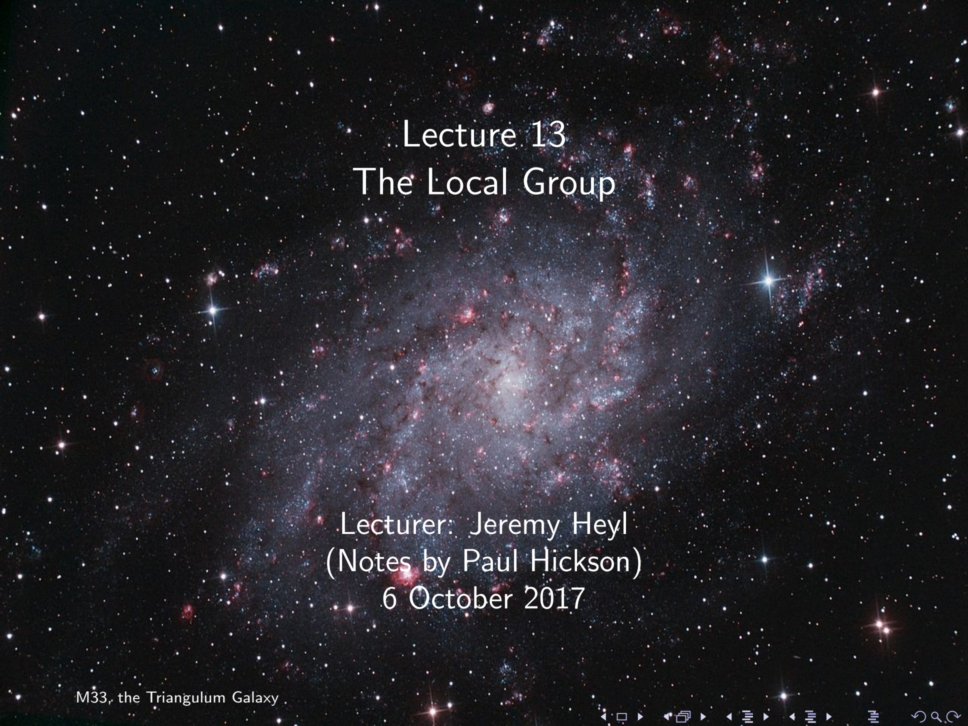
Lecture 13
The Local Group



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(Notes by Paul Hickson)
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M33, the Triangulum Galaxy

Introducing the Local Group

About half of all galaxies are found in clusters or groups that are dense enough to have decoupled from the cosmological expansion.

The the Milky Way is a member of a group of about three dozen galaxies, called the **Local Group**, that are gravitational bound to each other. A list of members and their properties is given in Table 4.1 of Sparke and Gallagher.

The largest members are M31 (the Andromeda Galaxy), the Milky Way, and M33 – a small spiral in the constellation of Triangulum.

The group contains one elliptical galaxy, M32, a satellite of M31.

The other members are small irregular galaxies, dwarf ellipticals and dwarf spheroidals. Most are satellites of M31 or the Galaxy.

The largest satellites of the Milky Way are the Large and Small Magellanic Clouds.

