

Dwarf Galaxies of the Local Group

A review paper by Mario Mateo

Vithal Tilvi

Journal club
Instructor: Dr Rolf Jansen

March 02, 2007

The Local Group in brief

- Few Mpc in diameter
- ~ 40 objects
- Dominated by 2 giant spirals, MW & M31
- Mass $\sim 10^{12} M_{\odot}$

The LOCAL GROUP

Figure 18.17 These are the galaxies of the Local Group, arranged to represent their actual physical relationships to the Milky Way <http://astro.colorado.edu/fig/18.17.html>.

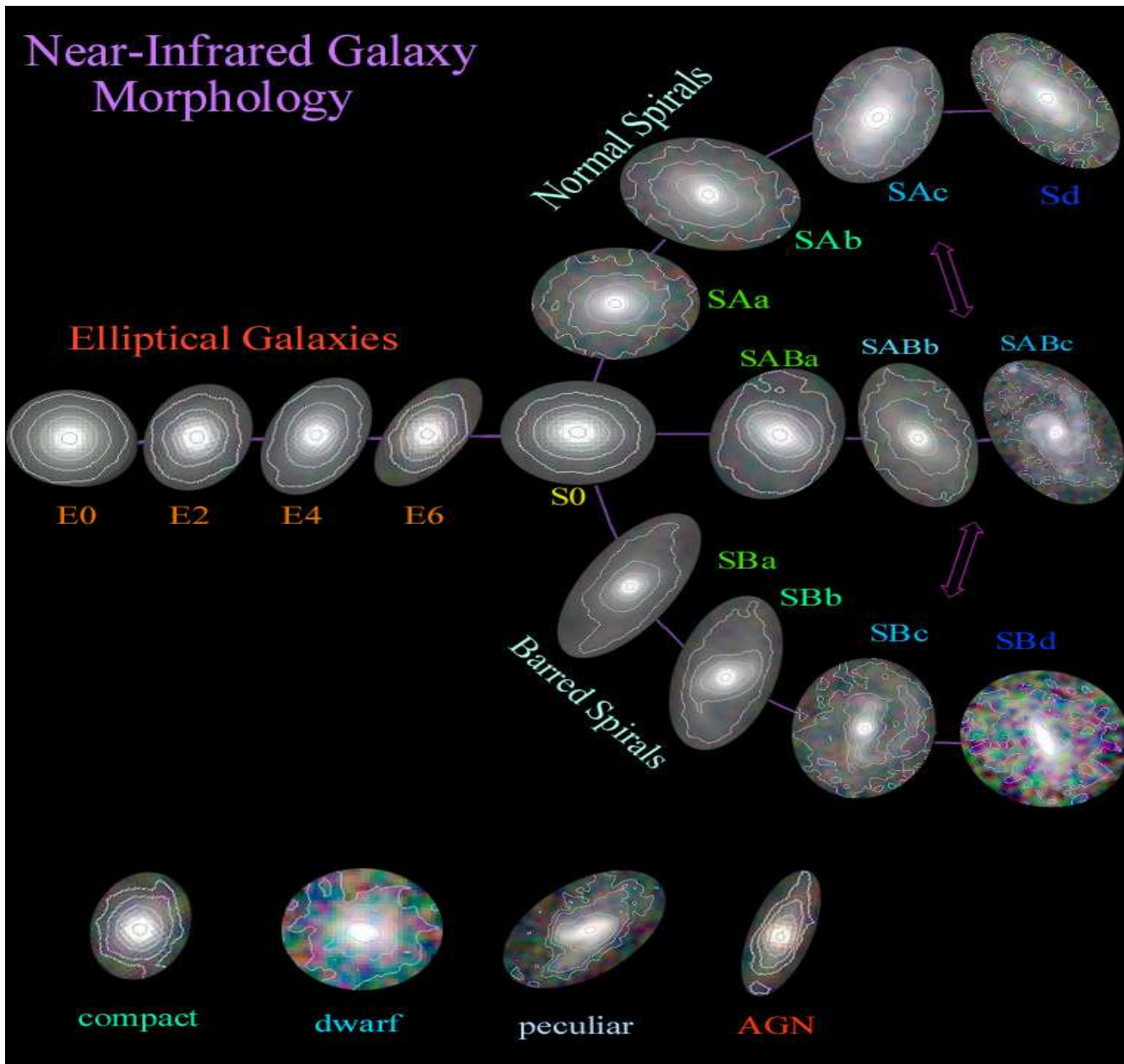


- | | |
|----------------|----------------------------|
| (1) Milky Way | (17) NGC 205 |
| (2) Draco | (18) M32 |
| (3) Ursa Minor | (19) Andromeda I |
| (4) SMG | (20) Andromeda II |
| (5) LMG | (21) Andromeda (M31) |
| (6) Carina | (22) M33 |
| (7) Sextans | (23) IGS 3 |
| (8) Ursa Major | (24) IC 1613 |
| (9) Pegasus | (25) NGC 6822 |
| (10) Sculptor | (26) Sextans A |
| (11) Fornax | (27) Leo A |
| (12) Leo I | (28) IC 10 |
| (13) Leo II | (29) DDO 210 |
| (14) Maffei | (30) Wolf-Lundmark-Melotte |
| (15) NGC 185 | (31) IC 5152 |
| (16) NGC 147 | |

Source: <http://www.iastate.edu/~astro.150/images/localgroup.jpg>

Why study the Local Group

- Mixture of galaxies which includes spiral, dwarfs, irregulars
- Large luminosity range
- Proximity
- Provides internal kinematics of less luminous galaxies



