Nathan Sivin

Medicine, Philosophy and Religion in Ancient China

Researches and reflections

VARIORUM
1995

V

On the Limits of Empirical Knowledge in Chinese and Western Science*

My theme is the limits of scientific inquiry, that is, ancient Chinese concerns about whether nature can be comprehended fully by rational, empirical investigation.[1]

We find the limitations of observational knowledge taken up regularly in writings on astronomy, the most exact of the ancient sciences, but not in astronomy alone. Because this theme mainly appears in technical discussions rather than in writings of a general kind, we can avoid the dangerous assumption that the opinions of philosophers determined what scientists thought in China. What does emerge from the writings of fifteen hundred years is an abiding interest in the idea that the scale of the cosmos is too large, and the texture of nature is too fine, too subtle, too closely intermeshed (*wei*, *miao* and so forth) for phenomena to be fully predictable. This proposition denies that the physical world can be fully penetrated by study or fully described in words or numbers. The cognitive strategy behind it evolved, and its history can be traced.

This is not the indeterminacy of contemporary theoretical physics, a point to which I will return in the conclusion, but a range of qualitative convictions drawn from mundane experience. A philosopher might divide this gamut into ontological and epistemological indeterminacy. Epistemological indeterminacy denies that it is possible to comprehend the order and regularity of the universe through study. Ontological indeterminacy asserts

* An earlier version of this article has been published in *Time, Science, and Society in China and the West* (*The Study of Time V*), J.T. Fraser et al., eds. (Amherst: University of Massachusetts Press, 1986.) It appears herein courtesy of the Publisher and the Editors.

that, beyond a certain point, the universe lacks the order and regularity that empirical study strives to find. The Chinese did not make such a distinction, which has analytic uses that will become clear when in my conclusion I summarize the evolution of thought about the limits of knowledge.

Before looking at this idea historically, let me introduce two short but typical statements about astronomy's inherent limitation as a science. Here is an early assertion of this idea, which the polymath Cai Yong wrote in A.D. 175:

> The astronomical regularities are demanding in their subtlety, and we are far removed from the Sages [who founded this art]. Success and failure take their turns, and no technique can be correct forever. ... The motions of the sun, moon, and planets vary in speed and in divergence from the mean; they cannot be treated as uniform. When the technical experts trace them through computation, they can do no more than accord with [the observations of] their own time. Thus there come to be [differences between] the techniques of various periods.[2]

Cai's lack of confidence should not be dismissed as a simple reflection of the crude techniques available in the second century, as we will see when we return to that period. First, let us take a passing look at a much later time, when Western astronomy was widely known. Perhaps the last such statement on the part of a scholar well qualified in astronomy comes from Dai Zhen (1724–1777), the leading philologist and in many respects the most influential intellectual of his time, in his essay on solar theory:

> In all prediction of celestial phenomena, as time passes there are bound to be errors that are due neither to inaccuracies in positional data nor to the need for periodic revision of computational methods. The sphere of the sky is so enormous that number and measure cannot get to the end of it, just as when we measure something an inch or a grain at a time, there is bound to be discrepancy by the time we have counted up to a foot or an ounce. Because this is so, we define units of time and observe phenomena so as to make the most of our techniques. Our best course is to continue using a technique so long as its inaccuracies remain imperceptible, and to correct it once they have been noticed. This is a matter of indeterminacy, as error accumulates over a long period.[3]

Now let us look at some of the early philosophical ideas that may have formed the backdrop to statements about cosmic indeterminacy. Then we can consider the historical development of such statements themselves, in astronomy and in other departments of knowledge. Finally, we can ask what light this theme casts on the character and history of prediction as a goal of Chinese science.

It is important to look at each statement, not as a great idea that must be taken at face value, but as a reflection of the viewpoint of someone with certain interests in certain historical circumstances. Since this is only a sketch of work in progress, I will consider only a few sources, and summarily indicate their circumstances.

In the pre-Han classics, it is remarkable how seldom words such as *wei*, *miao* and *xuan*, which later imply subtlety and indeterminacy, refer to the possibility of knowledge. One pertinent treatise is the Great Commentary to the Book of Changes, the major source of orthodox cosmology from the Han on. There the word *wei* refers to the gentleman's sensitivity to the ethical implications of a situation as soon as they begin to evolve, long before they become obvious. Its statements are clearly not about factual or theoretical knowledge of the natural world.

In the *Laozi* we find several other pertinent ideas. The Way itself in its constant and unchanging aspect, we are told, is shadowy and indistinct, and cannot be described. *Wei* and similar words are never clearly applied to the empirical world or to theoretical knowledge, but *wei*, *miao* and *xuan* appear together in one line that describes the exemplary gentleman:

> Of old those adept in the Way
> Their mastery recondite, subtle, and mysterious,
> Were too profound to be known ...

One might guess from familiarity with the *Laozi* as a whole that the Sage becomes indeterminate as he models himself on the indeterminate Dao that he contemplates, but the text does not go quite that far.[4]

To sum up, by 300 B.C. certain aspects of the Dao were described as indeterminate, but these aspects are not identified with the phenomenal world, which can be described. Words implying indeterminacy rather than ineffability are used to describe the character of the ideal person rather than that of the cosmos. Not surprisingly, the key words above, which later appear in astronomical discussions, do not occur in any germane sense in the *Zhuangzi*. That book consistently rejects the humanistic orientation that we have found in the *Laozi* and the Great Commentary, and finds the logical description of experience useless.[5]

The indeterminacy of the cosmos finally appears in less ambiguous form in the *Chunqiu fan lu* (135 B.C.), Dong Zhongshu's attempt to construct for the Han state a new intellectual orthodoxy that used the cosmic order to undergird the political order:

> The Ancients had a saying that if you do not know the future you can see it in the past. Now, in the study of the Spring and Autumn Annals, statements about the past are used to clarify the future. But because its words embody the subtlety of the natural order [*tian zhi we*], they are hard to comprehend.[6]

Dong is using the subtlety of nature, its resistance to being understood, as a metaphor for the arcane language of the orthodox classic.

