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OUR PECULIAR MOTION AWAY FROM THE LOCAL VOID

Much Ado About Nothing

Our Milky Way galaxy lies at the edge of a huge void and is being repulsed by the void at high speed. This observation provides astronomers with a fundamental insight into how dark matter is distributed and into the process of galaxy formation. Brent Tully of the University of Hawaii is discussing this discovery at the meeting of the American Astronomical Society in Honolulu, Hawaii. His collaborators in this research are Helene Courtois, Dale Kocevski, and Luca Rizzi, all at the University of Hawaii during the period of research, Ed Shaya and Alan Peel at the University of Maryland, and Igor Karachentsev of the Special Astrophysical Observatory in Russia.

Two decades ago, Brent Tully and his collaborator Richard Fisher (National Radio Astronomy Observatory, Charlottesville, Virginia) noted that our galaxy lives adjacent a vast empty region that they called the 'Local Void'. Today, thanks to the contributions of many astronomers around the world, there is information on the distribution of hundreds of thousands of galaxies and an increasingly detailed knowledge of the rich tapestry in the distribution of galaxies. Galaxies collect along filaments and in clusters, at places where the filaments intersect. Elsewhere there are empty regions called voids. Our galaxy resides in a filament that bounds a void. We call this filament the 'Local Sheet'.

It has also been known for two decades that our Milky Way galaxy is traveling through intergalactic space at high speed. The Cosmic Microwave Background (CMB) is radiation that comes to us in all directions from the time when the universe was a hot plasma, 3 hundred thousand years after the Big Bang. A tiny one part in a hundred systematic variation in frequency of the peak of the CMB radiation is taken to be a Doppler shift caused by our motion with respect to the ensemble of all other matter. Some of the components of our motion have been known for a long time. The Earth orbits the Sun once a year and the Sun orbits the center of the Milky Way Galaxy every 250 million years. We also have known that our galaxy is being pulled toward neighboring concentrations of matter, particularly our nearest giant neighbor, the Andromeda Galaxy, at a distance of 2 million light-years and the nearest rich cluster of thousands of galaxies, the Virgo Cluster, at 55 million light-years. It has also become clear that there are very long-range forces pulling on us. We have a motion in a direction toward two huge concentrations of galaxies that happen by chance to line up, one behind the other, at distances of 200 and 600 million light-years. The relative importance of these two attractors has remained a detail in dispute among astronomers.

Yet until now part of our motion inferred from the variation in the CMB remained unexplained. It is in a direction aligned with the flattened disk of our galaxy and there was the possibility that something important was being hidden by the veil of obscuring dust clouds in the plane of the Milky Way. However, radiation at X-ray, infrared, and radio wavelengths are not blocked. Years of observing by many astronomers have failed to reveal anything important.

Now, another kind of observation has resolved the mystery. Astronomers have been measuring the distances to galaxies with precision techniques. With accurate distances it is possible to distinguish between the motions of galaxies due to the general expansion of the universe and the local deviant motions caused by the way matter is clumped, with its consequent gravitational effects. It is found that galaxies are flowing in streams, with coherent flows caused by large attractors far away and eddies caused by modest attractors nearby. The influences on our motion discussed above have been confirmed. In addition, features of the local streaming pattern reveal the source of the additional component.

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The critical new information comes from observations of relatively nearby galaxies with Hubble Space Telescope. Accurate distances to galaxies are provided by measuring the luminosities of the brightest old stars that lie on what is known as the Red Giant Branch. These stars have well established properties. The accurate distances give a detailed map of the flow pattern of nearby galaxies and reveal several remarkable things. First, the direction of our motion with respect to the nearest several thousand galaxies is well defined. Second, all the galaxies within 15 million light years, within our Local Sheet, are moving together. Third, this motion is NOT shared by galaxies just beyond our Local Sheet and, in fact, we are moving on a collision course toward the nearest adjacent filament, the Leo Spur (it will be at least 10 billion years before the Local Sheet and the Leo Spur pancake together).

These patterns reveal the cause: the Local Void. Whereas concentrations of matter pull, a void pushes! If an object is surrounded uniformly by matter in all directions, except for one sector in which there is nothing, then the absence of a pull is a push away from that sector. The effect can be astonishingly large. Our velocity away from the Local Void is 600,000 miles per hour.

To generate such a large velocity, the void must be very large and very empty. The current standard model of the universe with dark matter and dark energy does allow for voids that are as large as we infer for the Local Void, but it is impressive that we should live next to such a large feature. More importantly for our theoretical understanding, we conclude that the void is really empty. Only a small fraction of the matter of the universe is in a visible form, so it is not a given that an apparently empty region is truly empty. However, the large push we are getting from the Local Void is convincing evidence that it really is empty!

