Thursday, 04 December, 2008

PHYS-1060 (1)

Fall 2008

3:30-4:45pm Tu Th 1104 Rood

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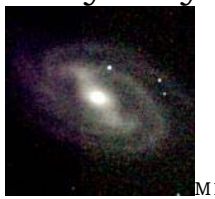
Unit 4

Unit 4 Galaxies & Cosmology Reading Assignment:
Chapter 14 (14.1, 14.2: skim to p. 391, then read pp. 392-394, and 14.3),
Chapter 15 (15.1, 15.2, 15.3), Chapter 16 (16.1, 16.2 through p. 443 and then skim rest of this section, plus 16.3),
Chapter 17 (17.1, 17.2 and 17.4). NOTE: THE WORD "SKIM" DOES NOT MEAN "SKIP". A nice summary of the evolution of structure in the universe is provided on **pp. 492-493**. These readings constitute Unit 4 and you are responsible for this material plus what we cover in lecture. ~~Roughly 45 questions on the Final exam will cover Unit 4.~~

The Milky Way Galaxy

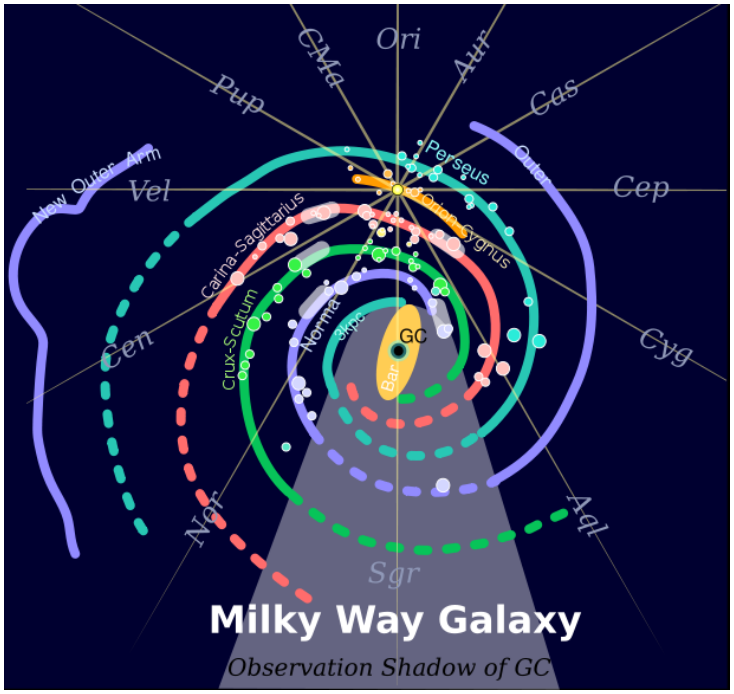


M109

Barred Spiral, 2 Main Spiral Arms

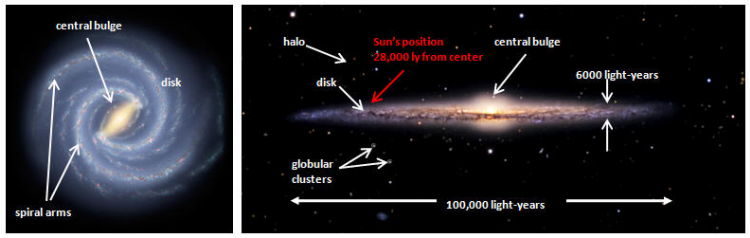
About 100,000 LY across the main disk
Main disk about 1000 LY thick
Sun located about 28,000 LY from galactic center
Thickened bulge in center
Spherical halo around (globular clusters)

Orion Arm – stub arm…



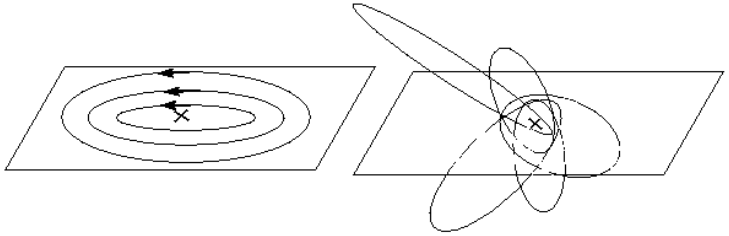
The Sun orbits the Galactic Center

v = 220 km/sec = 800,000 km/hr
T = 230,000,000 years



Disk stars bob up and down as they orbit – gives disk thickness

Gravity from the disk pulls them down
But the gas in the disk is too thin to stop the stars, so they plow on through until gravity pulls them back up and the cycle repeats.



Population I stars: ordered motion. Circular orbits in the disk plane; younger, more metal-rich.

Population II stars: random motion. Eccentric orbits passing through disk plane; older, more metal-poor.

Star-Gas-Star Recycling

Hot gas erupting from the disk can condense in the halo and rain back down (or up) on the disk.
Atomic hydrogen H (21cm band) –
Molecular hydrogen H_2 (hard to see) –
Other molecules: H_2O (water) CO (carbon monoxide) NH_3 (amonia) C_2H_5OH (ethyl alcohol)
Radio to gamma rays.

