The Local Universe

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Ask yourself…

What is the Milky Way Galaxy, and how does it compare to other galaxies?

How do you define a galaxy?

What is the Local Group?

Do all galaxies have close neighbors?

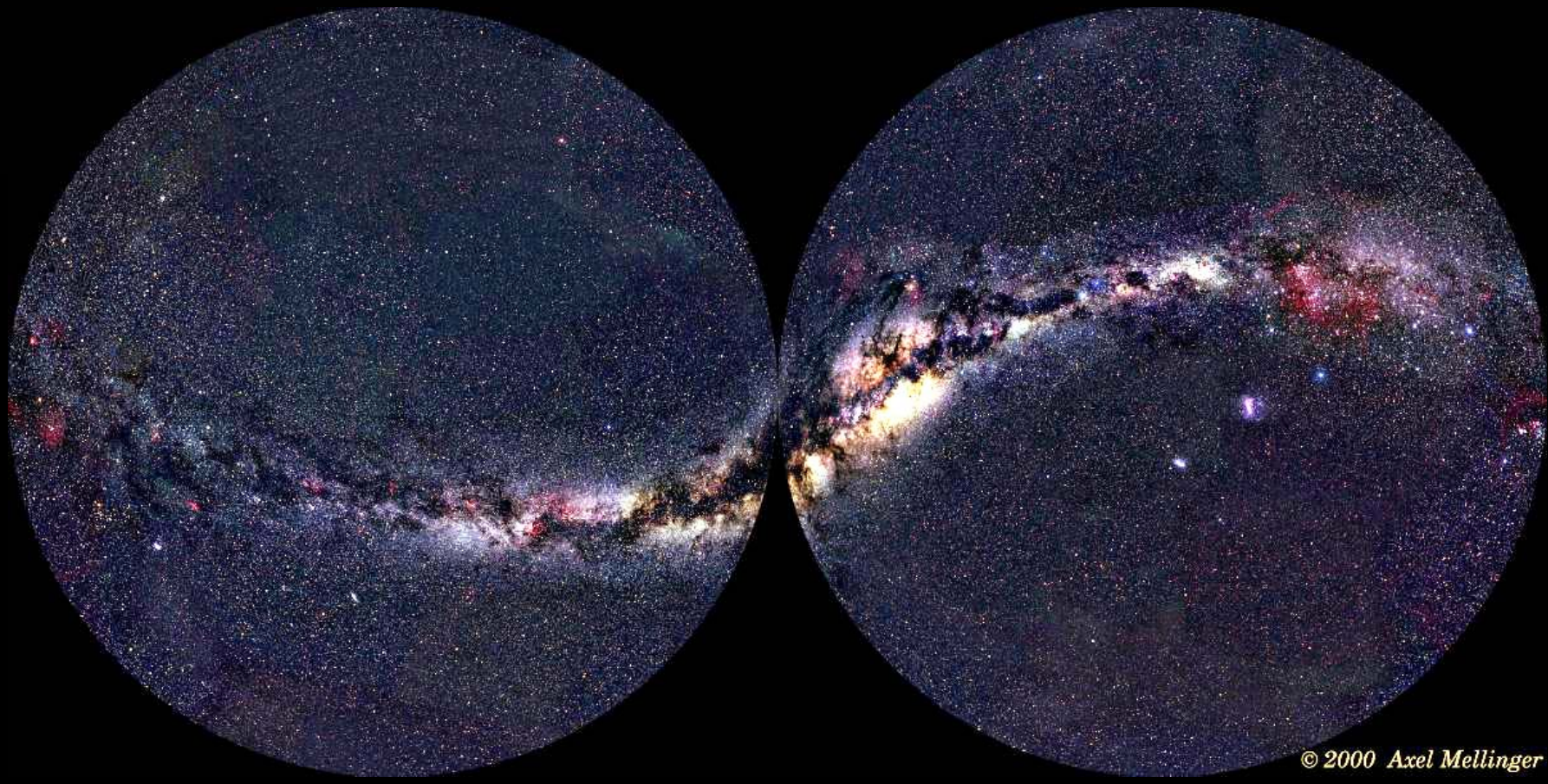
What happens when galaxies collide?

A quick note on units…

- Distances: 1 kpc = 3.08×10^{19} meters
- Mass: $10^6 M_\odot = 1.98 \times 10^{36}$ kg
- Rates: 100 km/s ~ 100 kpc/Gyr

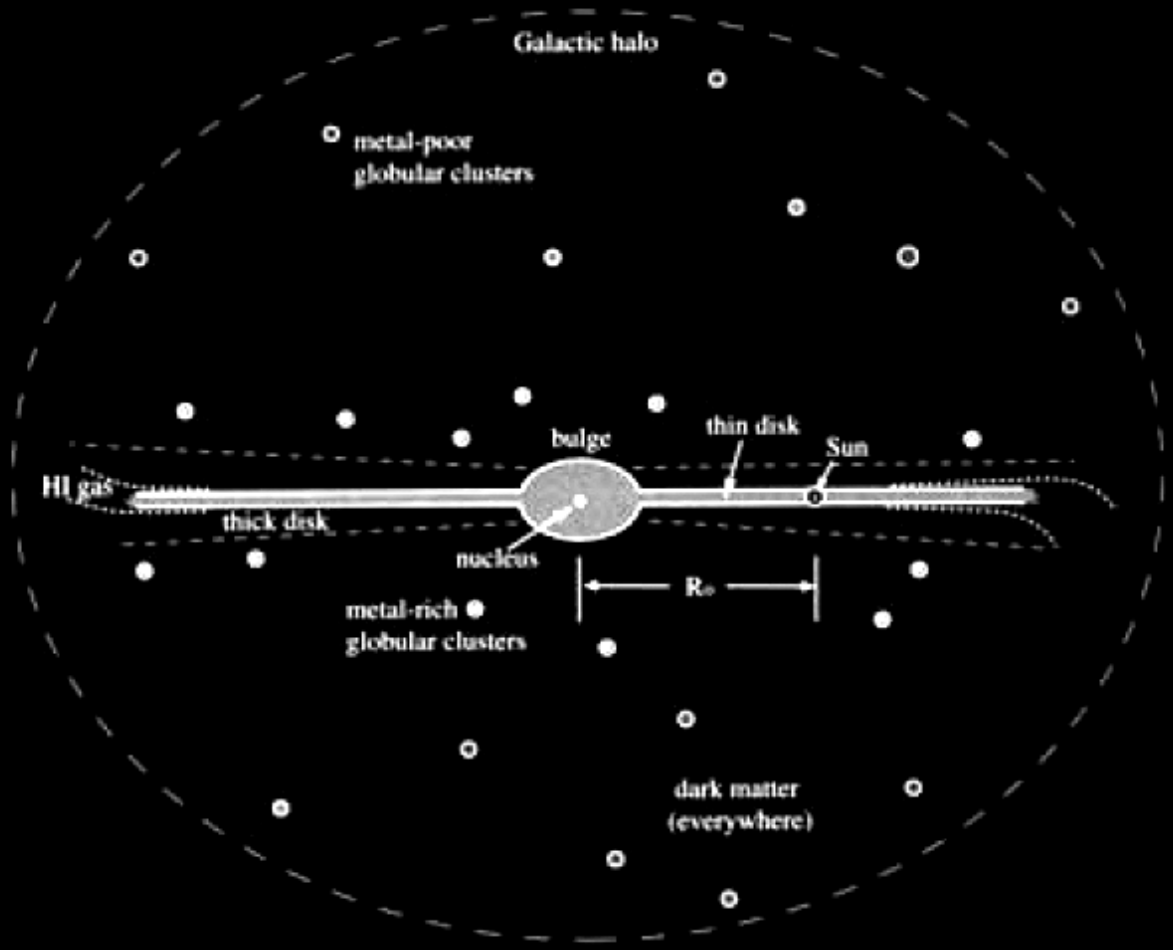
A close friend: Our Milky Way Galaxy

- An Sbc galaxy that is 30 kpc in diameter



Anatomy of the Milky Way

- R_0 ~ 8 kpc
- 200 billion stars
- 5 x 10^{11} $M_\odot$
- SFR ~ 3 $M_\odot$/yr
- Bulge ~ 3 kpc in diameter



A useful tool: Redshift

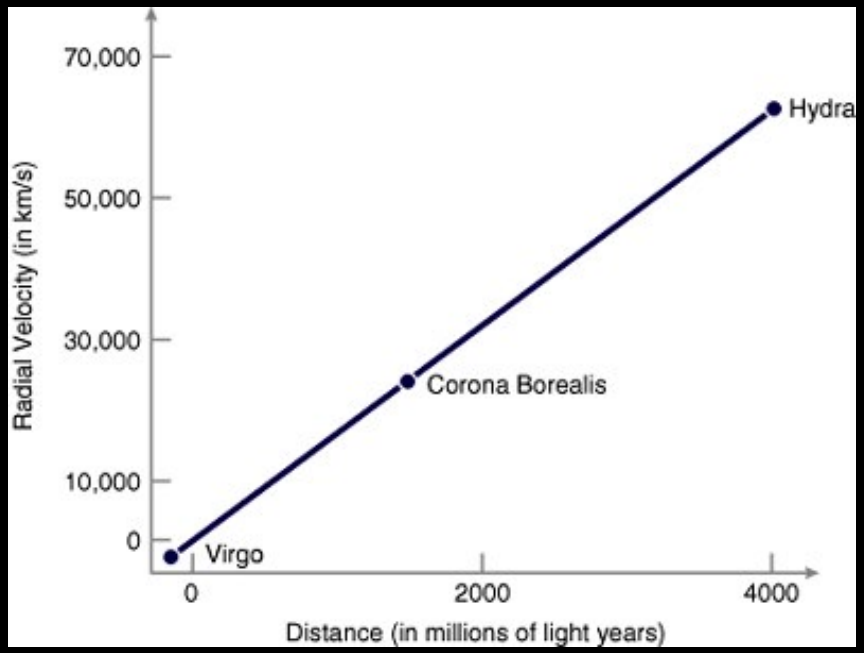
$$z = \frac{\lambda_{obs} - \lambda_0}{\lambda_0} = \frac{f_0 - f_{obs}}{f_{obs}}$$

- Measure the shift in a spectral line – f_0 is the rest frequency (λ_0 the rest wavelength)
- Extragalactic objects often identified by their *cz* measurement.
- ALFALFA will cover *cz* = –2000 to 17000 km/s

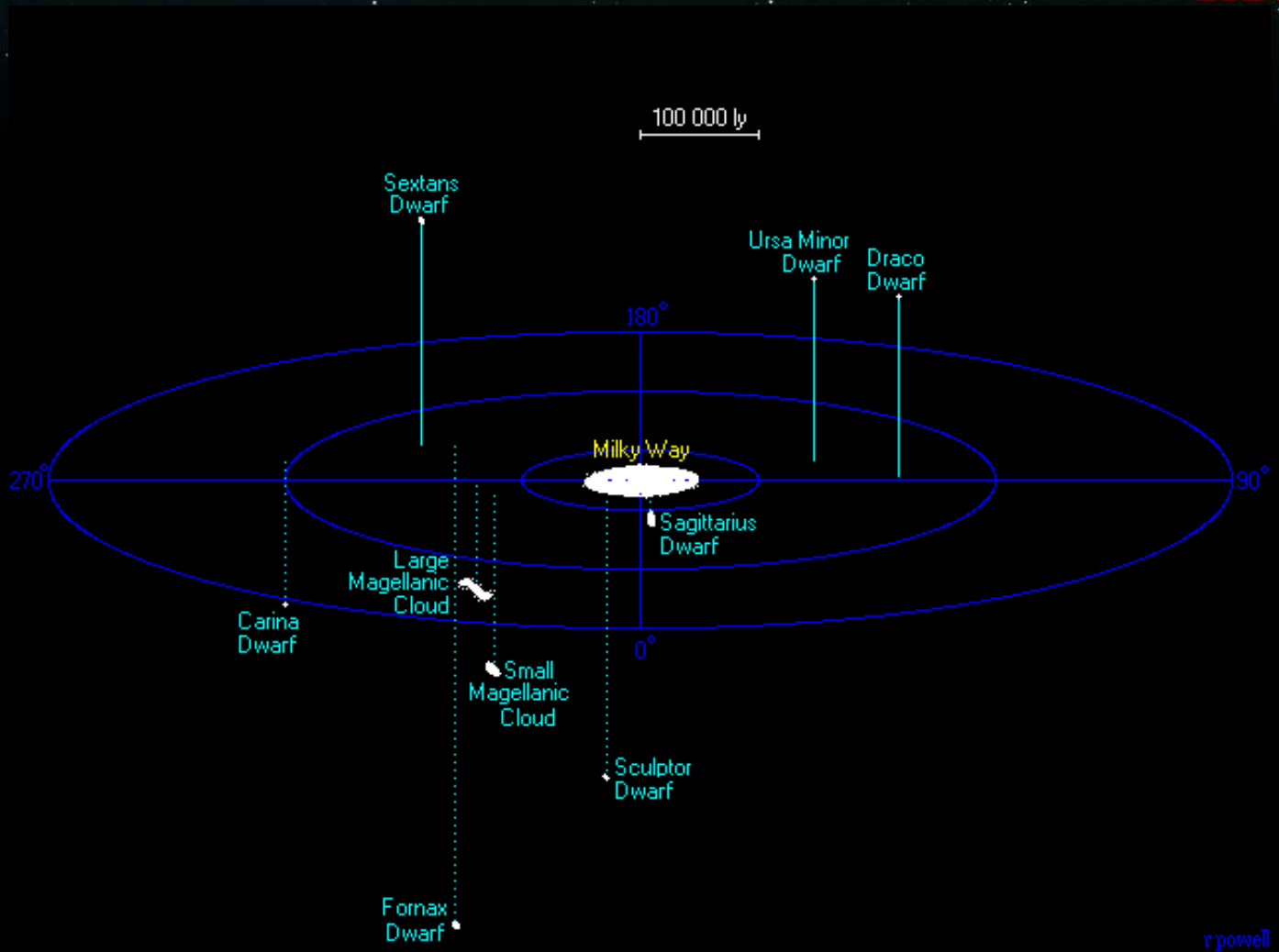
Expansion of the Universe

- Edwin Hubble (among others) showed the Universe was expanding!
- However, there are other factors to take into account in the local Universe – peculiar velocities! Deviations can be quite large depending on the galaxy, and whether it is part of a group or a field galaxy.

