Studies of the Stellar System

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THROUGHOUT THE FIRST 50 YEARS OF the Yerkes Observatory investigations on galactic structure have been carried out on a substantial scale. Some of the principal efforts are described below.

The knowledge of our stellar system at the beginning of the century was only rudimentary. It was assumed from star counts to the 10th magnitude that the galaxy was a flat, disk-like system with the sun roughly at the center. But the overwhelming majority of the stars are fainter than the 10th magnitude. In fact, if all stars brighter than the 10th magnitude were eliminated, the Milky Way would not appreciably change its apparent shape and brightness; only the bright stars dotted on the luminous background would be missing.

One might suppose that, if star counts were made to the 18th instead of to the 10th magnitude, in fields properly distributed over the sky, the true picture of the galaxy would emerge. This approach was advocated by Kapteyn in 1904 in his Plan of Selected Areas, and the observations accumulated since then at several collaborating observatories have indeed led to a far more precise and complete outline of the galaxy. But progress in the interpretation of these star counts was seriously hampered by the lack of knowledge of so-called interstellar absorption. In fact, the first results based on counts to the 18th magnitude, made on the assumption that interstellar absorption was not important, have proved to be seriously wrong.

The Milky Way studies of Barnard and Ross at the Yerkes Observatory are complementary to the studies of the smoothed-out galaxy of the Selected Areas school. Barnard, in his beautiful *Atlas of selected regions of the Milky Way*, published by the Carnegie Institution of Washington in 1927, has shown the Milky Way to consist of a highly complex array of star clouds and dark markings. His efforts were a continuation of his earlier work at the Lick Observatory between the years 1892 and 1895 (Lick Publication 11, 1913) and owe their success to the gift by Miss Catherine Bruce, in 1897, which enabled Barnard to acquire a 10-inch "portrait lens," as he preferred to call it, figured by the great optician, Brashear. Ever since its completion in 1904, the Bruce telescope has aided the Yerkes astronomers in their galactic studies.

The tradition of high-quality Milky Way photography set by Barnard was continued by F. E. Ross. Ross had introduced into astronomy a new tool, the "Ross lens," an F/7 system with superb field qualities. With a 5-inch lens of 35-inch focus he obtained a set of extraordinarily fine negatives which have been reproduced in the Ross-Calvert *Atlas of the northern Milky Way*, published by the University of Chicago Press in 1934.

Both atlases are based on plates obtained by their authors largely at other observatories, notably Mount Wilson, and are fine examples of the value of interinstitutional cooperation.

Barnard's work with the Bruce telescope included one other program that has been a rich source of astronomical results. He covered a large part of the northern skies with first-epoch plates for subsequent proper-motion surveys with the aid of the blink microscope. The remarkable star, BD +4°3561, which carries Barnard's name, still holds the record in the amount of its proper motion (10″.3 per year). Barnard's star, discovered in 1916, must have been a great stimulation for the completion of this program.

The proper-motion program was taken up by Ross after Barnard's death (1923). With great care he duplicated the Barnard fields and embarked upon the arduous task of examining the millions of faint stars on the plates for proper motion. The search was completed in about 8 years, during which well over 1,000 stars with large proper motion were announced. Among these Ross stars are some of the most interesting and faintest of the sun's neighbors in space. They have been a fruitful program for parallax determinations and statistical studies of the stellar population of the galaxy.

On a much smaller scale proper-motion searches have been carried out also on fields photographed with the 24-inch reflector. The first-epoch fields were taken for the study of variable stars, mostly by Parkhurst, and more recently for comets and asteroids, primarily by Van Biesbroeck. In 1916 Hubble repeated some of the former fields, as did Luyten and Ebbighausen more recently; while Van Biesbroeck quite recently duplicated many of his comet and asteroid fields. In all, an appreciable number of stars with large proper motion were found; the precision of the results was considerably higher than those obtained with the Bruce telescope.

