

THE STRUCTURE OF THE UNIVERSE :
SYNCRETISM AND CONTINUITY OF THE CHINESE
COSMOLOGICAL THEORIES

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Cosmological Theories: Continuity in Diversity

There were fundamentally three Chinese cosmological theories:

Gai Tian theory: represented the heavens as a hemispherical cap which covered a square Earth;

Hun Tian theory: envisaged a spherical Earth floating inside the celestial sphere;

Xuan Ye theory: hypothesized that the celestial bodies were immersed in empty and infinite space.

Despite the fact that the relative documents are often patchy, it is possible to reconstruct an initial map of the ancient Chinese cosmological theories thanks to a passage by the writer, historian and astrologer Cai Yong (2nd century A.D.). This passage was taken from a report presented to the emperor, and, in 983 (Song Dynasty) included in the Taiping Yulan (Imperial Encyclopedia of the Taiping Rule):

"Those who talk of the heavens form three schools. The first is the Zhou Bi school, the second is Xuan Ye and the third, the Hun Tian. The teachings of the Xuan Ye school are interrupted, there are no more teachers."
 (Taiping Yulan, II, 4a)

Later, in the 5th century A.D., the astronomer and mathematician Zu Gengzhi, in his Tian Wen Lu (Principles of Astronomy), referred to the same schools but called the Zhou Bi school by another name, Tian Gai.

As regards the translation of these Chinese terms into Western languages, it is worth mentioning that there is not always agreement in attributing to those terms one same identical meaning. The most reliable definitions are those which refer to one single view of the structure of the Universe:

zhou bi: circular orbits and gnomons of the heavens;

xuan ye: light and darkness; night which pervades everything; infinite and empty space;

hun tian: celestial sphere;

tian gai: celestial hemisphere; celestial cap.

Recent revisitations of the classic Chinese hypotheses on the form of the universe have broadened the panorama increasing the number of these theories, and the schools which propagated them, from three to six: Tian (diurnal rotations), Qiong Tian (vastness of the heavens), and An Tian (conformation of the heavens). These last three represent nothing more than variations of the first three.

The cosmological theories had to provide the theoretical substratum to the enormous mass of data collected since the most remote times of astronomical observations. They also had to support the dominating philosophical doctrines: in particular, from the Han Dynasty onwards, Confucianism. Even the earth-heavens relationship, which held so much weight in Chinese culture, greatly influenced the formulation of the various schools of astronomy. They are, therefore, affected by an enormous number of factors which bear upon the speculative aspects as well as the more exclusively technical aspects.

Although the systematic arrangement of these theories requires that a historical period is attributed to each of them in order to allow their developments and their rises and falls to be followed, one could, nevertheless, affirm that in no period of the history of Chinese science was only one of the theories adopted at the exclusion of all the others. Rather, with the characteristic syncretism which dominated ancient Chinese thought, the different cosmological theories aimed at describing the structure of the world have cohabited in Chinese culture often providing cues for correlations and integrations. Among the elements which make up the links in the united chain of the different theories, the concept of qi, used in all of them, will be discussed here. Due to its doctrinal importance, qi proves how significant the points of contact between the theories have been.

Generally translated as "air", "gas" or "vapour", qi is a conceptual element which probably originated from Taoist philosophy, which permeated the foundations of Chinese scientific thought to such an extent that it can be found in all speculative fields. In a broader sense, all the substances that, even if not subject to a sensorial impression, exercise however an action of the energetic type and imply a change in nature, can be identified in qi.

Above all, qi was considered by the first Taoists as primordial, a sort of energy-matter in the state of chaos from which the Universe was to have originated; Tao was the

spiritual force which gave rise to qi. In the Zhuangzi phase, which appeared after the Taoism period (4th-3rd century B.C.), qi and Tao were identified and later on (3rd-2nd century B.C.) qi was considered as a vital force which belonged to the heavens (the qi of the heavens) and Earth (the qi of the Earth) and its perpetual movement between the celestial and earthly spaces gave life and form to things. Even for living bodies, qi is a force which gives impulse and movement to all the organs.

Within the field of the natural sciences, cosmological theories are a good example for demonstrating the influence of the concept of qi. Indeed, the Gai Tian theory, which would have appeared already in the late Zhou period, during the Warring States epoch (475-221 B.C.), envisaged the heavens as a hemispherical cap, a type of lid which covered the Earth. In its earliest form, this theory sustained that the heavens were round and Earth was square; in one of its latest formulations (3rd century), it sustained that the heavens were held in suspension thanks to the support of the "primordial vapour", qi. The Hun Tian theory, mentions of which date back to the 2nd century B.C., envisaged a spherical Earth which floated in celestial space which was in turn supported by qi. Even the Xuan Ye theory (the first written evidence of which can be traced back to the 4th century), which is very suggestive for its intuition of empty space and the concept of infinity, made use of qi. It used qi in an even more evident way and, in some respects, in a more advanced way since it anticipated modern astrophysics by two thousand years and hypothesized that the stars were made up of gaseous qi in tumultuous rotation along with the heavens.

The concept of qi is not limited to being a founding element in the field of astronomy; its functions and its meanings invade other aspects of ancient Chinese scientific thought, from medicine to geology, from hydraulics to geomancy and in all the other fields of science and technology, the analysis of which would sidetrack us too much. It should be stressed, however, that qi, precisely because of its doctrinal omnipresence, represents one of the elements of continuity in Chinese thought. Its determinant presence in the formulation of all the ancient cosmological theories confirms that even for Chinese astronomy one can talk of "continuity in diversity", or a scientific system which advances without negating its past, and therefore without breaking off from preceding experiences, which evolves and transforms itself without losing sight of those conceptual roots which, supplying nutriment for the evolution of thought, guarantee their survival by regenerating themselves.

Now let us examine in detail the Chinese cosmological schools, outline the literary evidence, the philosophical relationships and the technical aspects.

