Astrometry

G. Van Biesbroeck

THE CONTRIBUTIONS OF THE YERKES Observatory to astrometry were influenced during the first years by the two outstanding visual observers who joined the original staff. The first, S. W. Burnham, was at that time the recognized leader in the field of double stars. He discovered a great number of interesting pairs, the components being either very close or very unequal in brightness, and he used the 40-inch telescope to its full power to follow the orbital motion of the more difficult pairs. His monumental *General catalogue of double stars*, published by the Carnegie Institution in 1906, remained for many years an indispensable tool for all workers in that field. Since his retirement in 1915, the work on double stars has been continued by G. Van Biesbroeck, G. P. Kuiper, and, lately, D. Harris. This work has been the basis of most orbital computations done on visual binary stars in the last score of years. A large amount of micrometric work on double stars has also been done with the 82-inch McDonald reflector by Van Biesbroeck and Kuiper.

The second early observer, E. E. Barnard, had a much wider field of interest than Burnham. His enthusiasm as an observer established at the Yerkes Observatory the tradition of all-night work and of the utilization of every minute of available clear sky. He devoted the major part of his time at the telescope to the measurement of the relative position of stars in clusters in the hope of establishing internal motions in such systems. This was started at a time when it was not realized that photographic processes were infinitely superior to visual micrometric triangulation for that type of work and when no information was available concerning the great distances of clusters and the extremely slow motions to be expected in them. In Barnard's hands the micrometer was used more profitably in many other lines: he measured the diameters of planets, asteroids, and satellites; he followed the relative positions of Saturn's satellites and contributed many measures of the positions of comets as well as nebulae. He never failed to record the elongation of Jupiter's fifth satellite, the small body discovered by him in 1892 at the Lick Observatory.

The possibility of using the 40-inch telescope as a photographic instead of a visual instrument was not foreseen when it was first put in operation. At about the turn of the century Ritchey showed that by working in yellow light, for which the telescope was achromatized, excellent photographic images were given. For the best results this required the combination of isochromatic plates and a yellow filter as well as the double-slide guiding plateholder. The large scale given by the 62-foot focal length of the big lens procured a means of measuring positions with a precision never before attained, and at once the problem of stellar distances was inaugurated. On a grant from the then newly-established Carnegie Institution, F. Schlesinger spent the years 1903–1905 at Williams Bay, developing the method and investigating exactingly the precautions to be used in this most delicate operation. He obtained parallaxes for 27 stars, and the result was so successful that it marked the opening of a new era in astronomy. Up to that time only a handful of stellar distances had been obtained, none of which was too reliable. The gain in precision and speed with the new method made it possible to reach many stars and much greater distances. After Schlesinger left, the work was continued successively by Slocum and Mitchell, Lee, Joy, Van Biesbroeck, Mrs. Pettit, Moffit, Hetzler, Titus, and, after an interruption by the World War, Strand and Hall. Several other observatories joined in the campaign of measuring stellar distances after Schlesinger standardized the method of procedure. During the first third of this century several thousand stellar distances became thus available. Indirect methods calibrated by the photographic determinations allowed thousands of stars to be investigated for distance. Thereby the basis was laid for our knowledge of stellar luminosities and masses, for our modern concept of the size of the visible universe, and for far-reaching consequences in all branches of astrophysics. At present, stellar parallaxes are no longer determined wholesale with the 40-inch lens; the work is concentrated on a special group of stars, mostly faint, which have been shown by indirect methods to be at a measurable distance. The photographic process at the 40-inch refractor has been used in several other astrometric investigations: in the determination of mass ratios of binary stars (Van Biesbroeck, Huffer, Strand, Hall), in proper-motion work in the Kapteyn areas centered at +45° declination (Lee), and for the precise measurement of wide double stars by Hertzsprung's method (Strand).

