Galaxies
and the Universe

Our Local Group

Galaxy Types

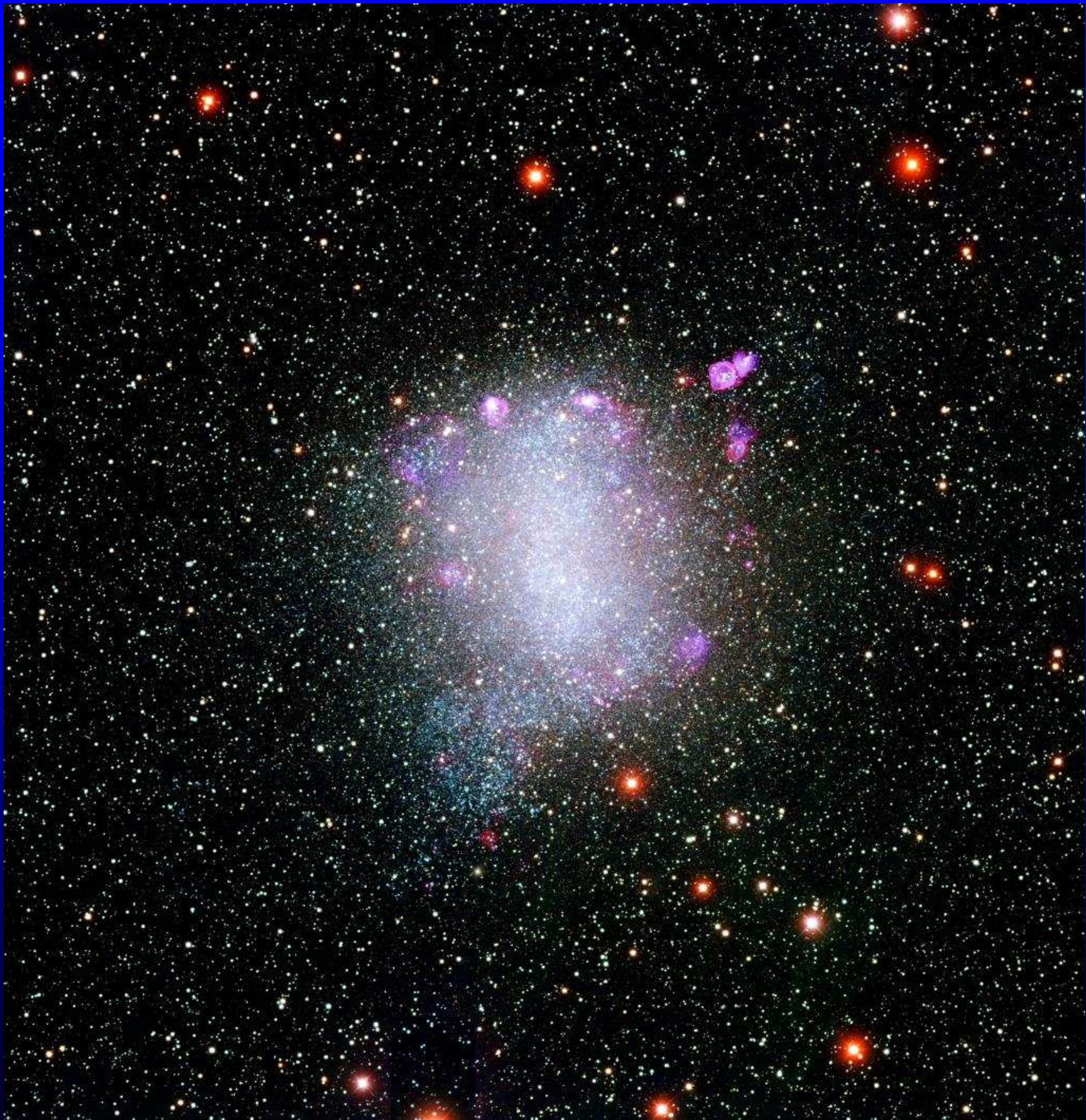
Groups, Clusters and Super-clusters

Large Scale Structure of the Universe

Our Local Group

Large Magellanic Cloud

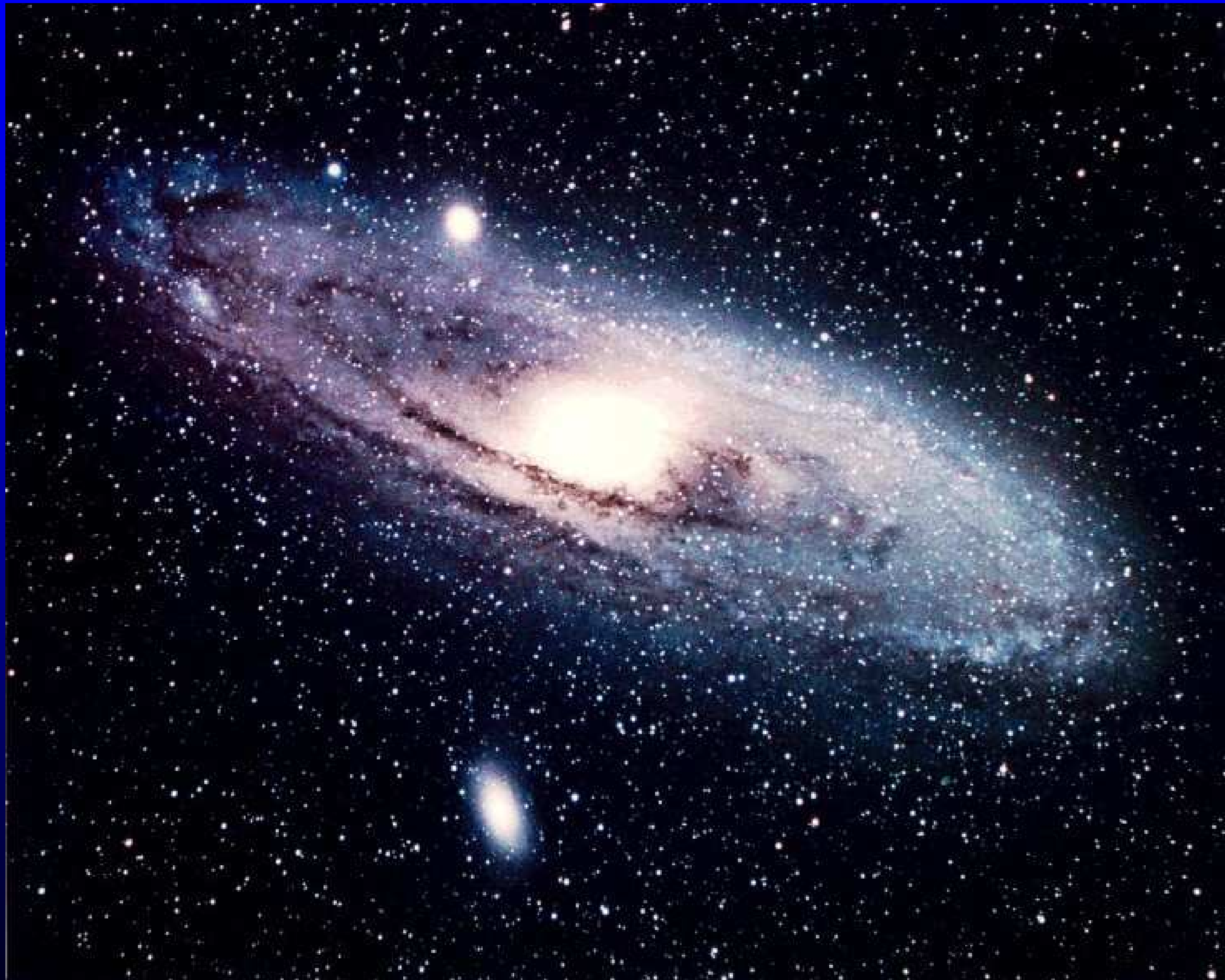
Small Magellanic Cloud



Dwarf Irregular

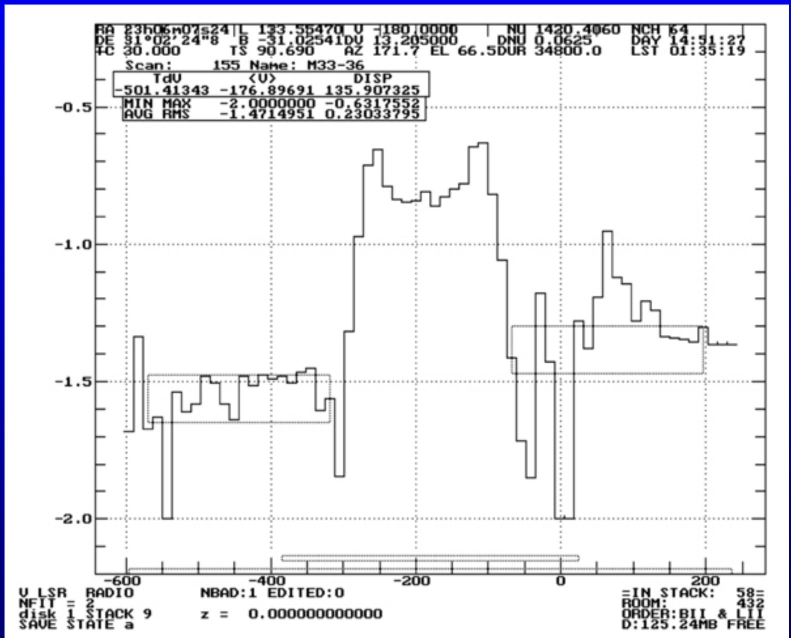
IL 613

The Andromeda Galaxy

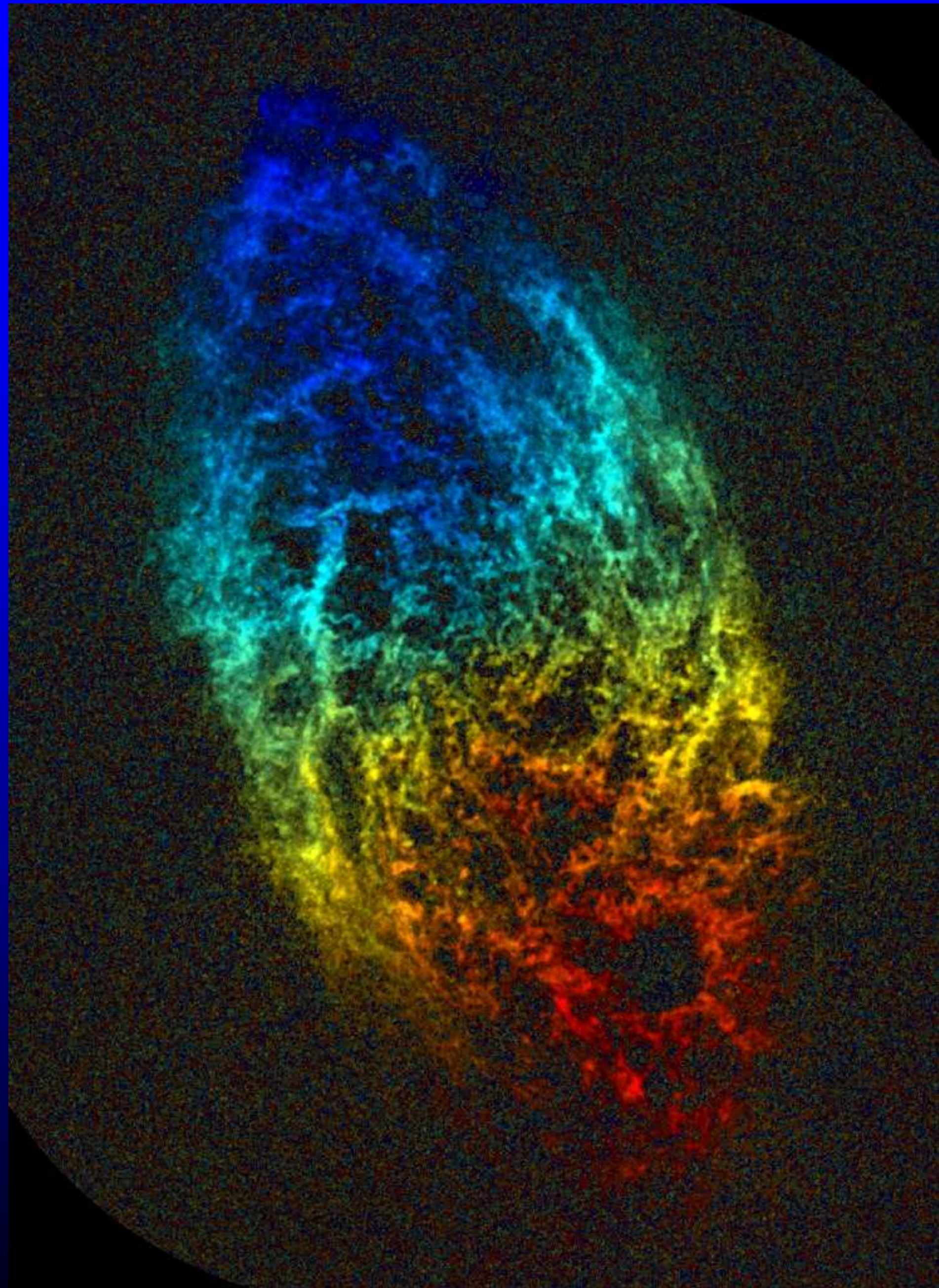


M33

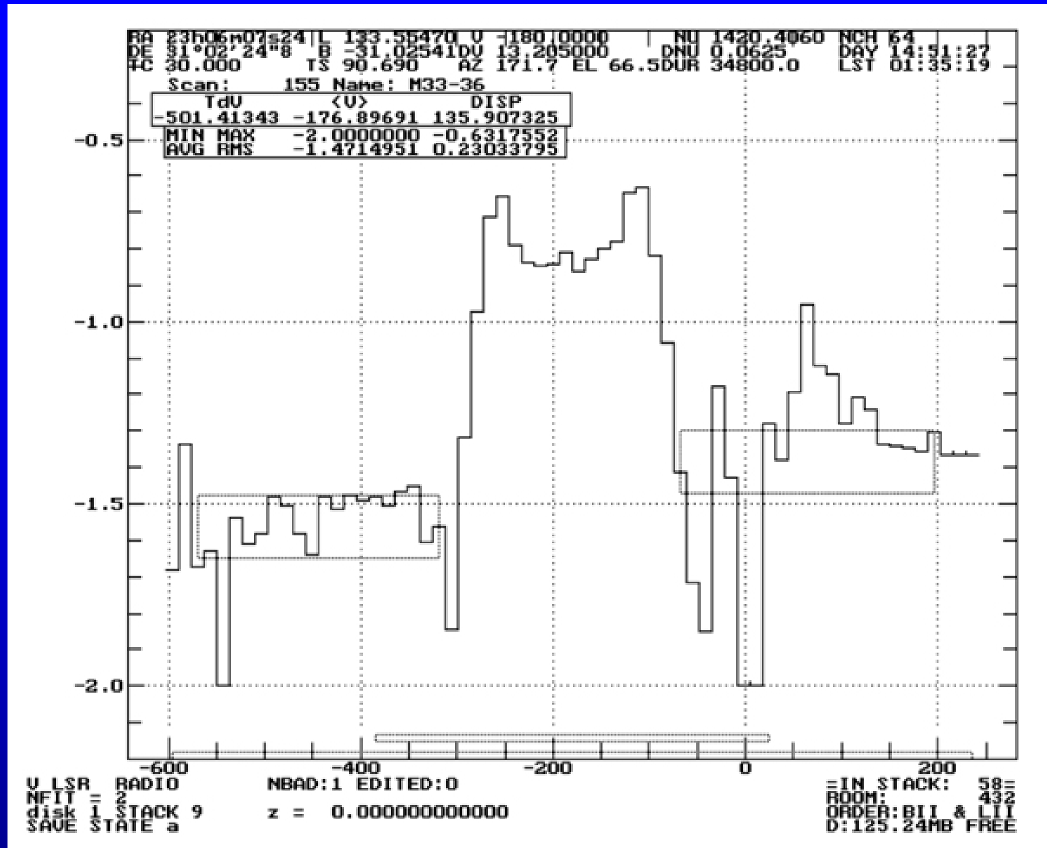
M33 Doppler



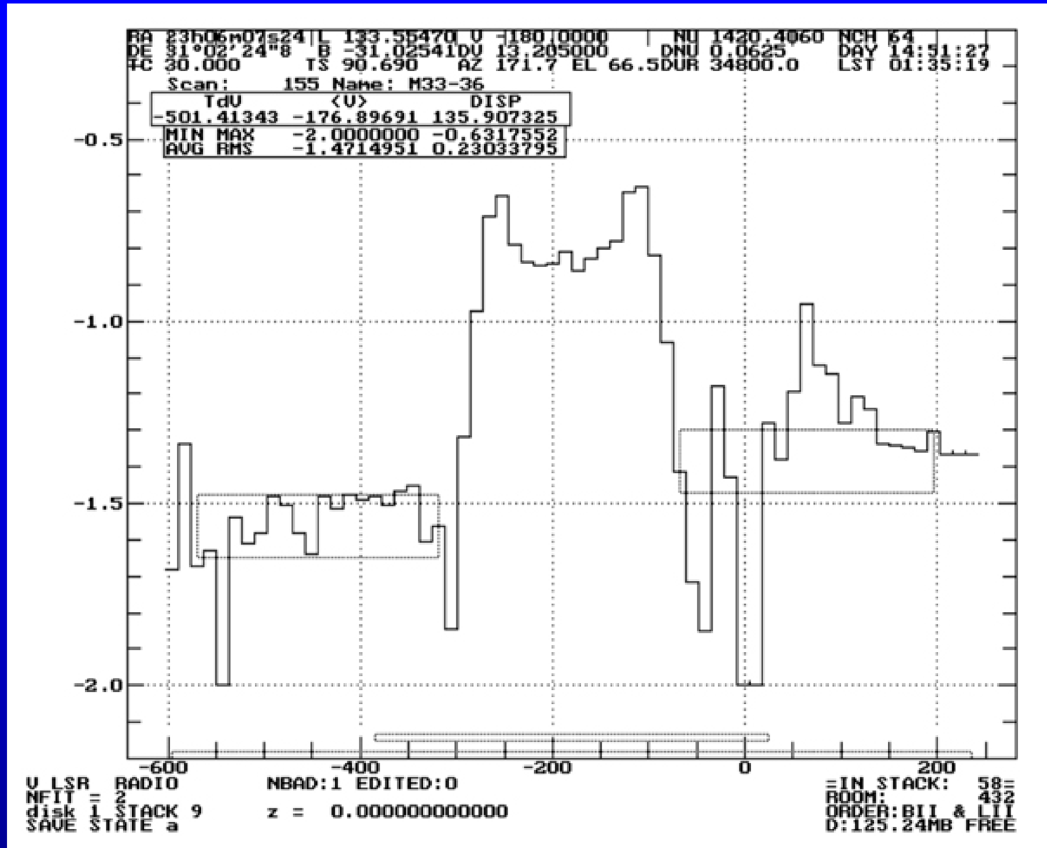
RA 23h06m07s24 L 133.55470 V -180.0000 NU 1420.4060 NCH 64
DE 31°02'24"8 B -31.02541 DV 13.205000 DNU 0.0625 DAY 14:51:27
TC 30.000 TS 90.690 AZ 171.7 EL 66.5 DUR 34800.0 LST 01:35:19
Scan: 155 Name: M33-36
TdV <V> DISP
-501.41343 -176.89691 135.907325
MIN MAX -2.0000000 -0.6317552
AVG RMS -1.4714951 0.23033795
-0.5
-1.0
-1.5
-2.0
-600
-400
-200
0
200
V LSR RADIO
NFIT = 2
disk 1 STACK 9
SAVE STATE a
NBAD:1 EDITED:0
z = 0.000000000000
=IN STACK: 58=
ROOM: 432
ORDER:BII & LII
D:125.24MB FREE



M33 Spectrum



1) The H-line spectrum is centred at a velocity of –175 km/sec. This tells us that the Galaxy as a whole is coming towards us at a speed of 175 km/sec. (- values towards us!)



