RE-CONFIGURING ANCIENT GREEK MUSIC THEORY THROUGH TECHNOLOGY

AN ADAPTIVE ELECTRONIC TUNING SYSTEM ON A RECONSTRUCTED ANCIENT GREEK BARBITON

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RESUME

RE-CONFIGURATION DE LA THEORIE DE LA MUSIQUE GRECQUE ANTIQUE PAR LA TECHNOLOGIE : UN SYSTÈME D'ACCORD ELECTRONIQUE ADAPTATIF SUR UN BARBITON GREC ANTIQUE RECONSTRUIT

Etat de l'art en théorie musicale et philosophie grecques anciennes. La base de la musicologie comme discipline scientifique avec ses thèmes et sa terminologie bien définis, pourrait être retracée à partir des écrits d'Aristoxenus de Taras, un des élèves d'Aristote. En outre, les racines épistémologiques des harmoniques et les origines en philosophie pythagorienne, font remonter la musicologie au 6ème siècle. D'autre part, le développement d'un système mélodique de notation a été considéré comme un facteur crucial pour élever la musicologie au niveau d'une ''science'' du raisonnement logique. De manière intéressante, et sans véritable explication, la notation de la musique comme moyen d'expression approprié a été brusquement rejetée par Aristoxenus.

Etat de l'art en technologie musicale et traitement du signal. Le traitement du signal est considéré comme la base de la technologie musicale moderne, elle-même provenant du domaine de l'analyse harmonique. Ce domaine est devenu de plus en plus approprié à la musicologie moderne, à travers l'apparition de l'ordinateur comme laboratoire du processus musical. A l'aide des nouveaux outils qui traitent le son en temps réel, tels que le suivi et le détecteur des hauteurs, nous pouvons étendre les capacités acoustiques des instruments acoustiques antiques par des moyens électroniques. Ceci permet de poser des questions archéomusicologiques, et d'envisager des interprétations herméneutiques.

Objectifs. Tout en réactivant certaines configurations historiques, la théorie des médias appliqués fournit un cadre peu usuel pour lier les deux domaines d'une manière anachronique. En pratique, le but de la présente approche interdisciplinaire est de contester des exégèses communes touchant à l'essor de la théorie de la musique grecque ancienne. D'autre part, nous envisageons de fournir des hypothèses testables permettant de corroborer une situation modifiée et de dépasser l'antithèse périmée proposée depuis la période hellénistique et encore répandue aujourd'hui, du point de vue pythagoricien sur la musique contre le point de vue aristoxénien, c'est-à-dire numérologie contre phénoménologie.

Contribution principale. Dans cet article, nous faisons aussi une sorte de revue du fond historique et des circonstances épistémologiques qui ont conduit à la formation de la musicologie comme un champ de la connaissance à part entière. Au cours de la discussion « la notation d'un codec pre-Aristoxenian » est mise à jour et reliée avec différentes références à la barbiton-lyre. C'est l'importance acoustique de ses origines, qui nous conduit à la reconstruction d'un tel instrument électroniquement. Pour ce faire, nous reconstituons un modèle perceptuel de la mélodie qui relie logiquement et unifie des champs théoriques considérés jusqu'ici comme inconciliables. Dans ce cadre, nous procédons à la description de la technologie et de la méthodologie nécessaires pour réaliser cet instrument électronique.

Implications. Vers la fin du 5ème siècle, de nombreuses sources parlent d'une « musique révolutionnaire » attribuée à une richesse de modulations et différents styles et techniques de jeu. Prenant cette révolution au sérieux, le présent article construit une histoire de l'écoute en proposant une rupture dans la « sonosphère » grecque antique. En ce sens, le changement d'écoute peut être considéré comme la vraie cause de la séparation aristoxénienne de la musicologie. Aujourd'hui, le point de

départ pourrait concerner le champ plus général du « temps des processus critiques » (« time-critical processes ») par le calcul et le traitement du signal, dont l'application nous permet de comprendre le remodelage de la théorie de la musique et de sa conception philosophique. Par extension, cette réflexion pourra nous inciter à repenser la musique en tant que champ épistémologique essentiel, et nous encourager à former un nouveau domaine de recherche que nous pourrions appeler « archéomusicologie computationnelle », qui, identifiée avec méthode, pourrait être étendue à d'autres domaines que la Grèce antique.

ABSTRACT

Background in Ancient Greek Music Theory and Philosophy. The foundation of musicology as a genuine discipline with a clear-cut subject matter and a well-defined terminology can be traced back to the writings of Aristoxenus of Taras, a pupil of Aristotle. However, its epistemological roots in harmonics and origin in Pythagorean philosophy reach back until the 6th century. Ad interim the development of a melodic notation system acted as a crucial factor to grow musicology into a 'science' of logical reasoning. Interestingly, and still without satisfactory explanation, notation as an adequate medium of music was brusquely rejected by Aristoxenus.

Background in Music Technology and Signal Processing. Besides the thought-provoking fact that signal processing as the foundation of modern music technology itself originates from the domain of harmonic analysis and, similarly, became relevant to 'musicology proper' only by extension with a discrete agency purely logic in nature—i.e. the computer—now, real-time pitch-tracking and pitch-shifting can be used to augment ancient instruments electronically in order to pose archaeological questions and challenge sedimented hermeneutical interpretations.

Aims. While re-enacting historical configurations, applied media theory provides an unconventional framework to interlink both backgrounds anachronistically. In practice, the aim of the present interdisciplinary approach is to take issue with common exegeses of the rise of ancient Greek music theory, deliver testable hypotheses to corroborate a modified picture and finally to overcome the outdated antithesis of Pythagorean vs. Aristoxenian views on music—i.e. numerology vs. phenomenology—propounded since the Hellenistic Period and still prevalent today.

Main contribution. The historical background and epistemological circumstances that led to the formation of musicology as a separate field of knowledge are reviewed. During the course of discussion a "pre-Aristoxenian codec of notation" is uncovered and linked with scattered references to the barbiton-lyre. The acoustical significance of its origin becomes 'instrumental' to augment a self-made reconstruction of such an instrument electronically. Hereby a perceptual model of melody is re-enacted that logically connects and unifies theoretical camps previously considered irreconcilable. The technology and methodology necessary to achieve this is described.

Implications. Towards the end of the 5th century, many sources ascribe a revolutionary 'new music' to the advent of frequent modulations and different 'styles' of playing techniques. Taking this revolution seriously, the present paper constructs a history of hearing that proposes a rupture in the ancient Greek sonosphere. Accordingly, the changed strategy of listening is regarded the true cause of the Aristoxenian separation of musicology. Today, the 'kernel' of this parting can be identified with the more general domain of "time-critical processes" in computation and signal processing whose application enables us to understand the subsequent reshaping of music theory and the radical remodelling of its philosophical conception. By extension, this lesson in *mousiké* may make us rethink music as still a vital epistemological field and may encourage us to form a new research domain possibly called computational archaeomusicology.

ἄγε Μοῦσα λίγει', ἄρξον ἀοιδᾶς, Ἐρατώ, νόμους
Σαμίων περὶ παίδων ἐρατᾷ φθεγγομένα λύρᾳ.

Στησίχορος, in Στράβων, Γεωγραφία 8, 3, 20

Come, o clear-voiced Muse, Erato, begin your song,
voicing to the beautiful lyra melodies about the children of Samos.

Stesichorus of Sicily, fr. 278, in PMG[1]
trans. as given in Maas & Snyder [2]

0.0. Proem

Sound matters. It mediates between the real and the virtual, connects the physical reality of acoustics with the mental reality of the muses. Only by considering this phenomenon in its entirety we may grasp the true strain of Greek melodies. In listening to the reasoning of this voicing, the barbiton has been built.

The whole impact of a technically informed media theory, while tracing matters of the vowel alphabet all all the way through to digital signal processing, brings about one insight: that far more than ideas, it is the 'instrumentality' of thought, or the means of communication which establish the dominant regimes of knowledge that shape historical realities and their associate notion of truth. Media, therefore, are no tools. Far more than things at our disposal they constitute the interaction of thinking and perception—mainly unconsciously. What then does it mean to augment an ancient instrument electronically and to consider it to be a medium?

1. INTRODUCTION

To answer this question, the present paper proposes a novel approach for the interpretation and testing of ancient Greek music theory based on a media theoretical point of view.[3] Following considerable efforts to carefully collect, philologically ascertain and cautiously construe the manifold relations of music related texts[4] scholars have begun to review the scarce evidence of musical fragments[5] in order to trace historical changes in the development of ancient Greek music. Recent research has mainly concentrated on scales and tuning[6], evidence of modulation[7] and the relationship between music and philosophy.[8] Generally, since the days of Pythagoras, the 'episteme'[9] of music encompasses a fertile field of knowledge that Andrew Barker outlines as "harmonic science".[10] However, despite those best endeavours, if one adheres to hermeneutic interpretation alone, then the agency of musical notation (*parasēmantikḗ téchnē*) as a medium and the overarching *paradigm of enharmony* as the defining framework for "the noble style of music that is specifically Greek"[11] are prone to be underestimated or even misunderstood.

[1]PMG = Page, D.L., *Poetae melici graeci*, 1962.
[2]Maas, M. & Snyder, J.M., *Stringed instruments of ancient Greece*, 1989, 35.
[3]Ernst, W. & Kittler, F., *Die Geburt des Vokalalphabets aus dem Geist der Poesie: Schrift, Zahl und Ton im Medienverbund*, 2006; Kittler, F.A., *Aphrodite*, 2006; Ofak, A. & Kittler, F.A., *Medien vor den Medien*, 2007.
[4]Barker, A., *Greek musical writings. The musician and his art*, I, 1984; Barker, A., *Greek musical writings. Harmonic and acoustic theory*, II, 1989; West, M.L., *Ancient Greek music*, 1994.
[5]Pöhlmann, E. & West, M.L., *Documents of ancient Greek music: the extant melodies and fragments*, 2001.
[6]Franklin, J.C., "Musical syncretism and the Greek orientalizing period", 2002; Franklin, J.C., "Hearing Greek microtones", 2005.
[7]Hagel, S., *Modulation in altgriechischer Musik: Antike Melodien im Licht antiker Musiktheorie*, 2000; Hagel, S., "Reversing the abstraction of Ancient music theory. The case of the genera", 2008.
[8]Barker, A., "The journeying voice: melody and metaphysics in Aristoxenian harmonic science", 2005.
[9]*Episteme* taken in the Foucaultian sense, meaning the antecedent dispositive according to which a field of knowledge is considered to be scientific.
[10]Barker, A., *The science of harmonics in classical Greece*, 2007.
[11]Lasserre, F. & Pseudo-Plutarch, *Plutarque de la musique: texte traduction commentaire précédés d'une étude sur l'éducation musicale dans la Grèce antique*, 1954.

While our title contends to 're-configure' ancient Greek music theory, we have no intention to minify the mainly philological and musicological accomplishments in that field. On the contrary, our approach aims to deeply engage with this extensive discourse. Hence, it requires us to discuss several rather complex issues in order to justify the connections drawn and to substantiate the view we propose. These issues are in particular (i) Aristoxenus' harsh dismissal of musical notation, (ii) the o*rigin of enharmony*[12] closely connected to the 'inventions' of Olympus, Terpander and Sappho, which were to determine the inner correlation of the instrumental notation, (iii) the dependent question hereupon, whether Aristoxenus' *Harmonic Elements*[13] with their notorious reference to a natural or "emmelic" intonation of the voice must be regarded as a system of equal-temperament or, instead, as one relying on justly intonated reference tones, and finally—wherein all these topics culminate—(iv) the resulting struggle of 'enharmonically ingrained ears' with the proliferation of modulations. Undoubtedly, the latter characterises the 'new music'[14] towards the end of the 5th century BC but still remain under debate and without coherent explanation. 'Instrumental' to the theory we are developing is a device that will *incorporate* our explanation and *mediate* the given issues in accordance with the literal evidence we refer to.

1.1. The electronic barbiton as an instrument of theory

On these lines, the present project employs a reconstruction of an ancient Greek *bárbitos* as an experimental basis. Its acoustic behaviour can be regarded similar to the type we consider epistemologically at work then in antiquity. By studying ancient manufacturing techniques[15] and materials (turtle shell, goat skin, antelope horns, gut strings, etc.) a native sound as well as an authentic experience in playing the instrument can be expected. It is said that the *bárbitos* was introduced by Terpander, the quasi-historical founder of classical Greek music in the first half of the 7th century*[16]*, that it was a "polychordal"[17], multi-stringed instrument (with supposedly more than 7 *chordaí*) but—most relevant to our context—that is was utilised to 'magadise' or answer in concords (ἀντιφθέγγομαι)[18]. Its deep sound, 'resonating' in concordance[19] below the lyre, became attributed to Sappho, a Lesbian like Terpander, both of them renowned for introducing the 'bitter-sweet', wistful Mixolydian mode into the Greek sonosphere. Thus, the *bárbitos* always ranked as a somewhat eccentric 'organ' of the arts, favoured at symposia and Dionysian festivities, and only fell into disuse as late as in the days of Aristotle when post-mortem—that is after its authentic use—it was also referred to as a *bárbiton*. Altogether, this unorthodox device appears to be the appropriate archaic instrument to augment electronically and to venture a still unconventional 'close reading' of Aristoxenian theory that should lead to testable hypotheses concerning historical, aesthetical and philosophical issues related to music whose elucidation, in the long run, may 're-configure' our understanding of the speculative nature intrinsic to melodic processes and harmonic theory *through* technology.

1.2. Outline

In order to provide the necessary backgrounds that enable a thorough understanding of our interdisciplinary approach, the paper is structured into different thematic stages, which

[12]Vogel, M., *Die Enharmonik der Griechen. 2. Teil: Der Ursprung der Enharmonik*, II, 1963.
[13]Aristoxenus, "ΑΡΙΣΤΟΞΕΝΟΥ ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 1954.
[14]Richter, L., "Die neue Musik der griechischen Antike. Teil I: Die literarische Überlieferung", 1968.
[15]Roberts, H.D., "Reconstructing the Greek tortoise-shell lyre", 1981; Creese, D.E., "The origin of the Greek tortoise-shell lyre", 1997.
[16]Pindar fr. 125.3 PMG.
[17]Theocritus, 16th Idyll, 45, in Gow, A.S.F., *Theocritus. Introduction, text, translation: ed. with transl. and commentary*, I, 1950.
[18]Pindar fr. 125.3 PMG.
[19]Cf. Ps.-Aristotle Probl. XIX, 39, in Jan, K.V., *Musici scriptores graeci*, 1895.

build on each other's results. Firstly, it surveys the general field of discussion concerning chordophones and ancient Greek music. Secondly, melodic abilities and limitations of these instruments give rise to questions about the tonal system and the role of musical notation as means of practice and theory. Thirdly, diverse and rather fragmented reports will be investigated which are related to musical innovations, advanced playing techniques and the 'invention' of the *bárbitos* in order to corroborate a theory of scale development rooted in acoustics. Fourthly, this theoretical basis serves to explicate the epistemological and aesthetical foundations established by the 'character' of a certain, early enharmonic 'genus', which then was challenged by the proliferation of extensive modulation. Fifthly, we generally indicate how the 'logic of harmony' developed until then was reapplied to access and theorise the temporal unfolding of melody. It should become apparent how—dependent on a certain philosophical disposition—the consequent inquiry into the specific field of 'harmonically guided' melodic processes was to disclose a new epistemological domain that, today, we may identify as the more general one of *time-critical processes*. However, instigated as it was by a unique correlation of music theory and artistic practice, this transient domain of knowledge, then in antiquity, together with the ontological claims derived from it, appeared impossible to verify empirically. Thus, with the decline of the cultural configuration that first instantiated and developed the researched musical phenomena, the epistemological reality of this domain was all too quickly buried and replaced by the rather narrow opposition of a Platonising Pythagoreanism versus an Aristotelian empiricism. Sixthly, the electronics and software of an adaptive tuning system mounted on the reconstructed barbiton are described as essential parts of an archaeological method designed to experimentally support and test the established hypotheses. Finally, general considerations on interdisciplinary musicology, cursory thoughts on the *episteme* of music and a short outlook sketching further steps of the current project conclude the paper.

Those who are not inclined to follow the intricacies of ancient Greek music theory but are still interested in the technological and methodological approach may immediately refer to the central hypothesis of chapter 7.2 that proclaims two ways of listening towards the end of the Classical Period, and then proceed with chapter 8.

2. CHORDOPHONES

For their seminal work *Stringed instruments of ancient Greece* Martha Mass and Jane McIntosh Snyder examined almost all the archeological evidence of chordophones available at the end of 1980s. Critically comparing the vast number of vase paintings with the philologist's catalogue of textual references, the scholars were led to the following cardinal conclusions: (i) that harps (*psaltḗria*) like the *mágadis* and *pḗktís*, though familiar to Alkman of Sparta and Sappho of Lesbos, or the *trígōnos* and other many-stringed instruments, played a minor role in archaic and classical Greece until the second half of the 5th century,[20] (ii) that "in essence", the norm for all members of the lyre-family (*phórminx*, *kithára*, *chélys-lýra* and *bárbitos*)[21] "from before the days of the Trojan War to the time of Alexander the Great and probably beyond"[22] was 7 strings and—last but not least concerning the playing technique—(iii) "that the right hand does not pluck the strings or perform any maneuver designed to change their pitch; that the left hand is restrained in its movements by the wrist sling and also does not press against the strings to change their pitch".[23] Cautiously enough, Mass and Snyder left notable freedom to the melodies whilst pointing out that it

[20]Maas & Snyder, *Stringed Instruments*, 202.
[21]Still (Ibid. 201), *sambýke-*, *phoênix*, *klepsíambos*, *skindapsós* and *enneáchordon* mentioned in Athenaeus, "Deipnosophistae", II, p. , 1987, 182f, or Athenaeus, "Deipnosophistae", VI, p. , 1993, 636b, couldn't be matched pictorially.
[22]Ibid. 203.
[23]Ibid. 200.

remains unknown "whether all the notes of the melody were available on the lyre" or whether "the left hand played all the notes of the melody sung".[24]

About the *sound* of the instruments however, they had little more to say than the poets, following the epithets of Homeric tradition. Obviously, the *kithára* sounded louder due to its enlarged and more sophisticated sound-box than the *chélys-lýra* or the *bárbitos*, as the latter was furthermore based on a tortoise-shell. This elegant, long-armed variant of the *chélys* with its extended string lengths however covered a lower pitch range "as if the name were *barymitos* ('low-stringed')", as this apparently wrong etymology found in Euripides' *Alcestis* nicely confirms.[25] But apart from appeal, volume and ambitus, the sound quality of all lyres appears the same, namely "clear-voiced/sweet-toned" (λιγυρός) or "bright-sounding" (λιγύς), that is in no way different to the voices of the muses and sirens themselves.

2.1. Polychordia

Having all this evidence at hand, Martha Mass condensed her findings and came back a few years later with a rather revolutionary attitude to totally do away with the whole plethora of tales and stories telling about a constant increase in the quantity of strings on the lyre[26]— from as far back as Terpander to Melanippides and Kinesias, Phrynis and finally Timotheus, this infamous red-head eventually 'terminating' the 'golden age' of Greek music with his intricate melodies and outrageous style of playing the *kithára*. In particular, those spectacular reports arising in the Roman era and evolving in the Christian Period poking fun at the strictness of the Spartans for their uncompromising habit of cutting off any strings exceeding the sacred number 7, now seem to be effectively disproved since they would just not refer to the lyre. But even the more trustworthy fragments stemming from contemporaries (snippets from Ion of Chios, a passage from the *Cheiron* of Pherecrates and, of course, Timotheus about himself in *The Persians*) could be taken apart by showing convincingly that (i) the term *polychordía* and all its periphrases are used metaphorically, (ii) that by reference to Plato's *Republic* 399c–d they are to be interpreted in the sense of *panharmonía* and finally (iii) that "Ion's '*endekachorde lyra*' may well be an eleven-stringed 'instrument,' i.e., harp"[27], since this type of chordophone appeared 'a novelty' to Athenians in the days of Ion, and only from then on it is seen depicted on vases, too.

2.2. Panharmonia

'*Panharmonía*' instead, as Plato spells out sharply, was not played on the lyre but realised on the *trígōnos* and *pḗktís*. However, the 'superlative' version (πολυχορδότατον) of all 'many-stringed' instruments would still be the "panharmonian *auloí*"[28] which are merely imitated by the former. Here, Plato's almost proverbial conservatism outstrips even the Lacedaemonians' as his autocratic attempt proposed not only to expel all instruments other than *kithára* and *chélys* from the city but also to restrict the acceptable *harmoníai* solely to the Dorian and Phrygian.[29] After not merely assaulting the 'new-music' but also denouncing the aulos tradition as a whole, the philosopher's true motivation is better understood in the *Philebus*. There again, the *aulós* is called 'many-stringed', yet the reason for the dismissal of this windy sound device is told with brutal frankness:

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[24]Ibid. 201.
[25]Ibid. 123.
[26]Maas, M., "Polychordia and the fourth-century Greek lyre", 1992. This article may be seen as a reaction to West, M.L., "Review: Stringed instruments of ancient Greece by Martha Maas and Jane M. Snyder", 1991 questioning the cogency of their book on this point for, as far as the "relevant literary evidence" is concerned, they would "have missed a number of useful particles of information lurking in corners." (276)
[27]Maas, "Polychordia", 88.
[28]Platon, *Platonis opera*, 1903, *Republic*, 399d.
[29]Ibid. 399a.

> Music, first of all, is full of [conjecture]; it achieves concordant sounds by guesswork based on practice, not by measurement; in aulos-playing throughout [the piece] one gages each pitch (*chordḗ*) as it is sounded by guess, so that the degree of uncertainty involved in it is great, and the degree of certainty small.[30]

Hence, *measurability* of pitch plus *awareness* and *reliability* of its articulation define the adequate sound medium. Only then *mousikḗ*—the *téchnē* of the muses—appears aesthetically worthwhile and educationally valuable.

In the case of Plato it seems to be exactly this which is lost, if *'panharmonía'* or *polychordía* is excessively applied. Apart from metaphysical bias, there must certainly have been a perceptible kind of lawfulness in melody threatened in his days by the use of frequent modulations for Plato to profess such a reactionary position and to bear so much grudge against it. Pointedly, it is due to this very difference of cultures and likewise a gap in our understanding, if we translate νόμους (custom, law, ordinance, musical mode or *strain*) as simply equating 'melodies', as seen in the opening quote from Stesichoros above.

2.3. Criticism

Though Maas does not fail to cite where Plato's reservation against *polychordía* truly stems from, her 'breakthrough' may still serve as an exemplum for the limitation of "historical and philological criticism" which only scratches the surface of deeper musicological issues —once comfortably communicated by such tales—but henceforth put on "shaky ground"[31]. While explicitly targeting Otto Gombosi's theory[32], her attack still echoes an older argument inextricably linked with another medium also questioned for its ability to measure and suitability to qualify musical comprehension—but by far more central to Gombosi and the subject here at stake: the *epistemological* role and the *different* applications of musical notation in ancient Greece.

Hearkening back for the source of the echoed argument, we need to call on another great critic's work, namely Reginald Pepys Winnington-Ingram and his important article *The pentatonic tuning of the Greek lyre: a theory examined*.[33] At least appreciating Gombosi for his "interesting speculations", Winnington-Ingram nevertheless believed that "it is surely better to confess ignorance than to build an elaborate structure upon a foundation which is (as I fear) unsound."[34] Should we comply in any case with this Socratic attitude, or is there a specificity to the organisation of musical sounds in Greek melodies which asks for a certain type of theory that needs (as I fear) to be fundamentally 'unsound'?

3. PARASĒMANTIKḖ TÉCHNĒ

3.1. Fingerings

The bulk of the narrative of an ever increasing '*polychordía*' signifies little more than melodic and harmonic innovations either impinging on, or originating from stylistic, technical and theoretical developments in the music of ancient Greece. Nonetheless, the current among these narratives answered well the modern musicologists' conviction that at the beginning of the story there should have been solely a note-for-note accompaniment. 'Naturally', as commencing from a rather 'primitive' pentatonic scale, the art of music would eventually arrive at a full-fledged system of 'keys' with 'accidentals'—a maturation for the good, pretty much resembling the Western circle of tempered fifths. On these lines, the ori-

[30]Plato, *Philebus* 56a. Generally, Maas quotes from John Burnet's *Platonis opera*. The above translation reproduces the one given in her article with "assistance" of Jane MacIntosh Snyder.
[31]Maas, "Polychordia", 87.
[32]Ibid. pointing to page 77 of Gombosi, O.J., *Tonarten und Stimmungen der antiken Musik*, 1939.
[33]Winnington-Ingram, R.P., "The pentatonic tuning of the Greek lyre: a theory examined", 1956.
[34]Ibid. 170.

ginal hypothesis brought forward by Curt Sachs[35] and then further developed by Gombosi holds, that the complete tonal system may still be set to work by employing only two basic pentatonic tunings of the lyre: E G A B D E and F G A C D F. The main support for this type of theory however, was not sought in stories or paintings but in the triadic structure of the so-called *instrumental notation* putatively representing open strings and 'fingerings' to manipulate pitches of the chords. However, concrete elaborations of their theories caused more difficulties than they solved. It is this, until then widely accepted hypothesis born from evolutionary thinking and modern aesthetic prejudice that the detailed inspection by Winnington-Ingram has blown to pieces.

