AST 301, Lecture 2

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Cosmic Catastrophes (AKA Collisions)

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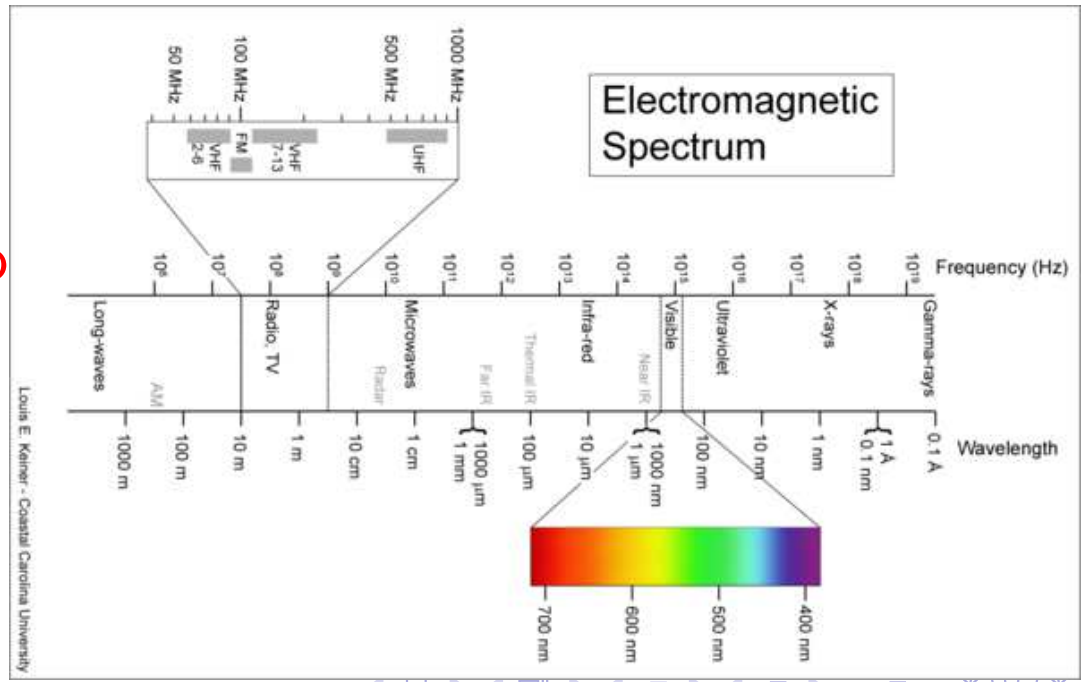
Properties of Light and Radiation

- Speed is $c = 3 \times 10^{10}$ cm/s $= 186{,}000$ mi/s $= 6.7 \cdot 10^8$ mph.
- Distance traversed in 1 year is called a light-year.
- Has properties characteristic of both waves and particles.
- Wave nature: Wavelength $\times$ Frequency $= c$ (Speed)
  $\lambda \times \nu = c$

- Wavelengths from $\gamma-$ rays ($\lambda \sim 10^{-13}$ cm) to radio ($\lambda \sim 10^3$ cm).
- Visible light is optical radiation, 3×10^{-5} cm $\lambda < 7 \times 10^{-5}$ cm.

