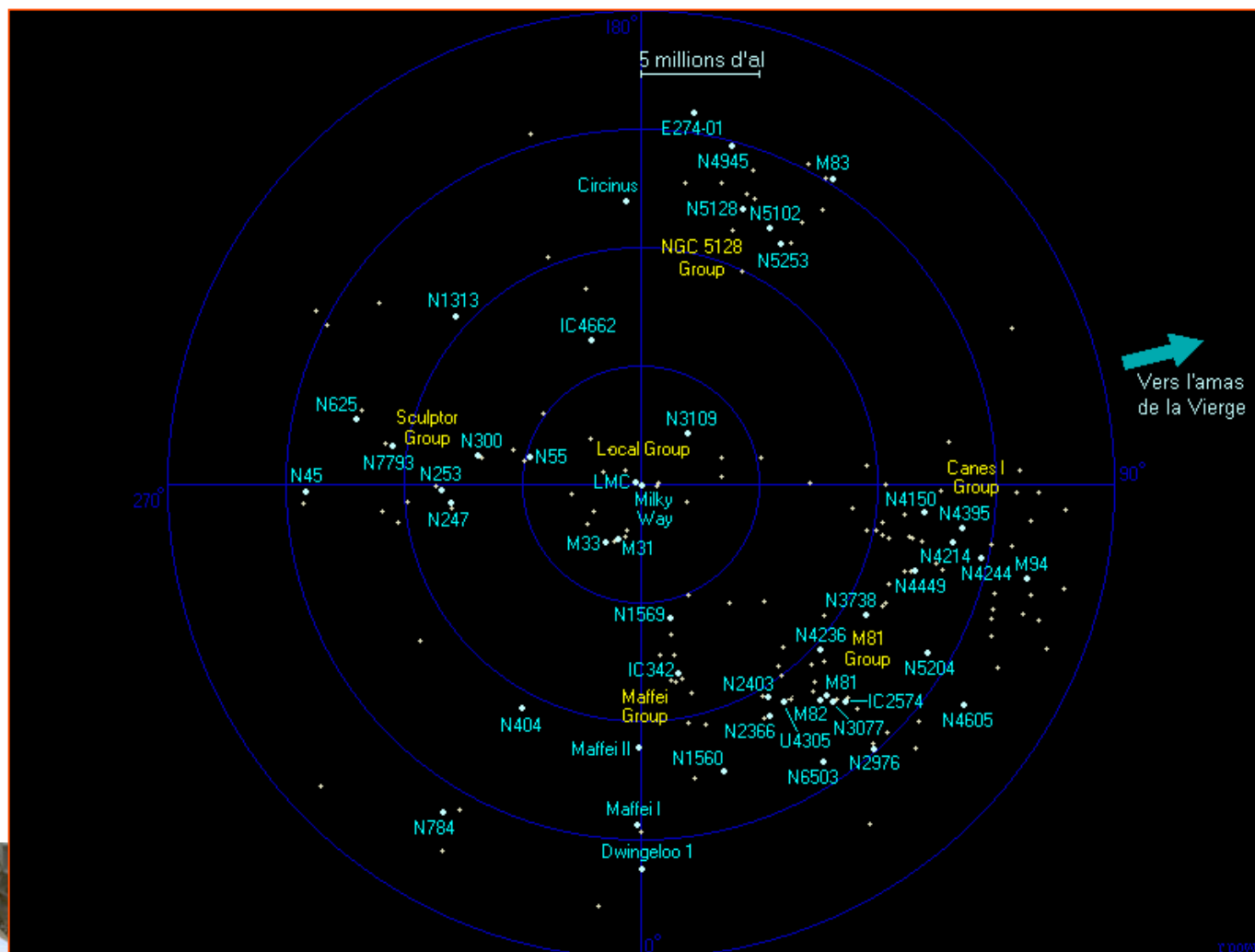


Extragalactic Astronomy

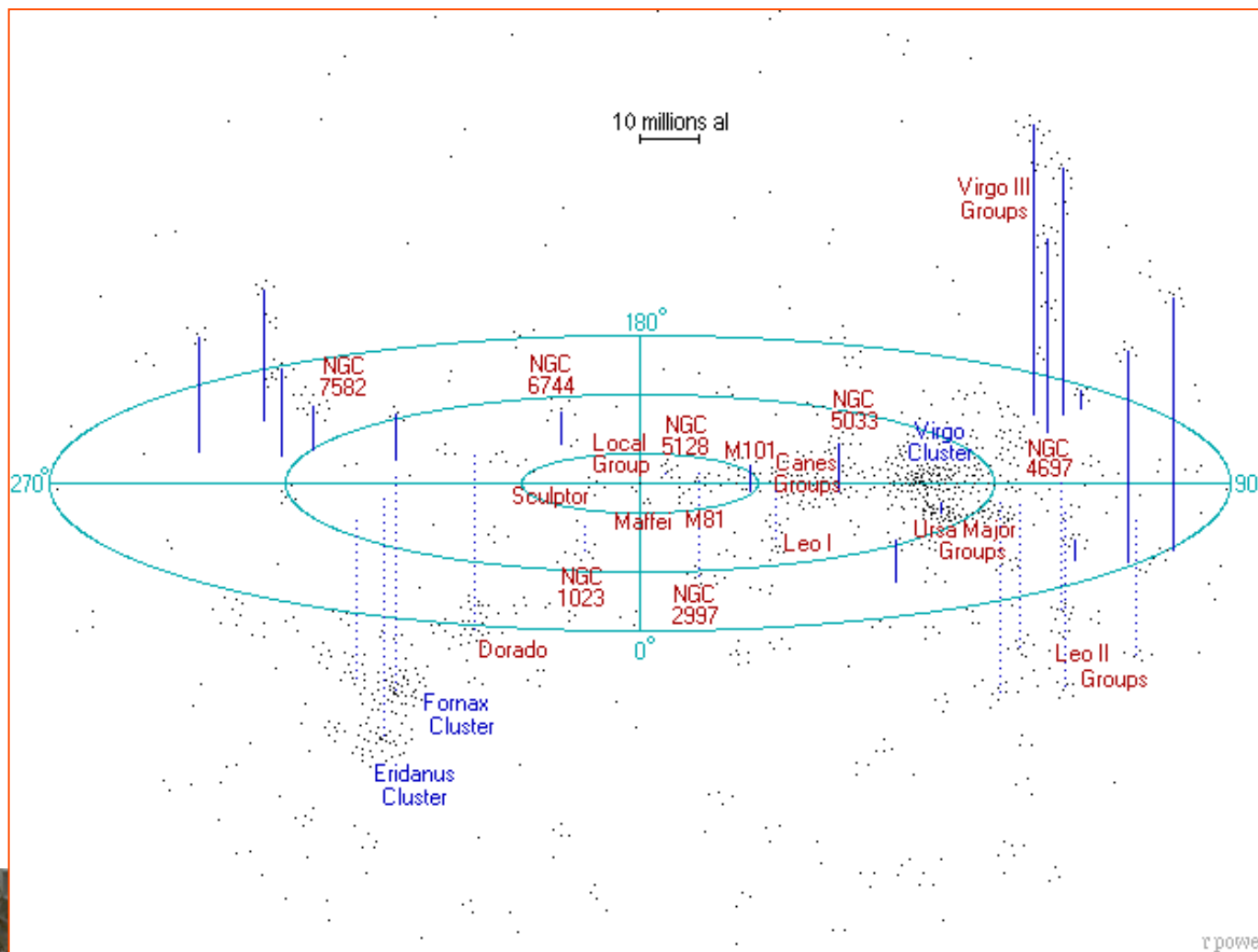
Lecture 11: From the Local Group to the Large Scale Structure



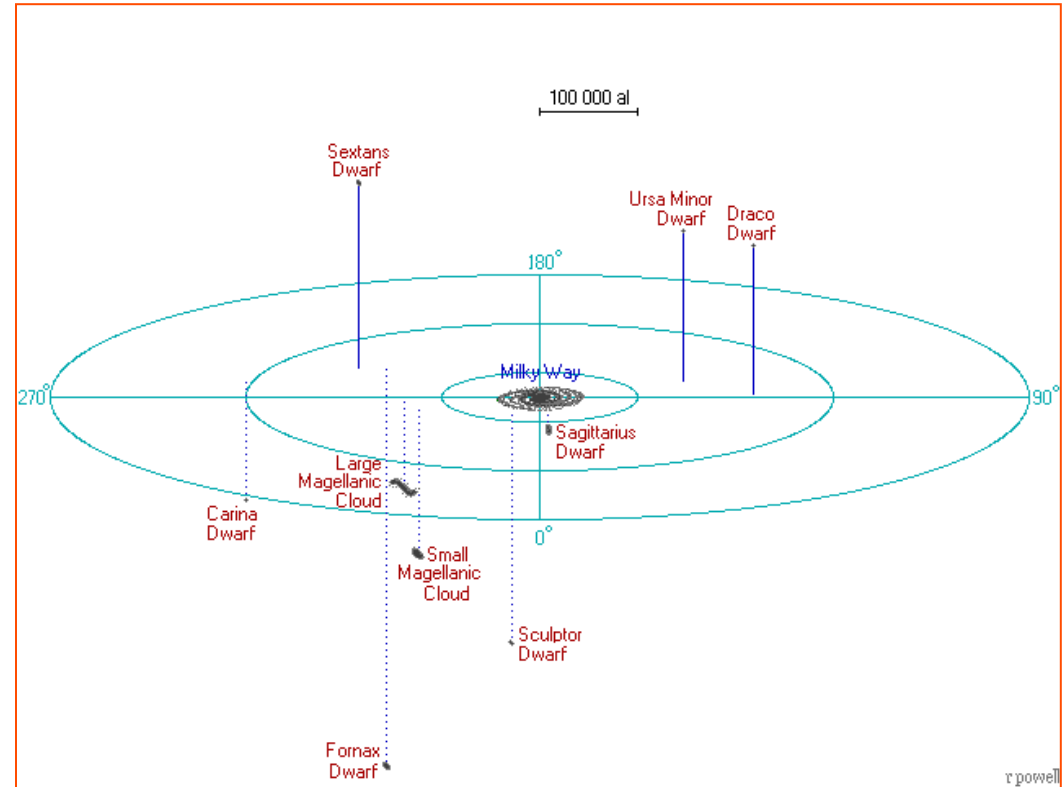
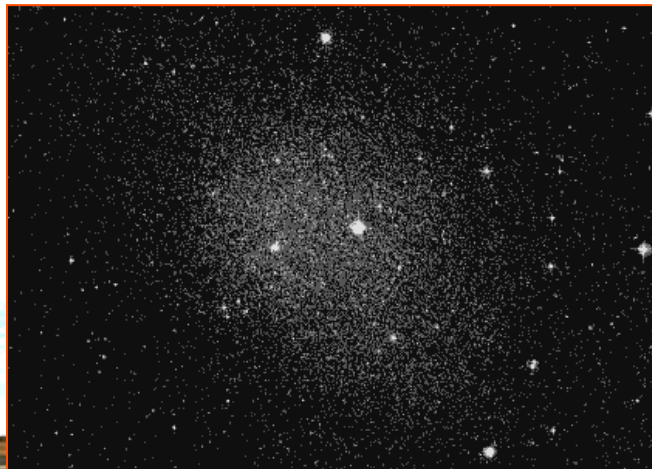
Nearby groups ($D < 6$ Mpc)



