volker Bialas, 19 vols. (Munich: 1937-), to be cited as KGW, followed by volume number and page, here 6:302. I will also cite the fine modern translation, Johannes Kepler, The Harmony of the World, tr. E. J. Aiton, A. M. Duncan, and J. V. Field (Philadelphia: American Philosophical Society, 1997), as HW 411, in this case. Regarding the "Third Law," see J. V. Field, Kepler's Geometrical Cosmology (Chicago: University of Chicago Press, 1988), 142-163 and Owen Gingerich, "Kepler, Galilei, and the Harmony of the World," in Music and Science in the Age of Galileo, ed. Victor Coelho (Dordrecht: Kluwer Academic, 1992), 45-63. Though he exults over the result, Kepler himself did not use the term "law." This appellation is due to later scholars, who thereby emphasized Kepler's anticipation of crucial Newtonian results. See Curtis Wilson, Astronomy from Kepler to Newton (London: Variorum Reprints, 1989).

[3] The most comprehensive modern account is Michael Dickreiter, Der Musiktheoretiker Johannes Kepler (Bern and Munich: Francke Verlag, 1973), whose title emphasizes Kepler as theorist, though Dickreiter also gives extremely helpful material concerning Kepler's larger musical education, as I shall cite below. Regarding the details of Kepler's arguments, see the excellent treatments in Bruce Stephenson, The Music of the Heavens: Kepler's Harmonic Astronomy (Princeton: Princeton University Press, 1994), Field, Kepler's Geometrical Cosmology, 96-166, and Rhonda Martens, Kepler's Philosophy and the New Astronomy (Princeton: Princeton University Press, 2000), 112-141. The new entry by Susi Jeans and H. F. Cohen, "Johannes Kepler," in the New Grove Dictionary of Music and Musicians, ed. Stanley Sadie, 29 vols. (New York: Grove Dictionaries, 2001 [second edition]), 13:487-88, gives helpful attention to Kepler's awareness of musical practice; see also H. F. Cohen, Quantifying Music: The Science of Music at the First Stage of the Scientific Revolution, 1580-1650 (Dordrecht: Kluwer, 1984), 13-34. Among earlier works, I am particularly indebted to D. P. Walker, "Kepler's Celestial Music," Journal of the Warburg and Courtauld Institutes 30, 228-250 (1967), included in his Studies in Musical Science in the Late Renaissance (Leiden: E. J. Brill, 1978), 34-62 (from which edition I will cite this work), whose approach my paper aims to correct and extend particularly by amplifying the Kepler-Lasso connection. See also Eric Werner, "The Last Pythagorean Musician: Johannes Kepler," in Aspects of Medieval and Renaissance Music, ed. Jan LaRue (New York: W. W. Norton, 1966), 867-882; W. Harburger, Johannes Keplers kosmische Harmonie (Leipzig: 1925); Alexandre Koyré, La Révolution astronomique (Paris: 1925); Max Caspar, Nachbericht to the Harmonice mundi, KGW 6:461 ff; and Gerald Holton, "Johannes Kepler's Universe," in his Thematic Origins of Scientific Thought, 2nd ed. (Cambridge: Harvard University Press, 1988), 69-90.

[4] I have already presented some of this material (the first two sections) in my essay on "Earthly music and cosmic harmony: Johannes Kepler's interest in practical music, especially Orlando di Lasso," Journal of Seventeenth-Century Music, 9 (2003), which contains some further details of musicological interest.

[5] HW 505 (KGW 6:374).

[6] Ibid. For an exposition of Fludd's views, see Peter J. Ammann, "The Musical Theory and Philosophy of Robert Fludd," Journal of the Warburg and Courtauld Institutes 30, 198-227 (1967).

[7] Erwin Panofsky, Galileo as a Critic of the Arts (The Hague: Martinus Nijhoff, 1954). See also the excellent essay by Claude V. Palisca, "Scientific Empiricism in Musical Thought," in Seventeenth Century Science and the Arts, ed. Hedley Howell Rhys (Princeton: Princeton University Press, 1961), 91-137 and Stillman Drake, "Music and Philosophy in Early Modern Science," in Music and Science in the Age of Galileo, ed. Coelho, 3-16.

