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A Multi-dimensional Approach to Research on Ancient Science*

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Cultural Manifolds

The Way and the Word exemplifies a method of historical study that makes sense of the past in ways that more conventional approaches frequently fail to do.[1] Historians of Asian science tend, for instance, to look at computational techniques and the social relations of mathematicians as distinct areas of inquiry. Putting something in context is, as one author after another reminds us, a good thing, but doing so is a voluntary matter of connecting two things that exist quite separately. Scholars rarely ask what unifies a problem's philosophical, technical, social, economic, political, literary, and other dimensions. Choosing one of these dimensions to study, ignoring the rest because one is not a specialist in them, is more usual. The cost is often a stunted understanding.

The Way and the Word is an experiment in doing away with foreground and context, and studying the emergence of science in each culture as what I call a cultural manifold. Cultural manifolds include not only the various dimensions of a complex phenomenon, but also the interactions that make all of these aspects into a single whole. That whole includes how people make a living, their relation to structures of authority, what bonds connect those who do the same work, how

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[1] Lloyd and Sivin (2002).

they communicate to each other and to outsiders what they have understood, and what concepts and assumptions they rely on. I do not think of social factors determining thought, nor of ideas determining social change. The point is to comprehend the interactions within each manifold as thinkers respond to, but at the same time influence, institutions and prevalent values.

That is why in *The Way and the Word* we do not speak of inquiry in context. Context is not an autonomous setting that may or may not be pertinent to inquiry. Technical work and its circumstances are parts of a single complex phenomenon. Our effort to show the differences in how people thought about the physical world in early China and in the domain of Greek culture led us toward what we believe is a more productive approach to comparison. It is not new in general historical studies, but little work on Chinese science and medicine has taken advantage of it.

The Calendar Reform of 1280

The purpose of this essay is to apply the concept of cultural manifolds to several additional examples, some comparative and some not, to demonstrate the range of its usefulness. My main example comes from a study of the Season-Granting astronomical system *(Shoushi li* 授 時 曆, 1280).[2] Historians of astronomy often call this system the high point of the Chinese computational tradition. If we study all of its dimensions, we can understand why this remarkable group of innovations came together during a wrenching transition between dynasties.

Many kinds of technical novelty converged in the Season-Granting reform—to name a few, a remarkable simplification in recording numbers, a new method of exact interpolation, a greatly improved approximation of spherical trigonometry, redesigned instruments, and a survey that collected observational data over an unprecedented range of sites. It is hard to imagine more unlikely circumstances for them to coincide. This reform, after all, was planned to begin a Mongol occupation. The Yuan was the least Chinese of all major dynasties, ruled in 1280 by an emperor who could not read Chinese and probably spoke little of it.[3]

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2 Although *li* often refers to a calendar (or, more accurately, an ephemeris), the "Treatises on Mathematical Astronomy" (*li zhi* 曆 志) use *li* primarily to mean the schemes of computation that I call astronomical systems. They reduce the complexity of the celestial motions to a series of routine steps that functionaries with limited skills can use to calculate the ephemeris for the coming year.

Speaking of mathematical astronomy as "calendrical science" misses the point. It obscures the basic similarity between the Chinese technical literature, Islamic tractates (usually called "tables"), and Western treatises from Ptolemy to Peuerbach. The calendar was the political rationale of palace astronomy, but it was the astronomers' least challenging work.

Pp. 97-104 of this essay is an abridged and revised version of Sivin 2005.

3 Franke (1953), pp. 28-41.

This regime ended a devastating war that the Mongols had waged for forty years since they conquered North China. The dynasty was to last less than a century.

In 1276, the Song government in Hangzhou surrendered. It appeared that the war was over, although it actually dragged on for three more years. To celebrate the prospect of victory, in that year the Mongol ruler launched the Season-Granting reform, putting in charge seven Han Chinese, only one of them an astronomical official. This was at a time when the Yuan authorities generally gave Chinese officials as little independent authority as possible.

