Combination tones artificial?

A combination tone is a psycho acoustic phenomenon of an additional tone or tones that are artificially perceived when two real tones are sounded at the same time. Their discovery is credited to the violinist Giuseppe Tartini and so they are also called Tartini tones. (Wikipedia.)

If Tartini tones do not exist it is a bit unpractical if you find them in a spectrum of your violin. Yes, It is a nice selling point to claim that it is scientifically proven that this violin is enchanting your ears. But it does not help me in the design, I want to know why and how.
This is what I found:

3 reasons to question the validity of the proof that combination tones can't exist.

1 logic
2 The use of data
3 Information is not the same as energy

1 logic: cause and effect

It is all about definition: What is sound?

- -Sound is a vibration that propagates as an acoustic wave through a transmission medium such as a gas, liquid or solid. (wikipedia)
- -Something that you can hear or that can be heard. (Cambridge)
- -The perception of audio information (My definition)

This shows how cause (wikipedia) and effect (Cambridge) are both used to describe sound.
Cause and effect are not the same. The one implies the other.
The realization that this may be the case for our vision started with a painting:

Réne Margritte Painted this in 1928/29 and he called it : The Treachery of Images

A poster published in 1920 in Brussels where Margritte lived

You can interpreted this painting in many ways, in this case the physical layer is important:
What we see is an representation of our surroundings with layers of extra knowledge based of experience.
There is no reason to believe we can "see" the actual electromagnetic frequencies.
Our optical nerves are not made of glass fibre. All objects we see are interpretations.
The fact that we name a bunch of vibrations (or photons) a "pipe" makes that clear.
There is no reason to believe that sound is any different.
So we need to distinguish between cause en effect.

In an easy everyday way we use 261 Hrz. and the tone C4 as equals: 261 Hrz = C4
Like if you translate Fahrenheit in to Celsius.
261 Hrz is a description of a vibration (261 movements in a second)
The tone C4 is the name of a perception of a pressure pattern with that speed. It may be a tone of a piano, organ, steam whistle, a human voice, the list is endless.
It is just a name to indicate how high the fundamental is.
So 261 Hrz implies C4.
In logic "implication" is not as straightforward as "equal"
It looks like this: 261 Hrz ⇒ C4 and not like this: 261 Hrz = C4

261 Hrz =P
C4 =Q
T =True
F =False

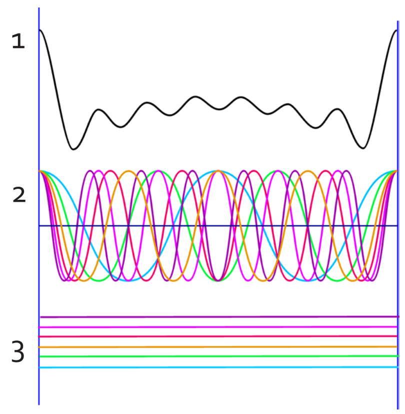
P	Q	$P \Rightarrow Q$
T	T	T
T	F	F
F	**T**	**T**
F	F	T

P	Q	P = Q
T	T	T
T	F	F
F	**T**	**F**
F	F	T

The truth tables show the consequences.
Any proof based on line 3 is debatable.

2 The use of data: The case of the missing fundamental

The Fourier spectrum is brilliant, it is a tool to analyze waves.
It gives us a total administration of frequencies and energy, expressed in sine waves.
It is much easier to "read" then the wiggly line of air pressure.
And that is something to be aware of: There is a difference between calculation and presentation.
The fact that all information is present, does not mean it is all visible:



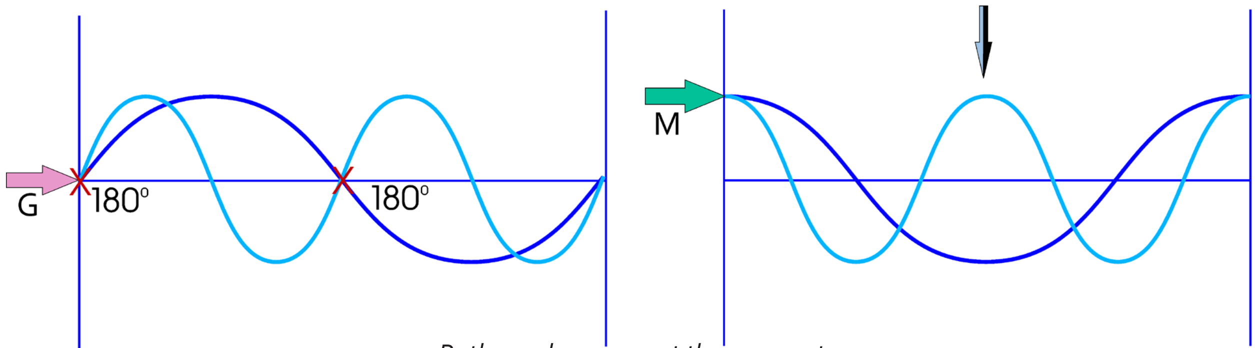
1 Input
2 Result of the calculation
3 Presentation

