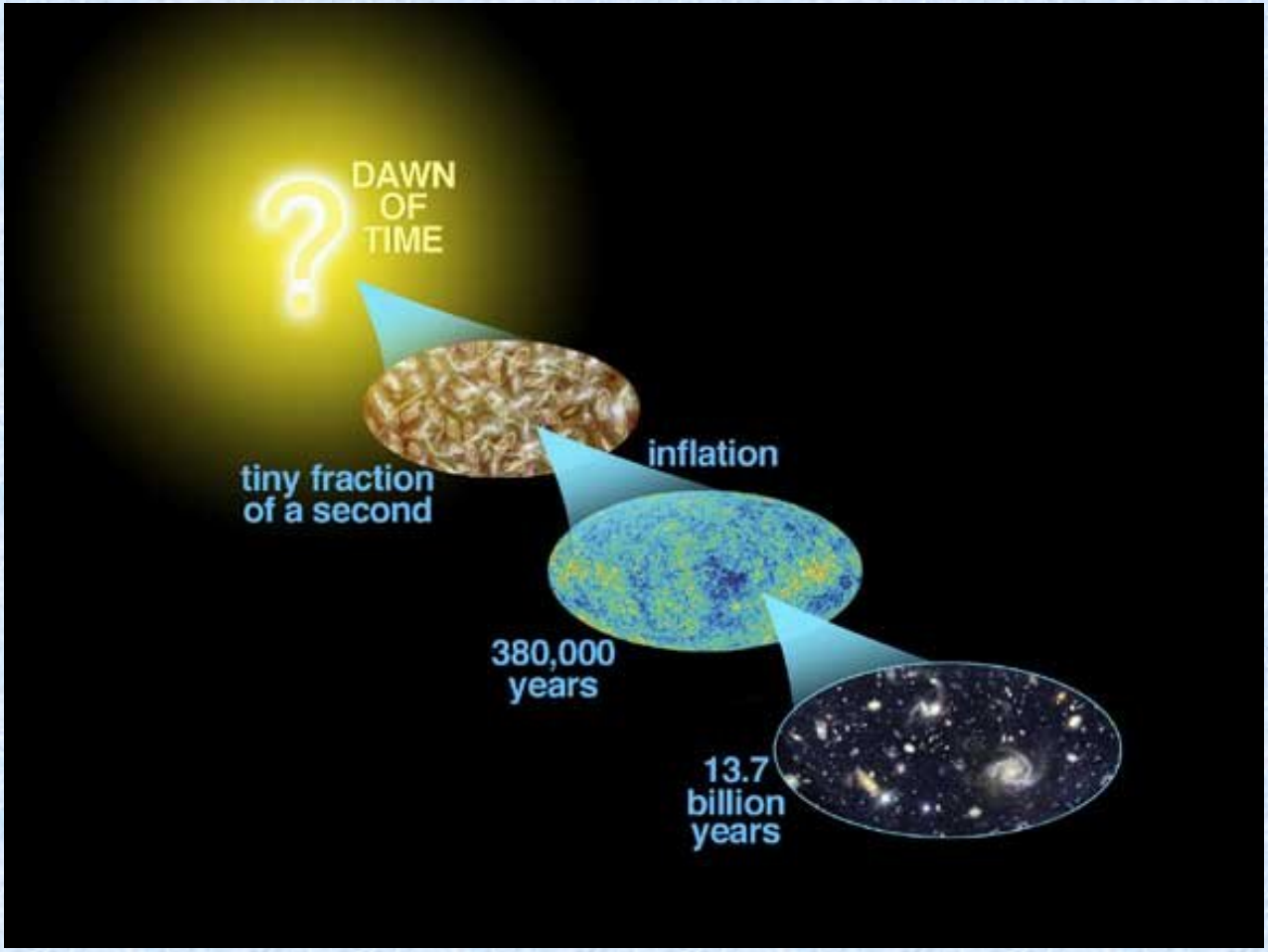
Physics 133: Extragalactic Astronomy and Cosmology



