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SETH WARD AND GHULĀM HUSAIN'S PROBLEM FOR DETERMINING THE PLACE OF A PLANET

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Ancient star gazers might have gained the notion of circular motions of planets through the observation that the sun, moon and other stars always move from east to west in circles parallel to each other and these bodies begin rising from *below the earth* and rising gradually to their highest point and then decling downwards until they finally disappear *behind the earth.* And this cycle of rising and seting of heavenly bodies goes on every day. And so, many effort have been made by ancient as well as modern astronomers to find the actual structure of this universe. In this paper a brief historical development of planetry motions from hypothesis to experiment will be sketched, but particularly an Indian mathematician and astronomer of early nineteenth century Ghulām Husain's goemetrical interpretation of Seth Ward-Khar Allah's model of the universe will be presented.

In the history of astronomy Aristotelion-Ptolemaic geocentric hypothetical model of the universe dominated for centuries. It employed that the earth is at the centre of the universe and the stars and planets revolve in circular orbits about it. This simpler model, indeed, required certain modifications because the fact that the velocities of the sun and the planets were not uniform. This had to be overcome by the suggestion that the circular paths did not have their centres directly at the centre of the earth and so Ptolemy introduced, in addition to circling the earth, rotation in an epicycle, a secondary, smaller circle, and that this latter motion was superimposed upon the principal form of motion[1] and this model from the point of view of accuracy was a great step forward, indeed the best representation of planetary motion before Kepler.[2]

To explain the Ptolemaic system, consider a geocentric model : a planet moves on the circumference of a circle (the epicycle[3]), whose centre moves in the circumference of another circle. If the earth was at the centre C of another circle, the system was concentric but if the earth E did not coincide, then the system was eccentric and the planet could move uniformly with respect to the point *Q* called the *equant* and this point is chosen along a diameter of the circle containing *E* and *Q* in such a way that $EC = CQ$. Thus a moving planet along the circle makes uniformly increasing angle.

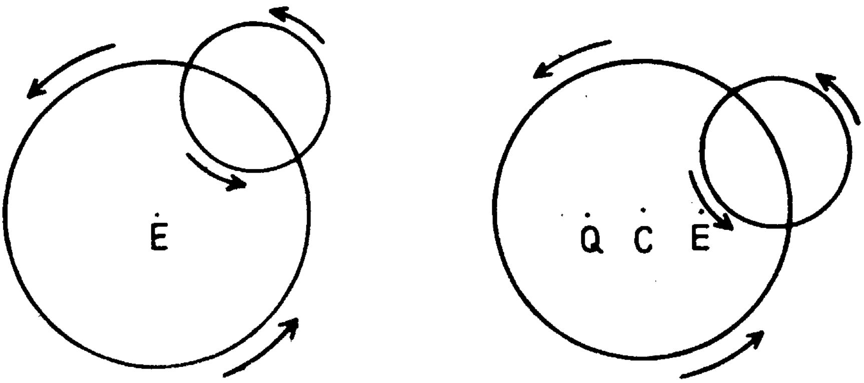

Fig. 1

It may be noted here that the Ptolemaic geocentric model was used fairly well up to about the year 1500 A.D. But in India even in 18th century this system was continued through the master piece *Almagest* perhaps its prediction of the phenomena is on the whole as adequate as the instruments used—they were surprisingly accurate—could possible allow for.[4]

COPERNICO-KEPLER MODEL :

The first astronomical scientist of importance after the European Dark Ages was Nicholas Copernicus, born in 1473 A.D. when man's view of the universe was still fashioned on the idea of the Ptolemaic model. It was Copernicus who attempted to restore ancient physics by constructing a model of the solar system which would fit the observations of planetary motions available to him. His mind was wedded to the ancient ideal of circular motions, and in the words of Kepler in the seventeenth century Copernicus tried to interpret Ptolemy rather than nature.[5]

Thus in Copernican system sun stands still at or near the centre of the universe and the earth moves around in circular orbit and further in his view circular motion is always uniform.

Copernicus, like Aristotle, believed that the perfect motion is only in a circle. Regarding it he wrote, "because it has a cause that does not slaken." He observed that planetary motions seemed different at times, but he thought the irregularies could all be explained. May be the motions only seemed unequal because the planets are located at different distances.

This change of the stationary midpoint of universe from earth to the sun is infact a reform in the fundamental concept of astronomy.

