IV

Copernicus in China

or,

Good Intentions Gone Astray

Dedicated to my beloved teacher Giorgio de Santillana, from whom I learned the difference between mathematics and physics. As an earlier Tuscan put it, "We are concerned with a real universe, not with a paper one."

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Abstract

Historians generally claim that Chinese rejected the early fruits of modern science because of some intellectual or linguistic failing, or a metaphysical indisposition. To the contrary, those best prepared to judge were quite receptive. What matters more, certain key issues were so garbled in the process of transmission that no Chinese could have comprehended them.

Jesuit missionaries, who alone were in a position to introduce contemporary scientific ideas into China before the nineteenth century, were not permitted to discuss the concept of a sun-centered planetary system after 1616. *Because* they wanted to honor Copernicus, they characterized his world system in misleading ways. When a Jesuit was free to correctly describe it in 1760, Chinese scientists rejected the heliocentric system because it contradicted earlier statements about Copernicus. No European writer resolved their doubts by admitting that some of the earlier assertions about Copernicus had been untrue.

The Jesuits were also unable to discuss the wider repercussions of the Scientific Revolution, in particular Galileo's central idea that the only firm basis for knowledge of nature was the work of scientists themselves. The Church's injunction of 1616 against the teaching of heliocentricism was meant to reject this notion. To the very end of the Jesuit scientific effort in China, the rivalry between cosmologies was represented as between one astronomical innovator and another for the most convenient and accurate methods of calculation, rather than between the Scholastic philosopher and the mathematical and experimental scientist for the most fruitful approach to physical reality. The character of early modern science was concealed from Chinese scientists, who depended on the Jesuit writings. Many of those curious about astronomy were brilliant by any standard.

As is easily seen from their responses to the European science they knew, they would have been quite capable of comprehending modern science if their introduction to it had not been both contradictory and trivial.

Introduction

The singular career of Copernicanism in China deserves attention because astronomy and mathematics played such an important part in the early phase of the European conquest of China. In addition, the Copernican episode emphasizes the need for care when thinking about how one culture accepts and rejects the scientific ideas of another. Any generally applicable model has to reflect the interaction of two systems of science, the one traditional and the one newly introduced. A linear theory which sees Western science imposed on a passive recipient culture, perhaps by some inevitable sequence of steps, cannot do justice to the vast historical differences in receptivity. An obvious case in point is the feverish Japanese enthusiasm for European medicine, especially anatomy and surgery, from the seventeenth century on, whereas the Chinese could hardly have been less interested for two centuries longer.

Recent generalizations about the spread of science in the past four centuries have tended to overlook this complexity. It is true that in many cultures the theory and praxis of indigenous natural science lacked conceptual strength, was unable to generate technological benefits, or was not differentiated enough from everyday knowledge, to compete for survival with Western ideas. To a large extent, too, the effective grounds for choice between old and new sciences had little or nothing to do with their content. Decisions about what aspects of Western science to accept (that is, to teach) often ignored the character and implications of the latter. They were settled by the outcome of competition between two political, economic, and cultural systems. The dynamics of interaction between the scientific traditions of two societies have a great deal in common with the dynamics of scientific revolution within a single society.

Only habit prevents us from recognizing that in the importation of modern cosmology or mechanics into France and their introduction into China, if the historical processes were not precisely equivalent, they share many dimensions. It is as much beside the point to ask why France was incapable of developing modern science solely out of her own inner resources as to pose the same question about China.[1]

As Thomas Kuhn and others have shown, our comprehension of scientific change depends only to a limited extent on the comparative merits of old and new ideas, estimated abstractly with the indispensable aid of hindsight. It is essential to know who holds them, and how this scientific public envisions the cost, necessity, and benefits of revolutionary innovation.

In a transitional society, of course, the old scientific public and the enthusiasts of modern science may have little in common. In fact the latter may be quite marginal to the old social order. They are often chosen, educated, and protected from social pressure by privileged foreigners, and are often unconcerned with the survival of structures which serve only to hold them down. This was the case in late nineteenth-century China under the régime of the treaty ports. But in the seventeenth and eighteenth centuries in China, amateurs of modern science were

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1. See Chapter VII. I am grateful to Nakayama Shigeru, the late Robert Somers, Donald Wagner, Yabuuti Kiyosi (Yabuuchi Kiyoshi), and James Zimmerman for having thoroughly read and criticized an earlier draft, and to Owen Gingerich, Harold Kahn, David McMullen, Victor Thoren, Laszlo Tisza, and James R. Voelkel for helpful consultations. I thank Wang Aihe and

on the whole members of the old educated élite, imbued with its values. Their first impulse was to supplement and strengthen the indigenous science, not to discard it, and their loyalty remained with their ancestral world view. In this sense they resembled their contemporaries, the Galenist professors in the European medical schools.

Another and perhaps less obvious factor is bound to complicate any general model of transmission between cultures. The transmitters themselves are sometimes unable to communicate the contemporary understanding of science. There are many ways in which this situation might arise—defective education or knowledge on the part of a traveller would be one, language problems another, narrowly defined goals leading to an overly partial representation of the science might be a third. But in focussing on Copernicanism in East Asia we find that the propagation of modern astronomical ideas was blocked, and scientific communication was distorted, by administrative decisions.

The Astronomical Missionaries

A great deal has been written on the introduction of Western science into China. It is common knowledge that for about a century and a half the Society of Jesus had a monopoly on this transmission. This monopoly came about because of the Jesuits' strategy as missionaries. By about 1600 Matteo Ricci and his colleagues were convinced that their most practical policy was to convert China from the top down, rather than from the bottom up. Since they were laboring under the inconvenience of being foreign barbarians, to make a long story short, their only

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Nakayama for help in procuring new copies of the illustrations for this revision, and to Asaf Goldschmidt for scanning them.

sure means of access to the court was as technicians, and the one technical skill which they could count on to admit them was astronomy.[2]

It was an urgent matter of national security, as we would put it today, for the Imperial Directorate of Astronomy to be able to predict solar eclipses and other celestial events. This was because if not predicted they were ominous; that is to say, they could be interpreted (and exploited by prospective rebels) as warnings from Heaven that the virtue of the ruling house was failing. Avoiding this potential tool of political opposition was so important, in fact, that the Chinese had resigned themselves for many centuries to making use of first Indian and then Islamic specialists.

For the missionaries to establish themselves as the best astrologers was not very difficult. That was not good enough to bring them the respect they needed to become, eventually, spiritual advisors to the Chinese élite. Since the Chinese in 1600 had not yet been exposed to inundation by narcotics and diplomacy by gunboat, they were still convinced that they had nothing to learn from foreign barbarians. The Jesuits had to demonstrate that they were not really barbarians, and that Europe had a culture comparable with that of China. Religion itself was not accepted by most educated Chinese as a mark of high culture. That is why,

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2. I have been brief concerning points well established and generally known. The major previous studies and reference works on the introduction of modern astronomy into China prior to the mid-nineteenth century are listed in the Bibliography at the end of the next chapter (V 20). Full references given there are not repeated in the footnotes.

Most of the earlier writings in European languages which dealt with the introduction of Copernicanism into China were written by historians within the Society of Jesus, and were meant primarily to demonstrate the contributions of Jesuits to the diffusion of science. Their viewpoint dictated a different weighting and treatment of sources, and a differently balanced assessment, than my own emphasis on central doctrines of the Copernican Revolution. Scattered through the footnotes of this chapter are examples of points on which we differ.

although the Jesuits were first and last committed to the salvation of souls, they devoted a great deal of effort to the diffusion of science.

This won them a number of highly placed converts, and eventually a secure place in the Forbidden City. Their patrons established a Calendrical Office *(Li chü* 曆局) in which they worked. Despite imperial recognition for their technical publications, the Jesuits failed in the Ming to take over the official calendar and the Directorate of Astronomy *(Ch'in t'ien chien* 欽天監). The hereditary officials in the Directorate, some of them Muslim, were all too aware of the competition, and worked hard to minimize the missionaries' status. By the end of the Ming, the government had reduced the staff of the Office. This pressure motivated the European astronomers to keep writing about the superiority of Western science.

Another reason this effort was so considerable is that European science, especially cosmology, changed drastically in the century and a half that the Jesuit monopoly lasted. Let me review summarily some pertinent characteristics of this change in the West before examining its repercussions half a world away.

Cosmological Background of the Jesuits' Astronomical Writings

The Scientific Revolution began with a recasting of cosmology. In classical times the word "cosmos" implied an order, which was in a sense humanity's order, finite and symmetrical about us, but at the same time serving as our pattern for ideal and eternal relations. Aristotle's conception of the world, which came to be predominant in late antiquity, was largely deductive, based on philosophical thinking about how celestial motions could be both eternal and knowable. It succeeded because it was integral with a truly universal philosophy, which provided consistent and commonsensical answers for any philosophical question that a reasonable person might ask. The integrity of Aristotle's model of the cosmos, that is to say, lay on the level of metaphysics. Professional astronomers could not be allowed to tinker with it. Modifications in the world picture, if they violated first principles, could throw the all-embracing structure of knowledge out of kilter. Although certain speculations about cosmic dimensions from Ptolemy's Planetary Hypotheses were widely diffused before the Renaissance, they were not interpreted as a challenge to Aristotle's basic conceptions; nor, indeed, were they so intended.

Ptolemy, in the Almagest, accepted the notion that the astronomer took his physics from the philosopher but could impose no constraints in return. He constructed a great system of computational astronomy whose authority lasted a millennium and a half. It was impossible for his system to yield accurate predications and, at the same time, to conform perfectly to Aristotle's reasoning about the structure of the cosmos. As a compromise his system is admirable, but he was stuck with shortcomings which sooner or later were bound to bother someone more than they had bothered him. It is well known that Islamic astronomers long before the Scientific Revolution mended what they saw as Ptolemy's compromises with conceptual rigor.[3]

Copernicus himself was at heart no revolutionary. He was a mediocre observer and a mathematician of limited competence, but he had a sufficient feeling for theoretical elegance to take the consequences of demanding it. He saw that if the sun were considered static, rather than the earth, certain factors that

3. See, for instance, George Saliba, "The Astronomical Tradition of Maragha: A Historical Survey and Prospects for Future Research," *Arabic Sciences and Philosophy,* 1991, *1.* 1: 67–99. When I refer to "the Ptolemaic system" below, I mean the several combinations of models and methods, derived from Aristotle, Ptolemy, and diverse early modern philosophers and astronomers, that were taught in Europe ca. 1600.

made no real sense in the old schema fell into place, and tied the new schema together to make a world that was coherent as well as conceptually simpler. At the same time he remained close enough to his work to ignore the price of this increase in simplicity and elegance, namely the wrecking of the traditional world view of Western man. Once the earth was moved out of the center of the universe to become a mere planet, we have gradually discovered that it goes round a second-rate sun which occupies an undistinguished location in what seems to be a commonplace if somewhat larger than average galaxy. The universe this galaxy moves in is hardly tailored to man's measure.

The philosophical consequences of Copernicus' innovations were not pressed home for more than half a century after his death in 1543. It was Galileo who saw the Aristotelian philosophy of his time as worn out to the point that it was no longer worth patching up,[4] and who insisted that the structure of natural knowledge be defined by astronomers and other scientists who could apply mathematics to the phenomena. It was precisely in that sense that he was a revolutionary. Although in many ways he remained a man of his time, he had no sympathy for the goal that had animated Copernicus to design an essentially Aristotelian universe around a static sun and moving earth.

Galileo's ambitious bid to launch a new dispensation for astronomy was backed first by the Medici court and then by the Roman papacy.5 He was armed not only with a first-rate instinct for the patronage game, but with the new

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4. Charles Schmitt and others have documented the flexibility and diversity of early modern Aristotelianism, but it would distort the tenor of their findings to argue that Counter-Reformation scholasticism ca. 1600 encouraged the fundamental changes that took place in the ensuing century.

5. Mario Biagioli, *Galileo, Courtier. The Practice of Science in the Culture of Absolutism* (Science and its Conceptual Foundations; University of Chicago Press, 1993).

astronomical telescope. What he saw through it provided him with lethal ammunition against his philosophical target. If the sun was spotted and the moon covered with mountains, how could the earth be uniquely earthy? If Jupiter and Saturn had what appeared to be planetary systems of their own, how could the earth be the unique center of symmetry? Only the phases of Venus could serve as a direct challenge to Ptolemaic mathematical astronomy; the other discoveries warned that responsibility for defining the texture of physical reality could no longer remain in the hands of schoolmen. At about the same time, Johannes Kepler, who maintained even higher standards of rigor and who had the unprecedented observations of Tycho Brahe to apply them to, reluctantly brought himself to reject the idea of eternal motion as necessarily circular. This essentially demolished what was left of classical cosmology, opening the way for modern celestial mechanics.

The Catholic Church had benefited greatly for centuries from its sponsorship and patronage of the latest developments in natural philosophy—in the first instance, medieval Aristotelianism, on which its emerging universities were based. Galileo's proposition was that it continue to reap this benefit by actively supporting the new science. But his suggestion came at a stage of the Counter-Reformation when makers of policy could view a new cosmos only as a dangerous distraction.

The Decree of the Congregation of the Index in 1616 braked the Copernican Revolution in the Catholic countries. This ruling made it clear that Galileo had gone too far, that the doctrine of the earth's motion was not to be defended, and that *De revolutionibus* was not to be read as written. For our purpose Galileo's trial and capitulation of 1633 were anticlimactic. The Church removed *De*

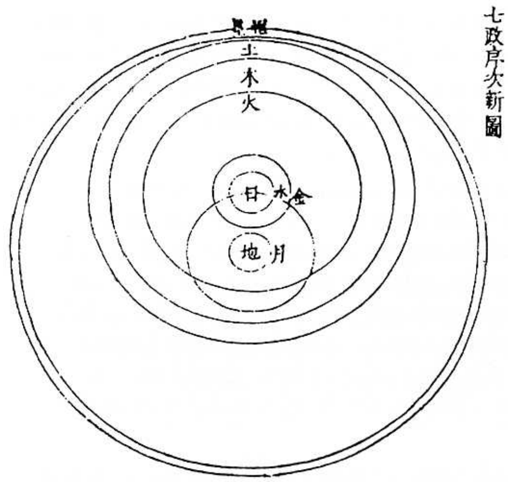

Figure 1. The Tychonic world model (from Rho). The lower of the two central characters stands for the earth; the upper is the sun, rotating about it and carrying the orbits of the planets.

revolutionibus from the *Index* of prohibited books only in 1757, allowing Copernicus' world view—by that time Newtonian—to be taught in the Catholic world. Still, Galileo’s name could not be mentioned in connection with it.

In 1588 the great Danish astronomer Tycho Brahe had published in rather summary form a model that made the planets revolve about the sun, which in turn revolved about the static earth (Figure 1). Tycho’s world model offered many of the same systematic advantages as the Copernican system. Although he did not originate it, as the best naked-eye observer in Europe he made it influential. Besides not threatening to upset theological applecarts, this system was extremely attractive to working astronomers. They respected Tycho’s attitude toward observational data, which was much more demanding than that of his predecessors had been. When the flurry over Copernicanism began, Tycho’s mathematically and theologically sound replacement for Ptolemy’s system generated more and more enthusiasm. By the 1620’s it had become the “third system of the world,” and still had supporters in the Catholic countries well into the 1680’s. A critical survey of Tycho’s and other similar geo-heliocentric systems concludes: “It is noticeable . . . that its supporters were particularly numerous and vociferous where the influence of the Catholic Church was most strongly felt, and the impression gained is that relentless theological opposition to the Copernican system perpetuated the Tychonic system long after it was seen to have become obsolete on physical grounds." Perhaps the most balanced evaluation of Tycho Brahe's place in the evolution of modern science is that of J. L. E. Dreyer in his biography of Tycho:

> The Tychonic system did not retard the adoption of the Copernican one, but acted as a steppingstone to the latter from the Ptolemean. By his destruction of the solid spheres of the ancients and by the thorough discomfiture of the Scholastics caused by this and other results of his observations of comets, he helped the Copernican principle onward far more effectually than he could have done by merely acquiescing in the imperfectly formed system, which the results of his own observations were to mould into the beautiful and simple system [that of Kepler] that is the foundation of modern astronomy.[6]

The situation in China was much more complicated. There the missionaries substituted the Tychonic model for the Ptolemaic in the 1630's, but the Tychonic system itself was not superseded in training astronomers until the late nineteenth century. It was still being used as a stepping-stone long after the brook had dried up at its source. So long as the stepping-stone was still there, it was easy to avoid noticing that there was no water left to cross.