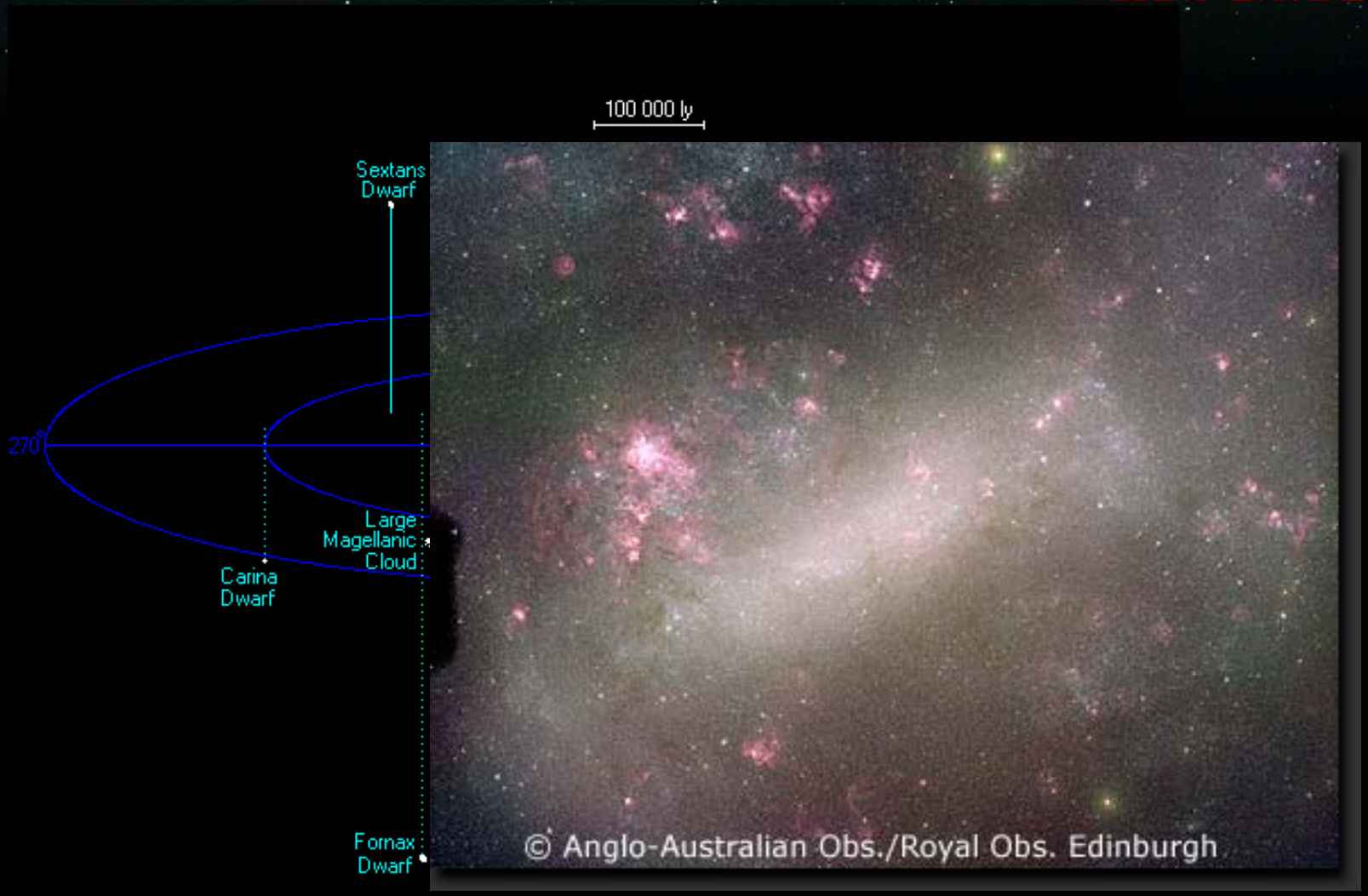
$$cz = H_0 d$$



Around the Milky Way…



Around the Milky Way…



Around the Milky Way…

The Andromeda Galaxy

- Sb galaxy 770 kpc from the Milky Way.
- Larger, more luminous, with a larger disk scale length than the Milky Way – it even rotates faster at 260 km/s!
- At least 9 known satellite galaxies – dwarf elliptical and spheroidals!

The Andromeda Galaxy: GALEX

M33

- Late-type spiral galaxy ~850 kpc from the Milky Way and ~200 kpc from Andromeda
- Disk scale length is around 1.7 kpc, rotating around 120 km/s.

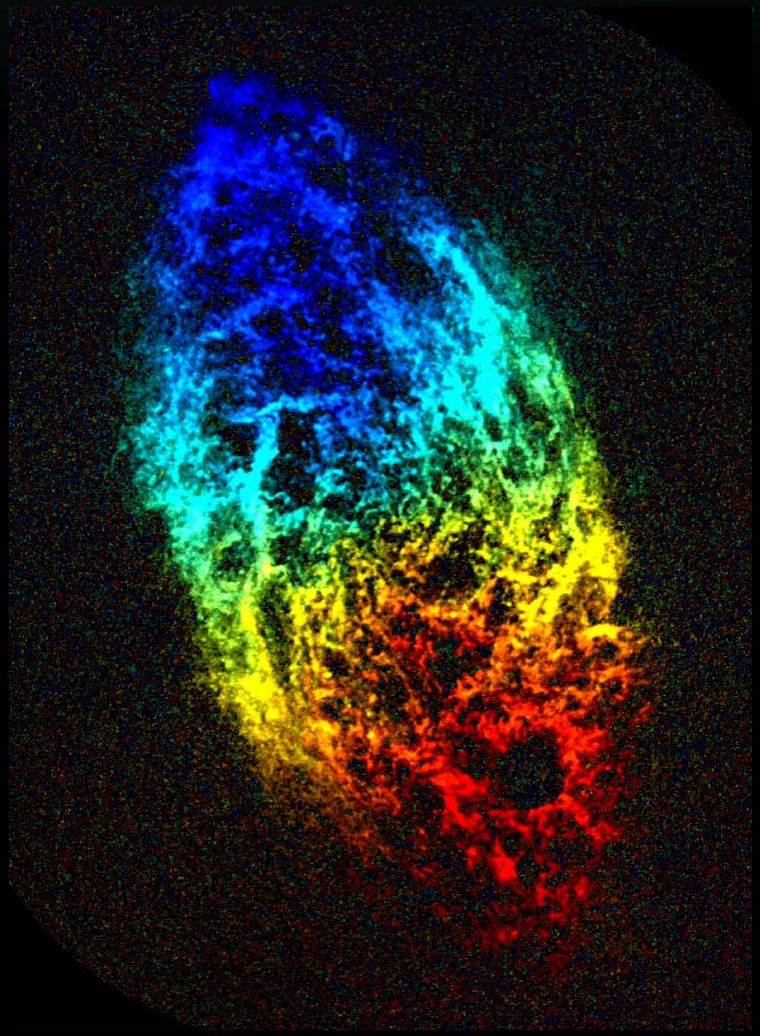
What are we missing!?!?!?!?

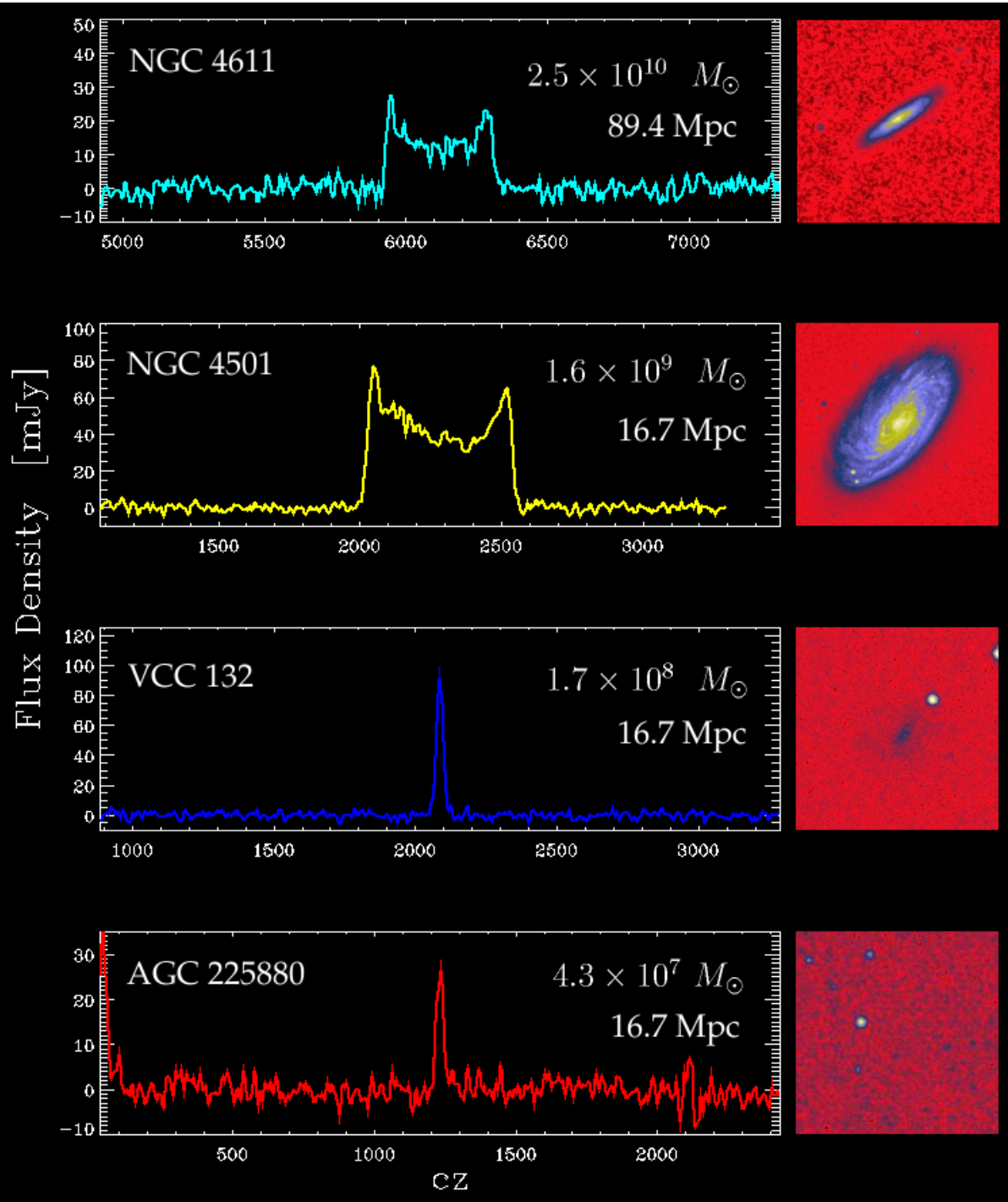
What are we missing!?!?!?!?

THE GAS!!!!!!!!!!

M33

- Richer in HI gas than M31 or the Milky Way – VLA doppler image show movement of the HI gas towards and away.
- The HI disk extends out to 30 kpc, enough for M31 to cause tidal effects and warp the outer disk!



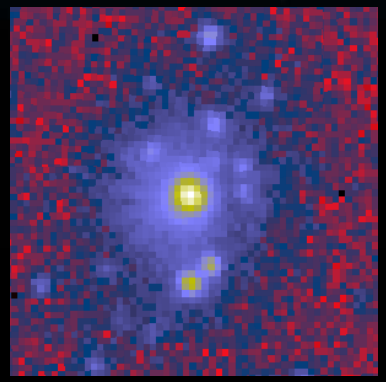
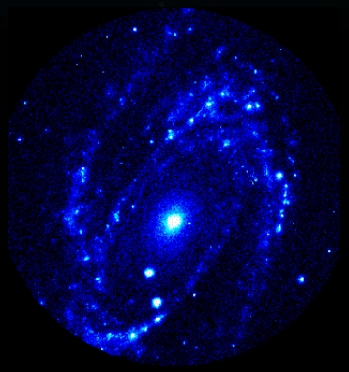

NGC 4611
2.5×10^{10} $M_\odot$
89.4 Mpc
NGC 4501
1.6×10^{9} $M_\odot$
16.7 Mpc
VCC 132
1.7×10^{8} $M_\odot$
16.7 Mpc
AGC 225880
4.3×10^{7} $M_\odot$
16.7 Mpc
Flux Density [mJy]
cz


Galaxy Morphology

What do galaxies *look* like?

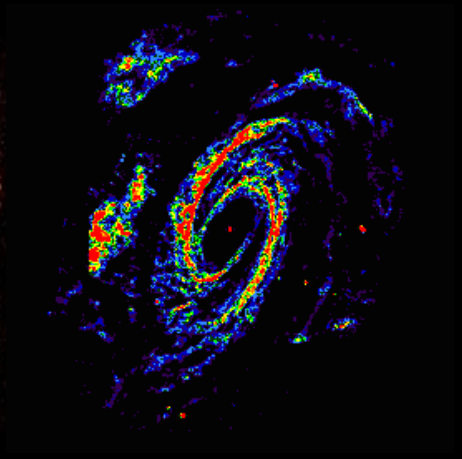
Well, it depends…

Galaxies across the spectrum

M81



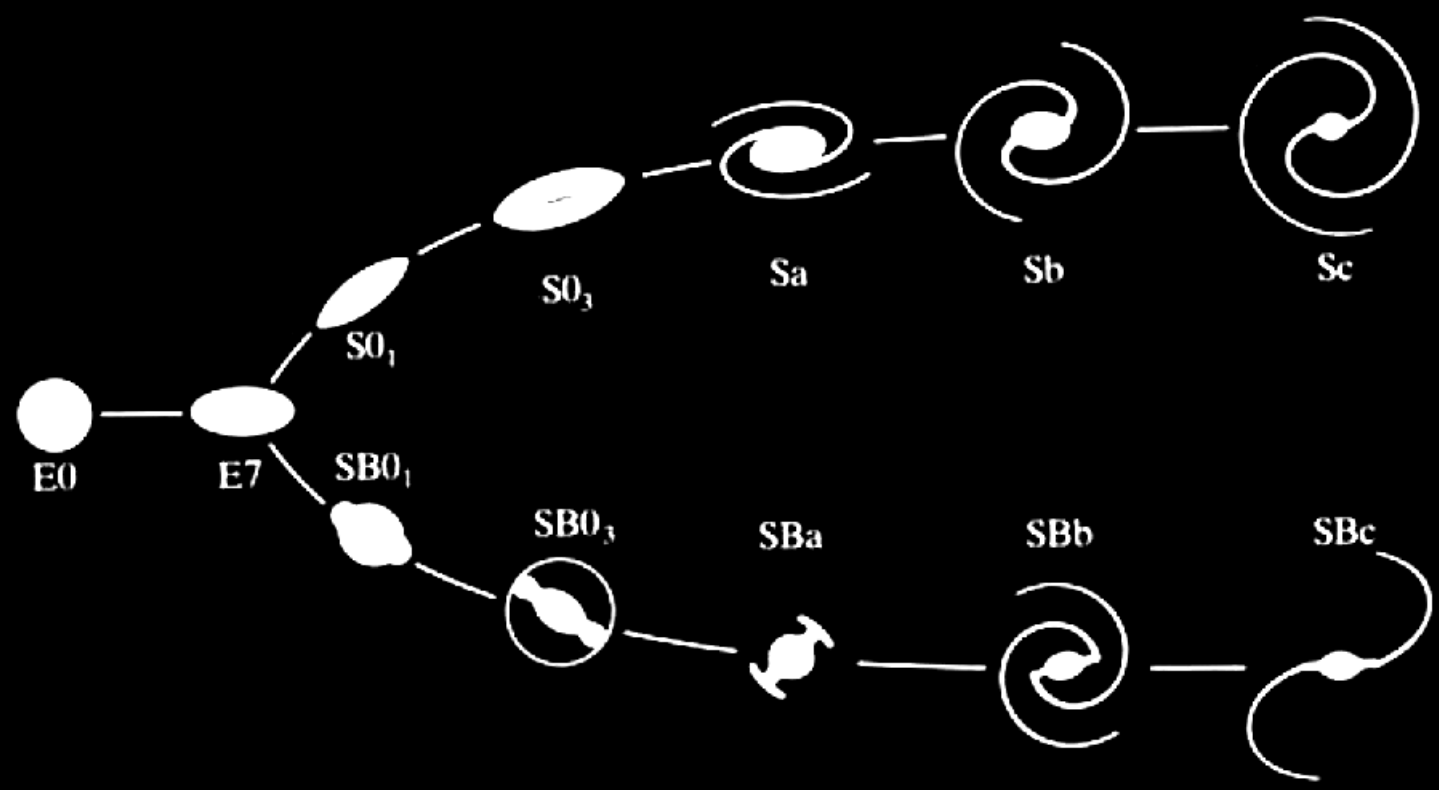



Radio Astronomy provides a ***crucial*** part of the picture!

