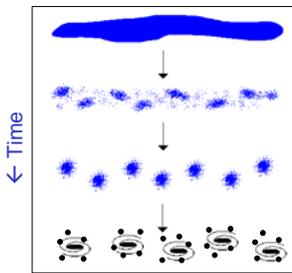


Dark Matter and the Formation of Structure



Top-Down:

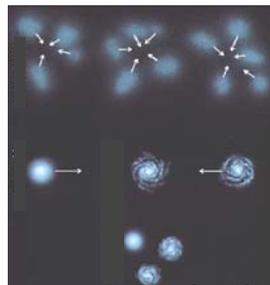
Large structures (e.g. galaxy superclusters, clusters) form first

Then fragment into galaxies

Then globular clusters, etc form within galaxies.

Predicted for Hot Dark Matter

Predicted for Cold Dark Matter



Bottom-up:

Small structures form first

- Dwarf galaxies
- Globular Clusters

Galaxies grow by cannibalism

Galaxy clusters form last

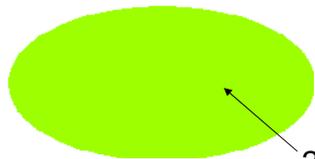
The Cosmic Microwave Background

Comes from all directions

COBE satellite (1989)

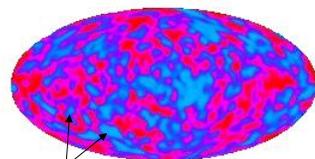


Whole-Sky Maps



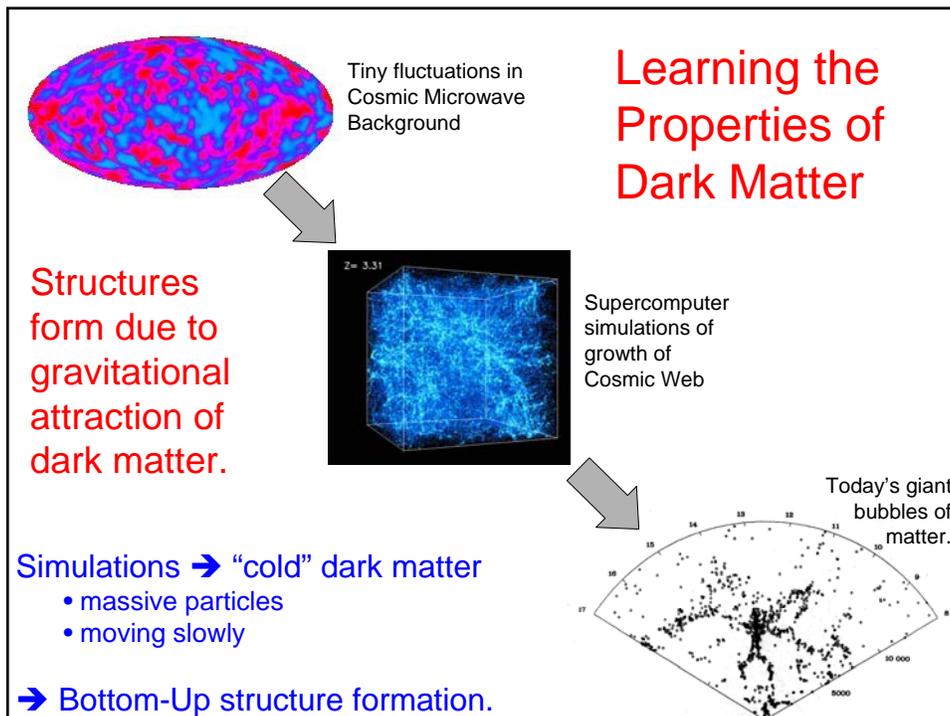
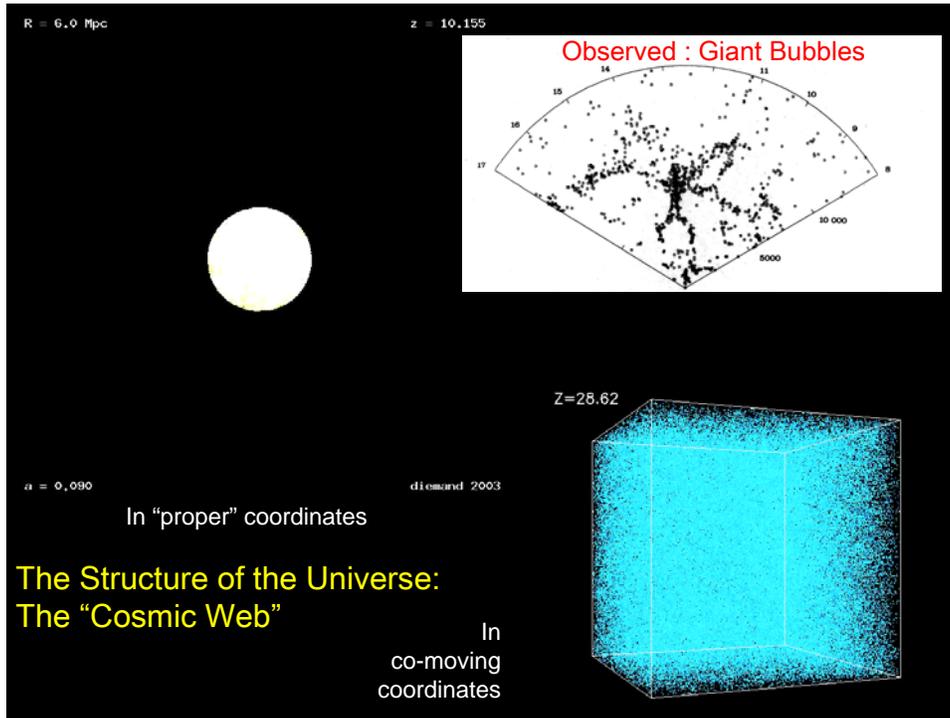
Blue = 0°K
Red = 4°K