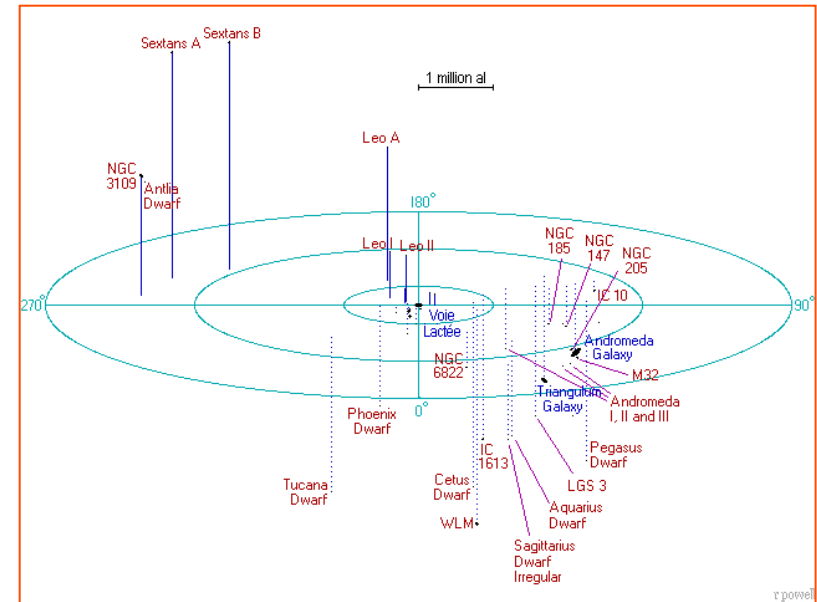
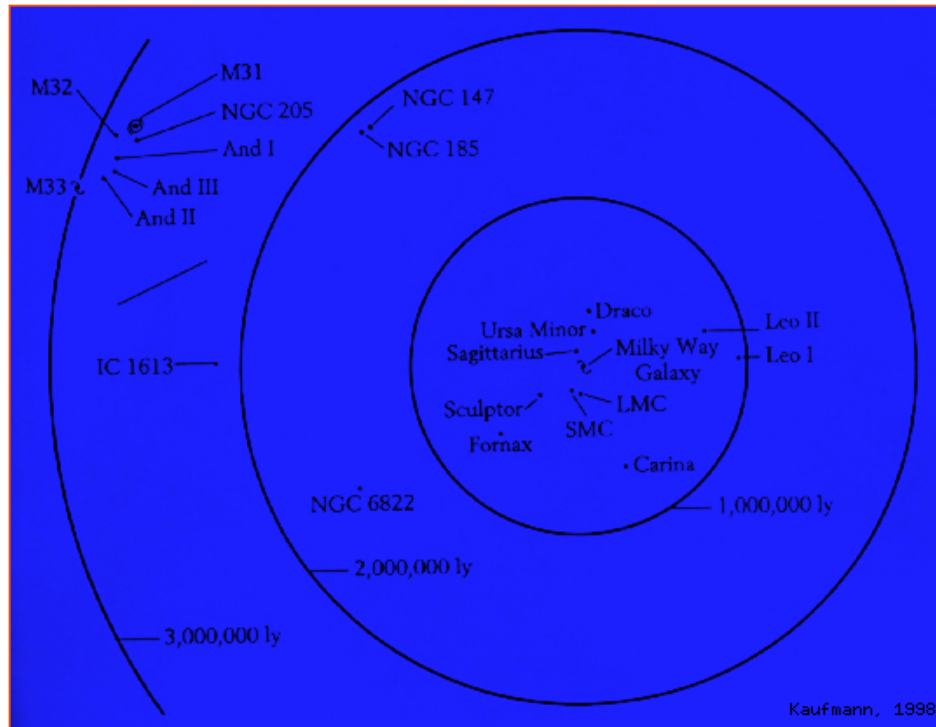
Nearby groups ($D < 15$ Mpc)



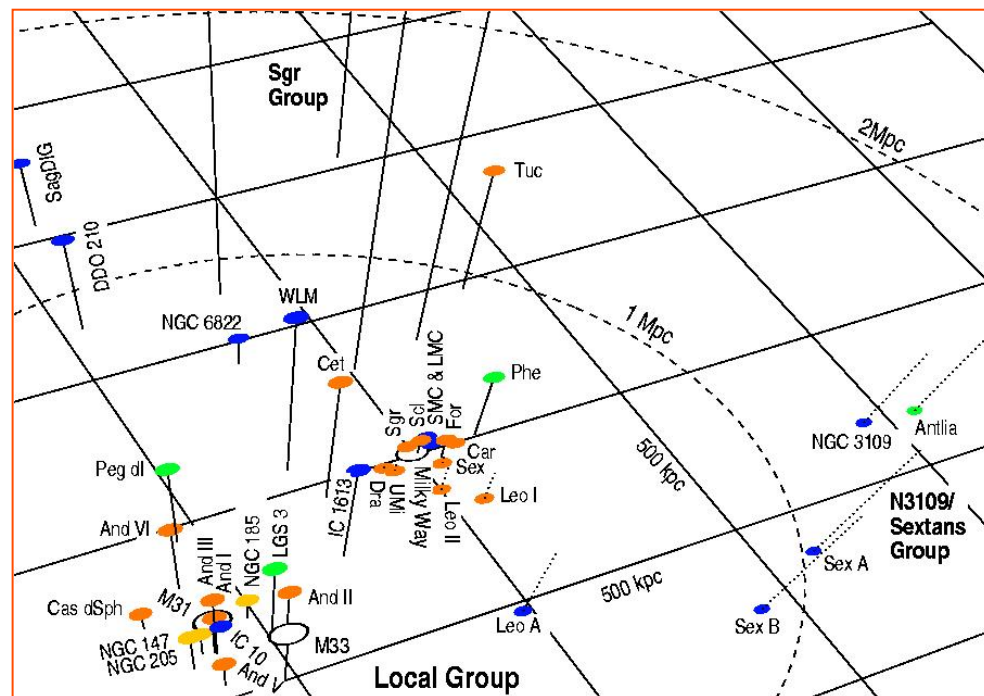
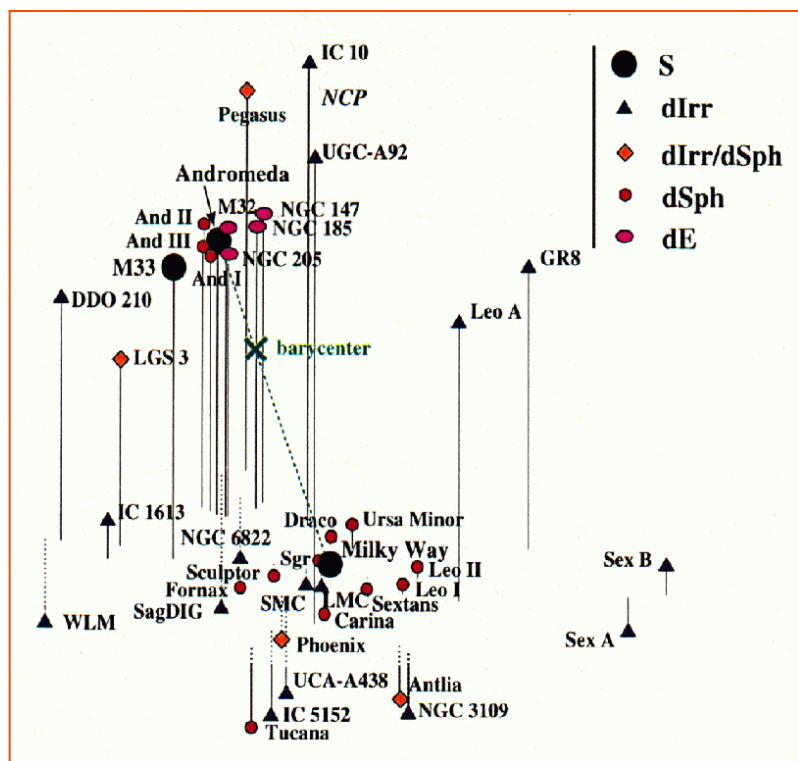
Satellite galaxies



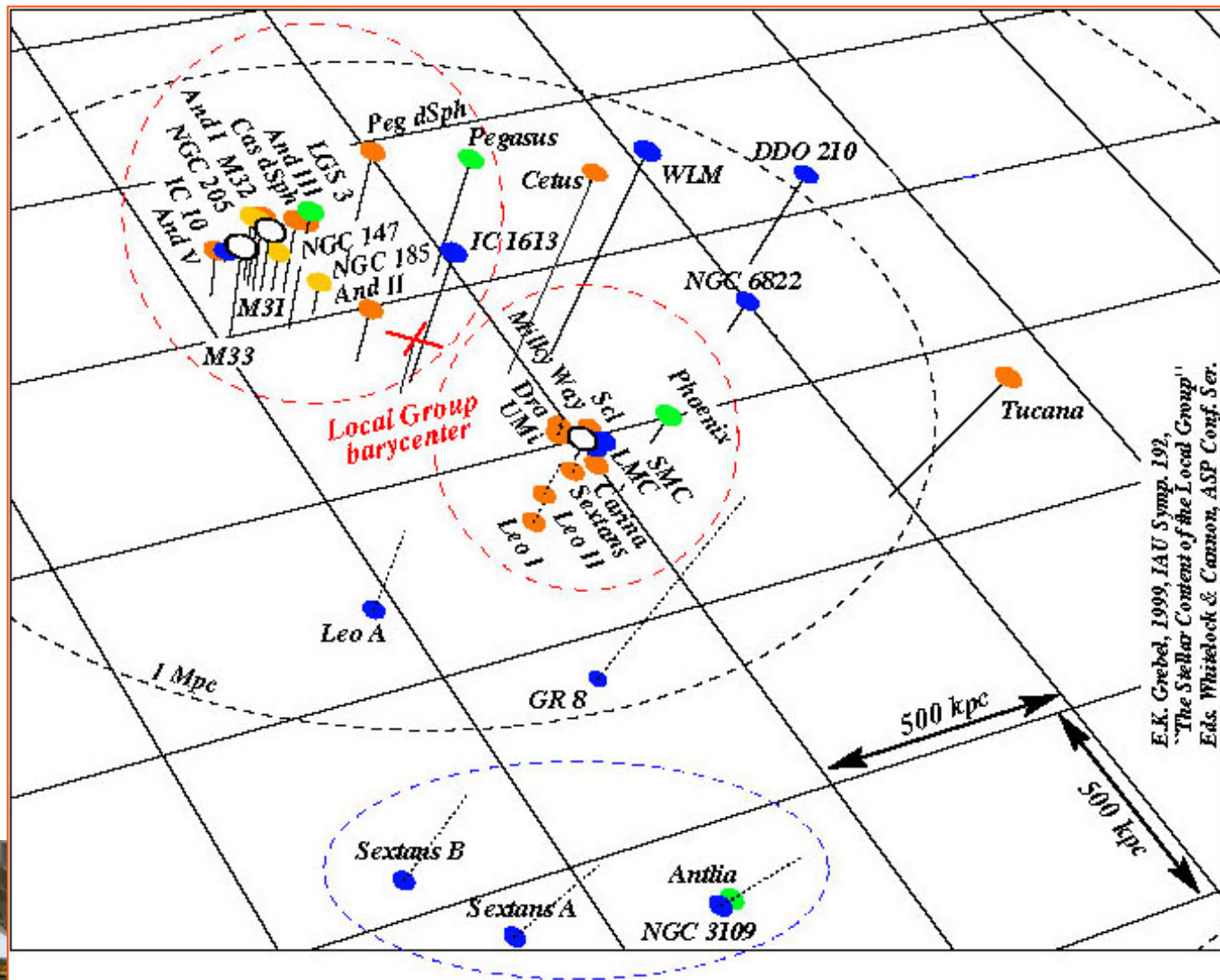
Local Group (D < 1.5 Mpc)