Galaxy Types

Galaxy Type	Hubble	de Vaucoulers
Spiral	S, Sa, Sb…	1 through 6
Elliptical	E	-6 through –4
Dwarf	dE, dSph	
Lenticular	S0, SB0	-3, -2, -1
Irregular	Irr	

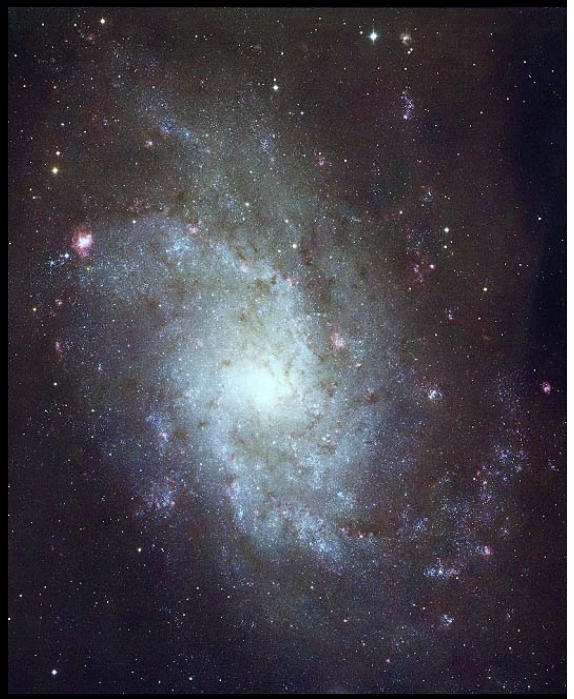
Hubble's Tuning Fork



Spiral Galaxies

- Thin disks
- Most have some form of a bar – arms will emanate from the ends of the bars
- Other classification:
  1. Relative importance of central luminous bulge and disk in overall light from the galaxy
  2. The tightness of the winding of the spiral arms
  3. Degree to which spiral arms are resolved into stars and individual HII regions

M51

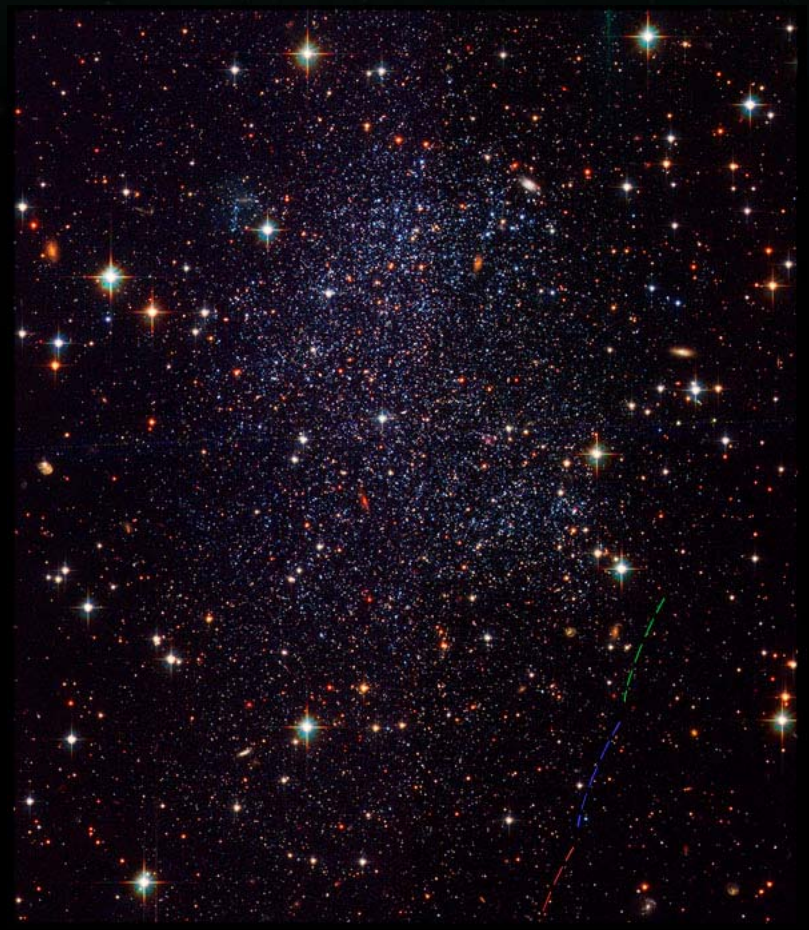


M33

Dwarf Galaxies

- Smaller size than giant elliptical galaxies
- Lower surface brightness

M32



Sagittarius Dwarf

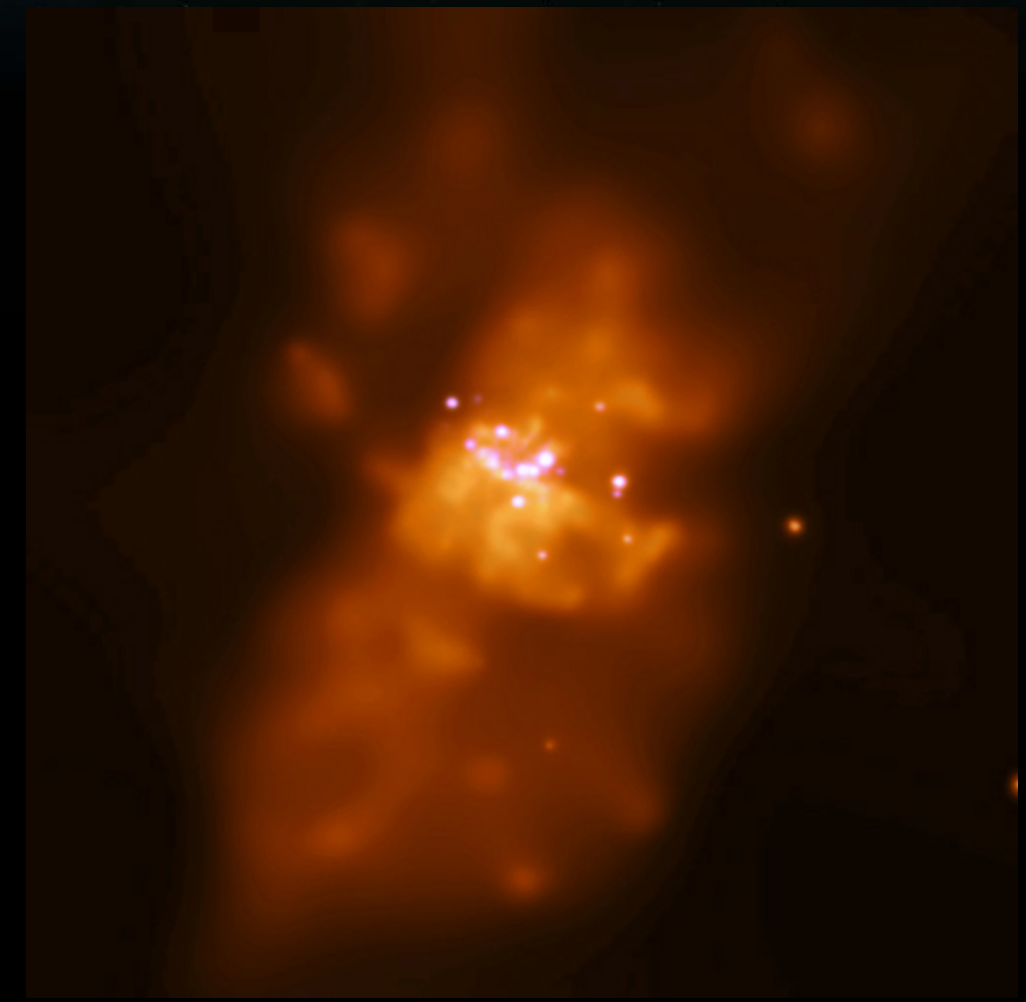
Irregular Galaxies

- LMC and SMC are satellite galaxies of our own – disrupted by gravitational interaction with the Milky Way…

LMC and SMC

Irregular Galaxies

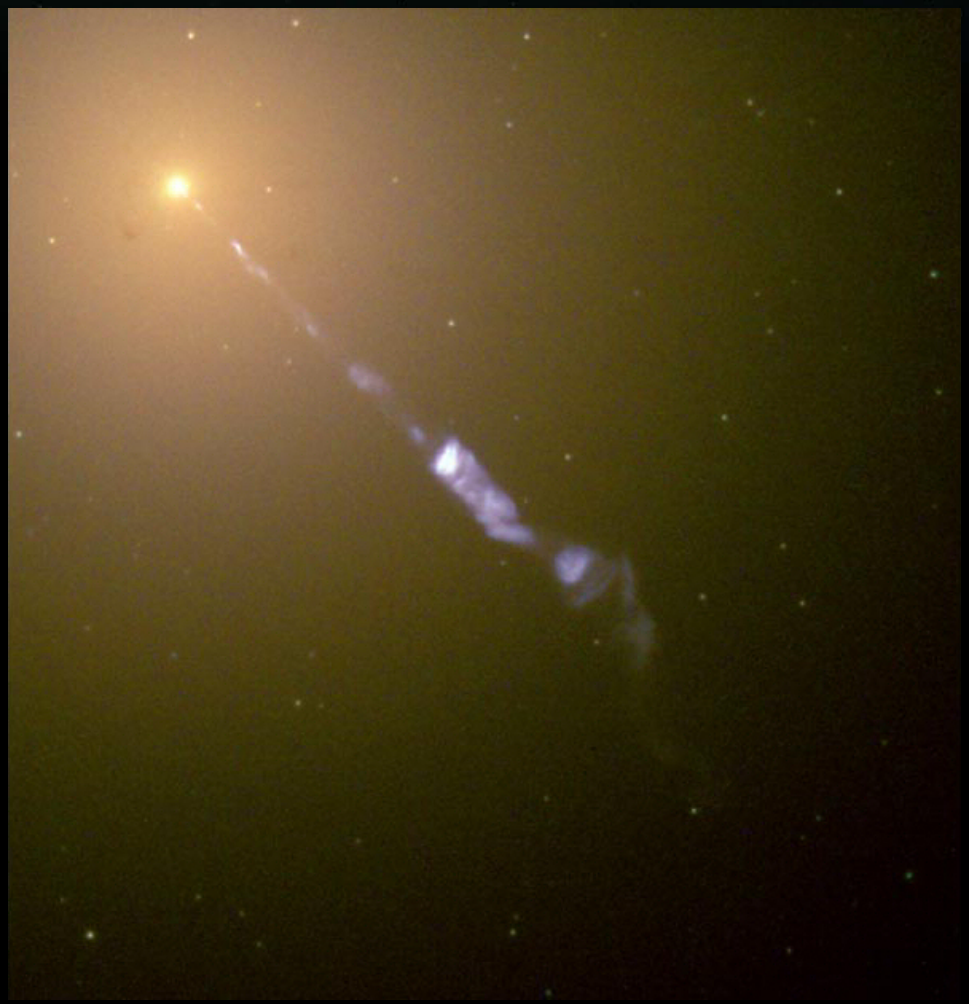
- M82 – irregular starburst galaxy
- Star formation rate at **10 times** the rate of our galaxy
- Chandra X-ray image reveals hot gas flowing out of the galaxy – hot spots indicate x-ray binary stars – some of the brightest known!



Elliptical Galaxies

- Smooth and very little structure; varying in shape
- Classified by EN where

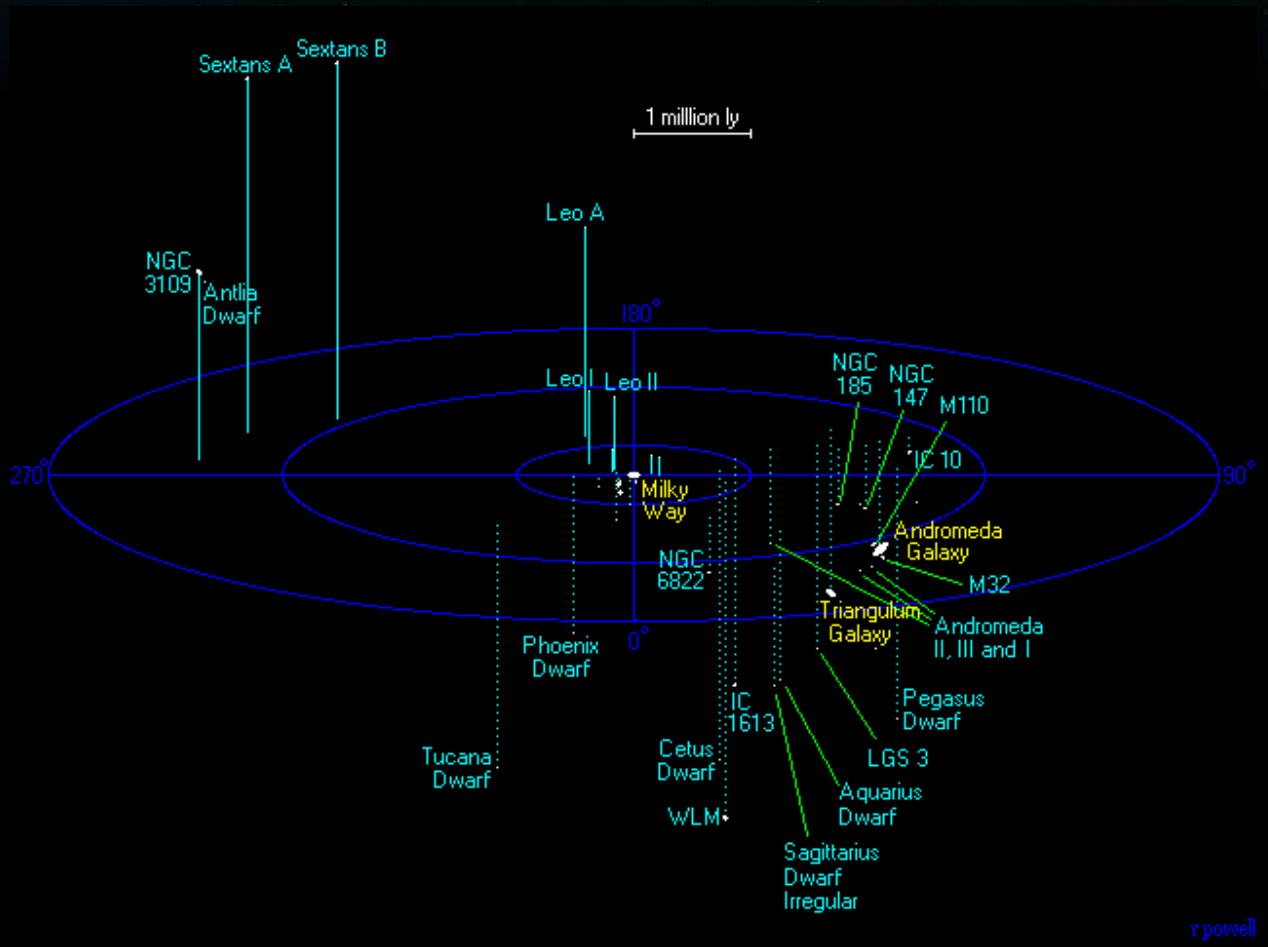
  N=10(1-b/a)
- Large populations in clusters.
- Little gas – don't see spectral HI lines



