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The pitch relationships of Venetian string keyboard instruments

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Introduction

The history of the early Italian string keyboard instrument is largely the history of Venetian instruments since they are those which have survived in the largest numbers. Following the writings of Russell and Shortridge, the question of Italian instruments being made at pitches so as to facilitate transposition was still a topic of active discussion in 1978 when Arthur Mendel, a researcher on the subject of pitch, made his last report[1]. Mendel summarised the work of specialists and reported the «whole spectrum of scales» which John Barnes had found[2]. When Andrew Parrott wrote his influential essay in 1984 on transposition in the Monteverdi vespers, the history of the Italian harpsichord was «still rather obscure»[3]. In the *New Grove Dictionary of Musical Instruments* (1984) under «Harpsichord» I reported some of my work in progress on Italian instruments and the paperback version which appeared in 1989 refined these views[4]. These writings, and Grant O'Brien's short review of Italian instruments in 1990 did

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[1] Raymond RUSSELL, *The Harpsichord and Clavichord*, London 1959, [2]1973, Faber, pp. 31-32; John SHORTRIDGE, *Harpsichord-Building in the 16th and 17th Centuries* in «United States National Museum Bulletin», no. 225, paper 15 (1960, [2]1970), pp. 93-107; Arthur MENDEL, *Pitch in Western Music since 1500 - A Re-examination* in «Acta Musicologica» L (1978), pp.1-93 and 328.

[2] A. MENDEL, op. cit. (in note 1), pp. 46-47.

[3] Andrew PARROTT, *Transposition in Monteverdi's Vespers of 1610* in «Early Music» XII 1984, p. 495.

[4] Denzil WRAIGHT, *Harpsichord* in *The New Grove Dictionary of Musical Instruments*, ed. Stanley SADIE, London 1984, Macmillan Publishers; idem, *The Harpsichord* in *The New Grove Musical Instruments Series, Early Keyboard Instruments,* ed. Stanley SADIE, London 1989, Macmillan.

much to remove the obscurity with which Parrott had to grapple[5], but it was not until more recently that I was able to report in more detail the results of extensive studies which substantially increase the amount of information available on Italian harpsichords, virginals, and clavichords and thereby remove some of the earlier uncertainties[6].

My purpose in this article is to describe the pitches of instruments made in Venice; this task rests on foundations which have been laid in my dissertation. It is outside the scope of this article to discuss in detail the difficulties surrounding the estimation of the pitch of individual instruments, but it would not be helpful to launch the reader into the deep end of these waters without some idea of the problems I have seen and the solutions I have offered.

My current catalogue contains 751 Italian harpsichords, virginals, and in lesser number, clavichords. Some 102 dated or attributed harpsichords between 1515 and 1650 are known, with 169 virginals, and 10 clavichords from the same period. I describe these figures as «approximate» for the reason that many unsigned, unattributed and undated instruments do not appear in my list of dated instruments, but nevertheless comprise a substantial part of the œuvre to be investigated. For example a further 25 unidentified polygonal virginals may have been made before 1600. Thus, the total number of instruments made before 1650 which have survived may be about 300.

Previous discussions of the problems of assigning a pitch to individual instruments concerned themselves with only a fraction of the total number of known instruments. It is not hard to see why: there has been no catalogue of Italian instruments and even the doughty Boalch, and its 3rd edition recently edited by Charles

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[5] Grant O'BRIEN, *Ruckers: A Harpsichord and Virginal Building Tradition*, Cambridge 1990, Cambridge Univ. Press, pp. 16-20. Many of O'Brien's views had been formulated in the early 1980s in some unpublished manuscripts, which I saw.

[6] Denzil WRAIGHT, *The stringing of Italian keyboard instruments c.1500 - c.1650*, Ph.D. dissertation, Queen's University of Belfast 1997 (UMI order no. 9735109).

Mould[7], concerned itself only with signed or attributed work, which is only half of that known. The practical problem of acquiring information on instruments scattered mostly throughout Europe and north America has meant that even the combined efforts of the authors Shortridge, Barnes, Thomas & Rhodes, and van der Meer (up to 1968) reported on only 43 of the 282 instruments I have listed as having been made before 1650[8].

On top of this problem of selection and access have been the difficulties presented by the alteration of instruments. John Barnes was instrumental in drawing attention to the modification of instruments which had obscured the **original** condition. A few errors resulting from not knowing the original string lengths are also present in the above-mentioned authors' work. The widely accessible book by Hubbard is more seriously flawed, coming as it did before Barnes' work; of the 15 scales given before 1600 only one is correct and one still undecided[9].

Thus it was that I saw the first task to be that of compiling a complete list of Italian instruments, separating the incorrect or falsified inscriptions from original ones, attributing unsigned work to a maker, and ascertaining accurate information about the original string lengths. Some 89 instruments have been attributed (with varying degrees of probability) to makers out of the total of 282 listed from before 1650. As may be expected, in many instruments it has not been possible to determine the original string lengths or attribute the instrument to a maker, but nevertheless we now know

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[7] Donald BOALCH, *Makers of the Harpsichord and Clavichord 1440-1840*, ed. Charles MOULD, Oxford [3]1995, Oxford Univ. Press.

[8] John BARNES, *Pitch Variations in Italian Keyboard Instruments* in «Galpin Society Journal» XVIII (1965), pp. 110-116; J. SHORTRIDGE, op. cit. (in note 1), pp. 93-107; W.R. THOMAS and J.J.K. RHODES, *The String Scales of Italian Keyboard Instruments* in «Galpin Society Journal» XX (1967), pp. 48-62; John H. VAN DER MEER, *Harpsichord Making and Metallurgy - a Rejoinder*, ibidem, XXI (1968), pp. 175-178.

[9] Frank HUBBARD, *Three Centuries of Harpsichord Making*, Cambridge, MA 1965, Harvard Univ. Press, p. 38. Readers should note that Hubbard measured the **short** string of two-register instruments, which makes comparison with single-strung harpsichords or virginals inaccurate.

the original scales of about 60% of the harpsichords built before 1650. In about 20% of the remaining harpsichords the original string lengths cannot be established, and the remaining 20% is accounted for by instruments whose location is not known or which have not yet been examined. In the case of the virginals and clavichords the results are more complete: about 80% of the original string lengths have been established. Thus, a substantial improvement on our previous state of knowledge has been achieved and it is on this new material that this article is based. There is now sufficient string length data to list 62 instruments by makers known to have worked in Venice (see Tables 2 and 3 below).

Determining the pitch of a string keyboard instrument

In order to be able to infer a pitch for an instrument from the string lengths one must be able to ascertain several details:

(1) The type of string material used.

(2) The tensile strength of the wire used.

(3) The stressing of the wire relative to the breaking point.

1. The type of string material used

The string material to be employed for an Italian instrument, is, in my view, not uniquely related to any one feature alone, such as compass, scale, or type of instrument. In this respect my solution of the problems of stringing Italian instruments diverges from most of what has previously been written, although it is in close agreement with many of the conclusions published by Grant O'Brien, albeit sometimes for different reasons[10]. My solutions suggest the use of stringing materials in the following way:

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[10] G. O'BRIEN, op. cit. (in note 5).

