Indian Journal of History of Science, 43.3 (2008) 425-436

KARKA-RĀŚI-VALAYA — THE INSTRUMENT ON THE BACK WALL OF THE MIŚRA YANTRA*

The Karka-Rāśi-Valaya is the dial (Fig. 1) marked on the back wall of the Miśra Yantra at the Jantar Mantar, Delhi. This is one instrument of the Miśra Yantra, that has not been discussed in detail, so far, in the literature.

Miśra Yantra, happens to be one of the most complex and unorthodox of instruments at the Jantar Mantar and yet, its serious astronomical usage seems somewhat overshadowed by its aesthetic presence and demonstration capabilities.

The Miśra Yantra consists of a combination of different instruments and capabilities. The main part (instruments) of the Miśra Yantra have been

Fig. 1. A view from the west of the Miśra Yantra, the Karka-Rāśi-Valaya can be glimpsed on its backwall, to the left of the photograph. (Photograph by C.B. Devgun)

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Fig. 2. Front view of the Miśra Yantra. (Photograph by Guntupalli Karunakar)

discussed elsewhere (Rathnasree, et. al 2006). The current article is mainly concerned with the envisaged usage of the Karka-Rāśi-Valaya by its original creator.

There is some uncertainty about the actual creator of the Miśra Yantra (Sharma 1994). All the other instruments at the Delhi Jantar Mantar – the main complexes of the Samrāṭ Yantra, Jaiprakāśa and the Rāma Yantra have been mentioned in early travelers' accounts of the Delhi Jantar Mantar. There seems no doubt that these instruments were erected by Sawai Jai Singh, around the time that the Delhi Jantar Mantar was built (presumed to be 1724 AD). Their usage is also mentioned in the *Samrāṭ Siddhānta*, the astronomical treatise written under the direction of Jai Singh. However, all these accounts have no mention of the Miśra Yantra and the first mention appears about 1790, by William Hunter.

It is therefore speculated that, perhaps, the Miśra Yantra was designed and erected by Madho Singh, one of the sons of Jai Singh, who also had some astronomical interests (Sharma 1994). The structure and utilities of the Miśra Yantra are a little different from the other instruments. Decidedly, the Miśra Yantra's capabilities are more towards demonstration and there is no evidence of its actual usage for serious astronomical observations since the time of its construction (unlike the other instruments mentioned in the

Samrāṭ Siddhānta). Later astronomers have, of course, studied its parameters and of these the most useful descriptions are those of G.R. Kaye(1916) and Virendra Nath Sharma (1995). The masonry parameters were studied using engineering instruments by G.R. Kaye, analytical methods by Virendra Nath Sharma and with modern engineering instruments by Anisha Shekhar Mukherjee (2003). However, many details of the instrument parameters of the Miśra Yantra are yet to be tabulated and we are in the process of estimating all the relevant parameters using a database of astronomical observations with the Miśra Yantra and the appropriate error analysis.

The interesting thing about the back wall of the Miśra Yantra is its inclination (visible clearly in Fig. 1). It is built exactly in the East-West direction and it is not a vertical wall - the wall is inclined by about 5 degrees to the vertical, towards the South.

Delhi has a lattitude of 28.67 degrees and a wall in the East-West plane, tilted by 5^0 towards South, from the vertical would be parallel to a vertical wall on the Tropic of Cancer. It is not immediately clear, what would be the astronomical significance of such a configuration and most astronomically minded visitors to the Delhi Jantar Mantar, since 1790, have left a one sentence speculation as to the possible usage of this instrument.

For most of the year, the back wall of the Miśra Yantra is in the shadow of the Sun. One passes it by and wonders what it would be like, on the Solstice day.

Around the Summer Solstice, the Sun shines exactly over this wall for a considerable part of the day and the wall seems to have been meant to indicate the entry of the Sun, into the Tropic of Cancer. However, the dial markings on the instrument seem to imply that the instrument was meant for more detailed observations than the simple observation of the entry of the Sun into the Tropic of Cancer.

