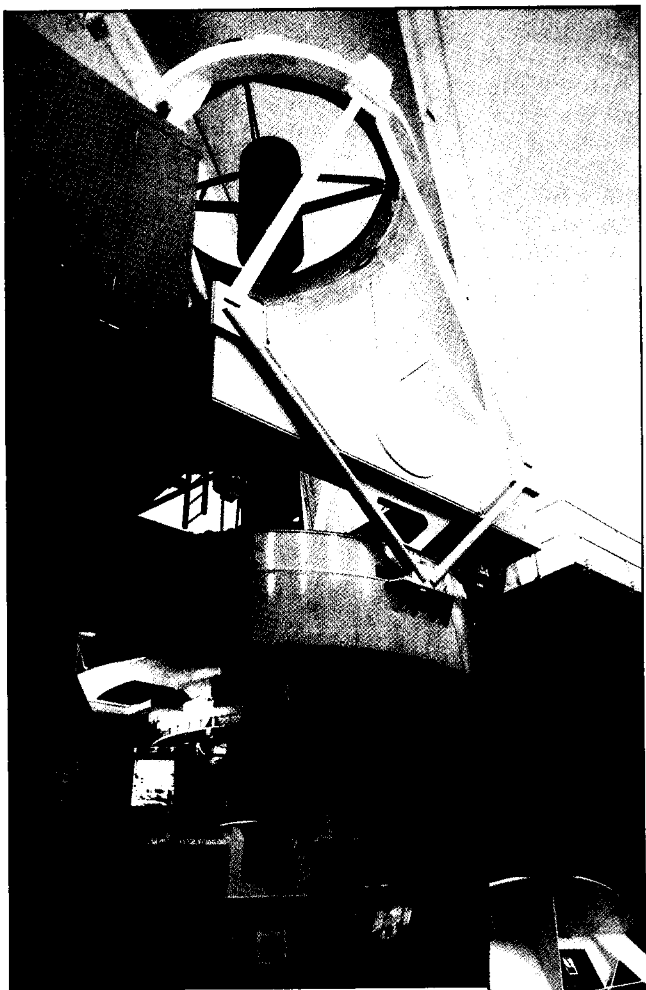
The William Herschel Telescope

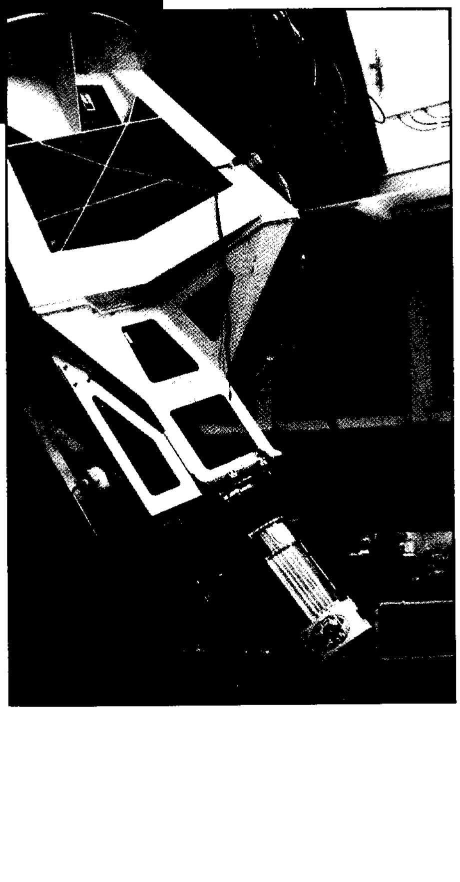
Ian Ridpath, Brentford, England

VIRTUALLY every major observatory claims that one of its telescopes is "the best" by one measure or another. But what makes one telescope truly better than all the rest? Optical excellence is essential. So, too, is the mechanical quality of the mounting and drive. Finally, its observing site must offer dark skies and dry, steady air. On these three counts the William Herschel Telescope (WHT) on the peak of La Palma in the Canary Islands deserves to be considered among the best ground-based optical telescopes in the world. The WHT, which saw first light on June 1, 1987 (*S&T:* September, 1987, page 237), is scheduled for official dedication in the near future.

