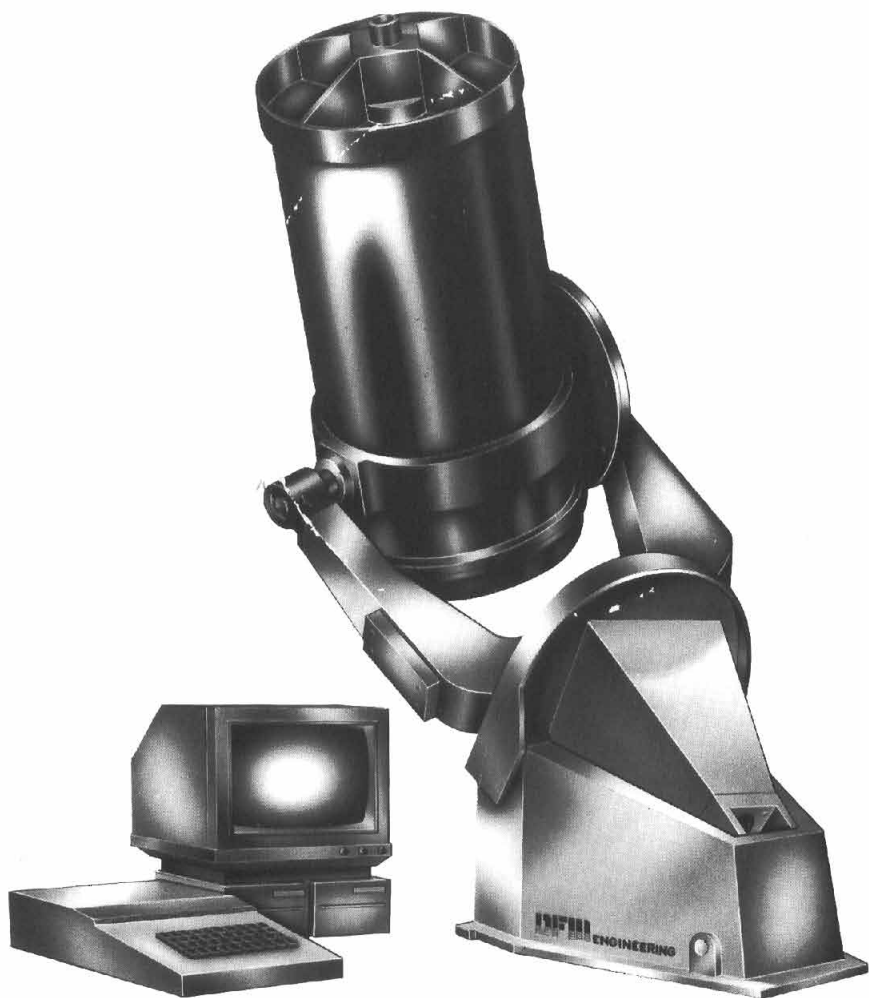


MICROCOMPUTERS IN ASTRONOMY II

EDITORS: Russell M. Genet & Karen A. Genet



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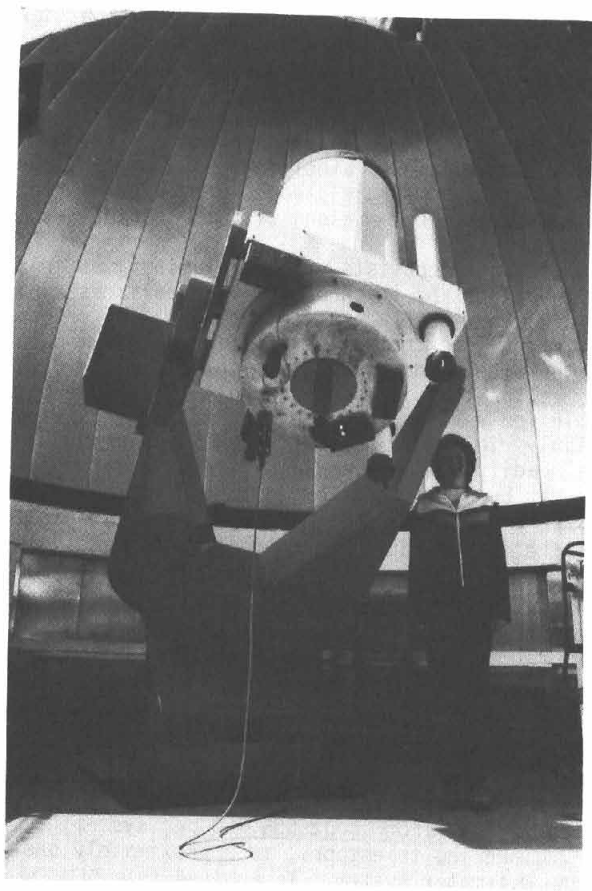


Figure 1. Kate Melsheimer stands beside the DFM Engineering 0.6-meter telescope shortly after it was installed at Grinnell College.

