Explaining the accelerating expansion of the Universe without Dark Energy

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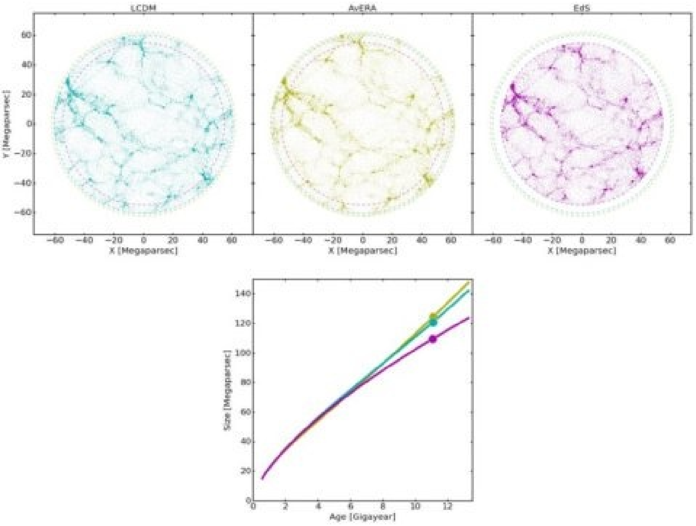

This display shows the expansion of the universe in the standard 'Lambda Cold Dark Matter' cosmology, which includes dark energy (top left), the new Avera model, where the structure of the universe eliminates the need for dark energy (top middle), and the original Einstein-de Sitter cosmology (top right). The panel at the bottom shows the increase of the 'scale factor' as a function of time (1Gy is 1 billion years). In the top panels one dot roughly represents an entire galaxy cluster. Units of scale are in Megaparsecs (1 Mpc is around 3 million million million km).

Current philosophy is that our universe was formed in the Big Bang, 13.8 billion years ago, and has been expanding ever since. **The key piece of evidence for this expansion is Hubble's law, based on observations of galaxies, which states that on average, the speed with which a galaxy moves away from us is proportional to its distance**. Astronomers measure this velocity of recession by looking at lines in the spectrum of a galaxy, which shift more towards red the faster the galaxy is moving away. From the 1920s, mapping the velocities of galaxies led scientists to conclude that the whole universe is expanding, and that it must have begun as a vanishingly small point.

In the second half of the twentieth century, astronomers found evidence for unseen 'dark matter' by observing that something extra was needed to explain the motion of stars within galaxies. Dark Matter is now thought to make up 27% of the content of the Universe (in contrast 'ordinary' matter amounts to only 5%).

Observations of the explosions of white dwarf stars in binary systems, so-called Type Ia supernovae, in the 1990s then led scientists to the conclusion that a third component, dark energy, made up 68% of the cosmos, and is responsible for driving an acceleration in the expansion of the universe.

New researcher question the existence of dark energy and suggest an alternative explanation. Conventional models of cosmology rely on approximations ignoring its structure, and matter is assumed to have a uniform density.

Einstein's equations of general relativity describing the expansion of the universe are so complex that for a hundred years no solution accounting for the exact effect of cosmic structures has been found. The coarse approximations of Einstein's equations introduces serious side-effects, and led to the need for Dark Energy to fit the observational data.

In practice, normal and dark matter appear to fill the universe with a foam-like structure, where galaxies are located on the thin walls between bubbles, and are grouped into superclusters. The insides of the bubbles are in contrast almost empty of both kinds of matter.

Using a computer simulation to model the effect of gravity on the distribution of millions of particles of dark matter, the scientists reconstructed the evolution of the universe, including the early clumping of matter, and the formation of large scale structure.

Unlike conventional simulations with a smoothly expanding universe, taking the structure into account led to a model where different regions of the cosmos expand at different rate. The average expansion rate though is consistent with present observations, which suggest an overall acceleration.

"The theory of general relativity is fundamental in understanding the way the universe evolves. But we must question the validity of the approximate solutions. Conjectures permitting the differential expansion of space (consistent with general relativity) show how the formation of complex structures of matter affects the expansion. These issues were previously swept under the rug but taking them into account explains the acceleration without the need for dark energy."

Models proposed by the UPV/EHU University of the Basque Country researcher are contributing towards understanding the nature of Dark Energy. Dark Energy is what makes the Universe expand in an accelerating way. If it does not exist, the gravitational pull exerted by matter should slow down the expansion of the universe, but observations have proven conclusively that the opposite is the case.
It was cosmology that drew **Irene Sendra** from Valencia to the Basque Country. Cosmology also gave her the chance to collaborate with one of the winners of the 2011 Nobel Prize for Physics on one of the darkest areas of the Universe. **And Dark Matter and Dark Energy, well-known precisely because so little is known about them, are in fact the objects of study by Sendra in the Department of Theoretical Physics and History of Science of the UPV/EHU's Faculty of Science and Technology.** She explains:

Irene Sendra-Server, PhD holder in Physics and research scientist in the UPV/EHU's Department of Theoretical Physics and History of Science

"Interpretations of standard observations tell us that about 5% of the universe is made up of ordinary matter; 22% corresponds to some dark matter, which we assume does exist, because of its apparent gravitational interaction with ordinary matter; another 73% is dark energy, which again is assumed to be there because without it we currently cannot account for the accelerating expansion of the Universe. We are now trying to find out a bit more about what this dark energy is".
Current philosophy demands a Dark Energy. If dark energy did not exist, the gravitational pull exerted by matter should slow down the expansion of the universe, but observations have concluded that the opposite is the case. Dark energy is needed to make the universe expand in an accelerating way, and Sendra's PhD thesis entitled: "Cosmology in an accelerating universe: observations and phenomenology" is contributing towards a better understanding of its nature.
Her research starts with the hypothesis that dark energy could be dynamic. The most widely accepted model, known as the Lambda-CDM, explains the acceleration of the universe by means of the cosmological constant, whose equation of state would have a value of -1, constant throughout the whole evolution of the Universe. However, there are observations which this model cannot account for . "We look for a dynamic, Dark Energy that would vary over time; we apply various models to the observable data, we play around with small disturbances, and we see whether they adapt better than a constant," explains Sendra.
Making use of mathematical and statistical tools, the values that the observation proposes for the parameters studied are compared with those proposed by the model. "So, through many iterations, we can see which values would take the constants of our model. The equation of state of Dark Energy is worth practically -1 now, but it appears to have evolved from different values in the past; however, there is still a high percentage of error in determining these values. "According to Sendra's calculations, these data are consistent with a dynamic Dark Energy, which would vary with the redshift observed in the Universe. Results yet to be published and obtained in collaboration with **Adam Riess**, the 2011 Nobel Prize Winner for Physics, go further in that direction.
In this PhD thesis a new model is proposed that would unite Dark Energy with Dark Matter. They could be the same thing, just manifested in different ways, depending on the context.
When Sendra peered at the oldest universe by means of the study of its cosmic microwave background, she found evidence that the number of neutrinos then is higher than the three known to exist in our Standard Model of particles. According to her results, this neutrino excess could be interpreted as the contribution of primordial gravitational waves, caused by the interaction of cosmic strings at the time when the cosmic microwave background was produced.

If these findings are upheld, it could have a significant impact on models of the Universe and the direction of research in physics. For the past 20 years, astronomers and theoretical physicists have speculated on the nature of Dark Energy, but it remains an unsolved mystery. With the new model, the teams expect at the very least to start a lively debate.

AK, with ScienceDaily Notes