The Farthest Galaxies: A New Champion

A survey of high red shift radio galaxies, which are the first cousins of quasars, has uncovered a galaxy called 4C41.17 that is roughly 15 billion light years away

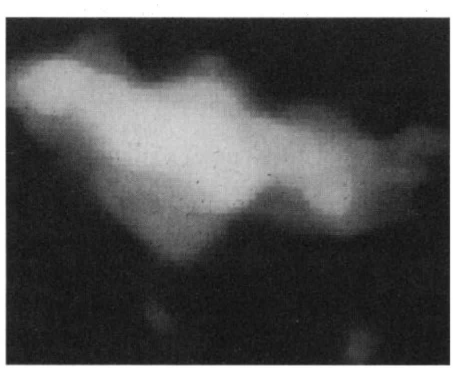
IN ASTRONOMY, as in the sports world, records are made to be broken. Witness the ever-changing title of Most Distant Galaxy: only a few years ago the record holders barely made it to a red shift of 1, corresponding to a distance of roughly 10 billion light years. And yet by 8 August, when a new champion was announced at the Baltimore meeting of the International Astronomical Union,* the winning red shift had risen to 3.8—a figure corresponding to a distance of some 15 billion light years and a time just a few billion years after the Big Bang.

The discovery was made during the thesis work of Johns Hopkins University graduate student Kenneth Chambers, who was working in collaboration with George Miley of Leiden University and Wil van Breugel of the University of California, Berkeley. (Miley has been stationed near Hopkins at the Space Telescope Science Institute by the European Space Agency.)

Of course, as Chambers is the first to point out, the competition for Most Distant Galaxy was a little one-sided in this case. "This is *not* an ordinary galaxy," he says. Quite the contrary: 4C41.17, as it is known, is a radio galaxy, which means that it is one of the most intrinsically powerful radio emitters in the universe. Flanking the central galaxy are the primary sources of the emissions—two lobes of magnetically confined plasma, each one millions of light years in extent, and together containing a total energy equivalent to more than 10 billion supernovas. These lobes, in turn, are thought to arise from back-to-back jets of material shooting outward at relativistic velocities from the galaxy's central powerhouse: a multibillion solar-mass black hole, the size of our solar system, hidden in the galaxy's core.

By no coincidence, says Chambers, this black hole model is exactly what theorists have proposed for the central engine of quasars, Seyfert galaxies, and other "active" objects.† Even though radio galaxies as a group seem to lack the quasars' extraordinary optical luminosity—in optical telescopes the nearby specimens most often look like conventional giant elliptical galaxies—there is a general belief in the astronomical community that all active galaxies are just different manifestations of the same phenomenon. And that, in turn, is why Chambers, Miley, and van Breugel happened to be surveying distant radio galaxies in the first place: "In some sense, all active galaxies are the same," says Chambers, "but *these* don't have bright nuclei. And that's great, because you can see the galaxy itself," without having to stare into a cosmic searchlight. So in principle, a study of distant radio galaxies ought to provide important clues to the origin and development of active galactic nuclei and their surrounding galaxies alike.

The basic strategy that Chambers, Miley, and van Breugel followed in their survey was to start with catalogues of known radio sources—the "4C" designation stands for the Fourth Cambridge catalogue compiled back in the 1960's, for example—and then look for the ones whose radio emissions fall off most rapidly with frequency. Phenomenologically, says Chambers, a steeper slope to this falloff tends to mean a higher intrinsic luminosity. So if you see a very steep spectrum in a source that looks very faint, then it is probably an energetic source that happens to be very far away.



A radio giant. *In this image of 4C41.17, taken at the red-shifted Lyman-alpha wavelength of ionized hydrogen, the galaxy is mysteriously extended along the line of its radio lobes.*

This first step was carried out at the Very Large Array of radio telescopes near Socorro, New Mexico, says Chambers. The result was a list of promising candidate sources that he, Miley, and van Breugel then took to Kitt Peak National Observatory, where they attempted to find visual counterparts to each source using long time exposures at the observatory's 2-meter optical telescope. In many cases they were successful; 4C41.17, for example, showed up as a blob about 8 arc seconds in diameter.

Finally, the three astronomers took their list of surviving candidates back to the Kitt Peak 4-meter telescope this past spring in an attempt to obtain optical spectra and thus red shifts.

"Each stage took a year," says Chambers. But it was worth it: not only did the astronomers find the astonishingly high red shift of 4C41.17, but they found seven more radio galaxies with red shifts greater than 2. "Up until a year ago you could only find radio galaxies out to a red shift of about 1.8," says Chambers. "So this has turned out to be a really productive way of studying these systems."

One conclusion that he and his colleagues have come to already is that radio galaxies show strong evidence of evolution, which is bad news for the oft-expressed hope that distant radio galaxies could be used as "standard candles," cosmic benchmarks to calibrate the overall expansion rate of the universe. At the (red-shifted) Lyman-alpha wavelength of ionized hydrogen, for example, 4C41.17 shows evidence for a faint halo of hydrogen stretched out for about 1 million light years in the direction of the radio lobes. Radio galaxies closer to Earth show no such thing. "What is it?" asks Chambers. "That's an outstanding question. Is it being ionized by stars? Is it being ionized by the active nucleus? Certainly nothing is coming out of the nucleus in our direction." One of the group's top priorities for future research on 4C41.17 is to analyze the dynamics of surrounding gas.

Meanwhile, of course, one has the question of how many more galaxies like 4C41.17 exist out there. The currently popular "cold dark matter" model of galaxy formation is consistent with there being a few such giant galaxies at red shifts around 4. But the model will be in quite a bit of difficulty if observers start finding lots of galaxies at high red shifts.

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*The 20th General Assembly of the International Astronomical Union, 2 to 11 August, Baltimore, Maryland.

†A quasar's luminosity is thought to arise from material falling into the central black hole: just before the material disappears, friction and compression push its temperatures so high that a substantial fraction of its mass is converted into radiation.