Still until today various methods for 'stopping' the strings have been proposed in order to suggest how versatile melodic accompaniments, changes of 'key', or 'accidentals' may have been realised.[36] Notation in most of these cases is regarded as some kind of tablature, not as a separate system to make precise distinctions of pitches.[37] Yet, by adopting the latter —and Winnington-Ingram is only pointing to the "formulas" of Archytas, this pre-eminent mathematician and highly trusted military leader of Taras living at the turn of the 5th to the 4th century—a whole lot of problems in attaining a consistent interpretation of notation do just fade away.[38]

By changing perspective, the acquired cultural technique of a melodic notation, natively termed *parasēmantikḗ téchnē,* with its conspicuously twisted and turned signs set next (*pará*) to the song's text (or semantics), reveals substantial insight into the maturation of Greek *mousikḗ* and the nature of its incipient theory. Though the basic structure of notation most probably emerged from different degrees of shutting the holes of an aulos[39]—and the Pythagorean Archytas, like Philolaus, was an aulos player[40]—(i) the signs were abstracted from the pipes, (ii) their intervals were measured by the 'harmonic scientists' procedures while (iii) detected patterns and features became subject to logical and mathematical systematisations. Finally, and as a second-order result, this generalised medium of pitch relations was used to record, to instruct and, possibly, to compose the kitharists' tunes as well.

3.2. Enharmony

If one adopts this view, and further thinks along the lines of mediation, the ensuing problem is that the apparent scheme-of-use of the original notation seems devised to fit only one of the three genera. This is qualified by another authority of Taras, Aristoxenus *ho mousikós*, still reputed to have been *the* midwife for "the birth of musicology".[41] Though notwithstanding the scholarly tradition which constructs the two 'scientific heroes' raised from the same Pythagorean stronghold—Archytas and Aristoxenus—as mere epistemological opponents, the arguable lack of generality in the system of notation, said to mirror this opposition, needs nonetheless to be explained. At first glance, indeed, coding principle and

[35]Sachs, C., "Die griechische Instrumentalnotenschrift", 1924; Sachs, C., "Die griechische Gesangsnotenschrift", 1925 and Gombosi, *Tonarten und Stimmungen der antiken Musik*.

[36]See e.g. Thurn, N., "Die siebensaitige Lyra", 1998 and again with some modifications in Thurn, N., *Die Geburt der Theorie aus dem Instrument: über Bedienung und Bedeutung der antiken Instrumente Groma und Lyra*, 2008, or Nikos Xanthoulis' live-demonstrations during the International Meeting: *Pythagorean views on music* 2009 at Samos, publ. 2012, forthcoming.

[37]See Thurn, "Die siebensaitige Lyra" argues for a rather cumbersome 'mixture' of tablature and interval notation, 426. Though Thurn, *Die Geburt der Theorie aus dem Instrument* avoids this wording and subscribes (115) to a coding of transposition scales as given in West, *Ancient Greek Music*, 255-259, he is still convinced that the 'systematised tablature' of notation may be reduced to only 3 possible tunings of the 7-stringed lyre (118).

[38]Winnington-Ingram, "The Pentatonic Tuning of the Greek Lyre"", 179.

[39]For an 'auletic origin' of the notation system see Hagel, *Modulation in altgriechischer Musik*, 31 and Hagel, S., *Ancient Greek music: a new technical history*, 2010, forthcoming.

[40]Athenaeus, "Deipnosophistae", II, 184e, in Barker, *GMW*, I, 172: "Many of the Pythagoreans also cultivated the art of the *aulos*, Euphranor, for example and Archytas and Philolaus and a good many others. Euphranor even left a treaties on *auloi* as did Archytas." The last author, Archytas, is neglected in Barkers translation. Why?

[41]Last purported by Gibson, S., *Aristoxenus of Tarentum and the birth of musicology*, 2005.

structure of the instrumental signs appear pretty remote from anything either designed for or influential to a concept of 'transposition scales'. Notably the notation of 'the semitone' actually obscures a comprehensive tonal system of 'keys' or *tónoi*, as identified by a central focal note and a minimal set of only 3, purportedly self-evident tonal characters or 'genera'. Consequentially, when seen from the 'mature' perspective of western tonality, the structural shortcomings of notation amount to a serious diagrammatic deficiency, as it has been ostensibly approved two generations after Archytas by the proud, self-assigned 'inventor' of the *tónoi*-system while levelling the accusation that:

> […] those who have previously taken up the study of harmonics were concerned to be truly 'harmonicists' and no more, since they dealt only with the enharmonic, and never gave a thought to the other genera. There is evidence of this: their diagrams are of the enharmonic *systḗmata* only, and no one has ever yet seen any for those in the diatonic or chromatic.[42]

This "allusive and punning statement"[43] puzzled scholars for centuries, especially since a 'theoretical preference' for the enharmonic genus seems to contradict the 'chronology of nature' as Aristoxenus asserts elsewhere in his *Harmonic Elements*:

> Now, the diatonic must be put down as the first and oldest of them [sc. the genera], for the natural state [φύσις] of man comes across it first, and afterwards the chromatic, and third and finally the enharmonic, for it is the last to which the perception grows accustomed—and with difficulty at that, after much labour.[44]

Following Winnington-Ingram's precious pointer and pursuing the laborious path of a 'true harmonicist', it was Martin Vogel who finally found himself in the position to solve "the riddle"[45] of Aristoxenus. He analysed the formulas of Archytas and set them in accordance with the instrumental notation. It is only by bringing together the *measure of numbers* and the *structure of signs* that the Aristoxenian equation of 'enharmony ≡ harmonic science' unveils the true profundity of its meaning.[46] Vogel took this equation literally, that is to say, in the sense that *operating solely within the enharmonic genus* equates to *thoroughly dealing with interlocking acoustic properties*. In tracking down this suspicion, Archytas' 'division of the canon' proves intriguing not simply for its numerical elegance but more strikingly for the structural beauty and musical richness that it discloses. Together, the tuning of Archytas and the structure of the instrumental notation interlock to form the sym-bol(s) of *en*-harmony. Their unity delivers the key to a historically grown tonal system constructed from different orders of beating-free to weakly beating intervals standing truly '*in*-harmony'. The following figure renders a concise 'decoding table' (in ratios and in cents) of these symbols reflecting Vogel's structural findings as 'buried' in Archytas' numbers.

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[42]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ",1.2; 6.6–12 da Rios. Trans. Barker, *GMW*, II, 126–127.

[43]Franklin, "Musical Syncretism", 449. Franklin e.g. quotes Proclus, who eventually seems to take Aristoxenus' innuendo as a vapid assertoric statement: "… here Aristoxenus says the incredible, that the ancients did not know the diatonic diagram", in Proclus, *Procli Diadochi in Platonis Timaeum commentaria*, 1903, 3.192A.

[44]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 1.19; 25.1–4 da Rios. Trans. Franklin, "Musical Syncretism", 447.

[45]Ibid. 449.

[46]The Anglo-Saxon reception of Vogel's work appears to have been rather unfortunate. The first review by Barbour, J.M., "Die Enharmonik der Griechen by Martin Vogel", 1963 seems rather biased, as Barbour did not find his own article on *The Principles of Greek Notation* mentioned in Vogel's "excellent Habilitationsschrift" (629). Even though Barbour's article deals with Archytas' numbers and also underlines the fact "that the musical notation of the ancient Greeks mirrored the tuning of Archytas" (Ibid.), Barbour, J.M., "The principles of Greek notation", 1960 could not draw further reaching conclusions from this finding (basically known since Tannery, P., *Sciences exactes dans l'antiqué: 1889–1913*, III, 1915 and already discussed by Düring, I., *Ptolemaios und Porphyrios über die Musik*, 1934 and Winnington-Ingram, R.P., "Aristoxenus and the intervals of Greek music", 1932). Nor did Barbour understand Vogel's comprehensive thesis of its origin, as his review of Vogel's 'interesting enough speculations' reveals: for instance, by absurdly defending the consistency of Archytas' divisions against Vogel who actually rooted his theory of enharmony in them.

As a result, this system of consonances crystallised into *parasēmantikḗ téchnē*, a technique we might better call an *acoustic diagrammatic*, rather than a 'musical notation' in today's understanding of the phrase. This is not to say that Archytas invented the instrumental notation[47] nor that it was him who generalised or first expanded it, but that from the rather precise and unique congruence between his *numbers of pitch relations* and the *instrumentality of signs* we do gain strong evidence to draw reasonable inferences about the tonal system used in practice and about an early concept of notation to *encode* melodic intervals.[48]

Accordingly, notation provided a practical, audibly verifiable and canonical basis for pre-Aristoxenian music theory which was certainly not restricted to a specific school of harmonicists, e.g. the Pythagoreans. On the contrary, the interval proportions responsible for its canonical basis reach far back into the Orientalising Period, to a half-mythical Olympus from Phrygia or to the widely travelled Terpander of

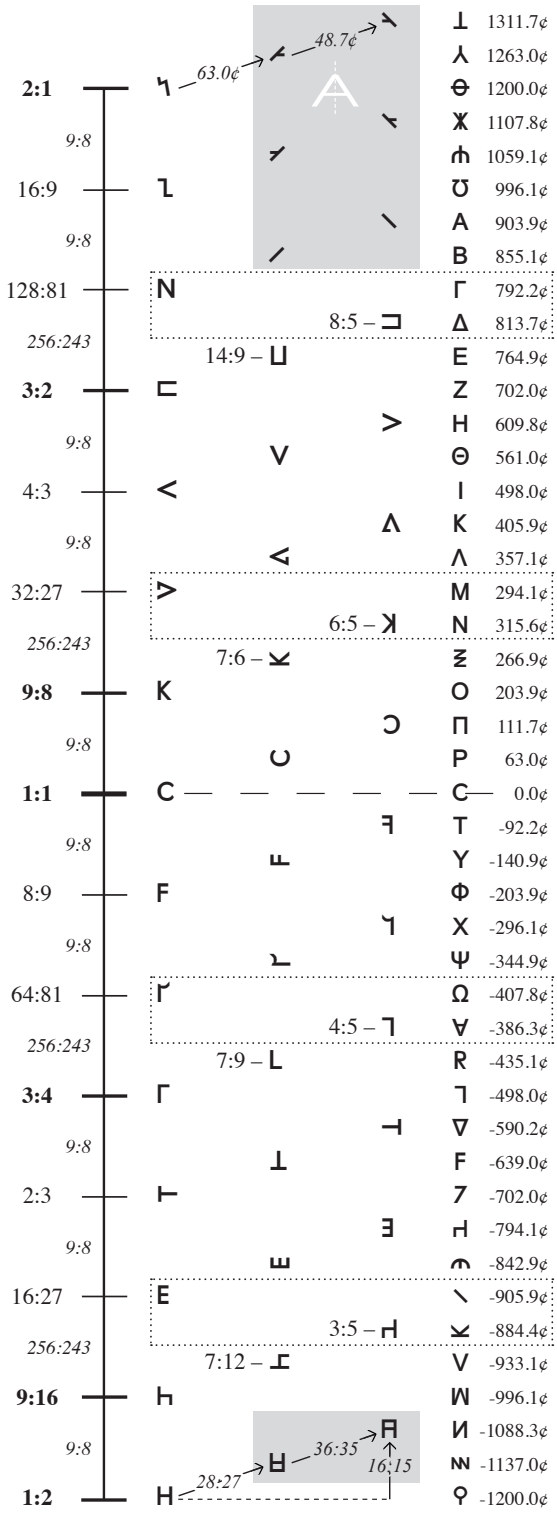

Figure 1. The three 'columns' of the instr. notation mapped against the pseudo-linear order of the vocal notation.

[47]As Reinach, T., *La musique Grecque*, 1926, 26.

[48]Although this congruence was first noted by Fortlage, C., "Griechische Musik", 1863, 195 scholars (since Jan, K.V., "Torr, On the interpretation of Greek music, Oxford 1896", 1896, 1548 until Hagel, S., "The context of tunings. Thirds and septimal intervals in ancient Greek music", 2006, 290) still belittle its testimony in pointing at the 'flaw' that, according to the Alypian tables, different notes in the chromatic and enharmonic genus would had been notated by the same signs. But this inconstancy (not true for the inferred coding principle shown in Fig. 2.), like other shortcomings, is due to later adoptions and a different usage of the signs. Hence, this sort of arguments are anachronistic and do not apply to support the conviction that "there was never a one-to-one relation between signs and pitches." (Hagel, ibid.)

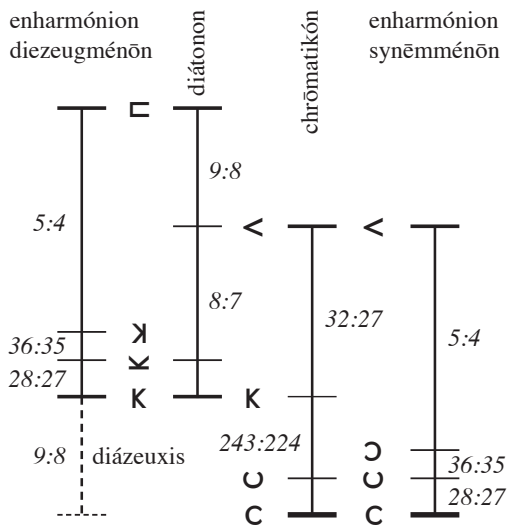

Figure 2. Derivation of the diatonic and chromatic genera from the enharmonic tetrachords above **C**.

Lesbos—in a word, *beyond* Greece. Still, to undertake the practical identification and theoretical systematisation of tunes and intervals necessary to actually conceive an appropriate *measuring system* and to devise a feasible *system of notation* in such a manner that both systems could ultimately coincide, is surely a Greek achievement.[49] As a consequence, the gradually developed structure of *parasēmantikḗ téchnē* consists of frozen theory still bearing the marks of its historical development. Yet, in addition to its mathematical features and the valuable observations of its irregularities,[50] Vogel could impressively show that an early *θεωρία* of notation, while supposedly dealing solely with the enharmonic genus, actually contained the diatonic and chromatic[51] as well (Fig. 2.).

[49]Frankly, it is hard to see what we gain by supposing that Eratocles' method of "'interval rotation'" for 'enumerating' the enharmonic octave species is identical with the diatonic "Old Babylonian 'Retuning Text' (UET 7/74), with its seven tunings arranged in a cyclical scheme" (Franklin, "Musical Syncretism"", 442). Without detailed reference to interval relations and scales produced by this rather unspecific method, the essential difference in structure, in nature and in meaning of diatonic and enharmonic 'arrangements' are unjustifiably neglected. Furthermore, by reducing the enharmonic to just another heptatonic scale of a certain 'colouring' with some 'regional micro-tonal deviations' the whole distinctiveness of Greek musical culture and theory—especially the astonishing peculiarity of a carefully instilled and preserved aesthetical preference for the enharmonic genus—is lost. Cf. Franklin, in particular his conclusion on p. 449.

Against such levelling tendencies of 'cross-cultural identification' Hagel, S., "Is nīd qabli Dorian? Tuning and modality in Greek and Hurrian music", 2005 already pointed out that "the fundamental difference between the Greek system, focussed almost entirely on melody, and the Near Eastern tradition, which gives prominence to the dyadic harmony of its dichords", would be "most easily explained by the different performance cultures, which form the respective contexts" (291). This hold true until the very extent that "in all three fields, fine tuning, modality and modulation" Hagel examined, thus he finally attests "that Greek and Hurrian music took fundamentally different paths (341). Accordingly, concerning the Orientalising Period, "the divergences between Hurrian and the later Greek treatment of the tonal material speak strongly against a major transfer of musical culture in the early first millennium". Hence, and in direct response to Franklin, "a heptatonic musical 'koiné' must be dated rather early, perhaps towards the end of the first half of the second millennium" (342–343). Thus, Hagel is convinced that even if the dichordal system "was ever exported to Greece", it "must have died out there at a relatively early date, giving way to a native Greek consideration of musical structure, and a melodic notation." (293)

[50]Regarding the shape of the signs, Barbour, "The principles of Greek notation", 5f corroborates the important hypothesis that the original compass of the instrumental notation was limited to the Greater Perfect System and that at a later stage the originally missing symbols (*mesó-* and *oxýpyknoi*) of the top three triads "were hastily developed from the letter Alpha to notate the pitches dependent on f' [ɴ], g' [ɼ], and a' [ʜ]." (Cf. the greyed out signs in Fig. 2). However, Winnington-Ingram, R.P., "Two studies in Greek musical notation", 1978 convincingly voted the 'accents' ˂ to form the primary model of extension and A to only present a subsequent recognition for the pair ˂˃.

[51]Ptolemy, Harmonics, 1.13 in Düring, I., *Die Harmonielehre des Klaudios Ptolemaios*, 1930, 30.19–31.6. The fact, that the chromatic is a secondary 'genus' and derived from Archytas' diatonic by lowering the *diátonos* (9:8) by the *leîmma* (256:243) to obtain the *chrōmatikḗ* at 32:27 below the upper tetrachord boundary was, though stated, overlooked by Ptolemy. But if acknowledging this, even the at first implausible assertion of Aristoxenus about the old age of the chromatic appears quite 'natural': for its structural origin is noting but an extract of the old Pythagorean tuning and thus directly accessible by the basic signs of the instrumental notation, e.g. **<>KC** (cf. Fig. 1). A look at the principles of notation would have helped to recognise that even Archytas' diatonic could be regarded 'secondary' and, likewise, be reduced to a 'superposition' of the enharmonic tetrachords *diezeugménōn* and *synēmménōn* (Fig. 2).

All in all, Vogel's historical examination of the *Origin of Enharmony* attained, to be fair, some 40 years ago the same principal insights now presented as "the hypothesis of syncretism".[52] The diatonic and even the aboriginal version of the enharmonic were imported from Asia Minor but cultivated and *systema*tised in archaic and classical Greece. Furthermore, the core of the tonal system and its native principles of construction from conjunct and disjunct tetrachords created a robust framework for (i) the intonation, (ii) the identification and (iii) the appreciation of (a) just-tuned intervals and (b) melodic differences of small magnitudes—"after much labour"[53]. Articulation, measurement and enculturation in concert were paving the way for the only later so-called *'Non-modulating' Perfect System* spanning the compass of two octaves.[54] This principal *sýstēma*, which comprises both conjunct (*synēmménōn*) and disjunct (*diezeugménōn*) tetrachords and which arranges its tonal relations around a middle root note, central to both, was well known to harmonic scientists and musicians by the second half of the 5th century at the latest.[55] More specifically, this tonal arrangement (in all three 'genera') was part and parcel of the instrumental notation before it had been adapted to serve an extended, though conceptually misguided[56] version, of the Aristoxenian *tónoi*-system, eventually symmetrised into 15 equal transposition scales with a span of two octaves each, shifted against each other by a semitone.[57]

3.3. Implications

Seeing through the ruse of Aristoxenus by help of Archytas' formulas,[58] another diagrammatic implication of the original notation scheme could be deciphered: the long-since[59] encountered 'pitch abnormality' of the so-called *vocal notation* (Fig. 1). This younger alternative built upon the standard Ionian alphabet purports to be synonymous with the instrumental notation. However, the pitches represented by the individual letters do not consistently follow the alphabetic order of the signs.[60] More importantly though, the *media commutation* from grouped triples to the linearly structured alphabetic signs obscures the underlying organisation of pitches still and distinctly visible in the diagrammatic representation of the instrumental notation. Significantly, the *diagrammatic function* of the secondary instrumental signs (in supine and reversed orientation) was to display a specific shift of pitch. These shifts were independent from the scale position of the basic note, represented

[52]Franklin, "Musical Syncretism", 446.

[53]This is not to claim that the Greeks had better ears than we have today, nor that they would have been able to qualify intervals presented in isolation (as in the case of Ptolemy's method) any better than other people (as Winnington-Ingram has been misunderstood e.g. by Hagel, "Context of tunings", 297 in quoting his 'belief' that "the Greeks used intervals strange to us with precision" [W-I. 1932, 206 n. 2]), but that they would have performed differently in probe-tone experiments à la Krumhansl, C.L. & Shepard, R.N., "Quantification of the hierarchy of tonal functions within a diatonic context.", 1979 in melodic context—because their 'perception grew accustomed' to enharmonic melodies "and with difficulty at that" as Aristoxenus admits. Cf. quote on p. 9 above.

[54]Many good introductions to the *sýstēma téleion ametábolon* exist. The presuppositionlessliest might be found in Barker, *The science of harmonics in classical Greece*, 13–18.

[55]Cf. the minute proof in Hagel, S., "Twenty-four in auloi. Aristotle, Met. 1093b, the harmony of the spheres, and the formation of the Perfect System", 2005.

[56]It will not be until the end of chapter 6 that the 'nature' of this misunderstanding will become clear.

[57]See Hagel, *Modulation in altgriechischer Musik*, especially his reconstructed diagrams (184 & 190).

[58]That Archytas' 'numbers' are in fact *formulas* becomes obvious if we recognise that the arithmetic and harmonic means of the octave ⊏-ᴦ (representable in Philolaian string lengths by the numbers 6:12) yield the fifth ᴋ-ᴦ (8:12) and fourth c-ᴦ (9:12), thereby establishing the bounding notes of the standard Dorian scale. A specific feature of Archytas' tuning, however, is that these 'formulas' (now reciprocally referring to the 'speed' of acoustic oscillations) have been reapplied to generate note ⩛ as arithmetic mean of the interval a fourth (4:3) above the tonal centre <-c and note ⟩ as harmonic mean from the fifth (3:2) above the same 'root' (1:1) ⊏-c. Taken together, these means are sufficient to determine the tuning of the complete tonal system as represented by notation. Cf. Fig. 1 & 2. Interestingly, it is exactly this feature Plato 'extracted' from Archytas in order to complete 'the soul of the universe' in the very same way. Cf. Plato, *Timaios* 35b–36b.

[59]Bellermann, F., *Die Tonleitern und Musiknoten der Griechen*, 1847, 44.

[60]Ibid. 35.

by the signs in normal orientation. In other words, the coding principle of the initial instrumental notation was acoustically straightforward and not designed to indicate a *tonal function* derived from any 'key' or *tónos* in a certain 'genus' to which a note belongs in Aristoxenian theory and, as we will see, by which its pitch is only indirectly determined. Consequentially, not every instrumental sign could be used to represent any 'notes' or tonal function as afforded by the Aristoxenian *tónoi*-system. Furthermore, since it is only what we might call *the pre-Aristoxenian codec of notation* which can explain the striking 'pitch reversals' at the notes ΓΔ, ΜΝ, ΩϠ and ϽϿ (highlighted by the dashed rectangles in Fig. 1), these exceptions most obviously undermine the suggestive scheme of a plain 'additive pitch space' as affected by the linear order of the alphabet. Whereas, on the other hand, the diagrammatic function of the triplets is reminiscent of acoustic proportions and thus bound to a 'rational' order of pitches from which the harmonic model of tones had primordially been derived. Hence, this finding in turn provokes another question to be delved into here: whether the supposed 'alternative' of a 'vocal' notation was, in fact, rather meant to be a revolution—designed to wilfully break with the confines of some older principles inextricably coded into the genuine 'instrumental' notation system.

