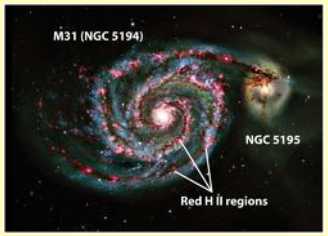
Galaxies

Galaxies

• ***Earl of Rosse*** built a 2m telescope in 1845

Rosse's "Leviathan of Parsonstown"



• believed ***galaxies*** were "*island universes*", *separate and beyond* the ***Milky Way***

• others felt "***spiral nebulae***" akin to ***globulars***

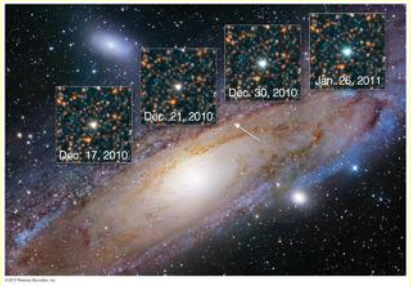
• ***no*** *reliable method* to *measure distances*, so *debate* over ***spiral nebulae*** *stagnated*

• ***Henrietta Leavitt*** (***1912***): ***Cepheid*** L vs period

• ***Hubble*** photographed ***Andromeda*** in ***1923***

• used ***Cepheids*** to calculate *distance*

• proved ***Andromeda*** far beyond ***Milky Way***



Galaxy Classification

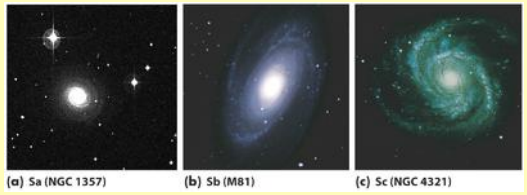
• ***Hubble*** classified ***galaxies*** into ***3 major types***

• ***spirals*** (77%), ***ellipticals*** (20%) & ***irregulars*** (3%)

• ***spiral galaxies*** have *new, hot stars* in spiral arms (“***Population I***” or *metal-rich*) and *older, cooler stars* in core (“***Population II***” or *metal-poor*)

CLICKER: *Which spectra below is Population I?*

• *subdivided* by *spiral arm tightness, dust, core size*



M77 (45 Mly, *Cetus*)

M104 (30 Mly, *Virgo*)

NGC 4565 "Needle" (30 Mly, *Coma Bernices*)

• ***barred spiral galaxies*** are similar to spirals

• formation of "*bar*" appears to be *gravitational*, and so depends *on amount of* ***dark matter***

(eg) Milky Way *is a barred spiral galaxy*

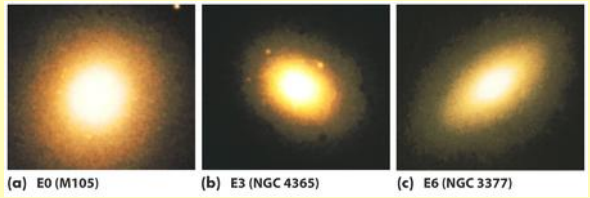
• *subdivided* by *spiral arms, bar, dust, core size*

M109 (85 Mly, *U Major*)

• ***elliptical galaxies***: *mainly* ***Population II*** *stars*

• ***infrared/radio***: *gas & dust poor, little rotation*

• *subdivided* E0-7 based on *"roundness"*

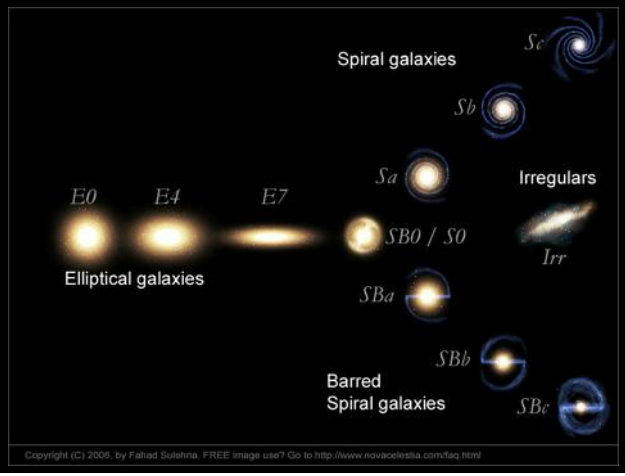


Q: *Why might* ***Hubble class*** *for an* ***elliptical*** ***not*** *represent the true shape of the galaxy?*

