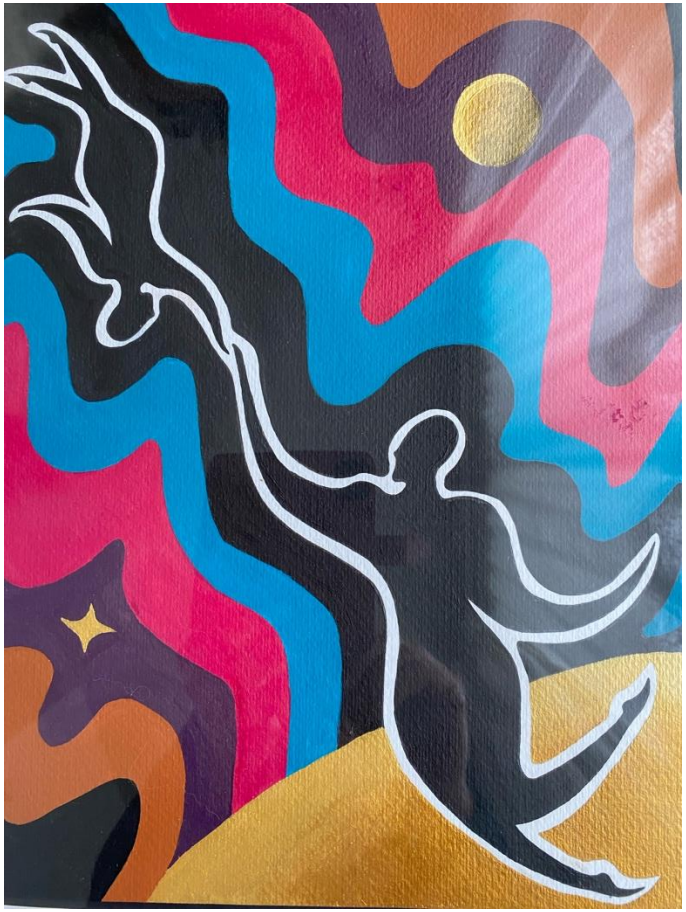
TAURANGA PUBLIC LECTURE SERIES
5.30pm 26th May 2025

Harmonies of the Universe-*Physics and Music*

Dr Simon Taylor
with special guests Tahangāwari Tangitu-Huata (pūtātara & kōauau)
Marion Arts (guitar)
Rachel Jenkins (piano)
Hugo Broad (French horn)



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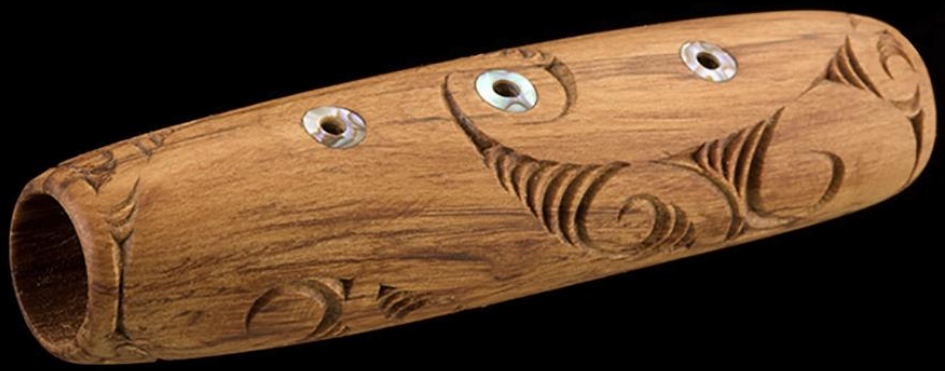
Te Whare Wānanga o Waikato
TAURANGA

Pūtātara (trumpet) & kōauau (flute)



- Musical instruments
- Waves
- Sound production
- Resonance
- Animal communication
- Celestial delights

“If I were not a physicist,
I would probably be a musician.
I often think in music.
I live my daydreams in music.
I see my life in terms of music.”

Albert Einstein

Figure 2.4: Chordophones are musical instruments in which a standing wave is initially created in the strings of the instruments. Guitars, violins, and pianos fall into this category.

Figure 2.5: Aerophones are musical instruments in which a standing wave is initially created in the column of air within the instruments. Trumpets, flutes, and oboes fall into this category.

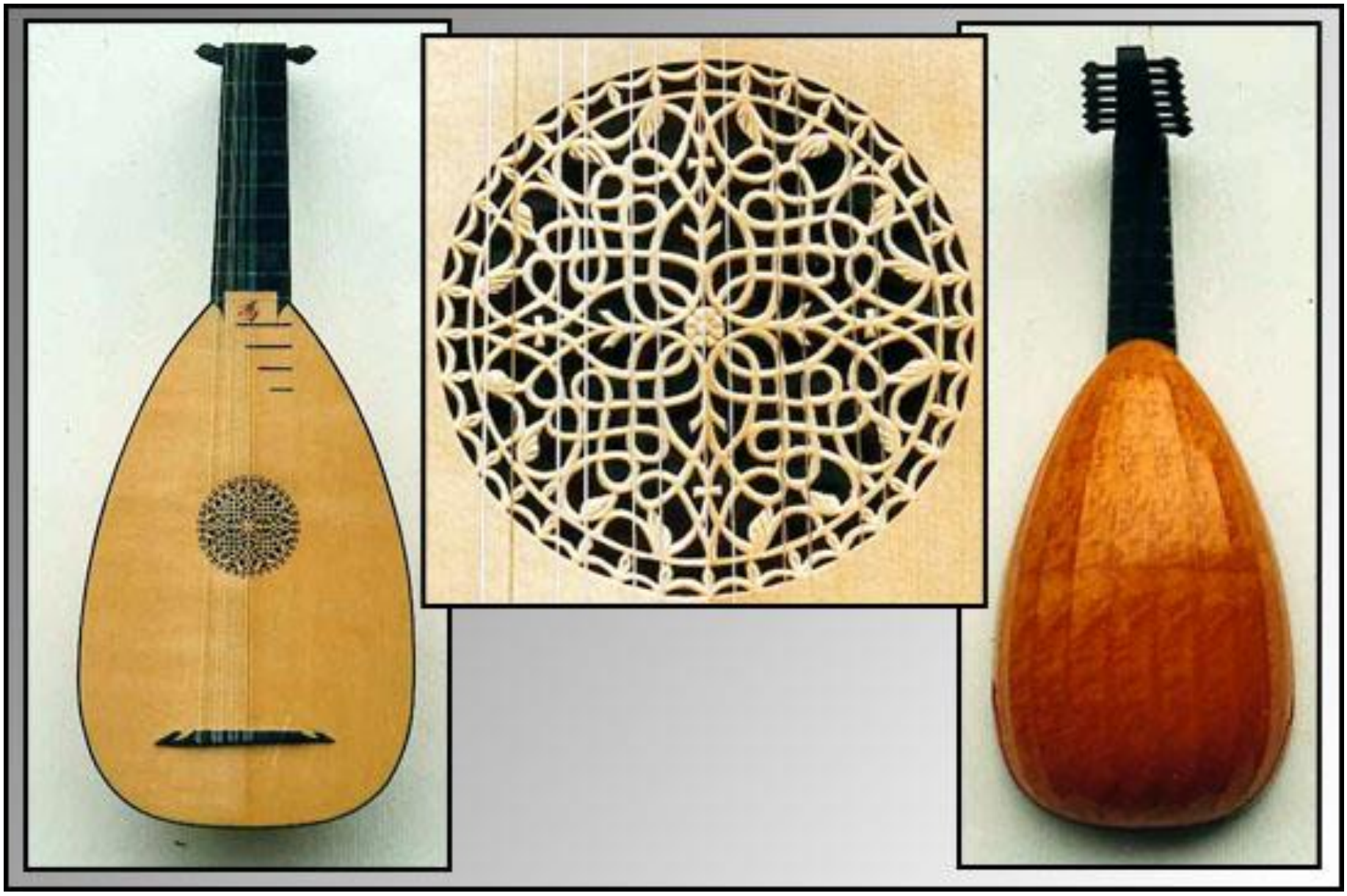
Figure 2.6: Idiophones are musical instruments in which a standing wave is initially created in the physical structure of the instruments. Xylophones, marimbas, and chimes fall into this

