

Measuring Motion, Doppler Effect—26 Oct

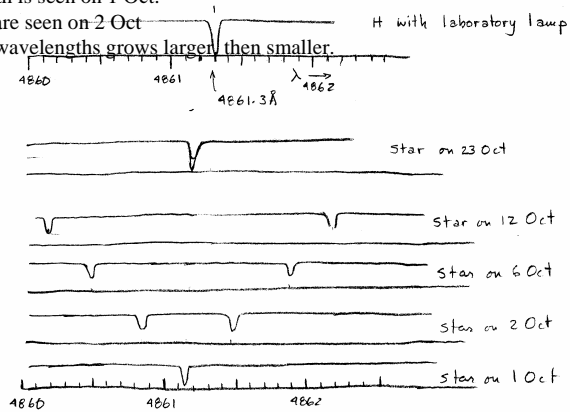
- Doppler Effect
- Pickering's spectra of Mizar
- What did Pickering discover?
- Doppler effect is the primary method for measuring speed of astronomical objects.
 - Later we will weigh galaxies using K's 3rd law
$$v^2=(P/R)^2=R/M$$
- Homework 6
 - Due Mon, Nov 2.
 - Missouri Club on Fri
- Modern cosmology starts on Wed with Hubble's Law
- Hubble used Slipher's measurement of the speed of galaxies moving away from us. (Doppler effect.)

Doppler effect: Summary

- Spectral line (6.4 in textbook)
 - Spectral lines are an element's finger print.
 - Eg, in the visible part of the spectrum, hydrogen emits and absorbs light at 656.2, 486.1, 434.0, 410.1nm.
- Doppler effect: Motion is encoded in the wavelength of light
 - Observe wavelength $\lambda_{\text{observed}}$ of a spectral line from a star.
 - Measure wavelength λ_{rest} of same line in the lab, where the source is not moving.
$$\lambda_{\text{observed}} / \lambda_{\text{rest}} = 1 + v/c$$
 - v is speed, positive if star is moving toward 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.

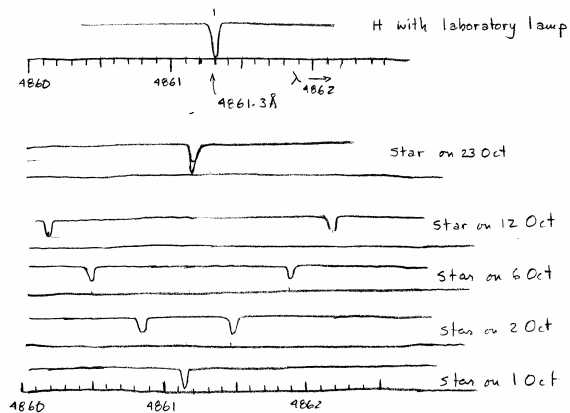
Pickering's discovery

- We are interpreting E. C. Pickering's spectra of Mizar (a star in the Big Dipper) in 1889.
 - Spectra showing the H β 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.



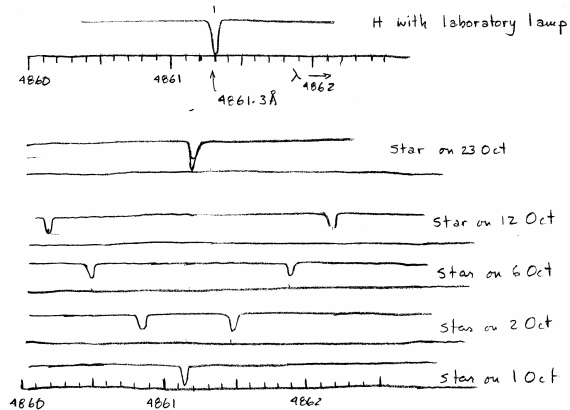
Pickering's discovery

- How can the spectral line of hydrogen appear at different wavelengths?
 - The star is moving.
 - Hydrogen emits at different wavelengths at different times.
 - There was something wrong with Pickering's spectrometer.



