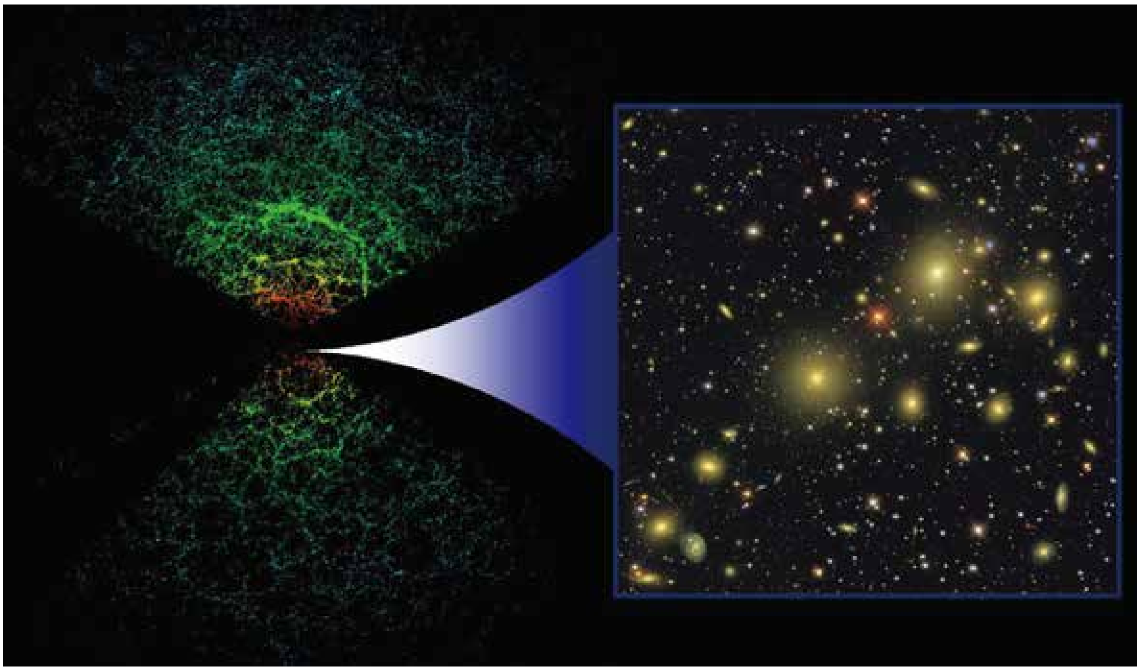
Evidence Shows Dark Energy May Be Dynamical, Not Constant

An international team led by ZHAO Gongbo from the National Astronomical Observatories of China, Chinese Academy of Sciences (NAOC) has used the latest astronomical observations to reveal surprising evidence for the dynamical nature of dark energy. Their discovery, which was reported in the August 28th issue of *Nature Astronomy*, suggests that the nature of dark energy may not be the cosmological constant introduced by Albert Einstein about a hundred years ago.

The discovery of the accelerating expansion of the Universe, which was awarded the 2011 Nobel Prize in Physics, was made independently by two research groups in 1998 using supernovae. In principle, the cosmic acceleration may be due to an unknown energy component with a negative pressure, called dark energy, which contributes to about 70% of the total energy budget of the universe. What is the nature of dark energy is one fundamental question of modern science.

Usually, the physical property of dark energy is represented by its Equation of State (EoS), which is the ratio of the pressure and energy density of dark energy. In the traditional LCDM model, dark energy is essentially a cosmological constant, i.e., the vacuum energy, with a constant EoS of -1. In such a model, dark energy has no dynamical features.



Large-scale galaxy surveys, such as the Sloan Digital Sky Survey (SDSS), probe the expansion history of the universe and are crucial to the study of dark energy. For instance, the SDSS is actually two separate surveys in one: galaxies are identified in 2D images (right), then have their distance determined from their spectrum to create a 2 billion light years' deep 3D map (left) where each galaxy is shown as a single point, the color representing the luminosity -- this shows only those 66,976 out of 205,443 galaxies in the map that lie near the plane of Earth's equator. *Credit: the SDSS collaboration.*

In 2016, a team within the SDSS-III (BOSS) collaboration led by ZHAO carried out a successful measurement of the Baryonic Acoustic Oscillations (BAO) at multiple cosmic epochs with high precision (Zhao et al., 2017, *MNRAS*, 466, 762). Based on this measurement and a method developed by ZHAO (Zhao et al., 2012, *PRL*, 109, 171301), the team went on to reveal evidence of dynamical dark energy at a significance level of 3.5 sigma (Zhao et al., 2017, *Nature Astronomy*, 1, 627-632). Their new finding suggests that the nature of dark energy may not be the vacuum energy, but instead a kind of dynamical field such as the "quintom" previously proposed by another Chinese astrophysicist ZHANG Xinmin and his group (Feng, Wang & Zhang, 2004, *PLB*, 607, 35).

"This paper presents a careful analysis of the most recent cosmological data claiming a detection at 3.5 standard deviation for a dynamical dark energy component, therefore ruling out a cosmological constant. The result is clearly extremely relevant," commented one reviewer.

"It is also shown that if dynamical dark energy is the true model, it would be decisively detected by the future DESI survey. If true, the detection of dynamical dark energy would be highly significant in theoretical physics and have wide ranging interest," another reviewer wrote.

The dynamics of the dark energy needs to be confirmed by next-generation astronomical surveys, said ZHAO. In the next five to ten years, the world's largest galactic surveys like the eBOSS (in which he serves as a working group co-chair), DESI, and PFS will provide observables which may be the key to unveiling the mystery of dark energy.

Their work was supported by the National Natural Science Foundation of China, the Chinese Academy of Sciences, and the UK Royal Society's Newton Advanced Fellowship.