Iron stringing (with a change to yellow brass, and possibly also red brass, where the scale permits)

- Most long-scaled (i.e. c^2 = c.300-350 mm) harpsichords. These are usually of 16th-century origin, often with a 4'.
- Most virginals, whether polygonal or rectangular.
- Some exceptional harpsichords with longer scales (c^2 = c.400 mm.
- Most clavichords with scales c^2 = c.180-240 mm.
- Some harpsichords and virginals with c^2 = c.240-280 mm.
- Octave virginals whether polygonal, rectangular, or trapezoidal where c^2 = c.170-180 mm.

Brass stringing (possibly with red brass for the last few notes)

- Many harpsichords after 1600 with scales of c^2 = c.260-280 mm.
- Some virginals, either polygonal or rectangular where c^2 = c.280 mm.
- Possibly some clavichords e.g. Leipzig no. 3, with c^2 = 199 mm[11].

It should be noted that following these suggestions the majority of 16th-century instruments were iron strung.

2. The tensile strength of the wire used.

The second question, relating to the tensile strength of wire has been answered by the testing of some samples of old wire and modern replica wire[12]. This work suggests that modern, hard-drawn brass wire (75% copper, 25% zinc) shows similar tensile strength to that found in old samples and is a useful guide to what was possible in former times. Thus we find that 0.305 mm brass wire at a pitch of a^1 = 415 Hz and using a scale of c^2 = 282.5 mm stands at about a whole tone to a minor third below its breaking

[11] Musical Instrument Collection, University of Leipzig.

[12] Some of this testing work has been undertaken by Malcolm Rose and has not yet been published. See note 13 for further details where the work is reported.

point. A sample of old wire of similar size which has been tested would show (under the same conditions of use) only a semitone margin of safety, but this sample was at the weaker end of the range of wire tested[13]. Depending on the scale design, it can be this size of wire at about tenor c which is the most highly stressed in an Italian harpsichord, not the wire in the treble. Thicker wire (suitable for the tenor and bass) also tends to have a slightly lower tensile strength than the wire used in the treble of the instrument, for which reason one cannot pay attention simply to the strength of wire used in the treble of an instrument in order to determine the maximum possible pitch.

Thus, it is technically possible for a brass wire to be used at a pitch of a^1 = 415 Hz when the scale is about c^2 = 285 mm. Iron wire strings 6/5 longer than this scale (i.e. c^2 = 342 mm) would also be usable at the same pitch. It is the brass strings which would probably be the more likely to rupture in a mixed iron/brass stringing, therefore my attention has been directed more to brass wire.

3. The stressing of the wire relative to the breaking point

This is the question which is the hardest to answer. There is evidence which shows that the string lengths which were used were intended for a specific pitch and were not meant to be tuned to any arbitrary pitch. However, it is by no means easy to present this evidence is such a fashion that a panel of non-specialists could come to a unanimous verdict. We should recall that even earlier discussions between specialists failed to produce a concensus. The evidence comes partly from documentary sources, from restorations, but also from the string lengths themselves.

Documents recommend that strings should be highly tensioned, and that a safety margin of **at least** a semitone should be maintained. Thus, a close relationship between string length and pitch is

[13] I have dealt with these matters of the wire strength in more detail in *Principles and Practice in Stringing Italian Keyboard Instruments* due for publication in «Early Keyboard Journal» XVIII (2000) in press.

established, but documents alone cannot really resolve the whole problem for us[14].

The alterations made to some harpsichords show that the string lengths were shortened in order to permit the raising of the pitch of an instrument by only a semitone. If the margin of safety of the wire before breaking had been substantial, then such a procedure would have been unnecessary.

A third source of information is a group of harpsichords made by Cristofori, Ferrini, Solfanelli, and unknown maker, and also a virginal by Antegnati which used two sets of bridges, intended for brass and iron strings at the same pitch. These instruments conveniently disclose that the length relationship between brass and iron wire was close to 5:6, which corresponds to the interval of a minor third.

It would stray too far from my main objective in this article to discuss the technical details involved in establishing the conclusions I am presenting[15]. Instead I would like to draw attention to the fact that until recently our estimation of Italian instruments has depended upon much misleading information. As I indicated previously, one of the preliminary tasks I envisaged was the removal of such inaccuracies.

What I see as a fixed relationship between string length and pitch is not in agreement with the views expressed by some earlier authors, such as, for example, John Shortridge[16]. However, the data which is now available suggests much more uniformity in the use of string lengths than did the data which Shortridge was able to collect. Thus, his earlier view would probably not have arisen if the present data had been available.

In 1990 Grant O'Brien wrote:

> *The early builders of virtually all European traditions designed their instruments so that the strings were, with a small safety fac-*

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[14] I have discussed these in detail in my thesis, see D. WRAIGHT, op. cit. (in note 6), Part 1, chapter 1, section IV.

[15] See ibidem.

[16] J. SHORTRIDGE, op. cit. (in note 8), p. 103.

> *tor, very close to the breaking point of the material being used. Instruments designed to sound at pitches different from one another would therefore have string lengths which differed in a regular way*[17].

I believe this statement is likely to be substantially correct, but it is hard to **prove,** and if one sets the standards of proof high enough, it is impossible to prove. It has certainly not yet become the concensus view and for this reason I am devoting a little more space to considering the difficulties involved.

This aspect goes to the very heart of keyboard instrument making, namely how the string lengths were designed. It reveals much about the way an instrument maker thought of the physical realities of sound and its production. It might be supposed that because we have three variables which affect the pitch of a string (or even only two once we have established which string material we will use) that it cannot be possible to determine the intended pitch of the string in a given instrument[18]. This is correct if we simply view the problem as that of a mathematical equation. However, it is more than that; it is the practice of a craft tradition.

If we approach this problem from the craft traditions of the organ and clavichord, which exemplify two of the oldest types of keyboard instrument, then it becomes clear to us that the whole method of laying out a **fretted** clavichord indicates a clear relationship between string length and pitch. This is illustrated by Ar-

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[17] G. O'BRIEN, op. cit. (in note 5), p. 17.

[18] See John Henry VAN DER MEER writing in the current MGG (1995) *Cembalo* p. 497: *Italienische Cembali mit kleinen Mensuren sind transponierende Instrumente; auch besonders große Mensuren kommen vor. Ob es sich in solchen Fällen etwa um Unterquart-, Oberquint- oder Oberoktavcembali handelt, ist nicht endgültig zu entscheiden. In der Taylorschen Formel sind in diesem Fall zwei unbekannte vorhanden: die Stimmtonhöhe und das intendierte Saitenmaterial.*

Translation: «Italian harpsichords with short scales are transposing instruments; especially long scales also occur. Whether in such cases we are dealing with lower fourth, upper fifth or upper octave harpsichords cannot be definitively decided. In Taylor's formula there are **two unknown factors**: the pitch and the intended string material.» [my emphasis] naut de Zwolle's instructions for the clavichord which use a string division starting from an organ pipe length[19]. It is only when when we consider unfretted clavichords and virginals or harpsichords that the technically necessary relationship between string length and pitch no longer holds. This need not lead us to suppose though that there is now **no** fixed relationship between string length and pitch. The nature of the relationship between the length of a pipe and its speaking pitch is such an obvious physical constraint for the organ maker, or any wind instrument maker, that they could not question the fixed relationship. When we recall that some of the most renowned Venetian string keyboard instrument makers also made organs, Vito Trasuntinis and Domenico da Pesaro, to name but two, then we can ask if it is really plausible to suppose that they thought of a fixed relationship between pipe length and pitch as organ makers, but abandoned this way of thinking when it came to making string keyboard instruments.

