Research Notes

Astronomical Association

After four years' observing, J. B. Oke and James Gunn, professors of astronomy and staff members of the Hale Observatories, recently provided a direct answer to a key astronomical question: Are quasars a separate class of object or can they be associated with ordinary galaxies? With the aid of an optical trick and a very sensitive spectrometer mounted on the 200-inch Hale Telescope, they were able to prove that the circle of fainter light around a brilliant quasar-like object named BL Lacertae is really a galaxy of ordinary stars.

For 50 years BL Lacertae has been listed in astronomical catalogs as a variable star. (In fact, "BL" signifies a variable star.) It is located in the Constellation of Lacerta (the Lizard) in the northern sky. But attempts to determine its distance have been unsuccessful by the usual methods of sorting out its light into the spectroscopic code, which describes its chemical and magnetic properties and, according to most astronomers, its distance from the earth—if it is beyond our own Milky Way.

The light from BL Lacertae did not show spectral lines even when observed with the 200-inch and the very sensitive 32-channel spectrometer designed by Oke. But at this point the optical trick changed the picture. Earle Emery, a research engineer, designed and built a tiny disk that could be mounted in a round aperture. With the disk in place in the telescope, BL Lacertae's central bright object was blocked out, and the Oke spectrometer recorded spectra of the stars that make up the outer ring.

The spectra show that the object is about a billion light years away and that its stars are typical of the older stars found in giant spherical galaxies. Indeed, the object surrounding the very bright central source has all the appearance of a normal spherical galaxy. Thus, BL Lacertae proves not to be a variable star in the Milky Way Galaxy but evidently is much further away and is itself a large galaxy with a quasar in it.

Like many quasars, BL Lacertae varies rapidly in brightness, sometimes from night to night. Flickers only two minutes in duration have been reported. The light varies eight to ten times in brightness—roughly from 13th to 16th magnitude. The variations come from the central quasar.

The rapid variability of the light (along with some direct measurements by radio telescopes) indicates that the diameter of the quasar is less than one light year. This is very small compared to the diameter of its surrounding galaxy, which is more than 100,000 light years.

In spite of being a billion light years away from earth, BL Lacertae is the nearest known quasar. In fact, if it weren't so near, and if the central quasar had not been dimmer than usual, it might not have been possible to obtain the spectra even using the disk to block out light from the central object. The quasar's brilliance might have swamped the dimmer light from its stars.

Sonic Booms

Caltech aeronautical engineers are now studying sonic booms—in the laboratory. They have an ideal tool for these studies in the 17-inch shock tube in the Graduate Aeronautical Laboratories.

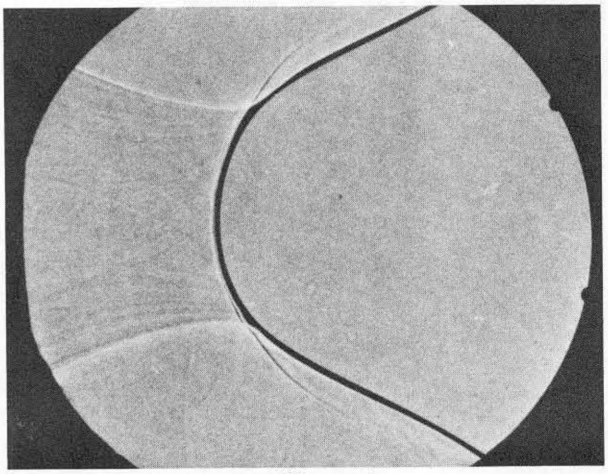
Measurements of sonic booms have been made in the field for some time, of course. The Air Force has flown airplanes at supersonic speeds over Oklahoma City, for example, measuring the sonic booms they create, and studying the effects of the boom; and the French government has sponsored a program in which airplanes were maneuvered so the sonic booms tended to concentrate or focus. But the Caltech studies of focused sonic booms are the first to be made in the laboratory, under controlled conditions.