3.4. Application

As a result, the structure of the instrumental notation as unlocked by Archytas' formulas, demonstrates its diagrammatic power and reveals a good deal of the harmonicists' theoretical knowledge wrought into this medium. The "neat tunings" of Archytas mutually interlock to form a single coherent structure which one might even embrace as 'natural' in the sense of Aristoxenus,[61] since it consists of 3 identical (cf. Fig. 1), perfectly *diatonic* 'columns' of traditional Pythagorean proportions.[62] Although an essential feature, later copied and generalised to organise the *tónoi*-system, this structure has been easy to overlook due to a common preoccupation with the concept of 'genus'. Though at some point in history certainly an important analytical category—we will need to take it up again at a later stage—the stubborn application of this concept already blinded Ptolemy, who recorded and saved Archytas' *formulas* only by disassembling them quite misleadingly to sit unconnectedly side by site as naked ratios, or in three columns of abstract numbers without any reference to notation.[63]

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[61]Regarding the antecedence of the diatonic consult the quote given on page 9 Its characterisation as πρεσβύτατον, standardly translated as the "oldest" by Franklin and Barker, *GMW*, II, 139, was recently 'enhanced' by Hagel, "Context of tunings", 293 n. 58 as to now render: the "most important".

[62]Cf. Hagel, "Twenty-four in auloi", 56–57 gives a numerical analysis of Archytas' "neat tunings". As a consequence, he rightfully accuses Huffman, C.A., *Philolaus of Croton. Pythagorean and Presocratic*, 1993, 368–374 of 'falsifying history due to mathematical ignorance' (our wording) because of dating the mathematically awkward fragment Philolaus A26 after the obviously more advanced, or in his words, "neat tunings" of Archytas. The argument has been repeated in Hagel, "Context of tunings", 286 n. 25. Huffman by contrast, while somehow believing that a numerological significance of cubics, or powers of 3, could only arise with Plato as seen in the Timaios, misplaces the fragment in the context of the early Academy, namely the days of Xenocrates. Merely on this grounds he tries to dispute the genuineness of the fragment—previously accepted as authentic by Burkert, W., *Lore and science in ancient Pythagoreanism*, 1972, 394–400 and recently by Barker, *The science of harmonics in classical Greece* (though on different grounds, we will come back to in sec. 5.3)—so that, after all, Huffman's refutation cannot be considered as conclusive.

[63]Cf. n. 51. By this obstacle, as it seems, also Hagel has been tricked: Although he recognises a diatonic substrate in Archytas' numbers and acknowledges its mathematical significance for being 'neatly' constructed from the arithmetic and harmonic means (cf. note 58 and 62 above), the plural form of "tunings" is enough to indicate that Hagel treats these highly interlaced tonal relations as still separate solutions for at least 2 of the 3 genera (cf. note 48 below). Obviously, he cannot accept the structure of an *emerging* mathematical kernel generating the whole scale system as represented by the instrumental notation. This is confirmed by Hagel, "Twenty-four in auloi", 79, where he deplores that "unfortunately, from Archytas' work, only his account of the divisions of the tetrachord survived, not the larger structures of music". Consequently, he limits the formulas of Archytas to merely provide a "numerical representation of the Perfect System" whilst dismissing the external evidence of notation (cf. note 48 above). The resulting prepossession, according to which the "beauty in music" in all occasions where it would

Yet, as the series of Pythagorean interval relations *are* apparently constructed from the primes 2 & 3, they were *transposed* by the reasoning of Archytas—once by the ratio 28:27 (rendering the natural seventh 7:4) and twice by the ratio 16:15 (establishing the just major third 5:4)—thus enriching the tonal system with intervals produced from the primes 7 & 5.[64] Still anchored in the diatonic and consolidated by reasonable superparticular ($(n+1)/n$) ratios or 'resonant' intervals,[65] the resulting proportions of the instrumental notation were pretty easy to install on the lyre by standard tuning procedures, such as the quasi-mathematical 'method of concords' realised by alternating fifths and fourths and additional help from 'finetunings' which directly explore the high pitch resolution of the ear when exposed to 'pure' *symphōníai*, or to the range of beating-free to weakly beating intervals.[66] Hence, enharmony with respect to notation literally meant *in*-harmony, highlighting only the pro-

coincide, or only possibly reveal a "beauty of [...] numerical structures" must *a priori* be approached with utmost suspicion, has even been raised to the dignity of a scientific method and was reinforced as such in Hagel, "Context of tunings", 284–285. ΣΣ: the ancient world of sirens and muses—all just too beautiful to be true?

[64] In his latest, perhaps most efficacious crusade against the erring sacrifice of truly musical practice on "the altar of superparticularity" (Ibid. 299), Hagel—without doubt—conquered "the mathematical chimera" of "'septimality'" (302) in Ptolemy's *Harmonics* and successfully exorcised any belief in the credibility of his 'empirical' method. Hagel convincingly eroded the authenticity of Ptolemy's measurements claimed to reflect contemporary tunings. By presenting the "fixed algorithm to produce possible mathematically acceptable tetrachord divisions" (298), the ontological bias running behind Ptolemy's scientific machinery could be unveiled as duly corrupting the setup of his advanced measurement equipment of the 2nd century AD to only render "mathematical idealizations" (298). Interestingly, however, just the very tuning that runs counter to the harmonicist's manipulative algorithm, and thus manifests itself credible to Hagel's critical methodology to possibly obey practical musical meaning (302), *still* contains septimal intervals. Yet, exactly this tuning (of Ptolemy?) appears *identical* with Archytas' diatonic whose conspicuously small superparticular semitone (28:27) was ruled out beforehand for being mathematically all-too suspicious and to be indeed "the culprit" that "constitutes the major aesthetical flaw of his [Archytas'] system" (290). Nonconformist to the standard genera of Aristoxenus, this septimal tuning was awfully discredited and had to be denounced a "mathematical fiction" (294). But, just because "it is extremely improbable that this second century tuning stood in any historical continuity with the music of Archytas' time" (302) both of Hagel's arguments—(i) the absence of 'septimally laden' divisions in all six centuries between and (ii) the 'uneasy' superparticularity of this very division compared to the various 'cleverer' ones deployed during the 600 years in between—actually speak against the absolute implausibility of septimal intervals in Archytas' time. All the more so since, the intricate 'mathematical fallacy' Hagel constructs (292–293) to doom Archytas' divisions by his methodology (cf. note 63 above) does not evince a nice algorithm as it does in the case of Ptolemy but merely presents a numerological tautology, itself derived by hardly more than 'mathematical speculation'. Hagel's delusion in the case of Archytas may well be the effect of his own scientific methodology and his disregard of the early acoustical logic of notation (cf. note 48 above) which would be far more likely to motivate Archytas' divisions than a blind deference to the Aristoxenian trinity of *génos*. This insight would have made it obvious that Archytas did not deface the standard diatonic since each of the three Pythagorean columns of normal, supine and reversed signs still hold it erect. Moreover, this finding may also made it possible that a true musical meaning of 'septimality' in Archytas' time would not necessarily be raised due to the psycho-acoustic effect induced by the overtone series 6–7–8 in representing the missing fundamental (282)—i.e. the way in which the respective septimal third 7:6 and the septimal tone 8:7 are probably employed for a proposed post-Hellenistic "G mode" (whose *harmonic* tension towards *lichanós* (the 'g') and *paranḗtē* (d') or *hyperypátē* (d) would consequently suspend "the old focal notes of a and e (*mésē* and *hypátē*)" (303))—but, instead, that an equally probable pre-Hellenistic 'septimality' could function beautifully due to the enriched melodic 'colours' provided by the dissonances and consonances of the intervals 7:6, 8:7, 9:7 *and* the natural 7:4 (cf.  ,  ,  ,  ,  in Fig. 1 above), that is to say, in oder to *melodically* (not tonally) explore the interval relations of just-tuning, generated from the root *mésē*. Also, this possibility would avoid to construct the 'classical' antagonism between "pure thirds" and "'septimal thirds'" (281) but, on the contrary, could help to explain the open, pre-Hellenistic tonal space where a reality of *chróai* (independent, it is true, of temperament owing to modulation) is quite naturally at home. Thus, if the apparent prevalence of enharmonic music developed in the course of the 5th century (as sedimented and still visible in the instrumental notation) is understood as not merely happening due to a vague supremacy of the 'enharmonic genus' but due to the exploration of just-tuned intervals, then the consequent practice of 'resonance' (cf. note 65 below) evoked by the authority of the old focal notes would had necessarily called forth the very *pyknón* (36:35 x 28:27 = 16:15) of Archytas—because "the involvement of the natural seventh (7:4) leads to an enharmonisation of melody" (Vogel, M., *Die Enharmonik der Griechen. 1. Teil: Tonsystem und Notation*, I, 1963, 97). Hagel, "Context of tunings" can point to contemporary fragments to corroborate his "new style of music" (303) whereas comparable ones for the old 'style(s)' do not exist (except the Vienna papyrus G 2315, in Pöhlmann & West, *Documents of Ancient Greek Music*, nr. 3 and Vogel 109–113). Admittedly, "perhaps it is too speculative" (303) but we think that Vogel's pioneering work, while pointing to notation, to disclose the principles of enharmony is at least equally convincing—musically.

fundity of the aforementioned 'punning statement' of Aristoxenus (cf. 3.2.). As a cunning opening to his discordant point of view, Aristoxenus' sophisticated play on words right at the outset of his oeuvre conveys two things: it hints at the achievements of acoustic music theory but also digs at the limitation of its implications. Yet, when taking into account earlier stages of the standard notation system,[67] we recognise that the 'irregular' traditional modes or so-called 'defective scales' were actually encoded as subsets of a comprehensive, overall enharmonic tonal system. Rooted in practice, this older, *acoustical unification* of scales is an eminent accomplishment of notation, not a defect resulting from lack of theoretical generalisation or empirical differentiation. In contrast, given enharmonic tuning, possible trans-positions even evoke or encode (depending on one's perspective) the *chróai*, or shades (literally *colourings*) of tuning, since these small pitch variations are 'natural' consequences of the shifted diatonic columns. Their pitch-shifting gives rise to musical commata which form an integral part of the tonal system as conserved by and accessible through notation.

Obviously, pre-Aristoxenian music theory concerned 'only' with enharmony and notation developed crucial concepts, like the transposition of scales and congruence of interval sizes in modes which then were recast to establish the *tónoi*-system—however, in itself incompatible with the former organisation of signs. Given that notation did not play a completely marginal role in the musical life or at least was not just a pet theory of some sort of 'harmonic mavericks', its development enforced communication between possibly different 'schools' of harmonic scientists and musicians.[68] Thus, already at this stage of our investigation we light upon that the prominence of the Perfect System[69] and the theory of octave

[65]Franklin, "Hearing Greek Microtones", 11–13 introduced the concept of 'resonance' as "the partial coincidence of two tones' waveforms", or "the inversion of harmonic refraction", though, as far as physics is concerned, the latter contradicts the former, which should read 'spectra' instead of 'waveforms'. Hagel, "Context of tunings", 281 n. 1. adopted Franklin's terminology "as denoting the objective physical basis of 'consonance'". However, we should keep in mind that the effective 'resounding' of 're-united' overtones series of two sounds is a far more complex phenomenon than expressed by superparticular, or epimoric ratios of their 'pitches' or harmonic fundamentals. Building on von Helmholtz' concept of *sensory dissonance*—which might come closest to Franklin's idea of 'resonance'—the breakthrough of Sethares, W.A., "Local consonance and the relationship between timbre and scale", 1993 extended the concept to incorporate the whole spectrum by factoring-in all partials of a sound. This is specifically relevant to music archaeology since it widens the 'objective basis' for dissonance minima (or audibly lesser beatings) at certain superparticular intervals by taking the timbre of ancient instruments into account. Notably, for 'purely' harmonic oscillations, such as open gut strings on lyres and the "whistling" (Franklin, "Hearing Greek Microtones", 12) of overblown (pan)pipes, the lesser beating intervals 5:4, 6:5, and 7:6 can be reasonably considered as locally 'outstanding' and prominent to the ear (cf. not 66 below).

[66]See Vogel, *Enharmonik der Griechen*, I, 55–57; Barker, *GMW*, II, 168 n. 111 on the "method of concords" in the context of Aristoxenus; Hagel, "Is nīd qabli Dorian?" on subsequent "fine tunings", on diatonic tuning in general and on 'resonant thirds' in particular Hagel, "Context of tunings", 283 (where, for his convenience, he approved of tuning them "directly"—straight by ear); and, last but not least, Franklin, "Hearing Greek Microtones" for supplying a practical 'how-to guide' in order to establish Archytas' tunings across "non-adjacent stings" by "the use of the lesser resonances 5:4, 6:5, and 7:6." (29–33) including an exhaustive Appendix (39–48) suggesting how to install even less reasonable superparticulars 'qualitatively' on a lyre.

[67]Aristeides Quintilianus, "ΠΕΡΙ ΜΟΥΣΙΗΣ", 1963, I, 7 preserved another set of notational signs ascribing them to "the ancients". Their structural organisation seems to match a plain grid of quartertones, reminiscent of Aristoxenus' scorn for those 'misguided' "harmonicists doing *katapyknōseis* with/to their diagrams" (28.1) and all of this while acting in complete ignorance of "the nature of continuity in melody" (27.21) for separating "the notes from one another by the smallest interval" (28.4–5). Apart from this, this principle of notation seems to have died out without further trace. Cf. West, M.L., "Analecta Musica. On the text of the Greek musical documents", 1992.

[68]For the evidence of such schools see Barker, A., "Οἱ καλούμενοι ἁρμονικοί: the predecessors of Aristoxenus", 1978 and especially Barker, *The science of harmonics in classical Greece*, 285–286 where he puts emphasis on his newly developed appraisal of the first ever Pythagorean to write, Philolaus, to actually *bridge* between the schools with his cosmological system, since "his approach combines calculations involving ratios with the 'linear' conceptions of practical musicians and empirical theorists, and it is the latter that play the most important part in his account of the system's integration and symmetry."

[69]Perfect System here and henceforth refers to the Greater Perfect System (*sýstēma téleion meĭzon*) spanning 2 octaves with two disjunct tetrachords as the central octave that were extended at both sides by one conjunct tetrachord each and harmonically 'perfected' by a whole tone at the bottom. Cf. n. 54.

species (as an immediate result of transposition, if confronting the former with notation) cannot be regarded as remote from the formation of the Aristoxenian *tónoi*-system.[70]

Conceptually, *parasēmantikḗ téchnē* served the same purpose in the realm of melody as the vowel alphabet in the realm of language, a comparison once applied by Aristoxenus himself[71], namely: to analyse the musical sonosphere into its basic components or *harmonic elements*. This is not to say that this (co-)incidence meets the intent of the Aristoxenian *Harmonic Elements*. Quite the contrary, Aristoxenus' harsh and historically unique denunciation of notation for any 'theory of music' agenda—while professing that "notation is not even a part of it"[72]—is, as we hold, in meaning and in tone, most significant to his project:

> For through the magnitudes as such, no knowledge (*sýnesis*) is forthcoming of the functions (*dýnamis*) of either the tetrachords or the notes, or of the distinctions between the genera, or, to put it briefly, of the distinctions between the composite (*sýnthetos*) and the incomposite (*asýnthetos*), of the simple and the modulating, of the styles of melodic composition, or, in a word, of anything else at all. If the so-called harmonicists adopted this supposition out of ignorance, there would be nothing perverse about their procedure, but their ignorance must have been powerful and profound. But if they propounded the doctrine while fully aware that notation is not the limit of the present science, aiming to please the general public and to give them some end-product visible to the eye, then they are to be condemned, instead, for gross perversity in their method.[73]

4. PRACTICE

If harmonic theory gave birth to a rather suitable notation system at least two generations before Aristoxenus, what then caused the need to overthrow it, or even attack its practitioners in abusive terms? A detailed investigation of the issue of *polychordía* and its yet unresolved relation with the *bárbitos* may help clarify the motivation behind this turn. To embark on that path however, requires us to trace somewhat involved arguments scattered among ancient sources of later antiquity. Here we shall concentrate on three sources: Athenaeus' *Deipnosophists,* the Pseudo-Plutarchian treatise *perí mousikḗs* and the so-called Aristotelian *Problems*.

4.1. '... sounding in answering strains'

ψάλλον δ΄ εἴκοσι χορδαῖσι μάγαδιν ἔχων, ὦ Λεύκασπι.
With mágadis in hand I sing to its twenty strings, O Leucaspis.

Anacreon, fr. 29

These lines of Anacreon mentioned in the fictional conversation of "The Deipnosophists" already posed a conundrum in antiquity;[74] To wit, while the deipnosophists were discussing musical innovations and their interdependence with developments in instruments, the question arose: How could there possibly have been so many strings mentioned by one of the nine melic poets—meaning, as early as in the mid-6th century when Anacreon was hosted by Polycrates in the heyday of Samos? To solve this enigma, the deipnosophists said that the historian and polymath Posidonius knew that with those words "Anacreon mentions

[70]Cf. Hagel, *Modulation in altgriechischer Musik*, 165–168: introduced such a 'remoteness' in order to corroborate his otherwise valuable revision of the "history of transposition scales" as hitherto presented by West, *Ancient Greek Music*, 223–233.
[71]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ"; 1.27; 35.10–12 da Rios.
[72]Ibid. 2.39; 49.7–8 da Rios. Trans. Barker, *GMW*, II, 156.
[73]Ibid. 2.40.–41 , 49.9–52.7 da Rios. Trans. Barker 156–57.
[74]Athenaeus, "Deipnosophistae", VI, 635c. Trans. Charles Burton Gulick 429.

three melodic scales (*melōdíai*)[75], Phrygian, Dorian and Lydian; these, in fact, were alone used by Anacreon; and since each of these requires 7 strings for their rendering, naturally he says that he sings to 20 strings, simply using a round number and subtracting the one."[76] "But", the discussion goes on, Posidonius of the 2nd century AD was "unaware that the *mágadis* is an ancient instrument, although Pindar says distinctly that Terpander invented the *bárbitos* […] when, at the feasts of the Lydians, he heard the plucking of high notes on the *pḗktís* sounding in answering strains (*antíphthongos*)."[77]

But, once more, what is the logic behind the disagreement, if Anacreon's instrument, though likely to be a harp, was most probably not a correspondingly huge sound device of 20 physical strings in his hand,[78] and if, on the other hand, the *bárbitos* was basically a low tuned *lýra* of 7 strings in about the baritone register? How else then is this related to *polychordía*, or playing in at least 3 different kinds of *melōdíai*?

To find out more about this, we follow at first Helen Roberts who committed herself to "reconstruct an authentic replica of the ancient Greek *lyra*"[79] and—to be complete—a *bárbitos* too. In her article *The technique of playing ancient Greek instruments of the lyre type* she takes up the old question of melodic accompaniment or solo playing which had been set aside ever since the critical objections of Winnington-Ingram (cf. sec. 3.1). But towards the end of the 1970s Roberts argued that the latter's intellectual reservations against allegedly 'intolerably thin' tones produced by stopping techniques ought to be verified experimentally —"for technical theories must finally be subjected to a practical test."[80]

4.2. The spectral chimera: *énaulon kitharisin*

Roberts does not mention the discussion above, but draws on Athenaeus' information about Lysander of Sicyon, who according to the historian Philochorus "was the first *kitharistḗs* to institute the new art of solo playing (*psilokitharistikḗ*), tuning his strings high and making the tone full and rich, in fact, giving that flute-like tone to strings (*énaulon kithárisin*)".[81] This poetic phrasing while transferring a quality of wind to stringed instruments already reminded E. Kerr Borthwick of "the traditional '*polychordía*' of the *aulos*"[82] and in particular of Plato's allegation that multi-stringed instruments would only imitate the fashion of pipe-playing. Recalling Theophrastus, who asserts "that a different quality of reed is required for the different playing styles"[83], Borthwick draws a parallel between the improved tone quality of *énaulon kithárisin* and a certain "elaborate style of playing"[84] *metà plásmatos* which would refer to the 'artificial style' of overblowing the *aulós* in order to utilise the upper harmonics of this instrument in melody.

Roberts however regrets Borthwick's interpretation since in her opinion *énaulon kithárisin* merely equals the "sustained sound of the aulos".[85] Yet, the following lines of

[75]Barker, *GMW*, I, 295 translates more modestly: "kinds of melody".
[76]Athenaeus, "Deipnosophistae", VI, 635c–d. Trans. Gulick 429.
[77]Ibid. 636d–e. Trans. Gulick 429.
[78]Barker, A., "Telestes and the 'five-rodded joining of strings'", 1998 while exhaustively discussing a fragment (PMG 808) of the distinguished poet Telestes which has survived in Athenaeus, Barker seems to espouse that the *mágadis* was not even a musical instrument. However, in his last note he admits that "in the remainder of Athenaeus' discussion (to 637a) a stringed instrument is plainly intended." (81, n. 22)
[79]Roberts, "Reconstructing the Greek Tortoise-Shell Lyre", 312.
[80]Roberts, H.D., "The technique of playing ancient Greek instruments of the lyre type", 1980, 49.
[81]Athenaeus, "Deipnosophistae", VI, 637f. Trans. Gulick 443.
[82]Borthwick, E.K., "Some problems in musical terminology", 1967, 152.
[83]Ibid. with reference to Theophrastus, *Historia plantarum: livres III et IV*, II, 1989, IV.II.4.
[84]Ibid. IV.II.5, Trans. in Barker, *GMW*, I, 186.
[85]Roberts, "Technique of playing instruments of the lyre type", 47 takes μακρούς τοὺς τόνους ἐντείνας καὶ τὴν φωνὴν εὔογκον ποιήσας as literally as possible to support her interpretation of an enhanced sustain by translating: "stretching the strings so that they became long" and that "he [Lysander] made the tone full and rich". Whereas not even Barker's closeness would allow going that far as we see by his rendering: "stretching the strings at great tension and giving bulk to the sound" (Barker, *GMW*, I, 300). Although Barker seems to dispute the 'sus-

Athenaeus about Lysander's achievement of *psilokitharistikḗ* enable us to interlink the technique of instrument construction and instrumental technique as prerequisites for coming up with a 'new art' in music:

> "He abolished the meagre simplicity prevailing among the solo cithara player, and introduced in his cithara playing highly coloured variations [χρώματα εὔχροα], also *iambi*, the *magadis* and the *syrigmos* as it is called".[86]

Hence, for Borthwick it was tempting to identify '*mágadis*' with the first harmonic overtone 'stopped' at the middle of an open string bringing forth the octave (2:1), and accordingly '*syrigmós*' with the second harmonic yielding the note an octave and a fifth above the fundamental, or the twelfth in just-tuning (3:1). Notwithstanding Borthwick's identifications, Roberts' restrictive argument for the use of "longer, and hence presumably thicker, strings" on Lysander's *kithára* does not contradict the physical plausibility of Borthwick's rendering. On the contrary, she asserts herself that the advantage of a literal interpretation would be: "having a heavier mass, they would vibrate longer than lighter and shorter strings. Harmonics stopped on such strings would also be clearer and more resonant."[87] Furthermore, experiments on her reconstruction proved—as we can confirm by our experience with gut strings—that "as natural harmonics become gradually weaker in ascending order of pitch, the second harmonic will be less resonant than the first, […] although it is by no means indistinct or inaudible, even when produced on an open string without a finger board."[88] As a result, the proposed 'flageolets', *mágadis* and *syrigmós*, were feasible on improved lyre strings without acrobatic fingerings.

Barker however, though not commenting directly on the argument between Roberts and Borthwick, was unhappy not so much with the increased "sonority of the instrument, perhaps, as the Loeb translator (Gulick) suggests, by augmenting the size of the sound-box;"[89] but more with the metaphorical translation of the latter in offering the above "…giving a flute-like tone to strings..." for *énaulon kitháristn*. Knowing of the "lascivious whine" and "sustained nasal blare" the *aulós* is gifted with, the impression Gulick's wording puts across would not only be physically but especially in the context of *psilokitharistikḗ* "surely impossible".[90] Instead, what Barker advocates is to read: "…giving an *aulos*-like performance on the *kithara*…"[91]. He bases this reading on not interpreting "the expression χρώματα εὔχροα"[92] as "a technical reference to 'chromatic' tuning, or forms of the scale"—for that was to come later—but on the idea that Lysander made "the kithara, for the first time, an instrument capable of 'realistic' imitative effects, in contrast to the usage whereby it merely sounded a tune or an accompaniment without substantial variation of tone-colour".[93] After supplying further literal evidence to support the 'flageolet' thesis for '*mágadis*',[94] he recognises '*iámbi*' and '*syrigmós*' as corresponding with the titles of the

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tain hypothesis' (cf. note 89 below), the physical implication of his translation serves Roberts' own acoustical in-tentions even better. By contrast, Thurn, *Die Geburt der Theorie aus dem Instrument* exaggerates when building his tuning hypotheses (cf. n. 37) on the interpretation of 'μακρούς τόνους' to indicate thicker strings that would be inserted much like in a 12-stringed guitar an octave below (114). Yet, since the classical lyre counts 7 stings, the thickened replacements needed to be tuned even a twelfth lower. Henceforth, melodies would mostly be heard as flageolets of the first and second overtone (109-111). As, in his opinion, strings are rather easily stretched after their excitation in oder to realise any finetuning within the limit of a tone (!), many notes of different scales could be fingered and thus, the problem of *polychordía* is solved. For sure, this kind of *psilokitharistikḗ* would enable all sorts of modulations and Timotheus could ultimately acts as the true master of this playing technique (141).

