

Astronomy in the News - New claims of detection of dark matter

Pic of the day - running chicken nebula??



Dark Matter

Previously known surprising result: Most *gravitating* matter in the Universe is mysterious *Dark Matter*

Not composed of p, n, e - the stuff of stars, galaxies, planets, and people

Dark Matter was *never* composed of that stuff (or would upset observed mix of hydrogen and helium from the Big Bang), so also not black holes once made from ordinary star stuff.

Some yet undiscovered particles that only interact by gravity and by the weak nuclear force, no electrical force, no strong nuclear force: 10 × more total mass than normal stuff stars, gas, etc.



Computer simulations show that from the tiniest wrinkles of quantum uncertainty in the Big Bang, the Dark Matter agglomerates to form all the *Large Scale Structure*, galaxies, clusters of galaxies of the Universe.

Ordinary matter, protons, electrons, settles to center of Dark Matter lumps to form galaxies and clusters of galaxies.

Density of Dark Matter is not enough to close the Universe \Rightarrow Universe is "open?" (3D Pringle).

Nature threw us a curve ball

SN were the key!

Use Type Ia supernovae (brightest, ~ uniform behavior)

Carefully map *distances* (dimmer appearance means further away), *velocities* (Doppler red shifts) in all directions

Do geometry - measure curvature - "sphere", "Pringle", "flat" closed, open, flat

More subtle techniques than making parallel lines or drawing triangles, but still amounts to "doing 3D geometry."

Type Ia supernovae are generally the brightest and can be seen at cosmological distances.

They were used as cosmological probes...



to discover the *acceleration* of the Universe...



the Science Magazine scientific Breakthrough of the Year in 1998



The supernovae were found to be a little too dim at given expansion velocity (red shift)

 \Rightarrow Further away than expected for a "normal" gravitating Universe

How do you get further away in a given time?

 \Rightarrow Universe has been *accelerating*!!

Throw ball

Other arguments, especially careful study of the small irregularities of the temperature of the cosmic background radiation left over from the Big Bang, confirm the evidence from supernovae

=> Accelerating Universe - confirmed by all tests applied so far.

 \Rightarrow Universe is filled with an even more mysterious *Dark Energy*,

The dark energy seems to be some sort of force field (like a magnetic field, only different), that permeates the vacuum, empty space, and that that *pushes*, *anti-gravitates!*

As space expands there is just more vacuum filled with this force field, so the effect is not diluted by the expansion.

Dark Energy Anti-gravitates: cannot be any particle, "normal" (p, n, e) or Dark Matter, that gravitates.

Dark Energy force field is not accounted for by any currently known physics.

A major challenge to fundamental physics!

<u>Pressure Gravitates</u> Dark Matter Gravitates 1/3 of that needed to be flat (3D) <u>Tension Anti-Gravitates</u> Dark Energy Anti-Gravitates 2/3 of that needed to be flat (3D)

Total 1/3 + 2/3 = 1 just the right total mass/energy to be flat (3D) within observational uncertainty of 10 - 20%.

The stuff that we and the Sun and stars are made of is essentially irrelevant to this argument, there is too little of it in the Universe.

Most of the stuff of which the Universe is composed is substances, Dark Matter, Dark Energy, completely unlike us.

The best current guess is that our real 3D Universe is essentially 3D flat - but accelerating!

The Universe is Flat (in 3D) on average

Still have individual stars, neutron stars, black holes, galaxies, that curve the space around them causing the small scale, local effects of gravity.

Just as a table top is composed of atoms and molecules on small scales, but is flat for all practical purposes when we sit down to eat.

We are in one of those concentrations of dark matter, our time passes more slowly than the average place in the Universe - does that make a difference to the analysis. Recent claims that data can be fit without Dark Energy. Need to be evaluated. One Minute Exam

Dark Matter is responsible for

- A) The acceleration of the Universe
- B) The dark space between stars and galaxies
- C) The clumping of matter to form stars and galaxies
- D) The Dark Ages after the initial Big Bang