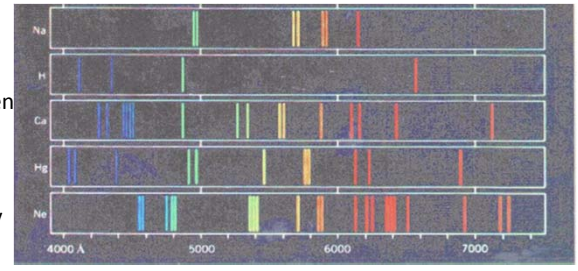
Measuring Motion, Doppler Effect—25 Oct

- Review Doppler effect
  - Doppler effect is the primary method for measuring speed of astronomical objects.
- Pickering's spectra of Mizar
  - What did Pickering discover?
- Modern cosmology begins in the "Realm of Nebulae" (galaxies)
  - Modern cosmology starts on Wed with Hubble's Law
- Homework 6
  - Due Mon, Nov 1.
  - If you downloaded from angel, check that the date is 2010, not 2009.
- Astronomical Horizons
  - Thurs, October 28, 7:30, Abrams Planetarium
  - Mars Meteorites: Rock Messengers from the Red Planet
  - Prof. Michael Velbel

An element's fingerprint

- Spectral lines are an element's finger print. (5.4 in textbook)
- Eg, in the visible part of the spectrum, hydrogen emits and absorbs light at 656.2, 486.1, 434.0, 410.1nm.

Sodium
Hydrogen
Calcium
Mercury
Neon



Emission spectra of hot gasses

Doppler effect: Summary

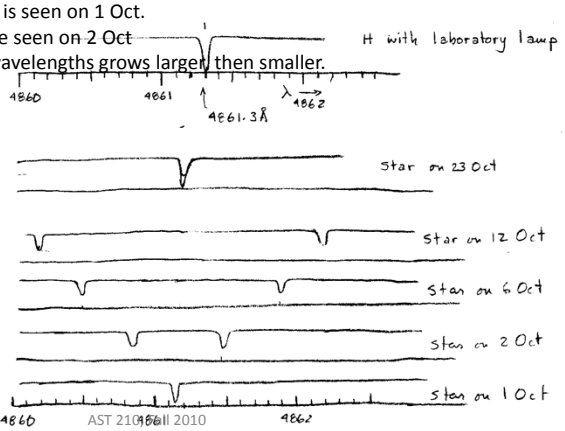
- Doppler effect: Motion is encoded in the wavelength of light
  - Observe wavelength $\lambda_{observed}$ of a spectral line from a star.
  - Measure wavelength λ_{rest} of same line in the lab, where the source is not moving.

    $\lambda_{observed} / \lambda_{rest} = 1 + v/c$
  - v is speed, positive if star is moving away from us.
  - c is speed of light.
- If motion is perpendicular to the line of sight, there is no change in wavelength.
  - In the formula, v is the component of the velocity towards or away from the observer.

1. Is it possible for a star to be moving and not show a Doppler shift? ___, and this is an example.
   A. Yes
   B. No

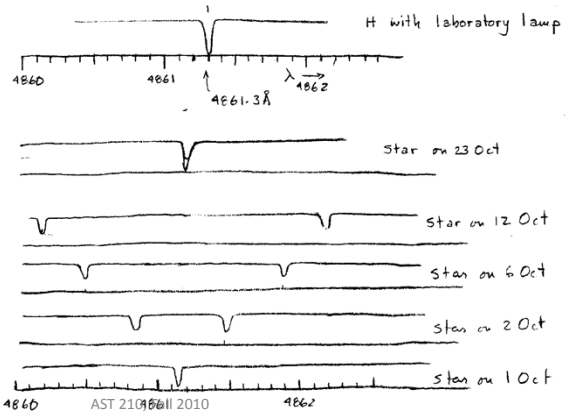
Pickering's discovery

- We are interpreting E. C. Pickering's spectra of Mizar (a star in the Big Dipper) in 1889.
  - Spectra showing the Hβ line of hydrogen.
  - These are *absorption* spectra: The amount of light is high except at wavelengths where hydrogen absorbs.
- Describe the changes in the spectra. (Spectra repeat.)
  - A single wavelength is seen on 1 Oct.
  - Two wavelengths are seen on 2 Oct
  - Separation of two wavelengths grows larger then smaller.



