The Monochord according to Marin Mersenne

Bits, Atoms and some Surprises

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ABSTRACT. Based on text and figure from Proposition XII of "Book of the Instruments" in *Harmonie Universelle* by Marin Mersenne, a digital-virtual monochord (multimedia and interactive) and a real-material one (wood and gut strings) has been made to investigate and verify, both numerical and sonorous, the musical science of this natural philosopher. This reconstructions help to read some chapters of the *Harmonie Universelle* in a multimedia way, convinced as we are that musical treatises - especially from 17th century - have to be "heard" in order to reach a full understanding of its propositions. Fundamental link for this essay is: http://www.calderon-online.com/mersenne/monochord_mersenne.htm

Introduction

Among the huge catalogue of instruments shown in Mersenne's *Harmonie Universelle* the monochord stands out by its two fundamentals tasks: to provide the exact intonation to calibrate musical instruments and to demonstrate, as Mersenne says, "all the science of Music" (MERSENNE [1636] 1965.Vol III, Liure I, p.16). The former is, at least in principle, a practical task for singers and performers; the latter a theoretical one for natural philosophers; both of them for the true musician[1]. This two-sided condition

[1] The discussion about what a "true musician" is, was early summed it up, in 6th century, by Boethius [see Cap. XXXIV of First Book of *De Institutione Musicae*] in three genres: the performers who take up only on instruments and the poets who deal only on verses. For Boethius the first has no musical understanding and act like slaves, the second has only natural instinct for their compositions, but the third genre, the musician – the true musician –, are those who have the ability to judge the musical rhythms, *cantilenas* and compositions in

is inherent to practically the whole discussion around music as an art-cum-science and it is well illustrated, as we will see, in the Mersenne's approach to the monochord. As is well known the monochord consists of an extended and resonant wood box in which a tense and vibrant string can be shortened by means of a movable bridge in order to define a certain relation or proportion (geometric, arithmetical and sonorous) between its greater and smaller parts. This simple technique was used from antiquity up to 17th century and Mersenne can be considered, as we will conclude, as a true highlight of it.

This essay intends to show a way to experimentation based on a reconstruction of the monochord designed by Mersenne. It offers a virtual-digital reconstruction to help to read some chapters of the *Harmonie Universelle* in a multimedia way, convinced as we are that musical treatises - especially from 17th century - have to be "heard" in order to reach a full understanding of its propositions.

In the first part of this essay we consider some aspects of the monochord as a scientific instrument especially in 17th century. Secondly we analyze Mersenne's Proposition XII of The Books on Instruments in which the

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general according to theory and calculation. Thus, Zarlino in 16th century kept the discussion in almost the same way setting the difference between *Cantore* and *Musico*, but clarifying that the perfect musician - *Musico perfetto* - is that one who gives to his expert practice the faculty to judge with reason, turning his science to perfection. [See Cap.11 in *Instittione Harmoniche*].

natural philosopher shows us the two-sided condition – practical and theoretical – of this instrument. Subsequently we explain both reconstructions – material and digital - and invite the reader to navigate to a web link where the virtual monochord can be manipulated according to Mersenne's instructions and watch some performance videos.

Preliminary thoughts

The monochord did not emerge like other new instruments into the scene of early 17th century - as did the telescope, microscope or vacuum pump - but from ancient times had appeared, with minimal modifications, down through history. Its simplicity and high precision has always been praised for philosophers and musicians and in the case of Mersenne it could serve as a testimony of what Crombie calls, in his *Styles book of Scientific Thinking in the European Tradition*, a "new science".

> The new science of music illustrates in this age of transition [between the middle of the 16th century and the middle of the 17th] how with new scientific experience a fundamental task came to be seen as that of tailoring ancient philosophical ambitions to the possible, the testable and the soluble. (CROMBIE 1994. Vol. 3: p. 786).

We only have to clarify that despite indeed a new science of music is arising, the monochord was not a "new scientific experience" and, as it is well known, it was already comprised in that “philosophical ambitions” and from its same origins. Conceived by Pythagoras - according to the story transmitted by Nicomacus of Gerasa, c. AD 100 - was used intensely during the Ancient, Medieval, and Renaissance periods.[2] For Boethius – 6th century - the monochord became the *regula* (canon)

> not merely because of the wooden scale by which we measure the dimension of strings and the corresponding sounds, but because any particular investigation of this kind made with a monochord [regula], is so firmly established that no investigation can any longer be misled by doubtful evidence. (BOETHIUS in LINDSAY, 1972, p. 39).

Ten centuries later in 1637, in almost the same terms as Boethius did, Mersenne stated about this musical experience saying:

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[2] As Jan Herlinger has quoted: “Ancient Greek music theory developed canonics [theory and practice of monochord] to a sophisticated degree …The *De Institutione musica* (early sixth century) of Boethius transmitted a number of … tunings to the Latin Middle Ages…Western musicians and scholars devoted a great deal of attention to *De Institutione musica* from the ninth century at the latest, and from about the year 1000 divisions of the monochord proliferated in Latin music theory. The extant corpus of texts dealing with canonics written in the West between c. 1000 and 1500 runs about 150 items; and the authors of any number of other Medieval treatises presupposed a knowledge of canonics on the part of their readers. (HERLINGER, 2002).

…that the monochord is the most suitable instrument and the most exact for regulating the pitches on harmony; it is not useless to know the construction. That is why it is called the *harmonic rule,* because it measures the pitch of sounds,... [3] (MERSENNE 1957, p.28-30).

Thus, it is clear that experimenting with monochords were not “new scientific experiences” and the experiments that Benedetti, Vincenzo Galilei, Zarlino, Kepler, Galileo and Mersenne carried out in 16th and 17th centuries to give birth to a “new musical science” could be seen as an expansion of the possibilities of this pioneer scientific instrument: the monochord.[4]

For instance, in 17th century the monochord for Fludd was an obviously symbolic and metaphorical object, and in the case of Mersenne - as we will see -, it was a full explained and detailed material object and undoubtedly a scientific instrument. [Fig.1]. Fludd based on an imaginary and simple string tightened by the hand of God, turned harmonic proportions into the divine plan that structures the macrocosmos and the microcosm, thus expanding the

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[3] “..le Monochord est l’Instrument le plus propre & le plus exact pour reglér les sons & l’harmonie, don’t il n’est pas inutile de sçavoir la fabrique qui fuit... De la vient que l’on la nomme *reigle Harmonique,* ou *Canonique,* par ce qu’il sert à mesurer le graue & l’aigu des sons,...”. (MERSENNE [1636] 1965.Vol III, Liure I, p.15-16).

