DARK&BRIGHT

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Three-dimensional distribution of dark matter in the Universe. 08 Jan 2007 Satellite:Hubble Space Telescope Depicts: COSMOS dark matter survey. Copyright: NASA,ESA and R. Massey (California Institute of Technology).

Universe's Bright and Dark Side

By Francesco Sannino

Several astronomical and cosmological observations via satellites, telescopes and other experiments indicate that only a few percent of the Universe is made by the same stuff that makes us, i.e. the bright matter. Over ninety percent is made by an obscure form of matter and energy coined dark matter and dark energy.

Our galaxy, the beautiful Milky Way, as well as any other galaxy, is immersed in a dark soup of energy and matter. Although dark matter and energy account for the vast majority of the mass in the observable Universe only recently we were able to detect their presence. The dark side is made up of invisible substances that do not emit electromagnetic radiation and therefore we cannot "see" these substances directly through telescopes. Their presence can, however, be inferred from the gravitational effects on the visible (bright) matter.

Dark matter was introduced, historically, to explain the flat rotation curves of spiral galaxies. We know now that dark matter and energy are both needed to explain structures larger than galaxies and even the very origin of the Universe per se, the Big Bang.

Dark matter can be understood simply as a bunch of heavy particles filling about 22% of the mass of the Universe. The heavier these particles are the fewer we have around. Dark matter is not distributed homogeneously in the Universe - see the picture above.

Dark energy is pure distributed pressure. Imagine somebody inflating a balloon. Dark energy inflates our Universe in a similar way. It is a substance homogeneously distributed not only in space but also in time meaning that its effects are not diluted as the Universe expands.

Origins of Dark & Bright Matter
What do we know?

By Francesco Sannino

Dark matter is crucial to understanding the formation of structures in the Universe and the evolution of galaxies while dark energy is directly responsible for the observed accelerated expansion of the Universe. In other terms galaxies go away from each other faster and faster.

Thanks to these experimental observations theoretical physicists are now faced with several fundamental puzzles to unravel: What makes dark matter and energy? When were they created and why? Is there a relation with the bright side of the Universe. Why do we observe only bright matter but no antimatter? A famous example of **antimatter** is the anti-electron known as the "positron". The positron is a particle identical to the electron except for its electric charge, which is opposite. If an electron and a positron meet each other, upon a metaphoric shake of the hands, they disappear in a burst of energy released in the form of pure light radiation. It is an experimental fact, and our own existence is a living proof, that the Universe is skewed towards bright matter. It is, however, natural to assume that at the beginning of time a more democratic Universe emerged from the Big Bang containing an equal amount of matter and antimatter. Something dramatic must have happened at very early times of the Universe's existence leading to the extinction of antimatter. Mankind produces antimatter in the laboratory, albeit in very modest amounts, yet nature does not like antimatter.

The ensemble of physical laws describing, at the fundamental level, all the chemical reactions and nuclear interactions constitutes the **Standard Model** of particle interactions. However, given that the Standard Model is unable to answer any of the questions above it is, at best, an incomplete theory.

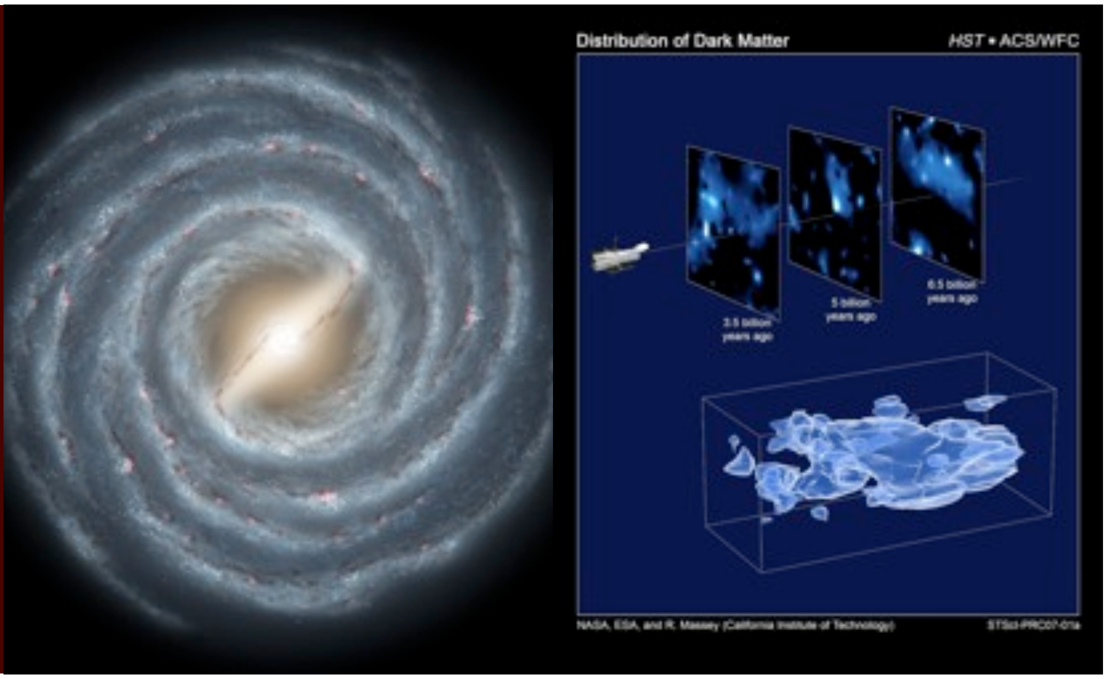
Theoretical physicists have already put forward several interesting ideas amending the Standard Model and being able to answer, at least partially, some of the questions above.