Even in this simple example, 2 is a lot to unpack.
Yet you need it to understand combination tones.
3 does not give you that kind of information

Fourier gives you dissected sound: all parts neatly separated.
Brilliant and also very classic science.
The connections between the parts is lost, and that is why combination tones are invisible
The fact that something is invisible does not imply that it does not exist, it could also mean that you reached the limit of your software.

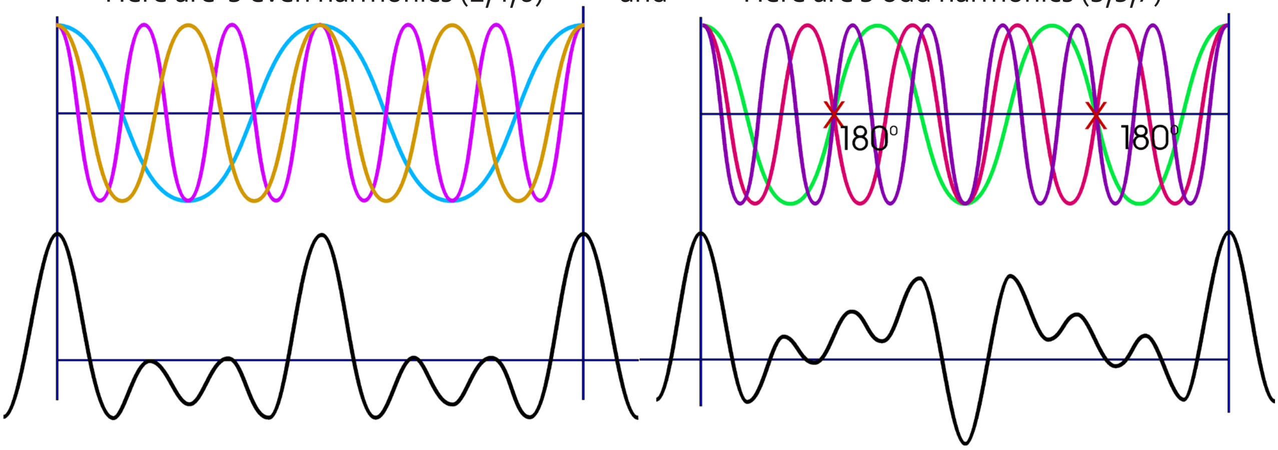
Combination tones are an interference pattern.
Those patterns change the amplitude not the frequencies.
You can compare them with graphic moiré patterns.
With one important difference: interference patterns work two ways: adding and subtracting,
Moiré works usually only one way.
So you can have a lot of frequencies causing one interference pattern.
This is key for the combination tones, they are caused by harmonics, the more the better.

It is not helpful that, if you want to illustrate this process, most software it starts a wave at the zero point(G) of the graph, instead of the zero point(M) of the movement (zero kinetic energy)
To understand these shapes we are using two types symmetry: mirror symmetry and rotating symmetry.
In this graph, if all lines cross the horizontal zero at the same spot, the hole pattern rotates 180°
Starting at G, forces that 180°rotation.
Starting at M, gives you one mirror in the graph, and the movements are synchronised on the beat.