Why then was this reform so successful? Scholars who believe that innovative science depends on Great Men have usually explained it by the genius of Guo Shoujing 郭 守 敬 (1231-1316), the lowest-ranking and the second youngest of those who planned and carried out the project. He was indeed a talented instrument designer and organizer of observations, and no doubt a competent mathematician. Still, historians who give him credit for the whole project are ignoring the others on what was after all a large team. He is so prominent, I believe, mainly because he was one of only two main participants to live past 1282—the only surviving protégé of the powerful man who first proposed the reform. He therefore became responsible for writing up the documents we depend on.

In order to investigate who did what work and why, we need to look at the cultural manifold of the project. To be brief, I will consider its political, bureaucratic, personal, and technical dimensions. Excellent modern studies by Professors Ho Peng-Yoke (He Bingyu 何 丙 郁), Li Di 李 迪, Pan Nai 潘 鼐, Xiang Ying 向 英, Yamada Keiji 山 田 慶 兒, and others have already described the historical events.[4]

Political Dimension

In the first half of the thirteenth century, it would be difficult to imagine a large people politically more unlike the Chinese than the Mongols were.[5] The way most Mongols lived made them highly adaptive, always ready to move, and used to fighting. They were tribal, originally with no overarching government. Exaction and division of spoils became the key to power beyond tribal boundaries. Large political forms came into being as individuals drew together federations that let them extort wealth from agrarian societies such as China. Succession to

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4 This essay draws on, among other sources, Li Di (1966); Pan Nai and Xiang Ying (1980); Yamada Keiji (1980); Ho Peng-Yoke (1993), pp. 282-299, and other essays in the same volume.

5 The most judicious account of the Mongol empire is in Fletcher (1986); for details see Thomas Allsen in Franke and Twitchett (1994). For a map of the Mongol empires at Khubilai's death in 1294, see Rossabi (1988), p. 111.

tribal leadership regularly involved violence; building wealth involved conquest or the credible threat of it; and everyone took part in internal and external war.

Chinggis Khan 成吉思汗 (r. 1206-1227) built an empire across an enormous swath of the earth; he and his immediate successors were aware that their new imperium could survive only if they kept pushing further and subjugating new peoples. They surged forth from their grasslands with remarkable and fearsome suddenness, doing enormous destruction as they spread. Chinggis kept this new culture expanding—to the gates of Vienna, as the cliché has it—by dividing his empire among his sons, but from 1242 on it lost momentum and fell apart as they died off. As their successors created hybrids of their traditional culture and those of the peoples they ruled, the cultures within what became five empires mutated variously and irreversibly. As part of this long process, the Mongols vanquished the Jin dynasty of the Jurchen people in North China in 1234, and the west and south of the Song empire by 1276.

The conquerors of North China were poorly prepared to rule over a sedentary agricultural and urban population. They saw their new subjects largely as providers of money, supplies and manpower for further conquests. Since the Mongol leaders were not used to reading and writing, they put together an administration from surrendered Uigurs, Jurchens, Khitan, Chinese, and others. It extracted wealth at high human cost. This new model of government terrified the Southern Song Chinese, and made a negotiated surrender unthinkable.

Khubilai 忽必烈 (1215-1294) was not only the first Mongol to rule all of China, but he made victory possible in the first place by inventing a style of government that the southerners could understand and eventually accept. He was able to do this because, as a young man, he gathered around him an inventive group of Chinese advisors. One of these was Liu Bingzhong 劉秉忠 (1216-1274). As a Chan monk, Liu joined Khubilai's entourage early, and became his main advisor and tutor in Chinese culture. Although he avoided official appointments, his informal power was immense. Liu was among the many Chinese literati whom Khubilai especially esteemed because of their skill at what he called "yin-yang." Mongols used this label to lump together the arts of prognostication: mathematical astronomy, judicial astrology, and every sort of divination. Educated people who studied one tended to study them all.

