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THE SPROUL OBSERVATORY OF SWARTHMORE COLLEGE.

JOHN A. MILLER.

In April 1907, William Cameron Sproul communicated to the Board of Managers of Swarthmore College his desire to provide the funds with which to purchase an equipment for an astronomical observatory for the College. It was his desire that the chief instrument of this equipment should be a refracting telescope of "not less than twenty-four inches aperture," and that it be provided with such accessories as would enable the staff, which is limited in numbers, to pursue, under excellent instrumental conditions, at least one line of astronomical research. In June 1907, the College entered into a contract with the John A. Brashear Co., Ltd., to furnish the entire equipment provided for by Mr. Sproul including a telescope of twenty-four inches aperture with the usual accessories, a photographic doublet of nine inches aperture, and a measuring engine.

The photographic telescope was completed and installed in 1908; the twenty-four inch was completed and mounted in its observatory in December 1911, the long delay being due to a somewhat tedious wait of four years for discs out of which the lens could be constructed. The order for these discs was placed by the Brashear Company early in 1907, with Parra-Mantois & Cle, who, in August 1909, delivered a crown disc and would have, but for an unfortunate accident, delivered a flint disc the same year. Subsequently Schott and Gennossen of Jena also undertook the manufacture of a set of twenty-four inch discs. Both firms produced several flint discs which were either broken in annealing or were imperfect because of striae. Finally in February 1911, Schott and Genossen delivered a flint disc; accordingly, the objective is made of a crown disc made by the Para-Mantois & Cle, and a flint disc made by Schott and Genossen. Of the optical quality of these discs Mr. McDowell says that every optical test shows both these discs to be as nearly perfect as any he has ever examined; the crown lens can be rotated in any position relative to the flint on any axis, without affecting in any way the character of the image.

It is a pleasure to acknowledge the kindly consideration, the unceasing care, and the thoughtfulness of everyone connected with the Brashear Company, and to acknowledge the great value of the suggestions of Director Schlesinger, of Allegheny Observatory, during the construction of the instruments, and to say that in every way the entire equipment is excellent, even when measured by the high standard of excellence which characterizes the work of the Brashear Company.

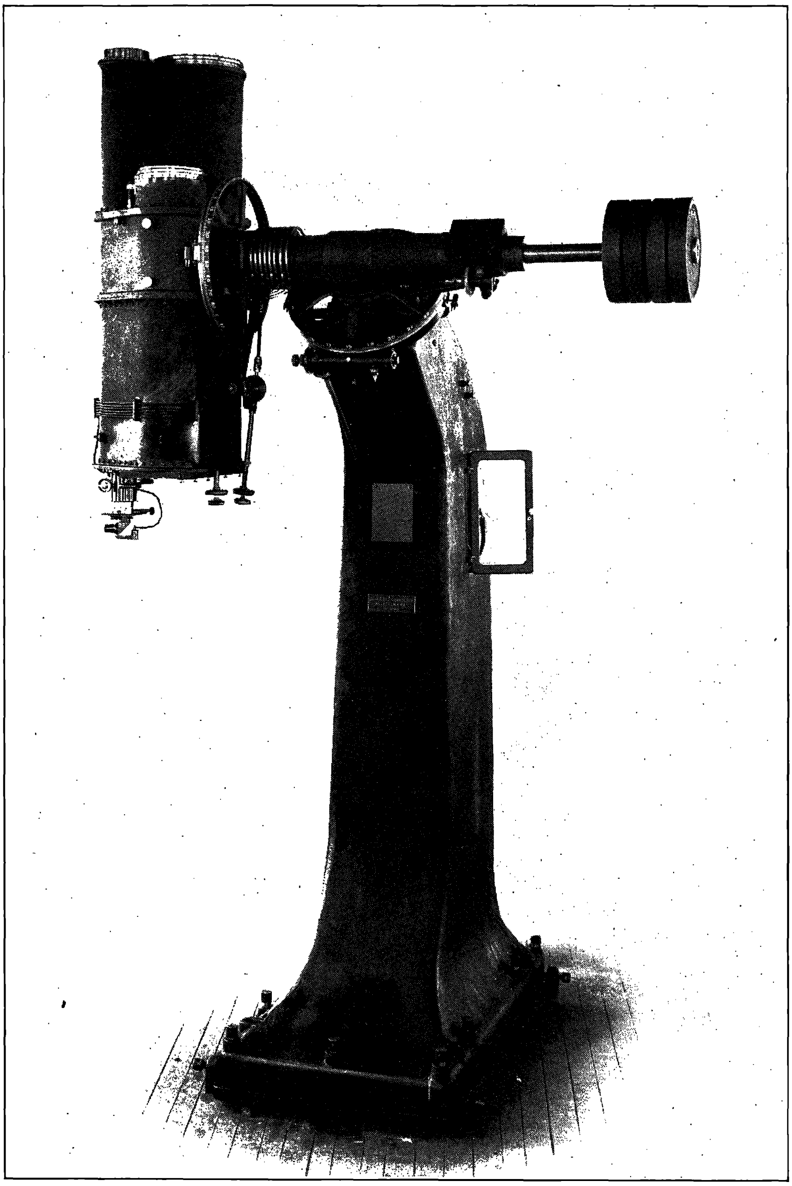
The Student Observatory.

