

Chapter 23: Dark Matter, Dark Energy & Future of the Universe

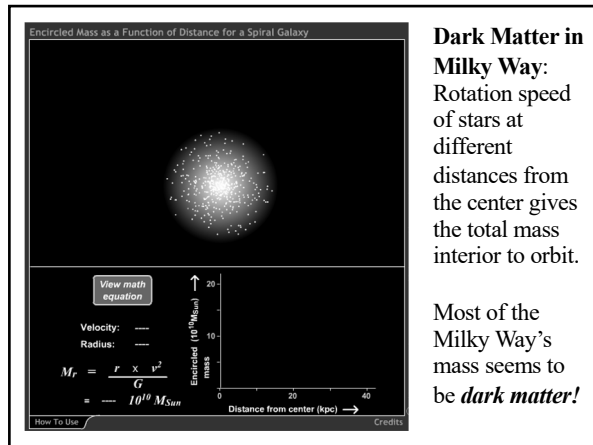


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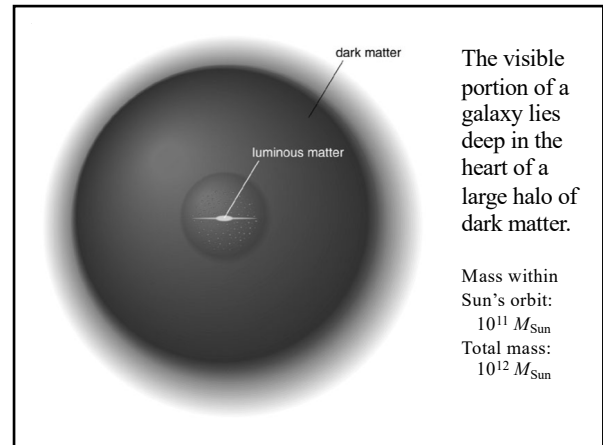
Galactic rotation curves

- Orbital speed as a function of distance from the center:
[mass vs dist galaxy.htm](#)
- Use Kepler's Third Law to get mass enclosed within a given radius

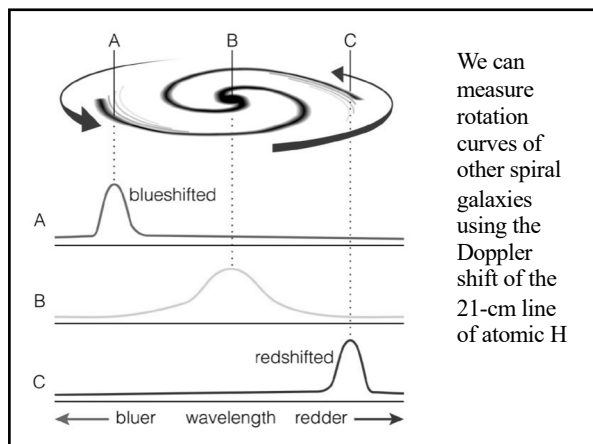
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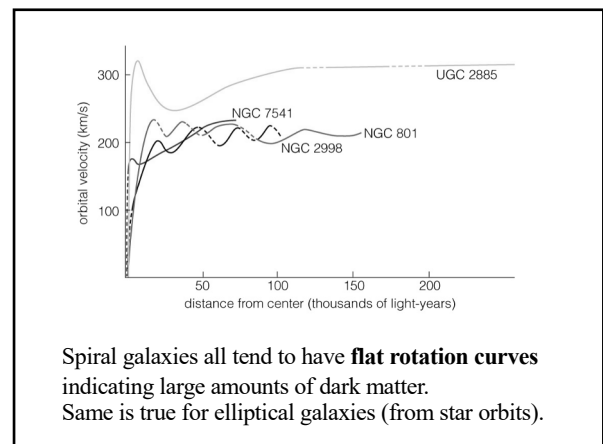
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4



5



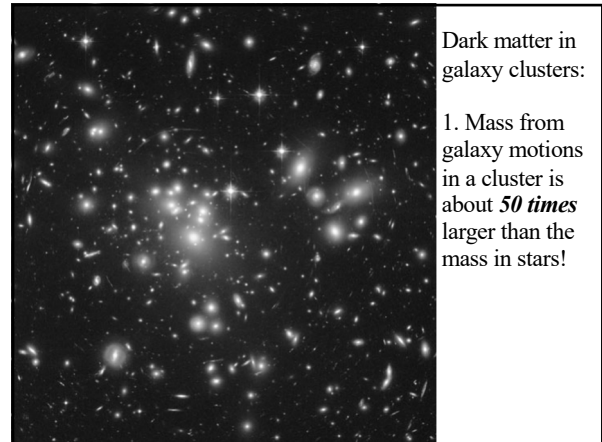
6

Thought Question

What would you conclude about a galaxy whose rotational velocity rises steadily with distance beyond the visible part of its disk?

