

Hubble detects ring of dark matter

Astronomers using the Hubble Space Telescope have discovered a ghostly ring of dark matter that formed during a titanic collision between two massive galaxy clusters. Because ordinary matter in the cluster shows no evidence of such a ring, this discovery is among the strongest evidence yet for non-baryonic dark matter.

Clusters of galaxies are the largest gravitationally bound structures in the universe. They typically contain hundreds or thousands of galaxies, forming at the knots of the filamentary sponge-like distribution of matter on very large scales. Numerical simulations show how the accretion of matter from the filaments to the knots make galaxy clusters grow in size. This one-dimensional accretion (along a filament) results in frequent, near head-on collisions among clusters or groups of galaxies, whereas interactions between individual galaxies usually occur only when there is significant rotation.

The galaxy cluster Cl0024+17 – some 5×10^9 light-years away ($z=0.4$) – is supposed to have experienced exactly such a head-on collision 1 or 2 thousand million years ago. The first evidence of this was obtained in 2002 by Oliver Czoske, from the University of Bonn, and collaborators. By studying the velocity distribution of the galaxies in the cluster, they found two distinct groups with opposite velocity, suggesting that there are two sub-clusters moving away from each other along the line-of-sight. Their numerical simulations confirm



This Hubble Space Telescope composite image shows in blue the ring-like dark matter distribution superimposed on the optical view of the galaxy cluster Cl 0024+17. (Courtesy NASA, ESA, MJ Jee and H Ford of Johns Hopkins University.)

the collision scenario and suggest a sub-cluster mass ratio of 2:1.

In 2004, when Myungkook Jee from the John Hopkins University started to study the dark-matter distribution in Cl0024+17, he was not aware that this was such a peculiar cluster of galaxies. He was at first annoyed when he saw the ring-like distribution because he had never seen such a pattern in other clusters, and thought it was an artefact. It is indeed

tricky to derive the dark-matter distribution in a cluster from the distortion it causes on the shape of background galaxies, but the analysis of this weak gravitational lensing now seems to be well under control, with the release of the first 3D map of the dark matter distribution (*CERN Courier* January/February 2007 p11).

The ring-like structure, which measures 2.6 million light-years across, is reminiscent of the famous Cartwheel Galaxy (*CERN Courier* March 2006 p12) shaped by a frontal collision with another galaxy. A similar scenario – but on the scale of galaxy clusters – is most likely at the origin of the dark-matter ring found by Jee and colleagues.

To validate this scenario, they performed a collisionless N-body simulation of the head-on interaction between two spherical dark-matter halos. The simulation shows how the cluster collision triggers a radially expanding shell of dark matter around each cluster core. These shells superimpose in projection on the sky to form the ring-like pattern.

The unique spatial distribution of this ring, compared with both the galaxies and the hot X-ray emitting gas in the cluster, is strong evidence for the existence of dark matter. It confirms a similar result found in the Bullet Cluster (*CERN Courier* October 2006 p9) and makes it difficult for any theory trying to reproduce the effect of dark matter by modified Newtonian dynamics (MOND).

Further reading

MJ Jee et al. 2007 *Astroph. Journal* **661** 728.

Picture of the month



This multiwavelength view of the nearby galaxy Messier 81 was obtained by combining observations in infrared, visible and ultraviolet light. This beautiful spiral galaxy is almost visible with the naked eye in the Great Bear (*Ursa Major*) constellation, which includes the seven stars forming the Big Dipper. The infrared view by the Spitzer Space Telescope and the ultraviolet image by the GALEX satellite were superimposed on the image from the Hubble Space Telescope. The infrared light (shown red in the image) reveals hot dust in the spiral arms heated by the intense ultraviolet radiation (shown in blue) emitted by young, massive stars. (Hubble data courtesy NASA, ESA and A Zezas of the Harvard-Smithsonian Center for Astrophysics; GALEX data courtesy NASA, JPL-Caltech, GALEX Team J Huchra et al. of the Harvard-Smithsonian Center for Astrophysics; Spitzer data courtesy NASA/JPL-Caltech/S Willner of the Harvard-Smithsonian Center for Astrophysics.)