The Gai Tian Theory (Celestial Hemisphere)

The Zhou Bi theory, later known as Tian Gai or Gai Tian, which would have already appeared in the late Zhou period during the Warring States epoch (475-221 B.C.), is the most ancient of the codified Chinese cosmological theories. It pictured the heavens as a hemispherical cap, a sort of lid, which covered the Earth. The most ancient formulation of the Gai Tian is that of the Zhou Bi Suan Jing (Classics of Arithmetic, of the Gnomon and of the Circular Orbits of the Heavens), the most ancient classic of Chinese mathematics which dates back to the 1st century B.C. (Han Dynasty) but which collects together debated material composed in the Warring States epoch and even, in parts, during the pre-Confucian epoch (6th century B.C.).

The essential elements which are gathered together in this text are: the Earth is flat and square and above it the semispheric heavens, on which the Sun, the Moon and the planets are mounted, rotate; it is the rotatory movement of the heavens which pull along the celestial bodies which, therefore, travel in circular trajectories above the Earth:

"The Earth is a square 8,110,000 li wide and is 80,000 li away from the Heavens. The Heavens fit together with the four sides of the Earth which is immobile, while the Sun, the Moon and the stars rotate with the celestial vault. The light of the Sun is able to illuminate a circle with radius 167,000 li and the distance at which one can see the Sun is equal to that which it illuminates."

(Zhou Bi Suan Jing, II, 1b)

Practically, when a man is less than 167,000 li away from the Sun, he can see it in the heavens; at a greater distance he cannot see it and so considers it as having set; the day and the night in a given place, therefore, are not due to the passage of the Sun above or below the Earth but to its distance from that place due to the rotatory movement inside the celestial "cap" on which the Sun is mounted along with the planets and the stars. The example used to explain the visibility or invisibility of the Sun was that of a lit torch in the night: if it is near to the observer it can be seen, if it moves away beyond a certain distance it cannot be seen.

The Sun is therefore considered as a circumpolar star; in particular, as will be seen further on in the ancient Chinese text, it varied its distance from the celestial North Pole according to the season, travelling through seven parallel circles of declination of which the furthest away from the Pole was that of the winter solstice, the nearest that of the summer solstice and the intermediary one the circle of the equinoxes.

Still from the Zhou Bi Suan Jing:

"The totality of that which the Heavens can illuminate in succession is a circle with diameter 810,000 li and circumference 2,430,000 li. When the Sun in its circular movement is North of the Pole, it is midday in the northern region and midnight in the southern region; when the Sun is East of the Pole, it is midday in the eastern region and midnight in the western region; when the Sun is South of the Pole, it is midday in the southern region and midnight in the northern region; when the Sun is West of the Pole, it is midday in the western

region and midnight in the eastern region."

(Zhou Bi Suan Jing, II, 1b)

The Gai Tian, as will be seen later, was a very long-lasting theory and cohabited with other cosmological theories. In the light of astronomical observations, it stimulated a close debate on the following two points:

- a) the structure of the Earth;
- b) theoretical devices for conciliating the Gai Tian with the Hun Tian.

At the time of the Warring States the structure of the Universe with a square Earth was widely sustained. It is precisely during this period that the philosopher, natural scientist and astrologer, Zou Yan (who lived during the 4th century B.C.), affirms:

"On the square Earth there are nine continents of which one is the holy Chinese continent; each continent is surrounded by a small sea; outside the continents there is the great sea which meets the Heavens at the four sides of the Earth".

(Shi Ji. Meng Zexun Qing Liezhuan, "Historical Documents. Biography of Meng Zexun, XXVII)

The Gai Tian theory, as it was formulated for the first time in the Zhou Bi Suan Jing, remained unaltered for several centuries. In 635 (Tang Dynasty), it would have still been possible to read of these theories as they were handed down from Chinese tradition. In fact, the historian Fang Xuanling in that year compiled a volume on the "History of the Jin Dynasty" (Jin Shu), the Dynasty which ruled in North China from 265 to 317, in which a memorial appeared dated about 180 (Later Han Dynasty). This volume talked of the "barriers" of the heavens which are nothing more than the seven parallel circles of declination which the Sun, fixed in the celestial vault, could travel in its annual movement. Of these seven, the highest in the heavens, nearest to the North Pole, was the circle the Sun travelled at the summer solstice; the lowest was that passed through at the winter solstice; the intermediary circle was that which the Sun covered at the equinoxes. The numerical measurements which the memorial supplied are very different from those provided by the Zhou Bi Suan Jing; in this case the concentric domes of the Heavens and Earth result as being flatter. Here is the passage:

"The Gai Tian theory was founded by Bao Xi (mythical hero deified with the name Fu Xi). He established the degrees for the circumference of the celestial vault and for the calendar. The theory was transmitted like so: the Duke of Zhou received it from Shang and Zhou's men recorded it. Thus it was known with the name Zhou Bi, since Bi indicated the perpendicular side of the right-angle triangle as well as the gnomon (which was used for measuring shadows).

The Gai Tian theory affirms that the celestial vault is like a bamboo hat which covers the Earth, like an upside-down bowl. The centre of the celestial vault and the Earth's centre are both elevated, while the peripheral regions are lower. Below the celestial North Pole are the centre of the celestial vault and the Earth's

centre. It is in this point that Earth has its highest point from which it slopes downwards in all four directions.

The Three Lights (Sun, Moon and stars) give rise to day and night according to whether they are hidden or shining. The centre of the celestial vault is higher than the outermost barrier, where the Sun is at the winter solstice, by a distance equal to 60,000 *li*. The Earth below the celestial North Pole is 60,000 *li* higher than the peripheric regions which are below the outer barriers of the celestial vault.

Below the North Pole, the outermost barrier of the celestial vault exceeds the Earth in height by 20,000 *li*. The celestial vault and Earth have edges which adapt to each other (like two concentric domes) and the constant vertical distance between the Sun and Earth is 80,000 *li*.