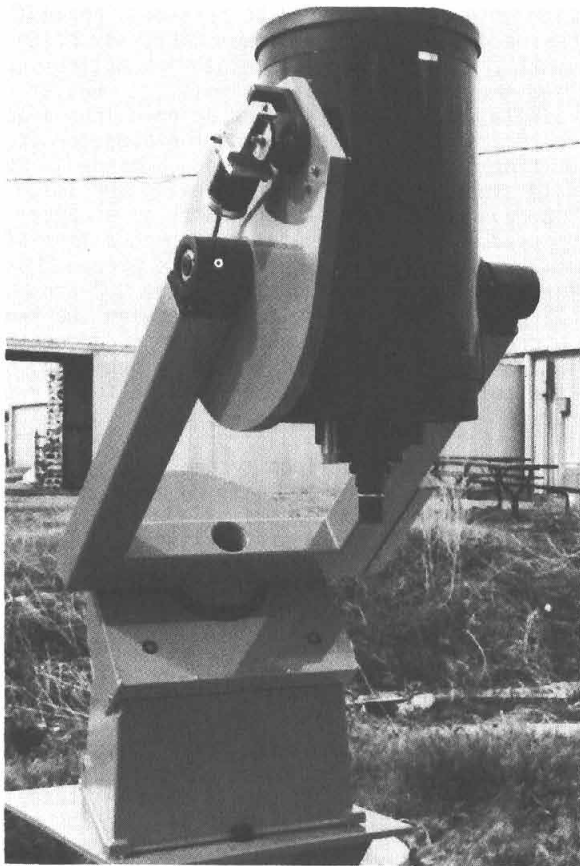


Figure 2. The DFM Engineering Small Telescope Mount shown with a Meade Instruments optical assembly. This photograph was taken at the Colorado plant during final checkout prior to shipment to the Fairborn Observatory.

II. TELESCOPES

Currently there are three automatic photoelectric telescopes (APT's) at the Fairborn Observatory. The system at Fairborn Observatory West in Phoenix, Arizona, is shown in Figure 1. It is a fork-mounted, 10-inch Newtonian telescope built by one of us (Boyd). Identical drives in RA and Dec consist in each axis of a 32-inch diameter disk driven by a stepper motor via a small worm gear, sprocket, and chain. This telescope has been fully operational since November, 1983, and has been described in some detail by Boyd, Genet, and Trueblood (1984).

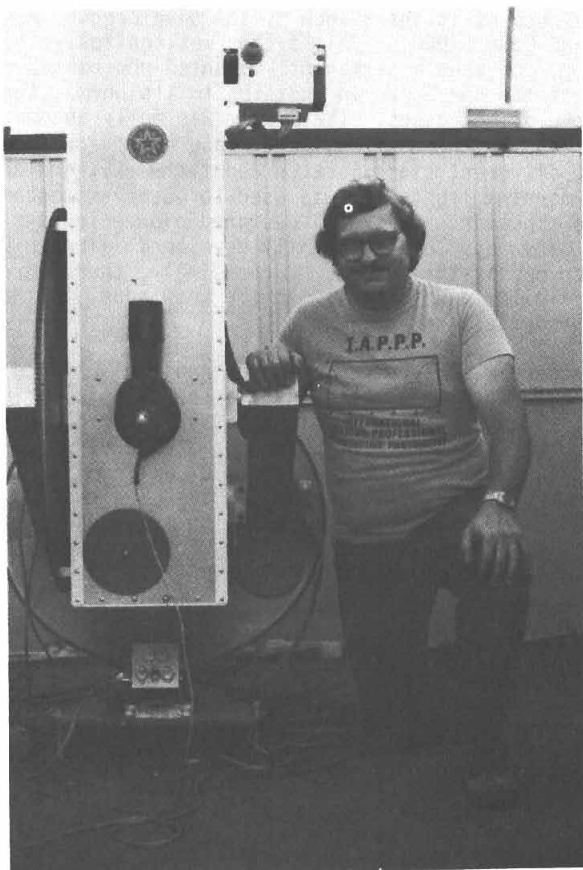


Figure 1. Louis Boyd and the Automatic Photoelectric Telescope (APT) at Fairborn Observatory West in Phoenix, Arizona.

One of the two APT's at Fairborn Observatory East, in Fairborn, Ohio, is very similar in its drive to the original telescope in Phoenix. It also uses identical drives in both axis consisting of 32-inch diameter disks driven steppers via worm gears, sprockets, and chains. As can be seen from Figure 2, it differs from the original system in that it uses a yoke mount, and 10-inch diameter Schmidt-Cassegrain optics.

