Staring at the Poles of the Sky

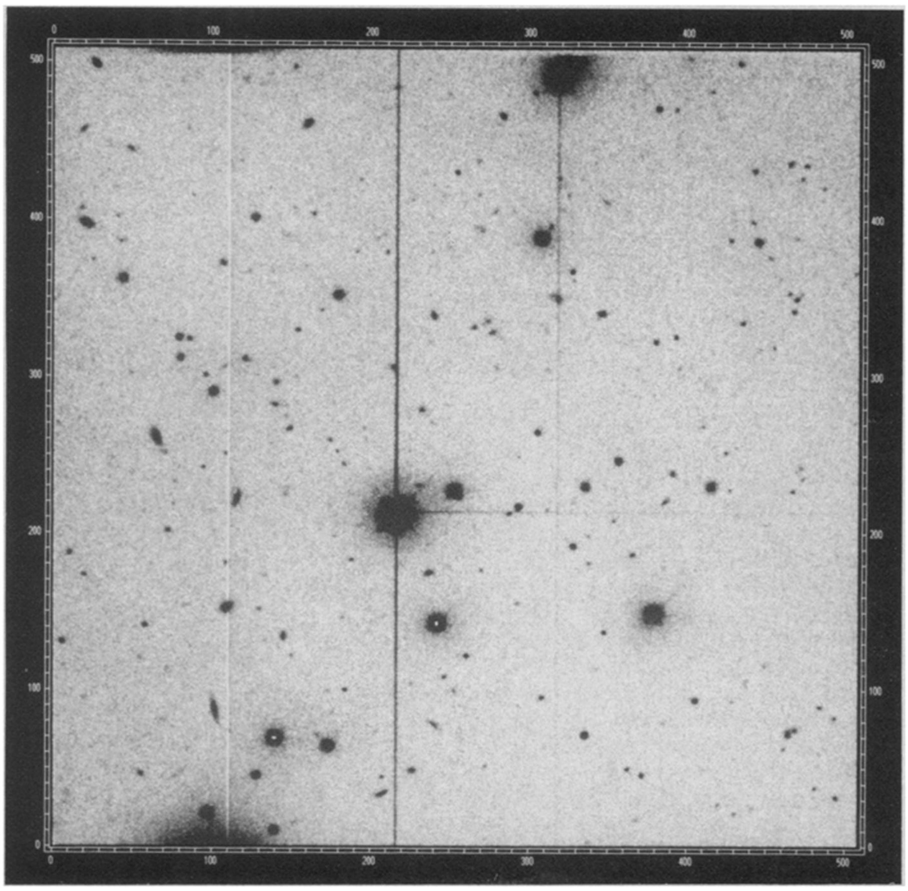
A telescope that looked at the North or South Pole for thousands of hours could see things too faint to be practical for ordinary telescopes or even for the Space Telescope

By DIETRICK E. THOMSEN

When choosing locations for telescopes, astronomers in the Northern Hemisphere look for the most southerly locations with good seeing conditions. In the Southern Hemisphere, they tend to seek the most northerly locations. They want to see as much of the sky as they can from one place, and the closer they can get to the equator, the more they can see. Commenting on this situation, a Canadian astronomer once remarked that observing from a far northern location — Edmonton, Alberta, was the specific place in mind — one sees only a few things, but one sees them for most of the time.

However, this drawback can become an advantage for astronomers interested in seeing very faint objects. A photoelectronic recorder such as a charge-coupled device staring at the same part of the sky for hundreds or even thousands of hours could build up images and spectra of very faint objects, down to 27th magnitude. Jacques M. Beckers, Roger L. Davies and Patrick O. Seitzer of the National Optical Astronomy Observatories (NOAO) in Tucson, Ariz., propose setting up a dedicated telescope to do just that, to stare steadily at either the North or South Pole. In a paper presented at the recent meeting in Ames, Iowa, of the American Astronomical Society, they call the project DEEPS for Deep Polar Spectroscopic Survey.

The poles are the obvious target for such long-period imaging. Each pole is visible all night, every night, from the middle or high latitudes of its hemisphere. The poles do not change position as the earth rotates, so a telescope pointed at a pole does not need a complex tracking mechanism to follow its target through the sky. Objects near the pole do trace out circular orbits around the pole as the earth rotates, but the DEEPS telescope could compensate for this by rotating around its own axis by an amount calculated to offset the earth's rotation — a much simpler motion than the two-dimensional tracking that other telescopes must do to follow objects in other locations.



