RESEARCH NOTES

A NEW DIMENSION—QUASARS

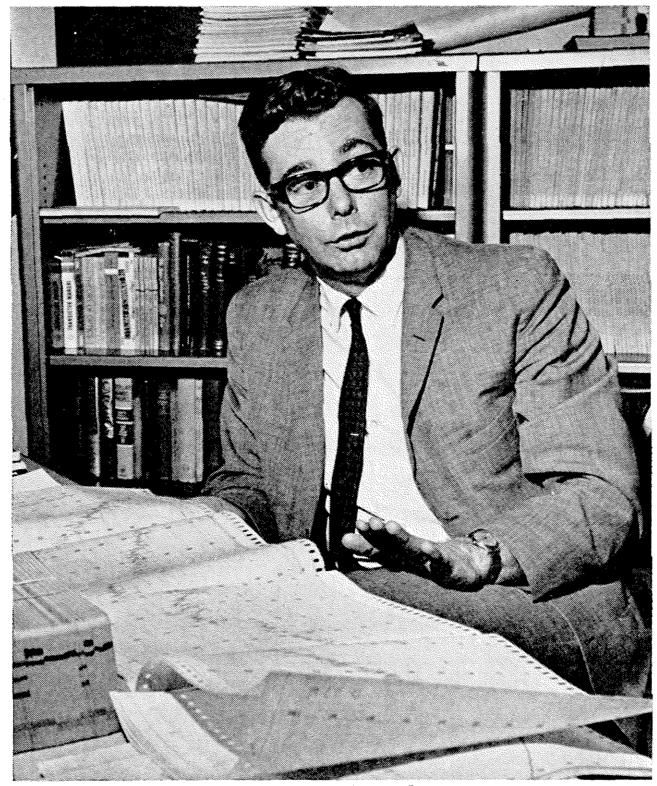
New evidence gathered by Caltech astronomers indicates that the size of the nuclei of quasars is much smaller than earlier studies showed—perhaps only one-hundredth the diameter that was previously estimated.

The new calculation is part of a tentative picture of quasars that is gradually emerging. Quasars, which are the brightest and probably the most distant known objects in the universe, are believed to consist of an immensely bright nucleus surrounded by an envelope of hot, luminous gas, perhaps in cloud form, that is at least 100 times larger than the nucleus itself.

The revised estimate of the diameter of the nucleus is based on observations by J. Beverley Oke, staff member of the Mount Wilson and Palomar Observatories and professor of astronomy at Caltech. He noted marked fluctuations of light, within 24-hour periods, on quasars 3C-279 and 3C-446. Because the velocity of light is finite, if a fluctuation occurs in a period as short as one day, then the source cannot be much more than a few "light days" in diameter. A light day is 16 billion miles, or the distance light travels in one day at the speed of 186,000 miles a second.

Dr. Oke estimates that, although the nucleus of each of the two quasars, 3C-279 and 3C-446, has a diameter only one-millionth as large as the diameter of a galaxy of a billion stars, that nucleus may be 100 times brighter than such a galaxy. How so small an object can produce so much light is still a mystery.

Dr. Oke made his discovery while conducting a survey of quasars whose light is known to fluctuate during intervals of months or years. He determined that 3C-279 increased or decreased in brightness by 25 percent within 24-hour intervals and that 3C-446 grew dimmer for several days at the rate of 10 percent per day. Last year Allan Sandage, staff member of the Mount Wilson and Palomar Observatories, discovered an increase in the brightness of 3C-446 of 20-fold. 3C-279 has changed in brightness six- to seven-fold over the past two years.



Astronomer J. Beverley Oke

Dr. Oke also found that whereas the nuclei of 3C-279 and 3C-446 varied markedly in brightness there was no corresponding variation in the light from the glowing clouds of hot, tenuous gas that envelop them. The enveloping clouds must, therefore, be much larger than the nucleus. Dr. Oke estimates the temperature of the clouds to be about 40,000° F. and their total mass to be at least one hundred thousand to a million suns. Photographing a quasar through a big telescope will not give a picture of the nucleus and its cloud halo. Optically, the objects appear as faint point images. Detailed observations are spectroscopic, and, in his survey, Dr. Oke uses a photoelectric spectrum scanner with the 200-inch Palomar telescope. The scanner, which he developed, measures light intensity very precisely and counts photons—the smallest units of light—one by one.