As early as 1251, Liu Bingzhong suggested a calendar reform, as one of the ways Chinese would recognize of asserting legitimate imperial authority. In 1273, he presented a concrete proposal, which would have put him in charge. Nothing came of it, and he died the next year. But in 1276, Khubilai, certain that all of China would soon be in his hands, gave the order. Ritually marking the unification of China was an important matter, and a new system for generating the calendar was symbolically indispensable. Liu had intended it to be more than a standard symbol of dynastic change. He wanted to take a step forward in technical practice as well.

Another characteristic of Mongol politics is very much to the point. Mongols enjoyed the diversity of their trans-Asian order. They did not think of other peoples as barbarians, as Chinese did, or want them to adopt their own culture. They drew avidly on the strengths of the many peoples they had brought under their sway. Among those who offered new systems of mathematical astronomy before the final victory of the Mongols, for instance, were Chinggis Khan's companion the Khitan statesman Yelü Chucai 耶律楚材 (1190-1244) as well as the Persian Jāmal al-Dīn (Zhamalading 札馬剌丁, fl. 1267-1291), who became a high official in China.[6] But by 1276 Khubilai appreciated Liu Bingzhong's point that to mark the victory, and to ease the occupation, a recognizably Chinese system was essential.

Bureaucratic Dimension

Song technical officials generally had been entrenched, with overlapping responsibilities. Sometimes they colluded to deceive their superiors, but did not necessarily cooperate when they were supposed to do so, and were always poised to evade responsibility if their predictions failed. Astronomy was, in other words, part of a true bureaucracy. This time, however, the organizers of the reform (I will introduce them shortly) got round the organizational inertia. They chose their own colleagues. They used the authority of the Great Khan to situate the project in a new, independent organization, with its own new observatory, insulated from the organizational inertia.

When the calendar reform group began organizing in 1276, it became the third of three contemporary astronomical institutions. There were already Chinese and Muslim Directorates of Astronomy (Han'er qintianjian 漢兒欽天監, Huihui qintianjian 回回欽天監). Both were expected to observe, compute annual calendars, interpret astrological omens, and file reports. The Islamic observers had a set of instruments that Jāmal al-Dīn brought from the observatory at Marāgha in northwest Persia—unless, as is more probable, what he brought were models. The newest armillary spheres the Chinese had were about 150 years old, and not in good working order. These institutions did not have the equipment they needed to operate effectively. No one expected their astronomers to do anything more than routine work.

It was essential to ensure that the bureaucrats in the older organizations could not hinder the ambitious new project.[7] Those in charge had enough power to situate it in a working group separate from the old offices, with a new observa-

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6 See Hartner (1950). Some documents give the name as Zhamaluding 札馬魯丁. Yamada Keiji (1980), pp. 48-52, has argued that he was not from Marāgha but from Bokhara.

7 Stasis seems to have been the norm in palace astronomical bureaux. For an example of Song sinecurists blocking innovation, see Shen Gua 沈括, *Mengqi bitan* 夢溪筆談 (Brush talks from Dream Brook), written between 1081 and 1095, *juan* 8, in Hu Daojing (1960), item 149.

tory and headquarters that they designed. The new group innovated greatly in four politically turbulent years. Seven people planned, directed and supervised the project (eight if we include Liu Bingzhong, the most important planner, but he did not live to direct it). One had been brought from the south. The rest held diverse non-astronomical posts in the middle and upper ranks of the regular civil service. The full staff of the commission included 77 officials, ranging in rank from 2a, a very high grade, to 9b, the lowest; 44 student observers; and employees below civil service rank whom no source took the trouble to count.

To comprehend how this diverse and highly competent group came together, we have to investigate the personal relations of its members. That is inevitably a long story, but as stories go, it has a simple plot.