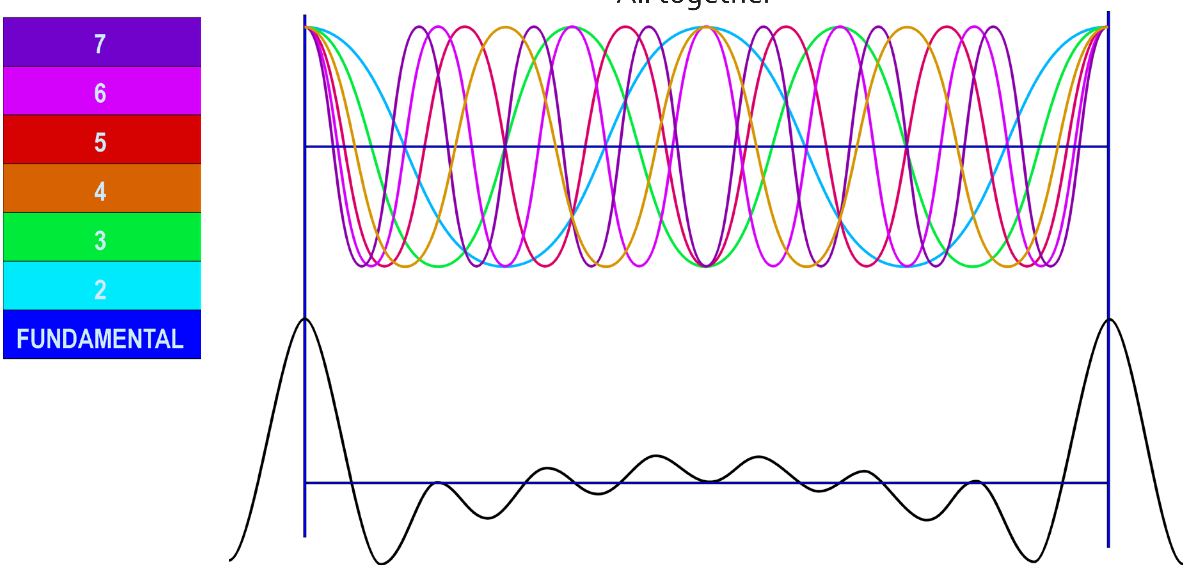
Both graphs represent the same octave.....

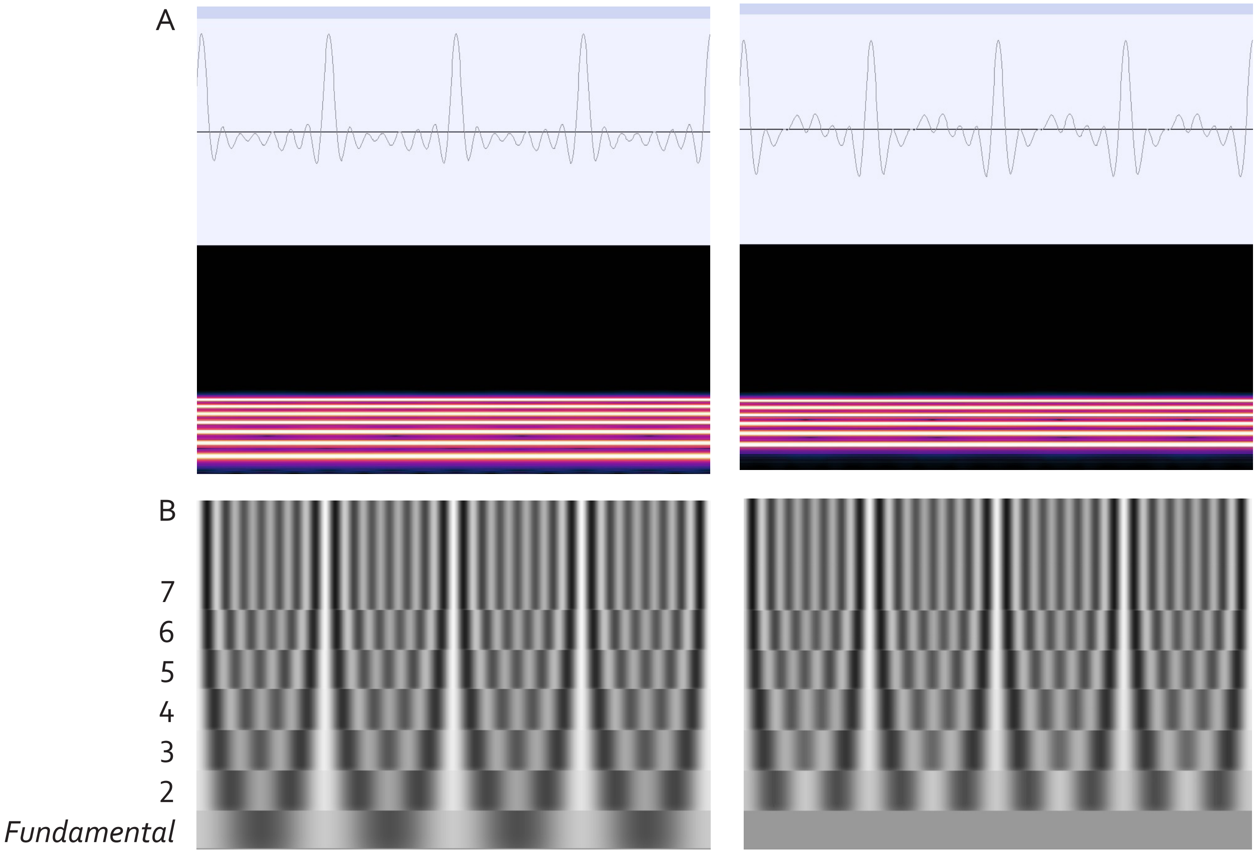
Here are 3 even harmonics (2,4,6) and Here are 3 odd harmonics (3,5,7)



