

The Origin of Pi, Tsung and Xuan Ji: A Theoretical Suggestion

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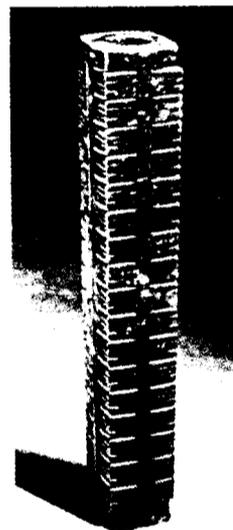
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Professor Ta-You Wu, besides being a world-famous physicist and a great teacher, is also interested in the development of Chinese civilization. This paper touches on one of the subjects that he likes.

The representation of Heaven in Chinese tradition is the jade Pi and that of Earth is the jade Tsung.

以蒼璧禮天
以黃琮禮地 (周禮)

Their shapes are aesthetically pleasing. Both are great artistic forms, yet their origin is unknown to us. In the following I would like to venture a new theory of mine: Perhaps both Pi and Tsung are artistic expressions of even earlier astronomical instruments.



Imagine yourself as one of our intelligent ancestors, living in neolithic times and looking at the sky on a summer night (but without the pollution of modern Beijing). As the night moves on, all the stars in the heavens slowly revolve around you. It would be natural to wonder: What cosmic forces can cause motion of such immense magnitude, night after night, with predetermined regularity?

Yet, there is one single point in the sky which is fixed and does not move. Why? All rotation must be around an axis. Therefore, the rotation of the stars in heaven has also to be around a fixed axis, though unseen to us. The intersection between this axis and the celestial hemisphere determines a fixed point in the sky (called 正極). We now know this axis to be the rotational axis of our earth. However, our ancestor would not know that but, being intelligent, would comprehend the basic importance of this fixed point, whatever the underlying mechanism. Therefore, to make a precision determination had to be a significant achievement.

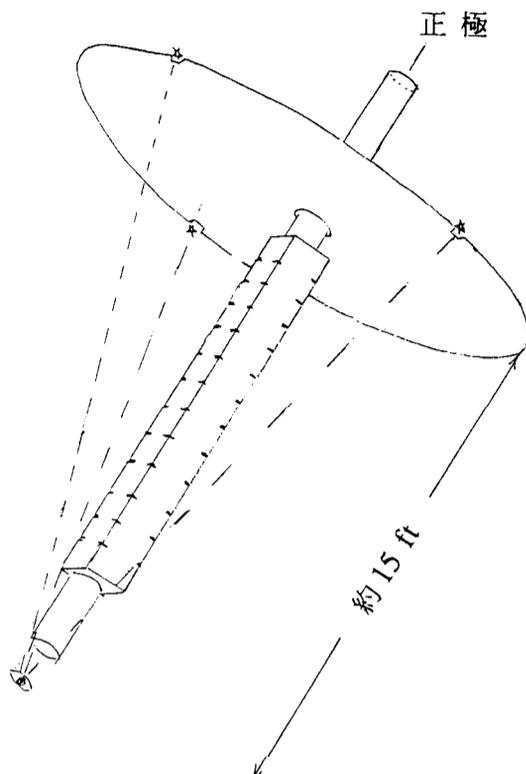
Xuan Ji is another mystery of the Shang and pre-Shang artifacts. The following is a picture of a Shang jade Xuan Ji, measuring 33 cm. According to ancient literature, Xuan Ji refers to a much larger circular disk. Therefore this Shang jade piece is very likely an artistic representation of an actual instrument used in the neolithic, before the Shang.