Membranophones

Castanets

The Neanderthal Flute

Renaissance lute



Citterns

Evolution of the guitar

The Vihuela-made in the 1500's

1688 Stradivari

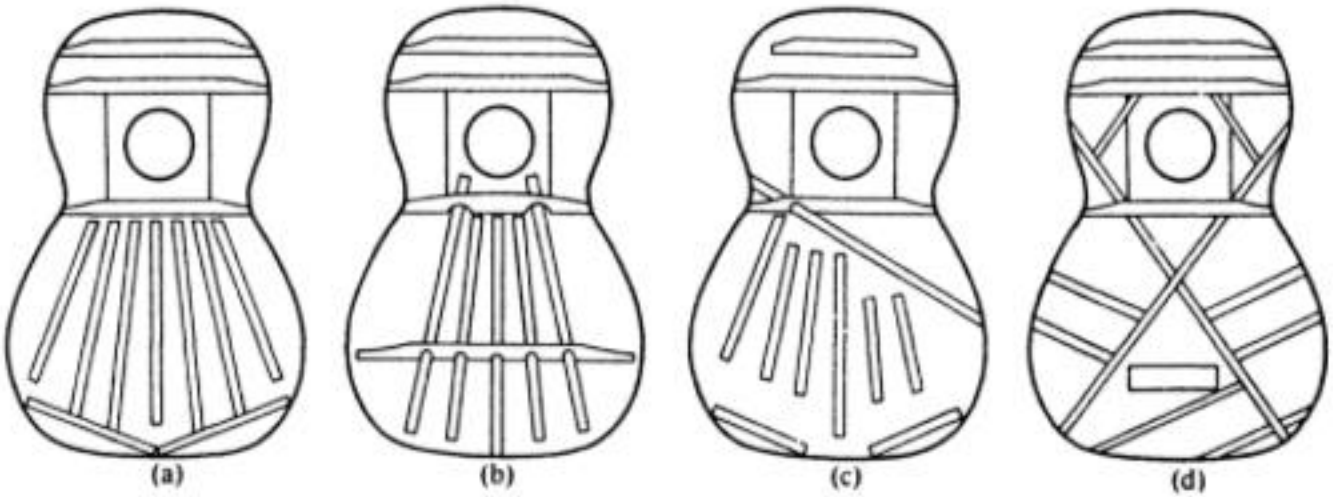


FIGURE 9.2. Various designs for bracing a guitar soundboard: (a) traditional (Torres) fan bracing; (b) Bouchet (France); (c) Ramirez (Spain); (d) crossed bracing (Rossing, 1982a).

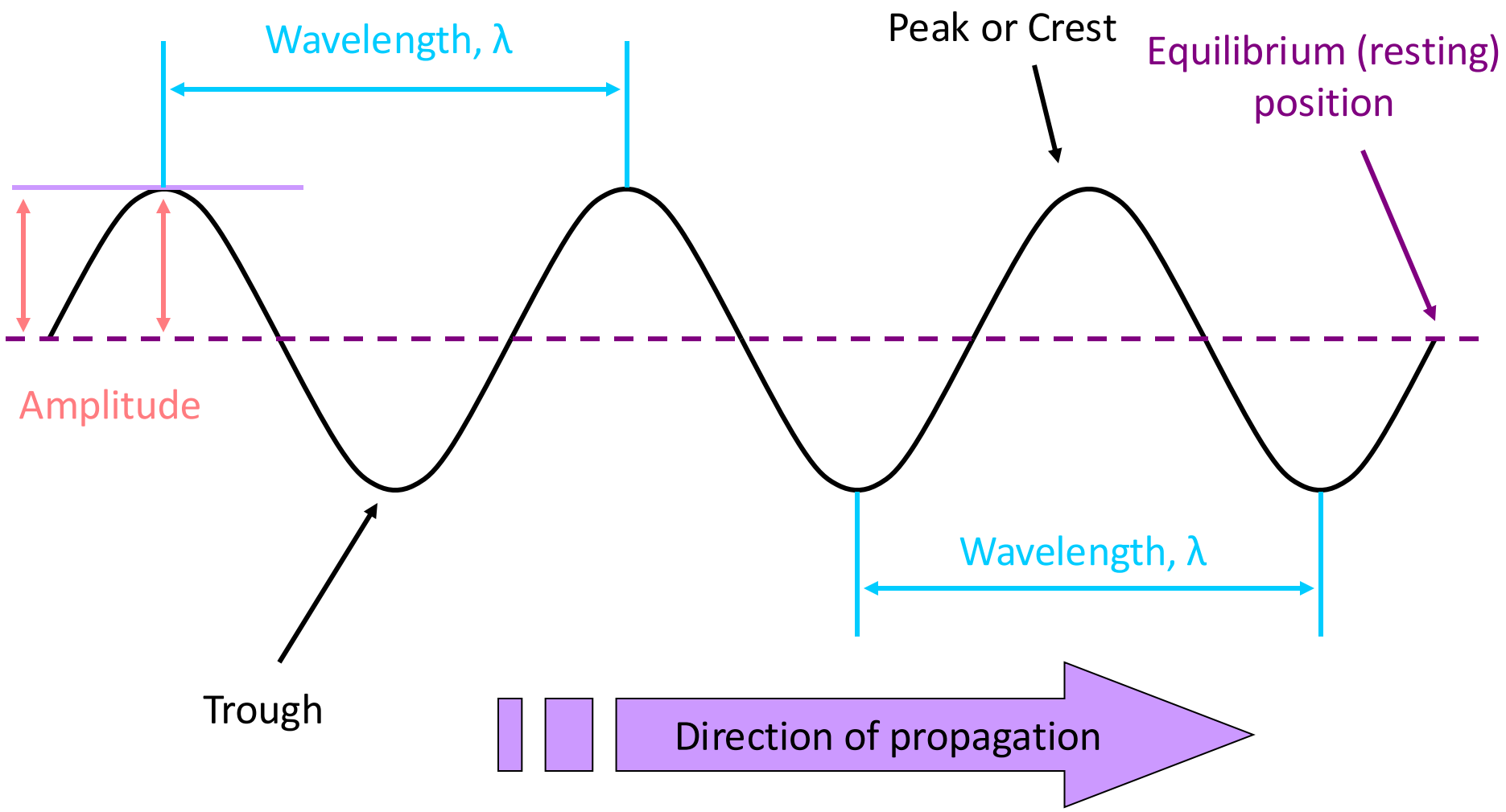
Antonio Torres (1817-1892)

Flamenco guitar

Resonant frequencies in a guitar

Guitar: Marion Arts
Blackbird sings and Rhythm of the wings

Travelling Waves



Higher notes have greater number of waves (cycles) passing a point per second (frequency)

Smaller objects generally vibrate faster and make high frequencies.

Any two notes that are an octave apart have a very similar sound quality because the higher note vibrates at exactly twice as fast as the lower one.

Notes are named using seven letters A to G.

Wave Equation

We have $v = \frac{d}{t}$

therefore $v = \frac{\lambda}{T}$

We know $f = \frac{1}{T}$

$$v = f \lambda$$

Speed in ms-1

Frequency in Hertz (Hz)

Wavelength in metres (m)

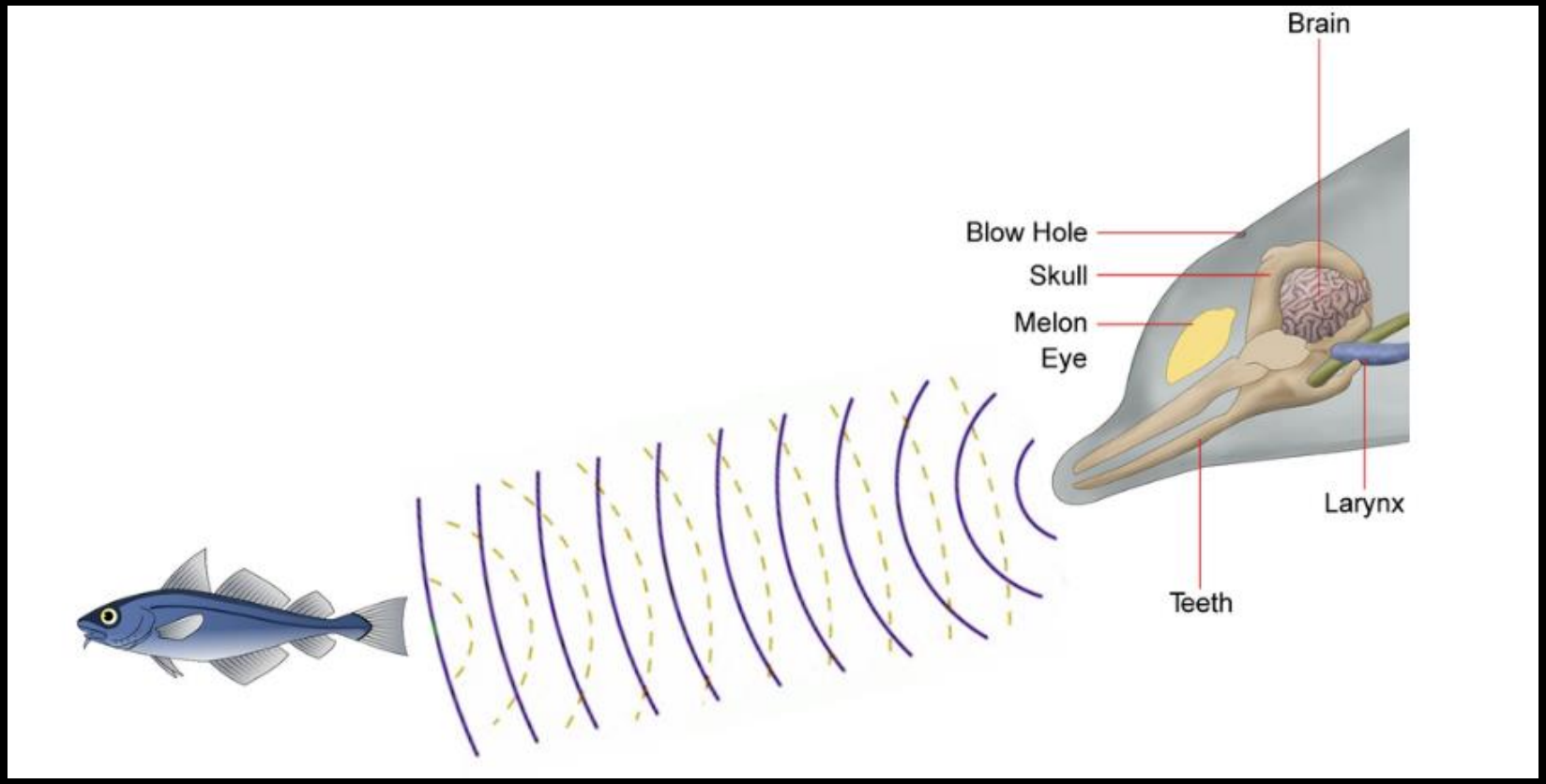
Sperm whales produce sound to communicate and to detect food