Indeterminacy in Astronomy

Now let us pass on to the earliest statements about the limits of astronomical prediction. Most such assertions appear in the Standard Histories that chronicle the affairs of each dynasty. Computing the ephemeris and interpreting ominous phenomena were matters of concern to the state, which attempted to center this activity in its Astronomical Bureau and Imperial Observatory. Once astronomy was thus tied to the imperial charisma, a succession of computational systems for predicting the positions and chief phenomena of the sun, moon and planets was officially adopted; there were nearly fifty such systems between the beginning of the first century B.C. and the middle of the seventeenth century A.D. Improvement in technique did not lead to revision of the system in use, but to its complete replacement by a new one. This, at least, was the principle; in practice we find occasional traces of piecemeal revision, and several replacements that were no improvement at all. New systems were sometimes ordered up to signal a new dynasty or to announce a "new deal." On such occasions innovation was too much to expect.

Nearly all the judgments about astronomical systems in the Standard Histories were set down when a new system was presented for adoption, or when an old system was regularly failing to give accurate predictions. Today a sensible person who plans to buy an automobile, and who wants to find out about the limitations of a certain design, would not ask a salesman who sells that model, but would consult someone who has been driving one for some time. In astronomy, as well, familiarity breeds frankness. We usually find doubts about the extension of knowledge expressed, not with respect to a system newly presented for adoption, but when the shortcomings of an established system have become apparent; and this is all the more true when, because a competitor is in the offing, the tenure of the established system seems limited.

Probably the most serious period of crisis and reassessment in early mathematical astronomy began shortly before the end of the first century A.D., when the Grand Inception system (*Taichu li*), adopted in 104 B.C. and greatly developed as the Triple Concordance system (*Santong li*) a century later, was about to be replaced.[7] In A.D. 92, Jia Kui presented the throne with the first major document of this crisis, his "Discussion of Calendrical Astronomy" (*Lun li*). He writes of what we would call the imprecision of constants. Even the constants instituted by the legendary Sages who founded astronomy in the Golden Age,

> unable to endure unchanged [lit., "run through"] for thousands and myriads of years, must be altered and replaced. We [in later times] first determine angular measures and numerical quantities from the observations made over long intervals, and select those that accord with the positions of the sun, moon and planets. ... [Our] methods will thus differ from one period to another. The Grand Inception system [of two centuries earlier] cannot give accurate predictions for the present day; nor can the new system provide correct computations back to the beginning of the Han period. The computational methods of a single school can only be applicable within an interval of three hundred years. ... When the Han first attained power, it would have been appropriate to adopt the Grand Inception system [because time had come for renewal]; but there was no such reform until 104 B.C., 102 years later. Thus, early in the dynasty, there were lunar conjunctions the day before the last day of the month [i.e., two days before mean lunation], but by the

> time of Emperors Cheng and Ai (32 B.C. to A.D. 1), the second day of the month was being taken as the day of lunation [i.e., the civil month was routinely set back one day], so that most conjunctions would occur on the last day of the month [which was allowable in the early Han]. This is clear proof [that calendar reform is periodically necessary].[8]

Why cannot even the Sages discover constants precise enough to be used forever? That Jia explained earlier in his report: "The Celestial Way being irregular, lacking uniformity, there are bound to be remainders. These remainders will have their own disparities, which cannot be made uniform."[9] Imprecision is not a characteristic of the constants, that is, but of the universe.

By the end of the second century, as my earlier quotation from Cai Yong indicates, the implications of indeterminacy had become much broader than in Jia Kui's time, and were affecting prediction in ways that did not depend only on the precision of constants.

Although the sun moves along the ecliptic, and the moon is never more than six degrees from it, Han astronomers measured their positions along the equator. The ability to convert mathematically from positions on the ecliptic and the lunar orbit to equatorial right ascension and vice versa was beyond the simple linear techniques then in use. This made major improvement in eclipse theory – the central problem in traditional astronomy – seem hopeless. A report of lunar-eclipse prediction of the late second century outlines this difficulty at some length, and then draws an eloquent conclusion:

> In view of this [limited feasibility of mathematical solution], there is no point in rejecting any method that does not conflict with observation, nor in adopting any method whose utility has not been demonstrated in practice. The Celestial Way is so subtle, precise measurement so difficult, computational methods so varying in approach and chronological schemas so lacking in unanimity, that we can never be sure that a technique is correct until it has been confirmed in practice, nor that it is inadequate until discrepancies have shown up. Once a method is known to be inadequate, we change it; once it is known to be correct, we adopt it: this is called "sincerely holding to the mean."[10]

The anonymous author is expressing resignation in the face of the crisis I have referred to. Imprecise constants could always be revised, but it was now clear – puzzlingly clear – that Han assumptions about the character of the celestial phenomena were beginning to break down. It was beginning to be apparent that certain phenomena, especially eclipses, could not be described by simple cyclic or linear methods. Finally, when this difficulty could not be resolved over several centuries, astronomers stopped trying. Cosmological hypotheses no longer ordered their computational techniques. They bought the power to predict in the simplest possible way, at the cost of the power to explain. This is a cost that greatly limits the power to predict in the long run, a lesson that did not become apparent until the seventeenth century, when the best astronomers of the time enthusiastically recognized the explanatory power of the geometric models introduced by the Jesuits.[11]

Not everyone had reason to accept the idea of astronomical indeterminacy. We might expect people defending new astronomical systems rather than criticizing old ones to argue against it; indeed, examples are not hard to find. There is the spirited and rather exasperated rejoinder of Zu Chongzhi, one of China's greatest mathematical astronomers, against the attack on his new system by Dai Faxing.

In or near 463, Dai developed an extensive argument along the lines of those I have quoted. Zu's defense, pragmatic rather than theoretical, is too long to cite completely:

> The writings of the Xia, Shang and earlier dynasties have been lost; but the historical chronicles of the Spring and Autumn period and the Han period record eclipses and lunations with care for detail; they constitute clear evidence. Testing my astronomical system by their use, I find the data entirely in accord [with my computations]. There is truly nothing speculative in [my system]. It takes precision as far as possible, so that over a span of a thousand years there is no discrepancy; whatever it be, far away though it be, it can be known. Now, I have studied all the ancient methods, and there I find much that is inexact. Computations are off by as much as three days, and the beginnings of *qi* periods by as much as seven hours. I know of no [ancient system] that can accurately predict the phenomena of the present time.[12]

Zu's claim that there would be no discrepancy in predictions over a thousand years was excessive. It did not accord with informed opinion, could not be proven in practice, and he did not make it persuasive in principle. For reasons as much political as technical, he did not carry the day. Despite its excellence, his system was not officially adopted for fifty years.

