

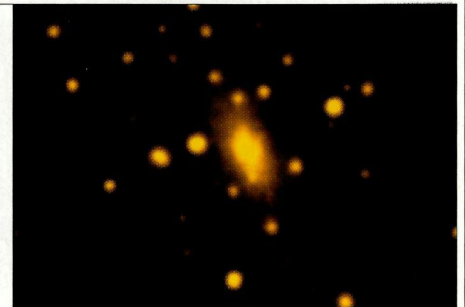
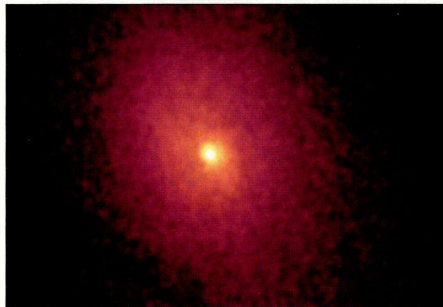
Hot gas reveals cold dark matter

The long controversy between cold-dark-matter and hot-dark-matter models is rapidly nearing an end. A recent study of the X-ray emission of hot gas in a massive cluster of galaxies has allowed astronomers to determine the distribution of its dark-matter content. The density of dark matter appears to increase towards the centre of the cluster in agreement with cold-dark-matter predictions.

The discovery that the dark-matter distribution could be tightly constrained is due to the high resolution of NASA's Chandra X-ray observatory and to the choice of a regular and undisturbed galaxy cluster called Abell 2029. This cluster is located about a billion light-years from Earth, and is composed of thousands of galaxies enveloped in a gigantic cloud of hot gas. At the centre is an enormous elliptical galaxy that is thought to have been formed from the merging of a number of smaller galaxies.

Hot gas is held in the cluster by gravity, but the mass of the galaxies in the cluster is not enough to explain the presence of this gas. Huge amounts of additional, invisible matter are needed for gravity to balance the pressure of the gas, which is at a temperature of more than 10 million degrees. This missing mass of unknown nature is what we call dark matter.

It seems the distribution of hot gas is mainly determined by that of the dark matter, rather than by the distribution of visible matter in the galaxies. Therefore, by precisely measuring the distribution of X-rays from the hot gas, Aaron Lewis of the University of California and col-



Analysis of Chandra's X-ray image (left) of the galaxy cluster Abell 2029 (optical image, right) reveals that the density of dark matter increases uniformly to the central galaxy of the cluster. (X-ray image: NASA/CXC/UCI/A Lewis et al.; Optical image: Pal. Obs. DSS.)

leagues were able to make the best measurement yet of the dark-matter distribution in the inner region of a galaxy cluster. The X-ray data show that the dark-matter density increases smoothly all the way into the central galaxy of the cluster. This agrees with the predictions of cold-dark-matter models and is contrary to other dark-matter models that predict a constant dark-matter density in the centre of the cluster.

Dark-matter particles must have the property of interacting with each other and with "normal" baryonic matter only through gravity. These so-called weakly interacting massive particles are difficult to detect and have been elusive until now. Massive neutrinos are a possible dark-matter candidate, usually referred to as hot dark matter because they travel at close to the speed of light. Due to this high speed, hot-dark-matter models of the early universe create big structures of the size of galaxy clus-

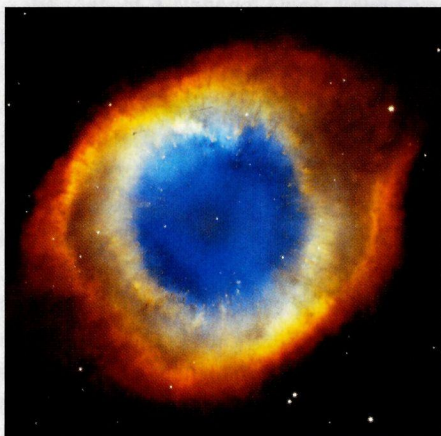
ters first, which then fragment to form galaxies. By contrast, the slower cold-dark-matter particles cannot travel as far and so form small galaxies first, which then merge to form bigger structures such as clusters of galaxies.