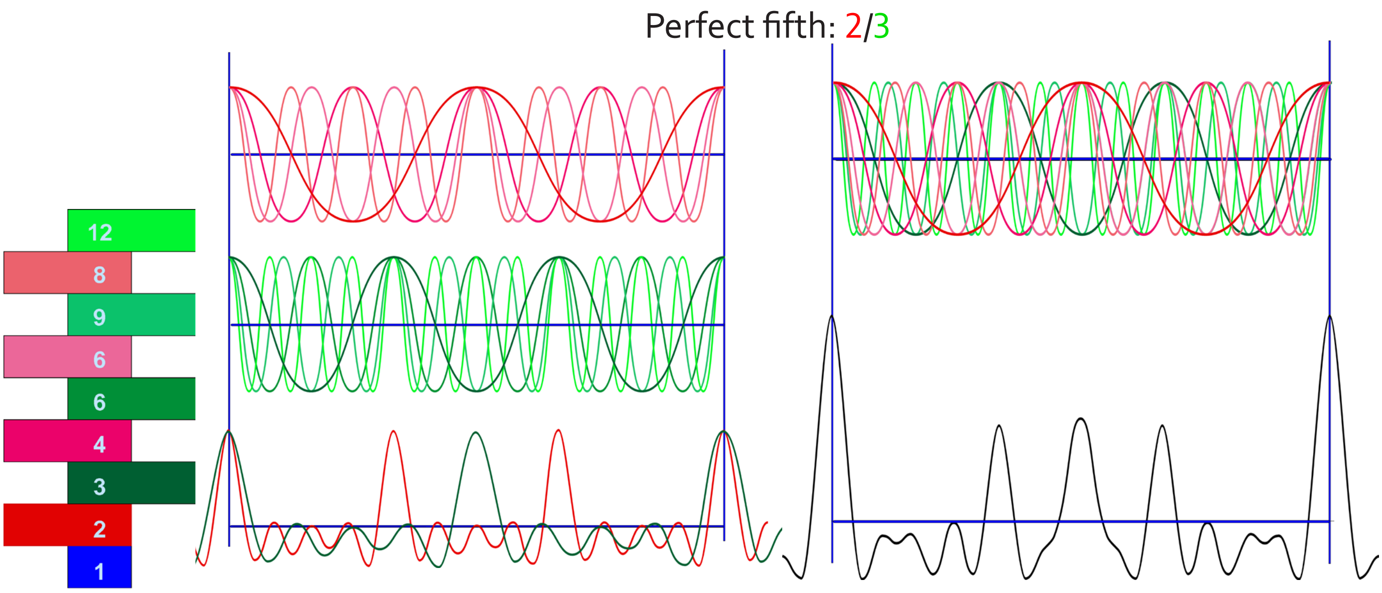
Every harmonic ads a layer of complexity to the sound.
All harmonics not only dance to the beat of the fundamental, they add to it.
These frequencies always have one beat in common with the fundamental, so that adds up.
This gives an extra accent to that beat without changing any frequently.
Taking the fundamental away *does not stop that dance.*

All together





A. Screens hot of Audacity of the same harmonics with and without the fundamental.
B. The translation of that screen shot in gray scale moiré patterns .