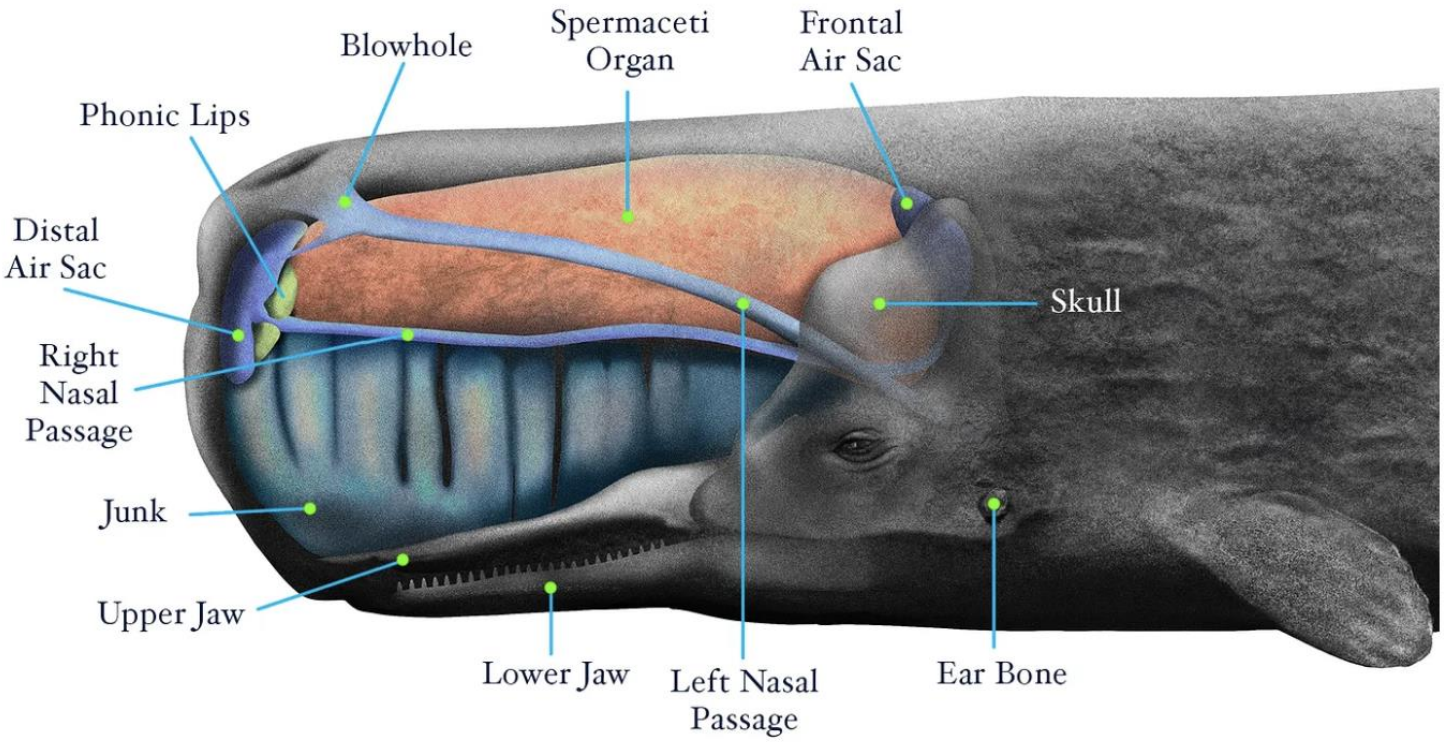
The waves are clicks that travel through the water.

Both the frequency and wavelength of the clicks form patterns.

These patterns form a language and they are also used for echo location

Echo location





Sperm whale head structure

Sound on Mars?

“The Martian” movie starring Matt Damon

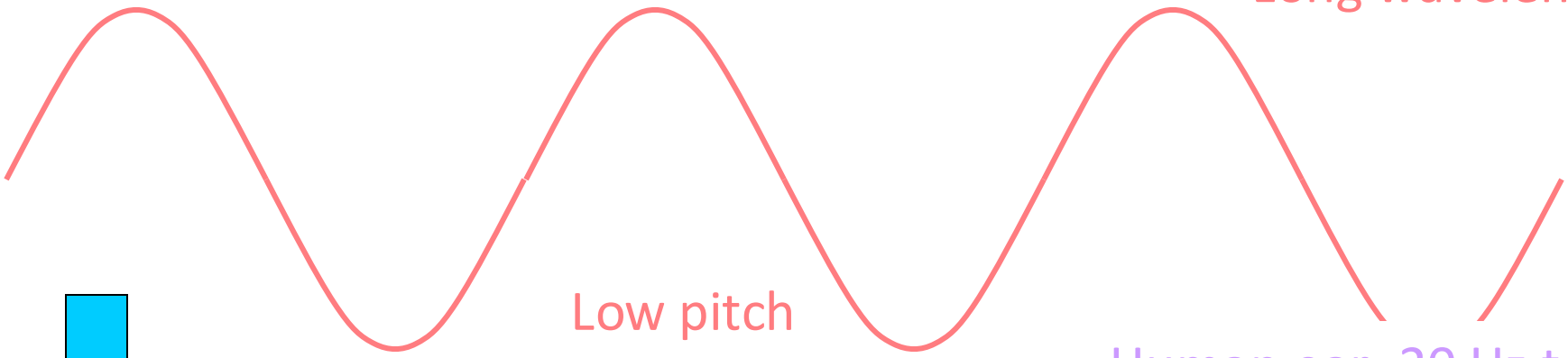
Sound Waves

- Longitudinal waves
- Cannot travel through a vacuum, need medium to travel through
- Speed of sound waves in air = 330 ms^{-1}
- Travel faster in solids than liquids or gases (travel faster in denser medium)
- The source of sound in a vibrating object. A sound in air is transmitted by the vibration of the air particles – sound therefore cannot travel through a vacuum.

