pany, funded a similar replication study by biologist Robin Hesketh of Cambridge University in England, an author of the other paper. Hesketh, too, had found the Goodman-Henderson work initially compelling: "First of all the effects were large, and they had been recording the effects for 10 years and had found very similar effects for a whole variety of cell systems. ... It was a general phenomena, and if it affected a gene like *Myc*, it was clearly of great importance."

While the two teams set out to duplicate the Goodman-Henderson experiments, they also tried to improve on the methodology, which, says Saffer, had some potentially serious flaws. In particular, he noted a lack of controls and internal calibrations. As Saffer explains the protocol, cells are exposed to EMF, and then the RNA is purified. A small amount of that RNA is then sampled and run on a filter, and the amount of *Myc* RNA in that sample is then measured. But Goodman and Henderson's technique didn't allow them to check whether they sampled identical amounts of RNA each time, he says. "So you would get a larger signal if the amount of *Myc* RNA was in fact greater in cells exposed to the magnetic fields. But you would also get a larger signal if in fact you had unknowingly [taken a larger sample of total RNA] to begin with." (Goodman admits this was true in her original experiments, but says her more recent work controls for this problem: "We started using internal controls about a year before they started pointing it out. Some of their criticisms were justified. When we started in 1982, things weren't so sophisticated.")

Both the Cambridge and PNL groups used methods that allowed them to compare the amount of RNA from *Myc* to another type of RNA from the cells known to be remarkably invariant under a variety of conditions. That gave them a yardstick against which they could measure the size of their *Myc* RNA sample. To enhance the replication attempt further, both groups played host and guest with Goodman and Henderson. Saffer and Thurston spent 2 weeks at Goodman and Henderson's lab running experiments there. "We used their exposure system," he says, "their cells, their methods." Goodman, meanwhile, visited the Cambridge group and briefed them on both her data and her methodology. Then Hesketh and his colleagues purchased the identical exposure system, as well as building a second exposure system that eliminated a potential flaw they spotted in the Goodman-Henderson protocol: The cells were manipulated for short periods outside a rigorously controlled magnetic field environment. They then did two sets of experiments, one with the Goodman-Henderson system and one with their own.

No matter how and where they ran the experiments, however, both groups came up empty. "We did not find any evidence for a magnetic field effect, even using their cells and their exposure system," Saffer says. EMF did not increase the amount of *Myc* RNA at all. And Hesketh concurs.

This doesn't quite lay the matter to rest. Goodman says that both the PNL and Cambridge groups still failed to replicate her protocol exactly. "Deviations, even in the guise of 'improvements,' can produce different results," she says. Moreover, she and Henderson have been working separately now, and yet both are still reporting *Myc* RNA increases of 50% to 60% due to EMF. "I'm not worried," she says. "I was a hell of a lot more worried before we started repeating our own experiments."

Yet another check should come soon: Although Boorman says the new work seems solid, the DOE-NIEHS program is still funding one more attempt to replicate the Goodman-Henderson results, this one at a Food and Drug Administration lab.

–Gary Taubes

ASTRONOMY

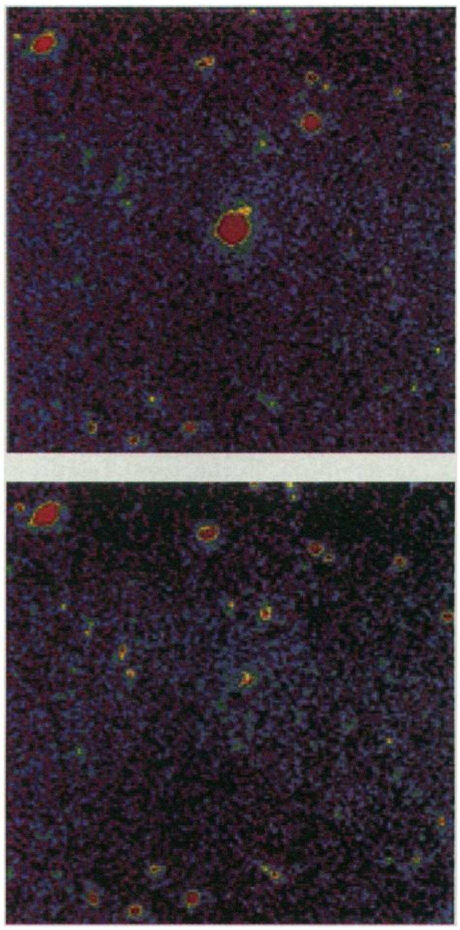
Is the Most Distant Galaxy a Star Factory?