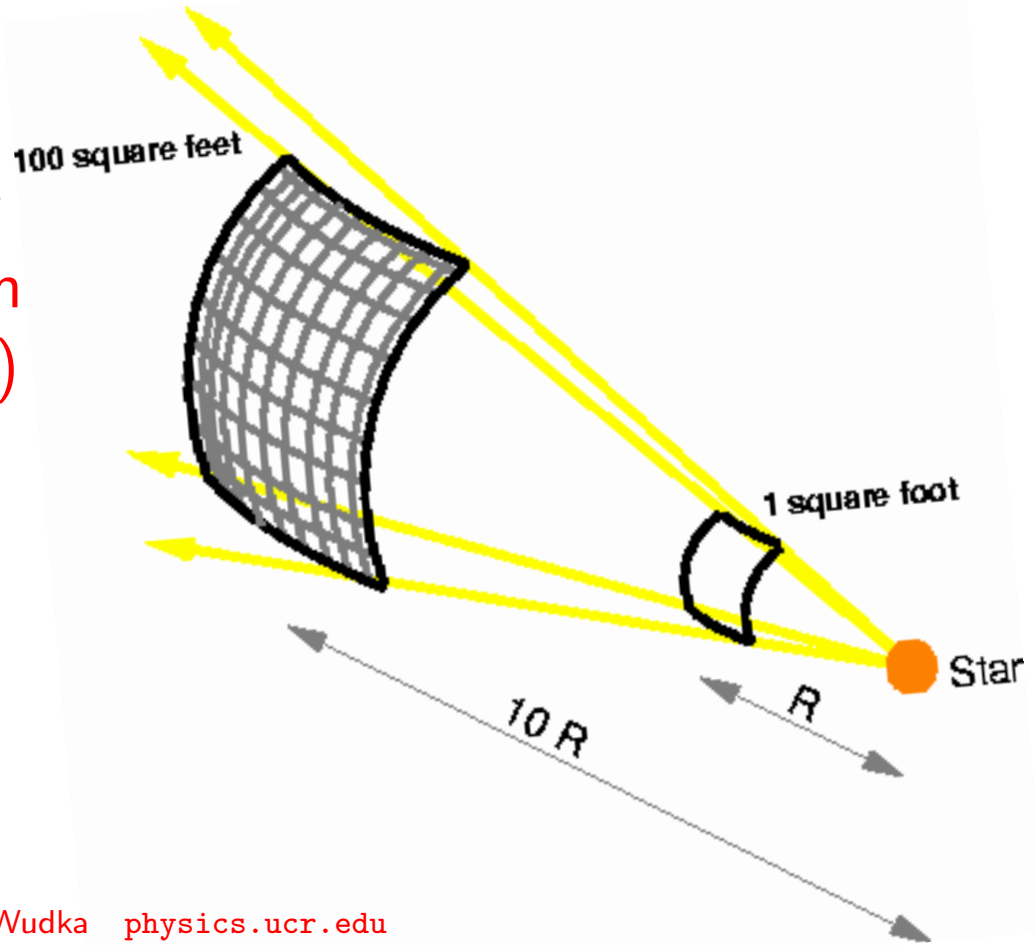


Photons and Inverse Square Law

- Particle nature: Smallest unit of radiation is a photon.
- Photon energy is proportional to frequency $E = h\nu$

h is Planck's constant,
$6.6 \cdot 10^{-27}$ cm^2 g s^{-1}

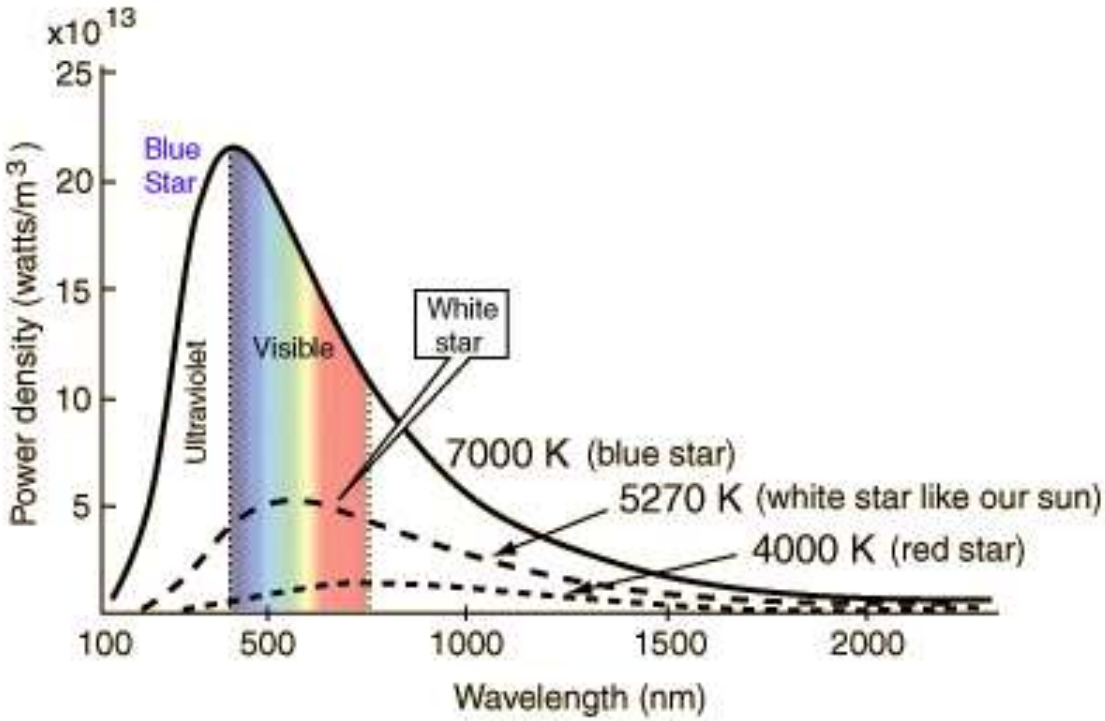
- Brightness (B) or Intensity (I) is apparent flux from an object while Luminosity (L) the intrinsic or absolute power output.
- Inverse square law of brightness – brightness (intensity) diminishes as distance squared:
$B = L/D^2$



