This can be done by a very simple method, which has been too lucidly explained by Mr. Rakshit in the November number of the Journal of this Society to require any repetition here. Some meteors, such as the Perseids and the Lyrids, have been found to shift their radiants from fixed positions, and it is just possible that there are others that might be classed with them. Observations must be taken at different nights and the results kept separate for future comparisons. They will then show whether the radiants are shifting or not, and if shifting, the rate and direction of displacement. In fixing the radiants at least 5 paths must be taken.

There are other things equally important to an observer. The direction of motion, the duration of flight, the observed paths in R. A. and Dec., whether the showers are continuous or intermittent, etc., etc., are to be carefully noted. The last Geminid shower, which I observed on the night of the 15th of December last, was interesting in many ways. Some of the meteors were long and bright not lasting more than 2 seconds, and others short swift and pale blue lasting less than a second. There were some small ones of the appearance of red-hot pieces of iron. The meteors were observed most towards the east and south, a very few towards the west, but none towards the north. Another interesting feature about this shower was its intermittent nature—there was a distinct pause of some 10 or 12 mts. after every shower.

The study of this branch of Astronomy is very interesting. Though much has been explained, much yet remains to be elucidated. Naked eye observations are bound to be imperfect and erroneous, but that cannot be helped. Our refined instruments are perfectly powerless to cope with these erratic, fugitive little bodies. So the eye must be trained to take such observations as are most near the truth.

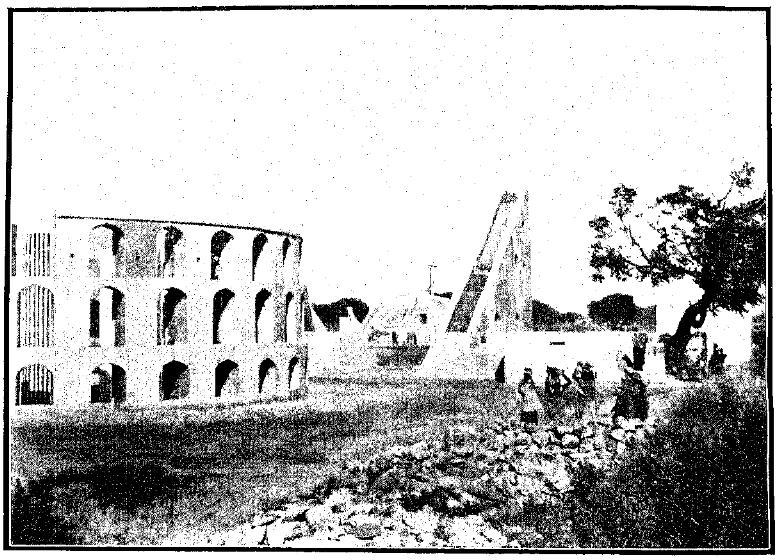
The Old Observatory of Jai Singh at Delhi.

BY H. G. TOMKINS, C.I.E., F.R.A.S.