[4] For experimental approach to music in hands of 17th-century natural philosophers see *Quantifying Music.* (COHEN, 1984) and essay by Stillman Drake "Renaissance Music and Experimental Science”. (DRAKE [1970] 1999: p.201).

metaphysical and philosophical tradition. [5] On the other hand, Mersenne, after reviewing all possible subdivision in the string, organized them into a sonorous measuring instrument with sensitive resolution for human ears. Mersenne show us a way - from sonorous experimentation through geometry and calculation using irrationals - to consider the monochord not as a metaphor but a true scientific instrument which describes, calculates and serves for several acoustical experimentation and prediction. Nevertheless Mersenne himself does not escape from symbolism around the vibrant string, and thus the unison is for him equivalent to the oneness of God

> …for the unison represents the state of the Blessed and the perfect union of the three Divine Persons who are in the unison in perfect equality.” [6] (Cited in GODWIN 1992, p.256).

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[5] In his work, *Utriusque Cosmi Historia* (1617), Fludd refers to the monochord in this way, “...let us begin with the material of world, which we have represented as the string of the monochord (whose great instrument is the Macrocosm itself), …*imagine* [my italics] a monochord stretching from the heights of the Empyrean heaven to the very bottom of the Earth,…if it were stopped half-way, it would give the consonance of the octave, which also occurs, as experience shows, on the instrumental monochord”. (Cited in GODWIN 1992, p.239). It is evident that Fludd was talking about symbolic (and impossible) representations but recognizing the experimental nature of the instrument.

[6] “… dautant que l’Vnison leur represente le sejour des Bien-heureuz, & la parfaite vnion des trois personnes diuines qui sont á l’Vnisson d’vne parfaite egalité”. (MERSENNE [1636] 1965.Vol II, Liure I des Consonances, p. 14).

Thus, is easy to verify how the monochord had sufficiently interesting behaviour to captivate philosophers throughout the history and especially, in Mersenne´s case, it is the only material, perceivable and experimental object that justified the tremendous title: *Harmonie Universelle*. We can say this because all the experimental demonstrations that the power of harmony can offer us are finally justified in this simple and vibrant box. As Peter Dear says,

> …the use of the monochord remained *the sole technique* [my italics] by which the intersection of ratios and musical intervals could be realized; without it, the ratios would have been meaningless. (DEAR 1988, p.142).

Hence the fact that from symbolic ratios of Fludd's imaginary monochord to the acoustical experiences using irrationals in Mersenne's real one, we have an only common conceptual and practical ground: the vibrant string in the resonant box. But not only this intersection of mathematical ratios and musical intervals is so important but the real fundamental basis for the whole corpus of harmonics remains in the aesthetic experience. The musical ratios are some kind of sonorous mathematics, but a beautiful one. The refined ear and the pleasant sounds are the final judges and the monochord as scientific instrument is the only place where this scientific-aesthetical practice could be experienced in both rational and empirical ways.

The Proposition XII.

Mersenne introduced the power of monochord in Proposition XII by stressing that the theoretical results provided in the preceding propositions were enough to provide the essence of the instrument:

> If one understands the preceding propositions, there is no need to explain the monochord here, inasmuch as I have discussed it so amply and exactly, that nothing more can be desired (it seems to me), unless it be that the performers think the discourse to be too speculative. The method of constructing it is seen at the end of the Fourth Proposition, where I have explained the harmonic rule of Ptolemy; nevertheless I am placing here a particular figure so as to come to terms with the practice and usage, so that there be no instrument maker or musician who does not comprehend it as well as I do and cannot restablish music by its means, even though it be lost and effaced from the memory of men.[7] (MERSENNE 1957, p.46).

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[7] "Si l'on entend les Propositions precedents, il n'est pas besoin d'expliquer icy le Monochorde, d'autant que i'en ay discouru si amplement & si exactement, que l'on n'y peut (ce me semble) rien desirer, si ce n'est que les Practiciens croyent que les discours en foient trop speculatifs. L'on void aussi la maniere de le construire sur la fin de la quatriesme Proposition, ou i'ay expliqué la regle harmonique de Ptolomèe; neantmois i'en mets encore icy vne figure particulaire, afin de m'accommoder tellement à la Practique & à l'vsage, qu'il n'y ait nul Facteur d'instruments ou Musicien, qui ne le comprenne aussi bien que moy, & qui ne puisse restablir la Musique par son moyen, encore qu'elle fust toute perduë & effacée de la memoire des hommes" (MERSENNE [1636] 1965.Vol III, Liure I, p.32).

The previous Propositions have shown a compendium of subdividing the string in a strictly mathematical-geometric mould and there is nothing explicitly material or sonorous in them. Mersenne aligns himself with the intellectual inheritance that had, from Boethius to Zarlino, paid attention to the monochord assimilated to a line, with all its abstract and geometric aspects. Nevertheless, Mersenne insists in offer a figure and a material object to guarantee the eternity of his science.[8]

This Proposition invites to pose this question: Can a material object or, only the figure of this one, reconstruct all the theoretical body of a science? Or, in other words: is theory so embodied in the materiality of a scientific instrument to hit you in the eyes when exerting its practice? This was undoubtedly the case for Mersenne when talking about the monochord, but without overstating we can say that Proposition XII shows a small but exquisite sample of

[8] Regarding the power of images displayed in his Book, Mersenne says: “It is certain that the shape of a musical instrument will aid greatly the imagination of the readers, and that they will understand more in a quarter of an hour than they would in a day without the help of these figures,…” [8] (MERSENNE 1957, p.15). “…il est certain que la figure des instruments de Musique soulagera grandement l’imagination des Lecteurs, & qu’ils en comprendront plus dans vn quart d’heure, qu’ils ne seroient dans un iour sans l’ayde desdites figures,…” (MERSENNE [1636] 1965.Vol III, Liure I, Preface au Lecteur, p. s/n).

scientific musical knowledge in early 17th century and, of course, the way Mersenne approaches it:

i. On one hand, we have the confidence in abstract and mathematical reasoning, that is to say, the speculative development of Pythagorean and Boethian lineage, which leads Mersenne to declare the figure of monochord unnecessary, and therefore, the material object in itself.

ii. On the other hand, Mersenne's awareness of practical and constructive aspects of experimental musical science induces him to grant this object such character and importance that is able to contain itself all the musical science.