Local Group (D < 1.5 Mpc)



Local Group (D < 1.5 Mpc)



Local Group ($D < 1.5$ Mpc)

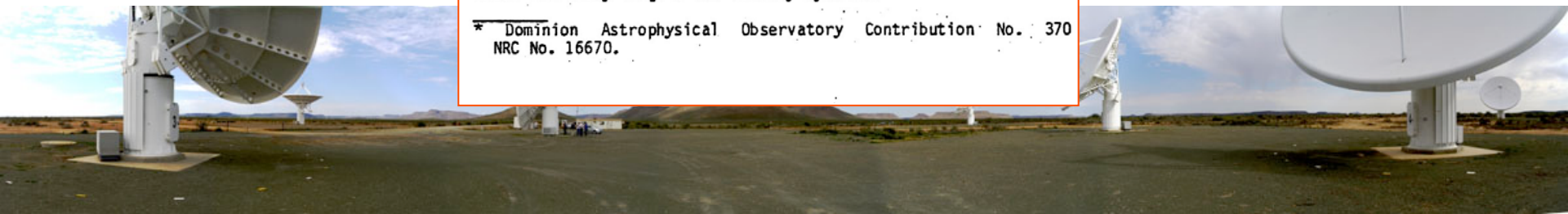
CHEMICAL EVOLUTION OF THE MEMBERS OF THE LOCAL GROUP *

Sidney van den Bergh

Dominion Astrophysical Observatory
Herzberg Institute of Astrophysics
National Research Council Canada
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Inspection of the prints of the Palomar Sky Survey shows that only a small fraction of all galaxies are either members of very rich clusters or isolated field objects. The overwhelming majority of galaxies turn out to be members of small clusters similar to the Local Group, to which our own Milky Way system belongs. In the past (cf. van den Bergh 1968) a distance limit of 1 Mpc has usually been used to define the extent of the Local Group. A more meaningful definition is a kinematical one such as that recently used by Yahil, Tammann, and Sandage (1977). These authors define the Local Group as a dynamical unit which does not expand with the Hubble flow. Using such a definition the diameter of the Local Group is found to be ~ 3 Mpc. An up-to-date census of Local Group members is given in Table I. The total number of probable Local Group galaxies listed in this table is 28. It should, however, be emphasized that the true number of Local Group members is likely to be even larger than this because existing surveys are incomplete for extremely faint galaxies. Furthermore, some fairly bright Local Group members might be hidden behind absorbing clouds at low galactic latitudes. Finally, the present number of dwarf spheroidal galaxies might be much smaller than it was when the Local Group was first formed because tidal forces may have disrupted many of these extremely fragile low-density systems.

* Dominion Astrophysical Observatory Contribution No. 370
NRC No. 16670.



Local Group (D < 1.5 Mpc)

TABLE 1
DERIVED PROPERTIES OF PROBABLE LOCAL GROUP GALAXIES

Name	Alias	DDO Type	$(m-M)_0$	M_V	l (deg)	b (deg)	D (kpc)	$\cos \theta$
M31	NGC 224	Sb I-II	24.4	-21.2	121.17	-21.57	760	0.88
Milky Way	Galaxy	S(B)bc I-II:	14.5	-20.9	000.00	00.00	8	-0.15
M33	NGC 598	Sc II-III	24.5	-18.9	133.61	-31.33	795	0.73
LMC	...	Ir III-IV	18.5	-18.5	280.19	-33.29	50	-0.80
SMC	...	Ir IV/IV-V	18.85	-17.1	302.81	-44.33	59	-0.61
M32	NGC 221	E2	24.4	-16.5	121.15	-21.98	760	0.88
NGC 205	...	Sph	24.4	-16.4	120.72	-21.14	760	0.88
IC 10	...	Ir IV:	24.1	-16.3	118.97	-03.34	660	0.94
NGC 6822	...	Ir IV-V	23.5	-16.0	025.34	-18.39	500	0.29
NGC 185	...	Sph	24.1	-15.6	120.79	-14.48	660	0.91
IC 1613	...	Ir V	23.3	-15.3	129.73	-60.56	725	0.47
NGC 147	...	Sph	24.1	-15.1	119.82	-14.25	660	0.92
WLM	DDO 221	Ir IV-V	24.85	-14.4	075.85	-73.63	925	0.32
Sagittarius	...	dSph(t)	17.0	-13.8	005.61	-14.09	24	-0.04
Fornax	...	dSph	20.7	-13.1	237.24	-65.66	138	-0.25
Pegasus	DDO 216	Ir V	24.4	-12.3	094.77	-43.55	760	0.76
Leo I	Regulus	dSph	22.0	-11.9	225.98	+49.11	250	-0.44
And I	...	dSph	24.55	-11.8	121.69	-24.85	810	0.86
And II	...	dSph	24.2	-11.8	128.91	-29.15	700	0.78
Leo A	DDO 69	Ir V	24.2	-11.5	196.90	+52.41	690	-0.14
Aquarius*	DDO 210	Ir V	25.05	-11.3	034.04	-31.35	1025	0.40
Sag DIG*	...	Ir V	25.7	-10.7	021.13	-16.23	1300	0.22
Pegasus II	And VI	dSph	24.45	-10.6	106.01	-36.30	830	0.83
Pisces	LGS 3	dIr/dSph	24.55	-10.4	126.77	-40.88	810	0.71
And III	...	dSph	24.4	-10.2	119.31	-26.25	760	0.86
And V	...	dSph	24.55	-10.2	126.22	-15.12	810	0.87
Leo II	...	dSph	21.6	-10.1	220.14	+67.23	210	-0.26
Phoenix	...	dIr/dSph	23.0	-9.8	272.19	-68.95	395	-0.30
Sculptor	...	dSph	19.7	-9.8	287.69	-83.16	87	-0.06
Tucana	...	dSph	24.7	-9.6	322.91	-47.37	870	-0.44
Cassiopeia	And VII	dSph	24.2	-9.5	109.46	-09.95	690	0.98
Sextans	...	dSph	19.7	-9.5	243.50	+42.27	86	-0.65
Carina	...	dSph	20.0	-9.4	260.11	-22.22	100	-0.85
Draco	...	dSph	19.5	-8.6	086.37	+34.71	79	0.77
Ursa Minor	...	dSph	19.0	-8.5	104.88	+44.90	63	0.66

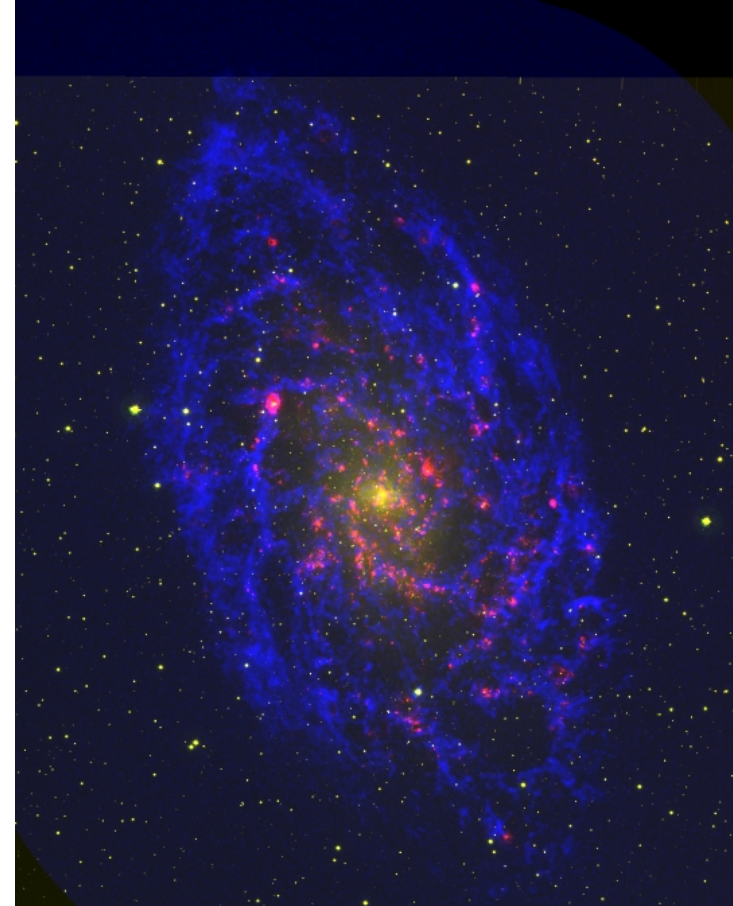
Note.—Colons denote uncertain values.
* Membership in Local Group not yet firmly established.

- Composition (< 1.5 Mpc)
 - 3 Sp (MW, M31, M33)
 - 2 E (M32 & NGC 205)
 - 10 Irr
 - 2 dIrr/dSph
 - 18+ dSph
- ~ 35 galaxies of which 30 dwarfs
- Mass mostly in MW & M31

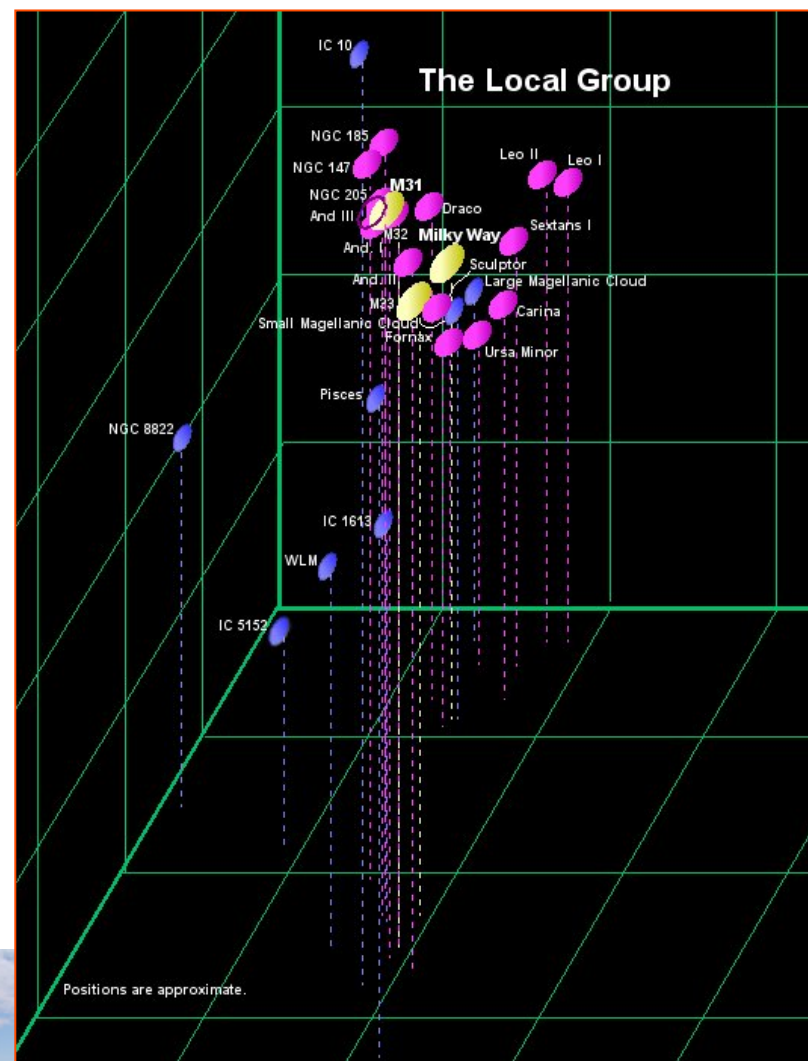
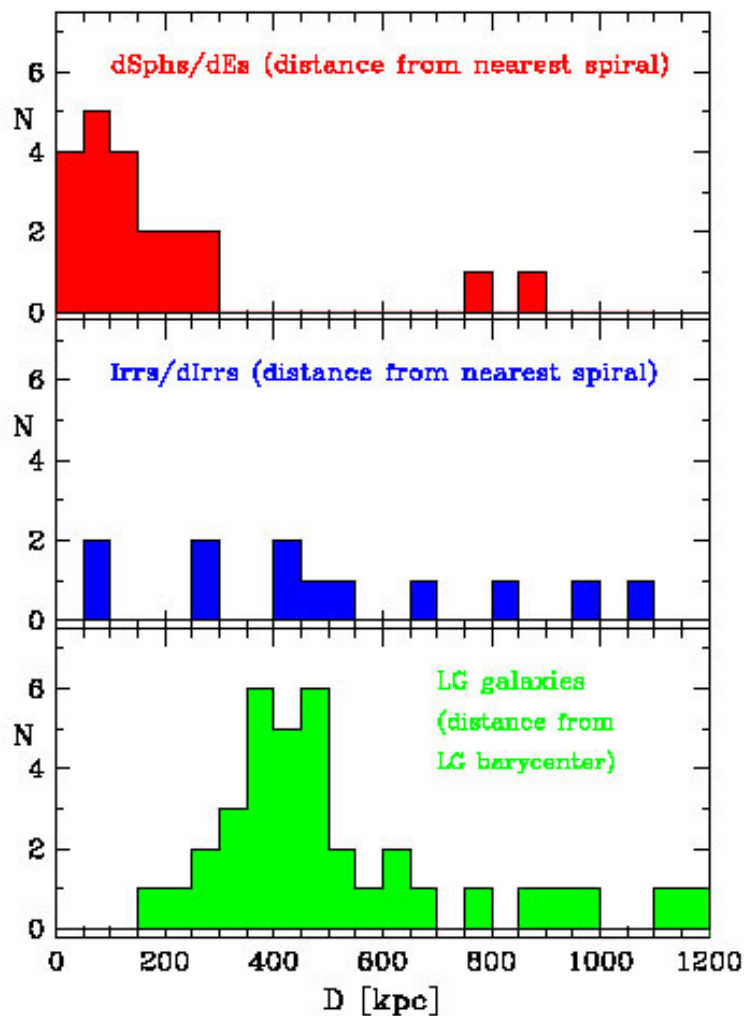
Pritchett & van den Bergh 1999