Pitch

Low frequency

Long wavelength



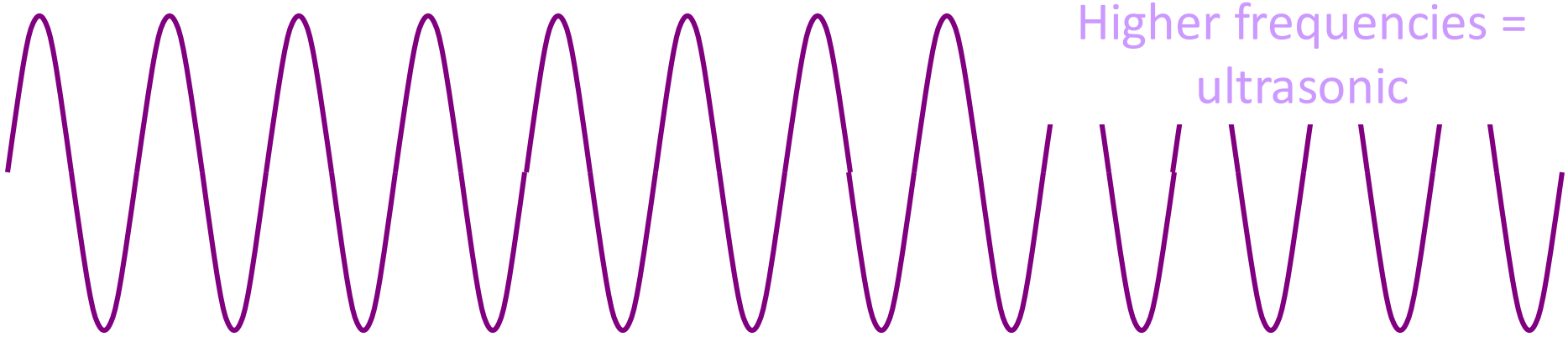
Low pitch

Human ear: 20 Hz to 20 kHz

Lower frequencies = subsonic

Higher frequencies = ultrasonic

Higher frequency = Higher pitch

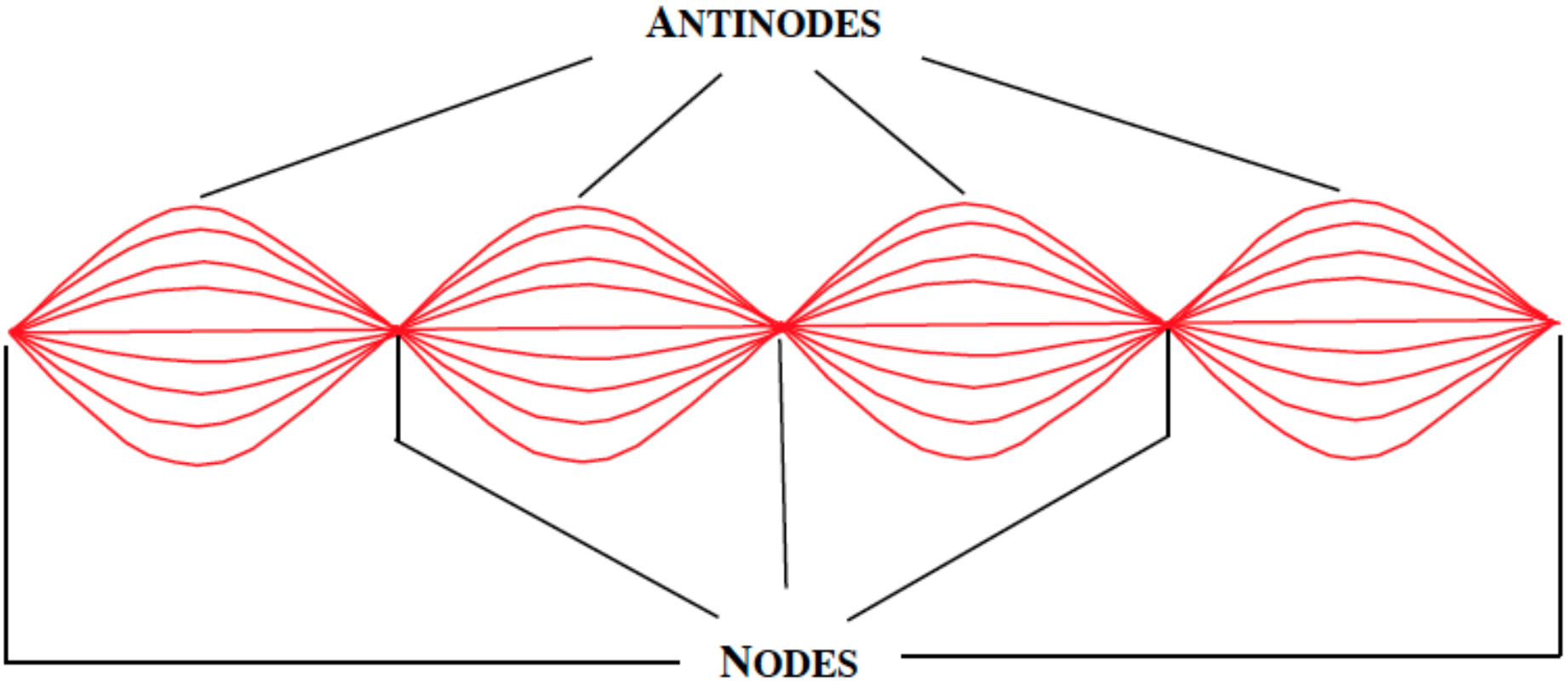


High frequency

High pitch

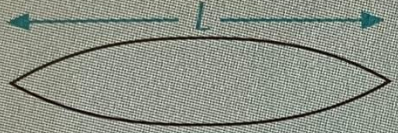
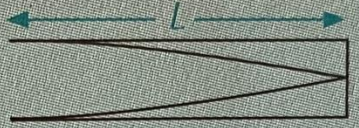
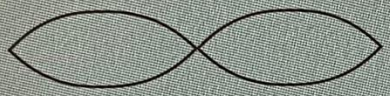
Short wavelength

A Standing wave

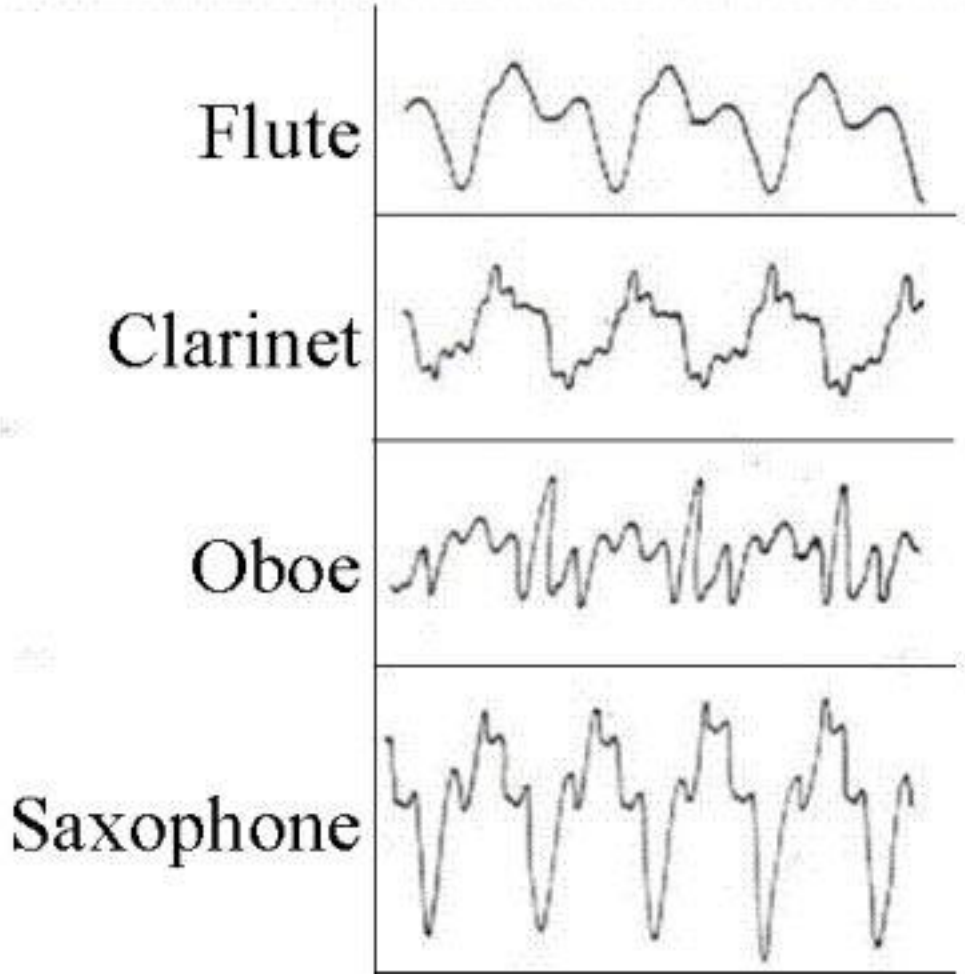


Standing waves occur whenever two waves with equal frequency and wavelength move through a medium so that the two perfectly reinforce each other.