Population I Stars

Disk stars · ~ 2% heavy elements
Old and new stars

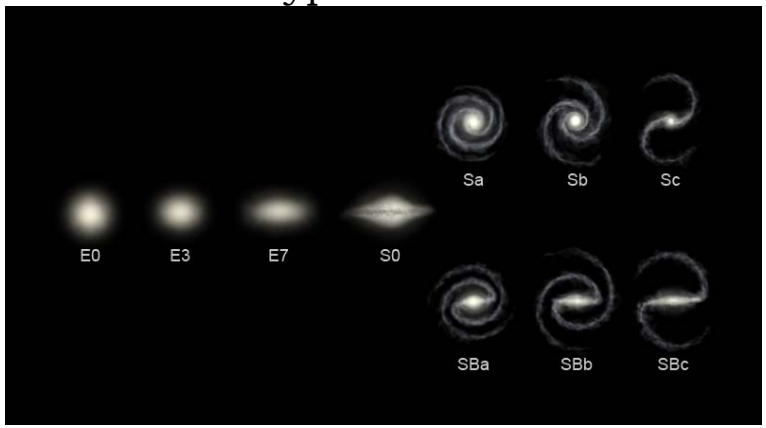
Population II Stars

Halo and Bulge stars · ~ 0.02% heavy elements
Old stars (metal poor) and small.
Lack of gas in the halo means no new star formation regions there.

Protogalactic clouds

The galaxies have to form from something and the matter from the earliest universe condensed into these protogalactic clouds.

Three Types of Galaxies



Spiral Galaxies (regular and barred)

as previously described

Elliptical Galaxies

redder, more rounded – spheroidal galaxies
includes the largest galaxies – old stars
results of collisions?

Irregular Galaxies

are neither spiral nor elliptical
example, a ring galaxy

The Last Class

	X3rraw	X3raw	X3curv
	30	150	150
	29	145	146
	28	140	142
	27	135	138
	26	130	134
	25	125	130
	24	120	126
	23	115	122
	22	110	118
median/ mean	21	105	114
	20	100	110
	19	95	106
	18	90	102
	17	85	99
	16	80	96
	15	75	93
	14	70	90
	13	65	87
	11	55	81
	10	50	78
	9	45	75
n	103	103	103
hi	30	150	150
lo	9	45	75
ave	20.66	103.3	113.5
s.d.	4.419	22.09	16.23

Groups

Spiral galaxies mainly in loose collections
up to a dozen members

Clusters

Elliptical galaxies mainly found in clusters
of hundreds or thousands of members

- half the objects in central regions of clusters are ellipticals
- but only 15% of large galaxies outside of clusters are ellipticals.

Distances by Standard Candles

Can't Use Parallax (nearest stars)
or Radar Ranging (solar system)

Inherent problems with any Standard Candle
Comparing to Known Star Types (G2)
Main Sequence Fitting

Cepheid Variable Stars

- Period-Luminosity Relation

HST measuring out to 100,000,000 LY

Redshift vs. Distance

Hubble's Law $v = H_0 \times d$
Expanding Universe – Everything Expanding

Age of the Universe

$1/ H_0 \sim 14$ billion years

Lookback Time

"When did an event occur?"
Easiest to say, "It occured 400,000 LY away."

Redshift Significance

Are distant galaxies really moving at near *c* ?
Or is Space merely expanding and carrying
distant galaxies along for the ride?

Most Galaxies Are The Same Age ~ 13 billion years

As pointed out before, we cannot observe one star or one galaxy over its lifetime –
instead we compare similar galaxies at different Lookback Times.

Galaxies formed by 2 billion years from start of the Universe

Protogalactic Clouds

Spin and Density

Starburst Galaxies

Extremely rapid star formation
Exhausts gas supply so no disk forms.

Quasars (Quasi-Stellar Objects)

Output massive amounts of energy
(more than entire energy output of Milky Way)
Very distant / early / old
(halfway to cosmological horizon)
Massive Black Holes with giant accretion disks

Fusion converts ~1% of mass to energy
Fall into black hole – 10-40% of mass to energy

Supermassive Black Holes and Galaxy Formation

Central Black Holes have about
$1/500^{th}$ mass of central bulge mass

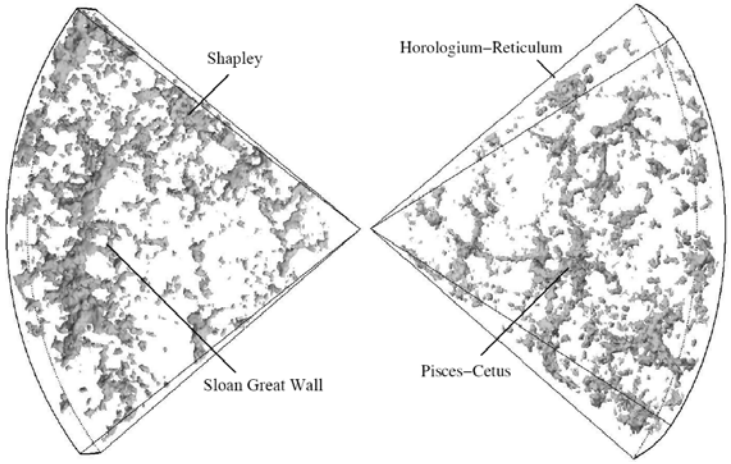
Holds true for small spirals (bulge = 10^8 M_{sun})
to giant ellipticals (bulge = 10^{11} M_{sun})

Dark Matter

Ordinary Dark Matter
MACHOs
Extraordinary Dark Matter

Sloan Great Wall of Galaxies

Largest Structure in the Universe (versus Voids)



Expansion of the Universe