Luminous Arcs Dwarf the Galaxies

A serendipitous discovery has revealed the largest optically visible structures known; now the problem is to figure out what they are and how they formed

As so often happens in astronomy, a routine survey—in this case, a survey of galaxy clusters—has uncovered a bizarre new phenomenon: great, glowing arcs that curl through the clusters like bands of luminous paint. Researchers have only the vaguest idea of what these structures are, or how they formed. But whatever the arcs are, they are huge; indeed, they are the largest optically visible structures yet observed in the universe.

The discovery was reported at the January meeting of the American Astronomical Society in Pasadena, California, by Roger Lynds of the National Optical Astronomy Observatories and Vahe Petrosian of Stanford University.

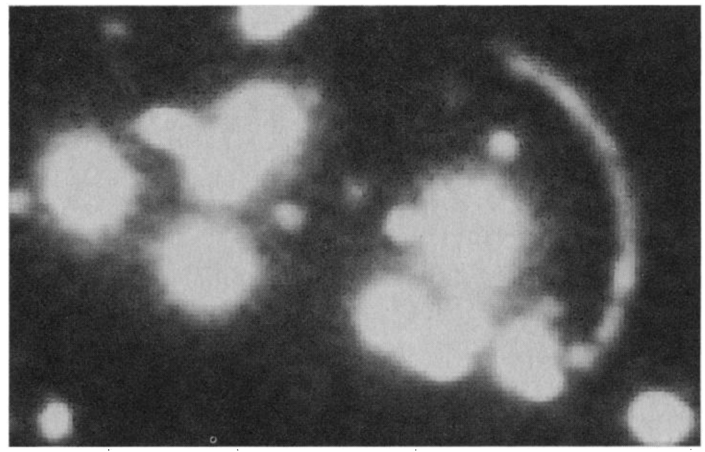
Three arcs are now known, they say. One, in a cluster known as Abell 2218, is wispy and fragmentary. The other two, however, located in clusters known as 2242-02 and Abell 370, are clear, wide swaths some 10,000 parsecs wide and 100,000 parsecs long. (A parsec is 3.26 light-years, or about 19.2 trillion miles. For comparison, our own sun lies about 7000 parsecs out from the center of the Milky Way galaxy, which is roughly 30,000 parsecs across.) Each arc resides near the middle of a dense cluster of galaxies, each is a segment of a nearly perfect circle—one arc extends for 110 degrees—and each is nearly concentric with a bright, elliptical cD galaxy, which is thought to be a kind of celestial cannibal that has acquired its bulk by swallowing up neighboring galaxies in the cluster.

Ironically, Lynds and Petrosian first noticed the arcs in the late 1970s, during the course of a survey to calibrate the surface brightness of galaxies in distant clusters. They were reluctant to publish at the time, however; as Petrosian says, "We were concerned to make sure they were not artifacts." Moreover, the researchers were hampered by a lack of observing time—the arcs are comparatively faint and require hours of exposure on a large telescope—and by the fact that they were unable to get much quantitative information from the imaging instruments then available.

Since then, however, the advent of charged-coupled device detectors has made it possible to do much more sensitive imagery of faint objects. And, in the autumn of 1986, Lynds and Petrosian were allotted four nights to study the arcs on the 4-meter Mayall telescope at Kitt Peak National Observatory. "So we can now say something significant about the color, size, and uniformity of the arcs," says Petrosian.

The cluster 2242-02

The arc is very sharply defined and has few overlying galaxies. But it does show some evidence of breaking into clumps—with each clump being the size of a small galaxy.



At the moment, the researchers' best guess is that the arcs are lit up by masses of very young stars. Unfortunately, bad weather kept them from obtaining spectra, which would have given a more definitive answer. But nonetheless, the arcs have a distinctly bluer color than the surrounding galaxies, which is exactly what one would expect from hot, newborn stars. Furthermore, the light from the arcs is only weakly polarized, and their radio emissions are essentially nonexistent; both facts are consistent with star formation, but not with other astrophysical processes such as synchrotron radiation in a strong magnetic field.

Stars or not, however, one still has to explain how the arcs were formed. Yet any theory has to face some tough observational facts. For example, the arcs are strikingly uniform in width, like fat swaths of chalk on a blackboard. They show no variation in color from one end to the other. They begin and end abruptly, with no tapering off. They show no fragmentary continuations beyond the ends. They show no indication of any surface brightness in the interior, which is what one would expect if they were the edges of spherical shells.

The upshot is that none of the obvious explanations fit. Collisions between galaxies sometimes produce streamers of stars, but not abrupt, concentric circles like the arcs. Explosions tend to produce spherical shells. And jets from active galaxies tend to be linear. Even the exotic explanations seem hard to swallow. Cosmic strings? Massive black holes orbiting through some kind of intergalactic plasma?

"I think there is every likelihood that this is some shell-like mechanism," guesses Lynds. "For example, there may have been some kind of propagating shock front from the interior of the cluster that hits a preexisting filament of gas, initiates star formation, and regularizes the geometry. But this is ad hoc."

