V

Wang Hsi-Shan

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It is important that the first substantial encounter in China between its cognitive traditions and those of Europe was in mathematical astronomy. Medicine provoked no such response, the limited appeal of religion was to faith and not theology, and confrontations of political ideas were negligible. The style of the mid-seventeenth-century response to Occidental astronomy set the style of less abstract encounters later, as may be seen in the reaction to the all too tangible Western military technology of the late nineteenth century.

The early Chinese response to the exact science of Europe is poorly understood. The usual conceptual model for the travel of Western technical concepts and methods, which assumes that their wholesale triumph is automatic and that any hesitation must be the result of ignorance and xenophobia, is not a serviceable tool for this explanation. Experts on "China's response to the West" tend to chide their subjects for not rejecting their culture immediately and wholesale in favor of the new ideas. That expectation betrays a remarkable innocence about the way cultures work, as well as about the value of Occidental ways in Oriental circumstances. The broad pattern of response that we find generally in such historical confrontations—misconception, ambiguity, reinterpretation and selective adaptation over a long period—can be seen equally in American physicians' discovery of acupuncture from the 1970's on.

If we want to understand the indirect paths by which mathematical astronomy exerted its influence, a largely unexplored range of questions becomes appropriate. The last chapter has dealt with one of them, namely, what were the limits of the foreign knowledge that reached China? This one, using a single case, will take up a number of other issues. In what circumstances of society and culture were those who responded to European astronomy? What did they find familiar in it? What did they value as new and useful? For what did they have no use, and what reasons did they give for rejecting it? They lived in a society that esteemed the unity of knowledge. They did not delude themselves that the practice of science can or should be value-free. Like pre-modern European scientists, they would not have found a science divorced from values desirable. What values, then, did they perceive as inherent in the new science, and how were their own values affected by what they adopted from it?

This meditation on the career of Wang Hsi-shan is an experiment along these lines. Wang was a remarkable astronomer, and a lonely man in a dislocated time. His predicaments, social and intellectual, resembled those that formed the careers of many contemporaries and shaped trends of thought. Even the character of his approach to astronomy has much in common with what came to be the dominant trend in Ch'ing neo-Confucianism. I suggest below that this was no coincidence, but represents one of the most enduring influences of Western astronomy.

Life

Wang Hsi-Shan 王錫闡 was born 23 July 1628, and died 18 October 1682. His place of registration was Wu-chiang 吳江, Soochow prefecture.

Wang was the son of Wang P'ei-chen 培真 and his wife, née Chuang 莊. Wang Hsi-shan's epitapher, who would have been expected to cite distinguished ancestors in the preceding few generations, did not do so. Wang was designated to continue the family line of a childless uncle, which suggests that he was not the eldest child or that his family was poor. Nothing is known of his education except that he was self-taught in mathematics and astronomy. He probably did not have access to all the available treatises on the European sciences, for in a letter, probably of 1673, he asked a friend to look for some of them in Peking.

He had no son to arrange for posthumous publication of his writings. One of his few disciples sketched, in twenty-five Chinese characters, the impression Wang made: "emaciated face, protruding teeth, tattered clothes, and shoes burst through the heels. His character made him aloof, as though no one could suit him; but when someone inquired about a scholarly topic, he was forthcoming as a river in flood."[1]

The conventional road to social advancement for the son of an obscure gentry family was the civil service examinations, which required many years of preparation. This path was blocked by the Manchu conquest.

The invaders from the north overran Wang's district in 1645. Whether to collaborate with the alien government was an issue for all Chinese who in normal times would aspire to government service. Wang was only sixteen, but he made it clear that he did not wish to live with the new order: "In a burst of passion, wanting to die, he jumped repeatedly into the river. It

1. This and the next quotation are from the funerary inscription by Wang Chi, 16: 1a-1b. For full citations see the Bibliography, p. 32 below.

always happened that someone was there to save his life. He refused to take food for seven days, but still did not die. His parents were persistent; he had no choice but to resume eating. Renouncing worldly ambition, he dedicated all of his powers to learning." As he put it, in 1649 he closed his door to all worldly pursuits, including the examinations. Hopes for a Ming restoration faded, but in letters and manuscripts he never acknowledged the new Ch'ing dynasty, and reproached those who did.

His friends were like himself Ming loyalists prevented by scruple from following conventional careers. Among them were the great transitional figure of neo-Confucianism, Ku Yen-wu 顧炎武 (1613–1682), as well as P'an Ch'eng-chang 潘檉章 (also of Wu-chiang, died 1663) and Chuang T'ing-lung 莊廷鑨 (died ca. 1660), both of whom planned histories of the Ming, to be compiled by coteries of loyalists. Wang took part in the first, the result of which was destroyed in manuscript. Apparently, disguised as a Buddhist monk, he visited in prison some of the seventy people condemned to death in 1663 when the publication of the second led to a charge of sedition.

Wang was not widely traveled; he never met Mei Wen-ting 梅文鼎 (1633–1721) of Anhwei or the northerner Hsueh Feng-tso 薛鳳祚 (died 1680), now considered the other two great astronomical scholars of the time. Mei acknowledged Wang's preeminence, and wrote commentaries, never published, on several of his books.[2]

2. Described in Wu-an li suan shu-mu, 34b-35a. On the relations of Mei and Wang, see Hsi Tse-tsung, "Shih lun Wang Hsi-shan te t'ien-wen kung-tso." Reliable short biographies of Mei and many other figures mentioned in this essay appear in Goodrich, Dictionary of Ming Biography, and Hummel, Eminent Chinese of the Ch'ing Period.

Wang apparently made an indifferent living by teaching mathematics and astronomy to a few disciples. He was supported for a time by P'an Ch'eng-chang and later by Lü Liu-liang 呂留良 (1629–1683), another prominent Ming loyalist, who practiced medicine. Wang's career was impeded by isolation and illness, including partial paralysis in his later years. The year before he died, he wrote, in connection with the prediction of a solar eclipse: "Whenever there is a conjunction I have always checked the accuracy of my computations against observation, despite sickness, cold, or heat, for thirty years and more."[3]

Wang's technical writings circulated in manuscript among astronomers after his death. Their preservation was not guaranteed until a major composition was included in the enormous imperial manuscript collection of rare texts, the Complete Library in Four Repositories *(Ssu k'u ch'üan shu* 四庫全書, compiled 1773–1785). The descriptive and critical catalogue of this collection (printed 1794) brought Wang's contribution to general attention.

The Setting of Wang Hsi-Shan's Astronomical Career

Chinese astronomers formed their impressions of European astronomy and cosmology from writings that, about 1630, were typical of textbooks and handbooks current in the Church's educational institutions in Europe. After 1616—in other words, not long after the missionaries began writing about astronomy in Chinese—the Inquisition's warning to Galileo prevented them from describing current changes in cosmological thought. At the same time, their competence and good intentions led them to drop hints about these

3. Cited by Hsi (63) from "Wang Hsiao-an hsien-sheng i-shu pu-pien."

changes that turned out to be contradictory and in the final analysis misleading. It was with this in mind that Hsi Tse-tsung remarked "We can imagine, if Wang Hsi-shan had only come upon [Copernicus' *De revolutionibus,* Galileo's *Dialogo,* and Kepler's *Epitome astronomiae copernicanae,* all of which the missionaries kept for their private use in Beijing], how much greater his contribution to astronomy would have been."[4]

Wang, Mei Wen-ting, and Hsueh Feng-tso were the first astronomers outside the court to respond to the exact sciences that were being introduced from Europe, and to shape the influence of these new methods and conceptions on their successors. They were, in short, responsible for the scientific revolution discussed in Chapter VII. There I argue that the social displacement of that one transitional generation opened new possibilities of response.

At the time there were no socially marginal students of astronomy alienated from traditional values and protected by association with privileged foreigners, as would be the case in late nineteenth-century China and elsewhere during the heyday of imperialism. The only astronomers who could respond to the Jesuits' writings were members of the old intellectual elite. Yabuuchi Kiyoshi has noticed that among those interested in foreign scientific learning "many were members of the 'pure discussion' faction, related to the Eastern Grove Party (Tung-lin Tang 東林黨) and the Revival Society (Fu She 復社, two reform groups), who lived as commoners after the fall of the Ming. They mostly came from commercially and

4. Ibid.

industrially prosperous cities in Fukien, Kiangsu, Kiangsi, and Anhui."[5] Members of the upper social strata, whether descended from organized Ming reformers or not, were bound to evaluate innovations in the light of established ideals that they felt an individual responsibility to perpetuate.

