Dark Matter: Finding the Invisible

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Image courtesy of Hubble Deep Field

Overview:

Dark Matter:

-Why do we think it exists?
-Observational evidence
-What are its properties?
-What could it be made of?
-How do we find it?
-What if we never find it????

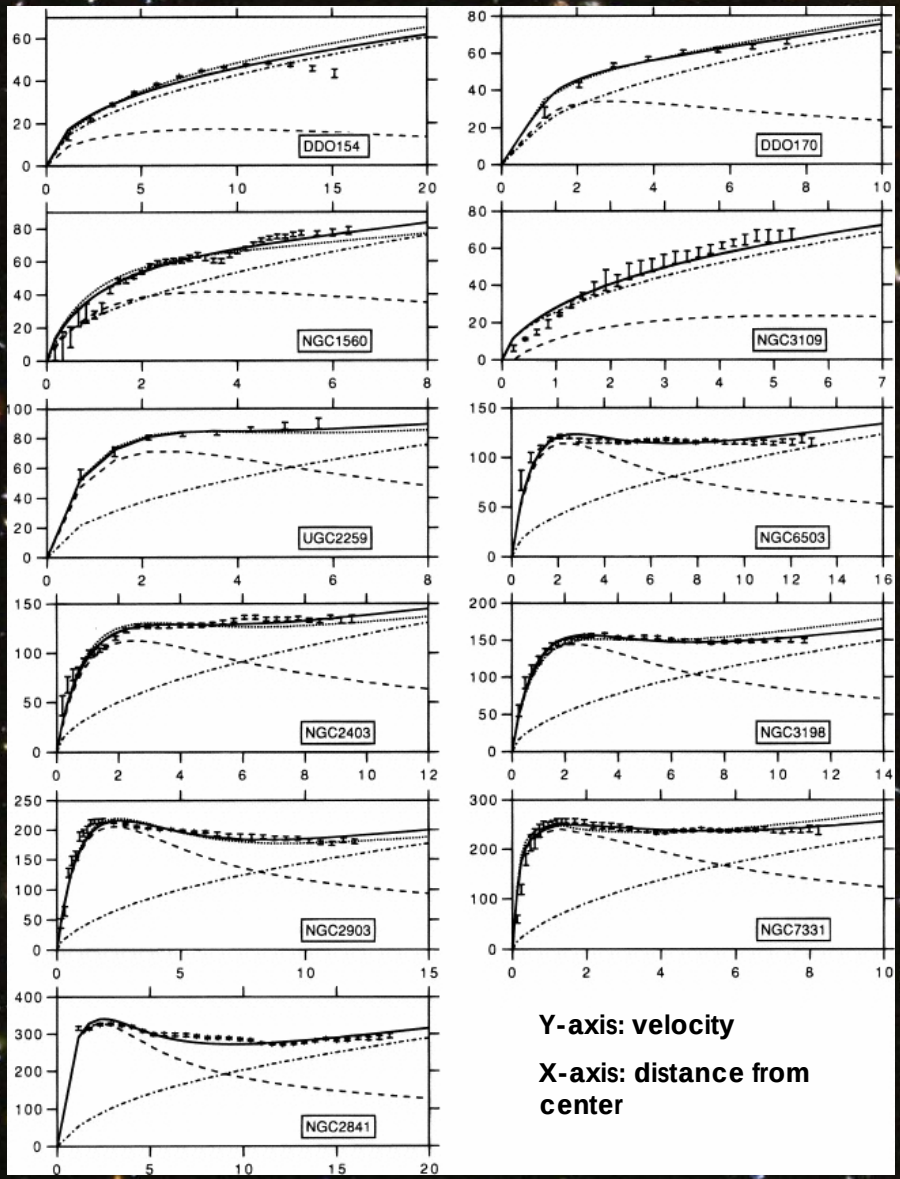
Why do we think dark matter exists?

-Galaxies

- Galactic Rotation Curves

-Galaxy Clusters

-Initial creation of cosmological phenomena



Courtesy of University of Chicago

Galactic Rotation Curves: Weird Behavior

-Why do the velocities remain constant after a certain distance from the center?

