Large New Telescopes for the Southern Hemisphere

London. Astronomers are preparing to build three great optical telescopes of nearly the resolution of Mount Palomar's 5-meter instrument in the Southern Hemisphere. Two of the telescopes will be built in Chile, one in Australia. The instruments are intended to measure such major features of the southern sky as the center of the Galaxy and the two Clouds of Magellan.

Recent radio observations of the galactic center have shown the region to be in turmoil. The Clouds of Magellan are galaxy-like systems far nearer to our own galaxy than the nebula in Andromeda, the most notable galactic systems visible in the Northern Hemisphere, and they have afforded much information about stellar and galactic evolution, as well as the cepheid-variable standard of stellar distances.

Studies of such phenomena are of first importance, according to many astronomers. Hence, they feel, the building of great telescopes in the Southern Hemisphere, which now lacks them, is crucial for astronomy now.

At the same time, there is no dearth of plans for building important optical telescopes in the relatively well-equipped Northern Hemisphere. The Soviet Union is considering construction of a 6-meter reflector; Britain will complete a 2.5-meter reflector around the end of 1965; and the United States is building a 3.81-meter reflector at Kitt Peak, Arizona.

Although there is widespread agreement among optical and radio astronomers on the importance of observations in the southern sky, there is debate about whether three Palomar-scale telescopes (costing over $11 million apiece) are required in a time when arrays of smaller telescopes might be more effective or when large orbiting telescopes should soon become available. Those who favor construction of the large telescopes make these replies:

1) The results obtained with the Palomar telescope in 15 years of observation have been of central importance to astronomy.

2) Yet, there are no telescopes in the Southern Hemisphere that even approach the resolution of the Palomar instrument. Below the equator, there are no telescopes with apertures as large as 2 meters. Only four have apertures larger than 1.5 meters; these are the 1.88-meter telescopes at Mount Stromlo in Australia and at the Radcliffe Observatory near Pretoria, South Africa, the 1.55-meter instrument at Bosque Alegre in Argentina, and the 1.52-meter instrument at the Boyden Observatory in Bloemfontein, South Africa, jointly operated by Harvard University and a European cooperative.

3) The relatively many major instruments in the Northern Hemisphere—the 5.08-meter telescope at Palomar, the 3.18-meter instrument at Mount Hamilton, the 2.60-meter instrument in the Crimea, the 2.54-meter instrument on Mount Wilson, and others in the U.S., Canada, France, East Germany, and Japan—are booked solid.

4) Interest in southern-sky phenomena has been great ever since observations of the southern sky were made at the Harvard Observatory station at Arequipa, Peru, at the end of the last century. (This station was later transferred to South Africa.) Chile, Argentina, South Africa, and Australia have constructed observatories; the British have built an observatory near Pretoria; the Dutch have a 91-centimeter reflector at Hartebeestport, South Africa; the Swedes have a Schmidt camera at Mount Stromlo; the British Royal Observatory has a 1.02-meter instrument at Capetown; and the Lick Observatory has a station in Chile. In addition, a group of American observers from the Kitt Peak Observatory is working in Chile, and French observers are working at Zeekoegat in the Grand Karroo region near Capetown. As with the Northern Hemisphere telescopes, time on many of the Southern Hemisphere instruments is scarce. Hence it seems evident that the demand for time on all three of the projected large instruments will be heavy.

5) It seems that it will be a long time—perhaps 20 years—before a fully-steerable satellite-borne telescope, accompanied by at least one skilled astronomer, will be in use for reliable, long-term observing programs in orbit.

Enthusiasm for making detailed studies of the Small and Large Clouds of Magellan seems to be high among astronomers. It was in these clouds that workers at the Harvard College Observatory found hundreds of pulsating cepheid stars, all roughly the same distance from the observer, and worked out the period-luminosity relationship which permitted them to make distance calculations by comparing the absolute and apparent magnitudes of these variable stars. Recent measurements based on observations of newly found faint stars of the RR Lyrae type, which pulsate with periods of less than 1 day, have shown the Magellanic Clouds to be about 180,000 light years away, or some six times the sun's distance from the center of our galaxy. The questions of distance still vex astronomers. Sir Richard Woolley, head of the British Royal Greenwich Observatory at Herstmonceux, Sussex, notes that the distance of the sun from the galactic center is known only to within about 10 percent, hence that the speed of the sun's revolution about the galactic center is so uncertain that astronomers cannot tell for sure whether the Magellanic Clouds are companions of our galaxy or are moving away from it.