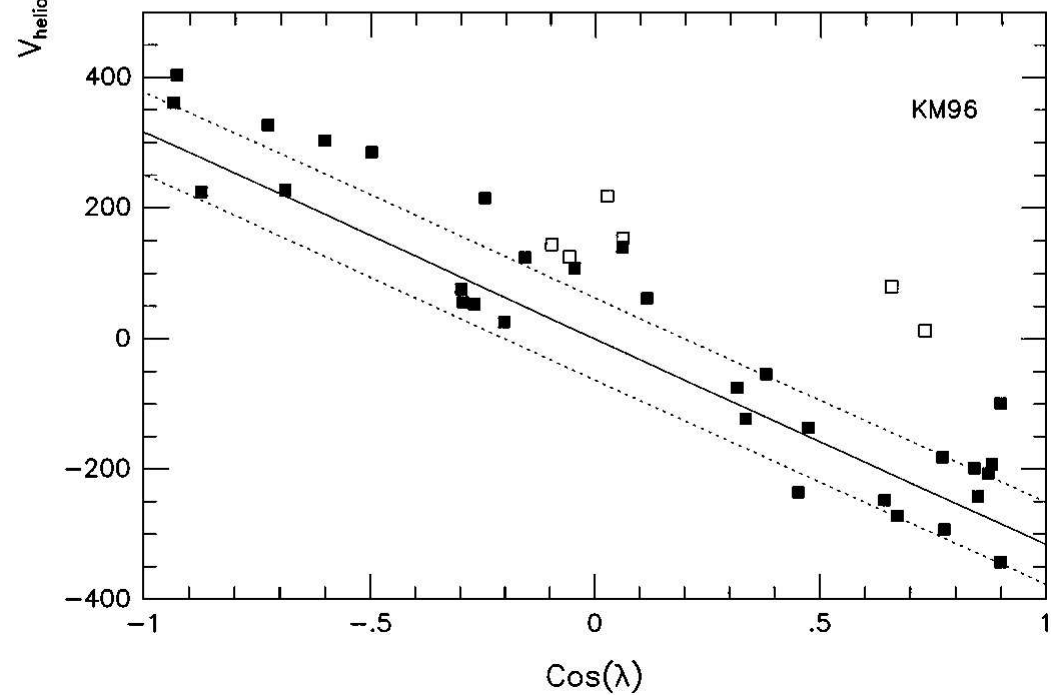
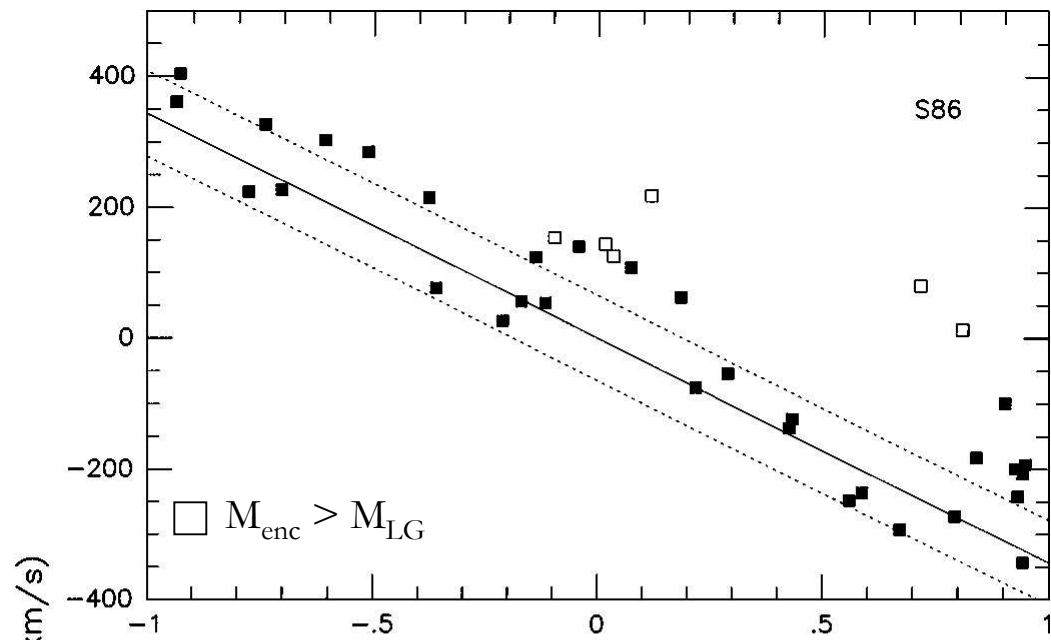
Source: <http://www.ipac.caltech.edu/2mass/gallery/galmorph/>

Are Dwarfs in the Local Group special?

- Comes in different shapes: dwarf irregular, dSph, dwarf elliptical
- Metal poor and might carry the imprint of the young universe, if haven't been disrupted by merger
- Distribution of the dark matter
- Star formation history
- ISM enrichment in the early universe

What to include in the Local Group?

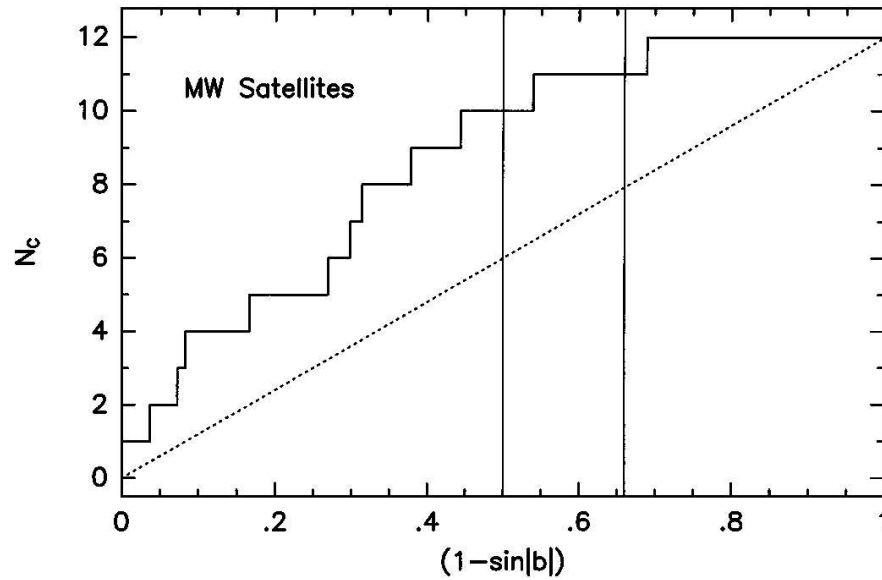
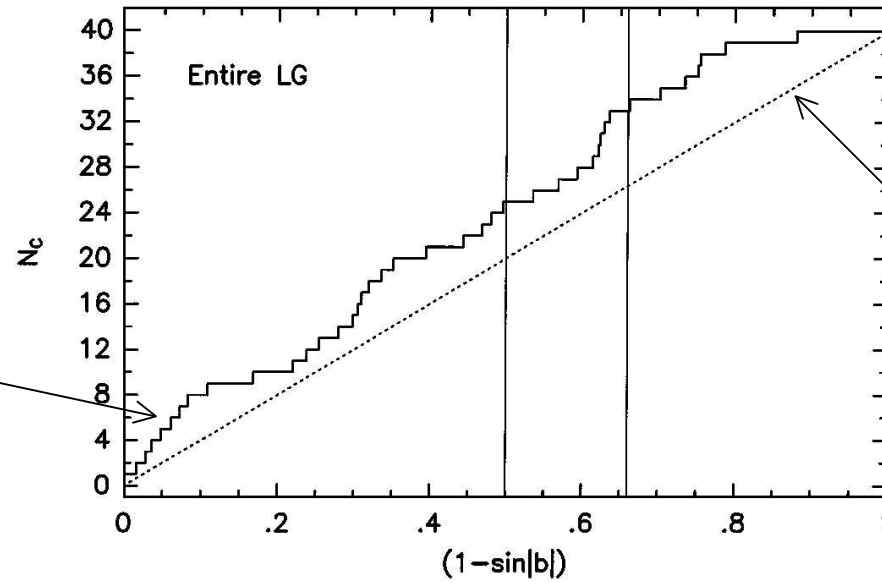
- Resolvability
- Low heliocentric velocities of bright stars
- Distances
- Dynamical considerations : radial velocities
- For luminous galaxies:
- SNe, Tully-Fisher, Cepheids
- $M_{\text{enc}} \gg \text{MLG} \rightarrow$ they are not bound

