ZAH - Astronomisches Rechen-Institut
Galactic and Extragalactic Astronomy (MVAstro3) - Winter semester 2021
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Exercise Sheet #10

Submit by Wednesday 31-03-2021

Exercise 1. - Galaxy Cluster

Go to `http://cas.sdss.org/dr12/en/tools/chart/navi.aspx` and enter the coordinates of the Coma galaxy cluster, 194.9531, 27.9807. Zoom in/out and move around (click on the image edges that are labeled N/S/E/W).

(a) Estimate visually the cluster's radial extent in pc, i.e. roughly the distance from the center where you can hardly notice any further cluster galaxies. At the Coma distance, 1 degree corresponds to 1.7 Mpc. (10 points)

(b) Can you find a few elliptical and spiral galaxies that probably belong to the cluster? What can you say about their location, with respect to the cluster? (5 points)

(c) When you select a certain galaxy with a single left-click, its apparent magnitude will appear in the top right panel, and a small preview of its spectrum will appear in the bottom right. When you click on that preview and thereby open a larger image, you can read the galaxy's redshift in the third line of the header. Try this for some objects!

Note: sometimes you have to really hit the center of the galaxy, otherwise the software targets a foreground star or background object.

The distance of the Coma cluster is 100 Mpc, and hence the distance modulus $m - M$ is 35.0 mag, so you can convert the apparent magnitudes into absolute magnitudes. Select a dozen galaxies with $z < 0.03$, read off their redshift, convert it into velocity, and compute the standard deviation and average of your velocity values. This is an approximation for the line-of-sight σ (velocity dispersion) of the cluster. (15 points)

(d) With the virial theorem, and assuming a homogeneous spherical distribution for simplicity, the virial mass is $M = 5 \cdot R \cdot \sigma^2/\mathrm{G}$. Where σ means the measured one-dimensional velocity dispersion from above. What virial mass do you find? Convenient units of the gravitational constant are: $\mathrm{G} = 4.3 \cdot 10^{-3}\ \mathrm{pc(km/s)^2\ /M_\odot}$. (10 points)

(e) You can assume that galaxies with stellar masses $\geq 5 \cdot 10^{10}\,\mathrm{M_\odot}$ add up to about 20 % of the total stellar mass in the cluster. If we assume for simplicity that $5 \cdot 10^{10}\,\mathrm{M_\odot}$ correspond to a luminosity of $5 \cdot 10^{10}\,\mathrm{L_\odot}$, then the absolute r-band magnitude would be $M_r = -2.5\log(5 \cdot 10^{10}) + 4.68 = -22.07$ mag where 4.68 is the Sun's absolute r-band magnitude. With $m - M = 35.0$ the apparent r-band magnitude is $m_r = 12.93$ mag, i.e. roughly $m_r = 13$ mag.

How many galaxies can you find at or brighter than this magnitude? Calculate approximately the sum of their stellar masses.

Useful hint: 0.2 mag difference corresponds to a factor of 1.2, 0.3 mag to 1.3, 1 mag to 2.5, 1.5 mag to 4.

Estimate the total stellar mass of the cluster from that. How does it compare to the virial mass you calculated? What do you conclude from this comparison? (20 points)