The Northern Song State’s Financial Support for Astronomy

Sun Xiaochun and Han Yi

Abstract: Astronomy was politically relevant to the imperial state in ancient China because a good astronomical system was believed to indicate the legitimacy of rule and symbolize good governance. This political significance meant that astronomy was a state enterprise. China saw many important astronomical achievements during the Northern Song dynasty (960-1127) when astronomy received sustained organizational and financial support from the imperial government. Alongside astronomy’s high profile in state politics, this fiscal support contributed to its development, along with the eight major astronomical reforms which the Northern Song dynasty made. It maintained a state-supported Astronomical Bureau which had more than 100 members of staff. In addition, the government invested...
a lot of money in astronomical instrument making. For example, the water-powered astronomical clock tower constructed in 1092 cost more than 5000 strings of money, accounting for about one thousandth of the total annual fiscal income of the imperial state.

The purpose of this study is to ascertain to what degree the state supported astronomical research financially. Based on sources such as the Song huiyao jigao 宋會要輯稿 (Re-Collection Draft to Essentials of the Song Period), we give an estimate of the Song government’s financial investment in astronomy—an investment which comprised a substantial part of the state’s total fiscal income. We believe that this investigation of the Northern Song state’s financial support for astronomy will help to explain why there were so many great innovations in astronomy during this period.

Introduction

In a recent study, Nathan Sivin applies the concept of “cultural manifold” to the Season Granting system of mathematical astronomy (shou shi li 授時曆) constructed by Guo Shoujing 郭守敬 (1231-1316) in 1280.17 His inquiry looks at many dimensions, including the political, the cultural, the personal and the bureaucratic. The astronomical system did not just consist of computational techniques for generating annual almanacs, but was also an important component of the imperial charisma, a means of livelihood for officials and others, a bureaucratic project. This concept of cultural manifold is therefore useful for studying astronomy during the Northern Song dynasty (960-1127), particularly the concept of astronomy as a bureaucratic project, because it was organized, sponsored, and controlled by the imperial government. The Northern Song period stands out in Chinese history for its many systematic and innovative contributions to astronomy. This was possible because astronomy was established in the imperial state’s highly developed bureaucratic system and received institutional support from the government.18

In this paper, we look at one specific dimension, the financial. Our question is, exactly how much did the Northern Song state invest in astronomy? Or to be more specific, what portion of the state’s fiscal income was spent on astronomical activities? Although it is difficult to determine the exact amount of financial input given to any science in the contempo-

17 Sivin (2009), pp. 11-34.
rary world, let alone in the Northern Song dynasty when financial information was fragmentary and incomplete, we nevertheless propose to provide an estimate of the expenditure on astronomy by the Northern Song imperial government. This is possible precisely because of the bureaucratic nature of astronomy. The expenditure on astronomy was largely spent on the salaries of astronomical officials in the state-supported astronomical institutions. The existent historic documents from the Northern Song dynasty contain much information about the establishment of astronomical institutions, the rank of astronomical officials and their salaries and subsidies. Using these data we can put together a fairly reasonable estimate of the Northern Song’s financial support for astronomy.

The Imperial Government’s Support for Astronomy

The imperial government supported astronomy through three major avenues. It established imperial astronomical institutions authorized to study astronomy. It funded large astronomical projects such as the construction of astronomical instruments and, sometimes, it bestowed imperial awards on successful astronomers.

The Imperial Astronomical Bureau was responsible for providing the astronomical system that not only served as the basis for calculating the annual calendar and almanacs, but also symbolized imperial authority. It devised and implemented major projects on instrument making, astronomical observations, calendar calculations and evaluations of the astronomical system 利 to see if there was any need to change it—such requirements usually came from the political side. As a matter of course, the bureau produced almanacs, observed celestial omens, and chose auspicious dates for imperial ceremonies. The astronomical bureau in the Hanlin Academy was the counterpart of the Imperial Bureau. It was established

19 The word 利, usually translated as ‘calendar’, means much more than just the arrangement of years, months and days. It means a whole set of mathematical techniques for computing the times and locations of certain astronomical phenomena, and for producing astronomical ephemerides. We follow Nathan Sivin to translate it as ‘astronomical system’. See Sivin (2009), pp. 38-40.

20 In the Northern Song, when a new emperor came to the throne, a new astronomical system would be issued, symbolizing a new political phase. For a very stimulating study on how politics influenced astronomical reforms, see Christopher Cullen (1993).