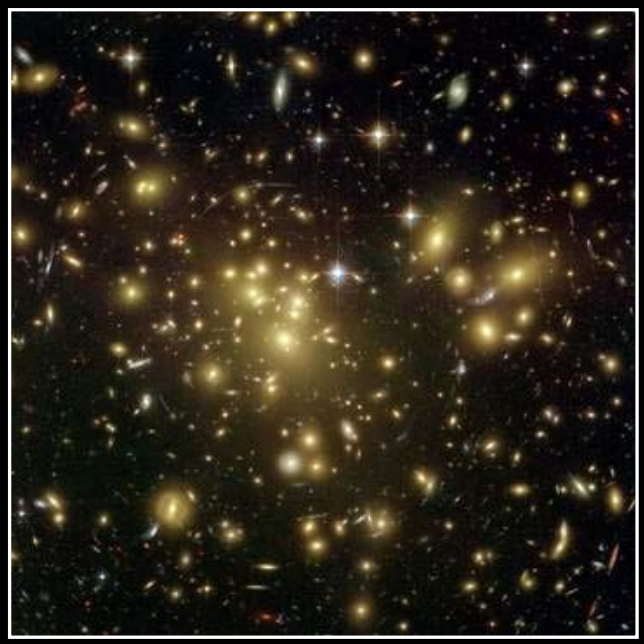
-Dark matter halos

-The dark matter in a galaxy is approximately four times more abundant than visible matter, and extends out far beyond the edges of the visible galaxy

-Computer-simulated galaxies composed only of visible matter fly apart due to their high velocity and low mass density

Galaxy Clusters

-Galaxies' velocities relative to each other would not keep them in clusters if only visible matter were present.



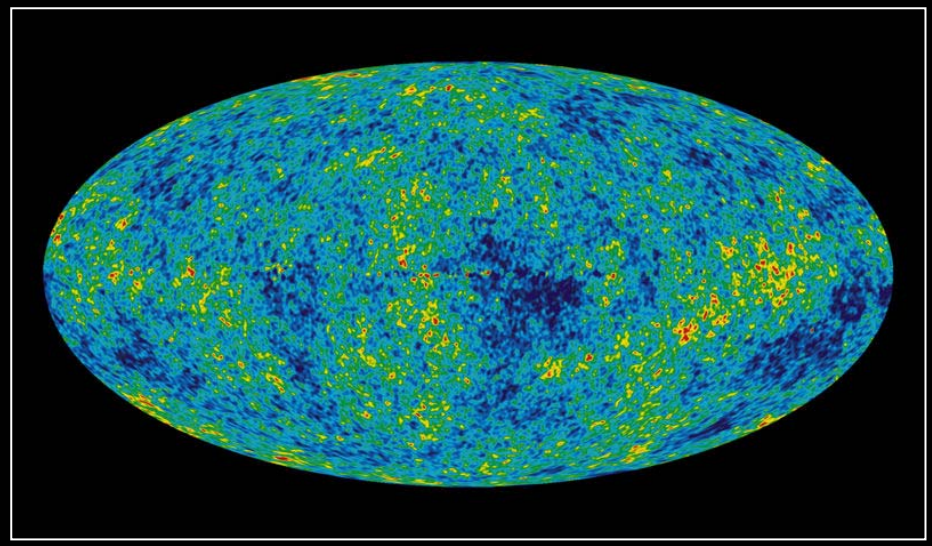
-Dark matter saves the day!

-Added matter means more gravitational attraction

-The dark matter (DM) halos keep clusters together

Courtesy of Space Telescope Science Institute

Birth of Stars and Galaxies



Courtesy of NASA

-The WMAP of the cosmic background radiation shows an extremely uniform early universe

-Would not allow for the creation of galaxies

-Dark matter does not interact with electromagnetic radiation, so it would not be detected on the WMAP

-Clumps of DM spread erratically throughout the universe would provide the gravity necessary to trigger the formation of galaxies

If we do not know what dark matter is, how can we know its properties?

