

## THE HARVARD OBSERVATORY AND ITS PROGRAM

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The Harvard Observatory maintains four observing stations: the Boyden Station near Bloemfontein, South Africa; the Oak Ridge Station in Harvard, Massachusetts; the Solar Station at Climax, Colorado; and the original observatory in Cambridge, Massachusetts. After years of hope and effort by interested citizens and members of the University, in 1839 the Harvard Observatory became a reality. In 1843 it was moved to the present location originally described as "an eminence fifty feet above the surrounding plain." The Boyden Station has existed in the southern hemisphere since 1890, first at Arequipa, Peru, and since 1927 near Bloemfontein, Orange Free State. At Cambridge, increasing sky light from the neighboring cities made observing inefficient, hence in 1932 the Oak Ridge Station was established twenty-seven miles northwest of the city.

The equipment at the southern and northern stations is comparable, ranging from the sixty-inch reflectors through the large refractors to the short-focus patrol cameras. When all stations simultaneously enjoy clear skies twenty-one telescopic cameras indelibly record the heavens. During the past year nineteen thousand photographs were exposed and shipped to Cambridge for detailed examination, cataloguing, and filing. Nine thousand plates came from the Boyden Station, nearly seven thousand from Oak Ridge, and over three thousand from the cameras remaining in Cambridge. Such systematic photography of the sky began in 1885, and the number of accumulated plates is rapidly approaching a half-million.

A solar station at an elevation of 11,500 feet has recently been established at Climax, Colorado, where a coronagraph of the Lyot type is installed. Final adjustments of the instrument are nearly complete and we hope that routine observations of the solar chromosphere and inner corona will soon begin. This instrument is the third of this type in the world and the first to be installed in the western hemisphere.

Numerous other instrumental developments are now in advanced stages of the construction. The largest of these is the transformation of one of the sixty-inch reflectors into a sixty-inch Schmidt-type camera. Although this transformation was originally planned for the telescope at the Boyden Station, world political conditions may force a revision of the plans. When completed, this instrument will be extremely powerful for the study of faint galaxies and stars over appreciable areas of the sky. A twenty-four-inch Schmidt camera for the Oak Ridge Station is nearly complete and will go into operation during 1941. Small experimental cameras of new design are also nearly ready for testing.

In addition to the photographic cameras at Oak Ridge, a twenty-inch reflector is fitted for photoelectric photometry and the sixty-one-inch reflector has been used considerably for photoelectric and thermoelectric investigations. A slit spectrograph containing a 15,000-line grating (made by Professor R. W. Wood) and an F/1 Schmidt camera has recently been installed on the large reflector.

This wealth of instrumental equipment is utilized in a variety of interlocking investigations upon the nature and distribution of celestial bodies throughout the Milky Way and extragalactic space. Surveys of the spatial distribution of galaxies to the 13th, 15th, and 18th magnitudes are among the largest of the current studies. Some two thousand three-hour exposures with the Bruce twenty-four-inch and the Metcalf sixteen-inch refractor, each plate covering more than twenty-five square degrees, record the galaxies to the 18th magnitude. The richest plates show more than four thousand new stellar systems. Up to the present the survey, more than half complete, has revealed half a million new galaxies; when complete the total will be not less than eight hundred thousand. For certain regions the examinations and measurements of position, brightness, size, and type are complete. These data reveal inhomogeneities in the distribution of galaxies—great clusters of supergalaxies, also a widespread metagalactic density gradient across the southern galactic cap. Regions or objects of special interest are scrutinized in detail upon photographs made with the large reflecting telescopes. In the course of the sur-

veys many peculiar objects have been discovered: new globular clusters and planetary nebulae, a streak-type of gaseous nebulosity, and the subluminescent star-clusters in Sculptor and Fornax.

The study of our own and the nearest galaxies, the Magellanic Clouds, is continually pushed. An extensive investigation of the several hundred Cepheid variable stars in both Clouds recently provided a redetermination of the well-known period-luminosity curve. A relation between the position of the variable stars within the Small Magellanic Cloud and their mean period of variation has also appeared—the stars with longer periods are concentrated toward the center of the system. The interpretation of this discovery in terms of stellar and galactic evolution is a stimulating but complex problem for the future.

The detailed picture of stellar distribution within our Milky Way system is under investigation through the analysis of star-counts and the colors of B- and A-type stars. They indicate the true stellar density and the quantity of interstellar obscuration in various directions from the sun. An extensive plan to examine the entire Milky Way to distances of three thousand light-years progresses, with the fields in Taurus, Cygnus, Cepheus, Cassiopeia, and Perseus practically completed. The galactic structure in the constellations Monoceros and Carina is now being probed.

Such analyses of stellar distributions take on added significance when we know the radial velocities of the stars. From objective-prism spectra photographed through a neodymium chloride screen (which introduces certain “stationary” absorption lines) the velocities of the B- and A-type stars are measured with an uncertainty of only ten kilometers per second; an accuracy sufficient for statistical analyses. Between forty and one hundred stars to the tenth magnitude can be “clocked” in this manner, from only four two-hour photographs of each region.

