Astronomy 150:
Killer Skies

<u>This Class (Lecture 13):</u>
Why is the Sun Yellow?

<u>Next Class:</u>
Classifying Stars

HW5 due tonight
Exam 1 is Friday!

Music: *Here Comes the Sun*– The Beatles

Exam 1

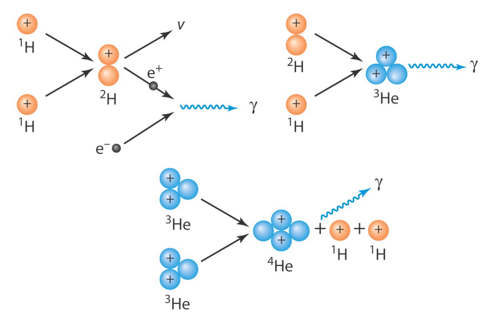
- Exam 1 in this classroom Friday (Oct 1st)
- 40 Multiple choice questions
- Will cover material up to and including last Friday.
- May bring 1 sheet of paper with notes
  - Both sides
  - Printed/handwritten/whatever.. I don't really care
- Major resources are lecture notes and homeworks
- Try to understand major points more than anything.
- Have created and posted a study guide

Outline

- Neutrinos mean nuclear reactions.
- The star's temperature defines its color.
- Taking the Star's physical so we can compare them to our Sun
- Distance

Nuclear Fusion in the Sun's Interior

- Proton-proton in stars like the Sun
  - Hydrogen fused to make helium
  - 0.7% of mass converted to energy

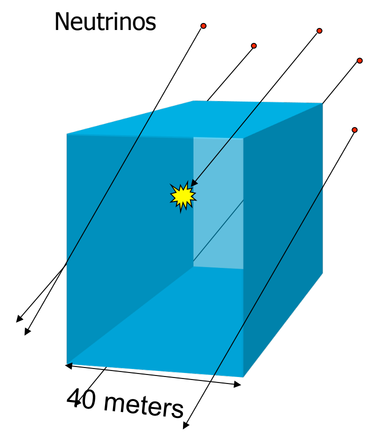


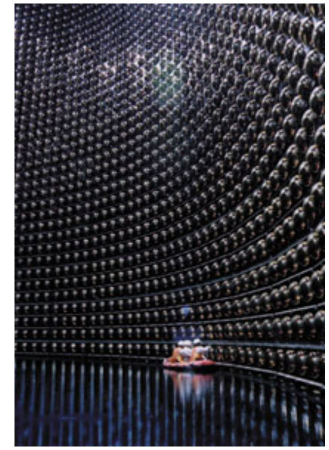
The Proton-Proton Cycle Makes Neutrinos

Sneaky Little Neutrinos

- If we could detect them, we would prove that the Sun is a thermonuclear reactor.
- Matter is almost transparent to neutrinos
- On average, it would take a block of lead over a quarter of a light-year long to stop one
- Roughly 1 billion pass through every square centimeter of you every second!

Detecting Neutrinos

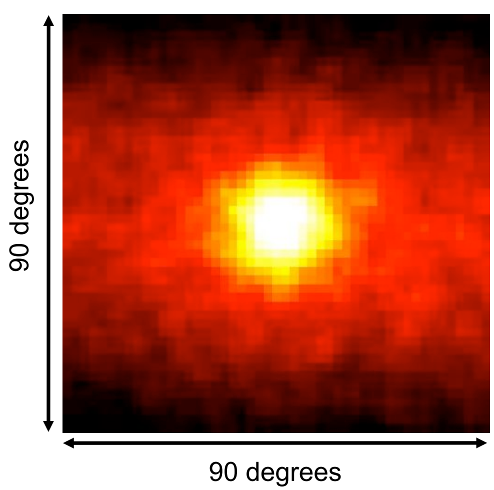




Super Kamiokande, Japan
50,000 tons of water & 11000 PMTs

The Sun in Neutrinos

- **Confirmation** that nuclear fusion is happening in the Sun's core
- 500 days of data
- As they can only be produced by nuclear processes, our energy source concept must be fundamental
- Proves nuclear burning!



Cosmic Gall

very little
hardly

NEUTRINOS, they are very small.
They have no charge and have no mass
And do not interact at all.
The earth is just a silly ball
To them, through which they simply pass,
Like dustmaids down a drafty hall
Or photons through a sheet of glass.
They snub the most exquisite gas,
Ignore the most substantial wall,
Cold shoulder steel and sounding brass,
Insult the stallion in his stall,
And scorning barriers of class,
Infiltrate you and me! Like tall
and painless guillotines, they fall
Down through our heads into the grass.
At night, they enter at Nepal
and pierce the lover and his lass
From underneath the bed-you call
It wonderful; I call it crass.