At 4.2 meters (165 inches) in diameter, its primary mirror is the world's third largest, behind the Soviet 6-meter and Palomar 5-meter reflectors. But observational experience has shown that the WHT is more powerful than these larger instruments. "On this site the WHT performs like a 6- or 7-meter telescope would at other observatory sites," says Alec Boksenberg, director of Great Britain's Royal Greenwich Observatory.



Left: With a primary mirror 4.2 meters in diameter, the William Herschel Telescope (WHT) is the third-largest single-mirror telescope in the world. Located at Observatorio del Roque de los Muchachos on La Palma in the Canary Islands, it provides British, Dutch, and Spanish astronomers with unique views of the northern skies.



Below: The faint-object spectrograph, designed to measure the redshifts of distant galaxies and quasars, was one of the first instruments to operate on the WHT. All photographs by Robin Scagell unless otherwise noted.

VISITING LA PALMA

Photographer Robin Scagell and I decided to visit La Palma to see this astronomical paragon in action. The Canary Islands lie off the coast of Morocco and are a well-known destination for European vacationers lured there by the sunny climate and extensive beaches. Equally attractive to astronomers is the uninterrupted air stream from the Atlantic Ocean that ensures steady star images. Located at the western end of this Spanish archipelago, La Palma, with a population of only 76,000, is free from light pollution.

To check the weather prospects for our drive to the summit we first stop at the observatory's headquarters in Santa Cruz, the island's main town. At 7:50 a.m. duty officer Chris Mayer radios down the news that there is ice on the mountaintop. Fortunately, however, the road up to the observatory is still passable. After a hurried breakfast we set out behind the convoy of observatory vehicles that makes the 44-kilometer trip up the mountain every day.

The road climbs steeply as it leaves Santa Cruz, and we quickly realize that La Palma is little more than a volcanic cone rising from the surrounding ocean. At first we drive past hamlets and isolated houses, but soon all habitation is left behind and we wind through a sunlit forest of Canary pine trees.

Some two-thirds of the way to the summit we pass a string of observatory cars coming down the mountain. There is ice on the road, and one car has already skidded, colliding with another. Astronomers in vehicles not equipped with four-wheel drive turn back, advising us to do the same. With bad weather closing in and a precipitous drop at the side of the road, the mountain suddenly seems much less friendly.

We wait an hour for the weather to improve before progressing. Higher up we encounter high winds and freezing rain that glazes the road with ice crystals. Even a group of optimistic German tourists is beaten back. One couple is forced to abandon their car on a particularly treacherous stretch of road.

Eventually, with the help of welcome sunshine and Robin's skillful driving, we reach the haven of the Residencia, the observatory's four-star living quarters. A journey that should have taken an hour has taken nearly four. It could have been worse — at times, the observatory has been cut off for days. Salting of the roads, incidentally, is prohibited to safeguard the island's water supply.