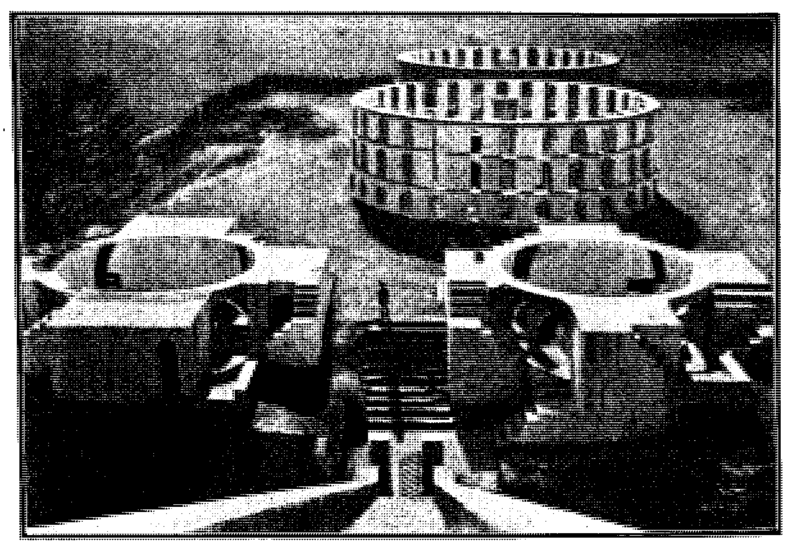
Visitors to Delhi will doubtless remember the quaint looking ruins which were until recently to be seen from the road leading from the Ajmere Gate of the City of Delhi to the Kutub Minar. They were the remains of an important observatory built by Maharaja Jai Singh in the year 1710 A.D. The observatory was the first built of five, the other sites being at Jaipur, Benares, Ujjain and Mutthra. The one at Benares is of course still well known. The Maharaja seems to have been an early astronomer who grasped the fact that the instrumental equipment of his day was defective, and that the tables and calculations as then existing had in them large errors arising mainly from this cause. He, therefore, set himself to build an observatory in which observations of the positions of the heavenly bodies could be taken with an accuracy exceeding anything which had gone before, and as will be said further and in this paper, he kept this object in view in selecting the various contrivances which he built. Further he built the four other observatories in India named above by which the observations at Delhi could be checked. It is clear, therefore, that his aim was to take many observations and to get rid of instrumental and personal errors by using the mean figures, a process which as we are all aware is still in use.

Until lately it was not possible for a visitor to do more than admire the ancient ruins and to surmise what their general use must have been. Lately, however, the observatory has been thoroughly restored ; the buildings have been repaired ; the dials have been reconstructed and the degrees and other dimensions re-marked ; so that it is now possible to take the observations of the heavenly bodies as of yore. Those who admire an ancient ruin will of course suffer some disappointment at seeing them disappear ; but to those who delight in studying old scientific ways and thought, the place is full of interest and struck me on my recent visit to Delhi as being a subject which might appropriately be brought before our Society in India.

The instruments were all designed to determine either time or the positions of the Sun and other heavenly bodies, and the measurements all depend on a direct reading of a dial marked on the stone of the observatory itself. When the Sun was observed, the shadow cast either by a stone edge as in the case of the sun-dial or by a ring or the top of a rod or pillar were made use of. There is no evidence that I can see of anything in the nature of a telescope or microscope of any form having been adopted either for observing or the reading of any of the circles, nor is there any substitute for them in some form of sighting apparatus beyond probably a plain straight rod or a string placed or stretched in the direction of a heavenly body so as to indicate the place on the dial. The principle of the vernier so largely used on instruments of the present day does not appear. Consequently the readings must have been



General view of the Observatory.



The Ram Zantra and the Jayprakash Zantra.

Views of Jai Singh's Observatory at Delhi restored by the Government of India in 1910. Taken by Mrs. Tomkins, December 1911.

Photo.-Engraved & printed at the Offices of the Survey of India, Calcutta, 1912

crude compared with those we now work with, and this I think would seem to be one reason for the number of instruments all devoted or capable of being applied to one or two classes of observation. The principles of these were time, altitude and azimuth, and right ascension and declination. The observations were made with more than one of the instruments, and thus a mean could be taken or one checked with the other.

There were four instruments in the observatory, the largest and most important of which was evidently the sun-dial known as the Samrath Zantra. The others were the Ram Zantra in two parts, the Jai Prakash Zantra in two parts, and the Misra Zantra in one part. The illustration given herewith shows a general view of the observatory. The gnomon of the sun-dial is in the centre of the picture, the Ram Zantra is the circular arched building to the right, the block to the left is the Jai Prakash Zantra, and in the distance on the right of the gnomon is the Misra Zantra.