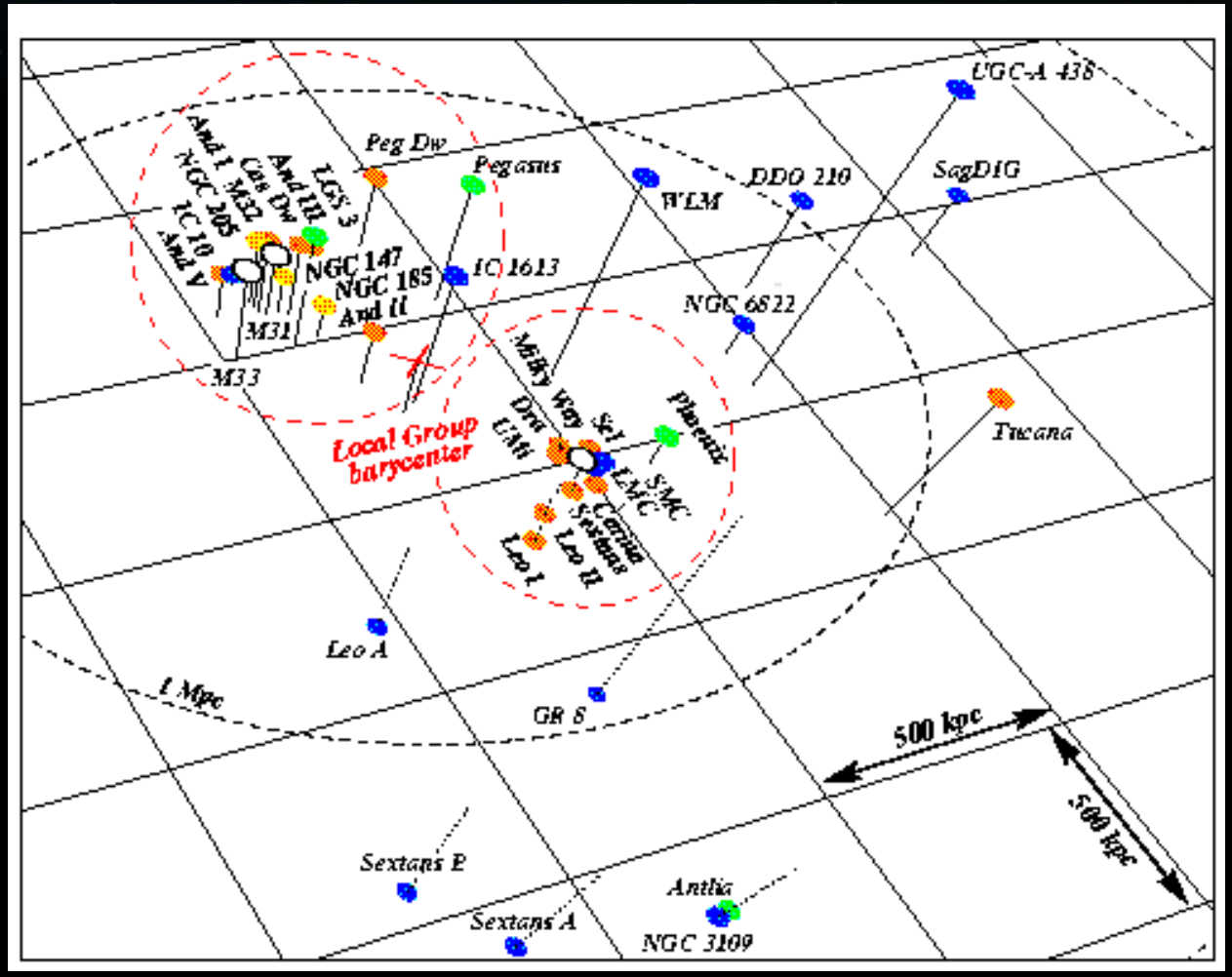
M87

The Local Group

- The Local group has 41 members, ranging from large spiral galaxies to small dwarf irregulars. Most galaxies are dwarf spheriodals…



The Local Group



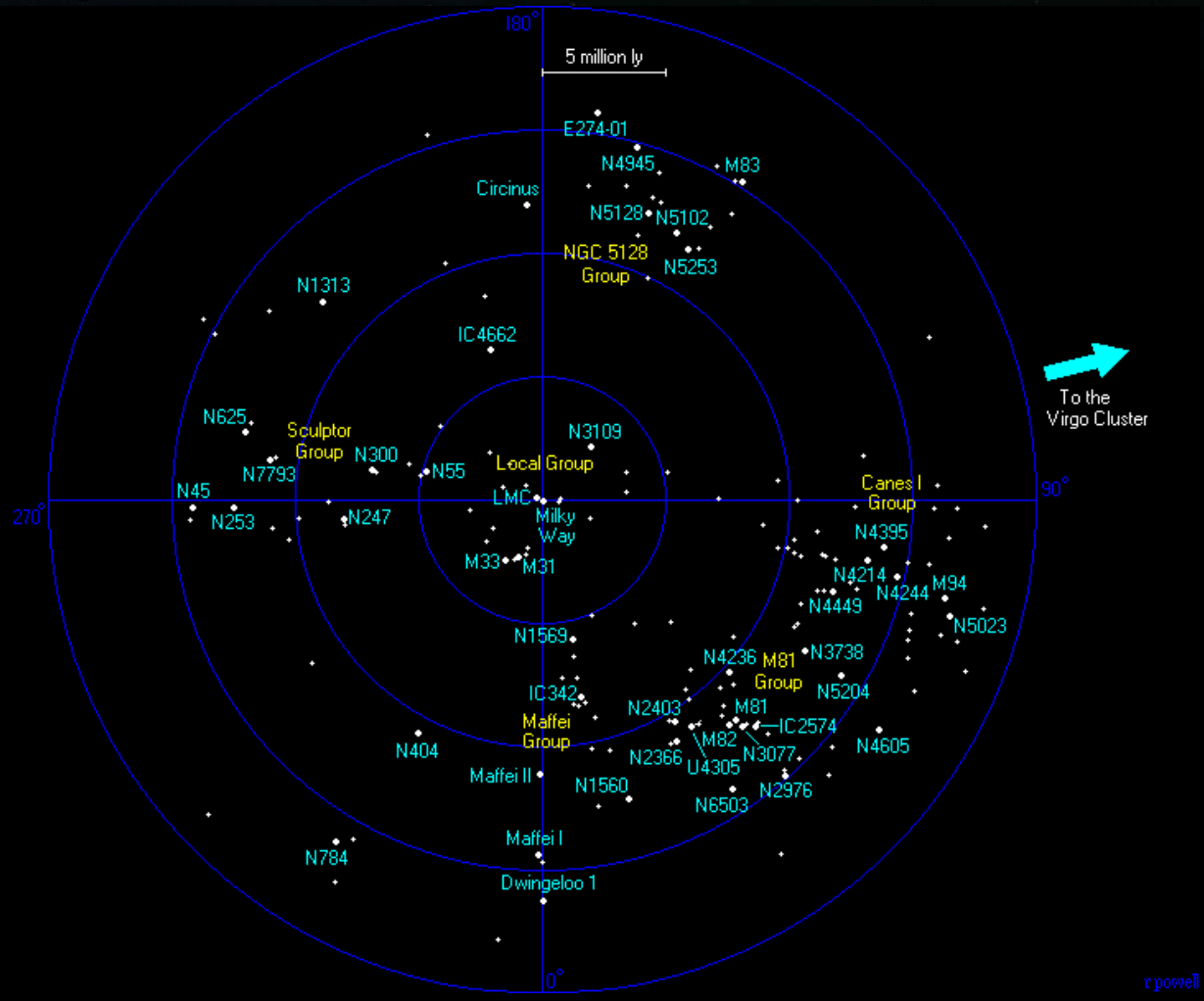
- Giant spirals
- dSph (+dEll)
- dIrr
- dIrr/dSph


Galaxy Groups

Groups of galaxies

- Galaxies can be gravitationally bound to each other, and undergo interactions and collisions.
- Separations across intergalactic distances range from 50 kpc up to 1 Mpc.
- Groups are important physically because one can determine a dynamical mass for the system.
- ALFALFA science goals include studying the effects within the group environment –
  - What is the HI mass function – the mass density of a given environment?
  - How do unseen HI clouds/starless galaxies effect dynamics?
  - Are their unseen tidal remnants or debris?
  - What are sizes of HI disks?