Personal Dimension

The seven Han Chinese officials who took the largest part in planning and running the project did not have much in common except for their interest and skill in astronomy and divination. The only specialist among them was Chen Ding 陳鼎, the official astronomer who had carried out the Southern Song dynasty's last calendar reform in 1271. He was war booty. When the Mongols conquered Hangzhou, they captured him and shipped him north. All the rest had been long-term protégés or supportive colleagues of the powerful Liu Bingzhong. Zhang Wenqian 張文謙 (1217-1283), as a child, had been a fellow student of his. Guo Shoujing's grandfather, who raised and educated Guo, was a close friend of Liu's. He sent Guo to become Liu's disciple. Wang Xun 王恂 (1235-1281, the operational head of the team) was another of his disciples. Zhang Yi 張易 (d. 1282) had been part of the same scholarly community as Liu. Liu or someone close to him introduced all of them to Khubilai, who took them into his circle of advisors. The ruler added Xu Heng 許衡 (1209-1281) and Yang Gongyi 楊恭懿 (1225-1294) to it because of their fame as exemplary teachers of the Song Confucian doctrines that were just reaching the north. They then stoutly supported Liu in adapting and building Chinese-style institutions

What first attracted Khubilai to each of them, in addition to their talent, ambition, and desire to please, was the same thing that drew him to Liu Bingzhong, that is, their "yin-yang"—skill at divination, astrology, and astronomy. They were working not for a faceless, alien state apparatus, but for a patron who knew them well and rewarded them generously.

Technical Dimension

Reforms of the century before 1280, such as the one that Chen Ding carried out for the Southern Song in 1270-1271, were perfunctory. Few were based on original observations or mathematical methods. Some were a little better than their predecessors, and some were worse. If all a ruler and his highest officials needed was something to symbolize a new cosmic order, they were likely to be satisfied with whatever their celestial bureaucrats could easily produce. But Khubilai and his advisors had devoted their lives to bringing China under Mongol dominion. With victory in sight, they wanted a political order on the Chinese pattern that would enable peace and stability without compromising the power of the Mongol nobles. Naturally, what mattered were the symbolic innovations that upheld the imperial charisma. Among the most important of them was a calendar reform.

As we have seen, the palace already had Jurchen (by Yelü Chucai) and Muslim (by Jāmal al-Dīn) astronomical systems and tables.[8] But it did not accord them official status. It demanded a system that its Chinese subjects could recognize as purely Chinese. It discouraged its Han, Central Asian, and other astronomers from sharing information. It is not surprising that the Season-Granting system shows remarkably little non-Han influence. Not until the Ming period could Islamic and Han astronomers communicate freely with each other.

One reason the new Chinese-style system was so impressive is that this was by all accounts the most elaborate and expensive reform ever carried out. It involved a new observatory, outfitted with a set of large bronze armillaries and other instruments, some of them unprecedented in design. Guo Shoujing also built two 40-foot high brick gnomons with a kind of pinhole camera that determined with remarkable exactitude the length of the tropical year, one in the capital (now Beijing) and one in present-day Dengfeng 登 封, Henan.[9] Teams of observers also carried out a great latitude survey with portable equipment at 27 locations scattered from Siberia southward for 3600 miles.[10] They recorded for each site time differences of eclipse observations, variations in the ratio of day length to night length, and changes in the latitudes of the sun, the moon, and possibly the planets.

Khubilai was also ready to pay for a new level of detail in evaluating the accuracy of the new system. The ancient observational records that the team used to test their new techniques are the same ones used for that purpose in one dynasty after another. Astronomers not only drew on data in books, but also chose from an archive of observations passed down from one dynasty's observatory to

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[8] Yelü's system was largely built on Chinese models, but was based on observations in Samarkand.

[9] Zhang Jiatai (1978); Bo Shuren (1963); Mercier (2003).

[10] Listed in *Yuan shi* 元 史 (History of the Yuan), Zhonghua shuju ed., 48: pp. 1000-1001.

the next. The Yuan astronomers included in their tests a series of early eclipse observations that specified not only the day but the time of the eclipse, often to the nearest quarter of an hour. Those records were, by and large, quite accurate. The Yuan group used them systematically and profusely, not only because of its high standard, but because its funds permitted it to do that.

At the same time, this massive support was double-edged. It enabled some kinds of innovation, and hindered others. It is easy to appreciate the ingenuity that went into the system's eclipse technique. It combined third-order interpolation that allowed a step ahead in accuracy with new developments in something close to spherical trigonometry. It comes as something of a shock, then, to see how stale and unimaginative its planetary technique is. Most of it, surprisingly, turns out to be a copy of its counterpart a century earlier in the Jin regime.[11] Although the Yuan astronomers did extend their improved interpolation method to the planets, on the whole their technique still could not have reliably predicted most planetary phenomena.