Jose Wudka physics.ucr.edu

Wein's Law

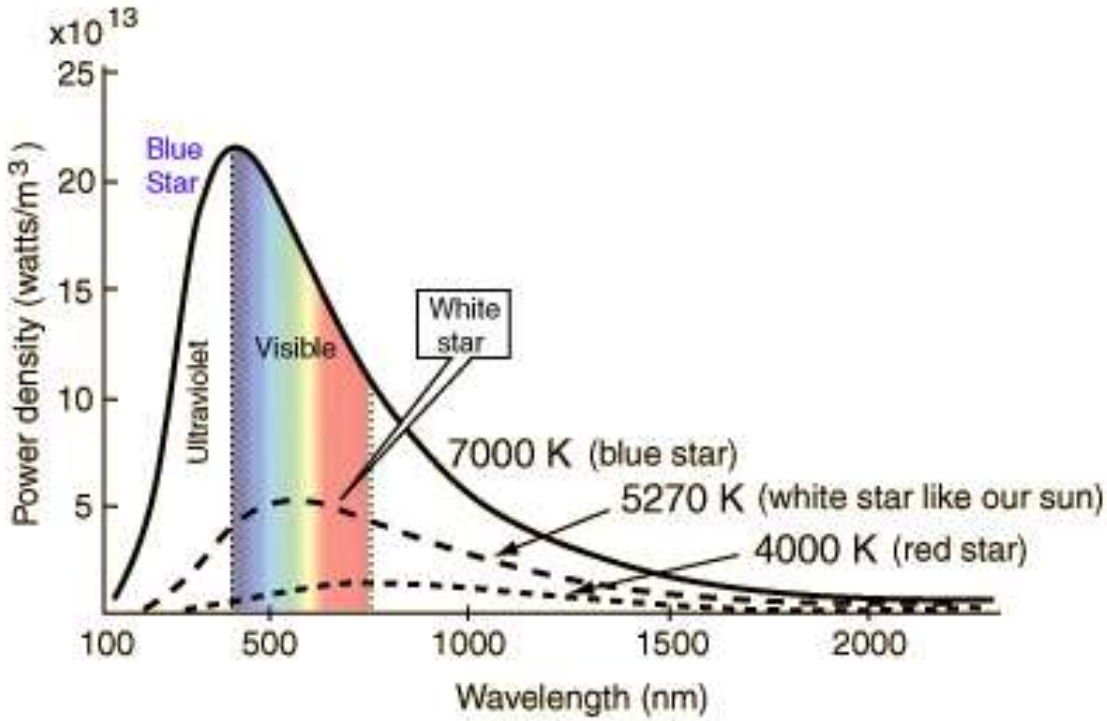
- Radiation from a luminous object is emitted at virtually all wavelengths, but peak wavelength of distribution is inversely proportional to temperature
  $\lambda = 0.29\ \mathrm{cm}/T^{\circ}\ \mathrm{K}$
  AKA **Wien's Law**
- Therefore the color of a star is a measure of its temperature.



hyperphysics.phy-astr.gsu.edu/hbase/wien.html

Luminosity

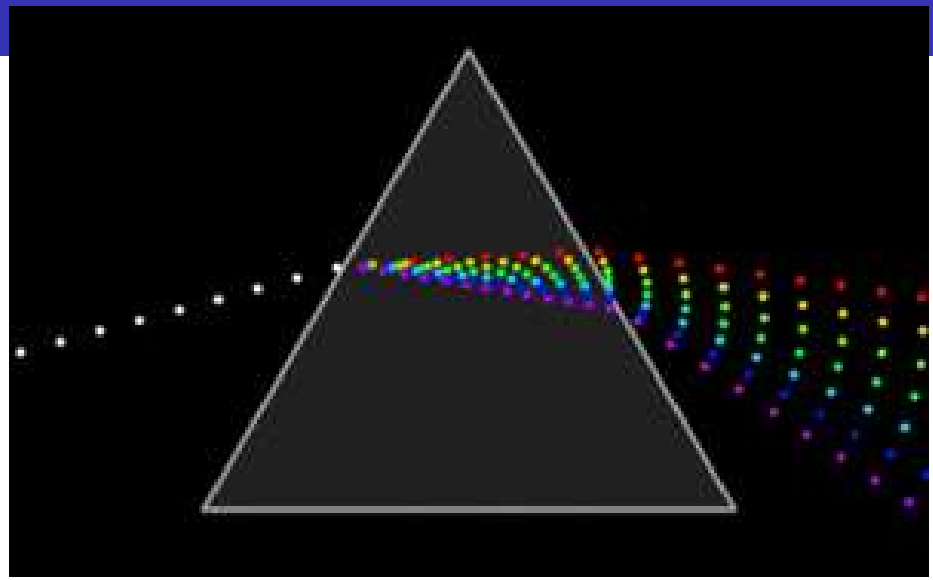
- Total power (luminosity) emitted by a luminous object (e.g., a star) is dependent upon both temperature T and object size or radius R: $L = 4\pi R^2 \sigma T^4$ $\sigma = 5.567 \cdot 10^{-5}\ \mathrm{erg\ cm^{-2}\ K^{-4}}$ is radiation constant
- This is seen by examing the total area under the emitted power density curves



