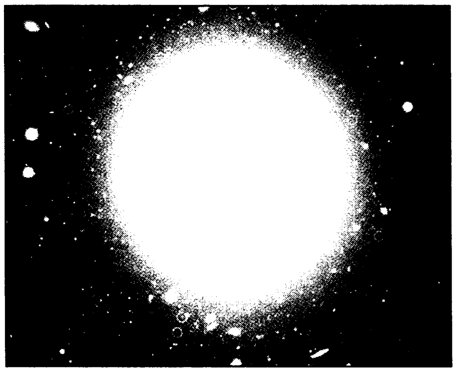
ASTRONOMY

Dying Stars Give Galactic Theory New Life

Death in the cosmos can shed light on birth. Astronomers are now using planetary nebulae, the wispy greenish halos around dying stars, to provide clues about creation—specifically, the creation of giant elliptical galaxies. These rare cosmological leviathans, when they are spotted, are often sitting at the center of swarms of smaller galaxies. Hard data about their genesis has been hard to come by, in large part because they're so far away, but new observations of the movements of nebulae—which will be discussed in the June issue of the European Southern Observatory (ESO)'s in-house journal *The Messenger*—appear to bolster the theory that such behemoths form through the merging of many smaller clumps of matter.


CTIO/ESO

Markers in motion. The pattern of movements of planetary nebulae *(circled)* around the bright core of galaxy NGC 1399 have been observed for the first time. The motion is consonant with a theory that the galaxy formed when numerous small clumps of matter came together.

Since the closest such elliptical galaxy, NGC 1399, is some 50 million light-years away, astronomers have been unable to get a good look at its dark outer realm which, in theory, holds clues about the galaxy's birth. So direct inquiries into that process have been stymied. "It's been an observational puzzle," says Ken Freeman of Australia's Mount Stromlo Observatory. But late last year at the ESO's 3.5-meter New Technology Telescope in La Silla, Chile, an international team of astronomers led by Freeman and colleague Magda Arnaboldi took up the challenge.

They were motivated by recent surveys of NGC 1399 that picked out 37 faint lights in its dim outer region—the planetary nebulae that form when a dying star sheds an outer layer of gas and then heats it until the gas becomes a glowing shell. The researchers believed these objects, some more than 100,000 light-years from the galaxy's bright, slowly rotating center, could be used to track the motion of rare luminous matter in that dark periphery. Some computer simulations of elliptical galaxy formation had offered specific predictions about that motion, and if the observations matched the predictions, it would be evidence that the simulations—and the model of galactic genesis they embrace—are accurate.

In these simulations, galaxies form through the aggregation of clumps of matter not quite developed enough to be called galaxies. The models predict that after the giant galaxy comes together, stars, gas, and other matter in the darker exterior should whiz around much faster than the slowpokes in the bright center. This rotational difference slowly emerges from the gravitational interactions that occur when the clumps of matter spiral inward to merge, explains theoretical astrophysicist Wojciech Zurek of Los Alamos National Laboratory, who helped develop the simulations that showed this effect.

To establish the rotation of the planetary nebulae, and thus NGC 1399's periphery, Freeman's group made use of an ESO spectrograph, a prismlike instrument that separates light into its component wavelengths. In particular, they looked at a specific wavelength of intense green light emitted by ionized oxygen atoms in the nebulae. Depending on each nebula's velocity with respect to Earth, the wavelength would be slightly longer or shorter than expected, a phenomenon known as the Doppler effect. Once they found each individual nebula's velocity, astronomers were able to derive the overall movement of visible matter in the periphery. Indeed, they found that it rotated around the hub faster than did more central material.

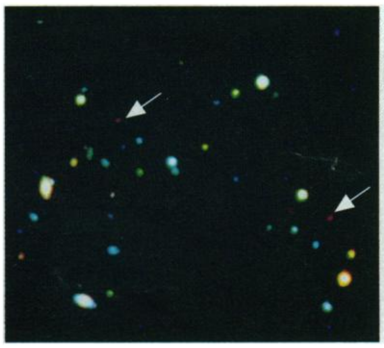
The outer rotation in NGC 1399 "matches very nicely" with the computer simulations made by Zurek and others, says Freeman. While other astronomers are reserving judgment on the match until they see the data, Alan Dressler of the Carnegie Observatories in Pasadena, California, does say the technique of using planetary nebulae as far-flung galactic probes seems promising. Freeman and his colleagues next plan to use them to study motions in another galaxy near NGC 1399, further proof that the moribund stars have given life to a new line of astronomical inquiry.

