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

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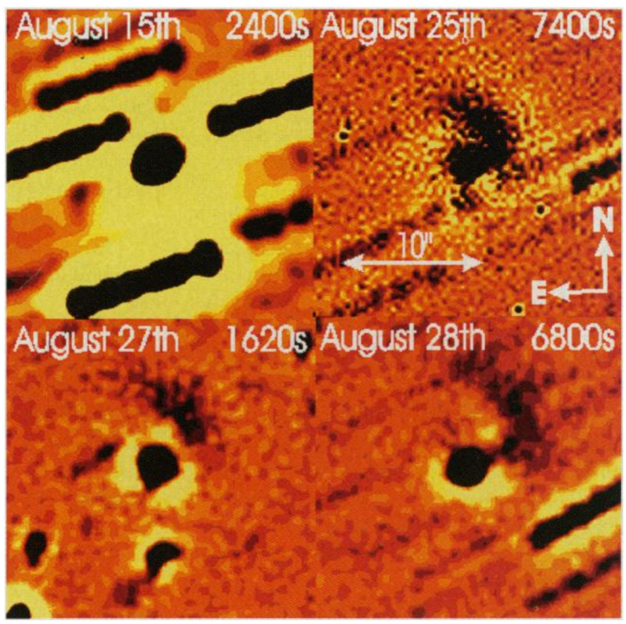
PLANETARY SCIENCE

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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