Galaxy Formation

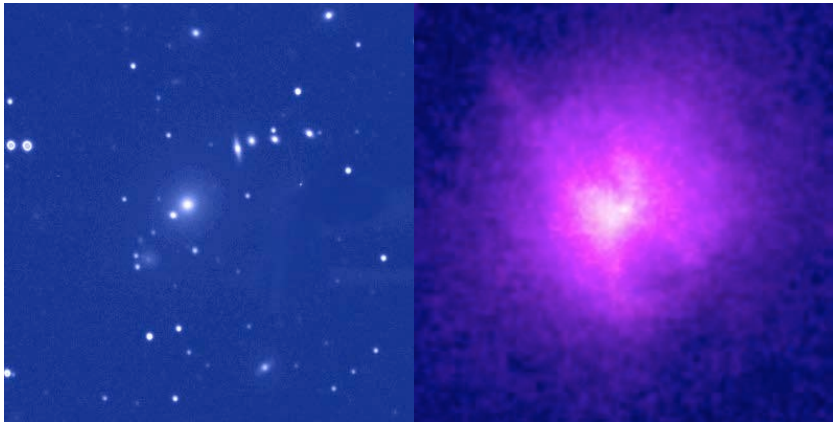
- Smooth density field
  - Gravity slowly amplifies "density fluctuations"
  - Protogalaxies form at the peaks of density fluctuations
  - The peaks begin collapse
- Star formation
  - At the center of the peak, clouds of gas condensate and the first stars form
  - Gas continues to fall into the center, and stars continue to form
  - Stars explode and enrich gas with heavier elements
- Formation of halos
  - Stars formed earlier make a spherical halo
- Merger
  - Protogalaxies merge together to form even bigger systems
  - Clusters of galaxies

Spirals or Ellipticals?

- Rotation
  - Initially rotating gas cannot collapse into the center (due to conservation of angular momentum)
  - Rotating gas forms disk; density waves emerge and form spiral galaxies
  - Gas with little rotation settles into the nucleus
- Density
  - The higher the density is, the easier the star formation becomes.
  - The early universe had the higher density → explosive star formation in the past
  - Small galaxies form first; thus small galaxies have higher density

Clusters of Galaxies

- Clusters of galaxies contain hundreds to thousands of galaxies
- Density is too low to form stars between galaxies
- Large gravity is supported by gas pressure → Hydrostatic equilibrium
  - Temperature is about 100 million degrees!
  - Emit X-rays
- Clusters are "young"
  - Small things form first – galaxies merge together to form clusters of galaxies.



Visible Light ***X-ray***

Hydra A