Members of the Local Group

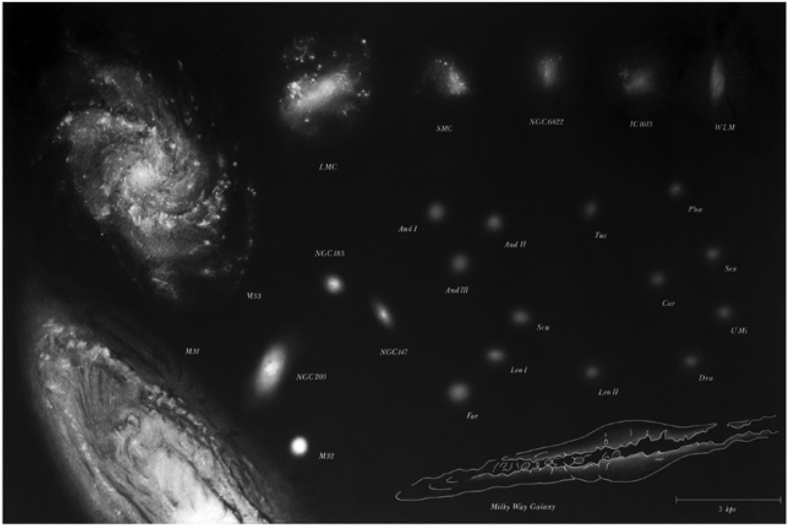

Fig 4.1 (B. Binggeli) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Members of the Local Group

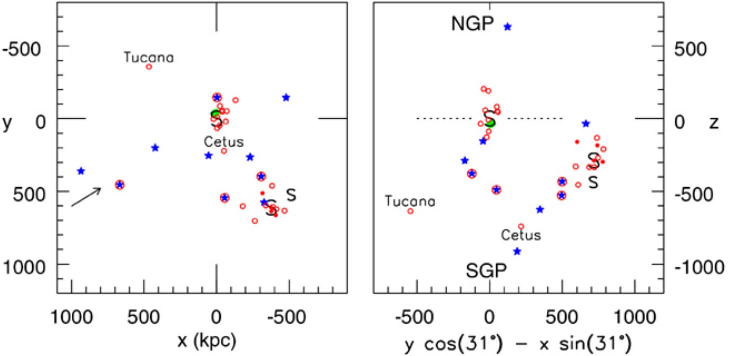

Fig 4.2 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

The Local Group: our Milky Way is at the origin. Spirals are designated S; green stars show the Magellanic Clouds; blue stars mark irregular galaxies; red circles are ellipticals or dwarf ellipticals (filled) and dwarf spheroidals (open). Left, positions projected onto the Galactic plane.

The Magellanic Clouds

The Large Magellanic Cloud (LMC) is about 14 kpc long and covers an angular size of about 15° on the sky. It's luminosity is $L \simeq 2 \times 10^9 L_\odot$.

The Small Magellanic Cloud (SMC) is has about the same length, but is cigar-shaped and seen end-on, so it covers a smaller area of sky. It has about one tenth the luminosity of the LMC.

Both are small gas-rich galaxies. The LMC has a central bar and a single short spiral arm. A prominent star forming region, "30 Doradus" is seen near the end of the bar.

21-cm observations reveal a disk of neutral gas rotating at about 80 km/s. In it one can see voids created by supernovae and stellar winds.

From the rotation velocity, one infers a mass of about $1.5 - 2 \times 10^{10} M_\odot$ for the LMC.

Large Magellanic Cloud

a) 21-cm neutral hydrogen shows a symmetric disk, with loops and filaments

b) H_α ionized hydrogen shows HII regions

c) optical image shows a strong bar and star-forming regions

d) 24-um infrared shows gas heated by massive stars

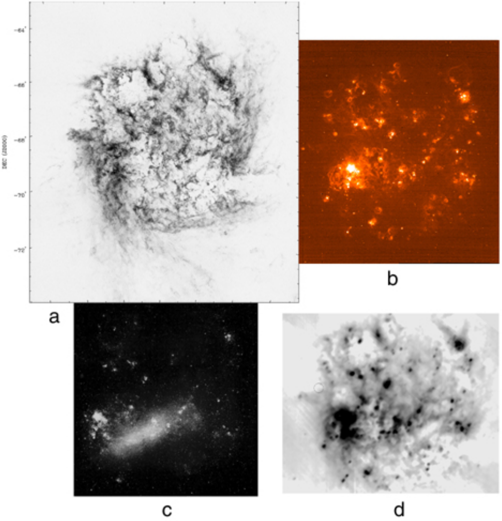

Fig 4.4 (Kim & Staveley-Smith, Henize, IRAS)
'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Cepheid variables in the LMC and SMC