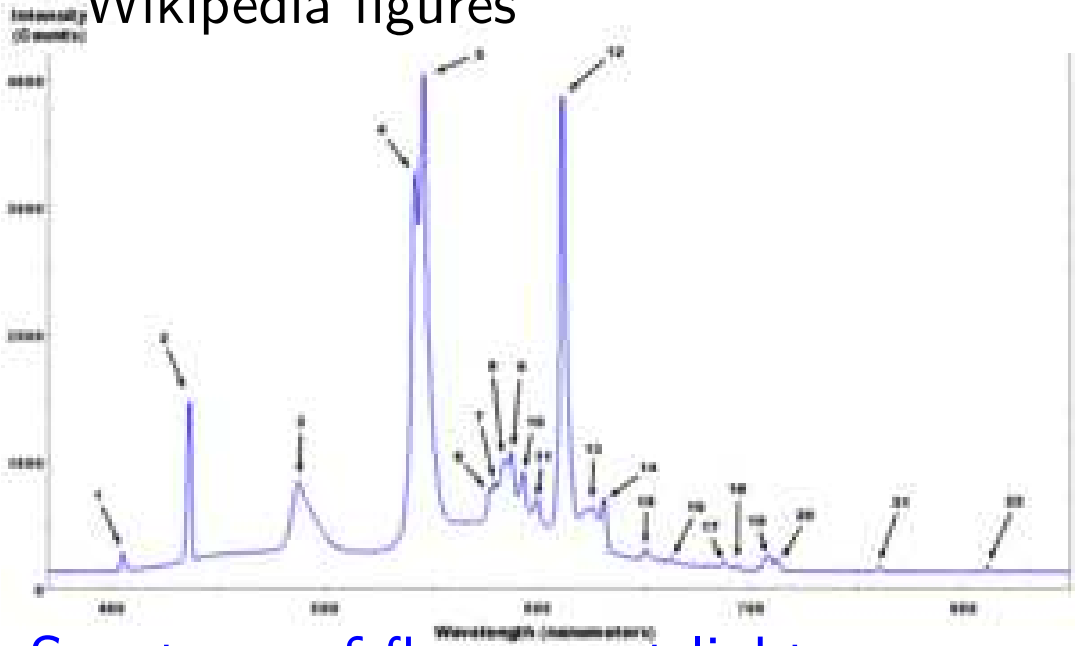
hyperphysics.phy-astr.gsu.edu/hbase/wien.html

Spectroscopy

- A prism can spread light into a spectrum.
- Spectra have absorption and/or emission lines, each characteristic of an electronic transition in an atom or molecule. Can deduce elemental or chemical composition of stars.

