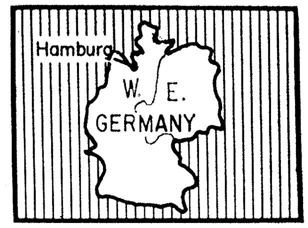
REPORT FROM EUROPE



Triennial Review of Astronomy

Hamburg. The 12th general assembly of the International Astronomical Union held here 25 August–3 September provided many signs of increased collaboration between optical and radio astronomers. The signs emerged from discussions reviewing numerous discoveries which have been made since the last general assembly in Berkeley, California, in 1961.

Dominating the discussions was the major unanswered question of how to account for the processes going on in radio sources generally, and particularly in the star-like visual-radio objects of galactic mass which have been dubbed "quasi-stellar." These objects—of which perhaps a dozen are now known—have been explored during the past two years in a collaboration between optical and radio astronomy. Discussions of these objects showed a heightened awareness of their implications for fundamental physics.

The links between astronomy and other topics of current interest to physicists also were emphasized by Leo Goldberg of the Harvard College Observatory. Goldberg reviewed the recent contributions of rocket- and satellite-borne equipment to investigations of spectra, for instance, in measurements of ultraviolet, gamma, and x-rays. He pointed to a rapid development in laboratory astrophysics, fed both by the new observations yielded by rockets and by the growth of studies aimed at understanding plasmas and the fusion process. One outcome of this work has been a good deal of speculation about the possibility that autoionizing transitions in negative ions may be a major source of opacity in very cool stars.

Noting that by means of rockets and satellites observations have been made which astrophysicists had not previously believed possible, Goldberg added that the very large rockets which will soon be available for carrying men to the moon could also carry orbiting telescopes much larger than the ultraviolet telescopes of the first Orbiting Astronomical Observatories or the 90-centimeter reflectors now being developed. "There is already an enormous gap between the size and weight of astronomical equipment planned for launching during the next few years and what can be handled by rockets that will be ready at the same time or a little later. This is an opportunity that astronomy cannot afford to ignore."

Optical and radio observations, such as the recent photographic studies of the galaxy M 82 or the radio search for clouds of hydroxyl radicals, have both contributed to a new picture of the nucleus of the Galaxy as a turbulent region. This concept was described by Jan H. Oort, who summarized data on and theories about the structure and evolution of the Galactic system.

Studies of the sun's magnetic field were reviewed by A. B. Severny of the Crimean Astrophysical Observatory. Although the average magnetic field in the sun's polar regions is only a few gauss, observations with high spatial resolution show that the field is not uniform and that there are small regions with fields of different polarities and magnitudes as high as 35 or 40 gauss.

A magnetograph at the Crimean Observatory utilizes both the longitudinal and transverse Zeeman effect to obtain a complete description of solar magnetic fields in the neighborhood of sunspot groups. Knowledge of the spatial pattern of magnetic fields permits determination of the system of electric currents in the sunspot which give rise to the fields. Severny emphasized the need for magnetographs with high spatial and time resolution and for additional theoretical work to help interpret the observational results.

At Hamburg, radio observers presented much new data on the temperature and electromagnetic environment of the planets which indicate that Mercury has an atmosphere which brings the temperature of its always-dark side to something near room temperature, that Mars may have an intense magnetic field, and that there is a layer in Saturn's atmosphere that is near room temperature.

Although the discovery of the quasi-stellar objects ranks as one of the notable advances in astronomy since 1961, the discussions of them at Hamburg showed little fundamental advance in understanding beyond what had been discussed at the special meeting on gravitational collapse held at Dallas, Texas, in December 1963.

William A. Fowler of the California Institute of Technology mentioned attempts to write equations describing how star-like objects with a mass some 10^8 times that of the sun could avoid a rapid gravitational collapse and continue for something like 10^6 years to emit huge amounts of radiation. So far, Fowler indicated, the equations indicate enormous instabilities very early in the lifetime of such objects. Hermann Bondi said that calculations by quite different methods bore Fowler out.