[86]Athenaeus, "Deipnosophistae", II, 638a. Trans. Roberts, "Technique of playing instruments of the lyre type", 47.

[87]Ibid. 47.

[88]Ibid. 48.

[89]Barker, A., "The innovations of Lysander the kitharist", 1982, 266.

[90]Ibid.

[91]Barker, *GMW*, I, 300.

[92]See the quote on page 18 above.

[93]Barker, *GMW*, I 268.

[94]Barker's reference is Michaelides, S., *The music of ancient Greece. An encyclopaedia*, 1978, 196 and 313–4.

fourth and fifth movement of the auletic *Pythikós nómos* as reported by Pollux (4,61). Now, since the former section mimics Apollo's victory over the dragon Python, the latter may well represent "the death-throes of the monster, as it breathes its last in τινὰς συριγμούς."[95] By virtue of these sort of "imitative tricks"[96] and as *syrigmós* would literally mean "a whistling or hissing noise"[97], Barker is convinced that in this case another artistry of Lysander, namely to "substitute one instrument for another (*órganon metélaben*)"[98], would rather mean: playing on the *kithára* "types of music which had previously been performed only on the aulos."[99]

Finally and by further contrast, it is precisely this manner of 'flageolet whistling', we might recognise as a 'spectral chimera'. At least Franklin, while again inclining to the acoustical side, explains such flageolet whistling as resembling the harmonic 'pureness' of sine tones. He considers it promising that the term "*syrigmós*, 'whistling' (< *sýrinx*, 'pan-pipe') […] would be appropriate since an isolated partial is a pure sine-wave, while many whistles and pipes create periodic tones of similar purity."[100]

Leaving the philologists' ongoing battle aside, we would rather like to call to mind another fact of acoustics; that overblowing an *aulós*—as traditionally performed on the *sýrinx*—does not produce an octave but just the very twelfth of our potential *syrigmós*.[101] Moreover, the technique of *syríttein*, as opposed to *auleîn*,[102] exhibits a clearly distinguishable tone quality fitting well the above comparison with stopped strings and the audibly different timbre of 'flageolets'. Drawing on this match, the playing with harmonics, on both wind and stringed instruments,[103] brings the *mágadis* of Anacreon back into play and may contribute to solving its enigmatic relationship with the birth of the *bárbitos,* as we were told—from a mere listening to 'answering strains' of the Lydian *pḗktís*.

4.3. An acoustic beginning of *psilokitharistikḗ*

To further substantiate an acoustic beginning of *psilokitharistikḗ*—regardless of whether one accentuates harmonic, organological or affective grounds first enabling the art of solo-playing—we need to bring in an additional perspective and slightly more sophisticated voices drawn together in the form of a symposium by the Pseudo-Plutarchian treatise *perí mousikḗs*. There, from one and the same sentence, we learn (i) that Terpander introduced "the Dorian *nḗtē* which had not been used in the melody by his predecessors" and (ii) that he had "invented the entire Mixolydian *tónos*".[104] The sequence of this information suggests a connection between the introduction of a certain note and the identification of a specific scale. But what exactly enables the link between the two pieces of information?

Elsewhere in the treatise and by testimony of Aristoxenus we hear that "it was Sappho who originally invented the Mixolydian and that the composers of tragedies learned it from her". They would have "adopted this *harmonía* and linked it with the Dorian, since the latter expresses magnificence and dignity, and the former emotion (*pathētikós*); and tragedy is a blend of both."[105] This time the logic of argument draws on a particular character or *êthos* of a certain scale or mode. The implication is that intervals characteristic of a certain mode

[95]Barker, "The innovations of Lysander the kitharist", 267. Cf. Strabo, "ΓΕΩΓΡΑΦΙΚΑ", 1877, 9.3.10.
[96]Ibid. 268.
[97]Ibid.
[98]Athenaeus, "Deipnosophistae", VI, 638a. Trans. Gulick 443.
[99]Barker, "The innovations of Lysander the kitharist"", 269.
[100]Franklin, "Hearing Greek Microtones", 12.
[101]Cf. Hagel 2005, 86 with reference to Howard, A.A., "The αὐλός or tibia", 1893, 32–35.
[102]See Hagel, "Twenty-four in auloi", 87.
[103]In fact, the whole wooly discussion in Athenaeus about these matters was started by the question, whether the *mágadis* is actually a wind or a stringed instrument. Cf. Athenaeus, "Deipnosophistae", VI, 634c.
[104]Ps.-Plutarch 1140f. in Lasserre & Pseudo-Plutarch, *Plutarque de la musique*.Trans. Barker, *GMW*, I, 233.
[105]Ibid. 1136c–d. Trans. Barker 221.

would be available within another mode, such that the sets of intervals of both scales could be linked or could even be merged together. Furthermore there is a link back to the instruments involved, because Sappho "lived before Anacreon" and also "was the first to use the *pḗktís*", as said in Athenaeus in the same passage about the invention of the *bárbitos* by Terpander.[106]

Last but not least, the relation given in Athenaeus between Anacreon, Sappho and Terpander relays on the assertion that—again according to Aristoxenus—"the *pḗktís* and the *mágadis* are the same instruments"[107] and "can be played without a plectrum, by plucking" which "is stated by Pindar in his *skolion* addressed to Hieron, where he describes the *mágadis* as 'a plucking that sounds in answer', because the two kinds of instruments together, *in octaves*, produce the concerted melody of men and boys."[108] Yet, the poet's testimonial from the beginning of the 5th century is still supported some 200 years later by the Pseudo-Aristotelian *Problems* where the "concordance at the octave" is scientifically explained to be "the correspondence" which "arises when young children combine with men, whose pitches differ as do *nḗtē* and *hypátē*" and that they would "*magadise* in the concord of the octave (ἐν τῇ διὰ πασών συμφωνία)".[109]

The following sections will undertake to assemble a coherent picture of the statements propounded so far.

4.4. Acoustics and music theory

With reference to notes (*nḗtē, hypátē*) and intervals (*diá pasṓn*) things become instructive. Apparently, the term to 'sound in answer' (αντιφθέγγομαι) is paired *acoustically* with the first harmonic and its musical exploration: Men and boys—fundamental and octave—sound together and blend into each other seamlessly. The semantic field discussed encompasses instruments (*mágadis* or *pḗktís*), a playing technique ('*mágadis*'), a musical practice (to magadise) and finally the magnitude of a particular interval (*nḗtē – hypátē*). Still, the key to all the collected information is confirmed to truly be a finding of *music-theoretical* recorded in the Pseudo-Plutarchian treatise: for Lamprocles the Athenian, who lived in about the early 5th century, had realised, "that the disjunction in this *harmonía* [the Mixolydian] is not where almost everyone supposed it to be, but at the top of its range, gave it the form of the series from *paramésē* to *hypátē hypatṓn*."[110]

This discovery is of great significance. With respect to the tonal system comprising the aforementioned Perfect System, it 'proves' (i) the compass (from *hypátē hypatṓn* to *paramésē*) of the Mixolydian *harmonía* to be the octave and (ii) its highest interval (from *paramésē* to *mésē*) to be the *tónos* (Fig. 3d). Furthermore, the magnitude of the *tónos* equals exactly the whole tone (9:8), since, undisputed in all sources, it is the difference of the perfect fifth (3:2) and the perfect fourth (4:3) produced by the disjunction (*diázeuxis*) of two tetrachords. By separation of the *tónos* (9:8) they span the range of the perfect octave (2:1) which then reaches from *hypátē* to the Dorian *nḗtē*. The perceptually anchored acoustic relations of the latter four intervals are modelled mathematically by the Pythagorean Tetraktys that—if seen as a mathematical operator[111]—*generates* the fixed 'standing notes', or *hestôtes* of *the* standard Dorian *harmonía*. In 'functional' nomenclature the Dorian frame of consonances consist of *hypátē, mésē, paramésē* and the therefore termed 'Dorian' *nḗtē*. Regardless of genus, the *tónos* marks the scale's centre which ever since was named *mésē*

[106]Athenaeus, "Deipnosophistae", VI, 635e. Trans. Gulick 431.
[107]Ibid. Trans. Gulick 429.
[108]Ibid. 635b–c. Trans. Barker 295. Italics are our emphasis.
[109]Ps.-Aristotle, Problems XIX, 39 in Jan, *Musici scriptores graeci*. Trans. Barker, *GMW*, I, 200.
[110]Ps.-Plutarch 1136d. Trans. Barker 221.
[111]Lohmann, J., *Musiké und Logos. Aufsätze zur griechischen Philosophie und Musiktheorie*, 1970, 74:"Etymologically, τετρακτύς is the verbal noun of τετράζομαι '*to operate with the tetrade*' which, up to now, has not been realised."

because it had literally been the ʻ*middle* note' when making the junction (*synaphḗ)* between the two tetrachords of the archaic heptachord (Fig. 3a). The smaller ambitus of the latter scale ran from *hypátē to nḗtē synēmménōn* without reaching the overarching consonance of an octave. This explains why in original nomenclature, when referring to the archaic heptachord, *para-mésē*—the tone next to *mésē*—could also be called *trítē*, the 3rd string from *nḗtē synēmménōn*.[112] When introducing the *diázeuxis* by the *tónos*, *trítē*—by testimony of Philolaus[113]—could even equal the 1st tone of the disjunct ʻtetrachord' which called for the subsequent disambiguation of *paramésē* and *trítē diezeugménōn*. So latest and throughout the period from Philolaus to Aristoxenus, the ʻDorian network' of *hestôtes* formed the nexus between acoustics and music theory. Ultimately, the *diázeuxis* will function as a finger-

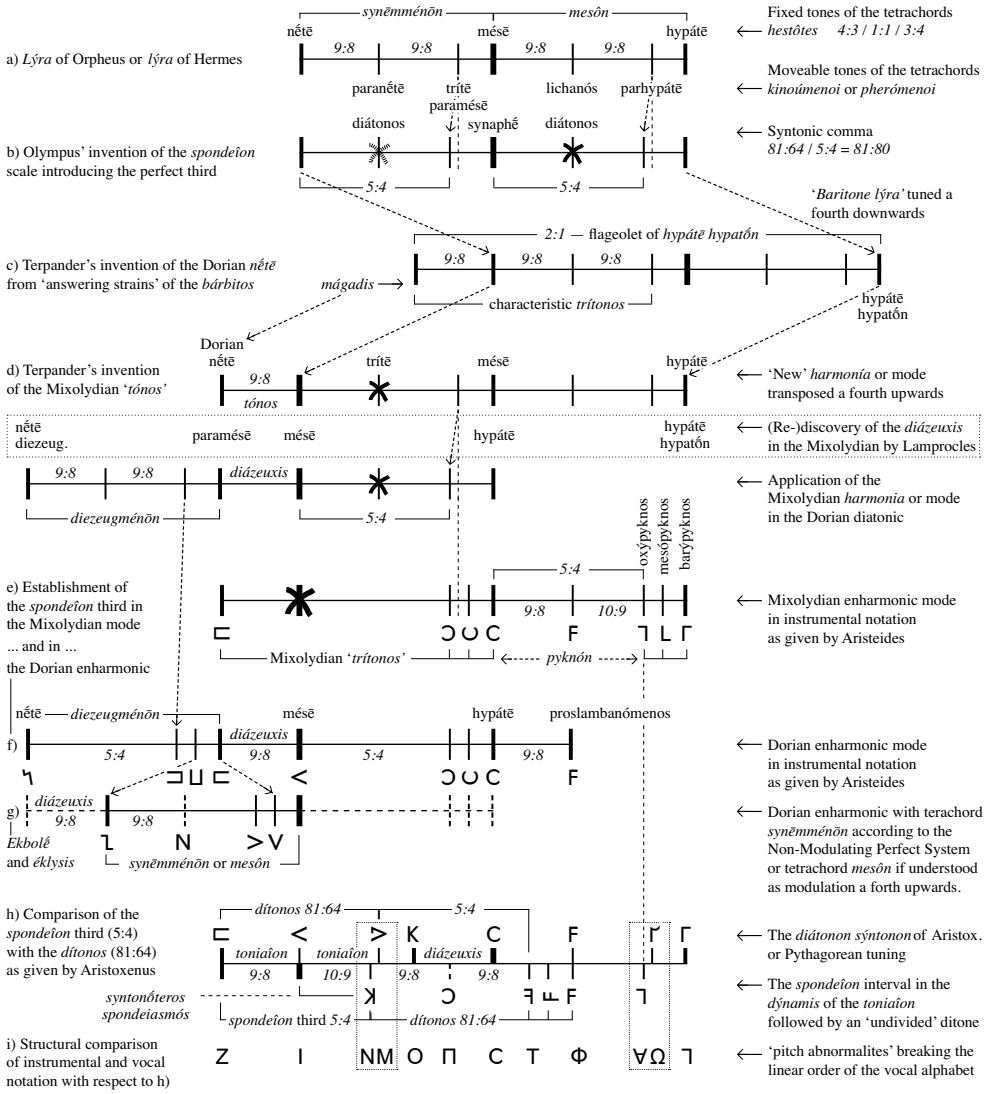

Figure 3. The ʻorigin of enharmony' and an early enharmonic concept of scale transpositions.

[112]Boethius, A.M.S., *Anicii Manlii Torquati Severini Boetii de institutione arithmetica libri duo. De instituione musica libri quinque*, 1867, Inst. mus. I, 20; p. 206 27–29: "Paramese vero, quoniam tertia est a nete, eodem quoque vocabulo trite nuncupatur".

[113]Cf. Philolaus fr. B6 in Diels, H. & Kranz, W., *Die Fragmente der Vorsokratiker*, 1954: "[...] ἀπὸ δὲ νεάτας ἐσ τρίταν συλλαβά, ἀπὸ δὲ τρίτας ἐς ὑπάταν δι' ὀξειᾶν."

print or 'key' to recognise the corresponding '*tónos*' in the Aristoxenian 'transposition matrix' (cf. 3.3), composed of 13 identical scales of Dorian shape. As they are spaced a 'semitone' apart, the lowest *tónos* just stands an octave below the highest.[114] Thus, if insinuating a circle of fifths, the 13th 'transposition scale' redundantly doubles the arrangement of both, interval sizes and tonal functions—just as if the extra *tónos* was designed to pay tribute to the 'magnificence' of the Dorian completeness? This question, however, shall concern us at a later stage.

Concerning the completion of the Dorian wholeness, we need to realise at first that the discovery of Lamprocles presupposes transposing the Dorian *nḗtē* of the Mixolydian a fourth down (Fig. 3d) to equal *paramésē* (*diezeugménōn*). By implication, this finding manifests an early concept of scale transpositions[115] long before Aristoxenus and stands in clear contrast to a 'mere gyration' of *harmoníai* around the octave.[116] Moreover, given that a certain Terpander first 'invented' the Dorian *nḗtē,* Lamprocles' theoretical finding implies that such a Terpander also 'constructed' the Mixolydian from the archaic heptachord of two conjoint tetrachords, simply by adding the octave to the fundamental (Fig. 3c).

What if this fundamental was indeed the *hypátē hypatṓn*, meaning the lowest string on a 'baritone *lýra'* just like the very one *bárbitos* Terpander had 'invented'—as well? So, is it really too audacious to contend that Lamprocles only *re*-discovered what had actually been the *acoustic emergence* of the Mixolydian *harmonía* by a melodic integration of the first harmonic '*mágadis*'—sounding full and rich in an answering strain?

In sum, the hypotheses developed with regard to the *bárbitos* and the practice of *psilokitharistikḗ* is that the utilisation of harmonics firstly inspired new 'melodic scales' or 'kinds of melody'[117], as in the case of Terpander and Lysander, and could be performed, as in the case of Sappho and Anacreon, with perhaps more than seven but still with a limited number of strings. Secondly, certain sets of intervals of these *melōdíai* crystallised to form 'irregular' scales, as in the case of the Mixolydian mode (Fig. 3e), which in turn becomes instructive for the concept of scale transpositions against a fixed grid of intervals anchored by acoustic proportions which subsequently were (i) encoded into, (ii) stabilised by and (iii) understood through *parasēmantikḗ téchnē*.

Yet, there is more evidence in the *'strain'* of this material to corroborate a tight link between musical developments, the creation of scales and their basis in acoustics. This touches the very *origin* of enharmony and urges us to consider its aesthetical and epistemological significance. Only by joining the following, 'steeply pitched' pathway, the issue of 're-configuring' our view on the inner workings of ancient Greek music theory can seriously be addressed.

5. THEORY

If acoustic and music theory ever sprang from a common beginning that would foreshadow its Greek destiny then it is to be sought in the enharmonic character of the *spondeîon* scale. As particulars about early stages of Greek music are meagre, these phases "take on an immense value for us"[118] but, naturally, over the course of their modern 'recognition' were subject to all sorts of emendations until Winnington-Ingram, again, was the first to stand up in order to "vindicate the manuscript reading"[119] that demonstrates its characteristics.

[114]Bacchius, "Bacchi Gerontis isagoge", 1895, 203.4–204.18.
[115]Calling into question the assumption that "initial stages of the systematisation of *tónoi* were almost certainly independent of the concept of the Perfect System." Hagel, "Twenty-four in auloi", 80. See also note 70 above.
[116]Cf. note 49 above.
[117]Cf. note 75 above.
[118]Winnington-Ingram, R.P., "The Spondeion scale. Pseudo-Plutarch de musica, 1134f-1135b and 1137b-d", 1928, 83.
[119]Ibid. 91.

5.1. *syntonőteros spondeiasmós* or the significance of the syntonic comma

No less a figure than Aristoxenus is called by the Pseudo-Plutarchian treaties to witness how a certain Olympus was "identified by the musical experts as the inventor of the enharmonic genus":[120]

> "Olympus was working within the diatonic genus, and bringing the melody frequently to diatonic *parhypátē*, sometimes from *paramésē* and sometimes from *mésē*, while omitting the diatonic *lichanós*, and he was struck by the beauty of the character (*êthos*) of this procedure. His admiration for the *sýstēma* constructed out of these proportions led him to adopt it and to create in this *sýstēma* compositions in the Dorian *tónos*. Now this *sýstēma* involved none of the features peculiar either to the diatonic or the chromatic, nor indeed those peculiar to the enharmonic. Nevertheless, these were the features of his first enharmonic pieces, since our authorities consider the first of these pieces to be the *spondeîon*, in which none of the divisions exhibits its special peculiarities. [(...)[121]] For the enharmonic *pyknón* used nowadays in the middle tetrachord is apparently not present in the music of this composer."[122]

Audibly, this distinct account of the derivation of an early enharmonic accentuates its singularity among the other genera. Regarding the notation system, the exclusion of *lichanós* literally erases the only note manifesting the genus in the tetrachord *mesôn* (Fig. 3b). Analogously, when the characteristic interval of the *spondeîon* was to be realised in one of the other tetrachords, such as in the *synēmménōn* (Fig. 3b) or the *diezeugménōn* of the Dorian scale (3f), the genus representative (whether a *diátonos*, or a *mesópyknos* of the developed enharmonic) had to be omitted likewise.[123] By this procedure the original enharmonic cracks the generic principle of the archaic heptachord (Fig. 3a). Moreover, it interrupts the sequence of fifths (Bb, F C G D A E) the conjunct diatonic (d' c' bb a g f e) was constructed from. Still, as elsewhere in the Plutarchian opus, the conservative author puts emphasis on the constraints of innovations and the genuine simplicity of newly introduced intervals that, as in the present case of the *spondeîon*, gave birth to the beauty of the enharmonic simply by replacing the genus indicating *diátona* by 'undivided' *dítona*. Consequently, it is the 'empty third' that defines "the character of the first enharmonic melodies" due to which "Olympus extended the resources of music by introducing something which previously did not exist, and was unknown to his predecessors", so that he became "the founder of the noble style of music that is specifically Greek."[124]

In order to determine the magnitude of this extraordinary *spondeîon* interval, the report inserts one of the most condensed and convoluted explanations of ancient music theory expressed in Aristoxenian technical terms. Complementing the indeterminate 'empty third' to the definite consonance of a fourth, it involves a certain *syntonőteros spondeiasmós*. Although we do need to manifest the size of this much disputed interval to proceed with our argument, we cannot exhaust all details of the passage in its native terminology here.[125]

[120]Ps.-Plutarch 1134b. Trans. Barker 215.

[121]This elision compresses the following testimony: εἰ μή τις εἰς τὸν συντονώτερον σπονδειασμὸν βλέπων αὐτὸ τοῦτο διάτονον εἶναι ἀπεικάσῃ· δῆλον δ' ὅτι καὶ ψεῦδος καὶ ἐκμελὲς θήσει ὁ τοιοῦτο τιθείς· ψεῦδος μὲν ὅτι διέσει ἔλαττόν ἐστι τόνου τοῦ περὶ τὸν ἡγεμόνα κειμένου· ἐκμελὲς δ' ὅτι καὶ εἴ τις ἐν τῇ τοῦ τονιαίου δυνάμει τιθείη τὸ τοῦ συντονωτέρου σπονδειασμοῦ ἴδιον, συμβαίνοι ἂν δύο ἑξῆς τίθεσθαι [δίτονα], τὸ μὲν ἀσύνθετον, τὸ δὲ σύνθετον. Instead of the generally accepted δίτονα, the handwritings give διάτονα which makes no sense among σύνθετον and ἀσύνθετον of the present context. In addition, the two words were mixed up many times by copyists.

[122]Ps.-Plutarch 1134f–1135b. Trans. Barker 216–217.

[123]For a concrete example see Figure 2 where the *diátonos* of the diatonic tetrachord ⊏<⩘K is <. Respectively, in the enharmonic tetrachords *diezeugménōn* and *synēmménōn* the *mesópyknoi* ⩘ or ∪ would be left out in order to realise the *spondeîon* in the Dorian scale.

[124]Ibid. 1135b. Trans. Barker 217–218.

[125]Barker, *GMW*, I, 255–257 devoted a separate Appendix to the "*spondeion* and the *spondeiazōn tropos*", but still

Fortunately however, the given parenthesis boils down to (A) a comparison of three different tunings which are tellingly and comparatively easily exemplified by (B) reference to the instrumental notation as decoded in Fig. 1.

A) Aristoxenus differentiates two principal *chróai* of his standard diatonic genus (tone-tone-semitone): one called *malakós* ('slack' or 'relaxed'), where the uppermost interval of the tetrachord counts 5 quarter-tones, and one *sýntonos* ('tenser'), where the same interval or string is stretched higher to count 4 quarter-tones or a whole tone, rendering his *diátonon sýntonon* equivalent to the old 'canonical' or so-called Pythagorean tuning.[126] As his nomenclature of a 'tenser' interval already implies, the tensest note is most tightened (*syntonőteros*) and thus stretched even higher. Yet, for an effective comparison of the resulting intervals the *diátonon sýntonon* needs to be transposed, or put (τίθημι) in the *dýnamis* (*power/function*) of the *tonaîon*, as Aristoxenus says, where the *mésē* is surrounded (περὶ τὸν ἡγεμόνα) by two whole tones. Markedly the form *tonaîon* underlines the magnitude of the two tones available at this position (<) of the tonal system to be exactly 9:8. Together, the *tónos* above (⊏-⊃) and the *diátonos* below (<-⊃) amount to a 'composite' (*sýnthetos*) ditone (81:64) to be evidently distinguished from the incomposite (*asýnthetos*) or 'undivided' ditone of the sought *spondeîon* interval[127] (Fig. 3h).

B) Now, as the transpositional logic of the instrumental notation introduces an enharmonic *pyknón* on each step of the basic Pythagorean scale, the necessary intervals for the comparison of the composite are properly described as the ones reaching from ⊏ to ⊃ for the tense (*sýntonon) dítonos* and from ⊏ to ↃI for the tensest (*syntonőteros*) *spondeîon*. Clearly, the *syntonic comma* (81:80) intrinsic to the tonal system is employed to determine the difference between the two intervals by the difference of the notes ⊃ and ↃI, or, if referring to intervals, by the *tonaîon* <-⊃ as against the very *syntonőteros spondeiasmós* <-ↃI, respectively. Instructively, it is precisely this difference perfectly in accordance with the instrumental notation (Fig. 1) that provides the reason for the 'pitch abnormality' in the vocal notation between M and N (Fig. 3i) as explained above (3.3). This case in point may deepen our understanding to what extent both merits of the instrumental notation—whilst acting as a medium—its *logic of transposition* and *display of measure*, are obscured by the former.