When sonic booms are focused, they can cause plenty of damage. Abnormally strong and damaging sonic booms are occasionally experienced after the overflight of supersonic aircraft—due perhaps to focusing caused by such aircraft maneuvers as accelerations, dives, or turns, or perhaps due to certain atmospheric effects. One spectacular sonic boom, caused by a jet plane flying in formation over the Air Force Academy in Colorado Springs in 1968, blew out more than 2,000 windows.

This kind of accident has encouraged researchers to study ways of predicting the pressure that a focused sonic boom, called a "super boom," would create.

In Caltech's 17-inch shock tube, Bradford Sturtevant, professor of aeronautics, and Vijay Kulkarny, research assistant, are able to create an idealized situation similar to a sonic boom coming into a valley. As the boom, or shock wave, moves down the 80-foot tube, it meets a parabolic reflector. As with light waves, the reflector—or mirror—focuses the sound waves. The Caltech researchers want to know what happens to the sound waves near this focal point—and, in the process, perhaps find out just how strong a sonic boom can get.

Photographing a Sonic Boom



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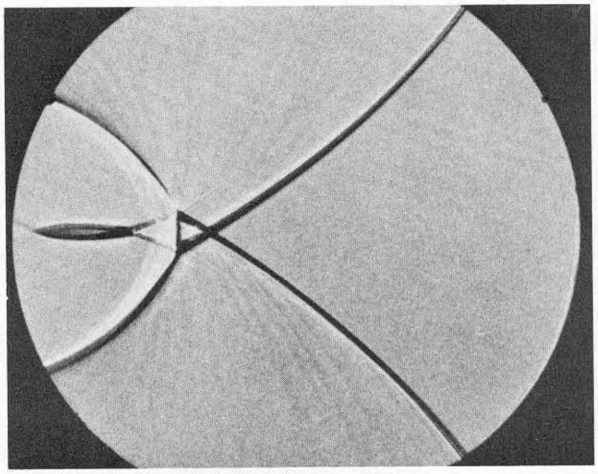

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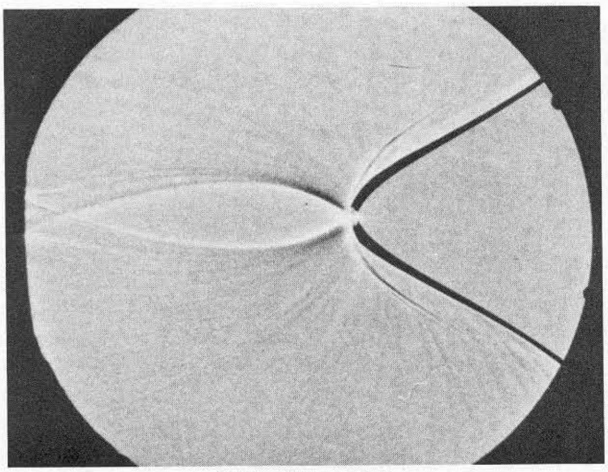

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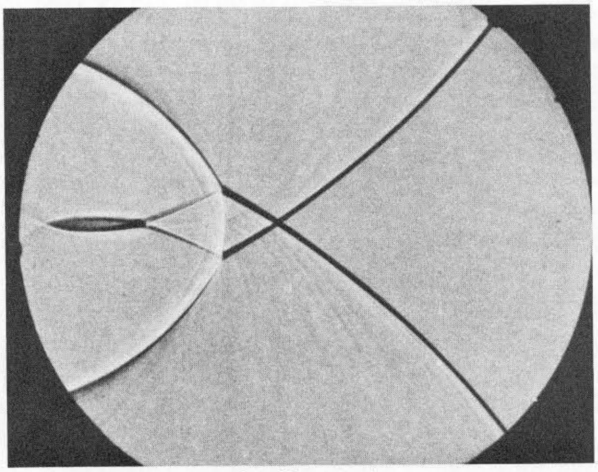