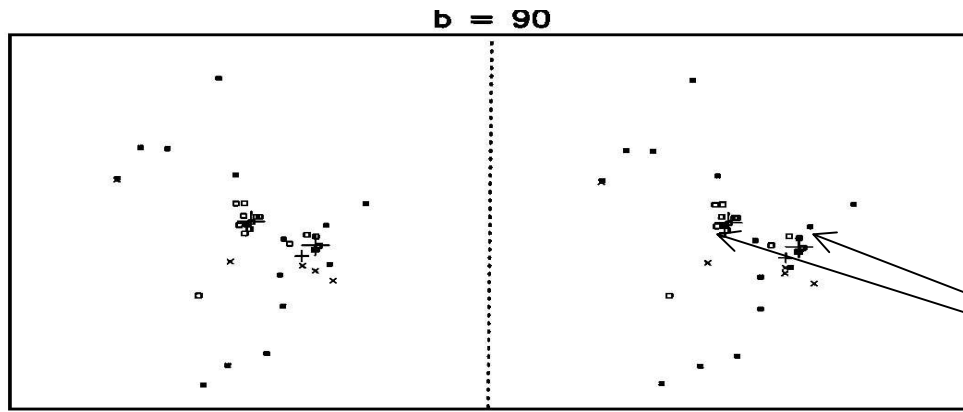


Mass of the Local Group

- $M_{\text{LG}} \sim 3 \times 10^{12} M_{\odot}$ ($\sim 98\%$ of the actual mass)
- Zero-velocity surface ~ 1.8 Mpc from the barycenter
- May still be unbound if they have lesser radial velocities and large tangential velocities

Missing Galaxies



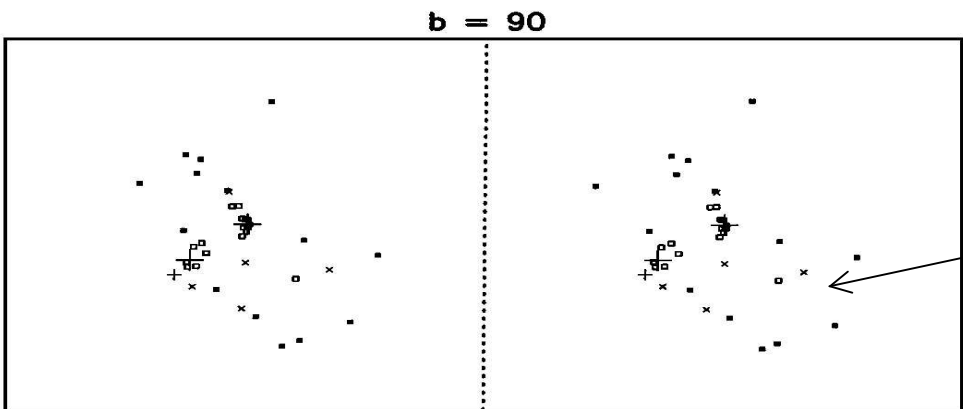


View from $(l,b) = (0,0)$

Structure of the Local Group

MW & M31

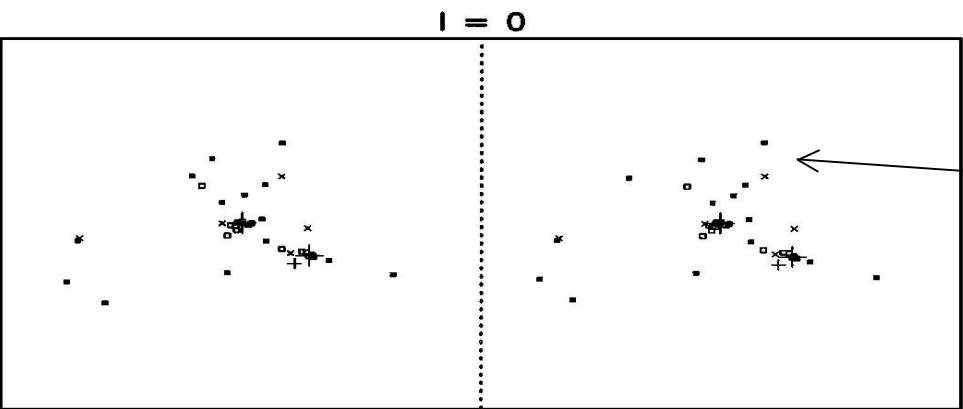
$l = 0$



View from $(l,b) = (90,0)$

Dwarfs

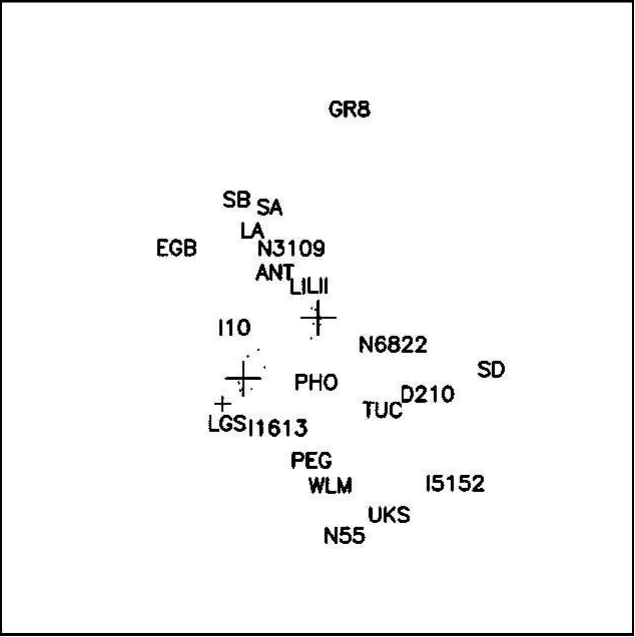
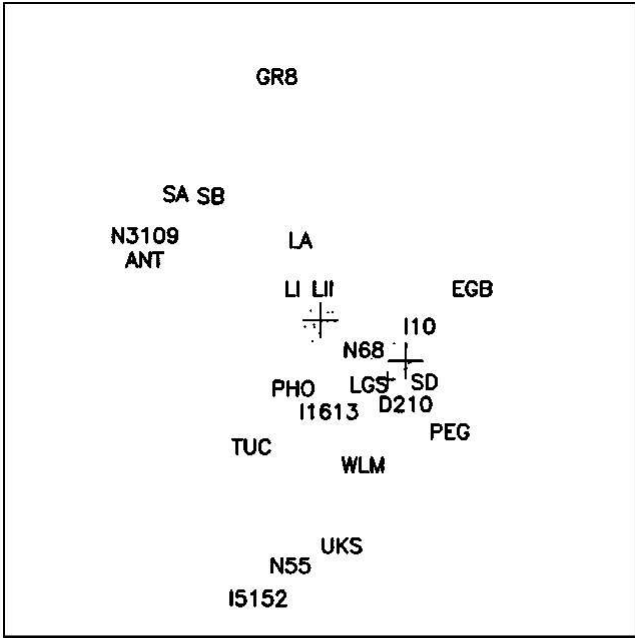
$l = 0$