21 The Hanlin Academy (Hanlinyuan 翰林院) had its origin in the seventh century. It had no significant status, but its members held substantial posts elsewhere
in 1027 by emperor Renzong 仁宗 (r. 1022-1063) as a fall-back institution, controlling the performance of the Imperial Astronomical Bureau. Officials from this department were often put in charge of testing and verifying the proposed new astronomical systems.\textsuperscript{22}

The number of officials and clerks employed at these astronomical institutions varied. According to an imperial edict from emperor Yingzong 英宗 (r. 1063-1067) in 1066, the Imperial Astronomical Bureau was established with a total of 127 positions, about 26 of which were for ranked officials, 35 for technicians and clerks, and 66 for students.\textsuperscript{23} In 1082, when the Northern Song dynasty reformed its bureaucratic institutions, the Imperial Astronomical Bureau had about 100 roles. The Hanlin Academy’s Astronomical Bureau was run by about 60 employees. All these positions were funded by the imperial government through its bureaucratic rank and salary system, and the annual salaries stipulated for these positions give an insight into the governmental investment.\textsuperscript{24}

\section*{Government Expenditure on the Salaries of Astronomical Personnel}

The salary system of the Song dynasty officials was complex.\textsuperscript{25} An official’s annual stipend consisted of many different forms of payment and benefits depending on their rank and function. An astronomical official received a basic salary and variable subsidies. Salaries were paid monthly or annually, including: a monthly salary in cash (\textit{yueliaoqian} 月料錢), a monthly food allowance (\textit{yuelushi} 月祿食), and an annual payment in cloth (\textit{yici} 衣賜), as a form of gifts from the emperor. Additional monthly subsidies (\textit{yuetianzhi} 月添支) were paid in cash. The amount of salaries and their configurations changed from year to year. In the year 1057, the imperial ‘Order Regarding

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\textsuperscript{22} Sun Xiaochun (2007), p. 37f.

\textsuperscript{23} Song huiyao jigao 宋會要輯稿 (1809), henceforth abbreviated as SHY, Zhiguan (Officialdom) 31, 3, p. 3002.

\textsuperscript{24} For the organization and management of the Imperial Astronomical Bureau in the Song era, see Dong Yuyu (2004), pp. 32-36, and Dong Yuyu (2005).

\textsuperscript{25} Shao Hongxia (1993); He Zhongli (1994).
Salaries in the Jiayou Period’ (Jiayou luling 嘉祐祿令) 26 determined a standard according to which, for example, the Director of the Imperial Astronomical Bureau received an annual stipend that consisted of the following items:

- Monthly salary in cash: 45 strings (guan 貫) of money;
- Monthly food allowance: 100 shí 石 of grain;
- Annual payment in cloth: 3 bolts (pi 匹) of damask silk (líng 绫) for spring and autumn respectively, 15 bolts of thin silk (juàn 絹) 50 liàng 両 of cotton for winter, and 1 bolt of silk (luó 紗) for spring;
- Monthly subsidy: none.

Qi Xia’s 漆侠 study of the Song dynasty’s economic history before reforms in the 1070s notes that the price for rice was 600-700 coins (wen 文) per shí. Wheat cost 300-500 wen per shí. The price for silks varied, depending on their quality, between 1000 wen and 1300 wen per bolt (pi). 27 For better comparability, we adopt the following exchange rates to estimate the monetary equivalent of the salaries:

- 1 shí of rice or wheat = 600 wen;
- 1 pi of silk of any kind = 1000 wen;
- 1 liàng of cotton = 760 wen.

Therefore, the director’s annual stipend can be converted to money as follows:

- Monthly salary in cash: 45 strings; annually: 45 × 12 = 540 strings.
- Monthly food allowance: 100 shí 石 of grain; annually: 1,200 shí 石 of grain. 1,200 × 0.6 = 720 strings.
- Annual payment in cloth: a total of 22 bolts of silk and 50 liàng of cotton per year. 22 × 1000 + 50 × 760 = 60 strings.
- Monthly subsidy: none.
- Total: 540 + 720 + 60 = 1,320 strings.

This calculation shows that the director’s annual stipend was equivalent to a total of approximately 1,320 strings of money (1 string = 1000 wen).

Tables 1 and 2 provide an overview of the ranks and roles of officials and clerks employed at the Imperial Astronomical Bureau and the Hanlin Academy’s Astronomical Bureau, together with information about their

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26 This document is cited in Songshi 宋史 (1343-1345), henceforth abbreviated as SS, and Xu zizhi tongjian changbian 續資治通鑒長編 (1183), henceforth abbreviated as XCB.

