The Gubbio organ: an intarsiatore's hoax?

Denzil Wraight
www.denzilwraight.com/Gubbio.pdf Version 21.10.2021

Abstract

The intarsia of a small organ in the Gubbio studiolo (1478-1482) of Federico, Duke of Montrefelto, is depicted with impressive realism, but the perspective and shading show errors, and the organ is found to be an impossible musical instrument. Nevertheless the organ's pipes reveal the use of a Pythagorean tuning, but the iconographical evidence of the keyboard compass is unreliable. Six other intarsie of organs were studied, showing that five of these also show errors, or modifications to pipe lengths or keyboards. The intarsia of the Barili organ in Siena and the clavichord in the Urbino studiolo are exceptionally accurate, but not the norm. The compass of the Gubbio organ is A-f²,g²,a², which is inherently unlikely, but the intarsia was based on an actual instrument, probably with an F,G,A-f² compass. This was too tall for the position in the panel so it was modified to give a better view of the fiddle in the niche behind the organ. Improvisation and appearance guided the construction of the organ panel. Nevertheless there are omissions in the intarsia, which might have resulted from the intarsiatore jesting with our willingness to accept every realistic representation as reality; a hoax cannot be excluded. No early intarsia can be accepted as inconographical evidence of instrument making without close scrutiny.

The Gubbio organ: an intarsiatore's hoax?

Denzil Wraight

The table organ with metal pipes in the Gubbio studiolo is one of the small marvels of the intarsiatore's art, depicting a musical instrument with astonishingly realistic detail, but with an unusual compass and pipe layout.[1] It is the primary aim of this study to examine whether, and to what extent, an actual organ is depicted, and thereby reveals information for our understanding of 15th-century instruments.

Fig. 1, Source: wikimedia[2], copyright: Metropolitan Museum of Art

[1] Metropolitan Museum of Art, New York, Rogers Fund 1939, accession no. 39.151. See Raggio, 1999, pp. 3-11, for details of the acquisiton and restoration of this collection of intarsias.

[2] https://upload.wikimedia.org/wikipedia/commons/7/7b/Studiolo_from_the_Ducal_Palace_in_Gubbio_MET_DT277752.jpg Other photos shown here of this table organ were derived from this file.

From an examination of the organ alone it is apparent that the eye of the onlooker is at the level of the top of the case, on the left side, for this is virtually a horizontal line to which we neither look up nor down.[3] The cupboard behind the organ agrees with this since we see the underside of a shelf, which is slightly higher than the organ.

Since the pipes are lower than the top of the organ case, we should find ourselves looking down into all the pipes, which is true, except for the longest one in the bass. Here we find ourselves looking up at the top of the pipe, although it is lower than the top of the case. This is an inelegancy of perspective.

Fig 2. Part of Fig.1

The case to the left and right of the keyboard is rendered inconsistently: at the right side the case is clearly higher than the keylevers, but at the left it is at the same level as the keycovers: an incongruence.

Fig 3. Part of Fig.1

[3] For an introduction to the methods of the intarsiatore see Tormey. Kemp investigates the Gubbio studiolo, showing orthogonal lines of construction. A detailed study of the Urbino clavichord has been produced by Verbeek, 2011, together with measurements of the height of viewing.

This gives us something of an "Escher effect", as in his "Watermill", that our eye travels around the keyboard from right to left, at the *same* level, but arrives at a lower point, then on returning arrives again at the higher level.

Fig. 4. Source: https://en.wikipedia.org/wiki/File:Escher_Waterfall.jpg

Here is Escher's visual joke in a similar, circulating fashion: a watermill that supplies its own power. After flowing downhill past the millwheel, water is fed back to the wheel. The geometric objects on top of the towers could be a reminder of the polyhedrons to be seen in an intarsia by Fra Damiano Zambelli in the Basilica of San Domenico, Bologna.

It is intially hard to believe that this disconcerting effect was intended in a realistic intarsia representation. This unsettling visual effect is compounded by the execution of the front of the keylevers which stand clear of the case at the right side, a rather impractical and improbable situation, yet the keylevers end level with the case at the left side. The whole keyboard area with the case is somehow out of kilter.

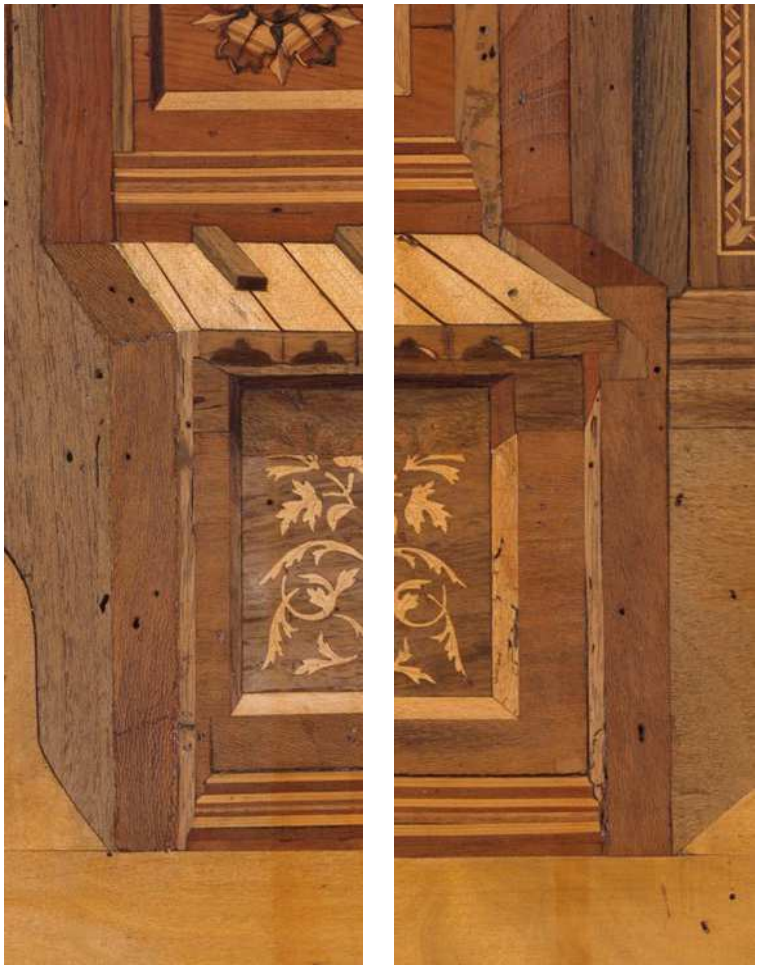

Fig 5. Part of Fig.1

This is not the only problem in this area: the moulding at the bottom of the case, in front of the keyboard is set correctly against the slightly projecting right case side (probably by 5-10 mm), yet at the left end the moulding is terminated with an angle which is incorrect from our viewing point. A similar moulding *above* the keyboard at the left side shows how the end should be terminated. Furthermore, full light on the vertical strip of veneer in at the right side of the case (below the keyboard) is repeated at the left side where shadow should fall.

It would appear as if the intarsia representation of this panel has not been executed with the level of skill we find elsewhere in the studiolo. Is this the work of an incompetant intarsiatore or a collection of small visual anomalies designed to stimulate and test our perception of the organ?[4]

[4] Raggio, 1999, p. 156, identifies the workshop of Giuliano and Benedetto da Maiano in Florence as responsible for executing the Gubbio intarsie.

These effects are not only visually disconcerting, but leave us unsure how to interpret some details of the organ. At this stage of the discussion we move from purely technical aspects of representation to the portrayal of the musical instrument.

The compass of the organ is A-f²,g²,a² (i.e. without f♯² and g♯²), but the last keylever in the treble (at the right) lacks an arcade on the keyfront. In a low-resolution black and white reproduction, such as appears in Winternitz, it appears as if this were a keylever.[5] In the colour reproductions now in the public domain, it could appear as if this last keylever were a keyblock since the arcade is missing. However a high-resolution colour reproduction shows that the line of the keyfronts projects beyond the case at the right side; we are even shown the shadow it casts on the case. This makes it unlikely that the last "key" is a keyblock. Is it possible that the present front of this key is in fact a repair and that the original arcade went missing?[6] I will assume for the purposes of this discussion that the last apparent key in the treble is in fact intended to be a key and not a keyblock.

Fig 6. Part of Fig.1

At the bass end of the keyboard a similar problem requires resolution. There is a small light coloured strip of wood immediately adjacent the left hand case side. This is too narrow to be a keycover and in low resolution reproductions it appears as if the case side obscures part of the "keycover". If this were the case, then the compass would start on G, and not A.

Fig 7. Part of Fig.1

[5] Winternitz, Plate 47a

[6] Although old photographs of the studiolo, made when it was acquired by the museum in 1939, might clarify this point, it is not of decisive significance for this study. Even if the present veneers are original, a projecting keyblock is a completely impractical and therefore unlikely detail in a real instrument.

However in high-resolution reproductions it can be seen that the left case side is at the same height as the keycovers in the bass and cannot obscure the first key. This strip makes little sense as a keyblock in the bass if we have none in the treble. It could simply be the result of inaccurate work in the widths of the keycovers, leading to a gap before the first key (A). It is thought that some inaccuracy of execution has led to this problem, and is discussed again later. The conclusion is that the representation of the keyboard was intended to start on A and end on a². A detail in support of this interpretation is that the A-f²,g²,a² compass contains 35 notes, which corresponds with the number of pipes we see in the front rank (26), combined with the *feet* of pipes in the back rank (9): 26 + 9 = 35.

Although the number of pipes matches the number of keys, the 9 feet of pipes in the back rank are only readily visible with high-resolution reproductions. From the viewing angle slightly to the left of the organ, we see that the feet of the pipes in the back rank are correctly shown as slightly to the left of the feet in the front rank of pipes. However, there are gaps between pipes in the back rank, as if some have been omitted (counting from the left):

one between 5 and 6 = a ♭
two between 6 and 7 = c¹ and d¹
one between 7 and 8 = g ♭¹
one between 8 and 9 = b ♭¹

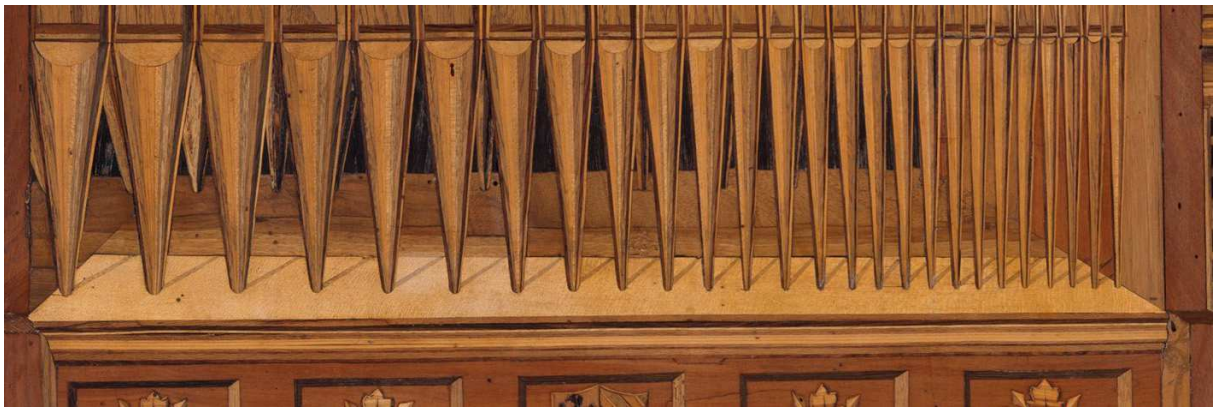

Fig 8. Part of Fig.1

If we are feeling generous and wish to allow that these missing back rank pipe feet *could* be obscured by the front rank, then we would have 5 extra pipes and a total number of pipes (40), that is, 5 in excess of the number of keys (35). In fact, from our viewing point of the organ *all* of the back rank feet should be visible; there are just gaps between the pipes.

There must be a back rank in an organ of this design since the front rank pipes (up to pipe 11, counting from the left) are spaced at whole tone intervals, which entails that the back rank contains the notes not found in the front rank. A two-rank organ design (with whole-tone pipe intervals) is obvious at a glance to the trained eye because the slope of the pipe tops is different to that where all the pipes (at semitone intervals) are in one rank.[7] This is where the problems with the organ become apparent.