The inclined back wall of the Miśra Yantra is equipped with a small straight rod (to act as a gnomon) centered in the East-West direction, and high on the wall a little below the central point of the wall at the top (Fig. 3). The Back wall has two small windows situated at the bottom and is otherwise bare, except for the long steel rod jutting out from it and the dial at a radius of about 11.8 m from it. This rod appears to be projecting outwards at an angle of 90^0 to the wall surface.

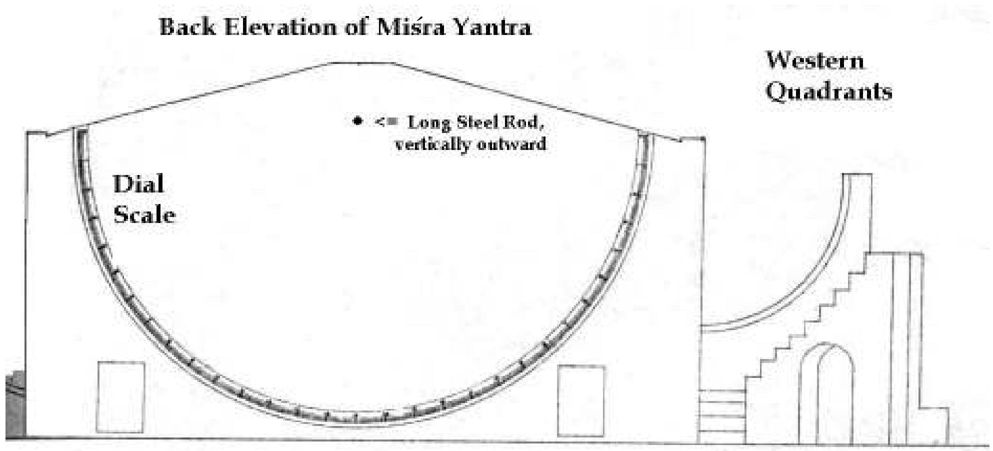

Fig. 3. Partial back elevation of the Miśra Yantra. (Adapted from G.R. Kaye).

During the preparations by our team, for measurements to be undertaken on the 2006 Summer solstice, the rod was found considerably skewed towards the west. With the help of the Jantar Mantar staff, the rod was straightened by gentle nudging, while checking from above, with a simple straight rod and a setsquare, that the rod finally rested in a perpendicular position from the wall.

As noted by Virendra Nath Sharma (1995), the instrument, in principle, could be used once every 24 hours, to measure celestial longitudes in the ecliptic co-ordinate system. However, no celestial longitude observations, taken with this instrument, are recorded in the literature. Some measurements were taken by our team and, after additional compilation of celestial longitude measurements, these will be discussed in detail elsewhere.

In addition to such celestial longitude measurements, one wonders whether the instrument was also meant to be used as a (non-standard) clock on the day of the solstice, using the shadow movements on the wall. This speculation arises, as the movement of the shadow of the gnomon on this wall is definitely very attractive to view and for a considerable portion of time before and after the local solar noon, this movement seems to be equal distance moved by the shadow in equal time intervals. An observation of the shadow movement on the wall, close to the Summer solstice, would also give a feel regarding any possible masonry irregularities that may be present on the wall and such observations would be useful for the restoration efforts by the Archeological Survey of India.

The construction and angle of the wall, is definitely non-standard, if meant to be used as a clock, although declining wall sundials with arbitrary angles of wall inclination, do exist around the world. However, the gnomons in these sundials, usually point to the celestial pole, while the gnomon in this case could point to the pole of the ecliptic at some specified times and point towards an arbitrary direction, at other times. This would make it an inclining sundial, with arbitrary inclination of the dial and the gnomon. Nevertheless, such a construction could function as a sundial when calibrated accordingly (Goyder 2006).