The problem we are dealing with here in understanding what relationship was intended by the old makers between string length and pitch is, I suggest, a modern one since in the 20th century we have come to a re-examination of the products of a craft tradition (that of harpsichord making) without having had training in that tradition. Viewed from a social perspective, the modern Anglo-American craft tradition, which has supplied some of the leading researchers, has usually been the history of a few pioneering, self-taught individuals, rather than the unbroken craft traditions one can find more easily in, for example, organ making in Germany. This is, of course, not to criticise those who previously came to different conclusions; it is merely to explain the factors which conditioned the answers they found. This research into instruments, of which mine is only a small part, is always a cooperative effort, drawing upon the efforts of those who have gone before us.

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[19] G. LE CERF and E.-R. LABANDE, *Les Traités d'Henri-Arnaut de Zwolle et de divers anonymes*, Paris 1932, Picard; reprint with comments by François LESURE («Documenta Musicologica», 2nd series, IV), Kassel 1972, Bärenreiter, Plate IX.

How could we decide if instrument makers always intended a fixed relationship between the string lengths they used and the intended pitch? The sobering truth is perhaps that in the absence of signed affidavits from the old makers we will not. However, I believe that if we can show **not only** that a single maker produced instruments with consistent string lengths, but that **other makers** in the same area did as well, then I think we have established a strong **prima facie** case for a degree of organisation in the use of certain string lengths for specific pitches. Grant O'Brien has already shown with his detailed study of the Ruckers' instruments the relationships of sizes and regularity of design[20]. The Venetian instruments described here give us evidence of several different workshops involved in producing instruments of the same size.

String lengths and pitch

We must allow a safety margin for inaccuracies of manufacture and normal tolerance, irregularities of the scale progression due to instrument type (e.g. virginals), variation in the strength of wire available, and for the pitch of a string to rise due to humidity changes affecting the soundboard. Documents and practice recommend **at least** a semitone safety margin. Given this allowance, we can expect a c^2 string of about 339 mm in iron wire (f^2 = 254 mm) or c^2 of about 283 mm in brass wire to have stood at about 498 Hz (i.e. a^1 = 413 Hz, or A-413), but hardly much higher[21]. A pitch for the same string length of a^1 = 439 Hz has already been suggested by O'Brien, which was probably technically possible

[20] G. O'BRIEN, op. cit. (in note 5).

[21] Why 413 Hz and not 415 Hz? (the reader may ask). There are two reasons: Firstly, it prevents an automatic assumption that 415 Hz is somehow «correct» simply because it has been repeated enough. Secondly, 413 Hz is A-440 minus 5 commas (syntonic commas of 22 cents), a system of the smallest feasible pitch steps which Bruce HAYNES devised and described in his paper *Principles and Problems in Studying Historical Pitch Standards*, conference on «Stimmton und Transposition im 16.-18. Jahrhundert», Bremen, 7. October 1999. Thirdly, the minimum tolerance (± 3 Hz) we must ascribe to this pitch designation covers 415 Hz anyway.

under optimum conditions, but may have been a little too high for average practice[22].

The main reason for giving a pitch level in this article is in order to make the data on string lengths accessible to musicians who think in terms of the pitch of instruments.

Although 498 Hz for a c^2 string of 283 mm in brass wire is about the maximum pitch which could reasonably have been achieved in practice, it is not possible to state with precision which pitch a string might have been tuned to on account of the variables involved. At least I believe our estimation is within the right order of magnitude; I suggest that it is plus or minus a semitone of being correct. If one wishes to seek more precision in the fixing of the absolute pitch levels used then one should look to wind instruments such as recorders, cornetti, and organs where it may be possible to fix the pitch to within a quarter tone, rather than harpsichords, virginals and clavichords.

Thus, armed with the knowledge of the original string lengths and following my scheme of string materials used I believe it is a realistic enterprise to derive the pitches at which these instruments would have stood. In any event, I would claim that given the assumption of a certain pitch for a **specified** string material and length, that other string lengths would have been intended by most of the makers of the instruments (at least in a particular locality) to be for strictly-proportional, higher or lower pitches. Thus, even if we are unsure of the correct absolute pitch of an instrument, we may derive the **relative** pitches of the instruments we study. Even this slightly more limited conclusion is of considerable value when it comes to understanding the use of instruments.

[22] G. O'Brien, op. cit. (in note 5), pp. 61-62, reports Lissajous' 1783 measurement of Taskin's tuning fork as being 409 Hz. O'Brien links this to Taskin's iron scale of c^2 = 364 mm, which implies a pitch of a^1 = 439 Hz for a c^2 string of 339 mm in iron wire. It is a moot point whether the pitch of 409 Hz should be applied to a c^2 of about 364 mm or to the shorter scales also used by Taskin of about 343 mm, as reported by Boalch (op. cit. in note 7), pp. 652-653.

Venetian string lengths

As a result of the new information on identifications it is possible to make several changes to the recorded history of instruments. For example, a harpsichord which had previously been thought to be Venetian and appeared to have had two sets of strings at pitches a tone apart can now be attributed to Boni c.1619, who worked in Rome. The original state is still unclear, but was more likely with three 8' registers at the same pitch[23]. A harpsichord with an unusually large compass of GG, AA-f^3 having an inscription attributing it to Celestini in 1605 turns out not to have been made by Celestini[24]. Of the 28 instruments linked with Domenico da Pesaro (who worked in Venice), only 15 are genuine products of his workshop. A number of Baffo instruments were not produced in his workshop, but acquired a faked inscription from Franciolini's hand; curiously enough, one of Franciolini's inscriptions is on an unsigned Baffo harpsichord[25]!

Much time can be spent in listing the history of instruments in this way, but the objective of all this preliminary work was to be able to examine the products of a single workshop. Here one can see how the same string lengths are often repeated in different instruments, or observe how the size and string length of one instrument is related to another of the same workshop. Those who are involved in organology will immediately realise the benefit which such information can yield: patterns emerge, traditions can be recognised, and sense can sometimes be made of unconnected detail. We are now virtually at the stage of being able to decipher production procedures for some instruments. This sort of view of the problem was previously not possible when comparing instruments from different workshops, and possibly made for different pitches as well.

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[23] A. PARROTT, op. cit. (in note 3) referred to this instrument, p. 495. See D. WRAIGHT, op. cit. (in note 6), Part 2, pp. 80-82.

[24] Denzil WRAIGHT, *The 1605 Celestini Harpsichord: another misleading Instrument* in «The Organ Yearbook» XIX (1989), pp. 91-103.

[25] Leipzig no. 79 in the Musical Instrument Collection, University of Leipzig. See D. WRAIGHT, op. cit. (in note 6), Part 2, p. 56.