[7] A single-rank design is the 19-note portative organ found on a door in the Gubbio studiolo; see Appendix, 5. I reserve the description "portative" for an organ which can be simultaneously carried and played by the same person. The Gubbio organ on the entrance wall (accession no. 39.151), the

Although we have 26 front rank pipes (fully visible) and 9 back rank feet, the tops of the back rank of pipes are not visible, except for 3 pipe tops (between the 15th and 18th pipes, counting from the left); for these pipes there are no feet, an obvious impossibility. This would then give us 3 more pipes than we previously counted, now 43 in total, but an *entire* back rank is implied, which is incoherent. In all there are (at least) 8 more pipes than there are keys.

Apart from the impossibility of the numbers, these three back-rank pipes would (following a conventional pipe layout scheme) be for d^2 and e^2, but the third pipe should not exist at this position since it is the $f\sharp^2$, a note missing from the keyboard!

Fig 9. Part of Fig.1

Since a conventionally-designed organ, with whole-tone spacing between the pipes, could reach the highest note (a^2) in the front rank with the 19th pipe, how should the remaining seven, shorter pipes be tuned? On this basis, the remaining pipes would supply the notes b^2-b^3, exceeding the keyboard range, but they are also far too long for these supposed pitches. In fact, the organ no longer maintains whole-tone spacing between the pipes in the front row after the 10th pipe: the intervals become gradually smaller, shrinking to a semitone size by the 17th pipe. All this is clearly impossible; one cannot make sense of nonsense.

---

subject of this study, is described as a "portative" in some publications, including Raggio, 1996, p. 24, but is in fact a table organ; it could not be carried and played by one person.

Despite correctly describing the practical requirement in such an organ for two ranks of pipes, Ripin, in his analysis, missed recognising the impossibility of the Gubbio intarsia, arguing that having 26 pipes was feasible in the front rank because the pipes had such a narrow scale that two ranks were only necessary in the bass.[8] As we have seen, there are gaps in the bass where there should be pipes so Ripin's analysis was mistaken.

Although Ripin concluded that a mismatch in the number of pipes and keys in van Eyck's painting of The Mystic Lamb (1432) was sufficient reason to disqualify the depiction of the organ as photographically realistic, and we have established the same sort of mismatch in the Gubbio organ, there is nevertheless value in further analysing this intarsia.

When we examine the practical *design* of the intarsia organ from the aspect of organ building then we have an impossible instrument. An organ of this type (*ad ala*, with the longest pipes at the left) is built with two ranks of pipes (usually with the same number of pipes in each rank), each pipe being separated from the adjacent pipe by the interval of a whole tone. Arnaut de Zwolle in a manuscript datable to about 35 years before this intarsa, drew the layout of the windchest of such an instrument.[9]

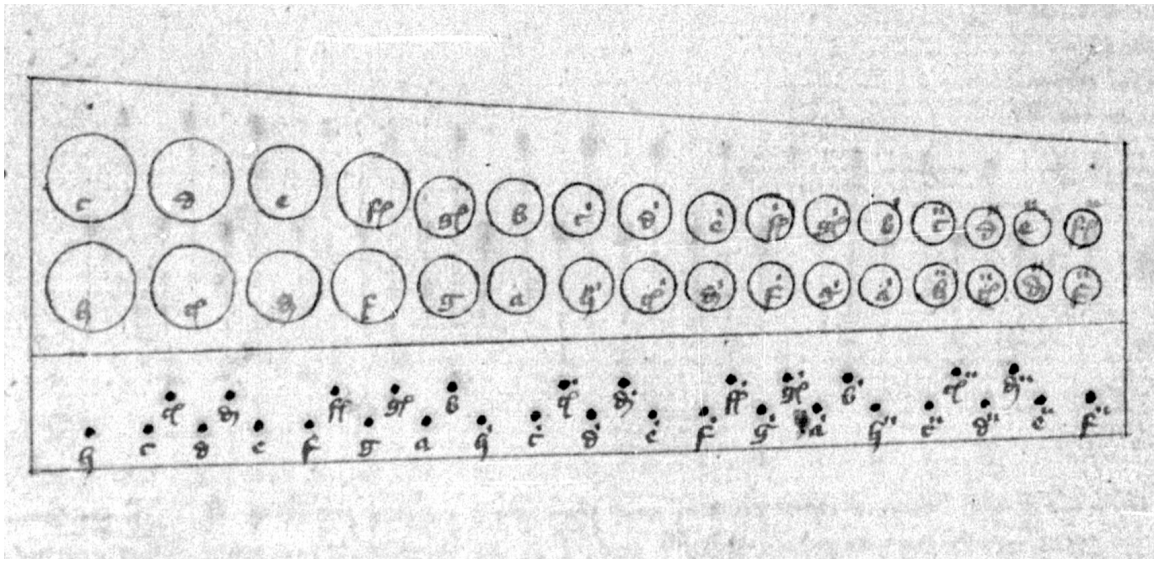

Fig. 10. A small organ windchest in Arnaut's manuscript, fol. 130v°
Source: https://gallica.bnf.fr/ark:/12148/btv1b90725989/f139.item.zoom

If there is an even number of keys in such an organ, then the two ranks will contain the same number of pipes. Arnaut's keyboard (B-f²) contains 31 notes yet 32 pipes are shown: the f♯² is clearly not required (at the right, back row). However, in his second drawing (at the top of the same sheet) Arnaut shows a design with an even number of pipes and keys (34 notes, with a compass B-g²,a²).

[8] Ripin, R/2009, p. 149, note 16. Ripin appears not to to have noticed the tops of three pipes in the back rank, in the treble, which testify to a two-rank pipe scheme *throughout* the instrument.
[9] Arnaut de Zwolle, fol. 130v°.

In the 35-note design of the Gubbio organ we would expect 18 pipes in the front rank and 17 in the back rank.[10] At the most there would be 19 pipes in the front rank, as the following table shows:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
B ♭	c	d	e	g ♭	a ♭	b ♭	c¹	d¹	e¹	g ♭¹	a ♭¹	b ♭¹	c²	d²	e²			
A	B	d ♭	e ♭	f	g	a	b	d ♭¹	e ♭¹	f¹	g¹	a¹	b¹	d ♭²	e ♭²	f²	g²	a²

Table 1.

That we have 26 in the front and (apparently) 9 in the back is a design so impractical that we can call it an impossiblity. The use of 26 pipes in the front rank implies an extremely narrow scaling in order to enable them all to fit and a system of extremely narrow channels to bring the wind to the correct pipe. In practice it would be well nigh impossible to supply each pipe in the treble with sufficient wind.

When we examine the pipe lengths of the Gubbio organ we can see more clearly what has taken place in creating this intarsia. The intervals between the pipes in the front rank should form a whole tone, but in the Pythagorean F♯ x B tuning (which we could expect in this period) there would be the normal whole tone (204 cents, ratio 9:8), but also a *smaller* interval at B-d ♭ and b¹-d ♭¹, of 180 cents.[11] The bass pipe lengths of the intarsia show exactly this pattern of smaller intervals and larger whole tones, as well as representing the absolute size of the intervals with reasonable accuracy.[12] This accuracy, and pattern, is maintained up to the 10th pipe (counting from the left = e ♭¹).

The fact that we have a pattern of larger *and* smaller tones in the A - e ♭¹ pipes eliminates the possibility that this organ was designed for a meantone tuning, which has equal whole tone sizes.

Regarding the accuracy of the pipe lengths, we find that the a¹ pipe has the length we would expect two octaves higher: 15.3cm; theoretically correct is 15.4 cm from the A = 61.6 cm, but this is well within the tolerance measured on old organs.[13] This is not to say that every interval is shown with the same accuracy, but in general the accuracy of the first 10 pipe sizes of the Gubbio instrument is better than that of the organ in the Urbino studiolo. (Appendix, 2)

---

[10] 19 pipes in the front rank, from A to a² is also possible, with 16 pipes in the back rank, which was the basis of calculation used earlier in the text.

[11] The F♯ x B Pythagorean tuning is implemented with 11 perfect fifths, the 12th fifth is narrow and lies between F♯ and B. The accidentals are all flats: d ♭, e ♭, g ♭, a ♭ and b ♭. This 180 cent interval is not a "whole tone", but results from the juxtaposition of two 90 cent semitones, with the ratio 256:243. It is not a minor tone, with a ratio 10:9, although that is close in size (182.5 cents). This inference of a Pythagorean tuning was reported for the Gubbio organ in Wraight, 1997, Part 2, p. 31.

[12] An "end correction" is necessary for determining the absolute pitch of an organ pipe because the vibrating column of air, which determines the frequency of vibration, is longer than the pipe itself. End corrections were made for this organ and examples of this type of calculation are found in Wraight, 1997, Part 2, pp. 202-206. Although end corrections were calculated for the Gubbio organ, they are not necessary in order to establish the *relative* sizes of the smaller and larger whole tone. The same result is obtained without end corrections.

[13] See Donati, 1979, p. 58, where the 16th-century organ of the Badia of Santa Fiora e Lucilla has 572 mm and 139 mm in the Ottava register, 570 mm and 139 mm in the Decimaquinta, both two octaves apart.

We can draw the conclusion that, despite all the doubts which the intarsia representation raises, a real set of pipes from an organ was almost certainly used as the model for at least the first 10 pipes of the front rank. Furthermore, the *pattern* of large and small whole tones confirms that a keyboard compass would have to start on A in order to match the pipes.

In a sea of uncertainty this information is of significance since we have found a consistency between keys and pipes which strongly suggests that the intarsiatore has worked from an original instrument as a model. It is probable that only a skilled musician or instrument maker would have understood how to calculate the pipe lengths appropriate to each note.

The length of the pipes indicates the pitch at which the instrument would stand, but decisive for this determination is whether the organ is depicted at its real size, which matter will not be treated fully here. However, the longest pipe of the intarsia is equivalent in length to Arnaut's pipe shown in his manuscript.[14] If the Gubbio organ is depicted in 1:1 scale, then it is a 4' instrument.

Although the length of the first 10 pipes clearly matches a practical tuning, the widths of the pipes remain to be investigated. Using the *fimbrie* [pipe scale diagram, Mensurtafel] which Arnaut gives in his manuscript (fol. 129v°) to find the lengths of strings or pipes, and also the circumference of the pipes, enables us to predict that when the circumference of the first pipe is about 1/5 of the actual length of the longest intarsia pipe, a rank of 18 pipes fills the windchest width.[15]

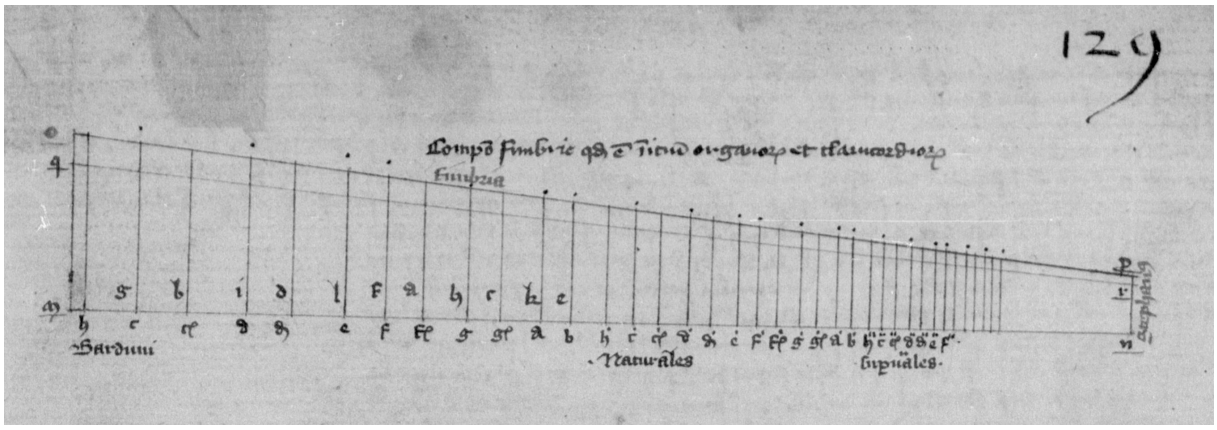

Fig. 11. Source: https://gallica.bnf.fr/ark:/12148/btv1b90725989/f136.item.zoom#

Arnaut's *fimbrie* is based on the scaling principle that the circumference of the pipe is halved at the second octave above the lowest note (i.e. from H to h¹ on Arnaut's *fimbrie*, the German notation for the English B to b¹). The horizontal line is marked off with the pipe lengths, the vertical lines show the circumference of the pipe. Thus, we find that the organ could have been designed using principles similar to those of Arnaut and these would have led to 18

[14] Assuming a scale of 1:4 in Arnaut's manuscript, as argued by Koster, p. 127.
[15] The fimbrie is shown at the top of fol. 129v° in Arnaut's manuscript, the top line representing a 1/6 scaling. Donati, 2007, p. 19 inferred the Gubbio pipe (A) to have a 1/5.5 scaling. Bormann, pp. 79-80, also discusses 1/6 scaling, testified by divider marks found in the Norrlanda organ (Statens historiska museum, Stockholm), with a straight line on the pipe scale diagram.

pipes, A - g², in the front rank.[16] Based on these dimensions the a² pipe would probably have been placed in the back rank.