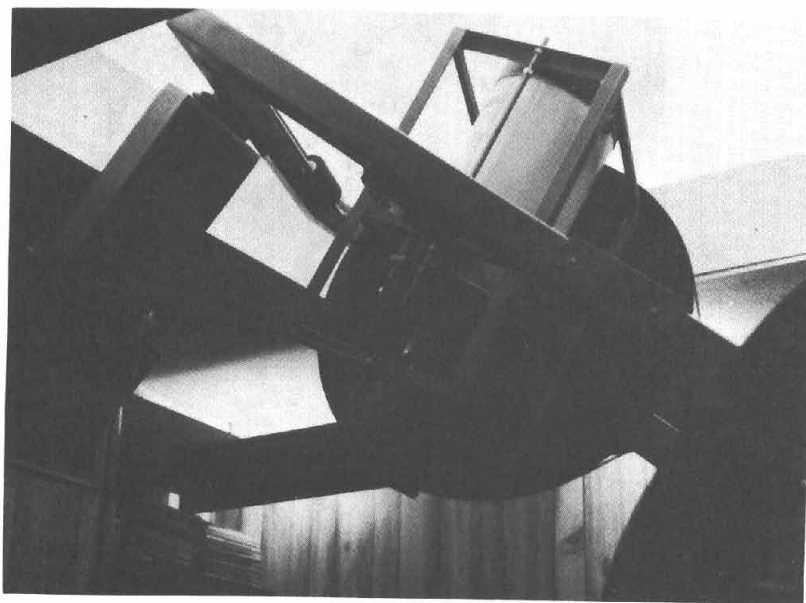


Figure 2. The yoke-mounted Automatic Photoelectric telescope at Fairborn Observatory East in Fairborn, Ohio.

The other APT at Fairborn Observatory East uses an extremely rigid mount and drive system designed and built by DFM Engineering. This system, shown in Figure 3, uses 15-inch diameter steel disks in RA and Dec that are driven by friction rollers. The rollers are in turn driven by steppers through worm gears. This arrangement provides the stiffest drive of any small telescope we have seen. The mount itself is made from generously proportioned aluminum castings that gives the system a very high natural frequency which facilitates very rapid movement under computer control. The optics on this system is a Meade Instruments 10-inch Schmidt Cassegrain. The same mount and drive is used in a commercially made, microcomputer-controlled 16-inch Cassegrain telescope made by DFM Engineering.

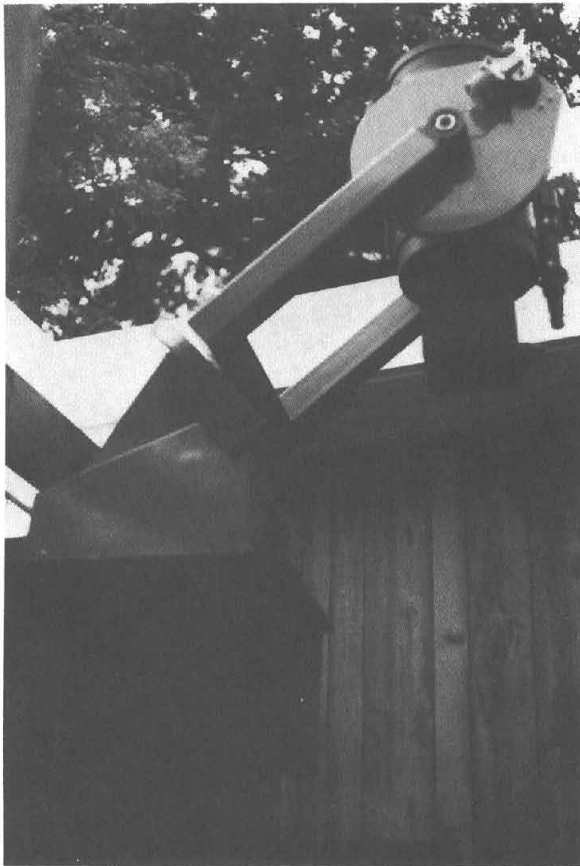


Figure 3. The DFM Engineering mounted Automatic Photoelectric Telescope at Fairborn Observatory East. The optical assembly is a Meade Instruments 10-inch Schmidt-Cassegrain.

III. CONTROL SYSTEMS

The original control system on the Phoenix APT has been totally redesigned, and is in a much simplified "second generation" form on the APT's in Ohio. The "brains" of the system is a 4-inch by 6-inch single board computer made by Peripheral Technology. This "PT69" computer costs less than \$300, and uses the Motorola 6809 microprocessor.

for unattended operation. Simply not requiring an operator makes the system perfect for remote sites. And the prospect of not having to stay up till dawn to get your numbers certainly seems a step in the right direction also!



Figure 1. Brasside Observatory houses a 16" Cassegrain constructed by Mr. Fried and resides in this 14" diameter aluminum dome. A control room is under the slanting portion of the building.

