Astro 350

Lecture 13

Sept. 21, 2011

Announcements:

- Hour Exam 1 next time, in class
  info on course website
- HW3 back today; all HW solutions posted on Compass
- Discussion Question 4 due *next Wednesday*

Last time: the lives an deaths of stars

Q: what life stages are the same for all stars?

Q: what are different star fates?

Q: what is left after stars die?

Q: if a bunch of stars are formed with a range of masses, what happens?

trends in star properties:

high mass $M \leftrightarrow$ high wattage $L \leftrightarrow$ short lifespan τ

e.g., massive star lifespans = few million years

low $M \leftrightarrow$ low wattage $\leftrightarrow$ long life

e.g., low-mass star lifespans = many billions of years

if many stars born at once–as in a cluster–then
massive stars die first (explode)
then only lower-mass stars left

observed! young cluster have massive stars
old clusters do not

Supernovae* and Cosmology

Supernova explosions are excellent cosmological tools for a number of reasons

Q: why? what is advantageous/interesting about observing supernovae all across the universe?

Q: what would be challenging about observing supernovae?

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*Cosmo-grammar tip: one supernova, many supernovae (it's Latin, dude!)

Cosmology with Supernovae: Pros

supernovae are powerful, very luminous explosions
marking the the deaths of massive stars
$\rightarrow$ handy tools for cosmologists

⋆ supernovae are very luminous
can see from great distances–across the universe!
and since telescopes are time machines...
SN are beacons revealing much of cosmic history

⋆ supernovae come from massive stars
short-lived $\rightarrow$ require ongoing star formation
$\rightarrow$ SN reveal presence and nature of star formation
at distant places and times

Cosmology with Supernovae: Cons

Supernova events are explosions of massive stars

- don't know ahead of time when a star will blow up
- explosion brightness temporary–dies off after a few months
- $< 1\%$ of stars are massive $\rightarrow$ few die this way
  only few each century in big galaxy like ours
  last observed SN in Milky Way was > 300 yrs ago

Practical challenges:

▷ have to monitor many galaxies
  to have good chance of finding a SN
▷ want to find peak brightness (flux) F_{peak}
  $\rightarrow$ have to observe ecah SN more than once
  as it flares up then dims

Observational Strategy:

- monitor lotsa galaxies
- observe each every few weeks

$\rightarrow$ requires huge data processing

powerful computers, digital cameras make this possible
e.g., can digitally "subtract" before/after images
$\rightarrow$ difference shows what's changed: SN

`www: SN search teams`

Standard Candles and Astronomical Distances

Supernovae* have very useful property
$\Rightarrow$ peak luminosity L_{peak} always the same ...as best can tell so far...
an extremely useful property!

recall: apparent brightness (flux F) depends on luminosity
but also on distance: $F = \frac{L}{4\pi R^2}$

⋆ imagine object with known luminosity: "standard candle"
e.g., 100 Watt lightbulb, or SN at peak `www: cartoon`
$\rightarrow$ can measure flux F_{obs}, and using known L_{candle}
solve for distance $R = \sqrt{\frac{L_{\text{candle}}}{4\pi F_{\text{obs}}}}$

Supernovae are great standard candles because
give distance measures across the universe

*In fact: a special kind of supernova: "Type Ia" = exploding white dwarfs

Supernovae Observed Across the Universe

Results thus far:

⋆ supernovae seen out to great distances $\rightarrow$ early times
star birth indeed occurred in the past, not just now!

⋆ in fact, birthrate *much* higher in the past!

⋆ also: SN as standard candles give very interesting result ...
will provide most direct evidence for bizarre dark energy!

Galaxies: Sweet Home Milky Way

iClicker Poll: Our Milky Way Galaxy

Milky Way to eye: irregular band of light `www: MW mosaic, closeup of dark lane`

What is the dominant Milky Way light source?

A predominantly gas

B predominantly stars

C roughly equal mix

Q: MW is band on 2-D sky–what about 3-D space?

Galileo's telescope showed: MW made of stars
eye can't separate, light blends together

MW band in 2-D sky $\rightarrow$ 3-D disk of stars
note similarity with planar concentration of planets in SS

where are we in the disk–near middle or edge?
`www: MW mosaic`
on MW band in sky, stars $\approx$ evenly distributed
Q: simplest interpretation? `www: Herschel model (1700's)`
Q: loophole in the argument?

clue: dark strips in MW

dust: absorbs light → only see small part of MW disk

this fact only verified in 20th century

But then: How to determine MW structure and size?

H. Shapley (1910's): **globular clusters** of stars

most lie out of disk plane → we have unobscured view

Q: how does sky pattern of GC's tell where we are?

If we are at MW center:
→ see GC's evenly spread around the sky

If we are off-center:
→ see GC's more on one side of sky
→ that's Galactic "downtown"

`www: observed GC sky distribution`
⋆ *we are not at the Milky Way center!*

high-tech update:
dust obscures *visible* light, but not longer wavelengths
dust "invisible" if $\lambda \gg$ dust size
so infrared, radio telescopes *can* see all of MW
will see: these confirm we are off-center

Revolution Revisited

Cosmologist Y. Berra: *It's déjà vu all over again!*

Copernican Revolution I (17th Century):
we're one typical planet among many
not center of solar system

Copernican Revolution II (earth 20th Century):
we're one typical star among many
not center of Milky Way Galaxy

... stay tuned for more...

Observed Milky Way Structure

Milky Way contains about $10^{11} = 100$ billion stars

I. Disk Components: most of luminous matter
radius $R \sim 15,000$ pc = 15 kpc (kpc = kiloparsec = 1000 pc)
thickness $h \sim 200$ pc at our location: thin!
`www: IRAS full sky: dust. False color, Galactic coords`
`www: DIRBE near-IR image: cool stars`
note—confirms our suburban location!
1. disk contains most stars
2. also dust, gas → fuel for star formation

Disk Structure

- disk thickest in center, tapers off outward
- disk shows evidence for spiral arms
  → we are spiral galaxy! (as in `www: M104`)

II. Spherical Components

1. bulge at center (old stars, can see in DIRBE image)
2. globular clusters
3. "halo" of old stars

Milky Way Dynamics

in MW, all objects exert gravity on all others

$\rightarrow$ everything accelerating

$\rightarrow$ everything is in motion

Hour Exam 1

`www: Exam Info on Course Website`

`www: Front Page: Instructions and Equations`

Any Questions?

Sample Questions

Multiple Choice

An object orbiting the Sun with a semimajor axis of 9 AU has what orbital period?
(a) 3 years
(b) 9 years
(c) 27 years
(d) depends on orbit eccentricity

Short Answer

Star cluster Gaga discovered, and is made of stars that were all born at the same time. Cluster Gaga is found to have no stars more massive than $1 M_\odot$.

- What is the most likely reason that cluster Gaga has only stars with mass $\leq 1 M_\odot$? Explain in 1–2 sentences.

- Do you predict cluster Gaga should contain white dwarfs? neutron stars? Briefly explain.