Chinese Science 11 (1993-94): 66-92

Space and Time in Chinese Texts of Astronomy and of Mathematical Astronomy in the Seventeenth and Eighteenth Centuries

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[This article is based upon a paper presented to the symposium on "Time and Space in the Encounter between China and Europe during the Seventeenth and Eighteenth Centuries," organized by Jacques Gernet, Paris: Hugot Foundation of the Collège de France, 14-17 October 1991. Jean-Claude Martzloff is Research Director of the French National Center for Scientific Research (C.N.R.S.), Institut des Hautes Etudes Chinoises.]

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The seventeenth and eighteenth centuries, in the course of which Jesuit missionaries came into contact with the Chinese elite, witnessed a succession of radical scientific changes whose powerful echoes reverberated as far as China.

The dialogue which was then established between missionaries and their Chinese interlocutors gave birth to a massive documentation written in Chinese other of all kinds of Chinese works stimulated by these adaptations.[1]

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[1]The best overall bibliography available to date on seventeenth- and eighteenth-century Chinese adaptations of works of European origin is still Henri Bernard-Maître, "Les adaptations chinoises d'ouvrages Européens, bibliographie chronologique depuis la venue des Portugais à Canton jusqu'à la mission française de Pékin, 1514-1688," *Monumenta Serica* vol. 10 (1945), pp. 1-57 and 309-388, with its continuation for the period 1689-1799, *Monumenta Serica* vol. 19 (1960), pp. 349-383. Bernard-Maître might be usefully supplemented by the detailed bibliographical note on pp. 113-114 of Nathan Sivin's paper, "Copernicus in China," *Studia Copernicana* vol. 6 (Warsaw, 1973), pp. 63-122, as well by as Willard Peterson, "Western Natural Philosophy Published in Late Ming China," *Proceedings of the American Philosophical Society* vol. 117, no. 4 (1973), pp. 295-322. See also Erik Zürcher, Nicolas Standaert S.J. and

Given the present state of research on the status of Jesuit science in Europe, not to mention China, given too the rudimentary character of what we know of the history of Chinese traditional astronomy, our knowledge of seventeenth- and eighteenth-century computational astronomy remains badly deficient.[2] We can nonetheless already say with confidence that the influence of the mathe-matical techniques of European astronomy on China was enormous: as Chinese mathematical and astronomical bibliographies very eloquently attest, seventeenth- and eighteenth-century Chinese astronomers largely used written reckoning, calculating instruments, plane and spherical trigonometry, geometry of the triangle and of the circle and, to a lesser extent, infinite series developments imported from Europe.[3]

The speediness and enthusiasm of the Chinese acceptance of this knowledge implies the existence from the outset of an area of agreement based on a kernel of Chinese and European common conceptions of space and time. Indeed, at the threshold of the seventeenth century, Chinese and Europeans had equally at their disposal various astronomical techniques in which:

1. space and time were both deemed quantifiable on the basis of the measuring and cataloguing of celestial positions;

2. eclipses of the sun and of the moon, ephemerides of the sun, moon and planets, solstices and equinoxes and other celestial phenomena, were considered mathematically predictable from sophisticated computational tech-niques, depending at the same time on ready-made computations (tables) and on particular algorithmic prescriptions[4] free from the hold of astrology;[5]

Adrianus Dudink, *Bibliography of the Jesuit Mission in China (ca. 1580 - ca. 1680)*, (Leiden: Center of Non-Western Studies, Leiden University, 1991), pp. 113-119.

[2]Although much valuable work has been published on observational astronomy (catalogues of stars, novae, comets, etc.) not much is known of the computational aspect of Chinese predictive astronomy: the very important problems of the reconstruction of Chinese techniques of eclipse prediction and of the comparison of the results so obtained with the recomputations of past eclipses using modern astronomical theory still awaits investigation.

[3]See J. C. Martzloff, *History of Chinese Mathematics*, translated by Stephen Wilson from *Histoire des Mathématiques Chinoises* (Paris: Masson, 1987), Springer-Verlag (forthcoming).

[4]In a series of papers published between 1982 and 1991, in *Kexue shi yanjiu* 科學史研究 (Academia Sinica, Beijing), Chen Meidong 陳美東 and other historians of Chinese traditional astronomy have convincing reconstructed algorithmic approximation formulas which played a role in mathematical astronomy (conversion of coordinates, equation of the center for the motion of the sun, the moon and the planets, etc.). See the table in *Kexue shi yanjiu* vol. 10, no. 4 (1991), pp. 375 ff.

[5]It is well-known that the various dynastic annals contained two basically well-differentiated monographs on astronomy, one devoted to the cataloguing of celestial phenomena (*tianwen* 天文) and the other to calendrics and mathematical astronomy (*lifa* 曆法)(as well as pitch pipes, but not always). What the present paper calls

3. the criterion of validation of predictions hinged on the agreement between the result of predictive computations and observation;[6]

4. the perfectibility of predictive systems, i.e. the possibility of reducing the margin of error between theoretical predictions and real observations was generally granted by the most influential astronomers.[7]

Without these common conceptions and without the superiority of Jesuit astronomy compared to any other system of predictive astronomy then available in China, Chinese imperial authorities would not have entrusted missionaries with the task of reforming the calendar and even less appointed them to head the Imperial Bureau of Astronomy. Notwithstanding the opposition of conservative forces, the reform of Chinese astronomy was promulgated as early as 1645, only half a century after the arrival of the first Jesuits in China.[8] Autochthonous attempts to renovate Chinese traditional astronomy proposed before and after the fall of the Ming dynasty always failed so that European mathematical and

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"predictive systems" refers precisely to the voluminous sets of *purely mathematical* algorithms preserved in the *lifa* chapters of the annals, especial those of the Yuan and Ming as well as other calendrical treatises by Chinese specialists on such questions such as Xing Yunlu 邢雲路 or Zhu Zaiyu 朱載堉. But of course this is not to say that astrology did not play any role in the history of seventeenth- and eighteenth-century Chinese astronomy. See for example Huang Yinong 黃一農, "Court Divination and Christianity in the K'ang-Hsi Era," *Chinese Science* vol. 10 (1991), pp. 1-20; (same author) "Yesuhuishi dui chuantong Zhongguo xingzhan shushu de taidu" 耶穌會士對傳統中國星占術數的態度 [The attitude of Jesuits missionaries toward traditional Chinese astrology], *Jiuzhou xuekan* 九州學刊 vol. 4, no. 3 (1991), pp. 5-23; and (same author) "Ze ri zhi zheng yu Kangxi liyu" 擇日之爭與康熙曆獄 [Selections of auspicious dates and the "Calendar Lawsuit" in the Kangxi period], *Qinghua xuebao* new ser., vol. 21, no. 2 (1991), pp. 247-280.

[6]Consequently, "predictive competitions" between Chinese, Muslim and European systems of astronomy organized by Chinese authorities during the first part of the seventeenth century—and which systematically turned to the advantage of the Europeans—played a key role in the process of acceptance of European astronomy.

[7]See Hashimoto Keizo 橋本敬造, "Seido no shisÐ to dentÐ chÞgoku no tenmongaku" 精度の思想と傳統中国の天文学 [Chinese traditional astronomy and its conception of precision], *Kansai daigaku shakai gakubu kiyÐ* 關西大學社會學部紀要 vol. 11, no. 1, pp. 93-114.

[8]The year 1645 corresponds to the promulgation of the *Shixian li* 時憲曆 a calendar based on astronomical computations of European origin expounded in Adam Schall's *Xinfa suanshu* 新法算書. On the *Xinfa suanshu* (initially called *Chongzhen lishu* 崇禎曆書 and later the *Xiyang xinfa lishu* 西洋新法曆書, or *Suanshu* 算書 , see Bernard-Maître, "Les adaptations" The *Shixian li* was revised once, in 1741, and remained in force until 1911. See Chen Zungui 陳尊嬀, *Zhongguo tianwenxue shi* 中國天文學史 vol. 3 (Shanghai: Shanghai renmin chubanshe, 1984), p. 1406 and 1489 ff. On the background of the reform prior to 1645, cf. Hashimoto Keizo, *Hsü Kuang-ch'i and Astronomical Reform: The Process of the Chinese Acceptance of Western Astronomy, 1629-1635* (Osaka: Kansai Univ. Press, 1988).

instrumental techniques supporting the reform were gradually assimilated to the detriment of Chinese traditional astronomy.[9] Beyond the narrow circle of technicians of astronomy, European astronomy was so much judged worth consideration that numerous authors developed the idea that the Chinese of antiquity had anticipated most of the novelties presented by the missionaries as European discoveries,[10] for example, the rotundity of the earth and the "heavenly spherical star carrier model."[11] Making skillful use of philology, these authors cleverly reinterpreted the greatest technical and literary works of Chinese antiquity. From this sprang a new science wholly dedicated to the demonstration of the Chinese origin of astronomy and more generally of all European science and technology.[12] Moreover, while this science of the origins of science grew deeper, the Chinese put their efforts into the difficult reconstruction of their ancient mathematical works lost or long forgotten but witnessing the greatness of past Chinese science and containing the seeds of a future scientific renaissance based on ancient Chinese knowledge.