This summary would be inexcusably oversimplified in any other context, but here it is meant merely as a reminder that in Europe the import of the Copernican Revolution was philosophical, that it implied a radical new view of the universe and of man's place in it. The opposition to heliocentricism became implacable

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6. The quotations are from Christine Jones, "The Geoheliocentric Planetary System: Its Development and Influence in the Late Sixteenth and Seventeenth Centuries" (unpublished Ph.D. dissertation, University of Cambridge, 1964), Abstract, and J. L. E. Dreyer, *Tycho Brahe. A Picture of Scientific Life and Work in the Sixteenth Century* (Edinburgh: Black, 1890), 181. Dreyer's book has

partly because these implications were repugnant, and partly because Galileo insisted upon a dimension of intellectual freedom that the administrators of the Church saw quite pragmatically as potentially subversive.

The Jesuits in seventeenth-century China were in what was to become an untenable position. They had hardly begun the labor of introducing Western astronomy when it became clear that certain developments were not to be freely discussed. It was only at the end of their period of influence in China that the Church lifted this restriction. The point is not that all the Jesuits in China would have become Copernicans promptly if the decree of 1616 had not been issued. Far from it, as I will show. But, to the extent that they were professionally concerned with astronomy and cosmology, the need at least to take the new point of view into account became steadily more pressing as time passed. By 1700, a reassessment was hardly optional. By 1740 a "modernized" epicyclic astronomy could still be taught, as it actually was in China, only at the cost of demanding that readers tolerate patent inconsistency. Although the Jesuits' Chinese writings at first reflected conservative but open-minded current thinking,[7] they gradually became hopelessly obsolete, out of touch with practice as well as theory. But the constraints under which they wrote, and the lack of competition from lay authors,

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been superseded in many respects by Victor E. Thoren, *Lord of Uraniborg. A Biography of Tycho Brahe* (Cambridge University Press, 1990).

7. It is well known, for instance, that Matteo Ricci's *Ch'ien k'un t'i i* (ca. 1608; see p. 13 below) was based on his master Christopher Clavius' *In sphaeram Joannis de Sacro Bosco commentarius* (1585), which explicated the standard thirteenth-century textbook. Ricci did not, however, follow Clavius so closely as to acknowledge that the Ptolemaic system was troubled, or to write of Copernicus as a restorer of astronomy. See Li Yen 李儼, *Chung-kuo suan-hsueh shih* 中國算學史 (History of Chinese mathematics, 1937; rev. ed., Shanghai: Commercial Press, 1955), 191. Hashimoto, *Hsü Kuang-ch'i and Astronomical Reform,* traces other sources used by the Jesuit astronomical authors in China.

meant that no one acknowledged or corrected crucial misstatements before the mid-nineteenth century.

As often happens with censorship, the injunction against Galileo did not prompt the missionaries to be silent about the new astronomy. They could speak freely about some aspects, for instance the telescopic discoveries. Taken out of context, they were mere curiosities, evidence of technical virtuosity. These and other novelties had implications for astronomical practice rather than physical reality. The Jesuit missionaries could and did give credit to Copernicus for computational improvements.[8] They could speak with caution and prudence about almost every other issue. They could even bring up the possibility of the earth's daily rotation on its axis, so long as they promptly refuted it. There was, in fact, only one untouchable aspect of Copernican astronomy, namely the heliostatic (or heliocentric) hypothesis, the revolutionary displacement of the center of the celestial orbits from the vicinity of the earth to the vicinity of the sun. This reorientation, mathematically so simple but physically and philosophically so momentous, could not be so much as mentioned in China in the seventeenth century.

Would Copernicanism have been Acceptable to Chinese Astronomers?

I do not wish to imply that traditional Chinese astronomers and amateurs of astronomy would have found the conceptual leap to Copernicanism trivial. But

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8. The mathematics associated with the Ptolemaic and Copernican systems differed significantly. When tracing the apparent courses of the celestial bodies, however, an astronomer could use most techniques regardless of whether the cosmological frame of reference in which they originated was geostatic or heliostatic. See, for instance, Needham, *Science and Civilisation in China,* III, 446, and Shigeru Nakayama, "On the Introduction of Heliocentric System into Japan," *Scientific Papers of the College of General Education,* University of Tokyo, 1961, *11:* 166.

the gap that only careful teaching could have helped them across was not that between Aristotle, Ptolemy, and Tycho on the one hand and Copernicus, Kepler, and Newton on the other. This they would have found much easier than the great majority of their European contemporaries, whose commitments to Aristotelian and Christian assumptions they did not share. Discoveries that Galileo announced triumphantly could hardly have come as a shock to the Chinese, who did not know the ramifications of the philosophy behind Ptolemy and had never felt its authority.

The early Chinese astronomer had been fairly successful at predicting the courses of the heavenly bodies algebraically, without depending on a physical or geometric model.[9] If he happened to believe that the planets went round the earth, his data came from common sense; it made no difference to his computations. His seventeenth-century successors had to learn the utility of astronomical schemata before the basic conflicts of the Copernican Revolution could make sense.

By a millennium before the Jesuits arrived, Chinese cosmological speculation and astronomical practice were no longer linked. This gap was of a different order than the discrepancies between Aristotle's Metaphysics and Ptolemy's Almagest. Far Eastern philosophers were as willing as their European scholastic counterparts to define the physics of the universe without drawing on the best astronomical knowledge of their time. Chinese astronomers, however, were quite free to reciprocate by ignoring the philosophers.

Chu Hsi 朱熹 (1130–1200) was perhaps the most influential philosopher in late Imperial China. His synthesis was comprehensive and his philosophy, aimed at individual sagehood, was adapted from the Yuan on as a base for the State's

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9. For the reasons, see Chapter II.

conformist ideology. He was more concerned with the sky as a cosmos than as the simple collection of stars and moving planets that the technicians dealt with. Astronomical opinion to the contrary, Chu Hsi did not hesitate to argue (with recourse to yin-yang physics) that, for instance, the real motions of the sun, moon, and planets are directed in the same sense as those of the fixed stars, only slower; that the retrograde motions of the planets are in absolute terms progressive too. He declared that in positing annual rotations in the opposite sense contemporary astronomers were misguided.[10] Considering Chu's great authority, it is remarkable that astronomers so consistently ignored his opinions. The astronomer Wang Hsi-shan 王錫闡 (1628-1682) argued, in fact, that there had been a permanent split: "When it came to the Sung period, astronomy *(li* 曆) bifurcated; there was one astronomy for scholars and another for astronomers. The scholars did not know astronomical mathematics, and so they depended upon empty principles in establishing their theories. The technicians did not apprehend the principles of astronomy, but merely settled upon techniques that managed to predict the phenomena. Apparently no one mastered the measures of sky and earth and the foundations of the celestial phenomena."[11]

The Jesuits' early writings prompted many discussions by native astronomers. They make it quite clear that Chinese were capable of learning and applying—but applying critically—anything the missionaries cared to teach them about the sky. On the whole the greatest hindrance was the limited depth of the Western writings, an inevitable result of the Europeans' limited objectives. The best of the

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10. *Chu-tzu ch'üan shu* 朱子全書 (Works of Chu Hsi), *ch.* 50; Yamada Keiji, "Shushi no uchûron 朱子の宇宙論" (Chu Hsi's cosmology), *Tôhô gakuhô* (Kyoto), 1966, *37:* 41–151. See also Needham, *Science and Civilisation,* III, 400, 474–478.

11. *Wang Hsiao-an hsien-sheng i shu,* 1a. On Wang and this source, see the next chapter.

Chinese astronomers eagerly accepted Tycho's world system in the seventeenth century, and Kepler's elliptical orbits when they were introduced in a partial way in the eighteenth. There was no effective metaphysical or religious orthodoxy to hold these scholars back, and on the whole they quite ignored the Jesuit digests of scholastic natural philosophy.[12]

Probably the most important immediate consequence of the Jesuit educational effort was to enable the Chinese to rediscover and revive their own tradition, which had been neglected for three centuries. By 1700 the best mathematical talents in China were getting their basic training in the more immediately accessible Western methods, and going on to devote their mature careers to the reconstruction and enrichment of the indigenous exact sciences. It was not until well into the nineteenth century that this order of study was reversed.[13]

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12. Among the main early sources were Francisco Furtado's *Huan yu ch'üan* 寰有銓 (1628), based on a textbook version of Aristotle's *De caelo et mundo,* and Alfonso Vagnone's *K'ung chi ko chih* 空際格致, a synthesis of scholastic meteorology and theory of the earth derived indirectly from Aristotle's *Meteorologica* and printed in 1633. In contrast to the Western writings on astronomy, these books are in many respects not as well informed and or as well reasoned as the better Chinese works of their kind. The missionaries exerted themselves sedulously to prove, among other propositions, that the Empedoclean four elements were correct and the traditional Chinese five were wrong (the *wu hsing* were not in fact elements). Willard Peterson studied the content of and response to this genre of missionary writings in "Fang I-chih's Response to Western Knowledge."

13. Attempts to show that Western science originated in China have been noted by many scholars. Mikami Yoshio 三上義夫 long ago concluded that the net effect of the Jesuits' scientific propaganda, after its original impact had worn off, "was the encouragement of the study of the ancient classics rather than that of the introduction of new ideas from European sources." The two kinds of effort were not actually in competition, but it is true that the new ideas were seen as a means toward this rediscovery. See Mikami, "Chinese Mathematics," 125, and "Chûjin den ron," 185–222, 287–333. The recovery of the Chinese tradition is traced in detail in Wang P'ing, *Hsi-fang li-suan-hsueh chih shu-ju*, chaps. IV and VII. For an English summary, see the review of her book in *Journal of Asian Studies,* 1970, *29:* 914–916. On other important changes of the time, see Henderson, *The Development and Decline of Chinese Cosmology.*

Seventeenth-century Chinese astronomers assert repeatedly that they learned gradually to value Occidental astronomy most for the explanatory strength of its models. Typical is a 1637 statement of Chou Yin 周胤 about the series of Jesuit astronomical treatises of the 1620's and 1630's that will be discussed anon. Because writings available earlier "did not fully set out the ideas on which the new methods were based, we still did not apprehend their scope, but were aware only of the fineness of design of the Europeans' instruments and the ease with which they worked out their predictions." Chou goes on to say that in sponsoring the new series of books, "the fundamental idea of Li T'ien-ching 李天經 [the official in charge of the Ming calendar reform] was that the tradition of mathematical astronomy [in China from the fourteenth century on] died out because while learning techniques we had lost sight of the principles [that determined why the phenomena were] as they were. [He felt that] the principles must be set out clearly before the techniques were taught."[14]

Influential Chinese astronomers were not only ready to rethink cosmology but ran no personal risk in doing so, as the study of Wang Hsi-shan in the next chapter shows. That this is true renders irrelevant the lists of "cultural factors" limiting the development of Chinese scientific thought that flow so readily from the pens of sinologists who have never found time to read the primary literature of science. The crucial limitation on the Chinese reception of modern cosmology, my reading suggests, was the quality and quantity of information available in China about what was going on at the other side of the world. Chinese could begin contributing to modern astronomy only after they confirmed for themselves

14. *Hsi-yang hsin fa li shu* 西洋新法曆書 (Astronomical treatises according to the new methods of the West, printed 1646), forematter, 277b-278a.

that the achievement of the Copernican Revolution lay in its description of physical reality. That they were not able to learn until a little over a century ago.

Cosmology in the Late Ming Jesuit Writings (1608–1640)

Let us first consider the Jesuit astronomical works published in Chinese before 1616, the year of the decree by the Congregation of the Index that first defined the theological status of the heliostatic idea. These books were all written entirely from the Aristotelian point of view prevalent in Europe at the time. Typical in this respect was Ricci's Cosmological Epitome (*Ch'ien k'un t'i i* 乾坤體義, ca.1608): "These nine layers enclose each other like the layers of an onion. They are all solid, and the sun, moon, and planets are fastened into their substance like knots in a board. The motions [of the sun, moon, and planets] are entirely due to those of their proper orbs. The celestial substance is clear and colorless, and thus transparent to light, in the same way as [light] is unimpeded by glass and crystal and the like."[15] He did not outline computational methods or geometric models.

Appended to Emmanuel Diaz' Catechism of the Heavens (*T'ien wen lueh* 天問略, 1615) was a short report on what he had just heard of Galileo's telescopic discoveries. Diaz did not mention Galileo's name, and did not point out to the Chinese reader the possibility of conflict with classical cosmology.[16] We can, in

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15. *Ch'ien k'un t'i i* (see note 7; *Ssu k'u ch'üan shu* ed.), *1:* 6a. Ricci's treatise has been studied by Imai Itaru 今井溙, "Kenkon taigi zakkô 乾坤體義雜考" (Miscellaneous researches on the Cosmological Epitome), in Yabuuchi (ed.), *Min Shin jidai no kagaku gijutsushi,* 35–47. D'Elia has collected Ricci's writings as *Fonti Ricciane* (3 vols., Roma: La Libreria dello Stato, 1942–1949). The "celestial substance" is the quintessence from which Aristotle believed the celestial spheres were formed.

16. D'Elia's translation of the pertinent passage of *T'ien wen lueh* (18–19) disproves Szcze_niak's statement that Diaz was "explaining astronomy according to Galileo's observations" ("Notes," 33). Diaz merely *reported* the discovery of what were then considered the stars that attend Saturn and Jupiter, and interpreted the Milky Way as "a great quantity of small stars." This

fact, hardly expect Diaz to have been concerned about a conflict, since his information was undoubtedly secondhand and fragmentary. We do not know whether he knew of the crucial phases of Venus. But ten years later, in 1626, we find in Johann Adam Schall von Bell's Monograph on the Telescope (*Yuan ching shuo* 遠鏡說) a full account, even including Galileo's observation that the satellites of Jupiter can be eclipsed. That Schall did not give Galileo's name is not surprising. By that time what the Jesuit historian Pasquale D'Elia called "the judgment of higher authority" had reached the missionaries in Peking.[17] More to the point, Schall did not even hint at the critical implications of the Galilean observations.

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passage is in an addendum to *T'ien wen lueh,* which was not affected otherwise by the Galilean discoveries.

17. P. vii. D'Elia in his preface was frank about constraints upon the missionaries, but offered a most unpersuasive argument further on (p. 34): "Galileo is not named either here or in following texts, unless in 1640, without doubt for the simple reason that for the Chinese of that time a European name, phoneticized in Chinese, something like *Chia-li-lê-io,* would have signified little or nothing more than a barbarian name. Let one think of the reverse case of the name of a Chinese scientist in an occidental treatise on astronomy." First, Galileo *is* named (as "Chia-li-lou 加利婁") about 1637 in Rho's *Wu wei hou lun* 五緯後論 (Sequel on the planets), as D'Elia acknowledges in his note 168. Rho's work was printed as an appendix to *Wu wei li chih*; see *9:* 14b-15a. Rho named Copernicus and Tycho Brahe in the latter work by 1634 (see p. 18 below). Schall, in *Li fa hsi ch'uan* 曆法西傳 (ca. 1640; in *Hsi-yang hsin fa li shu*), 12a, referred to Galileo differently, as "Chia-li-le-a 加利勒阿" , thus making it impossible for a Chinese reader to identify him with the astronomer mentioned by Rho (I take up a similar confusion in Copernicus' name below). The current standard transliteration of Galileo's name is "Ga-li-lueh 伽利略." See, for instance, the article by Yen Tun-chieh cited in the Bibliography.