Telephone Poles and Other Poems, John Updike, Knopf, 1960

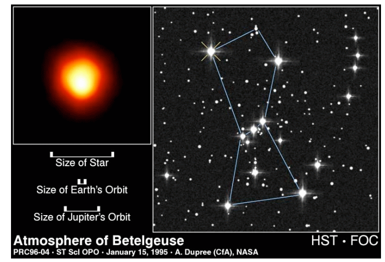
Question

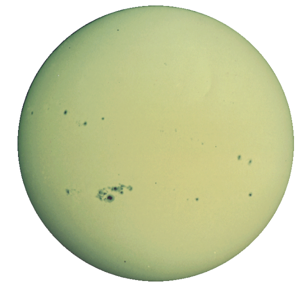
If we could sustain fusion in the lab we could meet humankind’s energy needs forever! Why is it so difficult to achieve this, when stars do it every day?

a) Need a lot of hydrogen, more than we can find on Earth.
b) Need freaky high temperature and pressure, which is hard to do on Earth, to overcome the natural repulsion of protons,
c) Need exotic mass particles, neutrinos, to glue the protons together, which don’t exist on Earth.
d) Need a really hot cup of really good tea, and that is hard to do.

Stars as Suns

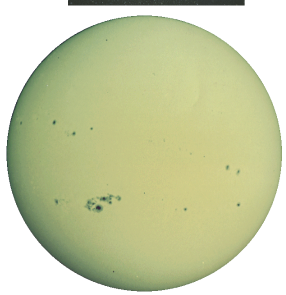
- The Sun is a nuclear reactor, but I'm saying much more than that: Sun is a typical star
- So all stars are run by thermonuclear fusion
- Night sky, Universe lit up ultimately by dense nuclear furnaces scattered everywhere
- How do we know Sun is typical?





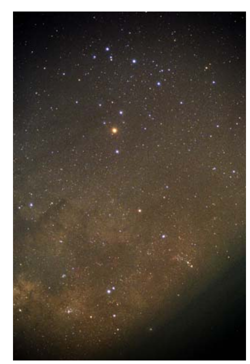
Why is the Sun Yellow-ish?

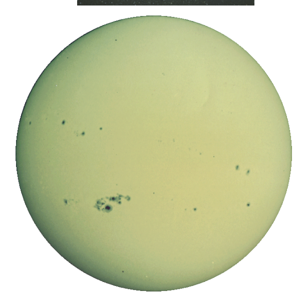
- If you look at the stars, you may notice that the stars have different colors.
- Blue, red, yellow.. etc..
- Why?



Why is the Sun Yellow-ish?

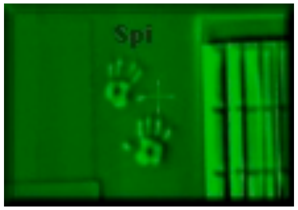
- They are all powered by nuclear fusion, so why so different?





Glowing Bodies

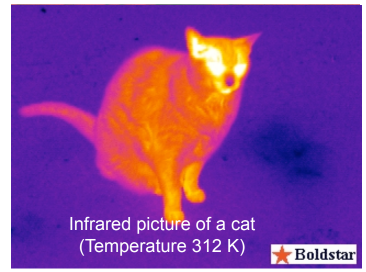
- Everything we know is in fact giving off light– as long as it has a temperature (T > 0 K), it is glowing.
- The higher the temperature the shorter the wavelength it glows in– compare the person on the right (in the near infrared) and a light bulb (in the visible).



http://www.x20.org/thermal/thermal_weapon_sight_TIWS320.htm

Blackbody Radiation

- Light that objects emit because of their temperature is called **blackbody radiation**
- Blackbody radiation is composed of a continuous spectrum of wavelengths
- The **hotter** an object gets, the **more intense** and **shorter wavelength** (blue-er) its blackbody radiation becomes



Infrared picture of a cat
(Temperature 312 K)

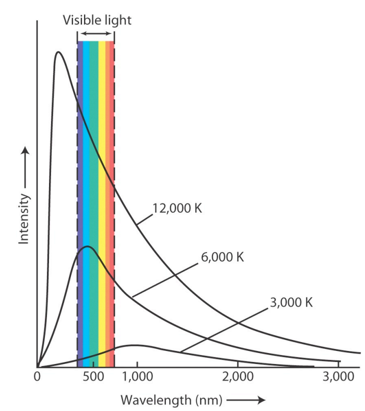
Visible-light picture of a stove element
(Temperature ~ 400 K)

Define Blackbody

- A body that re-emits radiation according to its temperature
- Therefore, “blackbody radiation" = thermal radiation
- Usually, most familiar objects are well approximated as blackbody radiators
- A clear exception is a laser pointer.
  - Why?
- The spectrum of this ideal, only depends on its temperature!