[8] See the exchange on Panofsky's thesis, expressed (with some revisions) in his "Galileo as a Critic of the Arts: Aesthetic Attitude and Scientific Thought," Isis 47, 3-15 (1956), followed by Edward Rosen, "Review of Panofsky, Galileo as a Critic of the Arts," Isis 47, 78-80 (1956) and Erwin Panofsky, "More on Galileo

and the Arts," Isis 47, 182-185 (1956).
[9] See Dickreiter, Kepler, 123-138.
[10] These are: "Wir glauben all an einen Gott" (KGW 6:162); "Nun bitten wir den heylgen Geist" (6:162); "Herr Christ, der eynig Gotts son" (6:162); "Nun komm, der Heyden ir Heyland" (6:162); "Mit Freuden zart" (6:141); "Christ ist erstanden" (6:159); and "Victimae Pachali Laudes" (6:158, 15:238, 15:397), to be discussed in detail below.
[11] Dickreiter, Kepler, 124, who also lists some of the polyphonic music used in Württemberg.
[12] Ibid., 125. For a helpful study of Kepler's whole milieu during this period, see Charlotte Methuen, Kepler's Tübingen: Stimulus to a Theological Mathematics (Aldershot: Ashgate, 1998).
[13] Dickreiter, Kepler, 126.
[14] Dickreiter, Kepler, 164 considers that Kepler learned of Glarean's work from his teacher Samuel Magirus, not to be confused with Johann Magirus, who will be mentioned below.
[15] For a fine examination of the rhetorical dimension of these works, see Bruce Stephenson, Kepler's Physical Astronomy (Princeton: Princeton University Press, 1987) and his Music of the Heavens. I have also treated Kepler's rhetoric (and his allusions to Virgil) in my book Labyrinth: A Search for the Hidden Meaning of Science (Cambridge: MIT Press, 2000), 87-112.
[16] Dickreiter, Kepler, 129: "mancher nicht weiß, ob er in der kirchen oder im Wirtshaus ist."
[17] Ibid.
[18] Ibid., 130; "Velim tamen ex aliquo excellenti Musico quibus abundat Italia," KGW 14:13. Kepler already refers to Lasso's motets in a letter of 1599 (KGW 14:9).
[19] Letter to Herwart von Hohenburg of 6 August 1599, KGW 14:29.
[20] Dickreiter, Kepler, 131, citation from K. Chytil, Die Kunst in Prag zur Zeit Rudolfs II (Prague, 1904), preface.
[21] Among recent studies, see Carmelo Peter Comberiati, Late Renaissance music at the Habsburg Court: Polyphonic settings of the Mass Ordinary at the Court of Rudolf II, 1576-1612 (New York: Gordon and Breach, 1987), Robert Lindell, "Music and patronage at the court of Rudolf II," in Music in the German Renaissance: Sources, styles and contexts, ed. John Kmetz (Cambridge: Cambridge University Press, 1994), 254-271, and his Stefano Rosetti at the Imperial Court (Firenze: Olschki, 1994), 157-181, and Steven Sanders, Cross, Sword, and Lyre: Sacred Music at the Imperial Court of Ferdinand II of Habsburg (1619-1637) (New York: Oxford University Press, 1995).
[22] Michael Maier, Atalanta fugiens (Oppenheim: Hieronymus Galler, 1618); English edition translated and edited by Joscelyn Godwin in Magnum Opus Hermetic Sourceworks, vol. 22 (1989), discussed by F. Lissem, Musik und Alchemie (Tützing: 1969) and Christoph Meinel, "Alchemie und Musik," in Die Alchemie in der europäischen Kultur- and Wissenschaftsgeschichte, ed. Meinel (Wiesbaden: Otto Harrassowitz, 1986), 201-227. Maier is treated briefly in the context of later works that synthesize music with alchemy in David Yearsley's valuable article, "Alchemy and Counterpoint in an Age of Reason," Journal of the American Musicological Society, 51, 201-43 (1998), at 221. Regarding the Hassler brothers, see Hartmut Krones, "Die Beziehungen der Brüder Hassler zu Kaiser Rudolf dem II. und zu Prag" in Die Musik der Deutschen im Osten und ihre Wechselwirkung mit den Nachbarn: Ostseeraum--Schlesien--Böhmen/Mähren--Donauraum (Bonn: Schröder, 1994), 375-381.
[23] The "perspective lute" is variously attributed to the court artist Giuseppe Arcimboldo (1530-1593) or to the magus and artificer Cornelius Drebbel; see Dickreiter, Kepler, 132-133.
[24] R. J. W. Evans, Rudolf II and His World (Oxford: Clarendon Press, 1973), 190-93.
[25] See Frances Yates, Giordano Bruno and the Hermetic Tradition (Chicago: University of Chicago Press, 1964), 78-83 and Gary Tomlinson, Music in Renaissance Magic (Chicago: University of Chicago Press, 1993), esp. 45-46.
[26] See the standard biography of Max Caspar, Kepler, tr. C. Doris Hellmann (New York: Dover, 1993), 262, from Kepler's letter to Philipp Muller after 13 September 1622, KGW 18:78-79, discussed also in my