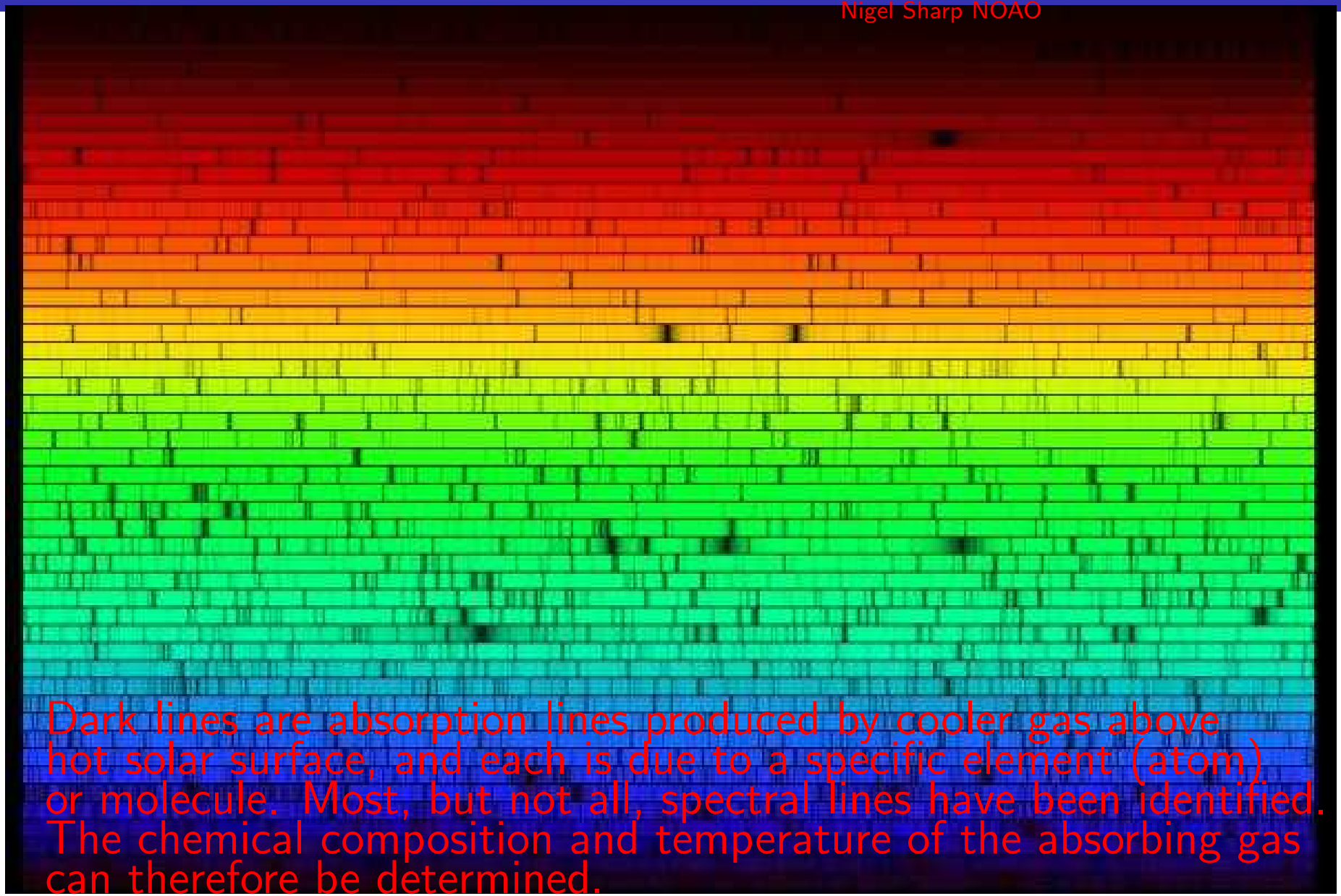


Wikipedia figures



Spectrum of fluorescent light

Solar Spectrum

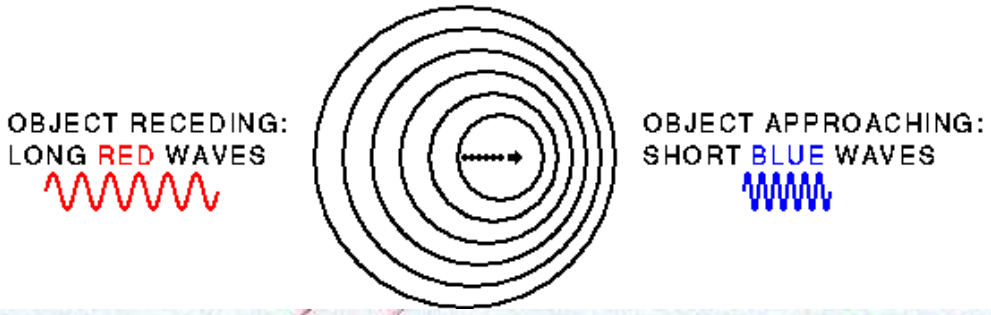


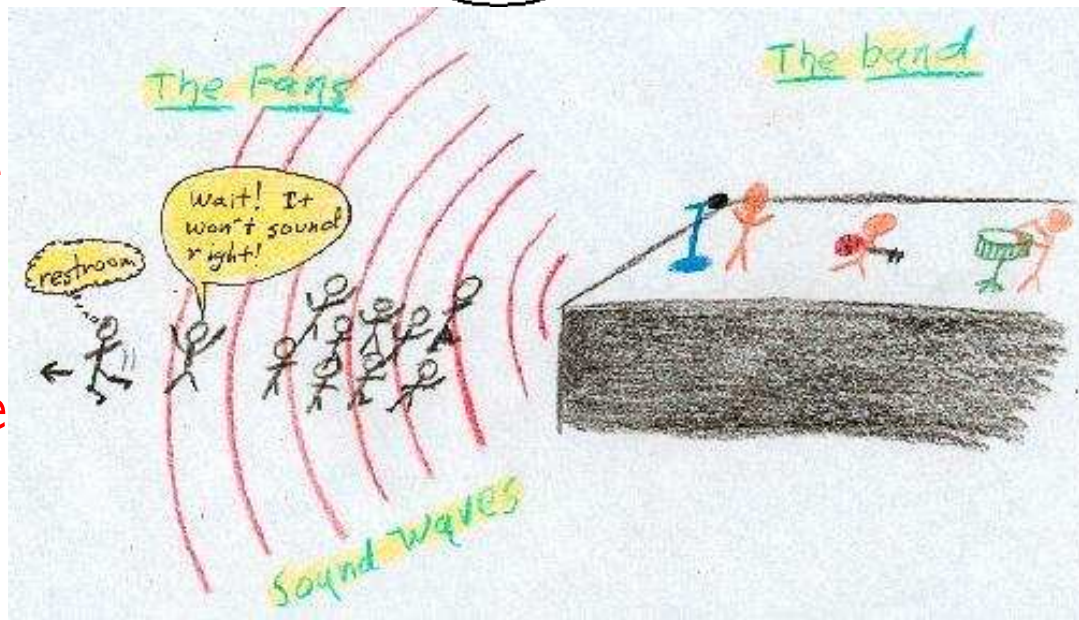
Dark lines are absorption lines produced by cooler gas above hot solar surface, and each is due to a specific element (atom) or molecule. Most, but not all, spectral lines have been identified. The chemical composition and temperature of the absorbing gas can therefore be determined.

