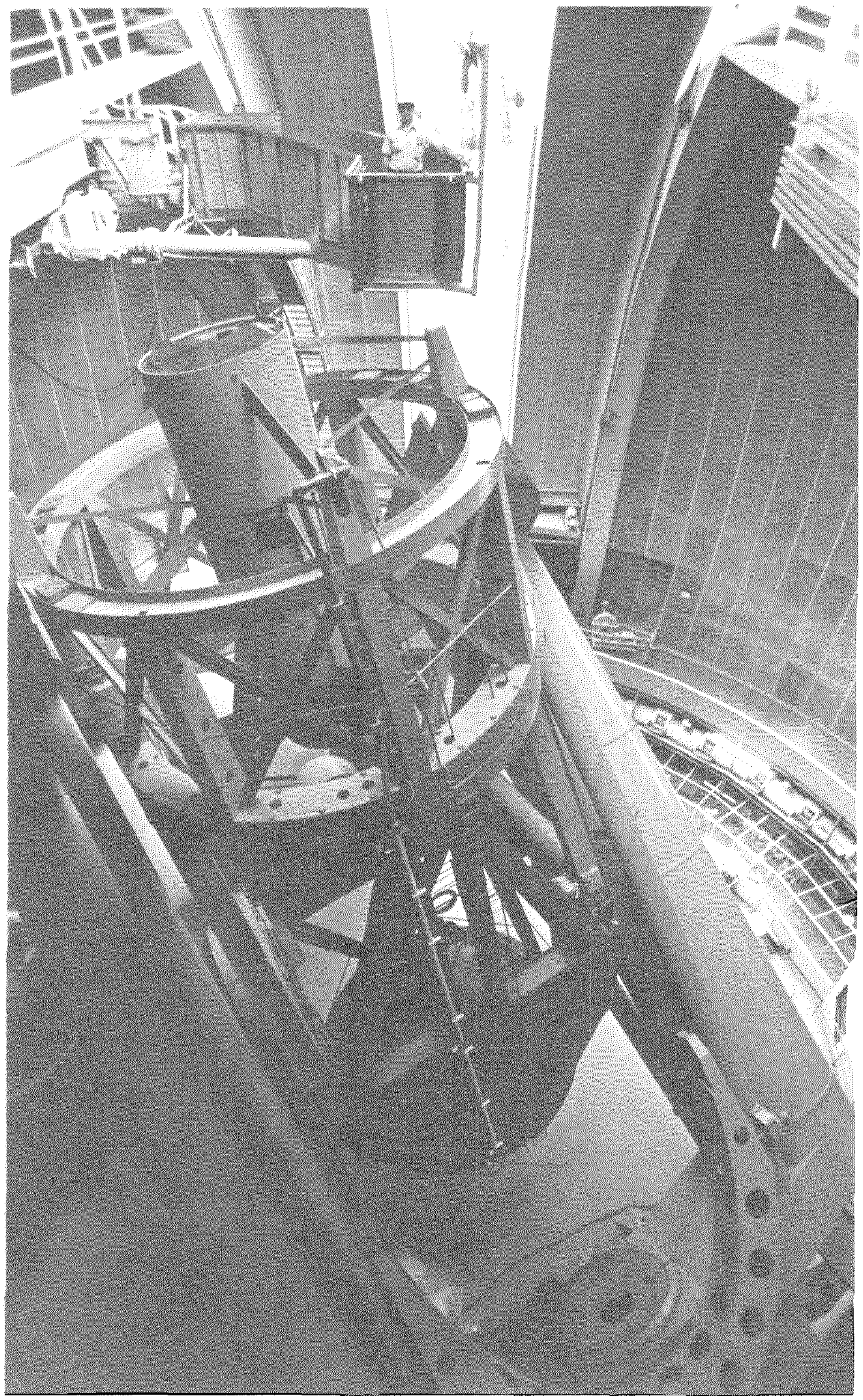
A Night on Palomar Mountain — 1983

by John Gustafson



Back in 1969, E&S *printed its first version of "A Night on Palomar Mountain." The article was written by Jesse Greenstein, now DuBridge Professor of Astrophysics, Emeritus, and it later appeared in* the 1970 Yearbook of Science and the Future. *But John Gustafson, who spent this summer at Palomar as an intern in science writing, noted that much about observing has changed in the last 14 years, and he wanted to describe some of those changes. His article appears below, accompanied by a few quotations from the original.*