Second, as early as 1607 Matteo Ricci and Hsu Kuang-ch'i 徐光啟 (1562–1633), whose combined competence in matters of mandarin psychology could hardly be surpassed, did not hesitate to mention the names of Euclid and Christopher Clavius in their translation of the *Elements.* See the translation of Hsu's preface and Ricci's introduction by D'Elia himself: "Presentazione della prima Traduzione Cinese di Euclide," *Monumenta Serica,* 1956, *15:* 185, 187.

Third, supposing that a Chinese had invented the astronomical telescope and was the first to explore the sky with it, what indeed would we think if the author of the first European monograph on the subject refused to identify this innovator on the ground that his name would sound foreign and thus be superfluous?

The Outline of Observational Astronomy *(Ts'e t'ien yueh shuo* 測天約說, 1628) by Galileo's whilom friend Johann Schreck (or Terrentius, 1576–1630), was more concerned with observation than its predecessors. Schreck alluded to the Tychonic system, but his extensive treatment of the world's construction was still Aristotelian-Ptolemaic. He merely noted in passing that

in modern times a celebrated mathematician in a kingdom of the Occident has constructed a telescope, with which he has observed Venus. [He thus saw that] sometimes it is dark, sometimes fully illuminated, and sometimes a crescent illuminated either in the superior or inferior quarter. It was calculated that Venus moves as a satellite of the sun. At maximum elongation, contrary to what happens with the moon, only half of its figure is illuminated. Thus one understands [the following:] Sometimes Venus is above the sun; it is then illuminated and small. (If the planet is in line with the sun and the earth, it cannot be seen. If it is only slightly distant from the sun but still above it, it resembles a nearly full moon). Sometimes it is below the sun, in which case it is dark. (Because it is in conjunction it is completely dark. When slightly distant from the sun, but still below it, it resembles the moon when it has just begun to wax; it is small but brilliant). When it is on a level with the sun, it is a crescent . . .

He said not a word about the significance of Galileo's discovery for cosmology. Nor, for that matter, did he acknowledge that his discussion of telescopic optics was mostly taken from Kepler.[18]

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18. *Ts'e t'ien yueh shuo* (in *Hsi-yang hsin fa li shu*), *1:* 16b; D'Elia, *Galileo in China,* 40. D'Elia's translation of the passage from Schreck is not very accurate, and omits without indication about half of the passage, printed in smaller type (I enclose such passages in parentheses). D'Elia's discussion of Schall's sources is also mistaken. Hashimoto, *Hsü Kuang-ch'i,* 182–200, documents in detail Schall's use of Kepler's writings on optics. On the introduction of the telescope, see Colette

Giacomo Rho (1592–1638), writing his Principles of the Planetary Motions *(Wu wei li chih* 五緯曆指) in 1634 or slightly earlier,[19] was more conspicuously evasive. His accounts of both cosmology and the telescope omitted Galileo's name.[20] Rho did explain the changing aspects of the Medicean Planets (as the satellites of Jupiter were called) and dealt more briefly with the other new phenomena, but did not hint that Galileo's observations could conceivably necessitate a major revision of the system of the world.

Rho nevertheless initiated an important cosmological reorientation. He was the first of the missionaries to substitute the Tychonic for the Ptolemaic world system in his published writings. There was, of course, the danger of confusing Chinese readers. If no explanation were given, they would wonder why the Europeans were suddenly changing their story. Rho dealt with this problem by speaking of Ptolemaic astronomy as the "ancient school." Even so, he obscured the difference by stating that, among other propositions, the sun's place at the

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Diény, "L'introduction du télescope en Chine," in *Nombres, astres, plantes et viscères. Sept essais sur l'histoire des sciences et des techniques en Asie orientale,* ed. Isabelle Ang & Pierre-Étienne Will (Memoires de l'Institut des Hautes Études Chinoises, 35; Paris: Collège de France, 1994), 177-191.

On Schreck, see G. Gabrieli, *Giovanni Schreck Linceo, Gesuita e Missionario in China e le sue Lettere dalt'Asia* (Rome: Royal National Academy of the Lincei, 1937). Needham *(Science and Civilisation,* III, 435, 447) has pointed out that Schreck described sunspots in this work in the belief that he was introducing Chinese astronomers to a novelty, but their predecessors had been recording them from the Han period on, and publishing extensive lists since the thirteenth century.

19. D'Elia gives the date of this work as 1637 (p. 97, n. 124), but it was presented to the throne in its present form on 21 January 1635. See Li Yen, *Chung suan shih lun ts'ung,* III, 37. Ch. 9, in which D'Elia noticed a date in 1636, is actually the supplement *Wu wei hou lun,* which was not submitted with the *Wu wei li chih* (see note 17 above).

20. Chap. 1 is devoted to introductory cosmology. On the telescopic discoveries see pp. 32a-35b.

center of the planets is "also doubted neither by the ancients nor the moderns."[21] Perhaps Rho meant "the ancients" as a euphemism for the conservative schoolmen of his time, in which case his statement would be very optimistic. In any case, because he did not define the term, no Chinese could have understood it to mean anything but people living in ancient times.

Rho discussed a number of topics drawn from Copernicus' *De revolutionibus.* In some cases he identified them with its author. He brought up the diurnal rotation of the earth, for instance, in order to refute it, but did not express or imply any connection with Copernicus:

Question: How about the rotation of the first moving orb[, the outermost sphere in Aristotle's cosmos, which drives all of those within]?

Answer: There are two theories. Some deny that the first moving orb makes a daily revolution of the sky, rotating leftward about the earth and carrying all the orbs westward with it. When above the surface of the earth we see the celestial bodies moving leftward, [according to this view] this is not their own motion. The celestial bodies do not have a daily revolution; rather the earth along with its air and fire move as one sphere from west to east, making one rotation each day. Like a man traveling in a boat who sees trees and other things on the shore and feels that not he but the shore is moving, people on the earth, seeing the westward motion of all the celestial bodies, reason analogously. Thus by the single motion

21. That Rho's writing was Tychonic is obvious in the passages cited in D'Elia, 54–56. The quotation in paragraph 2, p. 55, begins with a mistranslation, since D'Elia mispunctuated his text. At the end of paragraph 2, for "solar system" read "[orb of] the sun." In lines 2–3 of the same page, for "of small orbits, and of non-concentric circles" read "of epicycles and eccentrics." The passage which D'Elia claimed "openly alludes both to Galileo and to the heliocentric system" (p. 54) mentions neither, and does not even imply that anyone ever believed the sun is at the center of the world.

of the earth one avoids many motions in the heavens. By a terrestrial rotation of small radius one avoids a heavenly circuit of great radius [i.e. that of the first moving orb].

Nevertheless all the scholars of ancient and modern times agree that this is truly not a valid explanation. It would seem that, since the earth is the center of all the orbs, and a center is like a pivot, it cannot possibly move. Further, if from the boat one sees the shore moving, why should not someone on the shore see the boat moving? The simile offered does not constitute proof [of the earth's rotation].

According to the correct explanation, the body of the earth does not move. The first moving orb is a great sphere, the uppermost of the orbs, with its own poles and proper motion. The two poles of each of the orbs within, since they are contained by the first moving orb, cannot fail to move along with it. Like a man traveling in a boat, or ants moving on a millstone, although they have their proper motions they cannot fail also to follow along with the boat or millstone. Inquiries as to the thickness of the first moving orb, its substance, color, and so on, and the substance and color and so on of the other orbs, because they belong to physics [*wu li chih hsueh* 物理之學, literally "the study of phenomenal principles"],

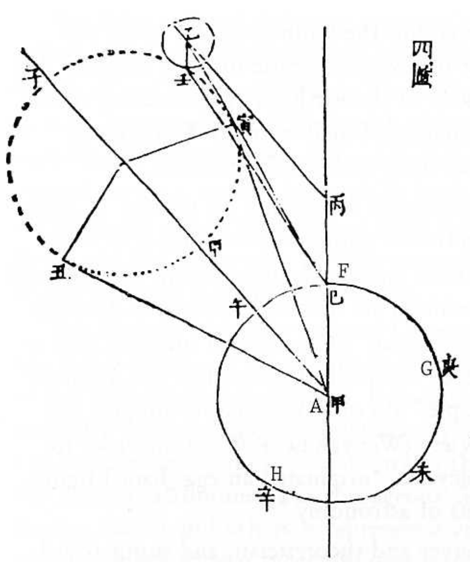

Figure 2. Rho on the General Method of Tycho and Copernicus.

are not the concern of mathematical astronomy. They are taken up in detail in other books.[22]

Why did Rho want to present an explanation that no scholar of ancient or modern times believed? If no one believed that the first moving orb moves, who was disagreeing, and why? Rho did not address these points. The application of the boat simile to the question of the earth's diurnal rotation, familiar in Europe since its use by Nicole Oresme in the fourteenth century, was by no means rare in the Chinese writings of the missionaries, as we will see anon.

Principles of the Planetary Motions failed to identify Copernicus as the one who had posited the rotation of the earth about its own axis, but Rho gave him credit for a discovery he never made: "In the Middle Ages, above the orb of the fixed stars were added one orb [to account] for the east-west precession of the equinoxes and one for the north-south precession [i.e. trepidation], making an eleven-orb heaven. (This is as determined by Copernicus; since Tycho's time they are no longer used.)"

Rho explained in some detail the differences in Ptolemy's, Copernicus', and Tycho's treatment of the annual motions of the superior planets. Using the diagram reproduced here as Figure 2, he demonstrated the equivalence of the Copernican and Tychonic constructions for the equation of center, which replaced Ptolemy's combination of equant and eccentric. Here is the accompanying text: "Figure [2] is the general method of Tycho and Copernicus. The sun is taken as

22. *Wu wei li chih, 1:* 7b-8a. A note in small type at the end of this passage refers the reader to *Huan yu ch'üan* (see note 12). "First moving orb" and other terms are discussed in the Appendix, p. 51.

the center of rotation of the Five Planets. *A* is the earth. *FGH* is the deferent of the sun. The sun being located at *F*, *F* is the center [of rotation of the planets] . . ."[23]

Rho's diagram, taken in conjunction with these words, plainly gives the impression that, for Copernicus as well as Tycho, the earth is approximately at the center of the solar deferent, the sun rotates about it, and the planets rotate about the sun. We will see that it was understood in that way by Chinese readers.

Rho used the Tychonic model heuristically throughout his work to demonstrate the equivalence of computational techniques. But since he did not make it clear that two distinct models of the world were involved, he was bound to impede his readers' understanding. The policy of the Church gave him no choice.

Rho was prudent and willing to leave to the philosophers the physical merits of the systems he was describing. The net result was that Copernicus appeared to be a rather shadowy precursor of Tycho Brahe. That was, in fact, the way many progressive Europeans were thinking of him in 1634.

Schall, on the other hand, was direct and certainly intent on giving Copernicus and Galileo their due. But Chinese readers could only interpret his words to mean that none of the cosmological changes was fundamental.

Schall's quasi-historical treatise On the Transmission of Astronomy in the West *(Li fa hsi ch'uan* 曆法西傳, probably written about 1640) placed Copernicus and Tycho in the ancient school along with Ptolemy.[24] Oddly enough, the modern

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23. Ibid., *1:* 1b, 29b. The diagram is on the same page. I have added Latin letters equivalent to the ordinal Chinese characters to this figure and to Figure 9.

24. This dating is tentative; see D'Elia, *Galileo in China,* 50. *Li fa hsi ch'uan* was not among the books presented to the throne by 1635. In addition to the version printed in *Hsi-yang hsin fa li shu*

school, to which he devoted the second half of the little treatise, was represented only by Schall and Rho and their European collaborators. This kept the focus on the Jesuit writings in order to widen support for the missionaries.

Schall began with an outline of the *Almagest* chapter by chapter. He then praised Alfonso X of Castille as a king learned in astronomy who spent a vast sum on the compilation of tables: "His merit is not inferior to that of Ptolemy." He went on: "And then, four hundred years later, there was Copernicus, who determined empirically that although Ptolemy's methods were quite exhaustive, there was a slight lack of clarity *(wei ch'ien hsiao ming* 微欠曉明); so he created a new figure and wrote a book in six chapters." The word "*t'u*圖," which I translate "figure," can mean anything from "picture" to "map" to "diagram" to "schema." Schall generally used it elsewhere in his treatise to denote a heuristic schema that accounts for one or more of the celestial motions. We know what Copernicus' "figure" was, but the Chinese reader could not. The summary of *De revolutionibus* that follows this praise of King Alfonso did not mention the daily or annual rotations of the earth, or the centrality of the sun. In fact, as a Chinese critic later remarked, Schall wrote of Copernicus' "seeking the sun's apogee and its annual, daily and hourly motions."[25]

At the end of this summary, Schall brought astronomy up to date: "Copernicus' work, as above, has been transmitted as authoritative by most of those who came after him. There was one Simon Stevin (Hsi-man 西滿), who proved that the

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(1646) there is a copy in a manuscript collection of Jesuit and Dutch material called *Ch'ung-chen lei shu* 崇禎類書 in the Tenri Library.

25. See below, p. 47. D'Elia translates the passage in which the word "*t'u*" appears (p. 34; cf. note 17 above). He is, however, wrong in translating "*t'u*" as "map of the heavens," as is clear from Schall's use of the word elsewhere in the book.

methods of Ptolemy and Copernicus are identical. Giovanni Antonio Magini (Ma-jih-no 麻日諾) adopted Copernicus' observational methods and revised Ptolemy's figure. We [thus] see even more clearly that they [i.e. Ptolemy and Copernicus] do not differ in principle." As observational techniques improved, progress continued. François Viète (Wei-yeh-ta 未葉大), in order to stop calculating with eccentrics and epicycles, "originated an egg-shaped figure (*t'u*) in order to explain the foundations of astronomy."[26]

Schall lauded Tycho as a great observer and theoretician, and summarized two of his works. He pointed out that Galileo's telescopic observations are important, but passed over what, aside from sheer novelty, makes them important. He also named Galileo as originator of a new "figure" that revealed what had never been revealed in all the previous study of the stars, and noted that the Tuscan wrote a book to include it. Schall had nothing to say about the character of this figure or the content of the book. He went on to discuss astronomical instruments and their applications, and what voyagers' observations had contributed to science. This remarkable sketch concludes by observing that as-

26. Schall could have been hardly ignorant that the ellipse was Kepler's. Kepler, in reply to Schreck's request for information concerning the newest results of astronomical research, wrote a report and had it printed in 1629. See Max Caspar, *Johannes Kepler* (Stuttgart: W. Kohlhammer Verlag, 1950), 396 and 420. The statement about Stevin is apparently based on the fact that the author of "the first textbook destined to give a simple and easy exposition of the heliocentric theory" (*Wisconstighe Ghedachtenissen,* 1605) explained computations by both systems. It ignores the fact that in doing so Stevin "expounded the Copernican as the true beside the Ptolemaic as the untrue system." See A. Pannekoek (ed.) *The Principal Works of Simon Stevin* (Amsterdam: C. V. Swets & Zeitlinger, 1961), III, *passim,* esp. p. 6.

tronomy in the West is the work of many hands over thousands of years, but "in its essentials it has not gone beyond the bounds [set] by Ptolemy."[27]

Schall introduced the same sequence of four great astronomers (Ptolemy, Alfonso X, Copernicus, Tycho), none of whom was to be considered inferior to the others in any respect, in his outline of Tychonic cosmology, Introduction to Astronomy according to the New Methods (*Hsin fa li yin* 新法曆引, 1635/1646). There he devoted only a few sentences to historical matters. He praised the four masters impartially (perhaps promiscuously in the case of Alfonso) for the proliferation of their writings, the accuracy of their observations, and the practicality of their computational methods.[28] Neither of Schall's books so much as mentioned Kepler.