Local Group ($D < 1.5$ Mpc)



Local Group (D < 1.5 Mpc)



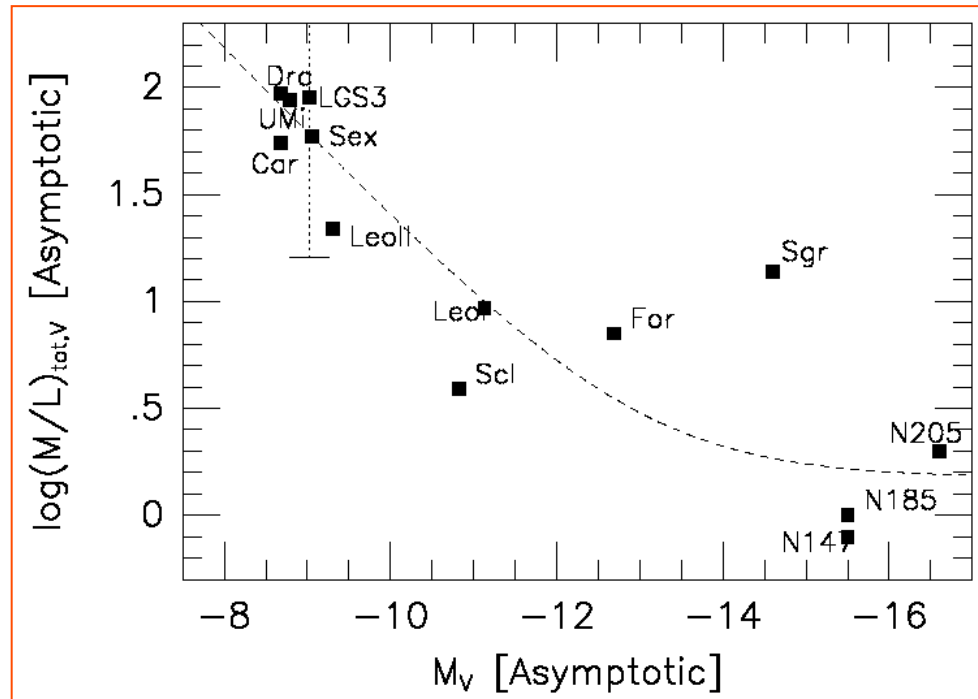
Local Group ($D < 1.5$ Mpc)

- In the Local Group:
 - Dwarf irregulars are in regions of low density
 - dSphs close to M31 & MW
- Similar situation in the LG and in rich clusters:
 - E & S0 in the center
 - Sp in the outer low density parts



Local Group ($D < 1.5$ Mpc)

In the Local Group, the dwarfs of low luminosity are the ones having the highest (M/L) , so the higher content of DM.



Local Group ($D < 1.5$ Mpc)

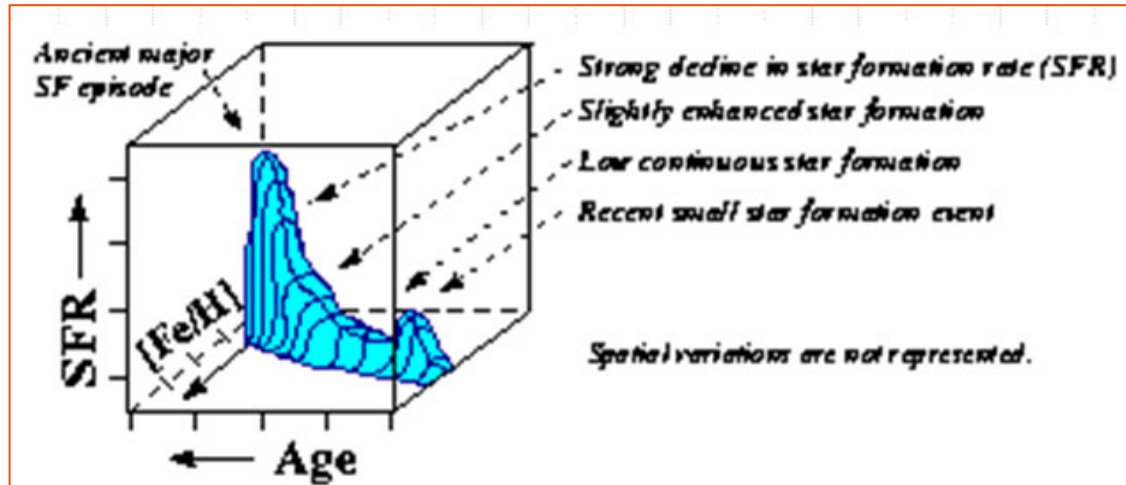


Figure 6. A sample population box for a fictitious galaxy.

Population Box (after Hodge, 1989)