Here is a combination tone: red is an **a** *and green is an* **e**.
The combination tone is an A, (*the number 1 in blue), all frequencies are in the harmonic series of that A*

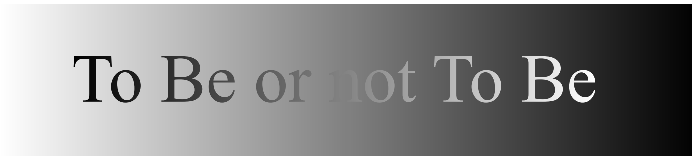
If you use sinewaves as building blocks, counting them is just admin.
If you want to analyse a building, you may want to do a bit more than that.
In order to find combination tones in a given sound, you want to look at the building as well.
Our humble tuners, we use to tune our instruments, do only that.
They are made to detect the longest pattern in a given sound.
That is why we use them to tune instruments without clear fundamental.
If you feed them combination patterns, they even respond with the fundamental of that combination.

These illustrations are made to show the process, in real sound it is not as clear.
The missing Fundamental is the clearest case , the fifth is next on the list. Most combination tones can be a bit vague, But if you know where to look, you will find them

Harmonics are the physical foundation of tonality. See (Harmonic series (music)) wikipeda)
If feels unreal to see them layed out, nicely dissected, while their major contribution to tonality is claimed to be illusive at best.

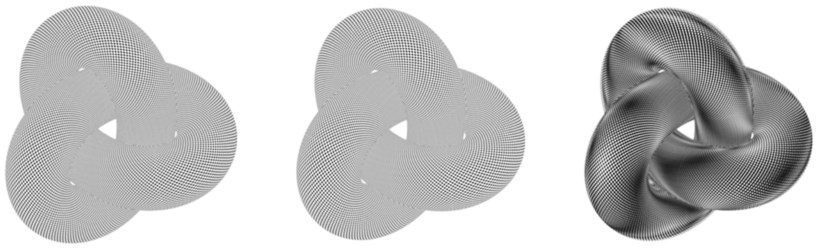
I was curious What would happen if I could only hear part of the harmonics.
My old ears hear frequencies up to 9000 Hrz at best. The software and loudspeakers go a lot higher
So I listened to this Series: 4000,6000,8000,10 000,12 000,14 000.Hrz.
The results are fascinating. As expected I did not hear the three highest tones individually.
In combination with the three lowest tones, that changed: not only I heard a clear combination tone, I heard quite a difference if the highest 14000 Hrz. tone was switched on or of.
Maybe something to keep in mind?

3 Information is not the same as energy



Information is about boundaries

Information is about boundaries. In our sounds cape we are able to locate and separate the different sources of sound. It is not unlikely that the interference patterns play a role in this ability.
My project “3D moiré” is a visual example of 3D information in a moiré pattern.



An Overlay of two patterns with a small change in perspective contains 3d information.

Conclusion:
For me the statement:
“Combination tones do not exist”
feels the same as:
“Shadows do not exist”

Clearly incorrect and jet a bit relatable.
And maybe shadow tones is not a bad way to describe those interference patterns.
There are a lot of similarities:
They can be vague or clearly defined
There are different types: internal and external.
They are usually near a boundary.
They add depth and relief .
They are both very important in art.

Frank van der Horst

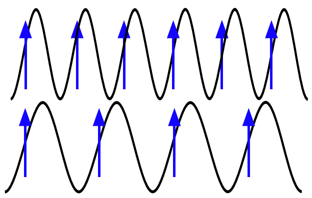
Tartini Tones
Something completely different.

Combination tones need at least two "real" vibrations. Those two vibrations need to be two **independent** sources of energy. If the two vibrations are dependent from each other, all bets are off. Then everything depends on the interaction between the two vibrations. Tartini tones are a good example [1]. They are real measurable vibrations.
They occur when a double stop is played (two strings together). In a violin that is a bonus.
Not every violin gives strong low Tartini tones, so there must be a physical difference between these instruments

Tartini tones are intertwined
The bow ads energy to the string by means of the stick/slip process.
In this process the *frequency* dictates the timing; the *amplitude* the quantity.
It relies on a delicate balance in direction and tension between bow and string.
This process is very sensitive and can fail, Wolfs* and Whistling as a result.
Using two strings causes a complex interaction between the bow and the two strings.
This cause the strings to somehow synchronize.*
The only frequency the two have in common is the low combination pattern.
So Tartini tones are not just combined but really intertwined.
This changes the result.