Writing in the *Scientific American* (January 1964), Bart J. Bok of the Mount Stromlo Observatory noted that recent radio and optical evidence indicates that the Small and Large Clouds are linked by bridges of stars and gas, that they have a common envelope of neutral hydrogen gas, and that they have the thin disk shape of our galaxy, although they are smaller: The diameter of the Large Cloud is 20,000 to 40,000 light years; that of our galaxy is 100,000. Bok expresses great interest in such features of the Large

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Cloud as Constellation I, discovered by Harlow Shapley and his co-workers. In this constellation, a few hundred stars less than 10 million years old are embedded in a cloud of neutral hydrogen of mass estimated at 5 million solar masses. "Nowhere in our Galaxy," says Bok, "do we find the processes of star birth and evolution so neatly portrayed as they are in the Large Cloud of Magellan."

Writing in the *New Scientist* (9 May 1963), H. H. Voigt of the Göttingen Observatory argues: "[Globular] star clusters occupy an important place in the study of the evolution of stars, and, as they are symmetrically distributed around the center of our Galaxy, they have to be observed in the southern sky. Statistics of star distribution also suffer from the asymmetry (between hemispheres) of stellar observations: questions concerning the motion of star groups, questions of the rotation of our own Galaxy, star counts of all kinds, the red shift of distant galaxies and similar problems. Statistically accurate results of all these can only be obtained if the whole sky is observed and not if a large sector of it remains below the horizon of the most powerful modern telescopes. We still have insufficient positional determinations of objects in the southern sky, such as we have for regions accessible to northern observatories. Many important star catalogues and star charts still show wide and highly undesirable 'southern gaps,' often making it exceedingly difficult to identify a particular star-field." Other astronomers point out that Voigt's statement could be misleading. None of the objectives mentioned will be accomplished by big telescopes alone. Indeed, some of the work is not done by telescopes at all. Positional determinations are made with small telescopes called meridian circles.

Of the three major projects, that of the European Southern Observatory (ESO) organization is most advanced. Last summer, Otto Heckmann (who is on leave from the directorship of the Hamburg Observatory in order to be ESO's first director) traveled to Chile to acquire an extensive tract of land encompassing a mountain called La Silla. The site is 400 kilometers north of Santiago, in a dry region near the towns of Vicuna and La Serena. La Silla was chosen after years of investigation, first by Americans led by Jurgen Stock of the Kitt Peak National Observatory in Arizona and later by Europeans using the same instruments they had used earlier in selecting sites in South Africa. The investigations showed the Chilean site to be a bit windier than Zeekoegat in South Africa but otherwise far superior. It had, on the average, 240 fully clear nights a year, and a temperature variation averaging only 2° or 3°C over the night viewing hours, a variation smaller than that in California. The ESO site is slightly to the north of that chosen for the southern observatory of the Association of Universities for Research in Astronomy (AURA), the consortium which operates the Kitt Peak Observatory for the National Science Foundation.

On La Silla, 2400 meters high, the five-nation ESO group will erect four telescopes, including one of 3.5 meters. This large telescope is likely to be ready earlier than a 3.81-meter instrument planned for Australia and one of 3.6 to 3.8 meters being considered for the American observatory in Chile. Astronomers in Australia and the United Kingdom have proposed that the two nations share equally the cost of a 3.81-meter telescope in Australia. The idea has been strongly endorsed by the British Advisory Council on Scientific Policy and drew warm support in special debates held earlier this year in both houses of the Australian parliament. But the position of the Royal Greenwich Observatory at Herstmonceux, which would figure strongly in the construction and operation of the proposed cooperative observatory, is now anomalous because of the incorporation of its old patron, the Admiralty, into a new Pentagon-style Defence Ministry, and because of the recommendation that responsibility for the observatory be transferred to the new Science Research Council proposed in 1963 by the civilian science organization committee headed by Sir Burke Trend. Also, astronomers in Australia are not unanimous in supporting construction of the 3.81-meter reflector. Nonetheless, a Royal Society committee of four British astronomers (Woolley, A. Hunter, and J. D. Pope of the Greenwich Observatory and R. O. Redman of Cambridge) visited their colleagues at the Australian Academy of Science in June and July to look at possible sites.