Each position regarded the other with apparent disdain. Both approaches have an accumulation of musical truths and nevertheless, neither seems to need the other. Theory and practice unenthusiastically face each other. And the field of battle– or of concordance– is the monochord.

Anyway, we can ask these new questions: Which aspect is more relevant: the theoretical foundation, although susceptible to be considered "too speculative", or the adjustment to experiment and practice? Is it sufficient to understand the subdivisions on the abstract line to take control of all musical science and consider all reference to a material object unnecessary? Or, on the contrary, is the figure of the monochord so necessary as to consider it the master plan for all musical science? Finally: is this material object really the safeguard of this knowledge?

In order to try to answer the preceding questions we made two reconstructions: a virtual-digital one that could be handled in the computer and a material one that would allow us to calibrate the real sonorous dimension. Both reconstructions assume that the monochord was a scientific instrument and answer to necessity of creating devices and multimedia-interactive projects to reach a wider and deeper understanding of some aspects of 17th-century musical science.[9]

For those who enjoy recreating instruments or experiments from the history of science and delight in denying or refuting the results that the scientist arrived at, this experience will defraud them. As we have said, the monochord has almost twenty centuries confirming its truths: the string sounds in a consonant way according to the Pythagorean proportions 1:2, 2:3, 3:4, subsequently Ptolemy and, much later, Zarlino, Kepler and Mersenne - with reasons ranging from numerology, geometry and acoustic experience - granted the proportions

[9] Another example of multimedia and interactive projects in History of Science is *Harmonice Mundi, Book V: multimedia and interactve version 1.0*. It could be played on-line in this link http://www.prodi-online.com/cc/kepler/harmonicemundi.swf (Flash application, 29.2 mb).

4:5, 5:6, 3:8 and 5:8 as consonances.[10] For the suspicious rebuilder, there will be no surprises. If there are, they are somewhere else.

The virtual reconstruction.

First of all, the figure shown in Proposition XII was digitized and with a digital ruler[11] we verified the precision of its marks and the accuracy of the measuring ruler that Mersenne set at the right margin of the instrument. We were surprised by its inaccuracy. [Fig. 2]. Not only is the central octave mark not in the mid point but also differs in both outer strings. The rest of the marks are also slightly displaced. Therefore, it was necessary to rectify the image, rearrange the measuring ruler and "move" - digitally speaking - the marks to the exact position according to the numerical proportions that Mersenne indicated in the text. If we faithfully reconstructed the monochord by following Mersenne's figure, our ears would have immediately noticed the errors. It was not necessary to experience it. In spite of being considered so essential, the figure was simply badly drawn and neither the printer nor Mersenne himself noticed it, or if they did, Mersenne took no action to correct it, or wrote anything about it in his handwritten annotation in his own edition.

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[10] For a revision of history of consonance and harmonic *ratios* see BARBOUR (1951).

[11] Adobe Photoshop CS2 Version.

Once the image was rectified, we took on the virtual reconstruction. Using Macromedia Director Software we reconstruct not only the apparatus to be manipulated and listened to in the way Mersenne indicated, but also the process for its construction. This way, Proposition XII is read interactively while the monochord is being constructed step by step on the screen. We kindly request the reader to play the software on-line at this link,

http://www.calderon-online.com/mersenne/monochord_mersenne.htm

or download it following the links (for Mac and PC) mentioned here.

Mersenne explains the monochord and his technique following these stages:

i. Let the monochord be of whatever length or width as long as you use the figure and his marks as master plan.

ii. Set three strings of the same length determined by two fixed bridges and attach them at the top to an iron nail and below to a peg. Use strings preferably from a lute or a spinet.

iii. Use a small bridge under the outer strings and move it along to shorten the string and produce whatever consonance or dissonance or interval is wished. The middle string has no division and always represents the entire tone sounding open against all the divisions of the two outer strings.

iv. Use the pegs to bind and loosen and put the three strings in unison.

v. Play according to the marks the outer strings against the middle one to produce the intervals in this order: 9:10 minor tone, 8:9 major tone, 5:4 major third, 3:4 fourth, 2:3 fifth, 3:5 major sixth, 8:15 major seventh and 1:2 the octave. Play the rest of intervals which are replicas of precedent.

vi. Pay attention to interval 80:81 *comma*, produced between major tone and minor tone. It is marked only in the first octave.

Users may notice that tension is a variable that Mersenne did not contemplate playing with. In his previous Proposition IV he has renounced using weights suspended on strings to calibrate pitches because

> One would not know the ratio of the weights which are necessary to place the strings at all sorts of pitches, and then the strings themselves often raise or lower their pitch, although they be held with the same weights, and were they perfect equal, they would not keep the ratios of the pitches,…[12] (MERSENNE 1957, p.28).

Mersenne is aware of the complex variables that affect pitch on a vibrant string – humidity, temperature, dimensions and quality, etc. - therefore the string in his monochord continues being assimilated to a line which, after all, can not be tensed or tuned, not in the abstract and geometric universe of 17th-

[12] "..on ne sçauroit treuuer la raison des poids qui sont necessaires pour mettre les chordes à toutes sortes de sons: & puis les mesmes chordes haussent souuent ou baissent leurs sons, bien qu'elles soient tédües auec mesmes poids; & quád elles seroient parfaictement égales, elles ne garderoient pas la raison des sons..:" " (MERSENNE [1636] 1965.Vol III, Liure I, p.15).

century musical science. The tension and its association with pitch and frequency belonged to the acoustic era that Mersenne himself was contributing to create.[13]

Leaving aside the "tension" variable, Mersenne did incorporates the tone colour – timbre - as a variable to play with. He suggests using gut strings (as in a lute) or metal string (as in a spineta) and encourages us to compare the tone colour. In this case, materials cannot be reduced to the abstract and geometric universe, but Mersenne is a devotee of 17th music and its well known coloured range of sonorities and instruments.

Once the three strings are tuned in unison and the type of string selected, the user can fit the sonorous and mathematical values moving the bridge directly or entering numerical values. [Fig. 3] It is still possible to zoom in for greater precision. Finally, we have placed a guided visual summary, to locate all the proportions that Mersenne has investigated throughout his Propositions V to VIII: from proportion 1:2 to proportion 1:161. [Fig. 4].

