Astro 210

Lecture 29

April 4, 2018

Announcements:

- **HW8 due online in PDF, Friday 5:00 pm**

ul **Solar Observing this week** April 2–5
Mon, Tue, Wed, Thurs. 11:00 am to 3:00 pm
Campus Observatory
allow 20-30 minutes. take **selfie** with telescope

- Night Observing: no clear last night so
substitute exercise posted on Moodle, due Friday 5:00 pm

Next semester (and beyond): Flex Your Astro Muscles

ASTR 210 prepares you for all upper level Astronomy courses!

Fall 2018

ASTR 330: Extraterrestrial Life

ASTR 350: The Big Bang, Black Holes,
and the End of the Universe

ASTR 404: Stellar Astrophysics

ASTR 406: Galaxies and the Universe

Spring 2019

ASTR 405: Planetary Systems

ASTR 414: Astronomical Techniques

Last Time: How the Sun Shines

Q: energy source for the Sun?

Q: how is the Sun an element factory?

Q: how do we know?

Q: Lessons from solar neutrino experiments?

Cosmic Gall

by John Updike

Telephone Poles and Other Poems

1963

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.

Cosmic Gall

by John Updike

Telephone Poles and Other Poems

1963 + 2018 Update!

Neutrinos, they are very small.
They have no charge and ~~have no~~ tiny mass
And ~~do not~~ hardly 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,
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The Stars as Suns

We've proved that that Sun is nuclear reactor
but (we'll see that) the Sun is a typical star
$\Rightarrow$ **all** stars run by thermonuclear fusion

The Night sky, the Universe lit up ultimately by nuclear power

STARS

iClicker Poll: Naked-Eye Stars

Vote your conscience!

On a clear night, outside of a city,
about how many stars can you see with the naked eye?

A More than the number of people in a packed movie theater

B More than the number of people at a UI football game

C More than the population of Illinois

∞

Stars: Brightness

to naked eye, in clear sky:
about 6000 (!) stars visible over celestial sphere
$\Rightarrow$ about 3000 at any one night
...but this is just the "tip of the iceberg"

directly measure **flux**
Q: for old time's sake, remind me–what is flux?

ex: Sun: $F_\odot = 1370$ W m^{-2}
Sirius ("dog star")

$$\frac{F_{\mathrm{Sirius}}}{F_\odot} = 7.6 \times 10^{-11}$$

tiny, but had to be–we know stars are much dimmer than Sun

iClicker Poll: Getting Sirius

flux comparison: Sirius vs the Sun

$F_{\text{Sirius}}/F_{\odot} = 7.6 \times 10^{-11}$

Does this mean that Sirius is less luminous than the Sun?

A yes

B no

C can't tell from this information alone

Luminosity

recall: apparent brightness $\neq$ luminosity!

- luminosity = power emitted from star: "wattage"
  units: energy/time, e.g., Watts
- flux = power per unit area (at some observer location)
  units: power/area, e.g., Watts/m^2

Apparent brightness and luminosity related by

$$\text{observer-dependent } F = \frac{L}{4\pi r^2} \frac{\text{observer-independent}}{\text{observer-dependent}} \quad (1)$$

inverse square law!
farther $\leftrightarrow$ dimmer
hence brightness is "apparent" – depends on observer
but L *is* intrinsic fundamental property of a star

Q: how measure star L?

To find $\star$ luminosities

1. Measure F
2. Measure d
3. solve: $L = 4\pi d^2 F$

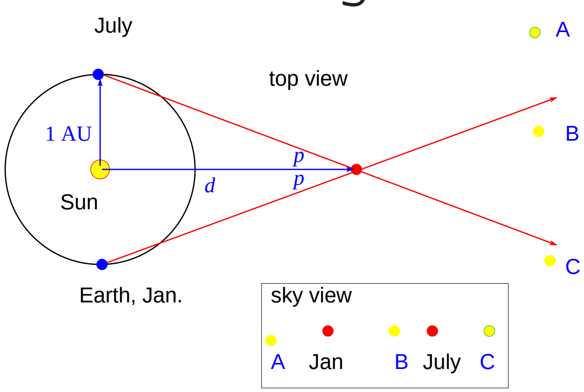
ergo: to compare wattage of stars, need **distances**!

Distances to Stars

a difficult, longstanding (ongoing!) problem
today many techniques exist
but technology good enough in last 2 centuries

Parallax – the "gold standard" of stellar distances
Demo: thumb's up–arm's length, halfway

as Earth orbits, our viewpoint shifts (slightly!)
$\longrightarrow$ nearby $\star$s appear to move w.r.t. background $\star$s
measure: angular shift p



Q: diagram is top view–what is sky view over 1 year?
Q: how are 1 AU, d, and angle p related?