In 729, Ixing discussed the technique for predicting lunations in his new Great Expansion system (*Dayan li*). He politely suggested that, even if the course of the cosmos were inherently too irregular to be fully comprehended – and he did not minimize its irregularity – that would be irrelevant to the work of prediction:

> If the anomalies in the celestial positions [of the moon] actually fluctuated with time, providing rebukes [to the ruler] that the regularity of astronomical constants cannot encompass, and substituting for regularity a mutability [that derives] from the inaccessible [fine structure of the cosmos], this would be a matter beyond even [the ability of] Sages to assess. It can hardly lie within the scope of mathematical astronomy.

This is a more meaningful statement than its brevity and skeptical tone make it look. In the first place, it reminds us that Ixing was anticipating exactly the sort of argument that Zu Chongzhi had had to fight off. The idea that astronomical knowledge was inherently limited was now being used even against the best new systems rather than just to explain the failure of old ones. Second, for Ixing the conceptual crisis I have mentioned was long over, and a disinterest in cosmology was the norm among astronomers. They rarely took up questions of the actual spatial relations or physical realities underlying the phenomena. It is curious, considering Ixing's lack of interest in these questions, that he remains the last great astronomer to give cosmology an important role in his computational system. His cosmology was not physical, however, but drew in a curiously antiquarian way on the numerology of the Great Commentary to the Book of Changes.[13] Still, his curiosity in such matters was much narrower than that of his Han predecessors. The astronomical systems that followed Ixing's were narrower still from the viewpoint of cosmology.

Decreasing interest in the metaphysical and physical patterns that underlie such phenomena is not necessarily associated with more "scientific" trends in astronomy, either in China or in the

West, because in scientific work (as distinguished from certain ideal schemes of philosophers and historians of science) analysis of data and thought about their ultimate significance interact. It was the demand for a coherent and intelligible cosmic order that motivated Copernicus, Galileo and Kepler to innovate in directions that became decisive for modern science.

New Issues in the Song

By the Northern Song period, discussions of the sort I have summarized were either too rare or too familiar to record. Many of the difficulties that had originally suggested inherent limitations to knowledge were no longer difficulties; for instance, the time of lunar eclipses could be predicted with some confidence. The issue for the working astronomer, as I have said, had become not knowability but technical progress. Whether some day his science might reach those ultimate limits, or would always fall short, was not an urgent problem.

In the Song period, the idea of indeterminacy suggested ultimate questions of a new kind. These questions came from astronomers better prepared than their predecessors to explore methodological and epistemological aspects of their science, and from philosophers whose main interest was those aspects. My examples will be Shen Kuo (or Shen Gua, 1031-1095), who counted professional astronomy as one of his enormous range of accomplishments, and Zhu Xi (1130-1200) and Cai Yuanding (1135-1198), to represent the philosophers.

In his Brush Talks from Dream Brook (*Mengqi bitan*), Shen summarizes the lost preface to his Oblatory Epoch system (*Fengyuan li*), an innovative document:

> Those who discourse on numbers [by which he means all regularities that make prediction possible], it seems, [can only] deal with their crude after-traces [*ji*]. There is a very subtle [*wei*] aspect to numbers that those who rely on mathematical astronomy are unable to know; [what they can know of] this aspect is, all the more, only after-traces. As for the ability [of the sagely mind as exemplified in the Book of Changes] "when stimulated to encompass every situation in the realm," after-traces can play no role in that [wisdom]. That is why "the spirituality that makes foreknowledge [possible]" cannot readily be

> sought through after-traces, especially when one has access only to the crudest ones. As for the very subtle traces I have mentioned, those who in our time discuss the celestial bodies depend on mathematical astronomy to know them, but astronomy is no more than the product of speculation [*yi*].

Shen proceeds to develop an epistemological point that comes up several times in his writing, namely that in order to know, we break the continuity of nature into blocks of time that we treat as though each were uniform. As he puts it,

> The uninitiated say that, mathematical knowledge of the heavenly bodies being difficult to be sure of, only correlations between the Five Phases and time periods are reliable, but this is also untrue. The uninitiated who discuss the cyclic alternations [*xiaozhang*] of the Five Phases consider only the year. Thus [they know that], after the winter solstice the sun's motion is in the phase of Expansion [i.e., the equation of center is negative] and thus yin, and at the equinoxes corresponds to the mean. They do not realize that in the course of a month there is also an alternation. Before opposition, the moon's motion is in the phase of Expansion and thus yang; after opposition, it is in the phase of Contraction and thus yin; and at the quadratures, it corresponds to the mean.

As for the associations of Spring with Wood, Summer with Fire, Autumn with Metal and Winter with Water, these are also true of the month, and not only of the month but of the day. The "Basic Questions" of the Inner Canon of the Yellow Lord [*Huangdi nei jing su wen*] says "when the disorder is in the hepatic system, the onset [of an attack] is between 3 and 7 A.M., and the most serious time is between 3 and 7 P.M. When it is in the cardiac system, the onset is between 9 A.M. and 1 P.M., and the most serious time is between 9 P.M. and 1 A.M." Thus a single day has four seasons of its own. How do we know that there are not four seasons in each hour, or in each mark,[14] each minute, each instant? And how do we know that there are not a greater four seasons in each decade, century, Era cycle, Coincidence cycle and Epoch cycle? As for the association of Spring with Wood, within a period of ninety days there must be one [completed] cycle of alternation within another. It is impossible that the last hour of the 30th of the third month should belong to Wood, and the first hour of the next day abruptly belong to Fire. Matters of this sort are not to be settled by the methods abroad in the world.

In this second part of his short essay, Shen is writing about techniques of foreknowledge that depend, not upon observations of celestial events, but on associating in rotation the Five Phases with periods of time (for instance, the year, month, day and hour of birth), in order to yield interpretations of the latter. This simple, repetitive approach may have begun with astrology, but has been completely abstracted from what happens in the sky. Such methods cannot be reliable, Shen argues, because they imply regular and abrupt transitions from one block of time with its corresponding phase to the next. But such "quantum" transitions belie the continuous variation in motion of the celestial bodies from which the validity of the methods ultimately derives. This underlying continuity of variation, ignore it though we may, pervades time at every level from the fleetest instant to the long cycles of calendrical reckoning (the Epoch Cycle of the Han was 4,560 years).