Even so, although declared Chinese in their origins, not all aspects of European mathematics and astronomy were approved unanimously even if some eminent personalities like Xu Guangqi 徐光啓 (1562-1633)—the instigator of

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[9]On the Ming dynasty projects of reform, see Willard J. Peterson, "Calendar Reform Prior to the Arrival of Missionaries at the Ming Court," *Ming Studies* no. 21 (1986), pp. 45-61. After the collapse of the Ming the most noteworthy Chinese reform project ever elaborated is Wang Xishan's 王錫闡 *Xinfa* 新法 [New Method]. Cf. Xi Zezong 席澤宗, "Shilun Wang Xichan de tianwen gongzuo" 試論王錫闡的天文學工作 [A tentative study of the astronomical works of Wang Xishan], *Kexue shi jikan* 科學史集刊 no. 6 (1963), pp. 53-65; Nathan Sivin, "Wang Hsi-shan," in Charles Coulston Gillispie (ed.), *Dictionary of Scientific Biography* (New York, 1976), vol. 14, pp. 159-168; same author, "Wang Hsi-shan," in L. C. Goodrich (ed.), *Ming Biographical Dictionary* (New York, 1976), vol. 2, pp. 1379-1382; Miyajima Kazuhiko 宮島一彦 "O Sekisen 'GyÐ'an shimpÐ' no TaiyÐ moderu" 王曉庵闡 "嘯庵新法膜"の太陽モデル [The Solar model of Wang Xishan's *Xiao'an xinfa*], in Yamada Keiji 山田慶兒 and Tanaka Tan 田中談 (eds.), *ChÞgoku kodai kagaku shiron* 中国古代科学史論 (Kyoto: Kyoto Daigaku jimbun kagaku kenkyÞjo, 1991), pp. 243-266.

[10]See Nathan Sivin, "Copernicus in China," p. 99 ff., and Harriet T. Zundorfer, "Comment la science et la technologie se vendaient à la Chine au XVIIIe siècle," *Etudes Chinoises* vol. 7, no. 2 (1988), pp. 59-90.

[11]That is, "celestial spheres" I borrow this expression (from the French "sphères porteuses") from Jean-Pierre Verdet, *Une histoire de l'astronomie* (Paris: Éditions du Seuil, 1990), p. 45. On celestial spheres see also Edward Grant, "Celestial Orbs in the Latin Middle Ages," *Isis* vol. 78, no. 292 (1987), pp. 153-173; E. J. Aiton, "Celestial Spheres and Circles," *History of Science* vol. 19, part 2, no. 44 (1981), pp. 75-144.

[12]On this well-known aspect of Chinese science see the excellent article of Jiang Xiaoyuan 江曉原, "Shilun Qingdai 'Xixue zhongyuan shuo'" 試論清代 "西學中源說" [A tentative discussion of the theory of the Chinese origin of Western science], *Kexue shi yanjiu* vol. 7, no. 2 (1988), pp. 101-108.

the reform of the calendar—or Jiang Yong 江永 (1681-1762)—the scholar with whom Dai Zhen 戴震 studied mathematics and who authored the *Shuxue* 數學 (Mathematics), a treatise of epicyclic astronomy[13]—adopted without reservation the main part of European theories to which they had access. In fact, most scholars advocated a selective assimilation of foreign learning, proclaiming that it would be proper "to retain the strong points (*chang* 長) [of European astronomy] while rejecting its weak points (*duan* 短)."[14] To what do these "strong points" and "weak points" relate?

"Strong points" clearly indicate instrumental and mathematical techniques of European astronomy. As Mei Wending puts it, "The excellence of their observations (*ce* 測 and mathematics (*suan* 算) make occidental methods indispensable." And, clearly showing the extent to which Chinese revised Jesuit astronomical texts, "weak points," in their turn, refer essentially to European theology and logic.

Sometimes Chinese were led to re-edit certain works of European origin without their origin prefaces. Such was the case, for example of the re-edition of Manuel Dias Junior's widely diffused[15] *Tianwen lüe* 天文略 (Compendium of astronomy) in the *Siku quanshu* 四庫全書 collection. In the corresponding bibliographical note, critics justified the deletion of the preface, stating that "they could not but suppress the absurdities contained herein."[16] The criticism leveled at the Jesuit treatise aimed at the fusion of the cosmology of celestial spheres with Christian theology.[17] Instances of such cases could be multiplied.

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[13]As noted by Qian Daxin 錢大昕, Jiang Yong's epicyclic astronomy was already antiquated at the time of publication of the *Shuxue* 數學; this book does not seem to have aroused any further interest among Chinese astronomers. Cf. Luo Shilin 羅士琳, *Xu chouren zhuan* 續疇人傳 [A Sequel to the biographies of mathematical astronomers] (1840), p. 641 in the Shangwu yinshuguan re-edition (Shanghai, 1935).

[14]See *Chouren zhuan* 疇人傳 [Biographies of mathematical astronomers], Ruan Yuan 阮元, 1799 (quoted from the Shangwu yinshuguan re-edition, Shanghai, 1935), juan 35, p. 446, Critical Notice 論, where Wang Xishan is praised for having retained the strong points of European astronomy while rejecting its weak points. A similar view is also expressed in Mei Wending's 梅文鼎 *Lixue yiwen* 曆學疑問 [Queries on calendrical science] (1693), juan 1, p. 3b, quoted from the re-edition of this treatise reproduced in *Meishi congshu jiyao* 梅氏叢書輯要 [The essentials of Mei Wending's collection of mathematical and astronomical works], (1874).

[15]See John B. Henderson, "Ch'ing Scholars' Views of Western Astronomy," *Harvard Journal of Asiatic Studies* vol. 4, no. 1 (1986), p. 131.

[16]See *Siku quanshu zongmu* 四庫全書總目, juan 106, bibliographical note devoted to the *Tianwen lüe* 天文略, p. 895 (quoted from the Zhonghua shuju re-edition, Beijing, 1987); Jacques Gernet, *Chine et christianisme, action et réaction* (Paris: Gallimard, 1982), p. 85.

[17]See J. Gernet, "Christian and Chinese Visions of the World in the Seventeenth Century," *Chinese Science* no. 4 (1980), p. 3; W.G.L. Randles, "Le ciel chez les jésuites espagnols et portugais (1590-1651)," unpublished paper presented at the International

In other cases, alterations were more radical and texts were so much recast that they became hardly recognizable. The example of Euclid's *Elements* (*Jihe yuanben* 幾何原本) which was re-edited in versions expurgated of nearly all the demonstrations remains typical in this respect.[18] The idealized space of geometry subservient to deductive logic in the Euclidean way seemed as superfluous to Chinese mathematicians for the mastery of astronomy as celestial space accommodated to theology. According to the author of a preface of an influential Chinese manual of geometry from the end of the seventeenth century—the *Jihe lunyue* 幾何論約 (An abridgment of the demonstrations of Euclid's *Elements*)—the Chinese lack of concern with Euclidean geometry stemmed from the fact that, in the eyes of Chinese readers, the demonstrative discourses of geometry were reminiscent of religious "quibbling," Christian or Buddhistic. Such a metaphysical literature of foreign origin was seen by the influential proponents of "solid sciences" (*shixue* 實學) as the root of all evil in view of its uselessness and indulgence in vain discourses.[19] A manual of geometry should only have contained tangible instructions so as to answer real problems without tying itself up in literary (theo)logical speculations. Discursive logic was deemed so unessential that an astronomer as eminent as Wang Xichan 王錫闡 (1628-1682) considered it irrelevant to discourse on logical principles of mathematical astronomy: On the whole, when the ancients established a mathematical method (*fa* 法 they necessarily relied on organizing principles (*li* 理) and yet they expounded their methods accurately without stating the underlying principles. In fact, organizing principles are contained in mathematical methods and those who are inclined toward study and thorough reflection might find inwardly the necessary energy to grasp organizing principles."[20]

Textual recasting not only affected demonstrations but also geometrical figures as well, and mathematicians of the first order such as Mei Wending 梅文鼎 (1633-1721) did their best to disassociate geometrical figures from the demonstrations to which they were attached. Thus, they sometimes redrew figures so as to make the corresponding theorems directly visible[21] (see Appendix 1).

Symposium "Les Jésuites et les Sciences dans l'Europe de la Renaissance (XVIe-XVIIe s.)," Paris, 18-19 Oct. 1991.