- The spectrum has a width of ~ 200 km/sec. This tells us that the galaxy is rotating. The outer parts on one side are coming towards us at ~100km/sec, the other away from us at ~ 100 km/sec.

We can calculate Mass!

- From an image of the galaxy and its distance we can calculate its radius.
- M33 is ~ 73 arc minutes across.
- It lies at a distance of 2.36×10^{22} m.
- 73 arc minutes is 73/ (60 x 57.3) = 2.1×10^{-2} radians
- Radius of M33 is thus $0.5 \times 2.1 \times 10^{-2} \times 2.36 \times 10^{22}$ m.

  = 2.47×10^{20} m.
- The gravitational force on a star at this distance to overcome centripetal acceleration
  - $G M m / r^2 = m v^2 / r$

  (M = mass of Galaxy, m = mass of star, r = distance of star from centre

  v = velocity of star around centre)

Mass of M33

- This gives: $M = r\,v^2/G$

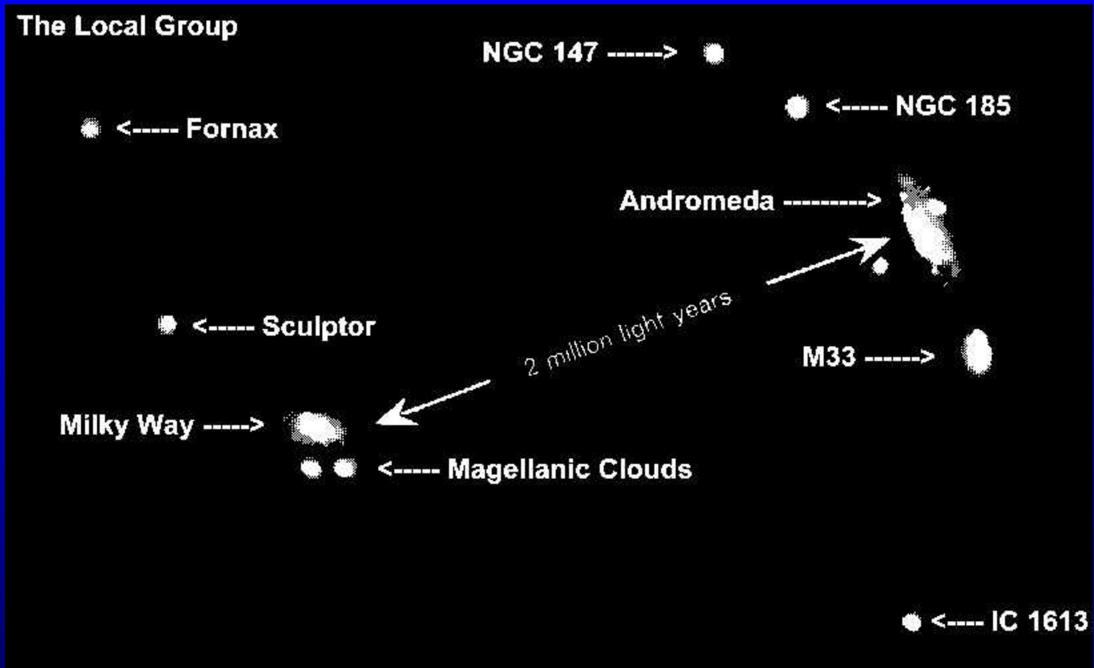
$= 2.47 \times 10^{20} \times (1 \times 10^5)^2 / 6.67 \times 10^{-11}$ kg

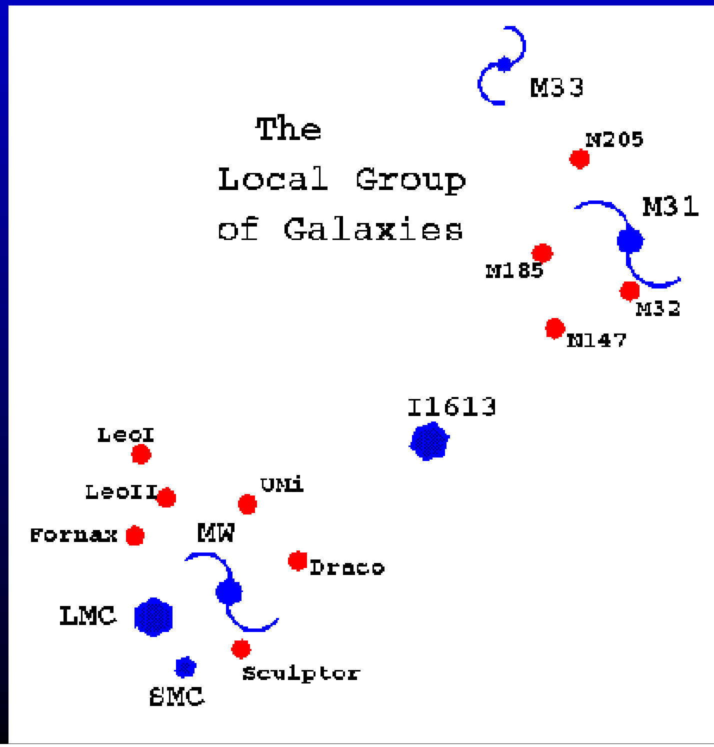
$= 3.66 \times 10^{40}$ kg

$= 3.66 \times 10^{40} / 2 \times 10^{30}$ solar masses

$= \sim 18{,}000$ Million solar masses.

The distribution of galaxies in our Local Group





Galaxy Types

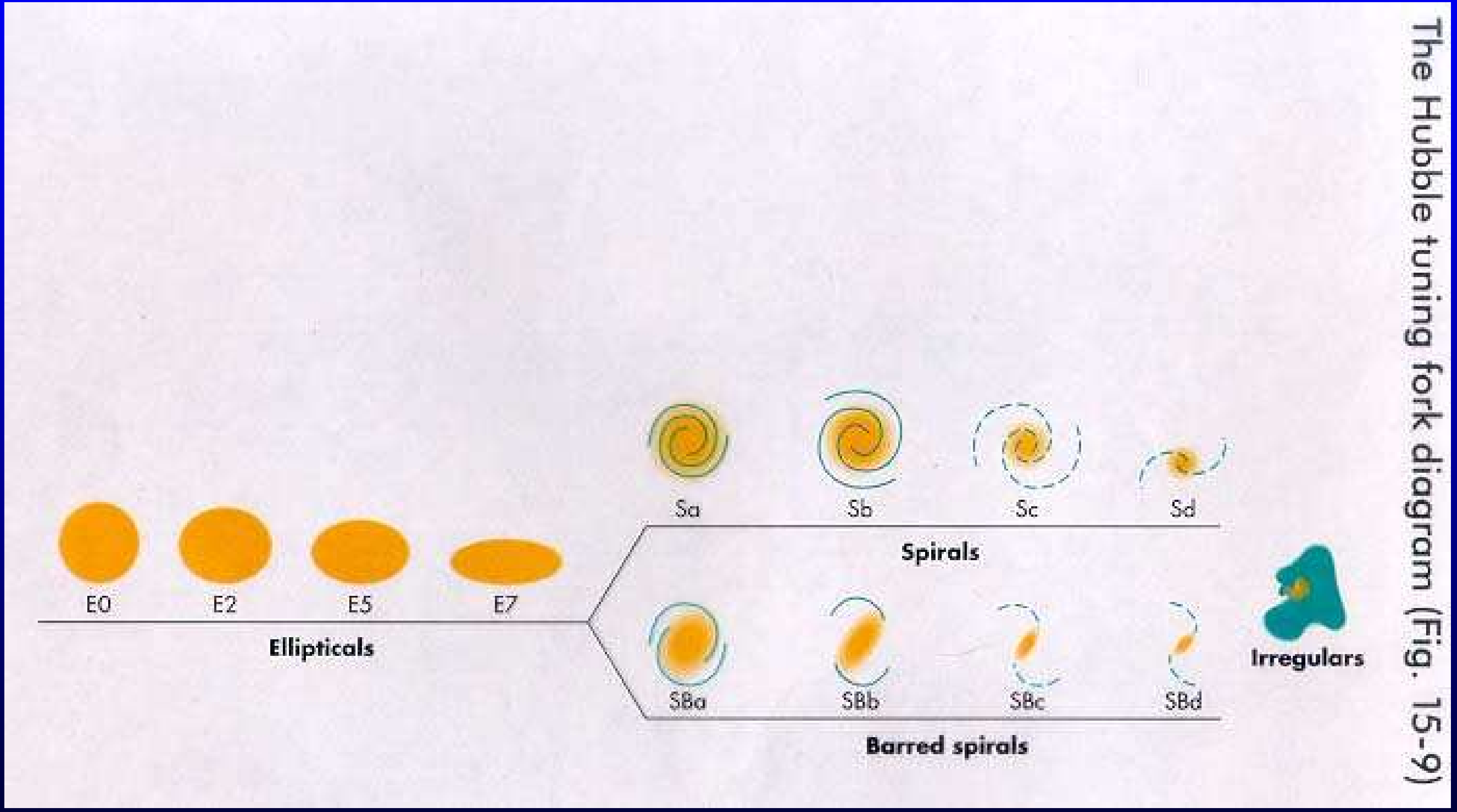
The Hubble Classification:

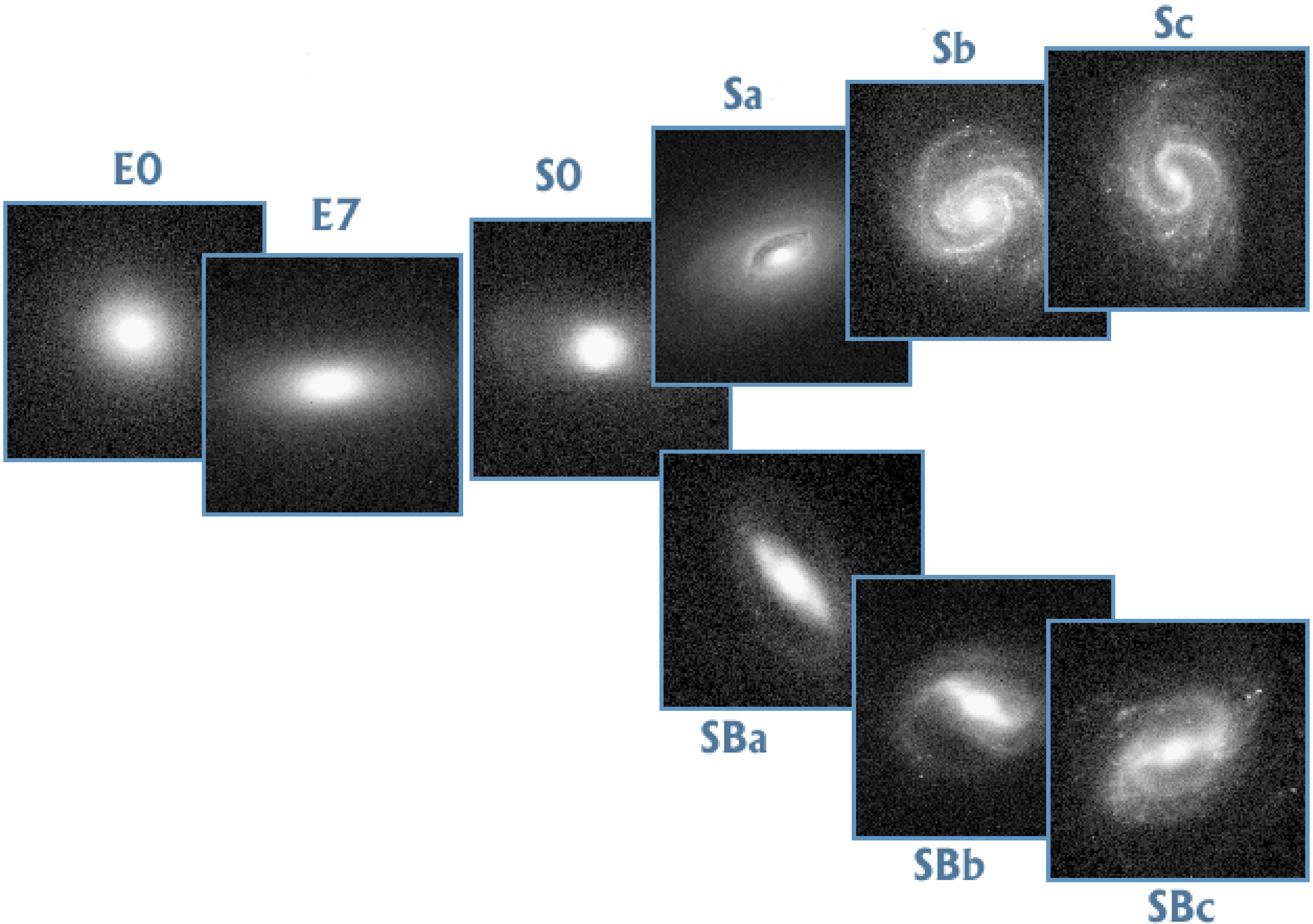
Elliptical Galaxies

Spiral Galaxies

Irregular galaxies

Hubble Classification





E0
E7
S0
Sa
Sb
Sc
SBa
SBb
SBc

Ellipticals

Giant Ellipticals

and

Dwarf Ellipticals

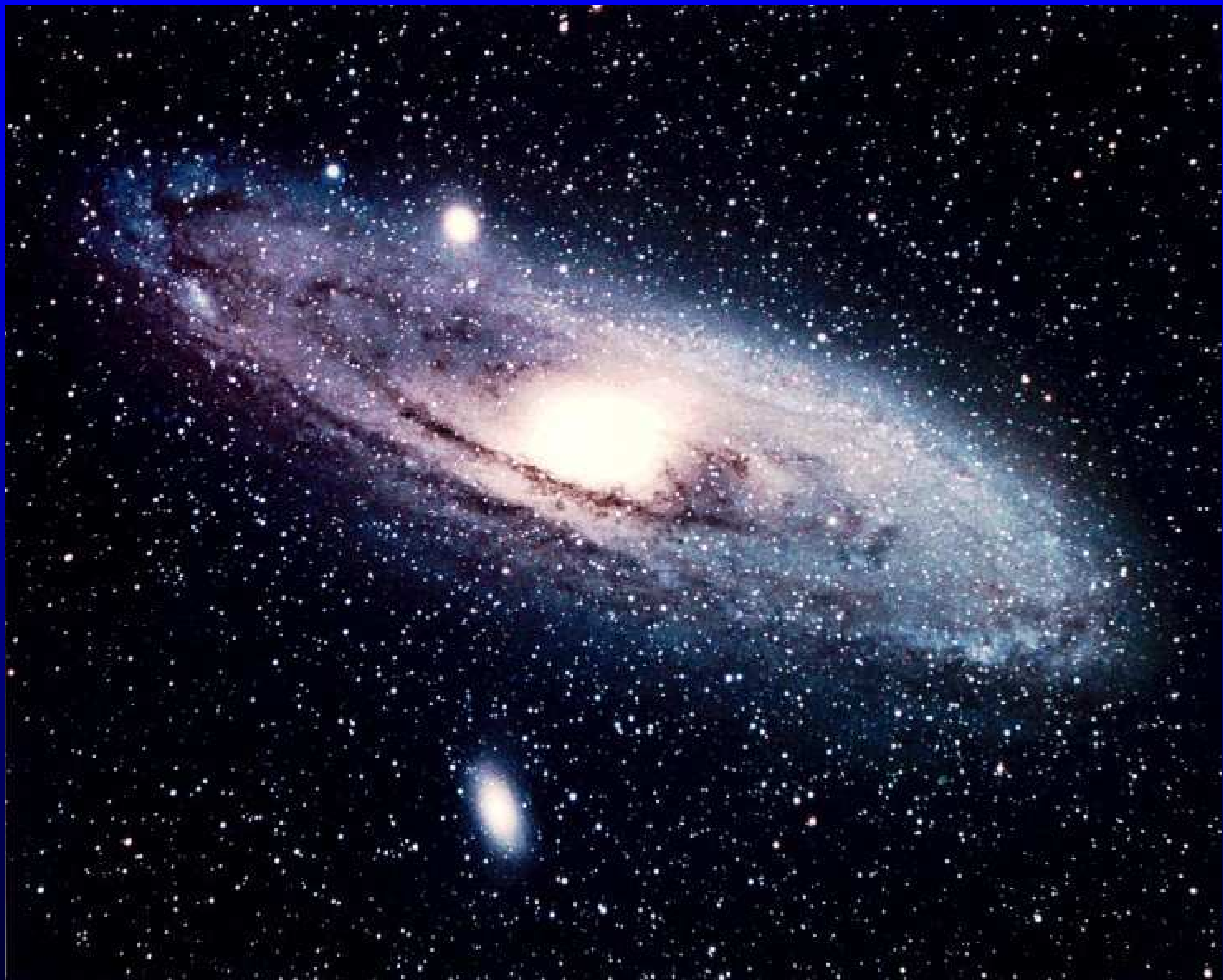
Elliptical Classification

- From E0 to E7 dependant on the perceived ellipticity.
- E0 spherical, E7 highly elongated.
  - NB a highly elliptical galaxy seen end on will still be classified as E0!

Giant Ellipticals

- Found at the heart of large clusters of galaxies.

Dwarf Ellipticals



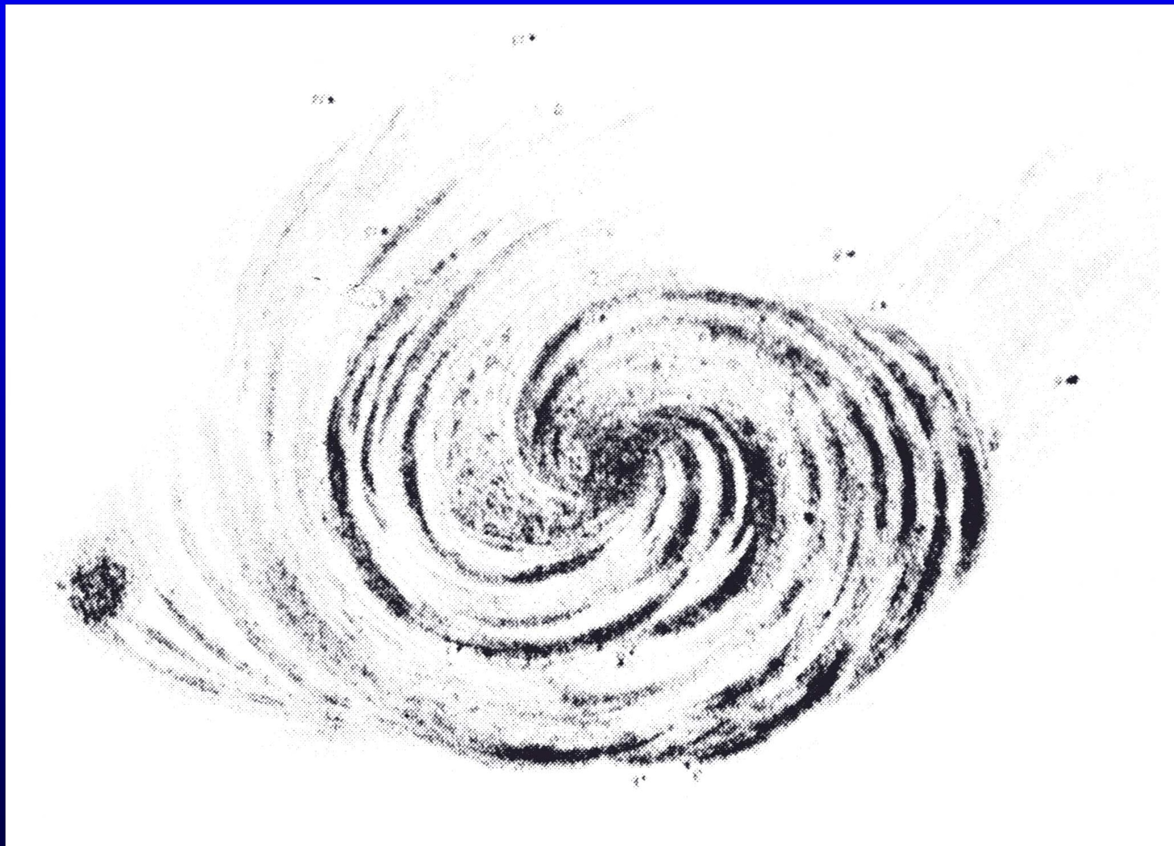
- Upper is M32 and an E2.
- Lower is M110 and an E5 or E6

- Giant Elliptical Galaxies are almost certainly the result of galaxy mergers.
- They contain ~ 10^{13} solar masses and are about 10^5 parsecs across (~ 300,000 ly)
- They are quite rare.
- Dwarf Elliptical Galaxies contain ‘only’ a few million solar masses and are about 2000 parsecs across (~6000 ly).
- Elliptical Galaxies make up 1/3 of all galaxies.

Spiral Galaxies

Birr Castle

M51 – The Whirlpool Galaxy



M51 – The Whirlpool Galaxy

Whirlpool Galaxy • M51

Hubble Heritage

NASA and The Hubble Heritage Team (STScI/AURA)
Hubble Space Telescope WFPC2 • STScI-PRC01-07

Spiral Classification

- Normal - S or Barred - SB
- S0, Sa, Sb and Sc. (or SBa, SBb, SBc)
- S0 spirals have a barely visible disc surrounding the nucleus of the galaxy.
- As one moves through Sa to Sc
  - The nucleus becomes smaller and less prominent.
  - The spiral structure becomes more open.