Catch the minimal sonorous differences and do what Mersenne did reading him in a full multimedia way. If you like placing numbers freely according to some criterion and verifying consonant or dissonant character do not expect

[13] For history of frequency in music see: *Early Vibration Theory: Physics and Music in the Seventeen Century*. (DOSTROVSKY, 1975).

big surprises. Just do what natural philosophers had been doing since ancient times and throughout musical science history: to find the exact proportions for consonance sounds and to be moved by verifying this ancient law of science which establishes correspondence between a numerical value and a physical – and an aesthetic – reality.

In summary, the Software has permitted:

1. To set the monochord (based on a rectified and essential figure).

2. To tune the three strings in unison.

3. To displace the bridges and experience sonorous harmonic proportions and freely to discern the phenomenon of consonance and dissonance.

5. To consider the relation tension-length-timbre-sonority.

6. To ponder the judgments of Mersenne not in an exclusively geometric or speculative way but a sonorous one.

The material reconstruction

Mersenne wrote indications sufficiently precise to make a monochord similar to the one in his illustration although some of them, including size, strings, woods and ornament details were *ad libitum.* For this reconstruction, we contacted the luthier, Ramon Elias Gavernet[14] who accepted the invitation based on his love for antique instruments. In the same website the reader may download - or watch on-line - a video of this reconstruction, step by step, following Mersenne's instructions as accurately as possible. [Fig. 5]

Here is a summary of the material characteristics for this "standard" Mersenne monochord:

Size: Mersenne left dimensions up to the reader and the string in his figure was

> only seven and a quarter inches[15], which can be doubled and multiplied as many times as one wishes…[16] (MERSENNE 1957, p.47).

In Proposition V, he is more explicit. The monochord could be as much of 3, 6, 12 or 24 feet in length. He recognizes that these immense monochords

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[14] Ramon Elias Gavernet. Luthier. Qualified as a Technician and Specialist in Liutaio, 2003, from the I.P.I.A.L.L. Istituto Professionale Internazionale per l'Artigianato Liutario e del Legno "Antonio Stradivari" – Cremona, Italia. Gavernet has his workshop in Altet, (120 km from Barcelona, Spain). For contact: ramoneg@telefonica.net.

[15] The equivalence is 2.735 cm for a Mersenne's inch and 32.8 cm for a foot. (LENOBLE 1943, Section IV p.LXIII).

[16] "…seulement donné 7 pouces &1/4 de longueur de celle cy, que l'on peut redoubler &multiplier tant de fois que l'on voudra:…" (MERSENNE [1636] 1965.Vol III, Liure I, p.32).

could be used for all kinds of experiences and to extract all types of conclusion about the nature of sound. However,

> For if one wishes solely to note the pitch of the sounds and all their differences, it is enough to have a monochord of one, two or three feet.[17] (MERSENNE 1957, p.30).

We chose the monochord that best-suited our purposes. According to Mersenne's value of 1440 units in the right margin of the instrument[18], we decided to build a 72cm monochord. This number is a simple divisor of 1440 and allows the marks to be transferred easily. Besides, 72 cm is equivalent to 2.20 of Mersenne's feet and is also an average dimension for lutes, the most frequently played instrument at that time.

Materials: Mersenne indicates in Proposition V that even though any material could be used, the preference was for

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[17] "car si l'ont veut seulement remarquer le graue & l'aigu des sons, & toutes leurs differences, il suffit d'auoir vn Monochord d'vn, de deux, ou de trois pieds:…" (MERSENNE [1636] 1965.Vol III, Book I, p.17). Mersenne indicated that his figure corresponds to a Diatonic monochord, but he assure having played a 4 feet monochord and due to its dimension is possible to experiment with "the three genres [Diatonic, Chromatic and Enharmonic] perfectly". (MERSENNE [1636] 1965.Vol III, Book I, p.34).

[18] In Proposition XII Mersenne uses the number 1440 to ease the building and calculations of mathematical proportions providing a sequence of entire numbers that matches the harmonic proportions. In Proposition IX, more abstract and speculative, he uses a larger number: 3600.

> …the fir, cedar and other resonant woods, of which are made lutes, viols and the other instruments. [19] (MERSENNE 1957, p.30).

Following these indications, fir was selected for the sides and top, and cedar for the bottom. The pieces were glued using parchment strips as Mersennes briefly describes for the construction of Lutes and following contemporary process of 17th century.[20]

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In order to obtain the best resonance, Mersenne suggests to

> …make some opening on the table or at the sides of the monochord, similar to the rose of the lutes, or the sound-holes of the harps or the viols.[21] (MERSENNE 1957, p.48).

In line with this, the luthier made a design of his own resembling holes of other instruments shown in Mersenne's book. [Fig. 6-7]

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[19] "…le sapin, le cedre, & les autres bois resonants, don't l'on fait les Luths, les Violes, & les autres instruments". (MERSENNE [1636] 1965.Vol III, Liure I, p.17).

[20] See Proposition II of Second Book of the Book on Instruments. (MERSENNE [1636] 1965.Vol III, Liure II, p.49).

[21] "…l'on peut faire quelque ouerture sur la table, ou aux costez du Monochorde, semblable à la rose des Luths, ou à l'ouye des Harpes ou des Violes,…" (MERSENNE [1636] 1965.Vol III, Liure I, p. 34).

Strings: Mersenne indicates that any kind of string can be used, but in his Proposition V he recommends that

> those of brass or steel are better than those of gut, in that they are not so subject to so many alterations and changes... [22] (MERSENNE 1957, p.30).

But, later adds,

> …whether one makes them of the intestines of sheep or of brass, for it is of no importance,…[23] (MERSENNE 1957, p.48).

For our reconstruction, we decided to use gut strings such as would fit into a lute of similar dimensions and the tensions it would be submitted to so that it produced an average sound of a G at 196,00 Hz (G3, G key in the third octave of the piano). Following Mersenne`s figure, these strings were fixed to an iron

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[22] "…mais celles de leton ou d'acier sont meilleures que celles de boyau, d'autant qu'elles ne sont pas suiettes à tant d'alterations & de changement,…" (MERSENNE [1636] 1965.Vol III, Liure I, p.17).

[23] "…soit qu'on les fasse d'intestins des moutons ou de leton, car n'importe nullement..:" (MERSENNE [1636] 1965.Vol III, Liure I, p.32). Mersenne gives us one reason for using gut strings: "are easily available because the great number of sheeps that are killed every day". See (MERSENNE [1636] 1965.Vol III, Liure I, p.32).

nail (typical of spinets) and pegs. The bridges and pegs were typically made of ebony. [Fig. 8]

Support: As an additional element, the luthier elaborated a pair of legs that serve as support for the instrument to allow the maximum resonance. These legs were made in the "French" style with its curvature and inclined cuts.