Astronomers, like everyone else, love to set records, and a team of European astronomers has just announced a new one: the most distant galaxy yet identified. Using the European Southern Observatory's (ESO's) New Technology Telescope at La Silla Observatory in Chile, the team has obtained images of a galaxy with a redshift of 4.4. Redshift is a measure of the extent to which light from distant objects is stretched out to longer wavelengths by the expanding universe: The farther the object, the faster it is moving away, and the more the light is shifted to the red end of the spectrum. This new galaxy, which appears to have a spiral or irregular structure, beats the 4.25 redshift of the previous record-holder, known as 8C1435+635 (*Science*, 11 November 1994, p. 974).

But astronomers are excited about this new discovery not just because it provides another entry in the record books. Although the light we see from it set out when the universe was only 10% of its current age, the galaxy shows evidence that stars within it had already formed, lived out their full lifespan, and died, spilling their contents out into the interstellar gas. Sandro D'Odorico of ESO's headquarters at Garching, Germany, together with Stefano Cristiani at Padua University in Italy and Adriano Fontana and Emanuele Giallongo of the Astronomical Observatory at Rome, obtained the first images of the new galaxy, and it was quite a feat to detect its faint starlight.

The first hint of the far-off galaxy came with the discovery in 1993 of a new quasar, one of the extremely bright but mysterious objects that often have redshifts even greater than those of the most distant galaxies. A British-American group led by Cyril Hazard of the University of Pittsburgh made a search for high-redshift quasars using the Anglo-Australian Schmidt Telescope at the Siding Spring Observatory in New South Wales, Australia. Most quasars have spectra with few features, but one of the quasars they found, known as QSO 1202-07—with a redshift of 4.7, making it one of the most distant objects known—caught their attention.

Its spectrum had dark absorption lines in it, indicating that some of the light was being absorbed by a cloud of gas between the quasar and Earth. "In 1993 we observed in the spectrum of the quasar many absorption lines ... due to clouds, mainly of hydrogen, and metal



PHOTOS BY ESO

Blinded by the light. Galaxy with redshift 4.4 is barely visible on the rim of the quasar QSO 1202-07 at the center of upper image. When astronomers summed 12 charge-coupled device images, with a total integration time of 120 minutes, and processed the image to subtract light from the quasar and a nearby star, the galaxy stands out more clearly (*lower image*). Among some of the other objects in this picture may be galaxies with even higher redshifts.

lines," explains D'Odorico, who studied Hazard's results at the time. The absorption lines are redshifted too, so the astronomers could tell how far away the cloud of gas is. "This spectrum shows one very strong absorption system at a redshift of 4.4," says D'Odorico.

The astronomers had good reason to believe that this gas cloud was not wandering lonely through space, but was part of a galaxy. For a start, the absorption lines were "damped," broadened out because of interactions between photons and matter, which happens frequently in galaxies. "At lower redshifts," says D'Odorico, "these [damped] systems are usually associated with the disk of a very young galaxy."

The most prominent absorption line among those with the high redshift is known as Lyman-α and is caused by hydrogen atoms that absorb the quasar's light as it passes, knocking an electron out of the atom in the process. Such hydrogen absorption is quite common, but the spectrum contained a surprise: absorption lines of other elements, also redshifted by 4.4, including carbon, silicon, aluminum, and sulfur—an unmistakable fingerprint of stars. "These elements are definitely not caused by the primordial reactions after the big bang," says Brigitte Rocca-Volmerange of Paris's Institut d'Astrophysique. "They have to be produced by nuclear reactions in stars. And when you have stars you can talk about a galaxy."

That's the theory at least. To prove it, someone had to spot light from the galaxy itself, not an easy task when it is sitting almost directly in front of the much brighter quasar. To find the galaxy, D'Odorico and his team used ESO's newest instrument, the 3.5-meter New Technology Telescope, which has adaptive optics—the shape of its main mirror is continually adjusted under computer control to compensate for distortions caused by Earth's atmosphere. The team took a total of 20 images at different wavelengths, and when they combined the images and processed them to remove the light from the quasar, they could see a spirallike galaxy that had been partially obscured. But was it the galaxy that was responsible for the 4.4-redshift absorption lines?

One strong piece of evidence that it is the correct galaxy comes from the color distribution in its light, says D'Odorico. It does not emit much light in the blue or middle part of the visible spectrum, but is very visible in the red and near-infrared bands. "This was the crucial information for us," he says, because that spectral distribution is exactly what galaxy models indicate a galaxy's colors would look like at a redshift of 4.4.

