All eyes open for dark matter

The quest for dark matter has drawn together the far ends of physics, says S.Ananthanarayanan.

Scientists propose that there is a thing called dark matter, an invisible substance that dominates the universe, because of what has been observed by astronomers and cosmologists. But what dark matter could consist of is still unanswered and has become the concern of particle physicists and String Theorists and answers may come from the results of the LHC!

Dark matter

It was the Swiss American, ***Fritz Zwicky*** who discovered that not all the mass of the universe was visible. In 1933, Zwicky was studying the ***Coma Cluster***, a group of over 1000 galaxies at a distance of 321 million light years. The light that comes from opposite ends of the cluster have differences of frequency, which shows that one end is moving towards us and the other end away from us, which is to say that the cluster is rotating like a spinning disk. Now, things that are spinning will fly apart and in the case of a cluster of galaxies, it is gravity that is keeping it together. Except that Zwicky found that the Coma Cluster was spinning so fast that the mass of the 1000 odd visible galaxies could not account for the necessary force of gravity. Zwicky worked it out that at least 400 times the visible mass should be there as ***dunkle Materie***, or ***dark matter***, to explain the gravity needed to allow the observed speed of rotation.

Apart from the speed of rotation of galaxies and clusters, there is other evidence, such as ***gravitational lensing***, which calls for the presence of more matter than is visible or has been detected. The temperature distribution of hot gases within galaxies or clusters, again, calls from more mass to be present than is visible. The estimate of the quantity of dark matter in the universe is placed at about 5 times more than ordinary matter and a great question is: “what dark matter could consists of.?”

Colour of darkness

One suggestion has been that it could be remnants of stars that have burnt out all their nuclear fuel and are no longer luminous. Or there could be the mass of gas that is yet to warm by coming together in the process of star formation. But these suggestions get eliminated because the generally successful theory of how the universe formed, the ***Big Bang Theory***, makes an estimate of the total mass of the universe, which is in keeping with the mass of the visible universe. The age of the universe, which has been otherwise determined, and the intensity of background radiation that persists are also in agreement with the Bing Bang. The existence of any more ordinary matter, like stars or gas, would thus overturn the current and soundly based theory. Dark matter must hence consist of some other form of matter, which has escaped detection for so long.

The candidate material for dark matter is the ***WIMP – Weakly Interacting Massive Particle –*** something that has the mass, for the gravitational effect that has been seen, but still interacts very feebly with ordinary matter, which is why it has not been detected so far in nuclear reactions or in particle accelerators, or even in cosmic rays, which are the products of nuclear reactions in the sun or in far off supernovae. Another property that dark matter material must have is that it should be stable, as it has been around for so long. Many different particles are created in reactions in particle accelerators, but most of them are unstable and decay into ***electrons and protons***, of which atoms are made, or ***photons***, the particles of light, or, ***neutrinos***, which are very light, uncharged and weakly interacting particles. Huge quantities of neutrinos were produced during the processes in early part of the Big Bang and are still being produced in energetic reactions in the sun and in supernovae. But neutrinos, despite being weakly interacting and abundant in number, have such little mass that they cannot explain the effect we are trying to understand. The quest for the nature of dark matter has become multidisciplinary and the ***Kavli Institute for Cosmological Physics*** at the University of Chicago, with the ***National Academy of Sciences*** recently organized a conference where cosmologists, particle physicists and observational astrophysicists came together to review where we stand.

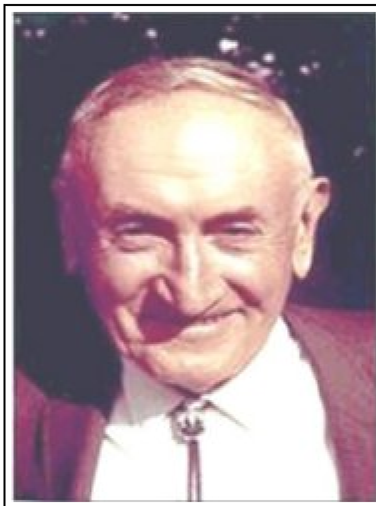
The currently accepted framework of the nature of matter is the ***Standard Model***, which explains the different nuclear and atomic interactions with the help of a set of basic elementary particles. Particles all have an intrinsic spin, or angular momentum and they are classified in two groups, based on the nature of spin. Particles with spin measured in whole numbers, like 0, 1, 2 are one category, called ***Bosons***, and the those which have spin in fractions, like 1 / 2, 3/2, 5/2, are the other category, called ***Fermions***.

The standard model is incredibly successful in describing atoms and nuclei, but it has this deficiency, that it does not deal with the nature of mass and General Relativity. A sequel to the Standard Model, to overcome limitations, is the ***String Theory***, which conceives not separate constituents of matter, but one, multidimensional entity, known as the ***String***, which shows different properties, based on frequencies of vibration, and can account for everything that the Standard Model can explain and also goes further to propose solutions to areas that are beyond the Standard Model.

Supersymmetry

Scientists think physical laws are elegant and symmetric, like being the same froo different viewpoints, or even when reflected in a mirror. One remarkable symmetry, proposed in 1928 by ***Paul Dirac***, is the existence of an ***anti-particle*** for every ***elementary particle***. Antiparticles are the same as the corresponding particle in all respects, except the charge. For instance, the ***positron*** is in all ways like the ***electron***, except that it has a positive charge. So also the ***anti-proton***, also called the ***negatron***, is like the ***proton*** except for the charge. And the anti-proton and the positron can also form an atom, which should be like hydrogen in all respects. Antiparticles had been predicted by Paul Dirac, based on solutions of the ***Dirac equation***, and their subsequent discovery in experiment consolidated the belief in theory and symmetry.

A similar symmetry that arises from String Theory, and this is called Supersymmetry, is that every Boson must have a corresponding Fermion. The suggestion that that supersymmetric partners should have the same mass is clearly not valid as no such partners have been discovered so far. But there bases to hold that the lightest supersymmetric particles, which may be WIMPY things we are seeking, would be 100 to 1,000 times as heavy as the proton. The Large Hadron Collider is an arrangement to attain very high energies where such particles may be found. The latest results show that supersymmetic particles would be heavier than the Higgs Boson and is is believed that they may be about 10 times heavier.



Fritz Zwicky

Paul Dirac