Swarthmore College is a small college founded by the Religious Society of Friends. The traditions of the college are, and always have been, that it is and shall remain a small college, and that its teaching energies shall be directed almost exclusively along undergraduate lines. It is the ambition of the present administration, however, to equip all departments of the college, so that first of all the teaching of the undergraduate shall be just as effective as it can be anywhere, and in addition to provide so far as possible library facilities and laboratory equipment so that the faculty of each department may engage in some line of research, with the hope of doing it effectively and producing creditable results. In almost every department, there are a few graduate students, but unless the student's interest and ability naturally lead him in the direction in which the professor is working, he is advised to pursue work in institutions that give their chief energies to graduate work. In accordance with this plan this equipment supplements, for purposes of research, a well equipped students' observatory which was placed on the College Campus about twenty years ago for instructional purposes. The funds for this observatory were secured through the efforts of Dr. Susan J. Cunningham, for thirty-five years Professor of Mathematics and Astronomy at the college, and since 1906 Professor Emeritus of Mathematics and Astronomy.

This observatory is only one of the expressions of the marked influence this great woman and great teacher has had, and in fact is having, upon the college, for she still contributes not only from her material resources, but gives her entire strength and influence to the upbuilding of the college.

The equipment of the student observatory includes a 6-inch equatorial refractor, the optical parts of which are by Alvan Clark, and the mounting of which, as complete as that of a large instrument, is by Warner and Swasey. It has as accessories, a position micrometer, and a spectroscope. There is a transit instrument, of three inches aperture, the optical parts and mounting of which are by the same makers. This instrument has a zenith telescope attachment. The observatory also contains a sidereal clock, a meantime clock, and a chronometer. The

PLATE XVI



Photographic Telescope of Sproul Observatory entire equipment has been chosen most wisely and in such a way as to illustrate effectively many of the fundamental phases of astronomical research.

In 1910 Stephen Loines, a friend of the College, expressed a desire to add to this student equipment a 6-inch telescope, recently put out by the Alvan Clark and Sons' Corporation, and called by them a "Polar Equatorial"—a quasi Coudé. The tube of the telescope is mounted parallel to the earth's axis with the eye-end pointing towards the North Pole. At the lower end of the telescope a mirror, rigidly connected to the tube, reflects the object into the objective. The mirror is subject to two motions; one a rotation of the tube about its axis, thus setting off the hour angle, and the second a rotation of the mirror about an axis, at right angles to this one, thus setting off the declination. The telescope is provided with circles, reading hour angle and declination. The advantage of this mounting is that the observer while making his observations sits in a warm room in a comfortable position. The amateur finds it a most convenient instrument and it is used rather effectively and more or less extensively by students who merely want to "poke around the sky."

