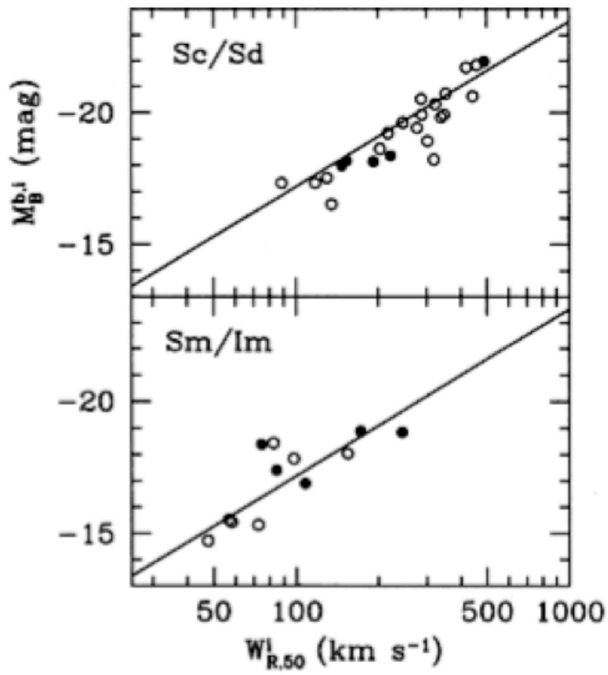
Werkcollege, Sterrenstelsels, Week 8

These are the assignments for the last week of the course *Sterrenstelsels*.
Every week, one of the problems provides credit towards the final exam. If at least 5 of these problems are handed in and approved, one question on the final exam may be skipped. The hand-in assignment for this week is **Problem 8.1** below.

8.1 Low Surface Brightness Galaxies and the Tully-Fisher relation



Tully-Fisher relation for normal spirals (open circles) and low surface brightness galaxies (solid circles).

The Figure shows the Tully-Fisher relation for a sample of disc galaxies observed by Zwaan et al. (1995). The velocity width $W^i_{\mathrm{R},50}$ and absolute M_B magnitude of the galaxies are related as $M_B = -6.59\log_{10}(W^i_{\mathrm{R},50}) - 3.8$, as shown by the straight line in each panel. Low Surface Brightness (LSB) Galaxies follow the same Tully-Fisher relation as the normal high surface brightness (HSB) galaxies. However, the surface brightness of the LSB galaxies is on average 1.5 mag fainter than that of the HSB galaxies.

a. Demonstrate that the M/L ratio (Υ) of the LSB galaxies must be a factor of 2 higher for the LSB galaxies.

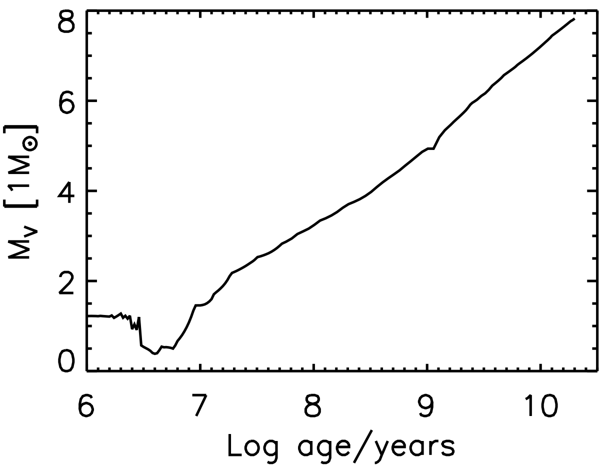
b. Show that, at fixed $W^i_{\mathrm{R},50}$, the LSB galaxies must have diameters that are a factor of two greater than the HSB galaxies.

The edge-on spiral galaxy NGC 891 has a $W^i_{\mathrm{R},50}$ of 448 km s^{-1} and an apparent magnitude $m_B = 9.37$ (corrected for internal and external extinction). The half-light radius of NGC 891 is $2'.23$.

c. If NGC 891 were seen face-on, what would be the mean surface brightness (in mag arcsec^{-2}) within the effective radius?

d. Estimate the distance of NGC 891.

8.2 Elliptical galaxies, mergers and globular clusters



Model calculation for the M_V magnitude per solar mass as a function of time after a burst of star formation.

Many elliptical galaxies are surrounded by large numbers of globular clusters (GCs). A convenient way to quantify the richness of the globular cluster population around a galaxy is the GC *specific frequency*, S_N, which is defined as

$$S_N = N_{\mathrm{GC}} \times 10^{0.4\times(M_V+15)} \tag{8.2.1}$$

where N_{GC} is the number of globular clusters and M_V the absolute visual magnitude of the galaxy. An early argument that was put forward against the idea that elliptical galaxies are the result of spiral-spiral mergers was the fact that elliptical galaxies can have much higher GC specific frequencies than spiral galaxies.

This is not easily explained if the GC population of the merging galaxy is simply the combination of the GC populations in the two individual galaxies. The counterargument is that new GCs might be formed during the merger.

In this exercise we look at these arguments.

Suppose that two Milky Way-like spiral galaxies are just about to merge. Prior to the merger, each galaxy has an absolute visual magnitude $M_V = -21.0$. Each galaxy contains 5×10^9 $M_\odot$ of gas, which is instantaneously turned into stars during the merger. Each galaxy also hosts 200 old globular clusters.

The figure above shows model calculations for the absolute M_V magnitude, normalised to a stellar mass of 1 $M_\odot$ for a single burst of star formation, as a function of time after the burst. At 10^8 years, the burst has a magnitude of $M_V =$ 3.3 mag per Solar mass.

a. Calculate the total M_V magnitude of the merged galaxies at 10^8 years after the merging, and give the specific frequency if no globular clusters are formed (or destroyed) in the merger. Assume that the magnitude of the pre-existing stellar populations in the original galaxies do not change. Also, ignore extinction.

A typical specific frequency for an elliptical galaxy is $S_N = 3$ and the average mass of a globular cluster can be taken to be $10^5 M_\odot$.

b. What fraction of the gas would have be turned into new globular clusters in order to get $S_N = 3$? If you did not find an answer in (**a**), you can assume $M_V = -22$ but note that this is *not* the exact answer.

8.3 Projected axis ratio for prolate spheroid

We have seen that the distribution of projected minor/major axis ratios q for *oblate* spheroids is given by

$$\frac{\mathrm{d}N}{\mathrm{d}q} = \frac{q}{\sqrt{(1 - B^2/A^2)(q^2 - B^2/A^2)}} \tag{8.3.1}$$

where A and B are the three-dimensional major and minor axes of the oblate spheroid.

Show that the corresponding formula for a *prolate* spheroid can be written as

$$\frac{\mathrm{d}N}{\mathrm{d}q} = \frac{1}{q^3\sqrt{(1 - A^2/B^2)(q^{-2} - A^2/B^2)}} \tag{8.3.2}$$