Anyone familiar with the philosopher of physics Alfred North Whitehead (1861–1947) will find this line of reasoning familiar. Shen, like Whitehead nine centuries later, was saying that a central problem for science is the gap that seems to separate our unconnected experiences from the unitary causal world that lies veiled in back of them.[15]

Scientific mensuration is necessarily an act of abstraction. Near the beginning of his proposal of 1074 for a new armillary sphere, Shen argues this point with great clarity – for the first time in history, I believe:

> Degrees [on the equator and ecliptic] are invisible; what is visible are stars. [The paths] followed by the sun, moon and planets are occupied by stars. Twenty-eight stars are located [exactly] on a degree division; they are called "mansions" [*she*]. It is mansions that make it possible to measure degrees, and degrees that make it possible to create numerical regularities. Degrees are things that exist in the sky. When we make an armillary sphere [to measure intervals between real bodies], the degrees exist in the instrument. Once the degrees are in the instrument, then the sun, moon and planets can be isolated [*tuan*] in the instrument, and the sky no longer is involved. It is because the sky is no longer involved that what is in the sky is not difficult to know.[16]

Shen implies that one can know either about the organismic universe as a whole ("the sky") or about particular phenomena in it. Observational, empirical science can yield only knowledge of the sécond kind (a point about which Whitehead would disagree). In doing so it rules out perceptions of the first kind. They can be reached only by other kinds of knowledge – intuition, illumination and so on – in which Shen is equally interested.

Cai Yuanding, another polymath, did away with one of the basic confusions of the Han astronomers. Cai wrote at least one book on mathematical astronomy. This detailed study of Ixing's astronomical system is lost, but certain important arguments are preserved in the conversations of Cai's mentor and friend, Zhu Xi, with Zhu's disciples. It is clear from Zhu's paraphrases that Cai believed inaccuracies of prediction do not imply indeterminacy. Beneath an irregularity may lie a more complicated regularity waiting to be discovered:

> When an astronomical system is first being designed, the discrepant measures of the celestial rotations are combined and included in the computations. So, many years later, there will be discrepancies of so many fractions of a degree, and after so many additional years, of so many degrees. If, from these discrepant quantities, correct quantities are computed, and this process is repeated to the limit [i.e., until the magnitude of the correction becomes negligible, *jintou*], the astronomical system can be made essentially correct and free of discrepancies.
>
> People today, never having reached a comprehensive and correct understanding [*da tong zheng*], simply claim that the discrepancies are inherent in the celestial rotations. They make systems of computation seeking accord with the celestial phenomena, but their ephemerides become increasingly discrepant. The point is this: they do not understand that, if the sky is able to manifest a certain discrepancy, it is precisely because the celestial rotation must be of that kind.

A discrepancy does not, as Cai's contemporaries think, reflect an anomaly in nature, but rather a more complicated regularity than originally assumed. Ad hoc technical adjustments simply obscure the discrepancies. In doing so they also obscure the underlying complex pattern that will keep generating discrepancies until it is understood.

This is an important perception about method. When we remember the gradual discovery in Europe of the various inequalities that complicate the moon's motion, we are reminded that the failure of Hipparchus' (fl. ca. 130–150 B.C.) first inequality to give perfect predictions suggested to Ptolemy (ca. A.D. 100 – ca. 165) the evection, the second inequality. The discrepancies for which the evection could not account suggested to Tycho Brahe (1546–1601) the third and fourth inequalities.

Similar processes of discovery can be traced in the history of Chinese astronomy, but Cai was the first (at least the first reflected in the surviving record) to make the point explicit. His own attitude toward the determinate character of the phenomena was decidedly nuanced, even though he did not accept his contemporaries' reasoning about what implies indeterminacy. Zhu quotes him elsewhere to the effect that "there is no constancy in the celestial rotations; the sun, moon, and planets are accumulations of *qi*; they are all moving things [*dong wu*]. Their angular motions may be faster or slower, beyond the mean or short of it; they are not naturally uniform."

We have already seen that Cai considers these motions predictable. As Zhu remarks, "Cai was not saying that there is nothing determinate in the rotation of the sky, but that the angular motions of the luminaries are as they are."[17]

The last quotation from Cai is best understood in the light of similar beliefs held by such Occidental luminaries as Plato and Ptolemy, for whom the planets are divine and self-propelled. This view was an alternative to the idea that the planets are passively driven in their rounds by some common source of motion that determines the speed of each. A philosopher who finds no evidence for mechanical linkages powering the celestial luminaries is likely to find the idea that each planet is the source of its own motion more plausible. Its velocity is thus internally determined and arbitrary with respect to those of other planets. If constant, it is arbitrarily constant. The 'erratic' retrogradations of the planets are thus accounted for; they could not be explained by those who considered the planets passive.

In Greece and Hellenistic Egypt, a source that determined its own motion would be divine; in China, it was an animal-like "moving thing." Neither implies that its motion must necessarily be irregular or unknowable. The astronomer simply attempts to impose order upon whatever irregularities his observations reveal. What matters about Cai's attitude is that he faced the issue of indeterminacy instead of making assumptions that render it all the more problematic. He could thus imply that, even when taken seriously, it need not impede astronomy.

Zhu Xi, like Cai Yuanding, did not believe that there were inherent limits to the astronomer's power to predict. His attitude emerges in several discussions of a chapter from the Mencius (*Mengzi*, 4B:26), which, in explicating the innate moral nature of man (*xing*), refers to the work of the astronomer. As Zhu explicates the relevant passage, it would mean: "Consider the sky so high, and its markpoints so distant; if we seek the traces of actual events [*gu*], without leaving our seats we can bring before us the solstices of a thousand years."

There is no basis for reading into Mencius' casual statement a pronouncement on the limits of empirical knowledge in astronomy. But Zhu Xi, in one of several conversations about the chapter, relates this passage to that question:

> Mathematical astronomers computing backward from the present day are able to proceed without error even to the moment when the physical cosmos was formed. This is possible only because they follow traces of actual events [*i ran zhi ji*]. There are sometimes irregularities in the true motions of the sky and of the sun, moon and planets, but as time passes these recur spontaneously to the norm.

