THE DOMINION ASTROPHYSICAL OBSERVATORY

By J. S. Plaskett, F. R. S.

The Dominion Astrophysical Observatory, Victoria, B. C., is one of the most recently instituted in the chain of observatories along the Pacific Coast and as an introduction to its description a short sketch of the events that led to the establishment of the observatory and its particular location will probably be of interest.

Historical Sketch

The observatory is a branch of the Department of the Interior of the Federal Government of Canada, the Department charged with the administration of the western lands of the Dominion. In the colonization of these lands, almost the first need was a survey of the boundaries and a subdivision into townships and sections. Hence the Surveys Branch of the Department was organized and out of the necessity of accurate astronomical observations to delimit the boundaries and define the positions of the base lines and meridians for the subdivision work, the astronomical branch developed and was separated from the surveys under the leadership of the first Chief Astronomer of Canada, the late Dr. W. F. King, C. M. G. Dr. King was a man of vision with sterling integrity and remarkable ability and it is to his genius that we owe the initiation and a large measure of the progress and advancement of astronomy in Canada.

His ability soon led to his appointment as H. M. Commissioner for International Boundaries and under the joint direction of the Commissioners for the two countries, the boundaries between Canada and the United States were resurveyed and marked. His ability in this work and in the preparation of the Canadian case for the Alaska Boundary Tribunal gave him such standing with the Government that his dream of a national observatory for Canada was realized in 1905 by the construction of the Dominion Observatory at Ottawa which served as the headquarters of the Astronomical Branch, of the International Boundary Surveys, and later of the Geodetic Survey of Canada, also organized by Dr. King.

The work with the 15-inch equatorial, the principal instrument of the Dominion Observatory was entrusted to the present writer and was developed principally along the lines of stellar radial velocities. The need of a larger telescope for extending this work was soon realized and was first brought to the attention of the Government in 1911. The relative success attained with the small instrument at Ottawa, the great success of the 60-inch reflector at Mt. Wilson, the prestige of Dr. King and the intensive educational campaign of the chief promoter were finally successful in prevailing upon the Government to authorize the construction of a large reflecting telescope. Contracts were let in October 1913 to the John A. Brashear Co. for the optical parts and to the Warner and Swasey Co. for the mechanical parts of a reflecting telescope of 6-foot aperture.

The Location

A stipulation of one of the assisting organizations, the Royal Society of Canada, provided that the telescope should be placed at the most suitable astronomical location in Canada. While the natural location and the one entailing the least expense would have been at the Dominion Observatory, Ottawa, direct tests of the conditions of "seeing," transparency, temperature variation, etc., were made at five selected places in Canada representative of varying climatic conditions. These places were Ottawa, representative of conditions in the East; Medicine Hat, of the prairies; Banff, of the mountains; Penticton, of the dry belt of British Columbia; and Victoria, of the Pacific Coast. The tests were made by Mr. W. E. Harper, astronomer at Ottawa, by means of a 4.5-inch Cooke Photo-Visual telescope and accessory apparatus. These tests were decisively in favour of Victoria on the score of "seeing" and small temperature variation, two very important factors, while the transparency and quantity of clear sky were practically equal at Victoria to any of the stations with the exception of Mecidine Hat where the seeing was hopelessly poor. As the exposure ratio on the spectrograms between bad and good seeing is at least five to one, there is no question of the wisdom of the selection of Victoria. While the conditions there are not equal to those at Mt. Hamilton or Mt. Wilson, it is undoubtedly the most suitable site in Canada for a large reflecting telescope and our experience has shown that at any other place tested not half the effective work could have been done.

Construction and Erection

After the decision to locate at Victoria, the writer early in 1914 selected as the site of the observatory an isolated monadnock of 730 ft. elevation, now called Observatory Hill, about seven miles north of Victoria and adjacent to the main road and the interurban railway. The Provincial Government agreed to give $10,000 towards the purchase of the site and to build a road to the summit at a cost of $25,000. The road, the walls of the circular double-walled steel building and the massive pier for the telescope were completed in 1915. The dome, also of ventilated double-walled construction, and made by the Warner and Swasey Co., was erected in the spring of 1916 while the mounting of the telescope was completely erected and adjusted by November, 1916, only three years after the contract was let. The mirror, however, for various reasons was delayed and was not finally completed and accepted until April, 1918. It was shipped to Victoria, arriving about May 1, was quickly installed and adjusted, the first star spectrum being obtained within the week. The total cost of this observing equipment approximated $155,000, made up of building and dome complete $57,000, and telescope and spectrograph $97,000. That this great undertaking was so promptly completed during the strain and stress of the Great War reflects great credit on all concerned and it is fortunate for the cause of astronomy that the Canadian Government was sufficiently liberal minded and progressive to complete this instrument for research in pure science when so many other more practical projects had to wait.