Whatever their origins, the arcs can hardly be called rare. Lynds and Petrosian only included 58 clusters in their survey, so three examples translate to a frequency of about 5%, or 1 in 20. Indeed, Petrosian told *Science* that other researchers have privately informed him of seeing similar features, although he cautions that he has not yet examined their data. In any case, there is nothing particularly strange about the arc-containing clusters themselves. They are somewhat brighter and more compact than average, but that may be simply a result of how Lynds and Petrosian chose their original sample.

One intriguing possibility, pointed out by Lynds, is that the arcs may represent a key step in the evolution of every cluster. "There's a possibility we're looking at late examples of something that was more prevalent in the past," he says. One very tentative picture is that the primordial gas coming out of the Big Bang somehow condensed into linear, or curved features before it collapsed into galaxies; the ones that he and Petrosian have found would thus represent the last remnants that have not yet collapsed.

There is some support for this scenario, says Lynds. The clusters where the arcs are seen are quite distant, about 5 billion light-years from Earth, which means that we are seeing them at a relatively young age. In cluster 2242-02 the arc does seem to have nodules along its length, as if it were beginning to break up into clumps about the size of small galaxies. And, he says, "The experience of people who study clusters is that they find more interesting alignments of galaxies than they would expect by chance. So it all hangs together in a vague sort of way."

Obviously, astronomers are going to need a lot more examples of the arcs before they can pin down any of these ideas. As Petrosian points out, "There is a limit to what we can learn from just three examples." Finding more may not be easy; if the arcs are primordial relics, then any other examples may well be further away. But then, a good many astronomers will certainly be trying.

And in the meantime, the original arcs are lost in the daytime sky until next autumn, when Lynds and Petrosian hope to observe them again. ■ M. MITCHELL WALDROP

Drug May Protect Brains of Heart Attack Victims

A controversial drug may reduce the damage to brain neurons that often occurs after the blood supply is interrupted

WHEN a heart attack or stroke deprives the brain of oxygen, nerve cell damage is often irreversible and virtually untreatable. This ischemic damage may be preventable, according to new results in experimental animals treated with a drug that was originally developed as an anticonvulsant. But some researchers challenge the basis for the drug's use and caution that it is still too early to know whether it will be effective in humans.

The potential for the drug, MK-801, to limit neuronal injury after ischemia depends on "the relatively new idea that excitatory neurotransmitters act as toxins and contribute to much of the brain damage," says Leslie Iversen of Merck Sharp & Dohme Research Laboratories in Harlow, England. He told participants at the recent American College of Neuropsychopharmacology meeting in Washington, D.C.,* that MK-801 penetrates the blood-brain barrier easily and blocks the effects of excitatory amino acids. These normally occurring transmitters, including glutamate and aspartate, are released at high, toxic levels when the brain is deprived of blood and oxygen.

The Merck researchers find, with gerbils and rats, that MK-801 protects neurons whether they give the drug before or after inducing ischemia to the animal's entire brain. As yet, they have no data suggesting whether MK-801 reduces neuronal injury when ischemia affects only a small area of the brain, a condition similar to brain damage from a stroke.

*The annual meeting of the American College of Neuropsychopharmacology was held from 8 to 12 December in Washington, D.C.

Two issues trigger controversy among other researchers who also study possible ways of limiting damage to neurons when blood flow to the brain is blocked. First, Fred Plum and William Pulsonelli of Cornell University Medical School note that the gerbil model used extensively by the Merck researchers is not representative of ischemic damage in other mammals because of the gerbil's propensity to develop prolonged seizures that may themselves produce and exacerbate brain damage. And because rodents are more susceptible to ischemic brain damage than primates, the Cornell researchers stress the importance of testing potential neuroprotective drugs in nonhuman primates before giving them to humans.

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A second area of controversy concerns the possible mechanisms of cell death in ischemia. Iversen points out that once the excitatory transmitter glutamate is released during ischemia, it probably triggers a feed-forward process: "The more excitation you have, the more glutamate release you have. Beyond a certain point nerve cells are no longer capable of surviving because they are being excited at the same time as they are being metabolically compromised."

According to Marcus Raichle of Washington University School of Medicine in St. Louis, however, brain damage in heart attack and stroke patients is a very complex process that cannot be explained solely on the basis of toxic levels of glutamate. Rather, ischemia produces "a terrible jungle of trouble," he says. It induces changes in oxygen levels, glucose metabolism, acidity, and calcium concentration, as well as the production of free radicals and other cellular substances that may be toxic. "But we can't throw up our hands and say that nothing can be done," he says. "We have to pick this thing apart, and excitatory amino acids may play an important role in the damage."

In the United States, MK-801 was tested initially as a potential anticonvulsant but the trials were suspended according to Marvin Jaffe of Merck Sharp & Dohme Research Laboratories in West Point, Pennsylvania. "We believe that MK-801, which was given orally to epilepsy patients, did not achieve adequate plasma levels," he says. "We are now entering into a series of studies to test the tolerance of healthy volunteers when the drug is injected systemically."

Iversen, Erik Wong, John Kemp, Tony Priestley, Antony Knight, Geoffrey Woodruff, and Ramy Gill, all of Merck, now find that MK-801 may salvage brain neurons from ischemia because the drug penetrates the brain in therapeutic quantities after a single injected dose, and it protects a large percentage (40% to 50%) of hippocampal neurons even 24 hours after ischemia occurs.