Given that the instrument was constructed for measurements of celestial longitudes, once in 24 hours, one is left with observations of the shadow movement on the wall, on the solstice day – wondering whether they were meant to be used in any way.

The inclination of the wall is such that the Sun is expected to shine over the wall on the Solstice day (Fig. 4). The shadow of the central rod, on the dial below, is then expected to move akin to a sundial, except that the inclination of the gnomon of this dial is towards the pole of the ecliptic, rather than towards the North celestial pole, as in standard sundials. Theoretically, one sees that this is an instrument that could be used to determine celestial longitudes. But, what about the swinging dial on the Solstice day? Was it ever used as a non-standard clock that works just

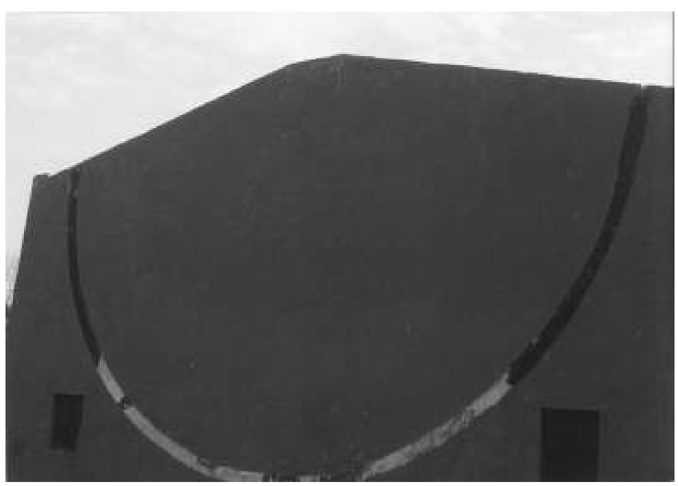

Fig. 4. A view of the back wall of the Miśra Yantra on 20th March 2005, deep in shadow.

around the Summer solstice? There are no records of such observations with this instrument. There are also no records of the usage of this instrument, to measure celestial longitudes. In fact, very little is written about this instrument in all available literature. What little exists, is merely theoretical speculation about its possible usage.

Nehru Planetarium, New Delhi, and a dedicated group of students and amateur astronomers of Delhi, have been working with the Jantar Mantar instruments since March 2004, using the instruments for quantitative observations of astronomical quantities. The initial efforts in this were towards arriving at an understanding of the usage of the instruments for astronomical observations. As our understanding grew, the work progressed towards obtaining a number of observed data points of astronomical quantities from these instruments, in order to study the accuracy of the original masonry parameters and the later markings on the instruments.

The group has also been active on many days, working towards generating public awareness about the Jantar Mantar instruments as well as involving school and college students in doing actual observations with the Jantar Mantar instruments. The group had planned to study the back wall of the Miśra Yantra and the usage of the Karka-Rāśi-Valaya on the Solstice Day 22nd of June 2005. A month prior to this, one of us (NRS) went over to view the back wall of the Miśra Yantra in order to decide on the mode of observations for the Solstice day and noticed the surprising fact that the back wall of the Yantra seemed sunlit (somewhat diffuse sunlight, with no shadow definitions) a full month before the Solstice day. On the 12th of June, the sunlight on the back wall of the Miśra Yantra had become intense enough to have sharp shadow definition on the wall and a clear shadow of the gnomon rod was visible on the wall at 2:15 PM stretched all the way towards the dial. Around 3:30 PM, it was noticed that the shadow had shortened in length and had shrunk away from the dial and no measurements could be made.

On the 22nd of June 2005, a small group of students from Delhi University and the Planetarium staff ensured that shadow locations were marked through out the Solstice day, whenever clouds permitted (which was seldom). From around 9 AM when the clouds cleared for a short while, to about 3:30 PM following which the shadow shrunk away from the dial, the location of the midpoint of the shadow was marked on the dial. After 3:30 PM, a plumb line was used from the top of the Miśra Yantra wall, at midpoint, to mark the centre of the dial below as a calibration point to compare with the other observations.