The Sun is mounted in the celestial vault and changes position with a regular movement according to the seasons of winter and summer. Its movement crosses the seven barriers and the six roads. The diameter and the circumference in *li* of each barrier can be calculated mathematically using the similar right-angle triangles method and observing the length of the shadow of the gnomon. The measurements of the distance from the Pole and of the approaching and receding movements can also be obtained by using the gnomon and the right-angle triangle it forms. For this reason the method is called Zhou Bi.

The Zhou Bi school sustained that the celestial vault is round, with the shape of an open umbrella, while the Earth is square like a chess board. The celestial vault rotates laterally towards the left just like a millstone turns. The Sun and the Moon move towards the right but, simultaneously, must follow the celestial vault which turns leftwards. Thus, if in reality they move eastwards, they are dragged by the circular motion of the celestial vault and appear to set in the West."

(*Jin Shu. Tian Wen Zhi*, "History of the Jin Dynasty. Monograph on Astronomy")

In the same Jin period, another text, the *Qing Tian Lun* (Discourse on the Celestial Vault), written circa 285 by the astronomer Yu Song, specifies the quantity and quality of the structure of the universe according to the Gai Tian theory. The passage is conserved in the "Collection of Books Lost from the Study of the Jade Mountain" (*Yu Han Shan Fang Ji Yi Shu*) compiled in 1853 by Ma Guohan who used fragments of ancient works to reconstruct texts almost lost:

"The celestial vault is high and has a concave shape like the membrane of a hen's egg. Its edges meet the surface of the four seas. These float on the primordial vapour *qi*. The celestial vault is like an upside-down cup which can move on water without sinking because it is full of air. The Sun rotates around the Pole, disappearing towards the West and returning from the East, but never appears from or penetrates the Earth.

Like a lid has a domed summit, the Heavens also have a pole of its own. The southern Heavens are 30° lower than the Earth. The axis of the celestial Pole is inclined northwards and forms a 30° angle as appears from the East-West line. Men live beyond 100,000 *li* south of the East-West line of the Pole. The Earth's centre, therefore, is not directly below the Pole but corresponds exactly to the East-West line of the Heavens and the earth. The Sun, in its journey, goes round the Pole. In the winter solstice the position of the Pole is north with respect to the ecliptic and the ecliptic is 67° south of the Pole. These figures are determined from the position of the solstitial points."

(*Yu Han Shan Fang Ji Yi Shu*, LXXVII, 5a)

As regards the quantitative aspects of this work by Yu Song, who was the grandfather of the discoverer of the precession of equinoxes, the astronomer Yu Xi (active in the period 307-338), uses some numerical data already known for nearly two centuries in China. Indeed, for the distance between the Sun and the Pole at solstices, Yu Song draws upon what had been written in 85 A.D. by the astronomer Jia Kui and included in *Hu Han Shu* (History of the Later Han Dynasty). But, even if there is no originality in the astronomical computations, the reference that Yu Song makes to

"primordial vapour" qi which supports the heavens is very important. The concept of qi which appears in Gai Tian, the most ancient Chinese cosmological school, was to outlive the theory even when the latter was replaced or integrated with more "modern" theories. The concept can be found in these new doctrines and many thinkers of later periods make continuous reference to it, such as philosophers of the calibre of Shao Yong and Zhu Xi (11th-12th centuries) who dedicated much attention to the "impetuous wind" which sustains and gives motion to the celestial bodies in the Heavens.

As already mentioned at the beginning of this section, the hypothesis of "round Heavens" and "square" Earth was the most ancient formulation of the Gai Tian. The supposed square form of the Earth went together well with the Confucian doctrine according to which the Heavens are "superior", mobile and positive (yang), while the Earth is "inferior", immobile and negative (ying). In Da Dai Li Ji. Zeng Ze. Tian Yuan (Document on the Rites Compiled by Dai the Elder. On the Roundness of the Heavens), a text composed between 80 and 105 A.D. when the Hun Tian theory would already have been codified and was to substitute the Gai Tian, one reads:

"The Master said: The road of the Heavens is round, the road of the Earth is square."
(Da Dai Li Ji. Zeng Ze. Tian Yuan, LVIII)

The road of the Heavens and that of the Earth mentioned in this passage is naturally the "road" in the philosophical sense of the word, or the Dao (better known with the phonetic transcription Tao). Tao is one of the syncretic elements between Taoism and Confucianism. In particular, it is constantly recalled in the Confucian classics not only in philosophical speculation but also in that which is more purely scientific. For example, in the section Ji Chun Ji. Yuan Dao (Memoirs of Spring. The Round Tao) from the compendium of natural philosophy Lu Shi Chun Qiu (Annals of Spring and Autumn of Master Lu) ascribed to 239 B.C. in the Qin dynasty, eighteen years prior to the unification of the Chinese empire, it is affirmed:

"Since the Tao of the Heavens is round, and that of the Earth is square, the ancient sages followed this principle to establish the social order of the Earth. Why does one say that the Tao of the Heavens is round? The vital force, qi, rises and falls making a complex circle and never stays still; therefore, the Tao of the heavens is circular. How can one say that the Tao of Earth is square? All things are of a different shape and species, each of which has a specific function and cannot be replaced by another."

(Lu Shi Chun Qiu. Ji Chun Ji. Yuan Dao)

The notion of a square Earth, which could have been suggested by the use of the four cardinal points (a fifth was on the Earth's own centre), also influenced daily aspects of Chinese life. Indeed, the form of the money which was used by emperor Qin Shihuang to unify the coinage of all the states which formed the first Chinese empire, was round (like the heavens) with a square hole in the middle (like

the Earth), to represent the structure of the world. This type of money remained unaltered for two thousand years. Moreover, for the imperial liturgies, the temple dedicated to the Heavens has always been circular in shape ever since most ancient times, while the temple dedicated to the Earth was square.