The Spectrum of Blackbody Radiation

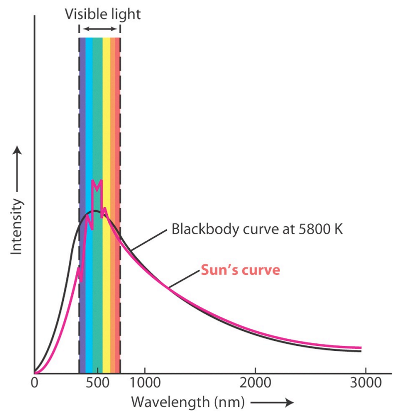
- For higher temperature objects the maximum occurs at shorter wavelengths.
- For lower temperature objects the maximum occurs at longer wavelengths.



The Spectrum of Blackbody Radiation

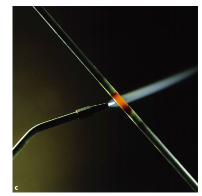
The Sun's spectrum looks almost like a 5800 K blackbody.

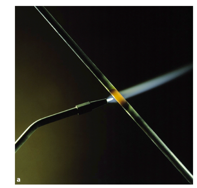
Color ⇔ Temperature!

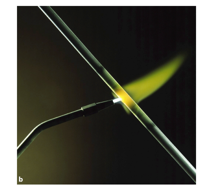


Red Hot?

- Actually Red hot is not too hot.
- Blue hot is hot.
- White hot is even hotter.







Common Error?

Think

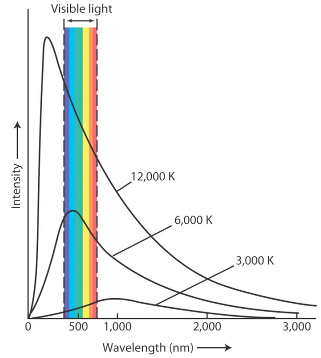
Which star is hotter?

a) Vega (blue)
b) Capella (yellow)
c) Antares (red)
d) Whatsit (striped)
e) Bang (polka-dots)

Note: It doesn't matter how far away the star is!

Blackbody Flux-ed

- Flux is the energy flow, or how rapidly energy flows out of the blackbody.
- The total flux from a blackbody is found by adding up the intensity in the spectrum.
- Do you think it depends on temperature?

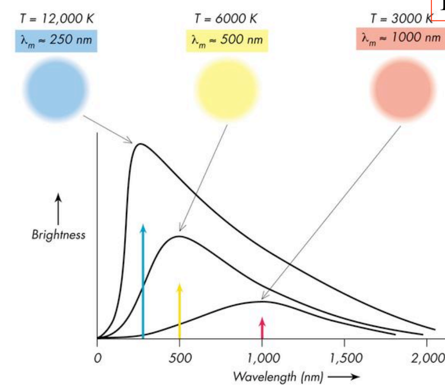


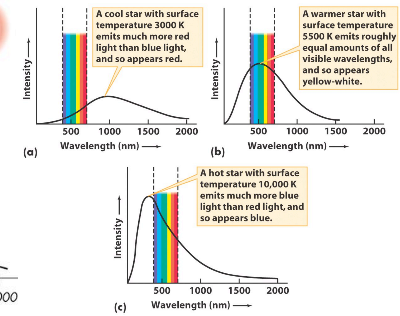
a) Yes
b) No

Stellar Colors

- Higher temperature → brighter, bluer
- Lower temperature → dimmer, redder

Brightness assumes same radius





Color me..

White hot Sirius to a red supergiant Betelgeuse

Still Why Different Colors

So, stars have different colors, thus temperatures.

Why different temperatures?

Stay tuned….

What about the brightness of stars?

Which is Brighter?