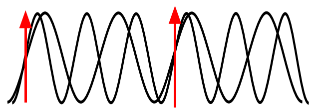
Possible mechanism:
If two players each play a different tone on a violin,
the energy from the bows is evenly distributed over the strings
of the two violins (1)

1



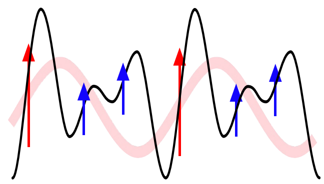
If you play two strings with one bow, the two strings may interfere with each others stick/slip process. This changes the energy transfer. The red arrows show were the optimum moments are for the energy transfer of the stick and slip process in this case. (2)

2



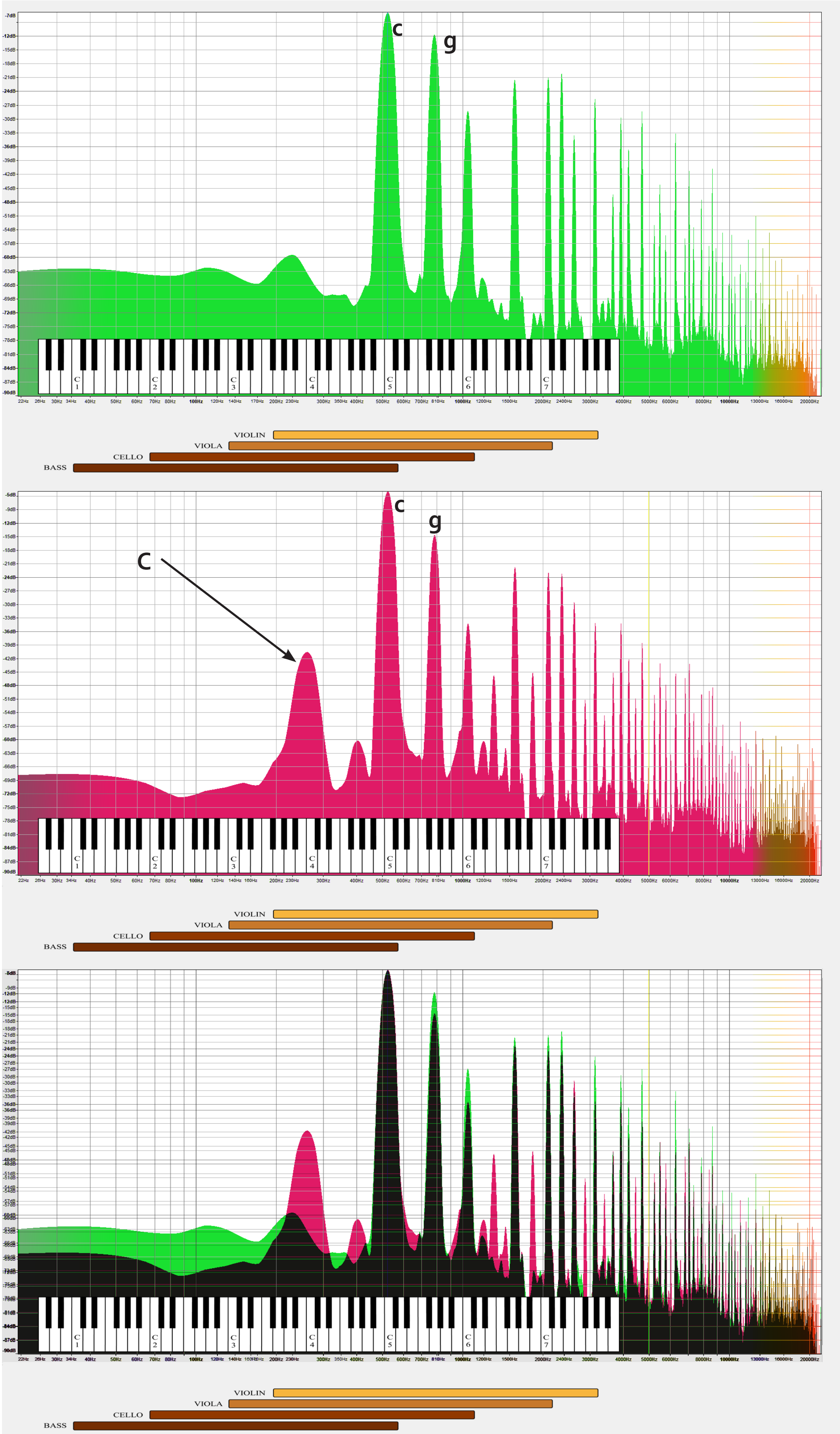
The bridge moves in the combination pattern.
Because of that movement both strings get their fair share
but not so evenly distributed .
A Tartini tone (pink) is the result. (3)
It looks like that the complex system is able to store more
energy than the two independent strings.