For the American observatory at Cerro Tololo, Chile, telescopes of 0.9 and 1.5 meters have been ordered, but funding for construction of an instrument of about 3.8 meters is some years off. AURA is paying, during fiscal year 1964–65, for the blank of a 3.81-meter telescope for Kitt Peak. Funds for a 3.81-meter telescope at Cerro Tololo have not been requested.

European Southern Observatory Organization

The five ESO nations are Belgium, France, Holland, Sweden, and West Germany. Their organization grew out of ideas proposed before World War I by the German astronomer Karl Schwarzschild, and in 1953 by Walter Baade when he visited colleagues in Leiden. Astronomers embraced the idea warmly and drew up a plan of organization as early as 1954. But there were many difficulties. Governments were slow to become interested or to agree with each other. British astronomers withdrew, to support a Commonwealth project that may now come to fruition in Australia and to work on plans for the 2.5-meter telescope (to be named for Isaac Newton) at Herstmonceux, which is likely to be finished by the end of 1965 after long delays caused by an unsuccessful attempt to depart from standard telescope design. Discussions among the other European nations languished until ESO representatives met in Paris in December 1960 (about the time that plans for the cooperative European space research and rocket development organizations took shape). A major spur to the project was the Ford Foundation's agreement to provide $1 million of the cost if at least four nations took part. The five nations signed a treaty in October 1962, which became effective in February of this year.

Planning and design studies for the four ESO telescopes began several years ago. These are the results:

1) A 1-meter reflector to be used only for photoelectric measurements should be delivered around the end of 1964 by the Dutch firm of Rademakers, with optics from the Zeiss works in Jena, East Germany. It should be installed at La Silla by mid-1965. The telescope will have a Cassegrain focus in which a hyperbolic secondary mirror just in front of the primary focus reflects light waves through a hole in the primary mirror; it will also be equipped with mirrors for bringing the light waves off to the side of the main instrument to a focus off the axis of the telescope (Nasmyth focus) or on its axis (Coudé focus).

2) A 1.5-meter reflector for spectrographic work is the responsibility of

the French. Cassegrain and Coudé focuses will be available. With the latter, light will be projected along the telescope's polar axis, so that elaborate fixed spectrographic arrays can be used to allow not only small but medium dispersions of the spectra (30 to 300 angstroms per millimeter). This telescope may be ready in 1965.

3) A 1-meter Schmidt telescope with a 3-meter focal length is planned for operation in 1966. This telescope will take photographs exactly comparable in scale to those taken by the Palomar Schmidt, which has an aperture of 1.2 meters, and will be used to extend the Palomar sky atlas into regions inaccessible from the Northern Hemisphere telescopes—that is, farther south than 24° below the equator. The smaller aperture will reduce the estimated cost of the new telescope and, at the same time, permit installation of an objective prism for stellar classification work. Voigt says the smaller aperture also will reduce chromatic aberration. This telescope is the responsibility of the Germans.