Lecture 10; February 12 2014

Previously:

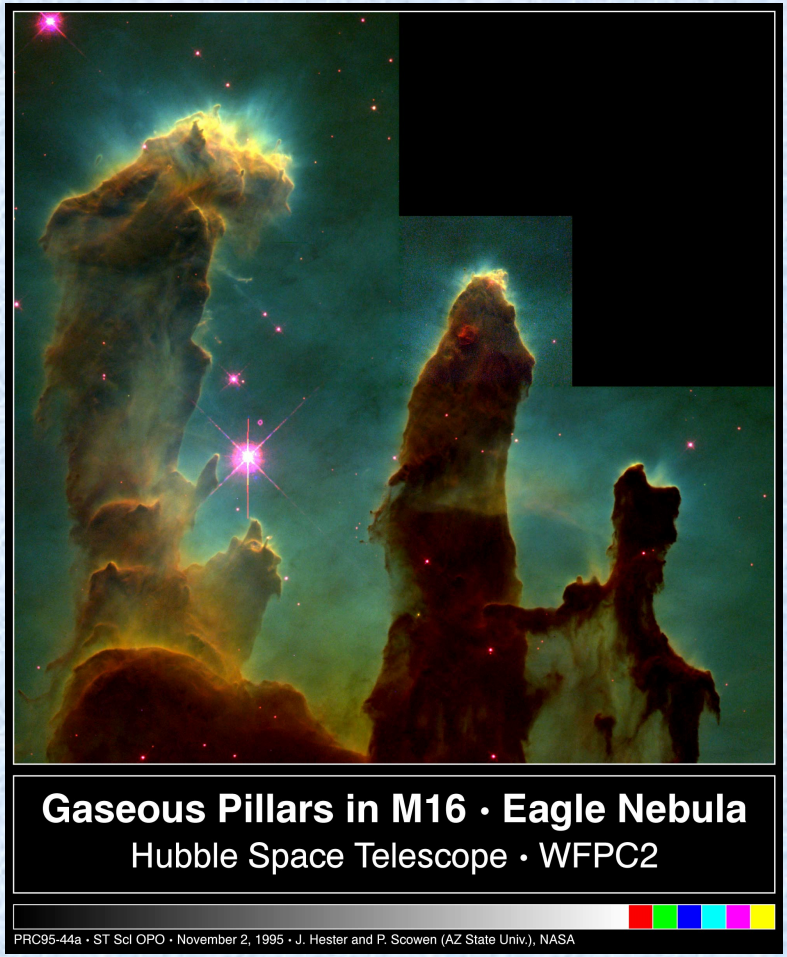
- How do we measure cosmological parameters?
  - The Hubble constant
    - Measuring v (peculiar velocities)
    - Measuring D (the cosmic distance ladder)
  - Cosmography
    - Luminosity distance and standard candles
  - Cosmic time
    - Ages of the oldest stars
  - Testing the expansion
    - Tolman's test

Outline:

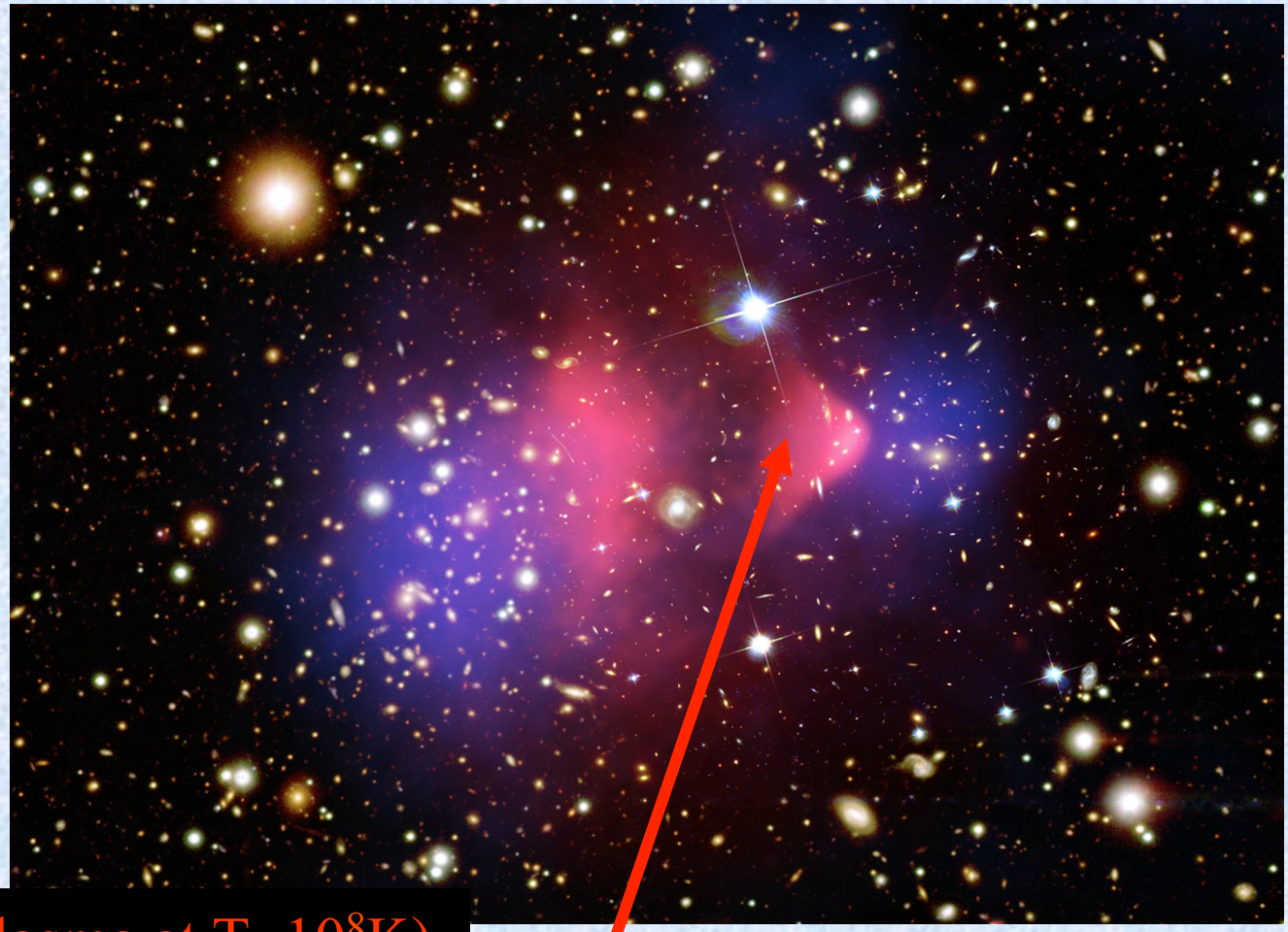
- Luminous and Dark Matters:
  - Luminous and baryonic matter
  - Dark matter in galaxies

Luminous matter in galaxies

- How much in stars?
  - Luminosity density
  - M/L
  - $\Omega^*=0.004$
- How much gas?
  - In galaxies a similar amount