The 27 surviving instruments made by Giovanni Celestini and Dominicus Pisaurensis, both working in Venice, give us the best opportunities of studying an individual maker's work. Instrument makers did not design a new instrument for every order. They were probably nearer to rationalised, large-scale production than our sometimes somewhat Romantic ideas of the past might have us believe. The use of some jigs can be proven and the string lengths of three Celestini virginals illustrate the consistency of the scales used over a period of 21 years[26].

Table 1

	1587	1608	Unsigned
f^3	**119**	**119**	**115**
c^3	142	142	145
f^2	**234**	**234**	**234**
c^2	304	305	302
f^1	**469**	**469**	**467**
c^1	591	597	604
f	**879**	**888**	**899**
c	1040	1095	1044
F	**1230**	**1224**	**1238**
C/E	1271	1260	1238

1587: now in the Beurmann Collection, Hasselburg.
1608: Kunsthistorisches Museum, Vienna.
unsigned (c.1587): Royal Ontario Museum, Toronto, no. 913.4.96 (I attribute this instrument to Celestini, W503 in my catalogue)

It was the f string lengths which Celestini used to set the position of the bridges (for which reason they have been set in bold type). This we can ascertain from the pin holes in the soundboard beside the bridges at the f notes, which were used to position the bridges prior to and during gluing. Thus, the difference at c of about 50 mm is not one of measuring error. Most of the 16th-century instruments were constructed from the f-string lengths, not using the c strings which modern organology tends to measure. Indeed, one finds in some instruments that even where the compass starts on C (of a short octave, written C/E), F is the first string length which was measured; it is of course also adjacent to the C string. Thus,

[26] In the Beurmann Collection, and the Kunsthistorisches Museum, Vienna.

the instrument maker appears to have understood his instrument as starting in the bass on F; notes lower than this were probably regarded as being **extra manum,** that is, outside the «Guidonian hand» and merely repetitions of the hand at a lower pitch[27].

Whereas in the 16th century most instruments were laid out for the f-notes, or were «f-based» as I have called it, in the 17th century and later it was the c-notes which were used. At one point in my research it appeared as if perhaps this feature might be connected with the problem of stringing, the pitches, and the possible «transposing role» suggested by Shortridge for some instruments. However, it later emerged that this f- or c-based construction mostly reflected the compasses used.

There is remarkably little variation in Celestini's string lengths indicating that he had a specific design and kept to it. The third, unsigned virginal has been included in the list because it has a polygonal case; the other two instruments have rectangular cases. We can conclude from this that the string lengths are the fundamental feature of the instrument, not the type of case. This priority of the scaling design also permits us to make valid comparisons between instruments of different type.

Despite the high quality of case making, the instruments produced by Dominicus, do not show such consistency in their string lengths. The correct explanation for this may or may not be manufacturing error, but between them, Celestini and Dominicus represent most of the string lengths used in Venice; the addition of another 35 instruments by makers **known** to have worked in Venice rounds out the picture and enables us to compile the following two lists of 62 string lengths (Tables 2 and 3). These are the original scales, compasses, and dispositions and will be at variance with some published data. Further identifications of Venetian instruments would enable us to increase these lists, but I have omitted

[27] Pier Paolo DONATI, *Arte nell'Aretino: seconda mostra di restauri dal 1975 al 1979 - La tutela e il restauro degli organi storici - Catalogo* (Florence 1979), p. 234 records a document of 1464 where an organ keyboard descends to the «vocem c faut extra manum».

some borderline cases such as Jadra's virginals until there is a consensus of opinion on their origin.

It is not my purpose here to discuss these lists in detail, but I have included them in order that the reader may assess the amount of information upon which the following combined list of string lengths and pitches is based (Table 4), and in order to be able to refer to particular instruments. The scale of Table 4 (and Table 5 which is based on it) is «linear» between 326 Hz and 585 Hz, that is, there is a separation of about a semitone between each line. This puts any intervallic spacing of instruments the same distance apart on the table. Above 585 Hz, for reasons of space, I have had to abandon the linearity.

Table 5 is a histogram showing the occurrence of virginals and harpsichords relative to the pitch groups to which they have been assigned.

Conventions for Tables 2 and 3:

bold type indicates data I have collected

W no.:	this is the catalogue number in my thesis
PV:	polygonal virginals; PV4: at 4' pitch
RV:	rectangular virginal; RV4: at 4' pitch
CD:	clavichord
?:	uncertain data
¢:	calculated string length
[A]:	attributed to this maker
" ":	indicates doubt about correctness
≈:	approximately

Table 2 Venetian harpsichord string lengths
ordered by f^2 scale (iron wire)
a line is left between each possible pitch group

W no.	Maker	Date	Compass	c^2/f^2	Registers
W100	**DOMINICUS,**	**1546**	**C/E-g^2,a^2**	**≈153/≈112**	**4+4**
W98	**DOMINICUS,**	**1543**	**C/E-g^2,a^2**	**¢157/118**	**4+4**
W618	TRASUNTINO, V	1591	C-c^3	≈202/≈152	6+6
W71	**CELESTINI,**	**1596**	**C/E-f^3**	**238/180**	**6+6**
W464	**BAFFO [A]**	**n.d.**	**C/E-c^3**	**235/182**	**6+3**
W74	**CELESTINI,**	**1608**	**C/E-f^3**	**254/192**	**6+6**
W508	**ANTONIUS[A]**	**-**	**C/E-c^3**	**254/188**	**6+6**
W270	**TRASUNTINO,V**	**1606**	**C-c^3**	**271/203**	**8**
W103	**DOMINICUS,**	**1554**	**C/E-c^3**	**275/209**	**8+8**
W54	**TRASUNTINO, A[A]**	***c*.1545**	**C/E-c^3**	**286/213**	**8+8**
W96	**DOMINICUS,**	**1533**	**C/E-f^3**	**¢301/226**	**8**
W112	**DOMINICUS,**	**1570-75**	**C/E-f^3**	**¢307/230**	**8**
W144	**BAFFO[A],**	**c.1579**	**C/E-f^3?**	**-----/≈230?**	**8+4**
W339	**DOMINICUS,**	**1570**	**C/E-f^3**	**¢308/231**	**8+8**
W268	**TRASUNTINO,V**	**1560**	**C/E-f^3**	**¢312/234**	**8+4**
W437	**DOMINICUS,**	**1563-70**	**F,G,A-g^2,a^2**	**¢316/237**	**8+4**
W336	**ANTONIUS[A]**	**-**	**C/E-f^3**	**≈311/¢233**	**8+4**
W294	**TRASUNTINO,A**	**1530**	**C/E-f^3**	**342/¢257**	**8+4**
W265	**TRASUNTINO,A**	**1538**	**C/E-f^3**	**¢353/265**	**8+4**
W458	**TRASUNTINO,V**	**1572**	**C/E-f^3?**	**355/268**	**8+4**
W269	**"TRASUNTINO,V"**	**"1573"**	**C/E-f^3**	**351/267**	**8+4**
W262	**TRASUNTINO,A**	**1531**	**C/E-f^3**	**≈359/≈273**	**8+4**
W547	**BAFFO,**	**1579**	**C/E-f^3?**	**410/281**	**8+4**
W18	**BAFFO,**	**1574**	**C/E-f^3**	**≈404/¢303**	**8+4**
W20	**BAFFO,**	**1579**	**C/E-c^4**	**416/¢302**	**8+4**
W137	**FRANCISCUS,**	**1561**	**C/E-f^3**	**≈471/323**	**8+4**