The Optical Parts

The principal mirror was cast and annealed at the Charleroi works of the St. Gobain Glass Co. and was shipped from Antwerp only about a week before the declaration of war. As received from the makers, it was 73.5 inches in diameter, over 13 inches thick, with a hole about 6 inches diameter cast in the center; and weighed about 5000 lbs. As finished, the diameter was reduced to 73 inches, the thickness to 12 inches at the edge, and the central hole enlarged to 10 inches. It is composed of hard plate glass and is apparently very homogeneous with only a few small bubbles in one place. The grinding, polishing and figuring required about three years and a half, the opticians, the J. A. Brashear Co., encountering many difficulties and having it nearly correct twice before the final figure was obtained. Tests by the Hartmann method both at Pittsburgh and Victoria, in addition to the usual knife edge tests at the optical works, showed the final figure to be practically perfect, a computation showing that no part of the surface deviated from the theoretical shape more than one four hundred thousandth of an inch. Mr. J. B. McDowell and his chief assistant Hegemann deserve great credit for their skill and persistence in obtaining this fine figure under difficult conditions. The focal length of the mirror is 30 ft. and it is provided with two secondary mirrors each 20 inches in diameter. One is a flat set at an angle of 45° reflecting the light to, and forming an image at the side of the tube for direct photography of stars, nebulae, etc. The high quality of the figure is clearly shown by the reproduction of the Ring Nebula made with the Newtonian arrangement. The Cassegrain mirror has a convex reflecting surface, a hyperboloid of revolution, and when placed about seven feet below the principal focus reflects the light back through the central hole, forming the focus at a point about two feet below the principal mirror, the combination having an equivalent focal length of 108 ft.

The Spectrograph

The stellar spectrograph, advantageously attached directly below the tube and used with the Cassegrain attachment, is a modified form of the original universal type. This was chosen to avoid the prohibitive expense of a number of separate instruments required for varied purposes with the 72-inch telescope. It can be used with one, two or three prisms at any desired central wave-length and with four different focal lengths of camera, giving twelve dispersions ranging from 90 A to 7 A per millimeter. The design is such that it can readily be changed from one form to another and adjusted in less time than would be required to change separate instruments, while each form is as rigid and in as constant adjustment as a single spectrograph. Another advantage is the use of prisms of ordinary, instead of the dense flint usually employed enabling the H and K lines to be more readily obtained; while the figure of the prisms and design of the lenses is such that the whole range of spectrum with each combination is sharply defined.

The Mounting

The main features of the mounting, such as the general form, well shown in the illustrations,[1] reaching every part of the sky, the elimination of all anti-friction devices such as mercury flotation, the polar and declination axes being carried on simple ball bearings, and the provision of accurately reading coarse circles for rapid setting were determined by the director. But these features were most skilfully adapted and all the details of the design were beautifully worked out by the Warner and Swasey Co., with especial mention of Mr. Swasey and Mr. Burrell; the result being an instrument unequalled, I believe, in simplicity and beauty of design and in accuracy and convenience of operation.

[1]An earlier description of the Dominion Astrophysical Observatory is published in the October, 1918 number of these *Publications* (**30**, 267, 1918). Readers are referred to this article for further details relating to the telescope, and for additional photographs of the telescope (p. 269) and dome (p. 267).—The Editors.

The tube of the 72-inch telescope, carrying the principal and secondary mirrors, is 31 ft. long, 7 ft. 4 in. external diameter and weighs 15 tons. The special features of this tube are the diagonal tension rods in each compartment of the skeleton section, each screwed up to a tension of about 2000 lbs., making it exceptionally rigid for its weight, and the method provided, due to the genius of Mr. Swasey, for changing the secondary mirrors. Instead of mounting each on a heavy and cumbrous section of the main tube, they are attached to relatively light adapters and can be changed easily in less than ten minutes. This tube is attached to the declination axis, 16 inches in diameter, which is carried on special radial and double thrust ball bearings and passes through the polar axis to the circular declination housing which not only serves as a counterweight to the tube but carries the motors and mechanism for quick and slow motion in declination.

The polar axis carrying declination axis and tube is 21 ft. long, built up of three hollow steel castings, and weighs 9.5 tons, the total weight on the S. K. F. ball bearings supporting it being about 45 tons. Notwithstanding this great weight, a pressure of two or three pounds on the upper end of the tube suffices to overcome the friction in these bearings, illustrating the striking advantage in simplicity and smoothness of operation of eliminating all friction relieving devices. This polar axis is driven to follow the diurnal motion through the very accurately cut worm wheel 9 ft. in diameter, also mounted on ball bearings, by a Warner and Swasey driving clock, connected directly to the worm by spur gears, thus eliminating the usual bevel gears, a frequent cause of periodic error. The slow motion in right ascension is effected by differential gearing on the main drive shaft, giving a very smooth action and completely eliminating all backlash. The mechanism is so accurately made that the driving, even with the long focal length of 108 ft. is practically perfect and no trace of periodic shift of the image can be detected.