The period of the Manchu conquest was crucial in more ways than one. The change of dynasty gave the Jesuits the official status in the court that they had been seeking for half a century, and encouraged the dissemination of their diverse writings. The takeover rent the lives of individuals all over China for that one generation and narrowed their career options to professions that in other circumstances, to conventional families, would not have been desirable alternatives to civil service. The children of those internal exiles did not have to face the same choice.[6]

The transition also encouraged elite scholars to seriously study Western astronomy, distinct from the traditional art in method and conception. Those who had first pursued it late in the Ming naturalized it by creating a foundation myth. They claimed that European mathematics had evolved out of certain techniques that had originated in China and had been transplanted to the extreme fringes of civilization (Europe and Islam) before being neglected and more or less dying out in their original home. This myth circulated by word of mouth until, once the Ch'ing regime was established, the K'ang-hsi

5. Yabuuchi, Min Shin jidai no kagaku gijutsushi, 26, n. 3.

6. This norm generally affected only the transitional generation in families that had served the previous dynasty. Refusing to take the examinations or accept office was in any case a matter of conscience, seldom of social coercion. Zurndorfer 1988, esp. 22–29, has some interesting things to say about responses to Western astronomy as a generational matter.

Emperor (r. 1662–1722), the most powerful of amateur astronomers, took it up. He prompted his scientific associates, including Mei Wen-ting, to take it seriously. Mei began propagating it in writing, and it spread widely.[7] Wang Hsi-shan was among the many who accepted it as a warrant for considering the two traditions side by side.[8]

This foundation myth, an appeal to the Chinese tendency to see perfection in high antiquity, connected Western science with certain ambiguous references in ancient historical writing. Since it was not intrinsically foreign, it could be taken seriously. Mei and his successors used this notion to legitimate the institutions—small private groups of masters and disciples—that organized themselves around the new astronomy and taught it. There is nothing inherently Chinese about the use of such myths. An analogy that comes to mind is the equally remarkable European myth that non-European societies could be "discovered," a change of status that authorized their economic despoliation and the systematic destruction of their ways of life during the Age of Discovery.

Mei, Wang, and others were aware that, whatever the lost grandeur of archaic times may have been, from about 100 B.C. through the thirteenth cen-

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7. Jacques Gernet has suggested (letter, 5 Oct. 1978) that Mei might have been influenced by his teacher Matteo Ricci's habit of claiming Western origins for things he saw in China. Chiang Hsiao-yuan, "Shih lun Ch'ing-tai 'Hsi-hsueh Chung yuan' shuo," believes that the notion of Western origins can be traced back to unpublished remarks by Huang Tsung-hsi 黃宗羲 (1610–1695). For the emperor's involvement see Wang P'ing, Hsi-fang li-suan-hsueh chih shu-ju, 77–79, 97–103. Martzloff, "Space and Time," argues that Mei, Wang, and others sincerely believed it.

8. See Wang's Tsa chu 雜箸(Miscellaneous Essays), in Hsiao-an i shu, XXXV, 1a-2a, 10b-11a.

tury, computational astronomy in China had actually continued, within its stylistic limits, to grow in power and range. From the Yuan period (1279–1368) on, it came very gradually to be little practiced outside the Astronomical Bureau, which was dominated by foreign technicians. In some periods, laws prohibiting unofficial astronomy were actually enforced.

By 1600 it is not clear that anyone was able fully to comprehend the old numerical equations of higher order, proto-trigonometric approximations, applications of the method of finite differences, and other sophisticated techniques. At the same time, the official system used to compute the Ming calendars was regularly failing. This was not surprising, for it had been in use since 1384, and was only a modified version of the Yuan system of a century earlier.

The major activity of the Directorate of Astronomy, as the Ming drew to a close, was repelling attempts of outsiders to revise the computational methods. A famous example was that of Hsing Yun-lu 邢雲路 (Presented Scholar 1580), who had a remarkably comprehensive knowledge of methods used in the past. His proposal for reforms, made in 1596 when he was a middle-level provincial official, was criticized not on technical grounds, but as seditious. The officials of the Directorate countered that publicly admitting official predictions had been failing would simply encourage insurrection. Given the general paralysis of government from ca. 1580 on, with attempts at reform savagely punished, Hsing was fortunate not to be prosecuted.[9]

9. Hsing's proposals are recorded in Ming shih 明史, 31: 527, and Ch'ou jen chuan, 31: 378–382. On the response see Ming Biographical Dictionary, I, 369. Hsing's Ku chin lü li k'ao 古今律曆考 (Studies of mathematical astronomy and harmonics,

A generation later, as the Ming slid deeper into crisis, the Jesuits, despite their record of accuracy and their support by several high officials, were unable to get permission to carry out an official reform.

With this debacle, unrelieved until the Manchu conquest, in mind, the greatest astronomical figures of the early Ch'ing era were convinced that the time was overripe for a renascence. That priority defined the proper field for application of Western knowledge. It was to be part of a larger rebirth, which I will take up below (p. 12).

The Chinese scholars' use of Western cosmology and computation, naturally enough, was highly selective and, in Wang's case, astutely critical. Logic and geometric rigor interested them a great deal less than tangible numerical methods. J. C. Martzloff has suggested that Mei's and Wang's appreciation of Western (Ptolemaic and Tychonic) cosmology was "global, concrete, qualitative, and topological," freely drawing for explanation on metaphors from anatomy, zoology, and so on. Martzloff has traced this selectivity to the difference in the two cultures' conceptions of space and time, and in their assumptions about the character of astronomical knowledge.[10]

Astronomical Work

Wang and his contemporaries were motivated by two central questions. The first was how the new knowledge from abroad might be useful in reviving the exact sciences. Traditional knowledge was recorded, and the

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ancient and modern, ca. 1600), is the largest and, in the parts I have used, most percipient survey of its kind. A particularly vivid picture of the setting is Ray Huang, 1587. A Year of No Significance (New Haven: Yale University Press, 1980).

10. Martzloff, "Space and Time," 73.

perennial problems of prediction were set, in the easily accessible standard histories of the various dynasties. Each incorporated technical treatises, which, among other matters, recorded in detail many of the complete systems for computing ephemerides that had been proposed or accepted for official use since about 100 B.C. Wang was familiar with the chief writings of this sort and with many of the Jesuit treatises of the early 1630's.[11] There is no reason to believe that he met any foreigner,

The second problem was how to resolve the internal contradictions of European astronomy. Since circumstances had ruled out a unified set of treatises, some discrepancies were due to divergences of approach and varying choices of constants, and some to limitations of the missionaries' skill. The most important source of inconsistency was the different cosmological viewpoints through which European writers tried to convey the best knowledge of their time, before and after the decree against the teaching of heliocentricism limited debate about the system of the world (see Chapter IV for details).

Historians have occasionally asserted that Chinese were incapable of responding creatively to geometrical models, or that a bias against abstraction would have prevented them from taking up Copernican cosmology had it been available. Wang's response to the Jesuits' astronomical writings belies these opinions. In adapting the missionaries' version of the Tychonic cosmos to his own uses, Wang was alert to contradictions in its presentation. He noted, for instance, that a secular diminution in the length of the tropical year

11. On his efforts to buy these treatises see Dictionary of Ming Biography, 1381a.

had been mentioned, but was ignored in a discussion of the precessional constant (which, by implication, should increase). This was not the modern variation in the length of the year, but one of much greater magnitude, introduced by the missionaries, that was obsolete in Europe by the time Wang wrote.

Wang's New Method *(Hsiao-an hsin fa* 曉菴新法, completed 1663) presented, in conventional form, a complete system of ephemerides computation centered on eclipse prediction, with tables that made only simple arithmetic necessary for calculating the ephemerides. It provided, for the first time in China, methods for predicting planetary occultations and solar transits. The missionaries had dealt with these problems only in principle. The Compendium of Observational and Computational Astronomy *(Li hsiang k'ao ch'eng* 曆象考成, 1713, printed 1724), part of a great survey of the mathematical arts sponsored by the K'ang-hsi emperor, included some of Wang's techniques along with post-Newtonian data.