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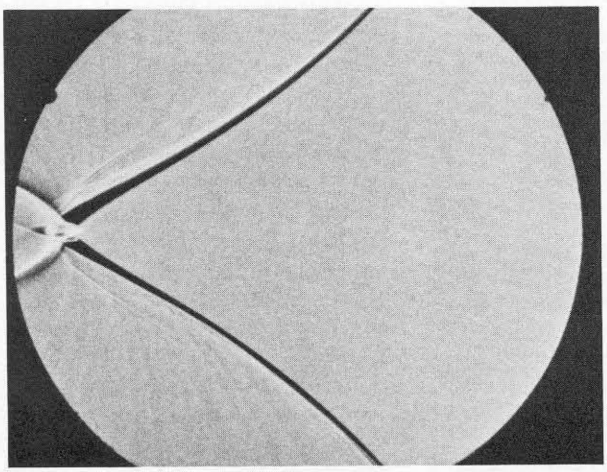

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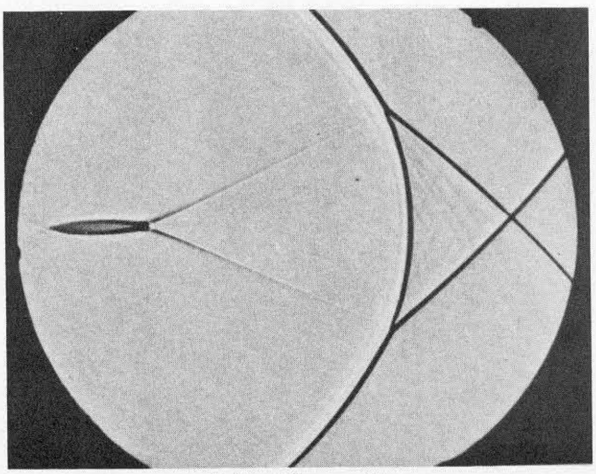


0.19 milliseconds

0.0 milliseconds—In the shock tube in Caltech's Graduate Aeronautical Laboratories, a shock wave comes in from the right, meets a curved wood surface, and is reflected back (black lines). The white lines at the left, behind the reflected wave, are diffracted waves; the upper one is traveling downward, the lower one is traveling upward.

0.05 ms—The shock wave is closer to the focus. The diffracted waves have crossed each other so that the one that started at the top is now on the bottom.

0.08 ms—The shock wave is at the focus. A hot blob of gas has begun to appear at the left.

0.11 ms, 0.12 ms, 0.19 ms—The shock wave is coming out of the focus, leaving the gas that was heated at the focus behind.

Riddle of the Rings

The bright rings around the planet Saturn may be made of ice, or even ice-coated chunks of iron. This is the tentative report of two Caltech radio astronomers, Duane Muhleman, professor of planetary science, and Glenn Berge, senior research fellow in planetary science and radio astronomy.

The combined information they get from radio signals, radar echoes, and infrared light observations suggests that whatever these chunks are in Saturn's rings, they at least have a layer of ice on them. So it's a strong possibility that the rings are made up of water ice.

It's also possible—but much less likely—that the rings consist of small bits of iron, covered with frost.

The Muhleman-Berge team has been studying radio signals from Saturn since 1965, using the big dishes at Caltech's Owens Valley Radio Observatory near Bishop, California. Similar work done by F. H. Briggs of Cornell University tends to strengthen the ice conclusions. Briggs did his observing with radio instruments at the National Radio Astronomy Observatory in Green Bank, West Virginia.

Right now the scientists have a massive amount of data which may tell them—when it's all processed—something about where in the rings the radio flux is coming from.

If the rings of Saturn were just thin, tenuous layers of gas, even thousands of kilometers thick, scientists wouldn't expect to see radio emissions. Early measurements of Saturn's radio noise indicated that at least 90 percent of the emission came from the planet itself, with the remaining 10 percent or less coming from the rings.

As the experiments progressed over the years the men also began to find that there are no radiation belts around Saturn like those found at Jupiter. This means one of two things. Either the planet has no significant magnetic field, or there are no high-energy particles there. One or the other is apparently missing. A radiation belt around a planet—such as those found first around the Earth, then around Jupiter—is made up of high-energy particles such as electrons and protons that are trapped in the magnetic field of the planet. It seems likely that Saturn does have a magnetic field, however, because it is a huge planet that is similar in most important ways to Jupiter.