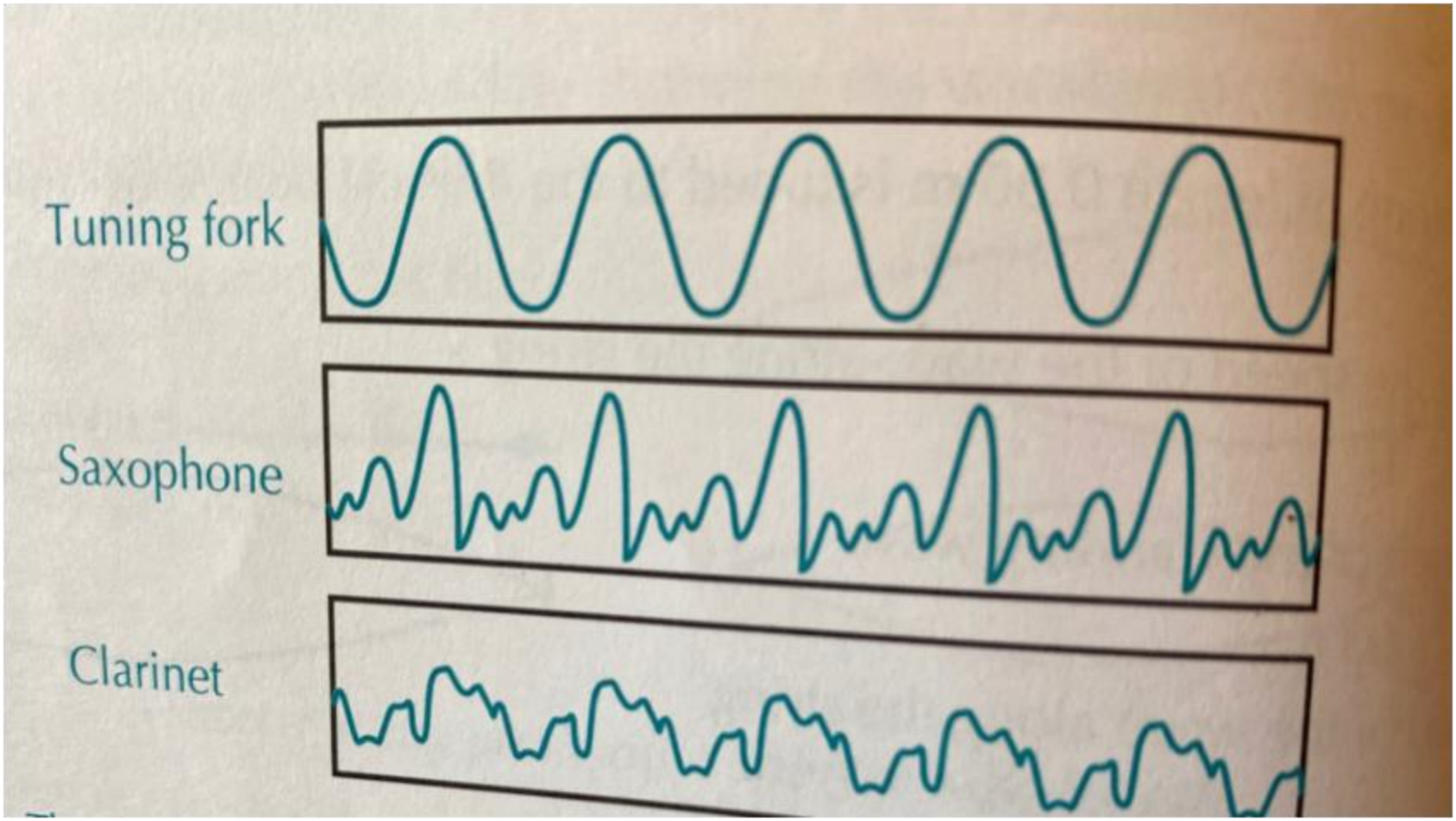
Harmonics in strings and pipes

Mode	String	Closed pipe	Open pipe
1st harmonic or fundamental	 $\lambda = 2L$	 $\lambda = 4L$	 $\lambda = 2L$
2nd harmonic	 $\lambda = \frac{2L}{2}$		 $\lambda = \frac{2L}{2}$
3rd harmonic	 $\lambda = \frac{2L}{3}$	 $\lambda = \frac{4L}{3}$	 $\lambda = \frac{2L}{3}$
4th harmonic	 $\lambda = \frac{2L}{4}$		 $\lambda = \frac{2L}{4}$
5th harmonic	 $\lambda = \frac{2L}{5}$	 $\lambda = \frac{4L}{5}$	 $\lambda = \frac{2L}{5}$

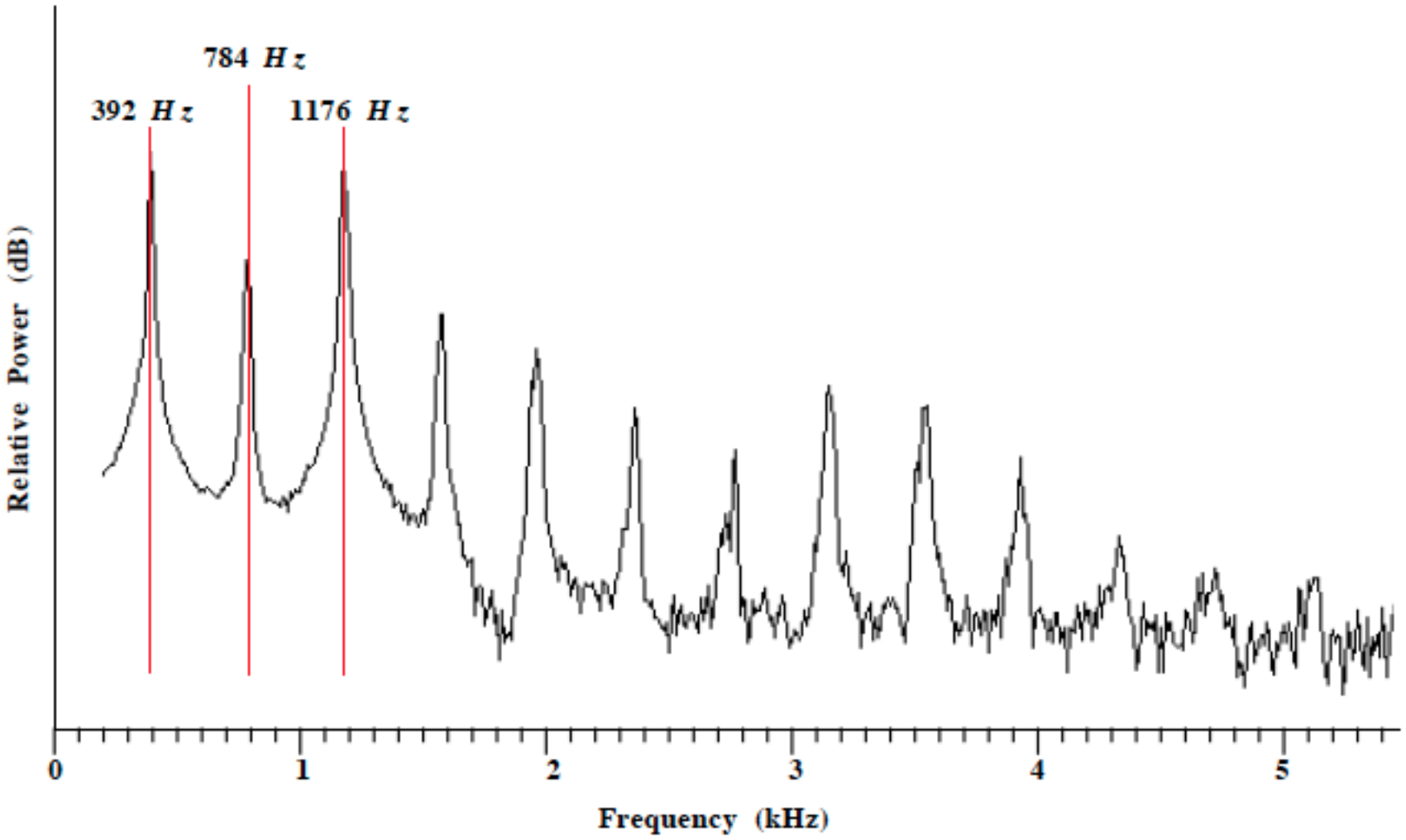
Musical instruments don’t produce pure tones while playing the same note, but the fundamental frequency is overlayed with a mixture of harmonics.



