



A Night on Kitt Peak Thomas A. Dooling

Astronomy probably boasts more amateurs than any other scientific discipline. There are, however, vast differences between the rooftop or backyard six-inch reflecting telescope or a pair of hand-held binoculars and the huge, expensive, and rare astronomical telescopes at the major observatories.

One such observatory is the Kitt Peak National Observatory located 40 miles from Tucson, Ariz. Kitt Peak is different from most major observatories because it is a National Research Center reserving the bulk of telescope time for the use of visiting astronomers. The observatory is owned by the NSF and is operated under contract by a university consortium, the Association of Universities for Research in Astronomy, Inc.

Members of *Mosaic* staff were privileged to spend some time in two of Kitt Peak's larger observatory domes to observe at firsthand what a professional astronomer really does, and why.

Mr. Dooling is a member of the Mosaic staff.

The visitors' book at Kitt Peak National Observatory, just next to the door as you leave the astronomical museum, has been signed by thousands of visitors since it was placed there. A surprisingly large number have left comments, the common theme of which is "I wish I could look through the telescope." It is, unfortunately, not possible for visitors to Kitt Peak to look through the telescopes there: major equipment is so scarce that

time on them is too precious to be reserved for anyone other than a working astronomer. Moreover, the conditions under which the telescopes are used—the darkness of night and the cold of high altitudes—would deter all but the hardiest.

Yet, the refrain echoes as a characteristic of astronomy that no other basic science shares: it is a study that has excited man's curiosity since the first of us

looked up at the frosty night sky—and that will continue to intrigue until the last of us looks up.

Many observational astronomers admit that the major motivation behind their choice of careers was this same curiosity, and many also admit that the beauty of the night skies keeps them at it.

The general public and the astronomer, then, look at the skies for very much the same reason, yet the life and

work of astronomers, and what goes on inside their observatory domes remain in many ways obscure.

What does an astronomer do when he is at work at a telescope? What are the reasons for what he does? What are the conditions in which he works? There is no obscurity in the answers to these questions.

INSIDE THE DOME

The darkness and the extreme cold heighten your other senses, particularly hearing—the groan of wind against the outside of the metal dome, the high electronic whine of small motors, bursts of muffled ticks from a relay box. From time to time you can hear nothing but a rumble very like that of a train passing close by as the dome rotates, punctuated by the racket of heavy-duty solenoids slamming closed—followed by the relative silence of small sounds.

The space around you is enclosed by the dome, but you feel, rather than see, its bounds in the dark. It changes shape; the floor rises and falls and moves back and forth. The dominating shape of the telescope changes its position. The faint spill of light from the sky now comes in from one direction, now from another. The voices of those around you are hushed, pressed, staccato—accompanied by a devils' dance of small red lights from the astronomers' shielded flashlights which flash and swoop around the base of the telescope and reflect dimly off the walls of the dome.

There are sound reasons behind each of the unusual phenomena in this environment—the nature of the big astronomical telescope and the practical requirements of a working astronomer. An observational astronomer spends only a fraction of his life actually at the telescope: the bulk of his work consists of analyzing the results of his observations—the pictures and records of light that fell on his telescope. For this, he needs to capture as many photons—units of light energy—as he can from a given light source, with minimum intervening interference, and then to obtain the maximum amount of information from them. His first require-

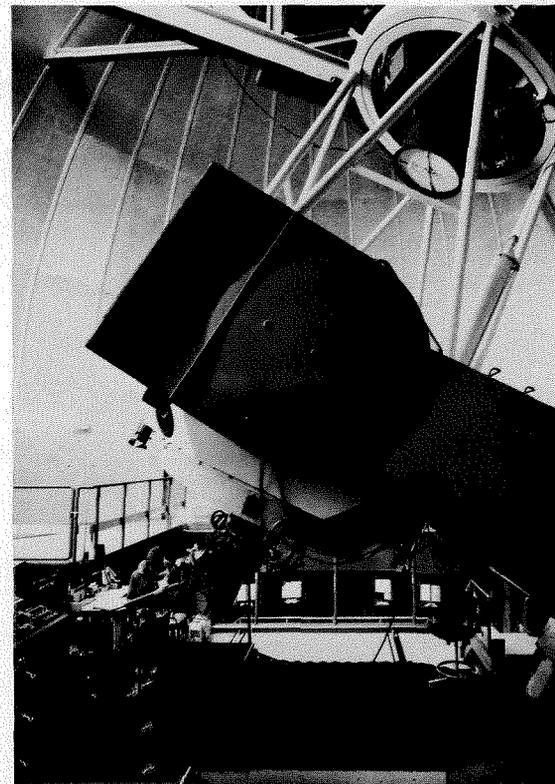
ment, therefore, is a lens or mirror in which to catch the photons. The bigger the mirror—and therefore the telescope—the more photons he'll catch. Second, the less interference in the atmosphere between the telescope and the source in the sky, the more photons will get through to the telescope.