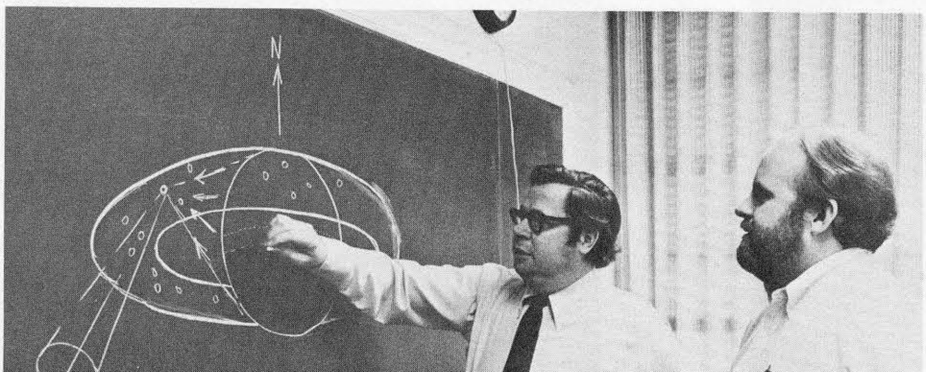
As for the high-energy particles, the scientists think the rings of Saturn probably soak them all up. In later observations there was definite evidence that about 5 percent of the radiation was coming from the rings.

Radar observations of Saturn and its rings have also been carried out by Richard Goldstein of Caltech's Jet Propulsion Laboratory, who is a research associate in planetary science on the campus. Goldstein did his work with JPL's big dish antenna at Goldstone, California, and got strong radar echoes back that have to come from the rings of Saturn, Muhleman believes. At the same time the radio response of the planet itself is peculiar. Saturn doesn't give the usual response of a circular, uniformly bright planet.

Putting their observations together with Goldstein's, Muhleman and Berge decided that a large fraction of the particles in the rings must be at least five centimeters in diameter to yield the radar echoes. This means that the ring particles are of sufficient size and number to block the planet's disk—to cast a shadow across the radiation we see coming from Saturn. This would explain the planet's peculiar radio response.

If the particles are big enough and plentiful enough to block emission from the planet, then we should be seeing scattered Saturn radio emission from everywhere around the rings—and this is what Muhleman and Berge think they do see.

The radiation being recorded from the rings, amounting to about 5 percent



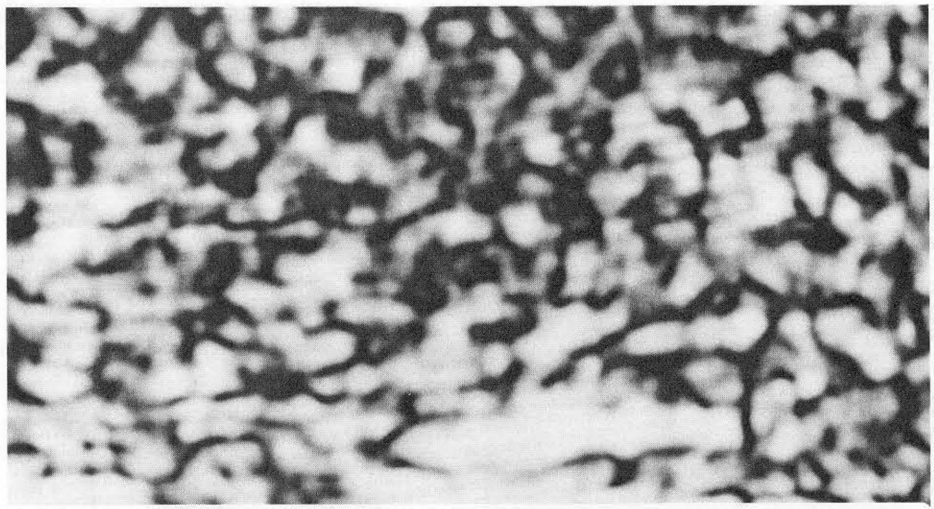
Interpreting masses of data from nearly ten years of observing and analyzing radio signals from Saturn is no easy task, but Duane Muhleman and Glenn Berge think they can conclude that the rings around the planet may be made up of chunks of ice that do not emit radiation themselves but bounce off signals emitted from the planet.

of the total, is scattered radiation; that is, the signals are emitted by the planet but bounced off the particles in the rings. But it is not clear yet whether the researchers are seeing the whole ring or some sort of internal structure. Their interpretation is that there's probably no radio emission from the rings themselves, just radiation that bounces off the ring materials.

