The universe is expanding at an accelerating rate—or is it?

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This is the "South Pillar" region of the star-forming region called the Carina Nebula. Like cracking open a watermelon and finding its seeds, the infrared telescope "busted open" this murky cloud to reveal star embryos tucked inside finger-like pillars of thick dust. Credit: NASA

Five years ago, the Nobel Prize in Physics was awarded to three astronomers for their discovery, in the late 1990s, that the universe is expanding at an accelerating pace.

Their conclusions were based on analysis of Type Ia supernovae - the spectacular thermonuclear explosion of dying stars - picked up by the Hubble space telescope and large ground-based telescopes. It led to the widespread acceptance of the idea that the universe is dominated by a mysterious substance named 'dark energy' that drives this accelerating expansion.

Now, a team of scientists led by Professor Subir Sarkar of Oxford University's Department of Physics has cast doubt on this standard cosmological concept. Making use of a vastly increased data set - a catalogue of 740 Type Ia supernovae, more than ten times the original sample size - the researchers have found that the evidence for acceleration may be flimsier than previously thought, with the data being consistent with a constant rate of expansion.

The study is published in the *Nature* journal *Scientific Reports*.

Professor Sarkar, who also holds a position at the Niels Bohr Institute in Copenhagen, said: 'The discovery of the accelerating expansion of the universe won the Nobel Prize, the Gruber Cosmology Prize, and the Breakthrough Prize in Fundamental Physics. It led to the widespread acceptance of the idea that the universe is dominated by "dark energy" that behaves like a cosmological constant - this is now the "standard model" of cosmology.

'However, there now exists a much bigger database of supernovae on which to perform rigorous and detailed statistical analyses. We analysed the latest catalogue of 740 Type Ia supernovae - over ten times bigger than the original samples on which the discovery claim was based - and found that the evidence for accelerated expansion is, at most, what physicists call "3 sigma". This is far short of the "5 sigma" standard required to claim a discovery of fundamental significance.

'An analogous example in this context would be the recent suggestion for a new particle weighing 750 GeV based on data from the Large Hadron Collider at CERN. It initially had even higher significance - 3.9 and 3.4 sigma in December last year - and stimulated over 500 theoretical papers. However, it was announced in August that new data show that the significance has dropped to less than 1 sigma. It was just a statistical fluctuation, and there is no such particle.'

There is other data available that appears to support the idea of an accelerating universe, such as information on the cosmic microwave background - the faint afterglow of the Big Bang -

from the Planck satellite. However, Professor Sarkar said: 'All of these tests are indirect, carried out in the framework of an assumed model, and the cosmic microwave background is not directly affected by dark energy. Actually, there is indeed a subtle effect, the late-integrated Sachs-Wolfe effect, but this has not been convincingly detected.

'So it is quite possible that we are being misled and that the apparent manifestation of dark energy is a consequence of analysing the data in an oversimplified theoretical model - one that was in fact constructed in the 1930s, long before there was any real data. A more sophisticated theoretical framework accounting for the observation that the universe is not exactly homogeneous and that its matter content may not behave as an ideal gas - two key assumptions of standard cosmology - may well be able to account for all observations without requiring dark energy. Indeed, vacuum energy is something of which we have absolutely no understanding in fundamental theory.'

Professor Sarkar added: 'Naturally, a lot of work will be necessary to convince the physics community of this, but our work serves to demonstrate that a key pillar of the standard cosmological model is rather shaky. Hopefully this will motivate better analyses of cosmological data, as well as inspiring theorists to investigate more nuanced cosmological models. Significant progress will be made when the European Extremely Large Telescope makes observations with an ultrasensitive "laser comb" to directly measure over a ten to 15-year period whether the expansion rate is indeed accelerating.'

More information: J. T. Nielsen et al, Marginal evidence for cosmic acceleration from Type Ia supernovae, *Scientific Reports* (2016). DOI: 10.1038/srep35596

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