The determination of distances from the properties of Red Giant Branch stars is based on observations by the authors and others made with Hubble Space Telescope. Distance determinations of many more galaxies have been made by a variety of methods, in part by the authors. This research has been supported by the National Science Foundation.

The Institute for Astronomy at the University of Hawaii conducts research into galaxies, cosmology, stars, planets, and the sun. Its faculty and staff are also involved in astronomy education, deep space missions, and in the development and management of the observatories on Haleakala and Mauna Kea.

Established in 1907 and fully accredited by the Western Association of Schools and Colleges, the University of Hawaii is the state's sole public system of higher education. The UH System provides an array of undergraduate, graduate, and professional degrees and community programs on 10 campuses and through educational, training, and research centers across the state. UH enrolls more than 50,000 students from Hawaii, the U.S. mainland, and around the world.

Color figure available at http://www.ifa.hawaii.edu/press-releases/AAS/ after embargo expires.

Caption: Distribution of galaxies in the region around our Milky Way in supergalactic coordinates. Each little dot represents a galaxy of typically 100 billion stars. The colors indicate the relative motions of galaxies with accurately measured distances, with shades of green and blue indicating motions toward us and shades of yellow to red indicating motions away from us. Our nearest neighbors have only small relative motions (represented by yellows and greens) as seen best in the exploded view of the right panel. The observed pattern of velocities is explained as follows. We, along with all these nearest neighbors, are moving together toward the lower right corner of the figures. The result is that all the galaxies in the lower right appear to be moving toward us and all the galaxies in the upper left appear to be moving away – but it is us and our neighbors that are moving. Our motion is represented by the orange arrow. We now understand that there are two main causes for this motion. The concentration of objects at the right of the figures is the Virgo Cluster and its mass of quadrillion (10^{15}) times the Sun causes an attraction indicated by the blue vector in the exploded panel. The red vector in this panel is what is left over and this represents our motion of 600,000 miles per hour away from the Local Void. In detail, the Local Void may consist of several components, identified in the left panel as the Local Void and the North and South extensions.

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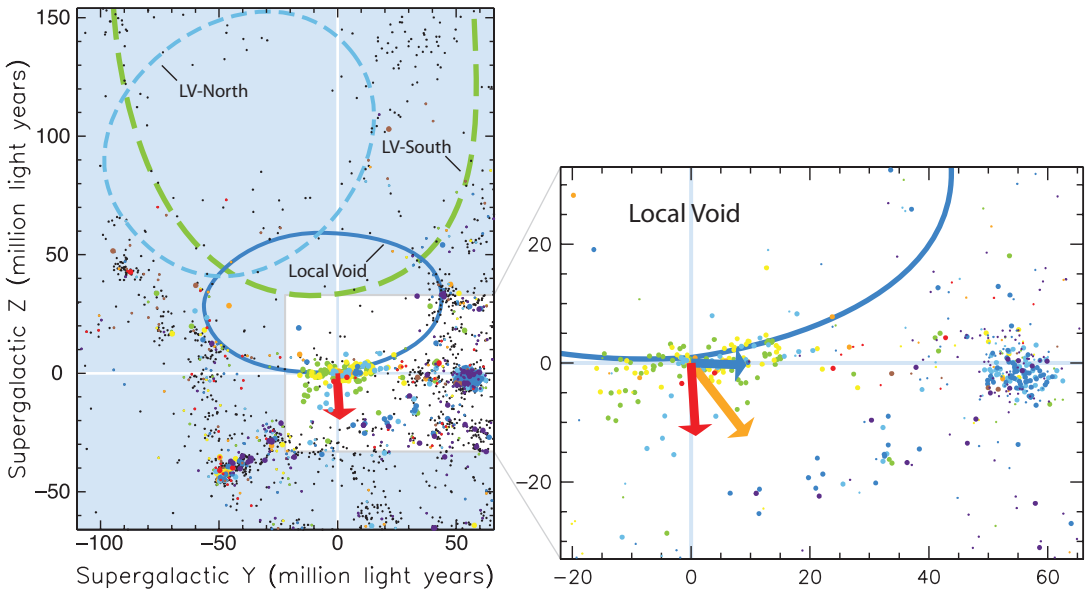
LV-North
LV-South
Local Void
Supergalactic Z (million light years)
Supergalactic Y (million light years)
150
100
50
0
−50
−100
−50
0
50
Local Void
20
0
−20
−20
0
20
40
60

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