The sun-dial consists of the huge gnomon seen in the photograph and the dial on which its shadow falls in order to indicate the time. This dial was a huge masonry construction below the surface of the ground. It has now been excavated and repaired so that the shadow of the gnomon falls accurately on it. I am sorry to say a large photograph whch I took of the dial has been destroyed by an accident. Its position, however, is round the foot of the gnomon and the arcs are described in the plane of the Equator. Thus as the angle of the gnomon is the latitude of the plane, the surface of the arc is normal to the edge which throws the shadow. The shadow before noon falls on the western arc and descends as the day goes on until at noon there is no shadow. Similarly after noon the shadow appears on the eastern arc or gradient and rises as the sun sets. The gradients are graduated so that the position of the shadow indicates at once the hour of the day. The gnomon is also graduated in order to determine the declination of the Sun north or south from the Equator. The method of observing this is well given in a little book on the subject by Lala Bholanath, Assistant Engineer of Jaipur, and I cannot do better than quote what he says :—" The graduations on the gnomon begin from the central points of the gradients on the edge of the gnomon and proceed upwards and downwards both ways. They are formed by engraving a scale of tangents for the different angles. The diversions counted upwards give the declination north of the Equator and those downwards give the declination south of the Equator. To measure the declination of the Sun, hold a rod with a sharp edge or point upright on the western edge of the gnomon before noon and on the eastern edge after noon and observe its shadow. Move the rod up and down on the graduation of the gnomon until its shadow coincides with the edge of the gradient." The graduation on the gnomon will then indicate the declination.

Similarly the R. A. and Dec. of other heavenly bodies may be obtained by means of a thread along which the body has to be sighted and the positions of the thread on the graduations read.

This is the most important of the instruments in the observatory and the most imposing. The author of the little book I have mentioned states that another instrument connected with this sun-dial existed at its base by which the altitude and azimuth of the Sun could be determined, but this is still buried.

We come now to the Ram Zantra, which is hardly less imposing than the great sun-dial. It consists of a high circular wall with a tall pillar in the centre. The walls are arched to enable the observers to observe the sky through the apertures. The pillar is graduated in degrees by bands of red and white from the top to the bottom, and these are extended to the base of the walls by means of stone radii and the graduations are then extended up the walls all round. By fixing the zero graduation due north, therefore, it is possible by means of the shadow thrown by the central pillar or by a rod held as a sight to determine the azimuth of the Sun or a heavenly body. Similarly the stone radii and the walls are graduated to determine the altitude of the Sun or body above the horizon, the graduations being of course concentric circles with their centres at the centre of the pillar. The height of the pillar has been so arranged that when the altitude of a body is 45°, the shadow falls exactly at the junction of the stone radii with the base of the walls. It will thus be apparent that when the altitude of a body is less than 45°, the shadow or end of the sighting rod will be on a spot on the walls above the ground and the less the altitude, the higher it will be. To get over this, footholds have been made in the walls and up these the observers had to climb in order to make his observation. I can only imagine the observers to have been young and active, as I very much doubt whether it would have been possible to persuade some of our present day astronomers to make the ascent. I certainly should not care to observe stars with this instrument at an altitude of, say, 10 degrees. With this description before him, the reader will of course understand the reason for the openings in the walls of the instrument. They were of course to enable the observer to get roughly the position of the body. Similarly the stone radii were built instead of a floor to enable an observer to get up to the pillar in the centre so as to make his observation. Otherwise there would of course have been no difficulty in making out the graduations on the floor. The consequence is that in certain positions of the heavenly bodies, the shadow or rod, as the case may be, falls on a space instead of on the graduation, and similarly with the openings in the walls. To provide for this a second structure has been made in which the apertures and spaces are supplementary to those in the other and we thus are able in one or other of the portions to observe the heavenly bodies in any position in the heavens except the zenith, when they are exactly over the centre of the central pillar.

The next instrument is the Jai Prakash Zantra. This is also in two parts for a similar reason to the Ram Zantra —namely, to enable the observer to approach the various graduations to read them. The instrument is a hollow hemisphere on which are marked out the various lines of right ascension and declinations, as well as circles to represent altitude and azimuth. It struck me that it would have been more clear had the astronomer who designed this instrument kept to one class of observation and left out the altitude and azimuth lines, as when viewed with the openings before referred to in the structure, the result of the two systems being in the one hemisphere is very confusing.