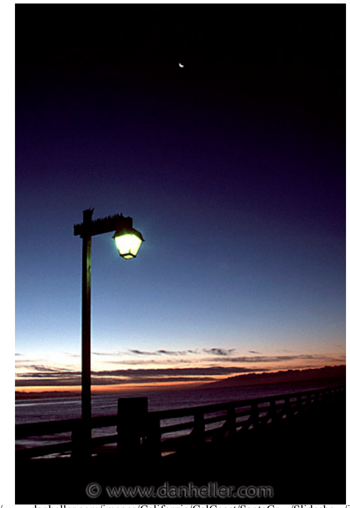
a) Moon
b) Streetlamp

- Why?
- *Apparent brightness* and *luminosity* difference.

http://www.danheller.com/images/California/CalCoast/SantaCruz/Slideshow/img13.html

Which is Brighter?

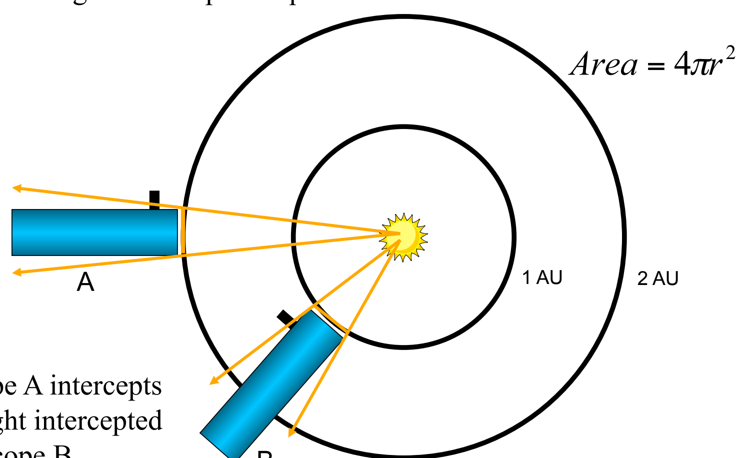
- Apparent brightness (flux) will depend on distance, but…
- Luminosity measures how much energy object emits per second, which is independent on distance.



http://www.danheller.com/images/California/CalCoast/SantaCruz/Slideshow/img13.html

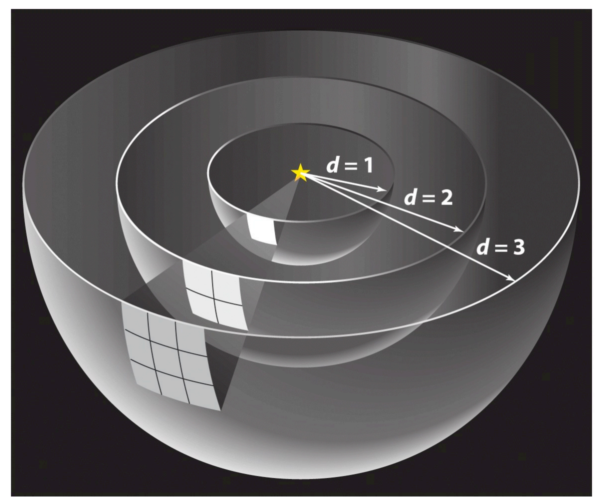
Why do more distant objects look so much fainter?

- More distant stars of a given luminosity appear dimmer
- Apparent brightness drops as square of distance



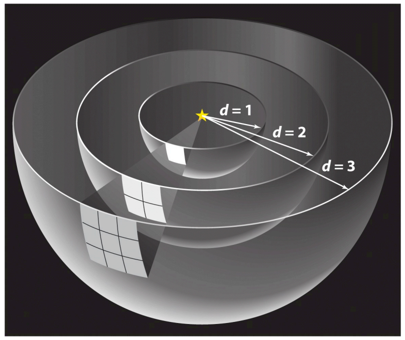
Telescope A intercepts ¼ the light intercepted by telescope B

Same number of Photons, but more area.



Luminosity

- Apparent brightness ≠ luminosity!
- Apparent brightness depends on distance away.
- The farther, the dimmer.
- That's why it's called apparent brightness.



Luminosity and Size

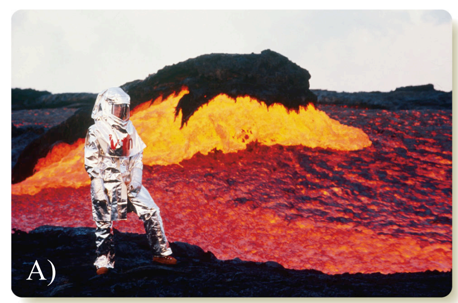
$$L \propto 4\pi R^2 T^4$$

A star's intrinsic brightness (luminosity) depends on its temperature and its size.