In the twelve months since the last great Fairborn meeting, we have produced 1150 differential points. When you include comparison and check stars, this amounts to almost 2500 individual star measurements, each one being measured three times in three colors and averaged. Most of our stars require a ten second integration time to support statistics. This works out to 370,500 seconds (6175 minutes, 103 hours or 4.3 days) of nonstop observing. When you break down these numbers into integrations per hour, in an appropriate manner we feel to analyze system efficiency, the answer comes out to be about 315 ten second integrations. This is with an experienced human operator and is conservative since some stars are easier to locate than others. Based upon the operation of an automatic photoelectric telescope (Boyd, 1984), we come up with a figure of 350 ten second integrations per hour. Clearly, the APT wins out by about 10% in this particular example. The APT derives its usefulness from the fact that it can operate unattended; and find its own stars without human assistance. And we find that in order to do this in a reasonable time, the APT must operate on stars several magnitudes brighter than its limiting magnitude.

Further, it must make some decisions based upon what it sees. Unlike a human operator, however, who must also base his decisions on what he sees, it must now test its decision by doing search and center routines on another star or two to confirm that it is where it thinks it is and this translates into nonproductivity, ie, no photon counting. The experienced human operator, on the other hand, will immediately recognize the target star, even the faint ones, quickly center it in the diaphragm and get on with the observation. The more populated the star field is, the longer it will take the APT to begin the actual data acquisition. Under the same conditions, the human operator will generally take more time also but remember, he doesn't have to test like the APT does and can, once again, get on with the observing.

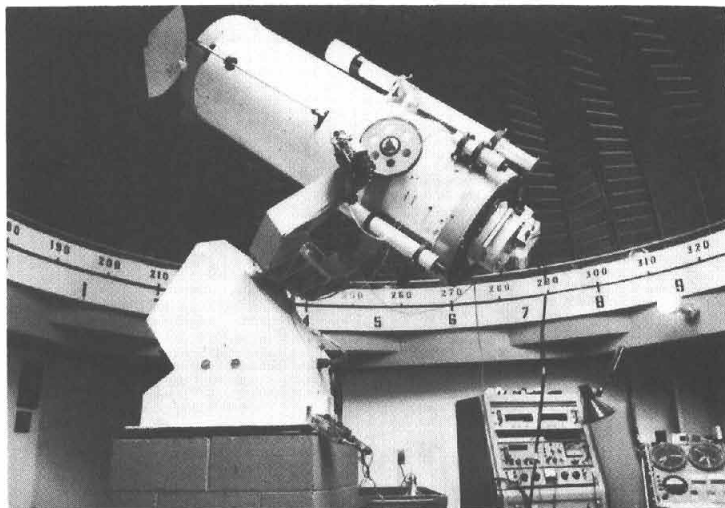


Figure 2. The Braeside Observatory 16" Cassegrain Telescope built in 1965 by Mr. Fried. Installed on the tailplate is the automatic GORT-1 photometer.

As you all know, the light-gathering power of an optical device generally follows the rule of the square of the objective diameter. Therefore, we find that a 16" mirror will gather 2.56 times as much light as an 10" mirror. This equates into a little more than 1.02 magnitudes, or in other words, a 16" telescope can see about one magnitude fainter than an 10" telescope. From the table below (Flammarion, 1964) one can see that if the 10" operates in the neighborhood of 6th magnitude with a stellar population of 3000 stars then the 16" would be able to work 7th magnitude objects and this means a population of nearly 10,000 stars through which it

must search. Based upon what we feel is a realistic analysis, then, the ability to operate unattended makes the APT a viable alternative to human operation only so long as you are neither working stars near the limiting magnitude of the telescope nor looking for a target in a crowded field. We further feel that the APT's usefulness would be superior to that of a human operated telescope, again, only so long as it is kept relatively small in aperture so that it only has to work the brighter stars. Finally, we believe that a human operator is essential in working stars fainter than 7th magnitude for as the table shows, by the time you reach 10th magnitude, for example, (BO has several program stars in that range) the stellar population has risen to 270,000. Only at a sacrifice in time can the APT lock onto a fainter target star and begin production. Were a speed contest to be held in which a 10" APT and a 16" or larger human operated computer controlled telescope with an automatic photometer were to work stars near their respective limiting magnitudes, I believe the human operator would win.



Figure 3. Mr. Fried sits at the control console of the Braeside Observatory 16" Telescope. The instrument is totally run by two Apple computers.