THE MASSIVE shutter doors, nearly half a football field long, part quietly in response to the touch of a button by the telescope operator. The fading light of dusk fills the cavernous dome of the 200-inch Hale Telescope. The telescope itself, a mammoth steel construct at the moment more silhouette than substance, waits silently amid a flurry of activity — the astronomers are making the final preparations for the night's observing. When finished, they will aim the telescope at a chosen spot in the sky, and the giant glass mirror will gather and focus light that may have been streaming across space for billions of years.

Billion-year-old starlight is what tonight's astronomers — J. Beverley Oke of Caltech, James Gunn of Princeton and Caltech, and John Hoessel of the Space Science Telescope Institute — are, in fact, collecting and studying. They are investigating distant groups of galaxies, galaxy clusters at the extreme limit of detectability. These galaxies, whose existence could only have been guessed at a decade ago, can be studied today because of sensitive electronic light detectors that have almost entirely replaced the astronomer's traditional aid, the photographic plate.

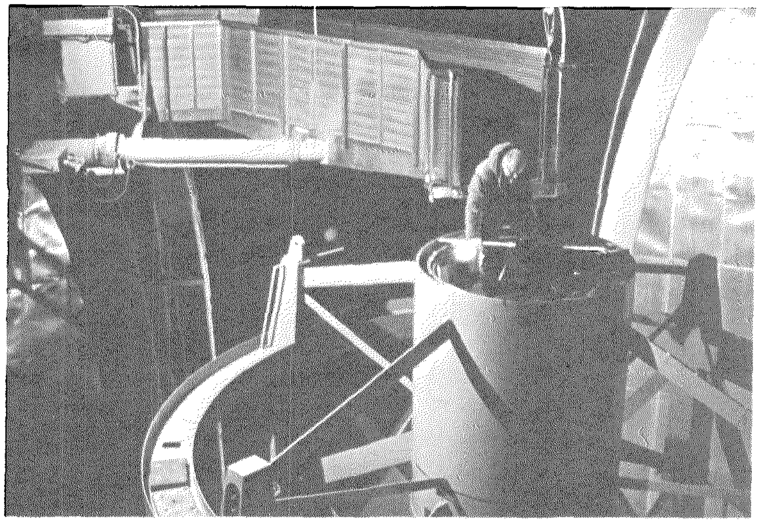
To a certain extent, modern light detectors — mainly the charge coupled device (CCD) — have changed the character of an astronomer's nighttime experience. For example, a single astronomer used to make the trek to the telescope to observe. Now it is more common for a team of astronomers — two, three, sometimes more — to work together through the night. Besides trading worried words about the clouds on the horizon, or opinions about recent research results, the team shares the variety of tasks that modern observing requires.

Tonight's team is using PFUEI (pronounced "phooey"), an acronym for Prime Focus Universal Extragalactic Instrument, which was designed by Gunn and James Westphal of Caltech. PFUEI has an optical arrangement that concentrates the converging beam of light from the 200-inch mirror onto a CCD, and electronics linking the computer that reads and controls the CCD. The device fits into the instrument holder in the prime focus observing station. John Hoessel is this night's choice to ride in the prime focus cage, a somewhat cramped metallic cylinder, suspended at the top of the telescope's frame 55 feet above the mirror, with displays and equipment lining its perimeter.