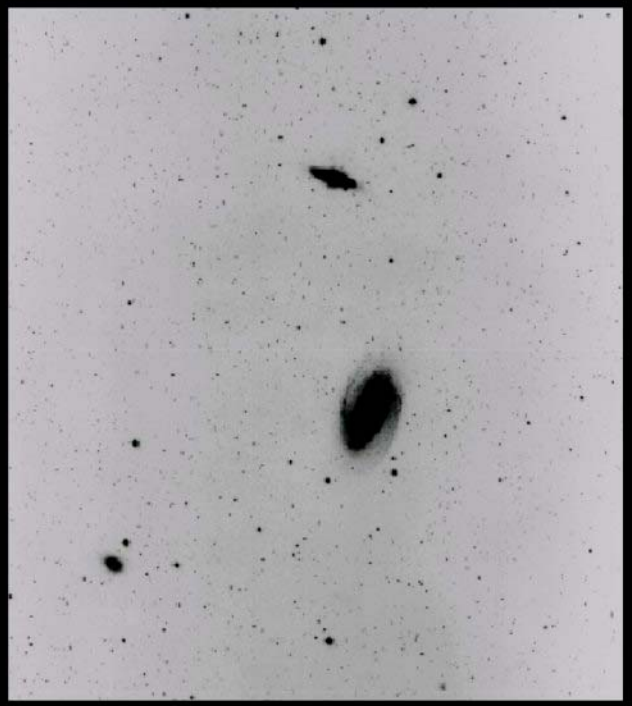
Neighboring Galaxy Groups



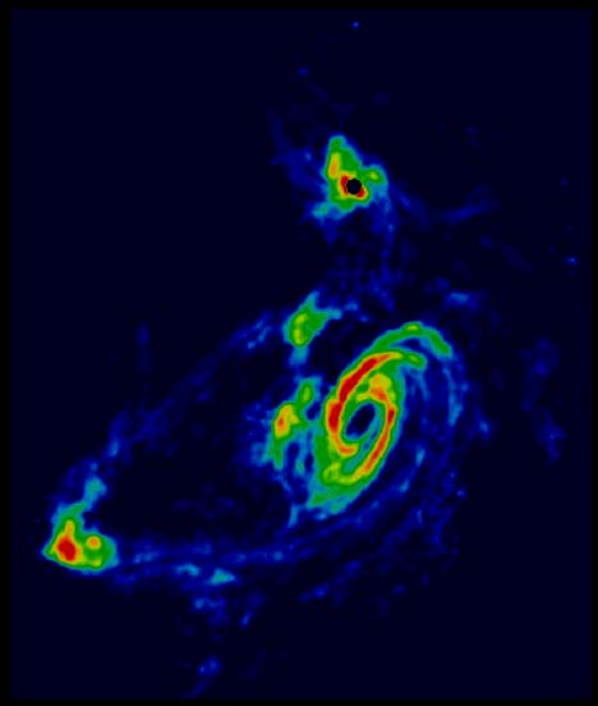
Groups of galaxies

TIDAL INTERACTIONS IN M81 GROUP

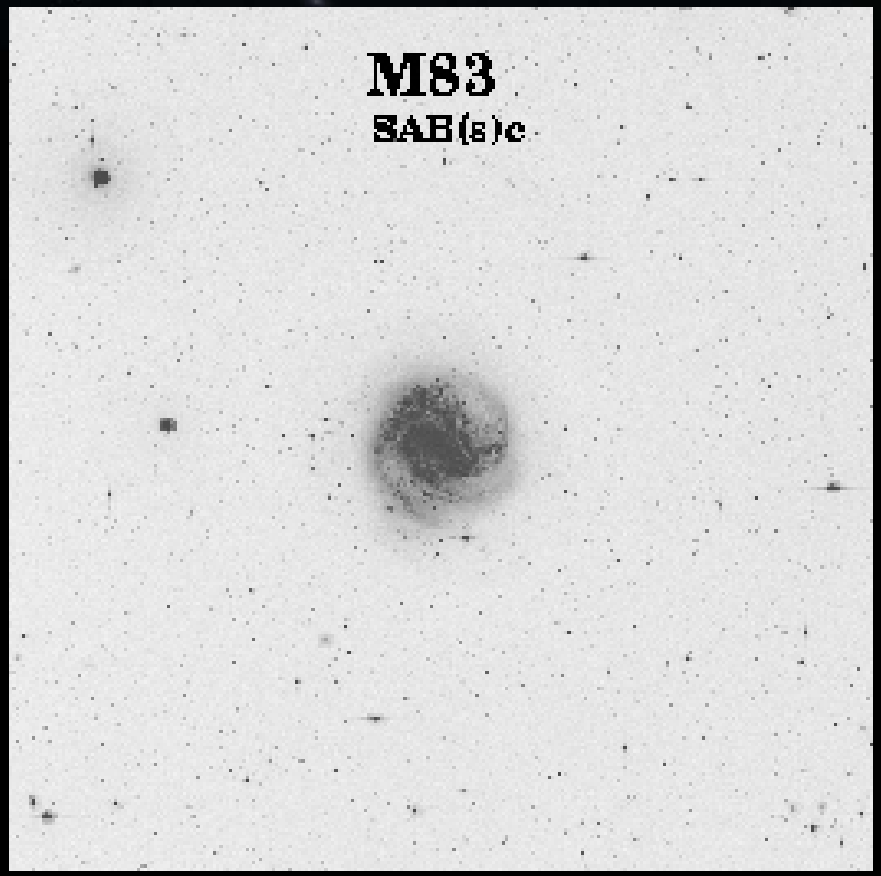
Stellar Light Distribution

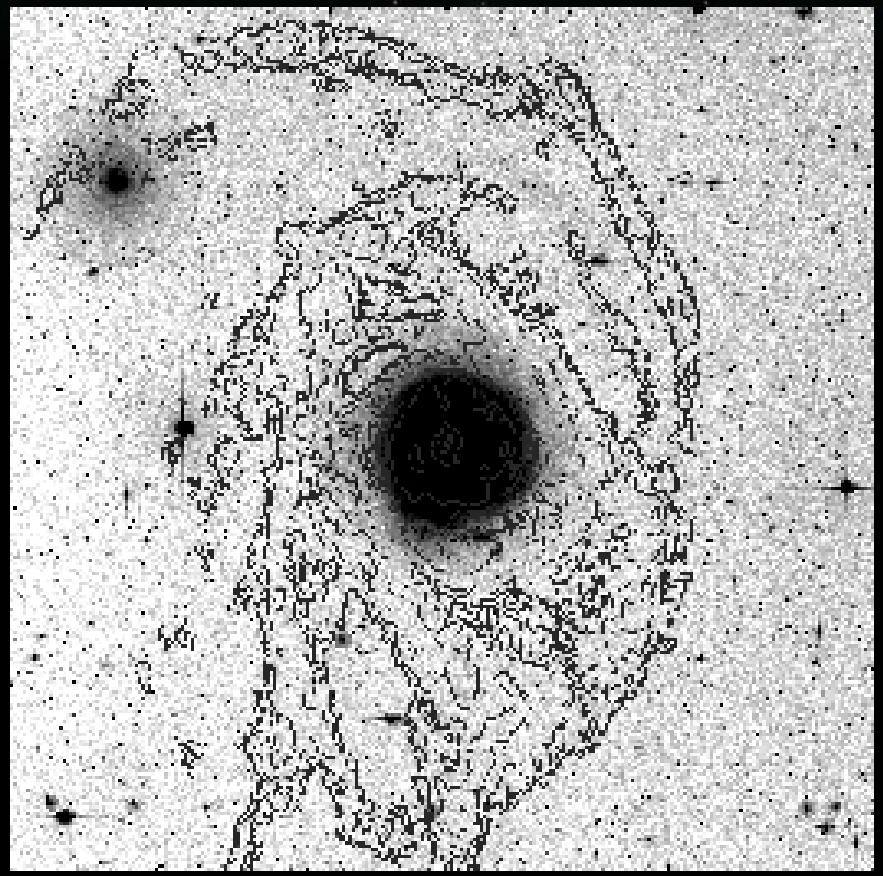


21 cm HI Distribution

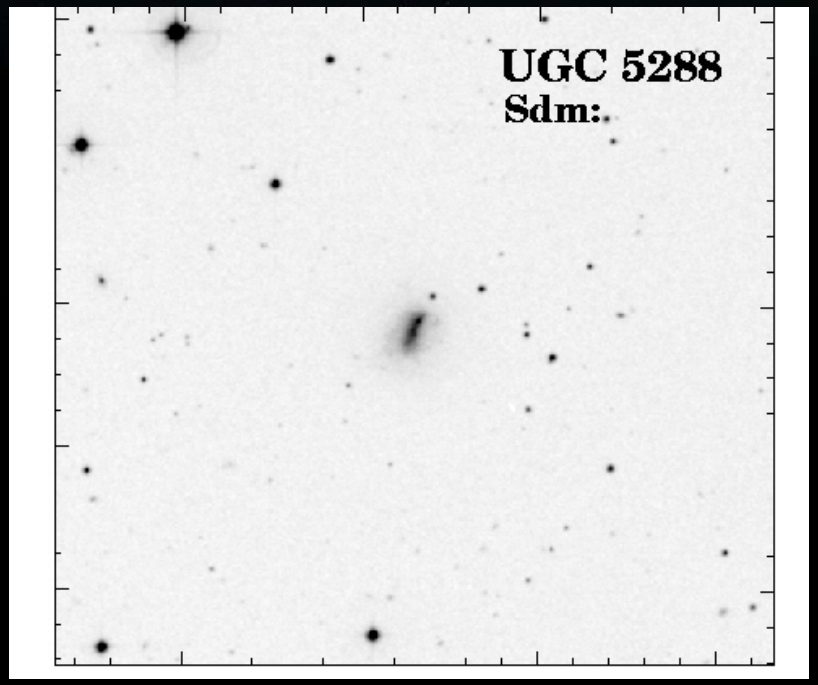


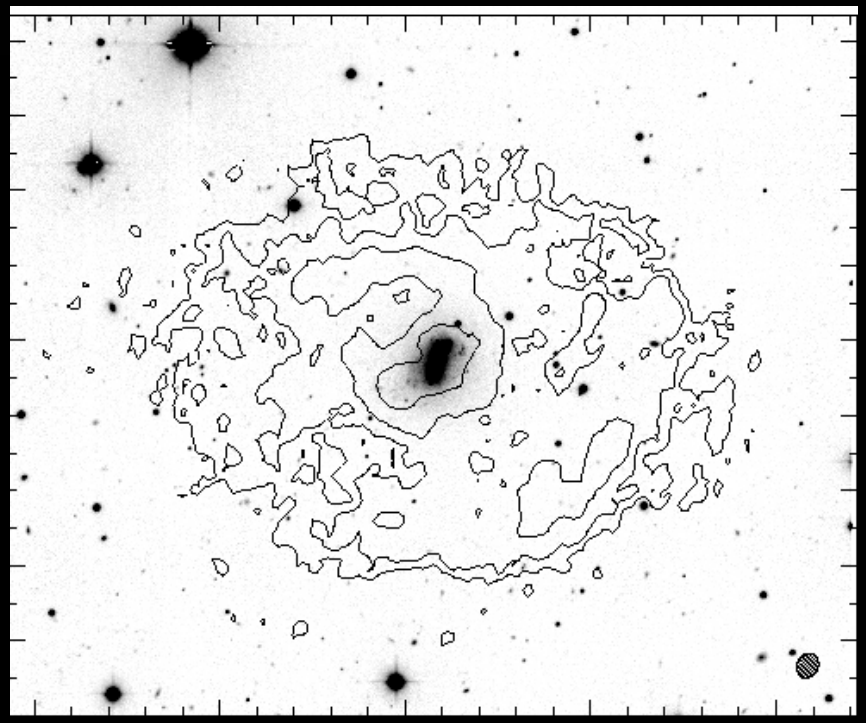
M83 Group



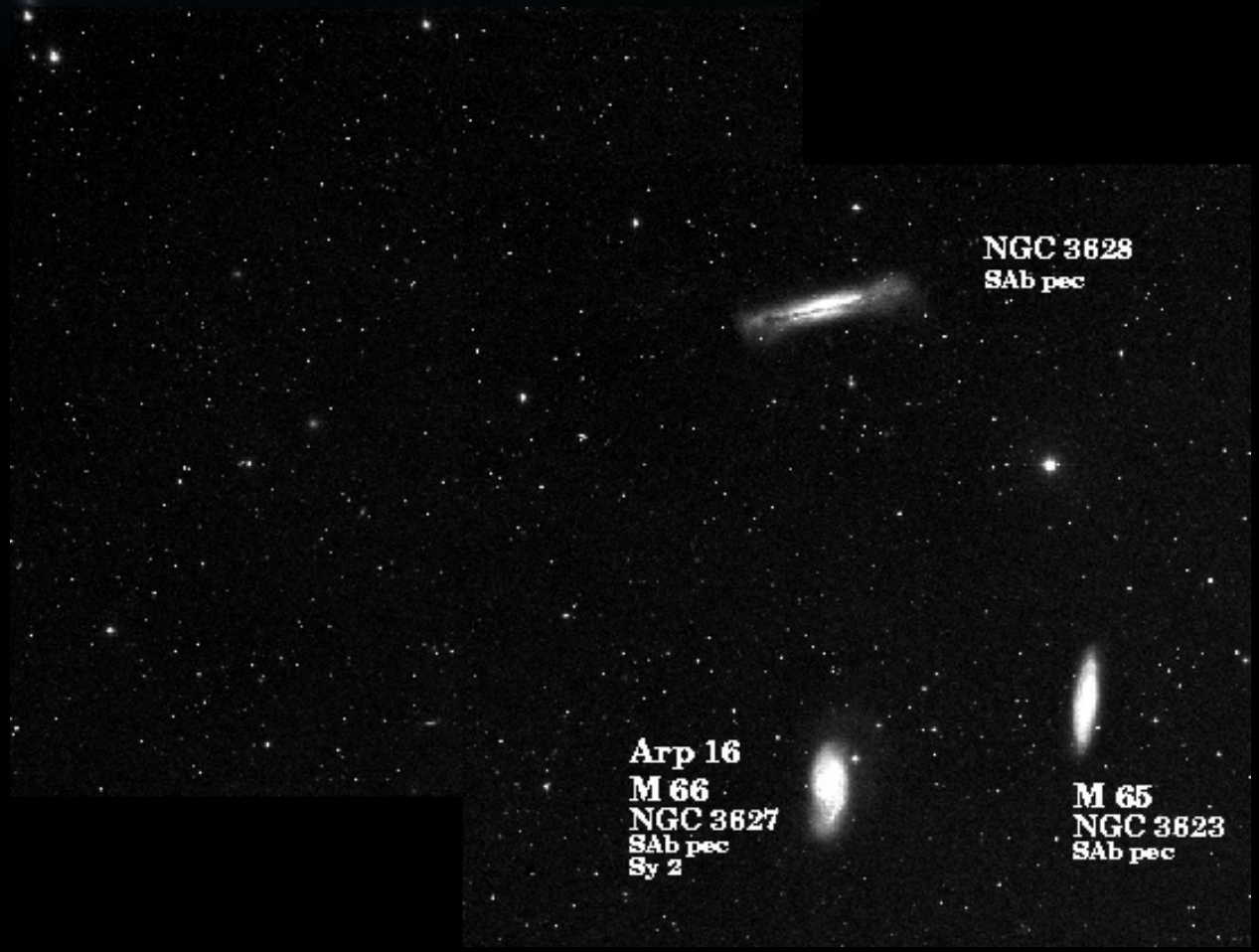


Extended HI Disk of a BCD

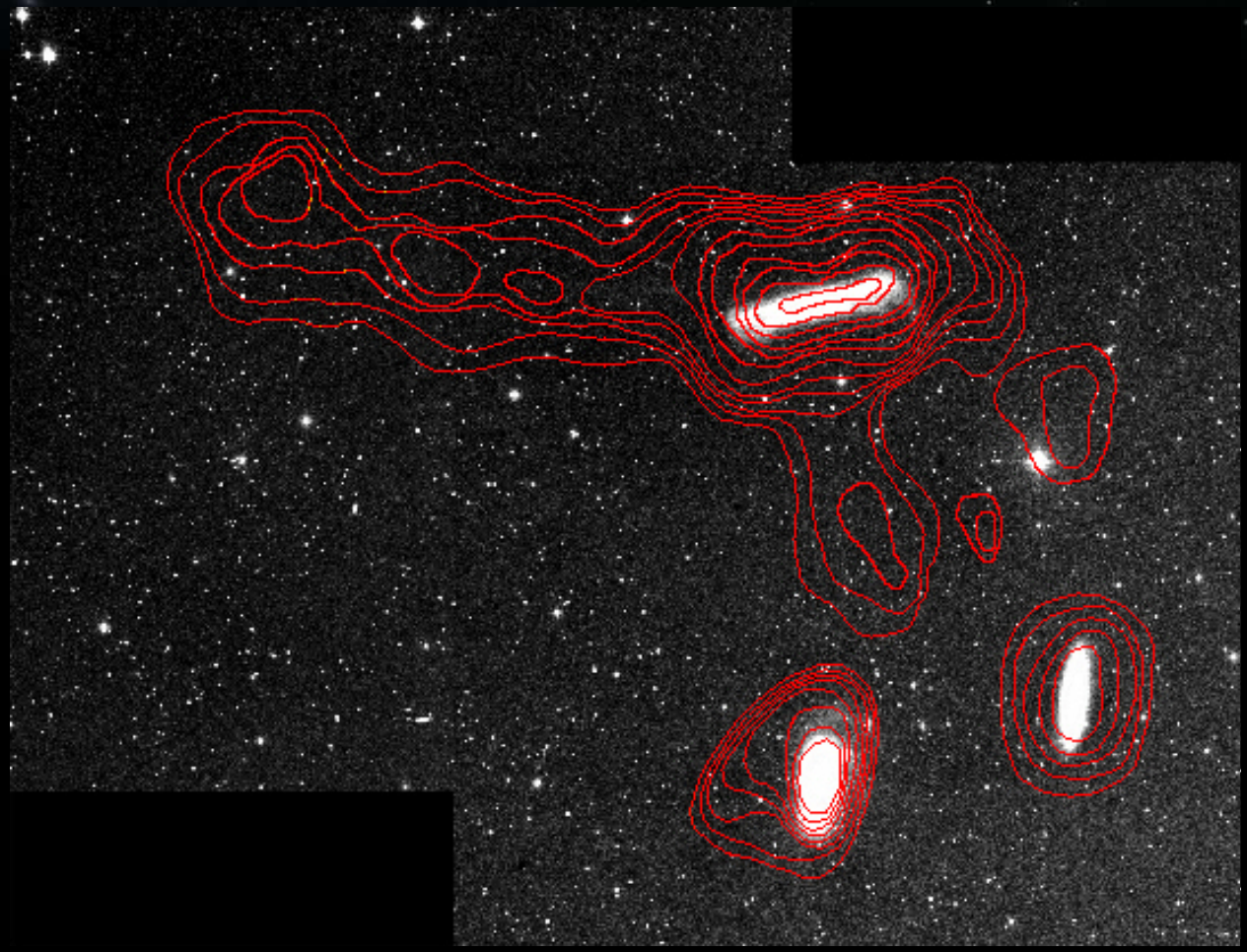




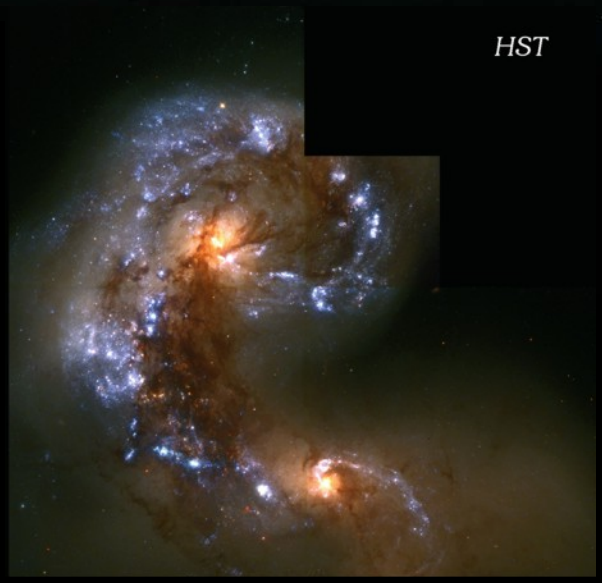
M66 Group


NGC 3628
SAb pec
Arp 16
M 66
NGC 3627
SAb pec
Sy 2
M 65
NGC 3623
SAb pec

M66 Group

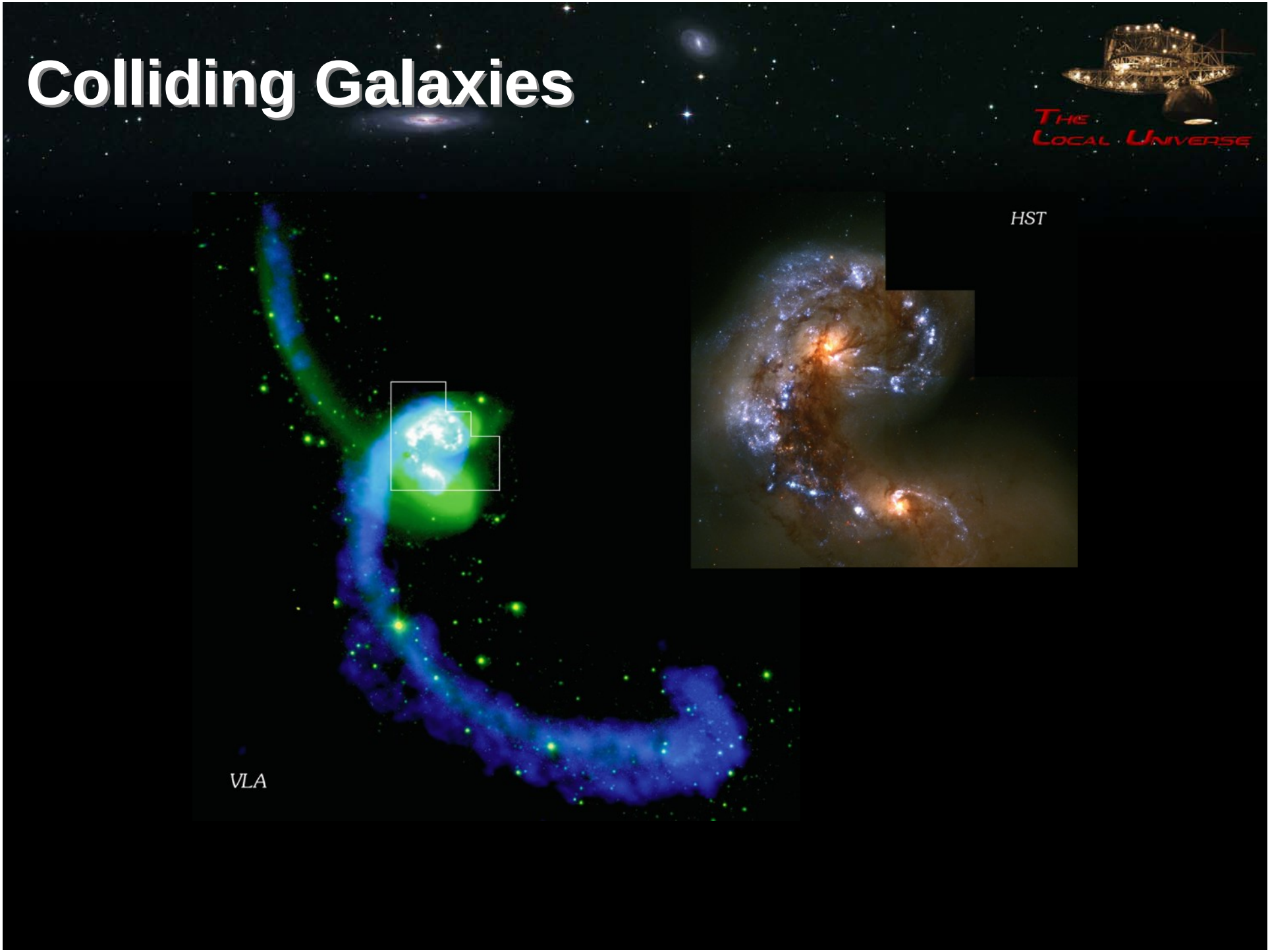


Colliding Galaxies

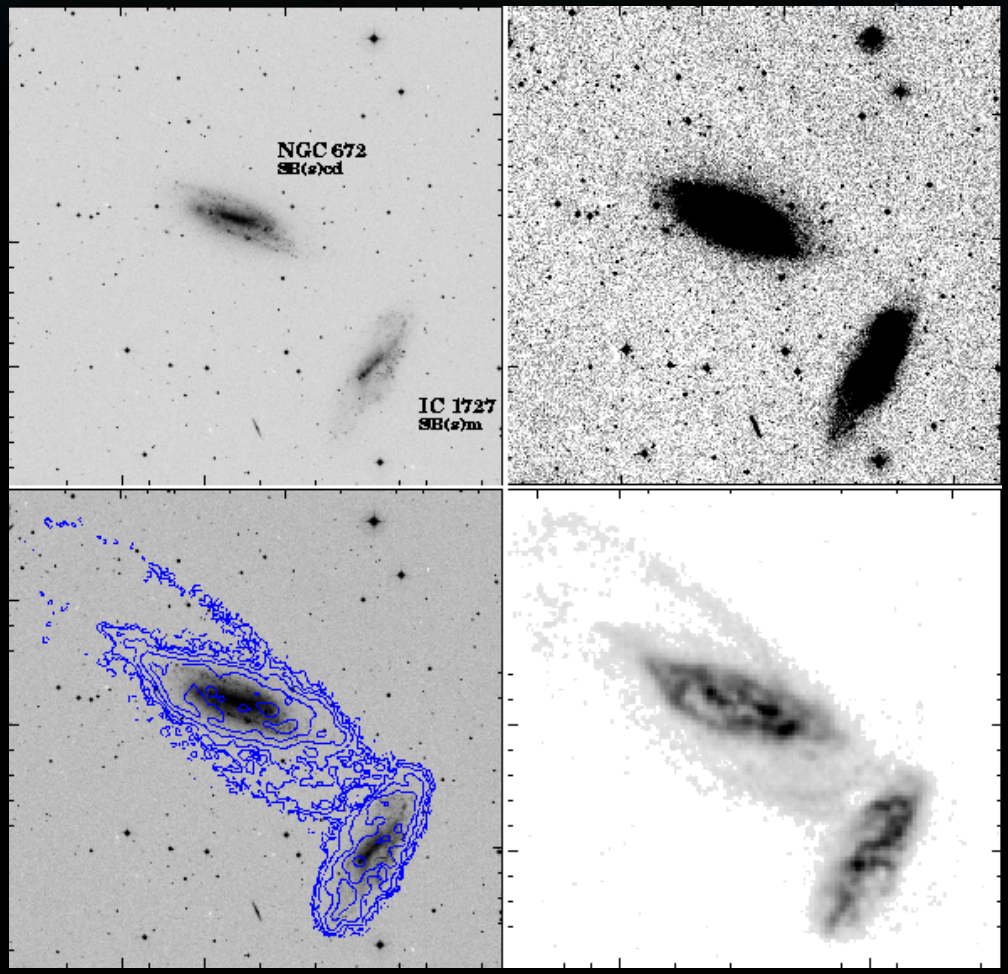