Table 3 Venetian virginal string lengths
ordered by f^2 scale (iron wire)
a line is left between each possible pitch group

Wno.	Maker	Date	Type	Compass	c^2/f^2
W136	FRANCISCUS Pat.,	1527	PV4	C/E-g^2,a^2	150/116
W657	ANTONIUS[A]	c.1550	RV4	C/E-c^3	192/133
W99	DOMINICUS, Pis.	1543	CD	C/E-c^3	235/180
W306	UNDEUS[A],	n.d.	PV	C/E-c^3	279/203
W102	DOMINICUS, Pis.	1548	PV	C/E-c^3	≈273/¢201-6
W306	UNDEUS[A]	-	PV	C/E-c^3	279/¢209
W75	CELESTINI,	1610	RV	C/E-f^3	294/215
W277	UNDEUS,	1623	RV	C/E-f^3	293/217
W334	CELESTINI[A],	n.d.	RV	C/E-f^3	300/223
W108	DOMINICUS, Pis.	1575	PV	C/E-c^3	305/224
W204	PORTALUPI,	1523	PV	C/E-f^3	309/225
W442	BAFFO[A],	n.d.	PV	C/E-c^3	306/¢230
W279	VI...IES,	1540	PV	C/E-f^3	320/230
W66	CELESTINI,	1587	RV	C/E-f^3	304/234
W503	CELESTINI[A]	c.1587	PV	C/E-f^3	302/234
W445	CELESTINI[A]	c.1587	RV	C/E-f^3	≈302/≈234
W73	CELESTINI,	1606	RV	C/E-f^3	305/234
W111	DOMINICUS, Pis.	n.d.	PV	C/E-c^3	312/235
W68	CELESTINI,	1593	RV	C/E-f^3	308/236
W387	DOMINICUS, Pis.	n.d.	PV	C/E-f^3	309/241
W14	ANTONIUS,	1550	PV	C/E-f^3	340/245
W17	BAFFO,	1570	PV	C/E-f^3	344/248
W274	UNDEUS,	1590	PV	C/E-f^3	324/249
W106	ANTONIUS[A]	c.1550	RV	C/E-f^3	351/248

W338	**FRANCISCUS Pat.,**	**1552**	**PV**	**C/E-f³**	**346/252**
W67	**CELESTINI,**	**1589**	**RV**	**C/E-f³**	**325/253**
W504	**CELESTINI[A],**	**n.d.**	**RV**	**C/E-f³**	**330/254**
W69	**CELESTINI,**	**1594**	**PV**	**C/E-f³**	**≈325/≈255**
W97	**DOMINICUS, Pis.**	**1540**	**PV**	**C/E-f³**	**330/255**
W552	**BAFFO[A],**	n.d.	PV	C/E-f³	331/255
W461	**DOMINICUS, Pis.**	**n.d.**	**PV**	**C/E-f³**	**333/260**
W132	**FLORIANI,**	**1572**	**PV**	**C/E-f³**	**338/261**
W463	**DOMINICUS, Pis.**	**1563**	**PV**	**C/E-f³**	**335/265**
W676	**BAFFO[A],**	n.d.	PV	C/E-f³	351/-
W299	**BAFFO[A],**	**n.d.**	**PV**	**C/E-f³**	**365/268**
W131	**FLORIANI,**	**1571**	**PV**	**C/E-f³**	**≈342/≈268**

As I indicated above, it was mostly the f strings which were measured by the makers. Thus, the modern convention of noting the c string lengths can be misleading, and in the virginals (which have an uneven scale progression) can even introduce errors. For example, the three virginals on Table 3 with f^2 strings between 223 mm and 225 mm could appear to belong to the pitch group a semitone lower, if one were to classify pitches using the c^2 string lengths. However, knowing that the instruments were built using the f strings enables us to prise a pitch distinction between the two groups. This is an example of the specialised practical knowledge of instrument making which is sometimes necessary in order to make sense of «raw data». Since, however, c^2 string lengths are the more familiar ones, for this reason they have been included; they are values calculated from the f^2 length in order to eliminate manufacturing error.

Table 4: Venetian string lengths and pitches (all instruments)

a^1	c^2/f^2 mm	Interval size cents	
893 Hz	157/118		
			Octave
		207	
792 Hz	177/133		
		533	
580 Hz	241/181		
	xxx	102	Quart
549 Hz	254/192		
	xxx	96	
519 Hz	276/203		Octave
		50	
504 Hz	279/209		Quart
		49	
490 Hz	287/215		
		71	
468 Hz	299/224 MP		
		76	
448 Hz	312/234 TP		
		87	
428 Hz	329/246		
		55	
413 Hz	339/254 TC		
		73	
397 Hz	353/265		Quart
	xxx	101	
375 Hz	375/281		Quart
	xxx	119	
350 Hz	401/301		
	xxx	122	
326 Hz	431/323		

xxx indicates that there is no example of this pitch

MP = mezzo punto, TP = tutto punto, TC = tuono chorista

N.B. The Trasuntino quart pair 519 Hz - 692 Hz does not fit on this table

Table 5 Distribution of Venetian string lengths and pitches (all instruments)

a^1	c^2/f^2 mm	Number of occurrences
893 Hz	157/118	HHV
792 Hz	177/133	V
692 Hz	202/152	H
580 Hz	241/181	HHV
	xxx	
549 Hz	254/192	HH
	xxx	
519 Hz	276/203	HVV
504 Hz	279/209	HV
490 Hz	287/215	HVV
468 Hz	299/224 **MP**	HVVV
448 Hz	312/234 **TP**	HHHHHHVVVVVVVVV
428 Hz	329/246	VVVVV
413 Hz	339/254 **TC**	HVVVVVV
397 Hz	353/265	HHHHVVVVVV
	xxx	
375 Hz	375/281	H
	xxx	
350 Hz	401/301	HH
	xxx	
326 Hz	431/323	H

xxx indicates that there is no example of this pitch
MP = mezzo punto
TP = tutto punto
TC = tuono chorista

The string lengths which have been given are those of single instruments, or of an average (arithmetical mean) of a group of instruments, whose scales are close enough that they appear to have been made for the same pitch. I have included instruments on the list such as the W336 Antonius for which we only have an approximate scale, since this scale can be assigned to Table 5[28]. However, it has not been used to calculate the average for the group.

In some instances the groups are clearly demarcated; others are less sharply defined. It can be misleading simply to take the f^2 string length and determine the pitch from that alone since inaccuracy in manufacture can obscure the original intention; this has been found to be true of the Florentine virginals made by Poggi, who came from Venice, but worked in Florence. For these reasons, the lists I have given should regarded as work in progress and further revision is possible. Through further analysis of a maker's instruments it may be possible to achieve a better understanding of the design intentions and thereby make corrections to the pitch scheme I have given.