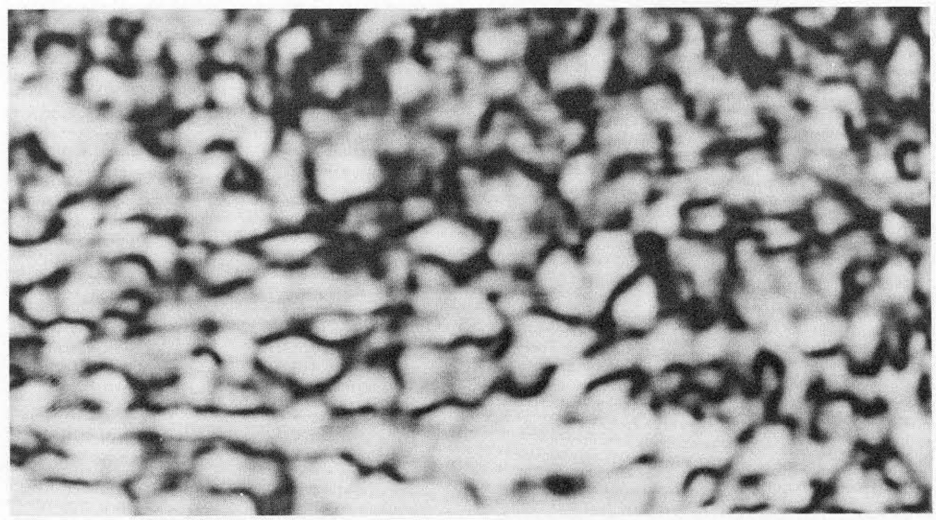
Since the size of the particle tends to govern what kinds of radiation will be seen, this conclusion says a lot about the particles in the rings. If the ice in the rings is in chunks bigger than about three and a half meters in diameter, there should be radiation at radio wavelengths—but there isn't. This means that a size boundary can be put on the ice particles—bigger than five centimeters but smaller than four meters.

This doesn't mean that there are *no* large chunks, but if there are big ones, they are not doing the job of radiating the signals.

Work at the Massachusetts Institute of Technology indicates through infrared observations that water ice is present in the rings, which suggests that, whatever these chunks are, they must have at least a layer of ice on them. The possibility of iron particles cannot be dismissed since they would also be excellent scatterers and very poor radio emitters.



A pattern of bright spots appears about the direct beam of a laser that is passed through a vial of large spheres suspended in water. This pattern of continually moving, twinkling spots is produced by the Brownian motion of the spheres.



A photograph taken just a few seconds later shows a changed pattern. The twinkling time of the areas of light is related to the diffusion coefficient of the spheres. The same principle applies to liquids and liquid mixtures and has been used to study diffusivities.

Light-Mixing Spectroscopy

Because the structure of liquids is so complex, coming to an understanding of their properties and predicting their reactions has been a notoriously unreliable, laborious, expensive, and time-consuming process. Methods in current use often require large quantities of material and weeks of experimentation.

Recently, however, C. J. Pings, professor of chemical engineering and chemical physics, and two of his graduate students, Ronald Brown and Erdogan Gulari, have developed a new method of determining two properties of liquids —the rate at which they mix (the diffusion coefficient) and the rate at which heat flows through pure liquids (the thermal diffusivity). This new technique, which is known as light-mixing spectroscopy, has several advantages over older methods. It is more accurate, it uses very small quantities of liquids, and it produces precise values in as little as 15 minutes to two hours.

Light-mixing spectroscopy is based on the fact that when a beam of light shines through a liquid some of the light will be scattered. Localized differences in temperatures and composition (due to the random thermal motion of the molecules in the liquid) slightly alter the frequency—that is, the color—of the scattered light. In time, these localized inhomogeneities dissipate by diffusion, and this gradual loss is detectable by light-mixing spectroscopy. The size and shape of the resulting distributed spectra are directly related to the liquid's transport properties.