Schall could also have ignored Copernicus, but he was too fair-minded and too conscientious an astronomer not to honor him in China as far as the spirit of the 1616 injunction allowed. Regardless of whether he knew of the final and generally unexpected proceeding against Galileo (1633) by the time he wrote On the Transmission of Astronomy in the West, the wording of his praise for the

27. This summary and the citations included in it are drawn from *Li fa hsi ch'uan*, 2b-14b. There have been several biographies of Schall, none of which pay adequate attention to his astronomical work. The most useful sources for his life are Alfons Väth, *Johann Adam Schall von Bell, S. J., Missionar in China, Kaiserlicher Astronom und Ratgeber am Hofe von Peking 1592–1666. Ein Lebens- und Zeitbild* (Cologne: J. P. Bachem, 1933), and Henri Bernard, *Lettres et mémoires d'Adam Schall S. J.* (Tientsin: Hautes Études, 1942).

28. In *Hsi-yang hsin fa li shu*, 2a-2b. The dating of this book is problematic. It was not among those presented to the throne prior to 1635. Bernard, "L'Encyclopédie astronomique," 578–579, noted a separate book entitled merely *Li yin* (Introduction to astronomy), by Rho and twelve Chinese collaborators, in the National Library of Peking. Bernard thought that the *Hsin fa li yin* is a new edition of this work, although the recorded length is different and he was unable to compare the two (476). He did not notice, however, that *Li yin* is also missing from the presentation lists. For the latter reason it is probable, although far from certain, that neither work existed prior to 1635.

Tuscan astronomer was courageous. Schall's attitude toward Copernicus, Kepler, Stevin and others is representative of many astronomers of his time, who quite agreed that what physical reality underlay their observations and formulas was none of their business.

In Europe, however, there was a dialogue. Many sagacious and prudent men of science, convinced that the Copernican issue was unimportant and could easily lead to errors of belief, preferred being forbidden to discuss it freely. But still in Europe there were countries where a scientist could not be punished or abandoned to damnation for seeking to separate experiential and quantitative knowledge from verbal philosophy. If what was subjectively prudence and the best of intentions led to misrepresentation, some would know the truth, and would not be silent.

In China only the safe side of the argument could be presented, even long after astronomers had abandoned it in the West. Since heliocentricism was unmentionable, any discussion that attempted to do justice to Copernicus in the realm of computational astronomy would have to pay the price of distortion in that of cosmology. As the missionaries acted surreptitiously on their good intentions, the compounded outcome led Chinese readers to an erroneous conception of Copernicanism, and provoked them to reject a correct explanation when it came. The central irony of the Jesuits' situation is that they could have avoided this ultimate rejection only by not writing about Copernicus at all so long as it was a matter of conscience not to describe his work fully.

Copernicanism in Shibukawa's Synthesis

For most Chinese readers of the Jesuit astronomical treatises before the mid-eighteenth century, Copernicus' historical position was clear. He was a vague but estimable figure of the Middle Ages whose work had been made obsolete by Tycho Brahe. This consensus appears, for instance, in the Queries on Mathematical Astronomy (*Li hsueh i wen* 曆學疑問, 1693) of Mei Wen-ting 梅文鼎 (1633–1721), the most influential writer of his time on the subject. While arguing that Western astronomy was as much a result of historical development as the Chinese art was, Mei noted: "With the coming of Copernicus, there were some revisions to Ptolemy's methods. With the coming of Tycho there was a great transformation of Copernicus' methods. The methods were now on the whole complete, but the making of the telescope happened still later, and led through the accumulation of observations to enhanced precision."[29]

Figure 3. Shibukawa Kagesuke's Ptolemaic schema.

Ample discrepancies remained, ready to confuse those who read widely. Indeed, as I will show, confusion became inevitable later in the eighteenth century as the true importance of Copernicus began to emerge.

To illustrate the kind of misunderstanding that was generated by a trustful reading of the late Ming treatises, consider an important

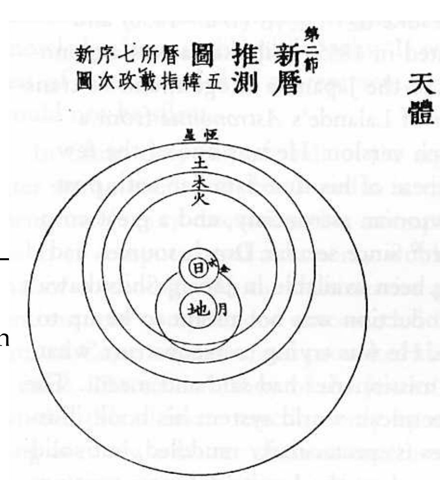

Figure 4. Shibukawa's Tychonic schema.

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suan ch'üan shu 梅氏曆算全書 (Wei Nien-t'ing 魏念庭 ed., prin … Buntei no rekisangaku."

Japanese book, now rare, the Introduction to the Astronomy of the Ming Jesuit Treatises (*Sûtei rekisho rekiin* 崇禎曆書曆引), completed about the end of 1847 by Shibukawa Kagesuke 澀川景祐 (1787–1856) and printed in 1855. Shibukawa was astronomer to the Japanese Shogun, and co-translator of Lalande's *Astronomie* from a Dutch version. He was one of the few Japanese of his time familiar with post-Newtonian astronomy, and a great compiler.[30] Since secular Dutch sources had long been available in Japan, Shibukawa's Introduction was not meant to be up to date. He was trying to reconstruct what the missionaries had said and meant. The Copernican world system his book illustrates is spectacularly muddled, but solidly based on the Jesuits' Chinese writings.

Shibukawa's Ptolemaic schema (Figure 3), according to its caption, comes from Rho's Principles of the Planetary Motions.[31] Shibukawa has merely added small epicycles between the planetary orbs to reflect Rho's verbal description. We see the earth at the center, the spheres of air and fire about it, and then the orbs of the moon, the planets, and the fixed stars. Shibukawa's Tychonic diagram (Figure 4) is a practically exact copy of the Rho illustration (Figure 1, page 11). The caption does not mention Tycho's name: "Figure for predicting celestial positions according to the new astronomy," and in smaller characters, "The new figure for the order of the Seven Governors [the sun, moon, and planets] as recorded in Principles of the Planetary Motions."

Figure 5 is Shibukawa's diagram for the Copernican system. Comparing it with the Ptolemaic figure, we can see two prominent differences. First, Shibu-

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30. On Shibukawa, see Nakayama, *History of Japanese Astronomy*, 200–202.

31. Vol. III (*zuhen* 圖編), section "On the order of the universe." The figures reproduced here are from pp. 3a, 3b, and 4a respectively.

kawa gave the central earth (!) features and left out its spheres of air and fire. Second, and obviously more significant, he added precession and trepidation spheres, the first moving orb, and a "sphere of the blest," all above the sphere of the fixed stars.

The captions deserve attention:

[In large type:] The Old Cosmos of the Westerner Copernicus [In smaller characters:] Recorded in Catechism of the Heavens

[On the spheres, reading from the earth outward:]

1. Sphere of the moon . . . [usual Aristotelian-Ptolemaic order of intermediate spheres] . . .

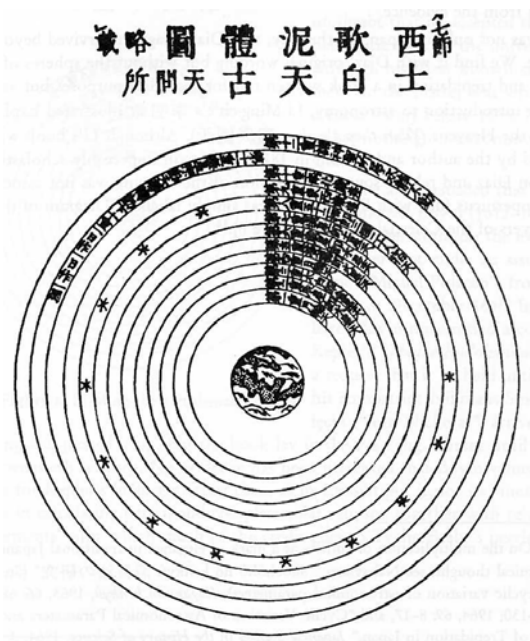

Figure 5. Shibukawa's Copernican schema. See the translation, page 24.

8. Sphere of the fifty-two [Western] constellations, that is, of the [Chinese] Three Walls and twenty-eight lunar lodge constellations[32]

9. Sphere of precession

10. Sphere of trepidation

11. The first moving orb, without stars, which carries with its motion the ten layers below, making one revolution per day

32. I. e., the sphere of the fixed stars. The fifty-two constellations are those known before the seventeenth century. Shibukawa's text (*1:* 18b) says: "In ancient Western astronomy there were also twenty-eight houses; their significance was the same as in the ancient Chinese [art] . . . In the West [the firmament] was further divided into sixty-two *[sic]* constellations, which were also given names." The Three Walls are three chains of stars significant in Chinese astrology. See Ho Peng Yoke, *The Astronomical Chapters of the Chin Shu* (Paris: Mouton & Co, 1966), 71, 76, and 84.

12. The abode of the saints, eternally immobile.[33]

It is possible to reconstruct what happened. Shibukawa found the original of his diagram in Diaz' *Catechism of the Heavens,* which does not even mention

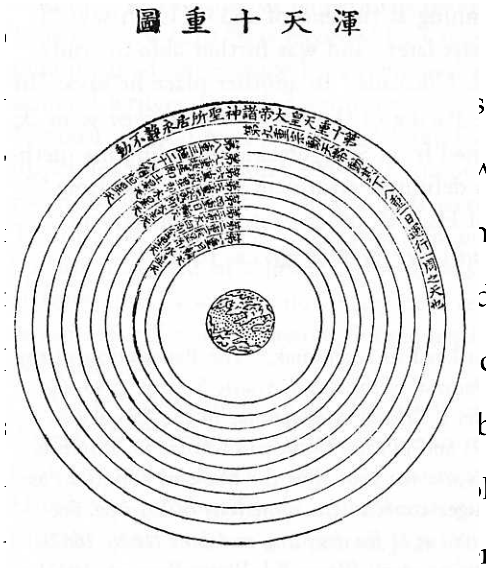

Figure 6. Li Ming-che's Ptolemaic schema.

reproduced the captions of the twelve spheres
so made the twelfth sphere the abode of God.
va Japan, had to be removed. The Chinese word
no specifically Christian connotation and by
d the spheres of precession and trepidation, the
centuries, come to signify the Jesuits' de-
bukawa's mind? He had it on Schall's authority
lemy's schema in some way that was significant,
ntal. In Shibukawa's search for the identity of this modification he came upon one that looked significant and had been wrongly but explicitly credited to Copernicus by Giacomo Rho in 1634, namely the addition of the two extra spheres. What, we can imagine him wondering, could merit the praise of that wise barbarian Schall more than placing two more spheres in the heavens?[34] Shibukawa can hardly be faulted for his deduction from the evidence.

33. Shibukawa's accompanying text (*1:* 3b) reads: "The ancients said that from the sphere of the moon upward there is . . . a total of twelve spheres, which enclose each other like the layers of an onion. But those beyond the fixed stars are no longer amenable to observation. Since observation is the proper concern of astronomers, how can they investigate the unobservable? Thus they do not discuss [these upper spheres]."

34. On the multiplication of entities as a mark of elegance in traditional Japanese astronomical thought, see Nakayama, "Shôchôhô no kenkyû 消長法の研究" (Studies on the cyclic variation of astronomical parameters), *Kagakushi kenkyû,* 1963, *66:* 68–84; *67:* 128–130; 1964, *69:* 8–17, and "Cyclic Variation of Astronomical Parameters and the Revival of Trepidation in Japan," *Japanese Studies in the History of Science,* 1964, *3:* 68–80.

It was not only in Japan, by the way, that Diaz' diagram survived beyond its time. We find it with Diaz' original wording but without the spheres of precession and trepidation in a book written not for historical purposes but as a popular introduction to astronomy, Li Ming-ch'e's 李明徹 Illustrated Explication of the Heavens *(Yuan t'ien t'u shuo* 圜天圖説). Although Li's book was prefaced by the author and printed in 1819, it was still impeccably scholastic, based on Diaz and related sources. Its version of the drawing was not associated with Copernicus (nor with Ptolemy). It was simply labelled "Diagram of the Ten Layers of the Celestial Sphere" (Figure 6).[35]

Putative Copernicans

Historians have claimed that various Jesuits not employed in the Calendrical Office may have been Copernicans in the seventeenth century.[36] Just as we have seen regarding those in the palace, there is ample evidence to the contrary. Of the earliest, the Bohemian Wenzel Kirwitzer (1588/90–1626), there is no doubt that he accepted the heliostatic view of the universe, although his latest known statement on the matter was written (in a Latin letter) before 1616. He wrote nothing on astronomy in Chinese.

Some are persuaded that the Pole Michael Boym (1612–1659) was a Copernican, on the evidence of a letter sent under an assumed name ("Miguel

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35. *Yuan t'ien t'u shuo* (Sung Mei Hsuan 松梅軒 ed. of 1819), *1:* 5b. Li knew of the Tychonic schema, and discussed its equivalence to the Ptolemaic in *2:* 3a-4a. I have not found a copy of *T'ien wen lueh* in which Diaz' diagram is printed clearly enough to reproduce here, but taken together Li's and Shibukawa's diagrams convey an accurate impression of it.

36. D'Elia, *Galileo in China,* 25–28 and 53, summarizes and adds to what has been written on this point. I sense that a reason for raising this issue was to refute charges that prejudice against the new science pervaded the Society of Jesus; or, as D'Elia puts it, to correct "a current opinion which would make all Jesuits think alike." Neither the charge nor the attempt to refute it by making the missionaries Copernicans has any merit.

Polacco") from Macao in December 1646. In this letter Boym transmitted a copy of Kepler's *Tabulae Rudolphinae,* with a request that it be held until he or his compatriot Nikolaus Smogułęcki ("Jean Nicholas") arrived at Peking and picked it up. But the book lay in the Pei-t'ang Library until late in the twentieth century. No evidence has been presented that Boym valued it more for Kepler's heliocentricism than, as he himself put it, for its "inestimable value in calculating partial and complete solar eclipses, together with celestial movements"—for which much of the credit goes to Tycho Brahe's peerless data.[37] Whatever Boym's private beliefs may have been, they were never food for Chinese astronomical thought.

Smogułęcki (1610–1656), the last of these putative Copernicans, left an ample heritage that his disciple Hsueh Feng-tso 薛鳳祚 (ca. 1620–1680) published in Chinese from 1653 on. Hsueh, the only Chinese pupil of Smogułęcki who published anything, had studied traditional calendrical astronomy with the conservative Wei Wen-k'uei 魏文魁 beginning at the end of 1633. Hsueh says "I came to Nanking—this was twenty years later—and was further able to study trigonometry and also logarithms with Nikolaus." In another place he says: "In 1653 I wrote True Foundations of the Pacing of the Sky (*T'ien pu chen yuan* 天步真

37. Boym's letter of transmittal is translated in Szcze_niak, "The Penetration of the Copernican Theory into Feudal Japan," *Journal of the Royal Asiatic Society,* 1943, 60; see also the same author's "Note on Kepler's *Tabulae Rudolphinae* in the Library of Pei-t'ang in Pekin," *Isis,* 1949, *40:* 344–347, and D'Elia, *Galileo in China,* 53. Boym is chiefly remembered as the author of *Flora sinensis* and, after the Manchu conquest, as the emissary of the beleaguered Ming refugee court to the monarchs of Europe. See Robert Chabrié, *Michel Boym, jésuite polonais et la fin des Ming en Chine (1646–1662). Contribution à l'histoire des missions d'Extrême-orient* (Paris: Ed. Pierre Bossuet, 1933), and, for his contributions to European botany, Szcze_niak, "The Writings of Michael Boym," *Monumenta Serica,* 1955, *14:* 481–538. There is an informative essay review of Chabrié's book by Paul Pelliot, "Michel Boym," *T'oung Pao,* 1935, *31:* 95–151, and a translation under the title *Pu Mi-ko* 卜彌格, tr. Feng Ch'eng-chün 馮承鈞 (1949; reprint, Taipei: Commercial Press, 1960).

