BRIEF

BASIC PHYSICS
Doppler Shift

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Overview

The Doppler Shift describes how light and sound waves are alerted based upon motion to/from an observer.

This is most typically observed with sound waves through their higher pitch when approaching and lower pitch when moving away.

This technology is also used in Meteorology in weather RADAR.

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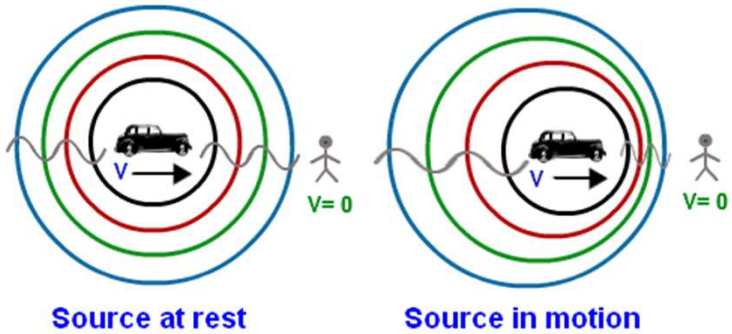
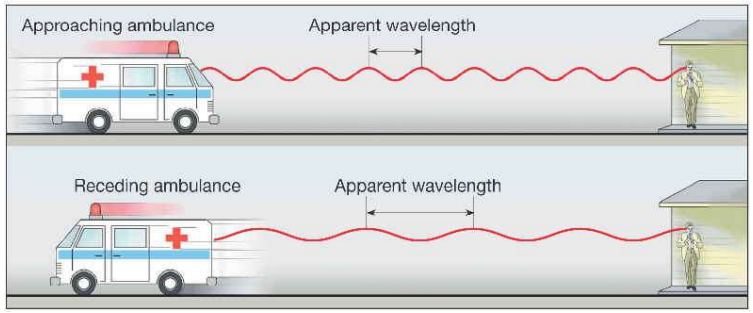
The Doppler Effect

- What is it:
  - The observed shifting of a wavelength (any wavelength) when *the source* of the waves and/or *the observer* are moving either towards or away from each other. OR, The change of a wavelength with motion
  - It tells you about the relative motion of an object with respect to you
- The amount of the shift and its sign depends on
  - Relative speed of the source & observer
  - Direction of motion (together or apart)
  - The greater the relative speed between the source and the observer, the greater the observed shift.





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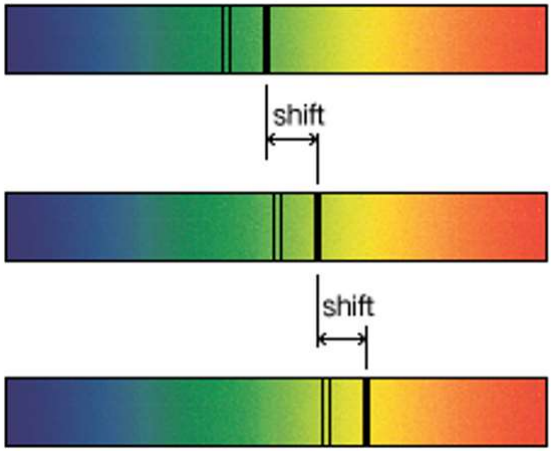
Doppler Effect In Light

- ***Blue Shift:*** Increasing frequency (radial motion towards the observer) toward the high-frequency, or blue, end of the spectrum.
- ***Red Shift:*** Decreasing frequency (radial motion away from the observer) to the low-frequency, or red, end of the color spectrum.
- Uses in Astronomy:
  - Starlight: determines if stars are moving toward or away from Earth.
  - Stars moving toward the Earth have their light wavelengths shortened.
  - Stars moving away from Earth have their light wavelengths lengthened.
  - **IMPORTANT:** The Doppler effect will not affect the overall color of an object unless it is moving very fast