History of SF in the LG dwarfs

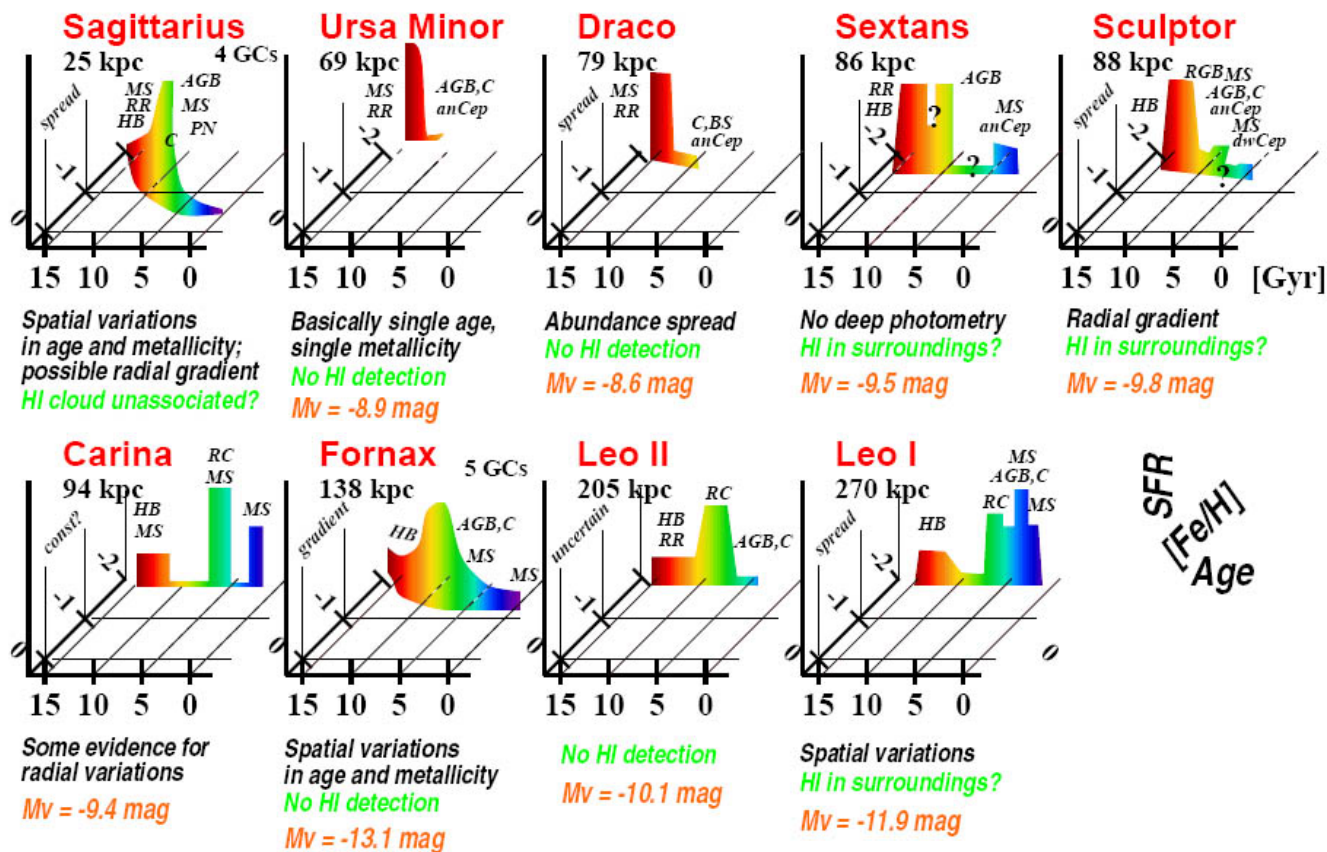
Grebel 2000



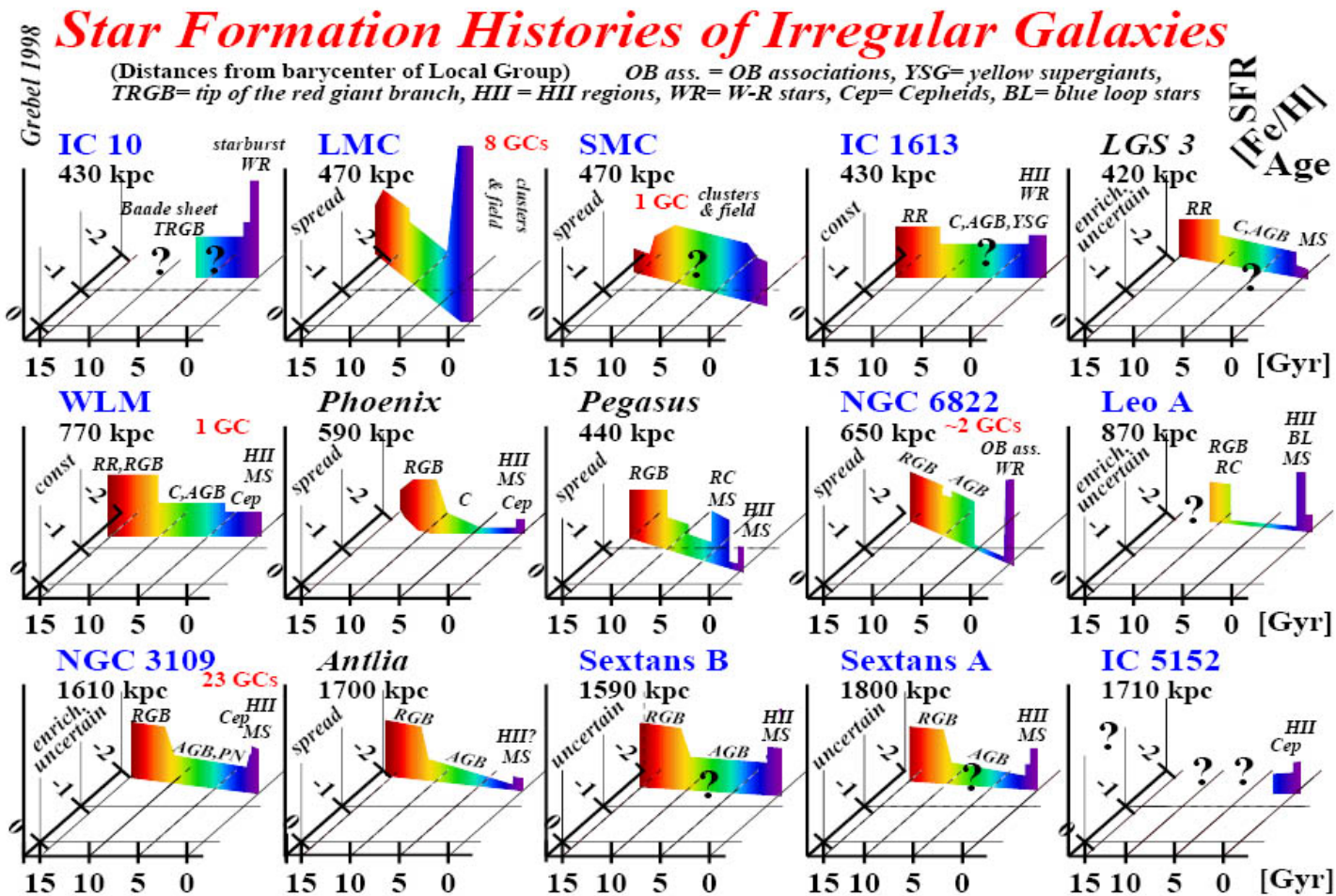
Local Group ($D < 1.5$ Mpc)

Star Formation Histories of MW dSph Galaxies

MS= main sequence, C = Carbon stars, AGB = asympt. giants, RC= red clump, PN=planetary nebulae, anCep= anomalous Cepheids, RGB = red giant branch, RR = RR Lyrae, HB= horizontal branch



Local Group ($D < 1.5$ Mpc)



Local Group ($D < 1.5$ Mpc)

- If the LG is representative of the Universe:
 - dlrrs and dSphs are the two most abundant types of galaxies in the Universe
 - **But** undetectable, even in the nearby groups, because of their low luminosity

Ex.: 10 Mpc ($m-M_0$) ~ 30 $M_B \sim -10/-11$ $B_T \sim 20$

- Not a solution for the DM since

$$M_{\text{dwarf}} \sim 10^6 - 10^8 M_{\text{sun}} \quad E_{\text{giant}} \sim 10^{11-12} M_{\text{sun}}$$



Sculptor Group (D = 2.5 Mpc)

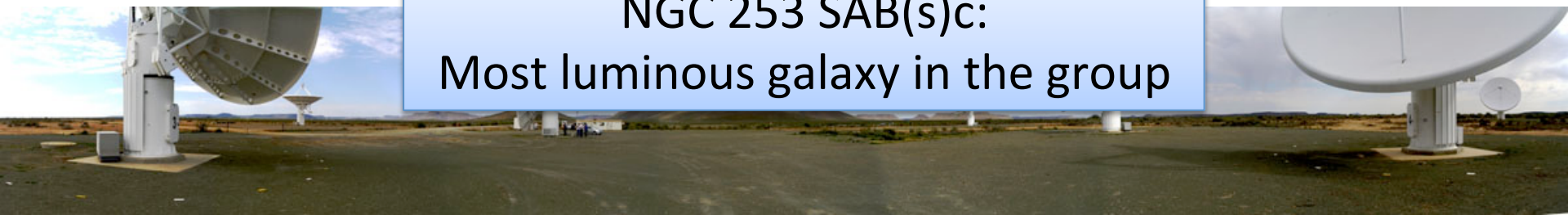
- Nearest Group to the LG
- Made of 5 late-type spirals (Sc-Sm)
- Distance: 2.5 Mpc ($1.5 < \Delta < 4.0$ Mpc)



Sculptor Group ($D = 2.5$ Mpc)



NGC 253 SAB(s)c:
Most luminous galaxy in the group



Sculptor Group ($D = 2.5$ Mpc)



NGC 55 SB(s)m: the closest



NGC 7793 SA(s)d: the most distant



Sculptor Group ($D = 2.5$ Mpc)



NGC 247 – SAB(s)d

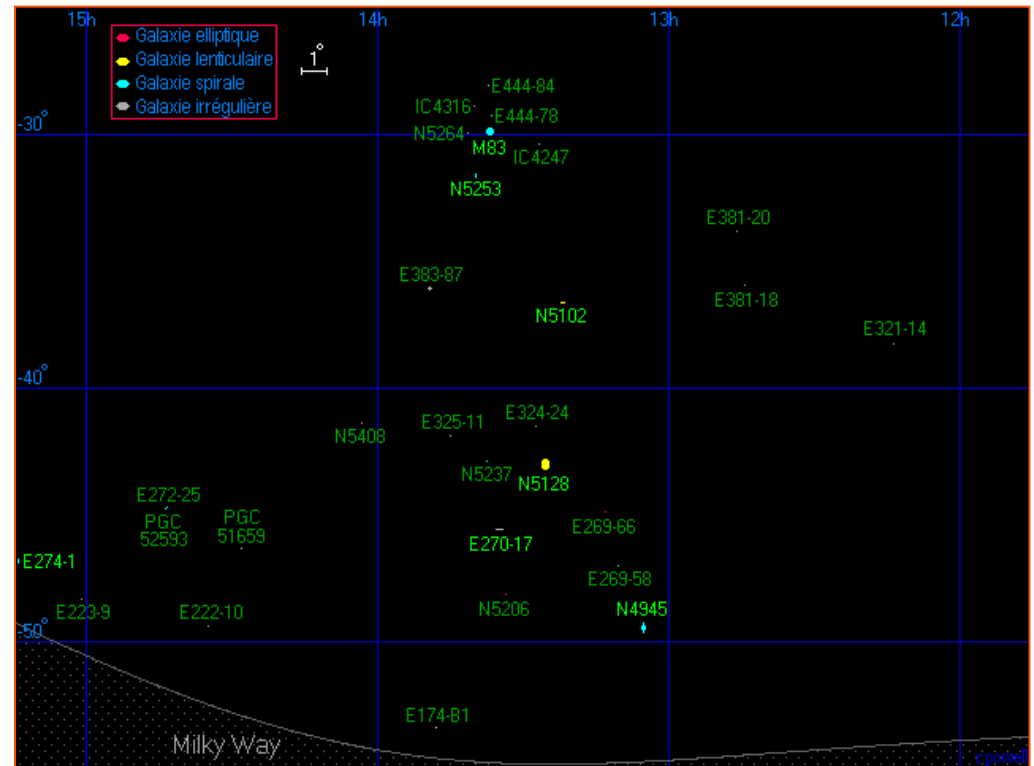


NGC 300 – SA(s)d



Centaurus Group

- Group containing many active galaxies:
 - Centaurus A: the strongest radio galaxy after Virgo A (M87)
 - M83

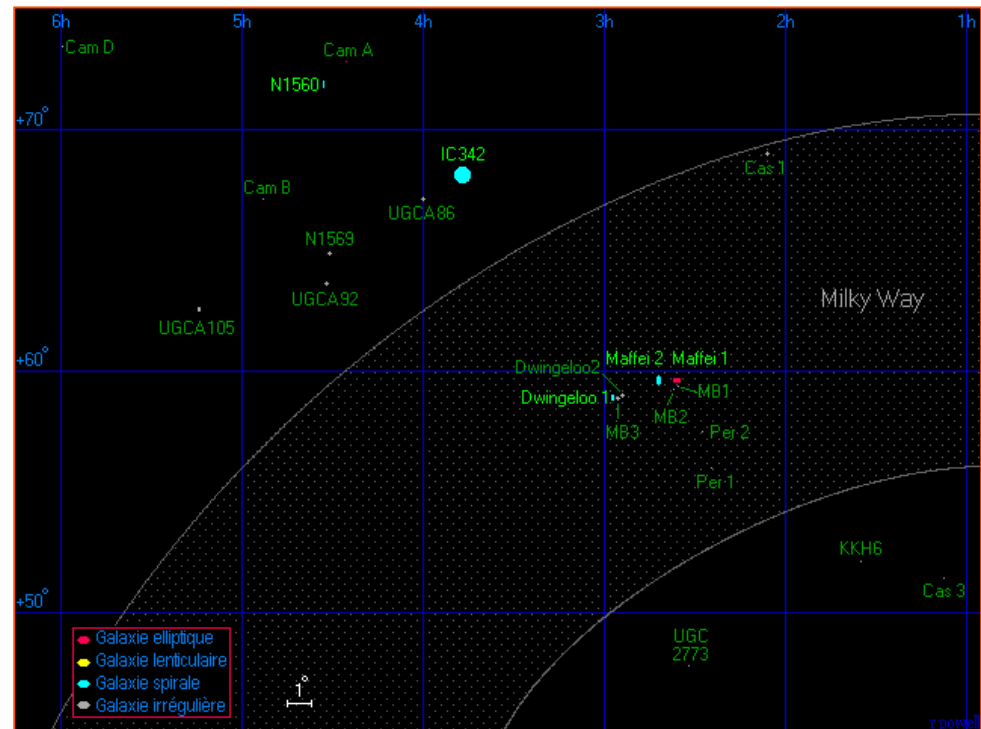


Centaurus Group

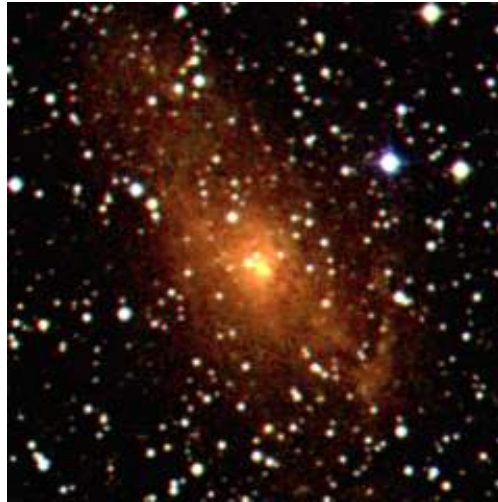


Maffei Group (IC 342)