3

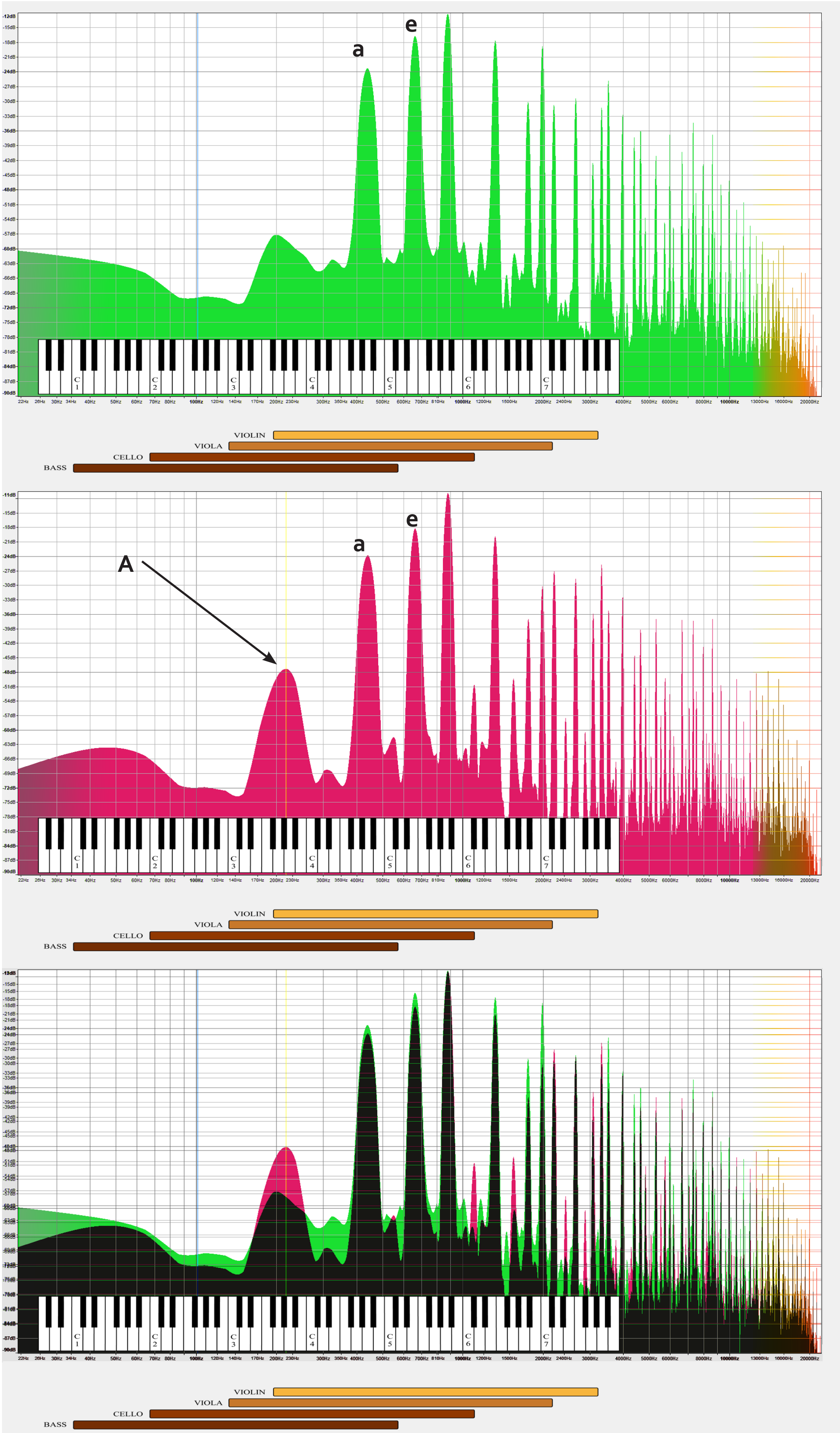


The measurements
On the next pages are some measurements:
Two different Dutch Violins were used "4mm" and "nr16"
Green: The spectrum of the two tones, played separate, one sting at the time.
Red: The spectrum of the two tones, played together as a double stop.
The overlay shows the differences, not only the Tartini tones but also the changes in the overtones.