Wang's On the Angular Motions of the Five Planets *(Wu hsing hsing tu chieh* 五星行度解, completed by the autumn of 1673) was a geometrical description of his own world model. The work reflected familiarity with European trigonometry. It drew on Tycho Brahe's scheme, but Wang was critically testing every assertion as he studied it.[12] His own system differed from Tycho's unfinished planetary theory primarily in substituting eccentrics for major epicycles, and making the superior and inferior planets rotate in opposite directions. His description, unlike those of most of his Chinese

12. The diagram from Wang's book reproduced by Needham (Science and Civilisation, III, 455) was not meant to explain the Tychonic theory, but Wang's own.

predecessors, was as unambiguously physical and spatial as Tycho's description of his own had been. Here is an example:

> Of the Five Planets, Saturn, Jupiter and Mars revolve leftward, carried toward the east by the sun. Venus and Mercury rotate toward the right on their own orbs, each with its own angular speed. They also accompany the orb of the sun in moving one degree daily. But the orbs of these two planets are too small to enclose the earth, so their mean motion must be that of the sun. According to Western [i.e. Tychonic] astronomy, all five planets rotate toward the right. This does not agree with the celestial motions [i.e. the phenomena], and will be corrected below.
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> In Western astronomy Mars, Venus, and Mercury are sometimes above the sun, so that their orbs should be outside that of the sun, and are sometimes below the sun, so that their orbs should also be within that of the sun. So it is said that the spheres are able to interpenetrate, and cannot be substantial. They do not know that the orbs of the Five Planets are all within that of the sun. But while the Five Planets are located on the periphery of their orbs, the sun occupies the center of its orb (this is also the center of the spheres of the Five Planets), except that it is displaced slightly upward (in the direction of the *primum mobile).*[13] The sun rotates with its sphere,

13. More precisely, it develops later, the earth is at the center of the sun's sphere, although it too is displaced slightly to account for the first inequality. The sun's displacement is of course approximately equal to the distance from the earth to the sun. The primum mobile is the outermost moving sphere of the cosmos, which drives

> [the points through which it passes] forming the "track of the sun's motion." This track is actually without solid substance, so the three planets pass through it without hindrance. As to the orbs of the Five Planets, they are all substantial.[14]

Wang Hsi-shan's feeling for rigor—necessarily exercised within the limits of what Tychonic cosmology had been described in Chinese—led him to criticize fundamentally the clarity, consistency, and accuracy of the Jesuit writings.

The most original idea in On the Angular Motions was a physical one. To explain the eccentricity of the sun-centered figure on which the centers of the planetary epicycles rotate, Wang posited a physical force radiating from the outermost moving sphere *(tsung tung t'ien* 宗動天, the Aristotelian *primum mobile)* and attracting each planet to an extent maximal at apogee. This theory used the old Chinese concept of *ch'i* 氣, which in modern terms would be to some extent pneumatic and to some extent energetic:

> The cause of the apogee and perigee of the orbit would seem to be that, as the *primum mobile* . . . carries the luminaries around . . . , its *ch'i* exerts an attraction upon the sun, moon, and planets like that of a lodestone for a needle. When one of the celestial bodies reaches a certain point, it rises toward the *primum mobile.* As it departs from a certain point, it sinks away from [?] the *primum mobile.* The mode of

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those within. The remarks enclosed in parentheses in this and later translations are notes in smaller type in the originals.

14. Wu hsing hsing tu chieh, 1a. On the Chinese term for "orb" in this quotation, see Chap. IV, Appendix A. The point about insubstantiality of the orbs was Tycho's.

its rising and sinking is not a rectilinear but a circular motion. (All celestial motions are circular motions).[15]

Wang's force, although not universal like Newtonian gravitation, applied to all the planets known to him. Wang went on to work this peripheral, oscillatory force, emanating toward what seems to be one point in each orbit, into his geometrically conceived model.

In Ptolemaic astronomy there was no need for forces to explain celestial motions, for circular motion, steady and closed on itself, was eternal by nature. Only when Kepler reluctantly did away with the millennial notion that orbits are compounded of circles did forces become necessary to explain why the heavenly bodies keep moving. Kepler's force, like Wang's only in its vagueness and lack of quantitative significance, radiated from the central sun rather than emanating from the periphery of a system.[16]

Kepler's new celestial dynamics had not been explained in China. The closest thing to an allusion was a vague statement in Giacomo Rho's Principles of the Planetary Motions *(Wu wei li chih* 五緯曆指, 1634 or slightly earlier). Rho's force was central and, unlike that of Kepler, implied no magnetic analogy. In the course of arguing for the *Tychonic* arrangement of the planets Rho simply asserted "As for Venus and Mercury, in ancient and modern times no one has failed to agree that the mean motion of the sun is the mean motion of their orbs. Thus the motions of the three orbs (sun,

15. Ibid., 7b. My translation of the next to last sentence is tentative, since the character ta 達, literally "to arrive at," is probably in error; a roughly opposite meaning seems to be called for.

16. Johannes Kepler, New Astronomy (trans. William H. Donahue; Cambridge University Press, 1993), 379–380 and elsewhere.

Mercury, Venus) are all due to one potential moving force. This potential force is located in the body of the sun" and, again, "The sun is to the planets what the magnet is to iron. The planets are compelled to revolve according to the revolution of the sun."[17]

In other words, the equal mean sidereal periods of the sun and the two inner planets point to a common motive force for the three. An obvious corollary would be that this force does not also affect the other planets, whose mean sidereal periods are not a year. Rho did not connect this assertion with the remainder of his planetary theory, and did not suggest that it could be extended to the superior planets. In context Rho's remark was too pointless to carry any Chinese reader far toward the concept of a universal force. After all, the Tychonic framework Rho was presenting needs no explanation for the periods of the lower or upper planets. Unlike Ptolemy, Brahe resolved the mean sidereal periods of the inner planets into the sidereal period of the sun about which they are rotating.

Wang Hsi-shan certainly knew of Rho's passage, although he did not cite it. He apparently made the leap on his own to a force that moves the sun, moon, and all the planets.

Wang's notion of synthesis went deeper than reconciling ancient schemes of calculation with foreign techniques. The power of Western models not

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17. Wu wei li chih (in Hsi-yang hsin fa li shu 西方新法曆書), 1: 6a, 33a. The first text reads "moon" for "Mercury," an obvious error. "Potential" tentatively translates neng 能, the rather clumsy phrase would mean merely "one force capable of causing motion." Hashimoto Keizô first noted this theme in Rho; "Rekisho kôsei no seiritsu," 86 and n. 122. On another anomaly in this treatise that caused Chinese astronomers some difficulty, see Martzloff, "Space and Time," 88.

only to predict phenomena but also to exhibit their inherent patterns attracted many Chinese. Wang sought to establish metaphysical links for further exploration into celestial reality. This motive lay behind his suggestion that the circle be divided into 384 degrees. The traditional division made each degree (*tu* 度) equal to one tropical day's mean solar travel (so that in Wang's system there would be 365.2422 degrees). He was aware that the European division of a circle into 360 ($2^3 \times 3^2 \times 5$) parts was convenient, especially in manufacturing graduated instruments. He did not copy this constant, but analogously chose the number 384 (3×2^7). As the number of lines (6×64) in the sixty-four hexagrams of the Book of Changes, it also related astronomical quantities to the fountainhead of conventional speculation about cosmic change, uncovering another layer of significance.[18]

Despite his dedication and critical intelligence, Wang could not hope, any more than his contemporaries, to succeed in a mature synthesis of traditional and modern science. Information from the West was inadequate in many respects, and several generations more were needed to reclaim the traditional corpus of Chinese mathematics and astronomy as part of the astronomer's repertoire. But the astronomers of Wang's generation provided tools and methods as well as a goal.

For many decades students began with the Western writings and went on to study the Chinese technical classics. The latter, once mastered, increasingly defined the style of research in the exact sciences, even as researchers concerned themselves with new problems. By the early nineteenth century,

18. Hsiao-an hsin fa, 2a.

Western mathematics and astronomy were no longer novelties. They had been studied continuously for two hundred years. The basic training in the decades before the Opium Wars (ca. 1840) was in the native writings.[19] They served as excellent preparation for up-to-date Western treatises that gradually began to appear as part of a new confrontation—this time a total confrontation—between China and the West.

