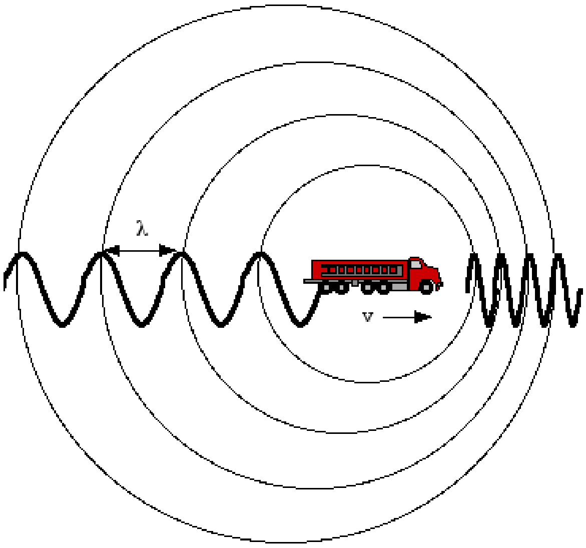
DOPPLER EFFECT

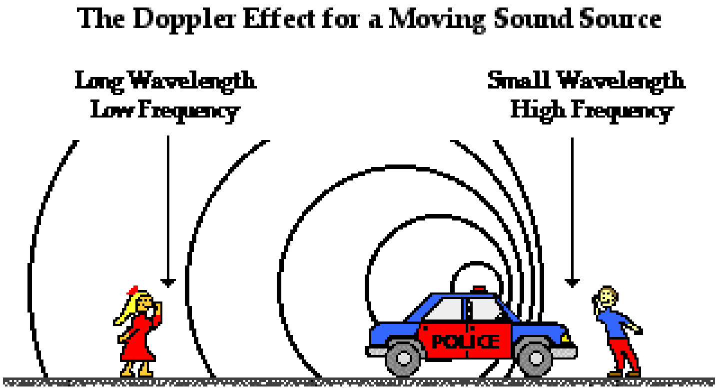
BASICS

- Discovered by the Austrian mathematician and physicist, Christian Doppler (1803-1853).
- Can be observed for any type of wave - water wave, sound wave, light wave, etc. We are most familiar with the Doppler effect because of our experiences with sound waves.
- Example: an ambulance traveling towards you on the highway. As the ambulance approached with its siren blasting, the pitch of the siren sound (a measure of the siren's frequency) was high; and then suddenly after the ambulance passed by, the pitch of the siren sound was low. That was the Doppler effect - an apparent shift in frequency for a sound wave produced by a moving source.
- Not an actual change in the frequency of the source! The effect is only observed because the distance between an observer and the source of the frequency is decreasing or increasing.
- Application in astronomy with electromagnetic waves: blueshift or redshift for a light coming from a star or a galaxy (blueshift: moving toward the observer / redshift: moving away the observer)
- Galaxies are moving away: it helped to prove the Big Bang Theory.

ADVANCED

- Illustration of the Doppler effect when you wait for your luggage in the airport (the bags travel under your hand with a certain frequency but if you move toward the source, you have the feeling that the frequency increases)
- Definition of the frequency and the wavelength of a wave.
- Then, using the following drawing, you show that the wavelength will increase or decrease (depending if the source is approaching or moving away)





- The wavelength, the frequency and the celerity of the wave (≠ from v, the speed of the car) are linked by the formula:

$$c = \lambda \times f \quad \text{or} \quad f = \frac{c}{\lambda}$$

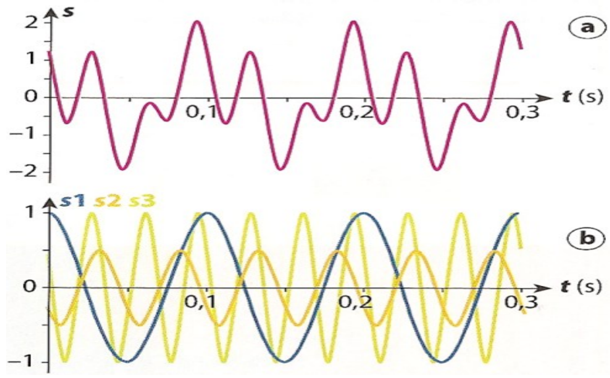
  So an apparent small wavelength will give an apparent high frequency
- Knowing the shift between the real and the apparent frequencies, the speed of the object can be calculated (you just have to say that it is possible)

LINKS

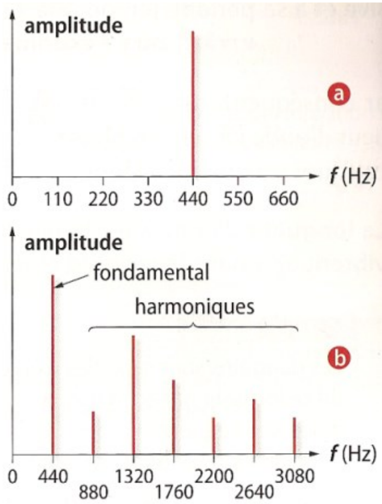
- Astronomy:
  - Old civilizations already started to study the Universe
  - Galileo's telescope allowed better observations (Moon's surface, Jupiter's satellites, …)
  - Empirical laws with Kepler
  - General laws with Newton (3 laws and gravity)

- Other tools now: we analyze the electromagnetic waves that we receive from the Universe (spectrum of absorption to know the chemical elements in a star atmosphere, Doppler effect with the blue shift/red shift to know if a galaxy or a star is getting closer or is getting further, …)

- You can explain the spectra of emission an absorption
- You can explain the experiment we made about the sound analysis:
  - We recorded and analyzed different steady tones (diapason, piano, voice)
  - We obtained periodic signals (Voltage versus time) and the analysis showed that these signals could be seen as the combination of simple waves with different frequencies



  - These frequencies are called harmonics. The 1st harmonic (the lowest frequency) is the fundamental harmonic. The frequencies of the other harmonics are multiples of the first one ($f_2 = 2xf_1$, $f_3 = 3xf_1$…)
  - 2 families of sounds: pure sounds (only the fundamental harmonic/sound of a diapason) and complex sounds (several harmonics/instruments, voice)



  - The same pitch means the same fundamental harmonic

- For a same pitch, you hear it's not the same instrument because the other harmonics and their intensity are different: it's the timbre of the sound
- It means that your brain can make this kind of analysis!
- When you think that 2 sounds are harmonious, it's because you can identify common harmonics!
- That's why sometimes you read that there is a link between mathematics and music (Planck, a famous scientist, was very good at music too)