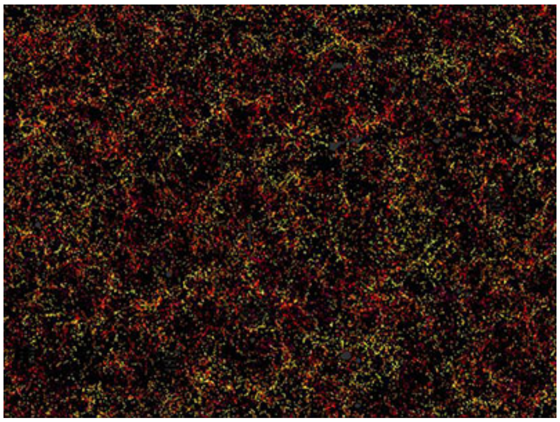
Dark-energy study maps 1.2 million galaxies in the early universe

Jul 15, 2016 9 comments



The dark sector: some of the 1.2 million galaxies surveyed by BOSS

Astronomers working on the Baryon Oscillation Spectroscopic Survey (BOSS) have analysed data from 1.2 million distant galaxies to gain further insights into the evolution of the universe. Acquired by the Sloan Digital Sky Survey III (SDSS-III) telescope in New Mexico, the data have been used to create the best map yet of baryon acoustic oscillations (BAOs). These are the relics of the early universe that chart-out how it has expanded over the past 13 billion years.

The BAO map is consistent with the current "Lambda-CDM" model of the universe, which incorporates dark energy and dark matter. Analysis of the data also shows that Einstein's general theory of relativity is correct at cosmological length scales.

BAOs were created when the universe was just 400,000 years old and the first atoms were forming. Light and matter in the universe decoupled in this epoch, with the light forming the cosmic microwave background (CMB) that is still visible today. When the matter decoupled, its spatial distribution was defined by the peaks and troughs of pressure waves that had existed throughout the universe. This distinct pattern of matter density – the BAOs – then began to evolve into a universe of stars and galaxies. Thanks to theoretical calculations and information gleaned from the CMB, astronomers have a very good idea of what the BAOs looked like in the early universe.

Galaxies and voids

As the universe expanded over the next 13 billion years, gravity pulled matter into regions of higher density to form galaxies, while regions of lower density became voids in space. This pattern of galaxies and voids resembles the early BAOs, with one crucial exception – the characteristic distances between galaxies and voids have increased greatly as the universe expanded. So by mapping the BAOs as a function of cosmic time, astronomers can chart the expansion of the universe over billions of years.

In this latest development, BOSS astronomers have mapped out the BAOs in great detail from 7 billion to 2 billion years ago. They did this by observing 1.2 million galaxies over one quarter of the sky. The distance to each galaxy – and hence the time at which its light began the journey to Earth – was worked out by observing the redshift of characteristic atomic emission and absorption lines in the spectrum of light from that galaxy.

The standard model of cosmology is called "Lambda-CDM", and it suggests that the expansion of the universe is governed by two competing agents. The gravitational tug of dark matter – which is about 85% of the matter in the universe – acts as a restoring force that tends to work against the expansion. On the other hand, dark energy – which appears to account for 70% of the energy in the universe – pushes in the opposite direction and is currently accelerating the expansion of the universe.

"Clean cosmological picture"

Dark energy does not appear to have played a role in the early universe, and seems to have kicked-in about 5 billion years ago, which is why BOSS was designed to study the BAOs over that time period. This latest study provides further evidence for Lambda-CDM, with an error of only 5% between the measured and theoretical value of the cosmological constant that describes dark energy. "Our latest results tie into a clean cosmological picture, giving strength to the standard cosmological model that has emerged over the last 18 years," says BOSS team-member Jose Vazquez of Brookhaven National Laboratory.

To create an accurate map, the team had to contend with the "peculiar motions" of galaxies, which refers to the movement of a galaxy that is not related to the expansion of the universe. This appears in the BAO map as an anisotropy that must be corrected for. This peculiar motion is caused by gravity working over huge distances in the universe and analysis of the anisotropy allowed the BOSS team to show that Einstein's theory of gravity – his general theory of relativity – is correct over very large distances.

The research is described in a series of papers in the *Monthly Notices of the Royal Astronomical Society*.

About the author
Hamish Johnston is editor of *physicsworld.com*

9 comments
Add your comments on this article

1 **John Duffield**
Jul 16, 2016 6:11 PM
United Kingdom

Polite cough: gravity alters the motion of light and matter through space, but it doesn't make "space fall down". In similar vein it doesn't stop space expanding.