On the assumption (discussed above: «String lengths and pitch») that an iron string of f^2 = 254 mm is equivalent to a pitch of a^1 = 413 Hz, I have given the other string lengths on Tables 4 and 5 an appropriately proportioned pitch. Thus, the lists can be assimilated by non-keyboard specialists more easily, the latter tending to refer to string lengths rather than pitches of instruments.

Venetian pitches

It should be stated at the outset that all we can establish here are the pitches of the instruments **made** in Venice, (or within the Venetian state). Instrument building proliferated in 16th-century Venice and many products went abroad or to other Italian cities. Since in most cases we do not know for whom the instruments were produced we cannot say if the surviving instruments were made for use in Venice or some other place; whether the customer received an instrument at Venetian pitch or one tailored to his local requirements. One exception is the virginal, possibly attributable to

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[28] It is an unsigned harpsichord in the Kunsthistorisches Museum, Vienna, no. SAM 123. See D. WRAIGHT, op. cit. (in note 6), Part 2, p. 44.

Antonius Patavinus, made in 1540 for the Duchess of Urbino[29]. However, this has the same pitch as five other Venetian virginals. The 1561 Francesco Ongaro harpsichord may have been intended for the Fugger family in Augsburg, S. Germany[30]. However, when we consider the pitches of instruments from Florence, Rome, and Milan (which I have described in my thesis) then we see that instruments made there used the same 8' range as in Venice[31]. Thus, the possibility that some Venetian instruments listed here were made for other cities will probably not seriously distort our understanding of Venetian pitches.

Normal 8' pitch

Following Bruce Haynes' investigation of the terms **mezzo punto**, **tutto punto**, and **tuono chorista**, and his suggested pitch designations for north Italian pitches in the 16th and 17th centuries, we can locate these on the list of Venetian pitch intervals. Haynes gives the following approximate pitches[32]:

mezzo punto:	$a^1 = \approx 470$ Hz
tutto punto:	$a^1 = \approx 443$ Hz
tuono chorista:	$a^1 = \approx 409$ Hz

My list of Venetian pitches derived by the methods described here is in good agreement with Haynes data, and suggests that where two different approaches arrive at similar conclusions there may be a basis in historical fact.

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[29] In the Metropolitan Museum of Art, New York, no. # 53.6: See D. WRAIGHT, op. cit. (in note 6), Part 2, p. 47.

[30] John KOSTER, *Italian Harpsichords and the Fugger Inventory* in «Galpin Society Journal» XXXIV (1981), pp. 149-151. The Franciscus harpsichord is in the Deutsches Museum, Munich.

[31] The string lengths in other cities are described in D. WRAIGHT op. cit. (in note 4), Part 1, chapter 6.

[32] Bruce HAYNES, *Pitch Standards in the Baroque and Classical Periods*, Ph.D. thesis (University of Montréal 1995), [UMI order no. NN08519], p. 70. An earlier article *Pitch in northern Italy in the sixteenth and seventeenth centuries* in «Recercare» VI (1994), 41-60, contains virtually the same information as volume I, section 2 of the thesis, and may be more accessible for some readers.

From the list of virginals it is clear that the majority of instruments have a pitch between a^1 = 397-468 Hz, which is a range of between a whole tone and a just minor third. It is nine cents smaller than a Pythagorean minor third (294 cents, ratio 32:27), which may or may not be relevent. Although in the initial stages of research on harpsichords two pitches a whole tone apart at a^1 = 397 Hz and a^1 = 448 Hz became obvious, the full list of virginals and harpsichords shows a fairly even distribution over this range of 8' pitch; Table 5 shows a trend towards a^1 = 448 Hz (**tutto punto**). If, however, we look at eight of the twelve instruments made by Celestini we find that he used only two 8' pitches: at a^1 = 413 Hz (**tuono chorista**) and a^1 = 448 Hz (**tutto punto**), about 2/3 of a tone apart. It is interesting to note that Venetian virginals were made for pitches as low as a^1 = 397 Hz, whereas iron-strung virginals from Florence (i.e. those made before 1650, not shown here) were not lower than a^1 = 413 Hz.

A few instruments, seven in total, were made for slightly higher 8' pitches, between a^1 = 468 Hz (**mezzo punto**) and a^1 = 490 Hz. Here the virginals are in the majority with five instruments, but it is difficult to know whether we should give any particular significance to this fact. In any event the virginals outnumber the harpsichords 36 to 26.

High 8' pitch

There are two harpsichords and three virginals at a still higher pitch of a^1 = 504-519 Hz. This is an unusually high 8' pitch and has rarely been described in the string keyboard literature, although there are instruments from other Italian cities at this pitch[33]. It is at the same level as that described by Alfons Huber in a set of Italian recorders with the maker's mark *HIER.S*[34].

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[33] It is the equivalent size of the 4 $^1/2$ *voet* Ruckers virginal (O'BRIEN, op. cit., in note 5, p. 58) or the 1548 Karest virginal (p. 25). O'Brien also sees these as iron-strung instruments.

[34] In the Kunsthistorisches Museum, Vienna. See Alfons HUBER *Baugrößen von Saitenklavieren im 15. Jahrhundert* in «Das Musikinstrument» XXXIX (1900), p. 178, who gives a^1= 520 Hz. Another keyboard instrument at this pitch

The c^2 string lengths of 271-279 mm for instruments at a^1 = 504-519 Hz (f^2 = 203-209 mm) represent the scales which in recent years have become associated with a stringing in brass wire; this would then come, conveniently enough, to about a^1 = 415 Hz, a pitch which has been widely adopted in recent years for instruments playing Renaissance and Baroque music. However, my analysis of the scale design for different pitches in Italian instruments has led me to the conclusion that these short scaled instruments were intended for iron wire and must have been tuned correspondingly higher.

The most convincing evidence for this view comes principally from virginals where the bass strings are always shorter than in harpsichords. Put very simply, it is the ratio of the bass strings to the treble strings which reveals the designers' intention. Such harpsichords and virginals are physically small, but when the strings are scaled to normal 8' pitch it will be found that the bass strings are longer than normal[35].

A further piece of evidence for my view is the 1554 Dominicus Pisaurensis harpsichord which **appears** to be of the same size as 18th-century harpsichords, for which we would normally prefer a brass stringing. Closer investigation shows that this particular instrument is a uniformly-scaled version of the 1543 Dominicus Pisaurensis octave harpsichord, scaled 16:9 longer, i.e. a Pythagorean minor seventh lower. Each f string has been scaled by the same amount, which is unusual in Italian design. Given that the octave harpsichord would have been iron strung, it seems correct to assume an iron stringing for the 1554 Dominicus[36]. It must be stated though that it may not be possible to tell, without the benefit of special knowledge such as the Dominicus' instrument confers, whether some such instruments are intended for brass or iron

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was described by Alfons HUBER, *Cembalowirbel unter der Mikrosonde* in «Arbeitsblätter für Restauratoren», no. 1 (Mainz 1989), note 10. The positive organ by Michael Strobel 1559 transposed by a whole tone between a^1 = c.520 Hz and a^1 = c.465 Hz.

35 This matter is discussed in detail in my thesis (op. cit., in note 6), Part 1, chapter 5.

36 Ibidem, p. 244.

stringing. One of these borderline cases is the well-known «clavemusicum omnitonum» harpsichord made by Vito de Trasuntinis in 1606, which I have provisionally entered as an iron-strung instrument[37].