- A. Its mass is concentrated at the center
- B. It rotates like the solar system
- C. It's especially rich in dark matter
- D. It's just like the Milky Way

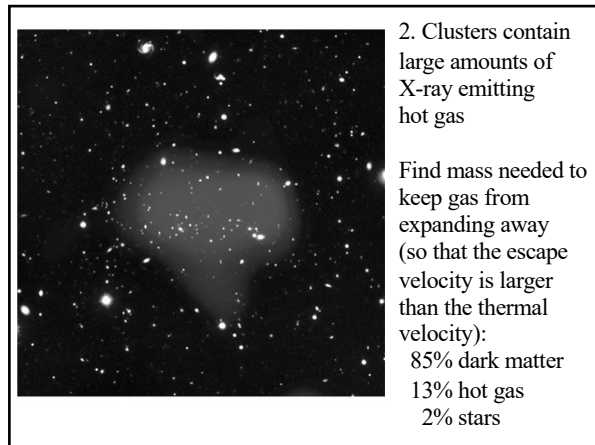
7



Dark matter in galaxy clusters:

1. Mass from galaxy motions in a cluster is about **50 times** larger than the mass in stars!

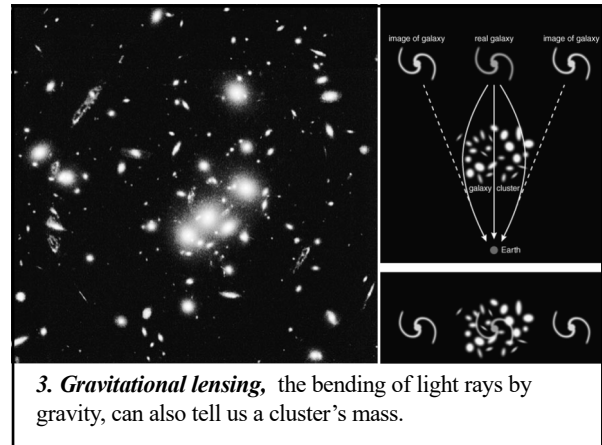
8



2. Clusters contain large amounts of X-ray emitting hot gas

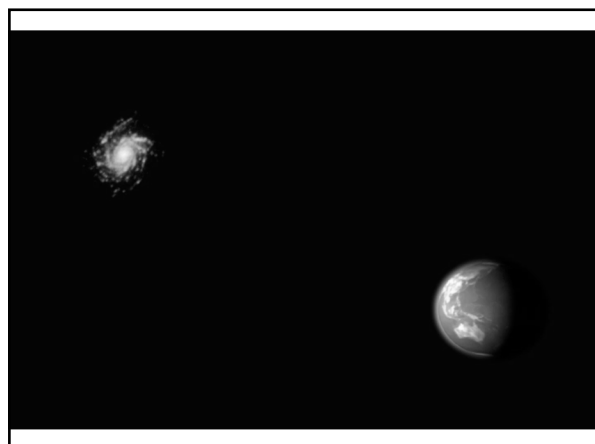
Find mass needed to keep gas from expanding away (so that the escape velocity is larger than the thermal velocity):
85% dark matter
13% hot gas
2% stars

9



3. **Gravitational lensing**, the bending of light rays by gravity, can also tell us a cluster's mass.

10



11

Thought Question

What kind of measurement does **not** tell us the mass of a cluster of galaxies?