The frequency shifts predicted by scattering theory are less than one part in one hundred trillion—a ratio that made it necessary for Brown and Gulari, under the supervision of Pings, to design and build a spectrometer a million times more sensitive than conventional ones. The system achieves this enhanced sensitivity by comparing the spectral curve of the light beam with that of a beam that has not penetrated the liquid. The new spectrometer is made up of an argon ion laser, a transparent cell that holds about four ounces of whatever liquid is being checked, and a photomultiplier tube plus instruments that analyze the current from it. The highly directional, monochromatic laser light beam is directed through the cell containing the sample fluid. The phototube then detects the light that is scattered by the sample. The resultant current from the phototube mirrors and amplifies the nature of the scattered light. This current is then analyzed by either a wave analyzer or a correlator, which are instruments designed to extract information from the photocurrent by generating the distributed spectra.

The technique can be used to study the motions of molecules by observing slight changes in the color of laser light passing through a fluid. Brown is currently using it to study the dynamics of closed, circular DNA in solution. In this case the scattered light yields information on the conformation and internal motion of the molecule, information that has been inaccessible by standard biophysical techniques.

Among the immediate practical applications of the new technique are the continuous monitoring and control of the stability of processes in chemical plants. It can also be used for such tasks as automatically changing heater settings and altering flow rates.

A few years ago chemical and petroleum companies built their plants sequentially. An experimental discovery in the laboratory would be followed by construction of a pilot plant to determine the feasibility of production. The next step might be a small demonstration plant with limited output. And usually it was only after this amount of trial-and-error effort that a full-scale plant was set up.

Building several generations of trial plants is, however, expensive in both time and money. Today, industry attempts to bypass these preliminary steps by having computers design large chemical processing plants on the basis of engineering measurements. For their design to be good, computers must be given very precise numbers, and that is exactly what light-mixing spectroscopy can do.

A Superconducting Alloy

New alloys are not unexpected in Pol Duwez' laboratory. In a special research project sponsored by the Atomic Energy Commission, he and his colleagues have been creating them one after another since 1960 (*E&S*, January 1966, May 1973). The most recent one, discovered by two of Duwez' students, may require extension of the theory of superconductivity.

Superconductivity, which is beginning to play a major role in the production and transmission of electric power, is a property of more than a score of metals and many alloys. At very low temperatures they lose all their electrical resistance, so that currents induced in them seem to flow indefinitely without loss of power. However, to date, this behavior has been observed in bulk metals and alloys only when the constituent atoms are arranged in precise crystalline lattice patterns. Now, William L. Johnson, a graduate student in applied physics, and Siu Joe Poon, a senior in electrical engineering, have demonstrated that a special alloy—made up of 20 percent gold and 80 percent lanthanum with their atoms in an amorphous state (jumbled randomly together)—can become superconducting.

Johnson and Poon melted the two metals together, and a drop of the resulting alloy was spilled from the crucible. An electronic eye observed the drop and triggered a pneumatic hammer that slammed the drop onto a heat-absorbing copper "anvil." There it spread out and was frozen almost instantly into a thin foil. The speed of the freezing is critical, because it doesn't give the atoms time to align themselves into a characteristic crystal pattern. With the atoms in an amorphous state, the alloy demonstrates new chemical bonding properties.

This alloy is not expected to be useful for engineering applications or superconducting materials, first because it can be obtained only in thin foils about two-thousandths of an inch thick. Second, the temperature at which the alloy becomes superconducting is very low—about 4 degrees Kelvin. It is not difficult to achieve this low temperature, but it is not practical economically to do so, since some alloys become superconducting near 20 degrees Kelvin.

"For ten years we have been looking for an amorphous alloy that is superconducting," says Duwez. "We wanted to prove that a superconductor doesn't have to have a crystal structure, and now we've done it. At this point it is of purely scientific interest, but we hope it will lead to a better understanding of one of the most fascinating properties of the metallic state." □