A charge-coupled-device image of a region near the North Celestial Pole records objects as faint as 24th magnitude in a 1,100-second exposure obtained by Seitzer.

According to Beckers, Davies and Seitzer, such a project would be simple and relatively cheap — they estimate about $1 million — if they can take advantage of the technical development under way for the National New Technology Telescope (NNTT) project. One of the trial runs for the NNTT's mirrors will be a 4-meter borosilicate glass mirror, which will be completely tested, shaped and supported so as to give an image accurate to a quarter of a second of arc. The mirrors for the actual NNTT are planned to be somewhat larger, so after this 4-meter mirror has been used for the testing and design procedures, it will be available to NOAO for other uses. DEEPS would be a good use for it, Beckers, Davies and Seitzer propose.

Such a pole-watching telescope would need only a simple shelter. It wouldn't need to rotate as telescope domes usually do. The dome for a conventional telescope represents a major part of the expense, usually about equal to the cost of the optics. Beckers, Davies and Seitzer estimate the shelter for DEEPS at $50,000.

If the primary mirror becomes available at no cost to the DEEPS project, the main expenses will be for the secondary mirror and for control and data-taking equipment, which together come to an estimated $500,000.

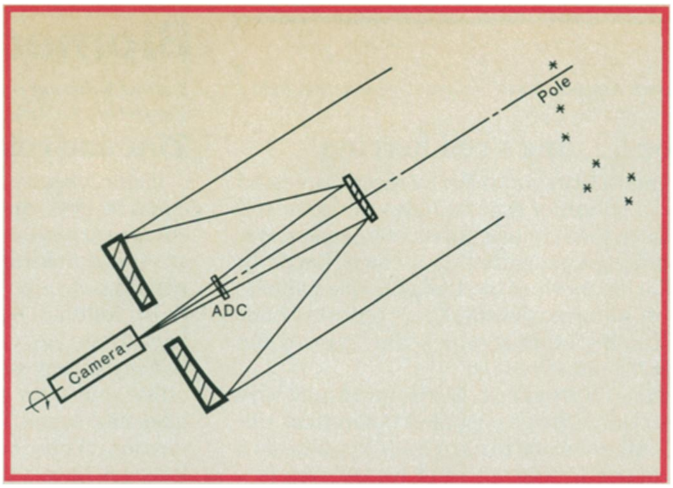
The 4-meter primary mirror would see an area 500 seconds of arc across centered on the pole. It would cast its image on a charge-coupled-device array that could be either 500 pixels by 500 or 2,048 by 2,048. With a spectrograph and up to 2,000 hours' time to build up images, it could obtain spectra of objects as faint as 27th magnitude.

"The sensitivity so achieved would be unequaled by any telescope now being built or contemplated because of practical limitations on obtainable integration times [about 10 hours]," Beckers, Davies and Seitzer write. Telescopes not dedicated to this kind of looking have so many astronomers clamoring to use them for so many different observing projects that they can't spare the time.

Beckers, Davies and Seitzer estimate that there are many thousands of objects of 26th or 27th magnitude, mostly distant galaxies, within the DEEPS field of view. The magnitude scale goes back to ancient times, when observers classed the brightest stars as first magnitude, the next brightest as second magnitude and so on down to as faint as they could see. Today the magnitude system is based on photometry, and it seems a little confusing that a higher magnitude number means a dimmer object, but that is the custom. The scale is logarithmic: Each unit of magnitude means a diminution of brightness by a factor of 2.512 (which is $10^{0.4}$). This factor was chosen because it makes the modern photometric scale correspond more or less to the ancient rankings of the stars visible to the naked eye. What it means is that an object of 27th magnitude is almost 100 billion (10^{11}) times fainter than one of 0 magnitude — for instance, the star Vega.

At 27th magnitude, astronomers would be looking mostly at very distant galaxies with redshifts greater than 1.5. Spectra of such galaxies would give information about very early stages of galactic and cosmic evolution, much earlier than astronomers now can study. The present limits on spectrographic study at the precision level they hope to reach with DEEPS are about 23rd magnitude using a 4-meter telescope and an exposure time of an entire dark night or about 10 hours, these authors indicate.