On this 1/5 scale calculation the lowest pipe would have had a diameter on the intarsia of 3.9 cm and the a² pipe 1.4cm. The measurement of width of the longest pipe in the intarsie given by the Metropolitan Museum is 3.6 cm so it is plausible that the intarsiatore took the diameter of the pipe from a real organ.[17]

Inspecting the 1/5 *fimbrie* for the Gubbio organ also shows that the progression of the pipe widths is correct until f¹. This observation, and the conclusions reached above about the tuning and compass starting on A, give us good grounds to conclude that a real organ stood as a model for the intarsiatore.

After f¹ the pipe scaling becomes much narrower in order to cram in the following 15 pipes. This reveals that the intarsiatore took 11 pipes from the front rank and then substituted 15 other pipes in the space of the original 6 (or possibly 7).

Why the intarsiatore should have gone to the trouble of producing a front rank with 26 pipes is not immediately obvious since this would have involved more effort in creating suitable widths than simply taking measurements from the organ, which we can assume must have existed and formed the basis of the design.

Although we have established that the pipes and compass match in the bass, yielding a keyboard starting on A, we can infer little about the treble end of the keyboard. A compass with an omitted f♯² is unknown and seems *prima facie* unlikely. From the history of instruments, a compass ending -g²,a² is therefore more likely, which would require an equal number of pipes, 18 in each rank, with a total number of keys or pipes equalling 36.

When perspective errors and missing pipe feet were found in the intarsia representation, the hypothesis was considered that the impossible layout of pipes was part of an elaborate hoax on the part of the intarsiatore to produce a realistic-looking instrument, which in fact had never existed, and would never have been built as such by an organ maker.

Part of this possible hoax might even have extended to creating a mirror image of the keyboard so that the unusual f²,g²,a² compass in the treble would in fact have been the bass octave.[18] If this were the case, then a compass with three "white" notes before c permits of two possible interpretations (both with 22 natural keys):

1. G,A,B-g² (no G♯ or B ♭)
2. A-g² (with B ♭ as a "white" note[19])

---

[16] A widening of the pipe scaling in the treble may have been used, which is what we can measure in the Barili organ, Appendix, 1.

[17] Olga Raggio generously supported this research in 1996 with measurements of all the pipes.

[18] This unusual compass in the treble was in fact the starting point of this study, because the Gubbio organ was initially selected as an example of how an early clavichord compass might have been made. See Wraight, 2021, p. 14.

[19] This unusual practice was known in the 14th century, an example of which has survived in the organ from Norrlanda. Bormann has given the most complete account of this, pp. 65-67. Ripin also examined the possibility that the organ in the van Eyck painting of The Mystic Lamb in the Ghent altarpiece was originally made with a chromatic keyboard starting on G, with f♯ as the first raised key. Meeùs, 1983, explained why such a keyboard would have been possible. However, Ripin's analysis

Since we know that the first 10 pipes length yield a credible F♯ x B Pythagorean tuning we can use the sequence of larger and smaller whole tones to test the compatibility with these two compasses. Compass 1 is unlikely anyway, but is impossible with this sequence. However, compass 2 is compatible with it, if unusual, and probably only relevant to the end of the 14th century. A-g² is a visual "palindrone" of A-f²,g²,a², and not merely a mirror image. Thus, it is conceivable that the intarsiatore was playing a joke on us and had reversed the keyboard so that the bass became the treble.

However, this "palindrone" hypothesis does not exhaust the possible explanations. A 15th-century instrument would usually start on B- (chromatic) or F,G,A- (lacking F♯ and G♯) so the Gubbio organ is unusual in starting on an A key. Although the match between pipes and keys in the bass is a necessary condition for the compass starting on A, it is not a *sufficient* condition in order to establish this as the *original* compass. We can imagine that this organ has been reduced in size, in order that it not dominate the background against which it is placed, and that this proceeded by removing keys for F and G and the first pipe for F in the front rank; the G pipe would be behind the F and is not visible anyway. This would have had the effect of reducing the height of the organ by 1/4 of the current, longest pipe (A). If the intarsiatore had then retained the original instrument width, thereby effectively "moving" the F and G natural key widths to the treble, then we could understand how the strange treble compass came about: originally the entire compass would have been F,G,A-f² (35 notes), with the apparent g² and a² keys being "transferred" from the original F and G.[20] This will be called the "adaptation hypothesis"

The motivation for such an alteration is not hard to discern: the original F pipe would have been above the level of the dividing shelf in the niche behind the organ and dominant in the view.[21] Moving all the pipes over to the left would have gained some 4.5 cm space (horizontally) so that a view of the neck of the fiddle behind the organ would have resulted.[22] Without this change the fiddle would only have been seen as a less comprehensible oval shape in the niche. Since the original f² pipe (and adjacent organ case) would have been some 2 cm longer, it is clear that this change in the bass also improved the view into the niche, and to the right of the organ. It probably also avoided a clash of the organ case with the the bottom of the latticework door of the niche. However, quite apart from this hypothesis, if this were a real room the organ would have to be moved anyway in order to open and close the latticework door.

---

appears faulty since the infra red reflectographic reproduction of the underpainting at Getty Images http://closertovaneyck.kikirpa.be/ghentaltarpiece/#viewer/=&sync=3&view=3&rep1=1&id1=23&rep2=1&id2=21 appears to allow one less natural key hidden by the angel's hand than Ripin counted. This would suggest an original compass with 6 naturals before the f♯, which could imply a B♭ for the first key, as a "white" note. None of this analysis can prove that van Eyck created a realistic keyboard, even in the underpainting, an inference with which Ripin could agree.

[20] In some Italian harpsichords, later modifications even involved physically moving keylevers from the treble to the bass, or vice versa, in order to change the compass. However the pieces of veneer from the F and G keycovers would not fit the intarsia keyboard at g² and a² because of the changing angle of perspective across the keyboard.

[21] A similar hypothesis has been proposed for an alteration of the Urbino organ's pipes: see Appendix, 2.

[22] 4.5 cm was derived graphically from the *fimbrie* with the existing, and correct, pipe widths for A-f¹.

This adaptation hypothesis has been illustrated with a photographic montage of the hypothetical, original organ, (Fig. 13 below, right).

Left: the actual Gubbio intarsia
Fig. 12. Part of Fig. 1

Right: the original F,G,A-f² organ
Fig. 13. Photo montage from Fig. 12.

In order to re-create the original organ in Fig. 13, the pipes for A-f¹ (pipes 1-11 from Fig. 12.) have been moved to the right in Fig. 13 by the space of the original F pipe, then the missing F pipe has been added. (The 15 new pipes of Fig. 12 have been left visible in Fig. 13). The organ case at the right in Fig. 13 has been extended upwards (without disguising the original height). In Fig. 13 the keyboard now has the original F,G,A-f² compass.

These considerations of the adaptation hypothesis imply that the position and width of the organ case was already fixed, or could not be moved further towards the entrance door. Perhaps the layout of the panels was improvised empirically as the required details of the design emerged.

Only as the montage was prepared did a detail of the intarsia become apparent which agrees with the hypothesis and indicates that the entire, original keyboard had probably been made before the modification to the pipes. There is a strip of wood just above the natural keycovers, which is jointed to the moulding above the keyboard. This strip extends across the entire width of the keyboard, but at the right hand side is a small piece of veneer, the width of two naturals, which has been added, with a slanting joint. This extension would have been necessary if the keyboard originally reached to f² and was moved in its entirety towards the bass by two naturals.

Fig. 14. Part of Fig.1

The slanted joint indicates that the f² keycover did not abut the case; there would have been a space of about 5mm. We now see a spacer in the bass of the keyboard (see Fig. 7) and this may well be related to the operation which removed the keyboard and translated it to the bass in order to create the A-f²,g²,a² compass. More speculation on this point is not fruitful.

Once this adaptation hypothesis has been formulated then something else becomes obvious: that the organ has an unusually squat height to width ratio (1.28). A comparison with the Barili organ (Appendix, 1), which also has an F,G,A-f² compass (ratio 1.64), makes this clear. We have to be careful not to exaggerate such details as "proof" since Arnaut's *ad ala* design (B-f²) has a similar ratio (1.3) as the Gubbio intarsia organ, largely because the keyboard compasses are similar in the bass.[23]

That an actual organ stood as a model for this intarsia is now practically certain so we can draw the following conclusions:

1. The first 10 pipes in the front rank (A-e ♭¹) were constructed for a Pythagorean F♯ x B tuning.
2. We cannot rely upon this intarsia as evidence of the unusual compass ending on f²,g²,a².
3. If the compass of an organ started on an A, then it was more likely A-g²,a² (36 notes).
4. The compass could have been A-g² (35 notes, with B ♭ as a "white" note) *if* the intarsia keyboard were a mirror image of the original.
5. The original organ was probably made with an F,G,A-f² compass, but the bottom two pipes and keys were removed (the "adaptation hypothesis") in order to give a better view into the niche behind the organ and harmonise with the surroundings.

[23] There are other implications, which will not concern the general reader, but indicate that the three-octave keyboard size (Stichmaß) is not independent of organ pipe design, but probably secondary to it, depending on the compass and the pipe scaling. Arnaut's *ad ala* design (fol. 130v°, B-f²) has a keyboard width 1:√2 of the fimbrie length for the longest pipe, but the other design at the top of the sheet (*al cuspide*) uses a different keyboard width since it has a wider compass (B-g²,a²). On the use of the 1:√2 principle in instrument making see Koster, pp. 127-135.

It remains only to take another look at the incongruences in the intarsia and consider these in the light of what we have gleaned about the representation of the organ.

We have described the "errors" of perspective and disconcerting details, which are incorporated in the organ case, particularly around the keyboard area. We could have been inclined to explain these through the inexperience of the intarsiatore, but a lack of skill cannot explain how an organ *design* with 18 pipes in the front rank is displayed with 26 pipes, 7 of which could have not have been used, 3 of which had no feet, and 1 of these which could not have stood at the position of the intarsia. Unexplained gaps in the back rank of pipes compound the difficulties. Furthermore, the effort of producing this improbable design exceeded that of simply copying the instrument which was standing as a model for the intarsiatore. The more one considers all these details, the more evident it becomes that not only is the organ an impossible musical instrument, but that it was intentionally and carefully constructed as such.

We have three different phenomena to deal with:

1. Different perspectives for similar pipes
2. Improbable and asymmetrical constructional details around the keyboard and case, with shade incorrectly cast.
3. An impossible musical instrument with a mismatch in the number of keys and pipes, missing pipe feet, and incorrect pipe lengths.

Although art historians have devised explanations for inconsistent perspectives in painting, one being to describe this as "a fragmentary way of seeing", this seems to miss the mark in this instrument regarding the pipes.[24] Here we are simply unsettled with a perspective which does not fit, but the adaptation hypothesis with the removal of the F pipe could explain this: the perspective for the A pipe could be correct; it is the top of the case in the bass which is incorrect, having been cut down from a higher level of an original F pipe. More detailed examination of the height of viewing in the entire studiolo would be required to clarify this matter.

A somewhat more obvious problem is the incongruence around the keyboard area, described above, which seems to have the sort of impish quality we find in Escher's "Watermill". Examples of this sort of possibly mischievous mistake are not limited to the Gubbio studiolo, but organs are depicted.[25] Of course, in illusions of this sort we can find our way out and realise, if we study the organ intarsia long enough, what the problem is. We can free ourselves from the illusion (if we even noticed it), that something is not quite right, just by studying the intarsia.