- Spiral Galaxies make up a large fraction of all galaxies – the majority in some clusters.
- They can be 25,000 to 80,000 parsecs across (80,000 to 250,000 ly)
- The rotate in the sense that the arms trail.
- They contain 10^9 to 10^{12} solar masses.
- More than 10^9 to 10^{12} stars. (Milky Way ~ 10^{12})
- In 1/3 of spirals, the arms unwind from a straight bar of stars gas and dust that extends both sides of the nucleus - barred spirals.
  - We now suspect that the Milky Way is a barred spiral

Spiral Galaxies

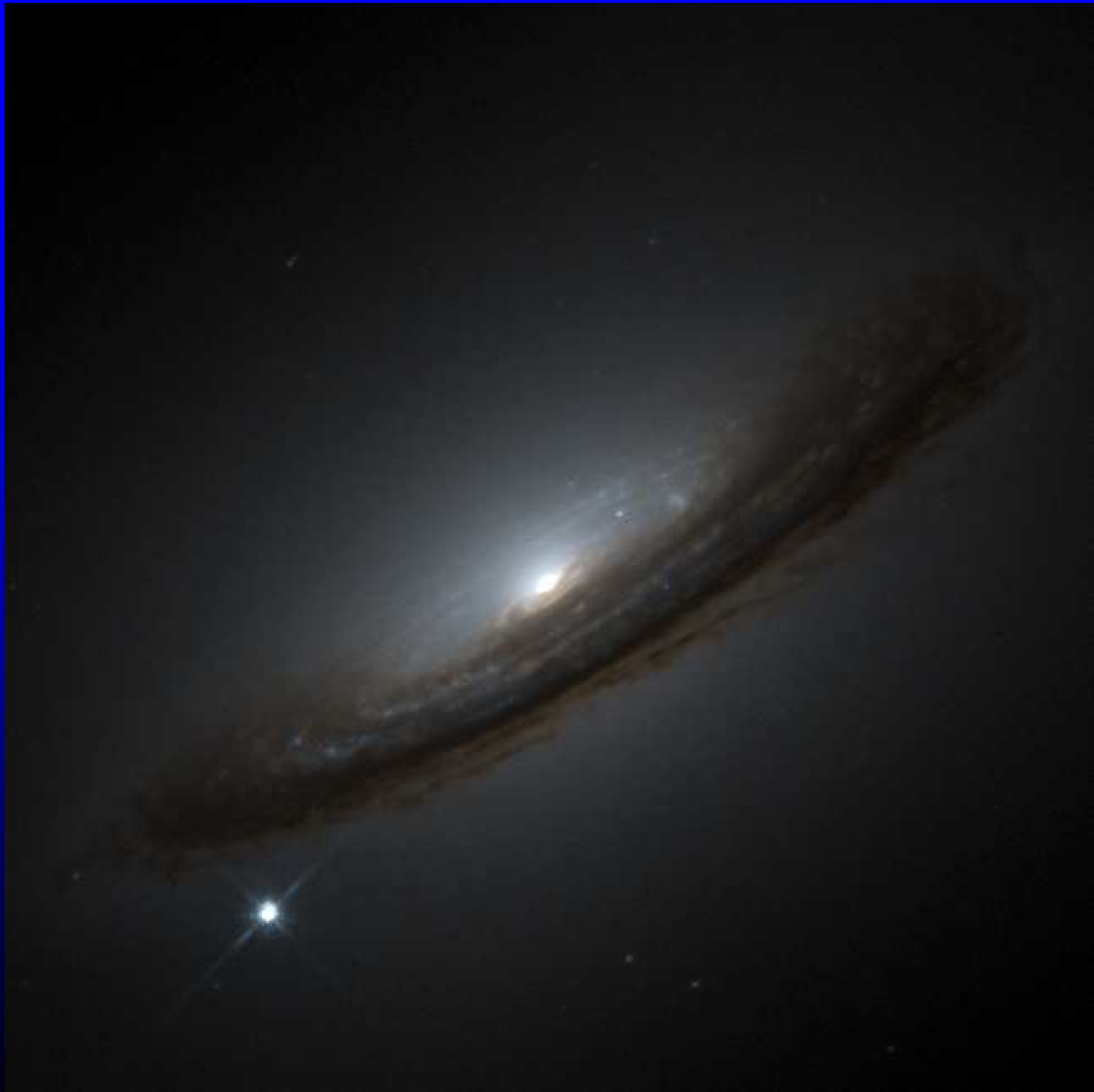
M81 and M82

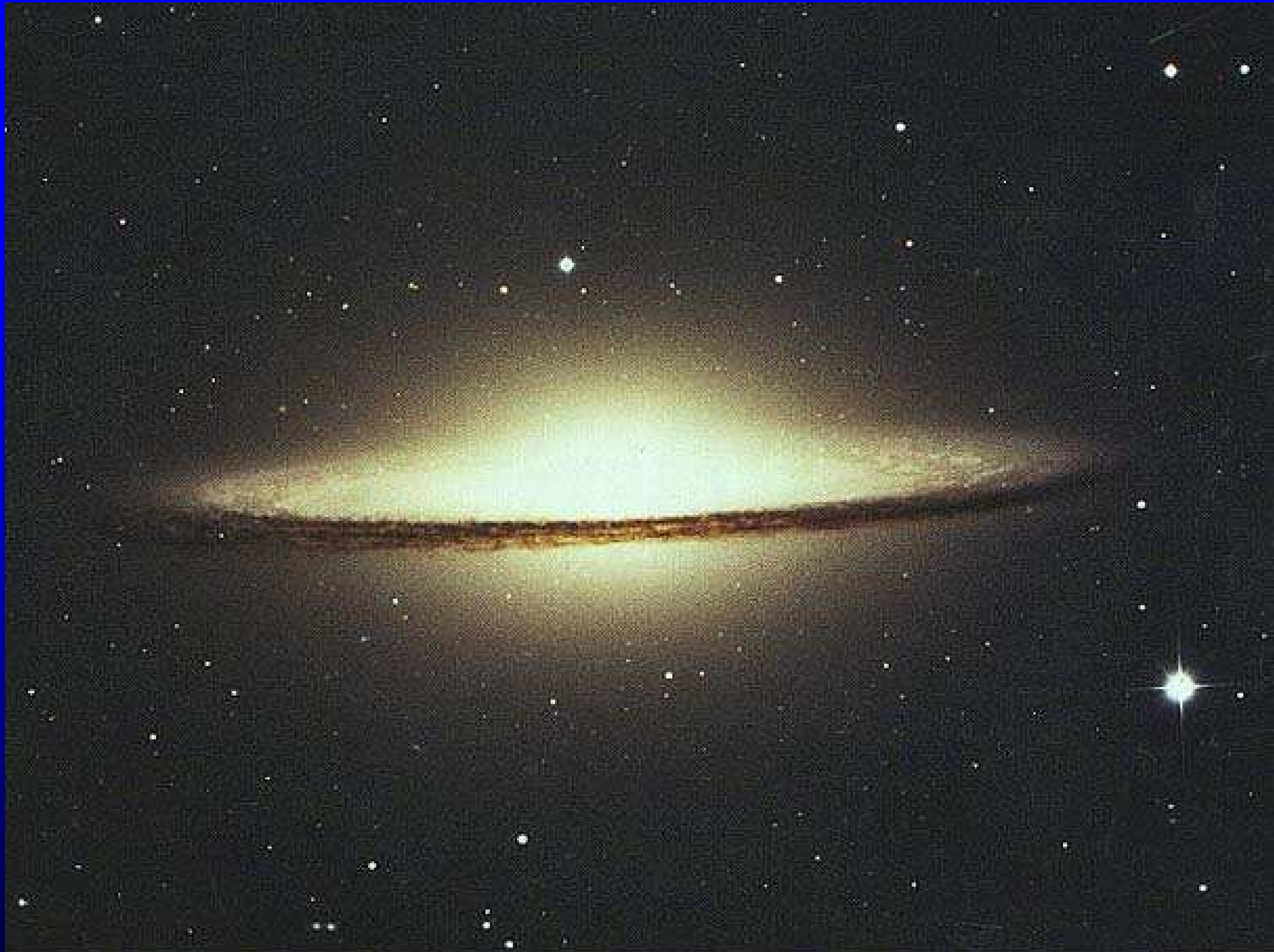
Nucleus and Spiral Arms

- Note that the nucleus is redder than the spiral arms in colour.
  - Nucleus older population II stars – any blue and white stars will have reached the end of their life and produced white dwarfs, neutron stars or black holes.
  - Spiral arms contain young Population I stars so many bright blue stars.
    - Their light is dominated by the blue stars as these are very bright.

Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1

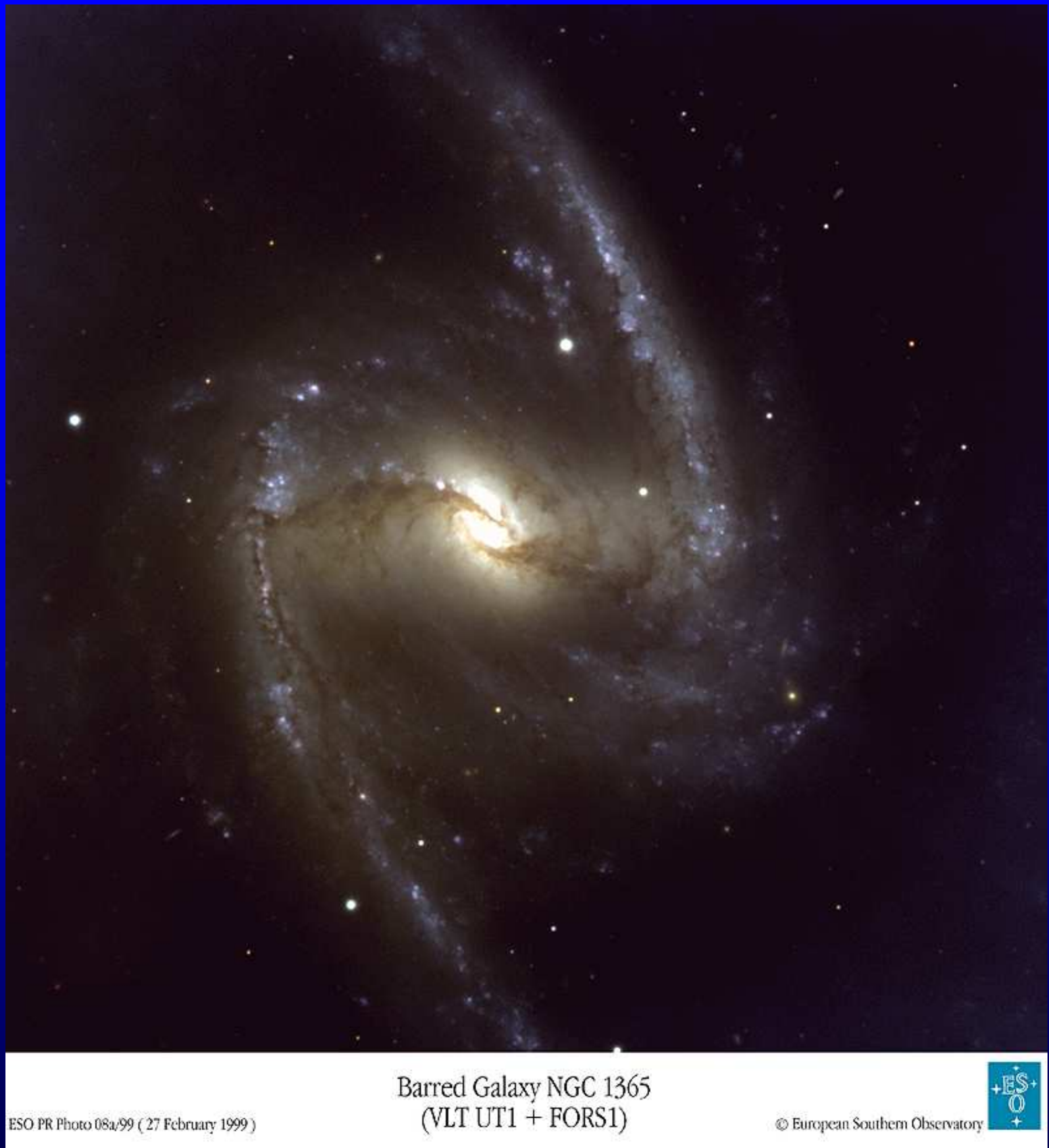
ESO PR Photo 37d/98 (23 September 1998)





M104 © Anglo-Australian Observatory Photo by David Malin

Barred Spirals



Spiral Galaxy Messier 83 (VLT ANTU + FORS1)

Galaxy NGC 6782

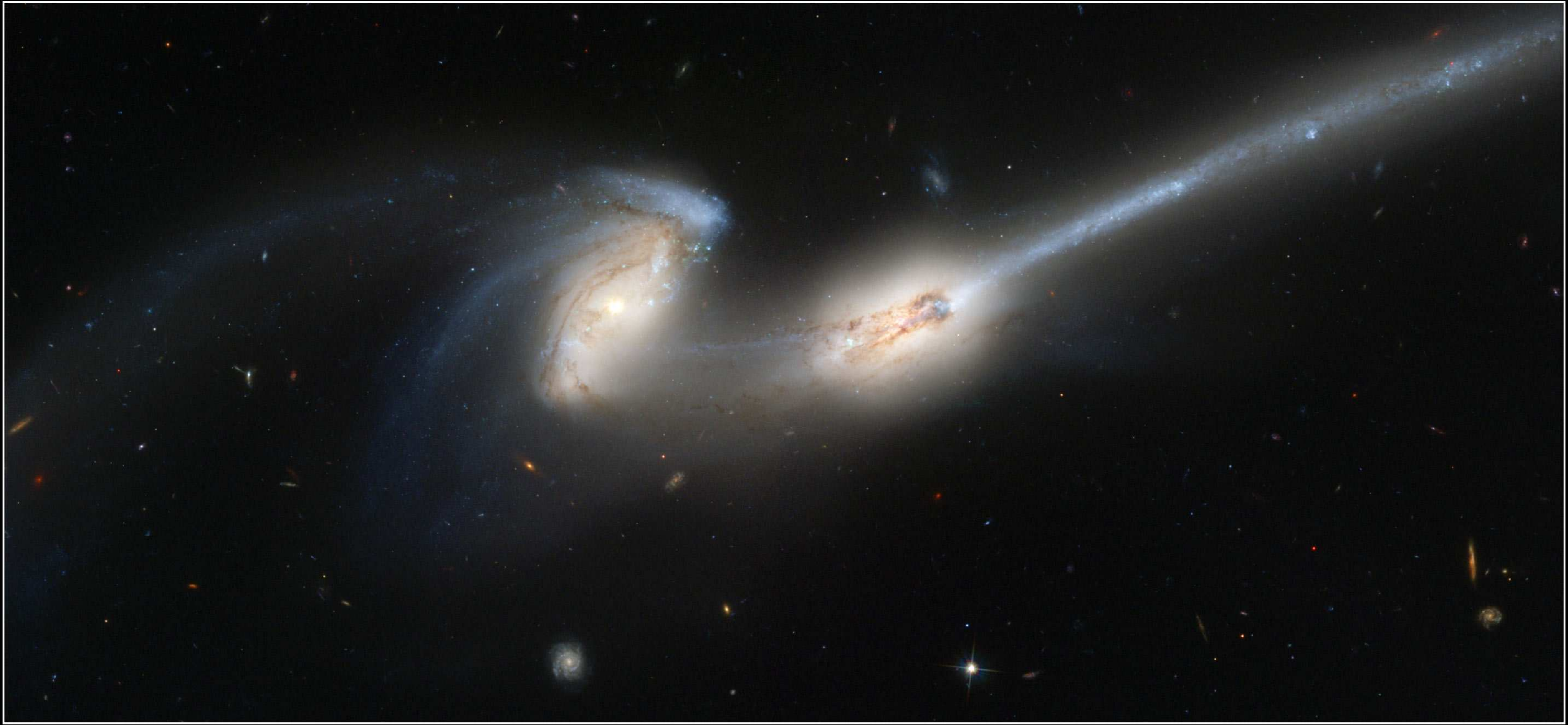
Hubble Heritage

NASA and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope WFPC2 • STScI-PRC01-37