The mirror may reflect a distorted image of the sky if it expands and contracts with variations in temperature. A solution to this problem is to keep the entire telescope at a near constant temperature—that of the night air—so astronomical domes are never heated. Over the years, astronomers have developed costumes much like those of Arctic explorers in order to work all night in temperatures which may go down to -30° F. in the cold, thin night air of an observatory's normal mountaintop location.

ROTATION OF SPIRAL GALAXIES

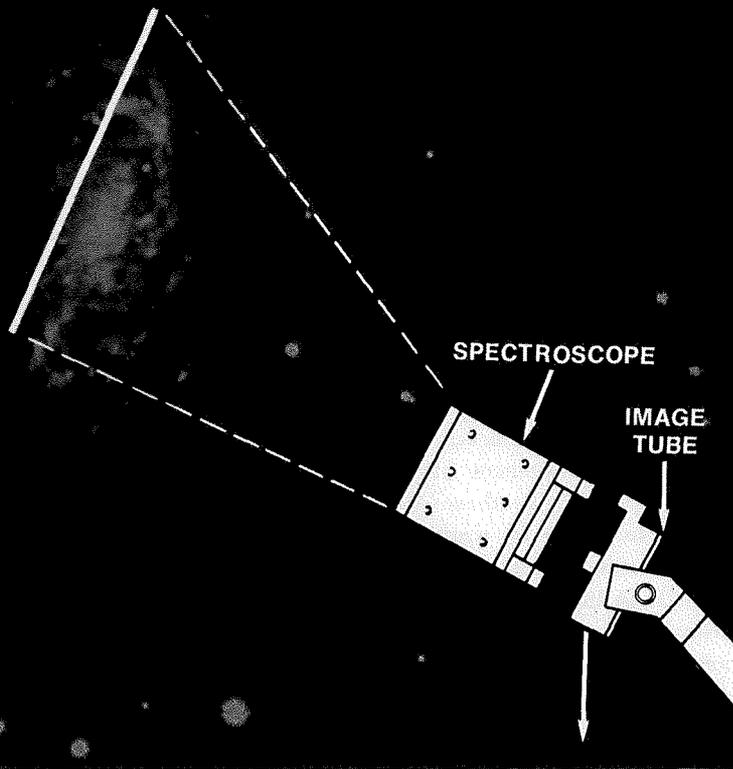
A visit to an observatory is an exhausting period of intellectual work and physical hardship for an astronomer. Most of the daylight hours must be reserved for catching up on sleep missed during the observing night. Moreover, the working nights are long—an astronomer may work for 14 hours from initial instrument checking before supper to closing up the dome at dawn. Nonetheless, astronomers eagerly wait for an opportunity to use the telescopes and travel from all over the country for three or four nights of observing time. One such astronomer, Dr. Susan Simkin, flew out from Columbia University early in January 1970, to spend nearly a week using several of the facilities at Kitt Peak.

Mrs. Simkin is interested in the rotation of distant galaxies, particularly spiral galaxies, like our own. The observational data she obtained are, in part, related to a theoretical study of the rotational dynamics of galaxies being performed by senior colleagues at Columbia. To obtain this information, her primary work at the observatory consisted of obtaining a number of photographs on glass plates of spectra. Spectra are sets of lines which are an array of the component

