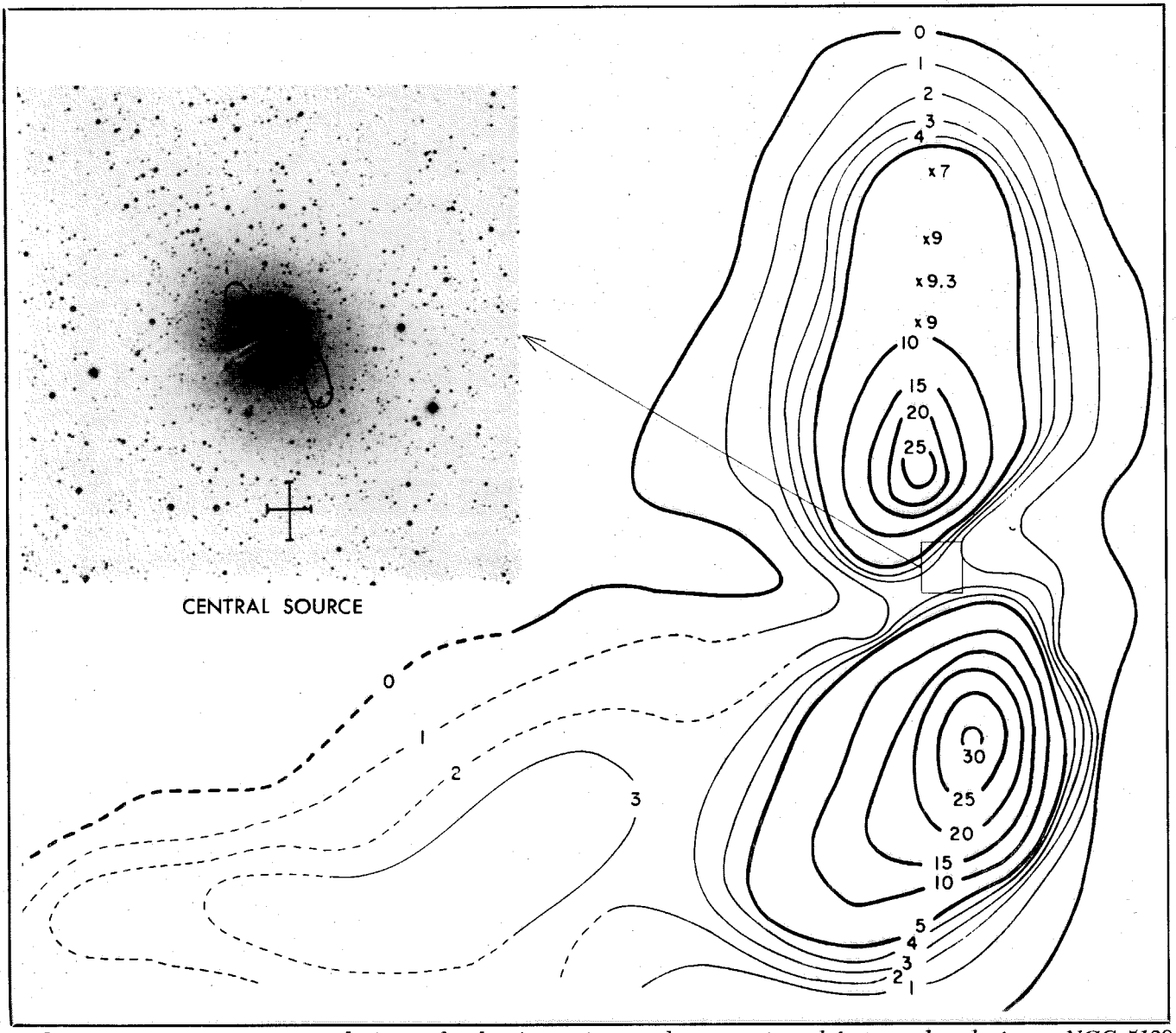


*Radio astronomers receive signals from clouds of cosmic ray electrons ejected from such galaxies as NGC 5128 (left). Ellipses indicate position of the two inner components of the radio source. Crossbars show allowable margin for error in positioning the radio source. In outer radio structure (right), numbers give strength of radio emission.*

# Radio Galaxies

— *the most powerful source of radio signals yet found in the universe*

Caltech astronomers have found, in recent studies on 24 radio galaxies, that these invisible sources of radiation from space are the most powerful objects yet found in the universe. One of the strongest of these radio sources, Cygnus A, which is half a billion light years away, has an output of 40 billion billion billion billion watts—which is equivalent to the energy radiated by 20 billion suns.

Using the twin, 90-foot dishes at Caltech's Radio Observatory in Bishop, California, as an interferometer, astronomers found that, in most cases, radio emission comes from two immense, optically-invisible clouds of gas that are associated with an optically-visible galaxy. Usually the visible galaxy, an island of stars like our Milky Way Galaxy, is located *between* the two invisible clouds.

In their study of these objects, radio astronomers Per Maltby, Thomas A. Matthews and Alan T. Moffett first mapped the locations and outlines of the clouds. Then they superimposed the radio maps on photographs of the regions of the sky from which the radio emission was known

to come. They found that usually one and occasionally two or more galaxies were located somewhere between each pair of clouds.

Spectrum studies by other astronomers, using the 200-inch Palomar telescope, indicated that the main optical galaxy was usually highly excited and displayed signs of a recent catastrophic disturbance.

Once these double sources of radio energy were associated with one or more galaxies, astronomers used the red shift of the galaxy to measure its distance from the earth. The farther a galaxy is from the earth, the greater the shift of its spectrum toward the red, or longer, wavelengths. Drs. Maarten Schmidt and Rudolf Minkowski (now retired) of the Mt. Wilson and Palomar Observatories determined most of the red shifts of the radio galaxies.

When their distances are known, the size of the radio clouds and the power of their radiation can be calculated.

The sizes of the clouds and the distances between them vary considerably. There may be as much as two million light years between the outside edges of a pair of clouds, and they may be many times larger than the visible galaxy. It seems that the farther apart the clouds are, the larger they are. This suggests a pattern which could be caused by enormous explosions.

Cosmologists Geoffrey Burbidge of the University of California in San Diego, Fred Hoyle of Cambridge University in England, and William A. Fowler of Caltech, are interested in how the enormous energies required for radio galaxies are generated. Dr. Burbidge believes that a chain reaction of thousands of exploding stars can cause it. Dr. Fowler and Dr. Hoyle suggest that a super star, millions of times more massive than the sun, may form and then explode in a galaxy's nucleus, ejecting vast amounts of matter beyond the galaxy which form the clouds.

Astronomers once thought that radio galaxies formed when two normal galaxies happened to collide accidentally. This theory has now been discarded because it appears that a galactic collision cannot possibly supply enough energy to make the observed radio clouds. Also, the fact that only one galaxy has been found in many of the radio sources cancels out the collision theory. Astronomers consider the radio galaxy to be a short-lived object which lasts probably a million years before it gradually fades away.