meeting. In an elegant if painstaking set of experiments, she showed that a flower's cup-shaped inner sanctum, called the carpel, has a lopsided beginning: One half forms first and then later drives an unusual developmental process in which cells in both halves redifferentiate. In the end, the two smaller carpels fuse into a single, symmetrical vessel that will hold the plant's seeds.

Not-so-twin peaks. As the periwinkle flower *(left)* forms, one bit of carpel tissue leads the way *(below)*.

PHOTOS: J. VERBEKE

Fused carpels—which allow fruits like tomatoes to grow large rather than being split into several smaller seed chambers—were a key evolutionary innovation and help distinguish flowering plants from more primitive gymnosperms such as conifers which have naked seeds, notes plant developmental biologist Ian Sussex of Yale University. The lopsided developmental progression seen in the carpel will also likely appear among other parts of flowering plants, says Verbeke: "I think [the pattern] will be absolutely general."

Verbeke made her discovery in an ornamental plant that is already famous: the Madagascar periwinkle, *Catharanthus roseus*, the source of two valuable anticancer drugs. She and her colleagues have spent more than a decade studying the early developmental stages of the plant's half-dollar–sized blooms and had already revealed one surprise: An as-yet-unknown substance from the developing carpel causes a cluster of epidermal, or surface, cells to switch fate abruptly and redifferentiate into parenchyma cells, a common internal cell type that allows a tight seam between the two parts to form (*Science*, 5 May 1989, p. 580). The fusion seems to require the unusual redifferentiation of cells already committed to a particular developmental path.

Verbeke's group probed this process further with a slew of intricate microsurgical experiments on the barely visible emerging flower bud and turned up a distinct biochemical difference in the two parts of the carpel. The researchers put an extract collected from developing carpels onto test carpels, using wisps of a polycarbonate membrane to transfer the extract and maneuvering the tissue and membrane with tiny instruments cut from razor blades or sheared from needles.

The technique is so tricky that Verbeke calls it "nuts," but others appreciate it: "It's a really beautiful system for identifying temporal differences in development," says plant geneticist Gregory Copenhaver at the University of Chicago.

When the carpel extract was randomly placed on emerging carpel halves, the cells redifferentiated in only 50% of the trials, Verbeke reported. Similarly, when one of the carpel halves was successfully transplanted onto other flower buds, cells changed course only half the time, indicating that only one of the halves was responding to the chemical signal. The distinction between the two halves was sewn up when Verbeke and her colleagues examined emerging buds under an electron microscope: They saw that one of the carpel halves pops up before the other. Additional experiments confirmed that this older tissue is what later induces redifferentiation in the "younger" half.

This early developmental difference between two halves of the carpel is also turning up in genes at the molecular level. Verbeke and colleagues found that some messenger RNA sequences were expressed only in the "older," inducing half of the carpel. So far these sequences have shown little resemblance to any in the plant data banks. The next step, says Verbeke, is to identify the powerful inducing substance, which seems to be a protein—and could be one more claim to fame for Madagascar's periwinkle.

—CHRISTINE MLOT

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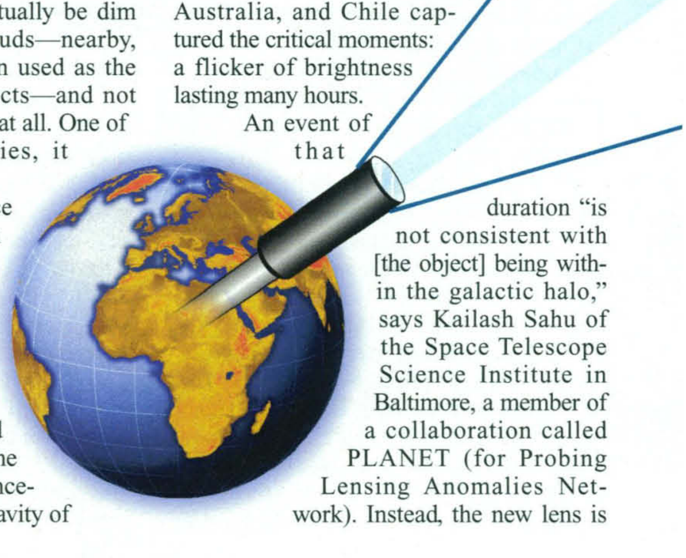
ASTRONOMY

A Dark Matter Candidate Loses Its Luster

The dark objects thought to inhabit the Milky Way's halo, accounting for its missing mass, may actually be dim stars in nearby galaxies