General Significance for Chinese Thought

Wang Hsi-shan's lifetime was a critical epoch in the evolution of Chinese philosophy. What Western historians call neo-Confucianism, like earlier Confucianisms, was a sustained quest for doctrines of education, self-cultivation, and moral conduct. Its successive new departures depended upon scrutinizing antiquity to identify and interpret (differently for each age) the authentic core of Confucian teachings. Well before the late Ming period, expanded scope for self-consciousness, increased blurring of social barriers, and the more penetrating influence of Buddhist and Taoist practices had deepened religious and moral awareness. This trend affected both the tradition of Chu Hsi 朱熹(1130–1200), which explored the phenomenal world (including the mind and experience recorded in books) to grasp the single coherent pattern inherent in all change, and that of Wang Shou-jen 王守仁 *(or* Yang-ming 陽明, 1472–1529), which emphasized enlightenment through self-awareness, particularly of the mind engaged in conscientious social activity.

19. This change in priority of learning is a main theme of Wang P'ing, Hsi-fang li-suan-hsueh chih shu-ju.

The great intellectuals of the dynastic transition were, on the whole, Ming loyalists. They were among the minority who did resist, in the main passively, and after the transfer of power had taken place. They were convinced that assessing the failure of their intellectual predecessors would guide them toward philosophical and spiritual reinvigoration, and responsible engagement in the world of affairs. Among the most influential was Wang Hsi-shan's friend Ku Yen-wu. He charged that his late Ming predecessors let themselves be distracted from moral commitment and public responsibility by sectarianism, by pedantry and triviality in the Chu tradition, and, in the tradition of Wang, by a subjectivity and individualism ignorant of the authoritarian and hierarchic requirements of social order. Above all, Ku and other Ch'ing survivors were convinced that the rivalry of schools, blinded by selfishness and pride, had corrupted Confucian doctrines, leaving them unable to rise above the political futility that led to the disintegration of the Ming.[20]

Ku's prescription for the ills of thought was to purge postclassical influences that hid the original principles of Confucius and his orthodox followers. Those who agreed with him needed a method for critically examining texts in order to determine what was authentic. The thorough research that widespread printing and large libraries had made feasible revealed to Wang's contemporaries how easily the understanding of their predecessors had been led astray. Some now endeavored to recover the

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20. I am grateful for this formulation, and for a number of helpful criticisms, to Lynn Struve. I am also thankful for suggestions by Judy Berman, Jacques Gernet,

earliest—the least corrupted—versions and interpretations of the classics. Others studied the working out of canonical moral patterns in the events of history. These reformers saw their work as the surest way to a living philosophy. The fortunes of the empire had given this search a new poignancy.

By the mid-eighteenth century, narrowly defined research methodology had become an end in itself, narrow in interpretation and intolerant of the urge to generalize. The call for "social utility, concrete practicality, and tangible evidence," which had promised philosophic regeneration at the beginning of the Ch'ing, outlived the openness to the unexpected that was implied in its original motivation.[21] Classicism flourished, despite the atrophy of metaphysics, because it yielded a succession of critical breakthroughs, and because it posed no threat to a state which insisted that collective intellectual activity be apolitical.

This final evolution of disciplinary specialization out of a philosophic renaissance is not of further concern here, but how the Ch'ing style of critical neo-Confucian scholarship began to take shape in Wang Hsi-shan's lifetime bears examination.

Many important neo-Confucians of the late Ming and early Ch'ing, especially among those close to the Chu tradition, wrote on mathematics and astronomy. A number of their treatises reconstituted early computational techniques, and about the same number used mathematics in chronological or

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Dianna Gregory, and Yü Ying-shih. The outline that follows draws on Elman, From Philosophy to Philology.

other studies of canonical writings before about 200 B.C.[22] In the mid-seventeenth century the people who innovated in both philosophy and the sciences eschewed politics and public service. This is perhaps not remarkable, since reevaluation and the eclecticism that yields new insights are likely to begin with talented and ambitious people subsisting on the margins of the elite. But in addition to obvious consequences of this social overlap, philosophers, scientists, and mathematicians shared important convictions about the means and ends of research.

To sum up the argument so far, certain critical motifs recurred in neo-Confucianism just after the Manchu conquest, pointing the way toward new departures. Intellectuals emphatically rejected what they saw as decadent and destructive tendencies at the end of the Ming. They believed that those tendencies arose partly because of inadequate study, misunderstandings and textual corruptions, and partly because heterodox ideas had insinuated themselves into texts and undisciplined scholarly writings. They were convinced that, to understand the inherent patterns of cosmic and human activity *(li* 理) and the moral imperatives they imply, they must critically reexamine classical literature and history.

All of these ideas motivated Wang Hsi-shan. We are told by his biographer that after he renounced worldly ambition, "he excoriated heterodoxy [this usually refers to Buddhism, sometimes to Christianity as well], attacked

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21. W. T. de Bary, "Neo-Confucian Cultivation and the Seventeenth-Century 'Enlightenment,'" in The Unfolding of Neo-Confucianism, 193.

22. See the list in the Appendix, p. 17. The scientific writings of orthodox scholars are an important source for Elman and for Henderson, The Development and Decline of Chinese Cosmology.

'innate moral consciousness' *[liang chih* 良知, the characteristic doctrine of the Wang Yang-ming school], and accepted the orthodox Confucian tradition of the Chu Hsi line *(Lien-Lo-Chu-Ssu* 濂洛洙泗) as his personal mission." The preface to his "New Method," instead of conventionally affirming the high antiquity of astronomy, began by taking up questions that had been raised about the authenticity of seven calendars that the historians dated prior to the Han period (206 B.C.). Wang stated flatly, "There is no doubt that they were forgeries of the Han." He declared that astronomers of the recent past comprehended less than their predecessors. The remedy was rediscovering the lost meaning of the technical classics.

Earlier scientists had argued that, although mathematical astronomy could provide useful knowledge and advance understanding, the subtle texture of the natural order could ultimately be penetrated only by illumination.[23] Wang did not reject this view, but he saw number as a means toward that penetration: "One who seeks rigor must reach it through computation. Numbers are not themselves the inherent pattern *(li);* but because the pattern gives rise to number, through number one may reach enlightenment as to the pattern."[24]

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23. See Sivin, "On the Limits of Empirical Knowledge in Chinese and Western Science," in Rationality in Question. On Eastern and Western Views of Rationality (ed. Shlomo Biederman & Ben-Ami Scharfstein; Leiden: E. J. Brill, 1989), 165–189, reprinted below as Vol. II, Ch. IV.

24. Tsa chu, 4a. This conviction was almost certainly influenced by the argument of Matteo Ricci, in his preface to the Chinese translation of Euclid's Elements (Chi-ho yuan pen 幾何原本, 1607), that geometry is a unique means to knowledge of li. Ricci consistently used li for Latin ratio, knowledge that does not depend upon individual belief and thus can overcome individual doubts. His Asian readers would not have understood him that way.

These parallels, and others in the writings of Wang's scientific contemporaries, suggest a close connection between the scientific revolution of seventeenth-century China and the evolution from philosophy to exact scholarship that took much longer to run its course. In particular, they suggest that Western influence on main currents of early Ch'ing philosophy—on the frontiers of Chinese self-awareness—should not casually be ruled out. Historians have usually ruled such influence out (or seen native thought as a reaction against it) because they have not studied the scientific literature and because they have relied on crude and narrowly defined tests for intellectual influence that ignore the mathematical dimension of human thought. A generation earlier Sinologists just as grossly overestimated Western influence. Elman has laid both fallacies to rest, showing in how subtle a way the influence exerted itself.[25]

This mathematical challenge to values coincided with an even more traumatic challenge, the Manchu invasion. Some shade of ambiguity toward Western science must have come from the Jesuits' prompt tender of services to the Manchus and the immediate official adoption of their astronomical system (although some missionaries accompanied the refugee Ming court southward to cover the eventuality of a restoration). It was not, however, characteristic of Chinese to reject what was foreign simply because it was foreign; by 1650 nationalism had barely been conceived. A willingness to adopt the behavior patterns and rituals of well-bred Chinese gave Manchus and Jesuits a right to be where they were—although nothing compelled

25. From Philosophy to Philology, 79ff and elsewhere.

loyalists to collaborate with either. But Wang Hsi-shan's type of loyalism had become, a generation later, only a memory, and no longer deterred the study of new ideas.