One would have to be naive to conclude that the group was good at lunisolar astronomy but incompetent at planetary astronomy. That much becomes clear when we examine the "Evaluation of the Season-Granting system" (Shoushi li yi 授 時 曆 議).[12] In this detailed report, the Yuan astronomers used ancient records to test the important features of the new system. They did not evaluate the planetary theory at all. In other words, they hid the inadequacies of which they were certainly aware. Among the project's voluminous unpublished documentation, the largest component was 50 *juan* of planetary observations. The most obvious explanation is that the authors were unprepared to do computational justice to these data.[13]

Their predecessors for many centuries had not been notably more concerned than they were. It was rare for a system to stand or fall on its planetary techniques. It is not hard to see why. From at least the second century B.C. on, the state came to be intensely concerned with eclipses as highly visible omens, threats to the dynasty's mandate. Once astronomers could regularly predict lunar eclipses, they ceased to be omens. The difficulty of prediction kept solar techniques at the center of attention until, by A.D. 500, the better systems were fairly successful. The political priority of eclipses kept planetary phenomena periph-

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[11] Their source is Zhao Zhiwei's 趙 知 微, *Chong xiu Da ming li* 重 修 大 明 曆 (Revised Great Enlightenment system), 1180, in *Jin shi* 金 史 (History of the Jin), Zhonghua shuju ed.; on the planets see 22: pp. 496-519.

[12] It accompanies Guo Shoujing's account of the Season-Granting system ("Shoushi li jing" 授 時 曆 經), submitted between 24 December 1280 and 21 January 1281, in *Yuan shi*, juan 52-55.

[13] See the list of documents in the main source of Guo's official biography, Qi Lüqian (1316), p. 720.

eral, no matter how technically interesting they were.[14] Astronomers recognized that the motions of the five classical planets were very different from each other, but coming to grips with those differences would have required sustained, precise measurement over many years. Yang Gongyi, one of the reform group, proposed a program of observations sustained over 20 to 30 years, but nothing came of it.[15]

Precisely because, through history, planetary prediction techniques were a weak point, challengers fairly often attacked a current system for such failures. By the end of the tenth century, one system was comparing its computations of planetary events with those of important predecessors, but even 200 years later that had not become the norm.[16]

To sum up, the computational power for which we remember the Yuan system was the result of a transient need for dynastic legitimacy, a remarkable collection of Chinese talent gathered by a Mongol patron, circumstances that made it possible to avoid the stasis usual in palace astronomical institutions, motivation to overcome technical difficulties that never before had been attacked all at once, and lavish support. The reform succeeded so well because of that remarkable combination of the economic, the political, the bureaucratic, the personal, and the technical dimensions. That same cultural manifold makes it possible to understand the reform's limits, particularly its stodgy planetary techniques. There would be no point in simply cataloguing all these dimensions separately. It is obvious in this example that the interactions within the whole form the dimensions.

Other Problems

Attention to cultural manifolds can be useful in clarifying other equally complicated historical problems. Let me give four examples.

Polymathy

14 Even in the *Chunqiu* 春 秋 annals that begin in the eighth century B.C., the concern with eclipses is not balanced by omens involving planets. Cf. Schaberg (2001), pp. 100-101.

15 "To set a standard for future dynasties, it is essential that every year we make [new] observations and revise, so that, as [improvements] accumulate over 20 or 30 years, we perfect our methods"; see Yang's biography in *Yuan shi*, 164: p. 3842.

16 See the evaluation of the Supernal Epoch system (Qianyuan li 乾 元 曆) in *Song shi* (History of the Song), Zhonghua shuju ed., 70: pp. 1592-1594.