George Djorgovski of the California Institute of Technology is not yet convinced, however. Djorgovski led a team that independently identified the galaxy at infrared frequencies with the 10-meter Keck telescope at Mauna Kea in Hawaii. "I obtained the image first in the infrared. But we didn't know at what redshift the galaxy is, and we still don't know," says Djorgovski. He thinks it is premature to say that this particular galaxy has a redshift of 4.4: "All we know is that there is an absorber, and that absorber probably is a galaxy. You can make a leap of faith and say this picture is the galaxy causing the absorption. This is possible, but not certain; there are other absorption systems in the spectrum of the quasar."

To be 100% sure that the imaged galaxy is the one that is doing the absorbing at a redshift of 4.4, the European astronomers are now hunting for the companion to the hydrogen absorption line in the quasar spectrum: a Lyman-α emission line in the spectrum from the galaxy. This occurs when atoms of interstellar hydrogen gas, ionized by young hot stars, regain an electron and emit a photon at the Lyman-α wavelength. Finding a strong Lyman-α emission line that is also at a redshift of 4.4 would indicate that the galaxy is really associated with the absorbing hydrogen cloud. So far, however, the astronomers have not been able to get enough light from the galaxy to obtain a spectrum showing the Lyman-α emission line. "Spectroscopy is very difficult because of the vicinity of the bright quasar," says D'Odorico.

The ESO team will try during the next few months to find the galaxy's Lyman-α line using the Keck telescope. If they succeed, it will be a major step, because relatively little is known about galaxies with strong Lyman-α emission. Says Hazard: "We don't have any details about an optical object which is definitely a damped Lyman-α system. If this thing could be pinned down as the galaxy, that would be really interesting, and this could lead to a very fruitful investigation."

–Alexander Hellermans

Alexander Hellermans is a science writer based in Amsterdam, the Netherlands.

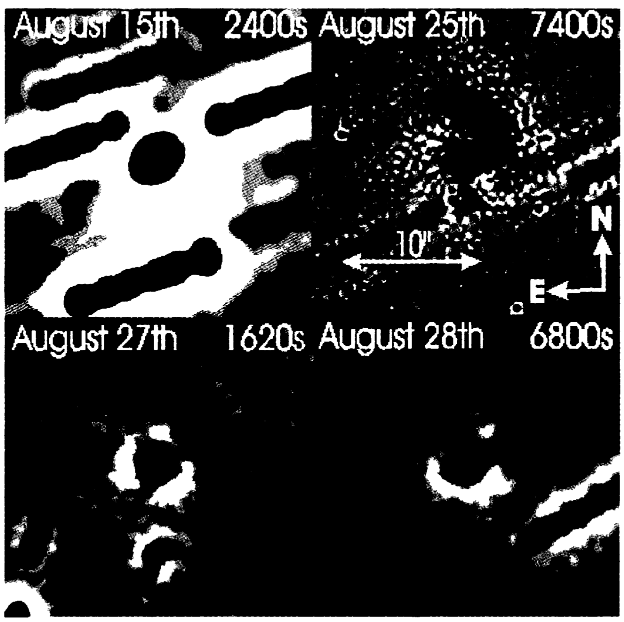
PLANETARY SCIENCE

Is Hale-Bopp the Next Great Comet?

If there were comet-watchers on Jupiter, they would be enjoying the view just now. Comet Hale-Bopp, named after the two amateur astronomers who independently discovered it on 23 July, is blazing away beyond the orbit of Jupiter 25,000 times more brightly than comet Halley did when it was at the same distance from the sun. If Hale-Bopp continues to brighten as rapidly as most comets do as it swings in toward the sun, it could put on a spectacular show around the time of its closest approach in March and April 1997. Solar heating could then drive off enough gas and dust from the "dirty snowball" at the comet's heart to make it as bright as some of the brightest stars in the sky or even as bright as Jupiter.

But Hale-Bopp's early brilliance could be deceptive. The discovery earlier this month of water ice in the cloud of dust surrounding the nucleus, reported on 9 September by John Davies of the Joint Astronomy Center in Hilo, Hawaii, and his colleagues, makes it risky to extrapolate from the present brightness, warns comet observer David Jewitt of the University of Hawaii. The highly reflective ice is boosting the comet's brightness now, Jewitt says, but a year from now, when the comet gets too close to the sun for ice particles to survive in the cloud, the comet's brightness will depend on how much of its darker mineral dust it puts out, something "we don't know how to predict," says Jewitt. "I've been telling people they should be optimistic but not too surprised if it's a dud."

–Richard A. Kerr



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