Finish: Although Mersenne did not mention it, transparent varnish with a minimum touch of colour was applied.

Once the instrument was built, the figure – with the rectifications mentioned above - was enlarged to 72 cm and printed in a transparent sheet in order to place it easily on the top of the monochord. Without affecting the loudness of the instrument – and its naked materiality – this transparent sheet serves as a guide and can be interchanged with others allowing comparisons of several subdivision of the string. [Fig. 9].

Playing the monochord and hearing the infinite.

Once tuned to unison the three strings and the transparent sheet placed perfectly with its marks, the performing of the monochord brought not surprise, but delight[24]. The octave is heard as the perfect consonance, and also fifths and fourths. The thirds and sixths show their consonant sound to our well-trained and contemporary ears. The differences between the minor and major tones and the comma are perfectly audible and recognizable. The high pitches are less resonant than low ones but discernible. In summary, Mersenne's monochord works. If we remove the transparent sheet, it would be easy to reconstruct the consonances and harmonic *ratios* through the fact of their own sonorous nature. There have been no surprises, only what we could call hearing the "infinite". It means that the bridge's displacement is so easy that once the string is plucked, if we move the bridge, the infinite succession of sounds will be heard so perfectly whether shortening or enlarging the string's vibrant length. [25]

Mersenne had already expressed the existence of this kind of "infinite" when talking about music of viols and violins.

[24] In the above mentioned link there is a video of a simple performing.

[25] In practical music this effect is called *portamento* and consists of a smooth glide from note to note in a continous way. In polyphonic music from 16th to 17th century was used as an embellishment effect in human voice and non-fretted instruments like violin and viols.

> For as there is an infinity of sounds between the low and the high there is, in a parallel fashion, an infinity of colors between black and white.[26] (MERSENNE 1957, p.27).

Later, adds

> …the violin….contains all imaginable intervals which are in potency on its neck, in such way similar to the primal matter, capable of all forms and figures, having no point on violin's fingerboard which can not produce a particular tone: thus, it is concluded that it [i.e. the fingerboard] contains an infinity of different tones, similar to string, or line that contains an infinity of points, therefore it could be denominated *Harmonie vniverselle*. [27]

Thus, we can see how Mersenne handles this concept of infinity associated to sound, color, geometry and therefore, our consideration, here called as an audible "infinite" lead us to conclude that, for Mersenne, the string was a

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[26] "..car comme il y a vne infinité de sons moyens entre le graue & l'aigu, il ya pareillment vne infinité de coluleurs entre le blanc & le noir". (MERSENNE [1636] 1965.Vol III, Liure I, p.15).

[27] "...le violon…contient toutes les interualles imaginables, qui son puissance sur son manche, lequel est semblable à la premiere matiere capable de toutes formes & figures, n'y ayant nul point sur la touche d Violon qui ne fasse vn son particulier: d'où il faut conclure qu'elle [i.e. la touche] contient vne infinité de sons differents, comme la chorde, ou la ligne contient vne infinité de points, & consequemment qu'elle peut estre appellé *Harmonie vniverselle*. (MERSENNE [1636] 1965.Vol III, Liure IV, pp.180-1).

continuum with all its infinity and – as we will see immediately - there are not forbidden places for the bridge and therefore for tones.

The preceding condition was required for his subsequent Proposition XIV which talks about "another monochord" - “more useful and easier” - in this case, set in equal temperament.[28]

The divisions for this monochord consist of eleven irrational proportional media included between number 200,000 and 100,000. [Fig. 10] These media are presented according to the numbers calculated by Monsieur Beaugrand[29] and their contemporary notations are shown here. [Fig. 11]

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[28] Equal temperament signifies to subdivide the string in twelve geometric proportional media with no numerical difference between tones and semitones. There were not exact mathematical and numeric methods for creating this division except approximations and the geometrical and wooden instrument called *Mesolabium* [See Zarlino, *Sopplimenti musical,* Lib. IV, cap.30, p.209]. Mersenne won’t use the *Mesolabium* for this subdivision but recognizes that easiness is to be paid by mathematics – to calculate irrationals numerical proportional media – , thus he warns us about “the greatest precision that can be imagined” which has been set in this new resolution of the instrument (MERSENNE 1957, p.52). “…un autre monochord plus vtile & plus aysé, c’est pourquoy ie le mets icy dans la plus grande iustess que l’on puisse l’imaginer”. (MERSENNE [1636] 1965.Vol III, Liure I, p.37).

[29] Beaugrand, Jean, (1595-1640). French mathematic close to Mersenne. He referred to him as “tres-excellent Geometre”. (MERSENNE [1636] 1965.Vol III, Liure I, p.37)

Mersenne displays no specific figure for this monochord - only the numerical table in Fig. 10. Nevertheless, we constructed a new transparent sheet - the "irrational" sheet - as precisely as possible to use on the previous monochord. [Fig.9]. When executing this equal-tempered monochord, we can agree with Mersenne that its division "does not offend the ear and there is no necessity to speak more of it"[30]. Mersenne, with only turning a page, eliminated centuries of discussions on harmonics and accepted the equal temperament – as later western ears will do - on the basis of the audible experience, the irrationals and the consideration of the string as a sonorous continuum with infinite positions.

Conclusion.

Once Mersenne finished his explanation on both monochords, his next Propositions were aimed to quantify the force applied to strings, to count vibrations and to calculate tension considering weights, thickness, length, and all physical characteristics of vibrant string. Mersenne did modern science - mathematical and experimental - in order to construct "the first determination of the absolute vibrational frecuency of a tone". (DOSTROVSKY, 1975).

[30] "…sans offender l'oreille: dont il nést pas besoin de parelr plus au long," (MERSENNE [1636] 1965.Vol III, Liure I, p.41).