Supersymmetric extensions of the Standard Model - **Supersymmetric Standard Model** - , for example, are theories whose net effect is to duplicate any single known elementary particle. The supersymmetric partners have funny names such as the "s"-electron for the electron "s"uper-partner or the phot-"ino" for the partner of the photon. Dark matter is identified with a super-particle. To help visualizing these extensions you can think of any particle to have two different identities, the normal one and the super one. Very much like Clark Kent and Superman. This model is, however, becoming progressively less favored by the existing body of experimental results.

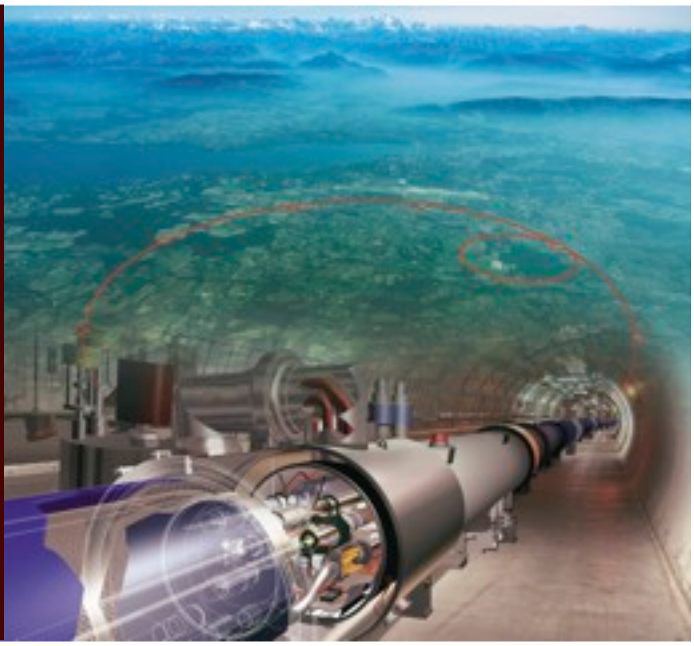
Models which are currently gaining momentum are the ones demanding the existence of a new force ruling the interactions among an entirely new set of elementary particles known as **techniquarks**. The new force is strong enough to bind them in composite particles similar to the ordinary neutron and proton which are made by the Standard Model **quarks** only thousands time heavier. These composite states are known as technibaryons.

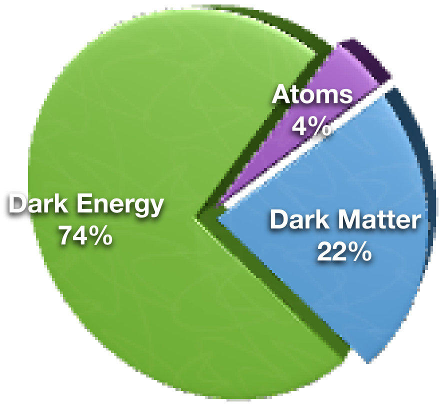
Milky Way & Distribution of Dark Matter
The Milky Way is an example of spiral galaxy. In the center the mega black hole is visible. The Sun is about 8.5 Kilo parsec away from the centre.

On the right panel one can see the reconstruction of the distribution of dark matter made possible via the Hubble mission.



Large Hadron Collider & The distribution of mass in the Universe





Technicolor versus Supersymmetry
A theoretical battle...

By Francesco Sannino

The new force is known as **technicolor** and the generic idea as **compositeness**. This approach has several theoretical advantages over the supersymmetric hypothesis, such as a fewer number of new particles and the fact that it is based on ideas realized in nature such as ordinary superconductivity. The framework was abandoned several years ago because the early incarnations were at odds with experimental data. The situation changed in 2004 when it was demonstrated that one can construct a novel class of models passing the experimental constraints. The new models are known as *minimal walking technicolor*. Dark matter arises here as a composite particle like the technibaryon. There is a concrete chance that the model will be able to explain simultaneously the origin and composition of dark matter, relate its existence to the bright one and even understand the reason for the absence of antimatter. Composite particles, being made by other elementary particles, are bulky objects. A possible superhero to identify with **t**ec**h**nic**o**lo**r** is then Thor, the son of Odin, who is without any doubt a very strong and bulky character.

The extensions of the Standard Model presented above will be tested not only via cosmological observations but also at the Large Hadron Collider experiment at the European Centre for Nuclear Research (CERN).

Is the dark side speaking? This is the title of the New York Time piece reporting on the recent results of two experiments looking at high energy cosmic rays via balloons (ATIC) and satellites (PAMELA). These experiments have reported an excess with respect to the expected astrophysical background in the total flux on Earth of high energy positrons. High energy **cosmic rays** are very energetic particles hitting the Earth's atmosphere. Typically they have astrophysical origins, meaning that they are produced, for example, when supernovae explode or when compact astrophysical objects such as neutron stars or black holes hit each other or accrete matter from a neighboring companion star. It might also be that dark matter itself may produce cosmic rays - this is supported by model building - in a modest quantity but compatible with the observations. This has been the reason of much excitement. The issue is not settled since it might very well be that the explanation is astrophysical. **Is the dark side speaking? Maybe.**

CP³-Origins

Particle Physics & Origins of Mass