Today +

- Effects of solar wind and activity
- What can we measure in other stars?
- How do we begin to classify other stars? Why O, B, A … such a nutty scheme!
- Read in detail Chap 16: Properties of Stars

- Review Session given tonight by Ben Brown, down hall in Duane E126, 7pm-9pm (enter via this hallway) [no new Homework this week]
- Review Sheet still available for Mid-Term Exam 1 in recitation this Mon 20 Feb

Clicker – Energy is how “old” ?

- Light radiated from Sun’s surface reaches us in about 8 minutes, but the energy of that light was released by fusion in the solar core about …
  - A. one year ago
  - B. ten years ago
  - C. a hundred years ago
  - D. a thousand years ago
  - E. a million years ago

Discussion

What are effects of solar activity on our technological society?
Now onward to measuring other stars:

Chap 16 – PROPERTIES OF STARS

- Measuring stellar luminosities
- Measuring distances
- Measuring temperatures

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

Inverse Square Law of Brightness

Apparent Brightness

\[ \approx \frac{L_0}{(\text{distance})^2} \]

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)

So what can we find out about other stars?

- APPARENT BRIGHTNESS
- POSITION
- SPECTRUM

What can we measure in other stars?

1. APPARENT BRIGHTNESS (or intensity)
   Measured as Point Source, $I_{\text{point source}}$
   \[ I_{\text{point source}} \approx \frac{\text{Luminosity}}{4 \pi R^2} \]
   \[ = \frac{1}{(4 \pi)^2} \times L_{\text{point source}} \]
   \[ = \frac{1}{(4 \pi)^2} \times \text{Luminosity} \]

2. POSITIONS (angular size of object)
   - Parallax => distance
   - Proper motion

3. SPECTRUM (number of photons per wavelength)
   - Temperature of object
   - Composition (which elements can we find)
   - Doppler shift in case of: relative velocity rotation
   - Redshift, evidence of waves propagating faster
Clicker – Dimming with distance?

- If you quadruple (x4) your distance to a light and look again, how much dimmer does it appear? **D.**
  - A. one-half as bright as originally
  - B. one-fourth as bright
  - C. one-eight 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 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

Stellar Parallax: measuring nearby distances

How Stellar Parallax Works

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?
Best parallax measurer:
Hipparchos 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)

Reading 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)

→ O B A F G K M !!

Which absorption (dark) lines are strongest?

Spectral Classification: O B A F G K M

- 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

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

B.

Brightness / Distance

- Leonardo has a larger parallax angle — thus he is closer to us
- They both have the same APPARENT brightness, but Leo is closer
- B. Guinevere must be more luminous
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)

**H – R Diagram**

- **Luminosity** (solar units)
- **Temperature**

- **10^6**
- **40,000 → 3,000**