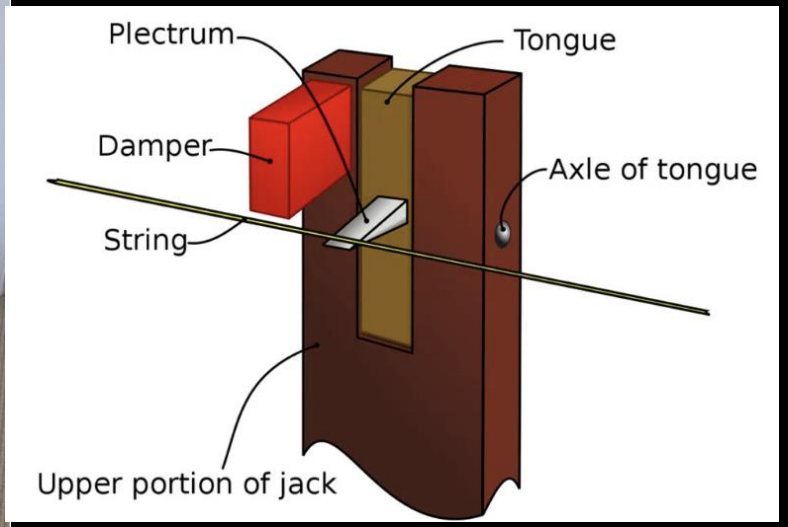
Timbre (characteristic tone)



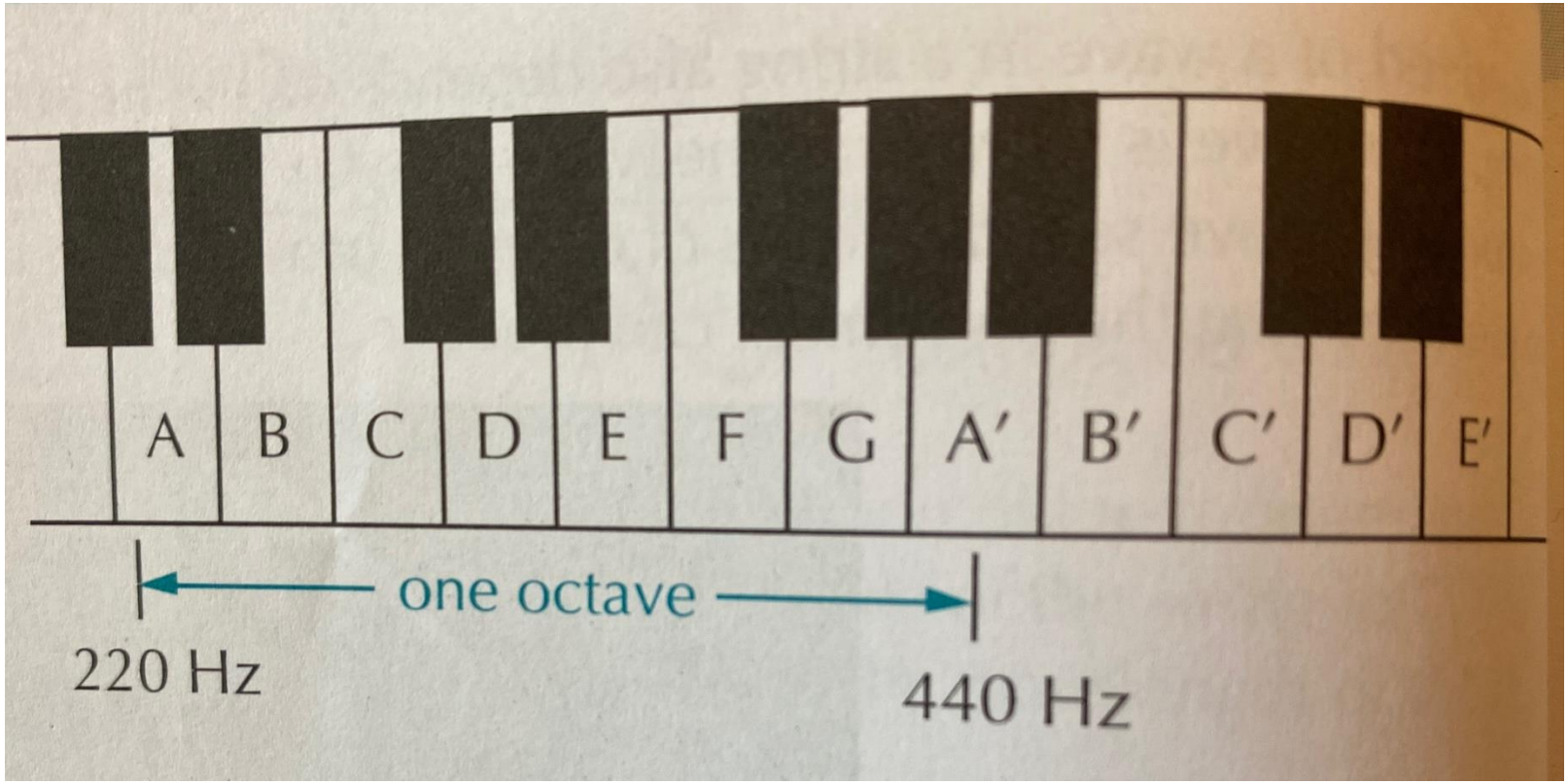
The “ **Sound spectrum**” of a flute when G4 note is played



Harpsichord



Musical scales on piano



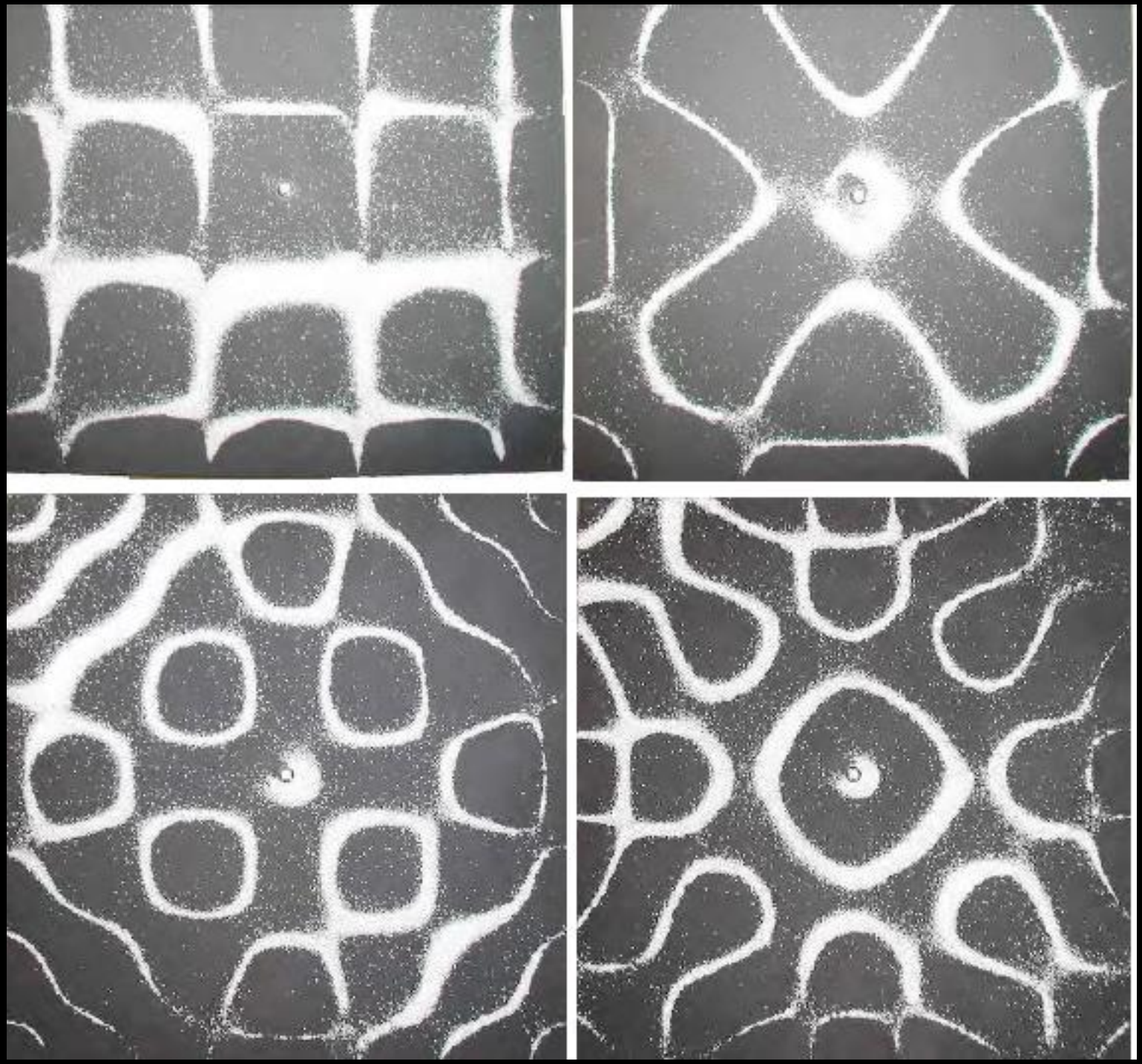
Rachel Jenkins on piano

Natural frequency

When a spoon is dropped on a concrete floor, we are not likely to mistake its sound for that of a tennis ball hitting the floor. This is because the two objects vibrate differently when they are struck. We speak of an objects' **Natural frequency,** which depends on factors such as the elasticity and shape of the object.