Doppler Effect

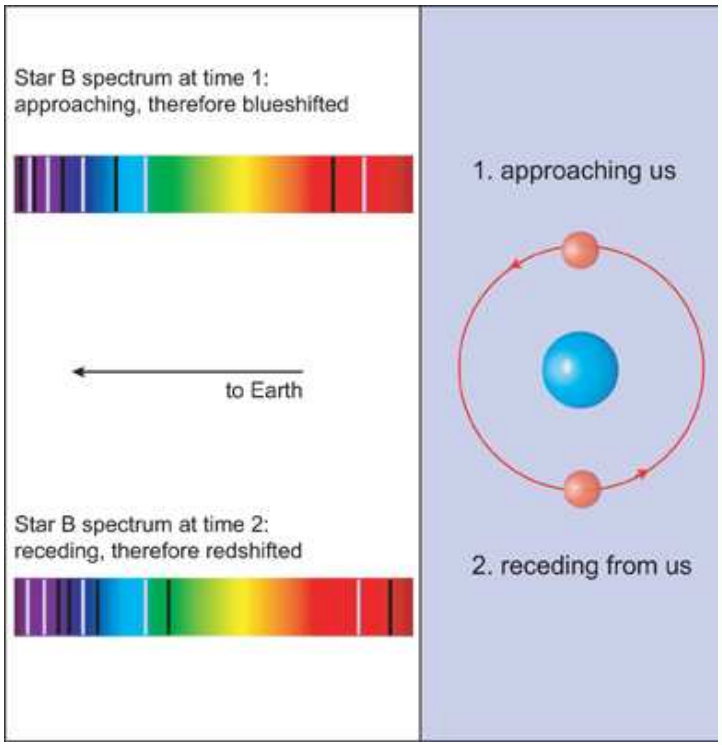
- Speed of light is independent of source's velocity (Einstein's Special Theory of Relativity)
- The observed wavelength of a photon or a spectral line depends upon the relative velocities of the source and the observer.
- The observed change in the wavelength, the Doppler shift, is proportional to the net relative speed difference between the source and observer: $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