The third error belongs to a different category: we require specific knowledge of organ building in order to understand that the instrument could not have worked. The adaptation hypothesis of the removal of the F pipe does allow an explanation of the strange pipe scaling in the treble since its removal created a gap of some 4.5 cm, with reference to the original case width. In fact the intarsiatore "discarded" the 6 original pipes above f^1, which means that he had to fill in a gap of some 15 cm with other pipes. That he chose to do this with 15 pipes is inexplicable from the organ builder's craft, since it could have been done with the original

[24] See Carnevale, citing Lionello Venturi on Ucello.
[25] See Appendix, 3.

number of 6 pipes. Whether he understood the impossibility of what he created, or was not bothered by it, is the crucial point for understanding his intention, but cannot be discerned from observation of this intarsia alone.[26]

At this stage we should consider the intarsia of the clavichord in the Urbino studiolo, completed in 1476 some seven years before the Gubbio studiolo. Verbeek has noted errors in the instrument, that the number of strings does not correspond to the number of tuning pins and that some tangents are missing, details which belong to the second category listed above.[27] There is a further difficulty with this intarsia, which Verbeek was able to establish through a reproduction: the intarsia shows a case which has insufficient depth (in the vertical plane) to allow the keylevers and tangents to work well.[28] Thus, Verbeek's finding was that the intarsia is a version which *improves* the view into the action of the clavichord, but at the expense of a realistic reproduction. Verbeek cites Arasse, who suggests that we should see these intarsie as a "representation", i.e. as works of art, not as photographic reproductions of an original instrument.[29]

This view of works of art was already reached in 1974 by Ripin in the study of a similar subject: the Ghent altar painting by van Eyck in 1432, which shows an angel playing an organ.[30] After establishing that the number of pipes did not agree with the number of keys, Ripin concluded that the instrument was unworkable and that "Clearly this organ - despite the extraordinary impression of verisimilitude that it gives - cannot be a literal quasi-photographic rendering of a real instrument."[31] Furthermore, he cautioned: "Accordingly, the general lesson for the musical iconographer to draw from the Ghent altarpiece would appear to be that he should be wary of representations that appear to be literal, realistic depictions and doubly wary of such depictions in the works of major artists."[32]

Despite this conclusion, Ripin had earlier observed that " 'Realistic' portrayal of an object does not necessarily mean that it has been represented with photographic accuracy" but considered that "...this sort of fidelity to the actual object would generally appear to be the case for such works as the intarsias in the Urbino and Gubbio studioli made for Federico da Montrefelto."[33]

However, the scepticism expressed by Ripin about realistic representation is exactly what we have to apply to the intarsie in Urbino and Gubbio. It is precisely the near-photographic quality of the intarsie which creates the paradox: how should we understand the elementary "errors" in the clavichord or organ intarsie when the intarsiatore have demonstrated so clearly their skill in realistic representation? In the Gubbio studiolo we can even read words in Virgil's manuscript depicted on a lectern, so accurate and detailed is the intarsia, yet pipe feet

[26] We might find some sense in the organ's pipe layout if the aim were simply to present a line of pipes which was similar to the shape of an upright harpsichord, in the sense of Koster's discussion, pp. 120-127, and Figs. 5 and 6.
[27] Verbeek, 2021, p.30.
[28] A more obvious example of exactly this defect is the intarsia clavichord (c. 1477) in the cathedral museum, Cremona, where the keys are at the level of the top of the case, leaving no space for tangents. See Brauchli, Fig. 2.18, p. 38.
[29] Verbeek, ibid, citing Arasse, whose text is to be found on p. 245 (Arasse, 1993).
[30] Ripin's publication first appeared in 1974 in a specialist Festschrift publication with limited readership. It was not even known to Van der Asperen de Boer, a scholar of the Ghent altarpiece.
[31] Ripin, R/2009, p. 150.
[32] Ripin, ibid.
[33] Ripin, R/2009, p. 148.

are missing in the organ.[34] The "errors" are not obvious and have no function, so they cannot be any part of a cultivated and contrived symbolic presentation of Federico's position as ruler.

It seems as if the Gubbio intarsiatore has created a treacherous hoax at the core of one of the symbols of the *vita contempletiva* in Federico's studiolo: the harmony of sound and number, which the pipes should symbolise, is absent, because the pipes are partly a nonsense and the instrument as a whole could not function.

This is a more fundamental failing in the organ intarsia than merely the incongruence of the numbers of strings and tuning pins, as in the Urbino clavichord. Is calling it a "hoax" the appropriate expression? The impossibiity of the design can be described, but what was the intention?

General appraisals of the studioli from art historians are inadequate to illuminate this problem so six parallel examples of organs in intarsie have been examined (see Appendix 2 for the detailed analyses).[35] This survey of organs shows us that whereas the accuracy of representation of the Urbino clavichord is high, as also is that in the Barili organ (Appendix, 1), these are exceptional examples. The norm for intarsie of organs is that even the number of pipes and keys do not correspond; for Ripin, such a discrepancy was a criterion of iconographical unreliability.

Despite its realistic appearance, the pipes of the well-known Urbino studiolo organ intarsia (Appendix, 2) are not tuned to correspond to the compass of the keyboard, so this is also an impossible design. If the intarsiatore worked from an existing organ, then the longest two pipes were shortened so that the organ fits better within the dimensions of the niche. The outer four pipes become progressively too long, which may have been for reasons of appearance. The centrally-placed Order of the Garter, conferred on Federico in 1474, in the centre of the instrument above the keys, and his coat of arms, may be emblematic inventions which required the outer pipes be adjusted to fit these devices.[36] This instrument accords with Verbeek's finding of "artistic licence" even better than the clavichord.

Exactly the same type of alteration in the outer pipes occurs in the Assisi organ (Appendix, 3), which suggests that the intarsiatore of the Urbino and Assisi intarsie did not find a real organ visually satisfactory. It also has pipes and a keyboard range which do not match so that it is not just impossible, but through the apparent extra "e" keys is improbable as well. Whether this is an intentional deception is difficult to decide, but on Ripin's criterion it does not qualify as a witness of iconographical detail.

The San Lorenzo intarsia (Appendix, 4) exhibits a mismatch between the keyboard compass and the number of pipes, although we could bring these into correspondence if we were to assume that an octave had been omitted from the keyboard for reasons of simplification.

Equally unlikely is the small portative on a door (Appendix, 5), which has 19 pipes and 19 keys, but none of these is a sharp. The pipe lengths exhibit impossible intervals, but this

[34] See Raggio, 1996, Fig. 5-128, p. 152.
[35] I am obliged to James Wraight for comments on an earlier version which caused me to look further for comparisons with other intarsie of organs.
[36] The order was conferred on Federico in 1474, two years before the studiolo was started. See also Appendix, 2, note 57. We can question whether Federico ever owned such an organ in Urbino, which may have been depicted solely for his studiolo.

instrument may, in view of its small size, never have been intended to give more than a general impression of an organ.

The Platina intarsia from Cremona (Appendix, 6) shows a portative with an awkward conflict of perspective and incompatible numbers of keys and pipes. It is therefore poorly executed as well as being an incoherent design.

Lastly, the organ depicted by Antonio Barili (Appendix, 1) is so accurately made that we can even infer a meantone tuning for the pipes. This intarsia, comparable to the Urbino clavichord, reminds us that intarsiatore were capable not only of photographic realism, but great accuracy as well.

This small survey readily shows two categories of intarsie:

Firstly, those instruments, the majority of which could not work, but give a recognisable semblance of an organ.
Secondly, two which show (or are close to showing) workable instruments.

The inaccuracies of the Urbino organ's pipes create an impossible instrument, but these appear to have resulted from aesthetic considerations. We have the impression there is nevertheless a sensible design once the pipe lengths are corrected. The Cremona and Gubbio portatives (Appendix, 5 and 6) are also impossible, but one hesitates to find an intentional deception in what is merely a small illustration.[37] The Assisi and Gubbio organs are comparable, since both are impossible, but unlikely as well, given a modicum of knowledge of the organ builders' craft.

Although the errors of perspective and shadow around the Gubbio organ create the impression for us that at least the intarsiatore is jesting with the viewer, if not purpetrating a downright deception, the description of a "hoax" would not be applicable if all this occurred through incompetance. However, the skill of the intarsiatore in the Urbino and Gubbio studioli makes it hard to believe that every incongruency was an unintentional error. Can it be that, in omitting the feet of pipes, the intarsiatore enjoyed poking fun at the then current fashion for realistic-appearing intarsie?

Until the adaptation hypothesis was formulated and confirmed, there appeared to be no explanation for the strange break of pipe scaling in the treble of the Gubbio organ. However, the modification indicates that visual criteria in the organisation of the panels created the requirement. That the changes were undertaken with so little accordance to organ building practice is the puzzle, not the changes themselves.

However, when we take into account the general level of accuracy in intarsie of organs it appears that we have perhaps developed too high a level of expectation. The majority of the intarsiatore were apparently satisfied if the instruments looked somewhat like organs. This could be seen as testifying that the intarsiatore understood their craft, but not that of the organ builders: they could copy an object before them, but not adapt it in a technically correct way.

If the intarsiatore were blissfully unaware of the symbolic "untuning of the skies" they wreaked on the studiolo with the unplayable organ, then it would require us to be more

[37] I reserve the description "portative" for an organ which can be simultaneously carried and played by the same person. See note 7.

circumspect in the interpretation we place on error and improvisation. However, we could resolve the paradox of intended symbolism and inadequate execution if we assume that the intarsiatore in the da Maiano workshop entrusted with executing Francesco di Giorgio's design simply lacked the level of education, training, and understanding to appreciate the implications of their clumsiness or error. Yet with the missing pipe feet and other incongruencies we wonder...a hoax is possible, but not proven.

The implications of the Gubbio and Urbino organs are wide-ranging, even if exact conclusions cannot be drawn about the intentions of the intarsiatore. We are cautioned, and the situation is even less reliable than Ripin supposed, that *nothing* we see, even in a realistic-appearing intarsia, can be accepted without scrutiny as iconographical evidence of instrument making.

Kirkbride reminds us of some advice given by Alberti that painters imitate directly from nature, but he also urges them to "leave more for the mind to discover than is actually apparent to the eye".[38] This seems apposite for the Gubbio organ and suggests that, even if it is not an arcane hoax, Alberti has given us a wise counsel, to apply careful observation in order to discover what we actually have before us.

[38] Kirkbride, online version, chapter 1, §8.

Conclusions

The Gubbio organ intarsia was made with sufficient accuracy that we can detect a Pythagorean tuning for the pipes.

There are dimensional incongruencies and shading errors in the casework around the keyboard.

The pipes and keys in the intarsia do not agree in number.

3 pipes lack feet and there are gaps in the back rank where there should be pipes.

The intarsia of the Gubbio organ shows an impossible instrument.

An actual organ stood as a model for this intarsia, but was modified to fit the panel.

The unusual compass A-f²,g²,a² is unknown in 15th-century practice; it results from a modification to the organ on the panel. The compass of the organ (which stood as a model for the intarsia) was F,G,A-f², from which the F and G pipes were removed. The keyboard then started on A and the space for two removed naturals (F and G) was added at the treble end of the keyboard.

A study of 6 intarsie of organs shows that 5 of them contain errors, making them impossible instruments.

The Barili intarsia depicts an organ with sufficient accuracy that we can detect a meantone tuning for the period before 1500.

The Urbino intarsia organ is also an impossible instrument, some pipes having been reduced in length in order to fit its panel.

Although the Gubbio studiolo shows a high level of accuracy of representation, there are incongruencies around the keyboard and omissions in the organ intarsia. These might have been intended by the intarsiatore to poke fun at the viewer's expectation of seeing real objects.

The improbable pipe layout might have been the result of ignorance, but could have been a hoax.

No early intarsie of musical instruments can be accepted without scrutiny as evidence of instrument making.

Appendix, Six organ intarsie

The studies of the following six organs are based on photographic reproductions of the intarsie, so the accuracy of the pipe lengths is limited. However, comparing the museum photo of the Gubbio organ with the museum's measurements showed that it is possible to extract pipe lengths from the photograph with an error not exceeding 0.55% (in total).

Assuming an intarsiatore incorporated the measurements of *actual* organ pipes one can expect to find pipe lengths in an intarsia, when working from a photograph of it, within about 5.5% of the *theoretical* length of a pipe; I call this the "uncertainty criterion" in the discussion below.[39] It is not essential for the purpose of this study to make end corrections; the relative proportions of adjacent pipes on the windchest are fairly accurate. Coning of metal pipes for the purposes of tuning, alters the actual pitch to some extent for the same length of pipe. Furthermore, one cannot even assume that there will be the same wind pressure at each pipe foot, which could also vary the required speaking length of the pipe.