Harlan J. Smith of the University of Texas presented further data on the variability of radiation from quasi-stellar objects. He and E. Dorrit Hoffleit have been studying two quasi-stellar objects, 3C 48 and 3C 273, using recent photoelectric observations and old photographic plates from a dozen observatories, especially plates from the Harvard College Observatory which date back to 1886. Although Allan Sandage of the Mount Wilson and Palomar Observatory has found photoelectric evidence that the light of 3C 48 can vary as much as 30 percent over a single year (*1*), Smith reported finding no long-term photographic variation greater than 50 percent in this source. From 3C 273, by contrast, Smith noted variations over periods of

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years, a sharp drop in brightness around 1929, and probable occasional sharp variations within the 100-day periods which he had been averaging to display the longer-term variability pattern. One of the short variations amounted within 10 days to a doubling of the source's light output, which has been estimated at 10^{46} ergs or more per second in the optical frequencies.

Quasi-Stellar Objects

The discovery of quasi-stellar objects grew out of the increasing accuracy of radio astronomy equipment, particularly the interferometry surveys at the Owens Valley, California, and Jodrell Bank, England, observatories, which made possible the identification of strong radio sources with diameters below 1 second of arc, and out of the lunar occultation techniques employed notably at the Parkes, Australia, telescope. All of this work is founded on the continuing surveys made under the direction of Martin Ryle at the University of Cambridge Mullard Radio Astronomy Observatory. (A fourth Cambridge catalog of radio sources is now being assembled.) These studies permitted confident identifications of the radio sources with optical objects, once thought to be very close but now revealed by the red shift of their spectra to be very distant.

Maarten Schmidt, who with B. Oke and J. Greenstein played a large role in the spectral work on quasi-stellar objects, reviewed their optical characteristics in the same heavily attended session on radio sources which Fowler and Smith addressed. Schmidt listed five optical criteria: (i) stellar appearance and an optical diameter less than 1 second of arc; (ii) a brightness 5 magnitudes greater than that of radio galaxies such as Cygnus A; (iii) an optical variability of the sort observed by Hoffleit, Smith, and Sandage; (iv) emission lines about 5 times broader than those of most stars except super novae; and (v) a strong excess of ultraviolet in the optical energy distribution.

Fitting most of these criteria were nine quasi-stellar objects: 3C 9, 3C 47, 3C 48, 3C 147, 3C 196, 3C 216, 3C 245, 3C 273, and 3C 286. Schmidt drew a table of the criteria and the sources and said that the few gaps mostly resulted from a lack of relevant observations. There was one negative finding: 3C 196 did not exhibit any emission lines. Sandage noted from the floor that 4 other sources fitted the ultraviolet excess criterion.

The radio characteristics of the quasi-stellar objects showed no such order, Schmidt said. Although a source like 3C 48 is less than 1 second of arc across, the diameter of 3C 47 is 1 minute. Hence it seems that quasi-stellar objects range in radio diameter from 5000 to 250,000 parsecs (a parsec is 3.26 light years or about 3×10^{13} km). The radio luminosity of the objects is high, but no higher than that of the very distant galaxy 3C 295 or of Cygnus A. There radio spectra often show curvature at lower frequencies, but four sources do not exhibit this curvature. There has been no definite finding of variability in the radio output of the objects.

Specialists are now convinced that the effects observed in the quasi-stellar objects are not due to some kind of gravitational red shift in stars within the Galaxy, Schmidt said. Could the phenomena be due to a neutron star nearby? Schmidt said no: the observations made so far could only be due to effects in a gas with an electron density below 10^9 per cm^3. The optical output of such a neutron star of solar mass would be so weak that it would have to be placed at a distance of 5000 kilometers from earth for it to have a brightness equal to that of 3C 273. If the star had a higher mass, it could be placed somewhat farther away, but its gravitational pull on the sun would exceed that of the Galaxy. Hence, specialists are convinced that the quasi-stellar objects must lie outside the Galaxy and that the red shifts observed in their spectra must be cosmological and their distances tied to Hubble's constant.