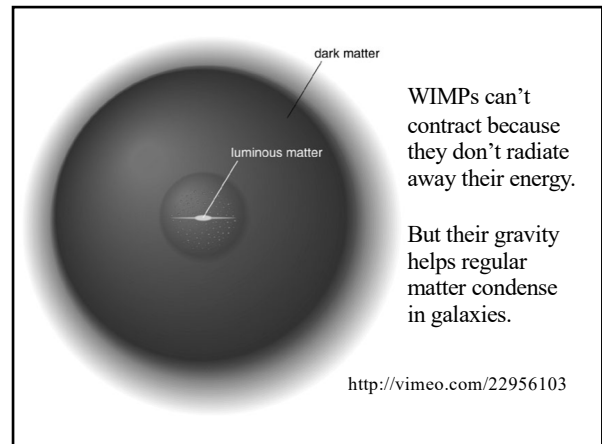
- A. Measure velocities of cluster galaxies
- B. Measure total mass of cluster's stars
- C. Measure temperature of its hot gas
- D. Measure distorted images of background galaxies

12

What is dark matter?

- Ordinary Dark Matter (MACHOS)
 - Massive Compact Halo Objects: red dwarfs, brown dwarfs, big planets, and/or white dwarfs in halos of galaxies
- Extraordinary Dark Matter (WIMPS)
 - Weakly Interacting Massive Particles: mysterious neutrino-like particles
 - *** currently favored explanation ***

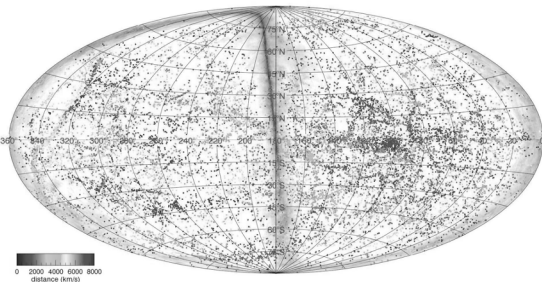
13



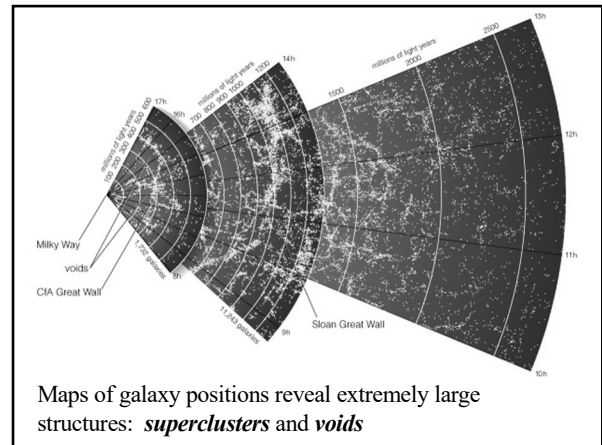
14

Cosmography of Local Universe

<https://vimeo.com/64868713>

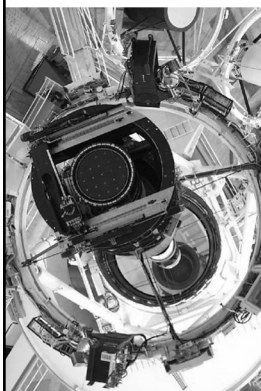


15

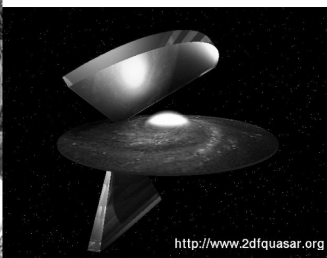


16

The Universe on Large Scales

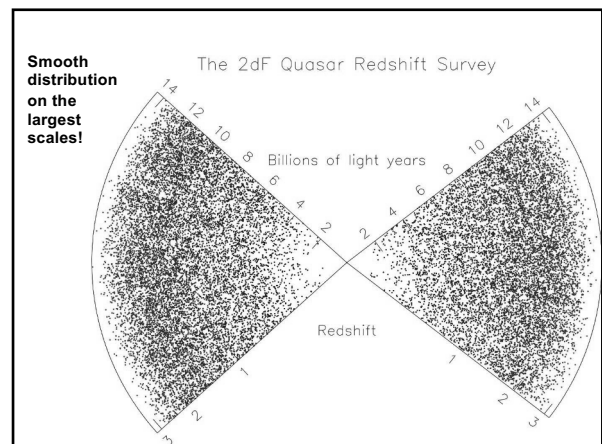


Anglo-Australian Telescope survey of 23,424 quasars in two strips on the sky.