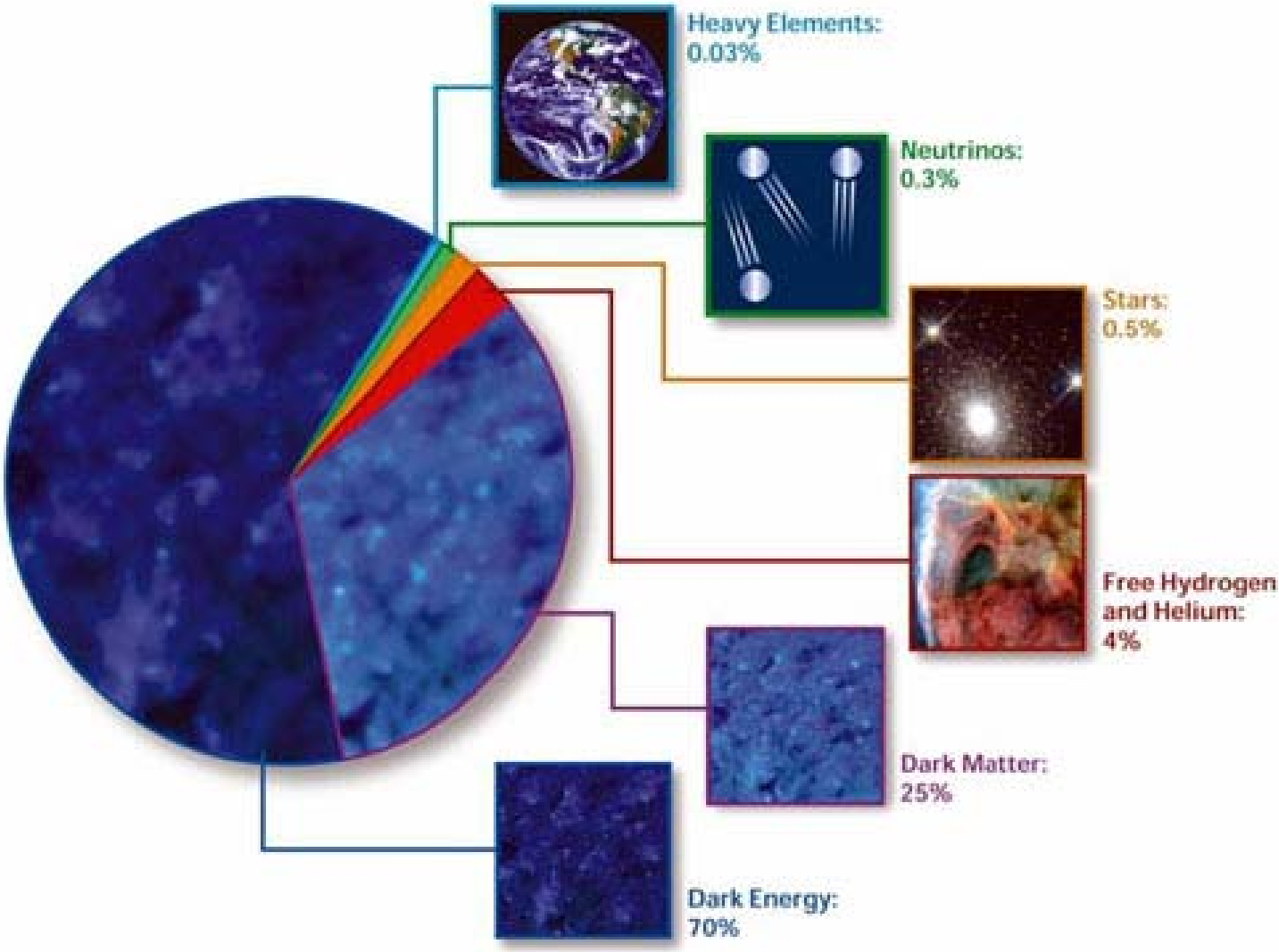
Astronomers have deduced the properties of dark matter through observational data and intelligent hypothesizing:

-Dark matter must not interact with the electromagnetic spectrum (or it would have been detected)

-Because it composes such a large percentage of mass in the universe, it has to be either very significant in size or very plentiful in number

- It has to be “cold” (slow-moving relative to the speed of light during clumping, which occurred shortly after the big-bang)

COMPOSITION OF THE COSMOS



Courtesy of LSST Observatory

A word about Cold Dark Matter

-The terms “hot” and “cold” refer to the velocity of the matter relative to the speed of light

-Cold dark matter was slow-moving in the early universe, this allowed for faster clumping at smaller scales

-Hot dark matter was moving relatively fast; this means very slow to clump, hard to clump on small scales

-In a universe composed of mostly hot dark matter, galaxies would only begin to form now!

-Cold dark matter wins! Creates far more accurate model of today’s universe

Dark Matter is composed of……. ???