The Galaxy

Summarizing astronomers' current view of the Galaxy, Oort said that 21-centimeter measurements of the distribution and movement of neutral hydrogen have revealed a sharply defined nuclear disk with a radius of about 800 parsecs (the sun is now thought to be about 10,000 parsecs from the Galactic center) in which the 4-component Sagittarius radio source is embedded and in which violent movements of gas are occurring. Outside the nuclear disk two "quite normal and fairly regular" spiral arms are pushing away from the Galactic center 1 solar mass of gas per year, a rate that would empty the observed gas from the whole region within 3000 parsecs of the center in only 30 million years. Oort suggested that the arms might have been produced by an explosion involving material totaling 10^7 solar masses about 10 million years ago. Although there is no proof that such an explosion occurred, Oort said the recent findings were suggestive: the Centaurus A radio galaxy (NGC 5128) appears to be in eruption, and M 82 provides "direct and convincing evidence" for an explosion involving some millions of solar masses 1.5 million years ago (*2*). Oort noted that Sandage and Geoffrey and Margaret Burbidge have recently surveyed the evidence for violent events in galactic nuclei and that the Burbidges have just studied turbulence within 600 parsecs of the center of M 51.

"Apparently the nuclei of galaxies can sometimes produce huge quantities of large-scale kinetic energy," Oort said. "How they do this is still an enigma. The idea that galactic nuclei may be the seat of unknown forms of energy and even of an unknown state of matter was put forward many years ago by [IAU president Viktor] Ambartsumyan. He has stressed on many occasions the enigmatic character of the nuclei of galaxies and the essential importance (of nuclei) for phenomena observed in these galaxies."

In the last year, knowledge of regions near the Galactic nucleus has been extended by the discovery of strong absorption by OH radicals at 18 centimeters. The measurements have indicated a concentration of OH about 1000 times higher than in the region of the sun, and very large movements of OH both toward and away from the Galactic center.

The first successful attempt to make such measurements was reported in November 1963 (*3*). S. Weinreb, M. L. Meeks and J. C. Henry of the Lincoln Laboratory and A. H. Barrett of the electronics research laboratory of the Massachusetts Institute of Technology reported 10 days of observations in the direction of Cassiopeia A between 15 and 29 October 1963, using an instrument at Millstone Hill at frequencies of 1665 and 1667 megacycles per second. These two frequencies characterize the two strongest of four characteristic OH absorption lines (*4*). The frequencies of these two strong transitions were measured in the laboratory in 1959 by G. Ehrenstein, C. H. Townes, and M. J. Stevenson. Although a search for OH absorptions had been suggested by Joseph S. Shklovsky in 1953, A. E. Lilley in 1955, and Townes in 1957, a search by Barrett and Lilley in 1956, before the laboratory determinations were made, had failed.

Weinreb and his colleagues reported observations of several clouds in the direction of Cassiopeia A which had different velocities of approach toward the observer. They estimated densities of OH of a few times 10^{14} radicals per square centimeter in the direction of Cassiopeia A. The abundance relative to hydrogen was about 1×10^{-7}.

Other reports of OH observations soon followed from groups at Parkes, Australia (*5*), the Air Force Cambridge Research Laboratory (*6*), the University of California (*7*), and from Weinreb and his colleagues (*8*).

The Parkes group, consisting of B. J. Robinson, F. F. Gardner, K. J. van Damme, and J. G. Bolton reported more detailed observations which showed very high OH densities near the Galactic center. In the direction of a cloud presumed to be near the nucleus of the Galaxy, moving toward the center at 40 kilometers per second, Robinson and his colleagues found an OH concentration of 3×10^{17} radicals per square centimeter, or 4 orders of magnitude higher than had been found in clouds between the sun and Cassiopeia A or the Crab Nebula. The apparent ratio of OH radicals to atoms of hydrogen was about 1×10^{-4} (*9*). This absorption feature at 40 kilometers per second is so strong that the Australians were able to detect in it the fainter pair of OH line components at 1612 and 1720 megacycles (*10*). The intensities of these fainter components were greater than anticipated, indicating that the stronger components have begun to saturate. Commenting on the work of the Parkes group, Oort said,