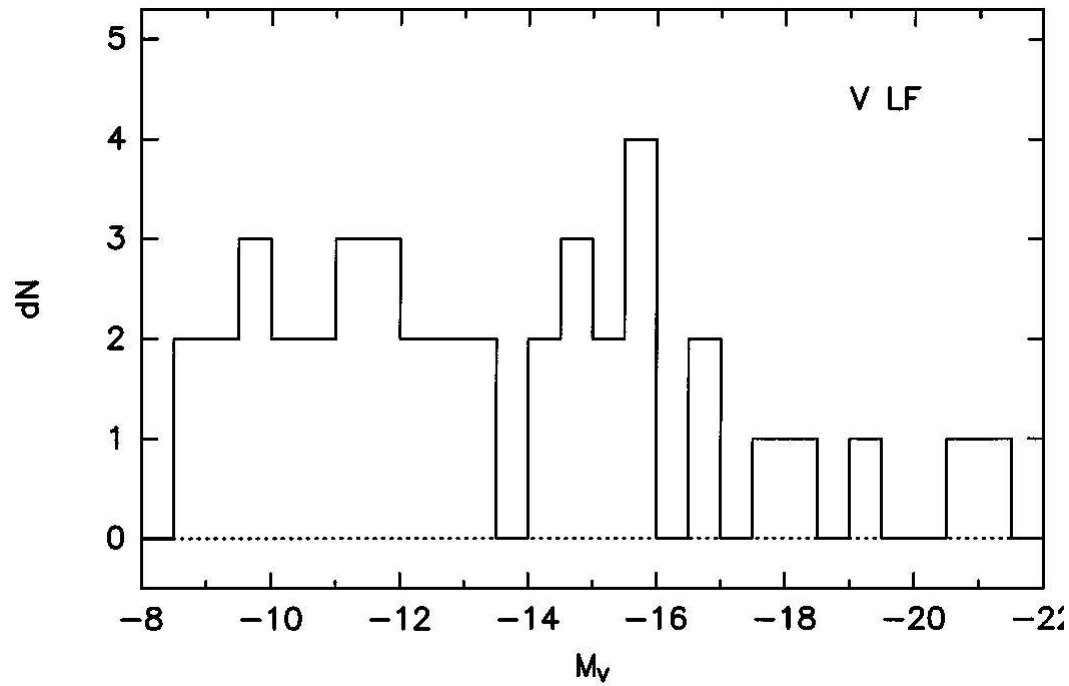


View from NGP ($b = 90$)

