

Astro 350
Lecture 14
Sept. 26, 2011

Announcements:

- HW4 available, due Friday
- Discussion Question 4 due *Wednesday*
- Hour Exam 1 grading underway

Breaking News! Report of faster-than-light motion!

result of a neutrino experiment

Q: what's a neutrino? how are they made?

- ν s produced in Switzerland `www`: CERN
- travel about about 700 km \approx 400 miles *under* the Alps

Q: what?! how?

- measured in Italy `www`: Gran Sasso

You can understand the calculation!

▷ precisely measure distance d travelled *Q: how?*

▷ precisely measure time t travelled *Q: how?*

▷ then solve $v_\nu = d/t$

\Rightarrow reported result: $v_\nu > c$! ν s faster than light!?!

`www`: actual research paper reporting result

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Q: why this this a very Big Deal?

Neutrinos

neutrinos (symbol ν) are subatomic particles

- electric charge $Q(\nu) = 0 \rightarrow$ neutral (hence the name)
- mass: we know $m(\nu) > 0$, and we know $m(\nu) \ll m_{\text{electron}}$ but as yet we do not know neutrino masses
- only made in *some* nuclear reactions (“Weak Interactions”)
for example: in Sun, first step in reaction chain for helium production is: $p + p \rightarrow d + e^+ + \nu$
 \Rightarrow the Sun is a huge source of neutrinos!
- *very* weakly interacting
most neutrinos born in Sun’s core pass entirely through Sun to effectively stop neutrinos from the Sun, would need a column of lead about 1 light-year long!

ω We will see: neutrinos are among the most interesting and possibly the most important particles in the Universe

iClicker Poll: Faster-Than-Light Neutrinos

Vote your conscience! Lay your bets!

What is your gut reaction to this result?

- A** Woo hoo! Sounds very likely, and I never liked speed limits anyway!
- B** Meh. Sounds iffy, but more likely correct than false
- C** Meh. Sounds possible, but more likely false than true
- D** No way! Sounds like it has gotta be wrong!

New result, nobody (including instructor!) knows where it will lead

Instructor's vote: *Gotta be wrong!*

Why? Because I am deeply convinced of relativity

Will try to give an idea why starting Friday

To make things interesting: *two wagers*

- *by this Friday*, new papers will appear with new proposed theories to explain results
if this is correct: *candy for everyone!*
- *before the last ASTR350 class*, new paper(s) will appear explaining the result as an error or a misinterpretation
if this is correct: *pizza for everyone!*

Our Milky Way Galaxy: Where are we?

recall MW structure: disk shape

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 \rightarrow fuel for star formation

Disk Structure

- disk thickest in center, tapers off outward
- disk shows evidence for spiral arms
 \rightarrow 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
- everything accelerating
 - everything is in motion

Milky Way Rotation

measure speeds of stars, gas via Doppler effect
complication: we are moving too

stars orbit MW center

disk stars: \sim circular orbit \rightarrow disk rotates

but disk stars *don't* spin like frisbee (i.e., a solid object)

Demo: frisbee: rigid rotation

in time Sun goes around once

stars closer to center go around more than once

stars further out — less than once

\rightarrow “differential rotation”

how measure rotation speeds?

use halo stars, globular clusters (don't rotate)

12 Sun orbit speed: $v_{\odot} = 220$ km/s

at our location $R_{\odot} \simeq 8$ kpc (about halfway out!)