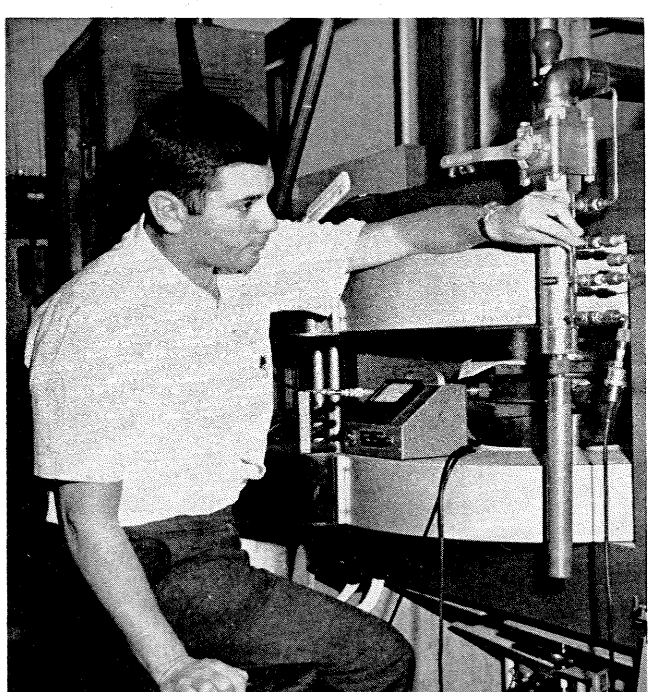
Dr. Oke's survey of quasars may help astronomers determine the size and shape of the universe and give them new insight about its early history.

A NEW POSITION—SHOCK WAVES

A major problem that has hampered experimenters in high-speed shock wave research—the inability to produce a shock wave in an electromagnetic shock tube that would travel *in front of* the current sheet used to drive it—has been explained by a Caltech graduate student in aeronautics, Alan Hoffman.

The electromagnetic shock tube has been in use in the laboratory for more than ten years. To produce a shock wave in the tube, several capacitors are discharged. These capacitors deliver an enormous amount of electricity for a very short time (hundreds of thousands of amperes for a few millionths of a second) through a conductor surrounded by a half-inch-diameter insulator located in the middle of a 10-inch-diameter cylinder containing a gas. The electrical discharge forms a current sheet around the outside of the insulator and expands outward into the tube at a speed of about 10,000 miles per hour. Researchers had expected this sheet of electrons to push the gas ahead of it and form a shock wave. Caltech experimenters found that the wave stayed within the current sheet. When they tried to remedy the situation by increasing the speed at which the sheet was driven, the shock wave formed at the rear.

"It was as if the shock wave was being dragged along," Hoffman says. "We needed to get the wave in front of the current sheet so that we could study the hot, ionized gas that forms between the two."



Alan Hoffman, Caltech graduate student in aeronautics, uses the Inverse Pinch electromagnetic shock tube to solve a puzzling problem involved in the creation of high-speed shock waves.

The shock tube used in the recent Caltech research, an Inverse Pinch, was designed and built in 1962 by Hans W. Liepmann, Caltech professor of aeronautics, and his students. Although it has been used successfully for some aspects of shock wave experiments, the problem of why the wave never *preceded* the current was, until Hoffman's recent work, never quite clear.

An analysis of the problem, which led to the solution, was made possible by the simplicity of the Inverse Pinch. Other types of electromagnetic shock tubes did not permit engineers to recognize that the problem even existed because they did not use pressure probes to locate the shock position within the current sheet. The Inverse Pinch gives a stable, reproducible, relatively thin, constant-speed current sheet—all necessary conditions for working out the position problems of the waves.

Hoffman devised a computer program to simulate the behavior of the laggard shock waves and then demonstrated that a wave could be pushed in front of the current sheet if a light gas—hydrogen—was used and if the starting speed of the current sheet was slowed to about 20,000 miles per hour. Earlier experimenters had tried to solve the problem by speeding up the rate to as high as 50,000 miles an hour. This approach had served only to complicate the problem. By driving a gas with a force field moving at supersonic speed, the Mach number—the ratio of the speed of the current sheet to the speed of sound traveling through that particular gas—is increased. However, when a gas with a higher Mach number was used, the shock wave formed further toward the rear of the current sheet.

Hoffman, by using hydrogen gas which has a high speed of sound and, therefore, a low Mach number and by driving it with a low starting speed, was able to get the shock wave started at the front of the current sheet before increasing the speed to the necessary proportions to produce the supersonic waves. Now waves can be produced that will travel at more than 100 times the speed of sound and that will move in the very front of the sheet.

The new development offers a better way to study shock waves at much higher speeds and will be helpful in the study of problems relating to the reentry of aircraft, the collision of solar wind with the earth's magnetic fields, the use of ionized gases for rocket propulsion, and plasma physics.

Perhaps one of the most significant implications of Hoffman's work is that the solution of the dragging shock waves problem indicates that fluid mechanics principles can sometimes be used to solve puzzling problems in the field of plasma physics.