> It looks as though almost all the oxygen in the [nuclear] disk is bound in OH radicals.
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> Because the absorption coefficient of OH is much larger than that of H I [neutral hydrogen], it can be observed in absorption over the whole of the Sagittarius source, and even against a rather weak source near +3° longitude. The observations indicate that large concentrations of OH probably occur over the whole nuclear disk. Locally these concentrations show large deviations from circular motion. In some parts there appear to be radial motions of about 130 kilometers per second directed away from the center. Near the most concentrated component of Sagittarius A a considerable amount of gas seems to be flowing *inward*, towards this component, with velocities ranging from 0 to 80 kilometers per second. The observations do not conflict with those of the 21-centimeter emission, but they show smaller-scale phenomena which were partly wiped out in the larger beam of the 21-centimeter emission observations. We must still conclude, from these latter observations, that for the bulk of the gas in the nuclear disk the principal motion is one of rotation.
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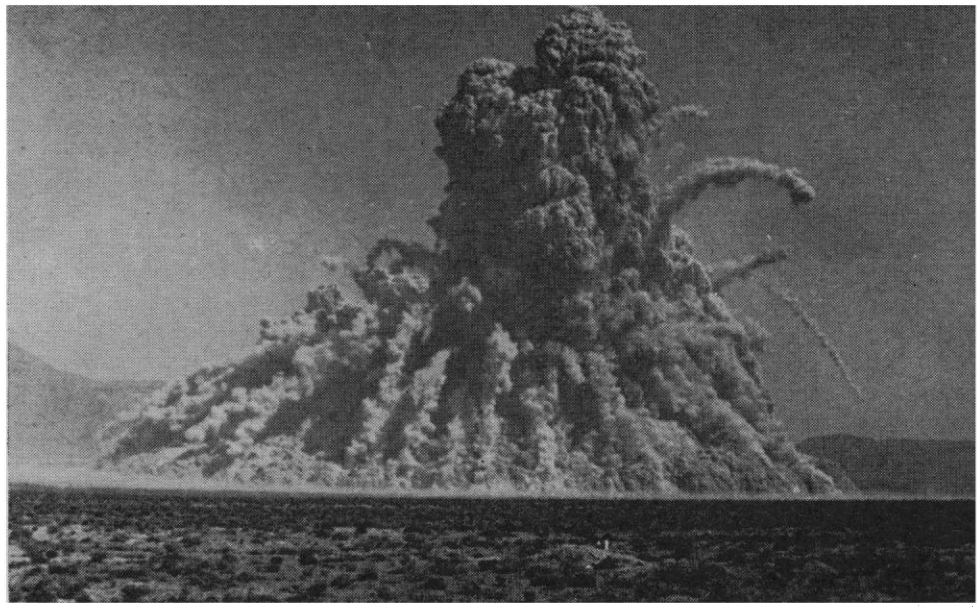
> Perhaps the most intriguing feature of these OH observations is that the intensity ratios of the 4 components of the OH band which have been observed indicate that everywhere over the disk the optical depth for the strongest components is between about 4 and 10. As the apparent optical depth is only about 0.5, this indicates that everywhere over the disk the OH must be concentrated in small clouds, each of which has a great optical depth, but which together cover only about half of the surface of the sources of continuous radiation.



Rocks and dust spewing out of craters caused by nuclear explosions in Nevada may help explain the rounding of small craters observed in the last stages of Ranger VII's journey.

Planetary Conditions

Planetary temperatures and magnetic fields attracted considerable interest at Hamburg. Further data on Jupiter, which rotates rapidly and has an intense and apparently asymmetrically disposed Van Allen magnetosphere, and Venus, which rotates slowly and appears to lack a magnetic field, were presented in addition to the indications of room temperature on Mercury and Saturn and the possibility of an intense magnetic field around Mars.