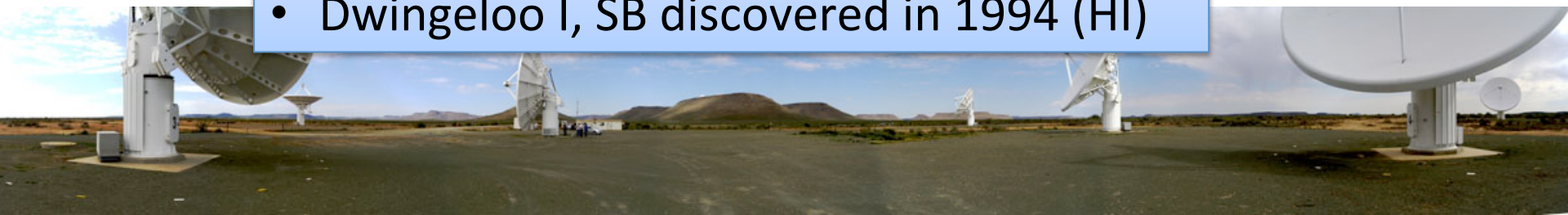
- Discovered in 1968 !
(highly obscured / behind the galactic plane)
- Majority of the galaxies unknown before 1980
- 16 known members (mostly dwarfs)



Maffei Group (IC 342)



- 3 very obscured galaxies
- Maffei I, large elliptical, the nearest to us
- Maffei II, barred spiral
- Dwingeloo I, SB discovered in 1994 (HI)



Maffei Group (IC 342)

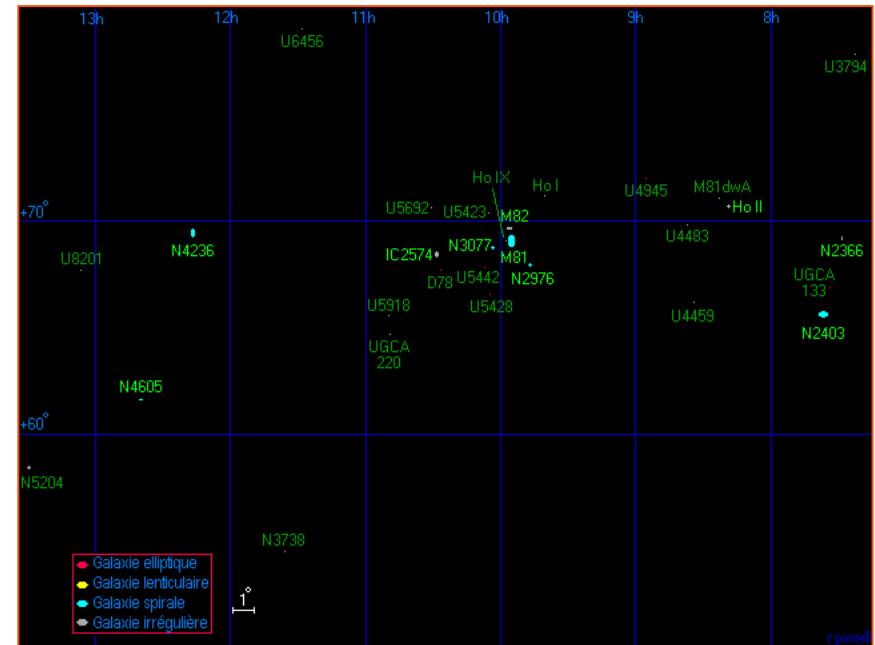


- The most important galaxy of the group
- If there was no obscuration by the MW, IC 342 would be the most luminous galaxy in the sky (visible to the naked eye)



M81 Group

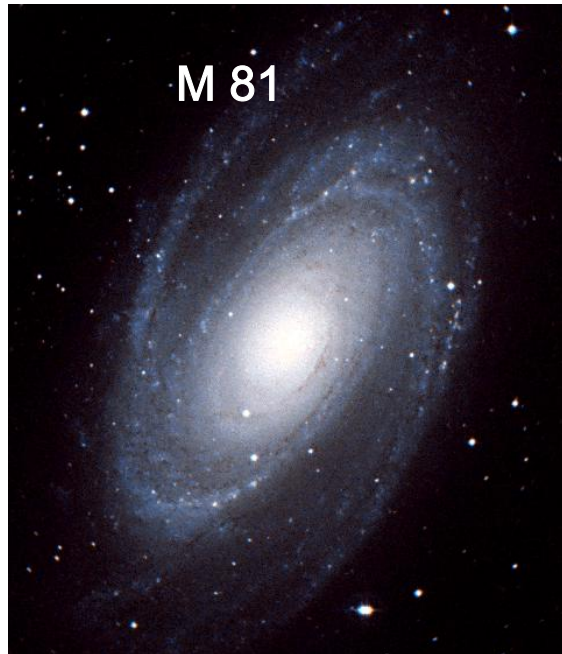
- Contain the famous M81/M82 pair
- M82 nearby starburst
- Other important spiral NGC 2403
- Contains ~ 30 spirals



M81 Group



M81 Group



Similar size than the MW

AGN

40 kpc from M81

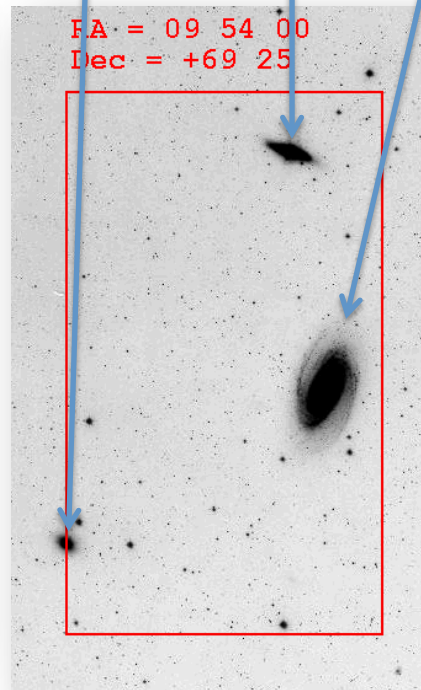


M81 Group

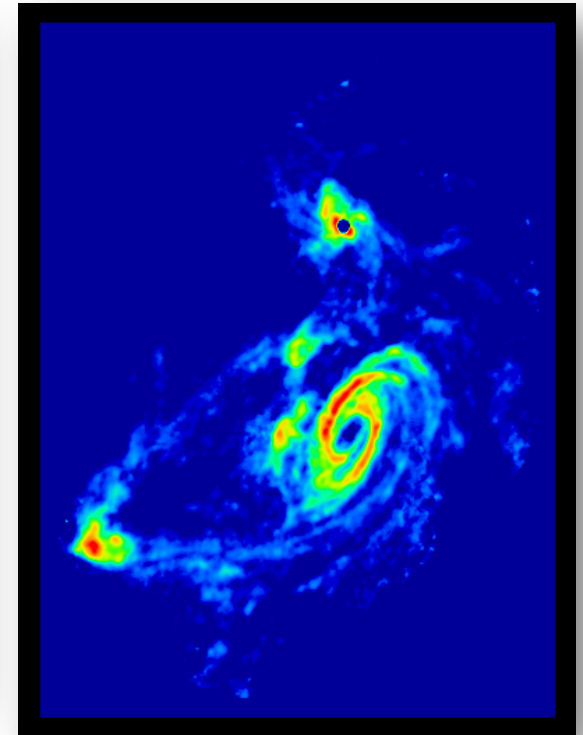
M82 – IR



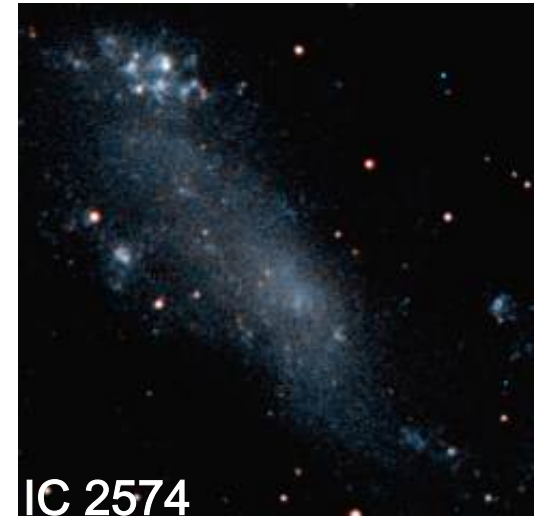
NGC 3077 - M82 – M81



Deep HI



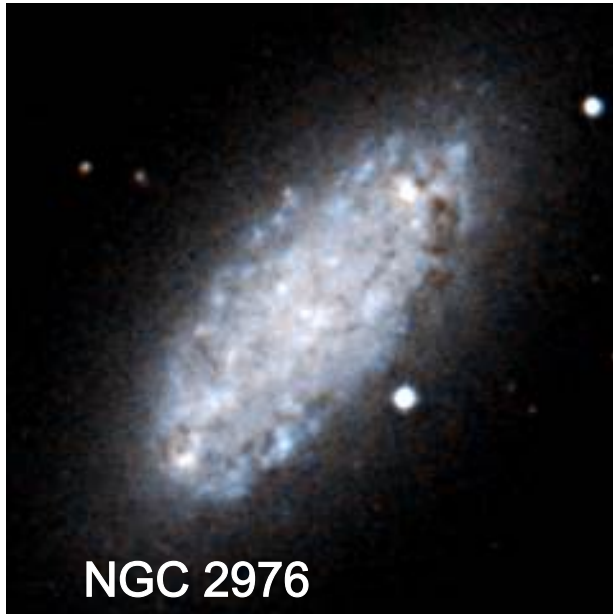
M81 Group



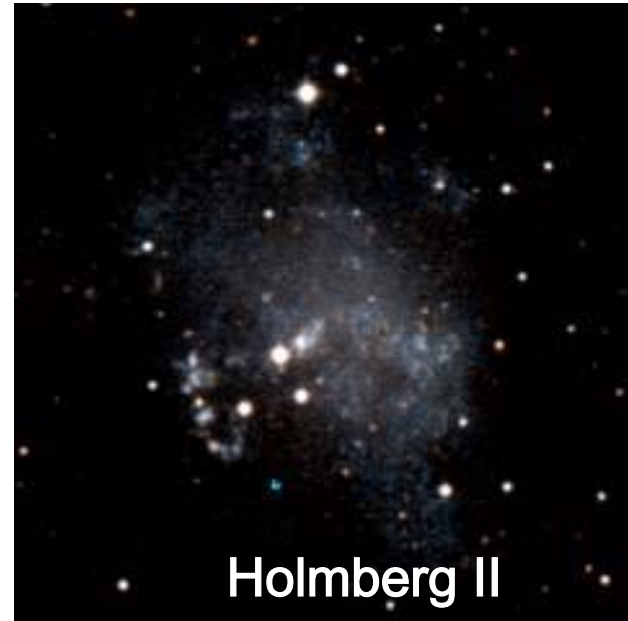
- NGC 2366: Irr with a high SFR
- NGC 2403: 2nd spiral of the group
- IC 2574:same size as M82 but LSB