[18]See J. C. Martzloff, "Eléments de réflexion sur les réactions chinoises à la géométrie euclidienne à la fin du XVIIe siècle—le *Jihe lunyue* 幾何論約 de Du Zhigeng 杜知耕 vu principalement à partir de la préface de l'auteur et de deux notices bibliographiques rédigées par des lettrés illustres," *Historia Mathematica* (forthcoming).

[19]J. C. Martzloff, "Eléments de réflexion."

[20]Wang Xishan, *Zazhu* 雜著, p. 3a, quoted from the *Muxixuan congshu* 木犀軒叢書 edition of Wang Xishan's collected works, Bibliothèque Nationale (Paris), Pelliot B 528 (8).

[21]See J. C. Martzloff, "La géométrie euclidienne selon Mei Wending," *Historia Scientiarum* no. 21 (1981), pp. 27-42.

Taking as it were the appearance of "monstrations,"[22] demonstrations changed of nature through the intermediary of tangible figurative representations. At the same time, this major transformation of Euclidean space was accompanied by an extensive "numerisation" of geometry: whereas in their underlying logic Euclid's *Elements* dealt with intrinsic properties of numbers in general without ever quoting any precise number, even when questions of area and volume were at stake,[23] Chinese geometers made massive use of explicitly mentioned particular numbers, computed if need be with a high degree of precision.[24]

Considering the Chinese rejection of speculation verifiable by the expedient of dogmas and axioms, it is quite understandable that seventeenth- and eighteenth-century Chinese astronomers attached a limited importance to cosmology. Although crucial in European intellectual history, the questions of the origin, end, finitude or infinitude of the universe, of the space and shape of the earth compared to the sun, the planets and the whole universe, did not much preoccupy Chinese astronomers.[25] It is significant that the introduction of heliocentrism in China, ca. 1760, in no way provoked a Copernican revolution of

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[22]I borrow this neologism from Arpad Szabo, *Les débuts des mathématiques grecques* (Paris: Vrin, 1977), p. 213 so as to denote "the act of showing in order to allow the truth of some proposition to be seen visually, without recourse to discursive reasoning" Grammatically, "monstration" is intended as a French noun derived from the verb "montrer" (to show) and morphologically akin to "démontrer" (to demonstrate).

[23]Admittedly, the particular version of the text of Euclid's *Elements* to which Chinese had access was not based on some reliable medieval Greek edition of the original but on Clavius's commentary which was partially translated (or rather adapted) into Chinese by Matteo Ricci and Xu Guangqi 徐光啓 in 1607. For various reasons, Clavius develops Euclid at length in his own prolix way so that he sometimes happens to use particular numbers to clarify one or another definition or theorem. But this intrusion of numbers remains always very limited and in no way entails a substantial recasting of the original apodictic structure of Euclid's text. Even in their Chinese version, Euclid's *Elements* are always Euclid's *Elements* and certainly not a manual of practical arithmetic or geometry. Cf. Clavius, *Euclidis elementorum* (Rome, 1574 first ed.); Pasquale d'Elia, "Prezentazione della prima traduzione cinese di Euclide," *Monumenta Serica* vol. 15 (1956), pp. 161-202.

[24]This aspect of the sinicization of Euclidean geometry is particularly obvious in Mei Wending's *Jihe bubian* 幾何補編 [Complements of geometry] (reproduced in *Meishi congshu jiyao*, juan 25-28). Here polyhedra are studied at length from the point of view of the *effective* numerical computation of volumes, areas, lengths of diameters of inscribed or circumscribed spheres, and so on.

[25]These questions are almost never considered worthy of more than a cursory interest in the works of the most renowned Chinese astronomers of the seventeenth and eighteenth centuries. The same conclusion also applies more widely to other Chinese scholars from the same period. Cf. "Ch'ing Scholars Anticosmological World View", in John B. Henderson, *The Development and Decline of Chinese Cosmology* (New York: Columbia Univ. Press, 1984), chap. 9, pp. 227 ff.

Chinese conceptions. While Mei Wending and Wang Xishan took Jesuit cosmology seriously, they developed their thinking along a global, concrete, qualitative and topological line from metaphors built upon zoomorph, phytomorph or more generally "ecomorph" images mainly intended for pedagogical purposes. For example, Mei Wending compares the motion of a planet on its epicycle to the displacement of an eye rolling in its socket.[26] In the eyes of Wang Xishan, the planets are to be considered in the same way as ants on a millstone moving in a direction opposite to that of the motion of the wheel.[27] According to other metaphors, birds flying through the air and fish swimming in the water[28] or even logs carried along by the current of a river[29] are adequate images of planetary motion worthy of discussion.

But if Chinese astronomers rejected theology and did not pay much attention to cosmology, they nonetheless appropriated computational techniques of European astronomy: they attached importance to it especially since predictive astronomy constituted a domain fundamentally independent of theology and cosmology. In Renaissance Europe, mathematical astronomy formed one of the four mathematical arts of the *quadrivium* whereas physical study of the heavens was the concern of natural philosophy.[30]Computations of predictive astronomy rested no more on the assignment of some date to the Creation of the world than on the assertion of the existence (or non-existence) of a "heavenly spherical star carrier." All of this means that *mathematical* astronomy possessed its own mathematical representations and that these representations were independent of *physical* cosmological models born of the association of Aristotelian physics with Christian theology. In fact, these representations were based on Ptolemaic, Copernican or Tychonic quantified cinematic geometrical models.[31] Chinese

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[26]*Lixue yiwen*, juan 2, p. 4a.

[27] The same naïve simile, which goes back to Vitruvius's *De Architectura*, and which appears also in Wang Chong's 王充 *Lunheng* 論衡 as well as in a Chinese Jesuit treatise by Giacomo Rho, does not explain the stations and retrogradations of the planets. Cf. Henderson, "Ch'ing Scholars," esp. p. 129; Vitruve, *De l'architecture, livre ix, Texte établi, traduit et commenté par Jean Soubiran* (Paris: Les Belles-Lettres, 1969), p.15.

[28]See Wang Xishan, *Zazhu*, p. 13a. The fish analogy appears also in a work of the humanist poet and courtier Giovanni Pontano (1426-1503). See N. Jardine, *The Birth of History and Philosophy of Science, Kepler's* A Defence of Tycho against Ursus *with Essays on its Provenance and Significance* (Cambridge: Cambridge Univ. Press, 1984), p. 233.

[29]See Henderson, "Ch'ing Scholars," p. 133.

[30]See, for example, Charles B. Schmitt and Q. Skinner (eds.), *The Cambridge History of Renaissance Philosophy* (Cambridge: Cambridge Univ. Press, 1990), p. 697 ("The status of astronomical hypotheses").

[31]As shown by Hashimoto Keizo, the Tychonic cinematical models of planetary motion of the *Xinfa suanshu* are borrowed directly from Longomontanus—i.e., Christian Severin (1562-1647)—*Astronomia Danica* (Amsterdam, 1622). See Hashimoto Keizo,

astronomers could not be unaware of the differences between these three representations for they were taken up at length in an important Jesuit technical treatise, Giacomo Rho's *Wuwei lizhi* 五緯曆指 [Principles of the motion of the "Five Wefts" (i.e. the five planets)].[32] With the publication of this work they could no longer ignore the fact that these representations were independent of cosmological commitments. As Rho writes, "Inquiries as to the thickness of the primum mobile, 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 zhi xue*, literally "the study of phenomenal principles"] are not the concern of mathematical astronomy."[33]

Nevertheless, even if mathematical astronomy as such did not present difficulties, Chinese astronomers came up against tenacious obstacles as soon as they confronted its particular mode of exposition (hypothetico-deductive logic) and wanted to relate it to the real world. However, this kind of difficulty was due in no way to the novelty or to the computational complexity of European astronomical techniques but rather to the incompatibility on essential points between Chinese and European conceptions of space and time.

Fundamentally, European science apprehended astronomical phenomena through the medium of mathematized causal explanations, based at the same time on logic and on axiomatics. The axiomatics consisted in a small number of inalienable, unverifiable and irreducible propositions and on logic founded on a set of formal rules of inference codifying once and for all admissible modes of reasoning. Stemming from the Platonic tradition, axioms asserted the principle of regularity and uniformity of the motion of celestial bodies in the course of time along immutably fixed circular orbits. In its turn, logic was based on not less absolute and immutable principles such as the principle of identity or the principle of non-contradiction as well as on rules of inference such as the *modus ponens* or the *reductio ad absurdum*. Resting on such a foundation, European predictive astronomy strove for the elaboration of theoretical geometrical models, not arbitrarily, but so as to carry out correct predictions in accordance with axioms and logical rules of inference.

Obtaining correct predictions was also the aim of the Chinese mathematical astronomy. But unlike European astronomy, its predictions were based on compilations of prescriptive computational receipts (algorithms) organized in an open system. In their compilations, Chinese assumed a priori various ar-

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"Longomontanus's *Astronomia Danica* in China," *Journal for the History of Astronomy* vol. 18 (1987), pp. 95-110.