paper on "Kepler's Critique of Algebra," Mathematical Intelligencer 22:4, 54-59 (2000). For excellent treatments of Kepler's attitude towards the occult arts, see Robert S. Westman, "Nature, art and psyche: Jung, Pauli, and the Kepler-Fludd poemic," Edward Rosen, "Kepler's attitude toward astrology and mysticism," Judith V. Field, "Kepler's rejection of numerology," and Brian J. Vickers, "Analogy versus identity: the rejection of occult symbolism, 1580-1680," all in Occult and scientific mentalities in the Renaissance, ed. Vickers (Cambridge: Cambridge University Press, 1984), 177-229, 253-272, 273-296.

[27] KGW 17:80, translated by H. Floris Cohen, whom I thank for drawing this passage to my attention.

[28] KGW 6:397.

[29] See William H. Huffman, Robert Fludd and the End of the Renaissance (London and New York: Routledge), 52-63.

[30] Dickreiter, Kepler, 134; KGW 16:153.

[31] Dickreiter, Kepler, 134.

[32] Ibid.

[33] HM 217 (KGW 6:158).

[34] O. Wessely, "Linz," MGG 8: 917 (1960); Dickreiter, Kepler, 135.

[35] Ibid., 137.

[36] Dickreiter, Kepler, 139.

[37] Caspar, Kepler, 248 and KGW 17:254.

[38] Dickreiter, Kepler, 138.

[39] Caspar, Kepler, 266.

[40] HM 137 (KGW 6:99).

[41] HM 138 (KGW 6:99).

[42] HW 192 (KGW 6:139) is the unique mention of Zarlino in Kepler's text.

[43] Walker, "Kepler's Celestial Music," 35-53.

[44] Ibid., 39-40.

[45] See my paper on "Kepler's Critique of Algebra," 57-59.

[46] HW 138 (KGW 6:99)

[47] HW 217 (KGW 6:158).

[48] Here I have silently altered the translation by using the modern convention for note names in different octaves.

[49] Note that Kepler's version of Victimae paschali includes the inflected tone F#; this was not novel, since Gafori used such an inflection in his "Salve Regina" of 1496. See Richard Sherr, "The Performance of Chant in the Renaissance and its Interactions with Polyphony," in Plainsong in the Age of Polyphony, ed. Thomas Forrest Kelly (Cambridge: Cambridge University Press, 1992), 178-208.

[50] See HW 218, n. 125; there is a parallel passage defining this terminology in Aristides Quintilianus, De Musica, available in Greek Musical Writings, ed. Andrew Barker, 2 vols. (Cambridge: Cambridge University Press, 1989), 2:430-431.

[51] HW 218 (KGW 6:158). In Victimae paschali, Kepler shows how the direct motion of ἀγωγὴ (as in the setting of "paschali laudes" or of "immolent") sets off the continuous intonation (τονὴ) of "-demit oves Christus in-" and the "playing" alternations (πεττεία) of "-cens ... re- ... li- ... peccat-" In contrast, the Turkish chant uses "a pure πλοκὴ, although not a natural one," throughout its course, meaning the continuous twisting or twining of the melodic line.

[52] Walker, "Kepler's Celestial Music," 38-40. Tomlinson, Music in Renaissance Magic, 76-84, discusses the views of Guido Anselmi, who wrote that "each sphere produces not merely a single harmony but many notes and leimmas and dieses and commas as those happy spirits, at one moment with the sounds of their own spheres or at another with those that sit near them, seem to leaad in song, or follow, or press upon [one another] and strike together ..." (76). Tomlinson interprets this as a kind of harmony produced by the complex motion of each planet. Further, Ramos de Pareia associated modes, rather than only tones, with

each sphere (78-84). However, neither of them contemplates an explicit polyphony between the different spheres, much less associates it with terrestrial exemplars.