Another astronomer Tycho Brahe (1546-1601 A.D.) later came to the conclusion that Copernicus' assumption that the earth moved in space defied the scriptures and violated the principles of physics, and so he set out to rehabilitate Ptolemaic astronomy. Brahe succedded in restating Ptolemy's system by showing that the sun revolved around the earth and the planets turned around the sun in epicycles.[6]

The most modern astronomer Johannes Kepler (1571-1630 A.D.) and a convinced follower of Copernicus who himself said, "What a wonderful thing it would be if I could prove Copernicus' theory," came in to the assistantship of Brahe. Kepler took over Brahe's record and was trying to prove the truth of the Copernican heliocentric model with Brahe's observations. But he never found circular orbits and even any of the explanations suggested by Copernicus. Thus the question arose, was planetary motion really non-uniform. Finally he put the sun in an off-centre positionanddrew lines considering points on the circumference of the circle for equal time. He found that nearer the sun the arcs were longer which meant that the planet was covering more distance in the set time. The arc farthest away from the sun was the shortest, showing that the planet covered very little distance in the same length of time. Finally he reached to the conclusion that the shape of the planetary orbit was elliptical. But for most planets (Mercury is an exception) the ellipses are not very different in shape from true circles, but the sun is not at or ever near the centre, the situation is very much like a circular orbit (or quasi-circular elliptical orbit) in which the sun is notably off-centre.[7] From this hypothesis Kepler stablished three laws of planetary motion. Amongst them one is :

"The orbit of every planet is an ellipse having the sun at one focus."

Kepler thus replaced linked circle with the simple ellipse but he did not guess why the ellipse appeared in nature.[8]

It will not be free from interest to mention that only in the eighteenth century Jai Singh's astronomers verified that the orbits of the sun and moon were ellipses. But he (Jai Singh) did not state anywhere that the same was true for other planets.[9]

SETH WARD-KHAIR ALLAH-GHULĀM ḤUSAIN MODEL

Late in the 17th century, a British astronomer Seth Ward determined "the place of a planet, by supposing its motion round the focus in which the central body is not, as equable"[10] and according to Cohen he had first geometrically_ demonstrated the Copernico-Elliptical Hypothesis to be the most genuine, simple and uniform.[11]

But in India during the eighteenth century Khair Allah, an associate of Jai Singh also asserted elipticity of all orbits in his *Sharḥ-ī-Zīj-e-Muḥammad Shāhī.* The details of this are found in *Jāme-i-Bahādur Khānī* of Ghulam Ḥusain Jaunpūrī (*b.* 1790 A.D.) a noted Indian mathematician-astronomer. According to him :[12] "The majority of ancient and most of modern observers have determined the orbit to be an eccentric circle, and have calculated the partial equation on this supposition, but not only that the orbit of the sun is eccentric, but that the orbits of all the planets are of an elliptical form. Our proof is that if we calculate the position of the sun and planets according to the equation of a circle we do not find them agreeable to observation. On the contrary to what takes place in the equation which is produced in the case of the ellipses and if we determine the position from that latter calculation, the determination will be more agreeable to observation. Hence it proves that the orbits are elliptical."

Ghulam Ḥusain explains this hypothesis as follows :[13]

This supposition (the orbits are elliptical) is realized by supposing the existence of two spheres (*aflak*) one agreeable (*muhassil*), the other eccentric (*kharij al-markaz*), so that the distance between the two centres should be equal to half the distance between the known centres, and on the circumference

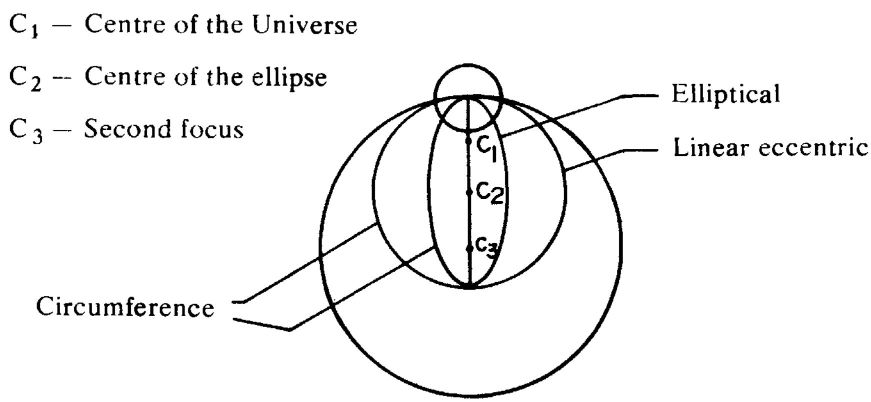

Fig. 2

of the eccentric sphere, an epicycle (*kharij al-markaz al-tadwir*) whose semidiameter is equal to half the difference of the two diameters, the major and minor of the ellipse (*baizawi*), that is in the figure of the solid sphere, the semidiameter of the epicycle is equal to the sum of this difference, and the semi-diameter of the sun, and the superior movement of the epicycle is to be in