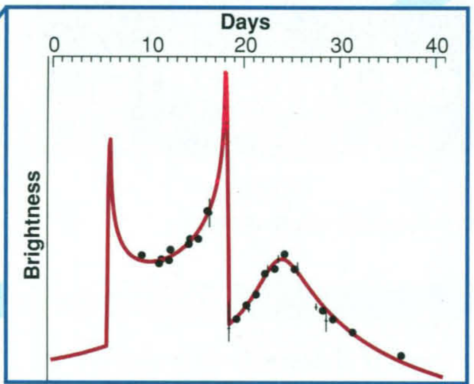
More than 2 years ago, a team of astronomers announced a major breakthrough in the search for the mysterious "dark matter" that makes up most of our galaxy. The flashing of distant stars implied, said the team, that the matter is swarming around the visible disk of the Milky Way in a huge halo of dark chunks, which occasionally pass between the stars and ground-based telescopes. Now, several teams have found that the unseen objects might actually be dim stars in the Magellanic Clouds—nearby, dwarf galaxies that had been used as the backdrop to reveal the objects—and not dark matter in the Milky Way at all. One of astronomy's great mysteries, it seems, is still unsolved.



The confounding evidence came just last month, when the original team, called the MACHO Collaboration (for Massive Compact Halo Object), alerted other astronomers to an unusual brightening of one of the stars in the Small Magellanic Cloud (SMC). Such brightenings—the basis for the original announcement—take place when the gravity of an unseen object focuses the light of a background star. The events ordinarily say little about the distance of the lensing object. But occasionally, for example when the lens is a pair of objects, the rapid, complicated flashing does carry the extra information. Ten days after MACHO spread the news that such an event was in progress, telescopes in South Africa, Australia, and Chile captured the critical moments: a flicker of brightness lasting many hours.

An event of that duration "is not consistent with [the object] being within the galactic halo," says Kailash Sahu of the Space Telescope Science Institute in Baltimore, a member of a collaboration called PLANET (for Probing Lensing Anomalies Network). Instead, the new lens is almost certainly in the SMC. Two earlier events, out of the 20 or so observed so far, had also revealed hints of their distance, and they too had seemed to be in the SMC or the Large Magellanic Cloud (LMC). “All the events where more information could be derived were located in the Magellanic Clouds,” says Nathalie Palanque-Delabrouille of the Centre d'Études de Saclay in France and a member of the EROS team (for Expérience de Recherche d'Objets Sombres). “Thus, a halo interpretation of the other candidates becomes dubious.”

That's bad news for astronomers who thought they finally had an answer to the puzzle of what could be holding galaxies together. Many galaxies spin too fast in their outer reaches for the gravity of visible stars and gas to do the job, implying that at least 90% of their total mass takes the form of a dark halo. (Astronomers have invoked “dark matter” to explain other problems as well, such as the reservoirs of unseen mass needed to account for the gravitational attractions that have shaped the growth of huge clusters and filaments of galaxies.) Some researchers think the galactic dark matter exists as a cloud of exotic particles, but others have favored a more mundane possibility: burnt-out stellar hulks or

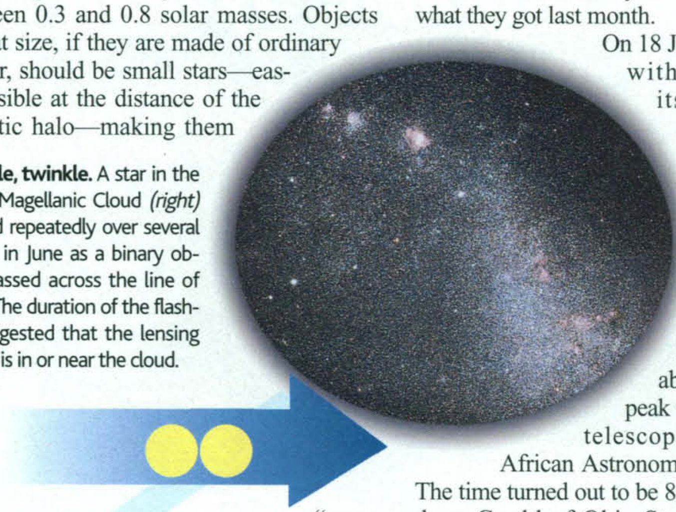


SOURCE FOR GRAPH: PLANET COLLABORATION

smaller chunks of ordinary matter.