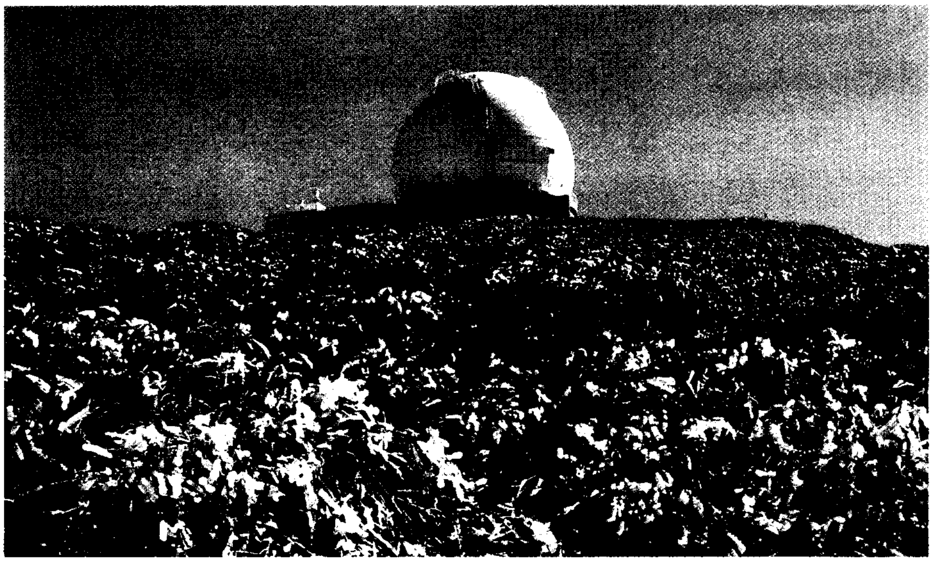
AN INTERNATIONAL OBSERVATORY

From the Residencia, the William Herschel Telescope dominates the scene. It rests like a huge vanilla egg among the codeso, a shrub that grows profusely in the mountain's brown volcanic soil. Nearby lie the domes of the 2.5-meter Isaac Newton Telescope and the 1-meter Jacobus Kapteyn Telescope, both of which began work in 1984 (*S&T:* March, 1984, page 214). All three are operated by the Royal Greenwich Observatory, with the observing time shared by Spanish and Dutch astronomers (and with Irish astronomers too at the Kapteyn Telescope).

Also on the mountain are a solar telescope and a 61-cm reflector, both operated by Sweden, and the Carlsberg Automatic Meridian Circle, jointly operated by the United Kingdom, Denmark, and Spain. Rounding out the complement is the recently dedicated 2.5-meter Nordic Optical Telescope, operated by Swedish, Norwegian, Danish, and Finnish astronomers (see the January issue, page 7).

The observatory, officially called Observatorio del Roque de los Muchachos, is Spanish owned and administered by the Canary Island Institute of Astrophysics, located on the neighboring island of Tenerife. The Muchachos (boys) are a group of eroded volcanic columns on the highest part of the mountain, overlooking the 2-km-deep Caldera de Taburiente. This whole area is a national park. The telescopes themselves are located somewhat below the Muchachos at an altitude of about 2,350 meters.

Perched precipitously on the rim of the caldera is the remnant of a site-testing station established in the early 1970's, when colleagues of ours tested various sites for what British astronomers were calling the Northern Hemisphere Observatory. Besides La Palma, locations in Spain, Italy, Madeira, Tenerife, Hawaii, and the Cape Verde Islands were tested.



The dome of the 4.2-meter William Herschel Telescope amid a sea of ice-covered codeso bushes. The telescope's short focal-ratio enables it to fit in a very compact dome.

The William Herschel Telescope uses computer technology to reduce an observer's workload. Conventional dials and switches are replaced by keyboards and monitors.

Hawaii and La Palma proved the best. La Palma was eventually selected because it does not have the extreme altitude problems associated with Hawaii's Mauna Kea and is more easily accessible to European astronomers. Experience has shown that the choice was a wise one. "For optical astronomy it is the best site known," says Boksenberg.

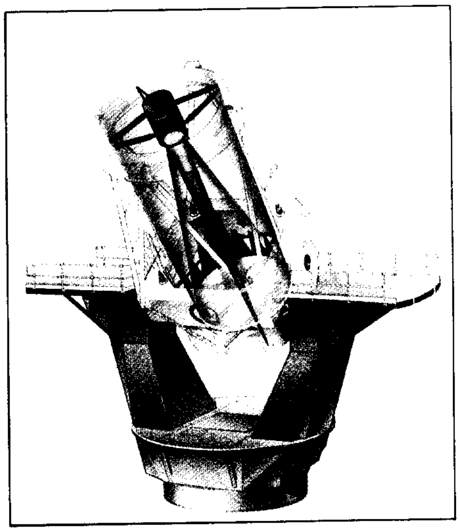
If La Palma has a drawback it is dust from the Sahara Desert, which affects observing very occasionally in June, July, and August. Indeed, dust storms turned the sky milky for a few days before our visit in February, 1988.