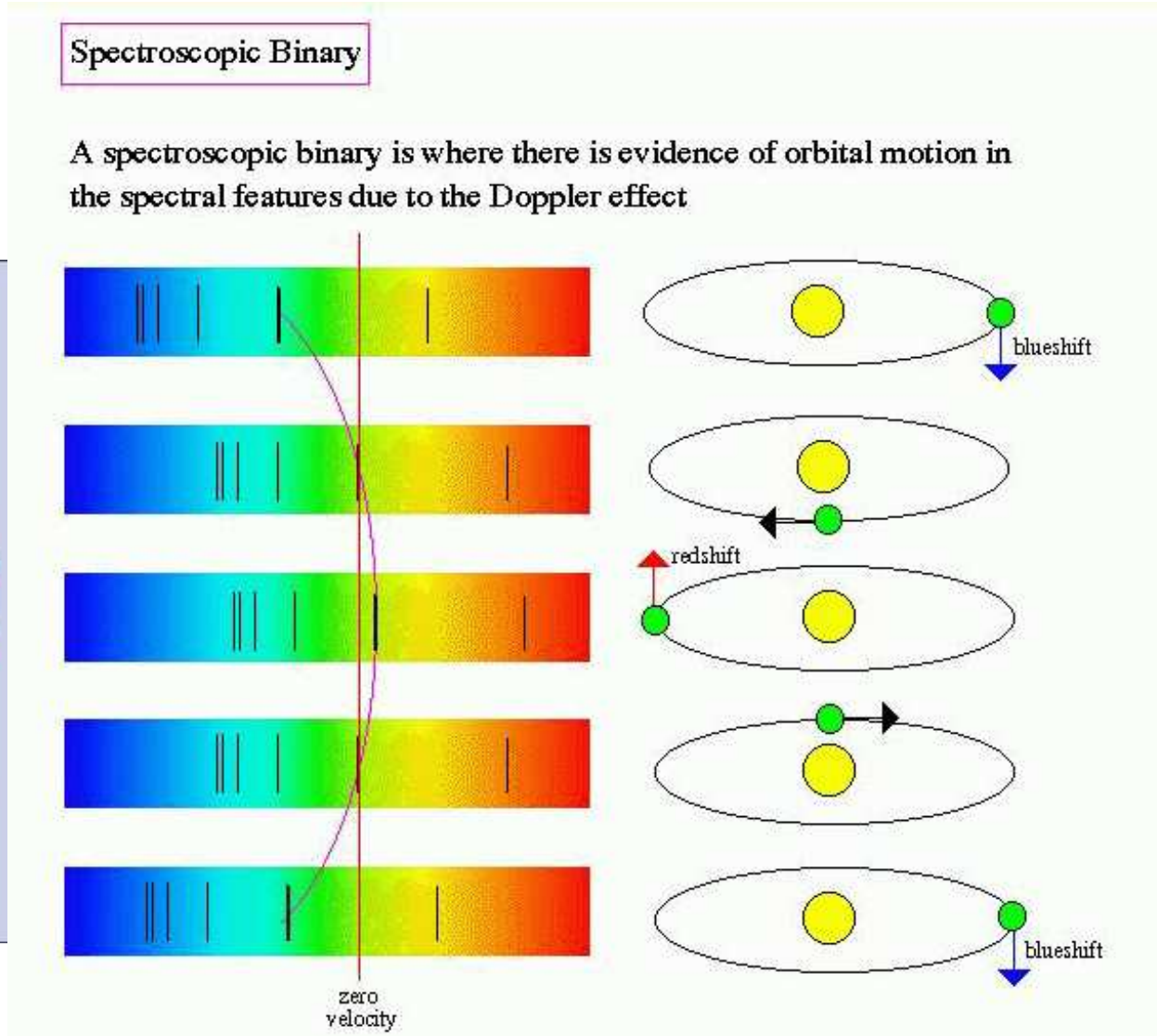
- If the source is moving towards (away from) you, you observe a blue- red-shift.
- Song to explain it all: www.astrocappella.com/doppler.shtml