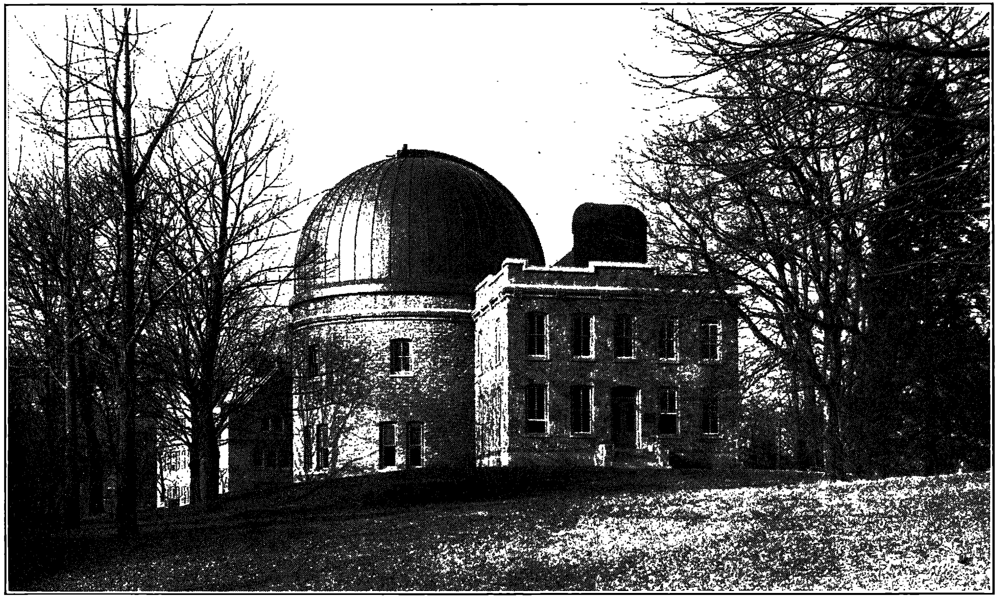
Descriptive astronomy in the college is elective, and, judging from the numbers enrolled in it, is a rather attractive course. There are enrolled in it at any one time from 15 to 20 per cent of the entire student body, which means that at least 60 per cent of the students who graduate from Swarthmore College, have done a year's work, meeting four times a week, in descriptive astronomy. One of these meetings is given to making observations with the telescope under best conditions, of at least one of each type of celestial phenomena. A considerable number of students use these telescopes for looking up objects, making micrometer measures, etc. The work is voluntary and no college credit is given for it. It can hardly be called serious work, but those who are interested and work faithfully derive a good deal of pleasure and considerable benefit from it.

A seismograph of the Milne type, presented to the college by Joseph Wharton, is mounted in a room adjoining the transit room. As is well known this instrument carries a horizontal pendulum, whose oscillations due to the vibrations of the earth's crust are recorded photographically. The instrument is very sensitive. It has recorded earthquakes from all parts of the world. There is a fairly continuous series of seismograms, extending through a long series of years, on file in the observatory. Some of these have been reduced but many have not.

The position of the transit instrument as determined by assistant Professor Barton is:

$$\text{Latitude} = +39^\circ\ 54'\ 23''.3$$
$$\text{Longitude} = 5^h\ 1^m\ 24^s.9 \text{ W of Greenwich.}$$

PLATE XVII



SPROUL OBSERVATORY, SWARTHMORE COLLEGE

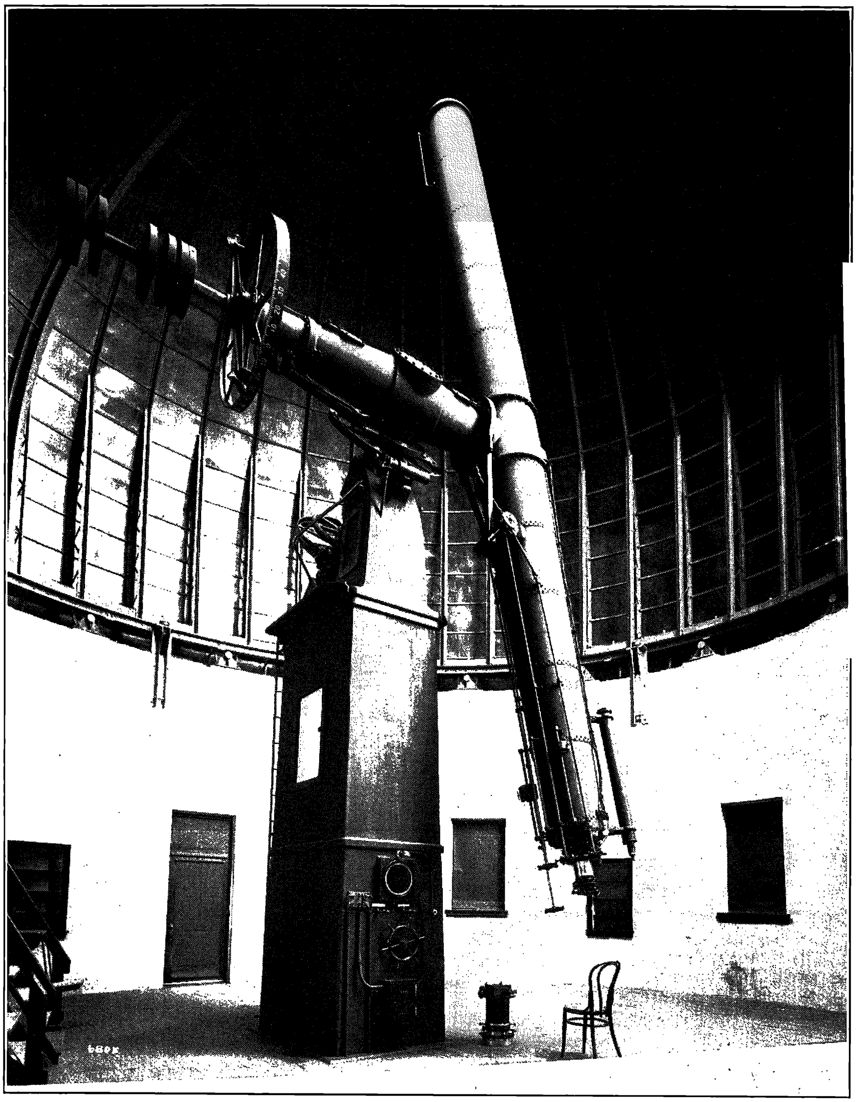
The Photographic Telescope.