Observations at 21 centimeters made at Jodrell Bank produced a value for the rotation of the magnetosphere of Jupiter of 9 hours, 55 minutes, 29.5 ± 0.29 seconds. This value agreed within a fraction of a second with the 1950–60 average value used in recent work by James N. Douglas of Yale University and Alex G. Smith of the University of Florida. In September 1963, Douglas and H. J. Smith of the University of Texas reported a slowdown of 1 second from the previous decades' average in the rotation period of the long-wavelength radio sources on Jupiter (*11*), and A. G. Smith corroborated these results with a report at the spring meeting of the American Physical Society.

A number of findings reported at Hamburg confirmed 1962 results which indicated that the rotation of Venus is in the opposite direction from that of the earth. In a session on astronomical constants, Gordon H. Pettengill of Cornell University reported that observations with the 305-meter hemispherical bowl antenna at Arecibo, Puerto Rico (*12*), begun in February and continuing into October, were showing that Venus spins slowly backward on an axis inclined a maximum of 6 degrees from the plane of its orbit. Pettengill said that the methods used at Arecibo (comparing echoes from opposite edges of the disk of Venus and selecting echoes from a slightly shorter single range) both yielded this finding, as did the method of finding a single target on Venus' surface used at the Goldstone, California, antennas of the Jet Propulsion Laboratory. This year's observations took advantage of a close approach of Venus on 19 June. At the last close approach in 1962, R. L. Carpenter of the Jet Propulsion Laboratory and O. N. Rzhiga of the Soviet Union obtained measurements indicating that Venus rotates retrograde with a period of 250 to 300 days. This year at Jodrell Bank, in measurements that began 5 June and ended 26 July, the retrograde motion was also confirmed, but the accuracy allowed J. E. B. Ponsonby, J. H. Thomson and K. S. Imrie only to fix limits of 100 and 300 days for the rotation period (*13*).

Studies of Mercury

For some time, investigators had thought that the planet Mercury might possess an atmosphere, despite its small diameter (4840 kilometers) and its extreme closeness to the sun. Optical astronomers such as A. Dollfus of the Paris Observatory at Meudon, France, and G. P. Kuiper of the University of Arizona (heads of the planetary data centers being set up under IAU auspices in Europe and America, respectively) have used double-image photographs, observations of passages of Mercury across the sun's face (such as the one on 7 November 1960), and photometric techniques recommended by Hertzsprung to study the mass and density of the planet. Some of these observations have been reviewed by Dollfus (*14*) and by Carl Sagan and W. W. Kellogg (*15*).

In 1961 W. E. Howard III, A. H. Barrett, and F. T. Haddock reported the first radio emissions observed from Mercury (*16*). Observing at 3.45 and 3.75 centimeters, near Mercury's maximum elongation, they found an apparent black-body temperature of 400°K. Assuming that the planet is smooth (as indicated by radar observations at 43 centimeters in the Soviet Union and at 12.5 centimeters at Goldstone, California), that it rotates once on its axis during each orbit of the sun, and that the temperature on the always-dark face of the planet is 0°K, the observed temperature was consistent with a temperature of 1100 ± 300°K at the sub-solar point of the sunward face. Bolometric measurements made in the infrared region (10 microns) had yielded a value of 610°K.

To explain discrepancies in the temperatures calculated for Mercury, George B. Field of Princeton University postulated a feeble Mercurian atmosphere (*17*) which would warm the dark side of the planet by convection to about 300°K. It was said that an atmospheric pressure of only 1 millimeter of mercury would be consistent with polarimetric measures made by Dollfus in 1950. Kuiper had suggested that such an atmosphere might consist of a quantity of argon-40, released from the Mercurian soil by radioactive decay and weighing about 1 part in 10^8 of the planet's mass.

At a session on radio observations of the planets, Ken Kellermann of Australia reported that the Parkes telescope had been used to observe Mercury during a considerable part of an orbit around the sun, from a point on the side of the sun toward the earth to a point on the far side. Although the margin of error increased from 30 to 160 degrees as the measurements continued, the values obtained were a maximum of 350°K and a minimum of 200°K, with most values somewhat over 300°; this indicates that the bright and dark sides of the planet do not differ greatly in temperature.