原) according to what I had learned from Smogułęcki, emending his methods in many respects and giving them definitive treatment for the first time."[38] We also have a large printed corpus of Hsueh's other writings, collectively called Eclectic Astronomy (*Li hsueh hui t'ung* 曆學會通, ca. 1663).[39]

Cosmology plays a negligible part in Hsueh's books, parts of which may have been dictated by Smogułęcki. These highly technical treatises, for the first time in China, applied spherical trigonometry and logarithms to calculate ephemerides. They reflect more detailed knowledge of European astronomers than could have been derived from previous publications in Chinese. For instance, Hsueh stated that an eclipse of 74 or early 73 B.C. is identically calculated according to Ptolemy or Copernicus (Ko-po-ni 歌白泥), and that another of 1509 or early 1510 "was recorded by Copernicus." Hsueh also mentioned computational advances made by Tycho, and recognized that the early Jesuit astronomical writers depended

38. Introduction to *Chung fa ssu hsien* 中法四綫 (Chinese trigonometry), I, 1b-2a; preface to the *K'ao-yen* 考驗 (Verification) section, VIII, 2a-2b, in *Li hsueh hui t'ung* 曆學會通(Harvard-Yenching Library copy). Cf. Li Yen, *Chung suan shih lun ts'ung,* III, 46, 546. The main account of the collaboration of Smogułęcki and Hsueh is in Mei Wen-ting's bibliography *Wu-an li suan shu-mu* 勿庵曆算書目 (1702; in *Chih pu tsu chai ts'ung-shu* 知不足齋叢書, 1st ed., vol. LXXII), 33b-34b. Mei stated that Hsueh "never became a member of the Catholic Church." D'Elia claims (53) that the Polish missionary "made some proselytes among the Chinese scholars," but the source cited in D'Elia's footnote does not give pertinent data.

39. In the twelve-volume copy that I have had an opportunity to read, the first preface, 11a (in vol. I), is dated 1662, and the preface to Hsueh's table of logarithms in vol. VII, the beginning of 1663. Books by Hsueh bearing the title *Li hsueh hui t'ung* range in length between 1 and 61 *chüan.* Some citations seem to apply the synonymous title *T'ien hsueh hui t'ung* 天學會通 to the same writings, but others use it for a distinct book in one *chüan.* See, for instance Chou Yun-ch'ing 周雲青 & Ting Fu-pao 丁福保, *Ssu pu tsung lu t'ien-wen pien* 四部總錄天文編 (General bibliography, section on astronomy; Shanghai: Commercial Press, 1956); *Ch'ing shih kao* 清史稿 (Draft standard history of the Ch'ing period, 1927; Lien-ho Shu-tien ed.), 579a; Li Yen, ibid., II, 277–278, and *Chung-kuo suan hsueh shih,* 205. In some versions many chapters are devoted to European astrology. No generalization about *Li hsueh hui t'ung* will be feasible until Hsueh's printed and MS writings in Peking, Rome, Tokyo, and other places have been compared.

upon him: "The esoteric aspects of the contemporary Western method were explained by the Far Westerners Schall and Rho. Their principles were recondite and their computations subtle, but there remains room for deliberation. Their methods were created by the Western savant Tycho. The Westerners considered him an eminent authority on the fixed stars, but his treatment of eclipses and such was never highly regarded in Western astronomy. His work is now sixty or seventy years old, and his rules of computation are still not exhaustive. Subsequently there were the methods of Nikolaus …"[40]

What little cosmology one finds not only is not heliocentric, it is not even discernibly Tychonic. It is impossible to tell whether this is because Smogułęcki took the same agnostic position with respect to cosmology as Schall, or because Hsueh was interested only in mathematical methods. Perhaps it is significant that the great amateur and patron Juan Yuan 阮元 (1764–1849), in his biographical survey compiled at the end of the eighteenth century, as well as Mei Wen-ting a century earlier, criticized Hsueh for concentrating too narrowly on technique without attending to its ramifications. Juan also thought Hsueh's translation poor, and noted that, lacking experience at observation, he had accepted Smogułęcki's theories ready-made.[41]

Yabuuchi Kiyoshi has noted that, in an annotation to the section on the Earth of Fang I-chih's 方以智 (1611-1671) compendium of notes on physics and natural history, his son Fang Chung-t'ung 中通 observed that "Master Smogułęcki also

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40. See, for instance, the pre-Tychonic diagram and its caption in *Li hsueh hui t'ung,* I, *4:* 1a. On eclipse predictions see *Chin hsi fa hsuan yao* 近西法選要 (Selected essentials of the modern Western methods), section *T'ai yin* 太陰 (The moon), XI, 21a, and, on Tycho, the first preface, I, 10a.

41. *Ch'ou jen chuan*, 449–450.

had a theory of the excursions of the earth" *(ti yu chih shuo* 地游之說).[42] It is tempting to see in this annotation a reference to the earth's diurnal rotation, particularly since it follows a passage that ends "like a man sitting in a boat; the boat is moving but the man is unaware of it." This is the famous argument for the relativity of motion used in Europe both to reject and to support the idea of the earth's daily turning on its axis (see above, p. 17). But Fang I-chih was applying the boat simile to the apocryphal Chinese idea of an annual cycle of terrestrial rising and subsidence, which had been formulated in terms of the ancient *kai t'ien* 蓋天 (literally, "the sky as a cover") model of the universe.[43] This cycle he was relating in turn to seismology.

Fang Chung-t'ung's annotation outlines Smogułęcki's theory and its context, typical of late scholastic physics: "The interior of the earth is mostly hollow, with *ch'i* 氣 moving about inside. Small movements [i.e. tremors] are normal occurrences everywhere. When they are intense, the ground caves in and mountains shift. I often reflect that Chang Heng 張衡 made a bronze-dragon seismoscope in order to respond to these movements of the earth, but I do not know what this instrument was."[44]

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42. Yabuuchi, "Min Shin jidai no kagaku gijutsushi," in the book of the same title (see note 15), 23. The passage discussed below is cited from *Wu li hsiao chih* 物理小識 (Little notes on the principles of the phenomena; Ning ching t'ang 寧靜堂 ed. of 1884), *2:* 22b-23a. This book contains notes written from 1631 on; Fang I-chih wrote his preface to the finished manuscript in 1643; he sent the MS to his son Chung-t'ung in 1650; and it was printed in 1664 (see note 12 above).

43. The *kai t'ien* cosmology is clearly explained in Nakayama, *History of Japanese Astronomy,* 24–35. For more detail, see the book on early cosmology by Christopher Cullen forthcoming from Cambridge University Press.

44. For a reconstruction of Chang Heng's earthquake-registering device see André Wegener Sleeswyk & Sivin, "Dragons and Toads. The Chinese Seismoscope of A.D. 132," *Chinese Science,* 1983, 6: 1–19. "I" refers to the annotator. For writings on the scholastic sciences of the earth available to Chinese thinkers, see note 9 above.

To sum up, although it is likely that individual members of the Society of Jesus in China would have accepted the idea of a solar system sooner or later if they had been allowed to do so, there is no serious evidence that Boym or Smogułęcki believed in the heliocentric theory, that they or the Copernican Kirwitzer made any contribution to the dissemination of the new world model, or that any of the three (not being members of the Calendrical Office) would have written on the subject in Chinese even if the injunction of 1616 had not intervened.

Jesuit Astronomical Writings in the Early Ch'ing (1646–1760)

The frustrations of the European astronomers ended with the end of the Ming. As the Manchus took over China, the Jesuits quickly attained the goal that had prompted them to disseminate the earlier astronomical treatises. Thanks to Schall's prompt support for the alien invaders, the Manchus retained him on a stipend within two weeks of their march into Peking in mid-1644, and gave him control over the official calendar and the Directorate of Astronomy before the end of 1645. He filled the new regime's need for a reliable calendar, traditionally one of the ritual underpinnings of dynastic legitimacy. The missionary was even able to force his old rivals, the Chinese and Islamic incumbents of the Directorate, to take an examination in Western astronomy—and soon fired the Muslims en masse. To accommodate an ephemeris of foreign origin, officials revised the ritual by which the Emperor bestowed the calendar at the New Year, asserting his control over the seasonal activities of his people. The Jesuits from that time on were in an ideal position to make converts among highly placed Chinese, in fact the only strategic position open to them.[45]

45. Huang I-nung 黃一農 has reconstructed this sequence of events in "T'ang Jo-wang yü Ch'ing ch'u hsi li chih cheng-t'ung-hua."

In the Ming the Jesuits had had to print their astronomical treatises privately for instructional use (the exemplars presented to the throne were manuscript copies). But under the Ch'ing these works, which usually had been collectively referred to as the Astronomical Treatises of the Reverence for Auspices Reign Period (*Ch'ung-chen li shu* 崇禎曆書), were published together for the first time by Imperial order as the Astronomical Treatises according to the New Methods of the West (*Hsi-yang hsin fa li shu* 西洋新法曆書, presented 1646).[46]

For nearly a century following the publication of the 1646 collection, no significant modern developments in world view were brought to the attention of Chinese astronomers.[47] What was taught privately to those working in the court,

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46. Bernard surveyed its history and content in "L'Encyclopédie astronomique." The Ming treatises were presented to the throne in five lots between 1631 and 1635. Some of these books were not printed before the Ch'ing, and others written after 1635 were added to the *Hsi-yang hsin fa li shu.* See, for example, notes 19 and 28 above. The question of whether the Jesuit treatises were printed collectively once, twice, or three times—in other words, whether *Ch'ung chen li shu* and *Hsin fa suan shu* (see below) are nothing more than conventional ways of referring to all the individual works printed separately and privately at the end of the Ming and about 1669 respectively—badly needs settling. I have found no evidence that there was ever an integral publication of either title. To give a single example, the manuscript of 1670 in 125 volumes entitled *Ch'ung chen li shu* in the Tenri Library contains post-Ming materials, and was patently copied from the *Hsi-yang hsin fa li shu.* An officially printed *Ch'ung-chen li shu* is occasionally cited (among several references I have collected is Li Yen, *Chung suan shih lun-ts'ung*, III, 37) but never with sufficient detail or precision to rule out the separately printed treatises and the 1646 collection.

Nearly four hundred pages at the beginning of the latter collection are devoted to documents concerning the Jesuits' activities in the palace in the Ming and at the beginning of the Ch'ing. Particularly informative evidence about the Ch'ing publication is given on 48b-49b and 59ff. The presentation of the completed compilation took place on 7 January 1646, and the order authorizing its use was dated 8 February. The accounts of Jesuit activities in the Standard History of the Ming (*Ming shih* 明史) and its draft (*Ming shih kao* 明史稿) were mainly based on documents in this collection. For an evaluation of the accounts in the two histories, see the long review of D'Elia's *Galileo in Cina* by J. J. L. Duyvendak in *T'oung Pao,* 1948, *38:* 321–329, especially 323–327.

47. Yu I's 游藝 *T'ien ching huo wen* 天經或問 (Queries on the astronomical classics, 1675) is a synthesis of traditional and Western knowledge, the latter derived from Hsiung Ming-yü 熊明遇 (Presented Scholar 1601), a friend of Diaz. Yu's superficial and confused book, which describes the

of course, we do not know. Only when rivals again threatened the Jesuits' position in the Directorate of Astronomy were they motivated to publish on the state of observational and computational astronomy. The writings of Ferdinand Verbiest (1623–1688), a skilled astronomer who came under strong attack from traditionalist zealots, concentrated mainly on tables, descriptions of astronomical instruments, and accounts of competitions in which the Europeans demonstrated their superiority over second-rate Chinese and Islamic astronomers by predicting eclipses and other phenomena. With respect to cosmology, Verbiest merely reprinted with minor revisions ca. 1669 some of the treatises from the 1646 collection. This last printing was generally referred to as the Mathematical Treatises according to the New Methods (*Hsin fa suan shu* 新法算書), in order to deemphasize the book's foreignness.[48]

When in 1722–1724 a large editorial committee brought together the Compendium of Observational and Computational Astronomy *(Li hsiang k'ao ch'eng* 曆象考成), the writings of Rho, Schall, and their colleagues remained the best available sources.[49] The Compendium was a Chinese project, meant to lay the

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Tychonic planetary system, had great influence in Japan but practically none in China. For a description, see Nakayama, *History of Japanese Astronomy,* 100–105.

48. Because Bernard saw a book entitled *Hsin fa suan shu* in the Peking Imperial Palace, he believed that this was the collective title of Verbiest's reprints. Since Bernard was unable to examine the book carefully, it remains likely that a librarian, as librarians often do, arbitrarily chose this title for the binders of a collection of individually printed treatises. I know of no evidence that Verbiest gave his group of reprints a title. On Verbiest, see R. Josson & L. Willaert, *Correspondance de Ferdinand Verbiest de la Compagnie de Jésus (1623–1688), directeur de l'observatoire de Pékin* (Bruxelles: Palais des Académies, 1938), and Noel Golvers (ed. & trans.), *The "Astronomia Europaea" of Ferdinand Vierbiest, S.J. (Dillingen, 1687).* Monumenta Serica Monographs, 28 (Nettetal: Steyler Verlag, 1993).

49. Hashimoto, "Rekisho kosei no seiritsu." *Li hsiang k'ao ch'eng* was one of the three parts of the K'ang-hsi Emperor's (r. 1662–1722) spacious survey, Sources of Mathematical Harmonics and Astronomy (*Lü li yuan yuan* 律曆淵源).

basis for a traditional calendar reform by adapting the Jesuit writings—and necessarily reconciling the discrepancies between the views of Rho, Schall, Schreck, and their colleagues. But these sources were nearly a century old. The most active members of the large editorial committee, Mei Ku-ch'eng 梅瑴成 *(or* Chueh-ch'eng, 1681–1763) and Ho Kuo-tsung 何國宗 (d. 1766), were among the experts of their time in Western astronomy, but they were not as up to date as Mei Wen-ting and his colleagues had been. They were unable to supplement the seventeenth-century Jesuit observations with enough new ones to meet contemporary expectations for accurate solar eclipse prediction. Their cosmology remained Tychonic.[50]

The Compendium became the basis of the annual ephemeris (*Shih hsien shu* 時憲書) from 1726 on. When an eclipse prediction failed in 1730, it became clear that the Chinese astronomers could not substantially improve their methods. The Jesuit head of the Directorate of Astronomy, Ignatius Kögler (1680–1746), and his assistant Andrew Pereira (1689–1743) were ordered to revise the Compendium. According to the memorial of the Manchu Ku-ts'ung 顧琮 proposing this revision, Kögler had earlier appended to the Compendium two substantial tables of solar and lunar motions incorporating post-Newtonian data. But he provided these tables with neither explanations nor instructions for computing. According to Ku-tsung only Kögler, Pereira, and the Mongol mathematician Minggantu 明安圖 (ca. 1692–1763) were able to use them. The tables do not seem to have been printed with the Compendium.[51]

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50. See, for example, *Li hsiang k'ao ch'eng,* A, *9:* 7a.

51. The memorial is given in the forematter of *Li hsiang k'ao ch'eng hou pien* 曆象考成後編 (1742; Li chih shu ya reprint of 1896), "Memorials," 4a-4b. On this compilation see Hashimoto, "Daenhô no tenkai"; Yabuuchi, *Chûgoku no temmon rekiho,* 164–168; Needham, *Science and Civilisation,* III,

In 1737 these three and others were ordered to revise the Compendium. In 1742 their sequel *(Li hsiang k'ao ch'eng hou pien*曆象考成後編) was printed. It definitively treated the solar and lunar motions in order to predict eclipses accurately. The Compendium's account of the planets was allowed to stand intact. This work is an anomaly of the most remarkable sort. On the one hand, it incorporated improved constants and tables based on the observations of J. D. Cassini (1625-1725) and John Flamsteed (1646-1719), and introduced the Keplerian ellipse. It informed the Chinese reader that, since epicycles and equants were unsatisfactory for computing the solar anomaly, Kepler "posited that the deferent was an ellipse, and took equal areas of the ellipse in order to derive the daily mean motion." The compilers stated elsewhere that "the ellipse method precisely reconciles eccentrics, epicycles, and equants."[52]

Nonetheless, sixteen years after the death of Newton, thirteen years after the announcement of Bradley's discovery of stellar aberration, heliocentricism was still tabooed in China. Kepler's old master Tycho Brahe still furnished the scenery. The earth was static, with the sun revolving about it on what Kepler would have considered the earth's elliptical orbit turned inside out.