It is merely reasonable to suggest that the early success of astronomers in applying the foreign tools (in eclectic combination with traditional ones) influenced philosophers to reexamine classical learning. Scrutiny of ancient observations and predictions was an established part of the astronomer's work. Not long after Wang Hsi-shan's lifetime, technical examination of the philosophic classics to fix dates and test authenticity became the explicit end of most astronomical exploration, with the revival of traditional science as an intermediate means that fully occupied many scholars.

Even more important in assessing this channel of European influence is the fact that as time passed, leading teachers also became mathematicians used to working with Western techniques and concepts. Elman has shown that these scholars congregated in private schools and maintained close relations. Even those who never applied European science in their writings were aware of it through discussing it with their associates and through reading their monographs.

None of this suggests a simple causal relation between European astronomy as described in the Chinese language in the early seventeenth century and the forms of Chinese thought that gestated then and became dominant by the middle of the eighteenth. Philosophy's relation with astronomy remained a dynamic one, despite the conventional moral and social focus of self-cultivation. At the beginning the new science offered what were seen as powerful tools toward a reformation of thought. Wang

Hsi-shan's belief that number could bring ultimate insight into the universal pattern was pregnant in precisely this way. Be that as it may, the consensus ultimately formed in more conventional quarters, and was barren for a new synthesis of nature, society, and man.

Still, the new techniques could never be mere tools. To use them, as so many thinkers did, was to form habits that reinforced long-held convictions about the usefulness of scholarship in exploring reality. Seventeenth-century European science was not, after all, modern science. In China the lack of sources alternative to the missionaries' writings artificially perpetuated it for two centuries. Orthodox thinkers, whose sense of man and the cosmos was in part formed by study of canonic books, responded to the universal explanatory character that this foreign science derived from its Scholastic framework much more than to the grip on direct experience of nature that Wang valued.[26] Astronomy, as Confucian scholars understood and used it, converged with philology, gave it added weight, and obviously played a part in tipping the scale.

It would be premature to suggest any particular line of development between the recourse to Western astronomy among philosophers at the beginning of the Ch'ing period and the eventual swamping of earlier philosophical concerns by exact scholarship—scholarship of a kind that finally integrated mathematical astronomy as one specialism among many. The career of Wang Hsi-shan suggests a range of possible patterns that,

26. Willard J. Peterson, in his perceptive "Fang I-chih: Western Learning and the 'Investigation of Things,'" has shown how Fang 方以智 (1611–1671) used his know-

tested against many other careers, can throw light on the central enigmas that shroud the collapse of imperial China.

Appendix

Writings in Mathematics and Astronomy by Important Figures in Late Ming and Early Ch'ing Neo-Confucianism

The list that follows is meant to demonstrate the ubiquity of mathematical studies among late Ming and early Ch'ing orthodox scholars. It will perhaps set to rest the hoary but far from dead generalization that the Chinese literati had only literary interests and were opposed to taking up technical studies. It also shows how pervasive the influence of European scientific learning was among leading intellectuals.

This list was compiled by comparing standard biographic sources on the history of Ch'ing philosophy with those on the exact sciences. It includes a representative assortment of the best-known authors, teachers, and patrons of the various schools from the Ming-Ch'ing transition to about 1800, as recognized by Ch'ing authorities. Their recognition is, in diverse ways, tendentious. There is room for disagreement about principles for compiling such a list, or about individual additions or deletions. Still, various trials suggest that so long as only major figures are considered, the general shape

ledge of Western sciences to argue for greater emphasis in philosophy upon accumulating knowledge of "physical objects, technology, and natural phenomena."

of the outcome will not vary significantly. I have excluded people such as Mei Wen-ting whose achievements lay *primarily* in the exact sciences. I have also excluded the subject of mathematical harmonics. Although traditionally linked to astronomy, it was little affected by European techniques. The list also considers cosmology only when practiced in conjunction with astronomy, natural history, geography, medicine, studies of the Book of Changes, and other pursuits that use number and measure in various ways but are not primarily mathematical.[27]

These limitations should not obscure the fact that many not included were strongly rooted in the traditional qualitative sciences. Chiao Hsun◎焦循 (1763-1820), for instance, was a polymath of the old type, with writings on medicine, agriculture, natural history, and applications of mathematics to the Book of Changes (a topic that interested several other renowned orthodox scholars of the time). Yen Yuan 顏元 (1635-1704) earned a living as a physician for part of his life, and Ch'eng Yao-t'ien and Chiang Fan are remembered for their contributions to natural history.

I list below eighteen names, in order of birth, along with a brief description of each individual's writings on mathematics and astronomy. I do not reproduce lists of the books, since the specialists who have use for them will find the particulars readily in the sources cited and in standard biographies in Chinese (they are often omitted from biographies in English). In order to provide ready access to traditional evaluations of these scholars' work in the sciences, each name is followed where possible with a page reference to *Ch'ou*

27. Cf. the list of early Ch'ing cosmologists in Henderson, Development and Decline, 142-147.

jen chuan 疇人傳 (Biographies of astronomers and mathematicians) and its supplements, as follows:

- Juan Yuan 阮元, *Ch'ou jen chuan*, 1799 (*ch.* 1-46 in *Wan yu wen k'u* 萬有文庫 ed.; reprint, Shanghai: Commercial Press, 1955; page number prefixed A in references below),
- Lo Shih-lin 羅士林, *Hsu Ch'ou jen chuan* 續疇人傳, 1840 (*ch.* 47-52 in idem; references prefixed B),
- Chu K'o-pao 諸可寶, *Ch'ou jen chuan san pien* 疇人傳三篇, 1886 (separately paginated in idem; references prefixed C), or
- Huang Chung-chün 黃鍾駿, *Ch'ou jen chuan ssu pien* 疇人傳四篇, 1898 (Shanghai: Commercial Press, 1955; references prefixed D).

In order to facilitate access to typical information about the neo-Confucian school with which historians have associated each of those listed, I also provide, following the reference to *Ch'ou jen chuan,* a citation in Liang Ch'i-ch'ao's 梁啟超 concise and accessible *Ch'ing-tai hsueh-shu kai lun* 清代學術概論 (1921), translated by Immanuel C. Y. Hsu as *Intellectual Trends in the Ch'ing Period* (Cambridge, MA: Harvard University Press, 1959; references prefixed by L).

1. Huang Tsung-hsi 黃宗羲 (1610-1695). Wrote at least a dozen books on such topics as trigonometry, Islamic and European astronomical methods, and chronological notation, and two textbooks for teaching the Yuan methods of calendrical computation (A, III, 455; L, 36).

Yen Jo-chü 閻若璩 (1636-1704). Applied Chinese and European astronomical techniques to test the authenticity of the Ancient Script version of the

Book of Documents in *Shang shu ku wen shu cheng* 尚書古文疏證, III, 502; L, 32).

Liu Hsien-t'ing 劉獻廷 (1648-1695). Jottings of scientific interest in his *Kuang-yang tsa chi* 廣陽雜記. Argued for including astronomical and meteorological information in local gazetteers (D, 84; L, 44).

Hsuan-yeh 玄曄, the K'ang-hsi Emperor (1654-1722, r. 1661-1722). He commanded neo-Confucian status in his capacity as, so to speak, pope of its established church. He was taught mathematics by Jesuit missionaries, and took a part in educating a generation of leading Chinese practitioners of the exact sciences. He write a book on geometry, *San-chiao-hsing t'ui-suan fa* 三角形推算法 (On computation involving triangles). It is appropriate to mention in passing one of the most interesting collections of jottings on natural history and physical studies of the early Ch'ing, his *K'ang-hsi chi hsia ko-wu pien* 康熙幾暇格物編 (K'ang-hsi's notes on the investigation of things in moments of respite from the minutiae of office).[28]

Hui Shih-ch'i 惠士奇 (1671-1741). Author of *Chiao-shih chü yü* 交食舉隅 (Eclipses: hints for the perceptive; A, III, 512; L, 23).