The effective temperature of Mars appears to be 1100°K at 21 centimeters, R. D. Davies of the Jodrell Bank Observatory reported at the same session Kellermann addressed. This value is far higher than the temperatures around 200°K arrived at last winter in unpublished 21-centimeter observations made by Frank Drake and others at Green Bank, West Virginia. To account for the startling high value—which Davies and many other astronomers hope to check at the next close approach of Mars early in 1965—Davies considered synchrotron radiation the most attractive explanation. Nonetheless, Davies noted that the density of electrons in a magnetic field around Mars would have to be very much greater than around the earth. Carl Sagan of Harvard asked if "free-free" emission in an extensive ionosphere could not explain the observation if the density were around 10^8 electrons per cubic centimeter. Davies thought a density of at least 10^9 was required and that this would rule out the free-free emission hypothesis.

Davies also reported weak signals at 21 centimeters from Saturn, indicating a temperature of $286° \pm 20$°K at some level in Saturn's atmosphere. The optical data indicate a temperature about 120° to 135°K, and measurements reported by B. F. Cooper and Kellermann and by Davies, Cooper, and M. Beard with the Parkes telescope on 11.3 centimeters indicate a mean disk temperature for Saturn of 190°K, which is close to a value reported by Drake at a nearby frequency. Measurements at Parkes at 21 centimeters had yielded a value of $300° \pm 100$°K. Kellermann thought the temperatures were purely thermal, but Davies felt that it would be hard to attribute all the radiation to a thermal contribution, as apparently must be done for Venus (which was shown by Mariner II instruments in late 1962 to lack a magnetic field).

During the conference, the IAU delegates assembled to see an extensive display of photographs taken by the three cameras of the Ranger VII spacecraft as it approached the moon on 31 July.

Eugene Shoemaker of the U.S. Geological Survey reviewed the question of how much dust there is on the lunar surface and how the dust and the many small craters would be generated. He felt that the large primary craters caused by the impact of objects from space have the appearance of being carved out of a dense medium, not a thick coating of dust. He showed pictures of rocks and dust spewing out of nuclear explosion craters in Nevada to explain the rounding of small craters observed in the last stages of Ranger VII's journey. Shoemaker presented a statistical prediction of the number of craters of various sizes that might have been expected. The number below 300 meters in diameter was smaller than expected, indicating that there is enough dust to fill the smaller craters at about the rate of their creation, Shoemaker speculated. His remarks were followed by much debate.

Assisted by Dollfus, who translated his remarks into French, Kuiper discussed the photographs and ended by showing a 6-minute film made of the sequence of 208 photographs taken by one of the Ranger cameras. The astronomers could watch features, such as an isolated mountain, resolve, grow large, and then pass out of the camera's field of view as the spacecraft approached the moon's surface. At the end of the sequence, the astronomers burst into applause.

Literature Citations

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2. See A. Sandage and W. C. Miller, *Science* **144**, 405 (1964).
3. *Nature* **200**, 829 (1963).
4. See *ibid.* **204**, 62 (1964).
5. See J. G. Bolton, K. J. van Damme, F. F. Gardner, B. J. Robinson, *ibid.* **201**, 279 (1964).
6. See N. H. Dieter and H. I. Ewen, *ibid.* **201**, 279 (1964).
7. See H. F. Weaver and D. R. W. Williams, *ibid.* **201**, 380 (1964).
8. See A. H. Barrett, M. L. Meeks, S. Weinreb, *ibid.* **202**, 475 (1964).
9. *Ibid.* **202**, 989 (1964); **204**, 30 (1964).
10. *Phys. Rev. Letters* **13**, 3 (1964).
11. *Nature* **199**, 1080 (1963).
12. See W. E. Gordon, *Science* **146**, 26 (1964).
13. *Nature* **204**, 63 (1964).
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16. *Astron. J.* **66**, 287 (1961); *Astrophys. J.* **136**, 995 (1962).
17. *Astron. J.* **67**, 575 (1962).