2.73°K

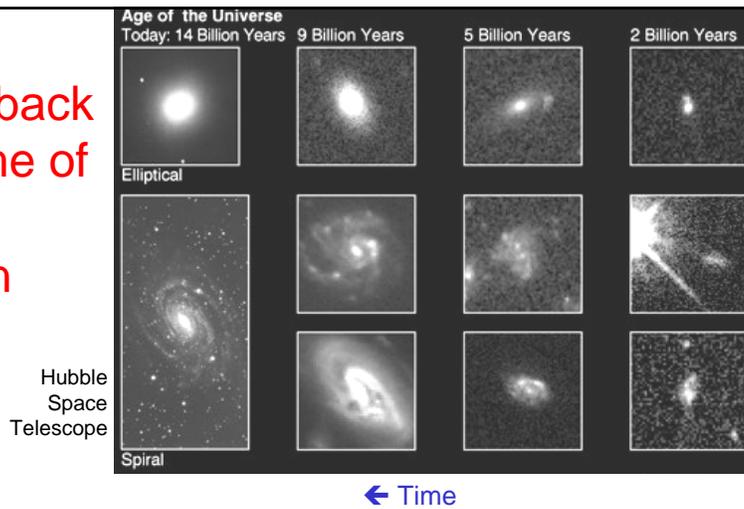


Blue = 2.7302°K
Red = 2.7300°K

Seeds of future galaxies and galaxy clusters



Looking back to the time of galaxy formation



Bottom-up structure formation:

- Galaxies were assembled from smaller units.
- Large galaxy clusters are still forming.

Life in the fastlane...

Colliding galaxies

Meanwhile, in a galaxy close, close to home...

The Milky Way Meets Andromeda

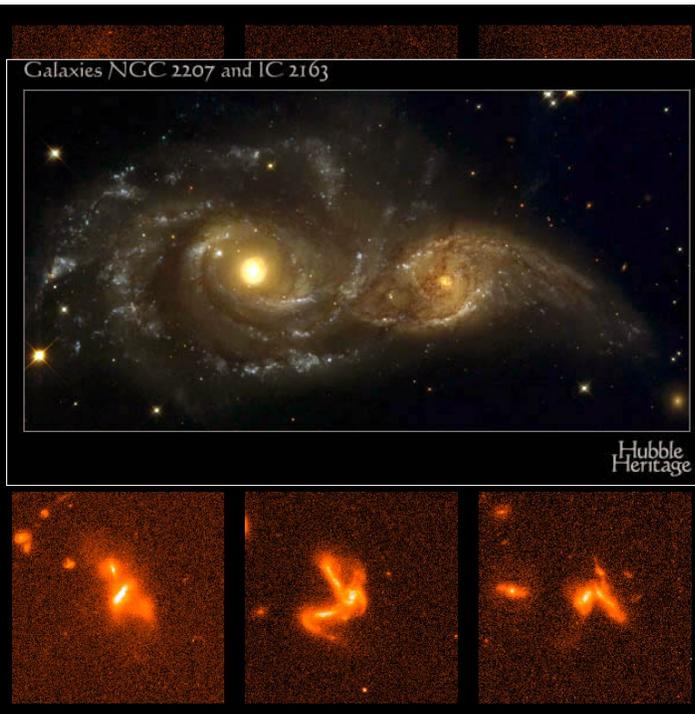
2.5 million ly away

Approaching at 500,000 km/hr

→ Collision in 3 billion yrs

Movie lasts 1.3 billion yrs.