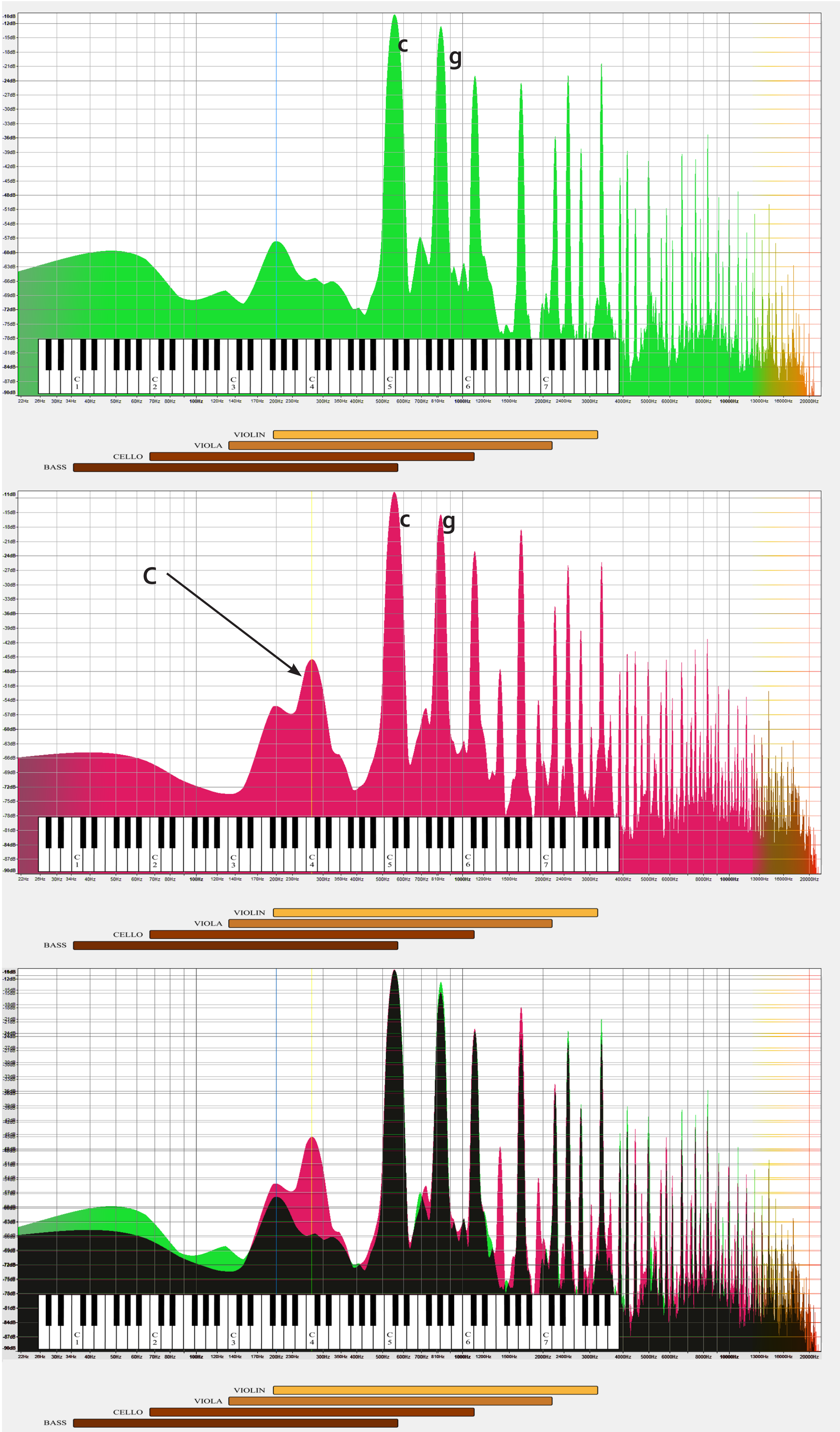
[1] An other example is: waves at sea with different frequencies, propelled by the wind.
* See video's Metronome on a swing 1 and 2.



The C and the G on "Violin 4 mm". The low C is the Tartini tone. (Fourir analysis)



Open A and E string on "Violin nr 16". The low A is the Tartini tone. (Fourir analysis)



The C and the G on "Violin nr 16". The low C is the Tartini tone. (Fourir analysis)