[53] Orlando di Lasso, Sämtliche Werke (Leipzig : Breitkopf & Härtel, 1894-1926; reprint: New York: Broude Brothers, 1973), 9:49-52. See Jerome Roche, Lassus (London: Oxford University Press, 1982), 5; for the context of other motets, see Noel O'Regan, "Orlando di Lasso and Rome: personal contacts and musical influences," in Orlando di Lasso Studies, ed. Peter Bergquist (Cambridge: Cambridge University Press, 1999), 132-157 at 145.

[54] In me transierunt is cited at HW 221, 234, 239 (KGW 6:161, 171, 174); "Ubi est Abel" and "Tristis est anima mea" are mentioned at HW 253 (KGW 6:184).

[55] Werner Braun, Deutsche Musiktheorie des 15. bis 17. Jahrhunderts: Von Calvisius bis Mattheson (Darmstadt: Wissenschaftliche Buchgesellschaft, 1994), vol. 2, 139-142, including mentions of the work by Gallus Dressler (1563/64) and Johannes Magirus (1596), not to be confused with Kepler's teacher Samuel Magirus. See also W. Boetticher, "Orlando di Lasso als Demonstrationsobject in der Kompositionslehre des 16. und 17. Jahrhunderts," Kongr.-Bericht Bamberg 1953 (Kassel and Basel: 1954), 124 ff.

[56] For a complete translation, see Joachim Burmeister, Musical Poetics (New Haven: Yale University Press, 1993), which discusses In me transierunt at 205-206. For the passage on In me transierunt, see the translation and commentary by Claude V. Palisca, "Ut Oratoria Musica: The Rhetorical Basis of Musical Mannerism," in The Meaning of Mannerism, ed. Franklin W. Robinson and Stephen G. Nichols, Jr. (Hanover, NH: University Press of New England, 1972), 37-65. Concerning Burmeister in general, see Martin Ruhnke, Joachim Burmeister: Ein Beitrag zu Musiklehre um 1600 (Kassel and Basel: Bärenreiter-Verlag, 1955), 130-135, 162-165.

[57] See Dickreiter, Kepler, 60-61 for the disappearance of Kepler's letters to Calvisius (whose dates are listed in KGW in the appropriate chronological place). The extant letters between them in 1607/9 are mostly devoted to detailed issues of chronology, especially their disagreement concerning the exact birth-year of Christ. See KGW 6:477, 15:469-476, 16:47-49, 16:55-59, 16:216-222, 18.455-459.

[58] Calvisius never uses this motet as an example in his ΜΕΛΟΠΟΙΙΑ, sive melodiae condendae ratio (Erfurt, 1592), though he cites five other works by Lasso, and includes it as the seventh out of eleven examples of the Phrygian mode from Lasso in his Exercitationes Musicae duae (Leipzig, 1600; reprint Hildesheim: Georg Olms Verlag, 1973), p. 51.

[59] For instance, Lasso's motet Locutus sum in six voices, which also begins with a prominent "mi fa mi," but only after an initial leap of a fifth, discussed by Marie Louise Göllner, "Orlando di Lasso and Andrea Gabrieli: two motets and their masses in a Munich choir book from 1564-65," in Orlando di Lasso Studies, 20-40 at 23-26. For the general problem of musical exempla, see Cristle Collins Judd, Reading Renaissance Music Theory: Hearing with the Eyes (Cambridge: Cambridge University Press, 2000).

[60] HW 221 (KGW 6:161).

[61] This is the observation and conclusion of both Dickreiter, Kepler, 175-176 and Braun, Deutsche Musiktheorie, 141. For the authentic text, see Lasso, Sämtliche Werke, 9:49. Kepler also misstates the final note of the incipit as a semibrevis, instead of a dotted minima.

[62] HW 234 (KGW 6:171). Kepler may well have known that this same example was cited by Lucas Lossius, Erotema musicae practicae (Nuremberg, 1570), book I, chapter 7 among his examples of church modes, for this book was in Kepler's school library in Linz, according to Dickreiter, Kepler, 145.

[63] HW 238 (KGW 6:173).