NGC 4472 (49 Mly, *Virgo*)

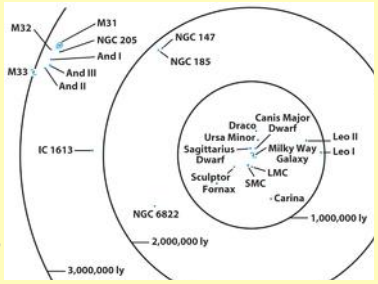
NGC 6822 (1.5 Mly, *Sagittarius*)

"Tuning Fork" Diagram



Galaxy Clusters

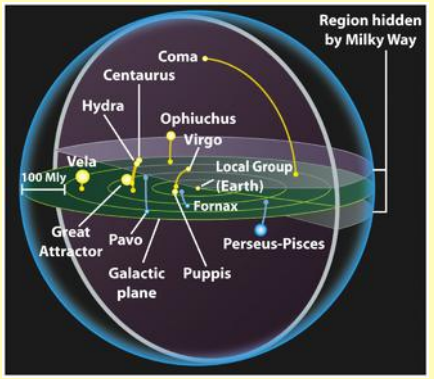
- ***galaxies*** form in groups called ***clusters***
- ***Milky Way*** one of ***~40 galaxies*** in ***Local Group***



*(eg) If **Milky Way** & **Andromeda** are **dinner plates**, ~ 2.5 m apart, how big is the universe*?*

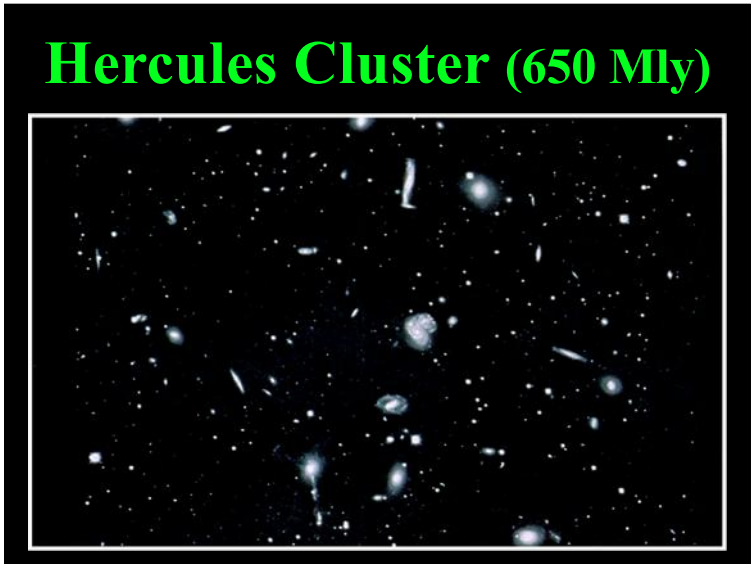
- *~ 15 km across at this scale*
- ***it would fit in Nanaimo, north-south!***

- *800 Mly* sphere showing nearby ***clusters***

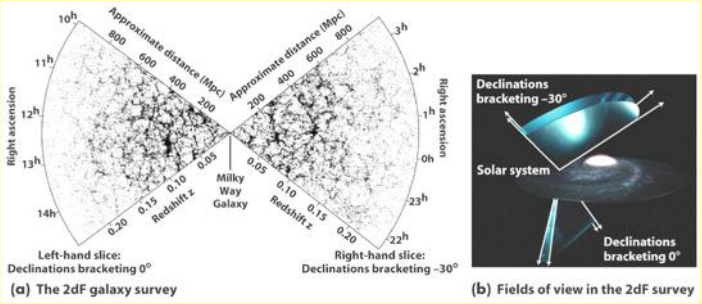


- ***cluster*** populations ***vary***

(eg) Coma cluster contains ~10,000 galaxies!