27 Qi Xia (1999), pp. 1239-1246.
In some cases, the number of people employed in a role is not specified in the original sources, so the calculation is based on the assumption that only one person was employed. In the tables we have converted all salaries in cash and kind into their money equivalent, as with the salary of the director (above). During the year 1057, according to this calculation, the government spent approximately 15,255 strings of money on the personnel employed at the Imperial Astronomical Bureau, and approximately 6,110 strings of money for the Hanlin Academy’s Astronomical Bureau. Based on the data presented in Tables 1 and 2, we estimate that the government’s total expenditure on salaries for those employed in astronomy in 1057 was approximately 21,365 strings of money. In addition, the sources also mention an unspecified sum of “money for public use” (gongshiqian 公使錢) which the government supplied for the daily maintenance of the two bureaus.

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For the translation of Chinese official titles we rely heavily, but not exclusively, on Hucker (1985). For some titles not treated in Hucker (1985), we make our own translations.
Table 1. Expenditure on Salaries at the Imperial Astronomical Bureau, as of 1057
Monetary unit: strings (1000 wen)

<table>
<thead>
<tr>
<th>Guanming 官名</th>
<th>Guanpin 官品</th>
<th>Bianzhi 编制</th>
<th>Yuefengqian 月俸錢</th>
<th>Yucheshi 月膳食</th>
<th>Yi 每</th>
<th>Yuetianzhi 月添支</th>
<th>Total Annual Stipend</th>
<th>Sources</th>
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<tr>
<td>Director (jian 監)</td>
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**Total**

15,255
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<th>Monthly Salary (food)</th>
<th>Annual Gifts (cloth)</th>
<th>Monthly Subsidy</th>
<th>Total Annual Stipend</th>
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Later Increases in Government Expenditure on the Salaries of Astronomical Personnel

Between 1060 and 1080, the economy of the Northern Song state expanded rapidly (see below). Astronomy received more support from the government because of this economic growth. The salaries of the staff of both the Imperial and Hanlin Academy’s Astronomical Bureaus were raised once in 1066, and again in 1071.

In the twelfth month of the third year of Zhiping 治平 (1066), emperor Yingzong stipulated that the 127 “[members of the Astronomical Bureau], from the Director and Deputy Directors all the way down in ranks, should be given [an additional] monthly food allowance of 10 strings of money.” This raise amounted to an increase of 15,240 strings of money in the state’s annual expenditure on astronomical personnel—a total annual expenditure of 36,605 strings. In the second month of the fourth year of Xining 熙宁 (1071), at the high point of Wang Anshi’s 王安石 (1021-1086) New Policies Reform, emperor Shenzong 神宗 (r. 1067-1085) adopted a proposal from the Secretariat (zhongshusheng 中書省) authorizing the Imperial Astronomical Bureau to print and sell copies of the civil calendar, even though private printing was then prohibited. The profit from this practice was used to raise money to fund Bureau staff salaries “68 staff members received increases in their monthly ‘salary for food’ (shiqian 食钱), those ranked as high as Vice Director receiving 7 strings of money per month, and those with lower rankers receiving 3 strings of money per month.”

This resulted in another increase in the government’s annual expenditure on the salaries of the astronomical personnel of about 2,928 strings compared to that of 1066, bringing the annual total expenditure to 39,533 strings of money.

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29 SHY, Zhiguan 31, p. 3002.
30 For more on Wang Anshi’s reform, see Liu (1959) and Deng Guangming (2000).
31 XCB, p. 5360.
Expenditure on Astronomical Officials’ Salaries after the Institutional Reform of 1082

By the Xining period (1068-1077) the bureaucratic apparatus had become costly and inefficient. In particular, officials’ responsibilities were not always clearly allocated. It had become a habit to dispatch (paiqian 派遣) officials that is, putting scholars who had assigned positions in one department temporarily in charge of another. This practice reached far into the echelons of the Song government. The overlap of responsibilities caused disputes over important tasks, leaving the officials to their own devices, or even entirely ignoring them. During the Yuanfeng 元豐 period (1078-1085) the imperial government was forced to implement a major institutional reform that redefined official ranks, and made sure that officials’ responsibilities matched their titles. In spite of the general rise in officials’ salaries, the status of ranks of astronomical officials at the Imperial Astronomical Bureau and the Hanlin Academy’s Astronomical Bureau was reduced, slightly reducing the government’s expenditure on their salaries. Tables 3 and 4 show the government’s expenditure on officials’ salaries at the Imperial Astronomical Bureau and the Hanlin Astronomical Bureau respectively. The government’s total expenditure on these astronomical personnel amounted to 36,248 strings of money in 1082, slightly lower than that of 1071 (39,533 strings of money, see above).

