

1. What is a Galaxy?

- (a) Baryonic Matter (Gas, ISM, Stars) + Dark Matter.
- (b) Some galaxies have very small amount of (100) stars! Some galaxies don't have gas! So, what makes a galaxy?
- (c) "*A galaxy is a gravitationally bound set of stars whose properties cannot be explained by a combination of baryons and Newton's laws of gravity.*"¹.
- (d) Sizes range from $1kpc - 10skpc$, and luminosities anywhere from $100L_{\odot} - 10^{12}L_{\odot}$. Amt. of dark matter varies from $10^8 M_{\odot} = 10^{13} M_{\odot}$. Compare this to the baryonic matter to get the "mass to light ratio", which is the ratio of the total mass to the mass that we can see.
- (e) But what if Newton is wrong? Use **Milgromian Physics** to explain away behaviour of galaxies without dark matter.

2. What are the components of a galaxy?

- (a) Baryons.
- (b) There are diff. distributions. E.g. Disk or Spheroid/Elliptical Distributions.
- (c) Centralized Supermassive Black Holes!
- (d) Dark Matter Halo: A spherical distribution of dark matter surrounding the disk/spheroid, extending to 10x the size of the disk (assuming Newtonian Dynamics).
- (e) Surrounding the galaxy...
 - Satellite Galaxies: smaller galaxies orbiting around the larger one.
 - Stellar Halo : Globular clusters, stellar streams, etc surrounding the disk.
 - Gaseous Halo : gas (typically "hot") $10^6 K$ (x-rays) to $10^4 K$ (HI).
- (f) Dust

3. How does a galaxy change over time?

- (a) They can run out of gas. This leads to them being *quenched*, as there is no detectable amount of star formation at that point. However, there may be mechanisms by which galaxies can be resupplied with gas.
- (b) Galaxies can collide!
 - This can speed up the process of gas turning into stars.
 - And black holes can grow by eating gas! The black holes of the galaxies can also collide and merge.
- (c) The colour of galaxies can change. Quenched galaxies end up with more reddish stars. So, generally, you go from blue- \rightarrow red.

4. What is a galaxy merger?

- Galaxy Pairs are different from simply Colliding Systems.
- The nuclei need to be merged for the galaxies to be fully merged. Yes, this is observationally limited.
- **Dynamical Friction** is important.
 - (a) The gravitational wake that forms behind a galaxy is moving through the dark matter halo of another galaxy.
 - (b) The wake pulls back on the galaxy, causing it to decelerate.
 - (c) And this acts as friction. Without this interaction, galaxies would not merge.
- **What is cosmology?**
 - How the universe began, evolved, and will eventually end.
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¹Willman and Strader 2012: "Galaxy" Defined