Distances: Geometry and Units

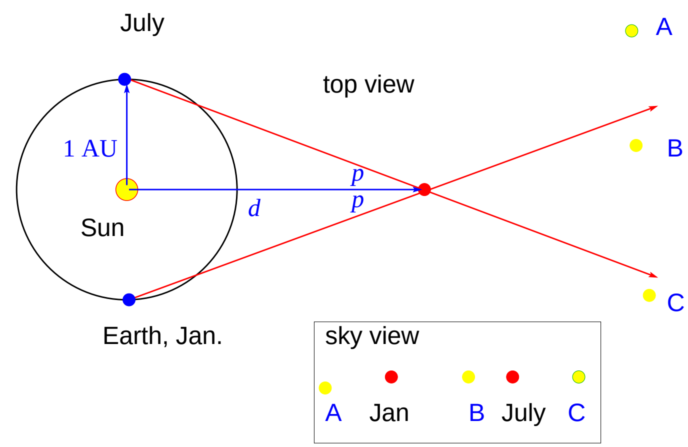
trig technology: $d \tan p = 1$ AU

$\Rightarrow$ distance $d = 1$ AU$/\tan p$

but p tiny! (≤ 1 arc sec $\sim 10^{-5}$ rad $\ll 1$)

$\rightarrow \tan p_{\text{rad}} \approx p_{\text{rad}}$, so

$d = 1$ AU$/p_{\text{rad}}$, or



$$d = \frac{1 \text{ pc}}{p_{\text{arcsec}}} \quad (2)$$

where p_{arcsec} is p in arc sec, and

$$1 \text{ pc} = 1 \text{ parsec} = 1 \text{ AU}/(1 \,\text{arcsec})_{\text{rad}} = 3.086 \times 10^{16} \text{ m}$$

parsec: distance to a star with $p = 1$ arcsec

occasionally use **light year** = distance light travels in 1 yr

1 lyr $= c \times 1$ yr $= 9.5 \times 10^{15}$ m

and so: 1 pc = 3.26 lyr

Distances: Observations

typical parallactic shift is tiny (if observable at all!)

all less than 1 arc**sec** $= \frac{1}{3600}$ deg $= 5 \times 10^{-6}$ radian!!

Sirius: $p = 0.366$ arcsec

$d = \frac{1}{0.366}$ pc $= 2.65$ pc $\simeq 5 \times 10^5$ AU

nearest stars to us: α Centauri triple (!) star system

αCen A & B, Proxima: $d(\alpha\text{Cen}) = 1.3$ pc $= 4$ lyr

note: even from nearest star, light takes 4 *years* to get here!

Lessons:

- 1 pc $\sim$ typical distance between neighboring stars in our Galaxy (and others) `www: 100 nearest stars`
- parallax p tiny at best
  $\rightarrow$ measureable only for nearest stars
  Q: what to do for more distant objects?

Star Brightness: Magnitudes

star brightness measured in **magnitude** scale
magnitude = "rank" : **smaller** $m \to$ **brighter**
Sorry.

Magnitudes use a logarithmic scale:

- difference of 5 mag is factor of 100 in flux:

$m_2 - m_1 = -2.5 \log_{10} F_2/F_1$ (definition of mag scale!)

- mag units: dimensionless! (but usually say "mag") because mags are *logs* of *ratio* o f two dimensionful fluxes with physical units like W/m^2

What is mag difference $m_2 - m_1$:
Q: if $F_2 = F_1$?
Q: what is sign of difference if $F_2 > F_1$?
Q: for equidistant light bulbs, $L_1 = 100$Watt, $L_2 = 50$Watt?

Apparent Magnitude

a measure of star flux = (apparent) brightness

- no distance needed
- arbitrary mag zero point set for convenience:
  historically: use bright star Vega: $m(\text{Vega}) \equiv 0$
  then all other mags fixed by ratio to Vega flux

- ex: Sun has **apparent** magnitude $m_\odot = -26.74$
  i.e., $-2.5 \log_{10}(F_\odot / F_{\text{Vega}}) = -26.74$
  so $F_{\text{Vega}} = 10^{-26.74/2.5} F_\odot = 2 \times 10^{-11} F_\odot$
- ex: Sirius has $m_{\text{Sirius}} = -1.45 \rightarrow$ brighter than Vega

so: $F_{\text{Sirius}} = 3.8 F_{\text{Vega}} = 8 \times 10^{-11} F_\odot$

- ex: $m_{\text{Polaris}} = 2.02$ *Q: rank Polaris, Sirius, Vega?*

⋆ if *distance* to a star is known
can also compute Absolute Magnitude

abs mag $M \equiv$ apparent mag if star placed at $d_0 = 10$ pc

Q: what does this measure, effectively?