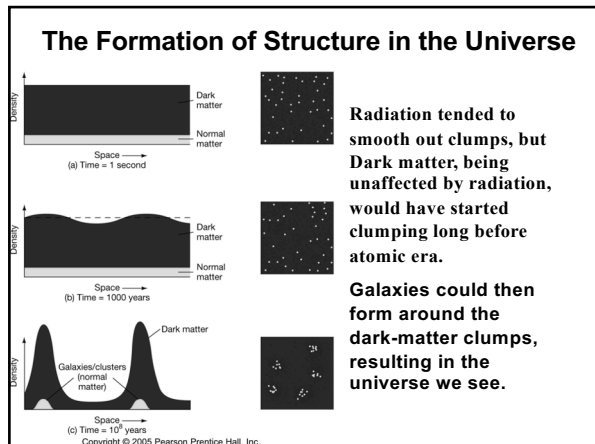


<http://www.2dfquasar.org>

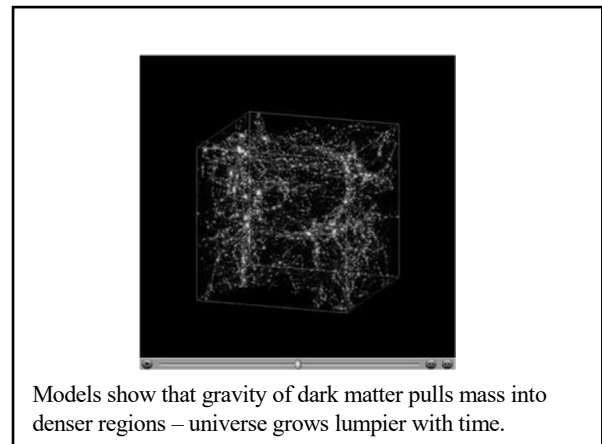
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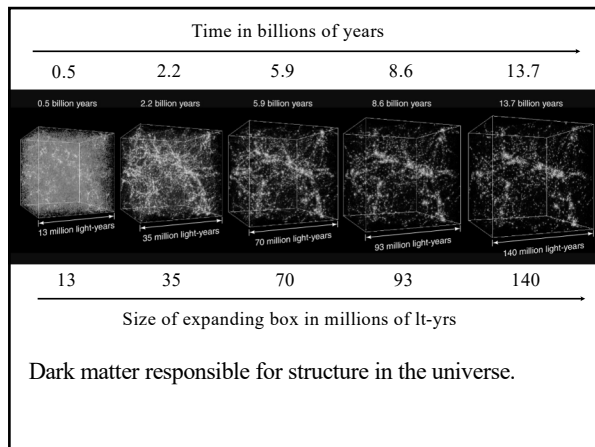
18