Still in the 7th century A.D., when this view of the structure of the Universe had been officially replaced by other theories, a popular song by the poet Hu Lujin of the Xian Bei ethnic minority affirmed:

"In the valley of the national minority Chilai (descendants of the Xiong Nu, who lived east of actual Qinnai) the moon sets behind the mountains. The vault of the Heavens, like a Mongol tent, covers the Earth in its four sides. The blue Heavens spread themselves over the immense grassland, while the wind blows and in the depths of the valley the goats and cows are exposed."

(*Han Wei Da Zhao Min Ge Xuan*, "Selection of Popular Songs of the Han and Wei Dynasties and of the Six Dynasties", Beijing 1959, p. 55)

This very suggestive song provides us with a starting point for the hypothesis that maybe it was precisely among the nomads in North-West China that birth was given to the idea that the heavens were a semispheric cap, a sort of large tent which covered the entire Earth. But, beyond this splendid poetic view, we can ascertain above all that the Gai Tian theory must have enjoyed a certain popularity to still continue existing when other theories, in particular the Hun Tian (celestial sphere), were firmly accepted and in favour among the social class which had access to culture.

However, as astronomical observations continued, the Gai Tian theory underwent a structural change regarding the shape of the Earth. Actually, already in the period of its first formulations, the Gai Tian system had raised a certain perplexity since for some it seemed impossible that the celestial spherical cap was able to completely cover a square, flat Earth. For this reason, the philosopher Zeng Shen, a student of Confucius, who lived between the end of the 6th century and the 5th century B.C. posed the problem:

"If the Heavens were round and the Earth square, the four sides of the Earth could not be completely covered."
(*Da Dai Li Ji*, LVIII)

The ancient hypothesis of the Earth being like a square, if not abandoned in the popular environments and in rough speculations, was eventually abandoned by the astronomers who were pressed by the imperial necessity to provide some rational explanation for the phenomena which they observed and which repeated themselves with a certain cyclicity. From being flat with a protuberance in the centre, the form of the Earth therefore underwent a change within the formulations of those who attempted to conjugate the theory with observatory experiences. In the end, a supposition was arrived at that Earth was not squashed but arched, in the form of a dome, just like the heavens, concentric to them, but smaller. As regards the structure of the base of this earth-

ly dome, the classical texts insist on the square figure but, from the argumentations quoted, this Earth, similar to a sheet folded into an arch below the celestial dome, respecting very precise values of distance, the issue is not very clear. Probably, the shape of the Earth proposed by the Gai Tian system was never fully defined.

Having ascertained that the literary evidence in favour of the square Earth covers a period of ten centuries (from 4th century B.C. to the 6th century A.D.), we can affirm that, at least for a certain long period, this argumentation became "classic" and therefore, as such, underwent a prolonged irremovability in Chinese culture, like all ancient concepts, traditional and therefore untouchable. So, with the peculiar syncretism (or compromise?) of Chinese thought, even this arched square which behaved like a spherical dome was possible. Thus, the "knowledge" of the ancients was conjugated with the accumulation of data from astronomic observations which played in favour of a round Earth. Among the latter, we can mention those which refer to the polar star which became gradually lower or higher according to whether one moves towards the South or the North: this would prove that the Earth is not flat, otherwise it would not have been possible to observe significant changes in the height of this star by varying geographical latitude.

In the end, the Gai Tian cosmological theory in its most mature formulation can be scientifically described through the following considerations:

- a) The heavens were envisaged as a hemispheric dome, a sort of lid placed on the Earth, which, in turn was similar to an overturned cup; the celestial and earthly domes were concentric and the distance between them was 60,000 li.
- b) At the centre of the celestial vault there was the Great Bear which, during the Warring States epoch, appeared at its zenith at the latitude of Hangzhou; the centre of the Earth was inhabited by men. Rain fell from the heavens and ran over the Earth towards the lower peripheral parts forming the four seas.
- c) The celestial cap rotated from right to left dragging along with it the Moon and the Sun which also had their own motion from left to right, but this retrograde motion was very slow with respect to that of the heavens.
- d) The setting and rising of the Sun and the Moon were attributed to their movement towards or away from the observer.
- e) The polar axis is sloping.

The Gai Tian theory (celestial hemisphere) was divulged until

the 6th century A.D. with wavering popularity due to the advance of the Hun Tian theory (celestial sphere) which proved more useful for explaining the astronomical phenomena observed. Attempts were also made to join the two theories especially in the court of the Liang Dynasty which reigned in southern China from 502 until 557. One of the argumentations adopted during the conferences and the oppositions organized in court for confronting and integrating the two cosmological theories sustained that hypothesizing a half-sphere meant possessing only a half-truth; the "Dynastic History of Liang" (Liang Shu, XLVIII) documents these dialectic attempts.

One must question why it was precisely during the Liang Dynasty that evident attempts were made to integrate two very different theories which belonged to groups of astronomers who were often hostile with each other and who, all said and done, had more interest in emerging as a single school than as a fusion of two streams of thought, simply for the scope of gaining prestige with the emperor. Probably, the breeding ground for tolerance, for confrontation and integration of the theories was provided by the Buddhist religion which, as an unrevealed doctrine, was also known in China with its quality of non-violence, liberality and openness to dialogue. It was in fact during the Liang Dynasty that Buddhism flourished in a massive way among the dominant classes and the same emperor Wu withdrew to a Buddhist monastery. The capital of the reign, Jiangang, had in that period more than five hundred monasteries and over a hundred thousand Buddhist monks and nuns. The introduction of Buddhism in China (at the beginning of our era), favoured the knowledge of the foreign arts: architecture, music, dance, etc., while the translation of the Buddhist canons gave impulse to philology and to the structure of languages. With these novel characteristics, Buddhism prepared, at least in the first centuries of its introduction in Chinese culture, the dialogue and confrontation. One should not be surprised therefore if this openness was also reflected in scientific fields (for example, influxes in the field of medicine and hygienic-athletic techniques were noteworthy) and in particular in the sector of astronomy, which played a very important role in Chinese political life. It should be added that the Gai Tian theory from the end of the 6th century onwards was practically abandoned and substituted by the Hun Tian and this coincided with the reunification of the empire on behalf of the Sui. To a renewed politico-administrative management there therefore corresponded a repristination of the cultural centralization of imperial power and the option of the Hun Tian, laid down by considerations of scientific reality because it adapted better to the experiences observed, soon became part of the dominant ideology and remained vital until the fusion with modern science, after the Gesuits' arrival in China.