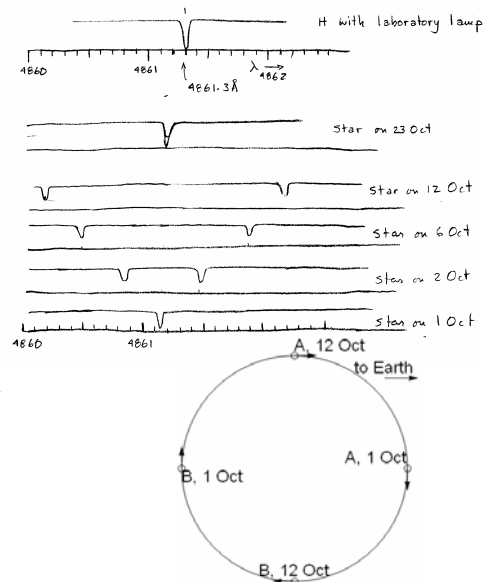
Pickering's discovery

1. Devise a model for Mizar that explains the data. How can a star move at two speeds? (5 min)



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 not 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.

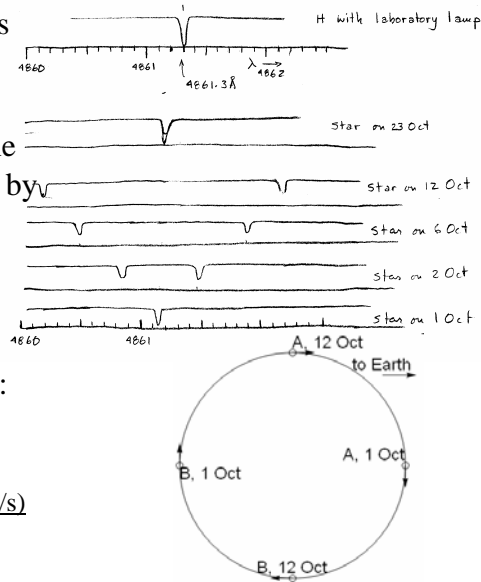
- What is the wavelength of the H β line of hydrogen emitted by star A on 12 Oct?

- 4860.18Å.
- 4862.17Å.

- What is the relative speed of stars A & B on 12 Oct? Hint: only one has the right units.

- $(1.99\text{Å}) / (4861\text{Å})$
- $(1.99\text{Å}) / (4861\text{Å}) \times (300,000\text{km/s})$
- $(1.99\text{Å}) \times (300,000\text{km/s})$

- Relative speed is 120km/s.



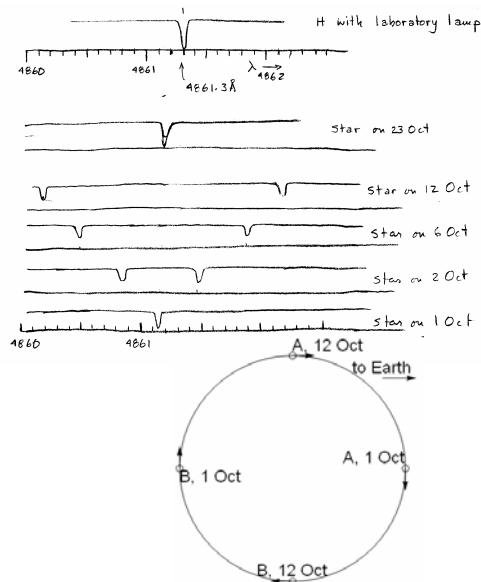
Pickering's discovery

- What evidence tells you whether the binary star system is moving toward or away from us?

- What is v/c , where v is the velocity of the binary star system?

- $-0.17 / 4861.13 = -3.5 \times 10^{-5}$.
- $-0.17 / 4861.3 = -3.5 \times 10^{-5}$.
- $4861.13 - 4861.3 = -0.17$
- $4861.3 - 4861.13 = 0.17$
- $0.17 / 4861.3 = 3.5 \times 10^{-5}$

- Pickering discovered the first binary star where the evidence was in the spectra.



Size of stars

- Thanks to Jayne Harper
- <http://www.youtube.com/watch?v=HEeh1BH34Q&feature=related>