The 24-inch reflector, which had been used mainly for photometric observations by Parkhurst and for studies on nebulae by Ritchey and Hubble up to 1922, has since proved increasingly useful for photographic astrometric work on faint objects: comets, asteroids, satellites, and proper-motion stars. With its aperture ratio of 1:4 it is a fast instrument photographically. It records in 5 minutes the faintest objects that can be seen in the 40-inch refractor. Many positions of asteroids fainter than are generally observed have been obtained with the 24-inch reflector by Van Biesbroeck, Struve, Chang, and, more recently, Harris. By repeating the earlier exposures with this instrument, the changes in star positions after an interval of more than a quarter of a century can be found by the "blinking" process. Van Biesbroeck has detected many faint proper-motion stars in this way. The same observer has published long series of comet positions obtained photographically with the 24-inch reflector; in order to improve the orbits of these objects it is essential that they be followed over as long an arc as possible. Measures of comets have often been continued for months with the 24-inch reflector after most observers abandoned them because they were too faint. Such extended series are especially valuable in distinguishing between parabolic or slightly hyperbolic orbits and the elliptic ones which indicate periodicity.

The brightnesses of comets and their puzzling fluctuations also constitute studies from these photographic documents.

Stellar Spectroscopy

Otto Struve

ON THE WALL OF THE DIRECTOR'S office hangs an autographed portrait of Sir William Huggins. Once the personal property of G. E. Hale, it was presented by him to the Yerkes Observatory at the time of his departure for Mount Wilson in 1904. Huggins was probably the most famous of the early pioneers in astrophysics. In 1856 he had built a private observatory in the garden of his London residence at Tulse Hill, and had engaged in the study of the spectra of the stars by means of a small visual spectroscope attached to a moderately large refracting telescope. Three years later, Kirchhoff had succeeded in reversing two strong, dark absorption lines of the spectrum of the sun by placing a flame colored by sodium vapor in front of the slit, so that the lines appeared as two yellow emissions on top of the usual background of the continuous spectrum. The intensity of the background spectrum of the sun was reduced by a filter in this experiment. When Kirchhoff removed the filter, allowing full sunlight to fall upon the slit, the two lines were again seen as black absorption features "with an extraordinary degree of clearness." His announcement of the solution of the mystery of the Fraunhofer absorption lines followed shortly thereafter, and it was this announcement which inspired Huggins to write:

> Here at last presented itself the very order of work for which in an indefinite way I was looking. . . . A feeling as of inspiration seized me: I felt as if I had it now in my power to lift a veil that had never before been lifted; as if a key had been put into my hands which would unlock a door which had been regarded as forever closed to man [from Macpherson's *Makers of astronomy*, Oxford Univ. Press, 1933, p. 167].

During the past 50 years three directors of the Yerkes Observatory have conducted their work under the watchful eyes of Sir William, and I believe that all three have often looked up to his portrait for guidance. My predecessors, Hale and Frost, had known Huggins personally, and his influence is easily discerned in their publications. My own work, though not so intimately connected with that of Huggins, unquestionably resembles his in character. Huggins was filled with the spirit of exploration. When he opened the dome of his observatory and took his seat at the eyepiece of his spectroscope, he entered on a perilous journey to distant worlds where only ingenuity in reading and understanding the records of his instruments could save him from wrong conclusions, and where great perseverance was needed to try again and again to solve those riddles of the universe which would not easily give up their secrets. The major part of the Yerkes Observatory's contributions to stellar spectroscopy has been obtained in a similar spirit of exploration. Our procedure has usually been to examine with the utmost care all stellar spectrograms at our disposal and to try to detect those features which were not already explained by existing theories. Less often our search would be guided by previous theoretical considerations. Having found and described a hitherto unexplained phenomenon, we would next look for related data and then, if possible, measure some recognizable characteristic feature of the new phenomenon as a function of the related characteristic. Our purpose would always be to find a physical explanation. More often than not, the true explanation would escape us time and again, so that the work would have to be laid aside until an advance in a different field would make it tempting to try again.

We have always recognized the importance of long routine programs in astronomy, such as the construction of great catalogues of star positions, of magnitudes, or of radial velocities; we have taken some part in programs of this kind, but we must now recognize that our contributions to such large-scale program work have been relatively slight. In stellar spectroscopy we are the successors of Huggins, not of Secchi with his famous catalogue of stellar spectra or of Vogel with his great and systematic work on stellar radial velocities.