Intracluster medium

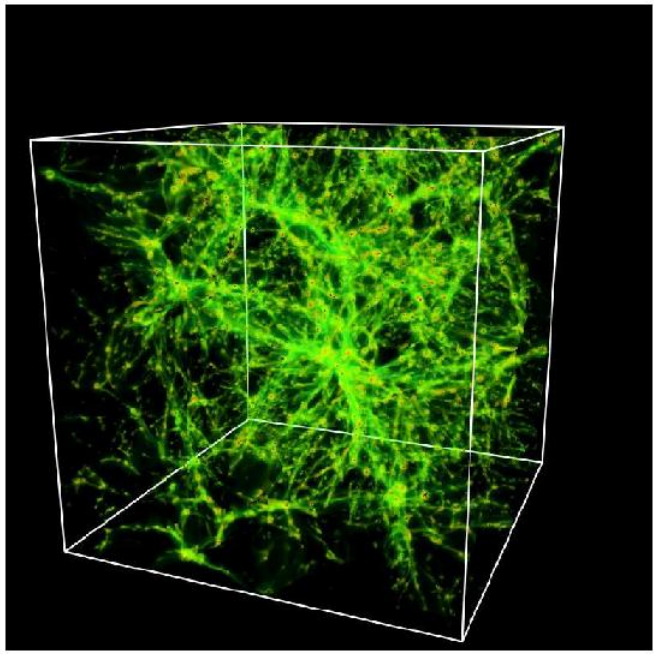


X-ray (plasma at T~10^8K)
Brehmsstrahlung Emission

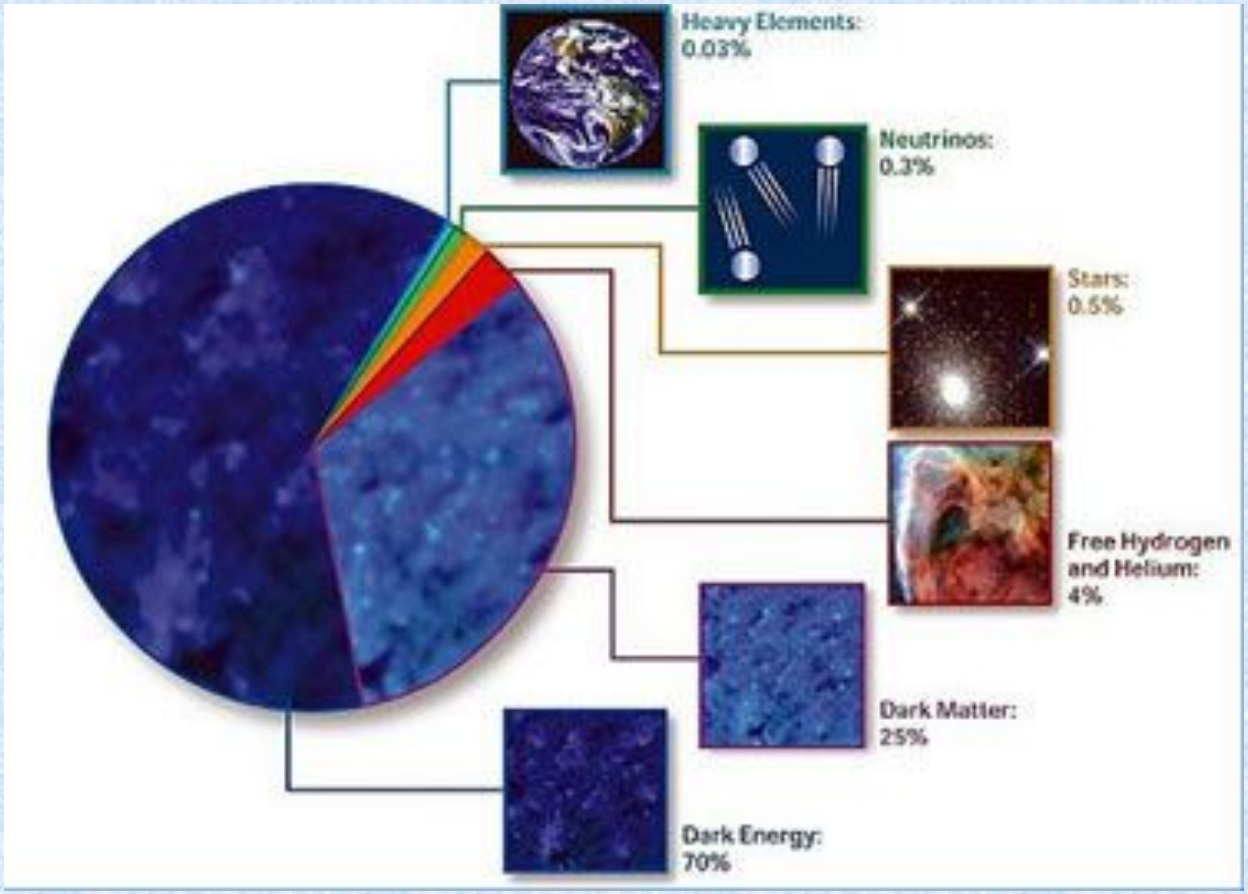
Mstars~15% Mgas

Intergalactic medium

- Not hot enough to be seen in X-ray but abundant