Chiang Yung 江永 (1681-1762). Author of half a dozen mathematical books, including the influential *Shu-hsueh* 數學 (The study of mathematics), and a book on mathematical astronomy (A: III, 527; L, 23).

28. For a variorum text and translation into modern Chinese see Li Ti 李迪, Kang-hsi chi hsia ko-wu pien i chu 康熙幾暇格物編譯注 (Shanghai: Shang-hai Ku-chi Ch'u-pan-she, 1993). Use of this notebook would have enriched an otherwise outstanding biography, Jonathan Spence, Emperor of China. Self Portrait of K'ang Hsi (New York: Alfred A. Knopf, 1974).

Hui Tung 惠棟 (1697-1758), son of Hui Shih-ch'i. Author of supplementary commentaries to the treatises on astronomy, astrology, and Five-Phases phenomena of the standard history of the Later Han period (L, 51).

Chiang Sheng 江聲 (1721-1799). Author of *Heng hsing shuo* 恆星朔 (On the fixed stars; D, 91; L, 23).

Wang Ming-sheng 王鳴盛 (1722-1798). Included mathematical jottings in *I shu pien* 蛾術編 (Antlike learning; L, 23).

Tai Chen 戴震 (1724-1777). Wrote half a dozen books on astronomy and mathematics, including one on Chinese Napier's Bones and a historic treatise on astronomy. Restored the Sung government's anthology of ancient mathematical texts, *Suan ching shih shu* 算經十書. Constructed models of ancient mechanisms, including an armillary sphere (A, III, 529; L, 54).[29]

Ch'eng Yao-t'ien 程瑤田 (1725-1814). Used mathematics generally in study of the classics; see *Shu tu hsiao chi* 數度小記 (Notes on arithmetic and mensuration; A, III, 654; L, 23).

Ch'ien Ta-hsin 錢大昕 (1728-1804). Wrote a textbook of mathematics and six technical treatises on early astronomy, including reconstitutions of Han computational methods. He was an editor of Benoist's account of Copernican cosmology, *Ti-ch'iu t'u shuo* 地球圖說 (see *Science in Ancient China,* Chapter IV).

29. Tai wrote Hsu t'ien-wen lueh 續天文略 (Sequel to the Treatise on astronomy) for a sequel to the twelfth-century T'ung chih 通志 (Comprehensive treatises). It has been translated into Japanese in Yasuda Jirô & Kondô Mitsuo , Tai Shin shû 戴震集 (Tokyo: Asahi Shimbunsha, 1971), 399-499. On the models, see the preface of K'ung Kuang-sen 孔廣森 to Tai's I shu 遺書.

K'ung Kuang-sen 孔廣森 (1752-1786, disciple of Tai Chen). His *Shao-kuang cheng fu shu nei wai p'ien* 少廣正負術內外篇 (Problems in "diminishing the breadth" and positive and negative numbers, with appended writings) includes a dozen additional titles, three of them geometrical. Some were published separately (B, 628; L, 88).

Ling T'ing-k'an 淩廷堪 (1757-1809). Wrote on mathematics and astronomy; co-compiler of *Ch'ou jen chuan* (A, III, 647; L, 23).

Chiang Fan 江藩 (1761-1831). Wrote eight treatises on varied issues in mathematical astronomy (L, 52).

Chiao Hsun 焦循 (1763-1820). Wrote more than a dozen books on geometry and other areas of mathematics, including a monograph on ellipses, and a detailed investigation of the date of a solar eclipse in the Book of Songs, as well as a supplement to Benoist's *Ti-ch'iu t'u shuo* (IV, 679).[30]

Juan Yuan 阮元 (1764-1849). Principal editor of *Ch'ou jen chuan* and *Ti-ch'iu t'u shuo* (C, 749; L, 54).

Wang Yin-chih 王引之 (1766-1834). Author of *T'ai-sui k'ao* 太歲考, a monograph on the fictitious counter-rotating correlate of Jupiter used for dating in the late Chou period.

30. See Wu Yü-pin 吴裕宾, "Chiao Hsun yü Chia chien ch'eng ch'u shih 焦循与加减乘除释" (Chiao Hsun and his Exposition of logistic operations), Tzu-jan k'o-hsueh-shih yen-chiu 自然科学史研究, 1986, 5. 2: 120-128.

Bibliography

I. Wang's Writings

Wang Hsi-shan's extant writings are listed in detail in L. Carrington Goodrich (ed.), *Dictionary of Ming Biography* (New York: Columbia University Press, 1976), 1379–1382, and in Chinese in *Wu-an li suan shu-mu* 勿菴曆算書目 (Bibliography of Mei's writings on astronomy and mathematics, 1702; in *Pai-pu ts'ung-shu chi-ch'eng*).

Shortly after Wang died, P'an Lei 潘耒 (1646-1708), a younger adherent of the loyalist group, gathered a number of his essays, some of them already circulating collectively as *Hsiao-an hsien-sheng I shu* 曉菴先生遺書 (Literary legacy of Wang Hsi-shan). P'an called his larger collection *Hsiao-an i shu* 曉菴遺書. The contents of greatest interest are *Yuan chieh* 圓解 (On trigonometry) and *Li fa* 厤法 (Astronomical methods, completed 1663), to which P'an appended 24 tables. *Li fa,* which embodied Wang's system for calendrical calculation, was included in the imperial *Ssu k'u chüan shu* 四庫全書 manuscript library under the title *Hsiao-an hsin fa* 曉菴新法, in 6 ch., without the tables. The *Shou shan ko ts'ung-shu* 守山閣叢書 collection printed it in 1838, and Wang's equally important *Wu hsing hsing tu chieh* 五星行度解 (On the angular motions of the Five Planets) in 1839. They were reprinted in *Chung-hsi suan-hsueh ts'ung-shu* 中西算學叢書, 1st ser. (1896) and *Ts'ung-shu chi ch'eng* 叢書集成, 1st ser. (1926). The first eds. are cited here.

About 1890 Li Sheng-to 李盛鐸 combined the two treatises with *Ta-t'ung li fa ch'i-meng* 大統厤法啓蒙, an elementary introduction to the Great Concordance system used officially for most of the Ming period (1384-1644, along with the surviving short essays, to form the *Wang Hsiao-an hsien-sheng i shu* 王曉菴先生遺書, vols. XXXI-XXXV in *Mu hsi hsuan ts'ung-shu* 木犀軒叢書.

II. Secondary Literature

The most thorough study of Wang's life and astronomical work, based on unpublished as well as published sources, is Hsi Tse-tsung 席泽宗, "Shih lun Wang Hsi-shan te t'ien-wen kung-tso 王曉闇先生遺书补编" (An essay on the astronomical work of Wang Hsi-shan), *K'o-hsueh-shih chi-k'an* 科学史集刊, 1963, 6: 53–65. Its references provide an excellent starting point for further study. Earlier sources cited here are the MS "Wang Hsiao-an hsien-sheng i-shu pu-pien 王曉菴先生遺書補編" (Supplement to the posthumous works of Wang Hsi-shan) in the Beijing University Library, and a biography by Wang Chi 王濟 in *Sung-ling wen lu* 松陵文錄 (Literary records of Wu-chiang, 1874).

The first detailed account of Wang's work, based mainly on excerpts from his writings before they had been printed separately, was in *Ch'ou jen chuan* 疇人傳 (Biographies of mathematical astronomers, 1799; Shanghai: Commercial Press, 1935), II, 421–446. This programmatic compendium, which included European as well as Chinese figures, greatly influenced the style of nineteenth-century and later investigations in the exact sciences. I cite it and its sequels in the Appendix.

No more than isolated sentences from Wang have been published in translation. I have translated *Wu hsing hsing tu chieh* for eventual publication in a source book of Chinese science.

III. European Science in Seventeenth-Century China

Western Sinologists used to pay little attention to the early mathematical encounter of East and West. Several important books have crossed the watershed, studying the broad context of changes in intellectual life and demonstrating the role of European science: Jacques Gernet, *Chine et christianisme. Action et réaction* (Bibliothèque des histoires, 39; Paris: Éditions Gallimard, 1982), translated by Janet Lloyd as *China and the Christian Impact: A Conflict of Cultures* (Cambridge University Press, 1985); Benjamin Elman, *From Philosophy to Philology. Intellectual and Social Aspects of Change in Late Imperial China* (Cambridge, MA: Council on East Asian Studies, Harvard University, 1984), and John Henderson, *The Development and Decline of Chinese Cosmology* (New York: Columbia University Press, 1984). More technical is Keizo Hashimoto, *Hsü Kuang-ch'i and Astronomical Reform—The Process of the Chinese Acceptance of Western Astronomy 1629–1635* (Tokyo University Press, 1988). Hashimoto examines closely the process that led to the Ming court's not-quite-sponsorship of the Jesuits' writings, and provides fresh information on the European treatises that they adapted.