M81 Group



NGC 2976



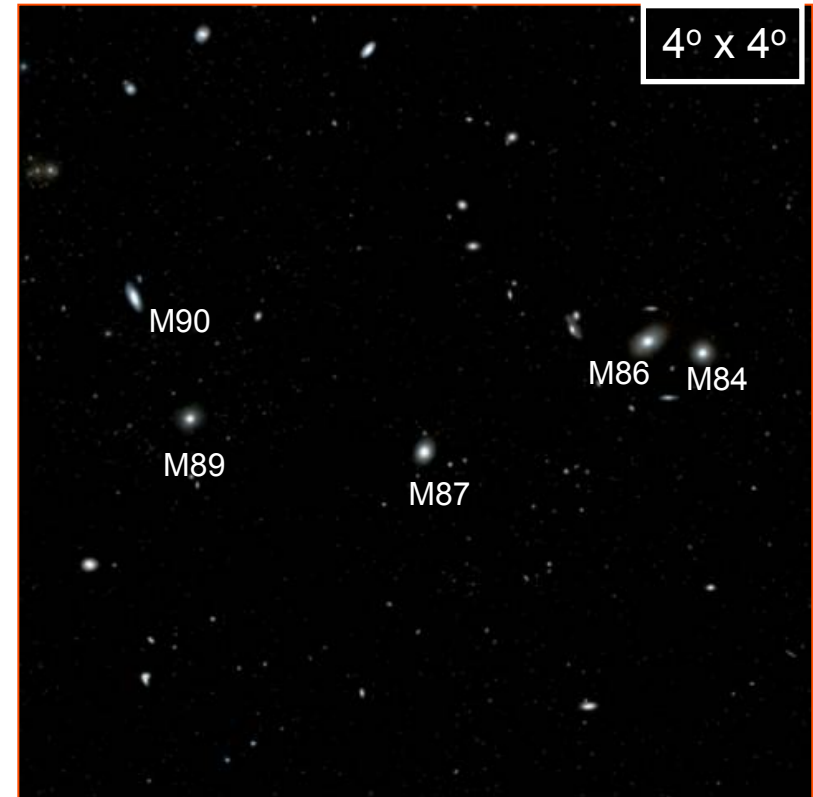
Holmberg II

- NGC 2976: small spiral 600 kpc behind M81
- Holmberg II: dwarf Irr, evidence for ram pressure



Virgo cluster

- 2000 galaxies (90% dwarfs)
- Not homogeneous: core & extensions
- $\Delta \sim 15$ Mpc
- Important IGM (X-rays)
- $R \sim 6^\circ \sim 72$ galaxies
 - 41 E & S0
 - 31 Sp
- $\langle V_0 \rangle \sim 1031 \pm 84$ km/sec
- $\sigma_v \sim 712$ km/sec

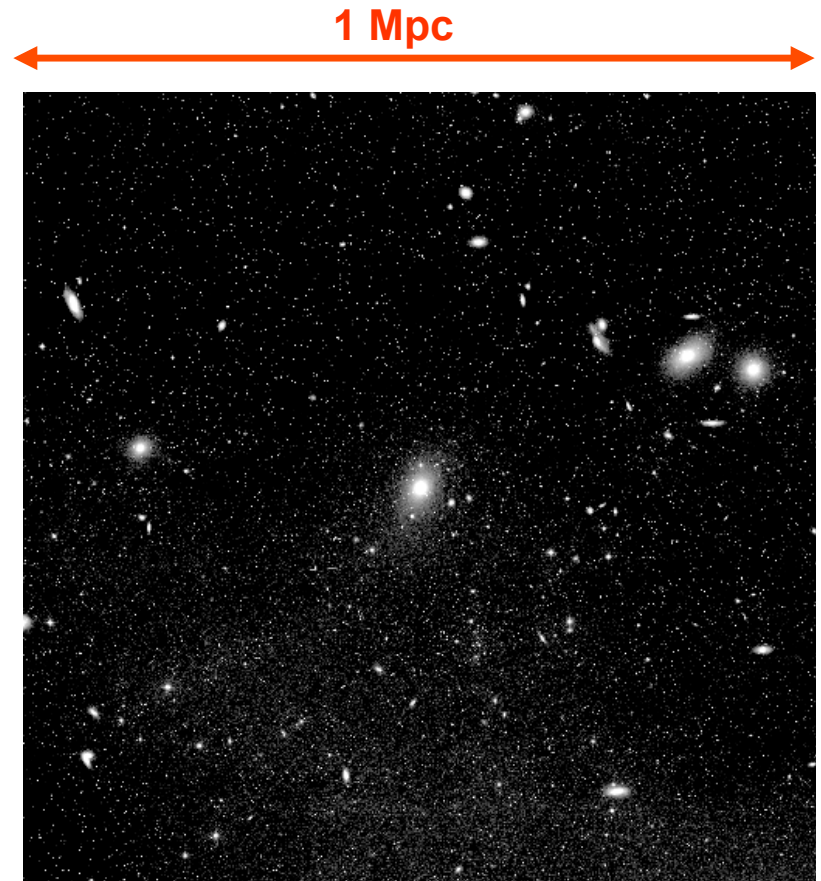


Spiral-rich

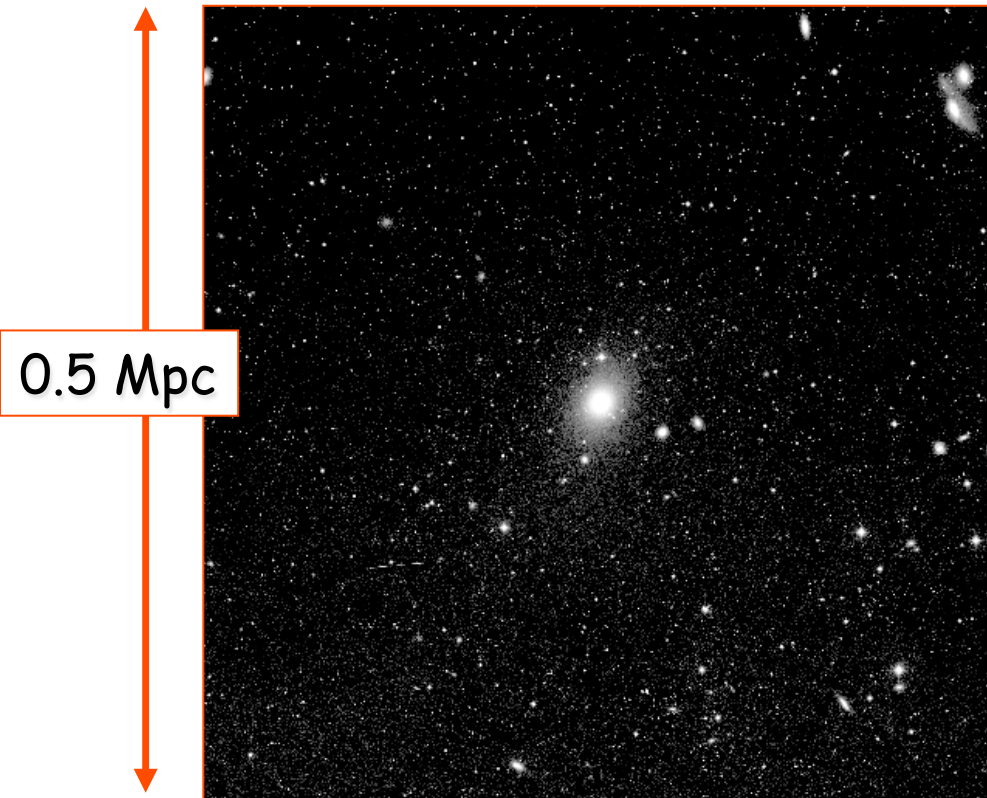


Virgo cluster

- Spirals: distributed uniformly (spatially & in velocities)
- Ellipticals: concentrated in the center