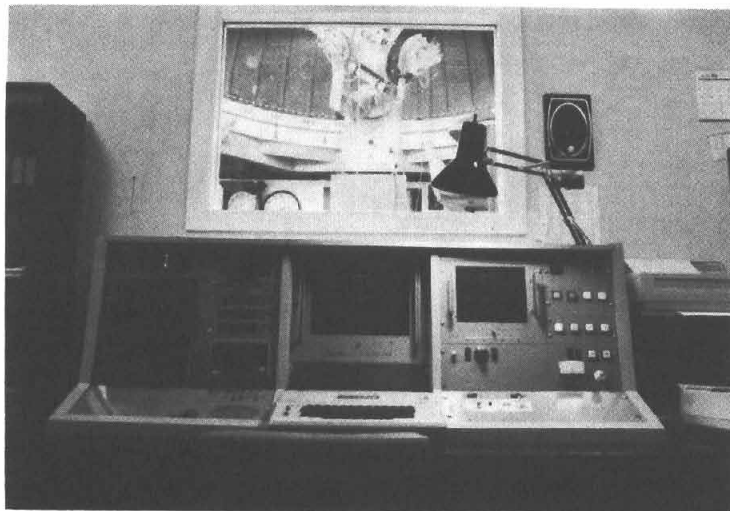


Figure 4. The Braeside Observatory 16" as viewed from the operator's station in the control room. The two high speed 10 MB disk drives are visible on the left side of console.



Figure 5. The GORT-1 automatic photometer installed on the tail-plate of the Braeside Observatory telescope. It is totally under control from the observation program and with its stepper motors, sequences all filters, diaphragms and sky offsets.

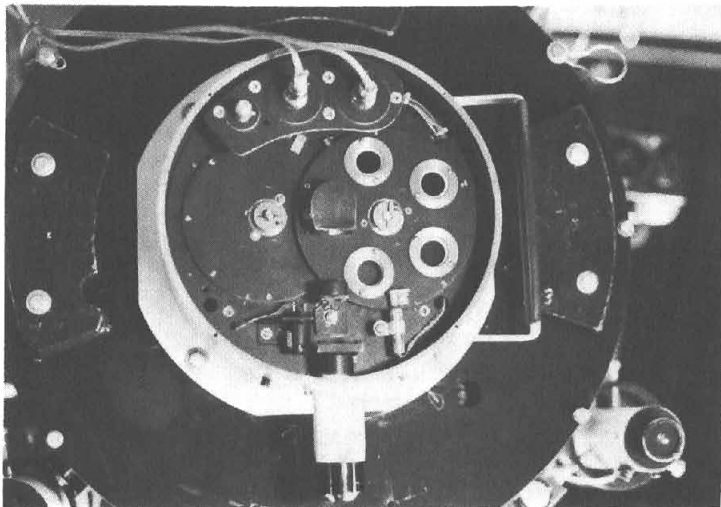


Figure 6. The inner workings of the GORT-I automatic photometer. The two motor operated disks are plainly shown together with the electrical dark slide mechanism and logic connectors from the Apple Computer.

When you consider the comparatively small population of stars brighter than 7th magnitude, it is rather easy to see why an APT can do the splendid job that it does. But when you start increasing the light gathering power of your telescope, you substantially increase the stellar population in which you work and with it the chance for target error. For example, in the hemisphere overhead it is estimated that there are the following number of stars per magnitude:

Magnitude	Number
1	6
2	25
3	75
4	250
5	750
6	3,000
7	10,000
8	32,000
9	97,000
10	270,000
12	1,800,000

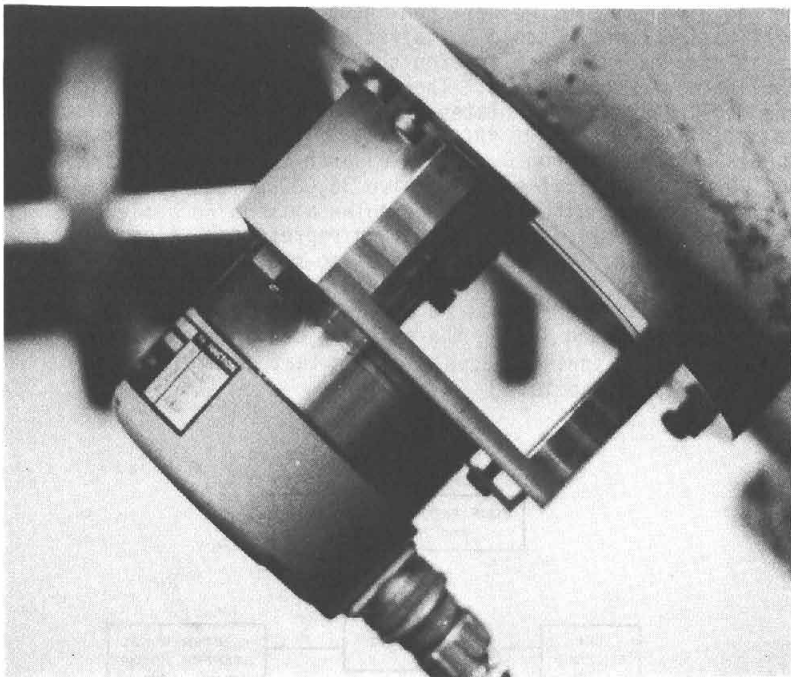


Figure 2. DRC model 35 encoder coupled to polar axis.