Since the dial markings were missing at many positions on the dial, for every shadow location marked, its distance along the dial, to the calibration point, was measured using a measuring tape. Using the dial diameter as 11.8 m (measured and compared with existing literature although accurate measurements with engineering instruments are needed) the lengths measured along the dial were converted to degrees away from the calibration point.

The irregularities of the masonry parameters, particularly where the dial is placed, give rise to severe problems in terms of calibrating the observations taken with the Karka-Rāśi-Valaya. There are sections of the wall where the dial markings are clearly visible. There are large chunks of the dial where the markings are missing. The dial itself has a finite width and the scale is placed between at least three different curves marked within the width of the dial. The width of the painted dial on the wall is not uniform and there are many cement irregularities along its width. While taking calibration measurements, it needs to be ensured that one follows any one of the curves marked on the existing scale, keeping to the same radius of the curve. Given the inaccessibility of the centre of this curve, that is, the gnomon, it is not a simple matter to ensure that one is making the calibration markings on a curve of the same radius around the gnomon.

One wonders about the fact that the back wall of the Miśra Yantra was seen to be sunlit, with sharp shadow definitions, from a little more than a month before the solstice to a month and a half after the solstice. What then, would be the sharp transition in the shadow behaviour that exactly signals the day of the solstice?

The sun having an angular width of about 0.5^0 as seen from Earth, it is not to be expected that the wall would become active on just the one day – the Summer solstice. In addition, the wall is only parallel to a vertical wall on the Tropic of Cancer, and not in the plane of the Tropic of Cancer, therefore, it is expected that the eastern and western segments of the wall would be active for a period before and after the Summer solstice. The same behaviour is also confirmed by using a model of a wall that could be tilted by the requisite amount, so that it points towards the declination of the Sun, for that day.

There is one other intriguing aspect. The shadow of the rod, is not visible on the wall, close to the transit time for the Sun. This behaviour was studied in detail, every few days, for two weeks before the Solstice during 2006 observations. About an hour before and an hour after transit, the shadow is generally not visible on the wall, but can be glimpsed on the ground, in front of the wall. The time for which the shadow is not visible on the wall decreases as the Solstice approaches and is the shortest on the Solstice day, which would be the one feature distinguishing the Solstice day from a few days before and after the actual date. Again, the same behaviour is repeated when studied with the constructed model.

Observations

We have a compilation of observations of the shadow movement on the dial, from the Summer solstice of 2005 and 2006. Anurag Garg, Chandrakant Misra, N. Rathnasree, Arpita Pandey, R. K. Chikara, C. B. Devgun and Ramveer were the observers during the 2005 Summer solstice. N. Rathnasree, R.K. Chikara, Dayal Singh, Varun Maheswari, K. Balachander, Vidushi Bhatia, Sneh Kesari, Vidur Prakash, Arpita Pandey, Pritpal Kaur, Naresh Kumar and Dinesh Kumar were the observers for the 2006 Summer solstice. The 2005 solstice had been cloudy most of the day and the data is sparse, while the 2006 solstice had been a sunny day and a good number of observations could be obtained. However, the 2006 Solstice day turned out to be a very busy day at the Karka-Rāśi-Valaya, with a large number of public visitors curious to know about the instrument as well as a lot of media. The observers ensured that care was taken to obtain the maximum possible accuracy of observations, within these constraints.

The first difficulty in obtaining the shadow positions on the dial, throughout the day, arose from the fact that there are large segments on the dial, where the original markings are missing. One complete semicircular arc on the dial was drawn temporarily, using a makeshift arrangement. This arrangement consisted of a long metallic pole, in which a hole was made, so that the pole could pass over the central rod (gnomon) on the wall. A small contraption to hold a chalk perpendicular to the pole, at the radius of the dial, then allowed us to use the rotation of the pole to draw a complete arc on the entire section of the dial where the shadow movement is seen on the Solstice day.