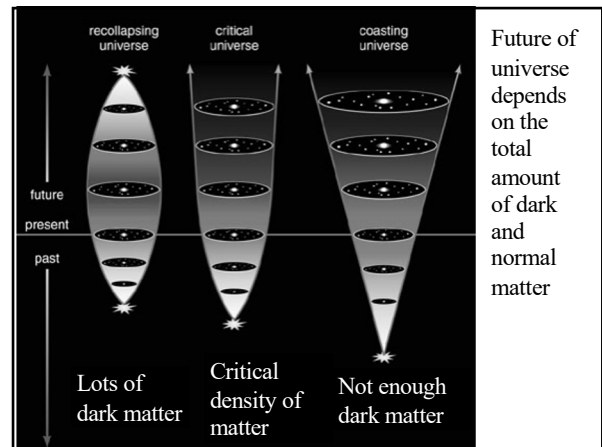
19



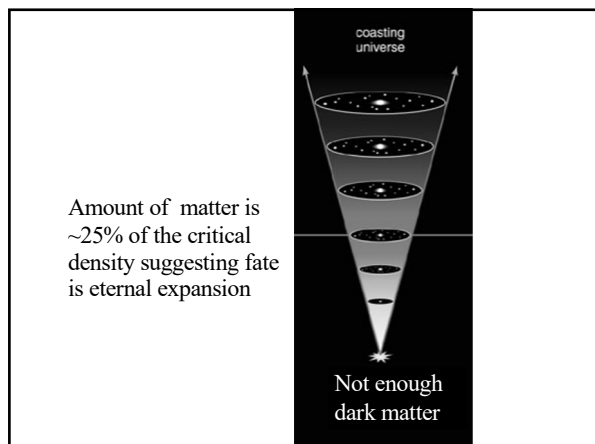
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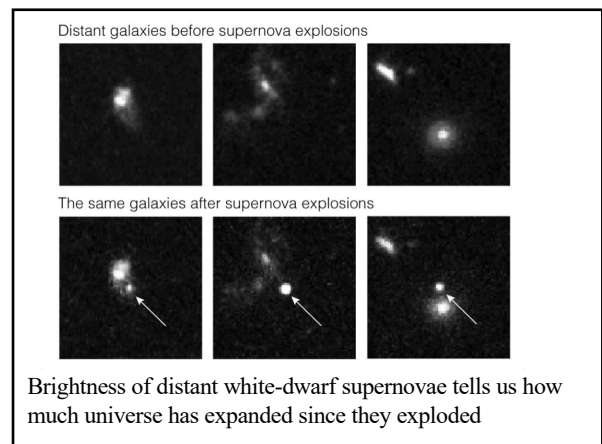
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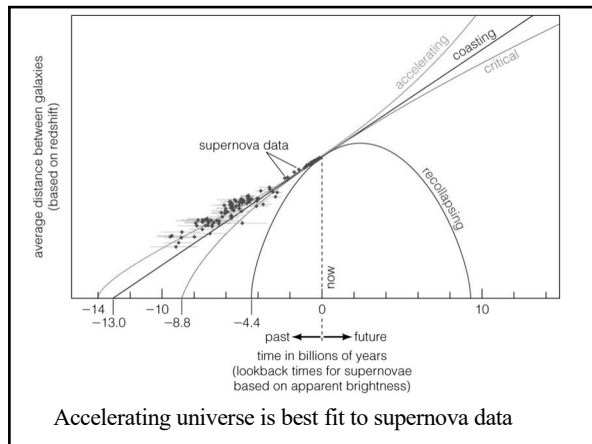
22



23

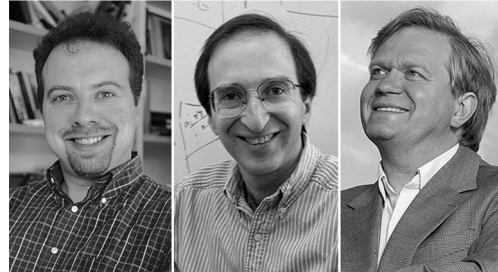


24



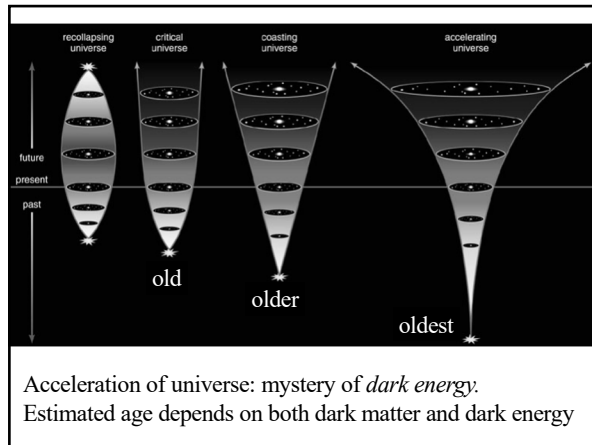
25

2011 Nobel Prize in Physics



From left, Adam Riess, Saul Perlmutter and Brian Schmidt shared the Nobel Prize for discovering that the universe is apparently being blown apart by a mysterious force that cosmologists now call dark energy.

26



27

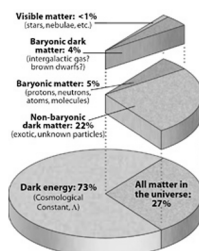
Deep Mysteries

Dark Matter: An undetected form of mass that emits little or no light but whose existence we infer from its gravitational influence

Dark Energy: An unknown form of energy that seems to be the source of a repulsive force causing the expansion of the universe to accelerate

28

Contents of Universe



29

Summary

- Current measurements indicate that there is not enough dark matter to prevent the universe from ever stopping expanding
- An accelerating universe is the best explanation for the distances we measure when using white dwarf supernovae as standard candles

30