[64] HW 243 (KGW 6:177).

[65] HW 441 (KGW 6:323).

[66] HW 449-450 (KGW 6:329).

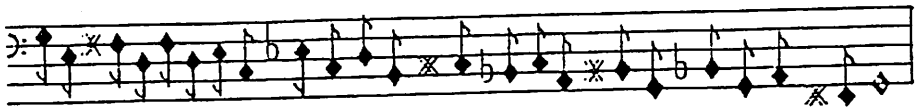
[67] Dickreiter, Kepler, 186, notes that Kepler's characterization of the narrow range of the alto contradicts the theory and practice of his contemporaries.

[68] HW 430 (KGW 6:316). For further discussion of planetary songs, see Tomlinson, Music in Renaissance

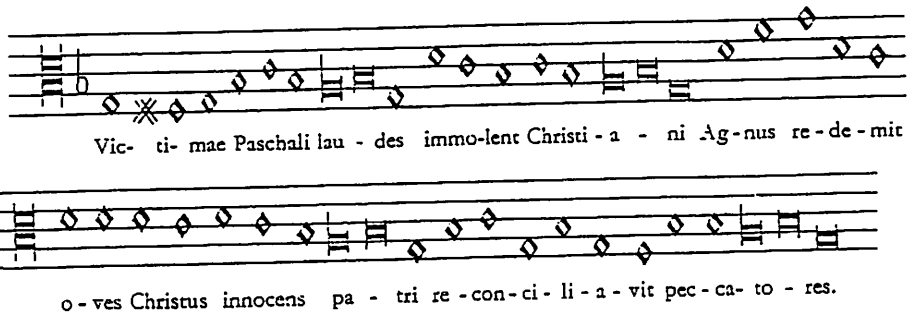
Magic, 63-100.
[69] HW 423 (KGW 6:311).
[70] HW 439 (KGW 6:322).
[71] Walker, "Kepler's Celestial Music," 59-60.
[72] HW 441 (KGW 6:323).
[73] Field, Kepler's Geometrical Cosmology, 118.
[74] Here I disagree with Claude Palisca's view ("Ut Oratoria Musica," 37-41): "If Josquin represents a classical moment in the music of the sixteenth century, Lassus is the epitome of mannerism," adducing Burmeister's rhetorical analysis of In me transierunt to show its mannerism. For Lasso as member of "the musical avant-garde of the sixteenth century," see also Edward Lowinsky, "The Musical Avant-Garde of the Renaissance or: The Peril and Profit of Foresight," in Art, Science, and History in the Renaissance, ed. Charles S. Singleton (Baltimore and London: Johns Hopkins University Press, 19), 113-162, at 139-144. To my ears, In me transierunt is not "manneristic" but "classic." Pace Palisca, its rhetorical stance is not so very different from Josquin's motets. See James Haar, "Classicism and mannerism in 16th-century music," International review of the aesthetics and sociology of music, 25:1-2, 5-18 (1994). About the Prophetiae Sibyllarum, see William Eastman Lake, William Eastman, "Orlando di Lasso's prologue to Prophetiae Sibyllarum: A comparison of analytical approaches," In theory only, 11:7-8, 1-19 (1991).
[75] HW 440 (KGW 6:322). For an interesting extension of Kepler's idea, see Herbert Anton Kellner, "Kepler, Bach, and Gauss: The Celestial Harmony of the Earth's Motion," Bach [Berea, Ohio], 25:1, 46-56 (1994). Penelope Gouk asserts that "the modern tonic sol-fa system used today (do re mi fa so la ti do) ... was known to scholars such as John Pell through Kepler's Harmonices mundi (1630) and Asted's Encylcopaedia (1630), but English musicians did not apparantly use the method"; Music, Science and Natural Magic in Seventeenth-Century England (New Haven: Yale University Press, 1999), p. 129. However, there is no evidence of this modern system of solmization to be found anywhere in Kepler's Harmonice.
[76] Even Lasso's Prologue to the Prophetiae Sibyllarum does not begin with such a direct use of the semitone.
[77] To be sure, other examples of "mi fa mi" would have worked as well, such as Josquin's "Miserere mei Deus," probably the most famous example in the sixteenth century. However, Kepler nowhere mentions Josquin, leading to the speculation that he was unacquainted with his works.
[78] For instance, consider the story of the young man incited to commit arson through hearing Phrygian pipe-music, then calmed when Pythagoras changed the mode; see M. L. West, Ancient Greek Music (Oxford: Clarendon Press, 1992), 31. Plato's "nuptial number" (Republic 546b-547a) may well have inspired Kepler's discussion of the "progeny" of geometrical figures (HW 253; KGW 6:184).
[79] See my Labyrinth, 108-112.
[80] Walker, "Kepler's Celestial Music," 53-57.
[81] KGW 16:154-165, at 157: "Non puto me posse clarius et palpabilius rem explicare, quam si dicam te uidere imagines illic mentulae, hic uuluae."
[82] HW 241 (KGW 6:175).
[83] Ibid.
[84] Marin Mersenne, Harmonie universelle (Paris, 1636), 3:188. For another example of the use of sexual imagery by Salinas, see Cohen, Quantifying Music, 64.
[85] HW 242 (KGW 6:176).
[86] Ibid.
[87] Although ἔκφυσις can mean "bursting out," as HW glosses, its far more direct meaning here is ejaculation as the act of begetting. Note also their misprint of ἀκμὴ ἄοχετος for ἀκμὴ ἄσχετος
[88] HW 354 (KGW 6:265); for the cube and octahedron as "spouses," see HW 407 (KGW 6:299).
[89] Walker, "Kepler's Celestial Music," 57.