M 83

Edge on Spirals

Interacting Spirals



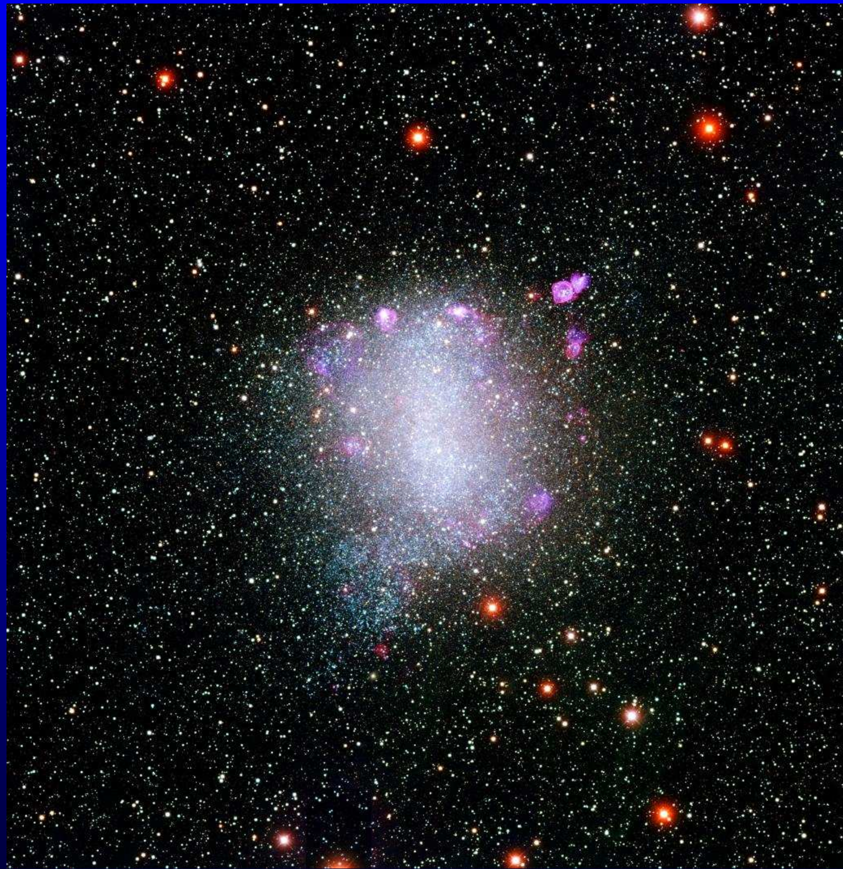
The Mice • Interacting Galaxies NGC 4676

Hubble Space Telescope • Advanced Camera for Surveys

NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI) and the ACS Science Team • STScI-PRC02-11d

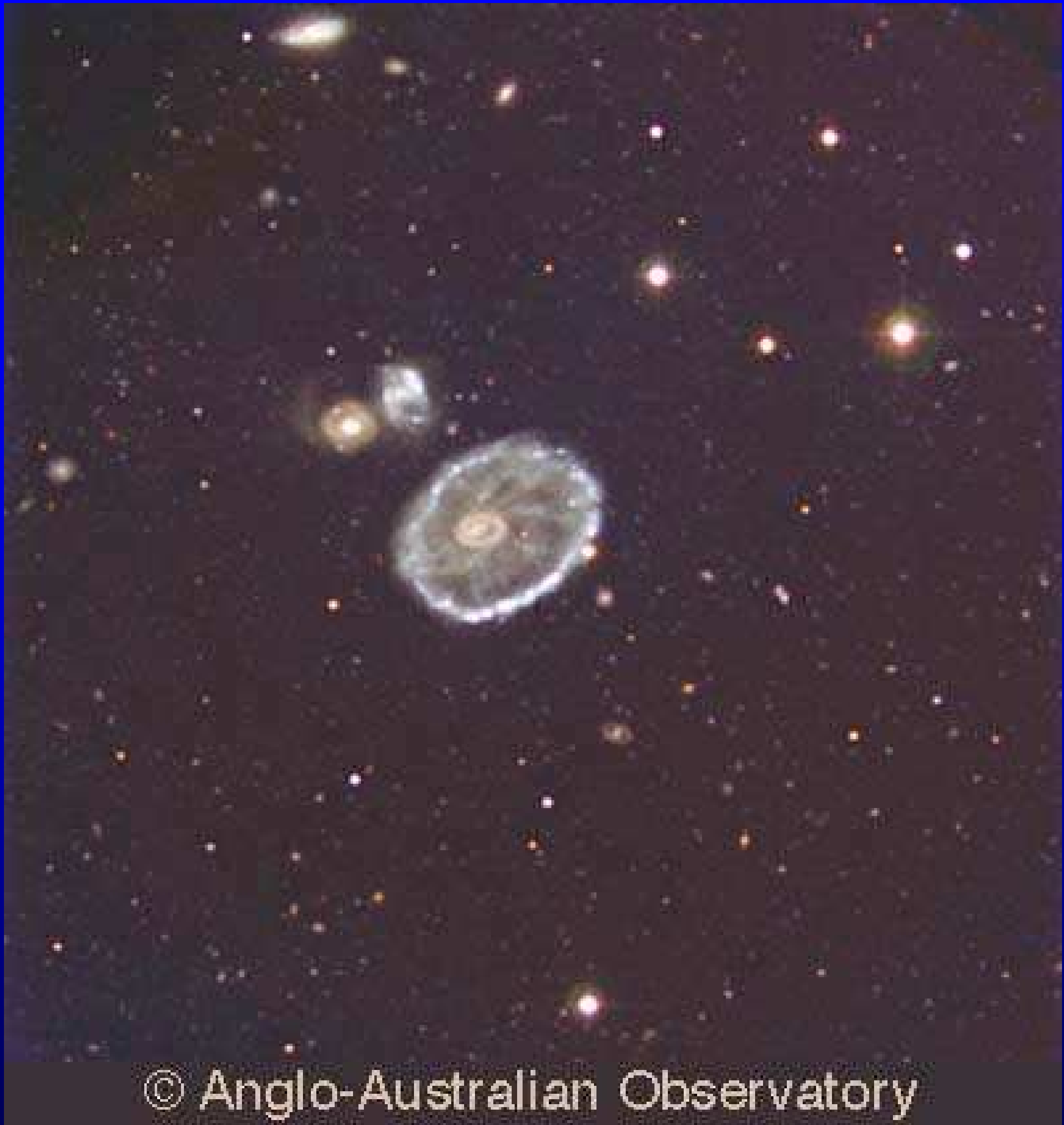
Irregular Galaxies

- These have no obvious form and contain relatively fewer stars than elliptical or spiral galaxies.
- They only make up a few percent of the total we see, (very faint !) but may be the most common type.



Magellanic Clouds

- Irregular galaxies contain relatively little dust - they contain fewer heavy elements in their interstellar medium.
- This makes it easier to observe the star formation regions!



Starburst Galaxies

Starburst Galaxy NGC 3310

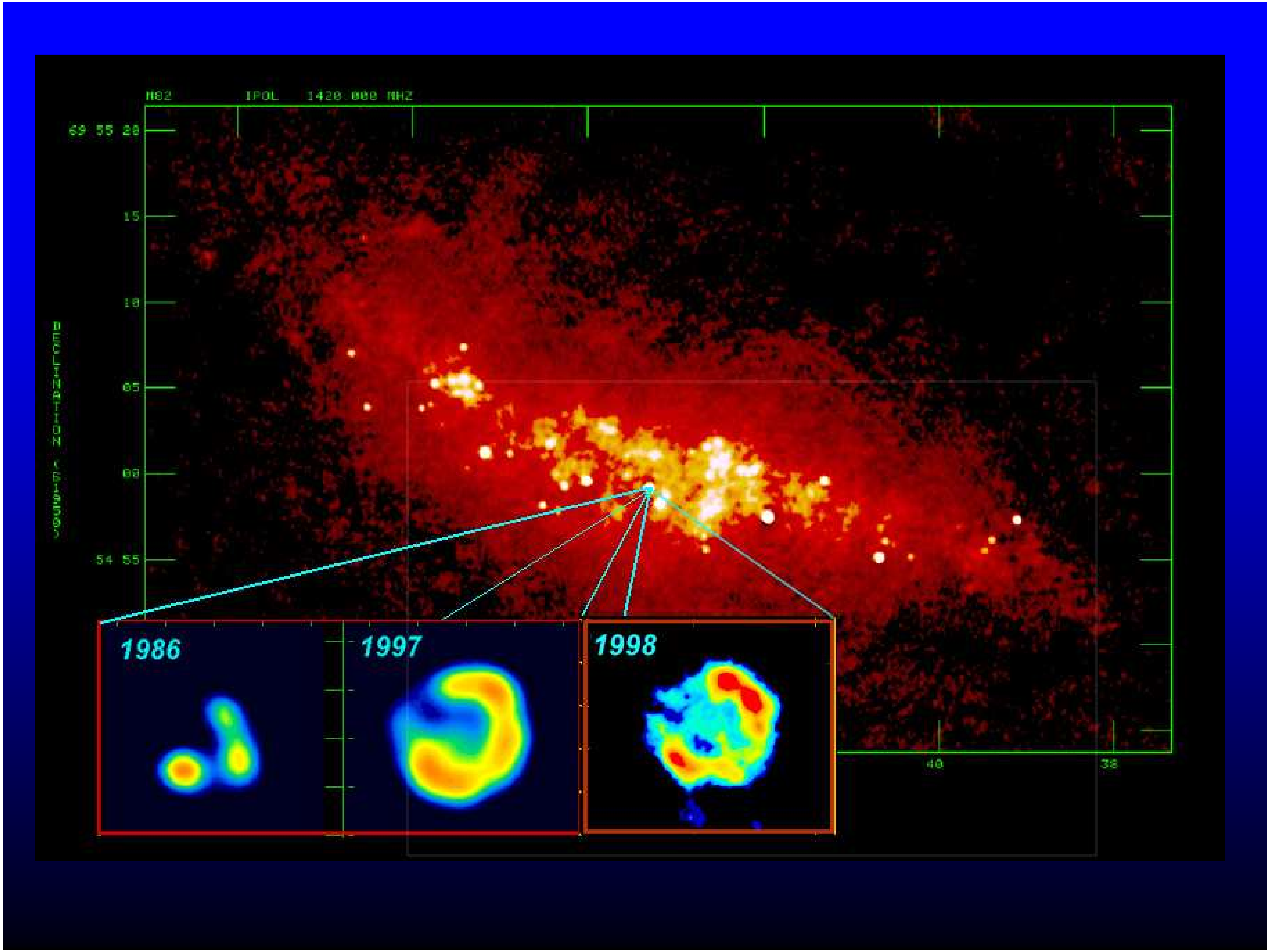
NASA and The Hubble Heritage Team (STScI/AURA)
Hubble Space Telescope WFPC2 • STScI-PRC01-26