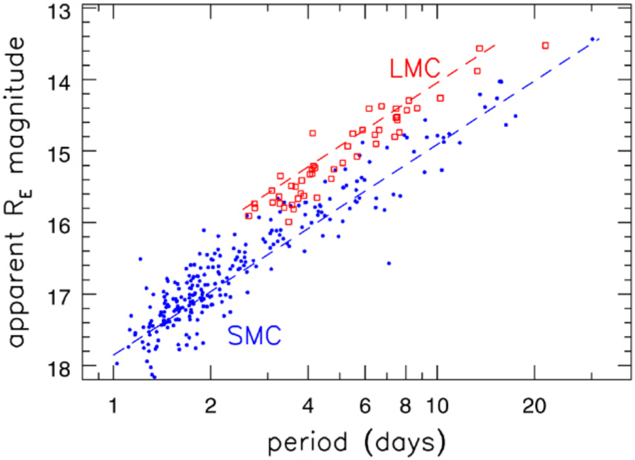

Fig 4.7 (J.-P. Beaulieu) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Apparent magnitude and period in days, for Cepheids in the Large Magellanic Cloud (squares) and in the SMC (filled dots); dashed lines show mean period – luminosity relations.

The stars of the LMC and SMC

Both galaxies are close enough that individual stars can be resolved and measured. Their distances can be determined by main-sequence fitting and from variable stars.
One finds distances of 50 and 60 kpc for the LMC and SMC respectively.

Both galaxies contain many young clusters that probably formed within the past 100 Myrs or so. The most luminous is R136 in the 30 Doradius region, with $L_B \simeq 10^7 L_\odot$.

The LMT and SMC orbit the Galaxy with a period of about 2 Gyr. They made a close approach to us about $200 - 400$ Myrs ago and likely came within about 10 kpc of each other at that time.

During that close approach, the tidal force of the LMC pulled a stream of gas out of the SMC.

The Magellanic Stream

A bridge of gas connects the LMC and SMC. as can be seen in this 21-cm map.

The map is centred at the south celestial pole, extending to $\delta = -62^\circ$; right ascension 0h is at the top.

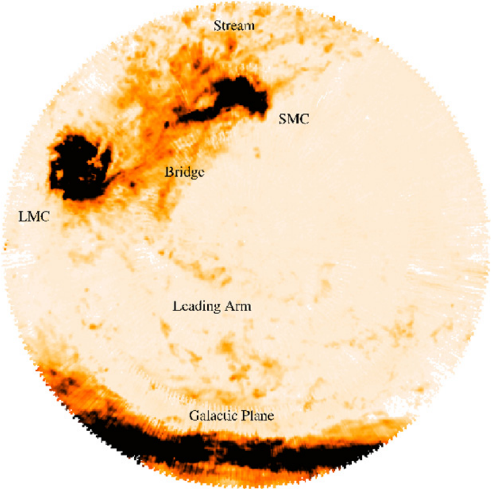

Fig 4.6 (Putman/Nature) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Fornax dwarf spheroidal galaxy

Fig 4.8 (D. Malin) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Dwarf spheroidal galaxies

Most of the galaxies in the Local Group are tiny dwarf spheroidals (dSph). About a dozen have been found orbiting the Galaxy.

Unlike the Magellanic Clouds, these galaxies are devoid of gas, virtually all of it has all been converted to stars.

They all contain at least some very old stars, such as RR Lyrae variables, which have ages greater than 10 Gyr.

Many show evidence for several populations, produced by bursts of star formation at different times.

Stars in these galaxies are metal-poor. It is likely that these galaxies have been unable to retain much of their gas, which has escaped into intergalactic space.

Dwarf spheroidals are found to have high values of M/L, by as much as an order of magnitude, and therefore a much larger fraction of dark matter.