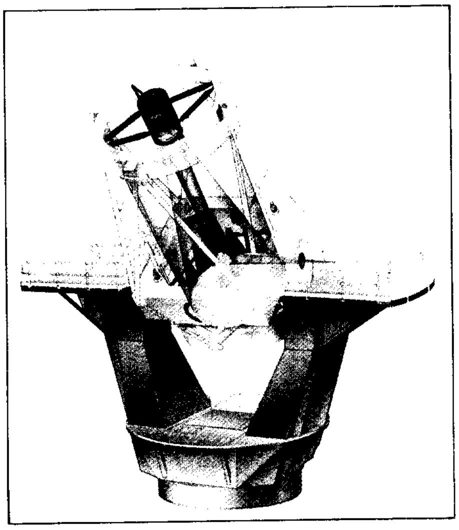
INSTRUMENTATION

You enter the WHT's dome through a pair of heat-lock doors that insulate the observing area from the surrounding building. On its dark green altazimuth mounting, the white telescope resembles the framework of a huge cannon. The primary's short focal ratio (f/2.5) makes the telescope very compact. Indeed, at 21 meters in diameter, the dome is almost 14 meters smaller than that for the 3.9-meter Anglo-Australian Telescope. The complete telescope, with its instruments and building, cost some $24 million.

Users of the WHT have a variety of instruments at their disposal. The f/11 Cassegrain focus shown on the top, left of page 138, is equipped with a faint-object spectrograph and an imaging Fabry-Perot interferometer called Taurus II. The former is regarded as the best redshift-measuring machine in the world by some of its users. The latter is essentially a camera behind a narrow-bandwidth, tunable filter. It is used to measure the Doppler shifts caused by gas motions in extended objects such as galaxies and planetary nebulae. Also available at the Cassegrain focus is ISIS, consisting of one intermediate-dispersion spectrograph optimized for blue light and another for red.

A distinctive feature of the WHT and many other altazimuth telescopes is the pair of observing platforms, one on either side of the tube. Here large and heavy instruments can be mounted at the twin f/11 Nasmyth focuses (see the top, right of the next page). At present one is reserved for the high-resolution Utrecht Echelle Spectrograph (*S&T:* June, 1989, page 585). The other contains GHRIL, the Ground-based High-Resolution Imaging Laboratory. This is essentially a large lightproof cabin housing optical equipment for image-sharpening experiments. There an intensified television system makes a sequence of rapid exposures some 20 milliseconds long. The best are electronically selected and combined to pro-





Schematic views of the principal optical configurations of the William Herschel Telescope. *Left:* The f/11 Cassegrain focus is used for conventional spectrographs and cameras. *Right:* The twin f/11 Nasmyth focuses are used for large instruments, too heavy to be mounted at the Cassegrain focus. Courtesy Royal Greenwich Observatory.

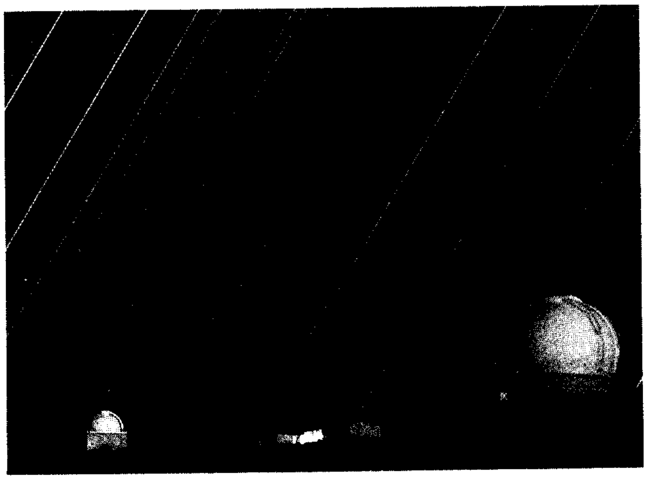
duce pictures with resolutions as high as 0.2 arc second. Ultimately, such experiments may lead to images that reach the telescope's diffraction limit of 0.03 arc second (see July, page 8).

Why have we seen no spectacular color photographs taken with the Herschel Telescope like those taken, for example, by the Anglo-Australian Telescope? The answer is simple: the WHT has no photographic instruments! In fact, the areas of the dome originally designed as darkrooms have been converted into offices. "All our imaging is done with CCD's," explains WHT astronomer Keith Tritton. Several of these versatile chips are available for use at the Cassegrain and Nasmyth focuses. There is no prime-focus camera at present. Incidentally, it is not possible to observe directly through the telescope, since there are no eyepieces.

