Today

- What can we measure in other stars?
- How do we begin to classify other stars?
- Why O, B, A … such a nutty scheme!
- Why temperature and spectral lines are closely linked in classifying stars O B A M
- Stars on “Hertzsprung–Russell” (or H-R) diagram
- Re-read Chap 15, ‘Surveying the Stars’
- Review tonight for Mid-Term Exam 1 on Mon
- Class meets in Planetarium on Tues: “Journey to the Stars”

Now onward to measuring other stars: Chap 15 – SURVEYING THE STARS

- Measuring stellar luminosities
- Measuring distances
- Measuring temperatures
Often only seeing a point of light

- Stars are so small compared to their distance that we almost never have the resolution to see their sizes and details directly – “point sources”
- We deduce everything by measuring the amount of light (brightness) at different wavelengths (color, spectra)

Most Basic Problem in Astronomy

Star of given APPARENT BRIGHTNESS could be either
- A. very luminous star far away
- B. low luminosity star closer by

Need to know the DISTANCE to the star

Clicker – Dimming with distance?

- If you quadruple (x4) your distance to a light and look again, how much dimmer does it appear?
  - A. one-half as bright as originally
  - B. one-fourth as bright
  - C. one-eighth as bright
  - D. one-sixteenth as bright
  - E. unchanged, since really same light

Stellar Luminosity

- What we measure: APPARENT BRIGHTNESS
  or how bright it appears to us here on Earth
- What we want to know: (absolute) LUMINOSITY
  or how much energy is emitted (joules/sec or watts)
- Need to know DISTANCE to the star
**Parallax – to determine distance**

- Measure the apparent movement of stars over a year
- Movement is caused by Earth’s movement around the Sun
- Closer objects will move more than farther objects

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**How Stellar Parallax Works**

Movement is caused by Earth’s movement around the Sun. Closer objects will move more than farther objects.

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**Class self-demo of parallax**

- Your nose is the Sun
- Your left eye is the Earth in January
- Your right eye is the Earth in June

Watch the apparent motion of your thumb against a distant reference point (repeat at arm’s length)

Which “move” more -- closer or farther objects?

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**Best parallax measurer: Hipparcos satellite 1989-1993**

- Space measurements not affected by atmosphere
- Measurement made many times until accurate to 0.001 arcsec (~3300 light years)
- 100,000 stars mapped
- (2.5 million to slightly lesser accuracy)

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**Summary Clicker -- Solar Wind E.**

- What are visible effects of the Earth being “bathed” in the wind of solar particles, especially when wind has strong hiccup?
- A. “Auroral lights” visible at night
- B. Electric power grids have problems
- C. Short-wave radio talk interrupted
- D. Satellites (and beepers) may get fried
- E. All of the above
Measuring Surface TEMPERATURE

Shape of spectrum good … but spectral lines much better

Spectra help classify stars

OBAFGKM ?!

• Spectral (color) classification
  
O = bluest, hottest
G = yellow (Sun)
M = reddest, coolest

A bit of history: Classifying Stars

World War I, Harvard College observatory

Women were hired by Pickering as "calculators" to help with a new survey of the Milky Way

Most had studied astronomy, but were not allowed to work as scientists

Devising the strange temperature code

• Original classification of spectra (1890) was:
  
A = strongest hydrogen feature
B = less strong hydrogen …C, D, etc.

• Annie Jump Cannon realized that a different sequence made more sense (~1910)

Which absorption (dark) lines are strongest?
Spectral Classification: O B A F G K M

- Which ABSORPTION lines are strongest
- Hottest stars: O B
  - ionized helium only
- Hot stars: A F
  - helium, hydrogen
- Cooler stars: G
  - hydrogen, heavier atoms
- Coolest stars: M
  - molecules, (complex absorption bands)

Stars and their spectral classification

<table>
<thead>
<tr>
<th>Star</th>
<th>Temperature</th>
<th>Surface Temperature</th>
<th>Distance</th>
<th>Luminosity</th>
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<tr>
<td>Alpha</td>
<td>30,000 K</td>
<td>10,000 K</td>
<td>100 pc</td>
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<tr>
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<tr>
<td>Gamma</td>
<td>5,000 K</td>
<td>3,000 K</td>
<td>1 pc</td>
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</tbody>
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Electric and magnetic fields

Demonstration of TESLA COIL and wild happenings
AIR NEARBY becomes IONIZED forming PLASMA CHANNELS

Brightness / Distance

- Leonardo and Guinevere are two stars that have the same apparent brightness. Leonardo has a larger parallax angle than Guinevere. Which star is more luminous?
  - A. Leonardo
  - B. Guinevere
  - C. Cannot determine from data given

Cecelia figured out WHY stellar spectra are so different: TEMPERATURE

- She showed that SURFACE TEMPERATURE is the big factor (not composition)
- She used the newly-devised SAHA EQUATION, estimating how many electrons remain attached to atoms as temperature is changed (or the level of ionization)

Cecelia Payne-Gaposchkin (Harvard PhD thesis 1925)

O B A F G K M → decreasing temperature
Spectral Classification: O B A F G K M

Hottest stars: ionized helium only
Hot stars: helium, hydrogen
Cooler stars: hydrogen, heavier atoms
Coolest stars: molecules, (complex absorption bands)

Why temperature and spectral lines are linked?

SAHA gives the answer:

- can estimate "population of different energy levels" in H, He...
- and ionization

SAHA predicts spectral line strengths with temperature