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32 Provisional chancellors were often even held in higher esteem than the regular holders of this post, see Schäfer (1995), pp. 78-172.
Table 3. Expenditure on Salaries at the Imperial Astronomical Bureau, as of 1082

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<th>Title of Position</th>
<th>Rank</th>
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<th>Monthly Salary (food)</th>
<th>Annual Gifts (cloth)</th>
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<th>Post Subsidy</th>
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<td>p. 408</td>
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<td>p. 178</td>
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<td>52.80</td>
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<td>Position</td>
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<td>Title of Position</td>
<td>Rank</td>
<td>No. of People</td>
<td>Monthly Salary (cash)</td>
<td>Monthly Salary (food)</td>
<td>Annual Gifts (cloth)</td>
<td>Monthly Post Subsidy</td>
<td>Total Annual Stipend</td>
<td>Sources</td>
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<td>Hanlin Astronomer</td>
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<td>4</td>
<td>35</td>
<td>53</td>
<td>91.5</td>
<td>40</td>
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<td>5</td>
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<td></td>
<td>288.0</td>
<td>SHY, Zhiguann 36, p. 3125</td>
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<td>Rated students (sichen軍內觀学生)</td>
<td>Military officer</td>
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<td>5</td>
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<td>1591.2</td>
<td>SHY, Zhiguann 36, p. 3125</td>
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<td>Added students (yuhu军外观学生)</td>
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<td>5</td>
<td>3</td>
<td></td>
<td></td>
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<td>SHY, Zhiguann 36, p. 3125</td>
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<tr>
<td>Scribe (liren手分)</td>
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<td>3</td>
<td></td>
<td></td>
<td></td>
<td>36.0</td>
<td>SHY, Zhiguann 36, p. 3125</td>
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<tr>
<td>Reception (bamen親事官)</td>
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<td>3</td>
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<td></td>
<td>72.0</td>
<td>SHY, Zhiguann 36, p. 3125</td>
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<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>72.0</td>
<td>SHY, Zhiguann 36, p. 3125</td>
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<tr>
<td>Cleaner (sashao靈台)</td>
<td>Clerk</td>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>288.0</td>
<td>SHY, Zhiguann 36, p. 3125</td>
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<tr>
<td>Observer (ceyan觀)</td>
<td>Technician</td>
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<td>5</td>
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<td></td>
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<td>120.0</td>
<td>SHY, Zhiguann 36, p. 3125</td>
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<td></td>
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<td>12721.2</td>
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Astronomical Projects—the Case of Su Song’s Clock Tower Observatory

The continuous increase in expenses on astronomical personnel in the period from 1068 to 1092 concurs with an extremely active phase of the astronomical bureau. One of the major figures was Shen Kuo [Shen Gua] 沈括 (1031-1095), who conducted an astronomical reform from 1072 to 1077. Apart from changes in the infrastructure of the Imperial Astronomical Bureau, Shen Kuo also promoted the construction of new astronomical instruments which we know from the three treatises on the gnomon, the armillary spheres and the water clock which he submitted to the emperor. It is not clear if the general budget for the astronomical bureau included funds for instrument making. Shen Kuo’s request had, however, multiple purposes. It certainly aimed to obtain sufficient money to construct the instruments, but it also aimed to gain official imperial support for his more practical approach to astronomical observation and his new methods. His interest in instruments was shared by many of his colleagues. In 1086, Su Song 蘇頌 (1020-1101), proposed the construction of a water-powered astronomical clock tower and other instruments. One year later, following an imperial edict, Su Song put together a team to implement the project, which took six years to complete and involved a number of officials. Su Song gave a brief account of the team in his ‘Report to Present the Instruments to the Throne’ (Jin yixiang zhuang 进仪象状) which is saved in his Xin yixiang fayao 新儀象法要 (Essentials of the New Instruments):

On the sixteenth of the eighth month of the second year of the Yuanyou 元祐 period (1087), the emperor issued an edict, giving orders to establish a department, to summon officials and to procure materials for construction in order to implement the project as I [Su Song] proposed. Following the imperial order I presented memorials asking for assistant magistrate Wang Yunzhi 王沇之, Assistant Magistrate of Yuanwu 原武 County of Zhengzhou 鄭州 Prefecture, also Master of the Prefectural School of Shouzhou 塞州, to take the responsibility of supervising the construction and to take charge of the accounting of materials for public use; asking for Zhou Riyan 周日嚴, Summer Fellow of the Astronomical

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Su Song’s team consisted not only of staff members of the Imperial Astronomical Bureau, but also officials from other government departments. Su Song himself served as Prime Minister during the project, the chief designer Han Gonglian was a low-ranked clerk from the Ministry of Personnel, the manager Wang Yunzhi was recruited from the local government, and the architect Yin Qing came from outside the Astronomical Bureau. The team members’ salaries can be seen to demonstrate additional governmental support for the astronomical project. As the positions and ranks of the people involved are known, it is possible to calculate that the salaries for the project team amounted to an additional 40,261.8 strings of money for the 6-year project. Su Song asked for 20,000 jin of bronze, equivalent to 5,000 strings of money, for the construction of the clock tower. All together, on average, the state provided an additional 7,543.6 strings of money every year to support astronomy during the period of the project.