–John Travis

ASTRONOMY

Red Galaxies Hint at an Old Universe

In galaxies, red is a sign of maturity. Young galaxies blaze with hot, short-lived blue stars, but after a galaxy has been around for a few billion years, those stars have spent themselves, and slower-burning red stars predominate. It's no surprise that red galaxies are common in the present universe, where they have had plenty of time to age. But it came as a considerable surprise to Esther Hu and Susan Ridgway of the University of Hawaii to spot what they think are two old, red galaxies in a much earlier phase of cosmic history.


HU AND RIDGWAY

Old and faded. The two objects color-coded red in this infrared image may be old galaxies in the early universe.

If Hu and Ridgway are right, the discovery could stretch out the cosmic timeline. This redating would be needed because Hu and Ridgway estimate that the galaxies are so far off that their light began its journey to Earth when the universe was just a sixth of its present age. Since the galaxies themselves would have to be at least 3 billion years old to shed their youthful blue, the distance implies a cosmic age of perhaps 19 billion years—almost twice the age some cosmologists favor.

Hu and Ridgway caution that their distance estimates are too uncertain for anyone to start revising cosmological models yet. In the meantime, other astronomers are delighted to have a new mystery to explore. "I am very enthusiastic about this discovery," says Mark Dickinson of the Space Telescope Science Institute, who has spotted several somewhat less red galaxies at large distances. Dickinson thinks the discovery could be a hint of many more, since the finding "encourages you to go out and look for such things in a systematic way."

Hu and Ridgway spotted their galaxies by chance, while they were using the University of Hawaii's 2.2-meter telescope on Mauna Kea to search for galaxies reddened by dust. The extreme redness of the galaxies, however, marked them as another kind of object, at an unknown distance. In astronomy, the usual way to determine distance is to break an object's light into a spectrum, then measure the extent to which certain features of this spectrum have been "redshifted" (displaced toward the red) by the expansion of the universe, which carries off more distant objects faster than it does nearby ones. But the objects Hu and

Ridgway stumbled upon were too faint to yield spectra, so they had to estimate their distance from other clues.

One clue was the intensity of the galaxies' light in various wavelength ranges. Together, these measurements gave Hu and Ridgway an overall color distribution, which they could compare to that of light from known galaxy types. The best match, they found, was to the reddish light of an old elliptical galaxy—displaced all the way to the infrared by the expansion of the universe. Based on that and other clues, Hu and Ridgway report in last month's *Astronomical Journal*, the objects are most likely elliptical galaxies at a distance equivalent to a time five-sixths of the way back to the Big Bang.

Not all galaxy researchers accept that conclusion. "Without a spectrum, it's hard to tell exactly how far away these things are," says George Djorgovski of the California Institute of Technology. Peter Eisenhardt of the Jet Propulsion Laboratory in Pasadena, California, adds that evidence for the proposed distance is "not very compelling."

Hu and Ridgway aren't disputing that, and they have suggested alternative explanations for the objects' faint, extremely red light. One possibility is that they are nearby galaxies of a hitherto unknown kind, consisting entirely of faint, low-mass stars that emit most of their radiation in the infrared region of the spectrum. A more exotic possibility is that they are precursors of present-day galaxies, located at a distance even greater than Hu and Ridgway favor—farther away and closer to the origin of the universe than any known object. In that case, their actual color could be the blue of a young galaxy, and the galaxies' redness could be entirely due to redshifting.

Both possibilities are startling, say other astronomers, but no less startling than Hu and Ridgway's favored explanation of aged galaxies in the early universe. The exceedingly old universe implied by that picture is in sharp conflict with recent hints that the universe is expanding rapidly and hence is comparatively young—a mere 10 billion years old. But whether this conflict is real or only apparent won't be clear until astronomers can record spectra of the two red galaxies to pin down their distance. And that may be a tough job for current telescopes, say Hu and Ridgway.

One clue, says Eisenhardt, may come when NASA's Space Infrared Telescope Facility (SIRTF) is launched later this decade. If Hu and Ridgway are right, SIRTF may detect peaks in the red galaxies' light at just the wavelength at which the red giant stars that are abundant in an old galaxy shine brightest. For now, says Djorgovski, the Hawaii finding is "a good beginning, but we have a long way to go."