Since the large semitone in a Pythagorean tuning (114 cents) is 6.7% larger than the adjacent notes, and exceeds the uncertainty criterion, it initially appears possible to predict with confidence the actual note intended for a given pipe length.

The criterion also does not permit us to determine whether a Pythagorean whole tone size (ratio 9:8 or ratio 1.127; 204 cents) or a meantone (ratio 1.118; 193 cents) was intended since the difference between these two is only 0.8%.

As has been argued above for the Gubbio organ, there are differences in the whole tone sizes, B - d ♭ being smaller in a Pythagorean tuning, which can be detected in an accurate intarsia, even if the finer detail of a tuning must remain unrecognisable.[40] It is not so much the absolute size which we need to establish, as the position in the octave where this different whole tone size occurs. That is, *if* we can reliably detect a difference in whole tone sizes, then the *pattern* of small or large intervals will permit an inference about the tuning system.[41]

In the examples considered below, some errors in the intarsie are considerably more than 5.5%, so that we can be confident of distinguishing between normal organ building practice and phantasy designs.

The following organs are considered in the order of descending accuracy in order that best practice be established at the outset of this brief survey.

---

[39] This was established empirically from measurements of a photograph of Winold van der Putten's reconstruction of the Barili intarsia organ. The errors for a, b, d♭¹ and e♭¹ were -4.5% to -5.4% compared wth the pipe lengths an octave lower. Winold van der Putten kindly supplied a higher resolution photograph than is to be seen at his website. See also note 45.

[40] The calculations involved in the examination of pipe lengths have not been presented here in order to offer an overview of the instruments. % differences in pipe length are given in preference to the less intuitive, logarithmic-based cent sizes. Cents are used mostly in the conventional way for defining the tuning scheme.

[41] Lindley's summary, pp. 6-10, of three 15th-century sources that the small semitone is always to be found in the lower half of the whole tone suggested for me a method for distinguishing the F♯ x B Pythagorean tuning from meantone. I applied this method in Wraight, 1997, Part 2, pp. 118-119, unaware that Tagliavini had previously used this procedure in examining the Urbino clavichord intarsia (Tagliavini, 1986, R/2017, pp. 81-82). It is unfortunate that Tagliavini's interesting essay is not better known; it was also unknown to Mondino in his study of the same clavichord.

1. Organ, San Giovanni, Siena, c.1490-1500 (now S, Quirico d'Orcia).

This intarsia by Antonio Barili is one of the most detailed in representing an organ.[42] The metal pipes, with several ranks, are depicted realistically and calculation of pipe length ratios shows that considerable accuracy can be found in this representation; it is therefore inferred that an actual organ stood as a model. The panel measures 34" by 22" (86.4 x 55.9 cm) from which the speaking length of the longest pipe can be calculated as about 56 cm long.[43] However, the organ is probably not represented at the original size.

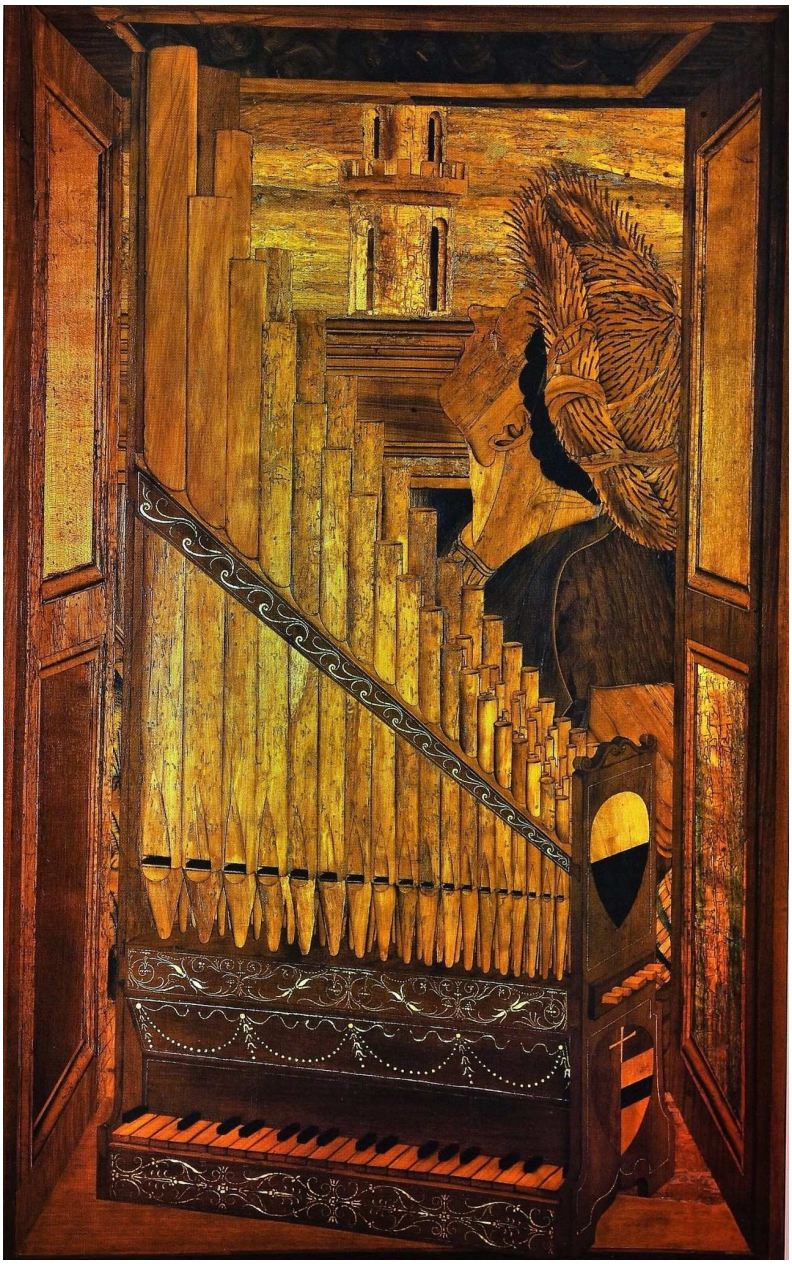

Fig. 15. Source: Gamelán[44]

[42] See Tarrini, no. 11, p.17. Donati, 2006, Figs. 1-2, shows the organ and a close-up view of the pipes in the treble.
[43] Kopf, p. 40.
[44] Source, photo: https://www.pinterest.de/pin/620511654881787312/ uploaded by Gamelán, accessed 17.05.2021. Original source and copyright holder unknown.

The front pipe rank and the keyboard agree in the number of notes, with a 36-note range F,G,A-f² (pitch not specified).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
G	B ♭	c	d	e	g ♭	a ♭	b ♭	c¹	d¹	e¹	g ♭¹	a ♭¹	b ♭¹	c²	d²	e²	f²
F	A	B	d ♭	e ♭	f	g	a	b	d ♭¹	e ♭¹	f¹	g¹	a¹	b¹	d ♭²	e ♭²	f²

Table 2.

There appear be accidental keys as the first and last notes, beyond the F,G,A-f² range (35 notes), which is obviously impossible, but rather than accept these as a hoax element, Tamminga has suggested they could be register stops for special effects.[45] An echo of this possible practice is found in some keyboard instruments by Cristofori and Ferrini from 1720 and 1731.[46]

Analysis of the pipe lengths in the front rank shows that they represent credibly an actual instrument with deviations from a hypothetical meantone temperament or Pythagorean tuning being no more than 2.7%.

This is remarkably close for an intarsia, but the 5.5% uncertainty criterion established above only permits us with reasonable confidence to identify which tuning could have been used via the c♯/d ♭ to e ♭ interval size; this exhibits a 14.7% difference between 1/4 comma meantone (234 cents) and F♯ x B Pythagorean (204 cents).

The interval between adjacent pipes for d ♭ and e ♭, as well as an octave higher, represents a 16.7% increase (1/4 comma meantone = 14.4%; 234 cents), with an error of +2.3% and thereby *suggests* that this organ was tuned with a "meantone"-type temperament.[47] A Pythagorean F♯ x B tuning should have a 12.5% increase (204 cents) at this interval which implies an error of +4.2% for a Pythagorean tuning.[48] The relatively large, and easily recognisable difference between the interval sizes in these two tuning systems results from having a c♯ in meantone and not a d ♭.

Furthermore, there are different *patterns* of the interval spacings in Pythagorean tunings and meantone temperaments. Compared with the normal, whole tone size, a Pythagorean tuning will exhibit a smaller interval (180 cents) at B-d ♭ whereas meantone has a larger interval (234 cents) between c♯ and e ♭. We find that the Barili intarsia shows a 14.5% increase between c♯ and e ♭, and c♯¹ and e ♭¹, which is noticeably larger than the whole tones in the pipe rank (average 7 intervals = 11.2%). The fact that this difference in the two semitone size is perceptible at all three occurrences of the c♯-e ♭ interval strengthens the likelihood that we have detected an intended design feature and not merely a random fluctuation of error.

[45] Kindly communicated by Winold van der Putten (14.06.2021) in an English version of his website text. The website describes the reconstructed organ: https://www.orgelmakerij.nl/2018san-quirico/

[46] See Pollens, Plate Xa, for the 1730 Ferrini instrument where the "sharps" are locking tabs for the keyboard mechanism.

[47] This could be 1/4 comma meantone, or a near, practical variant in which the major thirds are slightly tempered.

[48] Winold van der Putten used a meantone tuning for his reconstruction because he considered the date of the intarsia too late for a Pythagorean tuning (private communication, 14.06.2021). My analysis of the meantone tuning was undertaken before I learned of van der Putten's reconstruction.

In order to test the credibility of this procedure, Van der Putten's re-construction (tuned in meantone) was subjected to the same examination through a photograph of the pipes and yielded a similar result. Therefore the procedure is revealing enough and the conclusion is permissable that we have evidence of a tuning in the Barili organ which is not Pythagorean, but probably a meantone temperament. This finding is of significance since there are few indications from existing 15th-century instruments to document the change away from Pythagorean tunings.[49]

The instrument depicted in the intarsia is attributed by van der Putten to Alberto Aringhieri's ownership on account of his coat of arms on the side, and according to Tamminga could have been made by Lorenzo da Prato (the builder of the San Petronio organ in Bologna, 1471-1475).[50] Aringhieri played a central role in the construction of the chapel of San Giovanni in the Duomo at Siena in which the intarsie panels were installed.[51]

This intarsia represents a convincing instrument with surprising accuracy, and can be seen as a benchmark of best practice on the part of the intarsiatore, in comparison with which other intarsie can be assessed. It also permits us to infer the use of a meantone-type temperament, rather than the older Pythagorean tuning.

[49] In 1986 Tagliavini, R/2017, p. 82, indicated that the 1471-1475 Lorenzo da Prato organ in San Petronio, Bologna, might have had some sort of meantone tuning, but in the 2013 publication, Mischiati and Tagliavini, p. 177, this could not be clearly established.

[50] A document cited by Tamminga indicates that a simlar instrument was made for the Ospedale S. Maria della Scala, Siena, in 1460-1461 by Lorenzo da Prato. Private communications from Winold van der Putten (14.06 and 14.07.2021).

[51] His actual role is still the subject of scholarly investigation. See Smith p. 27.

2. Small organ, Studiolo, Palazzo Ducale Urbino, 1476-1482.

This organ is one of the better-known intarsie and has been executed with great attention to realistic detail. For example, the central pipe has been made of 8 lengthways strips of wood of different shades in order to create the illusion of a cylinder. The organ is shown here in its surrounding frame of the niche.