One unexpected problem (due to our inexperience) with the pointing system were the large errors encountered when setting on ephemeral stars of various declinations. In some cases the errors were as large as three minutes of right ascension. We had remembered to compensate for atmospheric refraction but ignored flexure in our German equatorial mounting. After several nights of trial settings, we found the error depended not only on declination but also on hour angle. Using our trial data and a versatile least-squares program, we were able to construct a polynomial equation (6th order in declination and quadratic in hour angle with cross terms) that would correct our right ascension values to ± 4 seconds of time. The declination correction was found to be linear with no dependence on hour angle. Both the right ascension and declination corrections had slightly different values on each side of the pier. Our mean setting error is now approximately 1.5 arc-minutes. This is close to our original goal and can probably be improved with refinement of our correction equations.

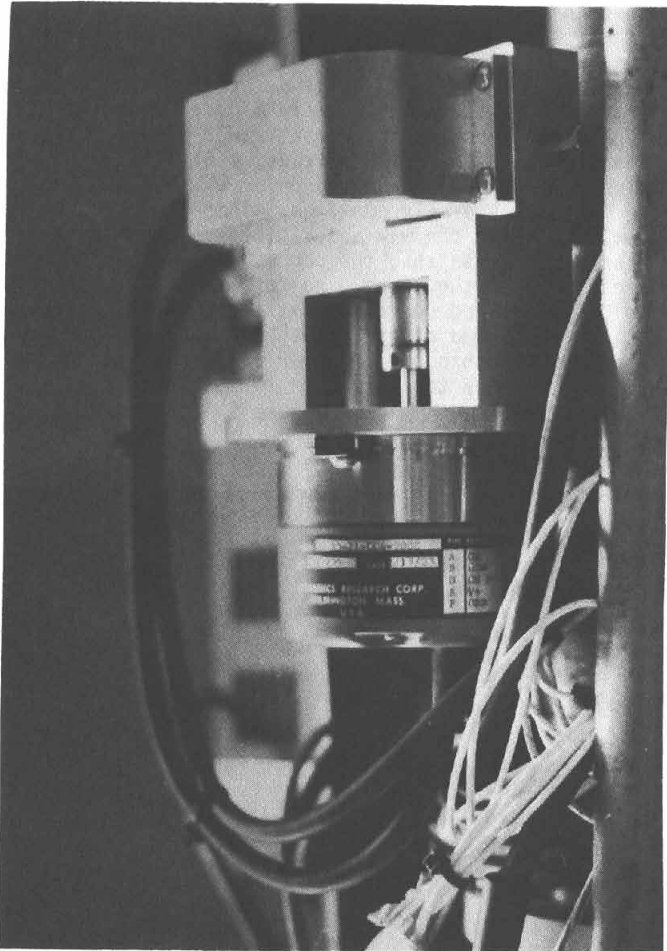


Figure 3. DRC model 35 and mounting assembly located on declination housing.

IV. TELESCOPE WIRING

Since our telescope was more than 25 years old, some problems would be expected in the wiring. Some of the older braided wiring had broken or had cracks in the insulation. Also, the slip-ring assembly that carried AC to the telescope tube was worn and at some declinations intermittent. Throughout the years there had been repairs and alterations to the original wiring. Some of these were well-done and documented. Others were middle-of-the-night patches that had been long since forgotten but would occasionally resurface. Finally, all of our high-voltage, signal, and thermoelectric power cables were external from the polar axis to the two-channel photometer that we generally employed. This large bundle of wires always seemed to be in the way and a tired astronomer could usually find some way to snag the cables while crossing over the pier in the middle of the night. We resolved this problem by removing old systems and controls that served no useful purpose and replacing all needed circuits with new Teflon wiring. All of the new wire was run through the polar and declination axes and into the inside wall of the telescope tube. The wiring bundle was terminated at a junction box (see Figure 4) near the photometer.