The photographic telescope is installed in a building (the dome to the extreme left in Plate XV,) adjoining the student observatory, the dome covering it being 15 feet in diameter. The photographic lens is a doublet of nine inches aperture and 45 inches focal length. The optical quality of the lens is very satisfactory. A field of 6° or 7° diameter is fairly flat. When the center of the field is in the very best focus the image of a star 2½ degrees from the center is excellent. With the center slightly out of focus, one may secure passable star images out to the edge of an eight by ten plate. Numerous photographs of comets and star fields and nebulous regions have been made with this instrument. Since its mounting in 1908, practically all the comets that have appeared have been photographed and in the case of some of the brighter ones, namely, Comet Morehouse and Brooks' Comet, a fairly complete series of each has been obtained. Owing to meteorological conditions the series made of Halley's Comet is very incomplete. Something of the quality of the performance of the objective may be seen by reference to Popular Astronomy of December 1908, page 664, in which a picture of Comet Morehouse is reproduced. The mounting of this telescope is a practical duplicate of the Bruce telescope at the Yerkes Observatory. Parallel to the tube that carries the 9-inch doublet, is another tube to receive a 6-inch doublet, which has not yet been ordered, and a third tube also parallel to the other two carries a 5-inch visual telescope of about 47 inches focal length, used for guiding. The visual telescope is provided with a diagonal eye-piece, which may be shifted somewhat so as to displace the center of the photographic field from the center of the plate in the case of comets, and which may be rotated into any position that the observer desires. The three tubes carrying the lenses are bound very rigidly together and the mounting provides that one may, without interruption, photograph objects in any position through the meridian. The driving clock is very large and massive and performs remarkably well. The telescope is provided with both electric and hand slow motion, and with coarse and fine position circles. Plate XVI shows the photographic telescope.

The Sproul Observatory.

The 24-inch telescope and in fact the remainder of the equipment is installed in a new building erected for the purpose, situated on the college campus about an eighth of a mile from the student observatory. This building consists of a rectangular part two stories high in which are situated on the first floor, the office of the observatory, the library, a computing room, a shop room, and two class rooms. On the second

PLATE XVIII



THE SPROUL TELESCOPE

floor is a large lecture room, seating 76 people. This lecture room is equipped with a lantern and some other illustrative material; the photographic dark-room is also on this floor. A common hall leads into the lecture room, into the dome-room and into the dark-room. The 24-inch telescope is in a circular stone building adjoining the rectangular two story building just described, and is connected to it by a short hall. This circular building is surmounted by a dome covered with copper, 45 feet in diameter and was built by the Russell Wheel and Foundry Co., of Detroit, Michigan. The frame work is of structural steel, built in the shape of a cylinder five feet high, on which is surmounted a hemisphere, the center of motion of the telescope being in the center of the hemisphere. The lower end of the cylinder is fastened to a heavy circular iron base plate, planed true on the lower side, which rests on eighteen iron casters or wheels, sixteen inches in diameter, which are fastened to the wall of the building supporting the dome; that is, instead of wheels moving on a fixed track, the track or surface in contact with the wheels, moves over wheels with fixed centers. These wheels are provided with adjusting screws so as to bring them all to the same level and also on the circumference of a circle. The dome is rotated by an endless cable which passes over a drum driven by a four horse-power electric motor, which is controlled by a switch situated on the north side of the pier of the telescope. It requires four and one half minutes to turn the dome through one complete revolution. The mechanism works perfectly, except that the gearing makes a little more noise than is desirable.