As a consequence, the only interval in question for the *spondeîon*—being slightly smaller than the ditone (81:64) but the first important, least beating interval beyond the diatonic

couldn't tell what kind of interval the *syntonőteros spondeiasmós* was. Due to his lack of understanding, Aristeides (I, 28.1–6) should have misunderstood the very passage while treating "the word *spondeiasmós* as itself referring to [a] ¾-tone interval of the *syntonőteros* form." (256). His translation of the "rather obscure" (255) parenthesis (216—217) is no less misleading and therefore cited in Greek without emendations in note 121 above. Although the latest reference to this notorious passage by Hagel, "Reversing abstraction", 466, corrected Barkers' opinion about the *spondeiasmós* (cf. n. 28) and his conclusion that the associated interval would only occur in the tetrachord above *mésē*, but not below in the tetrachord *mesôn* (cf. n. 30), falls flat in still searching the interval in question above *mésē*. In return, he incurs the impossibility to satisfy three essential conditions of the text, namely that the *spondeiasmós* (i) can (wrongly) be imagined as a *diátonos*, (ii) is indeed of a *syntonőteros* form and (iii) would (if it were a *diátonos*) give rise to two successive *dítona* (one σύνθετον, one ἀσύνθετον). Alone, if focusing on the acoustic significance of the characteristic intervals and when taking the transposition "ἐν τῇ τοῦ τονιαίου δυνάμει" for the required comparison into account (cf. Vogel, *Enharmonik der Griechen*, II, 92-101), the following 'proof' is able to solve the enigmatic passage without sophistry and unnecessary assumptions. As a result, however, and different to Vogel, the complete *spondeîon* scale remains underdetermined, and can take both of the forms, I><⊃C or IV⊏<⊃C. This however need not be considered a tradeoff, but may rather be regarded as an advantage, because the musically crucial characteristics of the anyway (re-)constructed source story are fully covered. Since the original enharmonic consists of trichords put together by a natural major third and its associate wide variant of the later *pyknón*, it can be and has been applied in all three relevant tetrachords, the *synēmménōn*, *diezeugménōn* and *mesôn*. After all, it is worth mentioning that if we recognise Olympus' *paramésē* as a note forming part of the archaic heptachord, an entirely enharmonic solution and consistent interpretation with Ps.-Plutarch's chapter 19 is feasible—without emendation or bracketing—and therefore the preferable historical model.

[126]Aristeides Quintilianus, "ΠΕΡΙ ΜΟΥΣΙΗΣ", I, 17.20 and Aristoxenus, "ΑΡΜΟΝΙΚΩΝ ΣΤΟΙΧΕΙΩΝ", 1.26; 33.15–16 da Rios.

[127]For the importance of that distinction cf. Aristoxenus' polemic against notation in chapter 3.4.

regime of tuning as established by proportions of the primes 2 & 3—is, beyond all doubt, the natural or just major third (5:4). This *justly* intonated interval *is* 'natural' because the *physical* overtones of pipes and strings contain it and 'just' because the simple epimoric ratio 5:4 is not only numerically but also *perceptually* significant. In particular so, if we recall the 'bright-sounding' (λιγύς) lyre with her 'clear-voiced and sweet-toned' (λιγυρός) chords. Aesthetically, the 'resonant' words of the poets state no exaggeration because gut strings, as opposed to their synthetic or even steel-wound successors, produce a clear spectrum facilitating, in turn, a distinct and thus superior perception of harmonics.[128]

Although the given distinction of the true *spondeîon* from the incomposite *dítonos* put forth in the name of Aristoxenus disregards Pythagorean proportions or overtone series unfamiliar to the Greeks, Aristoxenus nevertheless was minutely concerned with "the nature (*phýsis)* of continuity (*synécheia*) in melody"[129]. He decisively insisted that 'truly melodic' (*emmelés)* or "harmonically attuned (*ếrmosménon*)"[130] melodies are to be consistently composed from proper tetrachord structures. For, otherwise, if he had tolerated two *dítona* immediately following each other, two pivotal ingredients, (i) the analytical capacity of his *tónoi*-system and (ii) the unequivocal identification of these 'transposition scales' by the *tónos*, would have been threatened. However, even prior to the demands of Aristoxenian theory two successive *dítona* never occurred anywhere, either in any 'irregular' scale or anywhere else in the combinatoric universe of the instrumental notation as unlocked by the tuning of Archytas. Hence, we arrive at the important lemma: that it is the *logical consistency* of the tonal system naturally established by en-harmonic acoustic relations that allocated the very musical resources from which Aristoxenus, though much later, was still going to deduce his theoretical propositions.

5.2. A proof by contradiction

By entering the combinatoric logic of Greek pitch-space we encounter the 'sound' core of the above comparison that now—with the help of notation—can be demonstrated by a concise proof of contradiction. For this purpose the necessary proposition is given in Book III of the *Harmonic Elements*: "Two *dítona* will not be placed in succession", because if so "two *pykná* will be placed in succession" which is "unmelodic (*ekmelés*)"[131] and thus not within the confines of a proper unfolding of melody. Taking on this proposition, the intricate demonstration wrought into the involved parenthesis banished to footnote 121 can be unzipped as follows:

Since every proper enharmonic tetrachord in Aristoxenian theory consists of an incomposite ditone completed by a *pyknón,* the structure 𐤉𐤇𐤋𐤅 displayed in diagram 3h can be utilised to add the *spondeîon* interval 𐤒-𐤉 in order to form the interval sequence 𐤒-𐤉-𐤇. This yields the very hypothetical structure afforded by the Aristoxenian parenthesis to be possibly regarded as two successive 'ditones'. Consequently, we would expect a *pyknón* 𐤉𐤔𐤊 below the upper 'ditone' 𐤒-𐤉 as well. Under the assumption that we are able to differentiate the *syntonőteros spondeiasmós* 𐤑-𐤉 from the *tonaîon* of the *diátonon sýntonon* 𐤑-𐤓, which is exactly what the above comparison (sec. 5.1) was set up to achieve, there is no contradiction to the given proposition. But if we perceived the *spondeîon* 𐤒-𐤉 as a true ditone 𐤒-𐤓 and therefore equalised the syntonic comma between the notes 𐤉 and 𐤓, then and only then would the properly constructed enharmonic tetrachord 𐤂𐤀𐤑𐤓 (cf. Fig 1) *regularly* continue an enharmonic scale begun by the first sequence, yielding: 𐤂𐤀𐤑[𐤓𐤉]𐤇𐤋𐤅. This however produces the very misconfiguration within the tonal system the proposition was set out to avoid, because here two successive 𐤒-[𐤓𐤉]-𐤇 *dítona* necessarily entail the unmelodic suc-

[128]Cf. n. 65.
[129]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 1.27; 35.11 da Rios. Trans. Barker 145.
[130]Ibid. 1.15; 20.18 da Rios. Trans. Barker 136.
[131]Ibid. 3.64; 80.2–10 da Rios. Trans. Barker 175.

cession of two *pykná* Λ<[>ꓘ]⊻K. So, if this equally *perceptually and theoretically* relevant difference of > and ꓘ would be blurred, we would not be able to tell where the *tónos*, or harmonic root, of the corresponding ʽ*sýstēma*’ were to be located.

Inevitably, as this proof has demonstrated, coherence in Aristoxenian theory remains dependent on the tonal system from which the disciple of Aristotle derived his systematisations—no matter how revolutionary his refutation of acoustic theory may appear. This gesture rather adheres to the Aristotelian putsch against numerical relations as a valid basis for a ʽmetaphysically-proofed’ reasoning, whereas Aristoxenus, as we shall see next, could not subscribe to Aristotle’s own metaphysical conception as a truly ʽscientific’ alternative either.

5.3. Measurement

Nonetheless, Aristoxenus’ phenomenological approach of measuring intervals in quarter tones neglects the epistemological heritage and aesthetical essence of the enharmonic genus as being rooted in the harmonic nature of acoustics. As a prelude to this, the *Metaphysics* of Aristotle already shattered the ancient notion of *phýsis* for he rejected the ʽlogic of numbers’ to form an acceptable foundation of reason suitable for disclosing the ʽbeing of beings’ and the becoming of its phenomena. In place of harmonics as an early concept of mathematical modelling, which to him appeared as hardly anything more than a platonising philosophy, Aristotle proposed a multitude of elementary measures whereby dissolving the Pythagorean unity of knowledge into dozens of scientific disciplines, each of them held together solely by their own private ʽontologies’ of basic elements. As a result, "in music the measure is the quarter-tone (*díesis*), because it is the smallest interval; and in language the letter (*stocheîon*)".[132] But as a startling deviation from our understanding of a *scientific* measure to be commensurable, Aristotle holds "that the measure is not always numerically one, but sometimes more than one; e.g., there are two quarter tones, distinguished not by our hearing but by their theoretical ratios (*lógoi*); and the articulate sounds by which we measure speech are more than one"[133]. While juxtaposing phonetic and harmonic elements this example expressively attests Aristotle’s abyss of ignorance in music theoretical matters, for his comparison blends two incompatible systems of measurement—harmonic ratios (*lógoi*) and smallest perceptible units (*diéseis*)—into one argument.[134] As we have already shown, *only* an arrangement of intervals generated by enharmonic relations yields exactly two ʽsmallest’ *diéseis* that were practically distinguished in melodies and therefore used in the construction of the tonal system compatible with the instrumental notation (cf. Fig. 2). But these intervals 28:27 (roughly a third-tone of 63 cent) and 36:35 (nearly a quarter-tone of 48.8 cent) *are* by-products of the entire enharmonic system and by no means, as Aristotle alleges, basic *elements* of measurement. Moreover, the ʽrational’ approach is mediated by

[132]Aristotle, “ΠΡΩΤΗ ΦΙΛΟΣΟΦΙΑ”, 1924, 1053a13. Trans. in Tredennick, H., *Aristotle in 23 volumes*, XVIII, 1933

[133]Ibid. 1053a15.

[134]Barker, *The science of harmonics in classical Greece*, 349–353, in not "beating about the bush" (353), deals with this issue at some length. Although he enmeshed himself in a discussion where he implausibly proposes the two ʽsmallest’ *diéseis* of Aristotle to identify as the two rather (too) *big* halftones *leîmma* (90.2¢) and *apotomḗ* (113.7¢)—because they nicely result from a factorisation of the whole tone 9:8 into 256:243 × 2187:2048 and thus, as ʽa pair’, would also be able to ʽmeasure’ the fourth 4:3 as two *apotomaí* and three *leímmata*—Barker nonetheless reaches the decisive ontological point that "in the context of mathematical harmonics […] they do not have any fundamental status [..] and they are not mathematical minima"(352). (Cf. n. 58 above.) Despite knowing well about Archytas and his proposition that epimoric ratios *are* ʽundividable’ into two ratios of equal magnitude —which, as a consequence, rather suggests the two ʽsmallest’ *diései* to equate the two *smallest* musical intervals of Archytas (see above)—Barker concludes that the author of *the* meta-physics, "as far as this aspect of the subject is concerned, Aristotle [,] did not understand what he is talking about (353). For a further discussion of this subject see: Carlé, M., “Zeit des Mediums: Die Genese des Medienbegriffs im griechischen Denken – Das Samplingtheorem der Antike Teil I”, 2007

harmonic 'formulas' which, again, were empirically derived from concatenated tuning operations. As a result, they could claim to 'practically' spot out proportional interval relations by a chain of reference to minimal acoustic beat. This reasoning however is dramatically opposed to the plain empiricist's idea to linearly divide musical pitch space and to measure it by some smallest intervals considered to form *fundamental elements*. All the more so, as no alternative 'calibration method' other than consonance is available and while admitting that not even the deception maker, i.e. hearing, would be able to sufficiently define those 'smallest' elements. As a consequence, Aristotle's objective for an empirical science of harmonics is either self-contradictory or altogether unfeasible.

It is this *empirical aporia*, as we shall argue below, that drove Aristoxenus to re-import crucial Pythagorean principles such that it became the *temporalisation* of their stance which forced his 'harmonic elements' to step beyond the metaphysics of Aristotle. As a consequence, Aristoxenus finally developed his own, *divergent ontological concept* of *dýnamis* which did not rely on peripatetic elements but required investigations into the new field of an entirely procedural knowledge organisation. Epistemologically speaking, it is this unprecedented, 'temporal realm of being' solely to encounter by a rigorous examination of 'the nature of continuity in melody'[135] Thus, by agency of the latter already antiquity embarked upon a certain *reality of mediation* that is essentially controlled by a time-critical logic of conditionally unfolding processes.

For the moment, however, to keep within the scope of Aristotle, the two 'rational *diéseis'* mentioned in the *Metaphysics* are nonetheless significant in a musical sense: for the *oxýpyknos* (28:27 × 36:35) enables the *spondeîon* and the *mesópyknos* (28:27) remains unchanged in each genera while functioning as an intensified leading-note, either to the system's root note, *mésē*, or another 'standing note' of the harmonic framework, e.g. *hypátē*. Lastly, and in order to continue with Aristoxenus, we need underline once more that the latter indeed adopted the measurement of intervals in *diéseis,* though certainly not for the sake of his teacher's metaphysics. Although Aristoxenus' reasoning will become clear only at the end of next chapter, his incompatible position as far as the essence of measurement as such is concerned shall be stated right here: since seen "from a purely abstract point of view", he pointedly declares, "there is no least interval"[136]. And on top of this he brusquely answers those people (like us) who discuss "whether the *lichanós* stands at a ditone or is higher, as if there were only one enharmonic *lichanós*" that, in fact, "they are unlimited in number."[137] However, to be sure, the crucial ontological point is not whether the tuning of a 'one and only' enharmonic *lichanós* is *numerically* the ratio 5:4, or if it might be slightly detuned to become an 'irrational' magnitude, but—as we have just demonstrated with Aristoxenus' own arguments—it is the *perceptible significance* of the syntonic comma in melodic context which means nothing less than its aesthetical role, its epistemological impact and above all, its musical function.

5.4. Cultural impact of the *spondeîon*

By extension, while reducing the musical and acoustical significance of the typical, 'densely-packed' (*pyknós*) intervals of the developed enharmonic and while professing the compass of the enharmonic *pyknón* (e.g. ↄ∪ⅽ or ⅂LГ Fig. 3e) to equate a semitone,[138] Aristoxenus' *Harmonic Elements* cut the umbilical chord to the elements and instruments they were nurtured by. Again, it is the structural difference in thinking settled by media

[135]Φύσις τοῦ συνεχοῦς ἐν τῇ μελῳδίᾳ. Cf. n. 129.
[136]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.46, 57.11–12 da Rios. Trans. Barker 160. Besides this, Aristoxenus, in order to describe the *chróai* of his chromatic genus, simply divided the quarter-tone further into fractions of 2 and 3. This however, led him to differentiate 1/60-part of a tetrachord or to actually measure with a 'smallest' element of 8.3¢. Cf. Ibid. 1.25 & 2.51; 32.7–33.16 & 63.9–64.13 da Rios.
[137]Ibid. 1.26; 34.8–13 da Rios. Trans. Barker 144.
[138]Ibid. 1.24; 31.7–9 da Rios and 2.50, 64.10–13 da Rios.

exchange or the change in the instrumentality of communication—namely, music notation and the means of analysis or measurement—which sets the tone here and not any preoccupation with some "harmonic hero cult"[139] of ancient Greece. Accordingly, the beauty that Olympus admired is preserved if, and only if, its origin and ontology concerning the tonal system is taken into account, as this is the case in Archytas' tuning recorded about the beginning of the 4th century when the cultivation of enharmonic music was still alive.

Ironically enough, though, towards the end of the 4th century when the authority of this music lost its classical pre-eminence and seems to have existed merely for traditional reasons, Aristoxenus—himself a conservative author who tried to hold the enharmonic 'genus' in high esteem (cf. 3.2.)—was forced to admit that his contemporaries "with their endless pursuit of sweetness"[140], while performing the enharmonic would, "rule out the ditone *lichanós*, since most people nowadays use higher ones (*syntonōtérais*)"[141]. By this allegation Aristoxenus attempts to propagate the impression that the ancients had tuned the interval defining the enharmonic not according to its origins in the *spondeîon* but instead in compliance with his 'diatonic' *dítonos* of 8 quarter-tones, leaving the two remaining intervals of the *pyknón* with one quarter-tone each.[142] How unlikely this inference is should have become obvious, or better λιγυρός by now—especially, as we heard explicitly that the *spondeîon* had already been adopted in the Dorian '*tónos*' by Olympus (Fig 3d).

Once more we have revealed a case in place where aesthetical and acoustical reasons—the beauty of *êthos* and the order of *phýsis*—concur to constitute the ancient Greek tonal system entrenched in practice. The ramifications of this configuration are considered in the next chapter. It will hypothesise a diachronic model of two possible ways of listening to the Greek sonosphere and respectively propose the agency of ever increasing modulations to cause a historical transition between them.

6. PERCEPTION AND MODULATION — FROM *ÊTHOS* TO *GÉNOS*.

Having given the gist of the rendering of intervals and having pointed to the twofold aesthetical and epistemological implications of certain melodic steps and their omission respectively, we are prepared to pick up our line of argument for an acoustic foundation of early scale constructions left standing in chapter 4 and to resume with a similar case: the formation of the Mixolydian mode as related to (i) the melodic introduction of the Dorian *nḗtē* attributed to Terpander and (ii) the ethical application of its 'bittersweet' pathos in the Dorian *harmonía* by mimesis of Sappho's tunes (cf. 4.3).

To validate the fairly suggestive coupling of these two issues only present in the subtext of the Pseudo-Plutarchian treaties, the following inspection attempts to substantiate their structural solidarity by reference to acoustic diagrams. Yet, the aim of this move is to extract a general model that would explain according to which principles early scale relationships were established. As a result we expect that the logic of this model will explicate a certain modality of melodic perception that emerged in archaic Greece and then prevailed until the end of the Classical Period, when the analytical capacity meanwhile acquired was ultimately challenged by the 'new music' finally forcing a new listing strategy to step forth.

[139]Franklin, J.C., "Beyond the fragments: realizations in Ancient Greek music", 2008

[140]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 1.23; 30.4–5 da Rios. Trans. Barker 141.

[141]Ibid. 1.23; 30.1–4 da Rios. Trans. Barker 141.

[142]Cf. once more Hagel, "Reversing abstraction", 466, where he concludes that "at least the *spondeîon* the *mousikoí* referred to used a very wide variant of the enharmonic [*pyknón*], to which quartertone-oriented theorists ascribe the size of three-quartertones". A difference of about 50 cents, however, is hardly to be perceived as a 'sweetening', but rather as a more wilful change. Hence, a ¾-tone reality of the *spondeiasmós* (~150¢), as opposed to the consonant 'sweeter' one (~112¢), looses sight. All the more so, if one tends to believe Aristoxenus that "the usual performance employed a divided 'semitone'" and "that the unaware listener would hardly notice the difference, which is attributed more to the performer's intention than to the resulting sound" (466, n. 28). Yet, this contention downplays the obviously still perceptible aesthetic effect that gave birth to the "beautiful Greek music" and its theoretical focus, to testify about, the source story of the original enharmonic was set out and preserved.

In order to manifest this reasoning, we carry forward the entangled organological and theoretical impact of the *bárbitos*. According to the hypothesis of chapter 4, this instrument mediated the harmonic rise and theoretical display of the Dorian *nḗtē*, so that the first practical question to consider surely is: what note to omit, if (a) this 'novice' attained a firm place in melodies such as in the Mixolydian mode, (b) therefore did not remain a flageolet and (c) the lyre, still, has only 7 strings?

6.1. The Dorian *nḗtē* and the tonal pattern within the octave

For this inquiry we survey the Pseudo-Aristotelian *Problems* 7, 32 and 47 whose investigations appear homologous to each other. When taken together, they deliver a rather clear picture how the ancients (οἱ ἀρχαῖοι) proceeded "when they created the *harmoníai*".[143] In reflecting upon the archaic heptachord, Problem 47 shows some uncertainty whether it was "*nḗtē* that they took out" or "the string now called *paramésē* and the interval of the tone (*tonaîon diástēma*)".[144] But the former, *nḗtē synēmménōn*, was surely kept, otherwise there would have been no *diázeuxis* at the top of the Mixolydian to recognise for Lamprocles. But the latter, the *tonaîon* above *mésē* as present in the Phrygian diatonic, was not even part of the heptachord on Terpander's lyre, because if so, he would have become the 'inventor' of the Dorian, not the Mixolydian. Yet, problem 7, written in almost the same wording as problem 47, opts for *trítē* as the one which was cut out. Likewise does problem 32, where the question is why the octave is called *diá pasṓn* ('through all' strings) "instead of being called *di' oktṓ* to correspond with the number, such as in the *diá tettárōn* (through 4) or the *diá pénte* (through 5)?"[145] Without ceremony or any further transition—as if the current question was already a well established topic of music archeology in the Hellenistic Period—the answer immediately refers to the context that concerns us here: "Then Terpander took away *trítē* and added *nḗtē*, and that is why it was called *diá pasṓn* and not *di' oktṓ*, since there were seven strings."[146] Evidently, the rationale behind this answer is (i) to recall all possibly matching notes from a standard tonal system, (ii) to compare the emergent tonal structures and (iii) to single out the patterns of attunement or '*harmonía*' in question. The outcome of the discussed case is shown in Fig. 3e.

6.2. The Mixolydian *êthos* as example of an early modality of scale perception

Further, if correlating Lamprocles' finding with the answers provided by the Pseudo-Aristotelian *Problems* as drawn together in the cohering sequence of figures 3a-h, we realise the structural affinity of the omitted notes between the rise of the Mixolydian and the origin of enharmony due to the *spondeîon* interval of a just major third. Furthermore, we recognise how well the Mixolydian of the developed enharmonic preserved by Aristeides Quintilianus corresponds with this picture. "For the sake of clarity",[147] Aristeides has written down 6 *systḗmata* in both forms of notation while naturally calling them diagrams. By citing the very passage in Plato's *Republic* that started the above discussion about the 'decadence' of *polychordía*,[148] Aristeides claims that his list of scales represents exactly those "*harmoníai* by people of distant antiquity (οἱ πάνυ παλαιότατοι)"[149] "which they used to give, fitting the qualities of the notes to their respective moral character."[150] As the structure of these *harmoníai* fits well into figure 3, the corresponding, though independent sources of section

[143]Ps.-Aristotle, Problems XIX, 7 & 47. Trans. Barker, *GMW*, II, 97.
[144]Ibid.
[145]Ibid. 32. Barker, *GMW*, I, 198.
[146]Ibid.
[147]Aristeides Quintilianus, "ΠΕΡΙ ΜΟΥΣΙΗΣ", I, 9.19. Trans. Barker 420.
[148]Ibid. Aristeides quotes Plato, *Republic* 399a. Cf. note 29 and sections 2.1. and 2.2.
[149]Ibid. Trans. Barker 419.
[150]Ibid. Trans. Barker 420.

6.1 and 6.2 corroborate the historical coherence of our own acoustic diagrams. In order to draw an intermediate conclusion, it is tempting to analyse the irregularities of Aristeides' scales analogously to the example of Olympus in chapter 5. There, the model was, firstly, to expel specific intervals for to explore a new melodic character and secondly, to manifest the resulting harmonic relations in a well established *harmonía* or mode.

Accordingly, certain conspicuous intervals and harmonic relations ought to be considered responsible for the ethical quality or *êthos* of a particular mode. Thanks to a structural comparison enabled due to the 'acoustic diagrammatic' of the instrumental notation, the empty tritone ⊏-C of the 'classical' Mixolydian (Fig 3e) strongly supports this assumption. It's hard to dispute that this strikingly huge step should not be regarded as the characteristic interval of this mode. Now, employing the structural discovery of Lamprocles (Fig. 3d) for an harmonic analysis of this scale, we realise that it is indeed *mésē* (Fig. 3e) which was cut out additionally to the already empty *spondeîon* third. Hence, Mixolydian melodies making use of this modal feature would not just transcend the diatonic but would even skip the harmonic root of their interval relations. This, however, only underlines the obliqueness of the Mixolydian *harmonía*, not accidentally ascribed to Sappho's tunes.