Here Zhu Xi understands *gu* as traces of what exists or has existed; in other conversations, referring to other occurrences in the same chapter, he explains the word more subtly as "why something is so" (*suoyi ran*) and "what something does" (*suo wei*). He is using Mencius' undefined *gu*, relating it to Shen Kuo's undefined "traces," to refer to phenomenological patterns. In a society never touched by Plato's opposition of phenomenon and reality, this is a more original step than it might appear.[18]

In the discussion of astronomical prediction that provided the long paraphrase from Cai Yuanding quoted above, Zhu Xi begins more or less at the point where Cai stopped, but moves off in a significant new direction:

> Someone asked why calendrical systems are repeatedly inaccurate. "How can it be that in ancient and modern times no one has studied this matter thoroughly?" Zhu Xi replied: "It is precisely because no one has studied this

> matter thoroughly enough to rule out further change that there are repeated discrepancies. If it were studied with enough precision to yield a definitive method of computation, there would be no further discrepancies. ... The astronomical techniques of the Ancients were imprecise [*shukuo*, lit., loose], but there were few discrepancies. The more precise [*mi*, lit., tight] the systems of today are, the more discrepancies appear!"
>
> At this point, he measured off one side of his desk with his hands, saying, "For instance, if we divide this breadth into four sections, each is limited in width by its borders with the others. If a discrepancy [between the widths] appears, it will be restricted to one of the sections. Large though [the discrepancy] may be, even so extreme that it involved a second or third section, it would still be restricted to the four sections. So it would be easily computed, and any discrepancy could easily be seen. The astronomical systems of today [in effect] divide these four sections into eight, and the eight into sixteen. As the limits [of the sections] become more precise, the frequency of discrepancies becomes greater. Why is this? Because, as the limits become more precise, they are increasingly overstepped. The discrepancy may be identical, but the precision of ancient and modern systems differs."[19]

Zhu Xi is saying, if I understand him correctly, that increases of precision have led to greater expectations of accuracy, and that it is against these expectations that recent systems were failing; early systems satisfied lower standards. But that is not my point. This is the first clear explanation in Chinese, I believe, of the difference between accuracy and precision. This is not a small contribution to the methodology of the exact sciences. This was certainly not Zhu's aim, but it is hardly a by-product.

These concerns with method and with theory of knowledge, although ignored by modern historians, were carried on by the leading scholars of the Qing period. In a recent book, John Henderson traces the growing importance in Ming and Qing philosophy of arguments from mathematical astronomy. Henderson shows that these concepts of quantitative origin largely replaced earlier conceptions such as yin-yang and the Five Phases. For example, prominent humanists between the mid-seventeenth and late eighteenth century became aware, through Western astronomical writings which they studied eagerly, of such secular changes as the slow decrease in the obliquity of the ecliptic. They came to believe, as did many Europeans in the later part of the same period, that these were not entirely predictable, and their magnitudes could only be known through observation:

> A number of Ch'ing [i.e., Qing] scholars of varying scholastic affiliations thus identified several of the astronomical anomalies and deviations known to them as basically indeterminate, frequently drawing the conclusion that the patterns of the cosmos in general shifted in an irregular and even capricious fashion. They even regarded anomalies not so much as departures from a predictable order as themselves constitutive of the fundamental order, or disorder, of the cosmos.[20]

Limits of Inquiry in the Qualitative Sciences

It is not surprising that the issue of indeterminacy should have arisen mainly in astronomy, the one science that was both quantitative and concerned with prediction. The idea that empirical knowledge and understanding may be inherently limited also turns up in areas of inquiry that are not computational. Sometimes it is brought up by polymaths who are aware of the issue within astronomy. Shen Kuo, for instance, discusses a case in which lightning, striking a house, left its wooden structure unharmed but melted metal objects inside it.

> People insist that fire will burn things of vegetable origin before it melts things made from metals or minerals, but in this instance the latter all fused while not one of the former was destroyed by fire. This is not a matter that human capacities can fathom. A Buddhist treatise says "Water makes the Naga fire blaze up, but puts out the human fire." How true that is! People only know about matters in the realm of mankind. Outside that realm what limit can matters have? We may aspire, by our insignificant worldly wisdom and common sense, to get to the bottom of ultimate truths, but that is hardly possible.[21]

And I have already quoted one of Shen's references to medical theory.

We also find Fang Yizhi, in his Little Notes on the Principles of Things (completed 1643/1650), using what he had learned from Jesuit missionaries about optics to argue that the tendency of light rays to diverge and of shadows and images to converge renders certain optical phenomena unexplainable. Fang describes an experiment in which a piece of paper with four or five small holes yields multiple images of the sun. But, as the paper is moved upward, away from the surface on which they are projected, the multiple images blend – in a way that puzzles him – to form a single image of the sun. "Sound and light," he argues, "are always more subtle than the 'number' of things." By "number" Fang means amenability to exact quantitative description, as "by acute angles and straight lines," i.e., geometric constructions.[22]

In medicine, the idea that one can hope to understand only so much about the vital processes of the human body is natural enough. Ever since the sixth century, medicine has been strongly influenced by Buddhist ethics. Since its beginnings, physicians and medical scholars have drawn on numerology, yin-yang, and Five Phases cosmology, and even on astronomy, in order to investigate the links between the internal order of the body and the order of nature that surrounds it.[23]

An obvious example is Zhang Jiebin's statement, in his Collected Treatises *Jingyue quanshu* (preface dated 1593), about what is needed to comprehend vital processes: "Anyone who does not possess transcendent wisdom is not prepared to master their subtleties [*weimiao*]; anyone who does not possess clarity of moral judgment is not prepared to make fine distinctions concerning what is correct." Empirical observation, in other words, must be supplemented by self-cultivation.

In some such statements, Buddhist influence is plain to see. Typical is Yin Zhiyi's preface to his father, Yin Zhongchun's, little handbook of diagnosis and therapy, entitled Mental Dharmas of Eruptive Disorders (probably shortly before 1621):

> "Medicine" [*yi*] means "meaning" [*yi*]. [The inner meanings of medicine, the patterns of vital processes] may be apprehended by the mind, but cannot be transmitted in words. Because these inherent patterns attain such arcane subtlety [*weiao*], even though the mind may achieve great constancy [in contemplating them], in [therapeutic] doctrine there can be no fixed rules. The interaction of hot and moist as governed by yin and yang, the relations of mutual production and overcoming among the Five Phases, change from one moment to the next. ...

Yin begins with a familiar punning definition of medicine, and moves immediately to the Chan Buddhist notion of wordless teaching. Yin's word for therapeutic doctrine or method [*fa*] is the same as the term for dharma in the title of his father's book (in which "mental dharmas" means at one level "doctrines or truths to be grasped by the mind").