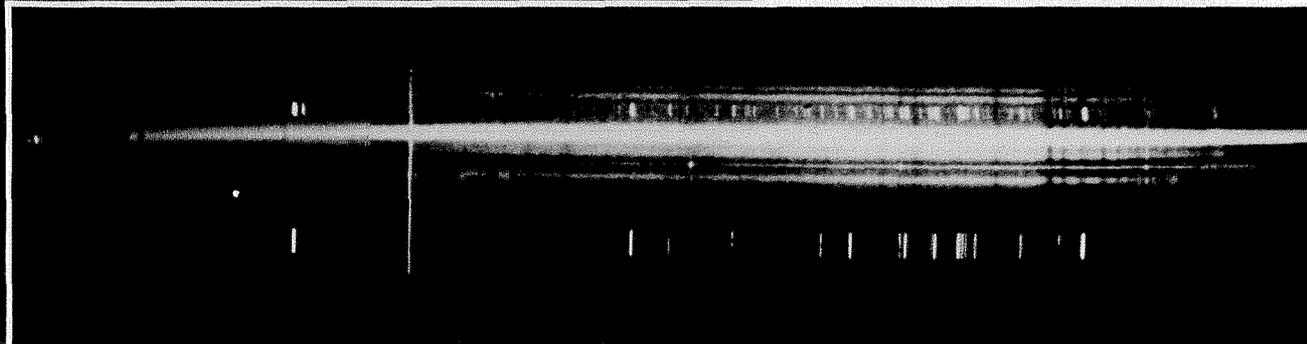


Kitt Peak 84-inch reflecting telescope.

waves of the light received from the galaxies by the telescope, arranged according to the lengths of the waves which make up the various colors. From these spectra, the velocities with which the galaxies rotate can be calculated by measuring changes in the spectral lines from their normal positions. This effect, known as the Doppler shifting, occurs because the waves which convey light (or sound) are foreshortened or pushed closer together if their source is approaching the observer. This makes the perceived sound higher pitched, and light bluer. If the object is receding, the waves are stretched out, and sound is lower pitched, light redder. (Common examples of Doppler shifts in sound waves can be found in the change in pitch of a railway horn as the train passes an observer at a crossing, or of engine noise as a low-flying plane passes directly overhead.)



Light from spiral galaxy (NGC 2903) falls on slit of spectroscope (shown here superimposed on galaxy). The light is broken up into a spectrum of its component wavelengths and the spectrum amplified electrically (below). Sharp lines at bottom of spectrum are from calibration source.



Carnegie Image Tube

To obtain the spectra which contain the raw information she needs, Mrs. Simkin used the largest of Kitt Peak's telescopes, the 84-inch reflector, with a Carnegie Image Tube Spectrograph attached to it. The image tube is an electronic light intensifier working along somewhat the same principles as television, developed by the Carnegie Institution of Washington with NSF support, for use in certain applications with astronomical telescopes.

The increase in light gathering power that the image tube gives to the big 84-inch telescope gives her a weapon against

one of her—and most astronomers'—worst enemies, dawn. With a smaller telescope, or without the image tube, she would be unable to obtain the amount of light she needs in any reasonable period of time because of the faintness of the objects she was looking at. In fact, some objects of interest to her are so faint that without this equipment, she would not be able to get enough light in an entire observing night.

PLANS AND PROBLEMS

No matter how carefully an astronomical observation is planned in the weeks and months prior to a visit to an

observatory, and no matter how painstakingly the equipment is set up in the days immediately preceding, accidents and problems occur during the working night. Many of these incidents could potentially destroy or invalidate observational data: the equipment holding the photographic plate can be physically jostled, causing a blurry image; high level clouds can move in, effectively cutting off observation; or electrical problems in the image tube can cause errors. The probability of a significant investment of time and work being spoiled is, of course, decreased by getting data in less time; but astronomers also plan around such eventualities. Virtually every manipulation or

change of the telescope is checked and rechecked, and experimental results are reviewed as soon as possible to assure that all has gone well.

Mrs. Simkin moved at what sometimes seemed to be a dead run—no mean feat in the pitch dark—between the darkroom, the telescope, and her office, to get maximum mileage out of her allotted time on the telescope. While an exposure was in progress, under her assistant's supervision, she would be in the darkroom developing the plate of the previous exposure, or handling necessary last minute preparations for positioning the telescope for the next observation, in view of the night's experience so far.

THE SPECTROSCOPE

Mrs. Simkin obtained spectra of the galaxies of interest to her by using the image from a slit-type spectroscope. She turned the telescope so that a portion of the image of the galaxy in which she was interested was reflected onto the entrance slit of the spectroscope. (Typically, the slit covered a thin slice of the galaxy from one side to the other, passing through the central region of the galaxy.)

The spectroscope reflected the image from a series of mirrors and a diffraction grating which disperse the light according to its component colors or wavelengths, producing a spectrum of a portion of the galaxy. This spectrum was amplified by the Carnegie image tube, and recorded photographically on a sensitized glass plate.

Guidance of Telescope

Obtaining data to be analyzed later sounds simple enough. However, the galaxies of interest to Mrs. Simkin are such faint sources of light that even with amplification, she had to take hour-long exposures. During that period of time, the position of the telescope had to be continuously adjusted to compensate for the rotation of the earth, which causes celestial objects to seemingly move in the sky. The major part of the resulting "tracking" of the source is done automatically by a drive built into the telescope. However, to ensure that the telescope did

not drift off the target, it was guided during each exposure by making minute corrections in its orientation.

