A Vast New Map of the Universe

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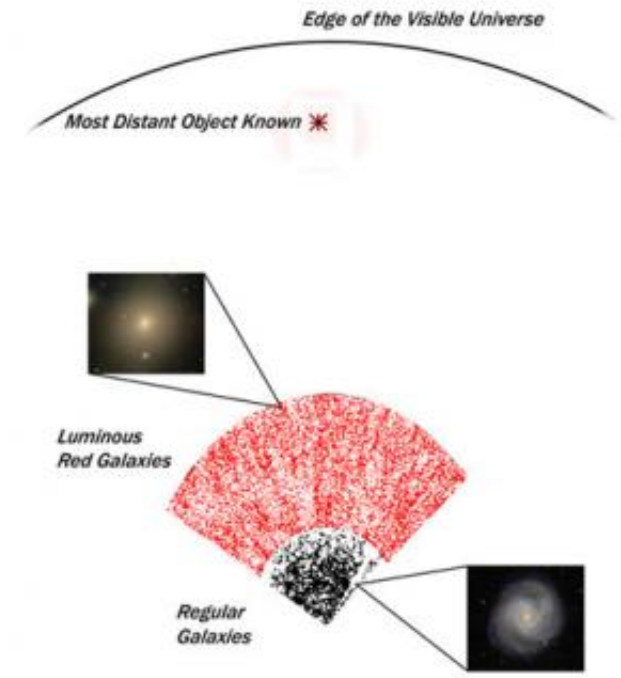

A schematic view of the new SDSS three-dimensional map, which includes regular galaxies (black points) and luminous red galaxies (red points) and extends 5.6 billion light-years, 40 percent of the distance to the edge of the visible universe.

A team of astronomers led by Nikhil Padmanabhan and David Schlegel has published the largest three-dimensional map of the universe ever constructed, a wedge-shaped slice of the cosmos that spans a tenth of the northern sky, encompasses 600,000 uniquely luminous red galaxies, and

extends 5.6 billion light-years deep into space, equivalent to 40 percent of the way back in time to the Big Bang.

Schlegel is a Divisional Fellow in the Physics Division of Lawrence Berkeley National Laboratory, and Padmanabhan will join the Lab's Physics Division as a Chamberlain Fellow and Hubble Fellow in September; presently he is at Princeton University. They and their coauthors are members of the Sloan Digital Sky Survey (SDSS), and have previously produced smaller 3-D maps by using the SDSS telescope in New Mexico to painstakingly collect the spectra of individual galaxies and calculate their distances by measuring their redshifts.

"What's new about this map is that it's the largest ever," says Padmanabhan, "and it doesn't depend on individual spectra."

The SDSS 2.5 meter telescope at Apache Point, New Mexico was used to create the new map of the universe.

The principal motive for creating large-scale 3-D maps is to understand how matter is distributed in the universe, says Padmanabhan. "The brightest galaxies are like lighthouses — where the light is, is where the matter is."

Schlegel says that "because this map covers much larger distances than previous maps, it allows us to measure structures as big as a billion light-years across."

A natural ruler in space

The variations in galactic distribution that constitute visible large-scale structures are directly descended from variations in the temperature of the cosmic microwave background, reflecting oscillations in the dense early universe that have been measured to great accuracy by balloon-borne experiments and the WMAP satellite.

The result is a natural "ruler" formed by the regular variations (sometimes called "baryon oscillations," with baryons as shorthand for ordinary matter), which repeat at intervals of some 450 million light-years.

"Unfortunately it's an inconveniently sized ruler," says Schlegel. "We had to sample a huge volume of the universe just to fit the ruler inside."

Says Padmanabhan, "Although the universe is 13.7 billion years old, that really isn't a whole lot of time when you're measuring with a ruler that's marked only every 450 million light-years."

The distribution of galaxies reveals many things, but one of the most important is a measure of the mysterious dark energy that accounts for some three-fourths of the universe's density. (Dark matter accounts for roughly another 20 percent, while less than 5 percent is ordinary matter

of the kind that makes visible galaxies.)

"Dark energy is just the term we use for our observation that the expansion of the universe is accelerating," Padmanabhan remarks. "By looking at where density variations were at the time of the cosmic microwave background" — only about 300,000 years after the Big Bang — "and seeing how they evolve into a map that covers the last 5.6 billion years, we can see if our estimates of dark energy are correct."

The new map shows that the large-scale structures are indeed distributed the way current ideas about the accelerating expansion of the universe would suggest. The map's assumed distribution of dark matter, which although invisible is affected by gravity just like ordinary matter, also conforms to current understanding.

Dead, red galaxies

What made the big new 3-D map possible were the Sloan Digital Sky Survey's wide-field telescope, which covers a three-degree field of view (the full moon is about half a degree), plus the choice of a particular kind of galactic "lighthouse," or distance marker: luminous red galaxies.

"These are dead, red galaxies, some of the oldest in the universe — in which all the fast-burning stars have long ago burned out and only old red stars are left," says Schlegel. "Not only are these the reddest galaxies, they're also the brightest, visible at great distances."

The Sloan Digital Sky Survey astronomers worked with colleagues on the Australian Two-Degree Field team to average the color and redshift of a sample of 10,000 red luminous galaxies, relating galaxy color to distance. They then applied these measurements to 600,000 such galaxies to plot their map.

Padmanabhan concedes that "there's statistical uncertainty in applying a brightness-distance relation derived from 10,000 red luminous galaxies to all 600,000 without measuring them individually. The game we play is, we have so many that the averages still give us very useful information about their distribution. And without having to measure their spectra, we can look much deeper into space."

Schlegel agrees that the researchers are far from achieving the precision they want. "But we have shown that such measurements are possible, and we have established the starting point for a standard ruler of the evolving universe."

He says "the next step is to design a precision experiment, perhaps based on modifications to the SDSS telescope. We are working with engineers here at Berkeley Lab to redesign the telescope to do what we want to do."

"The Clustering of Luminous Red Galaxies in the Sloan Digital Sky Survey Imaging Data," by Nikhil Padmanabhan, David J. Schlegel, Uroš Seljak, Alexey Makarov, Neta A. Bahcall, Michael R. Blanton, Jonathan Brinkmann, Daniel J. Eisenstein, Douglas P. Finkbeiner, James E. Gunn, David W. Hogg, Željko Ivezić, Gillian R. Knapp, Jon Loveday, Robert H. Lupton, Robert C. Nichol, Donald P. Schneider, Michael A. Strauss, Max Tegmark, and Donald G. York, will appear in the *Monthly Notices of the Royal Astronomical Society* and is now available online at http://arxiv.org/archive/astro-ph.

Source: Berkeley Lab