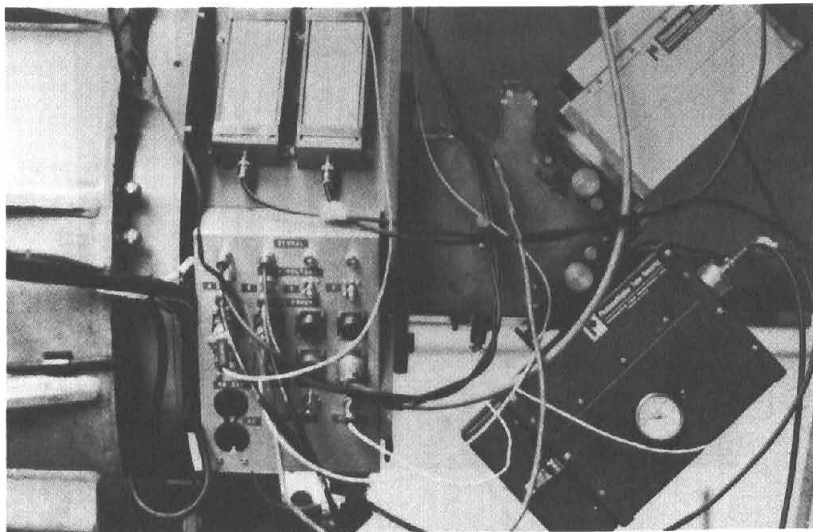


Figure 4. Junction box for photometer wiring and control. Note also the twin APED II discriminators and 2-channel photometer mounted on telescope.

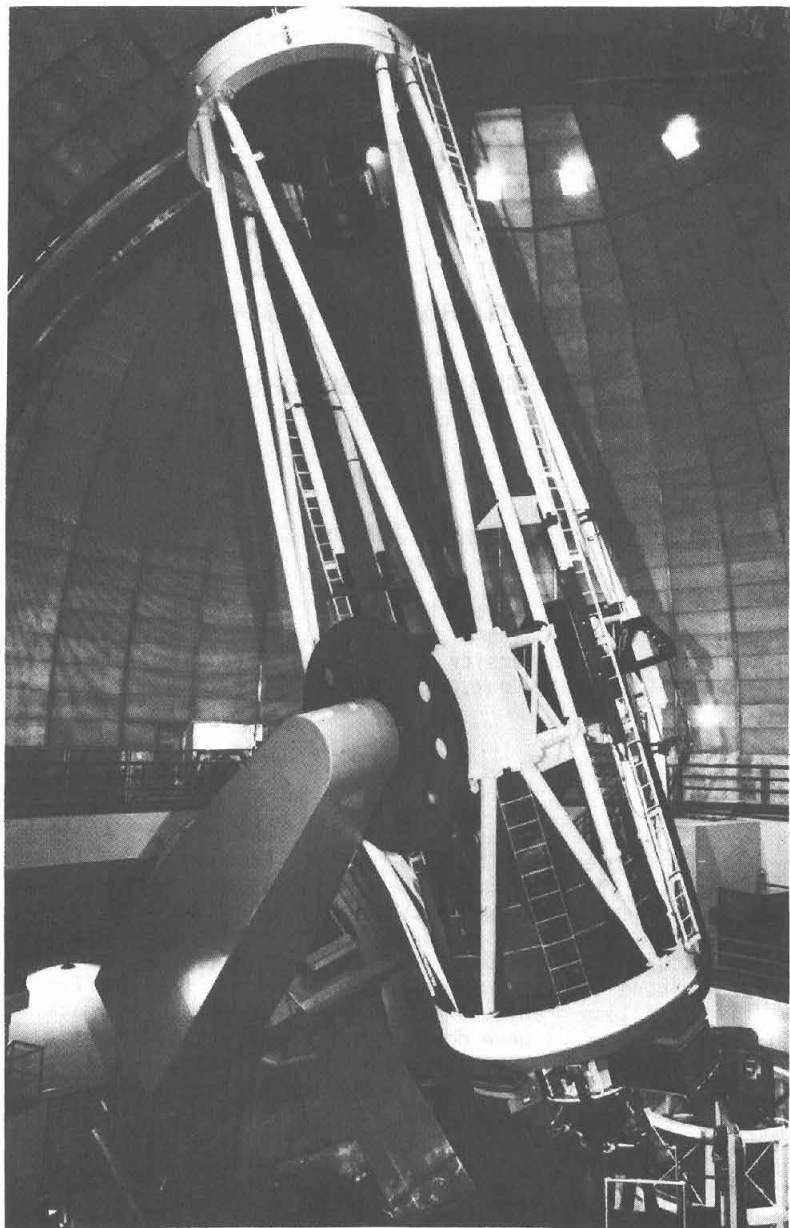


Figure 1. Lick Observatory's C. Donald Shane 3-meter Telescope.