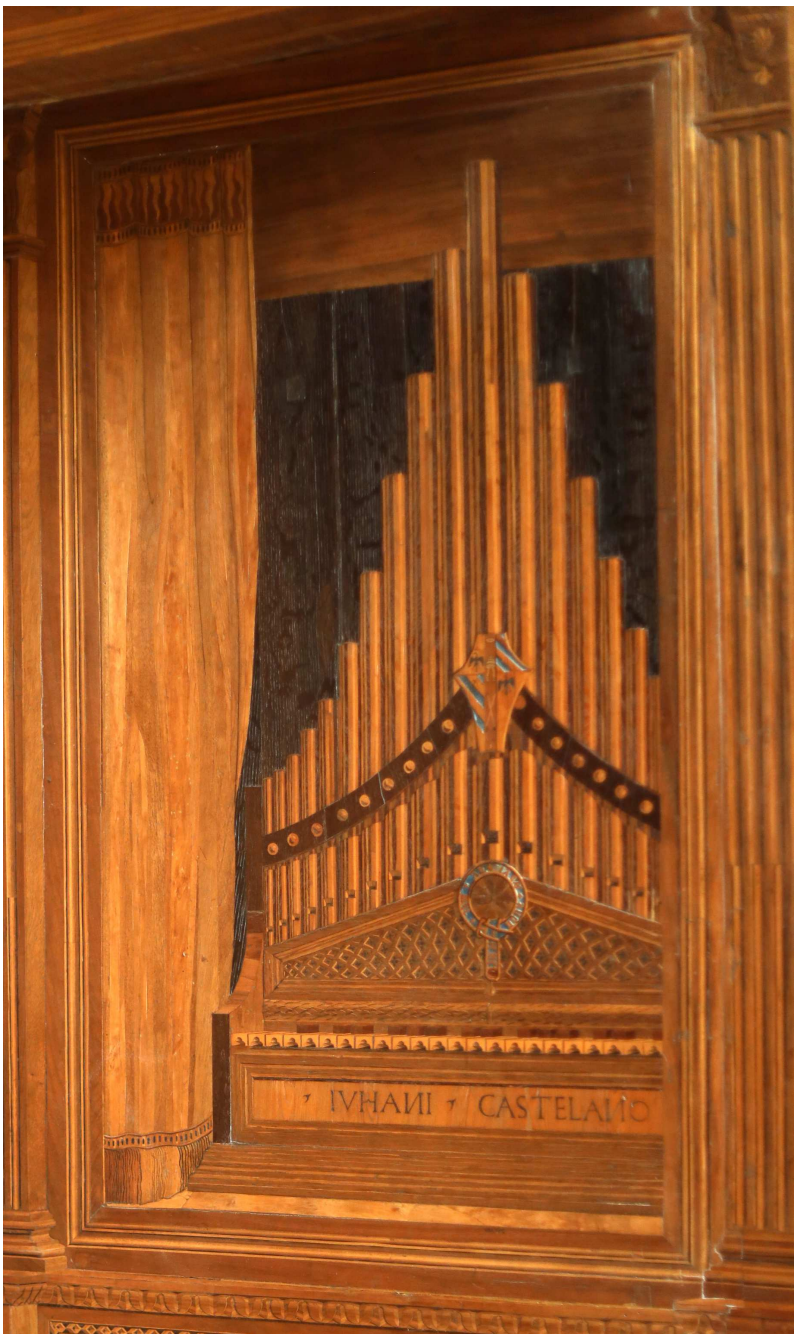

Fig. 16. Source: FabriGarri, wikimedia[52]

[52] Part of the file uploaded by FabriGarri: https://commons.wikimedia.org/wiki/File:Studiolo_del_Duca_34,_tarsia_della_parete_destra.jpg accessed 11.07.2021. A photo with higher resolution is viewable at Getty Images: https://media.gettyimages.com/photos/intarsia-decorated-with-trompe-loeil-14721476-studiolo-of-federico-da-picture-id154715451?s=2048x2048

Four pipes at the right are not visible, but a total number of 21 can be calculated from a symmetrical disposition. 23 natural keys (to g²) are visible and symmetry of the keyboard about the centre leads to a 26-note compass. Thus, pipes and keyboard agree in a 42-note compass of F,G,A-c³, with the pipe layout shown below.[53] The pipe for b², which belongs to the front-rank series, has to be placed in the back rank (no. 21).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
c³	a ♭²	e²	c²	a ♭¹	e¹	c¹	a ♭	e	c	B ♭	d	g ♭	b ♭	d¹	g ♭¹	b ♭¹	d²	g ♭²	b ♭²	b²
g²	e ♭²	b¹	g¹	e ♭¹	b	g	e ♭	B	G	F	A	d ♭	f	a	d ♭¹	f¹	a¹	d ♭²	f²	a²

Table 3.

Huber first alerted me to the incorrect interval size between G and A in this organ.[54] My examination of the entire series of pipe lengths shows that the instrument as it appears does not give a convincing progression of intervals.[55] The intarsia was made with some 38 mm above the F pipe to the top of the niche, but there would only be about 10mm if the first two pipes had their correct length with respect to A. The remaining pipes (from A) form a reasonably accurate series of intervals (i.e. no error more than 3.4%) from A to e ♭¹ on the left side, but only as far as d ♭ (pipe 13) on the right side. I infer that the first two pipes have been shortened from an actual instrument in order to fit the organ into the niche (in which this organ appears).

It is difficult to calculate how close the pipe would have been to the *inside* of the niche without knowing the perspective lines used in constructing the intarsia panels. The original size of the organ would have appeared as follows (Fig. 17, right, photo montage) and shows that the longest pipe appears as if stuck to the top of the niche. In fact it looks worse than calculation had initially suggested and makes the intarsiatore's intervention the more comprehensible.[56]

[53] Tarrini, p. 16, gives a compass of F,G,A-g²,a². A virtual realisation of the organ at https://physlab.uniurb.it/Mostra_internet/immagini/clavicordo2.jpg shows a compass of C/E-d³ for the 21-pipe front rank, i.e. 47 keys for 42 pipes, which is a modern example of an impossible instrument.

[54] Although I calculated pipe lengths and interval sizes in 2000 it was Alfons Huber's observation (email, 30.01.2020) of this discrepancy which alerted me to the difficulties concerning this instrument. Huber is preparing his own publication concerning this instrument.

[55] The longest pipe in the intarsia measures 552mm from the open end to the upper lip of the mouth, a measurement kindly supplied by Paolo dal Pogetto in February 2000. The remaining measurements have been scaled from a photo supplied by the Soprintendenza per i Beni Artistici e Storici, Urbino in 1996.

[56] It follows that the pipe scaling (length divided by circumference) as shown (1:6.25) is not that of the original organ. It would be 1:6.7 with the lengths as re-calculated, which is narrow, but not surprising for paper pipes, which lack upper harmonics, and consequently sound clearer with a narrow scale, as my own experience has shown.

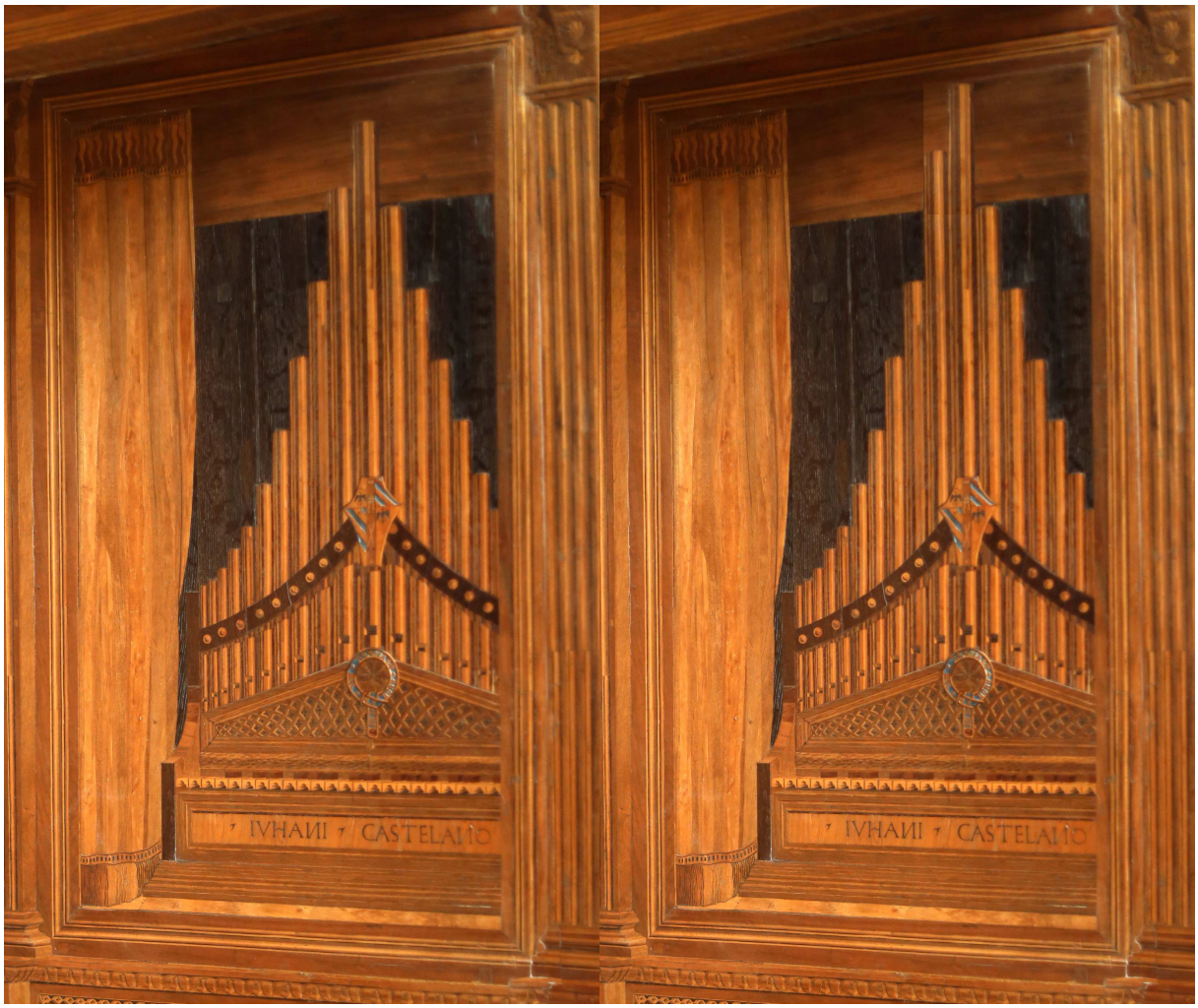

Fig. 17. Left = present intarsia, Right = with the F and G pipes at their correct length
Source: FabriGarri, modified.

However, despite this re-construction of the original pipe lengths, the series becomes progressively more inaccurate beyond the 5th and 13th pipes, reaching an error of +98% on the left hand side, almost an octave too low at g^2.

It seems that the pipe lengths have been modified in order to present a better appearance, in the same way as has been found in the Assisi organ (Appendix, 3, below), but the matter is more complicated. If we were to substitute the correct lengths of the outer pipes into the intarsia, then the tops of the pipes would be hidden behind the curved band which holds Federico's heraldic device. Below this, in the centre, is the Order of the Garter conferred on Federico by Edward IV in 1474.[57] It is conceivable that the size and position of this emblem, and the dimensions of the associated curved band, have influenced the pipe lengths, or even the line of the mouths of the pipes; this could explain the large distortion in the pipe lengths.

This is probably an example where the display of Federico's Order of the Garter took priority over a realistic intarsia of the organ. We have to question whether Federico ever owned such an organ since it may just have been an invention for the studiolo. The Order of the Garter also appears in Gubbio intarsie, and in one of them hanging in a cupboard, like a sausage

[57] See Raggio, 1999, p. 118.

being dried.[58] The intarsiatore certainly gave it pride of place in Urbino on the organ. As such it is an even better example of Verbeek's finding that the intarsie should be seen as works of art, where "artistic licence" can play a significant rôle.

Given these distortions in the pipe lengths, the d ♭-e ♭ check, used in the Barili intarsia organ above, is not available to us. The B-d ♭ interval is subject to more inaccuracy since the pipes are further apart. Thus, we are unable to draw any conclusions about the tuning system used for these pipes.

This organ probably represents in part an actual instrument, "cosmetically" modified to meet the requirements of the surrounding frame of the intarsia, Federico's coat of arms, and the Order of the Garter displayed on the organ. This inference, is similar to Verbeek's conclusion concerning the case depth of the clavichord, which was altered to improve the view into the keylevers and tangents, even at the expense of a realistic representation.[59]

[58] It is two cupboards to the right of the organ, see Raggio, 1999, Fig. 5-20, p. 91.
[59] Verbeek, 2021, p. 30.

3. Small organ, Basilica superiore di San Francesco, Assisi, 1471 or 1491-1501.

An intarsia organ in the choir stalls in Assisi, with a centrally-symmetrical pipe layout (*al cuspide*, mitre form), has 19 pipes in the front rank, therefore probably 38 pipes in total, but only 29 keys, including an extra natural between e and f in both octaves.[60] The feet of some pipes are visible in the back rank, and the slope of the pipe tops clearly indicates there must be two ranks of pipes. Thus, there is a fundamental disagreement between the number of pipes and keys, as also in the San Lorenzo organ (Appendix, 4, below).

