The Universe's Dark Side

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What is Cosmology? It is the study of the universe in its totality including its past and predicted future forms. During the latter half of the 19th and early part of the 20th centuries Physics underwent a revolution with the introduction of Einstein's theories and Quantum physics. At present cosmology may be undergoing an equally radical change. The ideas of Dark Matter and Dark Energy are certainly revolutionary. But as yet they are far from being understood. A conversation between a cosmologist and a non-cosmologist might go something like this:

Non-cosmologist:	What is the universe made of?
Cosmologist:	Dark Energy = 70% Dark Matter = 25% Free H and He = 4% Stars = 0.5% Neutrinos = 0.3% Heavy elements = 0.03%
Non-cosmologist:	What is Dark Matter?
Cosmologist:	We aren't sure.
Non-cosmologist:	What is Dark Energy?
Cosmologist:	We have no idea.

So if we have little or no idea what these 'dark' things are how can we say they exist? The answer begins with galaxies. To weigh a galaxy we can look at its distance, size and luminosity (how much electromagnetic radiation is emitted by the galaxy). From this we can estimate the mass of the galaxy. Or we can study the spectra of stars in different parts of the galaxy and from this estimate their velocities (the stars in a galaxy are rotating around the galaxy's centre of gravity). From these velocities we can estimate the galaxy's mass. The problem is when we use these two methods we get two very different results. Also, we expect the stars in the outer parts of a galaxy to have lower rotational velocities than the stars in the inner parts but this is not what we actually see. There are two ways we can interpret this:

1. Our observations are wrong or our interpretations of the observations are wrong.
2. The galaxies are much more massive than expected and consist of matter we can detect and something else we can't see i.e. Dark Matter.

So what might this Dark Matter be? Many cosmologists believe that it may consist of nonbaryonic particles. Baryonic matter is the family of subatomic particles which are made of three quarks, such as the familiar proton and neutron. Other possible candidates include ordinary and heavy neutrinos, dwarf stars and planets and clouds of gas. Whatever it is this matter must be considerably more common than 'ordinary' matter, in fact we are made of some of the most exotic material in the universe i.e. heavy elements such as carbon and iron.

Image Credit: NASA

Einstein Ring A gravitational lens created by a galaxy cluster believed to reveal the presence of Dark Matter.

Where does the Dark Energy come in? When we study the spectra of distant galaxies we see they are red shifted – we interpret this as the expansion of the universe – a consequence of the Big Bang. The problem is this expansion is accelerating…where does the energy to cause

this acceleration come from? Dark Energy? In this case the adjective dark suggests something unknown rather than something which doesn't emit radiation. How does Dark Energy fit into the evolution of the universe?

- The Big Bang – Universe expands rapidly
- Ordinary matter appears – stars etc.
- The mutual gravitational attraction between this matter slows the rate of expansion
- Once the universe is beyond a certain size Dark Energy, which is a repulsive force, forces galaxies apart. In other words it accelerates the expansion of the universe.

One possible alternative is Modified Newtonian Dynamics (MOND), this idea attempts to explain the observational data by making gravity stronger at great distances or in weak fields. The theory however has problems: it's difficult to construct a relativistic MOND. One or two recent attempts are looking promising, for example, the Nonsymmetric Gravitational Theory proposed by J.W. Moffatt. These ideas and another called Tensor-Vector-Scalar (TeVeS) may be able to match observational data without the need for exotic (i.e. nonbaryonic) dark matter. So there are two camps – on one side are the cosmologists who favour Dark Matter and Dark Energy (the Dark Side?) versus those who are searching for an alternative theory for gravity – eliminating the need for exotic unknown forces and matter.