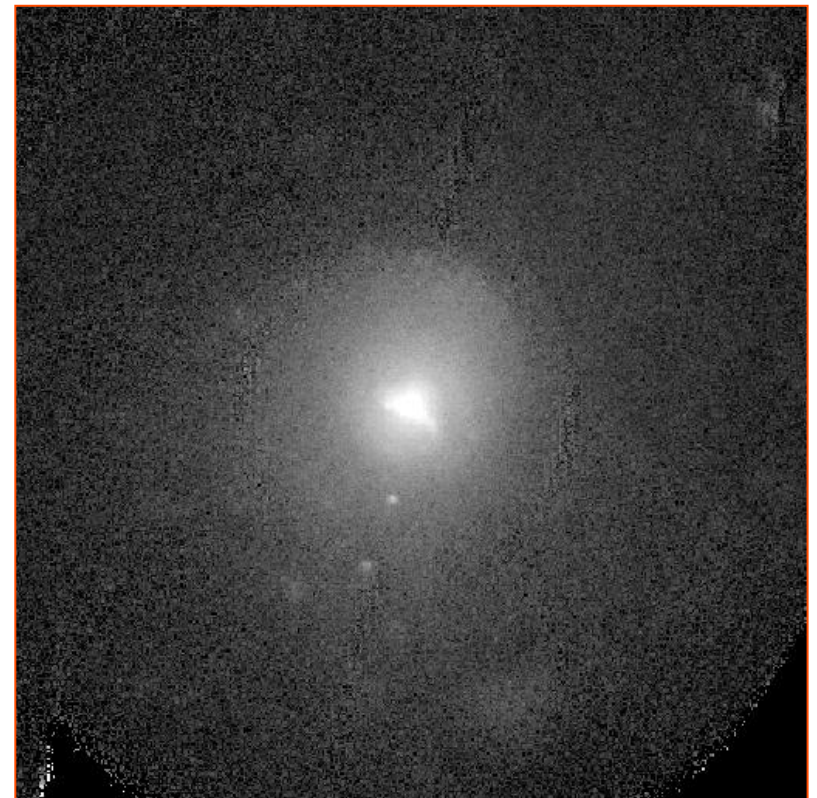


Virgo cluster



0.5 Mpc

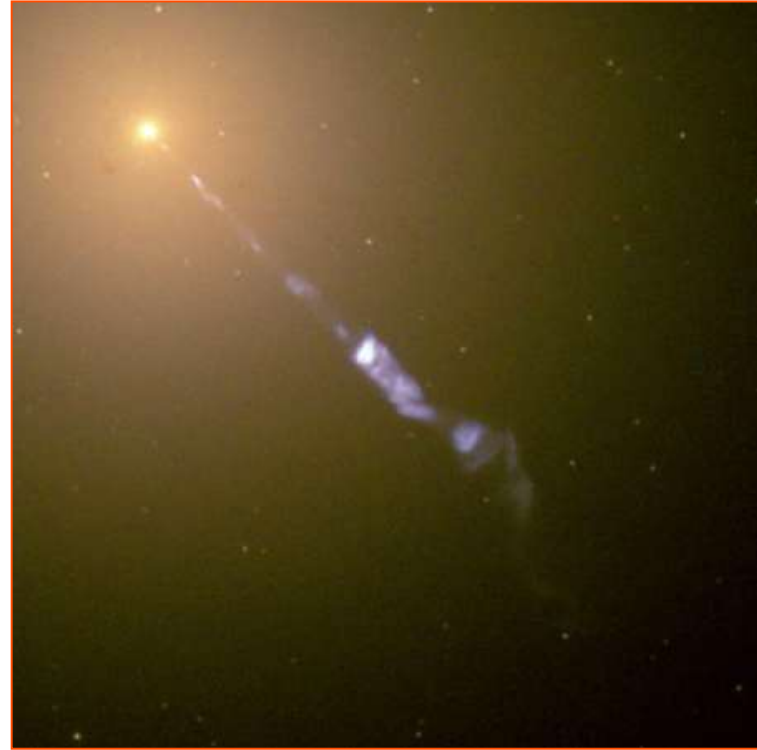
Visible



X-ray



Virgo cluster



M 87



Virgo cluster



Ram pressure

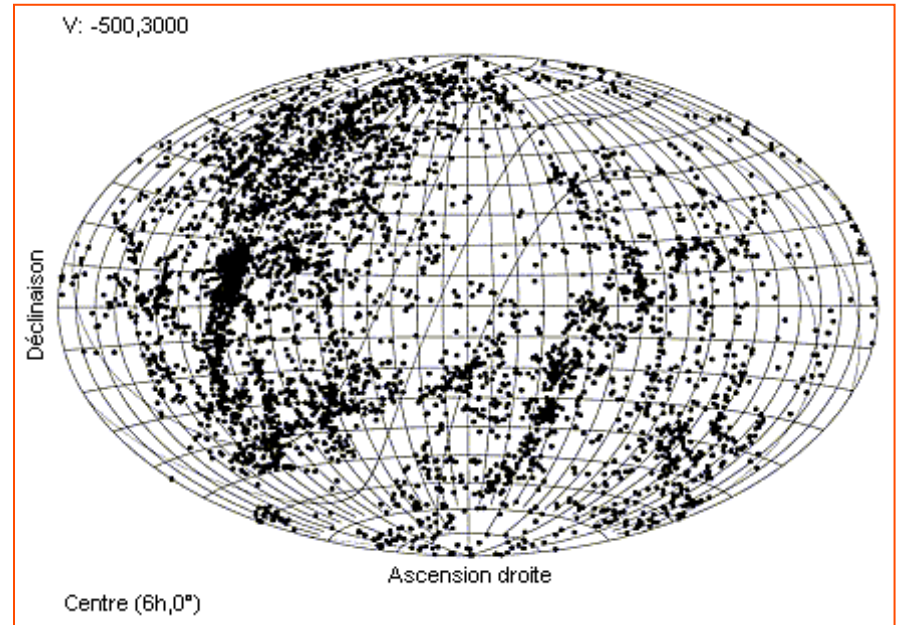


Optical warp

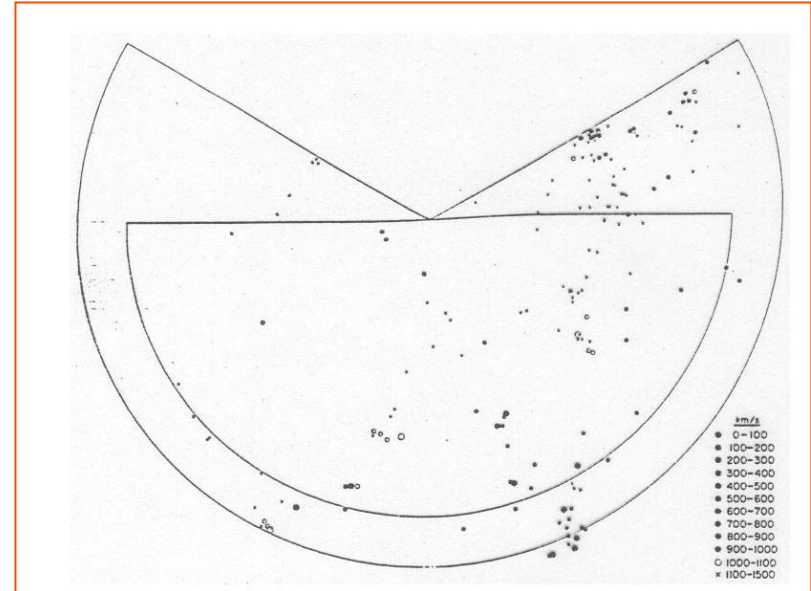
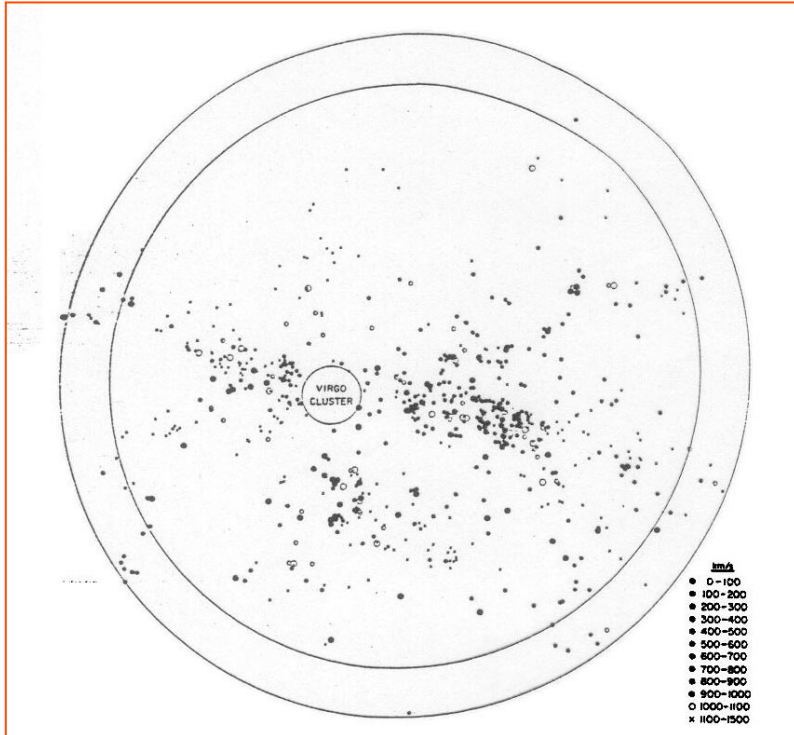


Local Supercluster

- The existence of the Local Supercluster was not suspected before serious studies started in the southern hemisphere
- Close clusters form a plane around Virgo, with the LG and Sculptor on the outskirts



Local Supercluster



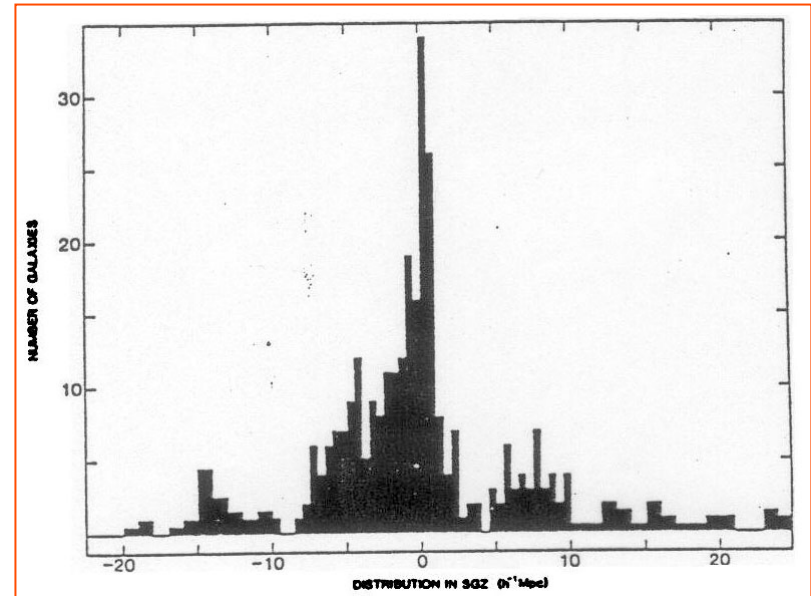
34 galaxies avec $V < 1100 \text{ km/s}$ & $b < -30^\circ$

378 galaxies avec $V < 1100 \text{ km/s}$ & $b > 30^\circ$



Local Supercluster

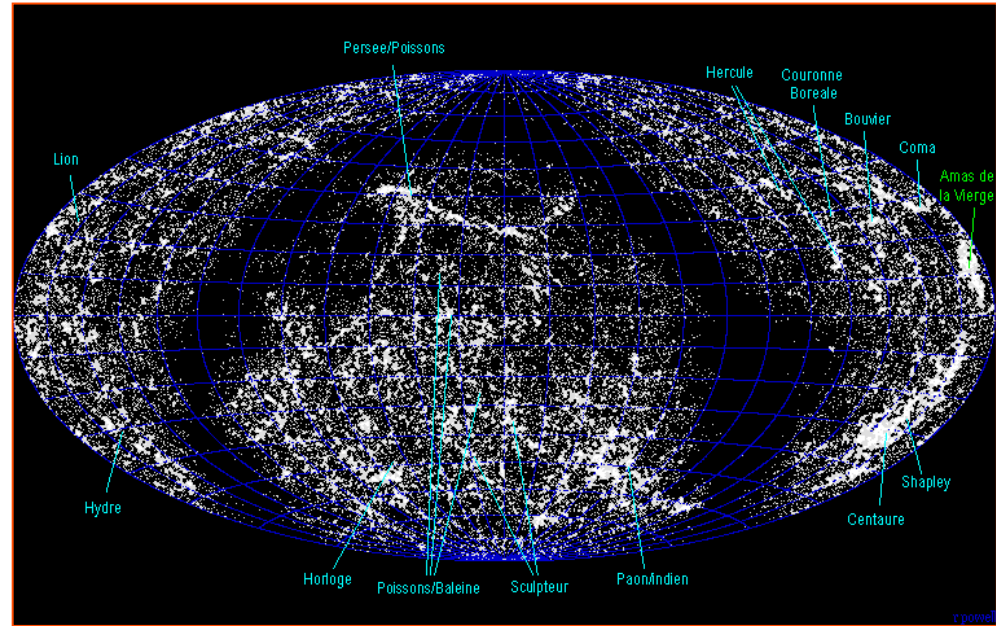
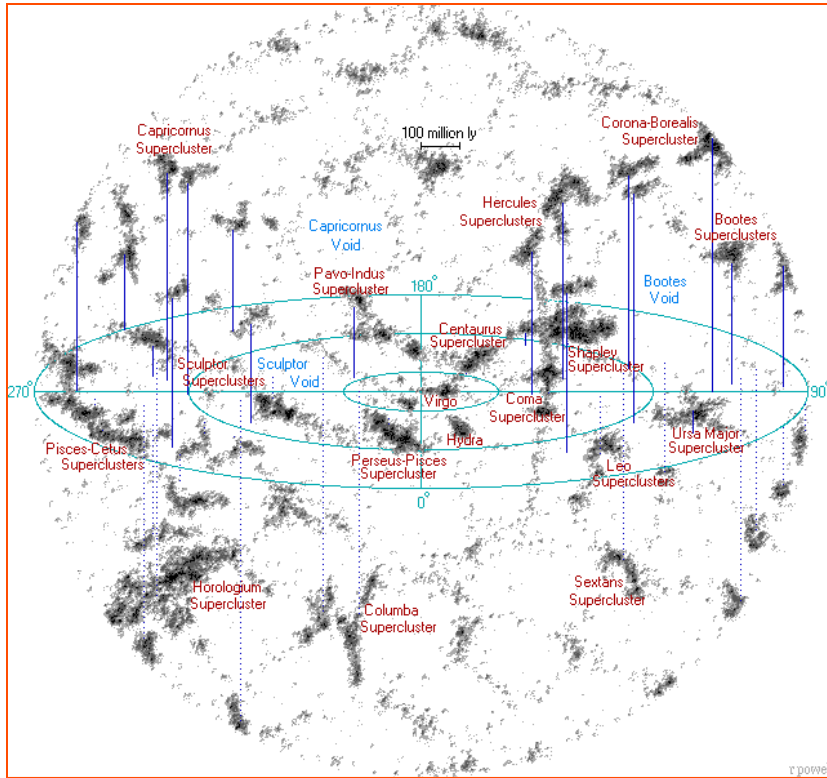
- Despite the evidence, the LSC was contested until 1978 (chance superposition)
- The existence was accepted when such large structures were seen elsewhere



Galaxies in the LSC in SG coordinates



Other superclusters



Large Scale structure

