Music, Science, and Mathematics
Mark Sullivan

MSU Science Fair – 2014

Hart Recital Hall
harmonics

A “sound” usually is made up of various vibrations that we hear as a single sound

Pythagorus discovered the mathematical nature of harmonic rations and of how they relate to a vibrating string

How to make a monochord:
http://www.youtube.com/watch?v=j4qC5a3m8w

from Harmonics, pythagorus, and ratios: (ray.tomes.biz/alex.htm )

After researching what notes sounded pleasant together Pythagoras worked out the frequency ratios (or string length ratios with equal tension) and found that they had a particular mathematical relationship:

The octave was found to be a 1:2 ratio and what we today call a fifth to be a 2:3 ratio.

Pythagoras concluded that all the notes could be produced by these two ratios as (3/2)*(3/2)*(1/2) gave 9/8 which is a second and so on.

The problem was that after applying these ratios repeatedly he was able to move through the whole scale and end up back where he started... except that it missed by a bit, called the Pythagorean comma. After twelve movements by a fifth (and adjusting down an octave as required) he got back to the same note but it had a frequency of 3^12 / 2^19 [Note ^ means to the power of] which is 1.36% higher in frequency than it should be.
Although Pythagoras did a wonderful job he did get it slightly wrong. The correct solution was worked out by Galilei (the father of the famous Galileo Galilei) who concluded that the best frequencies were in the proportions:

```
do re mi fa so la ti do l 9/8 5/4 4/3
3/2 5/3 15/8 2
```

Which may be represented as whole number proportions as

```
24 27 30 32 36 40 45 48
```

These proportions are called the Just Intonation music scale and are the most pleasing proportions for note frequencies for any one key. The differences from Pythagoras are small, so that mi is 5/4 (=1.250) rather than 81/64 (=1.266).

Ben Johnston, String Quartet No. 4 (Amazing Grace) – Kronos Quartet
https://www.youtube.com/watch?v=dw_H0kGdD6Q

Ben Johnston, String Quartet No. 5
https://www.youtube.com/watch?v=sG4Z8yVEHZI

The harmonic series:
http://www.youtube.com/watch?v=no7ZPPqtZEg
(standing waves generated by string vibration)

vibrations of a guitar string with iphone 4
https://www.youtube.com/watch?v=TKF6nFzpHBU
Ratios and Rhythm – Fractions

3 : 3 : 4 : 2 : 4  (aha, the clave!)

Musicians play ratios; hear ratios; and don’t necessarily think of them as ratios at all

Ben Johnston – Knocking Piece
https://www.youtube.com/watch?v=lnenN1YMbXE

Music as math happening – music is math performed, both the temporal and pitch dimensions of music are math in motion, dynamic and palpable forms of mathematical happenings, mathematical events

Sonogram – ExTempore

• Ruben’s flaming tube (mythbusters: http://www.youtube.com/watch?v=ynqzeIYA7Iw)

• Dubstep http://www.youtube.com/watch?v=Gqhd4BivPXo  from 2 min)

• Liquid on a speaker: http://www.youtube.com/watch?v=jwMq8mmqgQ4

Cymatic Experiments on harmonics, Atomic Alignment & Sacred Geometry
https://www.youtube.com/watch?v=lvKt9dfxHNI
• Cymatics2 – sound waves make shapes
  http://www.youtube.com/watch?v=ouAUo9jVtAU

• Mosh pit math: http://www.npr.org/2013/03/22/174962714/mosh-pit-math-
  physicists-analyze-rowdy-crowd

• Turning a glacier into a tuba
  • http://www.npr.org/2013/02/24/172818754/turning-a-glacier-into-a-tuba-ice-
    music-from-norway

![Image](Figure 3: Charles Mingus/Eric Dolphy “Better Git it in your Soul” (1959).16384/512/65/2080/25)

Vi Hart – The Mathemusician

• Blog: http://vihart.com/

• The Sound of Paper-Paper Didgeriduel:
  http://www.youtube.com/watch?v=y07LWM2Rz4o

Burning paper instruments https://www.youtube.com/watch?v=AKNdHEqXeUw

• Moebius music box
  http://www.youtube.com/watch?v=WkmPDOq2WfA
• Pachelbel’s Music Box Canon in D:  
  http://www.youtube.com/watch?v=3a9wWRxYSko

doodle music  https://www.youtube.com/watch?v=Av_U6xHkJUC

Daniel Kish - Is it possible?  
http://www.youtube.com/watch?v=vpxEmD0gu0Q

– the “real life Batman” – Echolocation  
http://www.youtube.com/watch?v=xATlyq3uZM4

Blind Vision  
http://www.youtube.com/watch?v=GYWpxmcHToc

Project Neptune (Ocean Networks Canada)  
http://www.oceannetworks.ca/

Sights & Sounds  
http://www.oceannetworks.ca/sights-sounds