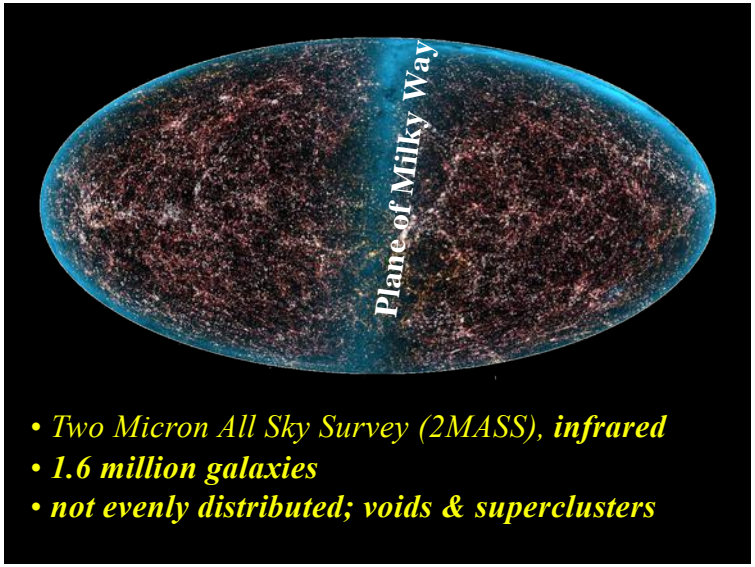


- ***galaxy clusters*** grouped into ***superclusters***
- *unlike* ***clusters***, ***superclusters*** are ***not*** grav bound



(eg) *2dF galaxy survey: 63,000 galaxies to 3 Gly*

- ***Local Group*** part of ***Virgo Supercluster***



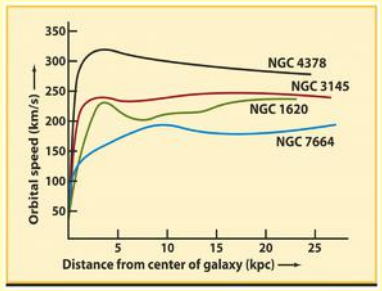
- *Two Micron All Sky Survey (2MASS),* ***infrared***
- ***1.6 million galaxies***
- ***not evenly distributed; voids & superclusters***

Rotation Curves

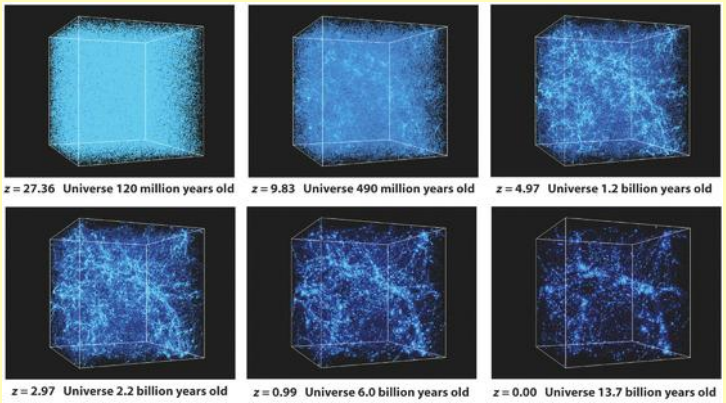
• ***clusters*** have *insufficient luminous mass* to remain *gravitationally bound* to each other

• examine ***rotation curves*** for ***galaxies***

• significant ***dark matter*** present in ***all galaxies***



• *computer simulations* can *reproduce* what we *see* ***if*** we include *"unseen"* ***dark matter***