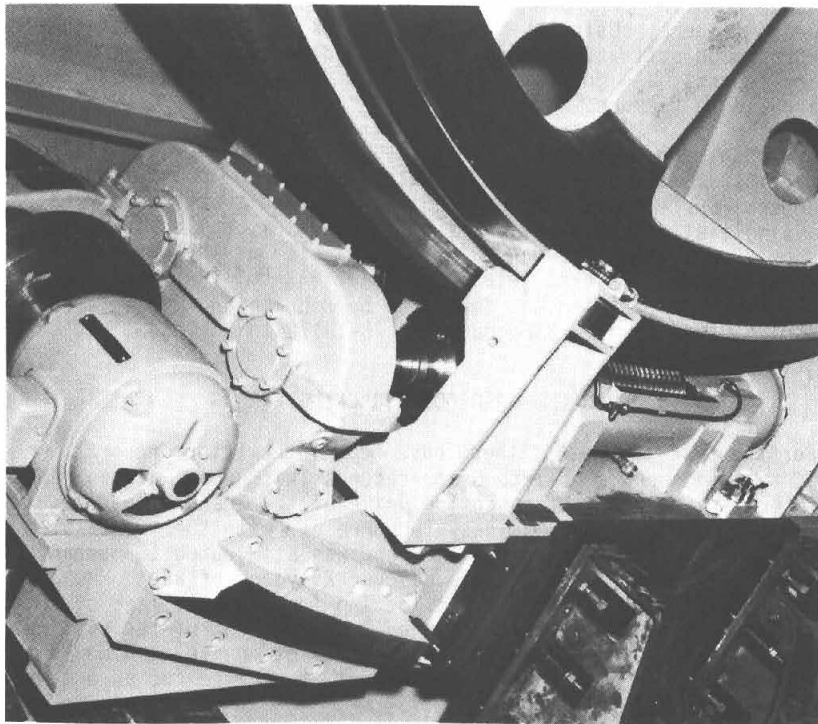


Figure 2. Worm gear and wheel assembly of polar axle. Note the two separate sets of gears, one for slewing and one for tracking, setting, and guiding. The slew motor and flywheel are the left side of the picture. This 1955 photograph was taken from the area now occupied by the Coude' slit room.

Lick has had a long tradition of improving instruments such as the Shane telescope whenever it is feasible. In 1969, Wampler led the installation of automatic Cassegrain focus instrumentation, including one of the first uses of a sensitive TV camera for acquisition and guiding of objects to be observed. In the mid-1970s, Robinson and Melsheimer improved the precision of the telescope position readout by installing incremental encoders with 1 arc-second resolution on both the right ascension and declination axes. Soon afterward, Osborne and Ricketts installed stepping motors on both axes so that precise manual guiding and computer controlled offsets could be done. The installation of the incremental encoders allowed McKenna to collect data on tele-

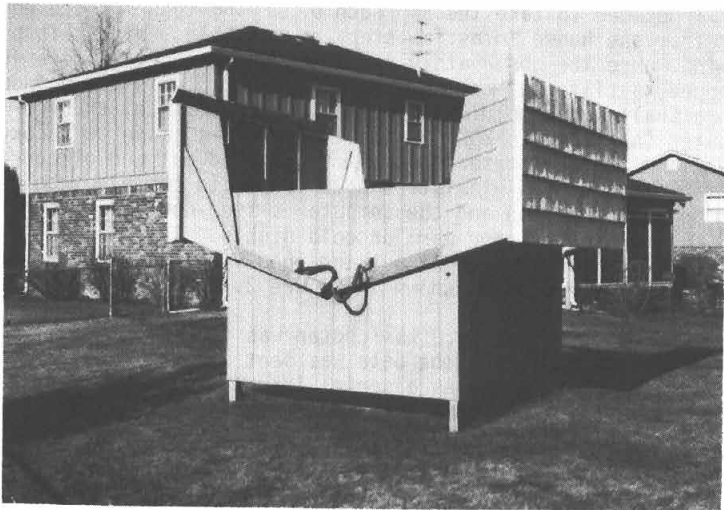


Figure 1. The Borlik Observatory with the clamshell roof in the open position.



Figure 2. The portable data acquisition system.

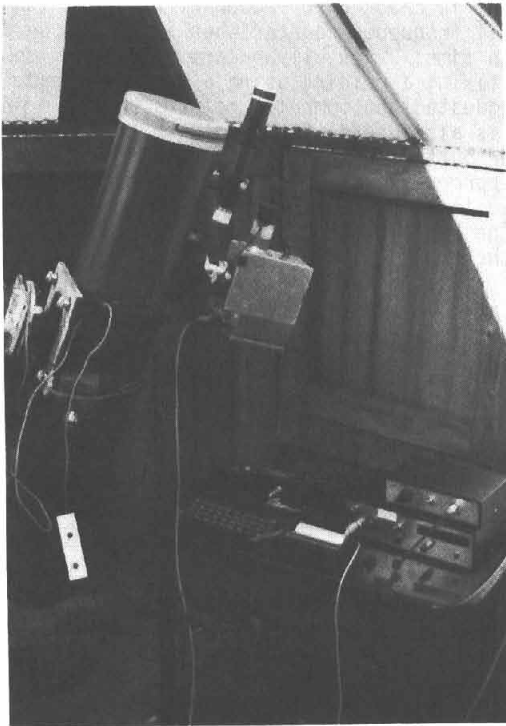


Figure 3 & 4. System set up without a TV monitor.

