Shining new light on dark energy with galaxy clusters

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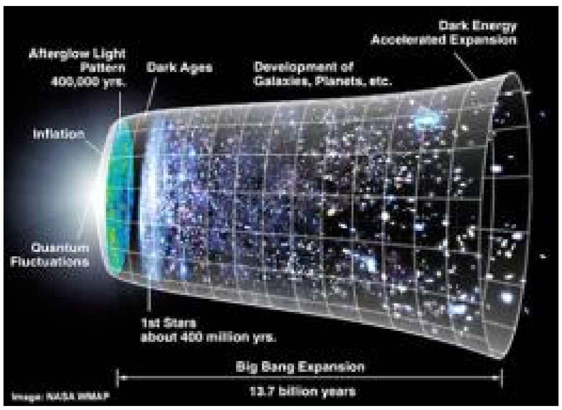

Dark energy, which is responsible for the accelerated expansion of the universe, holds the key to understanding the evolution of the universe following the Big Bang. (Image: NASA WMAP)

(PhysOrg.com) -- Scientists' murky understanding of dark energy may have just gotten a little clearer, thanks to recent work by a team of researchers that includes astrophysicist Neelima Sehgal of the Kavli Institute for Particle Astrophysics and Cosmology at SLAC. The team used observations from the Atacama Cosmology Telescope, or ACT, in the Chilean Andes to more narrowly define the properties of dark energy, that enigmatic entity that's thought to make up approximately 70 percent of the mass-energy of the universe and is pushing space apart.

The team's results are summarized online on the ArXiv.

Scientists have struggled to come up with a satisfactory explanation for the nature of dark energy ever since astronomical observations in 1998 first suggested its existence. Astronomers were surprised to discover that the universe's expansion was accelerating, a fact that could be explained only by a previously unknown source of energy.

"Basically the problem is that nobody knows what dark energy is," Sehgal said.

Dark energy may be the energy of the vacuum of space, which is one of the simplest theories to explain its existence. Vacuum energy is the background energy in otherwise empty space. Particle physicists theorize that this property of space could be the result of virtual particles constantly forming and disappearing. However, the virtual particle theory predicts a vacuum energy density that is 120 orders of magnitude larger than the observed dark energy density. The vast discrepancy has spurred the development of alternative dark energy theories, including dark energy whose density can vary in time or that results from a breakdown in the behavior of gravity at very large scales. To test competing theories, scientists need to gather more experimental data.

Sehgal, leading an effort by the ACT team, took an important step in this direction by analyzing the formation pattern of large galaxy clusters, enormous structures in the universe comprising dark matter, hot ionized gases and hundreds of thousands of galaxies. The formation of these galaxy clusters is governed by the interactions between dark energy and gravity. By examining the number of clusters and their distances from us, scientists can learn more about dark energy's properties.

The team harnessed the power of ACT to collect high-resolution microwave images of the night sky. Sehgal then identified large galaxy clusters by the telltale way the hot gases within the clusters dimmed or brightened the cosmic microwave background radiation at certain frequencies.

"The CMB acts as a backlight," Sehgal said. "The galaxy clusters scatter the microwave radiation as it passes through them, in effect casting 'shadows' that we have been able to identify. The really special thing about this shadow signal is that it does not fade with distance."

In its first season, the ACT team identified 23 clusters, approximately half of which were previously unknown. The discovery of new clusters highlights the power of CMB observations to spot extremely distant galaxy clusters. Once the galaxy clusters are discovered, optical wavelength observations are used to determine their distance. Sehgal led the effort to analyze the new data in order to distinguish between different competing dark energy theories.

"Each model for dark energy makes a prediction that you should see this many clusters, with this particular mass, this particular distance away from us," Sehgal said.

Sehgal tested these predictions by using data from the most massive galaxy clusters. The results support the standard, vacuum-energy model for dark energy.

These results are an important step toward settling the dark energy debate. Scientists will continue to probe the nature of dark energy by carrying out analyses similar to Sehgal's with additional sets of data, provided by new instruments such as the South Pole Telescope and the Planck satellite.

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