The large collection of proper-motion plates in existence at the Yerkes Observatory has been the incentive for the compilation by Kuiper of a manuscript catalogue of all stars with proper motion larger than 0″.3. Photographic observing charts were made by Kuiper and Miss Calvert for some 3,000 stars, all of which were observed for spectral type at the Yerkes and McDonald Observatories. Over 9,000 spectra were obtained which are used for the determination of spectral parallax and which, together with magnitude determinations, form an adequate foundation for the determination of the distribution of stars in the spectral type-magnitude or Hertzsprung-Russell diagram. If the distribution in this diagram is put on a numerical basis, it expresses better than any other diagram or table our information on the stellar population in space.

A final source of studies in proper motion, which has hardly been exploited so far, is found in the many excellent photographs of clusters taken with the 40-inch telescope. Both Ritchey and Barnard left many excellent negatives of globular and galactic clusters which are now invaluable because of the large scale of the 40-inch telescope and because of their age (many of them over 40 years). Some negatives have been recently duplicated and measured by Ebbighausen, but the greater part of this source of information is as yet untouched.

The importance of the proper-motion and subsequent parallax programs is not limited to the statistical data summarized in the Hertzsprung-Russell diagram. These programs are also basic for our information of stellar masses and absolute magnitudes (or luminosities). Together with data derived from eclipsing variables which can be observed spectroscopically, the parallax program, as applied to visual binaries, provides the basic data for the study of the mass-luminosity-radius relations. As such, they are fundamental for the present theories of stellar constitution and of energy generation. One important aspect of this work is the determination of mass ratios in visual binaries, which has been a subject of continuous study at the Yerkes Observatory for at least 30 years.

Mention should be made in this connection of a field of intensive activity throughout the Observatory's history—the observation and cataloguing of double stars. In the first two decades Barnard and Burnham contributed large numbers of observations to this field, and Burnham laid a foundation for all modern work on double stars by issuing his two-part *General catalogue of double stars within 121° of the North Pole* (Carnegie Institution of Washington, 1906). Later, this was supplemented by his *Measures of proper-motion stars* (Carnegie Institution, 1913). From 1916 to the present date, Van Biesbroeck has continued the tradition and has accumulated a great number of measures on many pairs of interest. Still more recently, Kuiper has paid special attention to pairs of importance for the mass-luminosity relation and has found a number of new objects in this class. The 40-inch telescope is equipped with an excellent micrometer, and the instrument as a whole is perhaps the best telescope of its kind for general double-star work.

Contributory to the study of the near-by stars have been important lists of radial velocities by Popper and Münch and of magnitudes by Seyfert.

Another kind of work now in progress with the 40-inch telescope is a program of spectroscopic absolute magnitudes and distances of the brighter stars, being carried on by Morgan and Bidelman. Among the most interesting types of stars for which information on the distances is being obtained are the luminous blue supergiants; these—even when apparently bright—are located at very great distances and thus allow us to obtain information concerning the absorption of light in space. Developments in methods in the course of the past few years now make it possible for us to determine the true brightness and distance of almost any kind of star now met with; the exceptional objects which cannot be dealt with directly form a vanishingly small percentage of the total number of stars which can be observed spectroscopically. Additional examples of these relatively rare, peculiar objects are being discovered in the course of the general spectroscopic program, and several remarkable and puzzling stars have been discovered recently by Bidelman. This research program therefore has a double result: the true luminosities and distances of the "normal" stars are being determined, and peculiar objects requiring investigation of an astrophysical nature are being discovered.

An entirely different field of galactic research, though connected with the pioneer work of Barnard, is that on the galactic nebulae. These studies have been important both for the distribution of nebulous material in the galaxy and for the scattering properties of such material. The research was carried out by Struve, Henyey, and Greenstein, after some remarkable early work by Hubble. In the course of this work Struve developed a novel instrument, the nebular spectrograph, which was first mounted on the 40-inch telescope and later transported to the McDonald Observatory. With it, extensive regions were found in the galaxy showing H_α in emission. Another notable contribution was the discovery by Elvey of the "galactic light," a dim reflection by interstellar material of stellar light falling on it. It was found as a residual brightness of the Milky Way after subtraction of all light attributable to stars.

A field of great promise lies in the application of the modern RCA photomultiplier tubes to astronomy. The Yerkes Observatory is participating in this development through the work of Hiltner, who has been observing eclipsing binaries of special interest.