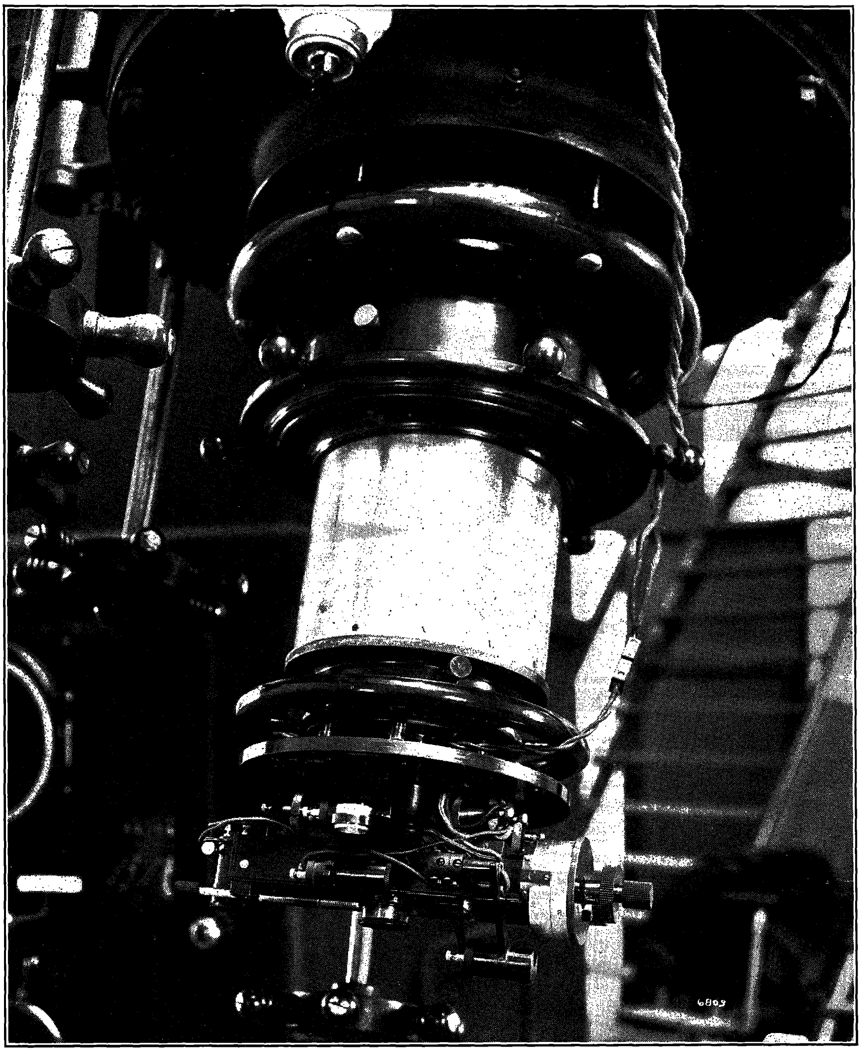
The shutter is a large one, giving a clear opening of seven feet three inches. It is a double shutter, half of it moving to the right, while the other half simultaneously moves to the left. It is operated by a rack and pinion, which is driven by an endless rope.

The floor of the dome is stationary; this necessitates a rather large observing chair, which was built by our college carpenter. Warner and Swasey very kindly furnished the plans from which the observing chair of the Flower Observatory had been built, and our carpenter made such modifications as were necessary. The chair at first was very difficult to move, but since mounting it on large fiber casters secured from the Lansing Wheelbarrow Company, Lansing, Mich., it is possible to move it into any position with one hand and it is not at all unwieldy.

The Sproul Telescope.

The mounting, as well as the optical parts of the Sproul Telescope, is by the Brashear Company. The mounting is an extremely heavy one weighing about fifty thousand pounds and in design is almost a duplicate of the mounting of the thirty-inch refractor of the Allegheny Observatory, the two mountings having been built at the same time.