However, this new task was independent of the aesthetic phenomenology. Nothing in these final Propositions refers to the pleasure or beauty of sound. Mersenne’s interest was the naked physical fact of vibrant string and so the antique harmony took steps towards modern acoustics. This disregard for sensitive experience - the non-aesthetic way - could be summarized in his “Deaf Man`s Tablature” which declares that a deaf person can tune the lute, the viol, the spinet and other stringed instrument and get the sounds he would like, if he knows the length and thickness of the strings.[31]

As we can see the monochord has served as an empirical base for the birth of this new musical science. The quantification of the musical effects like physical realities, and not exclusively aesthetic, can be considered one of the great contributions of music to scientific growth in the 17th century. Mersenne’s monochord - using Crombie's words – indeed has “tailored” metaphysical speculation and quantifiable experience- testable and soluble - . Looking for the reasons to pleasure, sounds connected sensitive world with intelligible one through the material nature of an object. Once the pleasure has been satisfied, the emotions adjectivally qualified and the affection stopped, modern scientific research unfolds. In this process, the monochord has appeared as an insistent backdrop, and in the case of

[31]“Un homme sourd peut accorder le Luth, la Viole, l’Epinette, & les autres instruments à chorde, & treuuer tels sonts qu’il vodra, s’il cognoist la longueur, & la grosseur des chordes…” (MERSENNE [1636] 1965.Vol III, Liure III, p.123).

Mersenne’s wooden box simultaneously has become – to my surprise - in cradle of the modern science of acoustics and sarcophagus for harmony’s philosophical ambitions and all its metaphysical derivations.

REFERENCE LIST

- ADKINS, C (1963). Ph Diss *The theory and practice of the monochord*, University of Iowa.

- BARBOUR, J. M. (1951). *Tuning and Temperament: A Historical Survey*. East Lansing. Michigan State College.

- COHEN, H. F. 1984. *Quantifying music: The science of music at the first stage of the scientific revolution.* Dohrdrecht, Holland: Kluwer Academic Publishers

- CROMBIE, A. 1994. “Science of Music” in *Styles of scientific thinking in the European tradition.* Vol. 3. London Duckworth.

- DEAR, P. 1988. *Mersenne and the Learning of the Schools*. Cornell University Press, Ithaca.

- DOSTROVSKY, S. “Early vibration theory: Physics and music in the Seventeen Century”. In *Archive for History of Exact Sciences* 1975, **14**. pp.169-218.

- DRAKE, S. (1970) 1999. “Renaissance Music and Experimental Science” in *Essays on Galileo and the History and Philosophy of Science*. Selected and introduced by SWERLOW, N. and LEVERE, T. University of Toronto.

- GODWIN, J. 1992. Editor. *Harmony of the spheres: a sourcebook of the pythagorean tradition in music*. Inner Traditions, Rochester.

- HERLINGER, J. 2002. “Medieval canonics” en *The Cambridge History of Western Music Theory* Edited by Thomas Christensen. University of Chicago.

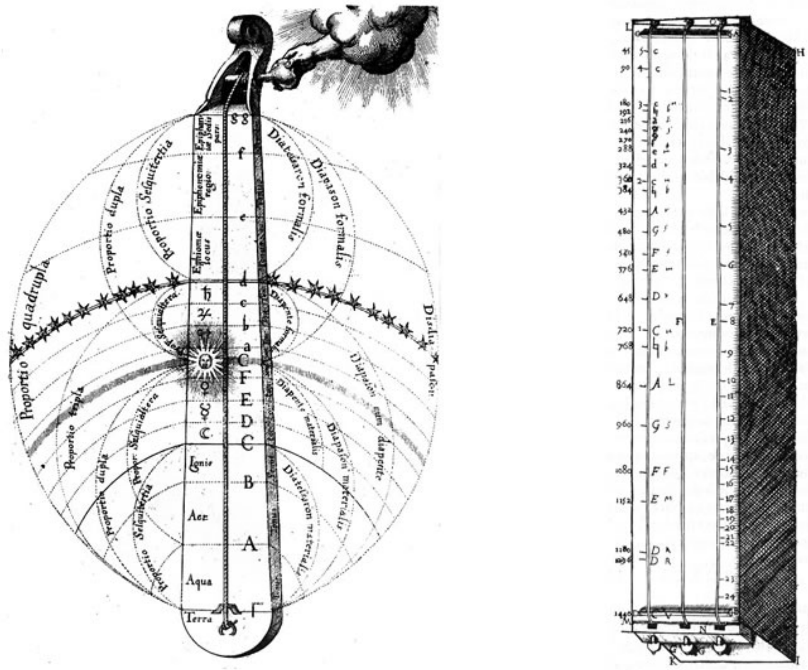
- LENOBLE, R. (1943) 1971. *Mersenne; ou, la naissance du mécanisme*, Vrin, Paris, 1971.

- LINDSAY, R. B. (1972). *Acoustics: historical and philosophiocal development.* Stroudsburg, Pennsylvania Dowden, Hutchinson and Ross.

- MERSENNE (1636) 1965, M. *Harmonie Universelle, contenant la theorie et la pratique de la musique*, 3 vols. (Paris: Sebastien Cramoisy, 1636; reprint ed., Paris: Centre national de la recherche scientifique.

- MERSENNE (1957). *Harmonie Universelle.* The Books on Instruments. Translated by R. Chapman. Martinus Nijhoff. The Hague.