4) Optical studies for a projected 3.5-meter telescope are near completion, and discussions with potential bidders have begun. The instrument will have a fused-quartz mirror blank more than twice the size of the 1.55-meter primary mirror of the U.S. Naval Observatory's astrometric reflector, which is located at Flagstaff, Arizona, and is used for stellar parallax measurements [*Science* **144**, 1299 (1964)]. The astronomers and engineers working on the 3.5-meter instrument (ESO is acting as its own prime contractor) are convinced that such a large blank can be fabricated and that its reflecting surface and the reflecting surfaces of secondary mirrors can be accurately shaped. They expect that the quartz blank, which will be thinly coated with an aluminum reflecting layer, will be even more rigid than the low-expansion glass used for the Palomar mirror. The greater rigidity should permit alterations from the parabolic shape used for the Palomar mirror, alterations which can be calculated with the help of computers and tested with new interferometric techniques. With accurately shaped secondary mirrors and the help of the low variation of temperature at the Chilean site, the ESO group feels it can get an effective field considerably larger than that obtainable with the Palomar instrument. A larger field is of much interest because accurate radio positions, determined by means of widely separated antennae as elements of an interferometer, have been obtainable only for the bright sources. For fainter sources, the limits of error are large; according to Voigt, the larger effective optical field will assist in identification of the fainter radio sources with optical sources.

Voigt describes the plans this way: "Following a suggestion of I. S. Bowen it is hoped to give this telescope a larger field of operation in the primary and especially in the Cassegrain focus than normally is possible with a parabolic mirror. Calculations show that a field at least 4 times larger than that of the 5-meter telescope at Palomar is feasible. But this can only be achieved if not only the secondary but also the primary mirror is shaped. This means in fact that the main mirror must have subtle departures from the conventional parabolic shape and additional correcting lenses are used for the primary focus."

Besides its telescopes on the relatively level top of La Silla, which is well away from the coastal earthquake zone, the ESO organization will maintain offices, a library, workshops, and a hostel in Santiago. There, too, according to Heckmann, a prism astrolabe will soon be installed. Until the site at La Silla is prepared, a French group will continue observations at Zeekoegat in South Africa. There, under the leadership of Charles Fehrenbach of the observatories of Marseille and Haute Provence in France, astronomers using a prism astrograph which displays the spectra of many stars on a single plate have discovered that a number of stars of high luminosity, which had been thought to be in this galaxy, are really in the Magellanic Clouds. These stars are brighter by a factor of about 10 than any hitherto observed in the clouds. Fehrenbach is chairman of the ESO instrument design committee. Its secretary, and assistant director of ESO, is Jöran Ramberg of the Stockholm Observatory.

The ESO project may also lead directly to construction of two more large telescopes by European groups. A German committee headed by Hans Elsässer, director of the Königstuhl Observatory, Heidelberg, is considering construction of a 3-meter instrument in South Africa or Southwest Africa. A committee of French astronomers is considering the desirability of profiting from the design experience with the 3.5-meter telescope and building one of the same aperture at the Haute Provence Observatory, whose largest reflector has an opening of 1.93 meters. The French 3.5-meter instrument would probably not be started until about 1970.

Hamburg Meeting

The plans for construction of large optical telescopes in the Southern Hemisphere were only a few of the telescope projects discussed at the recent 12th general assembly of the International Astronomical Union, held in Hamburg from 25 August to 3 September. The observatory at Ondřejov, near Prague, is planning to complete, before the next IAU assembly in 1967, a 2-meter telescope much like that completed at Tautenburg, East Germany, in 1960. In the area of radio astronomy, astronomers from Jodrell Bank could report successful operation of the computer-controlled drive of the 38- by 25-meter elliptical antenna designed to receive at frequencies up to 10,000 megacycles, but the computerized drive of the giant reflector plates of the French radio observatory being built at Nançay is being redesigned, and construction will not be completed until next year. After many political and engineering difficulties, the Belgian-Dutch project for an aperture-synthesis telescope (once dubbed the "Benelux cross") seems nearly ready for bids from industry.

Future Prospects

Now that their plans for an observatory are official, ESO's staff members talk with excitement about the observing program ahead of them. They look forward especially to making contributions toward measuring the shifts toward the red end of the spectrum which are apparently caused by the rapid retreat of distant light sources —shifts which have occasioned nearly 40 years of debate about an expanding universe. America's great telescopes have allowed her astronomers to get to the heart of astronomical problems. Ramberg observes, "These possibilities have hitherto been reserved to Americans. These questions about red shift have been a monologue. Now we can hope that it will become something of a dialogue."—VICTOR K. MCELHENY