–Ray Jayawardhana

ASTRONOMY

Keeping Tabs on Cometary Breakups

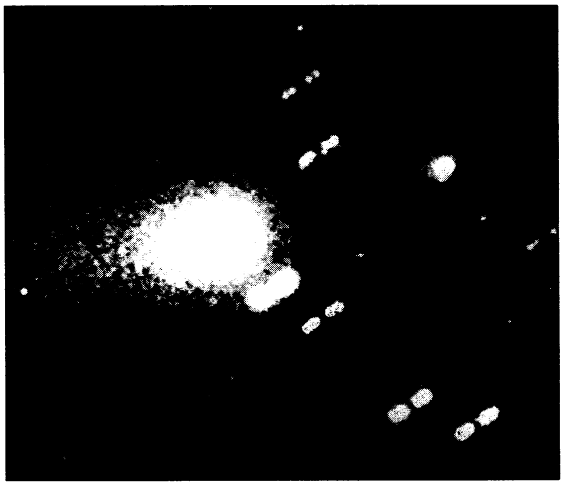
Comet Shoemaker-Levy 9 is now homing in on Jupiter, and many eyes are trained on it in anticipation of a collision in July. The comet initially caught astronomers' eyes for a different reason, however. During its last encounter with Jupiter (a near miss in July 1992), the giant planet's gravity tore it into some 20 fragments, transforming an unremarkable object into a celestial string of beads. But although Shoemaker-Levy 9 may be the most spectacular fragmented comet, two astronomers from the University of Hawaii report that split comets may not be unusual. And it doesn't always take a brush with a giant planet to produce them.

In a study reported in the April issue of *Icarus*, Jun Chen and David Jewitt searched high-resolution images of recent comets for signs of breakup. Only a few split comets had been spotted in the past, says Jewitt, but that may be because the fragments can be faint and move apart quickly: His and Chen's sensitive, systematic search suggests that an average comet nucleus splits about once a century—an unexpectedly high rate. "It's an interesting result because they have calculated the splitting rate from a homogeneous data set," says comet expert Michael A'Hearn of the University of Maryland, although he adds that the sample is too small to be sure of the result. But the finding already has investigators wondering why comets might be so unstable and pondering the possibility that some of the small asteroids inhabiting Earth's neighborhood are actually bits of passing comets.

Chen and Jewitt collected images of 49 comets made between 1986 and 1993 with charge-coupled devices (CCDs), an electronic imaging technology that is 100 times more sensitive than photographic plates. By rapidly displaying, or "blinking," at least four successive images of each comet taken a few minutes to an hour apart, they searched for multiple fragments moving together—evidence that they had once been part of a single nucleus. The researchers found that three of the 49 comets had fragmented nuclei.

Based on the rate at which the fragments move apart, the researchers calculated that their technique could only detect comets that had split within 6 years before the image was made; any longer and the fragments would no longer appear in a single CCD image. Since 6% of their sample exhibited split nuclei, they concluded that a typical comet must split once a century. One other study—15-year-old work by Paul Weissman of the Jet Propulsion Laboratory—had suggested a comparable rate of splitting, but it was not considered definitive because it was based on historical observations of widely varying quality.

The splitting rarely produces equal-sized fragments, Chen and Jewitt think; otherwise, few comets would remain large enough to be visible for more than a few tours around the sun. Instead, the researchers say, comets seem to "peel off" tiny fragments, containing perhaps a thousandth of the mass of the main body. Besides explaining some comets' longevity, that would also put the fragments in the right size range—tens of meters across—to account for some of the small, nearby objects that astronomers in NASA's Spacewatch program have recently detected.


CHEN AND JEWITT

Comet with a sidekick. A split comet nucleus.

Planetary scientist Eugene Shoemaker of the U.S. Geological Survey in Flagstaff, Arizona (a codiscoverer of Shoemaker-Levy) doubts that comets contribute much to this swarm of objects. "The orbits of Earth-crossing comets are very different from the orbits of most of these tiny fragments that Spacewatch detects," he says. That's true for many of the Spacewatch objects, Jewitt concedes, but he says that two or three of them do have orbits consistent with a cometary origin.

Just why comets are prone to breakup isn't clear. Most never come as close to a giant planet as Shoemaker-Levy 9 did, and although the heat of the sun might fracture a comet by boosting the pressure in internal gas pockets, some comets split long before they approach the sun. As Weissman puts it, "Random splitting events seem to occur for reasons we don't understand." Comets, it would seem, are just a fractious bunch.

–Ray Jayawardhana

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