The Hun Tian Theory (Celestial Sphere)

The notion of a spherical Earth is very antique and goes back to the school of Logic (4th century B.C.) and, more specifically, to Hui Shi:

The South is infinite but, at the same time, has some limits... I know where the centre of the Earth is. It is to the North of the state of Yan and to the South of the Yue state...".
(Zhuang Zi, "The Book of the Master Zhuang")

In these statements, using the dialectic expedients that were developed and formalized in the philosophical schools of the Moists and the Logics, Hui Shi explains that the Earth is round because if its surface is travelled towards South, it appears that the journey never finishes. However, in reality, once the South is reached, one can carry on walking not because the South is infinite but because there is a return to the starting point along the circumference of the Earth. Moreover, if one considers ancient Chinese geography, which placed the Yan state to the North and the Yue state to the South, one can understand Hui Shi's view of a spherical Earth with two points of reference (North and South) rather than a flat Earth.

The philosopher Shen Dao, a contemporary of Hui Shi, also stated:

"The planets are like marbles whose force constrains them to bend."
(Zhuang Zi, Tian Xia Pian, "The Book of the Master Zhuang. Chapter on the World")

Another reference to this vision of the world from the 2nd century B.C. can be found in the volume Fa Yan (Exhortative Maxims) by the astronomer Luo Xiahong.

For the formalization of these cosmological ideas into a true self-standing theory one has to wait until the end of the 1st century A.D.. Indeed, it is in this period that the astronomer and mathematician Zhang Heng (72-139) worked. In his Ling Xiang (The Spiritual Structure of the Universe) included in 1275 (Song Dynasty) in Yang Hui Xuan Fa (Calculation Methods of Yang Hui), he writes:

"In ancient times the sages wished to trace the roads of the heavens, fix the orbits of the celestial bodies and verify the origin of things. They built for the first time a celestial sphere, corrected the instrument and introduced the degrees, thus fixing the imperial pole. Every thing rotated around the celestial axis according to an ordered scheme which could be studied. Once the instrument was perfected and the observations made, it was seen that the heavens were regular... In the celestial vault there are phenomena and on Earth structured shapes... Phenomena and forms can be observed and measured... The diameter which surrounds the celestial sphere is 2,032,300 li, but it is 1,000 li shorter in the North-South direction and 1,000 li longer in the East-West direction...

Nobody knows what is beyond the sphere, and it is called cosmo (yu zhou). It has no shape and no boundaries."
(Yang Hui Xuan Fa, LXXVI)

This is the first conscious codification of the so-called Hun Tian theory (celestial sphere). It played an important role in the history of Chinese astronomy since it remained

the most consulted point of reference for all conceptual speculations on the heavens, the bodies which populated them and on the motion of these celestial bodies.

The work of Zheng Heng is of great interest because it probably permits the following considerations to be made:

- a) the Hun Tian theory took its cue from much more ancient ideas from the period in which Zhang Heng lived;
- b) in the first century the theory was already codified qualitatively and quantitatively;
- c) in the same period, the conception that the natural phenomena could be measured existed;
- d) the concept of infinite space was inherent in the theory;
- e) the armillary sphere was already in use as an instrument of demonstration as well as of observation and measurement;
- f) the microcosm as a mirror of the macrocosm in the relationship of reciprocal influence, which was so important in the history of Chinese thought, was rationally synthesized by the armillary sphere.

Another passage from the same Zhang Heng, the Hun Yi Zhu (Treatise on the Armillary Sphere), collected in 729 (Tang Dynasty) in Kai Yuan Zhan Jing (Treatise of Astrology of the Kai Yuan period), further defines these aspects:

"The Heavens are like an egg, they are round like a billiard ball; the Earth is like the yolk of the egg: it is inside the egg. The Heavens are large, the Earth is small. Inside the lower part of the Heavens there is water. The Heavens coat the Earth like the shell of the egg surrounds the inside. The Heavens are sustained by vapour (qi), the Earth floats in the water.

The circumference of the Heavens is $365^{\circ}+1/4^{\circ}$; dividing it by 2 one obtains $182^{\circ}+5/8^{\circ}$: that which covers the under side of the Earth is $182^{\circ}+5/8^{\circ}$, that which goes round underneath is of $182^{\circ}+5/8^{\circ}$. For this reason, of the 28 xiu, half is visible under the Earth and the other half is hidden. Its two summits are called North Pole and South Pole. The North Pole is the centre of the Heavens; it is exactly north and is 36° below the Earth; as a consequence of this, if we draw a circle with diameter 72° with centre at the North Pole, it is always visible. The South Pole is the centre of the Heavens and the Earth: it is exactly south and is 36° below the Earth; as a consequence, a circle with diameter 72° is always visible. The two poles are 182° and a little more than $1/2^{\circ}$ away from each other. The rotation of the Heavens is similar to that of the axis of a cart."

(Kai Yuan Zhang Jing, I, 4b-5a)

This passage reinforces, if this is necessary, the conviction that the "measurement of the heavens" referred to in the Hun Tian were already in current use during Zhang Heng's times. But the most important aspect which emerges from the words of the Chinese astronomer regards the fact that the Earth was not considered immobile but in motion, subjected to the action of the water on which it rose and fell, floating. Naturally this swimming movement, which became litera-

lly called "swimming", was not unanimously accepted. Indeed, it was precisely on the nature of the Earth's motion that the greatest changes were made in the Hun Tian theory, as we will see.