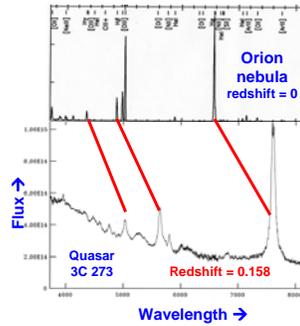
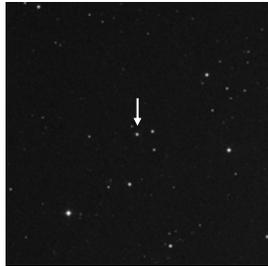
play



Quasars

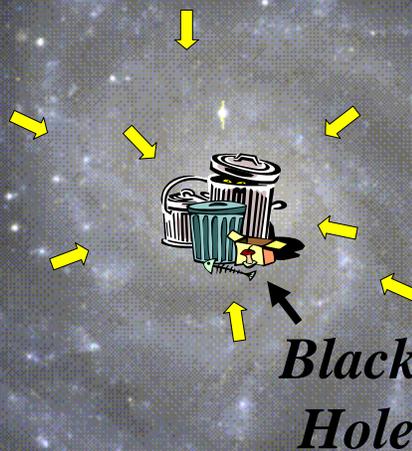
Quasi-Stellar Radio Sources The Most Energetic Objects in the Universe

Look like medium-brightness stars, but 1000 times more luminous than our galaxy.



- *Luminosity* = flux x distance²
- *Distance*: from redshift + Hubble's Law.
→ huge distance → **huge luminosity!**

Galaxy Formation
Gravity → Material Falls to Center



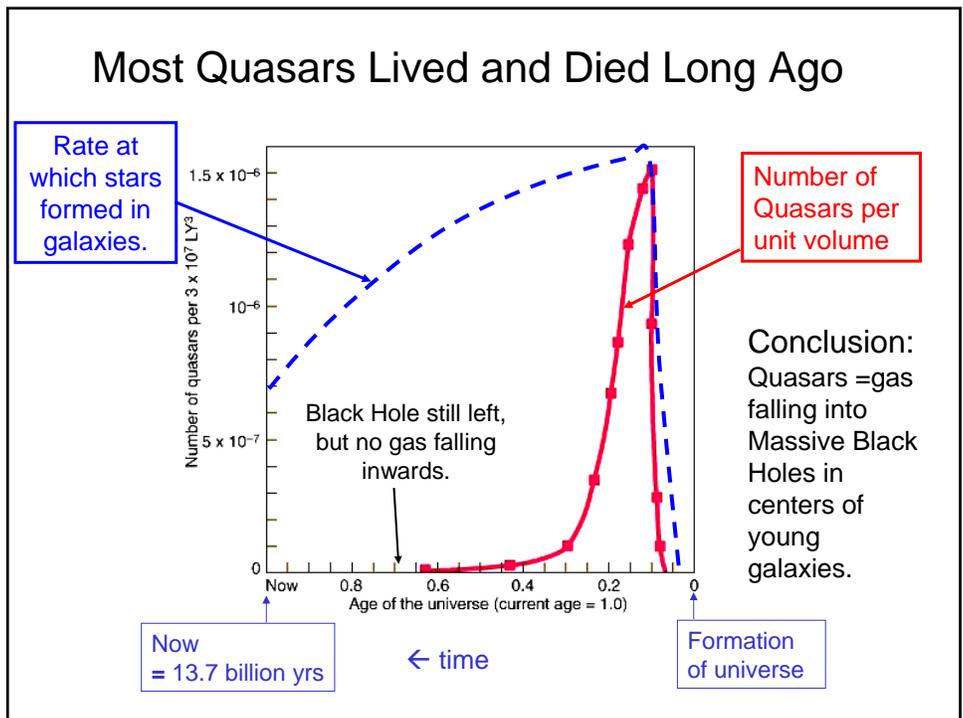
Accretion Disk forms around Massive Black Hole

Up to 100 million solar masses

The Source of the Luminosity:

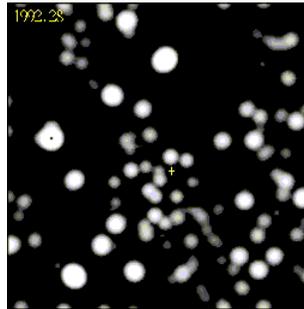
- Matter falls onto accretion disk.
- Disk heats up & glows.

Black Hole

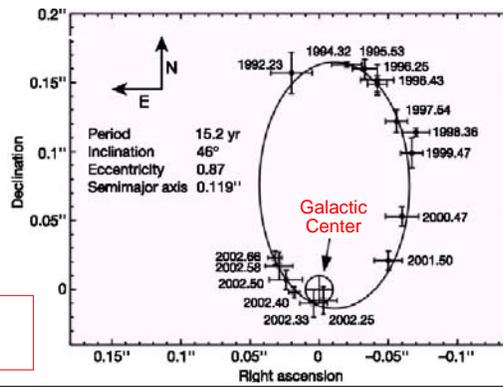


The Black Hole at the Galactic Center

1 million M_{\odot}



Infrared observations over 6 years.



A few Schwarzschild radii

Latest data follows complete orbits to within 60AU from black hole.