HST

Colliding Galaxies



Colliding Galaxies




Galaxy Clusters

Clusters of Galaxies

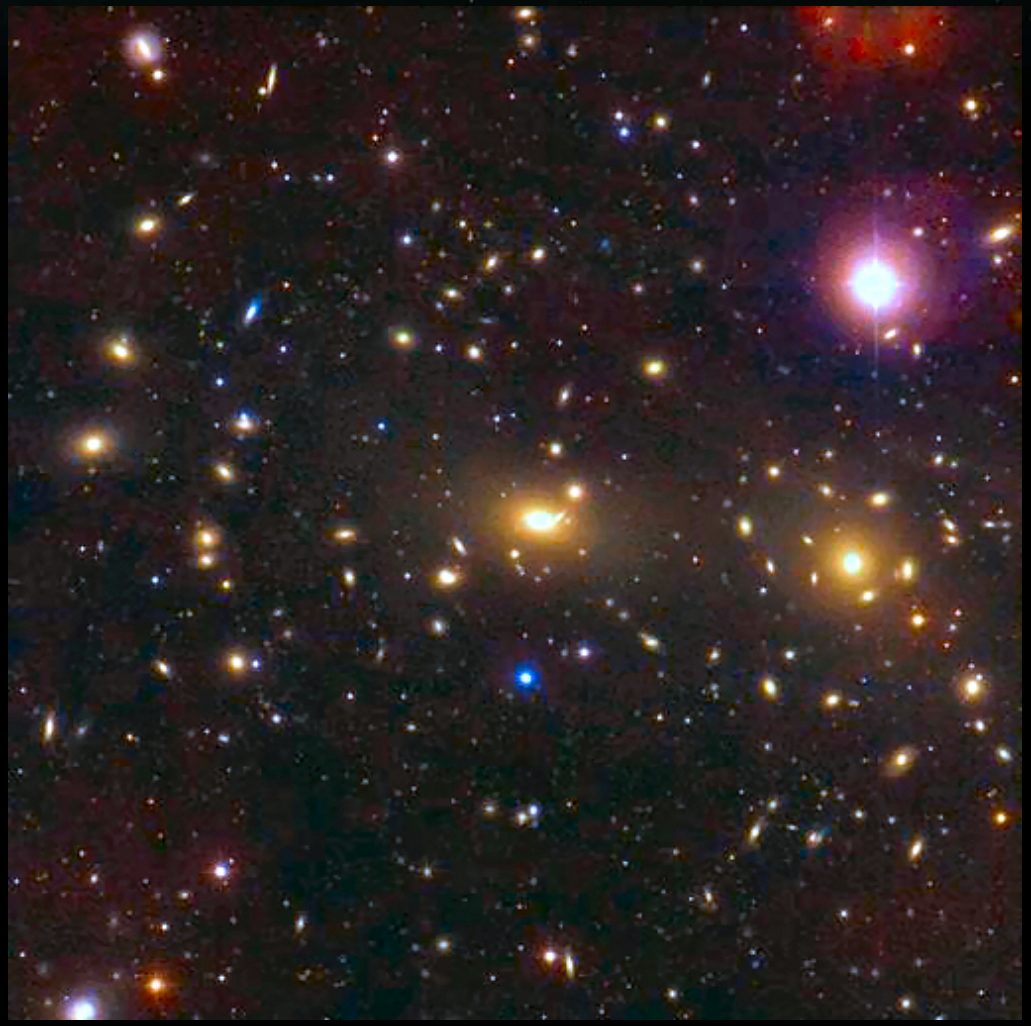
- Around half the galaxies in the Universe are found in clusters or groups.
- Cluster have a higher density than “loose” groups – brightest galaxies are S0s and ellipticals instead of spirals
- Abell Catalog contains 4073 rich clusters
- Gravity binds the members, as well as hot intracluster gas (seen in the X-ray)

Virgo Cluster

- cz ~ 1050 km/s
- Δv ~ 1000 km/s !!
- 1300 catalogued members!!
- Most galaxies are dwarfs
- Core radius ~ 500 kpc

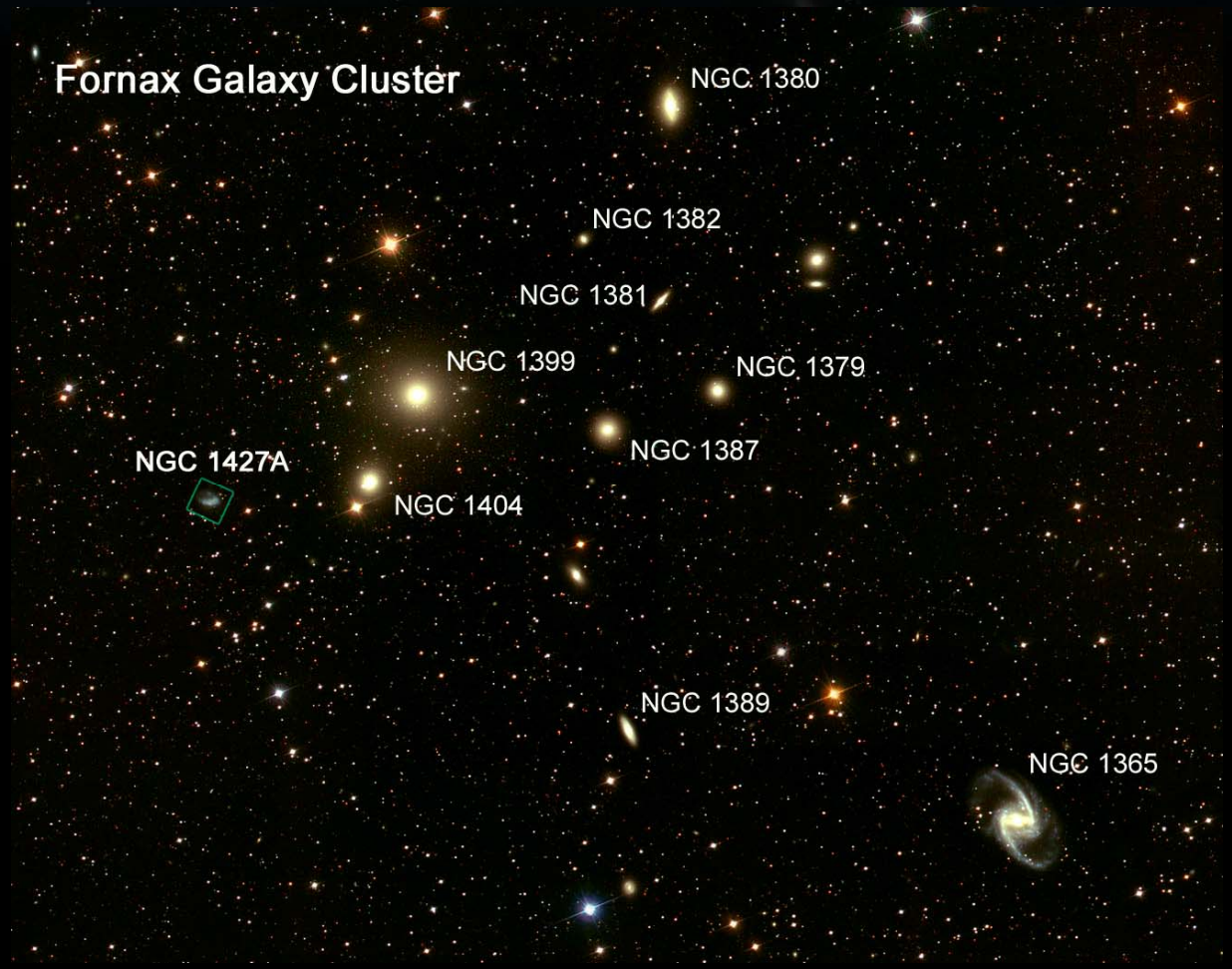
Coma Cluster

- At *cz* = 6900 km/s
- Four times the size of Virgo!!
- Core contains only ellipticals.