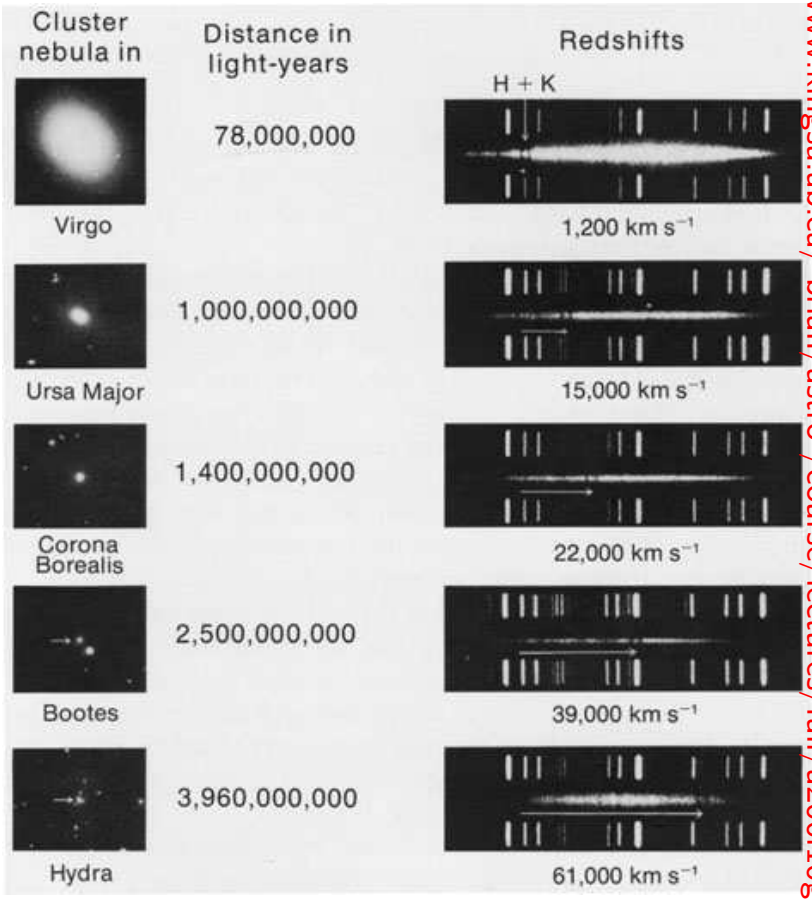


Doppler Effect in a Binary



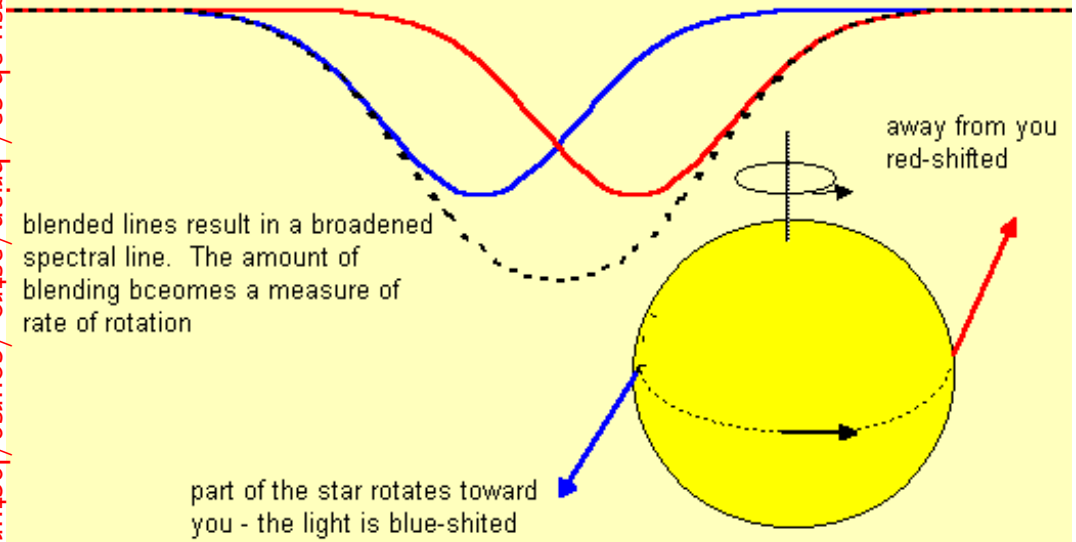


Doppler Effect Applications



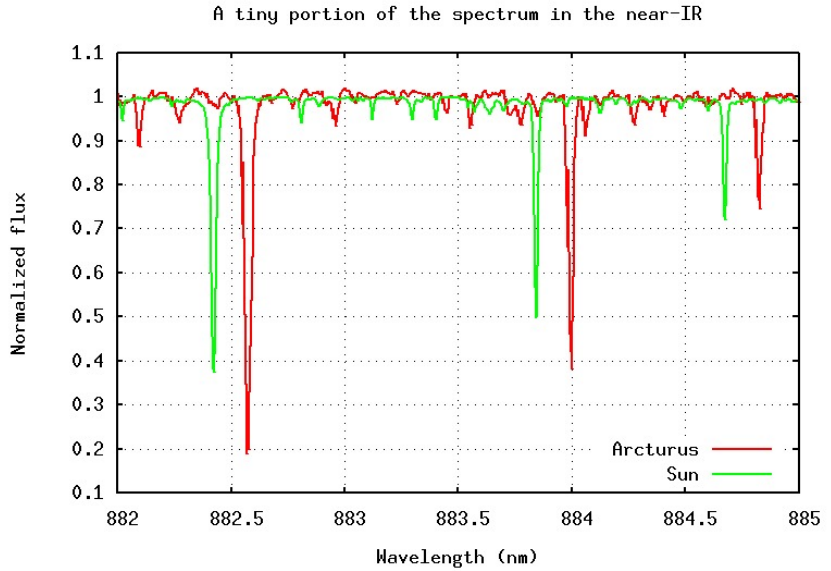
www.kingsu.ab.ca/~brian/astro_course/lectures/fall/a200l10g.htm

Rotational Broadening: a way of measuring stellar rotation



For an interesting demo about the Doppler effect in binary stars, see

instruct1.cit.cornell.edu/courses/astro101/java/binary/binary.htm



- $L_\odot = 4 \cdot 10^{33}$ erg/s
- Yellow color means that the peak wavelength of the Sun's spectrum is $\lambda_{max} \simeq 5 \cdot 10^{-5}$ cm
- Use Wien's Law to find the Sun's surface temperature: $T_\odot = 0.29\ \mathrm{cm}/\lambda_{max} \simeq 6000$ K
- Invert the blackbody luminosity formula to derive the solar radius: $R_\odot = \sqrt{\frac{L_\odot}{4\pi\sigma T_\odot^4}} = 7 \cdot 10^{10}$ cm

General Properties of Stars

- Masses: from 0.1 $M_\odot$ to 100 $M_\odot$
- Luminosities: from 0.0001 $L_\odot$ to 10^6 $L_\odot$
- Radii: from 0.1 $R_\odot$ to 1400 $R_\odot$
- Surface Temperatures: from 2000 K (infrared) to 40,000 K (ultraviolet)
- However, properties of white dwarfs and neutron stars can be more extreme.

Properties and Types of Stars

The main physical properties of stars are their luminosity L, surface temperature T, radius R and mass M. E. Hertzsprung and H. Russel discovered that plotting L vs. T was a useful way to discriminate types of stars.

www.daviddarling.info/encyclopedia/H/HRdiag.html