2 **M. Asghar**
Jul 17, 2016 5:16 PM

"Null point" in time

The repulsive and accelerating dark energy whose density is considered to be constant and independent of time, was not effective in the early early expansion of the universe, when the gravitational pull of the matter and dark matter dominated. After a certain time and due the expansion of the universe, the gravitational pull decreased and there was the "null point" in time, where the pull and repulsive push of these two forces was equal and opposite, and from there on, the repulsive push of the dark energy started to dominate and the accelerated expansion of the universe started to come into play. It will be interesting to pin down this "null point" in time.

3 **419211451**
Jul 18, 2016 10:50 AM

A Correction

"The gravitational tug of dark matter – which is about 85% of the matter in the universe – acts as a restoring force that tends to work against the expansion." That is not correct, firstly because dark matter supposedly works gravitationally the same way as ordinary matter and secondly because the gravitational effect of matter generally in the universe does not resist the expansion according to General Relativity. When Einstein formulated GR it was found that (in an infinite universe) it would result in expansion or a contraction. An initial expansion impulse (such as later proposed by Inflation theory) would result in an expansion but not an accelerating one. It is the discovery that the expansion is accelerating now that led to the term "dark energy"

4 **Xinhang Shen**
Jul 21, 2016 10:25 PM

Relativistic spacetime model is wrong

I will appreciate that you will tolerate different points of view here to let readers judge it themselves. I think this research should not rely on general relativity because its relativistic spacetime model can be disproved as follows: People are confused by the definitions of time. Actually there are three definitions of time existing in our physics: the first one is defined by the status of a physical process (called physical time or clock time), the second one is defined by Galilean Transformation (called Galilean time) and the last one is defined by Lorentz Transformation (called relativistic time). We should never assume that they are the same thing before you have verified them. The mistake of Einstein is to assume that clock time is relativistic time. Both classic mechanics and special relativity are physics theories used to describe physical processes. In classical mechanics, the status of a physical process can be calculated by the product of Galilean time and Galilean progressing rate of the process. Since Galilean progressing rate is invariant of inertial reference frames (i.e. invariant of Galilean Transformation), the status divided by the Galilean progressing rate becomes Galilean time. This is exactly how a clock can be used to measure Galilean time. Therefore, Galilean time is our physical time. In special relativity, the status of a physical process can be calculated by the product of relativistic time and relativistic progressing rate of the process. Since relativistic progressing rate is no longer invariant of inertial reference frames (i.e. not invariant of Lorentz Transformation) but experiences Transverse Doppler Effect, there is no way to separate relativistic time from the product of relativistic time and relativistic progressing rate to make a clock produce relativistic time. Therefore, relativistic time can't be measured by any clock and relativistic time is not our physical time but an artificial time introduced just for producing an artificial constant speed of light. On the other hand, the status of a physical process such as the angle of the arm of a clock rotating in a plane perpendicular to the motion of a moving inertial frame is invariant of Lorentz Transformation because space dimensions perpendicular to the motion of the frame won't experience any relativistic effects. That is, clock time is the same observed in all inertial reference frames. If all clocks are set the same initial time and frequency in one inertial reference frame, then they are the same observed in all inertial reference frames. Therefore, even in the framework of special relativity, clock time i.e. our physical time is absolute and universal. This discovery has been published on physicsessays.org…y-of-relativity.html and the press release for the paper is available at www.eurekalert.org…ngpi-tst030116.php . That is, the relativistic spacetime is just a mathematical coordinate system which has been wrongly applied to the physical world through the wrong assumption that clock time is relativistic time. As a recommendation of this comment, the research should still use the absolute Galilean time and 3D rigid Galilean space to describe the universe. Thanks for your tolerance!

5 **pauldesmondwhite**
Jul 22, 2016 2:27 PM

Sloppy

Thank you. But sloppy journalism should be weeded out before posting on physicsworld.

6 **pauldesmondwhite**
Jul 22, 2016 2:34 PM

Sloppy

Thank you. But sloppy journalism should be weeded out before posting on physicsworld.

7 **pauldesmondwhite**
Jul 22, 2016 2:41 PM

Sloppy

Thank you. But sloppy journalism should be weeded out before posting on physicsworld.

8 **xilman**
Jul 25, 2016 7:17 PM
Quote:

> *Originally posted by* ***John Duffield***
> Polite cough: gravity alters the motion of light and matter through space, but it doesn't make "space fall down". In similar vein it doesn't stop space expanding.

Au contraaire, gravity can stop space, or space-time anyway, from expanding. If the mass-energy density is high enough space-time contracts. The evidence suggests that the mass-energy density of the universe as a whole is insufficient to cause the universe as a whole to contract.

9 **C.motta55**
Jul 29, 2016 5:18 PM

the gravitational waves could carry

Dark energy in the beginning of the universe, then then gravity during the evolution of the universe was coupled for the gravitational field with the cosmological constant, that was being modified with the expansion of the universe.IS HARD TO EXPLAIN THE RELATIONS BETWEEN THE DARK ENERGY AND DARK MATTER