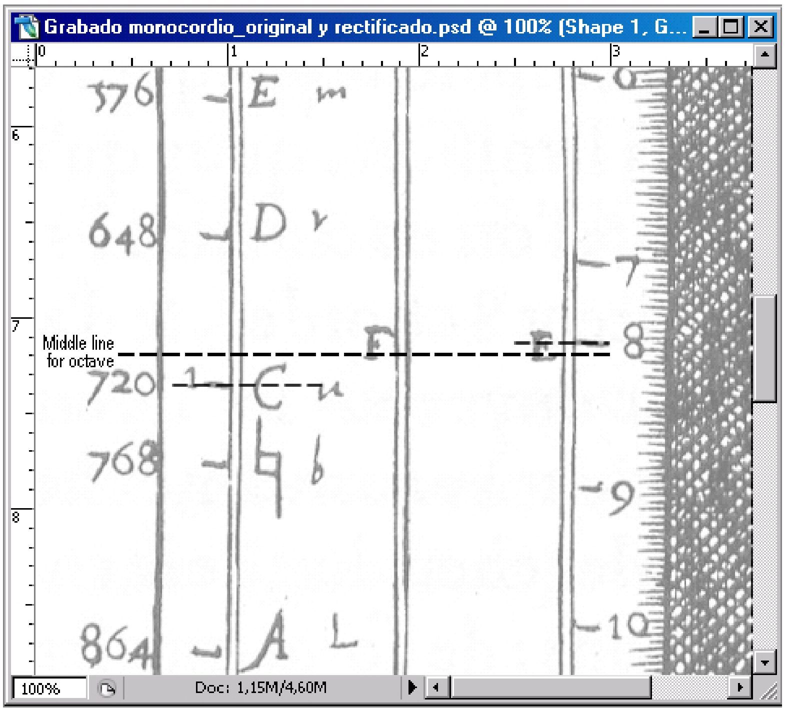
IMAGES LIST



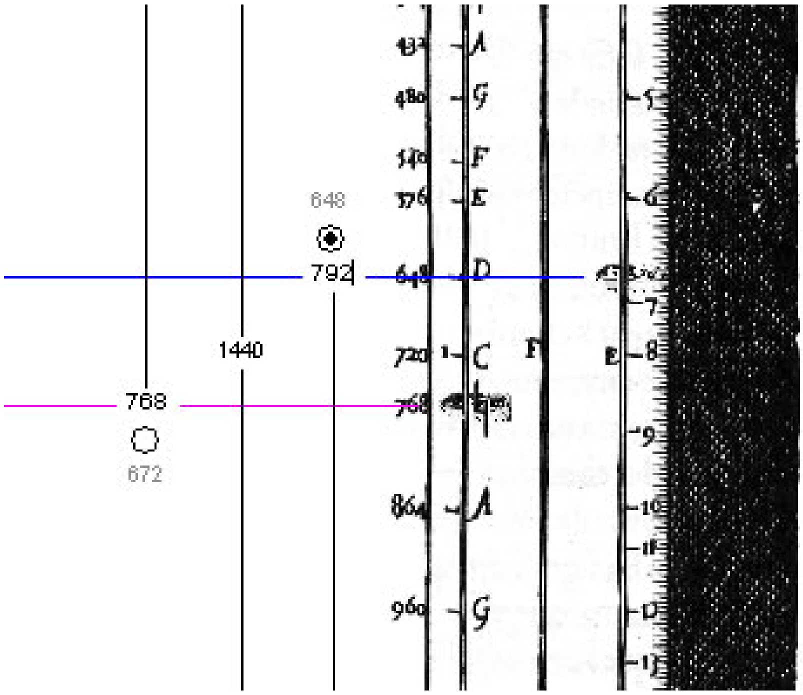
Robert Fludd 1617

Marin Mersenne 1636

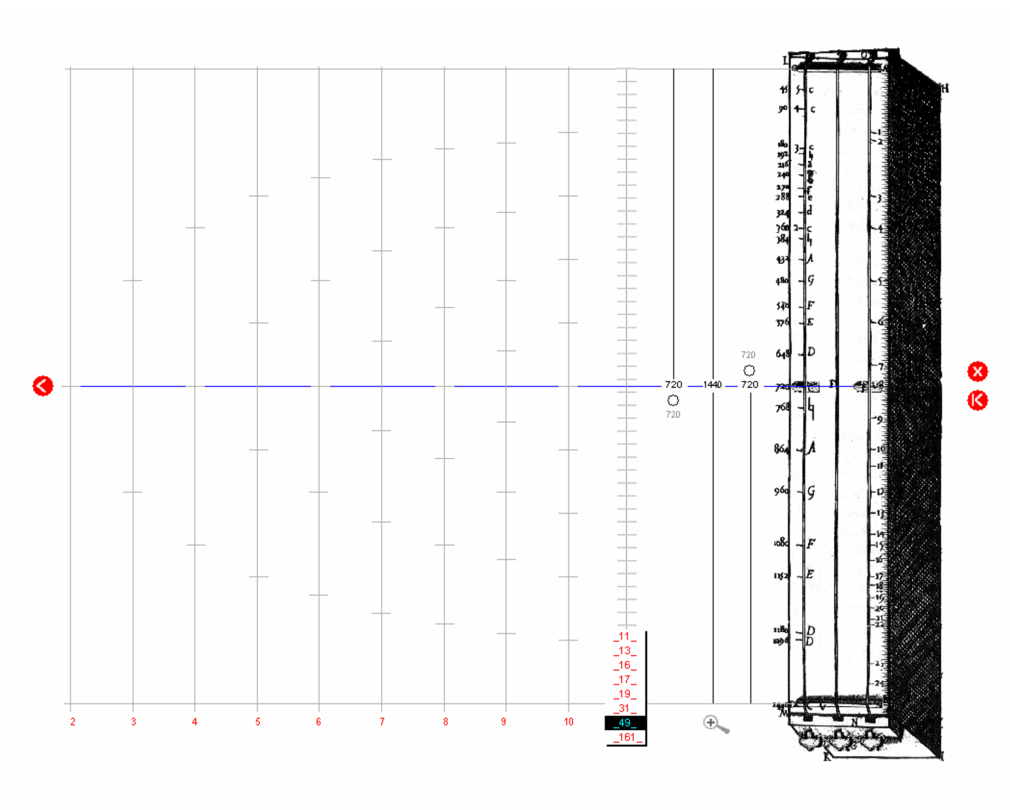
[Fig. 1]



[Fig. 2]

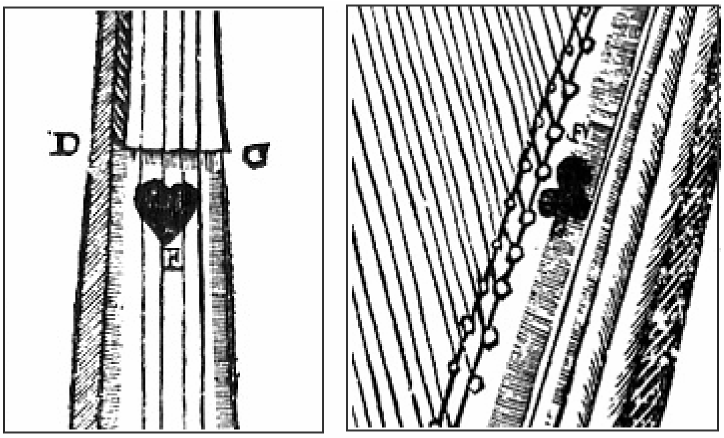


[Fig.3]



[Fig. 4]