Such instances from therapeutic manuals could readily be multiplied. In astronomy, as we have seen, the limit of observation was a live and evolving issue. In medicine, however, what we find is reiteration of a familiar theme – a formula, more or less – that is seldom examined critically. My preliminary conclusion, pending deeper study and reflection, is that indeterminacy in medical writings is less significant for the history of medical thought than for epistemology in general.[24]

Conclusion

The sources on which I have drawn indicate that, in Han astronomy, themes of both epistemological and ontological limits on knowledge appear, but that, as experience led to confidence, the limit came to be seen consistently as one of imprecision rather than of inherent disorder. This situation continued until the two postulates were again combined in the attack on yin-yang and the Five Phases, as the basis of Confucian orthodoxy that John Henderson has documented.[25]

I have suggested that ideas of astronomical indeterminacy first arose to explain what would now be considered the failure of crude predictive techniques, and that this idea gradually became established to account for what historians would now explain as the failure of crude assumptions about the character of the celestial motions. As these assumptions were given up, and the crisis subsided, it seems that ideas of indeterminacy were for a while used more as a weapon to beat back innovation than as a means to reexamine past failures. These ideas began playing a productive role once more from the Song on, when they were used for diverse purposes, among them to direct critical attention to issues of what we would now call epistemology and method. Some who used them, including Cai Yuanding and Zhu Xi, did not accept the idea that empirical knowledge was necessarily limited.

Why should a notion that looks so obscurantist, so opposed to the idea of progress, have played such an enduring collection of roles in the history of science? To take first things first, since the idea of progress entered Western scientific thought in the eighteenth century, and that of China much later, how progressive a given early idea seems to moderns is beside the point. The point is rather what it meant and how it was used in its time.

I suggest that the idea of indeterminacy was the one proposition that consistently challenged astronomers to come to grips with the distinction between two issues: First, what is involved in predicting future observational data from past observational data? And second, what is involved in making intelligible the nature from which we draw observational data?

This is the difference between astronomy as a collection of data and techniques, and astronomy as a science. Despite the crisis in astronomy that began in the Later Han, the urge to make astronomy a science again never entirely subsided. It became a strong motivation from the eleventh century on, as impulses from philosophy stimulated astronomers, and vice versa. I think that, ultimately, it will be possible to show that discussions of the limitations of inquiry in the Ming and early Qing encouraged both the concern for causes and explanations in the seventeenth century and the prompt and positive response of leading Chinese astronomers to Western astronomy.[26]

The issue I have outlined does not seem to have been important in Western science after Heraclitus and Parmenides. The concept of quantum indeterminacy in modern physics is concerned with a quite different, purely mathematical, issue. It states that there is a small, constant limit on the combined precision with which we can simultaneously measure two parameters, for instance position and momentum, of a particle event. The better we know one, the worse we know the other, up to that limit. In translating the equations into ordinary language, some popularizers have read into this very abstract scenario portentous implications about the subjectivity of the observer, and have even concluded that, at the limit, theoretical physics collapses (or rises, as the case may be) into mysticism. Sympathetic though one may be toward attempts to combat a mechanistic arrogance for which there is also no warrant in the equations, these reinterpretations are not a triumphant revival of an old theme, but rather bad philosophy of science. They are irrelevant to the present topic.

For Plato, observation of phenomena alone cannot lead to knowledge of reality. It can yield only a third-hand reflection of the abstract Ideas that real knowledge is about. The study of mathematics helps us toward them, but direct apprehension of the ideas is a contemplative, not an empirical, process. Aristotle believed that the reality of things was within them, and could be deduced directly from them, but "the advances made by the arts and sciences in each civilization were the fulfillment of the potentialities of their natural form beyond which they could not go."[27] The Skeptics denied that one could know with certainty; but their discussions of this point served to suspend judgment on all matters. This was not a doctrine that could greatly influence natural science.

The Stoics were the school closest in intellectual temper to Chinese cosmology, and they were influential in science, especially medicine. The empiricists among them opposed Skepticism and, thus, indeterminacy. They were much concerned with the possibilities of knowledge, and considered all truth built up from what the senses deliver, judged by what Stoics called "right reason."

In the European Middle Ages, the analogous issue – a weak analogue – was the relationship of faith and reason. In the mid-thirteenth century, we find St. Thomas Aquinas quoting with approval the words that St. Hilary of Poiters had set down nine hundred years earlier:

> For he who devoutly follows in pursuit of the infinite, though he never come up with it, will always advance by setting forth. Yet pry not into that secret, and meddle not in the mystery of the birth of the infinite, nor presume to grasp that which is the summit of understanding: but understand that there are things thou canst not grasp.[28]

The faith in unlimited knowledge, in untrammeled understanding, is not a characteristically Western faith; it is a modern faith. It is as welcome today in Beijing as in New York, perhaps more so as skepticism gains ground in the overdeveloped nations.

In seeking valid Western analogies to the role of indeterminacy in Chinese intellectual history, I would take an entirely different direction. I would prefer to ask whether we can find ideas that appear irrelevant or "unscientific" from a vulgar positivist point of view, but that nevertheless played enduring roles in encouraging discussions of scientific issues. It is not hard, in fact, to think of examples. One is Zeno's paradoxes. It is well known that every important discussion of the continuity of points on a line, from the Greeks to the end of the nineteenth century (Georg Cantor, 1845–1918), focused on those paradoxes.[29]

One more important contrast between East and West remains to be drawn. Whether one begins with Parmenides or Plato, classical European philosophers who wished to find a way past mere speculation about Nature insisted on asking, and arguing about, what they saw as the most fundamental question: How can knowledge be certain? What we know with varying degrees of likelihood, what is merely probable, has no place in science. This axiom dominated Western science until the advent of statistical thermodynamics made it meaningless. The modern vision of the world that we experience as merely the summation of innumerable random atomic, nuclear and subnuclear phenomena, left this drive toward certainty a quaint relic of a dead faith.

It had no analogue in Chinese thought. Empirical knowledge is neither certain nor probable, merely given. The pattern one discerns may or may not be objectively there, but that is no more than to say that one may be empirically right or wrong. For certainty, one looks to illumination, introspection and other alternatives to purely cognitive processes. Certainty is, in the last analysis, a spiritual and moral stance.

In conclusion, let me return to the beginning of this essay. J.T. Fraser once wrote that limits of inquiry divide the world into those phenomena that are predictable and those that are not. The dividing line between these phenomena constitutes a statement of belief, one of those irrationalities on which rationality must always rest. That demarcation usually amounts to a claim about the nature of time.[30]

As we consider the many Chinese statements that we have reviewed through history, the issue is indeed in one sense the domain of prediction. Even more fundamentally, it is what the activity of prediction rules out. What it rules out is an uninterrupted response, at once intuitive and rational, to the concreteness and endless variety of phenomena in nature. That response is what theory in the traditional qualitative sciences, such as medicine, alchemy and siting, seems always to have striven for.