A small hot star can be less bright than a huge cool star.

In Hawaii

Energy, Temperature, and Surface Area



Which has more energy output?

Maybe not in All Galaxies?

http://img.photobucket.com/albums/v480/punkboi/Parno2/lava_surfers.jpg

Compare to Other Stars

- We can’t wait for our Sun to die to get an accurate measure of what it’ll go through, so we have to look at other stars.
- How does our color (temperature), output Luminosity (Energy) compare to other stars?
- It’s hard to talk about the differences of stars, when they are so far away, and live astronomical time scales.
- We have to put them all on one diagram.
- We have to get physical.

Star’s Physical

- Please step on scale. Turn head. Cough.
- No, really. How to measure the properties of objects that are very, very far away?
- What properties would we like to know about the stars.

http://www.pemed.com/physof/scale.jpg

HR Diagram

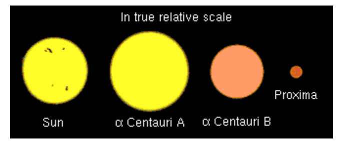
- To really explain the Sun’s evolution, I need to talk about the HR diagram.
- So, excuse me for a few (okay many) slides.
  - We need to know stellar luminosity (which means that we need to know their distances)
  - We need to know stellar temperature (can do better than blackbody color though).

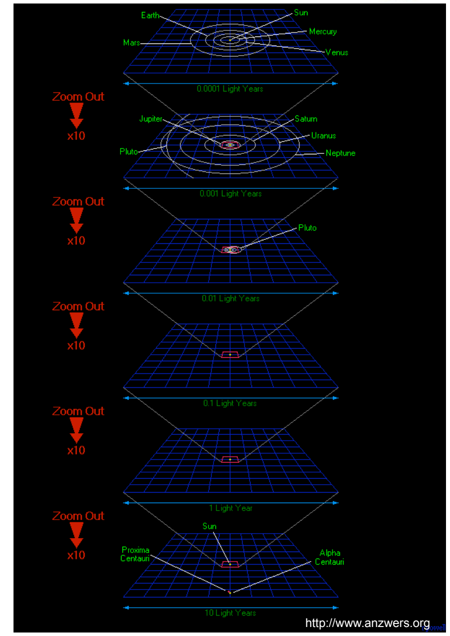
Distance

- We know that the stars must be very far away.
  - They don't move much as we orbit the Sun.
- But measuring the distance is a **hard** problem.
- We've only had the technology to do it for the last 200 yrs.

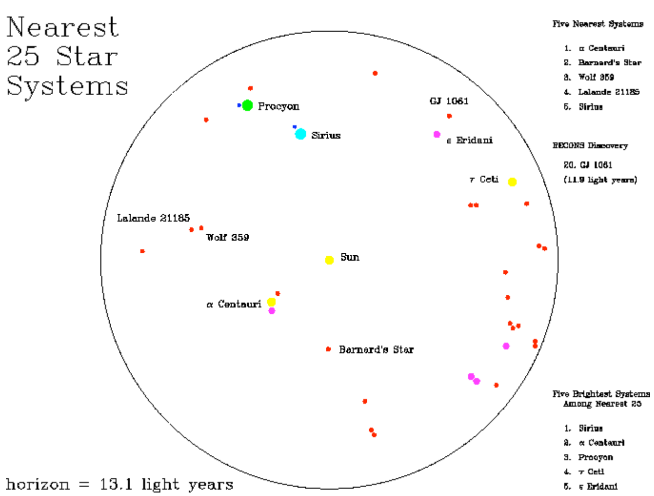
Leaving Home

- Nearest star is 4 x 10^{13} km away
  - Called Proxima Centauri
- Around 4 light years
- More than 5000 times the distance to Pluto
- Walking time: 1 billion years
- Fastest space probes: Voyagers 1 & 2, Pioneers 10 & 11) – 60,000 years at about 3.6 AU/year (38000 mi/hr)



