

Astro 210
Lecture 39
April 29, 2011

Announcements

- HW 11 due now
last one! no HW next week!
- Final Exam: **Monday May 9, 1:30–4:30 pm**
info online
- **ICES** course evaluation available online
please fill it out—I *do* read & use results

Last time: our home galaxy—the Milky Way

- *Q: basic shape? where are we??*
- ↳ ● *Q: rotation curve—what is it? what does it look like?
What does it mean?*

Dark Matter: Results to Date

Dark matter identity is still *unknown*

⇒ one of the top questions in all of science!

But we *do know* what dark matter *is not*

- hot gas **X ruled out**
- black holes/white dwarfs/neutron stars **X ruled out**
- neutrinos **X ruled out**
- ★ **exotic particles left over from big bang** *not ruled out*

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The most exotic possibility is the only one left standing!
more on this as we discuss cosmology...

Galaxies: Beyond the Milky Way

Edwin Hubble (1920's):

galaxies fill universe

typical separation $\sim 10^6$ pc = 1 Mpc (megaparsec)

most distant 1000's of Mpc

⇒ galaxies are huge masses of stars

Galaxies sizes range

large (like MW) to small “dwarf”

different structure (“morphology”) & star, gas contents

spiral galaxies

- morphology: disk+bulge
 - stars in both disk and bulge
 - gas, dust evident in disk → ongoing star formation
- www: barred spiral zoom: star formation

elliptical galaxies

- morphology: elongated sphere, no disk!
- stars in spherical/spheroidal distribution
- no/very little gas, dust!
→ no ongoing star formation—no ingredients!

irregular galaxies

- morphology: no clear, simple shape/symmetry
- stars, gas, and dust all present

www: HST merging galaxies

↳

Milky Way one of many galaxies—a typical spiral

Revolution Re-Revisited

Copernican Revolution I (17th Century):

Earth is one typical planet among many
not center of solar system

Copernican Revolution II (earth 20th Century):

Sun is one typical star among many
not center of Milky Way Galaxy

Copernican Revolution III (1920's):

Milky Way is one typical galaxy among many
Universe much larger than previously thought

51 ... stay tuned for more...

Motions Within Galaxies

galaxies have (huge) masses

→ each star feels gravity of all other stars

→ all stars are in motion

in spiral galaxies, disk stars in circular orbits around center

in elliptical galaxies, stars in elliptical-like orbits around center

Q: but then how does the galaxy have a spherical shape?

can measure rotation curves for galaxies:

→ in fact, it's easier than measuring our

o own Galactic rot curve

iClicker Poll: Dark Matter in Other Galaxies

Our Galaxy has a “flat” rotation curve → dark matter
But what about other galaxies?

Vote your conscience!

How common are flat rotation curves and thus dark matter?

- A dark matter found in $< 1\%$ of galaxies
- B dark matter found in $< 10\%$ of galaxies
- C dark matter found in $< 50\%$ of galaxies
- D dark matter found in $> 90\%$ of galaxies

If it isn't dark, it doesn't matter!

⇒ **All** galaxies have dark matter

Dark matter “halo” much larger than visible galaxy
diagram

and **most** of every galaxy's mass
is in the form of dark matter!

Dark Matter fills Universe!

COSMOLOGY

Structure of the Universe

www: 2dF survey and map

Galaxy distribution in space:

- small scales: clumpy
- large scales: smooth

on large scales, Universe is

1. **homogeneous**:

galaxies fill space with (nearly) uniform density

2. **isotropic**:

universe looks same in all directions

☞ Q: What's a U that is isotropic but not homogeneous?

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Motions of Galaxies

measure velocity respect to us
i.e., in galaxy spectra, look for shifts in lines

Results:

(almost) all galaxies show **redshift**

all galaxies move away from us!

Hubble (1929):

galaxy dist, speed **related**

$v \propto d$, or

$$v = Hd$$

(1)

11 → **Hubble's law**

Hubble Law:

$$v = Hd \quad (2)$$

H : “Hubble constant” (sometimes written H_0)

value: $H_0 \approx 70 \text{ km}/(\text{s} \cdot \text{Mpc})$

Hubble sez: farther \rightarrow faster

draw random (homog) dots

Q: add velocity vectors—what’s the pattern?

What does it mean?

OBAFGKM(LT) Contest Winners