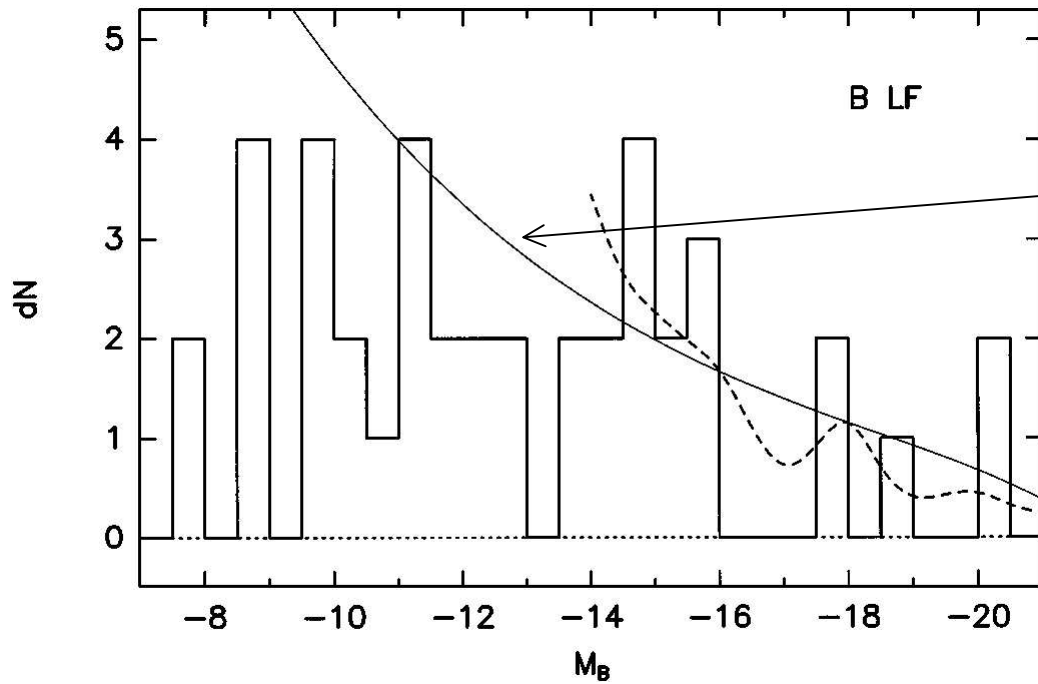
NGC 3109

$l = 0$





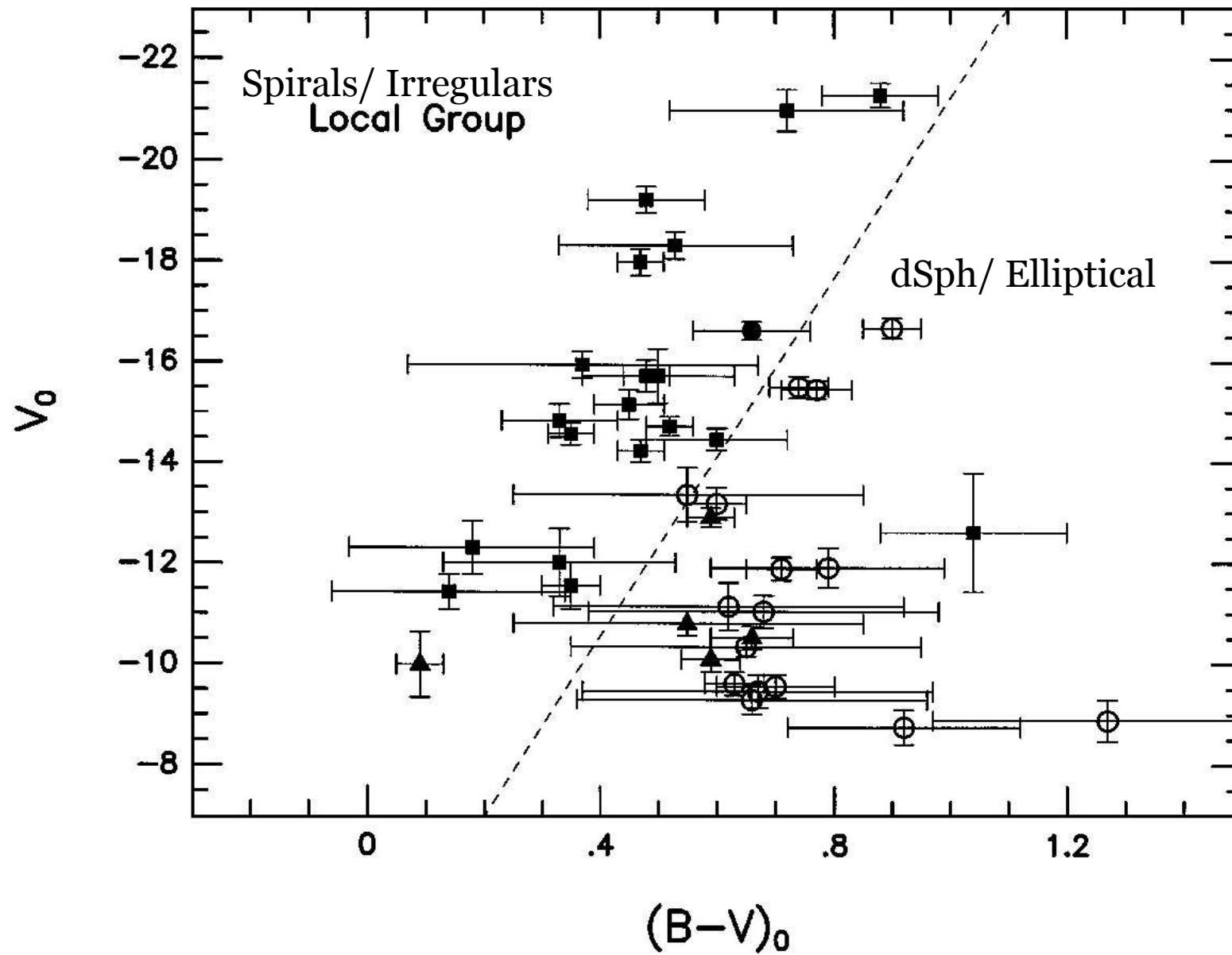
Luminosity function



Schechter fit

Good fit for $M_B < -14$

Color magnitude diagram



Structural properties

- dIrr are dominated by star forming regions
- NGC 3109 shows spiral structure
- Early- type (NGC 185) shows more symmetrical spheroidal component



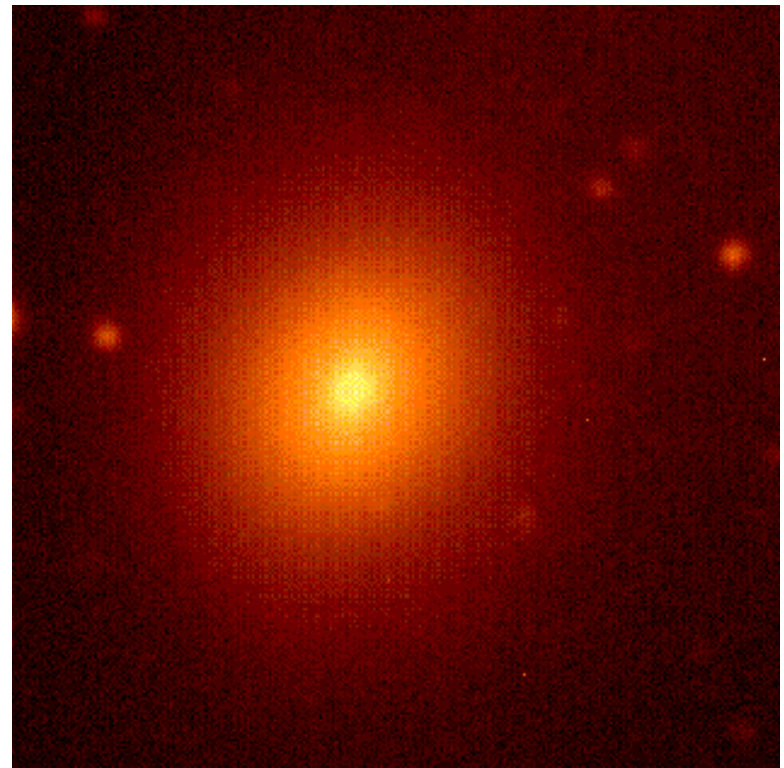
NGC 3109 Source: seds.org



NGC 185

Structural properties

- Only three LG Dwarfs contains nuclei : NGC 205, sagittarius & M32
- M32 is believed to have central MBH



M32

Source: Lowell, UA

Structural properties

- Historically, brightness profiles for dIrr are fitted with exponential profiles
- Early-type fits with the King profile
- All galaxies with exponential scale lengths > 500 pc are dIrr
- while 90% with smaller scale lengths are early-type

ISM in Local Group Dwarfs

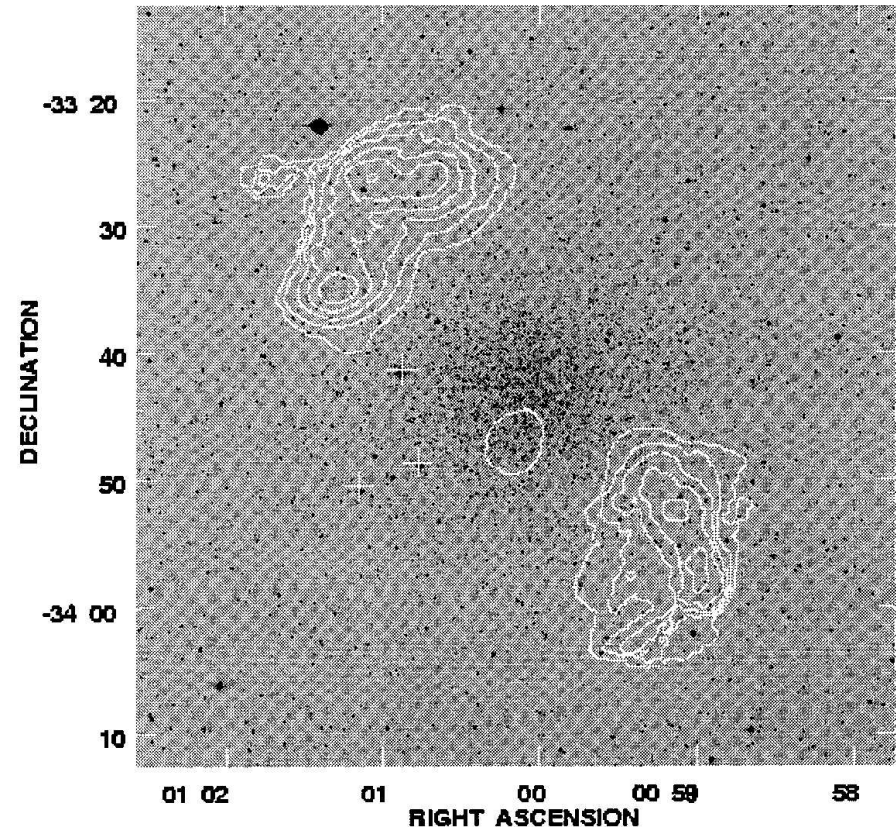
- H_I properties progresses from dIrr to dSph as expected in a standard closed chemical enrichment model
- Local group dSph are comparatively devoid of neutral hydrogen
- In dIrr, H_I shows clumpiness on scales of 100-300 pc
- The most luminous dwarfs have smooth H_I distribution