PLATE XIX



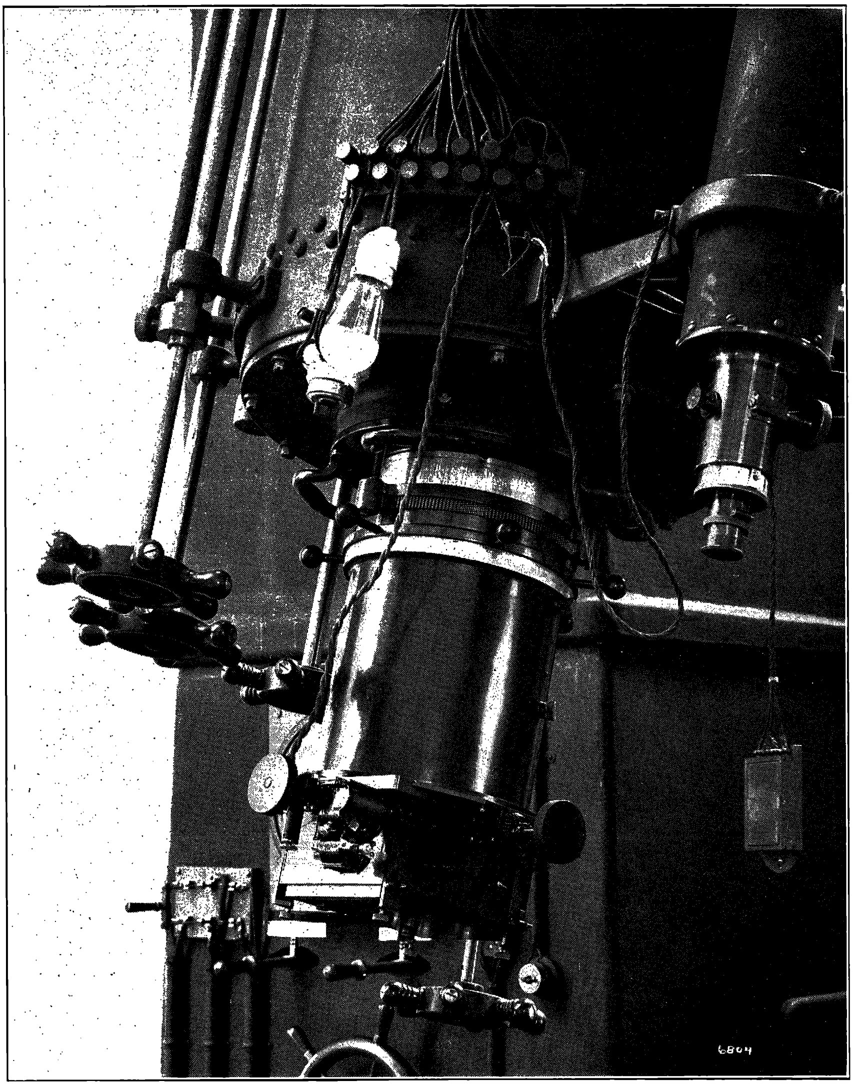
EYE-END SHOWING MICROMETER

The iron column rests on a concrete foundation which is set on a cushion of sand, the center of motion of the telescope being 28 feet above the concrete foundation. The polar axis rests on roller bearings in its journals, and a radial roller bearing takes the thrust of the axis. The worm wheel is 50 inches in diameter and seems to be of a high degree of mechanical perfection, The tube is made of heavy sheet steel and is very rigid. The center piece of the tube is of cast iron heavily ribbed; two rows of bolts running its entire length fasten the steel tubes to it. The distance from the center of the declination axis to the extreme outer part of the lens end of the tube is 19 1/3 feet; and from the center of the declination axis to the focal plane is 17 feet. From the center of motion of the telescope to the center of the tube is 54¾ inches, which allows a good clearance between the tube and the column when the telescope is pointed to the zenith.

The driving clock is an unusually heavy one, and depends for its control upon a conical pendulum which is actuated by a weight. When the weight driving the clock reaches its lowest point, it automatically completes an electric circuit, operating a motor which winds the weight up, and when the weight reaches its highest point it breaks the circuit. After the driving clock is started it runs continuously without the observer's attention. The clock is provided with two sets of gears, one of which drives the telescope at the sidereal rate and the other at the solar rate. The telescope is provided with the usual hand slow motions, operated in the usual way. In addition the driving clock is provided with an electric slow motion, which depends on a set of differential gears operated by a motor controlled by a switch at the eye end of the tube. The gears are thrown into train by a magnet which is operated by the same current that drives the motor; this renders necessary a rather complicated system of wiring, and for this reason requires considerable attention. The device has not been entirely satisfactory, probably because, since it is not indispensable, we have not given it the requisite attention. There is also an electric control for the driving clock. This is an old form of control; it depends upon the attraction of magnets for pieces of iron set in a brass circular disc whose plane is horizontal and whose center is the center of the vertical axis of the conical pendulum. The circuit through the magnets is closed once a second by a sidereal clock; hence, since the conical pendulum rotates once a second, the magnet will accelerate the pendulum if it is running slowly, and retard it if it is running fast, and not affect it if it is rotating just once a second. We have never used the control.