In the past few years there has been growing evidence in favour of the cold-dark-matter model. The Wilkinson Microwave Anisotropy Probe showed that "normal" baryonic matter only accounts for 17% of the matter content of the universe, the rest being cold dark matter of unknown nature (*CERN Courier* April 2003 p11). The study presented here supports this by determining the distribution of this matter in clusters of galaxies, but astronomers are still waiting for particle physicists to determine the nature of the elusive cold-dark-matter particles.

Further reading

A D Lewis et al. 2003 *ApJ* **586** 135.

Picture of the month

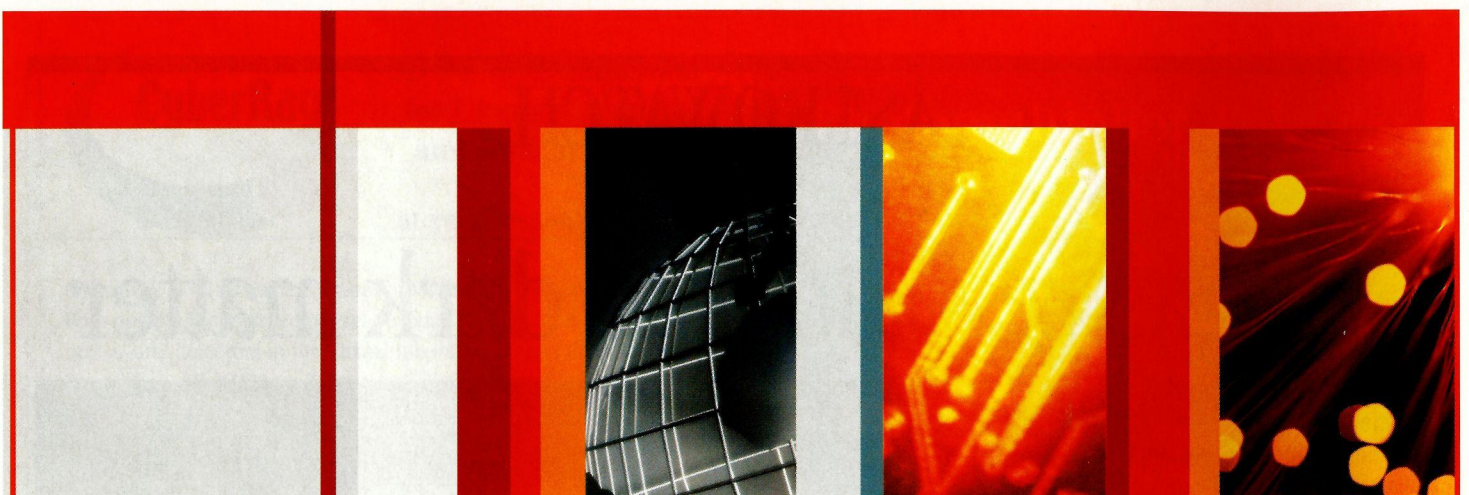


This picture from the Hubble Space Telescope is one of the most detailed celestial images ever produced. To capture most of this nearby planetary nebula – which appears in the sky as about half the diameter of the Moon – several shots were taken using the Advanced Camera for Surveys. These were then combined with a photo taken by Kitt Peak's Mosaic Camera.

This so-called helix nebula is popular among amateur astronomers. Viewed through binoculars, it appears as a ghostly, green-coloured cloud in the constellation Aquarius, which is 650 light-years away. Larger amateur telescopes can resolve the ring-shaped

nebula, but only the largest ground-based telescopes can resolve the radial streaks. Astronomers have concluded that this nebula is a cylinder that happens to be pointing towards Earth, rather than a bubble.

Planetary nebulae have nothing to do with planet formation, but get their name because through a small telescope they look like planetary discs. They appear during the final stage in the life of a Sun-like star. The outer layer of the star is expelled and a white-dwarf star remains at the centre of the nebula. (NASA, NOAO, ESA, Hubble Helix Nebula team, M Meixner (STScI), T A Rector (NRAO).)



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