The hollow sphere is plastered over inside and is then marked out with the various graduations. The very first thing one is struck with is the accurate idea that the inventor had of the fact that the pole of the heavens was inclined to the horizon at an angle of 28° 39′ and the consequent tilt of the equatorial line. The centre of the sphere corresponding to the pole is clear and the equatorial line is carefully put in its correct position, the lines of R. A. and declination falling into their right places so as to make observations easy. On these lines the paths of various heavenly bodies have been marked, representing probably the signs of the Zodiac. The maximum declination of the Sun is shown by means of a line. For purposes of observing the altitude and azimuth of a body, the rim of the hemisphere has been graduated, and there are also a set of graduations vertically to determine the altitude. For these purposes either a pole was fixed in the centre in order to obtain a shadow or to point a rod by, or else there was a ring tightly suspended from the four cardinal points of the ring. The rings are there, but I notice poles are being put in. Lastly we come to the Misra Zantra—a wonderful combination of four devices—namely, the Samrath Zantra, the Dakshinobhitti, the Niyat Chakra Zantra and the Kark Rashivala.

The first is a form of sun-dial for finding time and the Sun's declination. The instrument is, of course, inclined at the usual angle and set due north and south. The main part of the instrument forms the gnomons which is divided into three—namely, a central gnomon and two side gnomons. The shadow from this is thrown on the graduated gradients to the east and west in the usual way. This part, therefore, performs a similar office to the large sun-dial.

The Niyat Chakra Zantra is the portion consisting of four semi-circles and a central gnomon. The instrument is intended to determine the declination of the Sun at four different hours of the day, and also to ascertain the hour of noon at four different places in other parts of the world, of which Greenwich was one. The position of the Sun was observed by holding a stick in various holes from the different observations and observing the position of the shadow on the semi-circles. The instrument is so built that this shadow falls on the semi-circles only at the hours for which it is built.

The Dakshinobhitti is a form of meridian instrument. It consists of a graduated arc on a perpendicular wall built in the plane of the meridian, *i.e.*, due north and south. The centre of the arc is marked on a stone. I imagine that there must have been some kind of excavation here, as it is not otherwise easy for the observer to get his head into position in order to sight the rod to the star or other body being observed. It is obvious that by means of this simple arrangement it was possible to obtain the altitude of a star on its zenith distance as it transited the meridian and incidentally also of course its declination, as this was the latitude of the place *plus* the zenith distance when the star was on the meridian for N. declination and zenith distance *minus* the latitude for stars of S. declination. It is interesting to find this device in the observatory, as it is one of the standard methods adopted by all observatories, and its presence shows that the astronomers of India at that time fully appreciated the advantages which attach to making of observations of the positions of the heavenly bodies in the meridian.

The Kark Rashivala—consists of a semi-circle and the back wall of the instrument with a peg at its centre. This device was used for determining the longitude of the Sun when the sign of Cancer was on the meridian. This does not seem to have been very much used, but is interesting as giving a direct method of getting the position at the time for which it was built.

The above are the instruments of this very interesting observatory, and it will be clear from what I have said that the idea was evidently to aim at precision by taking observations of a similar class by different means and checking one with the other. The accuracy is now far surpassed by more modern methods. The pointing of a stick or thread or the reading of a shadow with a necessarily diffused edge could not of course be strictly accurate, and in many of the observatories the stick had to be held in particular directions—for example perpendicular. Possibly there may have been some aid to this, but any one who has ever tried it will be aware of the difficulties attending such a method from this cause alone. The place, however, is full of interest to the astronomer, and I would recommend any of our members who may be near Delhi to visit these most interesting remains.

Memoranda for Observers.

Standard Time of India is adopted in this Memoranda.

For the month of February 1912.

Sidereal time at 8 p.m.

				H.	M.	S.
February 1st	...	...	...	4	41	45
,, *8th*	...	...	...	5	9	21
,, *15th*	...	...	...	5	36	57
,, *22nd*	...	...	...	6	4	33
,, *29th*	...	...	...	6	32	9

From this table the constellations visible during the evenings of February can be ascertained by a reference to their position as given in a Star Chart.

Phases of the Moon.

				H.	M.	
February 3rd	Full Moon	...	...	5	28	A.M.
,, *10th*	Last Quarter	...	...	6	21	,,
,, *18th*	New Moon	...	...	11	14	,,
,, *26th*	First Quarter	...	...	0	57	,,