Shang Jade Xuan Ji (璿璣)
33 cm

書彞典(疏)
璿璣：
璿美玉也。
璣為轉運，徑八尺。
圓周二丈五尺強。
是王者正天文之器。
後世以策，謂之
渾天儀。

Recently, I have thought about how a Chinese astronomer in neolithic times might devise a precision scientific instrument which can determine the fixed point in the sky to a fraction of a degree. I think he would need a large, perfectly circular disk of about eight feet diameter. The disk should have three nearly square notches cut into its rim, as shown in my sketch below:



The whole instrument is mounted on a straight cylindrical tube, perhaps about fifteen feet long, which has a hole through its center. When the astronomer views through the three notches on the rim, each notch should contain a bright star; one of the three is perhaps the η of the Big Dipper (北斗) constellation and the other two are very likely to be the η and λ stars of the Draco constellation.* Each star sits in one of the notches. As the night moves on, these three stars would revolve and the disk should be turned to follow, so that each notch continuously tracks its same star (this makes a squarish notch the best shape). When this tracking is perfect, the viewing through the center of the cylindrical tube automatically points to the fixed point in the sky.

To have three notches on the rim is the necessary and sufficient condition to determine the center of a circle. Their spacing depends on the location of the stars chosen. A nearly equal spacing would be the ideal design to give the highest accuracy. Clearly, the larger the disk, the more perfect its circular shape and the longer the cylindrical tube, the better will be the determination. With the technology of neolithic times, a fifteen-foot straight tube probably would be near the maximum length that could be made of bamboo or wood. In order to keep it rigid and straight, the hollow tube had to be strengthened by a much stronger casing, one of rectangular shape and perhaps made of hard wood reinforced by stone.

*I wish to thank Professor Yang Pang for his help

The curiosity and the drive to determine 正極, the fixed point in the sky, would be greatest if that point were near a star. In our time, 正極 is near the α star of the Little Dipper. This was not so in the past, except around 2,700 B.C. (compare the star chart of 2,000 A.D., near our present time, with that of 2,700 B.C., on the next page). In that earlier time, the α star of the Draco constellation coincided almost exactly with 正極, the fixed point in the sky. In addition, there were three relatively luminous stars, the η and λ of the same Draco and the η of the Big Dipper. It is tantalizing to hypothesize that that was the time when the giant Xuan Ji instrument was constructed.

From neolithic times to the Shang Dynasty, the commemoration of this scientific achievement inspired artistic creation. The original large circular disk became symbolic highly polished jade pieces; the ones with accentuated notches are the Shang jade Xuan Ji and those without are the Shang jade Pi. The cylindrical tube and its square casing evolved into the Shang jade Tsung.

The circular disk follows the motion of the revolving heavens, whereas the square casing and the cylindrical tube are rooted in the fixed earth. This is why Pi represents heaven and Tsung the earth. Both are noble symbols of our civilization.

It is of interest to speculate on the accuracy that our ancestors could achieve with such an instrument. Assuming that the tube was made of a giant bamboo of about fifteen feet in length and that the "sighting tube" for viewing was achieved by puncturing a tiny hole of less than a centimeter diameter through each inside membrane of the bamboo, the angular position of 正極 could be determined to the accuracy of about one-tenth of a degree, or even less. Using that, they could locate the constellations and their apparent motions with great accuracy. This would be the beginning of a good almanac or calendar for farming. Such instruments are not too difficult to construct. We may speculate that it was widely in use by the general population over many parts of China.

Most other ancient civilizations developed near the sea, often around the deltas of some major rivers like the Nile, the Euphrates and the Tigris. The tides and the changes in the river's course provided a time reference and other resources for farming. Chinese civilization, however, developed along the Yellow River, in the interior rather far from the sea. Perhaps this is because, even in neolithic times, our ancestors were more advanced in science. Tsung, Pi and Xuan Ji are symbolic relics of that achievement. The early mastery of astronomy might make other differences. That the beginning of Chinese culture was not founded on any aristocratic deity may in part be due to the knowledge that the people possessed early on. The precision in observing stellar motions and the ability to predict seasonal changes impacted directly on the everyday lives of common people. This might also be the reason why, unlike other ancient civilizations, the Chinese culture is the only one that is continuous from neolithic times to the present.