Location of Light Source

While the positions of the galaxies are known, and coordinates which will orient the telescope towards a specific one can be found in an atlas and fed into the controls, the final positioning and adjustment of the telescope require skill and a trained eye. Many of the galaxies are so faint that even with a large telescope, the human eye cannot see them. Therefore, while Mrs. Simkin knew the galaxies were there, and could photograph them, she could not see them in the telescope. It was therefore necessary for her to compare the field she could see through the telescope to a photograph of the stellar vicinity of the galaxy of interest and, in effect, aim at a blank space in the field that her experience and measurement from time-exposure photographs told her contained a galaxy.

Although the guidance process was not continuous, it was necessary to check the eyepiece at frequent intervals, between monitoring other parts of the instrumentation. The continuous motion of the telescope made it necessary for the astronomers to change the position of the instrument platform, and from time to time their own position as observers—now looking down through the eyepiece as it was near the floor, later standing on a short stepladder and peering up.

The relative positions of the telescope and other equipment were never the same

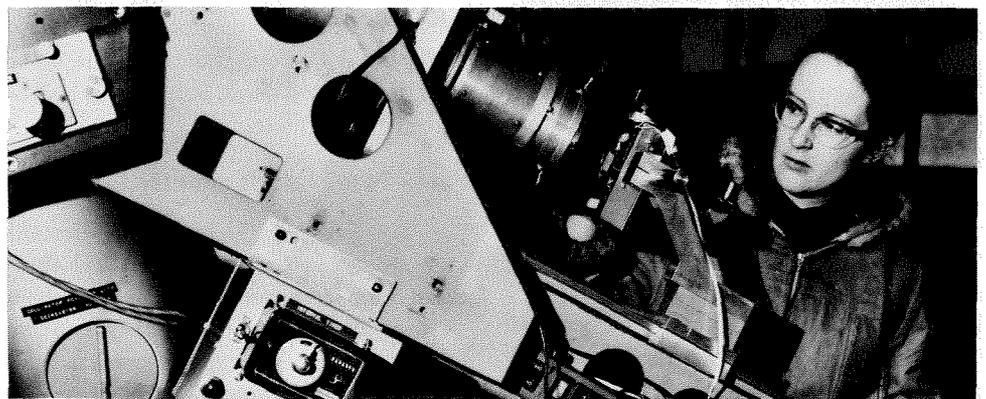
because of the motion, and in the dark occasional and painful collisions with the base of the telescope or other equipment are a good reason for many astronomers to wear "hard hats"—sometimes even motorcycle helmets.

While all observational astronomers are photon hunters, they differ markedly in what they do with the photons they catch. Mrs. Simkin, for instance, is amplifying very pale light to get a full spectrum of known lines, photograph them, and thereby determine galactic movements.