Given the necessity to relate Kepler's first and second laws to geocentric coordinates and a geostatic world system, the geometry of the ellipse could not be extended to the planetary orbits. While the sun and moon rode about the earth on ellipses, the planets were still making their rounds of the sun on the cranky

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448; and Hummel, *Eminent Chinese of the Ch'ing Period,* 285, a confused account. Li Ti 李迪 has written a biography of the scientific polymath Minggantu, whom that august amateur the K'ang-hsi Emperor taught astronomy: *Meng-ku-tsu k'o-hsueh-chia Ming-an-tu* 蒙古族科學家明安圖 (The Mongol scientist Minggantu; Hohhot: Nei-meng-ku Jen-min Ch'u-pan-she, 1978).

epicycles of Tycho. As Hashimoto Keizô has put it, "a determination to emphasize the continuity of [ellipses and compounded circles] can be discerned throughout the book. . . . The heterogeneous circular and elliptical forms of motion were transmuted into homogeneous forms as a means toward a pragmatic grasp of Keplerian cosmology. One can see in the Sequel that, considered as a form of motion *compatible with classic circularity,* the elliptical method could be set out as merely a more precise technique that agreed better with observation."[53]

Just so. In 1742 the Sequel treated elliptical orbits as perfectly compatible with the Platonic eternal circles because it ignored their physical meaning. They were included merely because it was impossible to introduce important post-Newtonian developments in eclipse prediction without them. The Keplerian third law was not mentioned, and Newton figured only as a source of data.[54]

These limitations were not at all disabling. Accurately predicting planetary phenomena had always been a peripheral issue in the minds of Chinese astronomers. On the other hand, the Sequel succeeded for the first time in substantially solving the central problem of eclipse prediction. Even a century later it became the basis of a calendar reform (epoch 1834).

Tycho Brahe expired hoping in vain that his data, once in Kepler's hands, would establish the Tychonic world system. It is one of the minor ironies of the history of science that this wish came true for a time on the other side of the world after both were long dead, and in circumstances that neither could have imagined.

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52. *Li hsiang k'ao ch'eng hou pien, 1:* 25b-26a, *1:* 103b. On the ambiguity of these astronomical terms see the Appendix, p. 51.

53. Hashimoto, "Daenhô no tenkai," 265, my emphasis.

Introduction of the Copernican World Model

At the very end of the long chain of Jesuit scholar-missionaries, the heliostatic world model finally received a hearing in China. Its champion was Michel Benoist (Chiang Yu-jen 蔣友仁, 1715–1774), a very competent astronomer.[55]

A series of clashes between the Jesuits and members of other missionary orders in China, centering on the extent to which converts should be permitted to maintain traditional beliefs and customs—the famous Rites Controversy—came to a head at the beginning of the eighteenth century. A papal legate was sent from Rome to ask the Chinese Emperor to stop siding with the Jesuits. The arrogant conduct of the poorly prepared emissary and his party in 1706 and 1707 made all

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54. Nakayama, *History of Japanese Astronomy,* 189.

55. The most extensive study of Benoist's writings is in Pfister, *Notices biographiques et bibliographiques,* item 377, pp. 813–826.

I believe it is to Bernard that we owe, among many other debts, that of pointing out to Europeans Benoist's importance, in his *Galilée et les Jésuites.* Presumably because by the time he wrote this article he had had no opportunity to study the Chinese treatises in detail, however, Bernard's interpretation is untenable: "As to the theories [of Galileo], they were practically useful only in the capacity of hypotheses to act as a guide in calculations, and the Chinese, who could know of geometry only what concerned straight lines, triangles, and the circle (to the exclusion of conic sections: ellipse, hyperbola and parabola), were thus incapable of understanding the laws of Kepler" (p. 380). On Benoist's introduction of the heliocentric theory Bernard asserted: "This resolution could hardly have had repercussions beyond the walls of the imperial residence, for the little old manual of Fr. Manuel Diaz, an abridged compendium of the Ptolemaic doctrine, remained almost the sole source of information for the savants of China. It was only more than a hundred years later, when the Elements of Euclid had been printed *in toto* (1865), that the principles of Galileo and Kepler could be divulged in the Far East" (p. 382).

We know, however, that Diaz' book was obsolete *as a source for Chinese* by 1635. The geometry of the ellipse was introduced in Schall's Tychonic *Chiao-shih li chih* 交食曆指 (Guide to the astronomy of eclipses, 1632). It was more fully treated in Verbiest's *Ling-t'ai i hsiang chih* 靈臺儀象志 (Treatise on Imperial Observatory instruments, 1674) and in the imperially commissioned mathematical encyclopedia *Shu li ching yün* 數理精蘊 (Treasury of mathematical principles, 1723). In 1742 *Li hsiang k'ao ch'eng hou pien* applied it to the solar and lunar orbits, with credit to Kepler.

too obvious what had been decently concealed through the seventeenth century: unlike the priests of other religions in China, the missionaries were obedient agents of a foreign power. The royal patrons of their order could wield them to subvert imperial authority.

By the mid-eighteenth century, despite the missionaries' attempts to recover the good will of the Emperor, the government was taking harsh measures against them outside the court. As a Jesuit historian has put it, "because they entered the Empire illegally and stayed there against the most explicit prohibition of the Emperor, the missionaries in the provinces were considered criminals, and, in the Chinese Empire, nobody could ask for favors for such persons."[56] A small group of technicians were still allowed to reside in the capital and serve the palace in such fields as astronomy, cartography, clockmaking, and optics. In the hope of moderating this persecution, Benoist, one of the group at the court, built fountains and ornamental waterworks (what George Kates has called Européenerie) to keep the Emperor amused.[57]

Every one of these books was printed and widely available, as were the other treatises on Tychonic astronomy and cosmology in the *Hsi-yang hsin fa li shu.*

56. Joseph Krahl, S.J., *China Missions in Crisis. Bishop Laimbeckhoven and his Times 1738–1787* (Analecta Gregoriana, 137; Roma: Gregorian University Press, 1964), 89. A useful work for the doctrinal history of the Rites Controversy is François Bontinck, *La lutte autour de la liturgie chinoise aux 17[e] et 18[e] siècles* (Louvain: Éditions Nauwelaerts, 1962). There is valuable information on the astronomical work of the mid-eighteenth century in Antoine Gaubil, S.J., *Correspondance de Pékin, 1722–1759* (Genève: Librairie Droz, 1970). On Benoist's observations in Peking, for instance, see 569, 732, 787, 832, and 843. One is left with the impression that despite skill and enthusiasm Benoist had little time for astronomical work except in 1755–1756. There is more information on the period in Camille de Rochemonteix, S.J., *Joseph Amiot et les derniers survivants de la mission francaise à Pékin (1750–1795)* (Paris: Librairie Alphonse Picard et fils, 1915).

57. George N. Kates, *The Years That Were Fat. Peking: 1933–1940* (New York: Harper and Brothers Publishers, 1952), 197–200, and Maurice Adam, *Yuen ming yuen. L'Oeuvre architecturale des anciens Jésuites au XVIII[e] siècle* (Pei-p'ing: Imprimerie des Lazaristes, 1936), 20–22, give information

Benoist was able to write on Copernican cosmology because the Church's formal ban on discussion of heliocentricism ended in 1757. Considering the time required for the news to reach Benoist, his alacrity in taking advantage of his new freedom is impressive. Here is his own description, in a letter to Europe (1764), of the occasion and how he rose to it:

I have already written you that, besides the hydraulic works with which I have been occupied for several years in the Emperor's service, I have drawn a world map of which the two hemispheres with their margins are thirteen to fourteen feet in length by seven high. In 1761,[58] when the fiftieth birthday of the reigning Emperor was being celebrated, I presented him with it, traced on [silk] gauze, which is very convenient for this sort of work here. His Majesty received my present with kindness, and kept me nearly an hour to ask me various questions on geography and physics. In the margins are drawn different mathematical diagrams, with some space left free in order to put there an explanation in Chinese of both the map and the diagrams. In my explanation I made a rather thorough exposition of the Copernican system, which was necessary because the Chinese had not yet adopted it.[59]

In another letter written three years later, Benoist offered more detail about the content and sources of his explanation. At the same time he provided a hint about the political motivation of his birthday gift to the Ch'ien-lung Emperor. The significance of this hint is clear in view of the intense rivalry between the French

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on Benoist's hydraulic works. Benoist "had at least one meal every day at the palace in the company of mandarins and nobles" (Krahl, 195).

58. This is an error for 1760. See the *Shih lu* 實錄 (Veritable records) for the Emperor Kao-tsung, *618:* 8, dated 19 September 1760.

and Portuguese missions of the Society in Peking, for this competition reflected the national strivings of their royal patrons:

I have added an explanation of the terrestrial as well as the celestial globe, of the new systems for the movement of the earth and of the other planets, and of the movements of the comets, the returns of which one hopes to succeed in predicting with certainty. I summarized the great enterprises ordered by our monarch for the perfection of the arts and sciences, and especially for that of geography and astronomy, which were the subject of my writings. I described the expeditions sent to different parts of the world to observe various astronomical phenomena, to measure exactly the degrees of longitude and latitude of our globe; the men of merit whom he sent for these observations; the welcome they were given in various kingdoms . . . I cited MM. Cassini, La Caille, Le Monnier, et al., from the learned writings of whom I have taken all that I have said in mine.[60]

Benoist's explication of the heliostatic concept was short but ample, and on the whole accurate. Considerably more space in the margins of his map was devoted to astronomy, in fact, than to geography. His text contained no mathematics, but then it was meant for the Emperor rather than for the Chinese officials of the Directorate of Astronomy. Under its Jesuit Directors they had already been using the post-Newtonian constants and tables of the Sequel since 1742, and had had access to gear-driven heliocentric demonstrational instruments before Benoist's

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59. Letter from Benoist at Peking to Souciet, 12 September 1764, in "Histoire ecclésiastique de l'Extrême-Orient," *Revue de l'Extrême-Orient,* 1887, *3:* 248–250.

60. Letter from Benoist in Peking to Papillon d'Auteroche, 16 November 1767, in *Lettres édifiantes et curieuses concernant l'Asie, l'Afrique et l'Amérique, avec quelques relations nouvelles des missions, et des notes géographiques et historiques* (Paris: Société du Panthéon Littéraire, 1843), IV, 121.

book appeared.[61] After a committee appointed to put Benoist's explanation into acceptable literary form spent nearly two years discussing the matter, Ho Kuo-tsung and Ch'ien Ta-hsin 錢大昕 (1728–1804) gave its style a final polishing and had it copied onto a redrawn map. They also made it possible to circulate the manuscript (without the illustrations) among some of China's leading astronomers.

In 1799 Juan Yuan copied the manuscript's account of Occidental cosmology into an article on Benoist in his Biographies of Mathematical Astronomers (*Ch'ou jen chuan* 疇人傳). This large book gave much more information about astronomers' technical work (often copying long excerpts from their writings) than about their careers.

Benoist's essay was published separately in 1802 or 1803 under Juan's sponsorship. For this edition, entitled World Map with Illustrated Explications (*Ti ch'iu t'u shuo* 地球圖說), Li Jui 李銳 (1765–1814) and Chiao Hsun 焦循 (1763–1820) reconstituted the illustrations on the basis of careful study of the text.[62] That they

61. See Hsi Tse-tsung et al., "Heliocentric Theory in China—in Commemoration of the Quincentenary of the Birth of Nicolaus Copernicus," *Scientia sinica,* 1973, *16:* 264–376, for photographs of a heliocentric orrery and planetarium. They are also discussed in Liu Ping-sen 刘炳森 *et al.*, "Lueh t'an Ku-kung Po-wu-yuan so ts'ang ch'i cheng i ho hun-t'ien ho ch'i cheng i. Chi-nien Ko-po-ni tan-sheng wu-pai chou-nien 略谈故宫博物院所藏七政仪和浑天合七政仪。纪念哥白泥诞生五百周年" (The orrery and armillary sphere in the Palace Museum. In commemoration of the 500th anniversary of the birth of Copernicus), *Wen-wu* 文物, 1973, 9: 40–44, pl. 6–7. There is a brief discussion in the original version of this chapter. See the Retrospect.

62. *Ti ch'iu t'u shuo* is also referred to as *K'un yü ch'üan t'u shuo* 坤輿全圖說, a slightly more literary way of saying the same thing, and possibly Benoist's original title. On the publication date of this work, see the remarks of Chiao Hsun in his collection of jottings *I yü yueh lu* 易餘籥錄 (Jottings stored in bamboo tubes *[or* written on odd pieces], set down in intervals between studies of the Book of Changes, printed 1886), *6:* 2a. Chiao provided what became Figure 10 of Benoist's book. My account of the vicissitudes of Benoist's manuscript is based upon Chiao's book, the prefaces to *Ti ch'iu t'u shuo,* and the letters of Benoist cited above and further on. For the biography

succeeded in doing so confirms that Benoist's account of heliostatic cosmology was lucid enough for Chinese outside the missionaries' ambit to understand it.

Because of the interest of its details, I translate below Benoist's account of four European cosmological systems, those of Ptolemy, Tycho Brahe, Martianus Capella (Ma-erh-hsiang and Copernicus, and his defense of the Copernican.[63] This is by no means all Benoist had to say about Copernicus, for his treatise is heliocentric from beginning to end. In this excerpt from his section on "The Order of the Seven Luminaries" there are many clues to his motives and intentions:

From antiquity on, astronomers have developed in great detail the methods of calculating the motions of the Seven Luminaries [i.e. the sun, moon, and planets]. The scholars of the West, making full use of their intellectual acuity, have hypothesized orders of the luminaries in the universe on the basis of their own computations, and have formed different traditions *(chia* 家), each with its own argument.[64] Let me take up the four most important founders *(tsung* 宗), but only to the extent necessary to determine [which tradition best corresponds to?] the motions of the luminaries.

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of Juan see Wolfgang Franke, "Juan Yüan (1764–1849)," *Monumenta Serica,* 1944, *9:* 53–80. Another good source of information and references concerning Juan and other Ch'ing astronomers is Hummel, *Eminent Chinese,* s.v.

63. This translation (of about an eighth of Benoist's composition) is based on the *Ti ch'iu t'u shuo* version (in *Wen hsuan lou ts'ung-shu* 文選樓叢書), 8a-11a. The *Ch'ou jen chuan* version (see note 41 above, *46:* 601–610) does not contain significant variants. It differs only in that Example 2, near the end of the passage translated here, is appreciably shorter. Because he omitted the diagrams, Juan excised the text that originally explained them.

64. Benoist naturally used the Chinese concept of *chia* to explain the relationship between the different cosmological doctrines. *Chia* were traditions of philosophy, cosmology, or for that matter any field of scholarship, often lineages based on the special teachings of a master passed down through generations of disciples. Benoist's Chinese readers would ordinarily have expected persuasions so described to coexist peaceably.

1. Ptolemy (To-lu-mou 多祿畝) claimed that the earth is the center of coordinates.[65] About the earth are the moon, Mercury, Venus, the sun, Mars, Jupiter, Saturn, and the fixed stars, each on its own deferent. All of these deferents [i.e. the spheres on which they are located] are solid; they do not join or intersect.[66] In addition to these deferents there are epicycles. Each of the Seven Luminaries travels on the periphery of an epicycle, and the center of the epicycle also travels on the periphery of the deferent. This argument, however, is inadequate to explain the principles underlying the motions of the Seven Luminaries, and today no one accepts it.