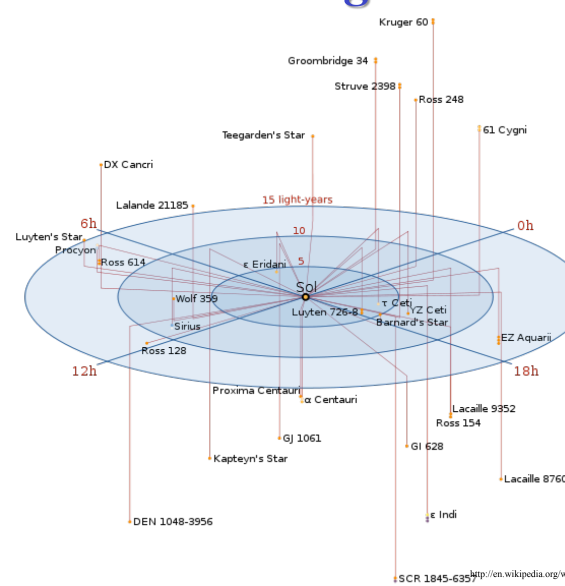


Our Nearest Neighbors



http://antwrp.gsfc.nasa.gov/apod/ap010318.html

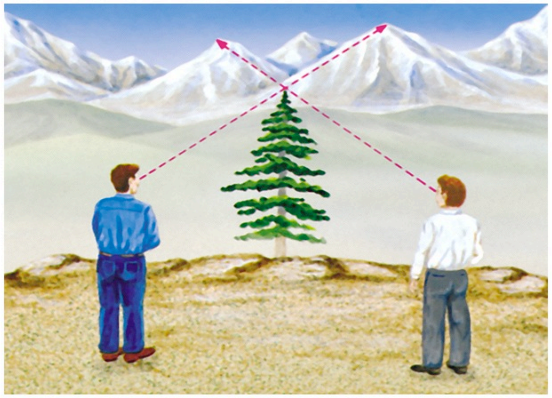
Our Nearest Neighbors: 15 lyrs



http://en.wikipedia.org/wiki/File:Nearby_Stars_(14ly_Radius).svg

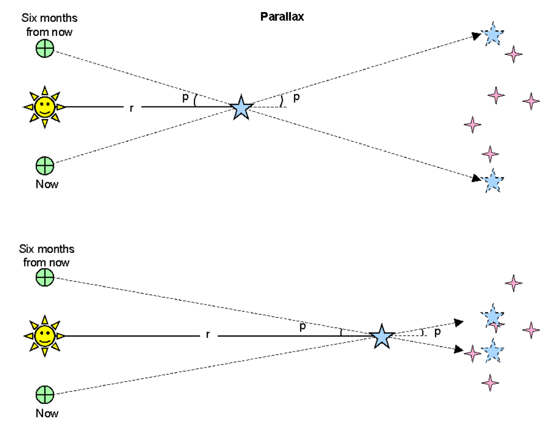
Parallax

How do astronomers measures distances to nearby stars?



How to Measure Parallax

- Look at a star compared to background stars– and wait 6 months.
- How much, if any, have the stars moved?
- That distance moved in arcseconds is called parallax.

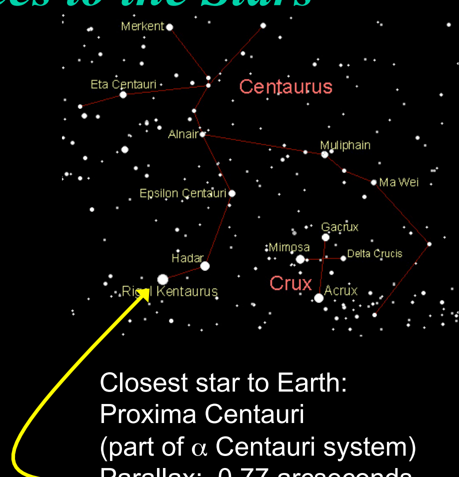


Distances to the Stars

Sun's disk seen from Earth

1/2 degree = 1800 arcsec

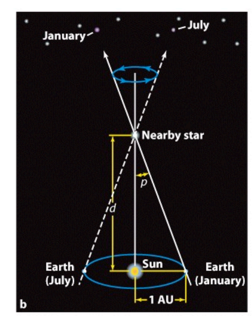
Dime at arm's length



Closest star to Earth:
Proxima Centauri
(part of α Centauri system)
Parallax: 0.77 arcseconds
Distance: 1.3 pc = 4.2 ly
like a dime 2 km away

Parallax Peril

- Drawback: measurable only for nearest stars
- Angular shift becomes tiny when star very far away
- Immeasurable when star is beyond few 100's of lyrs
- And Galaxy is 100,000 lyr across, Universe is 14 billion lyr
- What to do? ... stay tuned...



Question

Parallax can be used to measure the distance to

a) galaxies.
b) any star in the Universe.
c) only very nearby stars.
d) only far away stars.
e) the Big Bang.