- Can be seen in absorption in front of a luminous background source, e.g. quasar or gamma ray burst

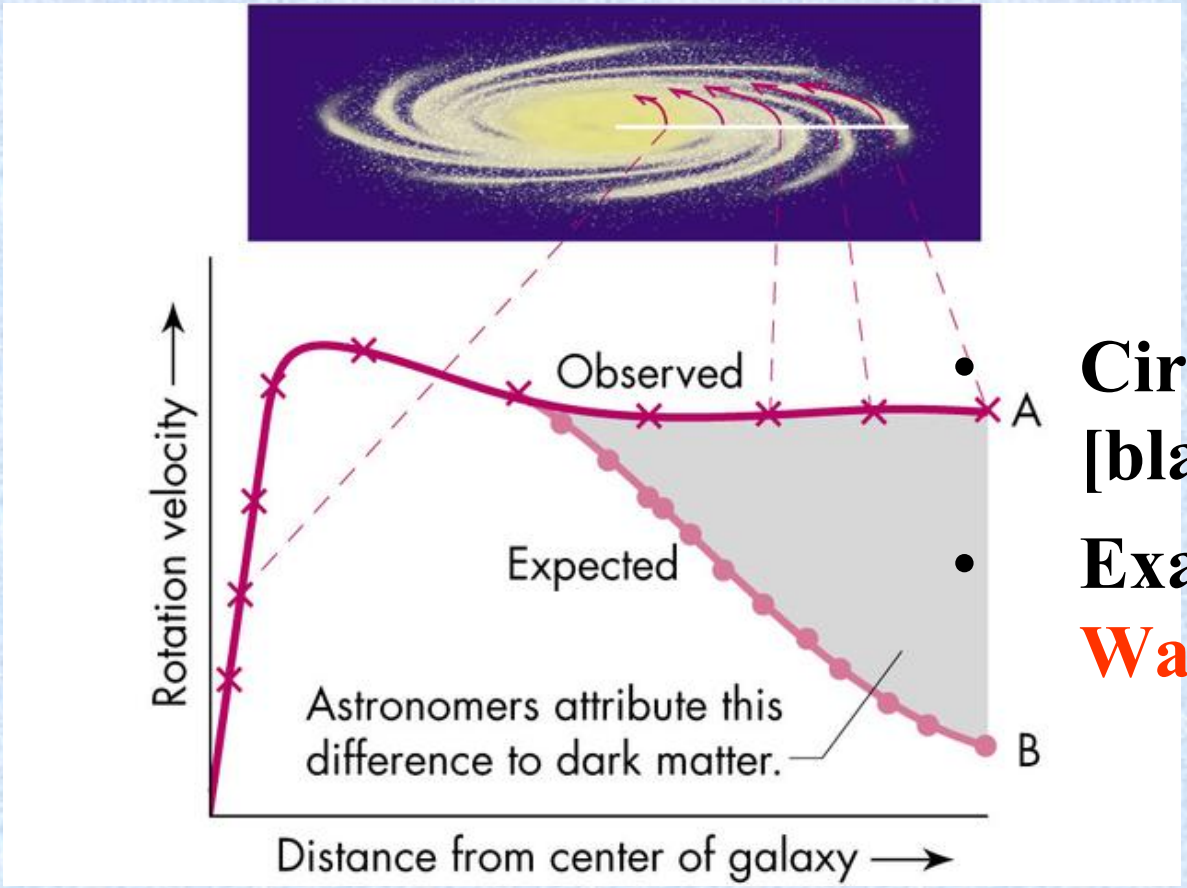


Inventory of baryons



How do we know it's 4% and not more?