Other special features of the mounting are the means provided for rapidly moving the telescope and setting to the desired position. Although the telescope could be easily set by hand, this is always done by electric motors, operated from convenient positions, giving a quick motion in each coordinate of 45° to the minute and slow motions of 10° and 0°.5 to the hour. Settings are made in right ascension by means of a sidereal circle carried by friction with the worm wheel and divided into single minutes of time, easily estimated to tenths. This can be set to the sidereal time at the beginning of the night and hence enables the telescope to be directly set thereafter to the right ascension of the star, avoiding all computation of hour angles. The large declination circle graduated to degrees is provided with a multiplying secondary wheel graduated to five minute intervals and enabling declination settings accurate to the nearest minute. Both right ascension and declination circles can easily be read directly from the setting switches and the operation of changing from one star to another rarely takes more than two minutes and is so accurate that no plotting of fields is generally required for stars brighter than the eight magnitude.

The design and construction of the mounting reflects great credit upon the Warner and Swasey Company, as after nine years' use there is no feature we would wish changed and no defect of construction has developed.

The Work of the Observatory

As there is only the one instrument and a relatively small staff of director and three astronomers, it was thought wiser to concentrate principally on one phase of astronomical research. As the experience of the staff had been mainly spectroscopic and as this seemed the work in greatest demand at the time, there was little hesitation in making stellar spectroscopy the main line of work. Although a few direct photographs were made in the early days, mainly to test the quality of the optical parts, the Cassegrain spectrograph, and occasionally an ultra-violet focal plane spectrograph, have been used exclusively since.

The first principal investigation was the determination of the radial velocities of about 800 Boss stars, the program being arranged in cooperation with Mt. Wilson to avoid duplication of effort. During the progress of this piece of more or less routine work, separate accessory investigations were carried on by individual members of the staff, consisting mainly of binary orbit determinations. Special mention might be made of the observation of all readily available eclipsing variables whose photometric elements were known, resulting in the determination of the absolute dimensions of eight systems in addition to the seven already known. In another important accessory investigation of three O-type stars, a new system of classification for the O's was devised, the enhanced helium components to the Balmer lines discovered and an independent astronomical determination of the fundamental constants of atomic structure and of the dimensions of the atom obtained.

After this first radial velocity program was completed in 1921, the next important investigation was the adaptation of Adams's spectroscopic method to the determination of the absolute magnitudes and parallaxes of the Boss stars whose radial velocities had been obtained here, and of a number of others, 1100 in all. New pairs of lines were obtained for the spectroscopic criteria, a new method of measuring relative intensity developed and other refinements introduced with the result that the probable errors of determination were reduced. A comparison with Mt. Wilson values shows good agreement in the values for F, G and early K but in the later K-types the Victoria values give brighter absolute magnitudes.

Another investigation was the determination of the radial velocities, mean parallaxes and absolute magnitudes of all the absorption line O-type stars within reach at Victoria, resulting in a high residual velocity, 25 km. per sec., and high average absolute brightness, -4 mag. A by-product of this investigation was the important result that the "stationary" calcium lines H and K were definitely shown not to be connected with the stars but to arise in intervening calcium clouds approximately stationary with respect to the local stellar system.

The important question of solar and stellar spectro-photometry has also been successfully attacked here by the application of a new method, the use of a neutral tint wedge in front of the slit, which successfully overcomes the numerous photographic difficulties attendant on such measurements. A preliminary paper describing the technique of the method and giving temperatures of the Sun and some typical stars has appeared. Since that time all sources of error in the method have been thoroughly investigated, methods developed for eliminating or correcting them, and a more extended program including specially the high temperature stars is in progress. There are large disparities between the available spectro-photometric temperatures of these stars and those deduced by ionization methods and it is hoped that these new measures will at least determine which is the more correct.

The investigations at present in progress and approaching completion are a complete spectroscopic research on all B0-B5 stars brighter than 7.5 visual magnitude and north of -11°, a continuation of the absolute magnitude work to the A-type stars, and a research on the constitution and physical condition of the gaseous nebulae.

The staff of the observatory is composed of the following members:

Director—J. S. Plaskett, B.A., D.Sc., LL.D., F.R.S.C.,F.R.S.
Assistant Director—W. E. Harper, M.A., F.R.S.C.
Research Astronomer—H. H. Plaskett, B.A.
Astronomer—J. A. Pearce, M.A.
Computer—S. N. Hill.
Observing Assistant—T. T. Hutchison.
Secretary—Miss H. R. Keay.

This staff, smaller in number in the first two years, in the 9 years the observatory has been in operation, have determined the radial velocities of 1150 stars of which 280 are unpublished, have discovered 360 spectroscopic binaries, 120 unpublished, and have obtained the orbits of 80 spectroscopic binaries, 10 unpublished, to say nothing of numerous other investigations.

The work of the observatory appears as "Publications of the Dominion Astrophysical Observatory" in separate quarto monographs collected into volumes of about 350 pages of which three volumes, 64 numbers, are completed.

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