The only general history of the Chinese response to European exact sciences is in Wang P'ing 王萍, *Hsi-fang li-suan-hsueh chih shu-ju* 西方曆算學之輸入 (The introduction of Western astronomy and mathematics; Monographs, 17; Nankang, Taiwan: Institute of Modern History, Academia Sinica, 1966), summarized in *Journal of Asian Studies,* 1970, *29:* 914–917. This book draws heavily on the materials in *Ch'ou jen chuan* for the seventeenth and eighteenth centuries. There is a good deal of technically sophisticated information on China in Shigeru Nakayama, *A History of Japanese Astronomy. Chinese*

Background and Western Impact (Harvard-Yenching Institute Monograph Series, 18; Cambridge, MA: Harvard University Press, 1969).

A useful tool for further study of both Jesuit and Chinese mathematical activities is Li Yen 李儼, "Ming-ch'ing chih chi Hsi suan shu-ju Chung-kuo nien-piao 明清之際西算輸入中國年表" (Chronology of the introduction of Western mathematics into China in the Ming-Ch'ing transition), in *Chung suan shih lun-ts'ung* 中算史論叢 ("Gesammelte Abhandlungen über die Geschichte der chinesischen Mathematik," vol. III; rev. ed., Beijing: K'o-hsueh ch'u-pan-she, 1955): 10–68. Yabuuchi Kiyoshi has ably surveyed Jesuit activity in *Chûgoku no temmon rekihô* (Chinese astronomy; Tokyo: Heibonsha, 1969), 148–174, and "Kinsei Chûgoku ni tsutaerareta Seiyô temmongaku" (On the Western astronomy transmitted to China in modern times), *Kagakushi kenkyû,* 1954, *32:* 15–18. A rev. ed. of Yabuuchi's book appeared in 1990. See also the important group of studies in Yabuuchi and Yoshida Mitsukuni , eds., *Min Shin jidai no kagaku gijutsu shi* (History of science and technology in the Ming and Ch'ing Periods; Research Report, Research Institute of Humanistic Studies; Kyoto: The Institute, 1970), 1-146. Joseph Needham, in *Science and Civilisation in China,* III (Cambridge University Press, 1959), 437–458, was the first to suggest that the limitations as well as the strengths of the Jesuit missionaries greatly affected the character of the Chinese response. His short and incidental discussion of Wang Hsi-shan (454) is, however, not very accurate.

The lives of the Jesuit missionaries and their publications in Chinese have been closely documented by historians of that order. See Henri Bernard, "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,* 1945, *10:* 1–57, 309–388; Joseph Dehergne, *Répertoire des Jésuites de Chine de 1552 à 1800* (Roma: Institutum Historicum S. J., 1973); and Louis Pfister, *Notices biographiques et bibliographiques sur les Jésuites de l'ancienne mission de Chine, 1552–1773* (2 vols., Shanghai: Imprimerie de la Mission Catholique, 1932–1934, completed before Pfister's death in 1891). Dehergne is a comprehensive guide to the extensive literature on missionaries, including archival sources; the last part includes aids to research. There are a number of useful essays in (Maur) Fang Hao, S. J., *Fang Hao wen lu* 方豪文錄: *Studies in the History of the Relations between China and the West* (Peiping: Institutum Sancti Thomae, 1948). For modern scholarship in Western European languages see Erik Zürcher, Nicolas Standaert, S. J., & Adrianus Dudink, *Bibliography of the Jesuit Mission in China (ca. 1580-ca. 1680)* (Center of Non-Western Studies, Leiden University, 1991). The essays in Charles E. Ronan & Bonnie B. C. Oh (ed.), *East Meets West. The Jesuits in China, 1582–1773* (Chicago: Loyola University Press, 1988) are on the whole conventional and superficial.

On the background of the mission to China see Juan Casanovas, "Alle origini del Missionariato Scientifico nell'Asia orientale: Clavio e il Collegio Romano," in Isaia Iannaccone & Adolfo Tamburello (ed.), *Dall'Europa alla Cina: contributi per una storia dell'Astronomia* (Napoli: Università degli Studi "Federico II" & Istituto Universitario Orientale, 1990), 75–84. Only a couple of the papers in this collection are concerned with the astronomical encounter between Europeans and Chinese.

For writings in Chinese, see Hsu Tsung-tse 徐宗澤, *Ming Ch'ing chien Ye-su-hui-shih i chu t'i yao* 明清間耶穌會士譯著提要 (Annotated bibliography of Jesuit translations and writings in the Ming and Ch'ing periods; Taipei: Chung-hua Shu-chü, 1958), with indexes of authors, titles, and subjects. On missionaries as Chinese officials 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. For the history of the Directorate see Jonathan Porter, "Bureaucracy and Science in Early Modern China: The Imperial Astronomical Bureau in the Ch'ing Period," *Journal of Oriental Studies* (Hong Kong), 1980, *18:* 61–76. Huang I-nung 黃一農 narrates the remarkable ascent of Schall in Ch'ing officialdom in "T'ang Jo-wang yü Ch'ing ch'u hsi li chih cheng-t'ung-hua 湯若望與西歷之正統化" (Schall and the legitimation of the Western calendar at the beginning of the Ch'ing period), in *Hsin pien Chung-kuo k'o-chi-shih* 新編中國科技史 (New history of Chinese medicine; Taipei: Yin Ho Wen-hua Kung-ssu, 1990), II, 465–491.

European scientific works owned by the Jesuits in Beijing—one of the world's greatest collections of scientific writings of the sixteenth through eighteenth centuries—are listed in H. Verhaeren, *Catalogue of the Pei-t'ang Library* (3 vols., Beijing: Imprimerie des Lazaristes, 1944–1948). This collection is now in the Beijing Library, where I have examined its two copies of *De revolutionibus.* A list of 251 astronomical books has been excerpted from Verhaeren in Henri Bernard-Maitre, "La science europééne au tribunal astronomique de Pékin (XVIIe-XIXe siècles)," in *Conférences du Palais de la Découverte,* ser. D, 9 (Paris: Le Palais, 1951). See also Boleslaw Szcze_niak, "Note on Kepler's *Tabulae Rudolphinae* in the Library of Pei-t'ang in Pekin," *Isis,* 1949, *40:* 344–347.

Among studies of Chinese responses in the mathematical sciences, the book of Wang P'ing is additionally helpful because of its index, still unusual in Chinese scholarly books. There is a penetrating analysis in Jean-Claude Martzloff, "Space and Time in Chinese Texts of Astronomy and of Mathematical Astronomy in the Seventeenth and Eighteenth Centuries," with a valuable commentary by Jean Gernet, *Chinese Science,* 1993–1994, 11: 66–102.

For systematic annotated bibliographies, see Ting Fu-pao 丁福保 and Chou Yun-ch'ing 周雲青, *Ssu pu tsung lu suan-fa pien* 四部總錄算法編 (General register of the Quadripartite Library, section on mathematics; Shanghai: Commercial Press, 1957) and *Ssu pu tsung lu t'ien-wen pien* 四部總錄天文編 (General Register . . . Section on astronomy; *idem,* 1956), supplemented by Li Yen, "Chin-tai Chung suan chu-shu chi 近代中算箸述記" (Notes on books about Chinese mathematics in modern times), in *Chung suan shih lun-ts'ung,* II (1954), 103–308; and "Ch'ing-tai wen-chi suan-hsueh lei lun-wen 清代文集算學類論文" (Articles that can be classified as mathematical in collected literary works of individuals in the Ch'ing period), *ibid.,* V (1955), 76–92. A useful fairly recent unannotated bibliography is Yen Tun-chieh 严敦杰. 1986. *Chung-kuo ku-tai k'o-chi-shih lun-wen so-yin* 中国古代科技史论文索引 (Index to articles on the history of science and technology in ancient China). Shanghai: Chiang-su K'o-hsueh Chi-shu Ch'u-pan-she.