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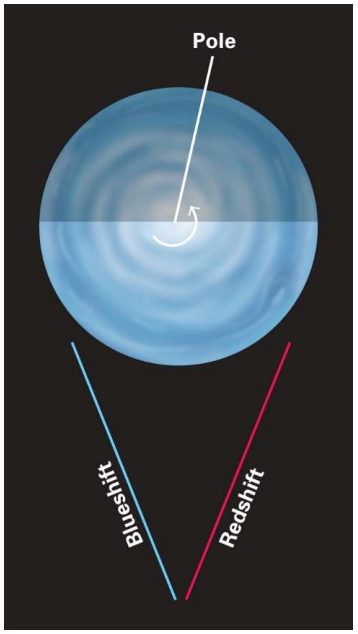
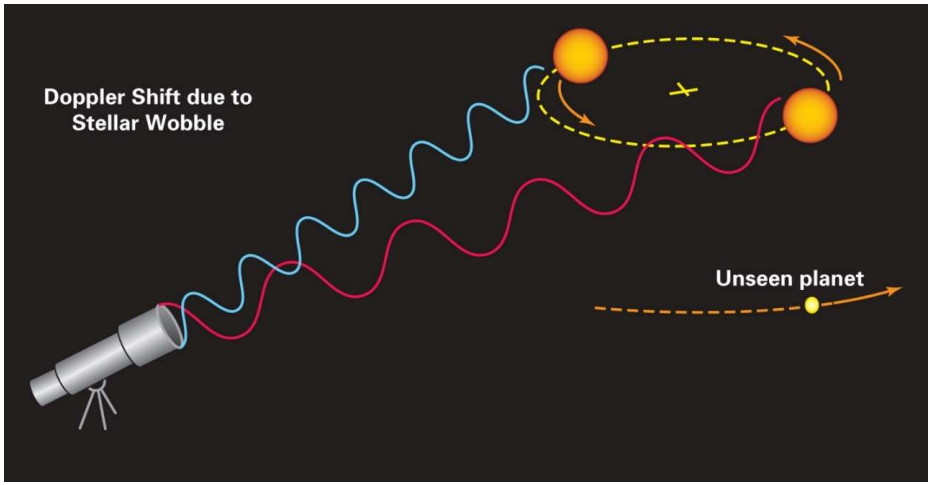
Doppler Effect Putting it to work

Planetary Motion



Stellar Motion affected by an Exoplanet



Pasachoff_Fig. 2.16
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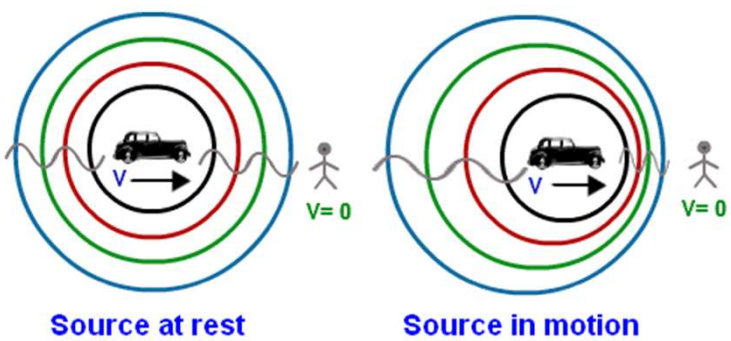
Doppler Shift A Way to Measure Speeds

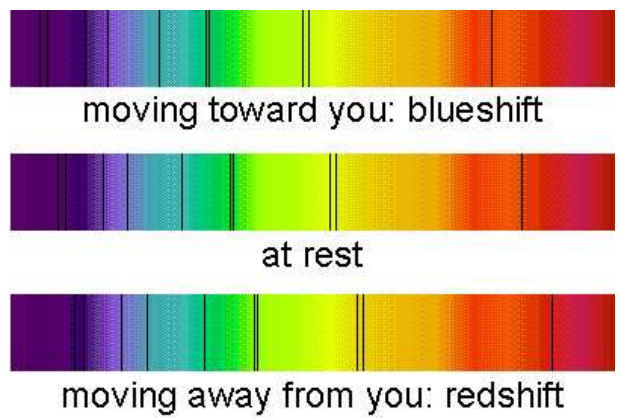
- Observe the wavelength λ_{obs} of a light source with a known emitted wavelength λ_{em}.
- The **difference** between the observed and emitted wavelengths is directly proportional to the speed of the source towards or away from you (**v**), given by the **Doppler Formula**:

$$\frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} = \frac{v}{c}$$

  - Here **c** is the speed of light
  - λ_{obs} is the wavelength observed
  - λ_{em} is the known emitted wavelength
  - *v* is the velocity

The size of the shift gives the speed of the source & The color of the shift (Red or Blue) gives the direction of motion (away or towards you).





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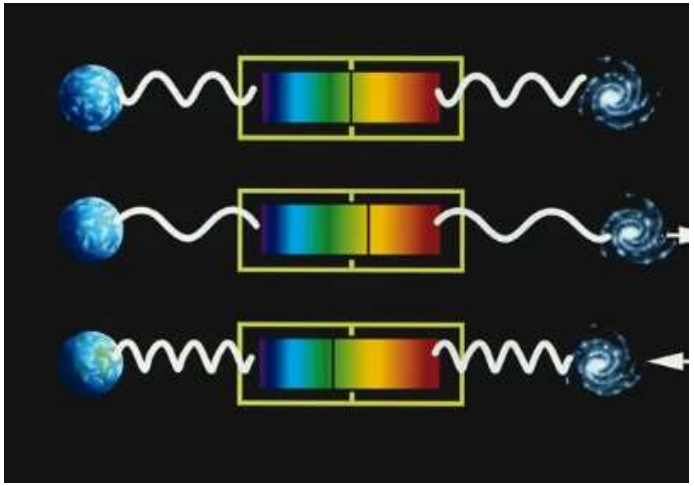
Doppler Effect Putting it to work