So, if our line of argument holds true, we have just ran across a mechanism that could explain according to which *perceptual principles* one scale has been adopted and merged with another. Seen as a model, this mechanism of interrelated harmonic patterns sheds light on the general practice of interchanging 'qualities of notes' and 'moral character' and thus elucidates the Pseudo-Plutarchian justification as to why melodies common in tragedy were understood as an ethical 'blend of both', the emotional pathos of the Mixolydian and the sober magnificence of the Dorian, namely—as far as modal melodies are concerned—due to the *structural compatibility* of the Mixolydian tritone ⊏-C with the *spondeîon* third <-C, since both intervals are well established and readily available in the Dorian enharmonic.

6.3. The 'irregular' pentachord and the development of the enharmonic 'genus'

In this regard, even the lately adopted *proslambanómenos*, the 'tone added' below a regular scale composed from proper tetrachords, could be interpreted as a melodic left-over, resulting from an early adoption of the Mixolydian in the Dorian (Fig. 3e + f). Reciprocally, now focusing on the same 'irregular' F in Aristeides' Mixolydian, this sign adds a fifth note to the ordinarily '4-noted' tetra-chord *mesôn* which thereafter was improperly constructed.[151] Yet, the 'tetrachordal' structure CF⅂LΓ is less stunning than it may at first appear. For if we just take it for what it is and decode the given sequence by reference to the instrumental notation, it reveals CFLΓ to be a proper diatonic and C⅂LΓ to be a proper enharmonic tetrachord. Thus, this observation suggests a practical utilisation of 'irregular' pentachords as late as in the days of Plato's Socrates. Accordingly, the 'fossil' scale sequence of this Mixolydian pentachord confirms that the above 'pattern-matching' mechanism of overlaying compatible interval structures was well at work even on the level of tetrachords.

Obviously, this early practice and *êthos*-driven custom, which matches well the habits of Olympus, Terpander or Sappho, is inconsistent with an axiomatic set of three clear-cut tetrachordal genera essential to the Aristoxenian 'Elements'. Hence, this deviation allows for an alternative interpretation of the pentachord CF⅂LΓ to be all the more plausible: Apart from the trivial case of the bounding notes, note L is common to both, the diatonic and the developed enharmonic tetrachord, shown in the former analysis above. Consequently, the same composition of the pentachord can be achieved by simply blending the *spondeîon* trichord C⅂Γ with the diatonic tetrachord CFLΓ. The advantage of this minimally different interpretation however is that it enables us to understand how the *historical* evolution from an original enharmonic *êthos* of the *spondeîon* to the developed enharmonic *génos* took

[151]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 3.58–59, 73.1–12 da Rios.

place: it emerged from a concurrent utilisation of the diatonic and the newly 'invented' harmony of the fairly consonant 'third' 5:4, as we have emphasised all the way through our investigation. But now, according to the latter analysis, we are able to specify that (i) the contemplable scale position of the originally omitted *diátonos* ꟻ, *lichanós*, later in the developed enharmonic, was actually transferred to give the *spondeîon* third ꓒ-ꟾ and by acoustically displacing the diatonic *dítonos* ꓒ-ꟿ that (ii) it was indeed the already slacker, diatonic *parhypátē* ꟿ (Fig. 3e + 3h) which had been tuned even lower to finally stay there, fixed and untouched on the lyre. In other words, the sharpened 'semitone'(ꓶ) remained the same in the diatonic and enharmonic and only *lichanós* became the sole genus-indicative note of the tetrachord. Consistent with this, we observe once again that it is the diagrammatic structure of the instrumental notation that conserved the inferred harmonic development, whereas the linear order of the alphabetic signs utilised by the vocal notation conceal the matter in suggesting, falsely, that Ω would be a higher pitch than ∀ (Fig. 3i).

But this history of development—indicating a general shift of attunement (ꟿ→ꓶ) from the diatonic *leîmma* (90.2¢) to the enharmonic *mesópyknos* of about a third-tone in size (63¢)—is absolutely irreconcilable with the impression that Aristoxenus tries to convey about the procedure that led to the developed enharmonic as purported in the Pseudo-Plutarchian report which claims that "later", after the discovery of the *spondeîon* third by Olympus, "the semitone was divided both in the Lydian and in the Phrygian compositions."[152] However, this allegation of an originally bisected semitone—which forces the developed enharmonic to become a 'quarter-tone music'—has no grounds, neither in notation, nor in acoustics, in organology, nor in any other sources we know.[153] On the contrary, Aristeides, who mainly follows Aristoxenus, still identifies *lichanós* as manifesting the pitches that differentiate the genera, since the corresponding notes "are called *enharmónios*, *chrōmatikḗ* and *diátonos*"[154] and analogously so in the tetrachords other than *mesôn*, too. Again, 'for the sake of clarity', Aristeides adds that "they are also called *paranḗtai*"[155], in perfect compliance with the notes ꓘ,ꓗ,ꓛ of figure 2 above.

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[152]Ps.-Plutarch 1135b. Trans. Barker 217.

[153]Hagel, "Reversing abstraction" in referring to organology and Martin West's thesis of a ¾–¾–1 tone boring in early auloi (467, West, *Ancient Greek Music*, 96–100) yielding a 150–150–200 cent division for the early enharmonic of Olympus' pipes, puts a strong case against the historical reliability of Aristoxenus' testimony that the 'standard definition' for *the* enharmonic would be 50–50–400 cent. On the ground of this consideration, Hagel needed to "take back"(465, n. 20) his former conviction that Philolaus (frag. A30) testifies for "an enharmonic of equal quartertones" and that an "equality of the 'quartertones' was commonplace at Philolaus' times" (287), such that the fragment "must" be read as a pro-Aristoxenian source against Archytas 'formulas'—what appears to drive his 2006 article anyway (cf. n. 63 above). Still, Hagel seams to trust the Aristoxenian 'bisection story' which in case of the early aulos would yield a theoretical 75–75–350 cent partitioning. Thinking of the 'guesswork' (cf. cit. n. 30) involved in half-stopping wholes of an aulos, a difference of some theoretical ±15¢ to the diatonic halftone (90.2¢) as well as to enharmonic third-tone of Archytas (63¢) would, "under realistic conditions, [be] tantamount to nothing" (472). Besides the difficulty that this reasoning assumes a common 'origin in bisection' for both, the enharmonic and the diatonic, not supported by Aristoxenus for the aulos tradition, the difference of the intervals in question are still some pretty noticeable 27¢ which are well differentiated by notation (ꓘ-ꓷ, ꓘ-ꓗ) if applying the 'auletic formulas' of Archytas, the pipe player (n. 40). However, another, more convincing organological case is put for a later quartertone variant of the enharmonic as effect of the new aulos made of different borings and mechanics directly featuring a grid of semitones. Thus, an ever expanding prominence of this technically 'advanced' instrument could explain the incompatible accounts for an 'early enharmonic' by Archytas and for a 'developed enharmonic' by Aristoxenus. Moreover, this would also give "the reason for this rapid decline of a formerly prevailing musical form". Furthermore on these lines, if we only think about the obsolete harmonic 'guesswork' (as it appears essential to the beauty of en-harmonic music (e.g. ꓛ-ꓵ, ꓒ-ꟾ ≙ 5:4 or ꓛ-ꓴ, ꓒ-ꓶ ≙ 7:9); cf. 5.1) then—when half-stopping the new, semitoned device—the resulting "quartertones were a more or less artificial substitution for the old auletic *pykná*." (472). Next to the helpful survey on extant early auloi that comes with Psaroudakēs, S., "The aulos of Argithea", 2002, further insights on early auloi boring can be awaited in future publication by Psaroudakēs.

[154]Aristeides Quintilianus, *De musica libri tres*, I, 8.25. Trans. Barker 408. In this series of notes the name *chrōmatikḗ* stands out as a feminine belonging to *chordḗ* (string) which hints to an early origin in the lyre tradition.

[155]Ibid.

Thus, the outcome of this section seriously questions a regular "distinction between the genera"[156] and, ipso facto, a commonplace perceptual reality of the very tuning borders that Aristoxenus claims obvious to the ear about a hundred years after a still active employment of 'irregular' pentachords and *harmoníai*. However, more importantly to our argument than some fiercely disputed tunings within the *pyknón*[157] definitely is that the above pattern matching process—while aligning harmonically determined and ethically charged interval structures—ultimately deconstructs any *empirical* validity for a universal axiomatic conception of genus as "the number one and first" (ἕν και πρῶτον)[158] of "the fundamental propositions [to be] true and evident" in harmonic science.[159] So, if the Aristoxenian assertion that "melodies fall into three genera, the diatonic, the chromatic and the enharmonic"[160] itself falls to be a catholic or ahistorical fact—namely and precisely along his own train of argument, meaning with respect to "ethos"[161] as "evident by perception"[162]—then the fundamental role that the category of genus serves in the basic configuration of his *Harmonic Elements* asks for another explanation. Also recalling the 'empirical aporia' concerning the epistemological state of measurement discussed in section 5.3, enough doubts are raised to quest for a re-configured understanding of the theoretical claims at stake in harmonic science. And all the more so, in oder to elucidate the alternative epistemological concept of an obviously rather 'trans-empirical' design of Aristoxenian theory.

7. HARMONY TO THE POWER OF MELODY

7.1. Affect and melodic 'strain' in early modulations

Owing much to Martin Vogel, the insight reached into the evolution of the enharmonic 'genus' is intriguing, because paying heed of a lowering of *parhypátē* rather than adhering to the traditional Aristoxenian view of a bisected semitone not only yields different magnitudes of the 'close-packed' intervals but enables us to trace otherwise concealed processes of early scale development. Moreover, the melodic procedures examined in the following appear intimately connected with modulation and were reportedly exclusive to the enharmonic.[163] The affective 'strain' of these moves and their 'logic of change' between *harmoníai* will finally lead us to differentiate the two modalities of melodic perception announced above.

Now, the two exceptional because unidirectional intervals, *éklysis* (3 *diéseis* down) and *ekbolḗ* (5 *diéseis* up), that would invoke a 'change' in melody, qualify well to exemplify the native term *metabolḗ* (change, changing). Especially so, since their scarce occurrence was pointedly described as "*páthē* of the intervals".[164] By this wording of Aristeides, a well

[156]See the long quote associated with n. 73 on p. 16.

[157]For instance the underived postulate of Aristoxenus and unnecessary assertion for any of his later conclusion stating that in the enharmonic *pyknón* the higher note could never be bigger than the lower (Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.52; 65.2–4 & 1.27; 34.19–35.3 da Rios) as this is obviously the case in Archytas' tuning.

[158]Ibid. 2.35; 44.10 da Rios.

[159]Ibid. 2.44; 54.22–55.1 da Rios. Trans. Barker 159.

[160]Ibid. 2.44; 55.8–9 da Rios. Trans. Barker 159.

[161]Ibid. 2.48; 60.11–15 da Rios. Trans. Barker 162.

[162]Ibid.

[163]Bacchius, "Isagoge", 37, p. 300.

[164]Aristeides Quintilianus, "ΠΕΡΙ ΜΟΥΣΙΗΣ", 28, 6–7. "πάθη τῶν διαστημάτων". Vogel, *Enharmonik der Griechen*, II, 150, who first succeeded to give a coherent explanation of *éklysis* and *ekbolḗ* in the sense of modulation, welcomes the term πάθη for manifesting a 'rare happening' or 'befalling'. By contrast, the scholarly tradition, in search for a solution within 'primitive' *harmoníai* or 'shades' of tuning, has difficulties to understand and translate the term. Barker, *GMW*, I, 235 n. 188, f.i. gives 'modifications' and expects *éklysis* and *ekbolḗ* to be "conceived as 'stretchings'" used for a "special melodic effect". On the other hand, Hagel, *Modulation in altgriechischer Musik*, whose explanation of *éklysis* and *ekbolḗ* mainly repeats Vogel's, keeps with "Abwandlungen(?)" (61) and after disputing with West, *Ancient Greek Music*, 166–170, concludes that the term may have been "placed in

perceptible ‘pathetic’ or ‘accidental’ metamorphosis affecting the course of melody is quite ‘dramatically’ expressed. This conspicuous characterisation of change is supported by the prefix ek- (out), meaning that these intervals would audibly step out of the previous tune and into a new scale arrangement, respectively. Though astonishing at first, we learn that both *ék-lysis* and *ek-bolḗ*—literally a ‘dropping out’ and ‘throwing out’[165]—are of great antiquity, as these intervals have been made "much bigger"[166] by Polymnestus, a celebrated *aulós* player who flourished as early as in the early 6th century. Regarding the Dorian *harmonía* (Fig. 3f) and considering the notational signs provided by Bacchius, the concrete moves can be reconstructed[167] for *éklysis* as ‘a drop’ from ⊏ to ∨ and for *ekbolḗ* as ‘a throw’ from ⊐ to ˩. The corresponding diagram (Fig. 3g) plainly unveils that in the first ‘change’ the first and in the second modulation the second scale position manifests a harmonically fixed note (⊏,˩), i.e. an instance of the steady framework of *hestôtes* (cf. 4.4). Consequentially, an enlargement of these intervals unmistakably entails that only the two ‘movable notes’, the *pheroménoi*[168] involved in these modulations could have been increased by Polymnestus. In respect to the tonal system, this again corroborates that in either case the later so-called *mesópyknos* (∨,⊐) was pitched down helping to bring the characteristic *pyknón*, i.e. the close-packed notes of the developed enharmonic, to pass.

Further, by recalling our discussion about the harmonic impact of the *spondeîon* interval and now thinking of the original magnitudes of *éklysis* and *ekbolḗ* before their enlargement by Polymnestus—that is, as they were used "by the ancients" (τοῖς παλαιοῖς) in order "to mark distinctions between the *harmoniai*"[169], as Aristeides explicitly says—the two ways of modulation just presented facilitate the following ‘change’: from the early enharmonic trichord (˥⊐⊏) located a tone above *mésē* into its counterpart (˩><) in the *synēmménōn* ‘tetrachord’ of the ‘archaic’ system directly connected to *mésē*. Actually, prior to the existence of the *pyknón* both of these ancient melodic moves were irrespective of genus and would had functioned equally well in a diatonic melody, possibly in order to prominently modulate form the tetrachord *diezeugménōn* into the tetrachord *synēmménōn* (˥˩N⊏→˩N[>? ∨]<). Yet, in the diatonic case the notes already in common (˩,N) would surely dilute an outstanding or ‘pathetic’ effect of modulation. But even when considering the *spondeîon* trichord to provide for the ‘*pyknón*-less’, proto-enharmonic case, a strong reservation against an interpretation of *ek-bolḗ* and *ék-lysis* as to yield a general scheme of change between the disjunct (*diezeugménōn*) and conjunct (*synēmménōn*) system is justified. Otherwise, the negating prefix of *a-metábolon* to characterise the *Non-Modulating* Perfect System comprising both patterns of attunement would make hardly any sense (cf. 3.2 & 4.4). Instead, it is highly probable that at some point of the assumed pattern-matching process any change between *diezeugménōn* and *synēmménōn* became so common a melodic figure that such moves—which anyway keep the same focal note—were no more, or never were perceived as ‘true’ modulations in the above ‘pathetic’ sense. In contrast, they were heard as a ‘colouring’ of melody and, as a consequence, integrated in *one* ‘perfect’ scale system. In this respect, an early melodic approval of a stand-alone ‘chromatic’ tetrachord, e.g. ˩⊏>< that simply results from a concurrent use or ‘mixture’ of the diatonic *diezeugménōn* (˥˩N<)

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the wrong context" (64) by Aristeides.

[165]Both Vogel, *Enharmonik der Griechen*, II, 152–153 and Hagel, *Modulation in altgriechischer Musik*, 61 underline the expressive names whereas the naïve ‘mono-philological’ study on the matter by Solomon, J., “Ekbole and Eklusis in the musical treatise of Bacchius”, 1980 completely neglects those "relatively obscure terms" (111).

[166]Ps.-Plutarch 1141b: πολὺ μείζω πεποιηκέναι. Barker, *GMW*, II, 235 ‘inventively’ translates "that [Polymnestus] made much greater use then before of eklysis and ekbolē" and then, while speculating on the rareness of these intervals (cf. n. 164), just follows one of the helpless proposals in Solomon, “Ekbole and Eklusis”, 118.

[167]Bacchius, “Isagoge”, 41–42, p. 301–302. Having pointed at the difficulties of the matter (n. 164–166), details of the intricate reconstruction can be skipped for the present purpose, since both relevant interpretations in favour of modulation, agree in results.

[168]Ibid. p. 300, 36. Φερόμενοι derives from φέρω, meaning "to carry a load, to move".

[169]Aristeides Quintilianus, *De musica libri tres*, I, 28.3. Trans. Barker 430.

and *synēmménōn* (ꞱNꞶ), makes perfectly sense[170] (Fig. 3f + g). Notably, only in the *spondeîon* case, as this attunement deliberately excluded the diatonic notes (Ʇ,N), the omission of scale degrees gave way to new melodic turns. Only such changes involving 'foreign' scale degrees were appropriate either, to strikingly demarcate *harmoníai*, or to highlight truly *harmonic* modulations. In fact, the latter case implies to audibly change the focal note as being the harmonic root of melody and, consequentially, to transgress the tonal arrangement of any one Perfect System.

For example, applying an *éklysis* the resulting 'accidental' drop can be *melodically* stabilised and *harmonically* exemplified as follows: by lowering the semitone of the target tetrachord a sharpened enharmonic 'semitone' was utilised in melody. The sharpening helps to melodically identifying the new tetrachord by the *mesópyknos* (V) that now strongly leads the melody to its harmonically fixed, lower boundary (Ꞷ). While melodically enhancing the perception of this harmonic modulation, the thereby condensed *pyknón* gains its general 'tagging power' to saliently mark the lower boundaries of tetrachords (⊏,Ꞷ). So, even at the time of integration of this move into the Non-modulating Perfect System, the improved *melodic* tagging strength can still be used to *harmonically* transform the former *mésē* (Ꞷ) to become *hypátē* and, as a consequence, to treat the upper boundary (Ʇ) of the target tetrachord not any more to function as *nḗtē* of the *synēmménōn* but as *mésē* of the *mesôn*. Hence, the note a fourth above the former focal note is melodically introduced to act as the new harmonic root of the ensuing melody (Fig. 3f + g).

Surely, the logic of this prototypical harmonic modulation can be interpreted in a more general fashion as well, e.g. as forming just one of the changes among other melodic procedures to move the *diázeuxis*, or the *tónos* a fourth upwards (⊏Ꞷ⟶ꟾꞱ), like Aristoxenus would had mostly possibly subsumed the fact. In his late, highly abstract and thoroughly systematic theory of 13 'transposition scales' of Dorian shape (cf. 3.2), such a change of *tónos*, or 'key', will be perfectly valid in the diatonic, too. But again, only in the enharmonic the new focal note (Ʇ) is strikingly introduced as a new scale degree. Therefore, such a conspicuous change of melodic order qualifies *ekbolḗ* and *éklysis* of causing truly 'accidental' perceptual discharges already within the early pattern-matching paradigm. Yet, right at the key spot of Aristoxenus' theory, there, where his notoriously alluding words define what modulation is, he still seems to recall the 'affective strains' of early modulations: namely in qualifying *metabolḗ* as a "*páthos* of melodic order"[171]—or in a more refined English—as that "what happens when the order belonging to the melody undergoes a certain kind of qualification".[172] However, only in the enharmonic case *ek-bolḗ* and *ék-lysis* were able to act as right that what they were: *out*-standing prototypes of modulation.

But originally, that is prior to an exhaustive artistic exploration of truly harmonic 'key'-changes, the *same* movements, according to Aristeides, were most likely be perceived as to 'pathetically' "mark distinctions between the *harmoniai*". In theory, such 'a case' can be demonstrated rewardingly with reference to Aristeides' ancient Lydian (Ꞵ⊏ꓘ⩡KCꟻL): since assuming a modulation into the Dorian *harmonía* (ꞱꟾꞱ⊐Ꞵ⊏ꞶↃ∪CF) by *éklysis* (K⟶∪) or by *ekbolḗ* ⩡⟶Ꞷ would have meant exchanging the Lydian *mésē* (C) for the Dorian *hypátē*

[170]Hagel, "Reversing abstraction", 471 n. 55 u. 56, this time explicitly drawing on Vogel (Vogel, *Enharmonik der Griechen*, II) 124-125) embraces a derived, secondary status of the chromatic genus since it allows him to expect very early modulations "between adjacent keys (e–f–g–a–b and e–f#–g–a–b)". The fact (cf. sec. 3.2 n. 51) that "a chromatic structure can be distilled from simple modulations in both genera", would ensure "that here, too, the 'colouristic' effect of f# is secondary to modulation." (471) Yet, regarding the 'colourfulness' of the term (cf. our discussion on the *chrōmata* of Lysander in 4.2), it seems still wise to hesitate in reading a late concept of modulation, such as a "transition to the neighbouring key (*tónos*)" (469), too far back into history. Instead, it appears more advisable, especially in view of irregular scales and *chróai* (cf. 3.4), to distinguish different types of perceiving a 'modulation', or change of melody (as elaborated on below).

[171]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.38; 47.18–48.1 da Rios: "[...]– λέγω δ' οἷον πάθους τινός συμβαίνοντος ἐν τῇ τῆς μελῳδίας τάξει –[...]".

[172]Ibid. Trans. Barker 154.

and, as a consequence, introducing the Dorian *mésē* (<) as a new scale degree. However, at this stage of a presumable history of hearing, when structural differences between *harmoníai* still prevailed, a proper *harmonic* perception of 'key', or root-change is highly improbable. Whereas, on the other hand, these moves were keenly instructive for a concept of scale transpositions relative to a steady grid of intervals. Anchored by acoustically fixed proportions, as discussed above, such a stationary model of scale transposition is obviously at work with the instrumental notation (Cf. 3.4 and Fig. 1).

As a result, the interlocking melodic and harmonic arguments drawn up with respect to *éklysis* and *ekbolḗ* yield a common background of modulation against which two principal modalities of melodic perception stand out: (i) one that *differentiates* patterns of attunement with respect to certain ethos-laden intervals, or an entrenched set of 'irregular' *harmoníai* and (ii) one that *integrates* a series of intervals with respect to the standard Dorian attunement in order to dynamically discern harmonic sequences and to identify their focal note or 'tonal' root. But do all the details covered not redouble what the *termini technici* 'mode' versus 'key' would already imply?

7.2. The central hypothesis: two ways of listening

Both modalities of melodic perception we propose to distinguish here, the pattern-oriented and the *tónos*-oriented, share a common analytical capacity 'imprinted' by harmonically anchored tetrachord structures. Both organisations of hearing, either when differentiating small interval sizes of modal attunements or while integrating harmonic interval relations relative to a tonal centre, rely essentially on a fixed grid of strong consonances. In the Greek case, this network of fourths, fifths and octaves is generated from a central root note which therefore must not be equated with Rameau's 'tonique fondamentale' derived from chord cadences, or be confused with a generalised polyphonic concept of tonality in von Helmholtz' sense as deduced from coinciding overtone series. Nonetheless,[173] the consonance-based theory pursued since chapter 3 holds that, in general, harmonic perception in the Archaic and Classical Period was oriented towards a minimum of sensory dissonance and that this preference for just-intonation structured the Greek en-harmonic sonosphere as accessible through the pre-Aristoxenian codec of notation (3.3).

But by the distance covered during the last 3 chapters we have reached a theoretical plateau enabling us to overview that the *melodic* integration of the consonant just major third—surprisingly and idiosyncratic as it may seem—(i) by displacing the diatonic rule, (ii) by introducing the syntonic comma and (iii) by facilitating the *pyknón* was actually encouraging early forms of modulation that had the makings to bridge between two ways of listening, namely, by transforming the perceived *êthos* of fixed *harmoníai* into a perceptible *páthos* of melodic order. In other words, we hypothesise that during the period of *polychordía* (2.1) and in contestation with the proliferation of truly *harmonic* modulations the entrenched perceptual ability to differentiate modal patterns of attunement was recast to *melodically* qualify a dynamic migration of harmonic roots during the course of melody.

It appears advisable for this hypothetical train of thought to lay emphasis on the emotional dimensions of embodiment[174] and to consider the structural pathways of understanding that they configured an indispensable factor for enabling the suggested perceptual upheaval to take place. In particular so, since the aesthetic preference, whose cultivation brought about the developed enharmonic which then—"after much labour"[175]—was 'subsidised' by 'deliberate restrictions',[176] at first created the melodic environment mandatory

[173]Cf. n. 65 on William Sethares.

[174]In particular, since *melody* in its Greek origin of the *plurale tantum* μέλη means just this: the (moving) limbs of the body.

