Is dark energy static or dynamic?

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(Phys.org)—While hypothesized dark energy can explain observations of the universe expanding at an accelerating rate, the specific properties of dark energy are still an enigma. Scientists think that dark energy could take one of two forms: a static cosmological constant that is homogenous over time and space, or a dynamical entity whose energy density changes in time and space. By examining data from a variety of experiments, scientists in a new study have developed a model that provides tantalizing hints that dark energy may be dynamic.

The scientists, Gong-Bo Zhao of the University of Portsmouth in the UK and the Chinese Academy of Science in Beijing; Robert G. Crittenden of the University of Portsmouth; Levon Pogosian of Simon Fraser University in Burnaby, British Columbia, and the University of Portsmouth; and Xinmin Zhang of the Chinese Academy of Science, have published their paper on the evidence for dynamical dark energy in a recent issue of Physical Review Letters.

In their paper, the scientists focused on constraining dark energy's equation of state, which has historically been a very difficult task. The equation of state characterizes the way that the universe is expanding, and scientists use observational data to constrain this parameter in an attempt to find its precise value in the real world.

Knowing the true value of the equation of state would not only lead to a better understanding of dark energy, but gravity as well. The key question is whether the value of the equation of state ever equals -1, since that might point to the breakdown of Einstein's theory of general

relativity on cosmological scales. Some models have estimated an equation of state very near -1, which has prompted the search for a quantum theory of gravity.

In the new study, the scientists' main finding is that the latest observations give a slight preference to a dynamical dark energy model whose equation of state evolves from less than -1 at low redshifts to greater than -1 at higher redshifts – at some point equaling -1.

"If this result were confirmed, it would imply an additional intrinsic degree of freedom of dark energy and could be a smoking gun of the breakdown of Einstein's theory of general relativity on cosmological scales," Zhao told *Phys.org*.

To attain this result, the scientists combined cosmological data from the latest supernova, cosmic microwave background, redshift space distortion, and baryonic acoustic oscillation measurements. Then they applied a new reconstruction method to the data, which has the advantage of minimizing the biases that occur in some other reconstruction methods.

"Perhaps the greatest significance of the work is the demonstration of the method as a means of determining whether dark energy is dynamical without relying on an arbitrary model for how dark energy could evolve," Zhao said. "It is quite interesting that when it's applied to the present data, these dynamical models do well, even when accounting for their larger flexibility."

The scientists' model allowed them to compare a range of dark energy models and determine which models best fit the combined data. Although the dynamical dark energy model was slightly preferred, the researchers noted that models with the cosmological constant still fit the data, though not quite as closely as the dynamical model.

The results are still far from conclusive, but the scientists hope that future data might narrow down the models with greater accuracy. They hope that observations by the Planck spacecraft (launched in 2009; first data available in April 2013) and the Euclid spacecraft (launch date is 2019) could help pinpoint the dark energy models that most closely describe our expanding universe.

The researchers explained that there are two general reasons why reconstructing the evolution of dark energy's equation of state is so challenging.

"There are two issues here; the first relates to the difficulty of observing changes to the rate of the Universe's expansion," Crittenden said. "It took us 70 or 80 years to realize that the expansion rate was even accelerating, and this is largely because it's hard to find the reliable standard rulers and standard candles which we use to measure it. We are now attempting to distinguish between models which predict very small differences, and to do this convincingly we need future data such as will come from the Euclid satellite.

"The second issue relates to our lack of clear alternatives to explain the acceleration; without knowing what it should look like, it's harder to recognize it. Previous work has tended to assume particular forms for the dynamics, but if these assumptions were wrong, they give us biased information and could miss out on seeing the dynamics entirely. We have tried to make fewer assumptions, which allows us to reconstruct a much larger class of possible models and capture the dynamics if it is there. By improving the quality and quantity of the data, we should be able to verify or falsify a very broad class of dynamical models, which will be crucial to understand the nature of dark energy."

More information: Gong-Bo Zhao, et al. "Examining the Evidence for Dynamical Dark Energy." *PRL* 109, 171301 (2012). DOI:

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