Dark Energy

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Astrophysics

History: Einstein's General Relativity

- In 1915 Einstein publish his theory of general relativity
- Eventually, Einstein decided to apply his theory to cosmology.
  - He discovered that his theory didn't allow the Universe to remain static
  - Thinking his theory was wrong, he decided to add a "Cosmological Constant" to the equation to allow the Universe to remain a static size.

History: Friedmann

- 1922, Aleksandr Friedmann decided to apply Einstein's theory without the "Cosmological Constant"
- Without the constant, Friedmann shows that the Universe is dynamic
  - It starts with a Big Bang
  - And then the Universe expands as the space itself expands
- 1929, Edwin Hubble studies Supernovae and determines that the Universe is in fact expanding, proving Friedmann
  - Einstein would later call including the Cosmological Constant his "biggest blunder"
  - Also this discover of the Microwave Background Radiation cemented Friedmann's Big Bang Theory

The Discovery

- Due to problems with the Microwave Background Radiation, a theory of inflation was created by Alan Guth in 1981.
- Due to this theory of inflation, scientists decided to determine the Energy-Density of the Universe to determine the fate of the Universe
  - If it was above a critical value, the Universe would eventually collapse in a "Big Crunch"
  - But if it was below a critical value, then the Universe would expand forever.
- Either way, scientists thought that the expansion had to be slowing down due to the effects of gravity. This prompted scientists to measure the deceleration of the Universe.

The Discovery

- In 1998 two independent research teams published their results after studying distant Type 1a Supernovae.
- Their results showed that the Universe was in not slowing down, it was instead accelerating!
- In 2011, Adam Riess, Brian Schmidt, and Saul Perimutter were award the Nobel Prize in Physics for their discovery of the acceleration of the Universe.

What is it?

Right now? No one knows exactly what it is.

What we done know, is that calculations have shown that the Universe it approximately:

- 5% Normal Matter
- 27% Dark Matter
- 68% Dark Energy

For something that makes up more than 2/3 of the Universe, we know very little about it. But there are a few theories that attempt to explain it.

Energy of Space

The main principal of Dark Energy is that empty space can posses its own energy.

There are a few main theories that attempt to explain how the space gets its energy.

- Einstein's Cosmological Constant
- Virtual Particles
- Quintessence
- Einstein's Theory of General Relativity is Wrong

Cosmological Constant

It turns out that the idea of the Cosmological Constant proposed by Einstein might not have been completely wrong.

The Cosmological Constant allows space to posses its own energy.

As space were to expand, more of this energy would come into existence.

Due to more and more of this "energy-of-space" coming into existence, the Universe would continue to expand faster and faster

Virtual Particles

According to the quantum theory of matter, empty space isn't truly empty

Temporary particles known as "Virtual Particles" are constantly coming into and out of existence.

Some scientists believe that maybe these particles leave behind some energy.

When scientists calculated how much energy this would give to the empty space, it came out to be 10^120 times to big to be the correct answer.

Quintessence

Quintessence is the name of a theoretical energy field that fills all of space

Quintessence would be different than normal energy and matter in that its effect on the expansion of the Universe

Quintessence has yet be observed.

Even if it was observed, we still wouldn't know much about it, including what it is like, what it interacts with, or even why it exists

Einstein is Wrong

It is entirely possible that Einstein's Theory of General Relativity is wrong.

If it shown to be wrong, not only would this effect the expansion of the Universe, but how normal matter behaves

Maybe a new theory is needed?

Attempts at Observation

The Dark Energy Survey (DES)

- Started in September 2012 and continuing for 5 years, a giant 570 Megapixel digital camera will survey distant galaxies attempting to search for answers.
- The DES combines four different Dark Energy probes
  - Tyle 1a Supernovae
  - Baryon Acoustic Oscillations
  - Galaxy Clusters
  - Weak Gravitational Lensing

References

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Questions

- Do we need a new theory of gravity to help explain what we obersve, or should we attempt to find evidence that works with the current model?
- If normal matter is so spare in the Universe, should we even consider it normal?
- Do you think we will ever find answer to what is really is?