The first resorts for biographies of the most prominent late imperial scientific figures are *Dictionary of Ming Biography* and Arthur W. Hummel, *Eminent*

Chinese of the Ch'ing Period (2 vols., Washington: U. S. Government Printing Office, 1943–1944). *Ch'ou jen chuan* mainly provides long excerpts from technical writings, without much biographical data.

A few topical studies throw light on fundamental issues. Pasquale D'Elia describes the genesis, content, and distribution of major Jesuit scientific writings in "Presentazione della prima traduzione chinese di Euclide," *Monumenta serica,* 1956, *15:* 161–202, and Henri Bernard-Maître, "L'encyclopédie astronomique du Père Schall. *'Tch'ong-tcheng li-chou,'* 1629 et *'Si-yang sin-fa li-chou,'* 1645. La réforme du calendrier chinois sous l'influence de Clavius, de Galilée et de Kepler," *ibid.,* 1938, *3:* 35–77, 441–527. Willard J. Peterson summarizes early European writings in Chinese on the qualitative sciences in "Western Natural Philosophy Published in Late Ming China," *Proceedings of the American Philosophical Society,* 1973, *117:* 295–322.

The life, associations, and work of Wang Hsi-shan's contemporary Mei Wen-ting have been treated at length in Li Yen, "Mei Wen-ting nien-p'u 梅文鼎年譜" (Chronological biography of Mei Wen-ting), in *Chung suan shih lun-ts'ung,* III, 544–576; in Hashimoto Keizô, "Bai Buntei no rekisangaku. Kôki nenkan no temmon rekisangaku 梅文鼎 " (The mathematical astronomy of Mei Wen-ting. Mathematical astronomy in the K'ang-hsi Period), *Tôhô gakuhô* (Kyoto), 1970, 41: 491–518, and "Bai Buntei no sugaku kenkyû 梅文鼎 " (The Mathematical researches of Mei Wen-ting), *ibid.,* 1973, 44: 233–279; and in Liu Tun 刘钝, "Ch'ing ch'u li suan ta shih Mei Wen-ting 清初历算大师梅文鼎" (Mei Wen-ting, master mathematician at the beginning of the Ch'ing), *Tzu-jan pien-cheng-fa t'ung-hsun* 自然辩证法通讯, 1986, 1: 52–64. On the traditional and European mathematical books that Mei read, see Martzloff, *Recherches sur l'oeuvre mathématique de Mei Wen-ting (1633–1721)* (Mémoires de l'Institut des Hautes Études Chinoises, 16; Paris: L'Institut, 1981), 25–31. On Mei Ku-ch'eng and his colleagues see Hashimoto's "Rekisho kôsei no seiritsu. Shindai shoki no temmon rekisangaku 曆象考成 (The compilation of the *Li hsiang k'ao ch'eng*. Mathematical astronomy in the early Ch'ing period), in *Min Shin jidai no kagaku gijutsushi,* 49–92. Hashimoto completed his chronological account in "Daenhô no tenkai. Rekishô kôsei kôhen no naiyô ni tsuite 楕圆法 " (The development of elliptical methods. On the content of the *Li hsiang k'ao ch'eng hou pien*), *Tôhô gakuhô* (Kyoto), 1971, *42:* 245–272.

The thought of Fang I-chih 方以智, probably the first Chinese to acquaint himself with the full spectrum of European sciences, has been examined by Sakade Yoshinobu 祥, "Hô Ichi no shisô 方以智 " (The thought of Fang I-chih), in Yabuuchi and Yoshida, *Min Shin jidai no kagaku gijutsu shi,* 93–134; and by Peterson, "Fang I-chih: Western Learning and the 'Investigation of Things,'" in W. T. de Bary and the Conference on Seventeenth-Century Chinese Thought, *The Unfolding of Neo-Confucianism* (Studies in Oriental Culture, 10; New York: Columbia University Press, 1975), 369–411, an important volume for seventeenth-century thought. For a more general study see Peterson's "Fang I-chih's Response to Western Knowledge" (Unpublished Ph.D. dissertation, Harvard University, 1970). Sakade and Peterson are best read together. Sakade pays little attention to Fang's treatment of European ideas and techniques, and Peterson is not concerned with the Chinese scientific tradition or the evolution of European science.

Peterson's biography *Bitter Gourd: Fang I-chih and the Impetus for Intellectual Change* (New Haven: Yale University Press, 1979), is mainly concerned with Fang as a humanistic philosopher. There is little overlap with his earlier work.

D'Elia narrates the introduction of cosmology into China in *Galileo in China, Relations Through the Roman College Between Galileo and the Jesuit Scientist-missionaries (1610–1640)* (trans. Rufus Suter and Matthews Sciascia; Cambridge, MA: Harvard University Press, 1960), but the emphasis on demonstrating Jesuit accomplishments obscures a number of basic issues. The same is true of Bernard, "Galilée et les Jésuites des missions d'Orient," *Revue des questions scientifiques,* 4e sér., 1935, *28:* 356–382. Somewhat more useful is Szcze_niak, "Notes on the Penetration of the Copernican Theory into China (Seventeenth–Nineteenth Century)," *Journal of the Royal Asiatic Society,* 1945, 30–38. A rather black-and-white analysis with important additional information is Hsi Tse-tsung *et al.,* "Heliocentric Theory in China," *Scientia sinica,* 1973, *16:* 364–376. More limited in scope is Yen Tun-chieh, "Ga-li-lueh ti kung-tso tsao-ch'i tsai Chung-kuo ti ch'uan-pu 伽利略的工作早期在中国的传布" (The early dissemination of Galileo's work in China), in *K'o-hsueh-shih chi-k'an,* 1964, 7: 8–27. On the notion that Western mathematics originated in China, see Chiang Hsiao-yuan 江晓原, "Shih lun Ch'ing-tai 'Hsi-hsueh Chung yuan' shuo 试论清代西学中原说" (An essay on the Ch'ing-period claim that Western studies originated in China), *Tzu-jan k'o-hsueh-shih yen-chiu* 自然科学史研究, 1988, *7.* 2: 101–108, and Sivin, "On 'China's Opposition to Western Science During Late Ming and Early Ch'ing,'"*Isis,* 1965, *56:* 201–205. See also J. W. Witek, *Controversial Ideas in China and in*

Europe. A Biography of Jean-François Foucquet, S.J. (1665–1741) (Rome: Institutum Historicum S. J., 1982). Foucquet wrote and circulated, but did not publish, a thorough critique of the first-generation Jesuit writings. A most interesting study is Harriet Zurndorfer, "Comment la science et la technologie se vendaient à la Chine au XVIII[e] siècle: Essai d'analyse interne," *Études chinoises*, 1988, *7*. 2: 59–90.

Mikami Yoshio 三上義夫 was the first to note that seventeenth-century Chinese astronomers used European techniques mainly to revive their own tradition, in *"Chûjin den* ron 疇人傳論" (A study of the *Ch'ou jen chuan), Tôyô gakuhô*, 1927, *16:* 185–222, 287–333. Mikami's argument was repeated in "Chinese Mathematics," *Isis*, 1928, *11:* 125.

Retrospect

This biography is in large part a revision of the one published in *Dictionary of Scientific Biography*, XIV (New York: Charles Scribner's Sons, 1976), 159–168. Because so few Chinese astronomers of this crucial period in which European science received its first responses had been studied, that article was quite broad in scope. It emphasized Wang's technical work. Shortly afterward I accepted the invitation of L. Carrington Goodrich to prepare for a Sinological readership an essay for his *Dictionary of Ming Biography* that would be more attentive to Wang's life outside science. Fang Chao-ying, who wrote most of the articles on scientists in *Eminent Chinese,* reviewed the MS, and made several excellent suggestions for placing Wang in the intellectual milieu of his time. I requested his name be added to the second article as co-author.

I have integrated into this version the fruit of both explorations. It also incorporates the appendix and other portions of a version slightly expanded in 1976 for a book of essays that was never published. This new edition uses and cites studies published after 1976. Readers will find it useful to consult the latter for evidence underlying my arguments here about the interaction of Chinese and European astronomy.