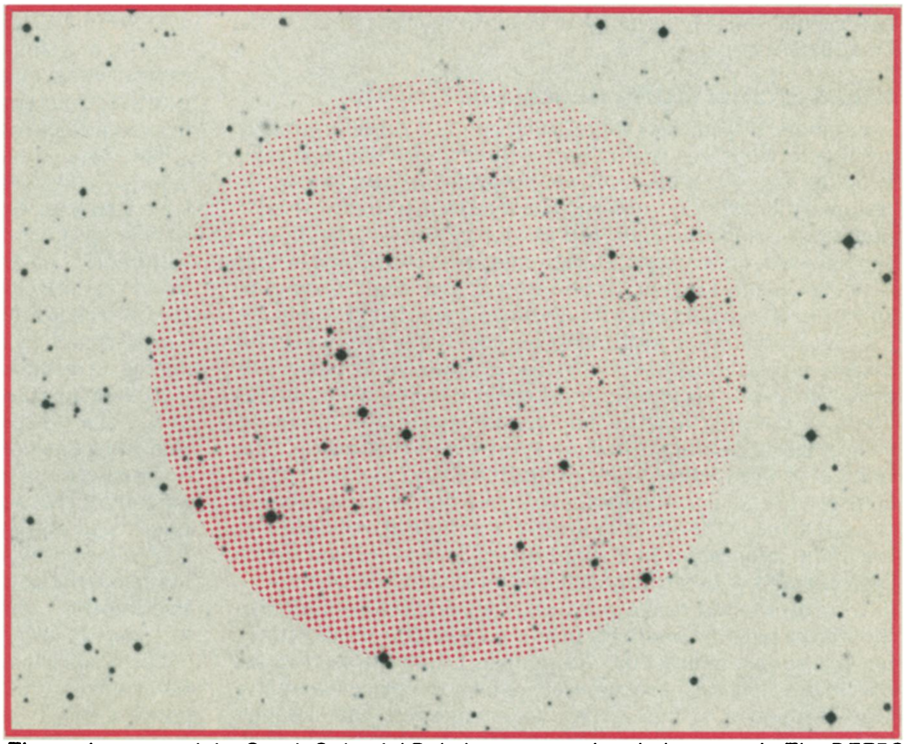
Recent studies of the distribution of galaxies have shown that they are clumped in superclusters with large void spaces between. A study of this kind could show whether that structure persists at lower luminosity levels and whether it extends farther back into the history of the universe. Beckers, Davies and Seitzer intend also to study the history of star formation within galaxies and how it relates to the morphology of galaxies — that is, whether a given galaxy is spherical, elliptical or spiral. They intend to investigate the distribution of physically active nuclei in these young galaxies and its relation to the history of galaxies. They hope to discover something about the forces driving the evolution of stars and the development of active galactic nuclei.



DEEPS telescope has a Cassegrainian geometry, in which a primary mirror reflects light to a secondary mirror that then sends the light back through a hole in the primary to a camera behind the primary. The whole arrangement would rotate around its axis as indicated by the arrow behind the camera.

At the beginning of each observing night, Beckers, Davies and Seitzer intend to take a 30-minute exposure without the spectrograph in the optics, looking for images of supernovas. If current estimates of the frequency of supernovas are correct, they expect to catch about 20 supernovas a year in the 1,000 to 10,000 galaxies likely to lie within the DEEPS field of view. The limiting magnitude for supernovas would be somewhere between 24.5 and 25.5, corresponding to a distance of about 2,000 megaparsecs or 6.5 billion light-years or 6×10^{22} kilometers. Supernovas are interesting both for their own development as giant stellar explosions and also as "standard candles," objects of known brightness that can be used to calibrate distance scales.

If NNTT development goes as planned, the 4-meter mirror should be ready by the middle of 1988, so DEEPS could start to work somewhere in the early 1990s. At least two years of observing, one in the north and one in the south, are envisioned. Sites already available to NOAO would be appropriate — Sacramento Peak (N.M.) in the north and Cerro Tololo (Chile) in the south. NOAO's most extensive northern site, Kitt Peak (Ariz.), is ruled out because the brightly lit city of Phoenix lies north of it. □


The region around the South Celestial Pole in a conventional photograph. The DEEPS telescope's projected field of view is superimposed in color.