

## 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.*"<sup>1</sup>.
- (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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<sup>1</sup>Willman and Strader 2012: "Galaxy" Defined