In a biography of the Song polymath Shen Gua 沈括 (or Kuo, 1031-1095), I sketched the remarkable breadth of Shen's interests.[17] The subjects about which he had something original to say ranged from geology to astronomy to mapmaking to linguistics, and on through ritual, music, diplomacy, military fortification, medicine, painting, poetry, tea, and any number of others. I concluded that we can explain this scope only when we recognize that in his life politics, civil service, personal experience, and technical skills were inseparable.

I noted in passing an odd phenomenon. Any historian of science will recognize the names of Yan Su 燕肅 (fl. 1016) and Su Song 蘇頌 (1020-1101). In the Northern Song period, these, along with Shen Gua, are the best known among a number of technically innovative scholars with universal curiosities.[18] The amateur ideal that began to form then regularly included technical enthusiasms. But from the Southern Song on, scholars of intellectual breadth rarely include science and technology in their writings.

In North China under the Mongols, as we have already seen, there was another shift. Astronomy, mathematics, and numerology became conventional subjects of study, but this trend faded away by the end of Yuan period. The reinstitution of regular civil service examinations in 1315 may have had something to do with it.[19] In the Ming, questions on astronomy and other technical topics appeared regularly in the imperial examinations. This forced every conventional young man to study these fields, but did not cause a rebirth of activity in them among graduates. At the end of the Ming, among the limited membership of what became the "evidentiary research" *(kaozheng* 考證) movement, writing on mathematics, astronomy, medicine and other fields flourished until the mid-Qing.[20] This is an instance of repeated transformations in the cultural manifold of one clump of technical problems. Understanding these odd vicissitudes will require considering many dimensions of intellectual, personal and social identity.

Comparative Studies

Let me give a couple of examples of comparative issues that are ripe for investigation.

We have all had to think critically about what has come to be called the "Scientific Revolution Question" or the "Needham Problem." I once argued that a

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[17] Sivin (1995).

[18] On Yan, see Zhang Yinlin (1956), pp. 116-124. For Su, there is a biography in Joseph Needham, Wang, and Price (1960), pp. 5-9, and a rich collection of studies in Zhuang Tianquan et al. (eds.) (1993). For another important polymath, see Li Di (1991), pp. 73–83.

[19] John Dardess in Franke and Twitchett (1994), pp. 564-565.

[20] Elman (2000), pp. 460-485; Sivin (1995a), pp. 17-20.

scientific revolution, by the definition that historians ordinarily use, *did* take place in China at roughly the same time it was taking place in France (and earlier than in many other parts of Europe).[21] In France as in China, this was a response to foreign influence. Some historians have denied that there was any revolutionary change in Chinese science. The seventeenth-century transformation in mathematics and astronomy did not have the social consequences that they assumed scientific revolutions must have, so they concluded that Chinese were incapable of fundamentally rethinking science. To do so they had to ignore the scholars of the time whose writings were fundamentally rethinking their tradition. The evidence such authors left dooms the assumption. The obvious conclusion is that scientific change does not entail social change. And if that is true of China, it is true everywhere. What calls for explanation is the idiosyncratic social revolution that eventually swept over Europe in the aftermath of its Scientific Revolution. By now, in fact, many specialists have shown that Europeans used new scientific ideas to block as well as to further social transformation.[22]

I encouraged my colleagues to move on and begin to examine systematically what did happen when Chinese began to think about Western science. Some, especially scholars in China, have done so.[23] Others continue to believe that the Chinese were not clever enough, or were too rigid, to make productive use of Western science until the twentieth century. They have found the "Scientific Revolution Question" a pleasant diversion from studies in which guesswork is not an option. It has attracted hundreds of disparate and mutually incompatible answers, and has led to no useful conclusions.[24] *The Way and the Word,* I hope, will encourage more scholars to undertake broadly conceived studies of Chinese responses, and perhaps even to compare them with responses in various European countries, setting aside worn-out assumptions about what the results ought to be.