Theory is necessarily abstract, based on rigorously defined concepts. Chinese scientists looked for a balance of concept and phenomenon, for accounts of nature that did justice to its richness. That, not Occam's razor, nor the necessity of geometric demonstration, was their aesthetic criterion.

No one familiar with the sources would argue that their stance is irrational. I would hesitate to say that it is less rational than that of the European positivists of half a century ago, whose starry-eyed faith led them to draw and defend an ultimately indefensible line between positive knowledge and the outcomes of all other mental activity. The Chinese thinkers I have cited were very much concerned with the theoretical ordering of phenomena, and with prediction, in astronomy and medicine. What we see them saying, more and more explicitly, is that prediction is a reductive act and thus an inherently limiting one.

Notes

1. *The Study of Time V* (Amherst: The University of Massachusetts Press, 1986), pp. 151–169 For Chinese characters, see the 1986 version.
2. *Hou Han shu*, "Lüli zhi," 2:1492. Astronomical and astrological treatises of the Standard Histories are cited from the series *Lidai tianwen luli deng zhi huibian*, 10 vols. (Beijing, 1975–1976).
3. "Ying ri tui ce ji," pp. 113–118, in *Dai Zhen ji* (Shanghai: Shanghai Guji Chubanshe, 1980); esp. p. 115. Let me reiterate that my use of the philosophical term "indeterminacy" here and below merely translates Chinese assertions that there are inherent limitations to observational knowledge.
4. *Zhou yi*, "Xici da zhuan," B:4–5; Wilhelm, *The I Ching*, pp. 367, 370, where *wei* is translated as "that which is hidden" and "first imperceptible beginning." *Laozi*, 21, 1 and 15; cf. the translation of line 15 with that of D.C. Lau, *Chinese Classics. Tao Te Ching* (Hong Kong: The Chinese University Press, 1982), p. 21.
5. The famous anecdote about Ding the Cook, in Chapter 3 of the *Zhuangzi*, is about a distantly related conviction, namely, that manual skill is not a matter of technical rules but rather of being "in touch through the daemonic in me," as A.C. Graham's translation puts it. A number of similar "knack passages" occur in chapters of the *Zhuangzi* outside the original corpus. In the story of Bian the Wheelwright in Chapter 13, for instance, the intuitive skill that comes from long practice is adduced to argue against learning from books, not just from orthodox classics, but from all books that purport to transmit human experience. For exceptionally perceptive translations, see Graham, *Chuang-tzu: The Seven Inner Chapters and Other Writings from the Book Chuang-tzu* (London: George Allen and Unwin, 1981), pp. 63–64, 135–141.
6. *Chunqiu fan lu* (Si bu bei yao ed.), 3: 10a.

7. The discussion of Han astronomy that follows is documented in Sivin, *Cosmos and Computation in Early Chinese Mathematical Astronomy* (Leiden: E.J. Brill, 1969). See also the insights of Yabuuti Kiyosi (Yabuuchi Kiyoshi), in "The Calendar Reforms in the Han Dynasties and Ideas in their Background," *Archives internationales d'histoire des sciences*, 2(1974), 51–65, and the monograph by Yabuuchi and Nōda Chūryō, *Kansho ritsurekishi no kenkyū* (Kyoto: Zenkoku Shobō, 1947).
8. *Hou Han shu*, "Lüli zhi," 2: 1482.
9. Ibid.
10. Ibid., p. 1496. For a fuller translation, see Sivin, *Cosmos and Computation*, pp. 61–62. The last line contains an allusion to the Confucian *Analects*, 20:1.
11. Sivin, "Copernicus in China," *Studia Copernicana* (Warsaw), 6(1973), 63–122, esp. pp. 72–73.
12. *Sung shu*, 13:1768–1769 *et passim*. The beginning date of each *qi* period, of which there were twenty-four in a tropical year, was a basic element of the Chinese ephemeris.
13. *Xin Tang shu*, 27A:2177. ~~Ixing~~'s computational system was in fact Yixing attacked in 733, four years after it was adopted and six years after the astronomer died. ~~Ixing~~ was not charged with technical inadequacy – perhaps because he had anticipated criticisms on that count – but with plagiarism from Indian sources. The best account is in Christopher Cullen, "An Eighth Century Chinese Table of Tangents," Chinese Science, 5(1982), 1–33, esp. 30–32. On the numerological cosmology of the Great Expansion system, see the section of Ixing's treatise on the "Rationale of the Basis of the Ephemeris," in *Xin Tang shu*, 27A:2169–2173, trans. in Ang Tian Se, "I-hsing (A.D. 683–727): His Life and Scientific Work," unpublished Ph. D. dissertation, University of Malaya, 1979, pp. 419–445.
14. A mark (*ke*) is 0.01 day, approximately fifteen minutes.
15. *Mengqi bitan*, Item 123 (*Mengqi bitan jiaozheng*; rev.ed., Beijing, 1960; I:292). Of the two quotations in the first part, one quotes the Great Commentary, A. 9, and the other alludes to it (see Wilhelm, trans., I:339). The *Huang ti nei ching su wen* citation is to 7(22): 125 in the Shanghai, 1954, edition. On the Era and other long cycles, see Sivin, *Cosmos and Computation*, pp. 12–21. For an extremely satisfactory discussion of Whitehead, see *Dictionary of Scientific Biography*, s.v.
16. The *Hun yi yi* is preserved in *Song shi*, "Tianwen zhi," 48: 800–808; I cite the critical text in *Mengqi bitan*, Item 127, note 6 (I: 297), and accept the emendation of *zhou* to *hua*. Shen is using *tuan* in a technical sense that draws on several of its early meanings: to shape into a ball with the hands, to gather, to tie in a bundle, exclusive. For further reflections on the complementarity of scientific and other modes of knowledge in Shen's thought, see Sivin, "Shen Kua," *Dictionary of Scientific Biography*, s.v.
17. *Zhuzi yu lei* (*Zhuzi yu lei da quan*, Kyoto, 1668, reprint by Zhongwen Chubanshe, Kyoto, 1973), 86: 12a; 2:14b–15a. There is an interesting

discussion of these and other passages in Zhu Xi's writings in Yamada Keiji, *Shushi no shizengaku* (Zhu Xi's studies of nature; Tokyo: Iwanami Shoten, 1978), pp. 279–301. Cai Yuanding's astronomical monograph was entitled *Dayan xiang shuo.* See his biography by Rulan Chao Pian, pp. 1037–1039, in Herbert Franke, ed., *Sung Biographies*, 3 vols. (Wiesbaden: Munchener ostasiatische Studien, 16, 1976).