The 34-year-old Hale Telescope was the first astronomical instrument large enough to carry an observer at the primary focal point, and a night in the observing cage is seen by some as an essential initiation into astronomy's inner orders. Others view the prime focus experience as one of professional astronomy's last remaining romantic aspects. Hoessel looks upon it as a necessary chore: "It was fun the first time I did it, but I quickly outgrew that." As Hoessel makes the trip above, Gunn and Oke take up their places in front of a variety of television monitors, instrument displays, and computer keyboards in a comfortable, well-lit room on the main observing floor. A few feet away from the astronomers, the telescope operator, Juan Carrasco, sits in front of his own bank of displays and controls, waiting to point the telescope toward the first object.

From the control room, besides offering Hoessel friendly jibes over the intercom, Gunn and Oke operate the computer that controls PFUEI and interprets the data it accumulates. The very nature of the dime-sized, light-sensitive CCD silicon wafer lends itself to on-site data reduction. A CCD contains thousands of individual cells that convert impinging photons to an electric charge. Each cell, or pixel, builds up a charge until the exposure ends. Then the computer records the charge level and position of each pixel on magnetic tape. Since the computer's presence is necessary to read the CCD, it's a simple matter to add another program that interprets the stored information and recreates and displays the captured image on the television monitor.

Palomar — 1969



Jesse Greenstein steps into the observing cage — in 1969 — from an elevator that climbs 60 feet up the inside curve of the observatory dome.

By unbreakable tradition, each astronomer makes his own observations at a large telescope. He is surrounded by engineering marvels and advanced electronic technology. But making a critical and delicate observation is still, ultimately, a one-man struggle.

The romance and beauty of the night, of the half-seen, faint glow of starlight, promise excitement and mystery. The observing process is an irresistible adventure for me, even after 30 years. I am a telescope addict, and in love with a 500-ton steel and glass monster, at Palomar.

The telescope slides a few degrees; I look down the tube at a black pool filled with tiny lights, the mirror 55 feet away catching starlight. Then, in the eyepiece is a strange, pale, white glow, shaped like a comet; at its tip, a star is being born. Our view is as old as civilization; the light is 5,000 years old.

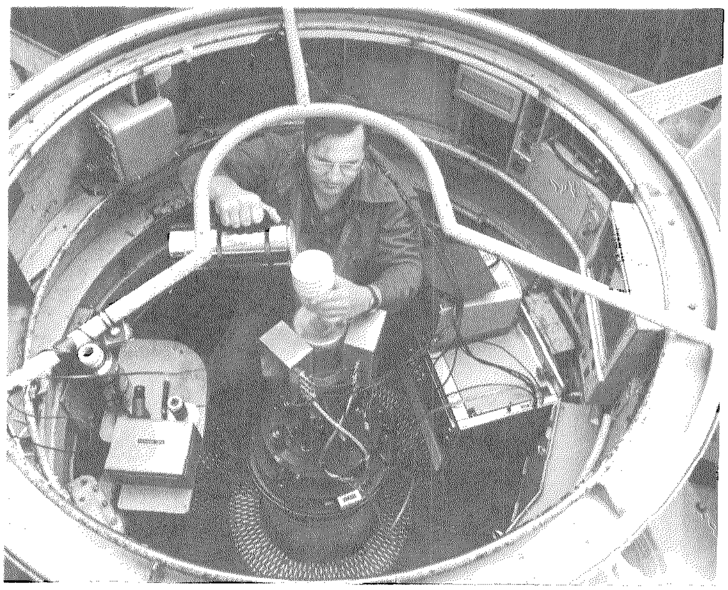
A bustle of final settings, calibrations, data for the observing record; I pull out the camera-cover slide, and the exposure begins. Then silence, only the distant pumps, and the passage of time. The telescope is turning 15 feet an hour to follow a star 3×10^{16} miles away! The star stays frozen on the spectrograph slit, but every few minutes I check and reset the fine motions of the telescope, perhaps a thousandth of an inch, to maintain centering.

The process of exposing a photographic plate, carrying it to the dark room, developing it, and scrutinizing it through an eyepiece seldom occurs now. These nights, the quick data display lets astronomers know immediately if their efforts were successful or not.