the same direction as that of the eccentric sphere, and of double the angular velocity and in the beginning of things the centre of the epicycle must have been at the greatest distance of the eccentric spehre, and the centre of the sun at the greatest distance of the epicycle. In this case, by the motion of the epicycle and the eccentric sphere, the centre of the sun will describe an orbit, similar to an elliptic orbit and the centre of the universe will be one of the two focal points of the ellipse, and the centre of the eccentric sphere will fall in the place of the centre of the ellipse and the other focal point, towards the other side of the eccentric sphere, in the direction of the apogee (*auj al-Aflak*), at the same distance as is between the centre of the universe and the centre of the eccentric sphere, and the distance between the two focal points is called the sine of the extreme equation, and the second focal point is supposed to be the known place of the eccentricity, so that the epicycle should be carried out of the middle, and all that has been said will be evident from this figure.
But G̲hulām Ḥusain remarks[14] that this demonstration will not prove the orbit to be exactly elliptical, but only that from the small space between the two focal points, it is very similar to an ellipse, and the equation which is produced on the supposition of an ellipse is not perceptably different.

To find the method of finding the equation in an elliptical orbit, G̲hulām Ḥusain states as follows :

Let *A B C D* be an elliptical orbit (*madar-e-baizawi*), *A C* is its major (*qutr-e-atwal*) and *B E D* its minor diameter (*qutr-e-aqsar*) intersecting at right angle, *H* the centre of the universe (*alam*) which is one of the two focal points, *G* the place of the eccentricity, which is the second focal point, *A* is the sun's point of apogee (*auj*), *C* the point of perigee (*hadid*), and we suppose *T*, in the circumference of the ellipse, to be the centre of the sun and we join *G T*, *H T*,

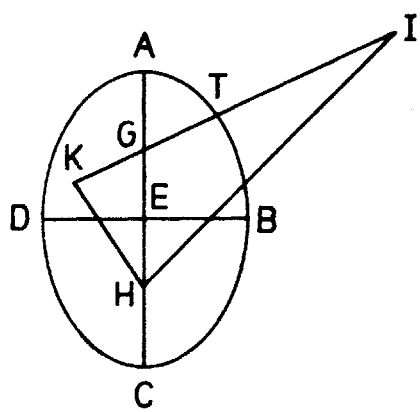

Fig. 3

and then the angle *A G T*, which is the measure of the motion of the sun's centre from the point *A*, is known. Similarly the angle *T G H*, which is the complement of the angle *A G T* to the half circumference is also known. And the two sides GT, HT, though they are not known separately yet their sum which is equal to AC the major diameter of the ellipse *i.e.* 120° is known. We produce GT towards I till GI be equal to the major diameter. Hence it is necessary that TI is equal to TH. We join IH so that the isosceles triangle HTI be produced. And we say that in the triangle HGI two sides HG, GI and the angle HGI are known. Hence the remaining sides and angle will be known. Therefore the side IH and the two angle GHI, GIH are known. Since the two angles THI, TIH on account of the equality of TI, TH are equal to the exterior angle GTH of the triangle HGT, which is the angle of the equation is known to be double of the angle TIH. That is what was required.

The construction is that from the point H draw a perpendicular HK to IG.

Since in rt. $\triangle HKG$, $GH = 2°0'37''24'''$

$\angle AGT = 60°$

so $\angle KGH = 60°$

and $\angle K = 90°$

hence $\angle GHK = 30°$

Therefore $HK = GH \text{Sin} (HGK)$

$= 1°\ 44'27''25'''$ where $\text{Sin}(HGK) = 51'57''41'''$

Similarly $GK = GH \text{Sin}(GHK)$

$= 1°\ 0'18''42'''$ where $\text{Sin}(GHK) = 30°$

Now in rt. $\triangle IKH$, $IK = 121°\ 0'18''42'''$

and sq. $IK = 4.4.2°\ 16'36''61'''$

and sq. $HK = 3°\ 1'11''15'''12^{iv}$

hence sq. $IK +$ sq. $HK = 4.4.5°\ 17'49''18'''13^{iv}$

so $IH = 121°\ 1'1''3'''$

and $\text{Sin}(I) = HK/HI = 0.51°\ 47'22''$

and the arc of this in the table of Sines is the magnitude of the angle of the equation GHT, $1°38'54''$.

And observe that the extreme excess of the annual equations of the point of the greatest and least distance, is $0°1'\ 58''$. If this difference be added to the mean daily (motion) of the sun, the sum *i.e.* $1°1'\ 6''20'''$ is the greatest daily velocity of the sun. And if it be substracted from the mean daily motion, then the remainder *i.e.* $0°\ 57'10''20'''$ is the least daily velocity.