Pitches a fourth higher and lower than 8' pitch

The majority of the Venetian instruments I have listed here were, therefore, built for normal 8' pitch (43 of 62 instruments at a^1 = 397-490 Hz), and a few for a somewhat higher 8' pitch (5 instruments at a^1 = 504-519 Hz). Thus, the idea that **many** instruments fell into two groups at pitches a fourth apart, as originally suggested by Shortridge, is not correct. Nevertheless, there were a few instruments made a fourth higher and lower than normal 8' pitch.

One harpsichord by Celestini made in 1596 has an f^2 string length of 180 mm, and therefore a pitch of a^1 = 580 Hz, which is a fourth higher than the pitch of the three Celestini virginals at a^1 = 448 Hz (**tutto punto**), whose string lengths were given in Table 1 above[38]. An unsigned Baffo harpsichord is also at this pitch[39]. The only authenticated clavichord by Dominicus Pisaurensis of 1543 is, assuming the use of iron strings, also at this pitch[40].

Another example of a quart pair of instruments comes again from Celestini's workshop: the 1608 harpsichord comes to the slightly lower pitch of a^1 = 549 Hz assuming the use of iron wire strings. It is then a quart pair to the lower of the 8' pitches which Celestini used, namely a^1 = 413 Hz (**tuono chorista**). Thus, Celestini made 8' instruments separated by 2/3 of tone at **tutto punto** and **tuono chorista**, and instruments a quart higher than these pitches. An isolated quart harpsichord is that attributed to Antonius

[37] Museo Civico, Bologna.

[38] The 1596 Celestini harpsichord is in the Royal Ontario Museum, Toronto.

[39] See D. WRAIGHT, op. cit. (in note 6), Part 2, p. 57: instrument no. W464, in private ownership in England.

[40] Musical Instrument Museum, University of Leipzig, no. 1. I have described my arguments for iron stringing of this and other Italian clavichords in D. WRAIGHT, op. cit. (in note 6), Part 1, pp. 215-224.

Patavinus[41]. Another quart pair, assuming the same stringing material, are two chromatic harpsichords, the 1606 «clavemusicum omnitonum» and the 1591 instrument by Vito Trasuntino (This latter harpsichord, restored by Christopher Nobbs, has only recently reappeared and could not be considered in detail for this article).

When considering the use of clavichords at these pitches a fourth higher than normal 8' pitch we should bear in mind certain technical restrictions: no 16th-century Italian clavichord is lower in pitch than a^1 = 490 Hz (f^2 = 215 mm), which is a semitone above **mezzo punto**; mostly they are at a^1 = 580 Hz (f^2 = 181 mm) or higher. Although none of the surviving Italian clavichords are fully fretted like Arnaut de Zwolle's octave clavichord design, even the partial fretting (to e flat) makes the use of a low pitch and consequently long strings inconvenient for the layout. The result of long strings is that the distance between fretted tangents becomes large and this in turn requires keylevers to be «bent» more than is practical. We have been so conditioned to seeing clavichords at normal 8' pitch, that it may be a surprise that these clavichords are not at this level. Indeed, rather than thinking of them as pitched a fourth higher than normal 8' pitch, it may be nearer the mark to imagine that they are a **fifth lower** than usual, that is, lower than the octave pitch level, which was the common size of string keyboard instrument in the 15th century.

There are also a few instruments a fourth lower than normal 8' pitch. The 1574 and 1579 Baffo harpsichords are such examples and would have presumably been the sort of harpsichord described as «alla quarta bassa»[42]. With their f^2 string length of 301 mm they come to a pitch of a^1 = 350 Hz, a fourth below a^1 = 468 Hz (**mezzo**

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[41] Metropolitan Museum of Art, New York, no. 89.4.1222.

[42] The 1574 Baffo is in the Victoria and Albert museum, London; the 1579 Baffo is in the Musée de la Musique, Paris. Oscar MISCHIATI in «L'Organo» XVII (1979) review: Donald H. BOALCH, *Makers of the Harpsichord and Clavichord 1440-1840*, Oxford, [2]1974, Clarendon Press, p. 223, reported that Padre Antonio Dalla Tavola of the Basilica di S. Antonio in Padua owned a harpsichord in 1674 made by «Viti de Trasuntinis anno 1570» which was «già fu con l'ottavina alla quarta bassa» [formerly with an octave stop, a fourth low].

punto) when strung with iron wire. The interesting feature of this pair of instruments is that they come from the same workshop and this helps us overcome the difficulties of interpreting the original condition, for both instruments were modified. The 1579 harpsichord experienced two alterations to the keyboard, but despite this all the original keylevers remain[43]. Since the 1574 harpsichord has the common C/E-f^3 compass, but the 1579 instrument a C/E-c^4 range, the 1579 harpsichord covers the normal 8' range as well, despite being a fourth below normal pitch. This is, in effect, a Ruckers «transposing harpsichord», but with one keyboard. Another harpsichord by Francesco Ongaro is at a slightly lower pitch and is therefore a fourth lower than a^1 = 428 Hz a pitch between **tutto punto** and **tuono chorista**. As I mentioned above, this instrument may have been made for the Fugger family in Augsburg and therefore reflect a pitch in use there.

When Italian harpsichords were first examined a scale of f^2 = 265 mm (or c^2 = 353 mm) was considered a long scale. Barnes argued that these instruments were strung with brass wire, which was the intepretation of low pitches reported by Mendel[44]. According to my understanding of Italian string keyboard design, it was principally iron strings which were used in the 16th century. Indeed, it may be true that none of the Venetian instruments described here was originally intended for brass strings. Thus, there were only a **few** low-pitched harpsichords, and not a **large** number of instruments at a low pitch.

The structure of Venetian pitches

After dealing with the pitches of the instruments I would now like to turn my attention to the structure of the pitch scheme. A curious feature of this list of string lengths and their corresponding pitches

[43] A brief description of the instrument and photo of the keyboard appeared in Denzil WRAIGHT *Nouvelles études sur les clavecins italiens* in «Musique Ancienne» XXIX (1985), pp. 67-81 and *Neue Untersuchungen an italienischen Cembali* in «Concerto» III (1986), pp. 28-38.

[44] See note 2.

is that the whole tone sizes are not divided into two semitones, but into three intervals. This division into three intervals can also be found in Florentine and Roman instruments and is not an isolated feature. At the least it appears to reflect the difference on a circle of fifths between a sharp and a flat, i.e. that the sharps were not represented in string lengths as being equivalent. However, any string lengths derived from a circle of perfect fifths would not show enough difference between the sharps and flats to account for the three similarly-sized intervals we find in the whole tone.

I have come across another, possible interpretation as a result of examining the fretting of Italian clavichords. To take the most direct route to the heart of the matter: if one divides an octave interval into 19 parts using the interval 5:6 (a just minor third) then one will find that **for all practical purposes** the division is exact. There is a small discrepancy, which expressed in cents is only 2.8 cents. In quarter-comma meantone a fifth is flattened by 5.4 cents, which indicates how small this error is.