[90] HW 360 (KGW 6:266); the quote from Virgil is Georgics 2:326.
[91] See ref. 56, above.
[92] HW 444-445 (KGW 6:325-326).
[93] See Glen Haydon, The Evolution of the Six-Four Chord: A Chapter in the History of Dissonance Treatment (Berkeley: University of California Press, 1933; reprint: New York: Da Capo Press, 1970), 133-134: "all the examples cited give overwhelming proof that the six-four chord is treated exclusively as a dissonance" from the thirteenth through the middle of the seventeenth century.
[94] HW 442-46 (KGW 6:324-328). Stephenson emphasizes this point in his Music of the Heavens, 170-185.
[95] HW 446 (KGW 6:328).
[96] Ibid.
[97] Gioseffo Zarlino, The Art of Counterpoint, tr. Guy A. Marco and Claude V. Palisca (New York: W. W. Norton, 1968), 151. Kepler refers to Giovanni Artusi, Zarlino's student, at HW 254 (KGW 6:185), though never to Zarlino directly.
[98] Palisca, "Ut oratoria musica," 42-46, which also brings in Francis Bacon's description (1605) of what Thomas Morley called the "false close."
[99] HW 447-48 (KGW 6:328).
[100] HW 442-43 (KGW 6:324).
[101] HW 449-450 (KGW 6:329).
[102] HW 417 (KGW 6:306).
[103] Johannes Kepler, Mysterium Cosmographicum (The Secret of the Universe), tr. A. M. Duncan (New York: Abaris Books, 1981), 223 (KGW 1:79).
[104] Ibid., (KGW 8:127).
[105] For Kepler's relations with different Christian denominations, see Caspar, Kepler, 77-85, 111-115, 146-148; for detailed discussion of his beliefs, see Jürgen Hübner. Die Theologie Johannes Keplers zwischen Orthodoxie und Naturwissenschaft (Tübingen: J. C. B. Mohr, 1975).
[106] HW 491 (KGW 6:).
[107] HW 488-489 (KGW 6:).
[108] KGW 7:330, cited in Panofsky, Galileo as a Critic of the Arts, 29-31 and translated here from Johannes Kepler, Epitome of Copernican Astronomy, tr. Charles Glenn Wallis in Great Books of the Western World (Chicago: Encyclopedia Britannica, 1952), 16:932.
[109] The final words of Kepler, Mysterium, 223 (KGW 1:79), "finitus & infinito similis," quoting Pliny, also discussed in my Labyrinth, 112.

Figures for Kepler and [illegible]



Concinnus igitur et humanarum aurium judicio aptus cantus est, qui exorsus à certo quodam sono; ab eo per intervalla concinna tendit ad sonos consonos et primo illi, et plerumque etiam inter se mutuò; dissona cursim pervolitans intervalla, in consonis verò immorans, seu mensurâ temporis, Syllabarumque longitudine, seu crebro ad illos reditu, veluti duarum vocum inter se consonantiam affectans, unicae vocis traductione à loco uno Systematis ad alium. Exemplum.



