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KAPĀLA B YANTRA AT SAWAI JAI SINGH'S JAIPUR OBSERVATORY

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At the Jaipur observatory of Sawai Jai Singh, the Jantar Mantar, there is an instrument known as Kapāla B which is not meant for observing but for graphically transforming horizon system of coordinates into equatorial system and vice versa. In literature the instrument is inaccurately described. The object of this paper is to rectify these inaccuracies.

Key words: Kapāla B, Kapāla yantras, Jaipur observatory, Jai Singh, Jantar Mantar, Coordinate transformation, Garrett, Bhavan, Soonawala, Kaye, Dhama, Sharma, V.N. Sharma, Virendra N. Sharma

Introduction

At the Jaipur observatory of Sawai Jai Singh, the Jantar Mantar, there is a pair of instruments on a platform, known as Kapāla or *Kapāli* yantras. The instruments are called Kapālas because they remotely resemblance the brain-cover (*Kapāla*) of a human being. Of the two instruments, the one toward the west on platform is termed Kapāla A and its sister unit to the east, Kapāla B.[1]

Kapāla B (Fig. 1) is the only instrument at the Jaipur observatory which is not meant for observing. Instead, its object is to transform graphically horizon system of coordinates into equatorial system and vice versa for the latitude of Jaipur. The transformation implies converting the zenith distance and azimuth of an object into its corresponding declination and hour angle respectively. These transformations require generally the application of the formulae of spherical trigonometry, which may involve lengthy calculations.[2] Kapāla B, in theory at least, is an ingenious device as it eliminates these

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Fig. 1. Kapāla B Yantra

calculations.[3] However, the instrument Kapāla B is somewhat inaccurately described in literature.[4] The purpose of this paper is to rectify these inaccuracies of literature.

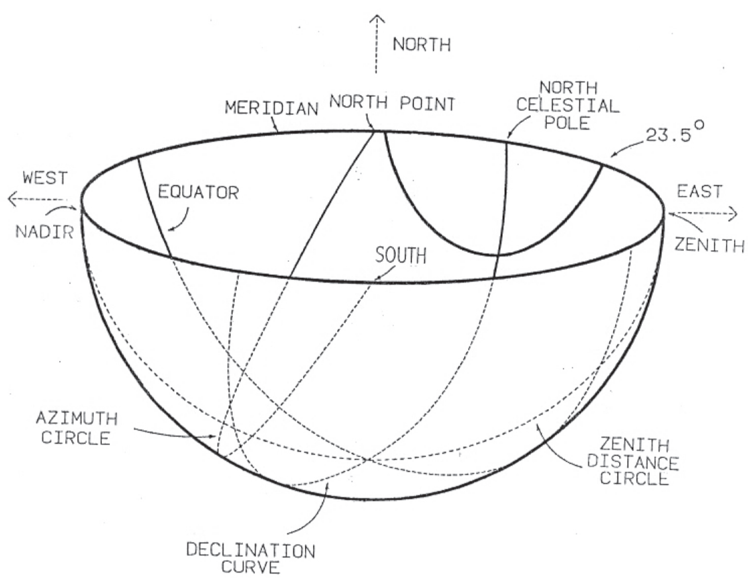

Fig. 2. Principle of Kapāla B

The surface of Kapāla B represents two sets of coordinate systems as pointed out, namely, the horizon and the equatorial. For the horizon system of coordinates, the rim of the instrument represents the meridian, and the east point on the rim the zenith. See Fig 2. The north point of the "original horizon" remains unchanged, i.e., it remains on north point of the rim. The "original horizon" lies in the vertical plane passing through the north-south points on the rim. In order to understand this peculiar arrangement of points and great circles drawn on surface of Kapāla B, consider its surface representing the celestial sphere. Rotate the celestial sphere by 90 deg, clockwise looking northward, about a north-south axis. With this 90-deg. rotation, the zenith point falls on the east point of the rim. The rim of the instrument becomes the meridian with celestial pole falling 27° to the east of the north point on the rim. The rim of the instrument, representing the meridian, has been divided into degrees and minutes, such that its small division measures 10′ of arc, and they are labeled in Devanagari.

In literature, the instrument, as stated earlier, has been described inaccurately. For example, Sharma conjectures that the peculiar markings of the instruments may be obtained by two orthogonal rotations of the celestial globe.[5] Garrett, who was in charge of the engineering of the restoration of 1901-02, states that there are latitude and longitude lines engraved on the instrument's surface and that the instrument is capable of converting declination and right ascension into these two coordinate angles.[6] In addition, he calls the rim of the instrument solstitial colure, which is also misleading.[7] In order that the rim may represent the solstitial colure, the colure must remain fixed in time on the instrument. However, the colure revolves along with the celestial sphere once in 24 hours and thus may not be considered fixed.