At the end of the 3rd century, the astronomer Yang Quan in his Wu Li Lun (Dissertation on the Origin of Things) included in 983 (Song Dynasty) as an appendix to the Tai Ping Yu Lan (Imperial Encyclopedia of the Tai Ping Rule), thus summarized this theory:

The men of letters have thought up the Hun Tian theory to imitate the form of the Heavens: for their theory they are inspired by the wheel of a cart... On this theory the Shuo Tian says: The Heavens are similar to the wheel of a cart and turn; the Sun and the Moon spend the morning keeping themselves on the upper part (of the wheel) and the evening on the lower part: for this reason they rise in the East and set in the West. Some oppose this theory because of the Pole... In the Hun Tian theory it is objected that the Pole is not at the zenith."

(Tai Ping Yu Lan, II, 4b)

The theory of the celestial sphere, as it has been outlined so far, did not remain rigidly defined in the history of Chinese scientific thought. There were various intrusions which enriched it, deformed it and to some extent contorted it. Among the most singular variations, even though it was not very diffused, we can cite that which was called the "theory of the two Earths" explained by Yao Xin, a 3rd century astronomer, in Xin Tian Lun (Dissertation on Diurnal Revolutions) of which some fragments still survive in encyclopedias of later periods like the Tai Ping Yu Lan, of the Song Dynasty, which we have already encountered. Yao Xin affirmed that:

"The lower Earth is the support of the upper Earth: the Heavens move between the two".

(Tai Ping Yu Lan, II, 4b)

The fact that the Hun Tian school later placed the Earth at the centre of the celestial sphere, raised various objections since it was in contradiction to the constatation that the celestial North Pole was not at the zenith, but inclined towards the North. Furthermore, the theory of the celestial sphere did not fully explain why the celestial vault appeared to be thicker underneath the Earth, or why the points on the horizon where the Sun rose or set changed, or why its journey was longer in summer and shorter in winter. To tell the truth, an approximate explanation of these two latter points already existed in the Former Han Dynasty (206 B.C.- 8 A.D.) when it was believed that the Earth had as many as four types of movement. In fact, this can be read of in the Shang Shu Kao Ling Yao (Apocryphal Treatise on the Shang Shu Section of the Classics of History. Exploration of Mysterious Lightness) written in the 1st century B.C. and also included in Tai Ping Yu Lan:

"The Earth has four movements. At the winter solstice, being higher to the North, it moves 30,000 *li* towards the West. At the summer solstice, being lower and to the South, it moves 30,000 *li* to the East. At the two equinoxes it is at the centre. Earth moves without stopping but men do not know it: they are like people sitting in a ship with closed windows; when the ship sails they do not realize it."

(*Tai Ping Yu Lan*, XXXVI, a)

So, the double movement of the Earth, vertically up and down and horizontally from West to East, could roughly explain not only the apparent variations of the celestial vault but also why the Sun moved towards the North in the summer and to the South in the winter. It was the Earth which moved in an inverse sense and so, when in summer it was South of the celestial sphere, the Sun appeared to be in the North and viceversa in the opposite sense with the Earth in the North and the Sun apparently in the South. It remained, however, extremely complicated to represent the double movement of the Earth along the vertical and horizontal axes of the celestial sphere, especially when considering that for the Hun Tian theory, the Earth should have been at the centre of the Universe. Zheng Huan (127-200), commentator of the *Zhou Li* (Document on the Rites of the Zhou Dynasty) and supporter of the Hun Tian school, interpreted the terrestrial dislocations in his commentary which was included more than a thousand years later in the collection *Gu Wei Shu* (Ancient Mysterious Books) compiled during the Ming dynasty in the following way:

"Here are the four movements. Starting from the spring position, the Earth and the (twelve) signs move towards the West; the spring equinox is the extreme point of their movement to the West but, although the Earth is (then) at the extreme West, it is at the centre of its ascending and descending movement. From here, the Earth and the twelve signs move towards the North; at the summer solstice they are at the extreme point of their northward movement; the Earth is then at the lowest point of its rising and falling movement; in the third month of summer, they are right in the centre. Starting from the autumn position, the Earth and the signs move eastwards; at the autumn equinox, they are at the extreme point of their movement towards the East; the Earth is then right in the middle of its rising and falling movement; in the third month of autumn it will again be right in the centre. Starting from the winter position, the Earth and the signs move southwards; at the winter solstice they are at the extreme point of their movement towards the South; the Earth is then at its highest point of its rising and falling movement; in the third month of winter it is right in the centre."

(*Gu Wei Shu*, I, 4a)

This description, from which it appears that the motion of the Earth in the celestial sphere is composed of two different movements, holds great interest because, even though it is remote, it predicts with great intuition the most evident two real movements of our planet: the rotation on the polar axis, which produces the alternance of days and nights, and the revolution around the sun which determines the cycle of the seasons.

As we have seen, even the quantitative issues relative to the measurement of the celestial sphere find a certain amount of space among the supporters of the Hun Tian theory; for example, the dictionary *Er Ya* (Literary Definer) compiled during the Qin Dynasty or at the beginning of the

Former Han Dynasty, between the 3rd and 2nd centuries B.C., fixed the following dimensions:

diameter of the celestial sphere = 387,000 li;

distance between Earth in a central position and the walls of the sphere = 193,500 li.

In He Luo Wei (Map of the River Luo) of the Han period, the distance between the Earth and the celestial sphere is valued at 678,500 li, while in the contemporary Ling Xian (The Spiritual Constitution of the Universe), Zhang Heng establishes the diameter of the celestial sphere as being 2,032,300 li.

Even if the calculation of the dimensions of the celestial sphere were subject to debate, it was never really firmly anchored to the theorists of the Hun Tian theory many of whom preferred the concept of space without precise dimensions. It is in this diffuse conceptual attitude that the influence of the Xuan Ye school (which hypothesized empty and infinite space) can be clearly traced and it can be featured as a large element of syncretism between the two notions about the structure of the world. It was probably the capacity to unite with the other schools of astronomy which determined the long success of the Hun Tian theory which remained the most officially followed until the introduction in China of European astronomy by the Jesuit scientists between the end of the 16th century and the 18th century.