The spectral classes of stars are fundamental in studies of the celestial population, both as individuals and *en masse*. Already four hundred thousand stars have been classified at Harvard on a uniform system. Recently a considerable portion of this work has been in co-operation with other observatories which were publishing catalogues and wished to add spectral types to their

other information about the stars included. At present the faint stars in selected regions, especially a large area around Carina, are being classified for use in studies of the Milky Way.

Nearly all problems in astronomy involve a knowledge of stellar magnitudes. Although certain sequences are known precisely, they are few and are all in northern declinations. Both photographic and photovisual magnitudes in the Harvard Standard Regions at  $+15^\circ$  are being checked with special care, for observatories south of the equator may use these stars in establishing the magnitudes of southern stars on the single homogeneous scale of the North Polar Sequence. We are also gathering plates for the establishment of faint magnitudes in the Selected Areas near the southern celestial pole.

An important phase of the Harvard Observatory's program is the analysis, both observational and theoretical, of astronomical spectra. One co-operative attack is upon the absorption and re-emission of radiation within planetary nebulae and similar "dilute" atmospheres. This analysis is not unrelated to the problem of the composition and physical state of the solar corona, which remains a mystery. The calculation of spectral-line intensities from a knowledge of the structure of various atoms, especially helium, is nearing completion and will first be applied to the interpretation of very hot stars.

Many members of the staff work upon problems of observational astrophysics. For example, the spectra of novae and supernovae are dissected and studied in detail or synthesized from a knowledge of what atoms should be present and a theoretical knowledge of how they behave under extreme conditions. The hundreds of photographs secured by the solar eclipse expedition in 1936 promise to force upon us a new and dynamic picture of the solar atmosphere; while the analysis of the sun's absorption spectrum permits an extensive investigation of the temperature, pressure, and chemical composition of the solar atmosphere.

That subtle differences in the spectra of stars, apparently similar, depend upon the pressures in their atmospheres and hence upon their size has long been known. When properly calibrated such criteria can be used to indicate the distances of these stars. Although many observatories apply this technique

to northern stars, the southern skies remained unexamined until recently when work began upon them at Harvard.

How certain stars are built and shaped has been investigated through the theory and observation of the effects the components of close eclipsing stars have upon each other and their orbital motion. Although the necessary precise and extensive observations are available for only a few systems, the stars composing these are constructed nearly in accordance with the "standard model" proposed in 1926 by Eddington. An attack from another point of view, the photometric consequences of such tidal distortions, also leads to the same conclusion.

The study of variable stars, the most idiosyncratic of the celestial population, has long been a major portion of the work at this Observatory. Since the number of known variable stars is now nearly seventeen thousand, professional astronomers are unable to keep more than a small fraction under constant observation. Therefore, the American Association of Variable Star Observers, including many amateur astronomers, was formed in 1911 to assist in this work by watching the brighter variables having periods of several hundred days. Their records come to the Harvard Observatory where they are collated and discussed. On the extensive collection of patrol plates a great quantity of data about all sorts of variable stars is permanently recorded. Recently the Milton Bureau was established to carry out the mass measurement of the two thousand variable stars brighter than the tenth magnitude. For a single star as many as five thousand observations covering a period of fifty years may be obtained. Persistent study of faint variables both near to and far from the plane of the Milky Way indicate how variable stars are distributed throughout the galaxy. The vast quantity of literature about the variable stars must continually be organized and indexed. Although previously done in Europe, this work is now continuing at the Harvard Observatory.

The small bodies that move between the planets of our solar system are not neglected. Their orbits, frequency, and physical characteristics are all under investigation. Especially significant are the accurate velocities and orbits determined for a few bright meteors photographed in duplicate from Cambridge and Oak Ridge.

No account of the work of this Observatory would be complete without a statement of the co-operative programs carried on with other institutions. Plates have long been taken for the investigation of magnitudes in the Standard Regions, work being done by Professor van Rhijn at the Kapteyn Laboratory in Groningen, Holland. For over nine years Dr. Luyten of the University of Minnesota has been measuring the proper motions of stars in the southern sky from plates taken with the twenty-four-inch Bruce telescope. Plates are also supplied for star-counting programs at the Armagh Observatory, Ireland; the University of Illinois, Denison University, Case School of Applied Science, Randolph-Macon College, Mills College, Vassar College, and the new Annie J. Cannon Observatory in Mexico. Magnitude and variable-star studies at the Princeton Observatory, the McCormick Observatory, the Maria Mitchell Observatory at Nantucket, Smith College, and Hood College are also assisted with the loan of plates and material. Numerous other institutions make occasional use of the plate files and of the series of *Announcement Cards* which call attention to discoveries requiring immediate observation.

The variety of problems under investigation at the Harvard Observatory is considerable, yet all the studies contribute to a composite picture of our stellar system and the extragalactic universe.\*

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\* The frontispiece to this number shows the Cambridge home of the Harvard Observatory. The five nebulae shown on Plates II, VI, and VII have been selected almost at random as illustrations of the many hundreds of remarkable objects that have been photographed with Harvard Observatory telescopes.—PUBLICATION COMMITTEE.