Observation :

From above Ghulām Husain concludes[16] that "European philosophers consider the earth as moving in an elliptical orbit, and the sun as fixed in the major diameter of the ellipse, so that the centre of the sun coincides with one of the two focal points, and the centre of the ecliptic is the centre of the sun.

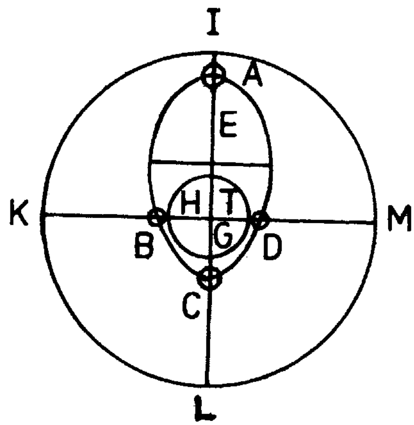

Fig. 4

For example, *A B C D* is the elliptic orbit of the motion of the earth and *A C* is the major diameter, and the two focal points on the major diameter are *E* and *G*, and H T is the sun's disk and *I K L M* is the ecliptic. Then after determining these lines, I (Ghulām Husain) say that if the earth passes over the point *C*, it is at its least distance from the sun, and with respect to the ecliptic it is in the point *L*. It is supposed that the place of the sun is in the point *I*, which is its higher apsis and is opposite to the point *L*. Thus the position of the earth in every point being known, the position of the sun is to be considered as opposite to that. And if the earth proceeds from the point *C* towards *D* it is suppòsed that the sun proceeds from *I* towards *K*, and the distance of the earth from the sun increase daily, till it comes to the point *A*, and then the earth will have come to its greatest distance from the sun, and the sun is seen in the point *L*, and this point *L* is imagined to be the higher apsis of the sun. The distance of its passage from the point *A* is the decremental distance, and when it reaches *C*, then it appears in its original state. As *B C D* is less than half of the elliptic orbit, and the part corresponding to it in the ecliptic is a semicircle, so an inhabitant of the earth passes over this half quickly. And hence he supposes that the sun passes through the half *M I K* quickly, and for the same reason the earth passes over the half *K I M*. And as it is certain that from the earth the situation of the sun appears opposite to that of the earth. So is (the spectator) be supposed looking at the centre of the sun, the place of the earth will appear opposite to the sun *i.e.* in that half in which the motion of the sun appears slow, and the earth will appear to go quick. And in the quick half, slow. Hence if the equation which has been found by the demonstration with reference to the focal point be brought into operation reversedly on the supposition of the earth's motion, and the place of the earth be determined, will be found. And it is sufficient for us, if after determining the sun's place we should add or subtract half a revolution to or from it, so that according to the phraseology of Europeans, we may obtain the earth's place."

Thus Ghulām Ḥusain tried to settle the Ptolemaic model of universe and this he does by a very reasonable hypothesis of a circle and epicycle. He shows the motion of the planet round the empty focus is uniform and the method of finding the true place of the planets is remarkable.

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[3] Clason, C.B., *Men, Planets and Stars*, G.B. Putnam's Sons, New York, 1959,—It is now believed that Hipparchus was the man really responsible for the epicycle theory of the way the planets behave. It become known as the Ptolemaic system. p.35.

[4] Ptolemy, *The Almagest*, Tr. By Catesby Taliaferro, Ency. Brit. London, p.1.

[5] Whitney, C.A., *The Discovery of Our Galaxy*, Angus and Robertson (U.K.) Ltd., 1972, p.11.

[6] Hurd, D.L., *Ibid.*, p.112.

[7] Cohen, I.B., *Ibid.*, p.128.

[8] Whiteney, C.A., *Ibid.*, p.27.

[9] Ansari, S.M.R., Introduction of Modern Western Astronomy in India during 18-19 Centuries, *Indian J. Hist. Sc.*, **20**, p.368, 1985.

[10] Tytler, J., Analysis and Specimens of a Persian Work on Mathematics and Astronomy, *Royal Asiatic Society of Great Britain and Ireland Journal*, IV, p.263, 1837.

[11] Cohen, I.B., *Ibid.*, p.496.

[12] Ghulām Ḥusain Jaūnpūrī, *Jāmes-i-Bahādur Khānī*, Calcutta, 1835, p.579. Translation of quotation from Jame-i-Bahadur Khani is taken from Tytler's paper (*sup.* 10), but verified from the original Text.

[13] ——— *Ibid.*, p.579.

[14] ——— *Ibid.*, p.579-80.

[15] ——— *Ibid.*, p.580.

[16] ——— *Ibid.*, p.581.