Resonance

When the frequency of forced vibrations (driving frequency) on an object matches the object's natural frequency, a dramatic increase in amplitude occurs. This phenomenon is called **resonance**.



268 Hz ($Q = 52$)

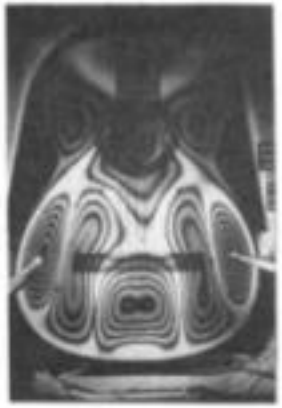
553 Hz ($Q = 66$)

628 Hz ($Q = 83$)

672 Hz ($Q = 61$)

731 Hz ($Q = 72$)

873 Hz ($Q = 75$)



980 Hz ($Q = 48$)

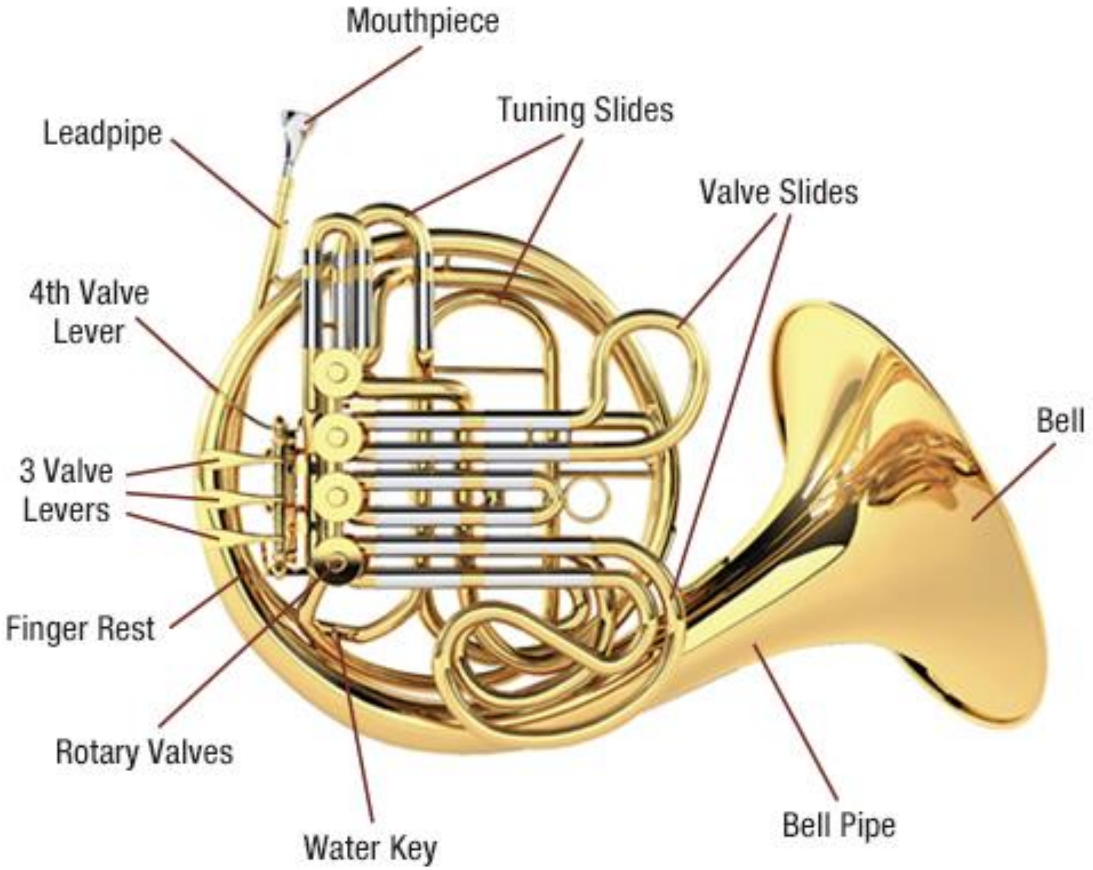
1010 Hz ($Q = 80$)