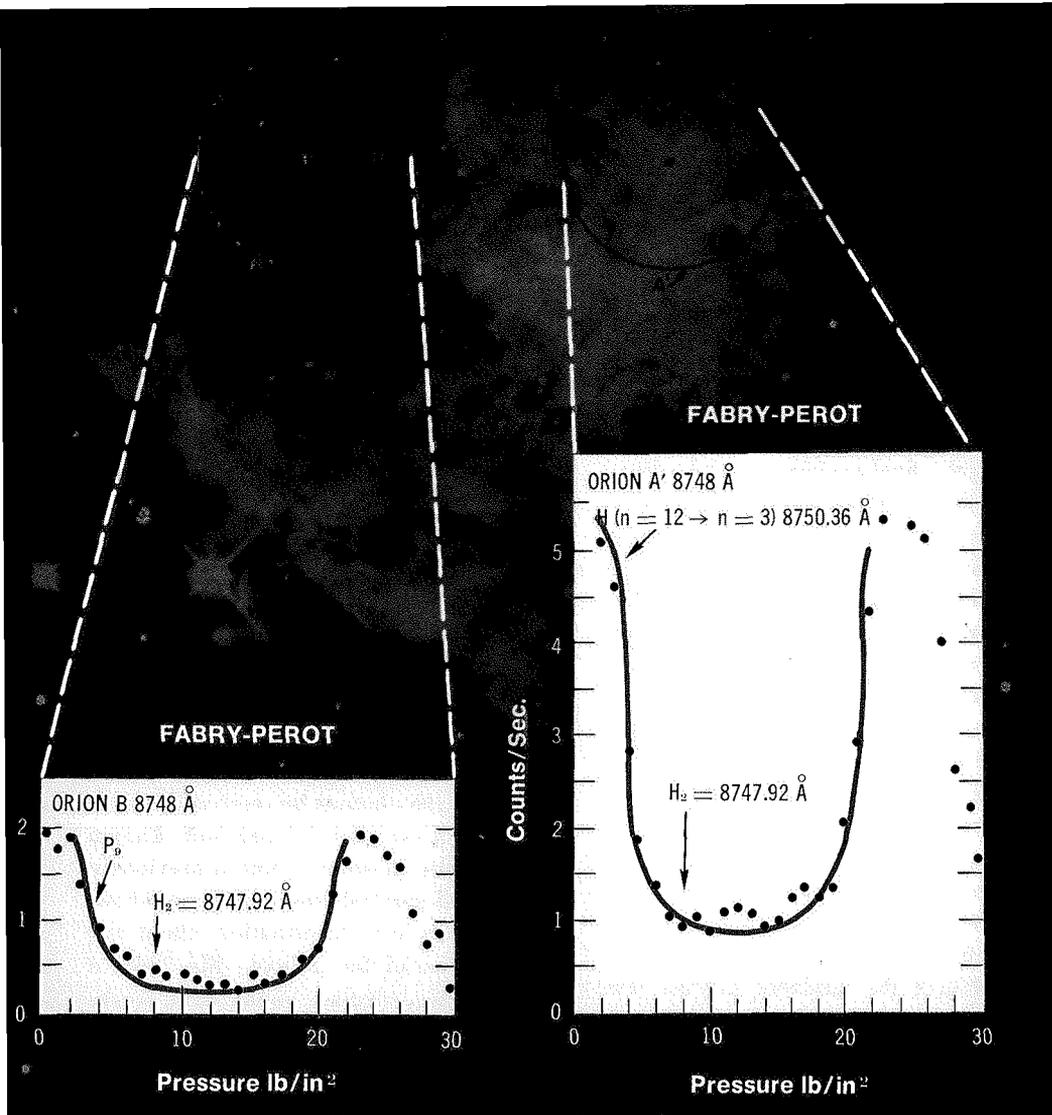
INTERSTELLAR HYDROGEN

In comparison, Ted Gull, a graduate student at Cornell University, working at Kitt Peak at the same time, was carefully screening the photons he received, recording only a very few of precisely known wavelengths, in order to find a previously undetected spectral line which would reveal to him new information about the composition of the galaxy. Mr. Gull, a soft-spoken, articulate young man, working under the direction of Cornell's Professor Martin Harwit, was not using the photons to produce images on a photographic plate, but was counting them individually. (While Mr. Gull's equipment was recording one or two photons per second, the small flashlight he used to check his equipment emits about one billion billion in the same time.)

The spectral line which Mr. Gull was looking for will, if it exists, help show the existence of clouds of molecular hy-



Dr. Simkin examines Carnegie image tube spectrograph on 84-inch telescope.



Photons from the sources circled in the photo of the Orion nebula yield typical spectra as shown here as the gas pressure in the Fabry-Perot interferometer is increased. The peaks are the strong emission lines of atomic hydrogen; arrows indicate the predicted position of the molecular hydrogen emission line.

with a partially reflective coating, enclosing a pressurized gas. The "tuning" is accomplished by varying the gas pressure, and the number of photons which come through at a given pressure is counted electronically and recorded in a small computing device.

Since wavelengths and pressure are correlated, the number of photons at each pressure is a measure of light intensity, and a graph can be constructed which shows whether there is a spectral emission line, a "peak of intensity," at a given wavelength.

KITT PEAK 50-INCH TELESCOPE

For the actual observational work in gathering the data to construct his graphs, Mr. Gull used Kitt Peak's 50-inch telescope and associated equipment of his own construction. This telescope and its dome are quite different from the 84-inch facility at Kitt Peak. While the 84-inch telescope is the fifth largest high resolution astronomical instrument in the United States, the 50-inch instrument is neither particularly large nor is its resolution extremely good. Originally designed as a remote control telescope, and used for that purpose until only very recently, its primary mirror is aluminum, not glass. The original use of the telescope was to determine what kind of work could be done, and what telemetry was needed to do astronomical work by remote control as a test against the day when unmanned astronomical telescopes will orbit the earth to perform experiments controlled by scientists on the ground. While the

drogen in interstellar space. As yet undetected in molecular form elsewhere than on the earth, where it is the most common form, hydrogen is the most plentiful element known in the universe.