Galaxy rotation curves



Circular Orbits [blackboard]

Example: The Milky Way [blackboard]

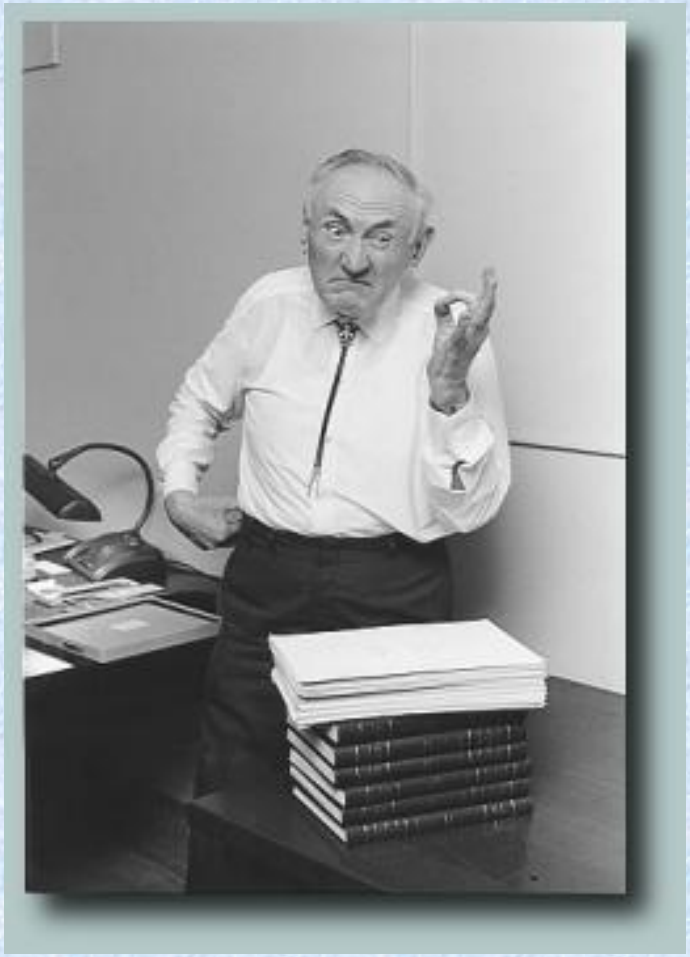
Stellar mass to light ratio ~ 5; total mass to light ratio up to150!

Implications

- There is dark matter, making up 40 times the stellar component: $\Omega=0.004*40 = 0.16>0.04=\Omega_b$
  - Non baryonic dark matter
- Gravity is wrong at small accelerations (modified newtonian dynamics) [blackboard]