[32]The translation of *Wu wei* 五緯 as "Five Wefts" has been coined by Edward H. Schafer in his *Pacing the Void, T'ang Approaches to the Stars* (Berkeley: Univ. of California Press, 1977), p. 211.

[33]*Wuwei lizhi* 五緯曆指, juan 1, p. 8a, in *Wenyuange siku quanshu* 文淵閣四庫全書 (Taibei: Shangwu yinshuguan, 1986), vol. 788, p. 636), quoted in Sivin, "Copernicus in China," p. 79.

rangements without feeling compelled to respect to the letter dogmatic or axiomatic constraints.[34] Moreover, the first and the foremost criterion of validity in Chinese astronomy was the agreement between predictive techniques and observation. In case of disagreement between a given predictive system and experimental results, Chinese tried to compile new systems which were submitted to the verdict of empirical reality. Consequently, inventors of predictive systems could a priori freely juxtapose various kinds of computational arrangements whatever they may have been.

For all that, it is impossible to say that Chinese astronomers denied that the motion of celestial bodies was devoid of any regularity. Quite the contrary; for example, in the *Shoushili* 授時曆 and in earlier systems of predictive astronomy the motion of the five planets uniformly obeys the same pattern which consists of phases of waxing, waning, stations, retrogradations, visibility and invisibility.[35] In his *Qi zheng* 七政 [The Seven Governors, i.e. the sun, the moon, and the five planets], Mei Wending criticizes the Tychonic system on the grounds of its lack of symmetry caused by what he understood as a reliance on heliocentrism in the case of Mars and on geocentrism in the case of other planets. Consequently, he devises a new system, half-geocentric, half-heliocentric (see Appendix 2). But neither Mei Wending nor any other Chinese astronomer ever found themselves forced to proclaim laws of nature on the basis of such regularities and still less to insert them into closed sequences of interdependent hypothetico-deductive reasoning, reducible to irremovable dogmas governed by eternal truths and aiming, in the last analysis, at the discovery of a unique point of view.

From the European and Chinese standpoint alike, celestial bodies moved unremittingly. But whereas the former considered celestial motions to be perfectly regular and describable from eternally valid fixed hypotheses, the latter judged that astronomical predictive systems should respond to change by being changing. Chinese predictive systems were thus always considered temporary by their authors. Significantly, whereas from antiquity to the Renaissance, European astronomy had remained axiomatically stable, during the same period Chinese predictive systems experienced not less than about fifty reforms and as

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[34]However, more restrictively, certain authors insist on the necessity of linking up, one way or another, predictive techniques with reality. Thus, Wang Xishan criticizes the division of the trigonometrical circle into 360 degrees which was introduced by Jesuits missionaries, and prefers the traditional Chinese division of the circumference in as many degrees as the number of days in a year, that is 365.25°. Nevertheless, the same Wang Xishan does not adopt an irrefragable realist position for he sometimes uses also his own curious artificial division of the circumference into 384 (= 4x96) parts. On other aspects of Wang Xishan's realism see Sivin, "Copernicus in China," p. 73.

[35]See, for example, Michel Teboul, *Les Premières Théories Planétaires Chinoises* (Paris: Collège de France, Mémoires de l'Institut des Hautes Etudes Chinoises, 1983), vol. 21.

many proposals for reform.[36] European astronomy was in fact so locked up by its axiomatic and dogmatic foundations that any modification called into question the whole edifice and threatened its stability: any evolution contained the seeds of revolutionary changes. Conversely, Chinese astronomy could evolve out of successive reforms for it depended on no unassailable system.

When at the beginning of the seventeenth century Matteo Ricci and Manuel Dias distributed their astronomico-theological manuals throughout China, they spread the vision of an immutable science into which scholastic reasoning and theological dogmas were inextricably associated so as to "prove" revealed truth.[37] But European science soon entered into such a zone of prolonged turbulence that what Jesuits made accessible to Chinese in their own language in their subsequent astronomical writings came ineluctably to contradict the initial affirmations of European astronomy.

Initially, while Jesuit publications assumed the world to have been created, not all of them assigned the same date to this Creation[38] and besides, twenty years after Matteo Ricci had introduced them, the number of celestial spheres of the "heavenly spherical star carrier" model began to vary.[39] Even more radically, between 1628 and 1644, the same spheres were temporarily replaced by liquid spheres before falling into disuse.[40]

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[36]See the complete list of Chinese calendrical systems in Chen Zungui, *Zhongguo tianwenxue shi*, p. 1399 ff.

[37]See Gernet, "Christian and Chinese Visions," p. 3.

[38]This point is noted by Mei Wending in his *Lixue yiwen*, juan 1, p. 7a. Concerning the various dates of the Creation in European sources, readers might consult the numerous references in Alain Segonds' annotated translation of Kepler's *Mysterium Cosmographicum* (A. Segonds, *Le secret du monde*, Paris: Les Belles-Lettres, 1984, pp. 340-341, notes 2-4). See also G. J. Whitrow, *Time in History* (Oxford: Oxford Univ. Press, 1989) who notes that "By 1660 at least fifty different dates had been assigned to Creation, depending on which version of the Old Testament and which counting method were used" (p. 131). Also see Ludwig Ideler, *Handbuch der mathematischen und technischen Chronologie*, vol. II (Berlin, 1826), p. 445, who lists 200 different dates for the Creation. (I owe this last reference to Claudia von Collani.)

[39]Noted in Mei Wending's *Lixue yinwen*, juan 2, p. 3b.

[40]See Jiang Xiaoyuan 江曉原, "Ming mo lai Hua yesuhuishi suo jieshao zhi Tuolemi tianwenxue" 明末來華耶穌會士所介紹之托勒密天文學 [The Ptolemaic astronomy introduced by Jesuit missionaries in China at the end of the Ming dynasty], *Ziran kexue shi yanjiu* vol. 8, no. 4 (1989), p. 306. It is nonetheless true that celestial spheres were still mentioned here and there in late Chinese astronomical works (for example, in the *Lixiang kaocheng*, juan 1, p. 8, *Wenyuange siku quanshu* re-edition, vol. 790). But these spheres were hardly more than "fossils remnants" of an antiquated European theory rather than an active concept: they were mentioned only in passing. For the European historical background of the celestial spheres see William H. Donahue, *The Dissolution of the Celestial Spheres* (New York: Arno Press, 1981); Michel-Pierre

Later, owing to instrumental and theoretical advances, fundamental con-stants and physical theories of European astronomy were affected by progres-sive modifications which slowly but surely changed the results that the first Jesuits had presented as immutable. In his *Lifa wenda* 曆法問答 (Dialogues on astronomy) (1715),[41] the French Jesuit Jean-François Foucquet went as far as to put forward a meticulously argued refutation of astronomical theories developed initially in the *Xinfa suanshu* (Computational astronomy of the new methods) of Adam Schall, Giacomo Rho and others. Drawing on scientific data from the *Comptes Rendus de l'Académie des Sciences* and relying on results established by contemporary astronomers such as Jean-Dominique Cassini, Pierre Gassendi, Edmund Halley, Ole Christensen Roemer, Jean Picard, and Philippe de la Hire, as a consequence of the development of precision astronomy and achievements of French geodesic expeditions throughout the world,[42] Foucquet showed point by point, mathematically and experimentally, how the new determinations of parallaxes and refractions, of the apparent diameters and distances from the earth of the sun and the moon, among other things, ruined the Ptolemaic, Copernican Tychonic and even Keplerian foundations of sinicized Jesuit astronomy. At last, the efforts of this iconoclast resulted in the Chinese translation of the astronomical tables of de la Hire.[43]

Lerner, “Le problème de la matière céleste après 1550: aspects de la bataille des cieux fluides,” *Revue d'Histoire des Sciences* vol. 42, no. 3 (1989), pp. 255-280.

[41]Vatican Library, manuscript Borgia Cinese 319 (1)-(2) and (3)-(4) [double of (1)-(2)]; cf. J. C. Martzloff, “La science astronomique européenne au service de la diffusion du catholicisme en Chine; l'oeuvre astronomique de Jean-François Foucquet (1665-1741),” *Mélanges de l'Ecole Française de Rome, Italie et Méditerranée* tome 101, no. 2 (1989), pp. 973-989.

[42]See Jean-Jacques Levallois, *Mesurer la terre: 300 ans de géodésie française: de la toise du Chatelet au satellite* (Paris: Presses de l'Ecole Nationale des Ponts et Chaussées, 1988).