We don't know, but here are some possibilities:

- Axions- weak interaction with baryonic matter, low speed (they're hypothetical particles introduced to clear up some perplexing aspects of quantum chromodynamics)
- The supersymmetrics
    - Neutralino – the lightest of the supersymmetrics, but more massive than the majority of elementary particles, zero charge, very stable (so it would still be in great abundance)

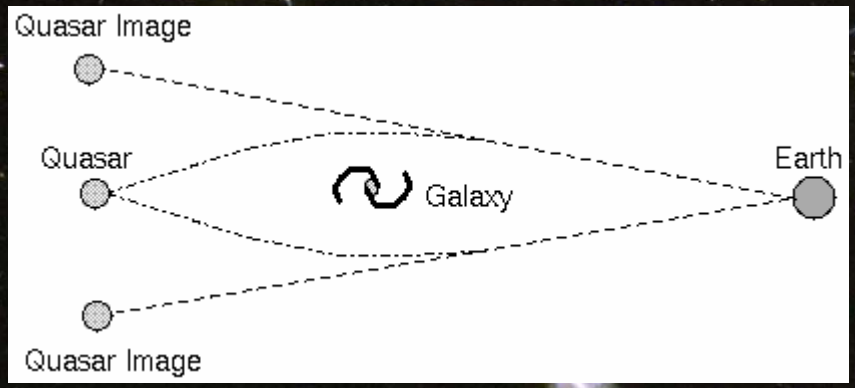
How do we find dark matter?

-Gravitational lensing

-Scintillation detectors

-Cryogenic detectors

Gravitational Lensing



Courtesy of www.astronomynotes.com

-The gravitational forces from distant massive objects distorts the light from celestial bodies behind them

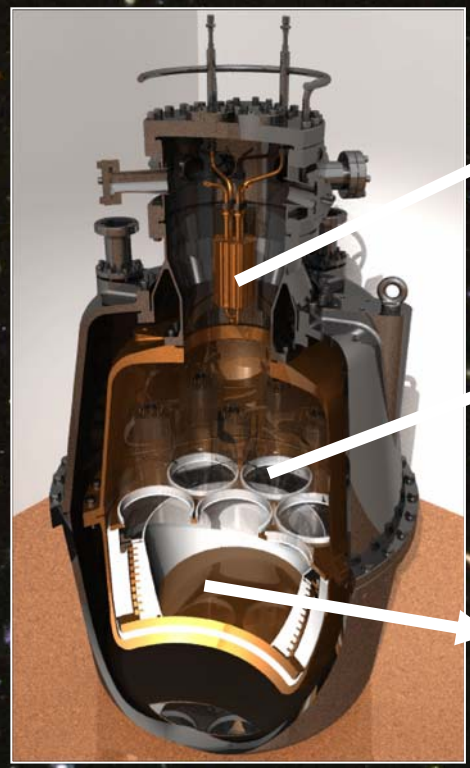
-Distortion can be measured, and is not accurately explainable when taking into account only the visible matter of the massive objects

-Dark matter accounts for this discrepancy, provides the needed gravitation to produce observed lensing effects

Scintillation and Cryogenic detectors

-Scintillators search for small bursts of light created by dark matter particles colliding with a given liquid or compound inside the detector, e.g. liquid xenon.

-Cryogenic detectors search for minute changes in temperature due to dark matter particles interacting with supercooled crystal



Courtesy of Sheffield Particle Physics

Some Past Experiments

MACHO (MAssive Compact Halo Objects) – Thought that the majority of dark matter in a galaxy consisted of planets, brown dwarfs, etc. After running for several years the data showed that this was incorrect

DAMA (DArk MAtter) – Extremely controversial. Hypothesized increase in detector hits seasonally as earth moved through dark matter cloud. Found positive results in data but has not been taken seriously due to detector's lack of ability to discern difference between dark matter and other particles, such as neutron.

Other dark matter experiments to date have been inconclusive, only recently have we developed the detector sensitivity needed to discover DM

What if we never find dark matter?

Back to the drawing boards...

-Modified gravity equations? (breakdown of Newtonian laws at certain distances)

-Miniature black holes saturating the universe providing the missing mass and gravitational lensing effects?

-Multiple dimensions that gravity interacts with?

-?!?!?!?!?

Conclusion

-There exists a plethora of indirect evidence suggesting that dark matter exists, but still no direct evidence

-Several candidates for dark matter, current experiments are searching for them

-If dark matter doesn't exist it means our equations are wrong, or something else exists that we have not thought of

-We should know within the next decade or so whether or not dark matter is real