[175]Cf. quote on p. 9 and n. 51 above.

[176]Ps.-Plutarch 1137e. Trans. Barker 225: "To this day [Agathon in the late 5th century] tragedy has never used the

for to 'charge' *harmoníai* with emotional dispositions and to accentuate harmonic relations by the *pyknón* while the empty third (or 'undivided' ditone) kept the room open to facilitate ear-catching changes of harmonic context. Thus, in its strong reading the hypothesis of an emergent *just-tonality* towards the end of the fifth century entails that for this 'evolution' to happen, meaning to shift from a pattern-oriented to a *tónos*-oriented listening strategy, the classical prevalence of the developed enharmonic was not only an encouraging factor but a necessary condition to re-configure the analytical capacity acquired, so that, metaphorically speaking, at the point of saturation, the 'strain' of the pattern-matching orientation could finally 'discharge' and auditorily induce conditional branches of parallel perceptual streams that were to track all possible harmonic pathways of an essentially temporal sequence of notes in order to discern—within the critical timeframe of perception—the currently active *tónos*, or present 'transposition scale' in which the melody unfolds.

Technically speaking, now seen from the perspective of today's computer science, the *time-critical, multithreaded algorithm* required to single out one *tónos* from a set of partly overlapping transposition scales is unavoidably ambiguous or 'undecidable' for every step in melody at a time. This is due to the temporal logic of melodic procedures, such that only after a certain sequence of notes a harmonic context is established and becomes assured. Though obviously anachronistic, these technical attributes describe concisely the musical phenomenon at stake. By implication, the new configuration of perception is of an irreducibly speculative nature, meaning that, for a logical description of the auditory scenery evoked by harmonic modulations, the virtue of simplicity in Occam's Razor cuts astray.

Still, this apparently complex and seemingly all-too 'elaborate structure' built 'on speculation' is not an end in itself but, on the contrary, an adequate approach to the epistemological subject of harmonic science that set itself to the task of dealing with modulation in a thoroughgoing and logical manner. In respect thereof the proclaimed 're-configuration of ancient Greek music theory' appears less a pretentious title than a necessary historical consequence that itself follows from a dynamisation of harmony and the resulting speculative fabric of melodic perception when tracing moving harmonic contexts in real-time. To engage with this destiny of Greek harmonic history, the next chapter will bring back the *bárbiton* connected to an electronic setup considered suitable for putting the above speculations into operation and thus to qualifying them experimentally. Accordingly, the remainder of this chapter shall at least point to the substantially speculative conception of the *Harmonic Elements* and briefly indicate the unorthodox view and answers an 're-configured' understanding of Aristoxenian theory permits.

7.3. The subject of reconfiguration: harmony to the power of melody

If, and we shall claim, *only* if we assume a perception of truly harmonic modulations as emergent from the Greek sonosphere then, and only then, Aristoxenus' cardinal epistemological assertions and philosophical peculiarities that led to the phenomenological secession of harmonic science can reasonably be explained. Here we shall concentrate on the most important ones and briefly show how the overall Aristoxenian project in the light of our

chromatic genus with its specific structure, whereas the *kithara*, which is many generations older than tragedy, has used it from the start." Furthermore, since an Aristoxenian understanding of a 'chromatic genus' is implausible for the times of classic tragedy (cf. 6.3), here the term 'chromatic' most likely refers to modulations (cf. n. 170). Their deliberate avoidance in respect for a certain nobility or other socio-musical restrictions are well portrayed in Ps.-Plutarch 1133b–c: "In general, the style of singing to the *kithara* employed by Terpander continued in a quite simple form down to the time of Phrynis. In the old day *kithara* songs were not allowed to be performed as they are now, or to include modulations of *harmoniai* and rhythms, since in each *nomos* the pitch which belonged to it was maintained throughout. This is why these pieces were given their name: they were called "*nomoi*" because deviations from the form of pitching established for each type was not permitted. After dedicating themselves to the gods in any way they wished, performers proceeded at once to the poetry of Homer or other authors, as is clear from preludes (*prooimía*) of Terpander." Trans. Barker 211.

proposed history of hearing can be identified as taking *harmony to the power of melody* and how this line of interpretation rationally solves the issues raised above: (i) the principle rejection of notation (3.3), (ii) the ontological concept of *dýnamis* (5.3) and (iii) the fundamental role of genus (6.3).

Nowhere in the *Harmonic Elements* the pivotal 'laws' of harmony, as symbolised by the Pythagorean Tetraktys, are abandoned. Quite the opposite, the strong consonances and tuning methods based on them still present the unquestioned origin and authority of sensory measurement.[177] Only for convenience, as is often forgotten, the 'rational' mathematical approach is considered irrelevant and was therefore rejected.[178] Accordingly, Aristoxenus contrives 'the' semitone as basis for a practical measure of an 'additive' pitch continuum whose commensurateness is 'sensibly' demonstrated by reference to the traditional, quasi-mathematical tuning procedure utilising the 'method of concords' (3.4). The mechanical manoeuvre thus employed should prove an 'empirical equality' of the whole tone (9:8) with the size of two Pythagorean 'semitones', or *leímmata* ((256:243)^2).[179] Still, the herewith achieved dispersion of the Pythagorean comma (23.5¢) among altogether 6 alternating 'perfect' fifths and fourths cannot serve as argument for an implicit equal temperament in Aristotelian theory. If so, the explicit ontological discussion whether tones "are *táseis* (pitches), as most people suppose, or *dynámeis* (functions/powers)"[180] and the strong assertion that the concords would have "no range of variation at all", or were "determined to a single magnitude" would be either superfluous or even contradictory.[181] Moreover, if one assumes a tempered circle of fifths which yields 12 keys, the extra 'key' of Aristoxenus becomes redundant to both accounts, the ontological and the empirical, for then the musical properties of the 13th scale would functionally *and* structurally only redouble the 1st (cf. 4.4). Hence, musically unmotivated as it seems, the last, 13th degree in a row of semitones only pays tribute to the 'completeness' of the octave. By contrast, however, in melodic context, that is, if approaching the transposition of scales from the perspective of moving harmonic roots in such a manner that the tonal centres would 'trail' their harmonic frame of reference —or better, *regenerate* their associated perfect fourths and fifths *during the progress of melody*—then the 13th *tónos* marks the first step into the spiral of just-tonality.

For instance, if we take the Dorian scale ⊏<ꓘ⪯KCꟻ⊥F with *mésē* C as the harmonic root represented by the ratio 1:1 and then assume an immediate harmonic continuation of some melody that would directly trans-pose its focal note into ꓘ, that is the semitone above the (former) *tónos* K-C, its enharmonic pitch (in the ancient and the modern meaning) would be 6:5 (cf. Fig. 1); whereas, if we assume a melodic continuation that would harmonically migrate the tonal centre C a fourth up C→<, a fifth down <→F and a fourth up again F→>, we were to expect the semitone above the (former) *tónos* K-C on pitch 32:27. This operation yields the significant pitch-deviation of, again, a syntonic comma (21.5¢). Yet, to encounter

[177]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.55; 68.10–15 da Rios. Trans. Barker 168.

[178]For instance, shortly after the definition of interval as "the difference between pitches (*táseis*)" and as the subject of a "greater or lesser tension" (Ibid. 1.15, 21.1–4), Aristoxenus adds that "the student should try to accept each of these [definitions] in the right spirit, without quibbling over whether the account offered of each is exact or rather approximate" (1.16, 21.7–10. Trans. Barker 136). Nonetheless, *we* should be able to distinguish where Aristoxenus' phraseology deliberately flattens important epistemological differences. Accordingly, we need to keep apart those "dismissing perception as inaccurate" (2.32, 41.19–20, 149) on numerological grounds of simple epimoric ratios—such that, e.g. 3:1, must count as a dissonance "totally in conflict with the appearances" (2.32, 42.2–3, 149)—from those 'rationalists' judged "altogether extraneous" (Ibid.) for their reasoning from mathematical models of acoustics (cf. 3.2–3.4). Or, to tell names, we shall sharply differentiate the Platonising strand of Pythagoreans from the mathematical tradition in the line of Archytas. The latter, however, which are "those who reduce notes to movements" (1.12, 17.4–5, 134)—such that the above problem does not occur—are treated rather respectfully for their account that "sound is movement" (1.12, 17.6, 134). For the followers of Aristoxenus, of course, also their theories are considered irrelevant, since they "need make no differences to us" (1. 12, 21, 135).

[179]Ibid. 3.56-58; 70.3–72.6 da Rios. Trans. Barker 169-170.

[180]Ibid. 2.36; 45.15–16 da Rios. Trans. Barker 152.

[181]Ibid. 2.55; 68.11–12 da Rios. Trans. Barker 168.

this difference of the two semitones (K-ϗ,K-ϟ) no more than half of the harmonic steps are necessary as compared to those utilised in order to blur away about the same magnitude by the tuning manoeuvre above. Anyway, the given sample is just one among the few harmonic modulations adequately representable by notation. Obviously, other melodic procedures that modulate by a semitone or carry out further reaching harmonic excursions will break with the inherited trans-positional coding principle of the instrumental notation. The same principle incompatibility applies to the *diagrammatic function* of the *pyknón*: either the vocal notation confuses the order of pitches (N↔M, cf. 3.3) or fails to display functional contexts altogether. As a result, systematically 'thinking in *tónoi*' causes three things: (i) it reveals a 'serious diagrammatic deficiency' of notation (cf. 3.2), (ii) rejects the concept of mere trans-positions against a fixed grid of pitches and, as a consequence, (iii) does unavoidably involve either a concept of special tunings for specific modulations of individual melodies, or a general theory open to adaptive tuning.

Following the lines of our explanations, the latter is exactly what Aristoxenian theory is designed for. From the outset and instead of thinking of temperament, Aristoxenus peremptorily abstracts away from all physical and organological reasoning.[182] Alternatively, he introduces 'the voice' (*phōnḗ*) as some kind of active matchmaker between pitches (*táseis*) and notes (*phthóngoi*). Hence, adaptive intonation, that the voice is most capable of,[183] acts as something like a 'harmonic rendering agency' while taking on two complementary tasks: (i) to interchange the analytical capacity of hearing with the practical abilities of the singing voice,[184] and (ii) to mediate the "movement of the voice"[185] through pitch-space with the melodic trajectory of notes through the harmonic arrangement of keys, or as it were, the *tópoi* of *tónoi*. Only by mediation of the "journeying voice"[186] the entity of 'tone' is eventually defined as "the incidence of the voice on one pitch"[187] which itself is "capable of being put into a position in a harmonically attuned melody".[188] Yet, the radical ontological reasoning of "the science concerned with harmonic attunement"[189] postpones the true cause of pitch even further. Ultimately, Aristoxenus states that "the most important factor, and the one carrying the greatest weight in the pursuit of the correct constitution of melody"[190] to be the phenomenological conception that an "harmonically attuned melody must not only consist of intervals and notes" but, would depend on a "wider scope" and the "way of putting them together which is of a special kind."[191] Significantly, this wider and mediating kind of harmonic com-positions, we have briefly touched upon in section 5.3, is not conceived as a mere subjective reality of some acute listeners but, on the contrary, objectively defined as "the nature of continuity in melody"[192]. Because, "when the voice places intervals and notes in succession, it appears to maintain a natural principle of combination"[193]. Similar "to that

[182]E.g. "The greatest and most preposterous of errors is to make the nature of harmonic attunement depend on the instrument." Ibid. 2.41; 52.5–7. Trans. Barker 157.
[183]And, as we know today, even professional choirs tend to intonate the 'natural' intervals like (2:1, 3:2, 4:3 and 5:4) as just intervals—unconsciously.
[184]E.g. "In their progress towards the small [intervals], voice and perception seem to reach the limits of their competence at about the same time." Ibid. 1.14; 19.13–14 da Rios. Trans. Barker 135.
[185]Ibid. 1.18, 23.11–13 da Rios. Trans. Barker 138.
[186]Barker, "The journeying voice", strongly argues against the common understanding that the '*tópos* of music' Aristoxenus develops cannot be read metaphorically to equate "'place' or 'space'" or any sort of "transmission of a sound to locations" (166). Since the 'melodic traveller' "as an inhabitant of the auditory domain" (172), while "'travers[ing] it completely'", performs "a very curious form of motion and continuous existence" (169), movement in this domain would mean to "disappear from one place and immediately reappear in another" (169) in such a 'puzzling' manner that during "its activity it must remain hidden" (168), *lanthánein*, as Aristoxenus puts it.
[187]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 1.15; 20.16–17 da Rios. Trans. Barker 136.
[188]Ibid. 1.15; 20.17–19 da Rios. Trans. Barker 136.
[189]Ibid. 2.38; 48.8–10 da Rios. Trans. Barker 155.
[190]Ibid. 1.18; 23.20–24 da Rios. Trans. Barker 138.
[191]Ibid. 1.18; 23.24–25.1 da Rios. Trans. Barker 138.
[192]Ibid. 1.27; 35.11 da Rios. Trans. Barker 145.
[193]Ibid. 127; 35.18–36.1 da Rios. Trans. Barker 145.

which in speech relates to the putting together of letters",[194] continuity in melody is concerned with the order of letters in syllables, but not—as we shall point out—with letters as static elements, that is the acoustic coding principle of the Greek vowel alphabet. For "there is a kind of natural growth in the process of putting together"[195] of 'notes' whose dynamic progress in pitch is *generated*, as we may rephrase, by the *procedural ability* of harmonic functions raised to the power of melody. In our reading, it is this double-bind of a combinatoric and procedural approach that calls forth the *conditional* essence of *dýnamis* to act as the conceptual nexus that allows for *dynamic* attunements of contextually invoked pitches. Philosophically speaking, it is the very *nature* of harmonic modulation as carried out by melodic progressions that drives the epistemological enterprise of the *Harmonic Elements* beyond any Aristotelian empiricism and into the trans-empirical realm of a transcendental act-phenomenology[196] which is rendered a reality by *taking harmony to the power of melody.*

7.4. Coding the dynamic nature of harmonically attuned melodies

Finally, if we acknowledge the power aspect of *dýnamis* to mean not just the 'virtual' power set of all potential harmonic relations that a given note entails—as this might be the widest, modern mathematical understanding of the term in its standard translation as *function*—but, in addition, that the meaning *dýnamis* also includes the 'real' power to *operate* adaptively, that is to dynamically attune a given note to its harmonic context, then the principle rejection of *any kind* of notation receives the status of a logical necessity. Because any notation system that is *written down* by a limited, static set of symbols, like letters of an alphabet, not only insufficiently represent the nature of melody in terms of dynamic pitches, but moreover—while involving the sense of vision—actually forestalls the crucial concept of a temporalised conditional understanding of harmonically attuned melodies as such.[197] In other words, letters of the Greek vowel alphabet represent sounds of another thing, that is language (*phōnè logikḗ*), whereas sounds in melodies (*phōnè melōdikḗ*) operate on themselves. In essence, any fixed display or, as Aristoxenus says, "some end-product visible to the eye"[198] implies a predetermined, or 'off-line' rendering of melody and thus runs counter the time-critical *êthos* of music that affects the listener when speculatively tracing the decision tree of possible harmonic contexts:

> "[...] for we have to perceive what is coming to be and remember what has come to be. There is no other way of following the contents of music."[199]

Of course, this speculative reality brought into being by Aristoxenus' 'metaphysics of melody'—or, as we have tried to say less pejoratively, the trans-empirical realm of his harmonic science—is easily cut away when reducing the *tónoi*-system to a set of transposition scales carried around the octave on a modal basis, as this was the 'ultima ratio' of Ptolemy.[200] Surely, if we return to a pattern-oriented understanding of melody, the power set of interval arrangements only yields 7 structurally different scales, or octave-species. So, the open quest, why there are exactly 13 *tónoi* in Aristoxenian theory, must still be solved on other lines. It was nobody less than Andrew Barker, the philosopher, who called this topic "the thorniest in Greek musical science".[201] In his latest great assessment of the matter he

[194]Ibid. 1.27; 35.12 da Rios. Trans. Barker 145.
[195]Ibid. 1.27; 35.17–18 da Rios. Trans. Barker 145.
[196]These terms are borrowed from Edmund Husserl as the first philosophical concept (again) matching the matter.
[197]Concerning the sense of vision, Aristoxenus scolds the practitioners of notation, because, "as their conception has it, they are reversing the proper order, since the limit of everything visible is understanding: for that is the ruling principle and judge of everything." Ibid. 2.41; 51.12–13 da Rios. Trans. Barker 157.
[198]Cf. cit. on p. 16.
[199]Ibid. 2.39; 48.16-18 da Rios. Trans. Barker 155.
[200]Ptolemy, Harmonics, 2.10–11 in Düring, *Harmonielehre*, 62.16–66.4.
[201]Barker, *GMW*, II, 18–19.

tried again to answer: why "Aristoxenus allows, as Ptolemy does not, that there is substantial musical value in a system that makes room for transpositions of 'key' across the complete range of semitones and so creates two differently pitched positions for any one octave-species".[202] Although Barker would not suggest an answer in musical terms and overtly sticks with the concept of 'key' to merely mean trans-positions by the 'semitone', his "speculations are on the right lines" when analysing the "stylistically bleak"[203] but "admirably rigorous" propositions of the surviving parts in Book III of the *Harmonic Elements* as a "theorematic mode"[204] of writing. Following Barker's observations, may lead us to the missing coherent picture of Aristoxenian theory, so that "all melodic phenomena are expressions of a single nature".[205]

Concordant with Aristoxenus' fidelity to head for such a unifying—rather Pythagorean than Aristotelian—goal,[206] our attempt to explain the "substantial musical value" of *tónoi* to consist in the ability to dynamically integrate the combinatoric richness and speculative freedom as as result of truly harmonic modulations, naturally, finds itself less compelled to account for the structural redundancy of transpositions along a steady grid of semitones than to elucidate why there are *just* 13 *tónoi*. Now, duly 'thinking in *tónoi*', as we have seen, not only requires a contextually mediated understanding of what a 'tone' is, but, as a consequence, also creates a theoretically infinite amount of dynamically attuned pitches. Respectively,"the facts about melody seem to be in some ways indeterminate"[207], so that theory is in need to define a sensible limiting principle which regulates the perceptual identification of legitimate tonal relations. This is the fundamental role the concept of genus serves in Aristoxenian theory. Although repugnant to tradition (cf. sec. 5.4), it sub-groups an earlier, probably ethically laden and modal-based variety of *chróai* into 3 perceptual archetypes or 'generic' tetrachord divisions.[208] The outstanding feature, however, through which the category of *génos* finally gains the dignity to become the first axiom of 'theorematic' writing, is the identification of the 'undivided' ditone with the empty *spondeîon* third, forcing the size of the enharmonic *pyknón* to equal the diatonic semitone.

Still, the significance and motivation of this conformity cannot be equated with an evidently earlier equalisation of 'semitones' by a measure of quartertones or smallest 'elements'.[209] By contrast, Aristoxenus elevates the uniqueness of his 'revision of the tetrachord' by claiming, that even those who "did perceptually discriminate each of the genera", would not tell "when it is that a form of the chromatic begins to emerge from the enharmonic."[210] Eventually, recalling the 'bleak' section entitled "a proof by contradiction" and the "important lemma" (in 5.1) that motivated our own 'theorematic' passage, we begin to understand that the convenience of a commensurable measure is indeed secondary in view of the complexity reduction of tonal relations that the superposition of diatonic and enharmonic properties achieves. It is the 'semitone limit' of his genera by which Aristoxenus appropriates—for the good or bad—musical features of a dying enharmonic music. The acoustic and once aesthetically decisive difference of the syntonic comma in an enharmonic musical environment reappears as a mere functional difference of the 'undivided' and 'divided' ditone. But also in terms of modulation, that is to say, when the journeying voice

[202]Barker, *The science of harmonics in classical Greece*, 227.
[203]Ebd. 228.
[204]Ebd. 227.
[205]Ebd. 228.
[206]For elaborations on this point see: Martin Carlé, "Archytas versus Aristoxenus—an outworn antithesis", International Meeting: *Pythagorean views on music* 2009 at Samos, publ. 2012, forthcoming.
[207]Cf. Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 3.69, da Rios, Barker 180.
[208]Already Mountford, J.F., "Greek music and its relation to modern times", 1920, pointed to the artifice of this move and sharply concluded that only in return "an elaborate theory of 'colours' or 'shades' was superimposed on the theory of the genera" (134).
[209]Cf. the discussion in section 5.3 and note 67 on *katapyknōseis*.
[210]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.35; 44.16–17 da Rios. Trans. Barker 152.

is guided by its harmonic rendering agency and thus unconsciously follows the chain of pitches along the natural growth of harmonic procedures, the same distance in pitch (e.g. K-ϗ,K-> cf. 7.3) seems not too far to travel—if we take the the venturous ride of a typical *polychordía* into account. Accordingly, it is the hidden dynamic of attunement that creates the theoretical 'backstage' of the sought 'room of musical value' in the *tónoi* system—or, the invisible auditory scenery of melodic progression that the Aristoxenian theatre of 13 *tónoi* puts on stage.[211] In general, it is through the 'generic' classification of pitches, on the one hand, and the harmonic 'travelling limit' by the semitone, on the other, that Aristoxenus gained coherent access to the melodic rules and acoustic laws inscribed into the Greek sonosphere. By this achievement, as our proof (cf. sec. 5.2) exemplified, Aristoxenus draws upon historically entrenched resources of music,[212] or a "continuity in melody" from which he extracts logical propositions about melodic sequences that allowed for a radical, thoroughly functional reframing of harmonic science.

In this respect, the very script of Book III virtually enacting the functional machinery of the *tónoi*-system turns out to be far more important to Aristoxenus' unprecedented approach to combinatorics than its side effect of a 13-limit semitone harmonics. In fact, his 'admirably rigorous' coding of admissible interval sequences—in essence and style—constitutes a most radical alternative to notation. For the fact, that his media-theoretical distinction actually created an epistemological hiatus, Aristoxenus' 'theorematic mode' of writing awaits still to be acknowledged. Unfortunately, the apparent 'indigestibility' of a music theory plainly laid out in logical constraints and statements, "does something to explain why, in its original form, it became neglected and ultimately lost", as Barker suggests.[213] Yet we fear—when considering the "generations of summarisers having found in it nothing more useful than a collection of conclusions"[214]—that their 'incomprehension' applies to his anachronistically advanced, well, let's say proto-computational spirit in general and especially to Aristoxenus' foray into a form of theorematic writing that, only today, we may realise as a venture into logical programming. If so, as most evident in Book III, not too far from the start the sequence of assignments and propositions broke, because the living musical tradition, indispensable to practically solve and carry out the Aristoxenian declarations, was most likely—and already in his days—in its final throes. Or, as we may say today, because the time-critical logical machinery necessary to compile and execute the Aristoxenian pseudo-code was no longer there, or has not yet been around—again.

As it is not possible to go in further details here, we end this chapter with a media-archaeological remark that literarily bridges over to what we are trying to 'excavate' with the electronic barbiton: Aristoxenian theory is not to be upheld as an antique crypto-theory of elementary temperament and key, but rather it is still to be discovered as devising the first theorematic machine of self-computing sounds operated by harmonically attuned melodies whose musicological fabric was coded in some sort of a constraint programming language like PROLOG[215] or OCL[216] as its ELEMENTS.

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[211]Barker, although keenly in search of an explanatory connection between the musical constitution of *tónoi* and the philosophical motivation for a 'theorematic mode' of writing (cf. n. 202), apparently overlooked the technical link operated by the procedural power of harmony tying the threads behind the metaphysics of melody in Aristoxenus. Consequentially, after arriving at the other side of his metaphysical journey through Aristoxenus, Barker, "The journeying voice", n. 17, still awaits a philosophical solution on the insisting epistemological problem: why is it, that for Aristoxenus the science of harmonics belongs to "one of the 'Aristotelian' sciences of nature" (184) whereas this is not true for the latter. Yet, the answer may well reside on the mediating, technical side, as well.

[212]It is telling to see how the entrenchment of these resources is involuntary confirmed by Ps.-Plutarch 1143e. Trans. Barker 242 while stating anachronistically that it would have been because of "the three genera into which *melodic order* is divided … [that] the people in ancient times only studied one" (which, naturally, was the enharmonic). Just the opposite reasoning, of course, can be found in Aristoxenus, e.g. 3.69, da Rios. Trans. Barker 180.

[213]Barker, *The science of harmonics in classical Greece*, 228.

[214]Ebd.

[215]PROLOG III is considered the first language of the constraint programming paradigm.