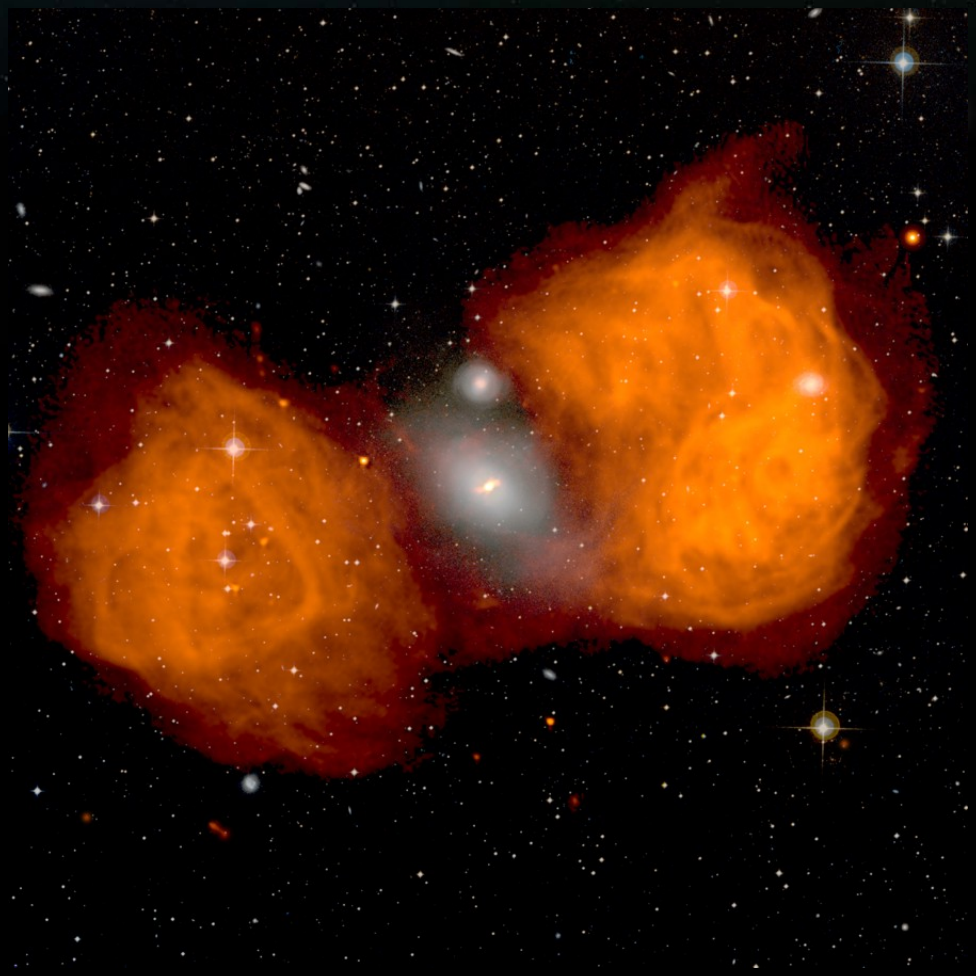
Fornax cluster

- $cz \sim 1400$ km/s



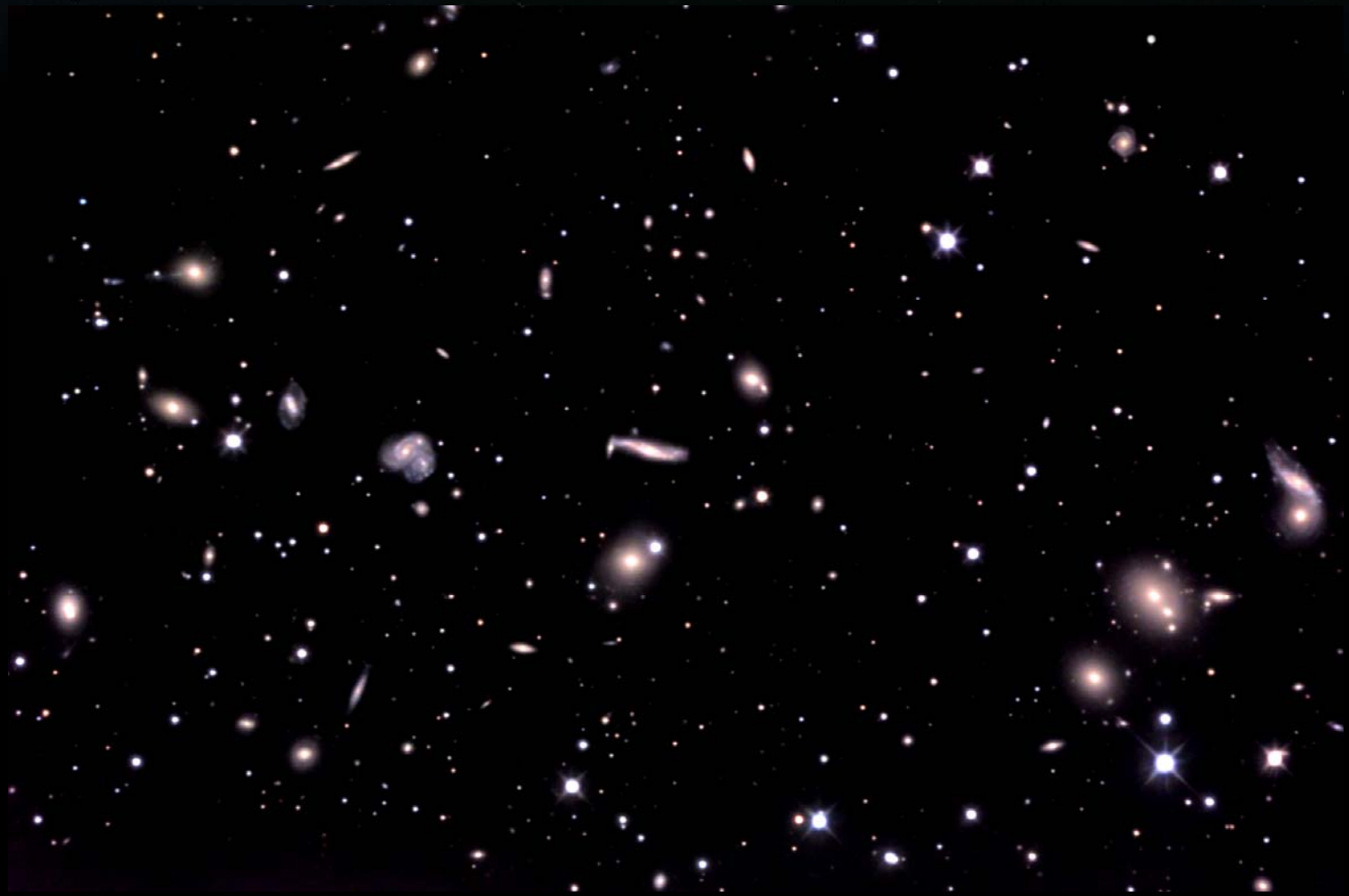
Fornax Cluster – Xray view

Fornax – optical + radio



Hercules Cluster

cz ~ 11,000 km/s



Perseus Cluster

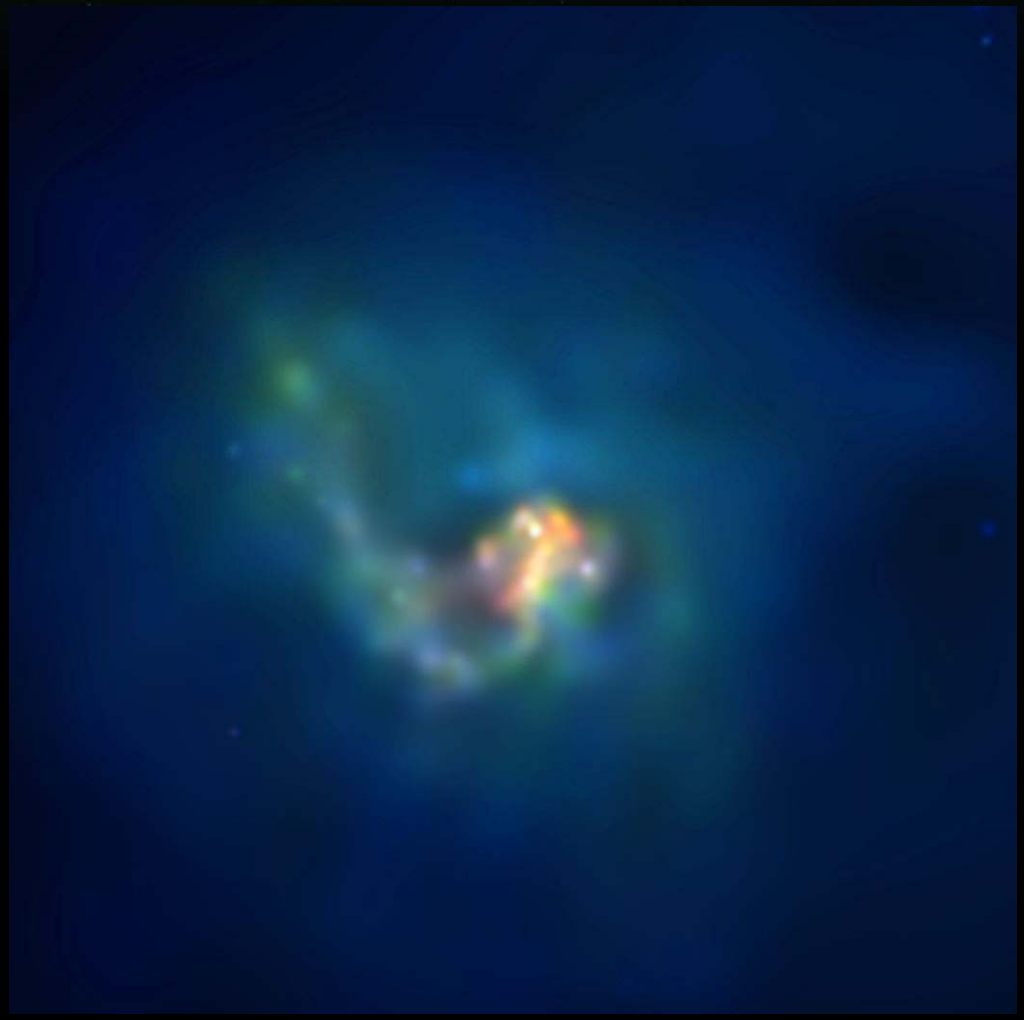
cz ~5000 km/s

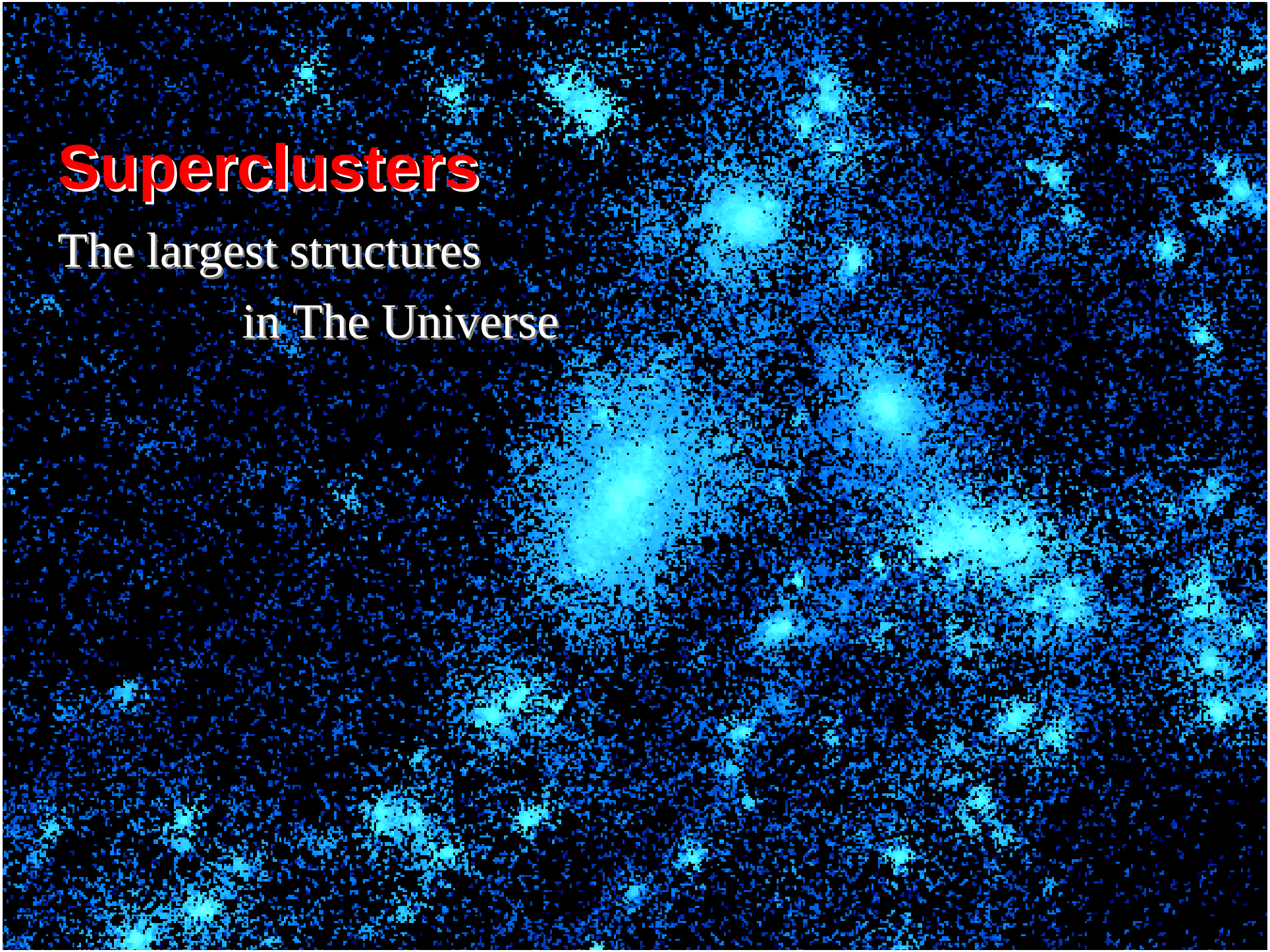
Leo Cluster

- *cz* ~ 6400 km/s

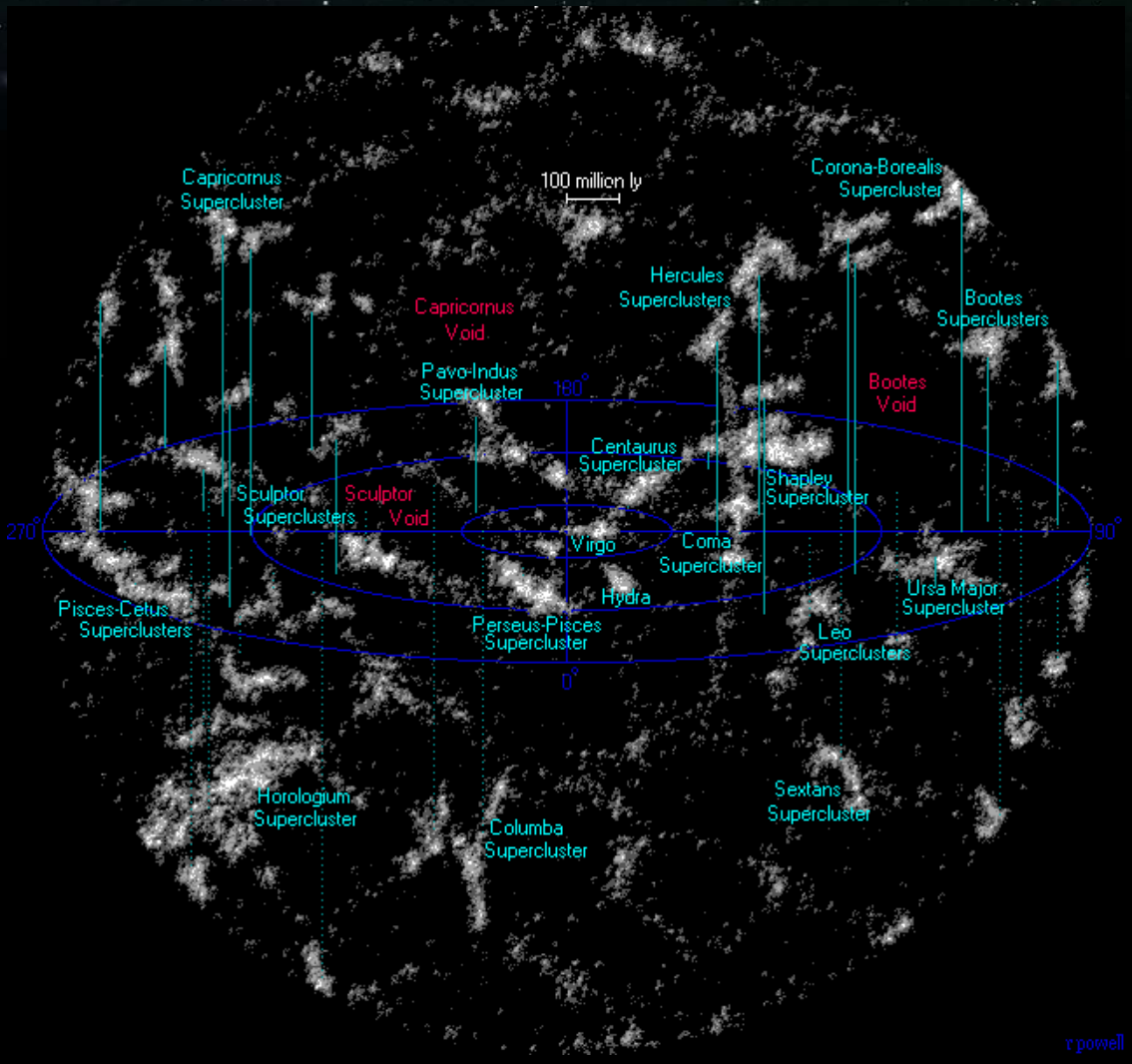
Centaurus Cluster

- *cz* ~ 3000 km/s
- Xray image shows gas expelled from the central member

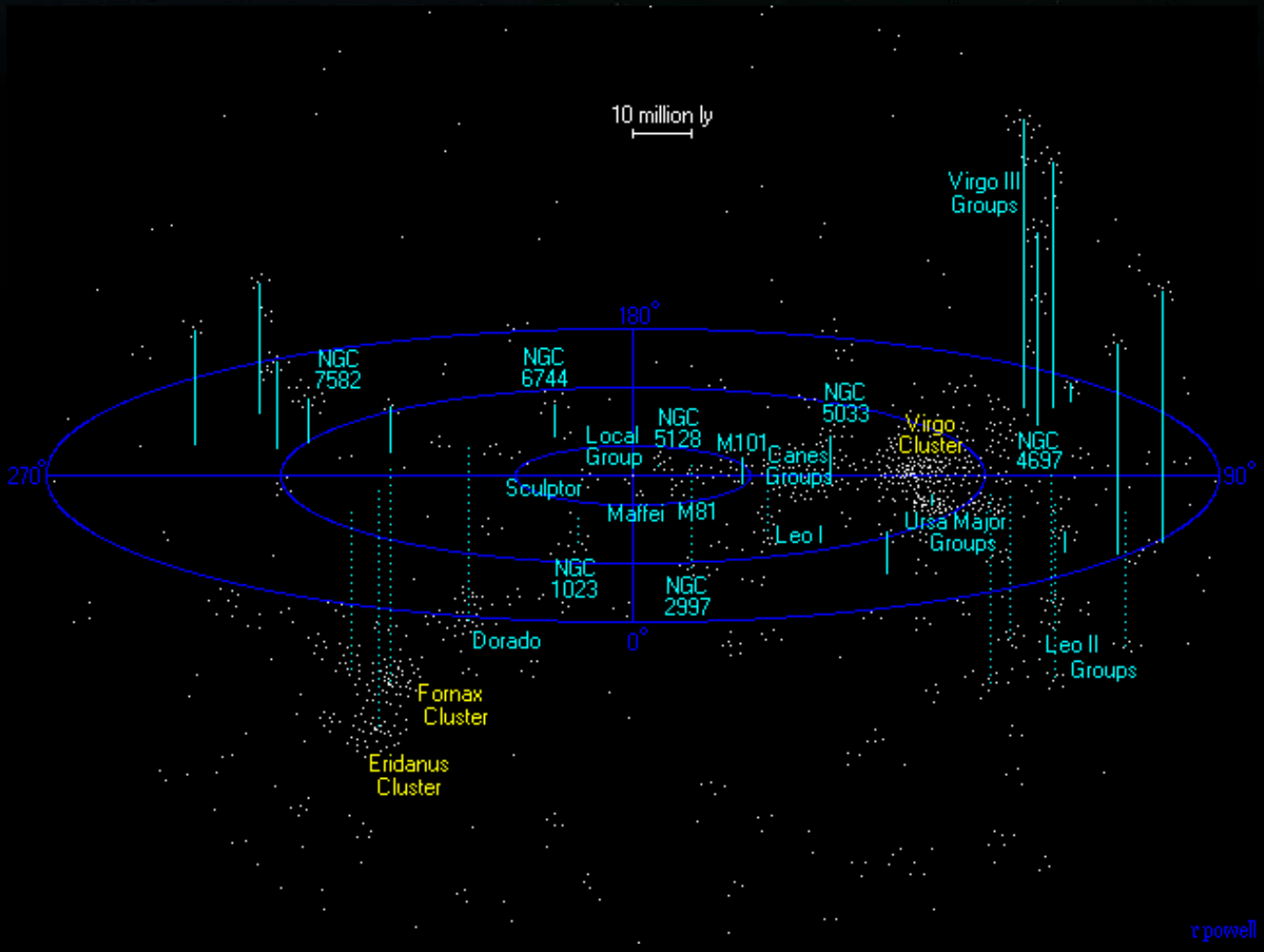



Superclusters
The largest structures
in The Universe

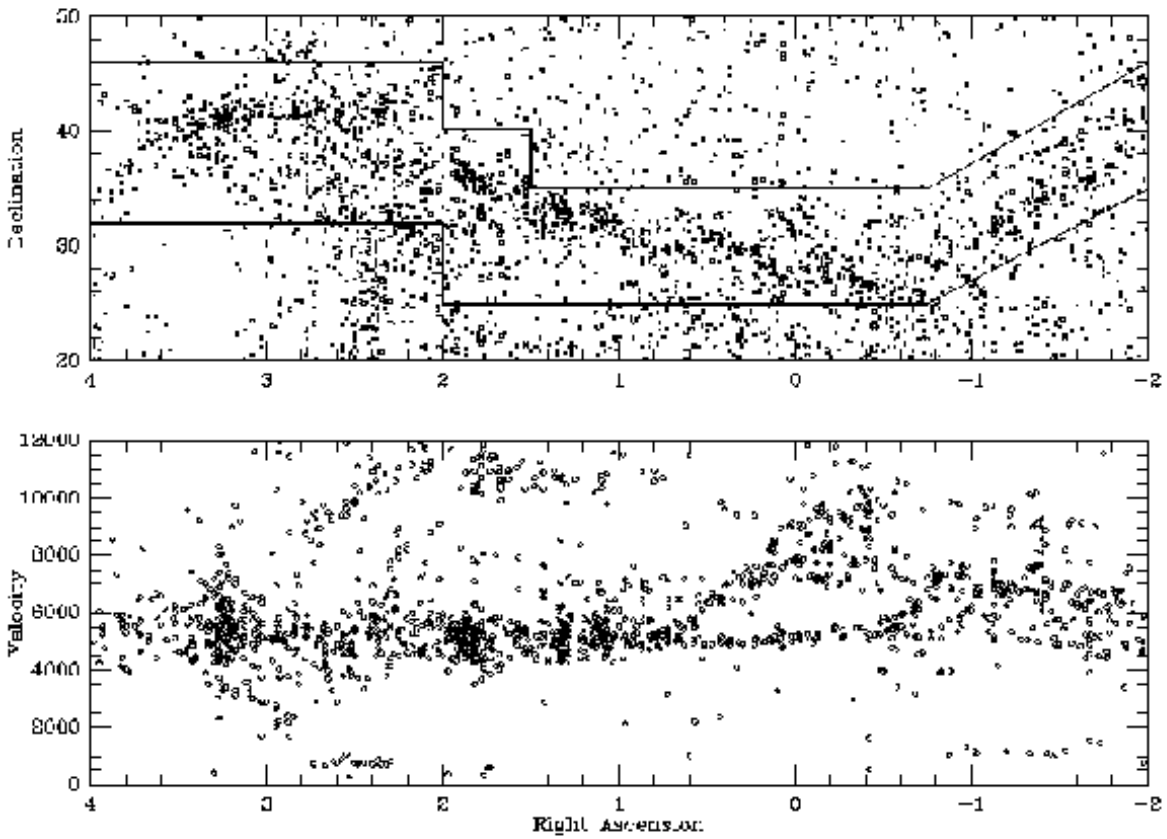