Galaxy NGC 7742

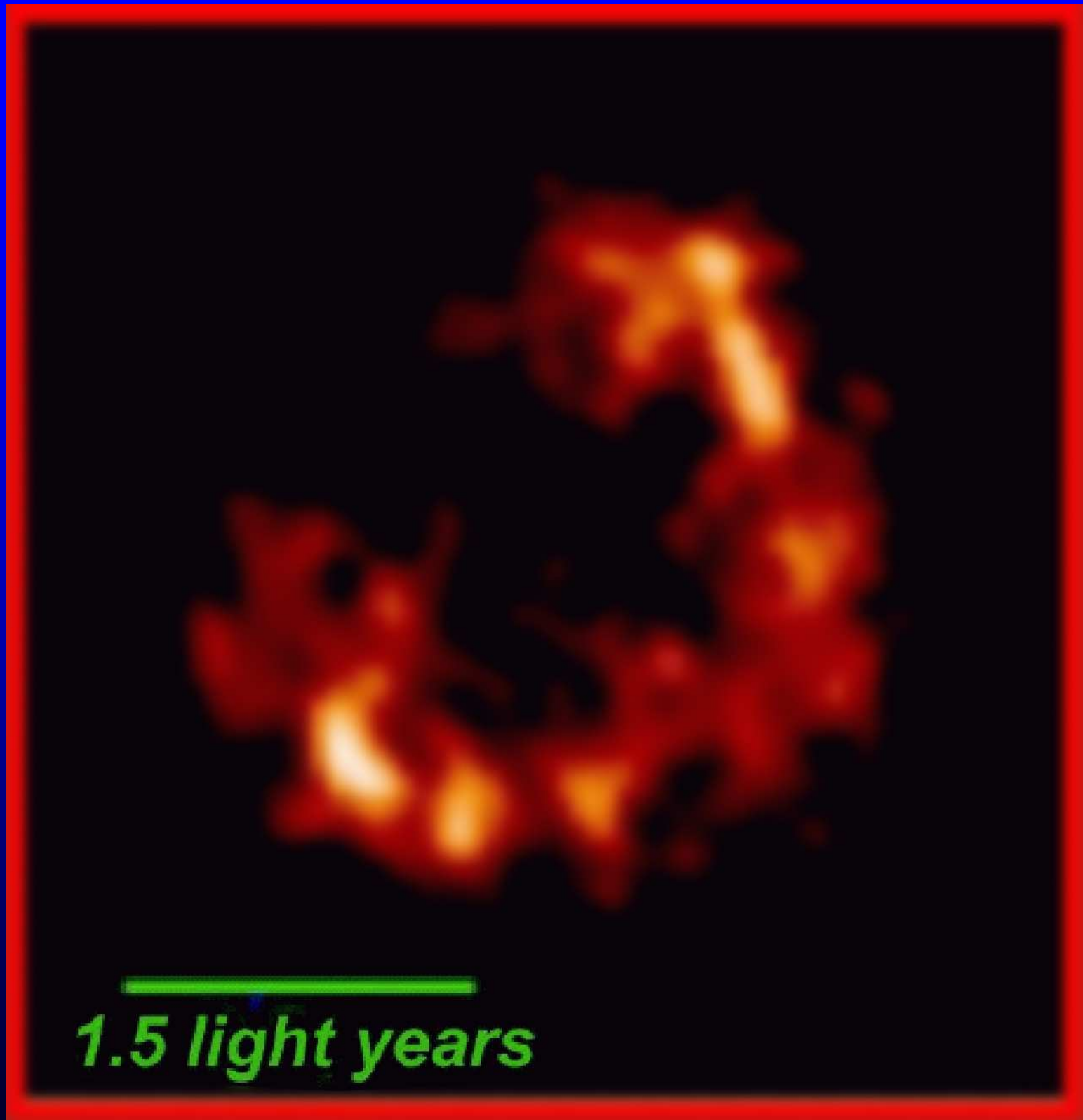
Hubble Heritage

PRC98-28 • Space Telescope Science Institute • Hubble Heritage Team

M81 and M82



M82 IPOL 1420.000 MHZ
69 55 20
15
10
05
00
54 55
DECLINATION (B1950)
40
38
1986
1997
1998


1.5 light years

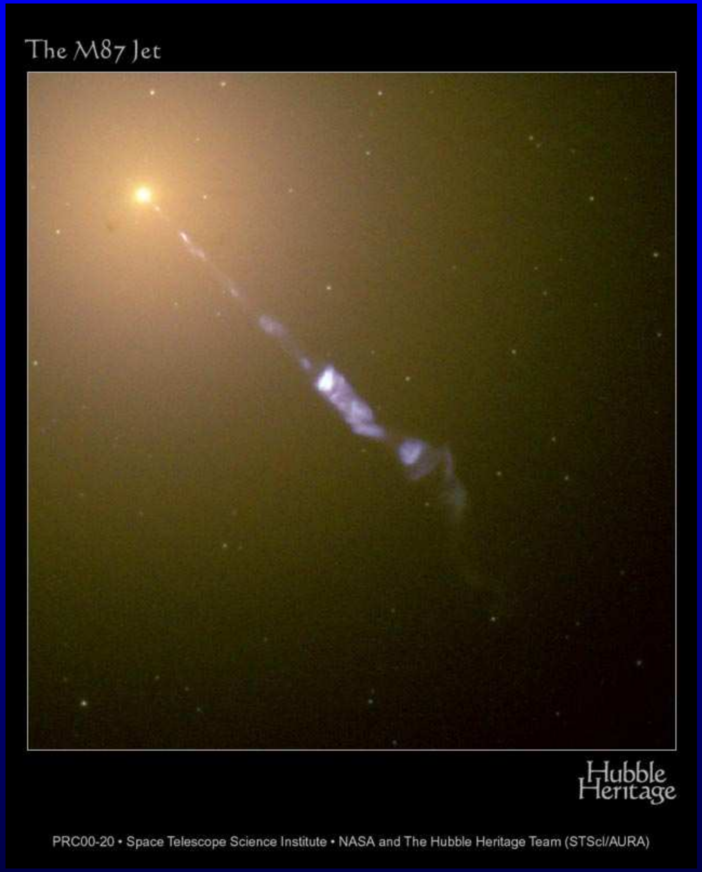
Starburst Galaxies

- These are undergoing a massive burst of star formation.
  - The almost simultaneous formation of many massive stars – hence much UV light.
  - Can cause outflows of hydrogen gas (M82).
  - Many supernova explosions as seen in M82.

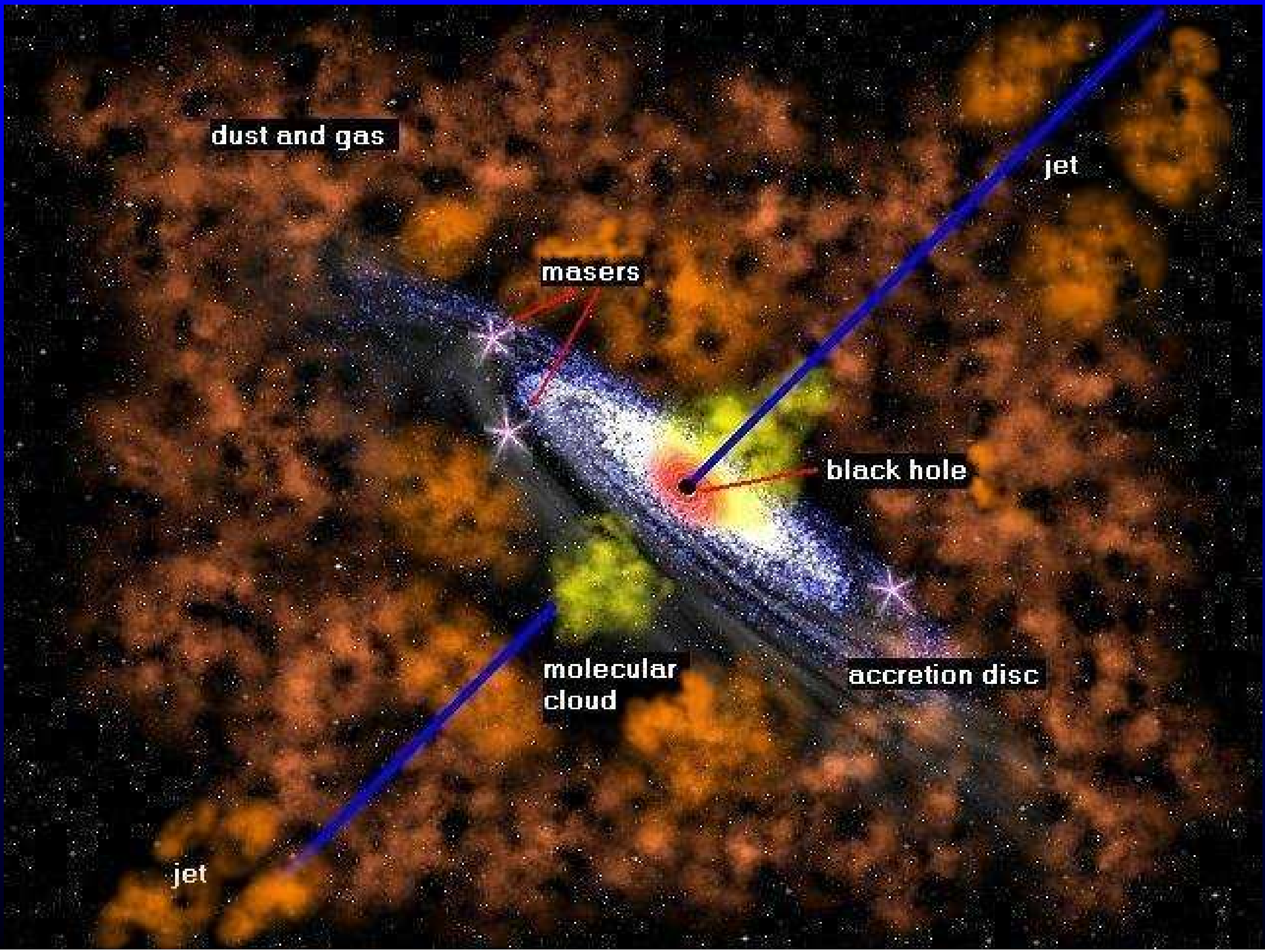
Active Galaxies

- Galaxies that radiate strongly in the radio and x-rays are called Active Galaxies.
- They often have especially bright nuclei and these are called AGN’s (for Active Galactic Nuclei)
- Quite rare.

They often show jets



What powers these objects?



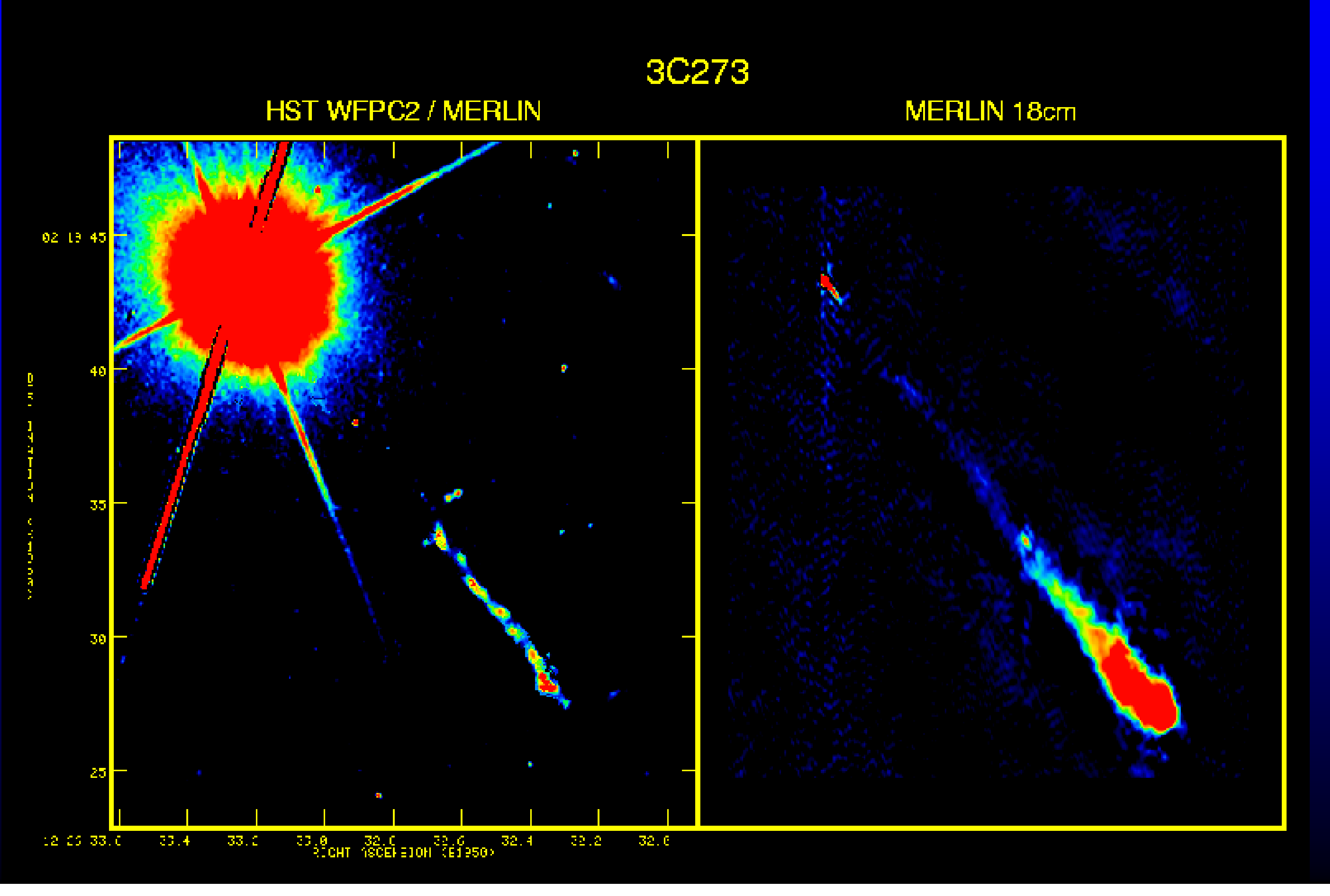
A Black Hole at the centre

- Material falling in towards a black hole gives up at least 10% of its rest mass energy BEFORE it enters the event horizon.
- The stars are broken up into dust which rotates around in an accretion disc as it spirals inwards.
- The differential rotation speeds cause friction which heats up the dust and gas to millions of K.
- Hence emits copious X-ray emission.
- Can only see if not obscured by the accretion disk.

Jets

- Some of the energy powers jets of relativistic particles which leave the black hole region along the magnetic field axis.
- As these particles are de-accelerated as they interact with matter within and beyond the galaxy they radiate at visible and radio wavelengths.
- These are called Quasars if the beams are pointing approximately towards us.
- Radio Galaxies otherwise.