Because Garrett did not fully comprehend the function of the instrument, the plaque erected by him at the instrument site is misleading. The plaque states, "Representation of the half celestial sphere. Rim represents solstitial colure. . . ." Bhaven in his book identifies the rim as the meridian correctly.[8] The Hindi plaque erected by him also states the rim accurately as the meridian. However, his statement that the instrument represents eastern half (*pūrvatara)* of the globe is somewhat misleading. It may be called, however, the representation of the "western half" of the globe.

Horizon or Altitude-Azimuth System of Coordinates

The north celestial pole is marked on the rim, at a distance of about 27 degrees to the east of the north point of the rim as pointed out earlier. The south celestial pole is, similarly, at a distance of 27 degrees to the west of the south point on the rim. Great circles or hour circles spaced six degrees apart are drawn from one pole to the other. Intersecting these hour circles are seven diurnal circles, with the one in the middle representing the equator, which divides the hemisphere into two equal halves. The diurnal circles have been drawn on either side of the equator at distances of approximately 11;20, 23;25 and 66;30, respectively. These arcs represent the declinations of the first points of the signs of the zodiac and the pole of the ecliptic. Some of these curves have not been drawn very accurately and are off by as much as 8′ of arc from their true values. The instrument does not have any identifying inscriptions on the curves.

In principle the instrument works as follows. If one wishes to convert the azimuth and zenith distance of a body into its hour angle and declination respectively, he should also know the time when the readings were taken. Plot a point on the instrument's surface whose zenith distance is measured from the east point on the rim and the azimuth from the north point. Next, draw a great circle (hour-circle) passing through this point and the celestial poles marked on the rim. Read the angular distance of this plotted point from the equator along the hour circle. The angular distance thus read is the declination of the body.

The determination of the right ascension is little more involved. Calculate the angular distance of the vernal equinox from the meridian at the time of the measurement. Mark a point on the equator depicting this distance. The angular distance from this point to the hour-circle intercept on the equator provides the right ascension of the body.

The angular distance between any two stars may be determined by plotting two points on the instrument surface according to their coordinates and spanning the points with a divider. Next, placing the ends of the divider on the graduated scale on the rim, the separation may be converted into degrees and minutes.

In principle, Kapāla B is quite elegant. However, its accuracy varies. Its scales have been divided at intervals of only 6 degrees, and their largest separation is about 18.26 cm. With careful interpolation, where the separation is largest, accuracies of the order 3′ of arc may be achieved. In this respect, the instrument has the same limitations as the Jaya Prakāśa or the other Kapāla. However, if a compass is used to plot the point, and divider and the scale on the rim used to read off the angle, full capabilities of the instrument may be realized.

Acknowledgment

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End Notes

1. For Kapāla A, see Sharma, 1995, pp. 161-164.
2. The equations for transforming the azimuth and the zenith distance to declination and to hour angle are as follows:

   $\text{Cos } z = \text{Sin } \delta \text{ Sin } \lambda + \text{Cos } \delta \text{ Cos } \lambda \text{ Cos } H$ and

   $\text{Cos } \lambda \text{ Sin } \delta = \text{Cos } A \text{ Sin } z + \text{Sin } \lambda \text{ Cos } \delta \text{ Cos } H$,

   where δ = declination, z = zenith distance, λ = latitude of the place, H = hour angle measured from the observer's meridian, and A = Azimuth.
3. Tycho Brahe also constructed a device for graphically transforming coordinates. His device was a sphere of wood covered with brass, about 1½ m in diameter. Later, he used the sphere to depict the stars whose coordinates he had measured. Victor E. Thoren, *J. for Hist. Ast.,* Vol. 4, pp. 24-25.
4. a. For instance see Sharma, 1995, pp.164-167.

   b. Dhama, 1974, p. 16.

   c. Garrett, 1902, pp. 48- 49.

   d. Kaye, 1982, p. 52.

   e. Singh, 1987, p. 69.

   f. Soonawala, 1952, p. 37. Soonawals's description of the two Kapālas is abridged into one, and it is thus misleading.
5. Sharma, *Op. cit.* p. 165.
6. Garrett, *Op. cit*. pp.48-49.
7. The solstitial colure is a great circle on the celestial sphere passing through its poles, the poles of the ecliptic and the solstitial points.
8. Gokul Chand Bhavan, 1911, p. 11.

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