ISM in Local Group Dwarfs

- Suggested column density for star formation $\sim 10^{21}$ cm^{-2}
- But some dwarfs with $N(\text{H}_\text{I}) > 10^{21}$ cm^{-2} lack star formation, probably due to absence of trigger mechanism
- While some dSph or transition galaxies with $N(\text{H}_\text{I}) < 10^{21}$ cm^{-2} shows evidence of recent star formation

ISM in Local Group Dwarfs

- In general, the H_I emission is centered on optical centroids of dIrr.
- But some dIrr (e.g. Phoenix) shows big offset from the optical centroid



Sculptor dSph

Non-thermal Sources in dwarfs

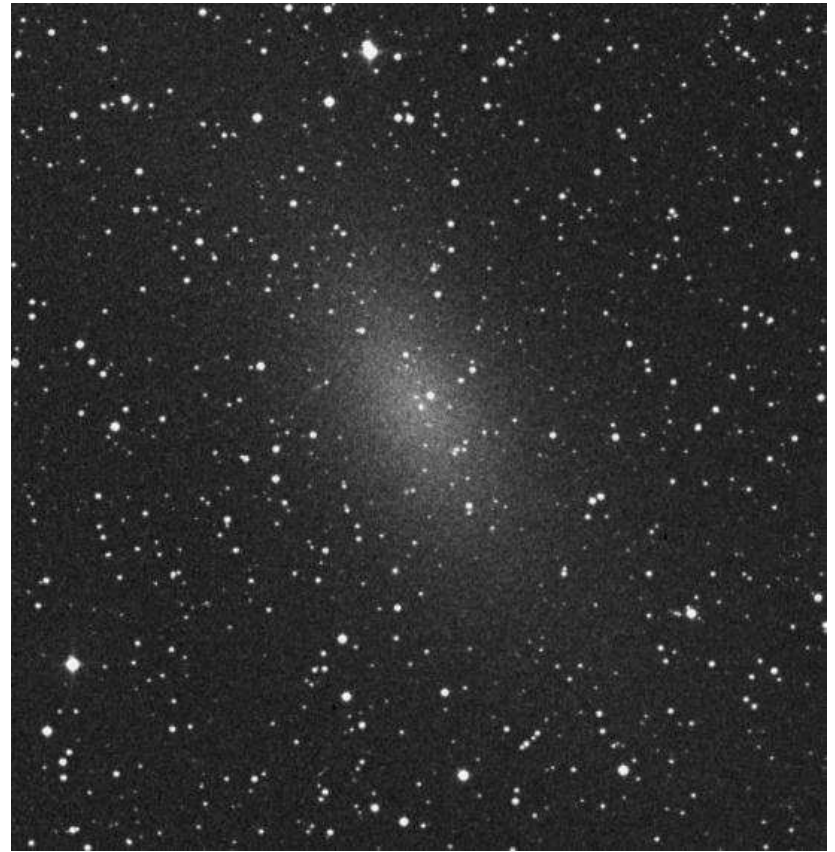
- IC 10, IC 1613 shows non-thermal radiations possibly from the recent SN explosions.
- No diffuse X-ray emission is observed

ISM crisis in dSph

- NGC 147 & NGC 185 have similar luminosities, masses, SFR, sizes
- But NGC 185 contains significant ISM while NGC 147 has none
- Some dwarfs shows evidence of star formation but lack any gas which could have fueled this activity
- So this gas might have come from the external sources or there are some ‘holding tanks’ or the “offset” seen in some dSph