What we can hypothesise is that this practical division of an octave string or pipe length into 19 parts was known to some practising instrument maker in Italy, probably before 1500. The semitone size (62.6 cents) of the 19-note division of the octave is remarkably close to a semitone size of the 1/3 comma meantone tuning (63.5 cents) which Salinas described in 1577[45]. The interval between a sharp and a flat in Salinas' tuning is 62.5 cents. Here again, the differences in practice are so small that one needs mathematical calculation to find them.

The next step is to report that in the 1543 Dominicus clavichord and the so-called «Onesto Tosi» one can find intervals which have about the same size as in the 19-note octave division or 1/3 comma

[45] Francesco SALINAS, *De musica*, Salamanca 1577, Gastius, ed. Macario Santiago KASTNER, (Reprint Kassel 1958, Bärenreiter («Documenta Musicologica», 1st series, XIII), pp. 143-145. In fact it was first described by Gioseffo ZARLINO, *Dimostrationi harmoniche*, Venice 1571, de Franceschi, («Monuments of Music and Music Literature in Facsimile», 2nd series, II), New York 1965, Broude Brothers), p. 221.

meantone[46]. It is obvious how small some semitones are, far too small in order to have come from a 1/4 comma meantone tuning. However, whether it is correct to say that the clavichord makers intended to construct a version of a 1/3 comma meantone tuning, or that they were simply operating with a measuring stick which had been laid out with the 19-note division is hard to say. At present I incline to the latter view, but perhaps both views are correct since I believe that indications of a 1/3 comma meantone tuning can be found in the paper pipes for an organ which Lorenzo da Pavia built in Venice in 1494[47].

If my hypothesis is correct, and I regard it as no more than that at present, then this would explain why the whole tone size is divided into three parts. This is a part of the puzzle that we seek to understand, namely how instrument makers **intended** their instruments to be pitched, for if we can understand their intention, we will shed more light on the pitch relationships of instruments.

What might have been their intention and how might the coordination of pitches have been achieved? It is sometimes supposed that organ pipe lengths were designed using a prevailing local foot and that there were different organ pitches **as a result** of different foot sizes. Were this the case for harpsichord makers then it would not explain how instruments from different cities (with varying foot sizes) were made at the same pitches[48].

The answer would appear to lie in organ building practice where the physical pipe length defines the pitch. This pipe length can be expressed in any convenient units of measurement for the purpose of defining its size and communicating the information to other makers. Originally, I suspect, the pipe length would simply have

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[46] This is described in my thesis (op. cit. in note 6), Part 2 under Dominicus Pisaurensis and Onesto Tosi, but a shorter version appeared in Denzil Wraight, *The Tuning of two 16th-Century Italian Clavichords* in «Clavichord International» I (1997), pp. 49-53.

[47] It is in the Museo Correr, Venice. This is discussed in detail in D. Wraight, op. cit. (in note 6), Part 2, pp. 194-210.

[48] In speaking of pitches used consistently throughout Italy I am drawing on material which I have already published (op. cit., in note 6), Part 1, chapter 6.

been communicated as a mark on a wooden stick or piece of paper, just as Schlick, Praetorius, and Vicentino give us lengths on a printed page in order to communicate pipe sizes and string lengths[49].

There is in fact **no necessity to measure the string lengths**, once one has a measured stick (a **Mensurstab** in German organ terminology) with the required octave division for string lengths at the same pitch as the organ pipes. Whether the string lengths are the **same** length as the organ pipes depends largely on the string material used and its stressing. Thereafter, the harpsichord maker, like the organ maker, derives the string lengths he needs for any size of instrument from his **Mensurstab**. If his **Mensurstab** were based on an f string at **tuono chorista** pitch and he needs an instrument at **mezzo punto** (please consult Table 4) then he uses the g string length from the **Mensurstab** for his f string; recall that it was usually the f strings which were measured in the 16th century. If he needs an instrument a fourth lower than **tuono chorista** then he takes the c from his **Mensurstab** for the f string. The string length for **tutto punto** does not exist on his **Mensurstab** unless he has a g flat. The **Mensurstab** is an elegant and accurate tool if the whole tone is divided into three parts. That would explain how a 19-note measuring stick for string lengths could have been such a useful tool in producing instruments at any required pitch level.

This use of a **Mensurstab** makes things very simple because no arithmetical calculation is involved, no geometrical proportion is needed, no drawings are required, and no lists of string lengths have to be compiled, remembered, or written down: there is simply one measured stick hanging in a corner of the workshop. In practice there would probably have been a number of **Mensurstäbe**, one for each size of instrument. There are some harpsichords and

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[49] Arnold SCHLICK, *Spiegel der Orgelmacher und Organisten*, Speyer 1511, Schöffer, ed. Ernst Flade, (Kassel 1951, Bärenreiter), *Das drit Capitell*; Michael PRAETORIUS, *Syntagma musicum*, vol. II, *De Organographia*, Wolfenbüttel 1619, Holwein, Reprint Kassel 1958, Bärenreiter («Documenta Musicologica», 1st series, XIV), p. 232; Nicola VICENTINO, *L'antica musica ridotta alla moderna prattica*, Rome 1555, Barre), ed. Edward E. Lowinsky, («Documenta Musicologica», 1st series, XVII) Reprint Kassel 1959, Bärenreiter, fol. 100^{v}.

virginals with construction lines for the strings on the baseboards. Since these lines do not occur on every instrument it appears that makers were usually producing standard designs, but occasionally had to produce a new instrument, such as, for example, the 1579 Baffo which has such construction lines for the f strings.

My suggestion that harpsichord makers may have used a **Mensurstab** is hardly novel; the backbone of all early descriptions of making a fretted clavichord concerns the division of the octave into the appropriate intervals. However, it seems to me that the consistent use of certain pitches in string keyboard instrument making throughout Italy requires an explanation which does not use local foot measurements **as its basis**. There is another solution to this matter: pitch standards were defined by the use of pitch pipes or, the minimal requirement, a wooden stick showing the length a pipe should have, and the requisite string lengths were defined in local units of measure. It would not surprise me if it should turn out that both approaches were in use. Further analysis of string keyboard design may shed more light on this matter.

Conclusion

I believe it is a compelling conclusion of the evidence that Venetian instruments were organised at certain pitches, even though this may apppear to be at odds with what is known of pitch through some earlier reports of documentary sources. What I wish to suggest is that even if the **use** of the pitches was not well organised or standardised, the pitch structure as understood by instrument makers **was** well organised. We see this not only in the scheme of string lengths I have given, but also in the fact that several different Venetian makers used the same string lengths **throughout the 16th century**. As a result they were able to produce instruments at the same pitches. Indeed, the evidence from other Italian cities provides a similar view of pitches, but it would be the task of another article to delineate this wider picture.

Although the now widely-used pitch of a^1 = 415 Hz (**tuono chorista**) can be found in Venetian instruments, slightly more use was made of the pitch of a^1 = 448 Hz (**tutto punto**). Some 8' pitches were at a^1 = 468 Hz (**mezzo punto**) and slightly higher (to a^1 = 490 Hz). A significant number of instruments were used at a pitch level of a^1 = 504-519 Hz. There were some instruments a quart higher than **tuono chorista** and **tutto punto**, but only a few, exceptional instruments «alla quarta bassa».