In 1986, Bohdan Paczyński of Princeton University realized that astronomers might be able to detect these objects as they drifted across the lines of sight to distant stars. An object's gravity would act like a magnifying glass passing temporarily in front of a distant streetlight, and observers would see a smooth rise and fall in brightness. Soon astronomers were fitting telescopes around the world with electronic cameras that could monitor tens of millions of stars in the Magellanic Clouds, and the hunt for halo objects was on.

Based on seven lensing events, MACHO announced in 1996 that compact objects could make up from 15% to 95% of the halo (*Science*, 2 February 1996, p. 595). But skepticism began to build almost immediately, when astronomers began estimating the lens mass required to explain the duration of the brightenings. The most likely mass range for the objects turned out to be between 0.3 and 0.8 solar masses. Objects of that size, if they are made of ordinary matter, should be small stars—easily visible at the distance of the galactic halo—making them “very hard to reconcile with any plausible scenario” involving dark matter, says Martin Rees of Cambridge University.



Twinkle, twinkle. A star in the Small Magellanic Cloud *(right)* flashed repeatedly over several weeks in June as a binary object passed across the line of sight. The duration of the flashes suggested that the lensing binary is in or near the cloud.

ROYAL OBSERVATORY, EDINBURGH/SCIENCE LIBRARY/PHOTO RESEARCHERS

Then came two unusual events. One lasted so long—more than 100 days—that the lens had to be a slow-moving object close to the background star. The other was apparently triggered by a binary lens—a pair of objects in orbit around each other. A binary lens acts like a magnifying glass with scratches or water spattered on it, so that instead of brightening and dimming smoothly, the “streetlight” flashes irregularly. “These are wonderful events,” says Rosanne Di Stefano of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, because they are unusually rich in information.

Like the streetlight briefly glimmering through a scratch, the duration of the brightness peaks, or caustics, depends on the size of the background star, and also on how fast the lens moves across the star—a function of the lensing object's speed and distance. One variable, the background star's size, can be inferred from its brightness and color. And although a very slow-moving lens in the halo could cause a flash that lasts about the same time as a very fast lens farther away in the background galaxy, for objects coasting through interstellar space at typical speeds there should be a marked difference in the length of the “caustic crossing”—less than an hour for halo objects versus most of a night for objects in the SMC or LMC.

Observations of the first binary lens were spotty, but they were enough to hint that the object probably lay hard by the background star in the LMC. Although some members of MACHO and EROS disputed the evidence, it supported an earlier suggestion by Sahu that *all* the lenses might be in the SMC and the LMC. And it left everyone eagerly awaiting a well-observed binary lens—which is just what they got last month.

On 18 June, EROS, along with MACHO and its collaborating GMAN network, caught part of the caustic crossing with telescopes in Chile and set a lower limit of about 6 hours. But PLANET was able to map the full peak with the help of a telescope at the South African Astronomical Observatory. The time turned out to be 8.5 hours, says Andrew Gould of Ohio State University in Columbus, a member of both PLANET and EROS. That stately crossing implies with 99.5% to 99.9% certainty that the lens is in the SMC, not the halo, Gould says.

PLANET has submitted a paper on the result to *Astrophysical Journal Letters*, while EROS has submitted one to *Astronomy & Astrophysics*. Reaction to the observation was swift. “My guess is that we do not have a proof yet, but we do have a very strong indication that Kailash Sahu was right,” and all the lenses are in the LMC and SMC, says Paczyński. But David Bennett of the University of Notre Dame, a member of MACHO, calls Sahu's interpretation “far-fetched.” He argues that the LMC, at least, is too small and contains too few dim stars to account for the number of lensing events seen in that direction.

Other astronomers note that it's still conceivable that the other lensing events really are due to halo objects. But if not, astronomers will face a double quest: for the galaxy's dark matter—at large once again—and for an undiscovered population of dim stars around the Magellanic Clouds or even a phantom, dwarf galaxy somewhere along the line of sight to the clouds.

For now, the results have put a new spin on MACHO's original press conference at an American Astronomical Society meeting in January 1996, which rated front-page newspaper coverage. “My guess is either they've solved the greatest mystery in astronomy—or we're confused about what we're doing,” commented John Bahcall, an astrophysicist at the Institute for Advanced Study in Princeton, New Jersey, at the time. Bahcall now says: “It certainly is beginning to look like the second possibility.”

–JAMES GLANZ