Galaxy survey reveals missing cosmic link

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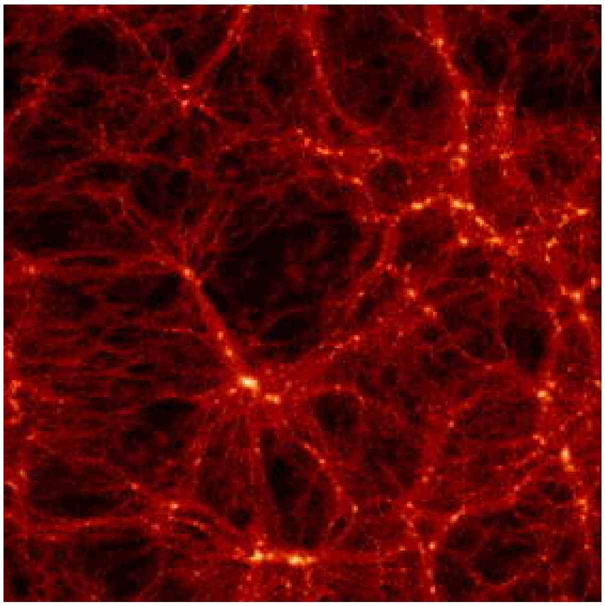

A team of UK and Australian astronomers today announced that it has found the missing link that directly relates modern galaxies like our own Milky Way to the Big Bang that created our Universe 14 thousand million years ago. The findings are the result of a 10-year effort to map the distribution in space of 220,000 galaxies by the 2dFGRS (2-degree Field Galaxy Redshift Survey), a consortium of astronomers, using the 3.8-m Anglo-Australian Telescope (AAT). This missing link was revealed in the existence of subtle features in the galaxy distribution in the survey. Analysis of these features has also enabled the team to weigh the universe with unprecedented accuracy.

Image: Computer simulation of matter forming into galaxies

The 2dFGRS has measured in great detail the distribution of galaxies, called the large-scale structure of the Universe. These patterns range in size from 100 million to 1 billion light years. The properties of the large-scale structure are set by physical processes that operated when the universe was very young indeed.

Dr Shaun Cole of the University of Durham, who led the research, explains: "At the moment of birth, the universe contained tiny irregularities, thought to have resulted from "quantum" or subatomic processes. These irregularities have been amplified by gravity ever since and eventually gave rise to the galaxies we see today."

Theorists in the 1960s suggested that the primordial seeds of galaxies should be seen as ripples in the Cosmic Microwave Background (CMB) radiation emitted in the heat left over from the Big Bang, when the Universe was a mere 350,000 years old. Ripples were subsequently seen in 1992 by NASA's COBE satellite, but until now, no firm connection could be demonstrated with galaxy formation. 2dFGRS has found that a pattern seen in these ripples has propagated to the modern Universe and can be detected in galaxies today.

The patterns in the CMB contain prominent spots about one degree across, produced by sound waves propagating in the unimaginably hot plasma of the Big Bang. These features are known as "acoustic peaks" or "baryon wiggles". Theorists had speculated that the sound waves might have also left an imprint in the dominant component of the universe - the exotic "dark matter", which itself drives the formation of galaxies. Physicists and astronomers set about trying to identify this imprint in maps of our own galactic neighbourhood.

After years of painstaking work taking measurements of galaxies at the

Anglo-Australian Telescope and modelling their properties with sophisticated mathematical and computational techniques, the 2dFGRS team have identified the imprint of sound waves in the Big Bang. It appears as delicate features in the "power spectrum", the statistic used by astronomers to quantify the patterns seen in maps of the galaxy distribution. These features are consistent with those seen in the microwave background - which means we understand the life history of the gas from which Galaxies formed.

The baryon features contain information about the contents of the universe, in particular about the amount of ordinary matter (known as baryons), the kind of stuff which has condensed into stars and planets and of which we ourselves are made.

Professor Carlos Frenk, Director of the Institute for Computational Cosmology of the University of Durham said: "These baryon features are the genetic fingerprint of our universe. They establish a direct evolutionary link to the Big Bang. Finding them is a milestone in our understanding of how the cosmos was formed."

Professor John Peacock from Edinburgh University, UK team leader of 2dFGRS collaboration said: "I don't think anyone would have expected simple cosmological theories to work so well. We're very lucky to be around to see this picture of the universe established."

The 2dFGRS has shown that baryons are a small component of our universe, making up a mere 18% of the total mass, with the remaining 82% appearing as dark matter. For the first time, the 2dFGRS team have broken the 10 percent accuracy barrier in measuring the total mass of the Universe.

As if this picture weren't strange enough, the 2dFGRS also showed that all the mass in the universe (both luminous and dark) is outweighed 4:1

by an even more exotic component called "vacuum energy" or "dark energy". This has antigravity properties, causing the expansion of the universe to speed up. This conclusion arises when combining 2dFGRS results with data on the microwave background radiation, which is left over from the time when the baryon features were created. The origin and identity of the dark energy remains one of the deepest mysteries of modern science.

Our knowledge of the microwave background improved hugely in 2003 with data from NASA's WMAP satellite. The WMAP team combined their information with an earlier analysis of part of the 2dFGRS to conclude that we indeed live in a dark energy-dominated universe. This was dubbed "the breakthrough of the year" in 2003 by Science magazine. Now, the discovery of the cosmic missing link by the 2dFGRS team, almost exactly a year later, crowns the achievements of a decade of painstaking work.

In an interesting twist, clues to the identity of the dark energy could be gleaned by finding baryon features in the evolving galaxy distribution halfway between now and the Big Bang. UK astronomers and their collaborators across the world are now planning large galaxy surveys of very distant galaxies with this aim in mind.

Independent confirmation of the presence of baryon features in the large-scale structure comes from the US-led Sloan Digital Sky Survey. They use a complementary method that does not involve the power spectrum, and study a rare subset of galaxies over a larger volume than the 2dFGRS. Nevertheless, the conclusions are consistent, which is very satisfying.

Professor Michael Strauss from Princeton University, Spokesman for the SDSS collaboration said: "This is wonderful science. The two groups have now independently seen direct evidence for the growth of structure by gravitational instability from the initial fluctuations seen in the cosmic microwave background."

The Hot Big Bang

Fred Hoyle coined the term 'big bang' in the 1950s to describe our state of ignorance about why the universe was expanding - it appeared to have started suddenly at some special time in a state of infinite density and temperature. Really, this term should have been withdrawn in the 1980s with the development of the theory of cosmic 'inflation'. This suggests that the expansion of the universe was started by the antigravity properties of vacuum energy - similar to what is seen in the accelerating expansion today, but much stronger. According to this theory, the inflationary period is when subatomic processes may have created the fluctuation to seed structure in the universe. However, the term 'big bang' is still used, for two reasons: we do not yet know if the inflationary theory is true; and even if it is, the universe was still very hot just after inflation finished.

Source: PPARC

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