[216]*O*bject *C*onstraint *L*anguage is a more recent development that supplements the *U*nified *M*odeling *L*anguage

Figure 4. barbiton from black-sea turtle (ποντιάς χελώνη) and antelope horns of genus *Oryx*.

Figure 5. 'unplugged' barbiton with snakewood bridge and tailpiece, gut strings and goat skin.

8. THE ELECTRONIC BARBITON
ἢ μία ΠΟΝΤΙΑΣ ΧΕΛΩΝΗ ΚΑΤΑ ΔΥΝΑΜΙΝ

In expectation that a modern sound device can act equally 'instrumental' to the epistemological enterprise of Greek harmonic theory as the original instruments surely did, the above depicted barbiton augments the ancient *bárbitos* electronically. Just like playing with harmonics on archaic strings was instructive to develop a pattern-oriented concept of scale trans-positions against a fixed grid of intervals (cf. sec. 4.4), the electronic barbiton enables a playing with harmonic modulations that shall become explanatory to the *tónos*-oriented modality of perception and the study of dynamic intonations as evoked by the 'nature' of melodic processes (7.2). Thus facilitating a 'potential' reading (7.3) of Aristoxenus' *dýnamis* experimentally, the electronic barbiton mediates between a static pre-calculation (*katà thésin*) and a dynamic on-the-fly rendering (*katà dýnamin*) of harmonic elements. Accordingly, already the basic elements of construction—the shell of a 'floating' black-sea turtle (*pontiás chelőnē*) in place of the 'grounded' tortoise carapace (*chélys*)[217]—drives home the

standard, invented for the single reason of providing constraints "that cannot otherwise be expressed by diagrammatic notation." http://en.wikipedia.org/wiki/Object_Constraint_Language.

[217]Roberts, "Reconstructing the Greek Tortoise-Shell Lyre", 303 gathered "from Pausanias (8.54.7) that the tortoise most suitable […] was the larger variety of Greek tortoise, the *testudo marginata*, which grows to a length of 220-300 mm". The others turtles (*testudo graeca*, *testudo hermanni*) not exclusively endemic to Greece are considerably smaller. Concerning the indication of size, elsewhere in Pausanias (1.44.8) we find that "sea tortoises are like land tortoises except in size and for their feet, which are like those of seals." in Jones, W.H.S., *Pausanias*.

message to music archaeologists that this ‘*órganon* of theory’ is less a reconstructed than a reconstructive instrument.

The following sections will shortly describe organological, technological and conceptual aspects contributing to the overall methodological setup to evaluate both, the plausibility of a perceptual rupture in the Greek sonosphere (7.2) and the epistemological soundness of Aristoxenian (media) theory (7.4).

8.1. Organological construction

Reminiscent of Helen Roberts’ ‘authentic replica’, the sound-box of the instrument "had to be substituted"[218] by a carapace from Southern Russia.[219] Yet, the arms made of antelope horn were found on eBay, hailing from some missionary residue. Compliant to Herodotus, the sharp-ended outgrowths are of the genus *Oryx* "whose horns are made into the sides of the Phenician lyre".[220] As simple as the historian put it, the hollow ends of the horns were slipped over a Y-shaped, properly tapered piece of wood locking the arms in place without any gluing, nailing or screwing. Due to the convenient option of this fastening, none of the 4 scholarly proposed ‘methods of fixture’ were applied.[221] However, the construction corresponds with "a very attractive proposition" of Bo Lawergren, according to which the metallic tailpiece holding the strings was "inserted into the lower ends of the arms, forming thus a rigid frame: arms-yoke-tailpiece."[222] Therefore relieved from the tension of the stings, the sound-box resonates loud and freely, while being clamped onto the frame only by a still rather archaic smelling goat skin, tightly stretched over the shell. Two wooden hooks with an eyelet are pulled over the tip of each horn retaining the crossbar. A tenon joint on each hook ensures "that the yoke would not be allowed to roll under the pressure of the strings."[223] For the tuning pegs, like for most other woodwork, dark oak (Deutsche Räuchereiche) was chosen as a material hard enough to avert one of Roberts’ unfortunate experiences that only "after a few days [...] the stings had cut into the crossbar and indentations appeared on the side of the peg in contact with the crossbar."[224] Also of hardwood, but altered for acoustical reasons, the bridge transmitting the vibrations from the gut strings onto the resonating skin has been made of snakewood (*brosimum guianense*) and comes in two versions: one ‘unplugged’ (Fig. 5) and one with piezo pickups (Fig. 6).[225]

Description of Greece, IV, 1918. The present *Chelonia mydas agassizi* carapace measures 425 mm in length and 354 mm in breadth.

[218]Roberts, “Reconstructing the Greek Tortoise-Shell Lyre”, 303.

[219]Sincere thanks to Joulia Strauss: without her essential pagan contributions the turtle were never captured.

[220]Herodotus, *The history of Herodotus, parallel English/Greek*, 1890, IV, 192.

[221]Dumoulin, D., “Die Chelys. Ein altgriechisches Saiteninstrument”, 1992, 332–334 contrasts the 3 ‘classical’, but considered "purely hypothetical" solutions of Phaklarēs, P., “Χέλυς”, 1977, Courbin, P., “Les lyres d'Argos”, 1980 and Roberts, “Reconstructing the Greek Tortoise-Shell Lyre”. However, Psaroudakēs, S., “A Lyre from the cemetry of the Acharnian Gate, Athens”, 2006, after carefully discussing the extant shells proposes that (generalisable at least for the bigger carapaces) the conspicuously "large holes on the sides of the shell very likely functioned as ‘nests’ of the lower ends of the arms" (65) so that "they came to a halt, without the use of any further fastening material, such as nails" (64).

[222]According to Psaroudakēs Ibid. 64, this idea has been recorded in an unpublished report at a conference in Eresos, Lesbos in 2000. Slightly divergent to this, the metal tailpiece of the present barbiton has a wooden finish.

[223]Creese, “The Origin of the Greek Tortoise-Shell Lyre”, 96 with reference to Bélis, A., “A propos de la construction de la lyre”, 1985, 214–215 and Anderson, W.D., *Music and musicians in ancient Greece*, 1994, who criticised Roberts for not having done so (174).

[224]Roberts, “Reconstructing the Greek Tortoise-Shell Lyre”, 205. Creese, “The Origin of the Greek Tortoise-Shell Lyre”, 92 n. 14 reckons that Roberts mistakenly "used the wood of *Acer pseudoplantanus*, the maple more commonly called "sycamore" in England, instead of *Ficus sycomorus*", the true sycamore of which the Elgin lyre’s arms and crossbar were really made. Had she been able to obtain true sycamore wood, she would likely have found it hard enough for the task."

[225]Since this piece is of importance for the actual loudness and possible playing techniques, Lawson, G., “Ancient European lyres: excavated finds and experimental performance today”, 2005, 113, pointed out that concerning the Mediterranean and Aegean areas "we have some putative tail-piece structures, but as yet no bridge. Not one. This

8.2. Electronic extension

Up to 12 strings are picked up by piezoelectric crystals attached to the barbiton's bridge. In virtue of their special slip casting,[226] cross-talk among the strings is strongly reduced. As a result, the pitch of each string can be rapidly determined and then shifted individually during performance without affecting the natural timbre of the instrument. The weak piezo signals only travel a short distance to a pair of 'sound spectacles' (Fig. 7) mounted between the arms of the barbiton.

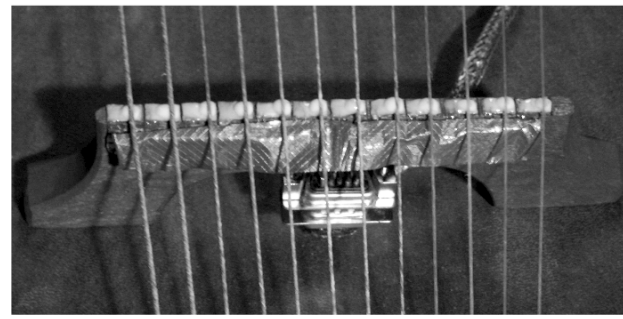

Figure 6. barbiton bridge with specially slip cast piezo crystals.

The tight-fitting 'eye-pod' contains two GHOST[227] Hexpander Pre-amp Plus with Acousti-Phonic Pre-amp and two LCD displays each connected to a USB to RS-232 converter. Fast and reliable pitch-tracking is carried out by two AXON AX 50 modules which have been modified to not only output the analysed pitches in MIDI-format, like the states of extra manual controls mounted on the 'sound spectacles', but also to route through all 12 audio channels into a computer in order to enable immediate manipulations by real-time signal processing. Hence, a naturally sounding, dynamic pitch-shifting algorithm that traces harmonic contexts 'on-line' and reflects them acoustically by just-intonation—or by other, more sophisticated techniques of perceptual highlighting—is feasible with this setup.

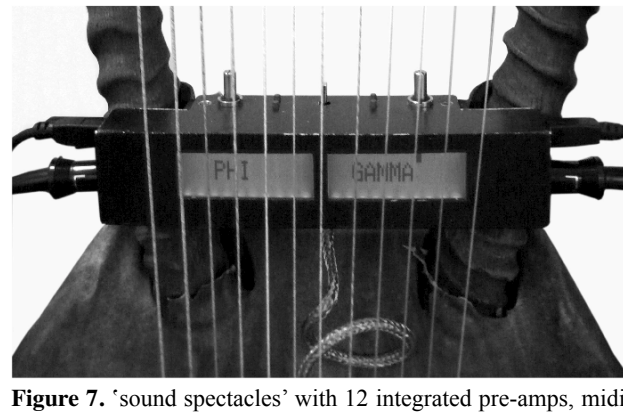

Figure 7. 'sound spectacles' with 12 integrated pre-amps, midi-controllers and 2 LCD displays, showing recently played notes.

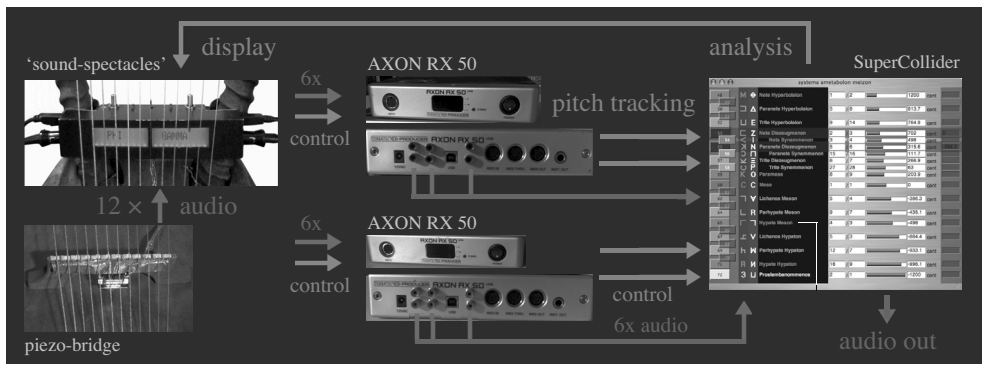

Figure 8. schematic signal routing of the electronic setup.

is surely, at best, a handicap!"

[226]Resourceful slip castings by Tito Toblerone-Knapp.

[227]http://www.graphtech.com/products.html

8.3. Link to ancient music technology and methodological advancements

For the persistent prejudice that "no instrument tunes itself"[228] was beyond debate among the ancients, any music technological approach that was about demonstrating 'moving' harmonic contexts in real-time, was forced to side-step methodologically and to invest in parallel hardware: As legend has it, the musician and musicologist Pythagoras of Zacynthos manufactured a complicated musical instrument with an explanatory function to the concept of modulation as early as in the midst of the 5th century. In this period, for which competing schools of harmonic scientists are named by Aristoxenus,[229] his so-called *tripod* enjoyed great popularity and "was admired exceedingly".[230] As if taking the Delphic tripod upside down, the ingenious demiurge of Zacynthos established 3 individually tuned '*kithárai*' between its outstanding legs. To each pair of legs, branching off from the same sound-box "which turned easily, like the bases constructed for revolving stools"[231], Pythagoras assigned "separately the three modes (*harmoníai*), the Dorian, the Phrygian and the Lydian".[232] Finally and effectively, "the easy motion of the base, responding to the touch of his foot, brought so quickly to his hand the several parts of the instrument (*systḗmata*) […] that if one did not see with his own eyes what was going on, but judged it solely from hearing, he would think he was listening to three harps (*kithárai)* scaled differently."[233]

Since the 'hardware parallelism' of the '*tripod órganon*' guaranteed that each '*kithára*' had identical properties of sound and since each of these implemented a 'separately assigned'—that is, in all likelihood, a just-tuned *sýstēma*—the straightforward message of the curious anecdote, that these otherwise indistinguishable '*kithárai'* were still perceived as

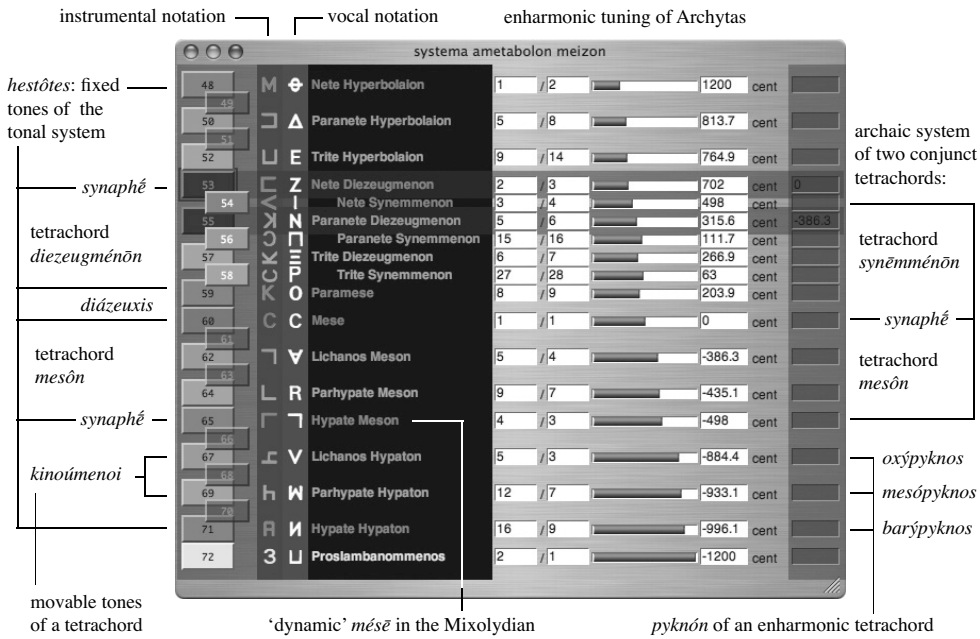

Figure 9. SuperCollider Interface Panel displaying the centre of the Non-modulating Perfect System.

[228]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.43; 53.16–17 da Rios. Trans. Barker 158.
[229]according to whom Pythagoras of Zacynthos (Ibid.,2.36–37, 45.19–46.16 da Rios) would be the originator of a certain school of harmonicists who actually 'tried to enumerate' "all the distinctions between *systēmata* and while doing so, did *not* 'devote' "their research only to the seven octachords which they called *harmoniai*". Trans. Barker 153. Cf. also Barker, "Οἱ καλούμενοι ἁρμονικοί", 7.
[230]Athenaeus, "Deipnosophistae", VI, 637f. Trans. Gulick 441.
[231]Ibid. 637c–d. Trans. Gulick 441.
[232]Ibid. 637d. Trans. Gulick 441.
[233]Ibid. 637e. Trans. Gulick 441.

different *harmoníai*, strongly indicates that just-intonation in the Classical Period must be considered a viable conceptual model, if not *the* perceptual basis, for an emergent *just-tonality* developed from harmonic modulations (cf. sec. 7.2). Hence, the 'Delphic device' of Pythagoras—in regard of its integrative construction and demonstrative aims—can well be identified a methodological forerunner to our hyper-integrated setup, where all signals culminate in one 'sound-box' running SuperCollider, an ingenious framework for real-time audio synthesis and algorithmic composition.[234] Figure 9 exemplarily depicts one 'view' of the software interface showing the Non-Modulating Perfect System in the enharmonic tuning of Archytas which can be altered to any *sýstēma*, or modified on-the-fly according to the harmonic trajectory of any modulating melody played on the electronic barbiton.

Concerning the theoretical objectives, however, the wired and algorithmically controlled barbiton is a 'sound medium' in the double sense of the phrase: Firstly, it has been freed from most organological restrictions of 'ancient Greek instruments of the lyre type' and thus allows even a playing of sounds *énaulon kithárisin*—for 'giving a flute-like *intonation* to strings' (cf. sec. 4.2). In fact, pitch deviations as operated by half-stopping holes on the old aulos, or as mechanised by movable metal collars on the new aulos[235] are both workable with digital pitch-shifting. The flexibility of intonation thereby achieved correlates well with Aristoxenus' rejection of any harmonic reasoning based in organology and thus directly meets the requirements and freedom of the 'voice'. To this extent, the present hyper-instrument seems just as suitable for theory as the very meta-physical instrument employed by Aristoxenian theory (cf. sec. 7.3). Secondly, by endowing a physical body to theoretical constructions and while implementing the thoroughly logical and radically temporalised listening strategy described in Aristoxenus by a multi-threaded, time-critical algorithm, the electronic barbiton might enable a 'deep-listening'[236] into time and help to soundly 'excavate' the speculative grounds causing, as we inferred, the harmonic 'strain' of late Classical and early Hellenistic melodies. As a sound medium, to sum up, the electronic barbiton acts re-constructive to the trans-empirical epistemology operating the *Harmonic Elements*.

As a result of methodology, however, the 'vague' definition and mediated understanding of the 'tone' in Aristoxenus' harmonics that—if seen from a scientific point of view predating the reality of real-time emulations—was often enough judged to cause an unsound theory and thus was simply cut away by Occam's Razor, may at last turn out to be its epistemological foundation. After all, the novelty of the present interdisciplinary approach is to be sought less in the sameness of re-construction than in the *mímēsis* of re-enactment.

8.4. Outlook for experiments

Now, "since it is obvious […]" that instruments can tune themselves "[…] but [also] that perception is [still] the authority in this matter"[237] it follows inescapably that, today, (even) phenomenological theories of music perception, no other than technical theories of melodic processes 'must finally be subjected to a practical test'. So, if we are willing to follow Aristoxenus 'in putting perception in the lead of harmonic science', then *measurability* of pitch plus *awareness* and *reliability* of its articulation (cf. sec. 2.2) still define the adequate sound medium that, today, in fact, does "provide the foundation for the nature of attunement".[238]

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[234]http://supercollider.sourceforge.net

[235]Metal collars, or rotating sleeves are a mechanical sophistication of auloi that, interestingly, appeared at about the same time (or even al little later) as the 'Zacynthian mechanism' and by which "it became possible to close and open individual finger holes during performance, and consequently to modulate different scales, and to extend the ambitus by changing the playing position of the hand" Hagel, S., "Re-evaluating the Pompeii Auloi", 2008, 53. On auloi cf. n. 153.

[236]Klotz, S. & Carlé, M., "Symposion: Deep Listening in the age of eloquent technologies", 2007

[237]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.43; 53.16–54.1 da Rios. Trans. Barker 158: "It plainly needs no arguing, since it is obvious, that no instrument tunes itself, but that perception is the authority in this matter."

[238]Ibid. 2.42, 53.4–5 da Rios. Trans. Barker 158: "But in fact neither *auloi* nor any other instruments will ever

Accordingly, the electronic barbiton facilitates a quantification of cognitive and emotional affect in relation to contextually intonated intervals. By a series of suitable experiments,[239] the ethical effect of intonation on the sensation of harmonic modulations in melodic context can be tested. A comparative study with ancient music fragments and newly devised melodies that focuses on the variables of difference between a pattern-oriented and a *tónos*-oriented perception is envisaged in co-operation with the Department of Informatics and Telecommunications at the University of Athens and the neuroscience lab at the ΕΠΙΨΗ research institute in Athens.[240]

Regarding the epistemological soundness of Aristoxenus' dynamisation of harmony, the complex temporal dynamics resulting from a 'thinking in *tónoi*' and the speculative unfolding of mutually exclusive harmonic trajectories that (i) disproved the usefulness of notation and (ii) asked for a logical machinery with constraint programming abilities right in antiquity (cf. sec. 7.4), require a tangible presentation, in order to be fully grasped and appreciated by a wider public. In this respect, a project with artistic collaboration is on the way[241] developing an alternative notation system whose workings reflect (amongst other things) on the ethical aspect of melody and the epistemological differences of diagrammatic writing and time-critical computation.

9. CONCLUSION

Having revisited deeply rooted and interrelated problems of harmonic science in ancient Greece, the interdisciplinary approach involving recent music technology and current epistemological questions discussed in the field of media theory, leads us to conclude about our new method to access the knowledge, either contained in, or provoked by *mousikḗ* in two ways: Firstly, the anachronistic inclusion of today's scientific instrumentarium re-orients the focus of investigation to shift from an hermeneutical interpretation of discursive statements to a computational modelling of the discursive elements in question, such that in our archaeological case—we hope—this will re-enact essential harmonic phenomena to be audibly studied, even by the present ear. Secondly, the mere use of these new 'instruments of thinking' cuts through not only the technical, but also the ontological preconditions of historical discourses, such that in our philosophical case, a then unconscious *episteme* of music, that we identified as the overarching paradigm of en-harmony, can become an operational epistemology at a much later date in history. In this respect, the epistemological frame forming the reasoning of Aristoxenian theory that, today, can be recognised as to imply parallel, time-critical processes, will be re-configured—we believe—by technology.

Therefore, if we are ready to assume that a certain 'nature' of music impacts on the historical fabric of our sonospheres and that the order of perceptible phenomena is not the only subject of knowledge the discipline of harmonic science deals with, the conclusion of this paper can be condensed into one single sentence raising the unorthodox view: while the ancient concentration on fixed harmonic intervals revealed the basic Pythagorean Tetraktys to function, indeed, as a mathematical operator (cf. sec. 4.4), today's operative computation of all conceivable melodic functions in real-time has the potential to re-enact the temporal epistemology of Aristoxenus' *dýnamis* as originally being the result of incorporating Archytas' formulas by taking harmony to the power of melody (cf. sec. 7.3).

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provide the foundation for the nature of attunement."

[239]For these experiments it maybe suitable to use further reaching perceptual highlighting techniques feasible by the electronic barbiton and to extend the order of pitches into the domain of timbre by a contextually controlled shifting of harmonic partials that, at least to some degree, would catch up with the 'nasal blare' and 'lascivious whine', the *aulós* is capable of. Cf. n. 90.

[240]These locations are promising, since the research group of G. Kouroupetroglou already proved to collect and evaluate similar empirical material: Delviniotis, D., Kouroupetroglou, G. & Theodoridis, S., "Acoustic analysis of musical intervals in modern Byzantine chant scales", 2008.

[241]Carlé, M. & Strauss, J., *Cat-Notation*, 2011.

To close, it seems adequate to put our perspective on the craft of the muses in tribute to the magical *chélys*, symbolising the intent of all Greek *mousiké*: In so far, namely, as the fatal message conveyed to the only being considered to live without a voice,[242] before 'turned' into a *chélys lýra* by the god of transitions, was contained in the promise of Hermes that "if you die, then you shall make sweetest song"[243]—the same hermeneutical promise may also convey today's computational message that the 'voice' of Aristoxenian theory containing all "the marvellous organisation which belongs to the nature of attunement as a whole"[244], if dead and turned into a *chélys* barbiton, will continue in

> "voicing to the tune of thy lovely lyre the strain of the children of Samus, [...]"[245]

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[242]Svenbro, J., "Wozu ist deine Laute gut?", 1996. Cf. also the telling formula uttered by the nymph of Mount Cyllene in Arcadia where Hermes found the tortoise: θανὼν γαρ ἔσχε φωνήν, ζῶν δ' ἄναυδος ἦν ὁ θήρ (it speaks now it's dead, though it had no voice when it was alive) Sophocles, Tracking Satyrs, 301. Trans. Anne Mahoney, Perseus Digital Library.

[243]Hugh G. Evelyn-White, "Hymn 4 to Hermes", 1914, 38: ἢν δὲ θάνῃς, τότε κεν μάλα καλὸν ἀείδοις.

[244]Aristoxenus, "ΑΡΜΟΝΚΩΝ ΣΤΟΙΧΕΙΩΝ", 2.42; 53.6–7 da Rios. Trans. Barker 158.

[245] Stesichorus fr. 278, cf. n 1. Trans. in Strabo, "ΓΕΩΓΡΑΦΙΚΑ", IV, 1927, 3.20.

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