NGC 185



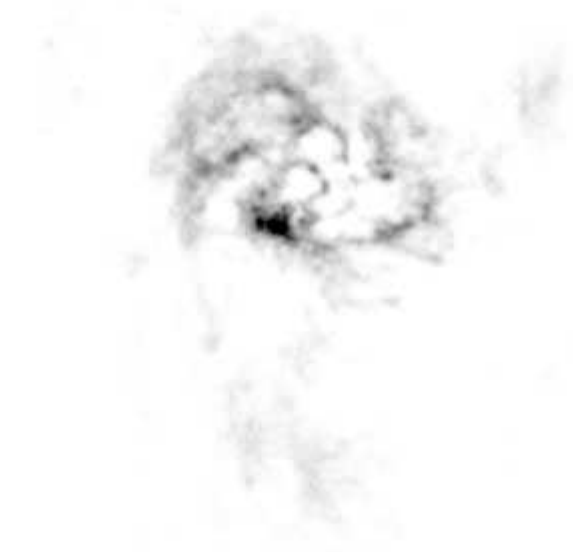
NGC 147

Source: SEDS

Disturber outer regions



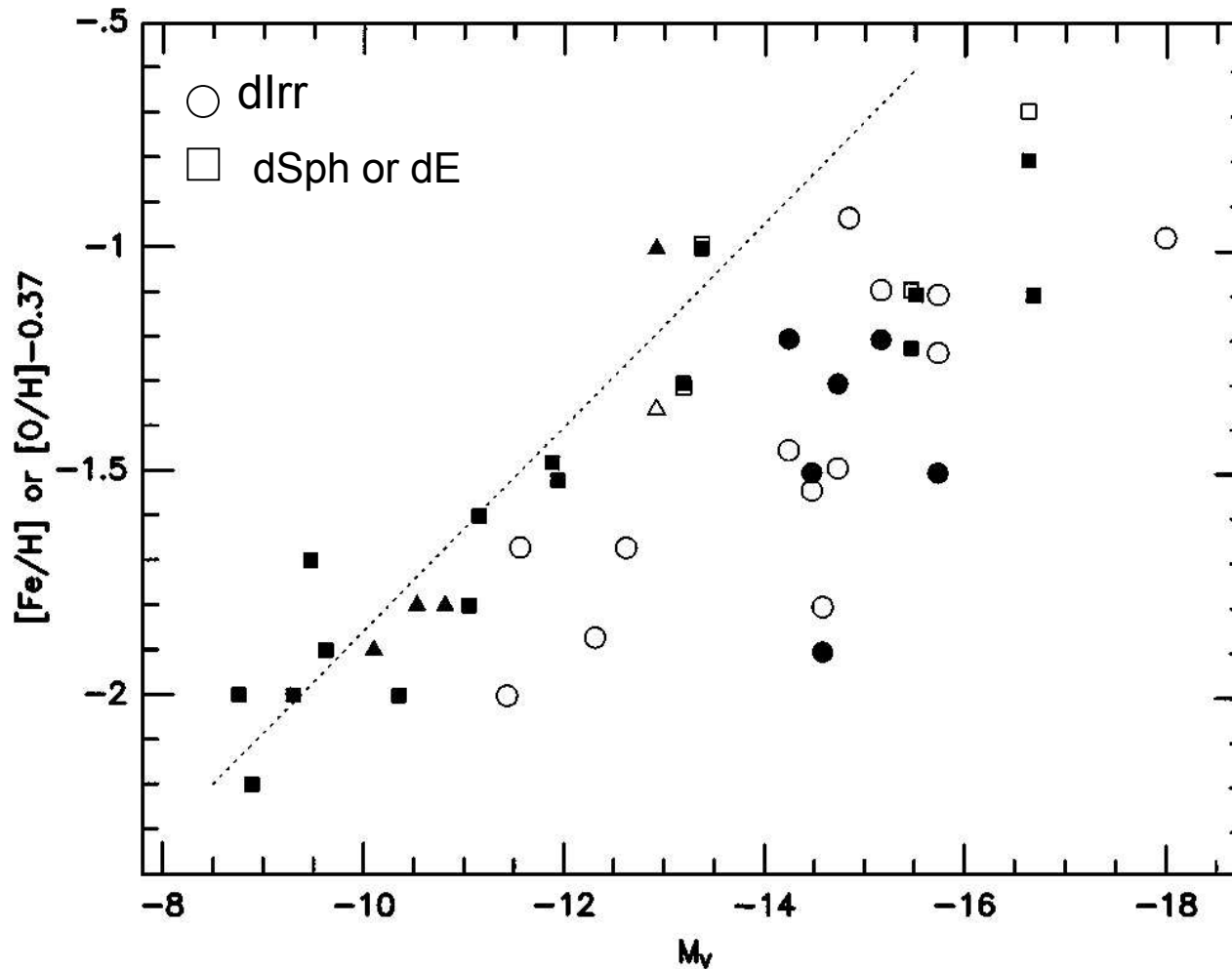
IC 10
NASA/IPAC ED



HI emission
Leroy et al 2006

Luminosity-metallicity (L-Z) relation

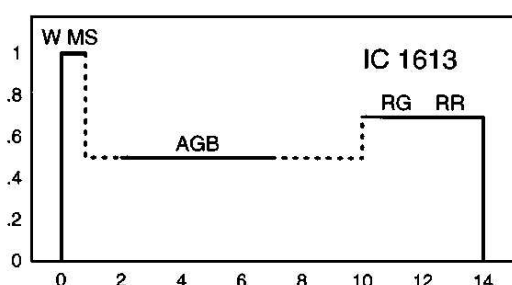
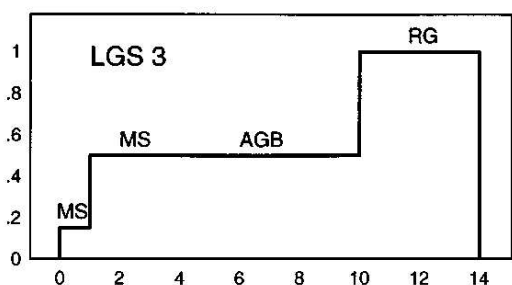
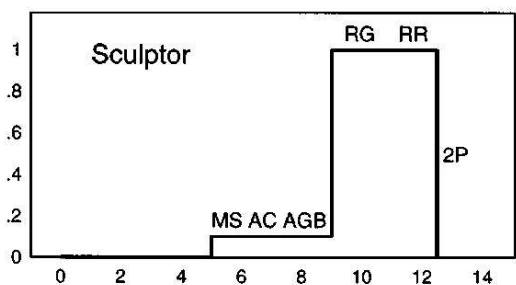
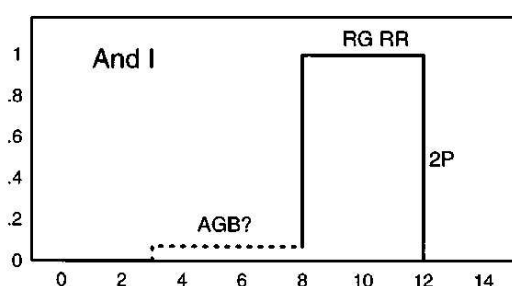
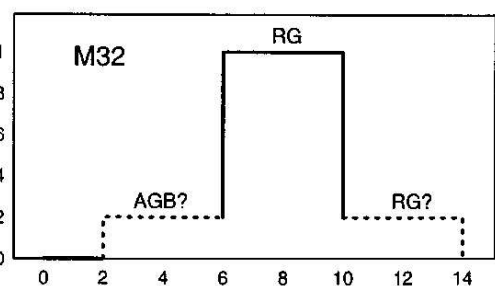
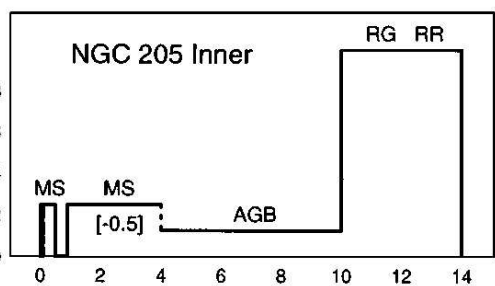
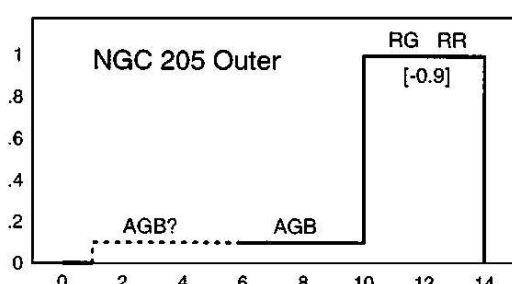
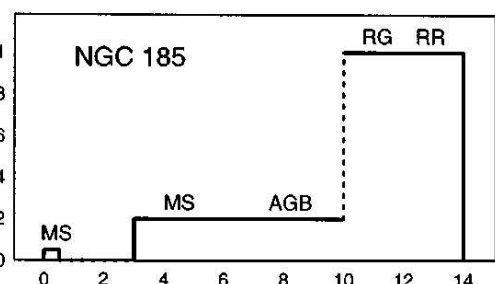
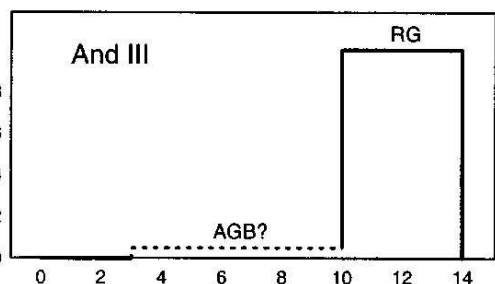
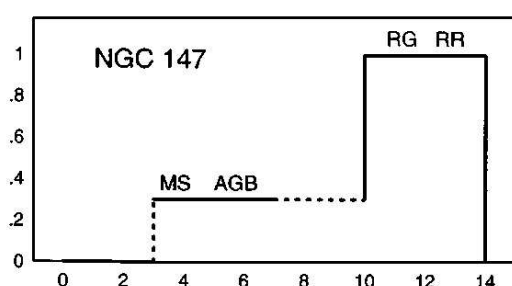
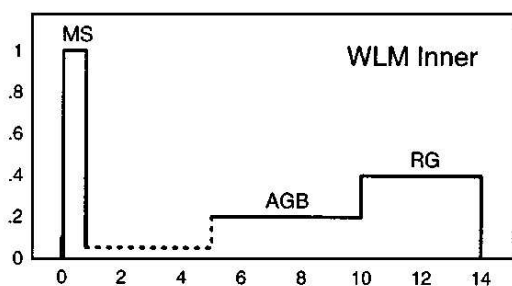
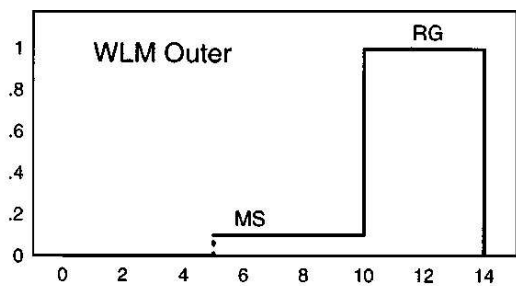
- Luminous dwarfs are more metal rich
- At given M_v , dIrr are metal poor than dSph



