IC200-Project/Report

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Deadline: 20 Nov. 2020, 11pm

Use the solar mass ($2 \times 10^{33}\,\mathrm{grams}$) as the Unit of mass, and pc or kpc as the unit of distance

Project is on Galaxies

A galaxy has three constituents: dark matter (also called dark matter halo), gas and stars. Read about it. M_h is the mass of the dark matter halo, M_g the mass of gas, and $M_\star$ is the mass of stars in a galaxy.

Write an introduction [5 marks]

You have to write a maximum 500 word introduction for this project on galaxies. Your introduction should motivate and set the stage for the mathematical model/calculations in the next section.

Mathematical modelling [20 marks]

The mass of the galaxy can be written as, $M = M_h + M_g + M_\star$ where,

$$M_h = [\text{Last 4 digits of your role number}]^2 \times 10^7 \times \mathrm{M_{sun}}$$

For example if someone's role number is 11940180, then for him/her, $M_h = [0180]^2 \times 10^7 \times \mathrm{M_{sun}} = 3.24 \times 10^{11}\ \mathrm{M_{sun}}$, where $\mathrm{M_{sun}} = 2 \times 10^{33}$ grams.
Similarly, find out your M_h and then calculate the following properties for your galaxy

1. Consider the dark matter halo to be a sphere of uniform density and assume that this density is 100 times the mean matter density of the Universe at present. Then calculate the radius (r) of the dark matter halo in kpc units. Further, if a star is orbitting the centre of the dark matter halo on a circular path, then calculate its velocity as a function of the radius (r) and then plot this velocity (in $\mathrm{km/s}$) as a function of the r where r ranges from 1 to 200 kpc.

2. Use the radius of the dark halo you calculated in the previous question, and then assume the galaxy is placed at a distance of 1 Mpc from us. What angular size will it have in the night sky? Also calculate the parallax angle if the galaxy were to be located at 100 Mpc and considering earth's orbit as the baseline. Draw diagrams as well.

3. Say we consider only the dark matter halo. If the density of the dark matter halo is given by $\rho(r) = \rho_0\ (r)^{-\alpha}$, where the unit of r is kpc, and $\rho_0 = 100$ times the mean matter density of the Universe at present. Then take $\alpha = 1$ and calculate the radius within which half of the mass of the halo is enclosed. Do the same for $\alpha = 3$ as well.

4. For your M_h, what possible M_g and $M_\star$ can be expected? Let's say you have 100 galaxies of the same M_h, then draw the histograms that show the possible values of M_g and $M_\star$ in these 100 galaxies. Also, plot M_g/M_h and $M_\star/M_h$ (on the same plot) as a function of time since the birth of the galaxy. Your answer must be based on a scientific evidence or physical logic.

5. Considering the dark matter and the gas components in your galaxy to be collection of particles subjected to their own gravity. What stops the gravitational collapse of dark matter (M_h) to a point? What stops the gas component (M_g) from collapsing to a point?
As we know that the dark matter halo doesn't collapse to a point, instead it is distributed over a volume. Read from the web and figure out the actual density distribution of the dark matter halo corresponding to your M_h. Write the functional form of the distribution, and plot the density as a function of radius for your M_h. Compare the functional form of the dark matter density distribution with the distribution of the air density with height in the earth's atmosphere.

6. The visible matter (gas and stars) can take a variety of geometrical shapes inside the dark matter haloes. Read about it. In the present day Universe, corresponding to your M_h, illustrate the shape you are most likely to find for gas, and what shape you are most likely to find for stars, and why?

7. The star formation rate (Ψ) in a galaxy can be deduced from the absolute magnitude in UV band ($\mathrm{M_{UV}}$). Explain why these two relate. What should be the apparent UV magnitude of your galaxy if it is situated at 10 Mpc and it has a *star formation rate*, $\Psi = \log_{10}(\frac{\mathrm{M_h}}{\mathrm{M_{sun}}})\ [\mathrm{M_{sun}/year}]$.
$[\mathrm{M_{sun}/year}]$ is the unit of Ψ.

8. The galaxy can have a black hole at its centre whose mass may be related to the mass of the galaxy, or may be related to the mass of the central spheroidal bulge of stars. Read about this. Then calculate the mass of the black hole (M_{BH}) for your galaxy. Your answer must be based on known scientific/observation facts or it must be logical based on physics.

9. Search the web and find 2 galaxies that have the halo mass approximately equal to your M_h. You can use the ViZier online data catalogues, or the SDSS website, or explore any other source on the web. Investigate and point out the major differences between the two galaxies that you found and why do they differ (maximum 100 words)

Conclusions [5 marks]

Summarize your findings and conclude scientifically in 300 words.

Presentation [10 marks]

You have to record a maximum 5 minute video clip of yourself speaking. Say your name and roll number in the first sentence. Then, talk about your galaxy and describe the result that you found most interesting, how did you obtain it and then end with a conclusion.

Note:

- **The report has to be submitted via Turnitin, and the video clip via WhatsApp. No submission after the deadline will be entertained under any circumstances, so better submit well before the deadline to avoid last minute rush.**
- **You can do the calculations, equations and plots on your notebook, take pictures/scans and include them in your report as images. However, the text in introduction, conclusions, discussions should be typed only.**
- **Keep the report precise, and your calculations neat and to the point. Report should be within 10 pages, but don't aim for 10. If you can do it neatly and precisely then a smaller report would be better.**