The WHT's primary mirror, one of the most accurate ever made for a large astronomical telescope, allows it to take full advantage of the exceptional sky conditions on La Palma. Thinner than most large mirrors, its ratio of diameter to thickness is eight. It is supported on 60 air pads that act as pneumatic springs.

The mirror has an interesting history. It was one of four Cer-Vit blanks made in 1969 by Owens-Illinois. The others were ordered for the 3.6-meter Canada-France-Hawaii Telescope, the 3.9-meter Anglo-Australian Telescope, and the 4-meter reflector at Cerro Tololo Inter-American Observatory. The largest of the series had no takers until it was purchased in 1979 for a little more than $1 million by the United Kingdom's Science Research Council (now the Science and Engineering Research Council). Thus the WHT's aperture was determined by the availability of this blank.

Grubb Parsons of Newcastle upon Tyne in northeastern England figured and polished the mirror so precisely that it concentrates 85 percent of a star's light into a disk only 0.3 arc second in diameter. In comparison, the Palomar 5-meter reflector and the European Southern Observatory's 3.6-meter concentrate 80 percent of the light in areas 0.7 and 0.42 arc second across, respectively. The newer Anglo-Australian and Canada-France-Hawaii telescopes do somewhat better at 0.3 arc second. Of the large astronomical telescopes, only the 2.4-meter Hubble Space Telescope and the 3.5-meter New Technology Telescope (with its computer-controlled "active" optics) do better than the WHT — they pour 80 percent of a star's light into a disk 0.1 arc second across (*S&T:* September, 1989, page 248). After completing the WHT's mirror Grubb Parsons ceased operations, thus marking the end of an era in telescope making that stretches back more than 100 years (*S&T:* March, 1984, page 227).



The domes of the 4.2-meter William Herschel (at right) and 1-meter Jacobus Kapteyn telescopes dominate this starlight view of Observatorio del Roque de los Muchachos. Courtesy Royal Greenwich Observatory.

OBSERVING WITH THE WHT

Often the observatory on La Palma stands like a knuckle above a billowing sea of clouds some 500 meters below. At such times you can look across the intervening ocean and see the peak of Tenerife 150 km away. But on our first night at the observatory the temperature falls to −6° Celsius, unusually cold for this site even in winter. We certainly can't see all the way to Tenerife; the mountaintop is enveloped in clouds and freezing rain. To make matters worse, the Herschel Telescope's dome is iced up and will not open properly. All attempts to observe that night are abandoned.

The next day, bright sunshine and the sound of melting ice crashing from the domes augurs well for that night. Shortly before 7 p.m. Jan Lub presses a button to open the dome and switches on the powerful fans that ventilate it. Lub, who has since left La Palma, was one of a dozen British, Dutch, and Spanish support astronomers on hand to help and advise observers on the big telescopes. The support astronomers also conduct their own research programs. "They are a very strong research team," says Tritton. "But they must win their own time on the telescopes in [open] competition — they do not get it by right."

In comparison with the control desks of other large telescopes, the WHT's looks rather bare. Observers are not confronted by banks of dials and switches, but by a few video screens and a conventional computer keyboard. Remarkably, at the time of our visit, no telescope operators were employed. Observers merely typed simple commands into the computer. For example, GOTO followed by the name or coordinates of a source causes the telescope to point at the object and track it. Type GOCAT, and the telescope moves to the next object in its on-line catalogue.

Lub runs through a selection of stars to check the pointing accuracy of the telescope and then hands it over to the visiting observers. "It's yours for the rest of the night," he tells Keith Mason of the University of London's Mullard Space Science Laboratory. Mason takes the chair and types in the first GOCAT command. Silently and unseen in the adjoining dome, the Herschel Telescope swings to its first target, one of a series of X-ray sources found by the European Space Agency's Exosat satellite. Mason and his colleagues hope to identify them by taking their spectra with the faint-object spectrograph (FOS).

FOS (shown on page 136) bears a sticker depicting a tortoise with the slogan "I may look slow but watch me go." Although modest in appearance, the FOS is more of a hare than a tortoise — arguably the fastest spectrograph in operation anywhere. "Its efficiency is about three times higher than that of a conventional spectrograph," asserts Tritton. I am about to see a demonstration.