Next, there are a number of striking differences of style in the ways Chinese and Japanese chose from and adapted Western learning. What principally interested Chinese was astronomy and mathematics. Within a few weeks after the Manchus marched into Beijing in 1644, they put a Jesuit missionary in charge of the Astronomical Bureau.[25] Many influential literati of the seventeenth and eighteenth centuries studied and wrote about European astronomy.[26] The early missionaries also wrote about European medicine, but Chinese showed practically no interest in that subject for another two hundred years. On the other

21 Sivin (1982).

22 See the many references in Shapin (1996).

23 See Han Qi (1999), and many studies by Huang Yilong (Yinong 黄一農; for instance, see note 25 below).

24 Many discussions, typically erudite but inconclusive and mutually contradictory, are gathered in Liu Dun and Wang Yangzong (eds.) (2002).

25 Huang Yinong (1990).

26 See the list in Sivin (1995a), pp. 17-20.

hand, in Japan, the Jesuits' Chinese writings (ca. 1725) and Dutch textbooks (half a century later) introduced astronomical knowledge, but it had no significant impact until the 1840's. Unlike the Chinese, Japanese were extremely interested in European medical books. Although the government forbade reading foreign publications, certain people got their hands on Dutch medical writings, translated, and taught them. By the late eighteenth century, there were many practitioners of Western medicine in Japan.[27]

Why were the Chinese and Japanese responses so nearly opposite? Several parts of an answer are already discernible. The sources of foreign knowledge differed. The involvement of the Chinese imperial government and the Japanese military dictatorship was not at all similar. The people who accepted or rejected technical knowledge came from different niches in quite dissimilar societies and political systems. Such knowledge yielded them entirely different kinds of livelihoods. In both countries European medical practice competed with that of various Chinese traditions. Chinese thought of the latter as their own millennial heritage, revealed by the archaic sages who invented civilization. For eighteenth-century Japanese, the Chinese and European versions were both foreign, and equally exotic. Only by looking at all of these facets and still others can we reach historical hypotheses worth taking seriously.

Finally, in addition to comparing two cultures in the same period of time, it would be interesting to compare one phenomenon in China at different times. An example that affected science was the ancient usage that forbade an official to serve two successive dynasties *(buerchen* 不 貳 臣). Many scholars went even further, refusing to serve a new dynasty even though they had had no prospects of a civil service career under the old one.

This taboo did not hinder the Mongols from enrolling Chinese astronomical talent. As we have seen, the southern official Chen Ding provided the Mongols with experience that no northerner had. He did not choose to die rather than serve, as others had done in previous dynasties. Liu Bingzhong, who came of a family that had served the Jin, eagerly went to work for Khubilai, and recruited many other experts in "yin-yang."

But in the transition from the Ming to the Qing, again from a Han government to an alien one, the outcome affected private science rather than that of the state. Many exceptionally able people refused civil service appointments, even though they had never been Ming officials. They became teachers of astronomy and mathematics, and physicians, instead. Mei Wending 梅 文 鼎 (1633-1721), Wang Xishan 王 錫 闡 (1628-1682), and Xue Fengzuo 薛 鳳 祚 (ca. 1620-1680), the best astronomers of their time, are examples. Fu Shan 傅 山 (1607-1684), an outstanding medical practitioner and author, equally celebrated as a

[27] The best account of the astronomical response remains Nakayama Shigeru (1969). For the early history of European medicine in Japan, see Sugita Genpaku (1969).

calligrapher and painter, was ready to die rather than to accept an appointment that the Qing court pressed upon him.[28]

What accounts for this contrast? A comparison of cultural manifolds in the same country but at different times can tell us. All it takes is hard work, thoughtful analysis, imagination, and an open mind. This list of examples could easily be extended, but what matters is what each scholar ready to do research of this kind is curious about.

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[28] See the biographies of Wang and Mei in Jin Qiupeng (ed.) (1998), pp. 660-675. For a biography of Wang in English, see Sivin (1995a). On Fu, see He Shuhou (1981) . There is no substantial biography of Xue, but see his writings in *Lixue huitong* 曆 學 會 通 (Eclectic astronomy, preface 1662); some versions carry the synonymous title *Tianxue huitong* 天 學 會 通. For the complicated bibliography of these two titles, see Sivin (1995b), pp. 28-29, note 39.

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