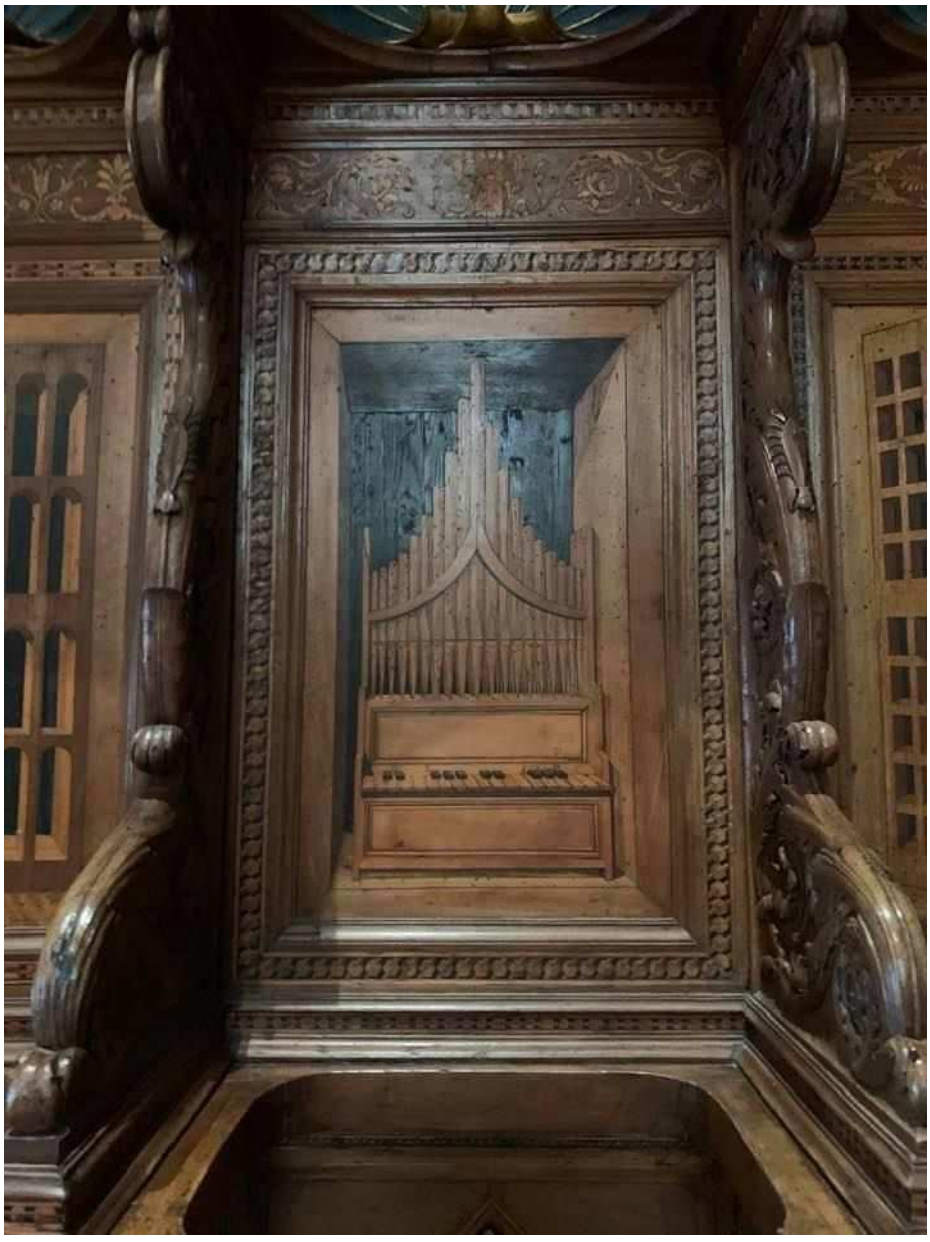

Fig. 18. Source: Jankees Braaksma[61]

With 19 pipes in the front rank, a compass starting on B would agree with the bass octave of the keyboard and imply the range B-c³, with the c³ pipe in the back rank. However, a B-c³ compass is uncommon and does not fit the pipe lengths as well as the more probable 38-note

[60] Barbieri, p. 20 gives a date of 1491-1501 for the intarsia citing Bonsati, vol. IV, p. 1086, fig. 2190, as the source. Donati, 2007, p. 39, gives a date of 1471, without citing a source.

[61] Downloaded from https://www.pinterest.de/pin/504614333254386286/

F,G,A-g²,a² compass.[62] Even this compass does not lend itself particularly well to the mitre form layout of pipes since g² and a² belong to the front rank, but have to be placed in the back rank when 19 pairs of pipes are used.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
g²	e²	c²	a ♭¹	e¹	c¹	a ♭	e	c	B ♭	d	g ♭	b ♭	d¹	g ♭¹	b ♭¹	d²	g ♭²	a²
e ♭²	b¹	g¹	e ♭¹	b	g	e ♭	B	G	F	A	d ♭	f	a	d ♭¹	f¹	a¹	d ♭²	f²

Table 4.

The pipe lengths are accurate as far as the fourth pipe either side of centre (i.e. pipes 6 and 14). From this we can infer that a Pythagorean tuning with its smaller B-d ♭ interval is *consistent* with the pipe lengths, although the size of the intarsia would hardly provide the accuracy we require for a firm conclusion. We do not have to draw the conclusion that a Pythagorean tuning was used in this period of the intarsia's construction (1471 or 1491-1501) since an older instrument could have served as a model.

The next intervals, formed by g or d ♭¹, are twice as large as they should be, increasing thereafter until the end pipes are 71% too long (left) and 101% too long (right). Thus, the pipe lengths show a realistic set of pipes from g (pipe 6) to a (pipe 14), but have been modified beyond this, presumably for reasons of appearance. The same sort of distortion of pipe lengths has been applied as in the Urbino studiolo organ, described above (Appendix, 2).

The apparent 29-note keyboard compass is B-c²,d² (lacking c♯²), including two extra "e" notes is unique. The pitch is undetermined.

The extra keys between e and f, and e¹ and f¹, are exceptional, but if in fact extra e notes, then the extra e pipes would be in the back rank, and inconveniently out of sight for verification.

However, Donati has interpreted these as *additional* e notes, a syntonic comma (ratio 81:80) lower than the normal e notes, in order to provide extra pure thirds (c-e and e-g♯) with a Pythagorean tuning.[63] This suggestion is technically sound, but otherwise unknown in keyboard instruments.[64] This would be a most unusual arrangement although "split naturals" are known in a harpsichord attributed to Boni (c.1619).[65] The Norrlanda organ (1370-1400) offers a possible point of comparison in having b ♭ notes as "white" keys, thereby increasing the normal complement of naturals in an octave. However, given the fact that the keyboard and the pipes do not yield the same compass, or even start on the same note, one is forced to consider the possibility that this representation is an intentional hoax, or results from careless or incompetant work.

[62] The compass B-c² is rare. Praetorius, p. 110, gives this compass for the organ (manual keyboard) in San Salvator, Venice (c. 1419). This is cited by Meeùs, 1976, p.5, as his no.3, but no further examples are found in his extensive list.

[63] Donati, 2007, pp. 38-39. Barbieri, pp. 20-21, repeats and cites Donati's interpretation of the extra notes.

[64] Adkins, p. 241, has drawn attention to a monochord division found on a fragment in Arnaut de Zwolle's manuscript (c.1440; fol. 128 bis r°, fragment) which describes a division with two e and two a notes, each separated by a syntonic comma. This division is shown schematically as Adkins' Diagram 64, p. 242.

[65] See Wraight, 1997, Part 2, pp. 83-84, where the front and back parts of the naturals have different pitches.

It may only be a coincidence, but the 19 naturals of the keyboard correspond to a B-f² compass (31 notes) found in early organs or portatives.[66] If this element from a real organ has been incorporated, then the distribution of accidental notes (with two missing) could merely have been thoughtless work, without the intention to deceive.[67] The size of this intarsia probably does not permit the level of detail we find in the Urbino or Gubbio studioli, since the entire panel has the width of a choir seat. Thus, a reduced size of keyboard might have been chosen merely to avoid complicated, fine detail.

[66] B-f² is found in portatives and organs described in Arnaut's manuscript, see fol. 130v° (lower) and fol. 131r°.

[67] An intarsia of a virginals in the choir stalls of S. Lorenzo, Genua, is represented in mirror image reversed form, with the treble strings at the left side. If the instrument is reversed to the normal form then it appears to lack b♭ and b notes in two bass octaves. However, the area where these notes are missing has been repaired, new inlays having been added, so the original state of the intarsia is probably unknowable. The instrument is illustrated at
https://www.beweb.chiesacattolica.it/benistorici/bene/1225149/De+Fornari+A.+-+De+Pantaleoni+G.M.+%281514-1529%29%2C+Tarsia+con+clavicembalo
Maurizio Tarrini kindly provided photos of the restoration work which made this assessment possible.

4. Portative organ in San Lorenzo, Bologna, 1467-1474.

This intarsia of a small organ, or portative, in the choir stalls of San Lorenzo, Bologna, was designed 1467-1474 by Francesco del Cossa and executed by Agostino de' Marchi da Crema.[68]

Fig. 19. Source: Jankees Braaksma[69]

[68] See the text under Fig. 40 in Mischiati and Tagliavini, which figure shows better detail than the photograph reproduced here.

[69] This was uploaded by Jankees Braaksmaa:
https://i.pinimg.com/564x/df/7b/5a/df7b5a9b3c86f014a233946fe978a459.jpg

There are 8 pipes to the left of the central one, but 9 to the right of it, making 18 in all, which is unsatisfactory for a centrally-oriented pipe layout (*al cuspide*); an odd number is needed. The pipes appear to be flattened cylinders, which is most improbable, but give the impression at first glance that there are two ranks of pipes, This would lead to a complement of 36 pipes.

The keyboard has 10 sharps and apparently 14 naturals, which appear to give a c-b¹ compass, including 24 notes. This compass does not correspond to the number of pipes, regardless of whether one construes the pipes as a single or double rank. However, if the compass were to include another octave, i.e. have the range c-b², then it would have 36 notes.[70] Can it be that the keyboard is merely a simplified version to avoid fine detail in what is probably a small intarsia?

Above the longest pipe is an unusual roof construction, which is depicted so close to the pipe that it would act as a tuning shade and modify the pitch of this pipe. It can be doubted whether this detail may be understood as literally correct.

The mismatch of compass and pipes is parallel to the lack of convincing detail in the pipes, which indicates that this intarsia is only an approximate representation of an actual instrument. Whether this is due to lack of care or an intention to mislead cannot be clearly discerned, but a simplification of the keyboard may have taken place.

[70] A replica instrument, made for Liuwe Tamminga, based on this intarsia has a 38-note compass, F,G,A-g²,a².

5. Portative organ in the Gubbio studiolo, 1478-1482.

This instrument is to be found on a panel of the audience chamber door so the intarsia will be relatively small. There are 19 pipes, but all the 19 keylevers (seen from below) are natural levers; there are no accidentals, which is obviously impossible.