The telescope can be moved rapidly in right ascension and declination, either by hand or by a motor which runs in one direction only. This motion is communicated to the telescope by means of friction clutches

PLATE XX



EYE-END SHOWING DOUBLE SLIDE PLATE HOLDER operated by levers on the north side of the pier. There is a lever for right ascension and one for declination, the telescope being moved in a positive or negative direction according to the direction in which the lever is thrown. The operator thus may with one motor, running in one direction only, move the telescope in both right ascension and declination simultaneously, or separately, into any position. The motors, since their first adjustment, have worked perfectly.

Situated by the side of these levers is a right ascension dial, fourteen inches in diameter, the face of which is graduated on silver to minutes of time. This dial is driven by an eight day Thomas clock regulated to sidereal time, and rotating past a fixed index gives the time of the observation. A pointer geared to the polar axis indicates on the dial the right ascension of objects, so that neither addition nor subtraction is necessary. Having set the Thomas clock to the proper sidereal time and the pointer so that, when the telescope is pointed to a star, it indicates the proper right ascension, one may without any knowledge of the sidereal time, so long as the Thomas clock is kept running, set the telescope on any object whose position is known, by moving it until the pointer indicates the proper right ascension on the dial. If he desires also the approximate sidereal time he may read it from the dial. The only attention the mechanism requires is that the Thomas clock be wound once a week. The arrangement is an ingenious one and is a model of convenience.

The motor for operating the dome contains its own starting box, and can be reversed by simply reversing the switch. The other motors are so small that they do not need starting boxes, and the clutches are so arranged that the motor need never be reversed; so that one may operate any motor, or as many as he wishes at any time, about the entire mechanism by simply closing the proper switches,—a great convenience These switches, the right ascension dial, and the levers for operating the rapid motion of the telescope are on the north side of the pier and so near each other that all are within easy reach.

The current for operating these motors and for illuminating the circles is a 110 volt alternating circuit, which is furnished by the college. For illuminating the micrometer, the guide wires in the guide telescope of the photographic eye-piece, and a hand reading lamp, the 110 volt circuit is transformed into a 5-volt circuit. This is more convenient than storage batteries.

The Micrometer and Double Slide Plate Holder.

The telescope is provided with two pieces at the eye end, either of which may be fastened to the telescope by a bayonet joint. One of these pieces carries the tail-piece for focusing, to which is attached either a position micrometer, polarizing helioscope, or the ordinary eye piece; the other carries a double slide photographic plate holder, and a focusing device.

The position circle of the micrometer is nine inches in diameter, is graduated to degrees, and, by a vernier, reads to tenths of a degree. The screw, which is longer than usual, seems from preliminary tests to be very evenly cut. One turn of the micrometer screw equals 9″.27. The illumination of the micrometer is very complete and convenient. The position circle is illuminated at two points 180° from each other by miniature electric lamps, which are on the same circuit, and controlled by the same switch as a little miniature lamp that illuminates the micrometer head. The wires are also illuminated by miniature electric lamps. Mr. Klages, who designed the micrometer and in fact was responsible for the design of the entire mounting, spared no pains to make this micrometer complete and convenient—a remark indeed applicable to the entire mounting. The lamps illuminating the circles are provided with conveniently placed rheostats, entirely out of the way, and also with shields that prevent light not reflected from the circles from reaching the eye. Small low power lenses are over the position circle and move with the indicator. The intensity of the illumination of the wires is controlled by separate rheostats, not entirely conveniently placed, but out of the way. There is a device for changing the color of the illumination which is not very successful; in fact the method of illuminating the wires is capable of considerable improvement. The instrument is provided with all the ordinary conveniences, and in addition to these and those mentioned, an ingenious device for rendering the wires parallel to each other in case they were not set parallel originally.

The double slide plate holder is essentially the same as that devised by Ritchey for use at the Yerkes Observatory. This is described in Volume **12** p. 355 et seq. of the Astrophysical Journal.

The Objective.