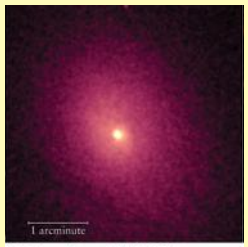


Galaxy Collisions

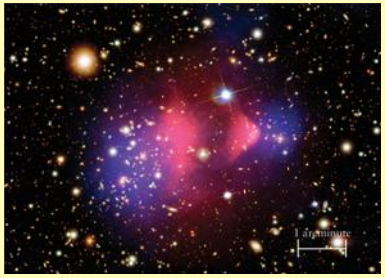
• ***collisions*** largely *"****gravitational interactions****"*

• ***gas*** & ***dust*** *collide & heat up*

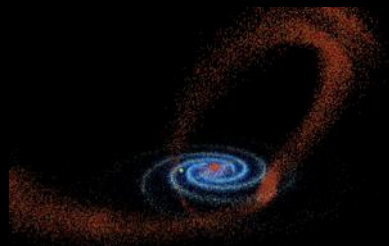
• ***dark matter*** behaves ***differently***!



(a) An X-ray image of Abell 2029 shows emission from hot gas.

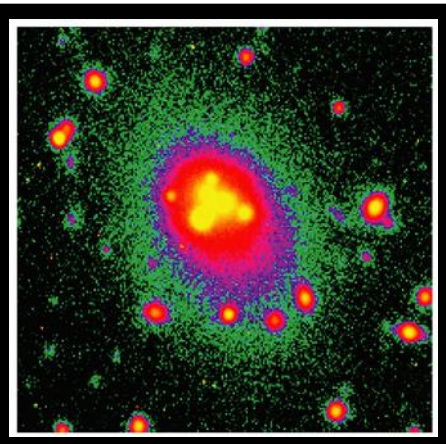


Sgr Dwarf galaxy

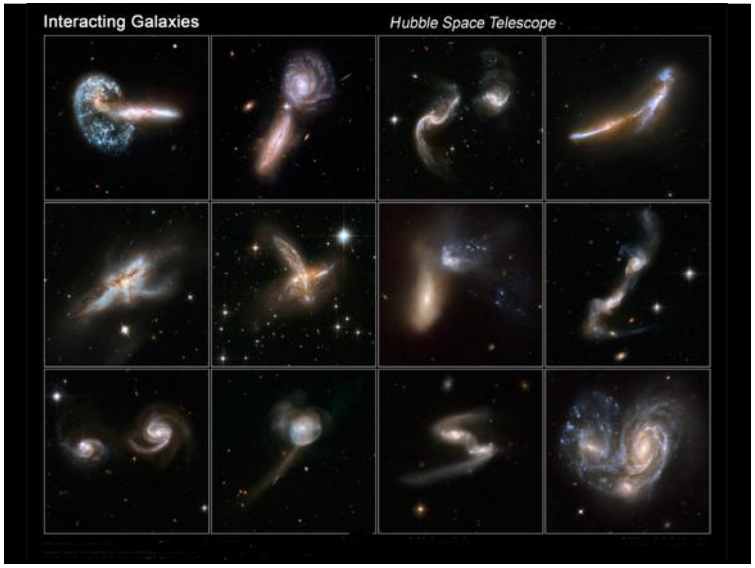


• MW ***currently*** interacting with (dwarf) galaxies

• ***source*** of our spiral structure?

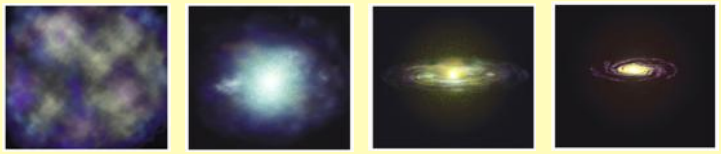


• ***Abell 3827*** shows multiple "***cores***" in this enhanced ***brightness image***



Galaxy Evolution

• ***galaxy evolution*** mimics ***solar system formation***: ***gravitational collapse of dense regions***