The Xuan Ye Theory (Empty and Infinite Space)

The Xuan Ye theory hypothesized that the celestial bodies were immersed in an infinite space. This view shows the astonishing intuitive precocity of the Chinese if one considers that such complete cosmological views were formulated in the West only many centuries later.

Literally, xuan ye means "dark night", or better "night which pervades everything", but the translation "empty and infinite space" seems more consistent and refers to the idea of the structure of the universe held by the omonymous school of astronomy.

The date of this theory is somewhat controversial and the high consideration that it has enjoyed in the field of historical studies of astronomy has also had ups and downs. Some would say that the Xuan Ye school dates back as far as the Xia period (from about the 21st century to the 16th century B.C.) giving it great weight in the formulation of all ancient Chinese thought, while others retain it as

having belonged to a later period and as being practically unknown if not for some rare literary mentions.

Indeed, the first written document which refers to Xuan Ye is rather late with respect to those of the Gai Tian and Hun Tian theories and belongs to the Jin Dynasty (4th century A.D.), but in it there is a clear reference to its antiquity and to the fact that the books that have dealt with this theory went missing. The text in question is attributed to the famous alchemist Ge Hong and is part of the "Dynastic History of the Jin. Monography on Astronomy" (Jin Shu. Tian Wen Zhi):

"The books of the Xuan Ye school were all lost but Chi Meng, one of the librarians (of the Han Dynasty, 2nd century A.D.) remembered what the teachers of this school, its predecessors, thought about the theory of empty and infinite space. They affirmed that the heavens were empty and lacking in substance. When we look towards them, we see them as being very high and far without boundaries. It is as if the human eye was unable to distinguish colours, and the pupil not able to see far away. This is why the heavens seem to be a deep blue. It is like looking at yellow mountains from the side and at a great distance, so that they all seem blue. Or when we look fixedly in a deep valley with millions of branches, this seems dark and black. But the blue of the mountains is not the real colour and neither is black the genuine colour of the valley. The Sun, the Moon and the myriad stars float freely in empty space, advancing and stopping repeatedly. All these planets are condensed vapour (qi). Like this the seven luminous bodies (literally the "seven sources of light": the Sun, the Moon and the five planets) sometimes appear, sometimes disappear, sometimes advance and sometimes retrocede, as if each one of them was following a different series of rules; they always advance and retrocede differently from each other. This is because they are not fixed to any (common) base or joined together, and so their movements can vary so markedly. Among the celestial bodies, the polar star always keeps its place, while the Great Bear disappears under the line of the Horizon to the East, as do the other stars. The seven luminous bodies all fall towards the East, the Sun makes one degree in a day, the Moon thirteen. Their speed depends on their different nature, which shows that they are not linked to anything, because if they were attached to the body of the heavens, it would not be that way.

(Jin Shu. Tian Wen Zhi, XI, 2a)

The philosophical influence which inspired this passage is evident from the presence of concepts such as "lacking in substance" (wu chi) and "without boundaries" (wu ji) which belong to that area of thought schematically denominated as Taoism which affected Chinese science very much. It should be emphasized that it is precisely the idea of "empty" and "infinite" which leads us almost automatically back to the "Large Vacuum" by Laozi, the legendary inspirator of Tao Te Jing (The Way of Life) which represented the bible of Taoism.

During the times of Ge Hong, author of the preceding excerpt, another character was favourably interested in the Xuan Ye theory. This was Yu Xi, discoverer of the phenomenon of the precession of the equinoxes, who wrote in An Tian Lun (Discussion on the Peaceful State of the Heavens) of 336 A.D., also included in Jin Shu:

"I think that the celestial vault is infinitely high and that the space below Earth is infinitely deep. Undoubtedly, the structure of the upper celestial vault is in a permanent state of rest, and the mass of the Earth below also remains quiet and immobile. One envelops the other: if the first is square so is the latter; if the first is round the other must also be round; they cannot differ in being square or round. The luminous bodies are distributed, each according to its course, like the ebbs and tides of the sea and of

the rivers, and like the millions of living creatures which at times reveal themselves and at others hide."
(Jin Shu. Tian Wen Zhi, XI, 2b)

This passage, in which the disagreement with the Hun Tian theory which proposed a "square earth" and "round heavens" is evident, demonstrates the existence of a cosmological debate during the Jin Dynasty. The formulation of the Xuan Ye proposed in the 13th century by Deng Mu in Bo Ya Qin (The Lute of Po Ya) is even more complex:

"The Heavens and the Earth are large and, although in the immensity of the empty space they are just grains of rice, it is as if the empty space was altogether a tree and the Heavens and Earth one of its fruits. Empty space is like a kingdom and the heavens and Earth are none other than a single individual in that kingdom.

On a tree there are many fruits, and in a kingdom there are many people. How irrational it would be to suppose that other than the heavens and the Earth which can be seen there are no other heavens and earths!"

(Bo Ya Qin, 22)

From the analysis made so far, one of the founding elements, together with emptiness and infinity, of the Xuan Ye theory has not yet fully emerged: the primordial vapour qi. Already encountered in the Gai Tian and Hun Tian schools, the concept of qi assumes particular relevance in the late formulation of the Xuan Ye theory. Indeed, in the Xuan Ye theory, it is possible to find the most modern of the current theories of the origin of the Earth and the celestial bodies which, according to the theory are formed by the progressive condensation of gaseous matter.

This hypothesis, which we have already mentioned with the words of Ge Hong in Jin Shu, was repeatedly put forward during the so-called Three Kingdoms period (220-280), when, with the decline of the Han Dynasty, the Chinese empire dismembered and three reigns were founded in three different key economic zones: the Yellow River basin (Wei, with Loyang as its capital); the fertile region of Sichuan (Shu, with capital Chengdu); and the land of the middle and lower Yangzi (kingdom of Wu, capital at Wuzhang and later at Nanchino). In this period, in the different geographic areas, China experienced a renewed economic and cultural development. We will briefly outline the characteristics of this period since they also had a great impact on the field of astronomy.