[43]Although Foucquet’s astronomical manuscripts were never published, they were presented to the Kangxi emperor himself and to the team of astronomers under the leadership of his third son, Yinzhi, who studied Western science at the so-called imperial “Tribunal of Mathematics”; see John W. Witek S.J., *Controversial Ideas in China and in Europe: A Biography of Jean-François Foucquet, S.J. (1665-1741)* (Rome: Institutum Historicum S.I., 1982), p. 184. Two copies of the two volumes (juan 卷 of the *Lifa wenda* 曆法問答 are still preserved at the Vatican Library. Mentioning this episode of the history of Jesuit astronomy in China, Joseph Needham writes that “in 1710 Jean-François Foucquet ... and others of the society wished to make use of the new planetary tables of P. de la Hire, but the Father-Visitor would not permit it, for fear of 'giving the impression of a censure on what our predecessors had so much trouble to establish and occasioning new accusations against our religion.'” (*Science and Civilization in China*, vol. III, Cambridge: Cambridge Univ. Press, 1959, p. 450.) In fact, the banning of the publication of the tables of de la Hire was effectively decreed, but *in 1716* and not in 1710 as stated by Needham, that is, much later, after Foucquet had finished translating them into Chinese. The attitude of Foucquet might seem strange but it should be emphasized that

With the publication of the *Lixiang kaocheng houbian* 曆象考成後編 [Sequel to the compendium of observational and computational astronomy] (1742) Chinese were once more brought face to face with Keplerian ellipses,[44] a new theory which contradicted former Jesuit conceptions. At last, twenty years later, the French Jesuit missionary Michel Benoist (1715-1774) gave an overall account of the Copernican heliocentric cosmology.

Thus the contrast between the fixed religious teachings and the variability of Jesuit scientific learning was enormous. One might legitimately wonder why the missionaries relied so much on astronomical science as the means for establishing themselves in China even though their Chinese opponents found in the continuous fluctuations of European astronomical knowledge proof of inanity of the religion to which the Jesuits wished to convert them. In fact, the Jesuit attitude towards experimental and instrumental astronomy can be understood only within the broader context of the scientific policy of the Company of Jesus in Europe.

In seventeenth-century Europe, and even during the eighteenth century, The Company of Jesus always attached importance to experimental sciences. As noted by the American historian W. B. Ashworth, "it was Riccioli—not Galileo and not Mersenne and certainly not Descartes—who first accurately determined the rate of acceleration for a free falling body."[45] Under these circumstances**,** the fact that the Jesuits of China had specially chosen Tychonic astronomy as the basis for their reform of Chinese astronomy is particularly significant: at the beginning of the seventeenth century, instrumental astronomy could not be offered a better support than the one which rested on the achievements of the master of Uraniborg, he who established an entirely new and lasting standard for

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the Company of Jesus was not a monolith. Unlike the Father-Visitor, Foucquet had no objection to the introduction to China of the most recent European scientific novelties for, as he cleverly explained, it would contribute to making the Chinese durably dependent on the Europeans (see the manuscript "Borgia latin 566" of the Vatican Library, p. 152, verso). It should also be noted that Foucquet was far from being isolated: other French Jesuits favored the same position (cf. Witek, *Controversial Ideas*, p. 184). Let us add in passing that de la Hire's tables were the best available in their time and that they enjoyed a lasting success in Europe long after having been made accessible to Chinese: they were reissued in Paris in Latin in 1702, 1722 and 1727, in French in 1735 and 1755, in German in 1725 and 1745. Cf. Curtis Wilson, "Predictive Astronomy in the Century after Kepler," in *The General History of Astronomy*, vol. 2, *Planetary Theory from the Renaissance to the Rise of Astrophysics, Part A: Tycho Brahe to Newton* (Cambridge: Cambridge Univ. Press, 1989), p. 190.

[44]See Sivin, "Copernicus in China," p. 93.

[45]W. B. Ashworth Jr., "Catholicism and Early Modern Science," in David C. Lindberg and Ronald L. Numbers (eds.), *God and Nature: Historical Essays on the Encounter between Christianity and Science* (Berkeley: Univ. of California Press, 1986), p. 155. Cf. Steven James Harris, "Jesuit Ideology and Jesuit Science: Scientific Activity in the Society of Jesus (1540-1773)," Ph. D. dissertation (Univ. of Wisconsin, 1988).

astronomical instrumentation and observation. Consequently, to the general satisfaction of most of the Chinese interlocutors of the Jesuits, the positions of the celestial bodies in space and time could be evaluated with an improved precision even in China.

Considering experimental astronomy as a key issue, missionaries could certainly not ignore that in the long run they would be constrained to deny what they had earlier asserted and thus find themselves in a delicate position. And this is precisely what happened: Tycho Brache's geo-heliocentric system was maintained in China long after having demonstrably fallen into obsolescence. But even so there was a way out and the ecclesiastical authorities managed to "immunize" their assertions against the contamination of experimental results, considering in advance new cosmological models as *fictitious* albeit efficacious hypotheses appropriate "to save the phenomena" though intrinsically false. In other words, the adoption of various astronomical models of the universe was easily accepted provided that these models were considered as mere mathematical devices deprived of any physical significance. Even heliocentricism was acceptable on such a ground: "there is no danger in saying that, by assuming the earth moves and the sun stands still, one saves all the appearances better than by postulating eccentrics and epicycles; and that is sufficient for the mathematician."[46] The domain of immutable theological truths was thus dissociated at little cost from the domain of predicative astron-omy, a domain always liable to fluctuation, accessible to human knowledge in a limited and imperfect way.

A little less than a century after the publication of the *Xinfa suanshu*, Foucquet resorted again to the same fictional argument that Andreas Osiander—the anonymous author of the introduction to Copernicus's *De Revolutionibus Oribum Coelestium*—had already developed so as to present heliocentrism as a theologically innocuous device:

> [In Europe] astronomers have two theories (*shuo* 說 . According to the first, the earth is immobile while the sun and the moon both revolve around the earth: this pattern (*li* 理 is absolutely certain. According to the second theory, the sun is immobile while the earth and the moon both revolve around it: this theory is no more than an hypothesis (*shexiang* 設想) devised by the new astronomers and it cannot be considered as a real, existing pattern. Even though both theories are appropriate to the prediction of the first contact, the middle, the end and other phases of eclipses, the new scholarship prefers the theory of the immobility of

[46]Quoted from Cardinal Bellarmine's letter to Foscarini (12 April 1615) translated by Maurice A. Finocchiaro, *The Galileo Affair, A Documentary History* (Berkeley: Univ. of California Press, 1989), p.67. See also Sergio M. Pagano (ed.), *I Documenti Del Processo di Galileo Galilei* (Rome, Vatican City: Collectanea Archivi Vaticani, 21, 1984).

> the sun which, in spite of its extravagance is nonetheless well-adapted to [eclipse] prediction. [Consequently] I shall follow it here.[47]

Chinese who took an interest in these questions approved of this instrumental approach to astronomical theories. As explains Qian Daxin 錢大昕 "Deferents and equants constitute fundamentally fictitious figurative representations (*jiaxiang* 假象). Presently they have been set aside and ratios based on ellipses have been invented instead. Ellipses are also fictitious figurative representations but the predictions of solar and lunar eclipses they allow agree with observation. It is thus equally possible to rely on big and small epicycles as well as on ellipses."[48]

Such an agreement between Chinese and Europeans on the fictitious character of astronomical systems follows from the way Chinese considered these systems within their own tradition. Nonetheless, this punctual agreement covers quite different realities.

In the seventeenth-century context, Jesuits were led, overtly or covertly, to take predictive systems as "crafty hypotheses" whose ultimate justification was often based on an argumentation borrowed from Aristotelian logic according to which it is possible to derive true propositions from false premises by the sole virtue of the logical structure of the argument, regardless of its particular meaning. Thus though false, certain predictive systems were endowed with the capacity to yield precise predictions of hitherto unobserved phenomena; hence the belief in the possibility of access to the world of irrefutable truths by means of discursive reasoning. The mathematical astronomy of Ptolemy, for example, offers a convincing illustration of such a conclusion for the mathematically equivalent geometrical models of the *Almagest* based on the one hand on eccentrics and on the other on epicycles, both of which have equal capacity to represent reality. But both of these two models cannot be physically correct at the same time. One of them is thus simultaneously correct from the point of view of mathematical prediction and physically false.

But Chinese did not consider that the fictitious character of predictive systems hinged on an argumentation borrowed from logic. Rather, they believed that predictions could not but be based on fictitious devices. Indeed, from a Chinese standpoint, astronomical systems were intrinsically submitted to a double limitation: first, a limitation due to the imperfection of instruments which

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[47]*Lifa wenda* (Vatican Library, Borgia Cinese 319 [3]), 2nd part, pp. 37b-38a.