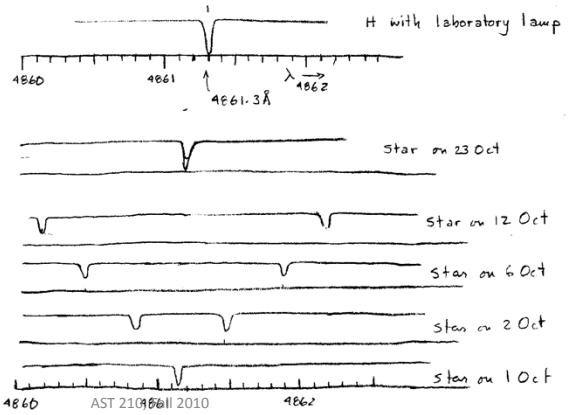
Pickering's discovery

1. How can the spectral line of hydrogen appear at different wavelengths?
   A. The star is moving.
   B. Hydrogen emits at different wavelengths at different times.
   C. There was something wrong with Pickering's spectrometer.
   D. Some other reason.



Pickering's discovery

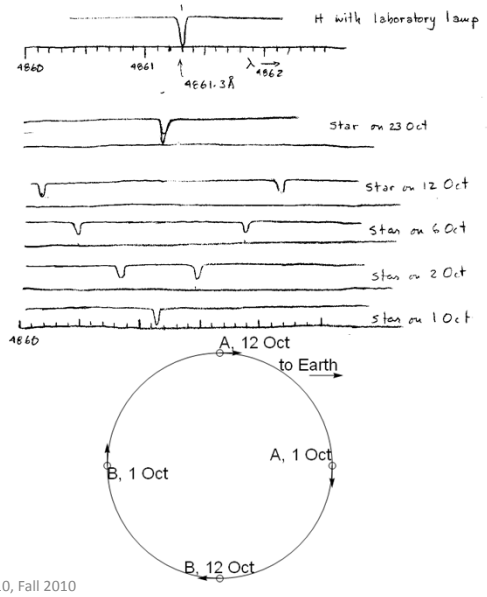
1. Devise a model for Mizar that explains the data. How can a star move at two speeds?



Pickering's discovery

- Provisional model: Two stars are in orbit. Test against evidence.

1. How can the two stars move so as to show the same wavelength, for example, as on Oct 1? (If possible, you want explanations that do no depend on special accidents.)
   A. The stars move in the same direction at the same speed on Oct 1.
   B. The Doppler effect is insensitive to the orbital motion on Oct 1.
   C. One star hides the other on Oct 1.

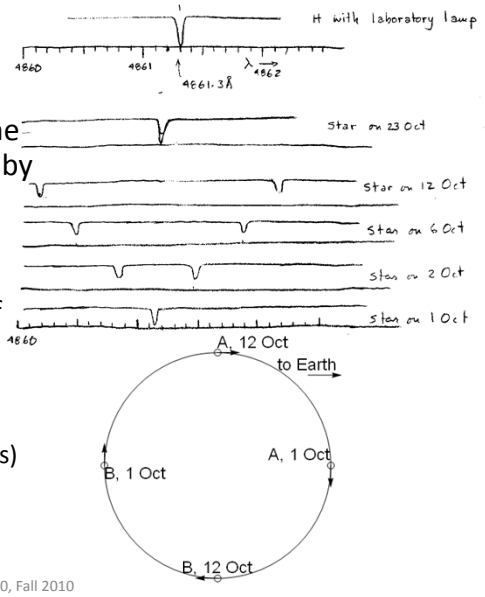


Pickering's discovery

- Provisional model: Two stars are in orbit. Test against evidence.

1. What is the wavelength of the Hβ line of hydrogen emitted by star A on 12 Oct?
   A. 4860.18Å.
   B. 4862.17Å.
2. What is the relative speed of stars A & B on 12 Oct? Hint: only one has the right units.
   A. (1.99Å)/(4861Å)
   B. (1.99Å)/(4861Å)×(300,000km/s)
   C. (1.99Å) × (300,000km/s)

- Relative speed is 120km/s.



Pickering's discovery

1. What evidence tells you whether the binary star system is moving toward or away from us?
2. What is v/c, where v is the velocity of the binary star system?
   A. $-0.17 / 4861.13 = -3.5\times10^{-5}$
   B. $-0.17 / 4861.3 = -3.5\times10^{-5}$.
   C. $4861.13 - 4861.3 = -0.17$
   D. $4861.3 - 4861.13 = 0.17$
   E. $0.17 / 4861.3 = 3.5\times10^{-5}$

- Pickering discovered the first binary star where the evidence was in the spectra, called a "spectroscopic binary star."