At the end of the Han Dynasty, the Yellow River basin had suffered extremely serious devastation and the population had diminished considerably due to the war, shortages and epidemics. The North of China, therefore, found itself in a favourable food situation since the small amounts of food available were more than sufficient for a population which was rapidly declining. So, it was relatively easy to relieve the hunger of the peasants and set up a military rural policy which slowly eased the agricultural economy and simultaneously assured provisions to the troops. In Southern

and Central China, the issue of development was in the same phase. What counts most is that the new economic drive had an important impact in the scientific and literary fields and, during the Three Kingdoms period, technological and artistic progresses were exceptional. For example, during the Shu rule, the ten-arrow crossbow and a human-drawn vehicle were invented; during the Wei rule, the catapult was improved and at Wu, enormous vessels able to transport 10,000 people were constructed. Moreover, at Wei, in North China, coal was used for the production of heat and weaving techniques were improved. In the literary field, during this period two forms of poetry took form: fu and shi, which still remain the most important examples of creativity in the history of Chinese literature. In philosophy, where Confucianism dominated, a stream was diffused which was sensitive to the problems of metaphysics and this had an immediate impact on scientific thought. Noteworthy contributions were made in the field of mathematics, especially at Wu and Wei; in this field, we can recall that at Wei, in 263, Hai Dao Xuan Jing (Marine Island Manual of Mathematics) by Liu Hui appeared, which was entirely dedicated to the measurement of distances and heights for military scopes as well as civil. This volume was integrally included in many mathematical texts of later periods.

In the field of astronomy, as told by the "Dynastic History of the Sui Dynasty" (Sui Shu, XIX, 2a,b), the Dynasty which ruled between 581 and 618, Wu's Royal Astronomer, Chen Zhuo, prepared in 310 a map of the stars and constellations according to the three schools, Gai Tian, Hun Tian and Xuan Ye, distinguishing with different colours the stars ascribed to each theory. Moreover, during the period of the Three Kingdoms, famous astronomers such as Wang Fang and Yang Quan were active. The first was one of the innovators of the armillary sphere since he placed a model of the Earth in the centre; he also wrote Hun Tian Xiang Shuo (Dissertation on Uranographic Models). The latter, Yang Quan, author of Wu Li Lun (Dissertation on the Origin of Things), became generally associated with the Hun Tian school, but was really the mediator between this theory and the Xuan Ye; he repeatedly advanced the hypothesis of the origin of celestial bodies being due to the condensation of qi and seems to provide a good representation of the cross between metaphysics, creativity and cultural renewal which was expressed during the Three Kingdoms period:

"The Heavens are made of vapour (qi), everything is made of vapour, there is nothing else. The Earth has a force, while the Heavens have no body; like vapour begins and rises, its essence starts to waver towards the heights softly following a path called the Milky Way, and like this the stars were born."

(Wu Li Lun, in Xu Bo Wu Zhi, "Supplement to the Document on the Investigation of Things", 12th century, I, 4b)

The conscientious integration between the concept of qi and the Xuan Ye theory was fully achieved only among the neo-Confucian philosophers (11th-12th centuries). Ma Yong-

qing in his Lan Zhen Zi (Book of the Master of the Truth through Laziness), in 1115, wrote:

"The Heavens are nothing more than a condensation of air; one cannot compare them at all to substances with form and limits. The higher you go, the further you will find yourself. I do not believe that there is a definite distance between the ground and the Heavens."

(Lan Zhen Zi, I, 12a)

Other neo-Confucian philosophers, like Shao Yong and Zhu Xi, often refer to the "impestuous wind" (gang qi or gang feng) which sustains the celestial bodies and makes them move. But it is in Zhang Zai that the Xuan Ye theory was fully reformulated and integrated into the Hun Tian. In synthesis:

- a) the Heavens are "the great emptiness, lacking in substance" (tai wu wu ti) and are made up of wavering yang;
- b) the Earth, at the centre of the Universe, is composed of condensed yin;
- c) the stars are composed of gaseous qi in tumultuous rotation along with the Heavens;
- d) to explain the westward movement of the Sun, Moon and planets, a retrograde movement with respect to that of the fixed stars, Zhang Zai theorized that it depended on their extreme nearness to the Earth, which, although still, has a qi in slow rotatory movement towards the left; it is precisely the qi of the Earth which creates obstacles to the bodies of our solar system which because of this have a slight delay with respect to the Heavens and appear to have a retrograde movement compared to the fixed stars which are not influenced by this phenomenon of "viscosity" because they are very far from the Earth;
- e) the most delayed is the Moon, which being composed of qi like the Earth is, therefore, influenced the most;
- f) the fastest is the yang Sun; the five planets have speeds which are intermediary between that of the Sun and that of the Moon.

Even in this late formulation, the Xuan Ye theory was known for its absolute lack of numbers. In other words, it was a qualitative theory but never a quantitative one. With respect to the measurements of the Universe, it therefore seems clear that the Xuan Ye is refractory as regards these evaluations. That is, it is in character with the grandiose notion of an incommensurable space. It was probably the very perception of the concept of infinity, with the consequent recognition of the uselessness of quantitative estimates of the celestial sphere, which was simultaneously a propulsive element of the theory yet also responsible for its decline. Indeed, a culture such as that of the Chinese, obsessively tied down to the search for numbers and numerical relations

in order to picture and synthesize the Universe, could not reinforce a school of thought which refused these numbers. Even if a certain theoretical influence was always attributed to the Xuan Ye school (one only has to think of the concept of infinity permeated in the Hun Tian), it did not, however, have any practical impact. The fact that the mathematical speculations connected with the calendar refer prevalently to the Hun Tian theory proves this point.