[48]That is, in the context of this quotation, epicycles successfully played their role in their time and the same obtains for ellipses in the present. Quoted from the *Xu Chouren zhuan*, juan 49, p. 640. But this does not mean that Chinese in general believed that completely different predictive systems could not be used simultaneously (cf. the example of the Muslim [*Huihui* 回回] astronomy in Ming China). Rather, Qian Daxin's claim reflects an aspect of the widely held belief of the non-existence of immutable predictive systems and, correlatively, an open attitude towards acceptable systems: as it were, "anything goes" provided that it stands the test of experimentation.

precludes the *exact* determination of the position of celestial bodies;[49] and, second, an observational limitation due to the necessarily short span of time during which observations were recorded,[50] which excluded the possibility of detecting infinitesimal, albeit cumulative, perturbations liable to affect surreptitiously but appreciably in the long run celestial positions. Experimental knowledge of the heavens was thus bound to remain approximative and predictive systems resulting from this approximative knowledge were necessarily imperfect, temporary and historically dependent on the particular epoch of their conception. Approximative from the start, the predictive systems that Chinese astronomers elaborated successively were thus doomed to irremediable alteration with the passage of time. But in view of the cumulative improvement of astronomical knowledge they admitted that they could succeed in keeping errors of predictions within acceptable limits, at least to a certain extent.

As Chinese criticisms of European conceptions (summarized below) indicate, Chinese astronomers saw the fluctuations of European astronomy as a confirmation of their conceptions and they found all the more absurd the pretense of European predictive systems to achieve perfection since the experimental basis of these systems was often extremely tenuous:

• Ptolemaic planetary theories are unreliable for they are based on an incredibly weak experimental basis. Indeed, these theories are always based on merely three observations since a circle is determined by three points.[51] This opinion is an expression of defiance against astronomical predictive systems stressing "theoretical reductionism" at the expense of empirical data.

• European astronomical theories have a limited value for some of their parameters are inherently inconstant. Thus it would be proper to take into account secular variations of the tropical year, of the obliquity of the ecliptic and related

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[49]Hence the recourse to huge instruments, especially on the occasion of the elaboration of the *Shoushili* 授時曆. But as a rule, such instruments were certainly not easily available, and even Zhu Zaiyu (1536-1611) complains of the inaccessibility of huge instruments and gnomons (*hong yi ju biao* 洪儀鉅表) (cf. *Shengshou wannian li* 聖壽萬年曆, quoted from the *Wenyuange siku quanshu* re-edition of the text, vol. 786, p. 454). Moreover, Qing astronomers such as Wang Xishan and Mei Wending had no more access to huge instruments than Zhu Zaiyu and hardly mention them.

[50]See Nathan Sivin, "On the Limits of Empirical Knowledge in Chinese and Western Science," in Schlomo Biderman and Ben-Ami Scharfstein (eds.), *Rationality in Question: On Eastern and Western Views of Rationality* (Leiden: E.J. Brill, 1989), pp. 165-189.

[51]See Wang Xishan, *Li shuo* 曆說 [On computational astronomy], second part, p. 6b (the *Li shuo* is a part of Wang Xishan's *Zazhu*). In Wang Xishan's own words, "Using a geometrical method, generally speaking, only three observations are necessary to compute the whole (circular) orbit. [But] Western annals have not limited their records to three observations [for a given planet] and even so [Westerners] have not yet found an [immutable] method."

phenomena.[52] Incidentally, while discussing these problems Wang Xishan considers, most remarkably, immense intervals of time (billions of years; *yi wan*, literally "*yi* times a myriad years," that is, millions upon millions of years).[53]

• European astronomical theories tend to claim to be valid without limit but nothing of the sort is possible since predictive theories of present day astronomy are valid only during a short span of time.[54]

Acknowledging the superiority of European predictive systems but refusing at the same time to endorse the conceptual framework on which they were built, influential Chinese authors such as Mei Wending and Wang Xishan emphasized the necessity to "save the phenomena" with hybrid and syncretic compilations of astronomical techniques grouped together in their operations independently of hypothetico-deductive systems, much in the same way as others did in mathematics.[55] As Ruan Yuan put it, "new Western methods have been repeatedly modified and found themselves subdivided into many different branches. The traditions transmitted by [ancient] masters of astronomical reckoning all differ the one from the other. Tang Ruowang [Adam Schall] emphasizes epicycles while Munige [Smogulecki] uses eccentrics; in their turn Dai Jinxian [Ignace Koëgler] introduces elliptical deferents in his translations and Jiang Youren [Michel Benoist] says that the sun is immobile and the earth mobile. These various conceptions are so incompatible that it would be difficult to synthesize them."[56] No astronomer ever realized the "synthesis" that Ruan Yuan call for.

If European missionaries and Chinese astronomers alike tried to refine their predictive tools using ever improved astronomical instruments and new computational techniques which they submitted to the test of reality, the former developed their predictive systems from axioms and logical rules of inference and the latter on a basis of an "asystemic" instrumentalism.[57] The Europeans clung to

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[52]Wang Xishan, *Li shuo*, p. 6a.

[53]Wang Xishan, *Li shuo*, p. 6a.

[54]Wang Xishan, *Li shuo*, first part, p. 4a.

[55]This aspect of Chinese predictive astronomy is particularly obvious in Wang Xishan's "new method" (*xiao'an xinfa* 曉庵新法) where results of Chinese or European origin are often merely juxtaposed to avoid the necessity of choosing between them in case of doubt.

[56]Ruan Yuan, *Chouren zhuan*, foreword (*fanli* 凡例), p. 4.

[57] "Asystemic": not confined within the limits of any system whatever (for example, mathematical or logical systems bound by axioms and formal modes of inference defined once and for all, closed physical systems originating from Aristotelian physics, etc.). To avoid confusion, we should point out that the "systems" taken here as examples have nothing to do with the "systems" studied by Ludwig von Bertalanffy in his *General System Theory* (New York: George Braziller, 1968). Instrumentalism: "The view that a

the ideal of the discovery of an ultimate immutable predictive model, while the Chinese steadfastly maintained variable, reformable and temporary models. In a word, they had fundamentally different orientations.

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scientific theory is nothing more than a device or instrument for yielding correct predictions about the course of Nature, and that theories must therefore be assessed not as *true* or *false* but only as *effective* or *ineffective* as prediction" W. F. Bynum and E. J. Brown (eds.), *Macmillan Dictionary of the History of Science* (London: Macmillan Press, 1983), p. 209.

APPENDIX 1

Mei Wending's Interpretation of Propositions 7 and 8 of Book 2 of Euclid's *Elements*

In his *Jihe tongjie* 幾何通解 (General explanation of [Euclid's] geometry) (cf. *Meishi congshu jiyao*), Mei Wending reinterpreted Euclid's *Elements* (1607) by means of well-known traditional algebraic formulae, intended for the resolution of right-angled triangles and usually regrouped in the Gougu 勾股 chapter of Chinese arithmetical manuals. Naturally, not all the propositions of the *Elements* can be interpreted in this way, but those of book 2, among others, lend themselves to Mei Wending's treatment which consists essentially in redrawing Euclid's geometrical figures and in considering that certain line-segments represent the lengths of the two smaller sides of a right-angled triangle. Thus, according to Mei Wending's interpretation, propositions 7 and 8 of book 2 of the *Elements* become respectively:

(1) $a^2 + b^2 = 2ab + (a - b)^2$
(2) $(a + b)^2 = 4ab + (a - b)^2$

where a and b represent the lengths of the two smaller sides of a right-angled triangle (the *gou* and the *gu* respectively). For example, in Mei's original wording II-8 becomes: 丁己和冪內有長方行四皆勾乘股之積。又有勾股較自乘冪一。即分餘綫上方形也。 "[Where *ding* = D and *ji* = F] The area DF contains (a) 4 rectangles whose (individual) areas represent the product of 'base times height,' and (b) a single area of the square of the difference between the height and the base, that is, the square on the remaining segment" (*Jihe tongjie*, p. 1b). Compare this with the Euclidean formulation as translated by Sir Thomas Heath: "If a straight line be cut at random, four times the rectangle contained by the whole and one of the segments together with the square on the remaining segment is equal to the square described on the whole and the aforesaid segment as on one straight line." *The Thirteen Books of Euclid's Elements*, trans. by Sir Thomas L. Heath (New York: Dover, 2nd ed., 1956), vol. 1, p. 389. There is no significant difference between Heath's text and that of Clavius on which the Chinese version of the *Elements* is based. Cf. Clavius, *Euclidis Elementorum* (Coloniae, 1591), p. 102.

Apart from the formulation, the most striking difference between Euclid and Mei Wending comes from the latter's redrawing of the initial geometrical figures. Sometimes Mei Wending complicates the original figure from the *Elements*, sometimes he simplifies it, but in any case he manages to produce a figure whose content tends to become directly visible or at least straightforwardly readable, using certain obvious and unformulated assumptions such as "the area of a certain given figure equals the sum of the various areas of the smaller figures into which the given figure can be decomposed." For example, in his reinterpretation of propositions II-7 and 8 Mei Wending uses the same figure twice: a square composed of four rectangles and an inner little square, that is, the celebrated "figure of the hypotenuse" (*xiantu* 弦圖) of Chinese traditional mathematics. In the first case, Euclid's figure is simpler and in the second, more complex. But within the original Euclidean context, the content of Euclid's propositions can hardly be rendered manifest independent of the apodeictic discourse which accompanies them whereas in the case of Mei Wending, the understanding of the content of a given "proposition" depends heavily on the particular way the corresponding figure is drawn rather than on deductive reasoning. See Figures 1 through 4, below.