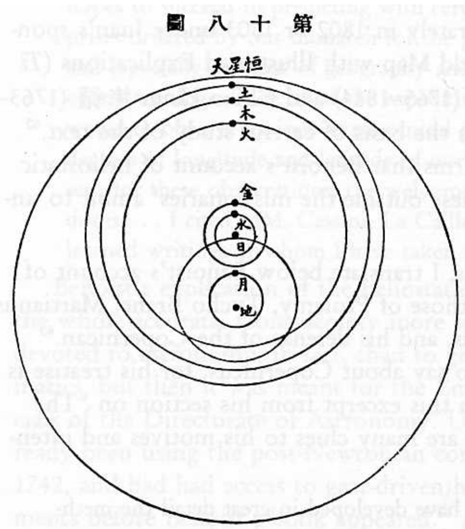

Figure 7. Benoist's scheme for Martianus Capella. The dot nearest the center is the earth. The sun travels on its second circle.

2. Tycho (Ti-ku 的谷) claimed that the earth is the center of coordinates, and that about the earth are the moon, the sun, and the fixed stars. Each has its deferent [i.e. sphere] that rotates about the earth. The deferents of the planets Mercury, Venus, Mars, Jupiter, and Saturn have the sun as their center, and on each deferent is an epicycle.

3. Martianus Capella (Ma-erh-hsiang 瑪爾象, ca. 365–440, Figure 7) held that the earth is the center of coordinates. Without leaving its place, each day it makes one rotation about its north and south poles. About it are the moon, the sun, and the fixed stars. Rotating about the sun are the circles of Mercury, Venus, Mars, Saturn, and Jupiter.

65. Literally, "the center of the Six Directions," which include the cardinal directions, up, and down.

66. Benoist's use of the term *pen lun* 本輪 is ambiguous. See the Appendix, p. 52.

Although in the teachings of these two traditions there are points worth taking up, they do not compare with the tradition of Copernicus in precision (*mi* 密).

4. Copernicus 歌白尼 (Figure 8) put the sun at the center of the universe. Closest to it is the planet Mercury, then the planet Venus, then the earth, then the planet Mars, then the planet Jupiter, and then the planet Saturn. The deferent of the moon circles the earth. Alongside the planet Saturn are five small stars that circle it. Alongside the planet Jupiter are four small stars that circle it. Each has its own deferent that [*or* and] moves about its planet. Furthest from all these circles is the heaven of the fixed stars, eternally immobile.

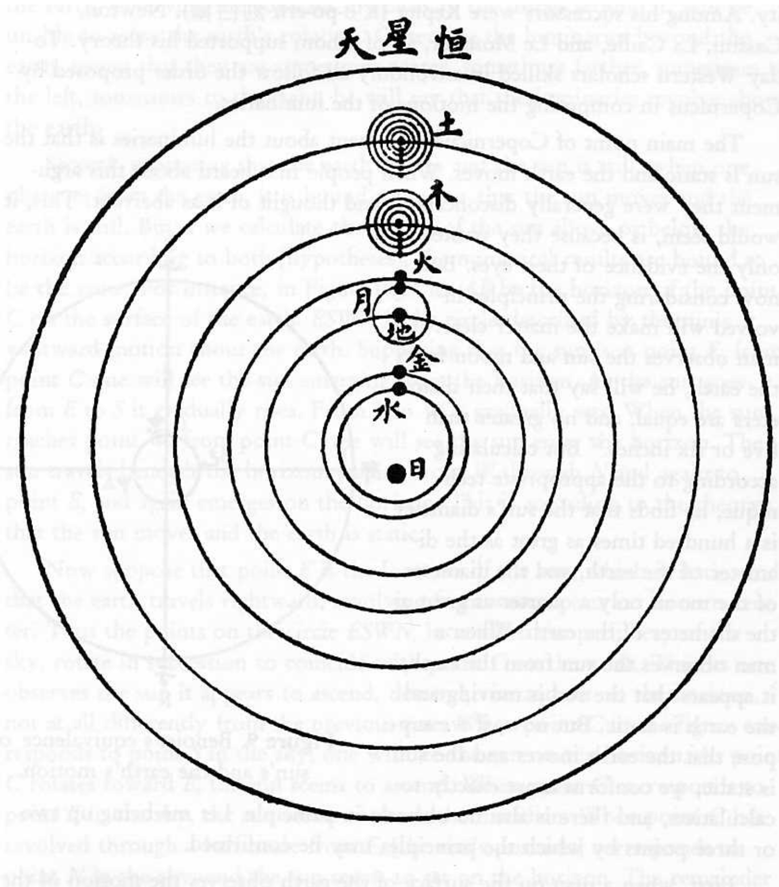

Figure 8. Benoist's schema for Copernicus.

The order Copernicus determined for the luminaries is, it seems, based on the argument of Nicetas, but Copernicus explained it with particular clarity. Among his successors were Kepler (K'o-po-erh 刻白爾), Newton, Cassini, La Caille, and Le Monnier, all of whom supported his theory. Today

Western scholars skilled in astronomy all follow the order proposed by Copernicus in computing the motions of the luminaries.

The main point of Copernicus' argument about the luminaries is that the sun is static and the earth moves. When people first heard about this argument they were generally disconcerted, and thought of it as aberrant. This, it would seem, is because they trusted only the evidence of their eyes. But now considering the principles involved will make the matter clear. If a man observes the sun and moon from the earth, he will say that their diameters are equal, and no greater than five or six inches.[67] But calculating according to the appropriate technique, he finds that the sun's diameter is a hundred times as great as the diameter of the earth, and the diameter of the moon only a quarter as great as the diameter of the earth. When a man observes the sun from the earth, it appears that the sun is moving and the earth is static. But now, if we suppose that the earth moves and the sun is static, we conform more exactly to calculation, and there is also no obstacle in principle. Let me bring up two or three points by which the principles may be confirmed.

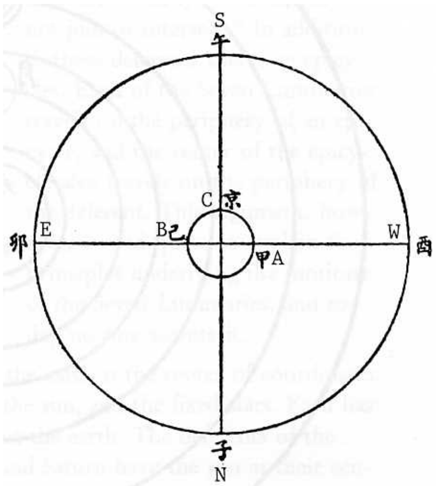

Figure 9. Benoist's equivalence of the sun's and the earth's motion.

First, when a man on the surface of the earth observes the motion of the luminaries, [they appear to] circle the earth, and the earth seems perpetually immobile. This cannot in fact be taken as evidence that the earth is still and the luminaries move. For example, consider a boat floating on the sea. When the people in it see that the relative distances of the things on the boat remain constant, they are not aware of the ship's motion. But when they see that the shore, mountains, islands, and things outside the boat are now nearer, now farther, now to the left, now to the right, they change their minds and suspect that it is in motion. In the present case, the earth and its surrounding air *(ch'i)*, unhindered, move equally. A man on the surface of the earth, observing the constant distances of the things around it, will be unable to sense the earth's rotation. Observing the luminaries beyond the earth, seeing that they are sometimes nearer, sometimes farther, sometimes to the left, sometimes to the right, he will say that the luminaries revolve about the earth.

Second, supposing that the earth moves and the sun is still, when one observes from the earth, it is bound to appear that the sun moves and the earth is still. But if we calculate the degree of the sun above or below the horizon according to both [hypotheses], the numerical results are bound to be the same. For instance, in Figure [9],[68] let *AB* be the horizon of the point *C* on the surface of the earth. *ESWN* is the circle described by the sun's westward motion about the earth. Supposing that the sun is at point *E,* from point *C* one will see the sun emerging from the horizon. As the sun goes from *E* to *S* it gradually rises. From *S* to *W* it gradually sets. When the sun reaches point *W*, from point *C* one will see the sun enter the horizon. The sun travels beneath the horizon, passing from *W* through *N* and again to point *E,* and again emerges on the horizon. This is according to the theory that the sun moves and the earth is static.

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67. Benoist or more likely his editors reverted to the ancient Chinese practice of estimating tenths of a degree of arc as *ts'un* 寸, literally "inches," decimal parts of a foot. The next sentence refers not to angular but to linear diameter.

68. The diagram is originally Figure 19 in *Ti ch'iu t'u shuo.* See note 23 above.

Now suppose that point *E* is the location of the sun, which is static, and that the earth travels rightward, revolving from west to east on its own center. Thus the points on the circle *ESWN,* located on the periphery of the sky, rotate in succession to coincide with point *C* on the earth. Thus as one observes the sun it appears to ascend, descend, rise and set on the horizon, not at all differently from the previous case. When point *C* in the figure corresponds to point *S* in the sky, one will see the sun on the horizon. As point *C* rotates toward *E,* the sun seems to ascend. When point *C* corresponds to point *E* in the sky, the sun seems to reach the meridian. When point *C* has revolved through a half-circle from *E*, [the sun's position] corresponds to point *N* in the sky, and the sun seems to set on the horizon. The remainder of the argument is similar in principle.

Third, the sun is itself a luminous body. The moon, Mercury, Venus, Mars, Saturn, and Jupiter are all dark bodies, which shine by borrowing the sun's light, as the earth does. Suppose there were men on the surface of the moon and the other planets. The earth as it appeared to them would resemble the moon seen from the surface of the earth—sometimes dark, sometimes fully illuminated, sometimes an upper or lower crescent. Everyone familiar with astronomy knows this. Now since the six luminaries all resemble the earth, how could it be that the six luminaries and the sun circle the earth, which alone is still? It is best to suppose that the sun is at the center of the universe, and that the earth and the other planets circle the sun, borrowing its light. Is not this argument simpler?

Benoist then proceeded to discuss the Keplerian elliptical orbit and the proper rotations of other bodies as well as the earth, even asserting that "although the sun has no deferent, it rotates on its own center like the planets."[69]

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69. P. 11b.

The contrast with the prudence of the missionary astronomers writing eighteen years earlier is equally patent in what Benoist found no need to say. He did not attempt to prove the superiority of heliostatic cosmology. He simply asserted that it was the only system in current use, its ultimate authority deriving from "more precise conformity to calculation." The three arguments at the end are not meant to prove the Copernican doctrine, but merely to show that its conflict with common sense and everyday observation is only apparent. The boat metaphor for the relativity of motion was not new in China, as we have seen.

Although Benoist was free to maintain that the concept of a solar system was mathematically superior, he did not assert that it was *physically* true. As he put it in another letter: "It is not, I added, that we are sure the universe is actually arranged as we suppose it to be; we simply propose this arrangement as the one that appears most appropriate and simplest to account for the various movements of the heavenly bodies and to calculate them." In this letter, and yet another probably a bit earlier, Benoist praised (excessively, by all accounts) the astronomical aptitude and understanding of the Ch'ien-lung Emperor (r. 1736–1796), to whom he originally made the above remark.[70] The monarch greeted Benoist's explication of the earth's motion with these words: "In Europe you have your way of explaining the celestial phenomena. As for us, we have ours too, without making the earth rotate." If Ch'ien-lung was as usual smug and unimaginative, the Chinese members of the Directorate of Astronomy (who for centuries had been mostly careerists rather than expert astronomers) saw Copernicanism merely as a threat to their undemanding sinecures. As Benoist put it in

70. Undated letters from Peking shortly following one of 4 November 1773, in *Lettres édifiantes,* IV, 217–225, 209–217.

1767, "our Chinese mathematicians do not approve of all these changes. They have often heard of the movement of the earth. The tables that our missionaries have given them, and that they use in their calculations, are founded upon this system. But although they make use of the consequences, they still have not admitted the principle. Perhaps they fear that, this hypothesis once favorably received by the emperor, they might be obliged to adopt it themselves."[71]

Whether these bureaucrats dreaded the Copernican system as a novelty is hardly to the point. Serious amateurs, in particular the outstanding group about Juan Yuan, had access to the manuscript of Benoist's explanation before Juan published it at the turn of the nineteenth century. They responded not with airy dismissal or defensive rejection, but with engagement. Juan's Biographies gave full and acute coverage to Copernicus, Galileo, and Benoist, even though the Jesuit writers' failure to settle upon a single Chinese transcription for the names of Galileo and Copernicus led Juan to treat each of them as at least two different people.[72]

Juan's Biographies is not simply a historical compilation, as it appears superficially to be. It juxtaposes traditional and Western astronomy, encouraging the study of the latter in order to improve the former. Juan emphasized the old idea that the roots of modern astronomy are to be found in ancient China, but that the

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71. Letter of 16 November 1767, in *Lettres édifiantes,* IV, 122–123.

72. Copernicus was given separate articles as two unrelated persons: Ko-po-ni , the Ptolemaist of Schall's *Li fa hsi ch'uan,* and Ni-ku-lao 泥谷老 (literally, "the old man of mucky valley"), who made observations in 1525 and whose computational innovation was later rejected as unsatisfactory by Tycho (*Ch'ou jen chuan,* ch. 43). Rho had also cited Copernicus' methods as those of Ku-po-ni 谷白泥; see *Wu wei li chih, 3:* 10b. The *Ch'ou jen chuan's* resumé of Benoist, which occupies two-thirds of ch. 46, or about fifteen per cent of the space devoted to non-Chinese astronomers, also cites Copernicus as Ko-po-ni. See also note 17 and p. 29 above.

tradition continued to develop in the barbarian outer reaches of civilization (that is, Europe and Islam) after it was lost in the Middle Kingdom. The observation that this thesis is historically untrue, although often ponderously set down by historians of science, is beside the point. Juan was not trying, as some writers who have not found the leisure to read him suppose, to denigrate European astronomy. Exactly to the contrary, he was providing a myth that would legitimize its study—not as an exotic novelty, but as knowledge affiliated with the classical tradition despite the unfamiliarity of its expression, and notwithstanding the unacceptable non-scientific ideas with which the foreigners associated it. Such a myth was indispensable in a culture that habitually used the past to sanction innovation, and that had long since lost the curiosity that could put such ideas in vogue *because* they were foreign.

Juan was not even an innovator in this regard. The myth of the Chinese origin of mathematical astronomy had been used effectively before him to justify study of the Western art by Mei Wen-ting and his grandson Ku-ch'eng, who were at the center of amateur astronomy in previous generations, and even by the K'ang-hsi Emperor (r. 1662–1722), the most able and learned patron of astronomy among the Manchu emperors.[73] This myth may be compared to the European notion that

73. Wang P'ing discusses the history and significance of the belief that the origins of Western astronomy lay in China in *Hsi-fang li-suan-hsueh chih shu-ju,* especially 69–74 and 97–103; see also note 13 above. Some modern historians have been so offended by the historical error that they ignored its purpose. It misses the point to describe Mei Wen-ting, probably the greatest expert in Occidental astronomy of his time and certainly the man who did most to encourage its study, as one "who, during his long life (1633–1721), never ceased to poke fun at those who, lacking patriotism, went to take lessons from foreign barbarians"; Bernard, "L'Encyclopédie astronomique," 479. The specter of nationalism which Bernard raises is quite irrelevant to the issue. On the role of the emperor see Catherine Jami, "L'empereur Kangxi (1662-1722) et la diffusion des sciences occidentales en Chine," in Ang & Will, *Nombres, astres* (see note 18), 193-209.

ancient and sophisticated societies could be "discovered," an accomplishment that justified subjugating them and destroying their traditional religions.

It was in the last analysis Juan Yuan and the scientific amateurs about him on whom the fate of Copernicanism in China was bound to depend. They, and not the functionaries, were the experts of their time. They often performed astronomical services for the government, as we have seen, but they did so as what we would call civil-service generalists or consultants rather than as career technicians. They had absorbed all the knowledge the missionaries offered. They were systematically reconstructing the mathematical methods of their forebears, which, although quite available in Matteo Ricci's time, few had read and hardly anyone comprehended.

In these men the values of their culture were still intact. As they learned modern astronomy they naturally tried to reconcile their new knowledge with the methods that had evolved in their own society. This reluctant but inexorable urge toward integration should hardly astonish those who study the growth of science. The difficulties we witness in China are comparable to those of seventeenth-century European astronomers facing aspects of the new science that could not be reconciled with late scholastic metaphysics.