One of the specific emission lines Mr. Gull was looking for is at a wavelength of 8,748 angstroms. (The angstrom unit, used to measure the length of light waves, is equal to about four one-billionths of an inch.) Proof of an emission line at that wavelength in the light from the sources he was looking at would constitute strong evidence of the presence of molecular hydrogen in that region of interstellar space. Since he was interested in only two or three spectral lines, his equipment was set up so that he looked only at a short segment of the spectrum centered around those wavelengths.

To do this, all the light received by his telescope from the source is directed first at a preselecting filter. This filter is similar to the color filter used on cameras, except that it is so coated that it filters out all but a very narrow "color band" of infrared light, a segment of the spectrum about ten Angstroms wide. All the other light is reflected back into space, or absorbed by the filter.

Fabry-Perot Interferometer

The remaining light is then directed at a second instrument, called a Fabry-Perot interferometer, which is, in effect, another filter, but one which can be "tuned" across the short segment of the spectrum received from the first filter. The Fabry-Perot consists of two very flat, nearly perfectly parallel plates covered

aluminum dish does not permit a very high degree of resolution, it is well adapted to catching large numbers of photons.

Instrumentation

The striking feature in the dome for the 50-inch telescope—other than the telescope itself—during the time Mr. Gull was using it, was a pair of sturdy plywood packing crates packed with instrumentation and swathed in plastic sheeting for warmth. These crates served the purpose of instrumentation racks while in the observatory. Mr. Gull, who has traveled between Kitt Peak and Cornell frequently, so designed and built them that, with a few minor changes in packing and the addition of lids, they could be used as shipping containers.

Mr. Gull began his observing night, as do most astronomers, before supper with an equipment check. Typically, he does any work that can be done before full darkness in the late afternoon and during twilight so that it will not encroach on his precious observing time. The heart of his system, the Fabry-Perot, received the most careful attention. The parallelism

of the two plates of the interferometer had to be checked and adjusted; this could take some time since the parallelism had to be checked under pressure, and the adjustments could only be made while the plates were not under pressure. Consequently, he sometimes had to repeat the sequence of adjusting and checking the plates 20 or 30 times until he was satisfied with the alignment.

Calibrations

Because of the sophistication of the equipment they use, astronomers must spend a substantial part of their observing time calibrating their equipment. Mr. Gull, for instance, took 40-minute observations of nebulae and spent at least ten minutes between exposures calibrating his equipment. This calibration consisted of a short scan of a known light source at the same infrared wavelengths he was examining from his interstellar sources. This comparison for his experimental data ensured that if the equipment sensitivity or spectral response were drifting, he could compensate for it.

An astronomer must also spend a certain amount of time maintaining his

equipment and coping with problems. Mr. Gull must keep his photon counter much colder than even the nighttime dome environment, so he had it housed in a dry ice chamber. The dry ice had to be replenished from time to time during the night, the process being complicated by the necessity of inserting the dry ice into the chamber in the dark, and without changing the position of the telescope.

Mr. Gull's operation differed somewhat from Mrs. Simkin's in that he did not have to devote so much of his attention and time to guiding the telescope. Where Mrs. Simkin had to develop photographic plates during the course of the night, out of a natural and necessary curiosity to know as soon as possible whether she had obtained any information during the observation period, Mr. Gull's data were more readily checked by reference to his electronic display. Mrs. Simkin is studying the dynamics of galaxies while Mr. Gull is interested in their composition. Mrs. Simkin obtains her data by photographing an amplified, broad spectrum of visible light where Mr. Gull is counting individual photons covering a very narrow band of the infrared spectrum.

More important, though, than the difference between them are what they have in common. Both are dedicated to the challenge of learning, by observation and deduction, previously unknown facts about the structure and behavior of the universe itself. Both cheerfully put up with the cold, long hours, disorientation, time pressures, and frustrations, not only with equipment, but with the threat of experimental failure that make up the life and work of an astronomer.

Both Mrs. Simkin and Mr. Gull have and will continue to work hard for the privilege of satisfying their curiosity about the nature of the universe, as it can be learned from looking at the stars—a curiosity that they share with all of us who have looked at the stars on a clear night. It has always been the nature of man to wonder at the stars and try to understand the universe he sees—there will be astronomers among us, both amateur and professional, as long as we can look up and see the stars in the sky. ■