18. These conversations are recorded in *Zhuzi yu lei*, 57: 14a-17a. James Legge, who in his 1861 translation of the *Mencius* often relied on Zhu Xi rather than on more philologically rigorous later commentators, translates *gu* as phenomena (Hong Kong: The Chinese Classics, 1861), II: 206–207. For an especially penetrating discussion of the passage from *Mencius*, see Patrick E. Moran, "Key Psychological and Cosmological Terms in Chinese Philosophy: Their History from the Beginning to Chu Hsi (1130–1200)," unpublished Ph.D. dissertation, University of Pennsylvania, 1983, pp. 68–71.
19. *Zhuzi yu lei*, 86: 11b-12a. "Definitive method of computation" is a tentative translation for *ding shu*, which may mean nothing more elaborate than "definitive constants," or conceivably (but in my opinion less likely), "measures corresponding to true rather than mean motions." I translate *cha* as discrepancies rather than anomalies, since the example concerns error in measurement rather than inequality of motion. A pertinent essay is Hashimoto Keizō, "Seido no shisō to dentō Chūgoku no temmongaku" (Ideas of precision and traditional Chinese astronomy), *Kansai Daigaku Shakaigakubu* Kiyō, 1979, 11. 1:93–114.
20. *The Development and Decline of Chinese Cosmology* (New York: Columbia University Press, 1984), p. 249. I am grateful to Prof. Henderson for his comments on an early draft of this essay. His doctoral dissertation, from which the book is extensively revised, was in part responsible for inspiring me to take up this topic, and provided useful references. I do not agree with some of Henderson's interpretations, but his work takes up heretofore neglected questions and demonstrates the importance of astronomical writing in research in Chinese intellectual history. id=hen
21. *Mengqi bitan*, Item 347. Mark Elvin has remarked on the implications of this passage for "the probable limitations of human understanding" in *The Pattern of the Chinese Past* (Stanford: Stanford University Press, 1973), p. 233, note.
22. *Wuli xiao zhi* (1st ed. of 1664), I: 34a–b. The whole passage is translated (with some misunderstandings) by Willard J. Peterson in "Fang I-chih: Western Learning and the 'Investigation of Things,'" pp. 369–409, in Wm. Theodore De Bary et al., *The Unfolding of Neo-Confucianism* (New York: Columbia University Press, 1975), esp. p. 391.
23. See, for instance, Sivin, *Traditional Medicine in Contemporary China* (Science, Medicine, and Technology in East Asia, 2; Ann

Arbor: Center for Chinese Studies, University of Michigan, 1987 [published 1988]), pp. 43–94.

24. Zhang, *Jingyue quanshu* (photolithographic reprint of 1624 ed., Taipei, 1972), 3: 75b; mistranslated in Paul U. Unschuld, *Medical Ethics in Imperial China: A Study of Historical Anthropology* (Berkeley: University of California Press, 1979), p. 82; Yin, *Zhenzi xin fa* or *Shazhen xin fa*, printed with Yin Dachun's *Yizang shumu* (Shanghai, 1955), pp. 107–108. The title of the latter work, meaning "Bibliography of the Medical Triptaka," also draws on Buddhist imagery.
25. For a number of additional quotations, see Henderson, ibid. (note 19), esp. pp. 246–253.
26. For useful data in this connection, see Henderson, and Benjamin Elman, *From Philosophy to Philology. Intellectual and Social Aspects of Change in Late Imperial China* (Harvard East Asian Monographs, 110; Cambridge: Harvard University Press, 1984), esp. pp. 29–32.
27. A.C. Crombie, "Some Attitudes to Scientific Progress: Ancient, Medieval and Early Modern," *History of Science*, 13(1975), 213–230. See also on this topic, which is best distinguished from the one discussed in the present essay, E.R. Dodds, *The Ancient Concept of Progress and Other Essays* (Oxford: Oxford University Press, 1973).
28. St. Hilary, *De trinitatise* 2: 10, 11, cited in *The Summa Contra Gentiles of Saint Thomas Aquinas Literally Translated by the English Dominican Fathers from the Latest Leonine Edition* (London: Oates, 1924), 1.8 (I, 16).
29. No adequately detailed monograph on the role of Zeno's paradoxes has been published, but see G.E.L. Owen, "Zeno and the Mathematicians," *Proceedings of the Aristotelian Society*, n.s., 58(1957–1958), 199–222.
30. Personal communication, 14 October 1982.

RETROSPECT

This essay emerged from studying a series of intriguing assertions that I encountered in various astronomical texts. The first time I read through the literature I did not notice them. Over a number of years, my increasing curiosity about how astronomy looked to its practitioners gradually alerted me to the frequent remarks on indeterminacy. In gauging the scope of this idea, I found that it was not a rare theme among philosophers who thought that Nature was important. Indeterminacy was not a common notion in medicine because of the emphasis on practice. Doctors did not need, and seldom wanted, to remind each other about the irreducible uncertainty of diagnosis and therapy. Still, medical examples were easy enough to find.

Like most authors, I write to find out what I think about a given topic, and what it is possible to say that makes sense. Writing is of course an excellent guide to further inquiry, since it makes the soft spots and gaps clear. I undertook this essay for one of the grand general meetings of the International Society for the Study of Time, held at the Castello di Gargonza in Tuscany in 1983. My initial hypothesis was that the idea of several complementary kinds of knowing is closely connected to the diversity of time concepts in China. Inquiry, reflection, and writing bore it out.

The essay was published in 1986, as indicated in n. 1. When the editors of the 1989 issue of the yearbook *Philosophy and Religion,* devoted to the limits of rationality, asked me to contribute a revised version, I left out most of the discussion of time concepts, which was not relevant to the new theme. It is available in the 1986 version for those who want to consult it.

Correction

In Pinyin romanization, "Ixing" should be "Yixing," and "*Sung shu*" should be "*Song shu.*" Note that the Index below uses Wade-Giles romanization. Cross-references are provided.