In order to comprehend the net effect of Benoist's labors, it is necessary to reconsider Juan Yuan's evaluation of Copernicus. Historians have derided statements like this one as typical xenophobia, because they had no better explanation for Chinese "failure" to adopt the concept of a solar system before the Opium War era:[74]

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74. L. van Hée, "The Ch'ou-jen Chuan of Juan Yuan," *Isis,* 1926, *8:* 117–118; George H. C. Wong, "China's Opposition to Western Science during Late Ming and Early Ch'ing," idem, 1963, *54:*

Michel Benoist says that Copernicus, in his discussion of the heavenly bodies, stated that the sun is static, that the earth moves, and that the sphere of the fixed stars is forever immobile. [Benoist goes on to say that] the finest students of astronomy among Western scholars support his theory. This differs considerably from what Schall says in On the Transmission of Astronomy in the West. According to Schall, Copernicus had an explanation of the celestial motions in terms of circles, and sought to determine the sun's apogee and its angular motions. Now if the orbs move in circles, and if the *sun's* distance varies and it has an angular motion, then the firmament and the sun must be moving, not static. How can the theories of one and the same Westerner be so self-contradictory?[75]

Juan saw this contradiction in his sources, but he had no way of knowing how it had come about. Benoist had said not a word about the vicissitudes of Copernicanism in Europe, nor did he admit that his account conflicted in any way with those of his predecessors. The simplest conclusion for Chinese readers—who had no reason to suspect that any of the missionary writers had been less than candid, or subject to any ideological restraint—was that Benoist was merely amplifying and reassessing earlier accounts, and that Copernicus was too inconsistent to take seriously.

Given the confusion that had been accumulating for nearly two centuries, it was inevitable that the skepticism of China's best astronomers at the turn of the nineteenth century should not have been limited to Copernicus alone. The Jesuits

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29–49. On the latter cf. Sivin, "On 'China's Opposition to Western Science during Late Ming and Early Ch'ing,' idem, 1965, *56:* 201–205.

75. *Ch'ou jen chuan, 43:* 554. This translation overlaps that given in Wong, 47. The point that Wong makes there depends on a serious misunderstanding of the phrase *t'ung i hsi jen* 同一西人

had taken great care to explain the transition between Ptolemy and Tycho as a historical development. Their Chinese readers, as we can see from *their* writings, generally understood the point clearly. But Rho and Schall had denied that there was any fundamental cleavage between Tycho Brahe and his precursor Copernicus. Early assurances that the Tychonic and Copernican world pictures were equivalent, given equal credence with Benoist's sanguine description of their differences, were bound to cast doubt upon the rigor of Tycho as well as of Copernicus. To make matters worse, Schall and others associated highly accurate constants with Ptolemy without explanation. They prompted Juan Yuan to charge that, although the computational methods of Europeans, like those of Chinese, had evolved gradually, in their discussion of Ptolemy "is it not that Schall and his ilk were boasting in order to deceive us Chinese, and that Hsu Kuang-ch'i and Li T'ien-ching were taken in?"[76]

For Benoist himself such issues were not urgent. Like his predecessors, he could draw cosmological distinctions without violating his conscience because he had been taught to think of the concept of a solar system as nothing more than a heuristic device. The limits of discussion had simply been widened by a new administrative decision.

Chinese readers who had explored the Jesuit astronomical literature thoroughly were left with no alternative but a position parallel to Benoist's own. They came to believe that Tycho was as internally contradictory as Copernicus, or else Rho and Schall would not have associated the two. If consistency was so

(literally, "one and the same man of the West") in the final sentence. Juan was using Schall and Benoist as sources, not as symbols.

76. *Ch'ou-jen chuan, 43:* 553.

unimportant to such eminent Europeans, their cosmology was obviously not meant seriously.

In the Ming, Chinese had quickly recognized and valued Western cosmologists' ability to explain the reasons underlying the phenomena. By the end of the eighteenth century, what had earlier asserted itself as a science, rather than a mere collection of computational techniques like late Chinese calendrical astronomy, seemed to have no more depth than the latter. The study of Western methods could be encouraged all the more because they could be adapted to the ends of the traditional art without endangering its essence. These themes emerge in Juan Yuan's evaluation at the end of his article on Benoist:

The ancient masters of astronomical reckoning, in ordering the motions of the Seven Governors, spoke of their inequalities but not of the reasons that their motions are irregular. Convinced that the Way of Heaven is too subtle for human power to spy out, they spoke only of what was appropriate for it to be, and did not press further to extort knowledge of why it is what it is. Such was the prudence of the men of old when they established their teachings.

Since the Europeans, attracted by the Emperor's civilizing virtue, came from afar and translated their techniques for pacing off the heavens, we have had the mathematics of deferents and epicycles. These, it would seem, are simply hypothetical figures, used to demonstrate deviations from mean values. Because they may be used to explain why [we observe] inequalities in the motions of the sun, moon, and planets, however, the undiscriminating make the mistake of believing that there actually are such circles in the blue heavens. This is truly a great delusion!

And then, after not very long, there was a change. For what have all along been called circles they have substituted ellipse techniques, and they hold that the earth moves and the sun is static. This means that the Westerners were unable firmly to maintain their previous arguments. If they were simply making use of figures to illustrate computational principles, then speaking of ellipses would be fine, and why not say that the earth moves and the sun is static? But in their [new] doctrines, going so far as to reverse above and below [i.e. the positions of the heavenly bodies with respect to the center], and turn moving and static topsy-turvy, shows them to be heretical, and incapable of edifying others [on the subject of physical reality]. Never has there been a worse instance. From Tycho's time to the present has been only somewhat over a century, but how many times have they changed his methods! I cannot imagine how much further they will go. They are certain to surpass these beginnings, boasting of knowledge that only they have, inventing absurd theories.

This being so, how, then, can claims that the Westerners' discourses on celestial phenomena can clarify their reasons make them comparable to the perennially flawless [Chinese approach to] analysis of irregularities in the celestial motions, which only asserts what it is appropriate for them to be, and not why they are what they are?[77]

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77. *Ch'ou jen chuan, 46:* 610. See the interesting discussion of this passage in John Henderson, *The Development and Decline of Chinese Cosmology,* 256. Henderson sees in this passage the denial of a cosmic order, a denial that he argues was peculiar to the Ch'ing. The issue, I believe, is rather the limits of empirical knowledge. Statements of the same sort can be found in astronomy from the Han on. See Sivin, "On the Limits of Empirical Knowledge in Chinese and Western Science," in Shlomo Biderman & Ben-Ami Scharfstein (ed.) *Rationality in Question. On Eastern and Western Views of Rationality* (Leiden: E. J. Brill, 1989), 165–189.

We have seen that the late-seventeenth-century Chinese astronomers were quite willing to explore the physical patterns of the cosmos, once encouraged by European approaches. They were also able to understand why the missionaries' accounts were inconsistent. Mei Wen-ting in 1702 explained that, although all the seventeenth-century writings were referred to as the "new methods of the West, what Schall translated was mostly based on Tycho, and diverged in many ways from Ricci's accounts. There was also the Westerner Smogułęcki . . . who in turn greatly differed from them. . . . as well as subtle differences in [the writings of] Verbiest. If we consider it analytically, Ricci and Schall, Schall and Verbiest all differ. That is why I say that [what they have described] is not a single 'Western method'; they have gradually refined their art through practice. Without reading their books in depth it is impossible to understand why this is so."[78]

This progressive view was no longer visible at the end of the eighteenth century. European cosmology had been discredited by its incoherence. Juan Yuan actively and effectively supported the study of Western mathematical techniques. But here he was voicing the definitive judgment of his era not only upon Copernicus but upon the claim of early modern scientists to be responsible for describing physical reality.

Benoist, who began the restoration of the balance, precisely marks the effective end of the Jesuits' effort in China. The failure of their hopes grew out of the Rites Controversy. The antagonism of the other missionary orders in China simply reflected a growing threat to the Society's existence in Europe. Benoist died of a stroke in October 1774, upon hearing the news that the Society of Jesus had been

78. *Wu-an li suan shu-mu,* 3b-4a.

abolished by the Pope.[79] The remaining missionaries made no significant contribution to the dissemination of modern cosmology.[80] Not until the mid-nineteenth century, when Protestant missionaries translated modern textbooks and used them to train professional astronomers who had no stake in the old society, did Chinese have an opportunity to accept post-Newtonian cosmology as one of the foundations of science.

APPENDIX

Chinese Epicyclic Terminology

Shifts in Chinese astronomical terminology before it was standardized in the late nineteenth and twentieth centuries deserve to be studied. This appendix is concerned with a subsidiary topic, the language of epicyclic astronomy as it appears in texts cited above.

Giacomo Rho (p. 16 above) used *t'ien* 天, literally "heaven," to refer to the celestial spheres. I translate this word consistently as "orb"; it does not connote spherical shape. Rho also used *ch'iu* 球, which exactly means "sphere," for other components of the Aristotelian universe—the earth with its upper spheres of air and fire, and the "first moving orb" (*primum mobile, tsung tung t'ien* 宗動天) at the

79. Pfister, *Notices biographiques et bibliographiques,* item 377; Krahl, *China Missions in Crisis,* 223. Krahl says simply that Benoist "died of grief."

80. The Lazarist Monteiro de Sera, the last European to serve as a member of the Bureau, resigned in 1826, after which the post reserved for foreigners was abolished. On Monteiro see the book review by Ch'en Hsiang-ch'un in *Monumental Serica,* 1938, *3:* 325. For a chronology of leading officials in the Directorate see Po Shu-jen 薄树人, "Ch'ing Ch'in-t'ien-chien jen shih nien-piao 清钦天监人事年表 (Chronology of personnel in the Ch'ing Directorate of Astronomy), *K'o-chi-shih wen chi* 科技史文集, 1978, 1: 86-101.

periphery of the cosmos, which imparts motion to all the orbs within. *Kuei-tao* 軌道 is "orbit."

Rho's set of terms for the geometric elements of the Ptolemaic, Copernican, and Tychonic models remained standard until the mid-eighteenth century. In his Ptolemaic theories the usual general term for deferent was *pen ch'üan* 本圈, literally "proper circle." He called the planetary deferents *hsing pen hsing t'ien* 星本行天, ("orb of proper motion of the planet"), shortened to *pen t'ien* 本天 ("proper orb"). Epicycles in general are *hsiao lun* 小輪 ("small wheel"). His word for "planetary epicycle" was *pen lun* 本輪 ("proper wheel"), and for "annual epicycle" *tz'u hsing ch'üan* 次行圈 ("circle of secondary motion").

In the Ptolemaic theory of all the planets except Mercury, the deferent is centered upon an eccentric point some distance from the earth, but the motion of the center of the planet's epicycle is constant not with respect to the eccentric point but to the equant, which lies on the other side of the eccentric point from the earth and at an equal distance. In other words, the three points Earth–eccentric point–equant lie equidistant in that order along the line of apsides. In Chinese the deferent, *chün ch'üan* 均圈 ("uniformity circle," a term derived from *chün hsing chih ch'üan* 均行之圈, "circle of uniform motion"), rotates about the eccentric point, halfway between the center of the earth, *ti hsin* 地心, and the equant point, *pen ch'üan hsin* 本圈心 ("center of the deferent"). Note the confusion inherent in the literal meanings of the terms Rho coined, all the more so because "uniformity" suggests "equant."

In the Copernican system, which abolished the equant, three-quarters of the Ptolemaic eccentricity of the equant point is assigned to an eccentric deferent and one-quarter to an epicycle. The terms for the eccentric deferent and its center were the same as above, but Rho called the epicycle *hsiao chün lun* 小均輪 ("small uniformity wheel"), perhaps to record its derivation from the old equant system. Additional compounded epicycles, as in the Copernican lunar model, were called *tz'u lun* 次輪 ("secondary wheel").

The Tychonic planetary system, which Rho recommended as modern, uses a simple geocentric deferent, *pen t'ien* 本天, and compounded epicycles. The first, whose radius corresponds to the Ptolemaic eccentricity, he called *pen hsing lun* 本行輪 ("wheel of proper motion"). This is equivalent to the Ptolemaic *pen lun* 本輪. But Rho called the second epicycle *chün lun* 均輪 ("uniformity wheel"), cognate to the Copernican *hsiao chün lun*.

Wang Hsi-shan 王錫闡 followed Rho generally, but in his planetary theory the centers of the planetary epicycles rotate on a figure "that resembles an ellipse" called the *li chou* 曆周, literally "perimeter of travel," a term used traditionally in other senses.

In the mid-eighteenth-century the *Li hsiang k'ao ch'eng* of Mei Ku-ch'eng and Ho Kuo-tsung (p. 33) still used the old terminology, but they distinguished more clearly *ch'üan* for both the orbit and for orbital motion, and *t'ien* for the physical orb.

Michel Benoist, writing forty years after Mei and Ho, used *pen lun* 本輪 to stand for both the geometric deferent and the physical sphere. I translate it "deferent" in the excerpt from the World Map (p. 40) in order to make this ambiguity manifest in English. This sense was a radical departure from the old sense of "epicycle," but Benoist did not point out the change. *Chün lun* 均輪 was his general term for planetary epicycles. He wrote, for instance, that in the

Ptolemaic system the sun, moon, and planets travel "on the periphery of a *chün lun*, and the center of the *chün lun* travels on the periphery of the *pen lun."*

Retrospect

This essay was commissioned by the International Union of the History and Philosophy of Science for the five hundredth anniversary of Copernicus' birth, and published by the Polish Academy of Sciences in one of the volumes of its series *Studia copernicana* devoted to this celebration. This version is revised in several respects:

1. The discussion of Wang Hsi-shan's response to the Jesuit writings overlapped the analysis in the biography of Wang (Chapter V). I have replaced it here with a cross-reference.

2. I have excised Appendix B, "Heliocentric Orreries in the Chinese Court." In 1973 this was the only study of these instruments in a European language, but two essays published in China in the same year offered details and actual photographs, making my discussion, based on a book of 1766, otiose (see note 61 above). I was able in 1977 to document these instruments, but the detailed discussion they deserve would be out of place here. Liu Lu 劉潞, *Ch'ing kung hsi-yang i-ch'i* 清宮西洋儀器。故宮博物院文物珍品全集 (Western instruments in the Ch'ing palace. Complete collection of rare artifacts in the Palace Museum; Ch'ing Kung Po-wu-yuan ts'ang wen-wu chen-p'in ta hsi 清宮博物院藏文物珍品大系; Shanghai: Shang-hai K'o-hsueh Chi-shu Ch'u-pan-she & Hong Kong: Commercial Press, 1998), pp. 11-13, reproduces excellent color photographs.

I have also expunged Appendix C, "The World System of Ma-erh-hsiang and the Copernicanism of Mersenne". I originally identified the mysterious

Ma-erh-hsiang as Marin Mersenne (1588–1648), merely mentioning the early medieval encyclopedist Martianus Capella as a less likely alternative. Several years after the essay was published, Bruce Eastwood, a scholar of early medieval science, told me he had discovered that Martianus included in his Marriage of Philology and Mercury *(De nuptiis philologiae et mercurii et de septem artibus liberalibus libri novem,* 410) a system that undoubtedly was Benoist's source. Martianus' survey of classical learning incorporated one of the few moderately sophisticated cosmologies available for some centuries after it was written. It has rarely been studied since Tycho used it as one of the sources of his model, and Kepler mentioned it rather unclearly, but a Jesuit astronomer would more likely be aware of it than of Mersenne's private thoughts.[81] Students of the Galileo affair and its aftermath, in which Mersenne played an important but enigmatic part, may find some parts of my investigation in Appendix C useful; they are welcome to consult the first edition of this study. Because the Bibliographical Notes overlapped considerably with the Bibliography of the next chapter, I have combined the two and placed the combination at end of the latter (V 20).

3. I have mended many typographical and other printers' errors that the original printers were unable to correct.

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81. See Eastwood's two 1982 studies reprinted in *Astronomy and Optics from Pliny to Descartes* (London: Variorum, 1989). On the role of Martianus' system in Tycho's cosmology see Thoren, *The Lord of Uraniborg* (see note 6 above), 239.