Fig. 5 shows the sunlit backwall of the Miśra Yantra on the Solstice day, 2006. The arrow points out the shadow of the central rod jutting out of the back wall of the Miśra Yantra.

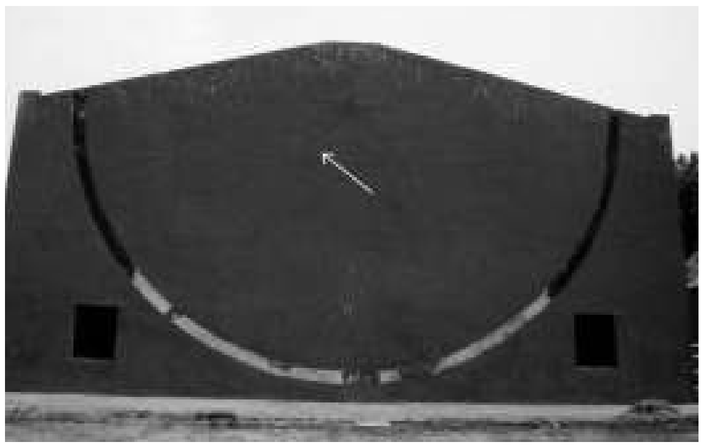

Fig. 5. On the Solstice day, 2006, the shadow touches the dial on the wall, from around 9 AM to about 3 PM. (Photograph by C.B. Devgun).

There are segments of the dial, which are difficult to reach. In addition, it was also noticed during the Solstice day 2005 and 2006 that the shadow of the gnomon shrinks away from the dial in the early morning and late afternoon hours. Therefore the data of shadow movements on the dial could be collected only between about 11 AM to 4 PM (Fig. 6).

For some time, even when the shadow did shrink away from the dial, it was possible to extrapolate the position of the shadow all the way up to the dial, by using a rope suspended with the vertical rod as the centre and rotating the length of the rope to exactly coincide with the visible length of the shadow, while an observer from a distance judged the absence of parallax between the rope and the shadow.

The cumulative distance covered by the shadow, in equal intervals of time (5 minute intervals whenever the data could be obtained) has been plotted in Fig. 7 and the slope of the fitted straight line turns out to be 0.08,

Fig. 6. A closer look at the shadow of the central rod on the back wall of the Miśra Yantra. (Photograph by C.B. Devgun).

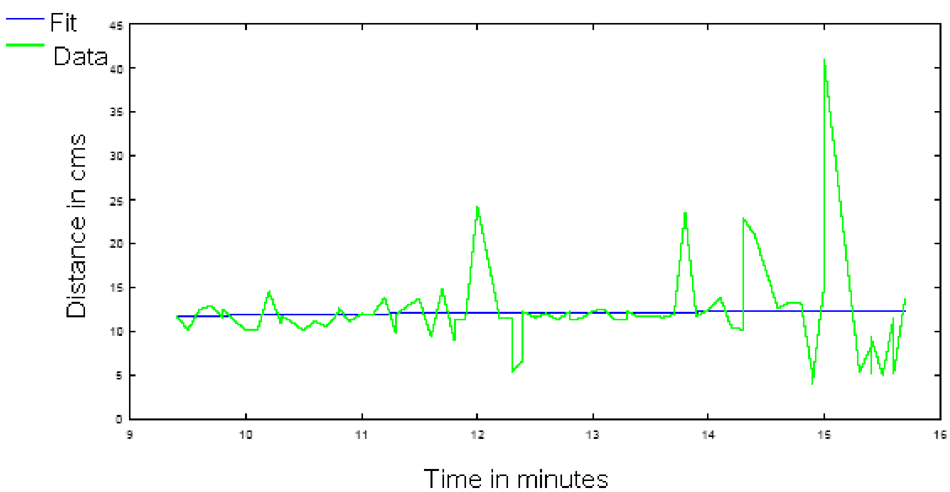

Fig. 7. The distance covered by the shadow of the gnomon, in equal intervals of time.

reasonably close to 0, to give us the confidence that this construction can function as a sundial, with equal distance being covered in equal intervals of time, on the solstice day.

