# RADIO ASTRONOMY

**The 200-inch Palomar telescope and the 100-inch telescope on Mount Wilson collaborate with the radio telescope to investigate "radio stars."**

THREE SOURCES of "radio noise" in the cosmos have been identified. after months of study. by the 200-inch Hale Telescope at Palomar and the 100-inch Hooker Telescope at Mt. Wilson. working in collaboration with one of the world's newest tools of astronomical research. the radio telescope.

Announcement of the discoveries was made last month by the Carnegie Institution of Washington and the California Institute of Technology. which jointly operate the Mount Wilson and Palomar Observatories.

Two of the sources identified appear to be turbulent gas clouds in the Milky Way. and the third the scene of a collision on a scale so gargantuan that it could occur only beyond the borders of our own galaxy and out in space. The identifications were made by Drs. Walter Baade and Rudolph L. Minkowski. staff members of the Observatories. working in close international co-operation with the active radio research centers in England and Australia.

The astronomers have identified the two outstanding radio sources so far discovered in the heavens—Cassiopeia A and Cygnus A—and a fainter one. Puppis A. (Radio sources are named for the constellation in which they appear. with the letter indicating the relative intensity of the signal emitted. Cassiopeia A. for instance. is the strongest source in that constellation.)

Two of the three newly identified objects—Cassiopeia A and Puppis A—are in our galaxy: Cygnus A is definitely outside it.

Cassiopeia A coincides with the center of a remarkable emission nebula. or galactic gas cloud. This is not just a quiet cloud suspended motionless in space. as are most of the galactic nebulae. It contains many filaments having highly random motions. like a crowd milling about. but at speeds of about 31 miles (50 kilometers) per second. and the filaments themselves apparently are in a high state of internal turmoil.

Spectrographic evidence secured by Dr. Minkowski indicates that the velocities of atoms within one filament vary over a range of roughly 1,800 miles per second. There is no evidence. however. to show that the nebulosity as a whole is blowing up. Hence. he says. the pattern of this peculiar nebula is almost the opposite of a supernova. or exploding star. in that the nebula formed by a supernova expands rapidly while the random motions within that nebula are minor.

## A sizeable discovery

The optical diameter of the emission nebula coinciding with Cassiopeia A is roughly 5.4 minutes of arc. While this is about one-sixth of the moon's diameter. the Cassiopeia A nebula is at an enormously greater. though undetermined. distance from us than the moon. and consequently our entire solar system would merely be a pinpoint in it. The optical figure agrees closely with subsequent radio measurements at the Cavendish Laboratory and the University of Manchester. England.

At the position given for Puppis A. a relatively weak radio source. Dr. Minkowski has found another mass of peculiar filaments in an emission nebula. The condi-

CONTINUED ON PAGE 36

tions existing in these filaments are very similar to those in the Cassiopeia source but on a much smaller scale.

Cygnus A is located about 100 million light years, or 600 million million million miles away. This source coincides with an extragalactic nebula (a large stellar system like our Milky Way, but outside it) which is the brightest member of a great cluster of nebulae.

The structure of this spiral object, says Dr. Baade, appears to make sense only if he assumes that he is dealing with two extragalactic nebulae in actual collision. The radio emitter at the scene of this mammoth collision has a power of about 400,000,000,000,000,000,000,000,000,000,000 kilowatts. This is trillions of quadrillions of times more powerful than all the radio stations on earth put together.

## Spectrographic findings

If red shifts in the spectrum of this source represent velocities of recession, as many astronomers believe they do, the source is moving away from us at more than 10,000 miles per second.

Spectra obtained by Dr. Minkowski at both the 100- and 200-inch telescopes suggest that something highly unusual is going on at the source of Cygnus A. They are emission spectra indicating high atomic excitation which would be characteristic of colliding gases.

Significant in the spectrum are lines traceable to neon V, a form of neon from whose atom four outer electrons have been stripped. This extreme stripping, or ionization, can occur only at very high energy atomic collisions, in which the atoms involved are traveling at speeds greater than 620 miles per second. The spectrographic findings thus support the assumption of a nebular collision.

## A new field of astronomy

Optical telescopes and their auxiliary devices for study of astronomical bodies are sensitive to radiations from stars and other objects which are in the visible or near-visible range—that is, to light whose wave length is anywhere from about one- to four-100 thousandths of an inch.

With the advent of radar during the second world war, new short-wave radio receivers were developed, which are sensitive to electromagnetic radiations in the range from a few twenty-fifths of an inch to a few yards in wave length. Radio men call these the "microwave" and the "very high frequency" ranges. The general range of wave lengths in the ordinary broadcast beam is about a quarter of a mile.

Before the war a few investigators had picked up radio signals coming from the general region of the Milky Way. When the new ultrasensitive short-wave receivers were directed to the sky it was found that radio waves were reaching the earth from the sun and from out in space in all directions. This opened a whole new field of astronomy—the systematic investigation of radiations in the radio range coming from a large number of relatively small sources in the heavens. These sources were called "radio stars" for want of a better name, although scientists engaged in radio astronomy research did not maintain that they actually were stars.

Astronomers recognized the great importance of identifying a radio source with a known object in the sky. This would make it possible to correlate the data gained from radio observations with those derived by the ordinary optical methods. Thus we would increase our understanding of how the object in question behaves and what are its properties.

The ratio of reflector diameter to wave length in an optical telescope is so large that it permits the precise location of an object in the sky. But radio telescopes have a much smaller ratio because radio waves are so much longer than those of light. Hence the determination of the position of a radio source is necessarily less accurate.

## Collaboration

The Mount Wilson and Palomar Observatories are equipped only for optical, and not for radio observations. But they early became interested in the optical correlations with radio astronomy, partly because one of the first objects identified as a radio source was the Crab Nebula. This remnant of a supernova—a giant stellar explosion which occurred in the year 1054—had been investigated extensively with the optical instruments on Mount Wilson just before the last war. A few other radio sources also were identified by radio astronomers during the past several years.

The two strongest sources, however, had not been identified and it was these that Drs. Baade and Minkowski set out to find. They arranged with Australian and English radio astronomers to supply them with the locations of these and other relatively accurately located sources.

Though the accuracy with which such determinations can be made is rather low, auxiliary methods can improve this accuracy for a few exceptionally strong radio emitters. And about two years ago a radio group at Sydney, Australia, under Dr. E. G. Bowen, found that many of the strong radio sources are not stars at all, but rather, they are extended objects whose diameters are measurable.

This latter fact makes a positive identification possible—if it can be shown that the radio and optical diameters agree and that the position of the astronomical object coincides with that of the radio source within the error of measurement of that source.

By these two yardsticks, and with spectrographic evidence, Drs. Baade and Minkowski have now identified Cassiopeia A, Cygnus A, and Puppis A with objects in the heavens.