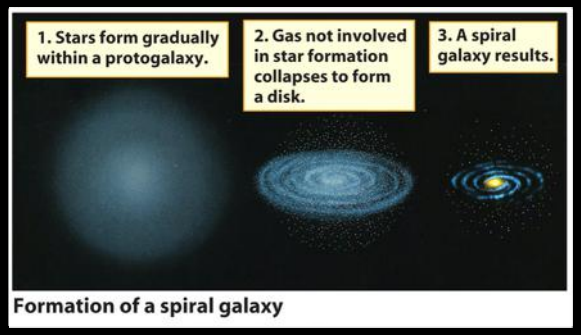


• "***bottom-up***" formation of ***galaxies*** since *small* ***irregular galaxies*** more common *in past*

Q: *Why do we get different kinds of galaxies?*

• *competition* between *star formation* & *flattening*

• ***higher density*** and ***low rotation*** ⇒ ***ellipticals***
• gas used up quickly, little left for new stars



Formation of a spiral galaxy

• ***lower density*** and ***high rotation*** ⇒ ***spirals***
• gas used up slowly, lots left in flattened disk

Evidence

• ***stellar evolution*** is *better understood* than ***galaxy evolution*** because *we can see stars in all stages*

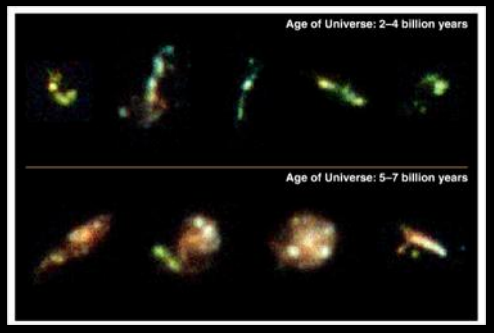
• examine *distribution* of ***Population I & II*** stars

• ***Population II*** rich ***globulars*** mainly in ***halo***
• ***old***; *gas* must have settled into ***disk long*** ago!

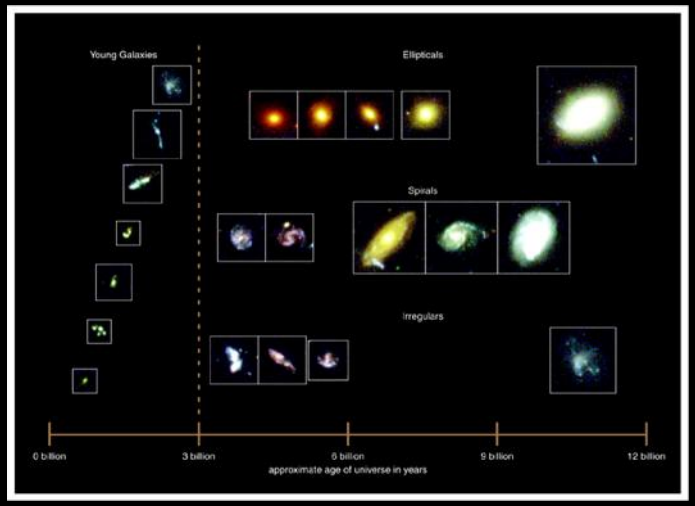
(eg) *simulations:* ***spirals*** *can collide* ⇒ ***ellipticals***

• use ***HST*** and others to look into *distant past*

Early Galaxies



• *distorted*, unlike ***spirals*** & ***ellipticals*** today
• evidence for common past ***collisional events***



CLICKER: Why should we not be surprised that galaxy collisions were more common in the past?

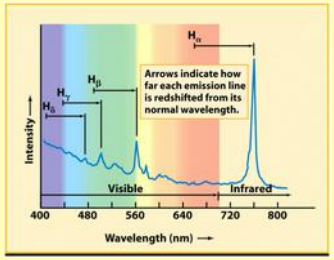
(a) galaxies moved faster in the past
(b) galaxies were larger in the past
(c) universe was smaller & more dense in the past
(d) supermassive black holes were stronger in past

Quasars

• *1960's*: ***Schmidt*** found "*strange*" ***spectral lines*** for an object at center of *strong radio emissions*