Superclusters in the Universe



Local Supercluster



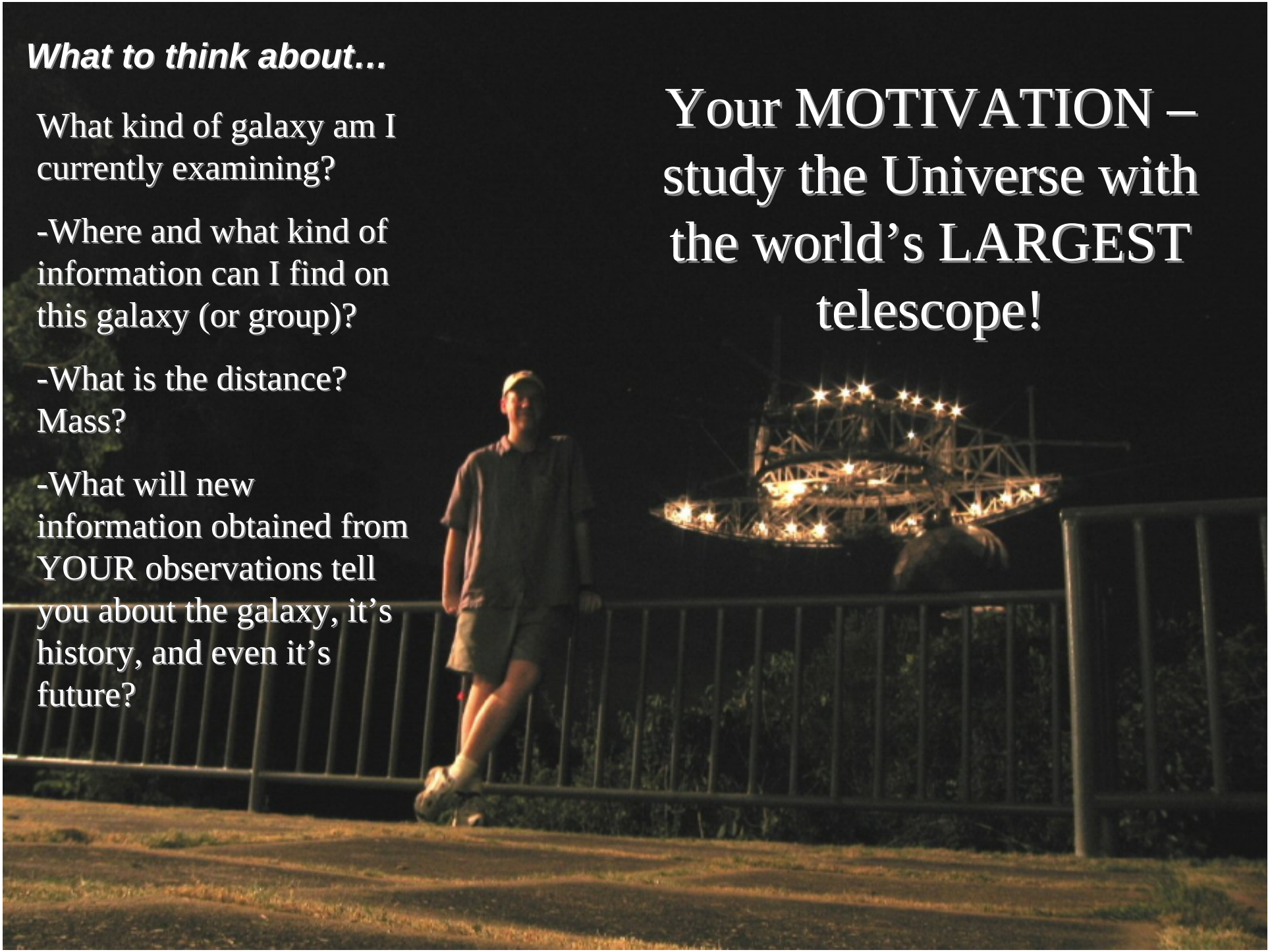
Pisces-Perseus Supercluster



Haynes & Giovanelli

The big picture

- 8800 galaxies from Springob, Haynes, Giovanelli, and Kent 2005 !
- A large collection of HI in galaxies!



What to think about…

What kind of galaxy am I currently examining?

-Where and what kind of information can I find on this galaxy (or group)?

-What is the distance? Mass?

-What will new information obtained from YOUR observations tell you about the galaxy, it's history, and even it's future?

Your MOTIVATION – study the Universe with the world's LARGEST telescope!