The nature of the CCD also determines some of the chores that face the astronomers when they arrive at the dome. After riding the elevator to the prime focus, Hoessel first fills a reservoir surrounding the CCD from a thermos of liquid nitrogen. Within the light detector's chamber, the temperature chills to 150 degrees below zero. A warm CCD spontaneously liberates electrons, which would mix with the real signal generated by the light. A cold CCD, however, looses substantially fewer extraneous electrons and has a correspondingly cleaner signal. After topping off the reservoir and sending the elevator back down, Hoessel tells his colleagues below that he is ready to take some "flats."

Flats are necessary because each CCD has its own unique response; some pixels are more, some less sensitive than average. When the device is exposed to a flat, uniform field of light, the resulting image will show light and dark spots. By storing this image in the computer, the chip's own response can be subtracted later from an actual exposure, called "flattening" the exposure, and so accurately reproduce what the CCD "saw."

Taking flats is a brief procedure, so soon after Hoessel has climbed into the cage, everything is set to go. In the control room, Oke leans back in his chair and asks, "Juan, can you give us a bright star near the meridian, please?" Carrasco, with anticipation born from years of experience, already has a star chosen. He types the star's designation into the computer, which displays the proper, updated coordinates on a monitor. With these as a guide, Carrasco presses buttons, and as the dome shutters spread open, the telescope swings over a few degrees.



Astronomers are not the only scientists who occupy the prime focus cage of the 200-inch Hale Telescope. Here, Edward Danielson, senior scientist on the planetary sciences staff, cools the CCD by pouring liquid nitrogen into it.

"It claims we're there," Carrasco says after aligning the telescope with the displayed figures.

And they are. A two-second exposure on PFUEI shows that the telescope has pinpointed a bright star. The astronomers use the star's image to make the final, precise adjustments to the telescope's focus.

Finally, all preparations are complete, twilight has faded into night, and the real observing begins.

"First object please, Juan," says Oke.

Carrasco refers to the prepared list that Oke gave him earlier and directs the telescope to object number one. High up in the dark dome, Hoessel has already been alerted to the upcoming motion and sits tight during the few-minute ride. Carrasco says the aiming is done. From above, Hoessel calls over the intercom that he has located a guide star, with which he will make minor corrections in the telescope's position and so keep the field centered on the CCD.

"OK, we're going to take a 150-second exposure," Gunn announces. He types rapidly at the terminal, giving the computer the appropriate commands, and then relaxes while the computer takes charge of the exposure.

Shortly, the image of the field unrolls on the monitor. Oke, holding a photograph of the desired field, leans forward to look at the screen. Comparing monitor and photograph he declares, "Looks like we've got it. Lets go with the red filter, a 900-second exposure."

Hoessel inserts the filter, Gunn keys the computer, and they're in business. Oke writes in the log all the pertinent information: the cluster's name, the time the exposure began, duration of the exposure, and what filter they're using. Then he takes advantage of the 15-minute exposure to go check the weather. Carrasco, who must shut the dome if weather conditions threaten, offers to go along.

Gunn, meanwhile, marvels at the image from the last exposure, which remains displayed on the monitor. There are a few bright stars scattered about the screen, and lying in the center about a dozen small, faint smudges —

the galaxy cluster under study. Such an image is a good reason for marveling. The new instrumentation has made it routine to examine galaxies with look-back times about half the age of the universe. Once that would have been unthinkable, as would the ability to study galaxy evolution not by inference but by direct observation. Astronomers can actually see the effects of the evolution of the universe in a few blots of light barely brighter than the background sky — vivid testimony to the power of modern light detectors.

Oke and Carrasco return before the exposure is done, having circled the dome's exterior catwalk, three stories above the ground. Oke bends over to the microphone and calls to Hoessel:

"The clouds seem to be getting higher in the sky."

"Yeah, my guide star keeps disappearing from time to time."