Stellar populations in the Carina dwarf spheroidal

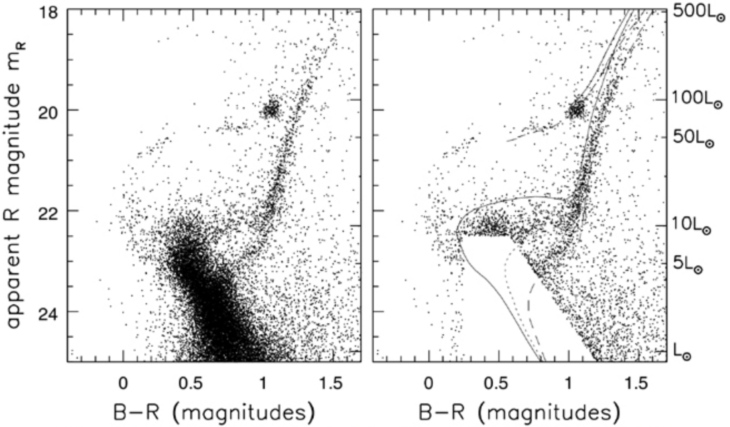

Fig 4.9 (Smecker-Hane, Cole) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Left, a color-magnitude diagram for the Carina dwarf spheroidal galaxy. Right, superposed isochrones give the locus of metal-poor stars ($Z = Z_{\odot}/50$) at ages of 3 Gyr (solid),7 Gyr (dotted), and 15 Gyr (dashed)

M32

M32 is a small elliptical galaxy, orbiting M31. It contains virtually no cool gas and no stars younger than a few Gyr.

The stars in its centre are red and have approximately solar metallicity. This is unusual for such a small galaxy. Normally more mass is needed to retain the gas that has been enriched by previous star formation.

M32 has a ratio $V/\sigma \sim 1$, where V is the average systematic rotation speed and σ is the random velocity dispersion.

In comparison, the Milky Way has $V/\sigma \sim 7$.

Since random velocities are relatively small in the Milky Way, we say that it is a *cold* system. In contrast M32 is a *hot* system.

Dwarf ellipticals

M31 has three dwarf ellipticals as satellites: NGC 147, NGC 185 and NGC 205.

These are more massive and luminous than dwarf spheroidals, and have a higher surface brightness. They appear compact as their outermost stars have been stripped away by the tidal force of M31.

These galaxies appear to have no overall rotation, and probably are **triaxial** systems having no axis of symmetry.

They generally contain old stars, although a few young stars of ages $100 - 500$ Myrs have been detected in the centres of NGC 205 and NGC 185. Apparently there has been *some* recent star formation, perhaps due to accretion of gas by these galaxies.

Galaxy central surface brightness vs absolute magnitude

Dwarf and giant galaxies occupy different regions in this plot. Luminous elliptical galaxies and the bulges of disk systems have high surface brightness.

The rightmost of the filled circles represent dwarf spheroidals; open circles mark irregular and dwarf irregular galaxies.

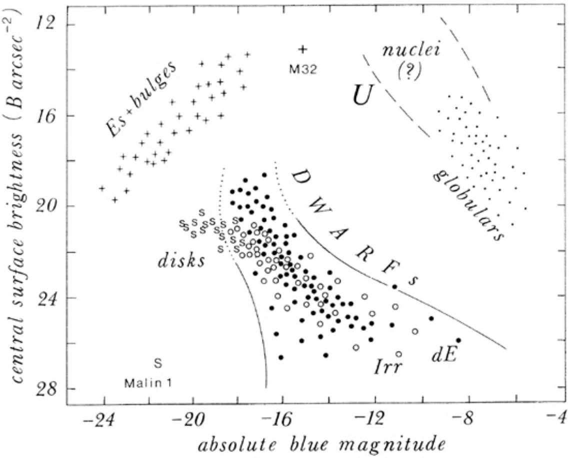

Fig 4.18 (B. Binggeli) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007