- In 1912 an astronomer named Vesto Slipher measured a red shift in the light coming from a distant galaxy indicating that the galaxy was moving away from Earth.
- He later discovered that the light from almost *all* distant galaxies was red shifted.
- Edwin Hubble later showed that the farther away the galaxies are, the faster they seem to be receding from us.
    - Distant galaxies show a red shift in their light.
    - A measurement of this shift enables astronomers to calculate their speeds of recession.
    - The red shift Is also a piece of evidence for the Big Bang theory.



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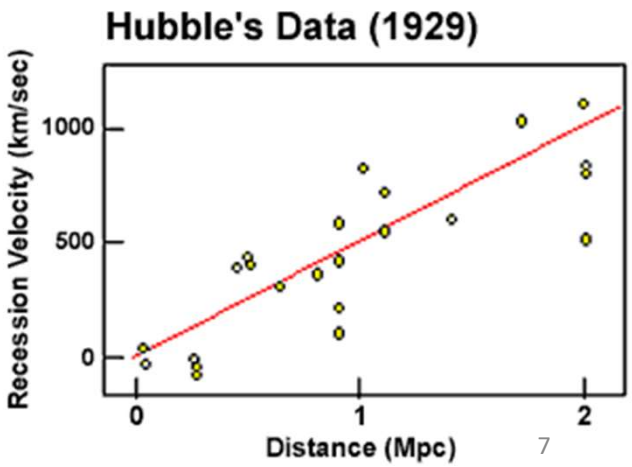
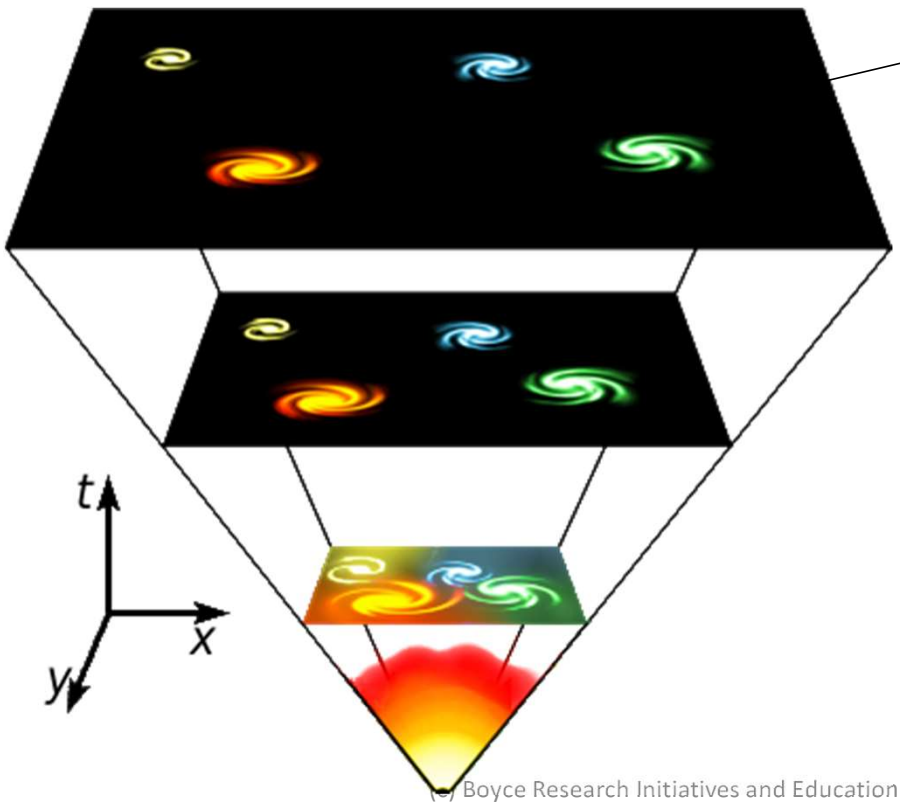


Expansion of the Universe



Light traveling between distant galaxies gets "stretched out" (red-shifted) as the space between the galaxies expands. The individual stars in galaxies don't move apart because they are held close together by gravity.

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Summary

The doppler shift is most used in Astronomy in the field of spectroscopy where the shifting of spectra shows relative motion, radial velocity, presence of a planet, etc.

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