The data has been also placed on a plan of the dial, in Fig. 8. This figure would be found useful by the ASI, when restoration work on the Miśra Yantra looks for correcting masonry irregularities on the backwall.

Karka-Rāśi-Valaya

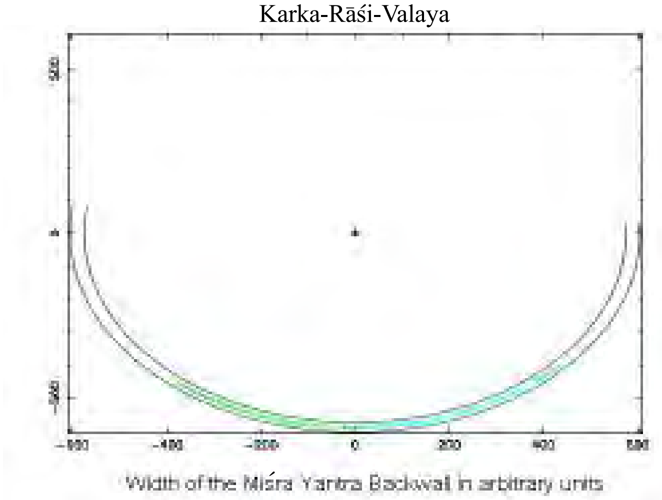

Fig. 8. Data taken on the solstice day 2006, displayed on the dial of the Karka-Rāśi-Valaya.

It is planned to repeat the data taking exercise during the Solstice day 2007, so that, aberrant data points that show up on the same locations, from all the years of observations, could definitely be taken as arising from masonry irregularities.

Conclusion

The standard astronomical usage of the Karka-Rāśi-Valaya, must have been for the measurement of celestial longitudes of objects in the sky. Such observations would have been possible only once in 24 hours. To use the *valaya* for celestial longitude measurements, knowledge of the exact time when the first point of the sign of Cancer crosses the meridian would have been necessary.

There is a possibility, that the instrument might also have been used as a non standard clock meant to be viewed just for a few days near the

Summer solstice. A clock, where a single hand moving with the diurnal movement of the Sun, could demarcate time as fine as 3 seconds close to the transit and even finer than that when the shadow movement is faster, late in the afternoon or in the morning hours. This fine least count in the shadow movement arises from the large dimensions and fine markings on this scale – making this the instrument with the lowest least count of all structures at the Jantar Mantar.

Studying the shadow movements on the dial of the Karka-Rāśi-Valaya, gives us an astronomical tool to study the masonry parameters and possible irregularities on the surface of the instrument. This could be a valuable tool towards documenting the structure of the instrument, while restoration work on the Miśra Yantra is in progress.

Acknowledgements

We would like to express our sincere appreciation of the help given to our team while working on the calibration of the Miśra Yantra, by the staff at the Jantar Mantar. Acknowledgements to C.B. Devgun, Guntupalli Karunakar, and P.S. Sharma for photographs of the instruments. Acknowledgements to all the enthusiastic observers (apart from the authors) who helped during the 2005 and 2006 Solstice day observations - Chandrakant Misra, Dayal Singh, Varun Maheswari, K. Balachander, Vidushi Bhatia, Sneh Kesari, Vidur Prakash, Pritpal Kaur, C. B. Devgun, Ramveer, Naresh Kumar and Dinesh Kumar. Acknowledgements to the National Culture Fund and the Apeejay Park group of hotels for partial support.

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