On the screen in front of the observers an image of the telescope's field of view begins to build up. A television camera points at the mirrored surface of the spectrograph's slit and reveals objects as faint as 20th magnitude or so. On the Palomar Sky Survey the target object appeared 17th magnitude, but the television view shows that it has faded significantly. "Is it dark outside yet?" asks Mason. Somebody consults a book of tables — no, the end of astronomical twilight is still 20 minutes away. No one actually goes outside to look at the sky!

Mason presses a button marked HANDSET, turning the computer's cursor keys into precise slow-motion controls. Slowly, he centers the object to within 0.3 arc second on the spectrograph slit. It is uncanny to watch a 200-ton telescope positioned with such fingertip precision.

Next begins a 2,000-second exposure as the X-ray source's spectrum builds up on a liquid-nitrogen-cooled CCD chip. In the darkness of the dome, the telescope goes quietly about its business. The only sounds are the rushing of air from the ventilation fans, a clicking as the mirror's pneumatic supports adjust their pressure, and the occasional whir of the motors as the dome moves in small steps. Inside the dome the temperature is 3° C, still only 1° warmer than the outside air even though the dome had been closed all the previous night. The astronomers in the control room's shirt-sleeve environment might just as well be in another country — and, indeed, the WHT is designed to be operated remotely over telephone lines from the United Kingdom.

Giant interlocking shells of gas are visible in this view of the dwarf galaxy IC 1613 made in red hydrogen-alpha light. This image was obtained with a CCD camera on the Manchester Echelle Spectrometer at the William Herschel Telescope. Courtesy John Meaburn.

Throughout the exposure the star image remains firmly within the 1.5-arc-second slit, a tribute both to the telescope's guiding and La Palma's consistent 1-arc-second or better seeing. When amateurs talk of good seeing, they tend to think of those brief moments when close double stars can be resolved. But when professionals say the seeing is 1 arc second they mean that star images are 1 arc second across and remain permanently steady. To an amateur observer used to watching star images dance like Jell-O, rock-steady seeing of this kind seems unreal.

The observing team clusters around the screens as the exposure ends and the CCD is read out. A few minutes later the computer displays the spectrum, estimates the magnitude of the object to be 20.5, and calculates that its redshift is 0.67. The object appears to be a quasar, but the spectrum is of poor quality, so Mason and colleague Jeremy Allington-Smith (Durham University) decide to repeat the observation.

That completed, they turn to another source. This time their first spectrum is that of an ordinary star — they have chosen the wrong candidate from the field. They are luckier with their next choice, which proves to be a galaxy. Someone in the control room puts a cassette in the tape player, and so the evening goes on.

IMPRESSIONS

I wander outside with my 10 x 50 binoculars to do some "eyeballs-on" astronomy. The silhouette of the Herschel Telescope's dome looms large against the sequined sky. In the west, Venus and Jupiter are setting and cast a faint but definite shadow in front of me. Evidently there is still some high cirrus around, for the sky is not as dark as I had anticipated. Toward the north are the identical twins of the Double Cluster in Perseus. In the south hover the contrasting clusters M46 and M47 in Puppis. Below them I spy the globular-like NGC 2477, forever beneath the horizon of a far-northern observer such as myself. Higher up, I detect the pale Moon-size nebulosity of the Rosette.

A few hundred yards away along the silent mountainside, a Dutch team is using the Isaac Newton Telescope to take spectra of faint radio sources. At the Kapteyn Telescope, Robert Joseph, now director of NASA's Infrared Telescope Facility on Mauna Kea, is making photometric measurements of galaxies.

Shortly after 7 o'clock the next morning the Herschel Telescope's dome closes after 11½ hours of observing. It has logged 16 objects, among them two new quasars to add to the 26 found the week before. A handwritten notice on the wall of the control room proclaims that a group from Queen Mary College and Cambridge and Durham universities has measured in only one month the redshifts of more than 1,000 galaxies spotted by the Infrared Astronomical Satellite.

This is production-line observing at a level no other telescope can match. The William Herschel Telescope is already fulfilling its promise of elucidating the structure of the universe, as did the great William Herschel himself.

Ian Ridpath is the editor of Norton's 2000.0, *the recently revised version of the classic star atlas. He also serves as editor-in-chief of* Popular Astronomy, *the journal of Britain's Junior Astronomical Society.*