1174 Hz ($Q = 58$)

1194 Hz ($Q = 39$)

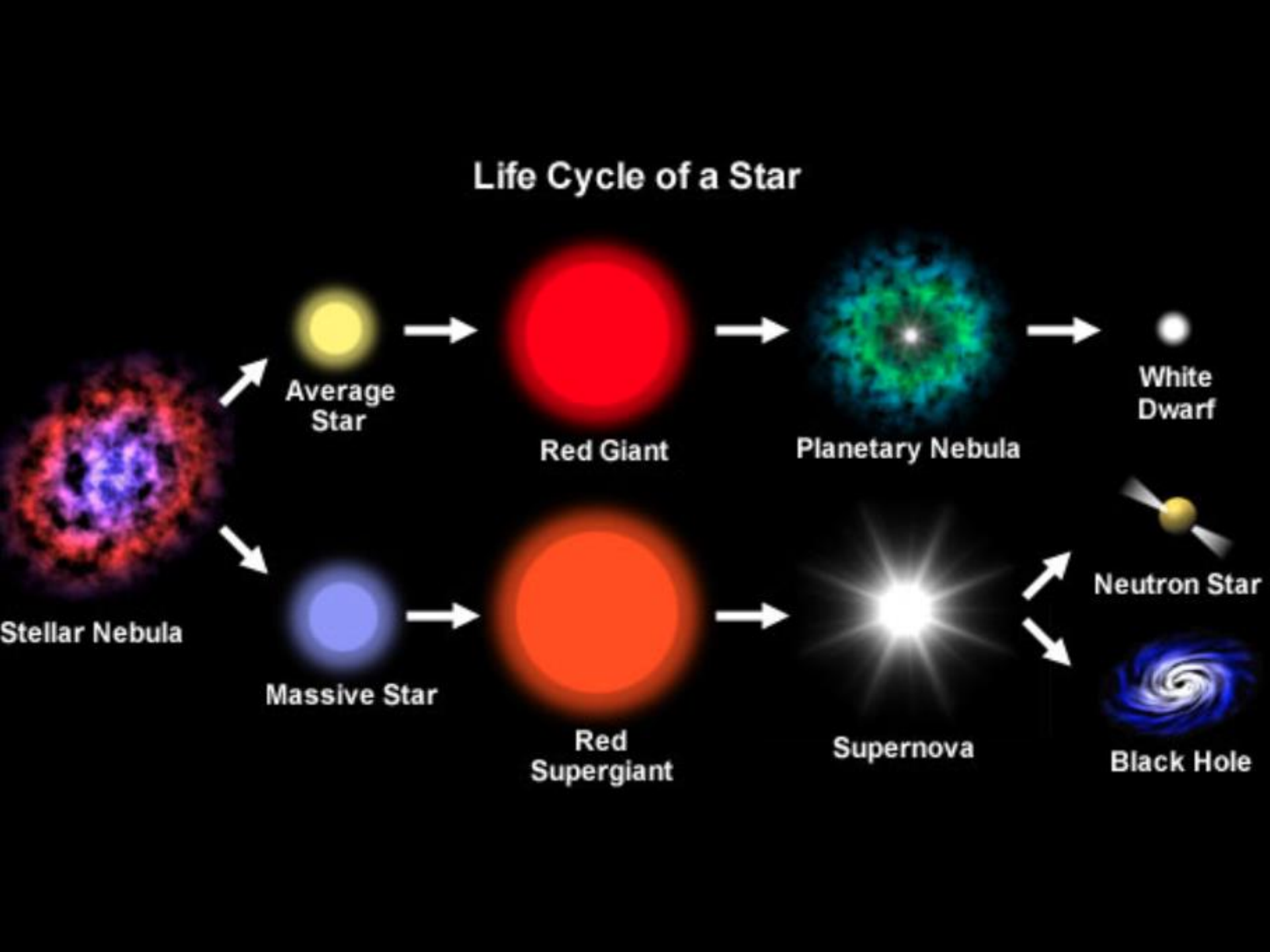
Hugo Broad on French horn

french horn

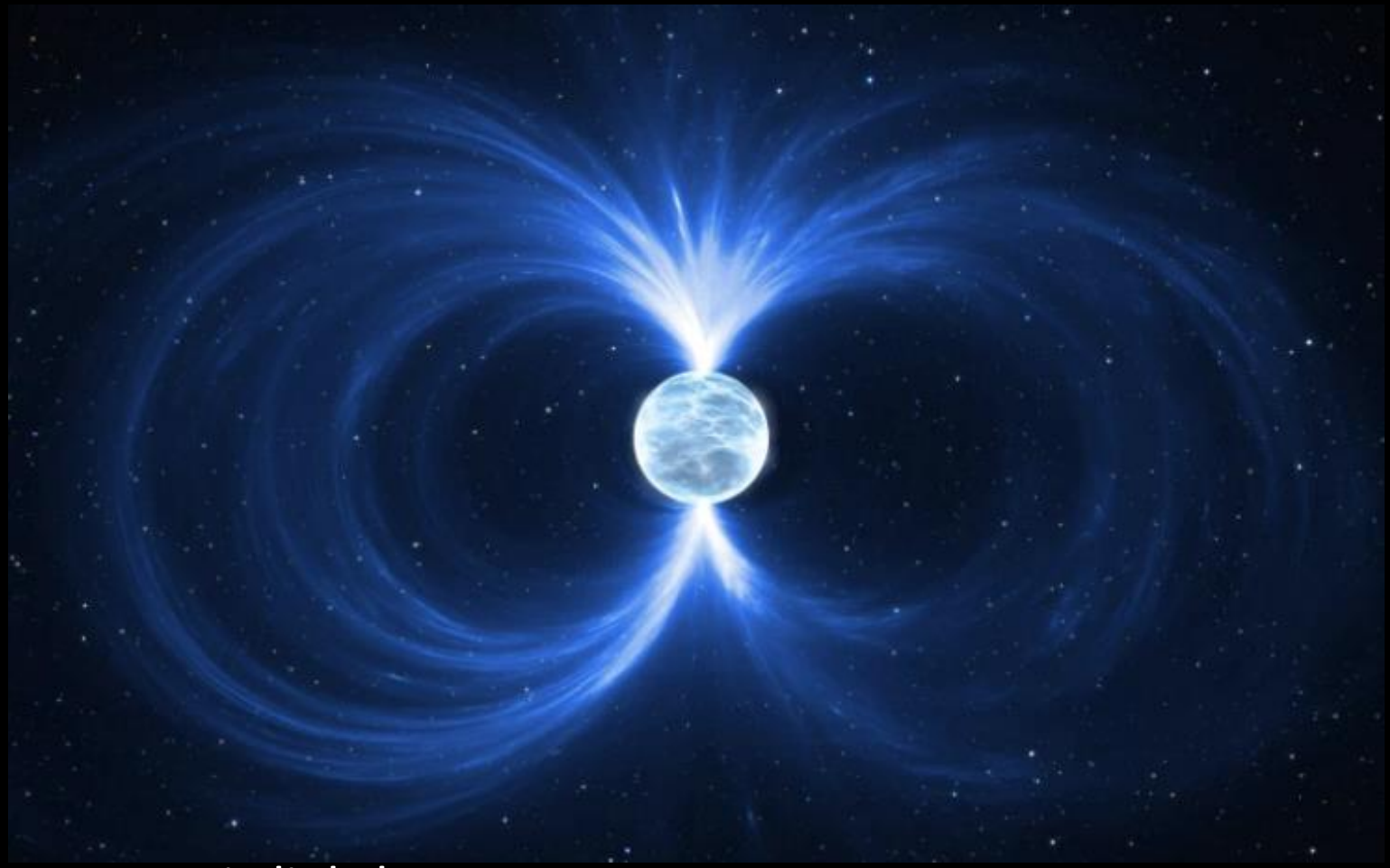

Mouthpiece
Leadpipe
Tuning Slides
Valve Slides
4th Valve Lever
Bell
3 Valve Levers
Finger Rest
Rotary Valves
Water Key
Bell Pipe

The STM
-Sonic Tonic
Machine
9 notes-9 pipes

Total length of the pipes including the bend:
D 1050mm
C 1180mm
B 1290mm
A 1460mm
G 1640mm
F 1830mm
E 1950mm
D 2220mm
Big C 2520mm

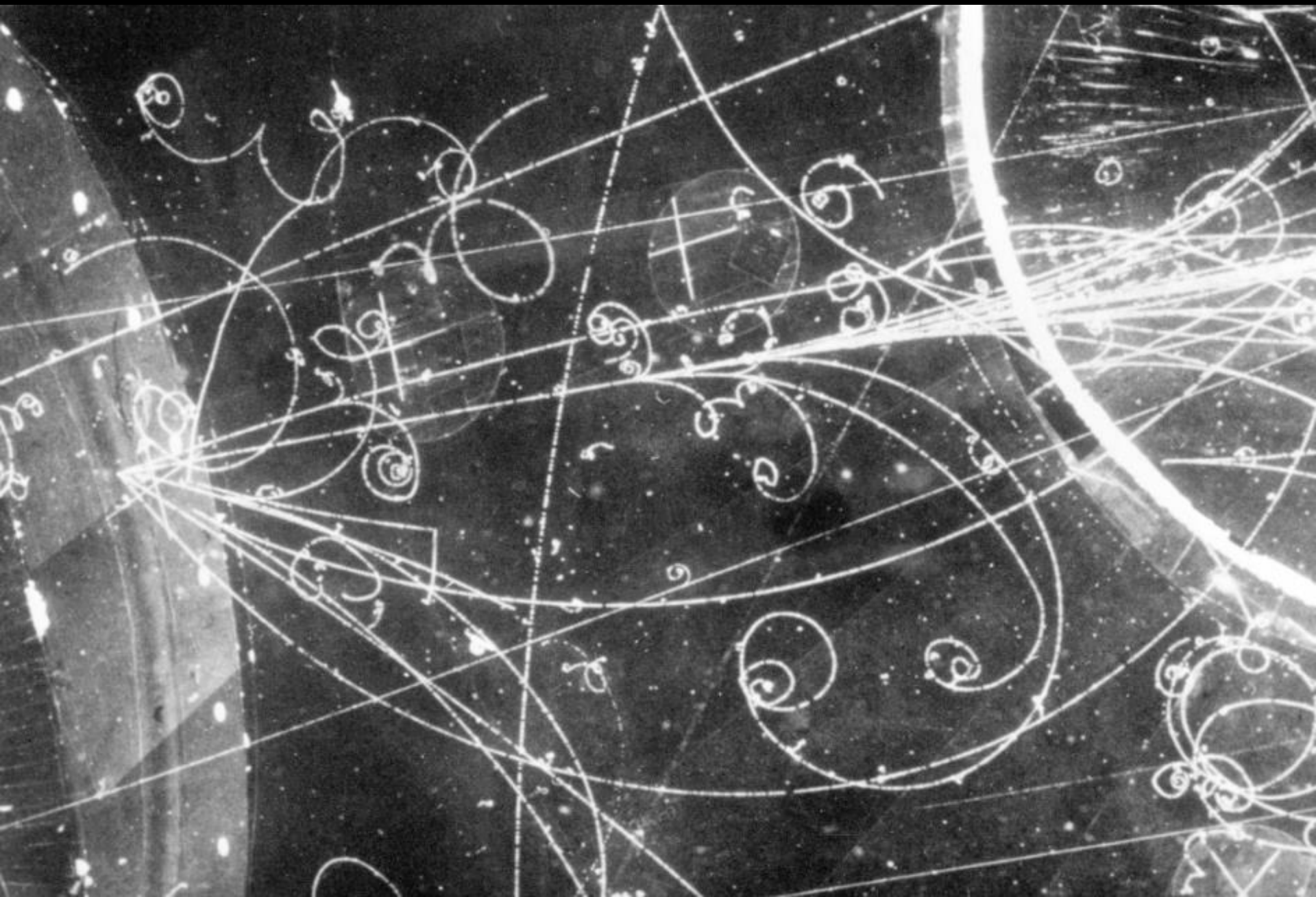

Life Cycle of a Star
Average Star
Red Giant
Planetary Nebula
White Dwarf
Stellar Nebula
Massive Star
Red Supergiant
Supernova
Neutron Star
Black Hole

Pulsar-spinning neutron star



Cosmic lighthouse

The Cosmic Dance



My final thoughts

I believe astrophysics, archeology, philosophy, and music merge together as realms to solve cosmic interactions, all can support the other in further understanding the universe, there are definitely parallels between them, the important thing for me is to keep an open mind.

The more I explore music and the universe, the more I sense that life is a cosmic dance.

Our own atoms come from an old star, we are the cosmic dance and perhaps the universe is a giant guitar that plays the beautiful music.

Simon Taylor

Special thanks to

- Tahangāwari Tangitu-Huata (Pūtātara & Kōauau)
- Marion Arts (Guitar)
- Rachel Jenkins (Piano)
- Hugo Broad (French horn)
- Nikki Hansen (Activation and Events Manager)
- Parehuia Buchanan (Senior marketing Adviser)

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