Hîc sonus initialis est in clavi *G*, cum quâ in cantu molli concordant *b. c. d. g.* Excurrit igitur Cantus (primùm flexu deorsum facto) ad clavem *c.* consonam, et transilit planè dissonum locum *A*; fuisset autem idem, si attigisset ipsum, sed brevi mora; tota verò series reliqua potissimùm in locis *b. d. g.* intonat, sceleton octavae tale exprimens, in *d.* creberrimè rediens, post in *b.* in superius vero *g.* se interdum efferens, in haec omnia loca signanter: non sic in *a.* vel in *f*, loca primo dissona: tandemque redit ad *G.* ibique finit.

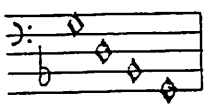


Figure 1: Harmonice mundi page 61, showing the Turkish chant compared to Victimae paschali and its skeleton

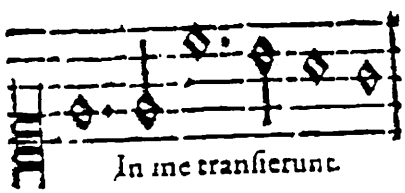


Figure 2: Kepler's citation of the incipit of Lasso's motet, In me transierunt

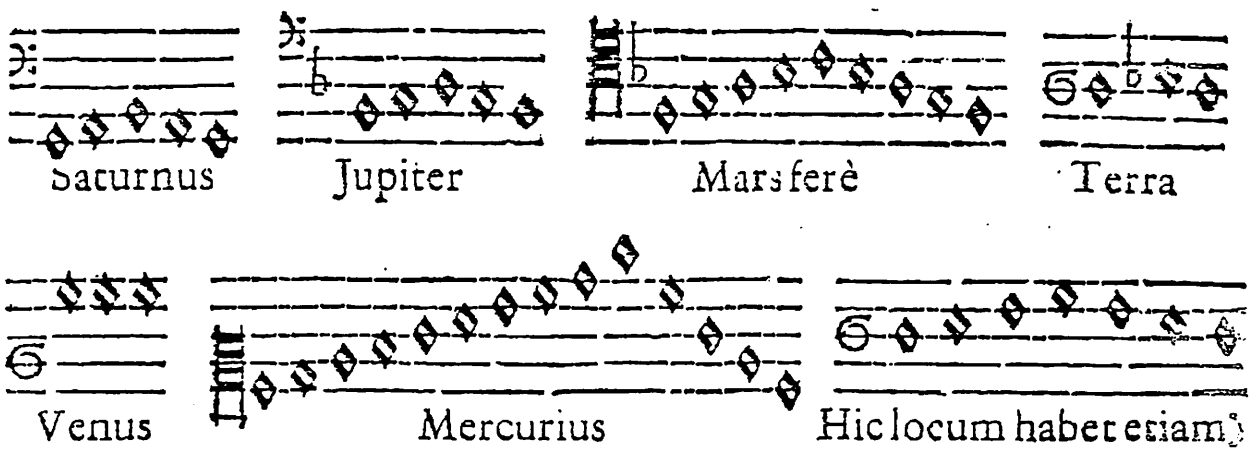


Figure 3: Kepler's version of the song of the Earth, along with those of the other planets.

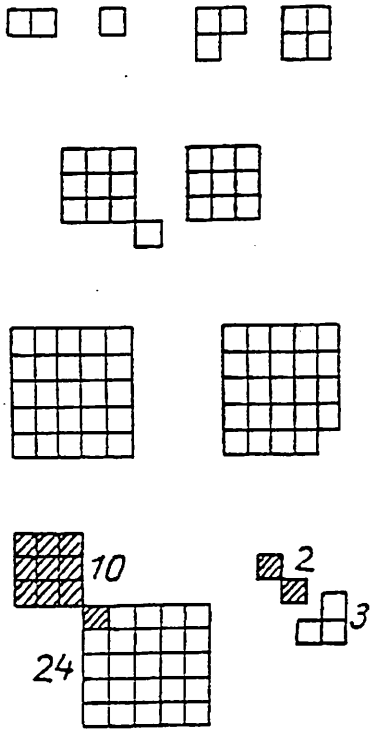


Figure 4: Kepler's depiction of the sexual intercourse of numbers.