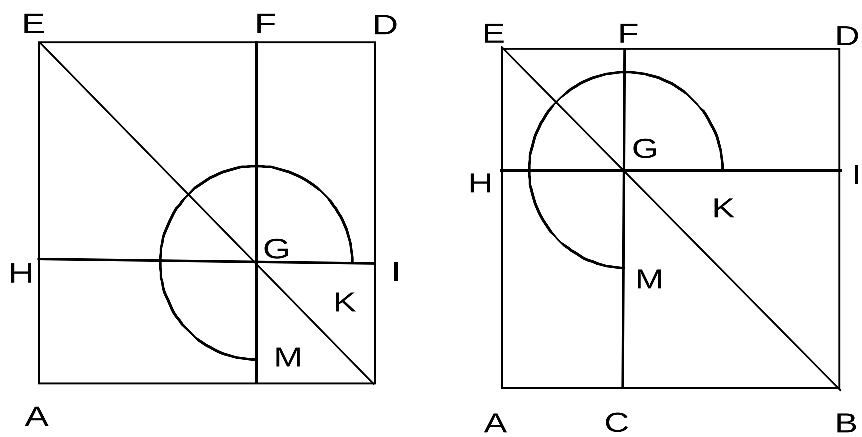

FIGURE 1: Clavius's two figures corresponding to *Elements* II-7 (from Clavius, *Euclidis Elementorum*, p. 101). Note that Clavius gives two figures in order to account for the two essentially different particular cases of proposition II-7.

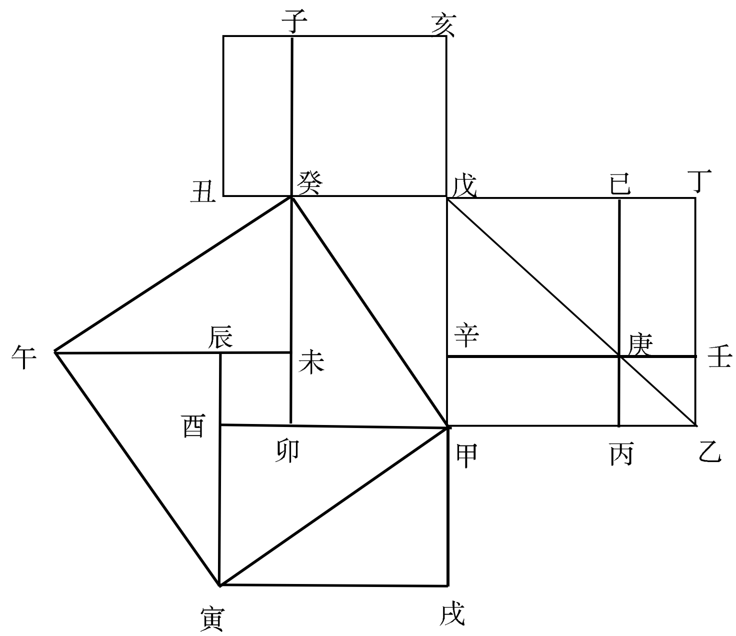

FIGURE 2: Mei Wending's redrawing of the preceding figures (from *Jihe tongjie*, p. 1a). Note the characteristic square composed of four right-angled triangles and one little inner square.

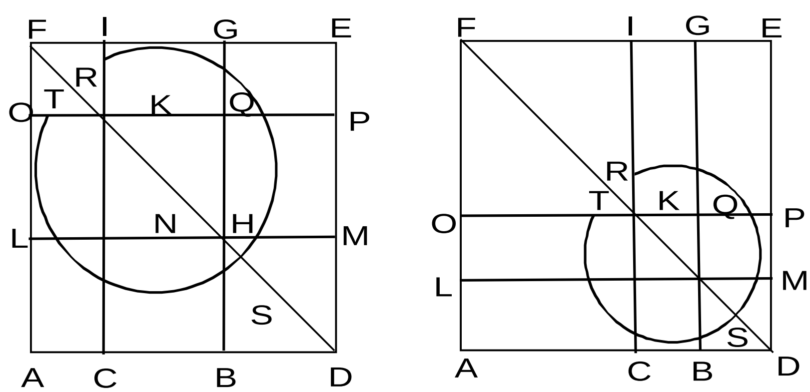

FIGURE 3: Clavius's two figures corresponding to *Elements* II-8 (*Euclidis Elementorum*, p. 102)

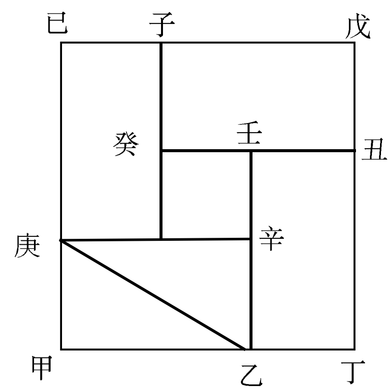

FIGURE 4: Mei Wending's redrawing of the preceding figures (*Jihe tongjie*, p. 1b). Same remark.

APPENDIX 2

Mai Wending's "Bicentric" Cosmological Model of the Motion of Mars

In his *Qi zheng* 七政 The Seven Governors, i.e., the Sun, the Moon and the five planets) (*Meishi congshu jiyao*, juan 56), Mei Wending expresses his astonishment over what he considers the irregular treatment of the motion of Mars as compared with the motion of the four other planets (i.e., Saturn, Jupiter, Venus and Mercury), as expounded in Giacomo Rho's *Wuwei lizhi*. Indeed, in Rho's *mathematical* Tychonic *models*, the deferents of the four planets are uniformly centered on the Earth, whereas the deferent of Mars is centered on the Sun. Mei notes that such a treatment contradicts the Tychonic world model (reproduced in Rho's *Wuwei lizhi*, juan 1), a model where the orbits of the four planets are all centered on the Sun. But considering Tycho's model as fictitious, Mei Wending devises a new model of his own in which Mars is characterized *simultaneously* by a geocentric and an heliocentric orbit. See the translation below of the relevant passages of Mei Wending's *Qi zheng* and the corresponding figure (Figure 3).

In fact, the particular treatment of Mars that Rho follows in his *Wuwei lizhi* originates from Longomontanus's *Astronomica Danica* (1622), book 2, chap. 9 ("Annua inaequalitate Martis exploranda ac restituenda"), pp. 222-231 which in its turn relies on a method developed in Kepler's *Astronomia Nova* (1609), (as indicated in a marginal note of Longomontanus, p. 225, under the elliptic form "Comment. Iohan. Keppl. cap. 24" [i.e. chapter 24 of the *Astronomia Nova*]). Kepler's study of Mars is concisely analyzed in Alexandre Koyré, *La Révolution Astronomique* (Paris: Hermann, 1961), chap. 2, p. 172 ff.

Mei Wending's reassessment of the theory of the motion of Mars did not go unnoticed and the editors of the *Lixiang kaocheng* (1723) noted that "Mars is the only planet whose 'orb' is centered on the Sun" and that Tycho Brahe had relied on "crafty computations" (*qiao suan* 巧算) i.e., on arbitrary computational techniques not submitted to the control of reality (quoted from the re-edition of the *Wenyuange siku quanshu* collection, vol. 790, p. 5).

Mei Wending on the motion of Mars (quoted from *Meishi congshu jiyao*, juan 56, p. 1a):

> Among the planets, the "Sparkling Deluder,"[58] [i.e., Mars] is the most difficult to compute *suan* 算[59] and the computation of its motion had to wait until Tycho to

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[58]I have borrowed this translation from Schafer, *Pacing the Void*, p. 212.

[59]Allusion to the text of the *Wuwei lizhi*, juan 4 (motion of Mars), p. 1a, quoted from vol. 788, p.685, of the re-edition of the collection *Wenyuange siku quanshu*: "*huoxing buneng ce*" 火星不能測 (literally "Mars is unobservable"). Such an idea originates in

> begin to attain precision. Indeed, Tycho's [geometrical] figures and [astronomical] tables have been wholly preserved and leave no doubt [about their accuracy]. But why do they [i. e., Jesuit missionaries] say that Mars does not follow the same rule (*fa* 法) as the four other planets and is the sole planet whose "orb" has the Sun for its center? Stating this point without warning, the authors of the *Lishu*[60] 曆書 have misled their readers by "brandishing a figure" to show the underlying structure of the corresponding figurative [phenomena] instead of relying on computational principles. [Chinese readers] do not know that mathematical astronomers (*lijia* 曆家) use both "solid" (or real) figurative representations (*shi zhi zhi tu* 實指之圖) and figurative representations (*jiexiang zhi tu* 借象之圖). When Digu [Tycho Brahe] represents [the motion of] Mars figuratively, he has in mind a fictitious representation and not a real (*shi* 實) one. My friend Yuan Shilong[61] from Qiantang [a *xian* in Zhejiang], styled Huizi, and who was taught mathematical astronomy by Master Huang Hongxian[62] from Renhe [a *xian* in Zhejiang], styled Sanhe, considered the *Lizhi*[63] (曆指) as a model of excellence (*jin ke* 金科).[64] I have thus composed the present treatise to discuss the most deeply possible [the motion of Mars] by using methods of division of angles and of tangents so as to render manifest the underlying principles.