Age Indicators in Local Group Dwarfs

- Chemical enrichment (not so intuitive)
- Wolf Rayet stars : → vigorous star formation during past 10 Myr
- Blue-Loop stars → 100-500 Myr (closely associated with cepheids). Luminosity decreases monotonically with age
- AGB stars are used to constrain lower age limit of ~ 1 Gyr

Relative SFR



Age (Gyr)

Star formation history

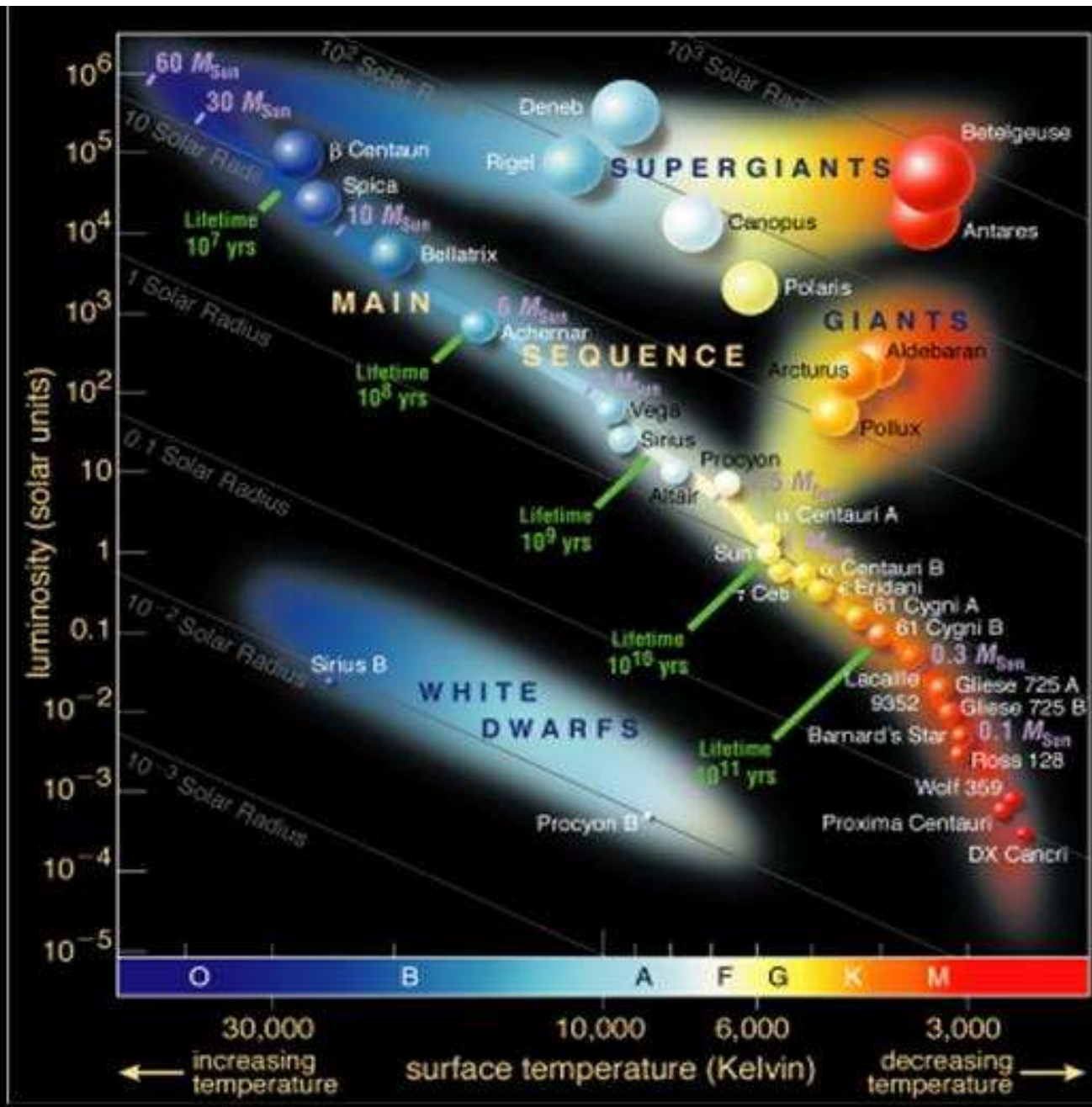
- No two Local Group dwarfs have the same SF history
- Many dIrr contains significant old population
- The most recent star formation episodes are relatively short
- Short bursts are typical in all dwarfs.
- None of the galaxies contain exclusively stars > 10 Gyr (possibly except Uminor)
- Inferred SFR in IC10 is the highest among Local Group Dwarfs

Internal Kinematics

- Expected central velocity dispersion $< 2 \text{ km S}^{-1}$
- But observed values $> 7 \text{ km S}^{-1}$ (independent of the galaxy)
- All the dwarfs require DM halo in order to fit the flat rotation curves
- Massive central BH models are incompatible with the generally smooth central surface brightness distributions

Interactions with other galaxies





Source: http://www2.sunysuffolk.edu/pappasm/AST101/Star_Properties.jpg

The LOCAL GROUP

Figure 18.17 These are the galaxies of the Local Group, arranged to represent their actual physical relationships to the Milky Way <http://astro.colorado.edu/fig/18.17.html>.



- | | |
|----------------|----------------------------|
| (1) Milky Way | (17) NGC 205 |
| (2) Draco | (18) M32 |
| (3) Ursa Minor | (19) Andromeda I |
| (4) SMG | (20) Andromeda II |
| (5) LMG | (21) Andromeda (M31) |
| (6) Carina | (22) M33 |
| (7) Sextans | (23) IGS 3 |
| (8) Ursa Major | (24) IC 1613 |
| (9) Pegasus | (25) NGC 6822 |
| (10) Sculptor | (26) Sextans A |
| (11) Fornax | (27) Leo A |
| (12) Leo I | (28) IC 10 |
| (13) Leo II | (29) DDO 210 |
| (14) Maffei | (30) Wolf-Lundmark-Melotte |
| (15) NGC 185 | (31) IC 5152 |
| (16) NGC 147 | |

Source: <http://www.iastate.edu/~astro.150/images/localgroup.jpg>