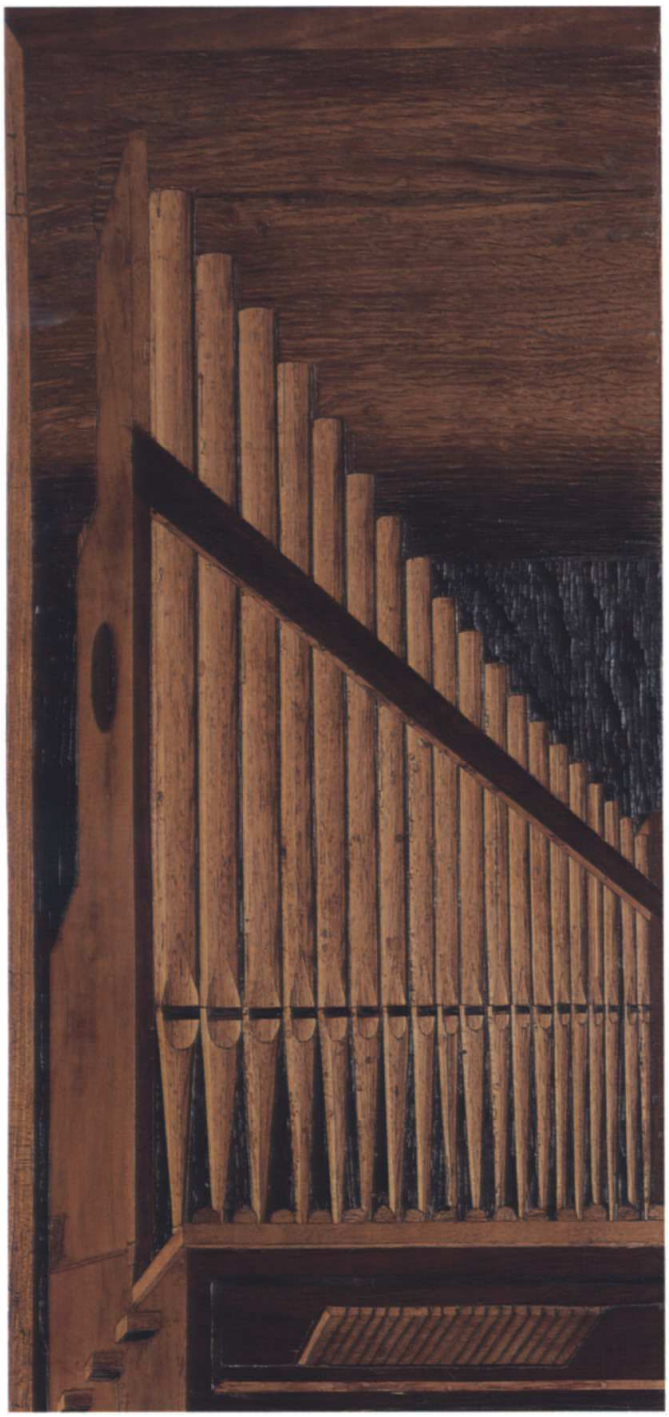

Fig. 20. Source: Raggio [71]

[71] See Raggio, 1999, Fig. 5-104, p. 139, description p. 132. The entire door is shown in Fig. 5-117 on p. 146. The door appears to contain niches with objects in them, which is unexpected from Raggio's description. A further portative with (apparently) two ranks containing 22 pipes is shown on the door of the Liberal Arts, see Raggio, 1999, Fig. 5-105, p. 139, but this is too small to yield much verifiable detail.

A 19-note compass could be an f,g-c² compass, but more likely is a b-f² compass.

19 pipes are visible in what is, from the angle of the top of the pipes, a single rank. Thus, for a Pythagorean tuning there should be small semitone (c. 90 cents) and large semitone (c. 114 cents) intervals between the pipes. The smallest interval is 124 cents, with an average of 149.5 cents. Only one interval is large enough to qualify as a whole tone (192 cents). Thus, the representation of the pipes is only schematic and cannot be taken literally.

The most probable interpretation is that the intarsiatore had not taken the trouble to show an actual instrument realistically, only elements which would be present in such a portative and permit it to be recognised as an organ.

6. Portative organ, Armadio of Giovannia Maria Platina, Cremona 1477-1478.

This small portative appears in a panel of 30 intarsie, all of the same size in square format, which also includes a clavichord. The organ is in the middle row, fifth from the left.[72]

Fig. 21. Source: Corriere della Sera [73]

This intarsia shows an awkward conflict of perspective, as well as incompatible numbers of keys and pipes. It is therefore poorly executed as well as being an incoherent design.

[72] A rotating view of the 30-panel collection is provided at https://documenti.comune.cremona.it/advanced/mcivico/madaschi360-ALL_devices/CR-AlaP-sPlatina/output/index.html

[73] https://images2-milano.corriereobjects.it/methode_image/2016/11/18/Milano/Foto%20Gallery/armadio8_MGZOOM.jpg This photo was from a slide show of the Armadio, in a report of 18.11.2016, accessed 20.07.2021. The slide show link is: https://milano.corriere.it/foto-gallery/cronaca/16_novembre_18/platina-armadio-unico-mondo-cremona-b4ed9198-ad84-11e6-97cf-b67e1016ae14.shtml

WORKS CITED

Adkins, Cecil Dale, 'The Theory and Practice of the Monochord', (Ph.D diss., State University of Iowa, 1963; UMI Dissertation Services, 1964, no. 64-3344).

Arasse, Daniel, 'Frédéric dans son cabinet', Nouvelle Revue de Psychanalyse, n° 48, L'Inconscient mis à l'épreuve, (Gallimard, Paris, 1993), 239-257, reprinted in 'Le Sujet dans le Tableau', (Paris 1997, R/2006), 27-55.

Arnaut, Henri Arnaut de Zwolle, Les Traités d'Henri-Arnaut de Zwolle et de divers anonymes, ms. B. N. Latin 7295 https://gallica.bnf.fr/ark:/12148/btv1b90725989

Barbieri, Patrizio, 2008, Enharmonic Instruments and Music 1470-1900, (Il Levante Libreria, Latina, 2008).

Bonsanti, Giorgio, (ed.), La Basilica di San Francesco ad Assisi. Basilica superiore, 4 vols., (Franco Cosimo Panini, Modena, 2002).

Bormann, Karl, Die gotische Orgel zu Halberstadt, (Merseburger Verlag, Berlin, 1966).

Brauchli, Bernhard, The Clavichord, (Cambridge, UK, 1998).

Carnevale, Antonio, 'A mistaken perspective on the Renaissance' https://www.conceptualfinearts.com/cfa/2020/09/14/mistaken-perspective-renaissance/?print=enabled (accessed 2.06.2021)

Donati, Pier Paolo et al., 1979, Arte nell'Aretino: seconda mostra di restauri dal 1975 al 1979. La tutela e il restauro degli organi storici. Catalogo, (Editrice Edam, Florence, 1979).

Donati, Pier Paolo, 1986, 'Nuovi Documenti Sulle Misure Delle Canne Ad Anima Nell'Arte Organaria Del Primo Rinascimento In Toscana', in Restauro Conservazione E Recupero Di Antichi Strumenti Musicali, Atti Del Convegno Internazionale. Modena 2-4 Aprile 1982, (Leo S. Olschki Editore, Firenze, 1986), 46-50.

Donati, Pier Paolo, 2006, 'L'Arte degli organi nell'Italia del Quattrocento, II: La comparsa dei registri', Informazione Organistica, Nuova Serie no. 14, Anno XVIII - no. 2, (August, 2006), 99-128.

Donati, Pier Paolo, 2007, 'L'Arte degli organi nell'Italia del Quattrocento IV: Gli ideali sonori, i protagonisti', Informazione Organistica, Nuova Serie no 16, Anno XIX - no. 1, (April, 2007), 3-55.

Kemp, Martin, 'Making it work: The perspective design of the Gubbio studiolo', in Raggio, Olga, The Gubbio Studiolo and Its Conservation. Vol. 1, Federico da Montefeltro's Palace at Gubbio and Its Studiolo, (New York, NY, Metropolitan Museum of Art, 1999), 169-177.

Kirkbride, Robert, Architecture and memory: the Renaissance studioli of Federico de Montefeltro, (New York, Columbia University Press, 2009). Online version: http://robertkirkbride.com/architectureandmemory.html

Kopf, Silas, A Marquetry Odyssey: Historical Objects and Personal Work, (Hudson Hills Press, Manchester, VT, 2008).

Koster, John, 'Some Remarks on the Relationship Between Organ and Stringed-Keyboard Instrument Making', Early Keyboard Journal 18, (2000), 95-137.

Meeùs, Nicolas, 'Tessitures d'orgues du 14e au début du 17e siècle', Communications des Archives Centrales de L'Orgue, (Musée Instrumental de Bruxelles, 1976/2).

Meeùs, Nicolas, 'Le clavier disparu. Le clavier originel de l'orgue de L'Agneau mystique', (April, 1987). uploaded 2014 to https://www.researchgate.net/publication/235005187

Mischiati, Oscar, and Tagliavini, Luigi Ferdinando, Gli organi della Basilica di San Petronio in Bologna, (Pàtron, Bologna, 2013).

Mondino, Angelo, Il clavicordo: Interpretazione e Riconstruzione di Antichi Strumenti a Tastiera, Musica Ragionata 5, Collana di studi musicali diretta da Alberto Bassi, (Libreria Musicale Italiana Editrice, Lucca, 1993).

Pollens, Stewart, 'Three keyboard instruments signed by Cristofori's assistant Giovanni Ferrini', Galpin Society Journal 44, (1991), 77-93.

Praetorius, Michael, Syntagma musicum II, (Wolfenbüttel, 1619, Bärenreiter, Kassel, R/1958).

Raggio, Olga, 1996, 'The liberal arts studiolo from the ducal palace at Gubbio', Metropolitan Museum of Art Bulletin, New Series, Vol. 53, No. 4, (Spring, 1996), 5-35. https://resources.metmuseum.org/resources/metpublications/pdf/The_Liberal_Arts_Studiolo_from_the_Ducal_Palace_at_Gubbio_The_Metropolitan_Museum_of_Art_Bulletin_v_53_no_4_Spring_1996.pdf

Raggio, Olga, 1999, The Gubbio Studiolo and Its Conservation. Vol. 1, Federico da Montefeltro's Palace at Gubbio and Its Studiolo, (New York, NY : Metropolitan Museum of Art, 1999). https://resources.metmuseum.org/resources/metpublications/pdf/The_Gubbio_Studiolo_and_Its_Conservation_Vol_1_Federico_da_Montefeltros_Palace_at_Gubbio_and_Its_.pdf

Ripin, Edwin M., 'The Norrlanda organ and the Ghent altarpiece', in Gustav Hilleström (ed.), Studia Instrumentorum Musicae Popularis 3, Festschrift für Ernst Emsheimer, (Stockholm, 1974), 193-196, plates 286-288. Reprinted in McGee, Timothy J., (ed.), Instruments and their music in the Middle Ages, (Routledge, London and New York, 2009), 145-155.

Smith, Timothy Bryan, Alberto Aringhieri and the Chapel of Saint John the Baptist: Patronage, Politics, and the Cult of Relics in Renaissance Siena, PhD Dissertation, (Florida State University, 2002). https://fsu.digital.flvc.org/islandora/object/fsu%3A176173

Tagliavini, Luigi Ferdinando, 'Notes on Tuning Methods in Fifteenth-Century Italy (1986)', in Charles Brenton Fisk: Organ Builder: Essays in His Honor: 001, ed. Jander, Owen, (Westfield Center for Early Keyboard Studies, Easthampton, 1986), 191-199, reprinted in L'Organo XLVIII-XLIX, (R/2017), 75-83.

Tarrini, Maurizio, 'Le più antiche raffigurazioni italiane di clavicembalo nelle tarsie dei cori delle cattedrali di Savona e di Genova', Informazione Organistica, Nuova Serie, Anno XXII, no.1, (April, 2010), 3-18.

Tormey, A. and Farr Tormey, J., 'Renaissance intarsia: the art of geometry', Scientific American 247, (July 1982), 116-122.

Van Asperen de Boer, J.R., 'A Scientific Re-examination of the Ghent Altarpiece', Oud Holland Vol. 93, No. 3, (1979), 141-214.

Verbeek, Pierre, 2011, 'The Urbino clavichord revisited' . https://harpsichords.weebly.com/uploads/2/5/0/1/25019733/verbeek_urbino_magnano_nov_2011_ver09_pub.pdf

Verbeek, Pierre, 2020, 'Technological aspects of the Urbino clavichord', Galpin Society Journal 73, (March 2021), 16-30.

Wilmering, Antoine M. 'The Conservation Treatment of the Gubbio Studiolo.' The Metropolitan Museum of Art Bulletin, vol. 53, no. 4, (1996), 36–56. https://resources.metmuseum.org/resources/metpublications/pdf/The_Liberal_Arts_Studiolo_from_the_Ducal_Palace_at_Gubbio_The_Metropolitan_Museum_of_Art_Bulletin_v_53_no_4_Spring_1996.pdf

Winternitz, Emanuel, Musical instruments and their Symbolism in Western Art, (New Haven, CT, 1967; 2/1979).

Wraight, Denzil, 1997, 'The stringing of Italian keyboard instruments c.1500 - c.1650', Ph.D. dissertation, (Queen's University of Belfast, 1997, Proquest order no. 9735109).

Wraight, Denzil, 2021, 'A 14th-century clavichord according to the book of Baudecetus'. www.denzilwraight.com/Baudecetus.pdf

Version history
V1.1; 17.10.2021

V1.2; 21.10.2021
article title in footnote 24 moved to Works Cited
corrected link for the virginal in footnote 67
improved links for the organ, Appendix, 6
copying to clipboard enabled