Pliny's *Naturalis Historia*, book 2, XV (p. 33 in the edition of the text established by J. Beaujeu, *Pline l'Ancien, Histoire Naturelle*, livre II, Paris: Les Belles-Letters, 1950) and the proper name "Pliny" is even explicitly quoted in the Chinese text of the *Wuwei lizhi* (under the form Biliniya 比利尼阿). Rho might have borrowed his reference to Pliny from many sources, but the most probable one is Kepler's introductory part of his *Astronomia Nova* (see Ch. Frisch, ed., *Joannis Kepleri astronomici opera omnia*, vol. 3, Frankfurt, 1860, p. 139) inasmuch as Rho's subsequent Chinese text corresponds closely to Kepler's Latin original (partially translated in Koyré, *La Révolution Astronomique*, p. 37). As noted by Jardine (*The Birth of History*, p. 37), in this context "observare" does not mean "to observe" but "to keep track of"

[60]That is, the *Chongzhen lishu* [Chongzhen reign-period calendrical treatise].

[61]See the *Chouren zhuan*, juan 40, p. 504.

[62]See the short biographical note in Zhongguo kexueyuan Beijing tianwentai 中國科學院北京天文臺 (ed.), *Zhongguo tianwen shiliao huibian* 中國天文史料匯編 (Beijing: Kexue chubanshe, 1989), p. 212. Huang Hongxian belonged to the team of astronomers which collaborated with Xu Guangqi on the reform of the Chinese calendar.

[63]*Lizhi* (literally "calendrical treatise"). This abbreviation designates globally the various treatises of the *Chongzhen lishu* devoted to the motion of the Sun (*Richan lizhi* 日躔曆指), the Moon (*Yueli lizhi* 月離曆指) and the five planets (*Wuwei lizhi* 五緯曆指 .

[64]*Jin ke*: One of the possible sources of this expression is juan 2 of the *Wenxin di-aolong* 文心雕龍. Cf. Vincent Yu-chung Shih (trans.), *The Literary Mind and the Carving of the Dragons* (Hong Kong: The Chinese Univ. Press, 1983), p. 22.

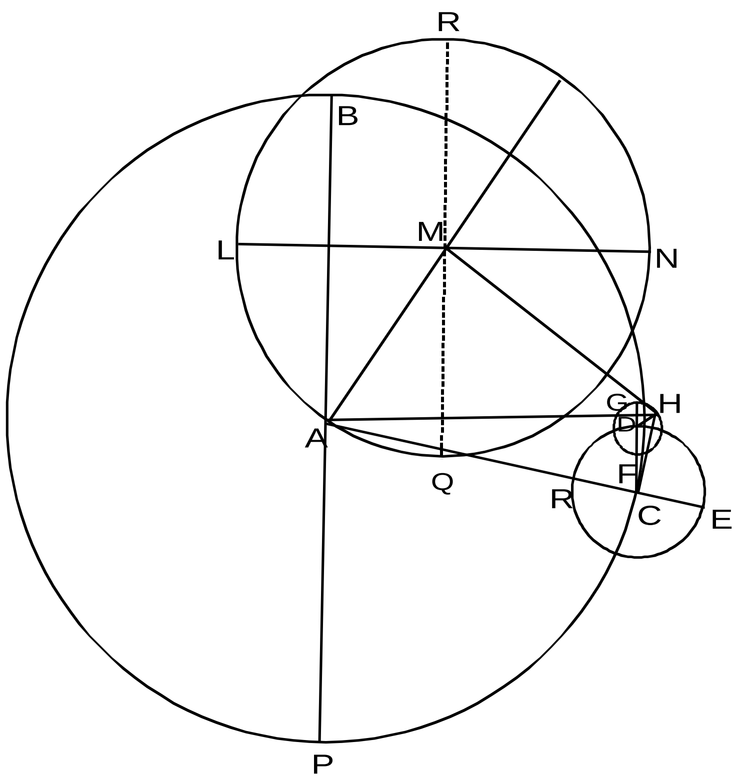

FIGURE 1: Longomontanus's figure for the motion of Mars (from *Astronomia Danica*, p. 224). Note that A represents the sun.

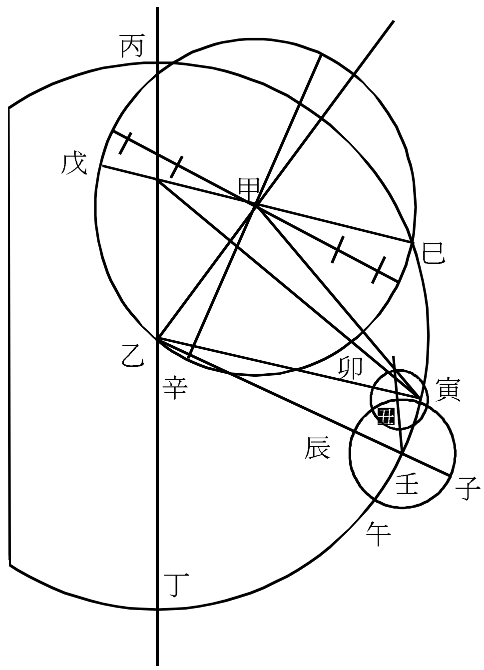

FIGURE 2: Reproduction of the preceding figure in Giacomo Rho's *Wuwei lizhi*, vol. 788, p. 695. Note that *yi* 乙 represents the sun.

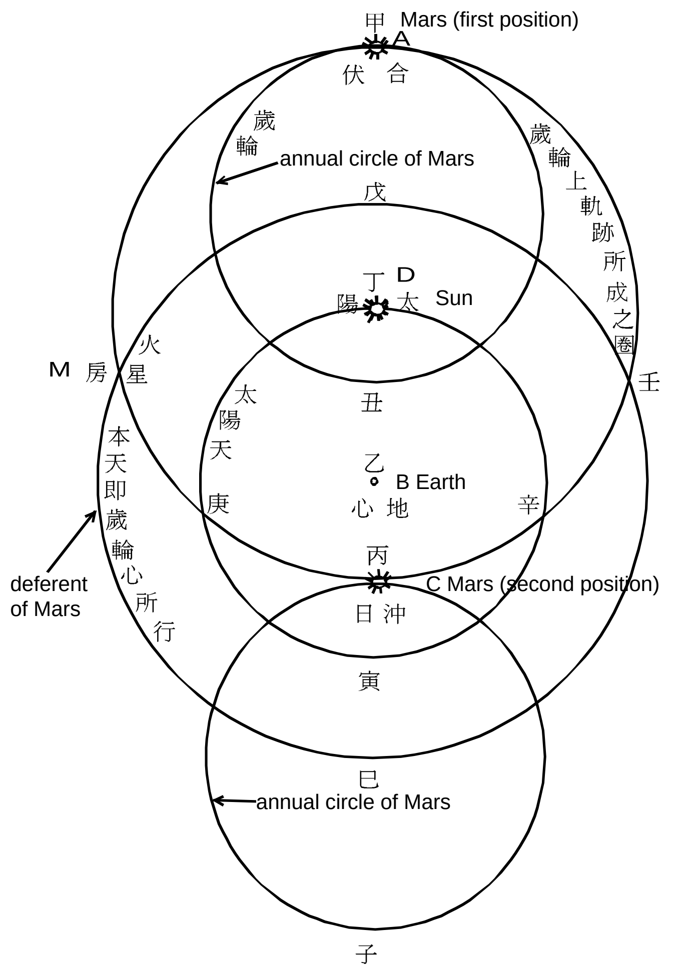

FIGURE 3: The figure represents two different positions of Mars in Mei Wending's "bicentric" system. The first position (Mars in A) corresponds to the "invisibility of conjunction" (*hefu* 合伏) of this planet and the second to its opposition with the Sun (*chong ri* 沖日). Moreover, Mars is fixed to its annual circle (*suilun* 歲輪) and the center of this annual circle is situated on Mars's deferent (*bentian* 本天) whose center is the center of the Earth (B). Consequently, Mars revolves physically on the circle AMCI centered on the Sun (D), whereas the Sun in its turn revolves around the center of the Earth (B). Note that I have added to the figure Latin letters and other non-Chinese elements.