'Missing' Dark Matter Is Really There, Says Hebrew University Cosmologist

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A new analysis that refutes challenges to the existence of dark matter in certain galaxies appears in an article published this week in the journal Nature. Leading author of the article is Avishai Dekel, professor of physics at the Hebrew University of Jerusalem.

Accepted cosmological theory postulates that every observable galaxy in the universe (each made up of billions of stars similar to our sun) is embedded in a massive “halo" of dark matter. Though unseen, dark matter can be clearly detected indirectly by observing its tremendous gravitational effects on visible objects.

This common understanding faced a severe challenge when a team of astronomers, writing in Science in 2003, reported a surprising absence of dark matter in one type of galaxy – “elliptical" (rounded) galaxies. Their theory was based on observations that stars located at great distances from the center in such galaxies move at very slow speeds, as opposed to the great speed one would have expected from the heavy gravitational pull exerted by dark matter.

The new analysis in Nature provides a simple explanation for these observations. “In fact,” says Dekel, “our analysis fits comfortably with the standard picture in which elliptical galaxies also reside in massive dark matter halos.

"A dearth of dark matter in elliptical galaxies is especially puzzling in the context of the common theory of galaxy formation, which assumes that ellipticals originate from mergers of disk galaxies," added Dekel. "Massive dark-matter halos are clearly detected in disk galaxies, so where did they disappear to during the mergers?" asks Dekel.

The Nature article is based on simulations of galaxy mergers run on a supercomputer by graduate student Thomas J. Cox, supervised by Joel Primack, a professor of physics at the University of California, Santa Cruz. The simulations were analyzed by Dekel and collaborators Felix Stoehr and Gary Mamon at the Institute of Astrophysics in Paris, where Dekel is the incumbent of the Blaise Pascal International Chair of Research at the Ecole Normale Superieure.

The simulations show that the observations reported in Science are a predictable consequence of the violent collision and merger of the spiral galaxies that lead to the formation of the elliptical galaxies.

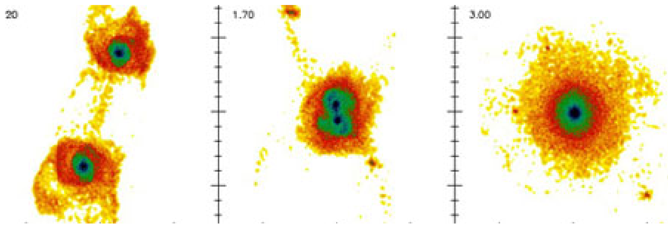

Illustration of computer simulation showing two spiral galaxies combining to form an elliptical galaxy at right.

Evidence for dark matter halos around spiral galaxies comes from studying the circular motions of stars in these galaxies. Because most of the visible mass in a galaxy is concentrated in the central region, stars at great distances from the center would be expected to move more slowly than stars closer in. Instead, observations of spiral galaxies show that the rotational speed of stars in the outskirts of the disk remains constant as far out as astronomers can measure it.

The reason for this, according to the dark matter theory, is the presence of an enormous halo of unseen dark matter in and around the galaxy, which exerts its gravitational influence on the stars. Additional support for dark matter halos has come from a variety of other observations.

In elliptical galaxies, however, it has been difficult to study the motions of stars at great distances from the center. The scientists writing in Science found a decrease in the velocities with increasing distance from the center of the galaxy, which is inconsistent with simple models of the gravitational effects of dark matter halos.

Part of the explanation for that phenomenon, put forth in the new Nature paper, lies in the fact that the velocities in the earlier study were measured along the line of sight. "You cannot measure the absolute speeds of the stars, but you can measure their relative speeds along the line of sight, because if a star is moving toward us its light is shifted to shorter wave lengths, and if it is moving away from us its light is shifted to longer wave lengths," Primack explained.

This limitation would not be a problem if the orbits of the observed stars were randomly oriented with respect to the line of sight, According to Cox's simulations, however, the stars in elliptical galaxies that are farthest from the center are likely to be moving in elongated, eccentric orbits such that most of their motion is perpendicular to the line of sight. Therefore, they could be moving at high velocities without exhibiting much motion toward or away from the observers.

Why this is so is traceable to the processes whereby disk galaxies merge to form elliptical galaxies. "In the merger process that produces these galaxies, a lot of the stars get flung out to fairly large distances, and they end up in highly elongated orbits that take them far away and then back in close to the center," explained Dekel.

"If we see a star at a large distance from the center of the galaxy, that star is going to be mostly moving either away from the center or back toward the center. Almost certainly, most of its motion is perpendicular to our line of sight," Dekel said. Under such circumstances, the star would appear to be moving quite slowly, when in fact this is not the case, based upon the models of simulated galaxy mergers studied by the Hebrew University-UCSC-Paris team.

"Our conclusion is that what the cosmologists described in 2003 is exactly what the dark matter model would predict," he said, “Our findings remove a problem which bothered them and make it possible to better understand the processes involved in creation of new galaxies in the universe.”

Source: Hebrew University of Jerusalem