The Quasar 3C 273



Galaxy Groups and Clusters

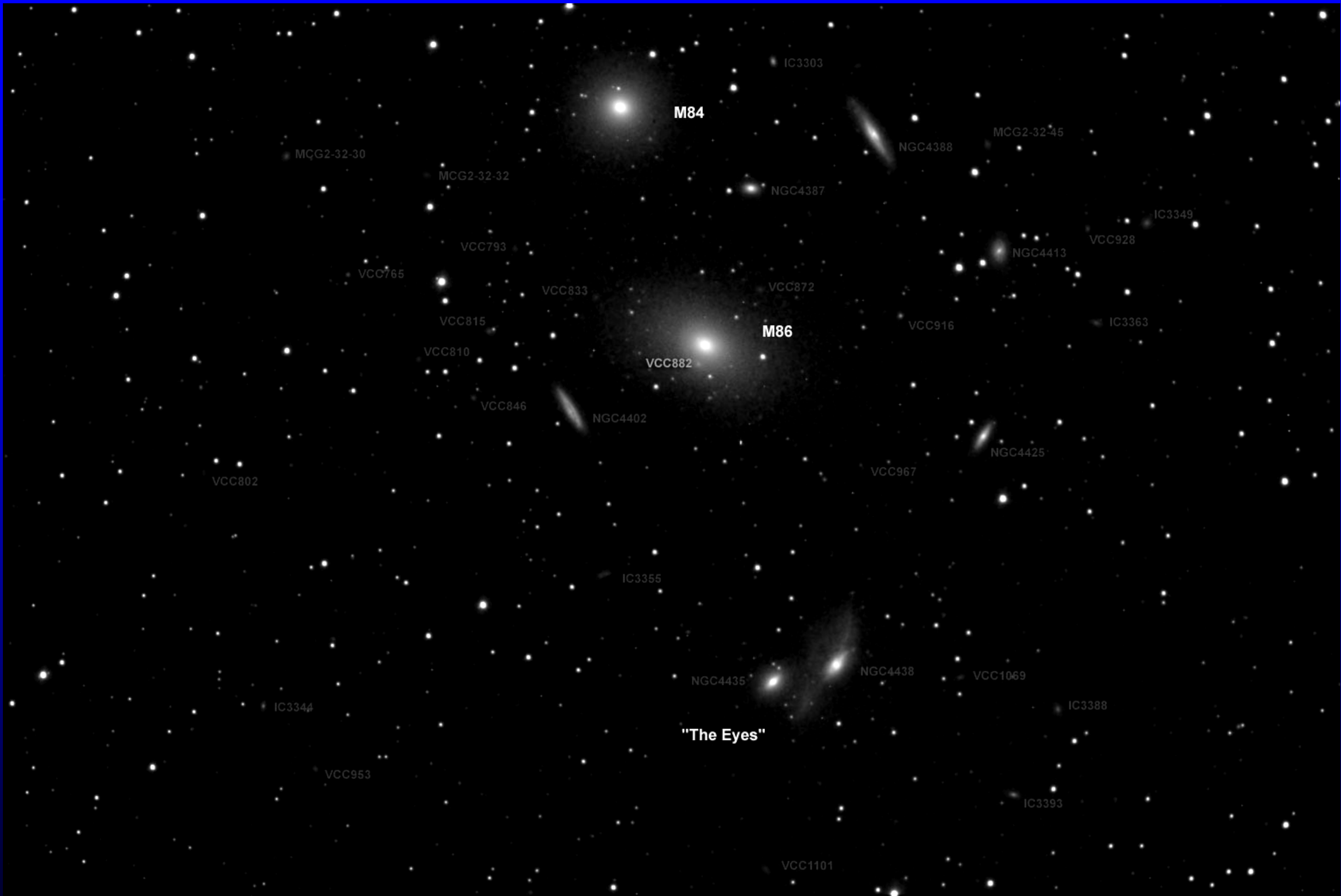
Groups and Clusters

- Galaxies congregate in Groups (< ~50), as in our Local Group, or in Clusters of ~ 50 to 1000 galaxies.
- We see these throughout the visible Universe.

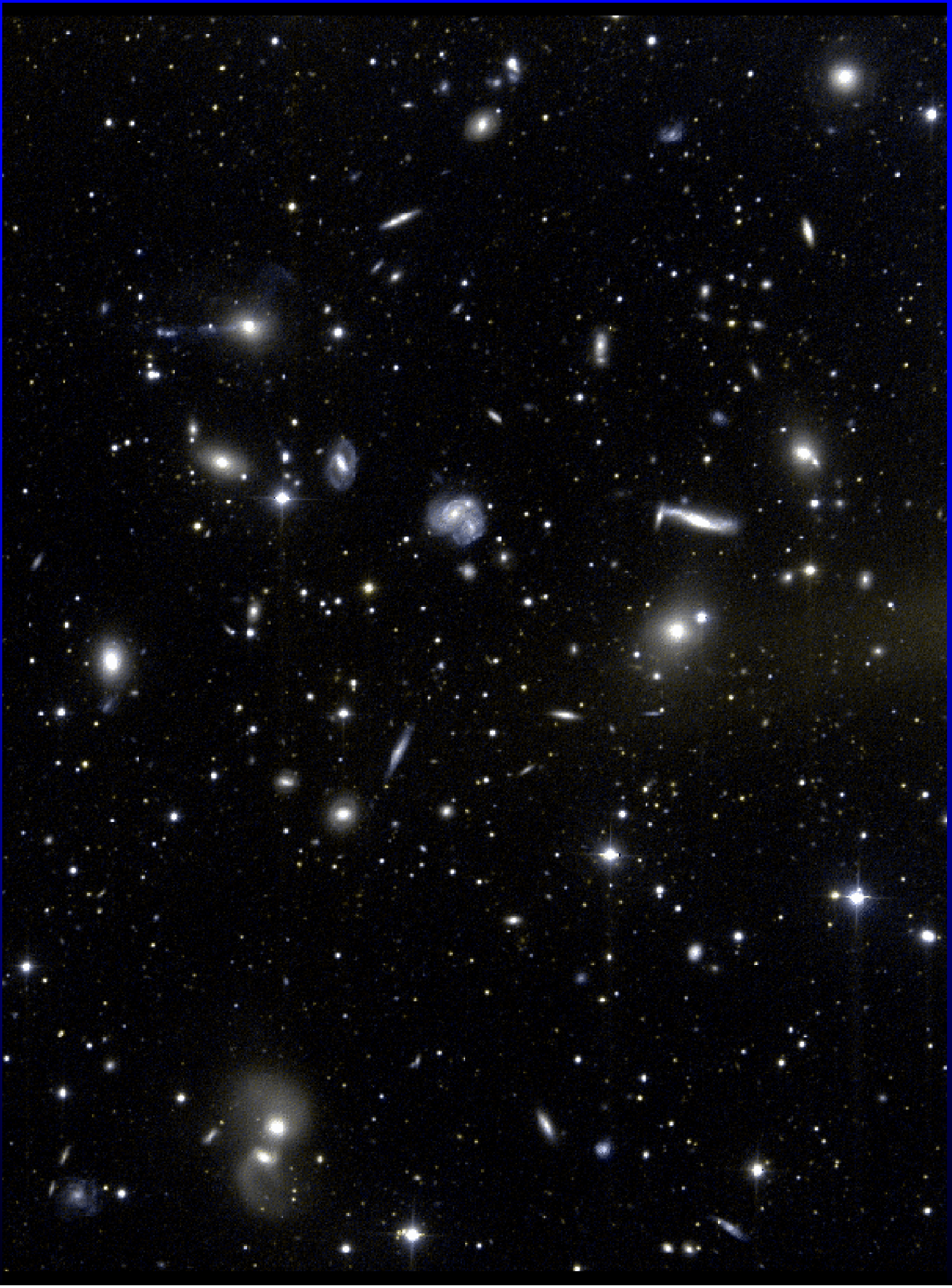

NGC 4881
Coma Cluster
HST · WFPC2
PF95-07 · ST ScI OPO · January 1995 · W. Baum (U.WA), NASA
1/27/95 zgl

Leo Group

Virgo Cluster



IC3303
M84
MCG2-32-45
NGC4388
MCG2-32-30
MCG2-32-32
NGC4387
IC3349
VCC928
NGC4413
VCC793
VCC765
VCC833
VCC872
VCC815
VCC916
IC3363
M86
VCC810
VCC882
VCC846
NGC4402
NGC4425
VCC967
VCC802
IC3355
NGC4438
VCC1069
NGC4435
IC3388
IC3344
"The Eyes"
VCC953
IC3393
VCC1101



Hercules Cluster

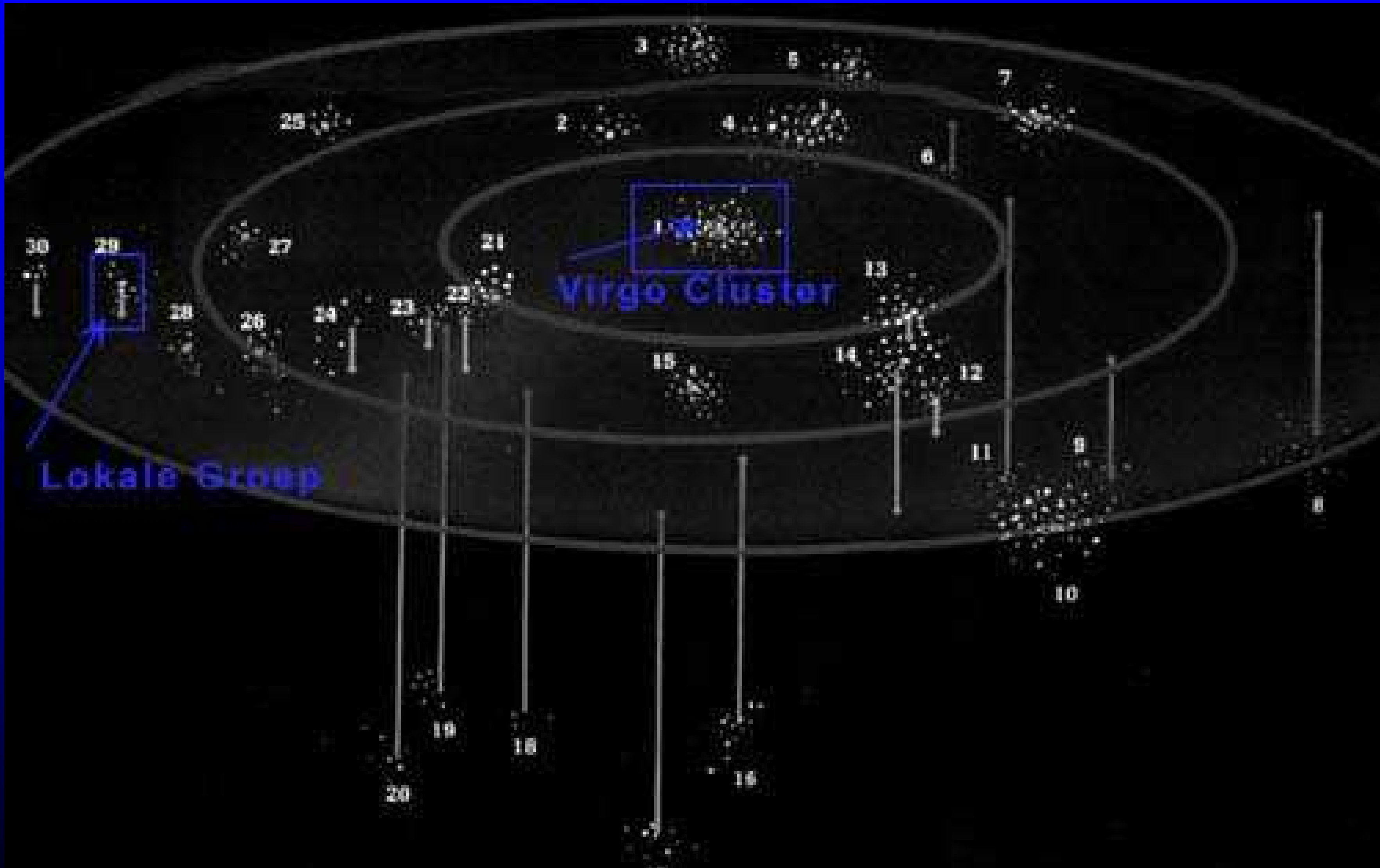
Cluster in Hydra

Distant Galaxy Cluster
HST • WFPC2

Galaxy Clusters exist in larger groupings called Super Clusters

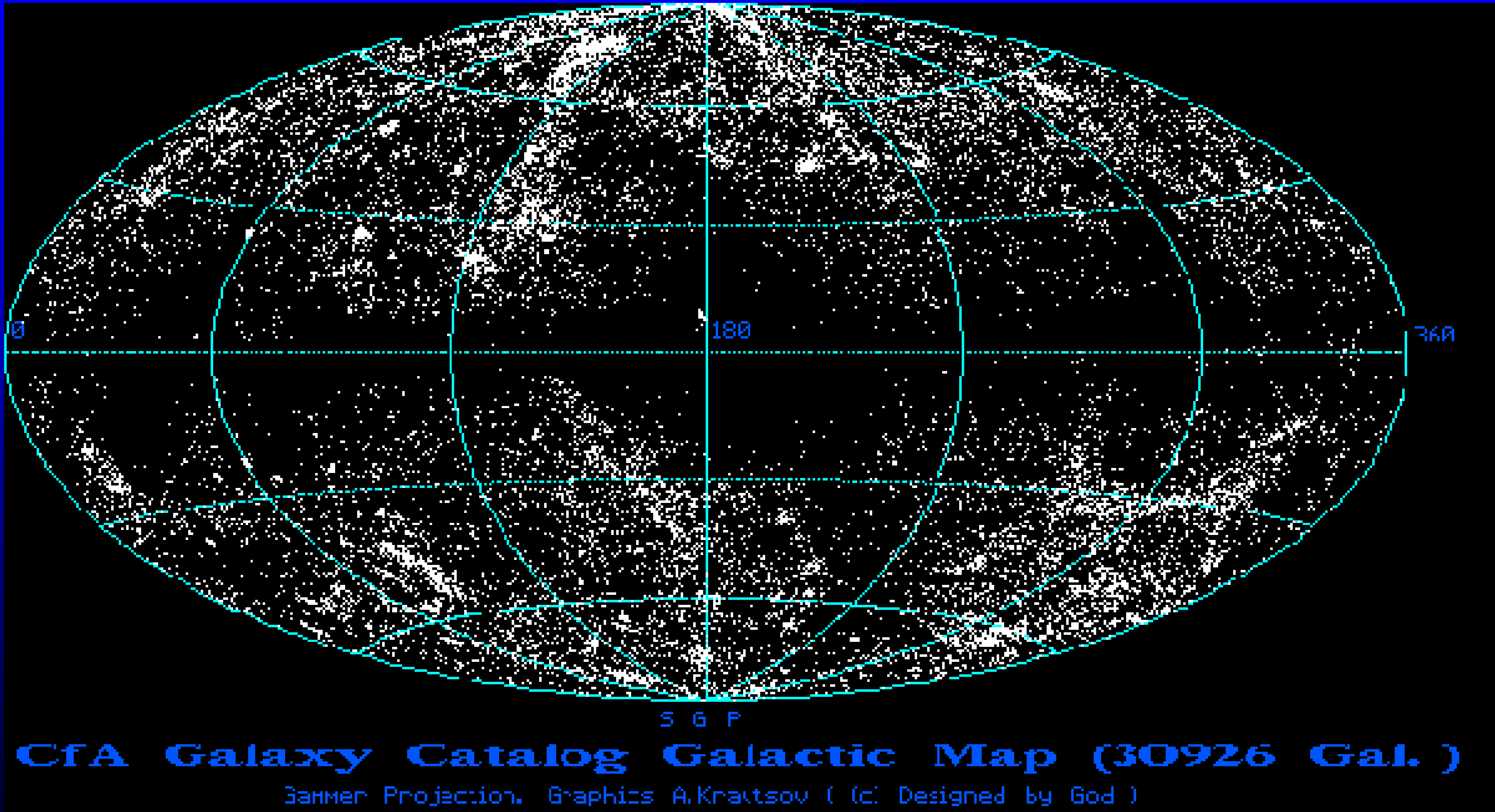
Our local group is part of the Virgo Supercluster