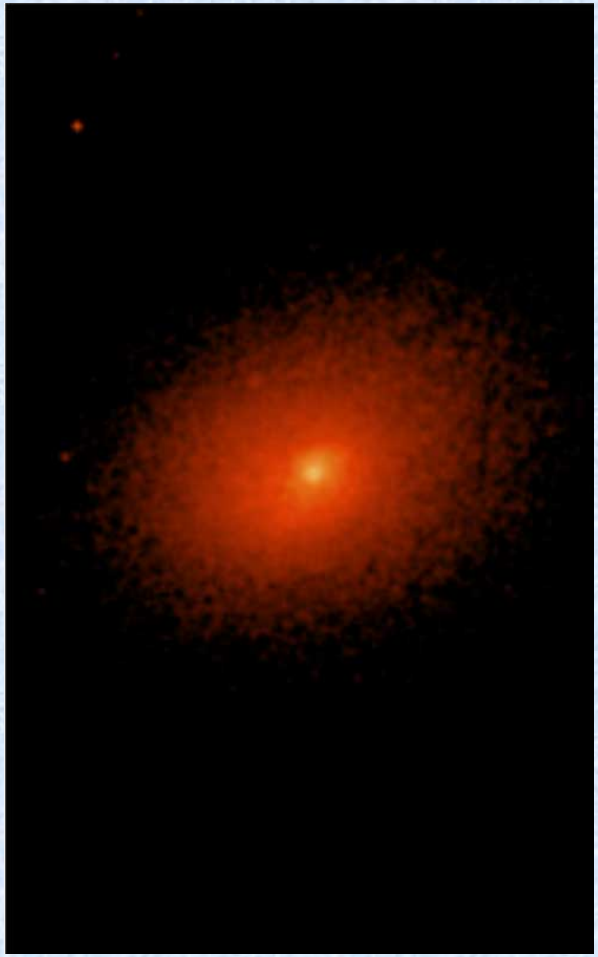
Dark matter in clusters. Virial Theorem

- First evidence for dark matter was actually discovered in clusters
- In the 1930s Zwicky used the virial theorem to derive the mass of the Coma cluster, finding it much higher than that of stars (he didn't know about ICM)
- Virial Theorem [Blackboard]



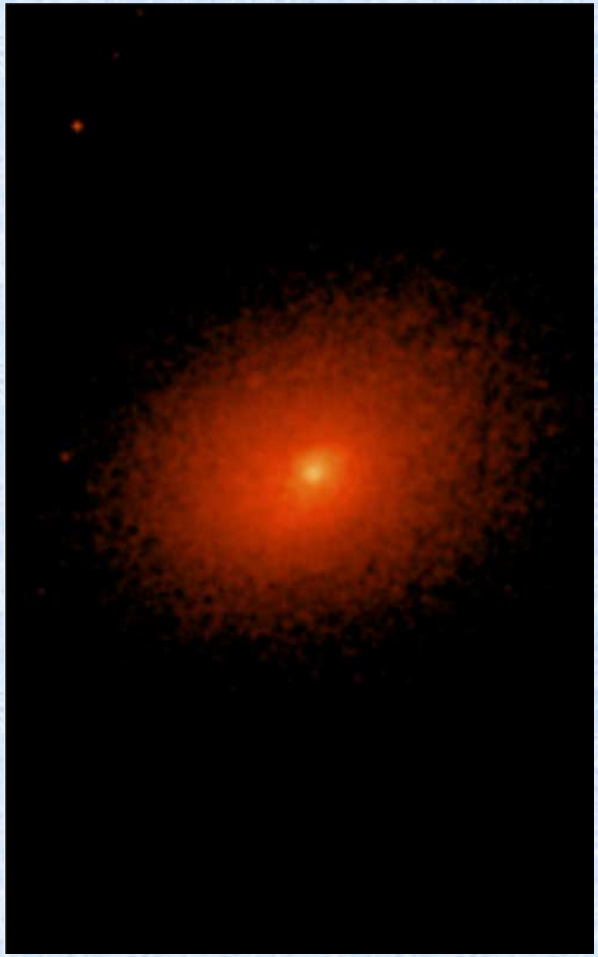
Dark matter in clusters. Hydrostatic Equilibrium

- A second method to determine cluster mass treats the X-ray emitting plasma as a fluid in hydrostatic equilibrium
- Pressure gradients vs gravity
- [Blackboard]



Dark matter in clusters. Implications for cosmology

- If clusters are fair samples of the Universe
- m(baryons)/m(total)= Ω_b/Ω_m
- Baryon density is known from primordial nucleosynthesis 0.04 -> Ω_m~0.2-0.3



The End

See you on Wednesday!

(Monday is Presidents Day)