The objective of the telescope is twenty-four inches in diameter and has a focal length of 432 inches; it is corrected for visual rays and is an excellent piece of optical workmanship. Soon after the telescope was mounted Professor Marriott and myself applied to the objective the method of extra focal images devised by Hartmann and described in the Publications of the Astrophysical Observatory of Potsdam. We covered the objective with a screen containing 44 circular holes 33mm in diameter. The centers of these holes were on nine different zones. Placing this screen we photographed Capella when it was near the meridian, photographing through a yellow ray filter, made by Wallace in accordance with the color curve of the objective. We used Cramer

Instantaneous Isochromatic plates. These plates when measured and reduced showed the presence of certain small astigmatic errors that Mr. McDowell asserted were not present in the objective when it was in the optical room. He surmised that it was due to the pressure of a spring used to prevent the objective from sliding in its cell. At Mr. McDowell's suggestion we repeated the test after reducing the pressure of the spring, using Arcturus instead of Capella, and using a screen containing 78 circular holes, distributed on ten zones. Notwithstanding the fact that Capella was photographed with the telescope east and Arcturus with the telescope west of the meridian, that one was north and the other south of the zenith, that the temperature was high when Capella was photographed and low when Arcturus was photographed, both tests showed qualitatively practically the same astigmatic errors, though they were smaller in the case of Arcturus than with Capella. These errors are not large,—in fact they are very small. With the values thus obtained we computed Hartmann's Characteristic T by which he measures the quality of an objective. Hartmann said when he devised this method of testing objectives that if T turned out to be less than 0.5, the objective is "preëminently excellent." The result which we obtained for the Sproul objective gives $T = 0.27$. If we grant this value of T to be correct this objective, according to the table given by Hartmann in Publications of the Astrophysical Observatory of Potsdam, is the third best in the world. We have decided however to repeat the extra focal test.

We are at present using the telescope for the determination of stellar parallax by means of photography; we photograph through the yellow ray filter mentioned above, on Instantaneous Isochromatic plates, and, when the seeing is good have suucceeded in getting small sharply defined images. For reducing the brightness of the parallax star we have used the occulting device designed by Schlesinger described in Astrophysical Journal Vol. 32 page 384. It has been found satisfactory.

Our observing program is made up pretty largely from the visual binaries whose orbits are fairly well determined. Some other objects of peculiar interest, for example Nova Geminorum, have been added.

The measuring engine upon which the plates are being measured was made by the Brashear Company. The plate is fastened into a heavy iron disc with an opening in it large enough to receive a 5x7 plate, the size that we are using. The disc is graduated, though not with extreme accuracy, and may be rotated about an axis perpendicular to its plane through any angle. The plate is fastened to a carriage, which may move up or down on guiding ways. The guiding way on the right supports one side of the carriage and also guides it. It consists of a triangular piece of iron accurately planed, fastened to the frame of the machine. This fits into a receptacle of the same shape inverted, fixed to the movable carriage. The guiding way on the left consists of two planes, whose faces are in contact, and merely supports the left side of the carriage. We have not made what might be called definitive determination of the errors of these guiding ways, but preliminary tests show that they are not absolutely straight, though the errors in them are not large.

The microscope for measuring moves on a microscope way, at right angles to the guiding way, so that one may easily find any object on the plate. A scale, graduated to millimeters, 760 mm. long is set parallel to the plane of the plate. By a rather ingenious arrangement one may, by simply moving a small lever, change the microscope so that it reads either the scale or the plate, as he wishes. This scale seems to be very well made. We had it calibrated by the United States Bureau of Standards. The Bureau found that the distance between two consecutive divisions is just a millimeter for about one third of the marks, and that none are in error more than 1.5 microns, the probable error of the determination being in some instances as much as 0.6 microns.

The Observatory is open to visitors on the second and fourth Tuesday nights of each month, except during the summer vacation. Many people have availed themselves of this opportunity to see through the telescope, and when the night is clear and the weather is not too cold there are likely to be as many visitors as can be accommodated.

THE INTEGRATED SPECTRUM OF THE MILKY WAY.

E. A. FATH.

In Harvard Annals, 56, No. 1, is given a study of the distribution of the spectra of over 32,000 stars. Among other results are found: (1) That over 52 per cent of the stars investigated have A-type spectra; (2) the ratio of A-type stars to all other types increases as the brightness decreases; (3) in the Milky Way two-thirds of all the stars investigated are of the A-type. in view of these observations we might seem justified in drawing the following conclusions: (1) If we could get out into space far enough to view our entire stellar system, which we call the Milky Way, in somewhat the same manner as we can see the Andromeda nebula, and then analyze its light with a spectrograph the spectrum obtained would not be far different from that of an A-type star; (2) since we are probably situated somewhere near the center of the Milky Way system we could probably get some idea of the spectrum of the whole by taking samples of various parts. To do the latter it would be necessary to use