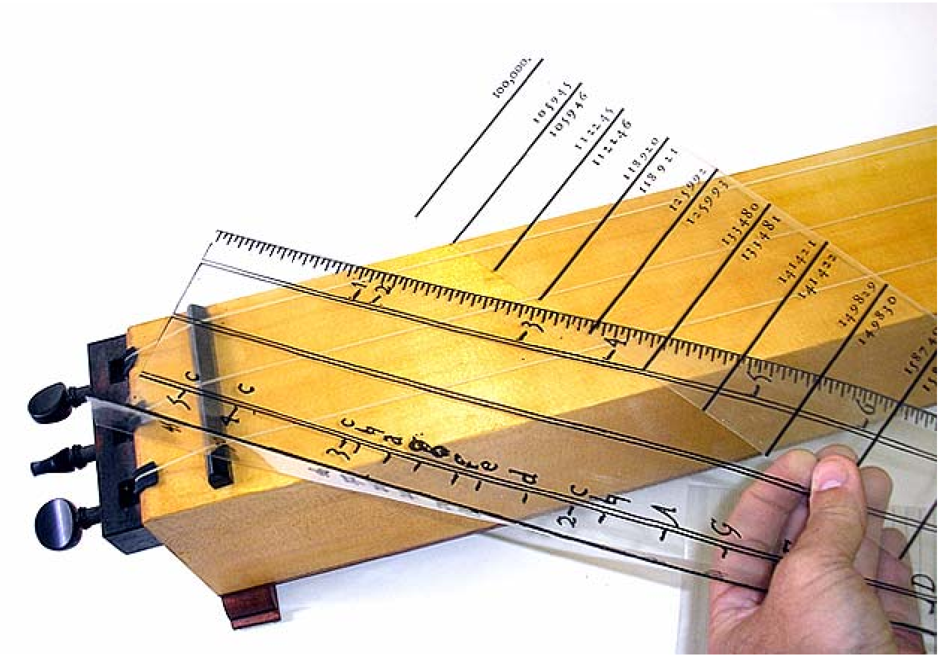
[Fig. 5]



[Fig. 6]

[Fig. 7]

[Fig. 8]

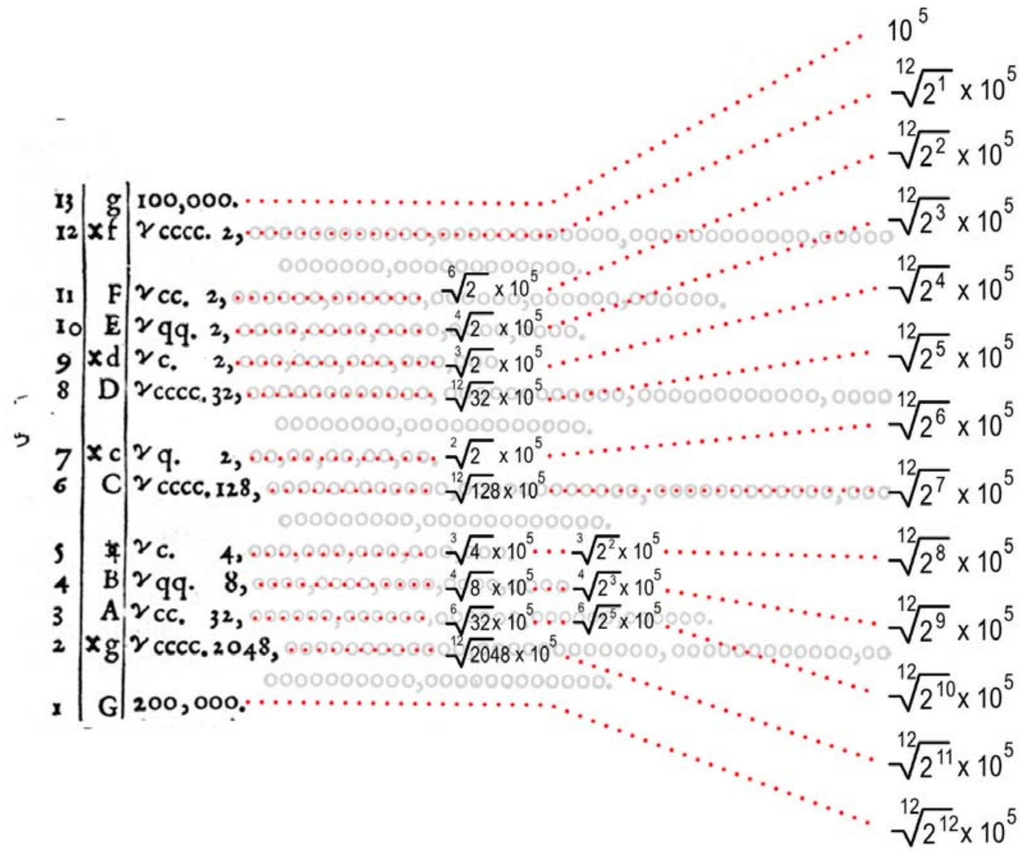


[Fig. 9]

Monochorde ou Diapaſon des touches

I	II	III	IV	V
a	100,000.	c.	100,000.	n
✕g	105946	♮	105945	m
G	112246	b	112245	l
✕f	118921	A	118920	k
F	125993	✕g	125992	i
E	133481	G	133480	h
✕d	141422	✕f	141421	g
D	149830	F	149829	f
✕c	158741	E	158740	e
C	168179	✕d	168178	d
♮	178172	D	178171	c
b	188771	✕c	188770	b
A	200,000.	C	200,000.	

[Fig. 10]


13 g 100,000.
12 x f ♈ cccc. 2,
11 F ♈ cc. 2,
10 E ♈ qq. 2,
9 x d ♈ c. 2,
8 D ♈ cccc. 32,
7 x c ♈ q. 2,
6 C ♈ cccc. 128,
5 ♈ c. 4,
4 B ♈ qq. 8,
3 A ♈ cc. 32,
2 x g ♈ cccc. 2048,
1 G 200,000.
10^5
$\sqrt[12]{2^1} \times 10^5$
$\sqrt[12]{2^2} \times 10^5$
$\sqrt[12]{2^3} \times 10^5$
$\sqrt[12]{2^4} \times 10^5$
$\sqrt[12]{2^5} \times 10^5$
$\sqrt[12]{2^6} \times 10^5$
$\sqrt[12]{2^7} \times 10^5$
$\sqrt[12]{2^8} \times 10^5$
$\sqrt[12]{2^9} \times 10^5$
$\sqrt[12]{2^{10}} \times 10^5$
$\sqrt[12]{2^{11}} \times 10^5$
$\sqrt[12]{2^{12}} \times 10^5$

[Fig. 11]