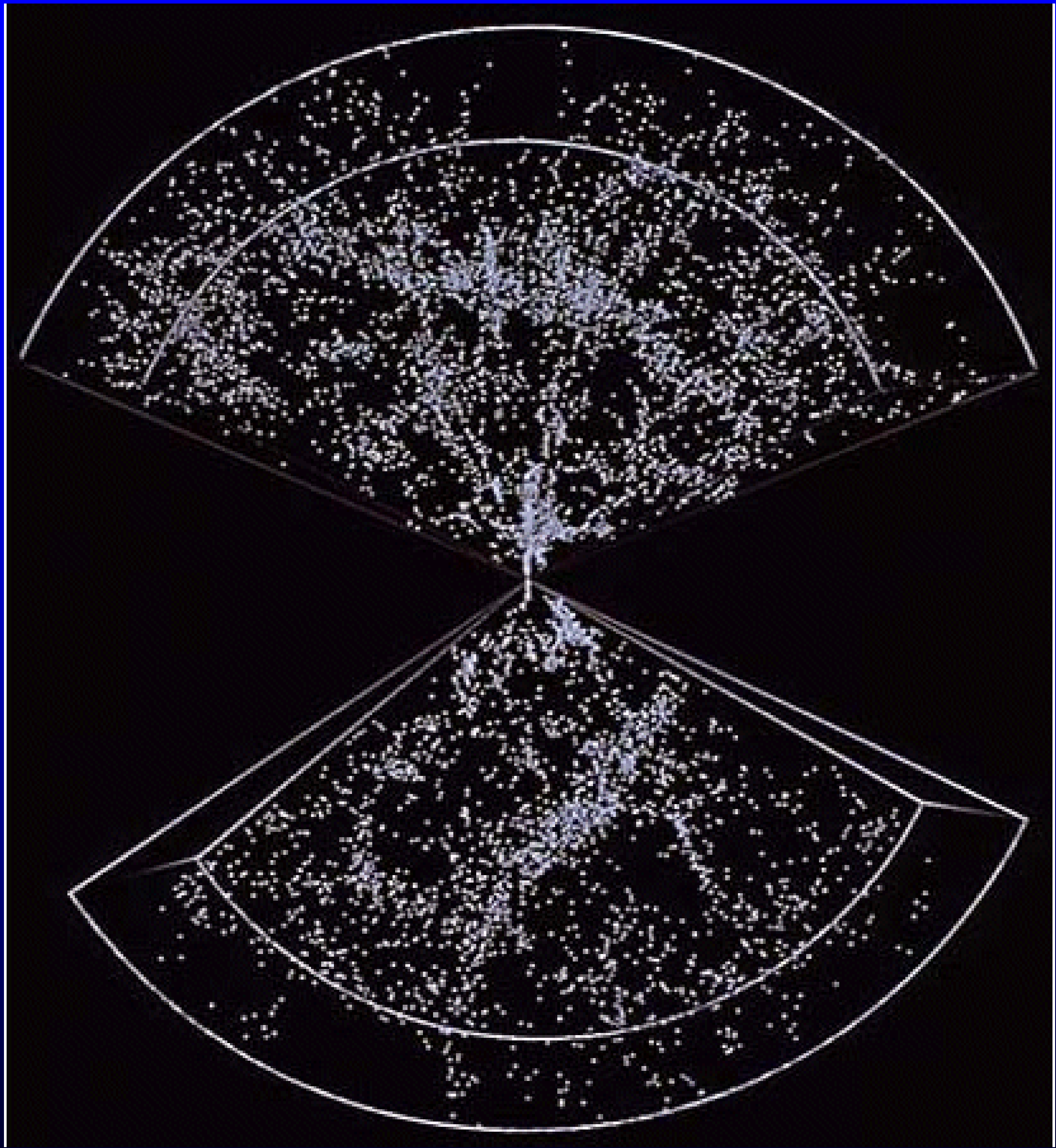
Our Super Cluster

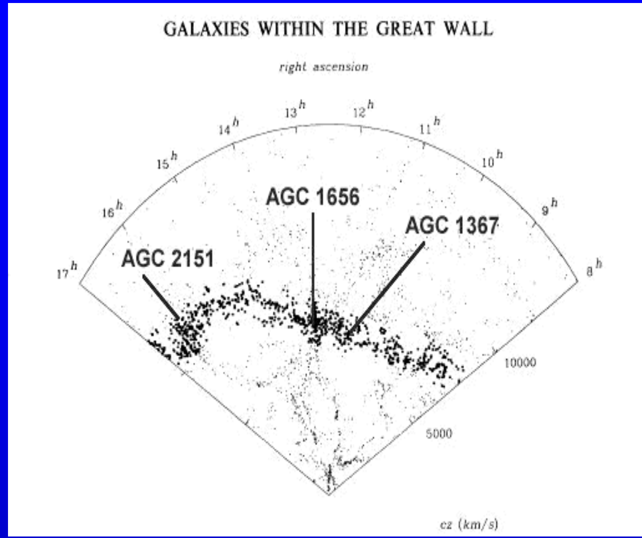


The distribution of Galaxies through space.

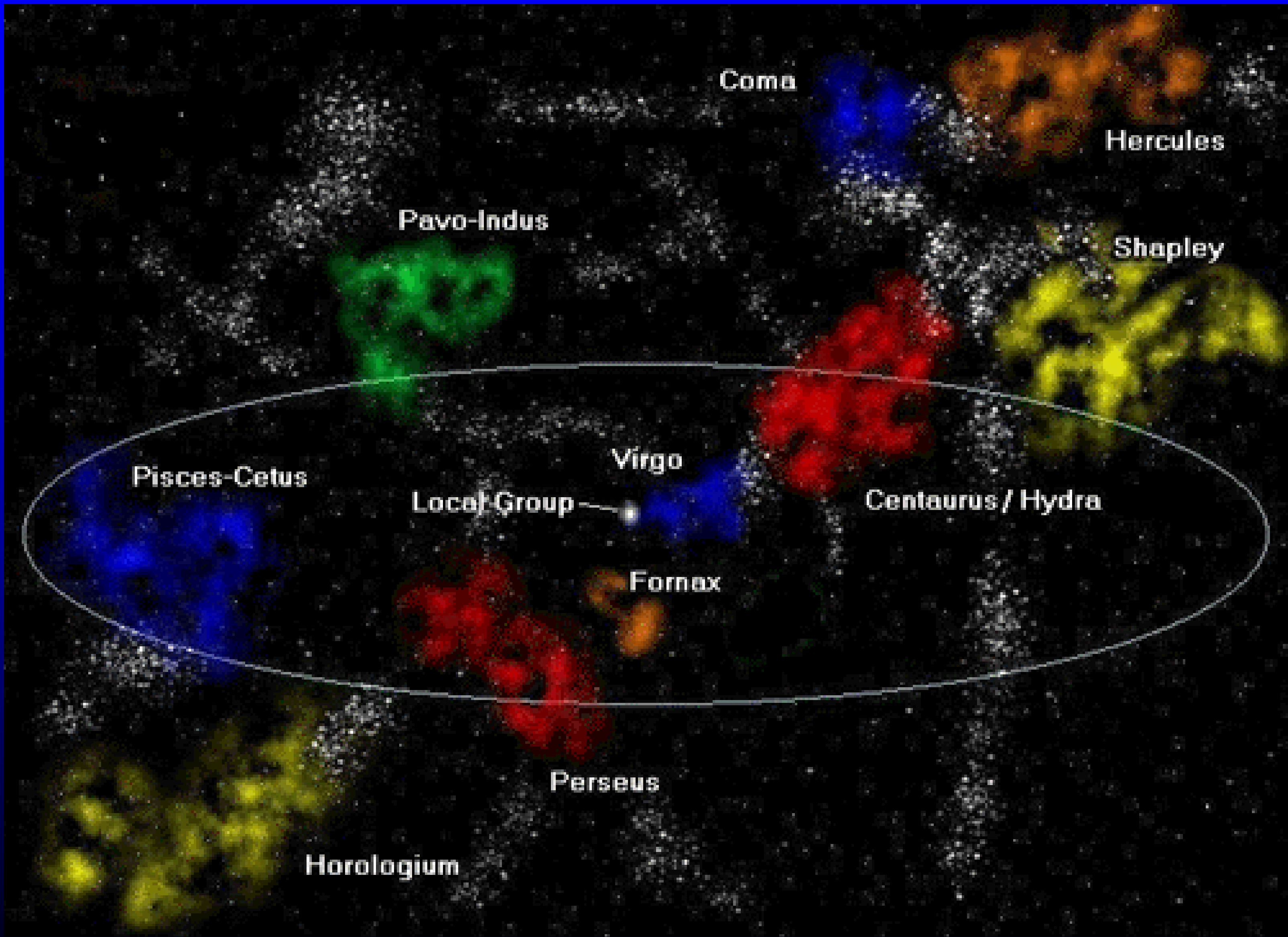
Distribution of Galaxies

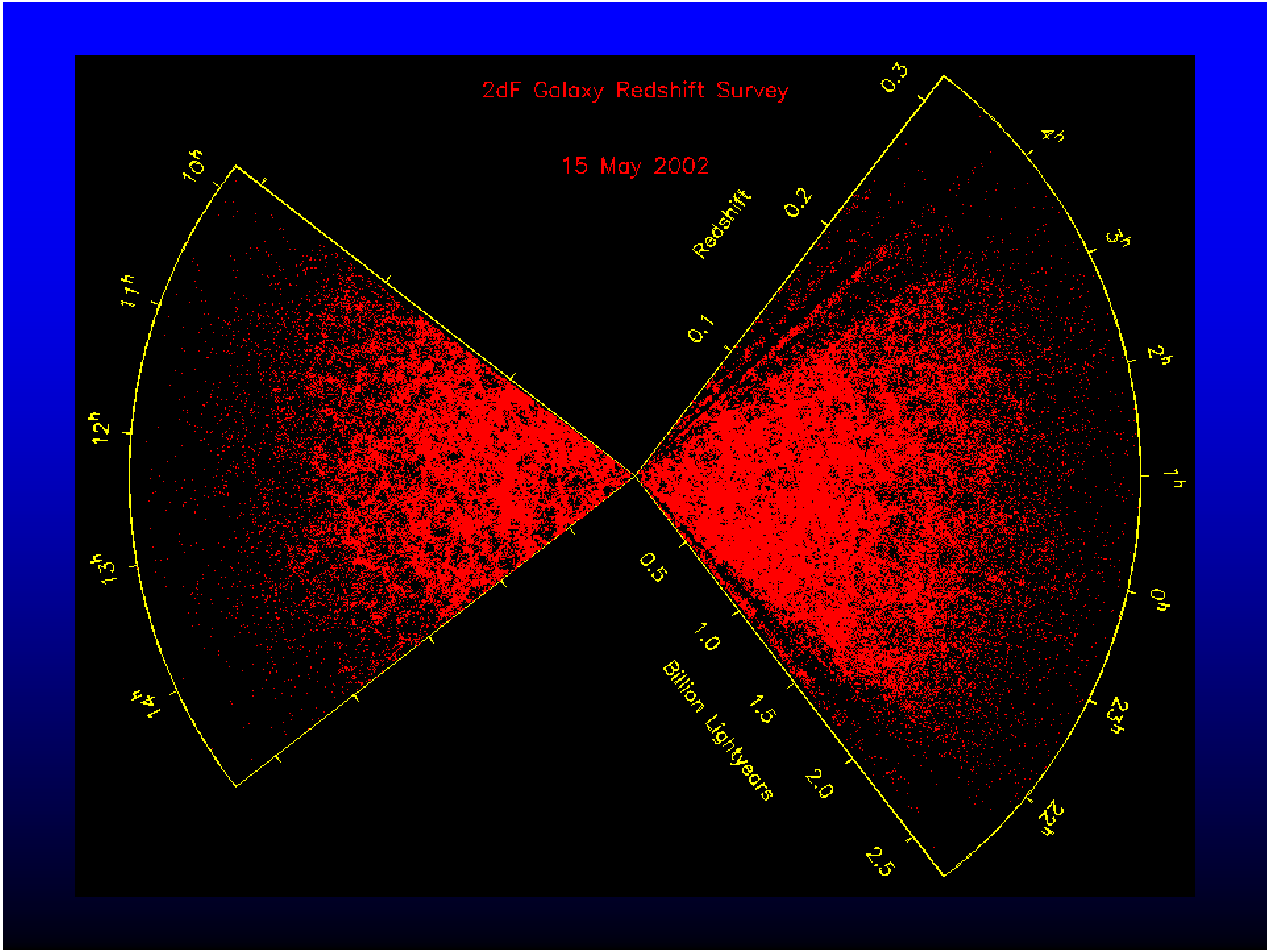






GALAXIES WITHIN THE GREAT WALL
right ascension
17h
16h
15h
14h
13h
12h
11h
10h
9h
8h
AGC 2151
AGC 1656
AGC 1367
10000
5000
cz (km/s)


Coma
Hercules
Pavo-Indus
Shapley
Virgo
Pisces-Cetus
Local Group
Centaurus / Hydra
Fornax
Perseus
Horologium



2dF Galaxy Redshift Survey
15 May 2002
Redshift
0.1
0.2
0.3
0.5
1.0
1.5
2.0
2.5
Billion Lightyears
10h
11h
12h
13h
14h
4h
3h
2h
1h
0h
23h
22h

- The distribution of galaxy clusters in space is similar to a sponge or a froth of bubbles.
  - Concentrations around the edge of “ voids”.
- A result of gravity – denser regions will tend to become denser as they attract matter to them, less dense regions will become emptier in time so producing the voids.