"Oh, you're just getting tired," Oke replies, and exchanges a grin with Gunn.

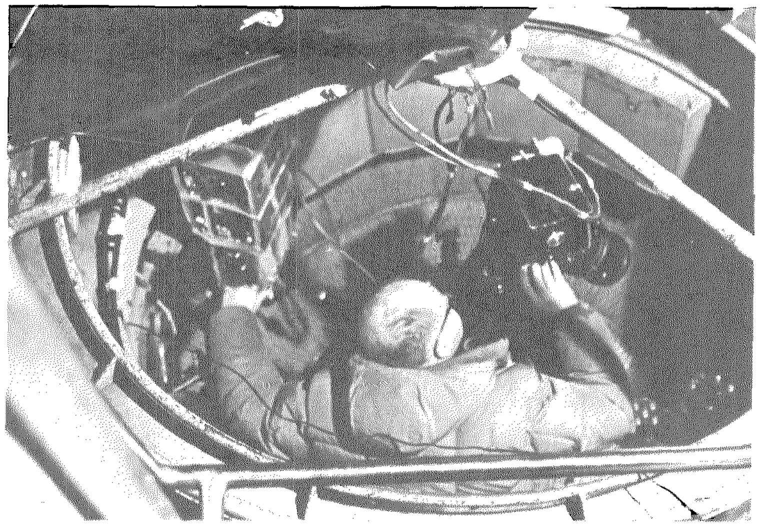
After the 15 minutes elapse, a buzzer signals that the shutter has closed, and lights on a wall panel flash to indicate that the computer is reading the CCD. By the time Hoessel has changed filters, the computer, primed by Gunn, is ready to start the next exposure. They observe this galaxy cluster through three different filters, examining each exposure on the monitor to ensure that all continues to function properly, before going on to the next object.

And so the night goes: an intense but efficient bustle of activity between the end of one exposure and the start of the next, and then a relaxed period — except for Hoessel, peering through the guider and manipulating the telescope — of contemplation and planning as the minutes of the next exposure slowly pass. For the faintest objects, exposure times of an hour or more are not uncommon.

This night the astronomers are fortunate — the clouds never become sufficiently bothersome to halt the observing. They work steadily through the night, until the approaching dawn begins to brighten the sky. Although the time often drags through a long exposure, with the coming day the night suddenly seems brief.

The elevator is sent to retrieve a stiff prime focus observer, and the trio strolls back to the monastery, pleased with their efforts and ready to sleep the morning away. They need to be well-rested for the next night's work, collecting and analyzing billion-year-old light in a continuing quest to decipher some of the mysteries of the universe. □

Palomar — 1969 . . . *continued*



Inside the cage, with spectrograph mounted, Greenstein adjusts his camera, checks his star charts, and settles in for a few cold hours of observation.

I retilt the seat. Once I climb on it to look out at the nearby sky; 42 degrees F feels cold if you sit still near midnight. What do I think of? Usually of nothing, hypnotized by the dulling reality of chill and fatigue, or of what I might have done incorrectly, or about the next exposure. But sometimes I think of what may be creating the dim glow I see.

After midnight I climb out of the tube, to the elevator, to descend to the darkroom, and have lunch. The plates, still wet, show the nebula spectrum was well exposed. The faint white dwarf gave a narrow streak of blackened silver grains that tells me something new. Up the elevators to the cage, to new objects and another four hours. At the end of the last exposure, dawn begins; the telescope is set vertical; the motors stop. . . . By dawn I am in the monastery, completely darkened and quiet, to sleep five hours till breakfast.

To the darkroom again at 1 p.m. to prepare for the next night. Are these objects interesting? Shall I change the program? It is the first of my four nights of this run. Tonight might be crucial; last night's plates suggested something new. I will be more tired; if there were only more time! Were I sensible, would I be an astronomer again? Of course, because next year, science will be better; new objects and instruments will be found; new ideas already are boiling, and there is so much unknown. What were all those flying specks of light in the mirror? What new marvels are waiting?