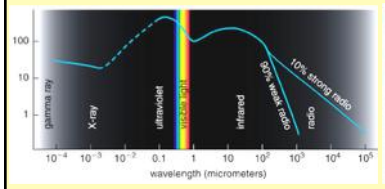
• actually ***enormously shifted emission (H)*** lines
• a *rapidly retreating* & *very distant* object

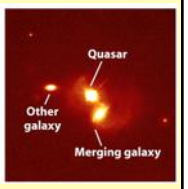
• ***luminosity*** of object: ***100x*** the entire ***Milky Way***



• ***Quasars***: ***QUASi-stellAR Sources***

• ~200,000 ***quasars*** (***Sloan Digital Sky Survey***)
• ***most*** more than 3 Gly away…
• emit across entire ***EM spectrum***
• *can* produce *strong emission lines*

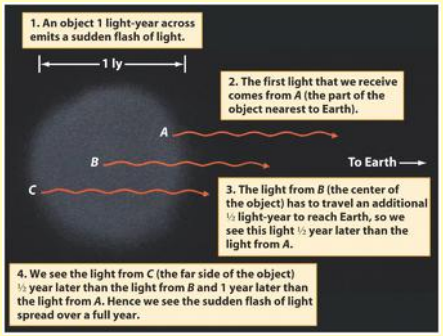


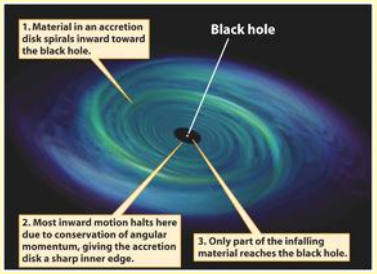


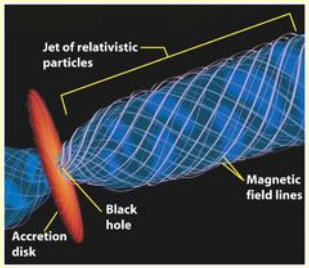
• ***incredibly*** *luminous sources* in *young* ***galaxies***

• ***quasar*** *source*: ***AGN*** (*Active Galactic Nuclei*)
• *in* ***X-rays*** *some* ***AGN*** vary over a span of ***hours***

• *timing pulsations in brightness* & *speed of light yield* ***AGN*** *the size of our solar system!*





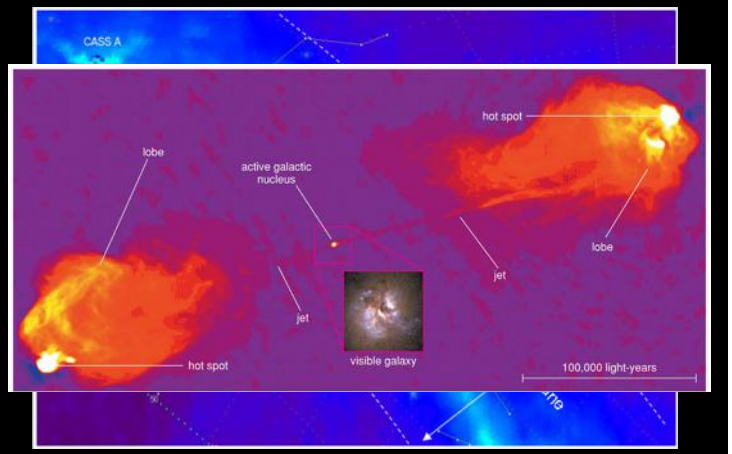


• ***supermassive black holes*** power *AGN*
• must be *"well fed"* to have such high ***luminosities***

(eg) *brightest quasars: 1000 solar masses per year!*

An AGN/quasar

Cygnus A (radio galaxy)



Centaurus A (Active Galaxy) (13 Mly, Centaurus)

• elliptical ***devouring a smaller barred spiral!***

CLICKER: Why have quasars gone "extinct"?

(a) AGN have evolved into supermassive BH's
(b) Quasars exploded as hypernovae long ago
(c) all active galaxies have merged
(d) AGN don't have sufficient quantitites of "fuel"