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FINAL REPORT
on

Standardization Work for the Calibration of
Intensities of Celestial Objects

NASA Grant NAGW-2911

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I. Proposed Research Program

Observations of celestial phenomena need to be calibrated, to be related, to some measurable quantity. There continues to be a long-term need for accurate photometric standard stars, those with known intensities and colors, so that brightness and color measurements made of various celestial phenomena by different observers can be integrated and compared with one another.

Toward this end, the author has been emphasizing data collection in recent years for stars of 'intermediate' brightness, those approximately in the magnitude range $11.5 < V < 16.0$. Photoelectric data have been obtained at the Cerro Tololo Inter-American Observatory's (CTIO) telescopes for stars in certain Selected Areas near the celestial equator. Stars of extreme color outside the Selected Areas, but near the equator, also were selected to provide a more broad and complete range in color index. It was proposed to complete the photoelectric phase of the program.

The author proposed developing extremely faint sequences of photometric standard stars useful for both large space-based detectors and for land-based detectors. These data were to be collected via charge-coupled devices (CCDs) at telescopes located at CTIO and at the Las Campanas Observatory (LCO), both observatories being located in Chile. It was hoped that accurate data could be collected down to the 21st or 22nd magnitude.

Calibration stars are needed for the Hubble Space Telescope (HST) in order that proper standardization can be achieved and maintained. It is desirable to calibrate all scientific instruments aboard spacecraft such as the HST with the same photometric and spectrophotometric systems. That way the magnitudes measured by one instrument can be compared to those obtained by another instrument. Another reason for standard calibration stars for instrumentation such as the HST's is that they will permit tie-ins with established ground-based photometric and spectrophotometric systems. It was proposed to complete data collection at the Kitt Peak National Observatory (KPNO) for these spectrophotometric standard stars for HST, and to prepare them for publication.

There are northern hemisphere observatories from which the author's celestial equatorial standard stars are said by some astronomers to be inconvenient to observe. And, there are occasions during observing programs when it is not desirable to swing the telescope and instrumentation through large arcs across the sky to pick up the necessary calibration objects. To solve that problem, the author proposed to begin an observational program at KPNO to establish a set of standard stars around the sky at +45 degrees declination.

II. Accomplishments via this Grant's Support

NASA Grant NAGW-2911 provided the author with 10% of the funds requested in the proposal. In essence, the funds were sufficient to keep the author's photometric standard star program viable, and enabled him to continue data acquisition, something extremely necessary in a basic, fundamental, long-term observational program. And, as noted below, the support permitted the author to complete certain intermediate aspects of the program.

The analyzation of photoelectric observations obtained over the past decade at the CTIO telescopes, mainly in the celestial equatorial Selected Areas, was completed, and the resulting paper was written and published (see reference 1 below in Section III).

A program of additional photoelectric observations of stars in small CCD-sized star fields was continued at CTIO's 1.5-m telescope. This observational program will continue over the next years until sufficient accuracies have been attained for stars in these areas on the sky.

The final analyzation of photoelectric data for the Baldwin-Stone southern hemisphere spectrophotometric standard stars was completed, the paper written, and published (see reference 2 below in Section III).

Data were obtained for very faint photometric stellar sequences through use of CCD detectors at both CTIO and LCO telescopes. Many years of work remain for additional data acquisition, and for analyzation of the CCD data.

Analysis of the photoelectric data obtained at KPNO for HST's spectrophotometric standard stars essentially was completed, and initial drafts of a paper were written. Neither time nor support was available to complete this aspect of the proposal. However, the HST staff have in hand essentially the final magnitudes and color indices for the stars involved.

Data acquisition for the proposed set of photometric standard stars around the sky at +45 degrees declination was begun at KPNO telescopes. Completion of the project at the telescope is projected some five or six years in the future.

III. Publications and Manuscripts

The following publications have appeared during the tenure of and with the partial support of this NASA grant:

1. "UBVRI Photometric Standard Stars in the Magnitude Range $11.5 < V < 16.0$ Around the Celestial Equator", by A. U. Landolt, 1992, The Astronomical Journal, 104, 340.

2. "Broad-band UBVRI Photometry of the Baldwin-Stone Southern Hemisphere Spectrophotometric Standards", by A. U. Landolt, 1992, The Astronomical Journal, 104, 372.

As of the writing of this report, some 250 reprints of item 1 and some 50 reprints of item 2 have been distributed world-wide. The tabular data in item 1 also are available to the community through astronomical databases, including the National Space Science Data Center and SIMBAD in Strasbourg, France. The author also has responded to many requests that the tabular material be supplied via e-mail, again world-wide.

3. "A Time of Minimum for GW Cephei", by A. U. Landolt, 1992, Publications of the Astronomical Society of the Pacific, 104, 336.

Reprints for items 1 and 2 are enclosed. None were purchased for item 3.