34 Xin yixiang fayao 新儀象法要 (1094), p. 123.
### Table 5. Expenditure on Salaries of Members of the Clock Tower Project

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Role in the Project</th>
<th>Rank</th>
<th>Annual Salary</th>
<th>Total for 6 Years</th>
<th>Sources</th>
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</thead>
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<tr>
<td>Su Song 蘇頌</td>
<td>Minister of Personnel, Prime Minister</td>
<td>General responsibility</td>
<td>2b</td>
<td>2910.5</td>
<td>17463.0</td>
<td>SS, vol. 171-172, pp. 4101-4152; SHY, Zhiguan 57, p. 3655</td>
</tr>
<tr>
<td>Han Gonglian 韓公廉</td>
<td>Clerk of the Ministry of Personnel</td>
<td>Design and computation</td>
<td>8b</td>
<td>434.4</td>
<td>2606.4</td>
<td>SHY, Zhiguan 3, pp. 2399-2419</td>
</tr>
<tr>
<td>Wang Yunshi 王允之</td>
<td>Construction Supervisor and Manager</td>
<td></td>
<td>6b</td>
<td>410.4</td>
<td>2462.4</td>
<td>SS, vol. 171-172, pp. 4101-4152</td>
</tr>
<tr>
<td>Zhou Rian 周日暖</td>
<td>Summer Fellow of the Astronomical Bureau</td>
<td>Observations</td>
<td>6b</td>
<td>787.8</td>
<td>4726.8</td>
<td>SS, vol. 171, p. 4105</td>
</tr>
<tr>
<td>Yu Taigu 于太古</td>
<td></td>
<td>Observations</td>
<td>6b</td>
<td>787.8</td>
<td>4726.8</td>
<td>SS, vol. 171, p. 4105</td>
</tr>
<tr>
<td>Zhang Zhongguan 張仲宣</td>
<td>Winter Fellow</td>
<td>Observations</td>
<td>6b</td>
<td>787.8</td>
<td>4726.8</td>
<td>SS, vol. 171, p. 4105</td>
</tr>
<tr>
<td>Yuan Weiji 袁惟畿, Miao Jing 苗靜, Zhang Duan 張端</td>
<td>Official Students</td>
<td>Calculation</td>
<td></td>
<td>288.0</td>
<td>1728.0</td>
<td>SHY, Zhiguan 22, p. 2878</td>
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<tr>
<td>Liu Zhongjing 劉仲景</td>
<td>Clerk</td>
<td>Clerk</td>
<td></td>
<td>87.6</td>
<td>525.6</td>
<td>SHY, Zhiguan 36, p. 3126</td>
</tr>
<tr>
<td>Hou Yonghe 侯永和, Yu Tangchen 于湯臣</td>
<td>Students</td>
<td>Gnomon and Water Clock</td>
<td>2</td>
<td>192.0</td>
<td>1152.0</td>
<td>SHY, Zhiguan 22, p. 2878</td>
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<tr>
<td>Yin Qing 尹清</td>
<td>Member of Chief Manufacture</td>
<td>Blueprint</td>
<td></td>
<td>24.0</td>
<td>144.0</td>
<td>SS, vol. 171-172, pp. 4101-4152; SHY, Zhiguan 57, p. 36958</td>
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</tbody>
</table>

**Total** 6710.3 40261.8
Financial Support for Astronomy in Relation to the Northern Song Government’s Fiscal Income

The period of the Northern Song witnessed a great expansion in the domestic economy. Rice production in the Yangtze basin and South China created enormous wealth.¹ Millions of shi of rice (1 shi is approximately 59.2 kg) were carried annually on the major canal connecting the Hangzhou and Suzhou regions with the capital Kaifeng. In addition to the rice economy, the state’s principal wealth came from commerce and craftsmanship, largely from: monopolies in salt, tea, alcohol and spices; taxes and duties levied on intense commercial activities in the fields of ceramics, silks, iron, paper, and printed books; and from a per capita tax and taxes on land.² The government’s fiscal income increased rapidly during the Northern Song period, whereas its expenditure was mainly on the imperial household, the bureaucratic system, the military forces, civil engineering, and disaster relief. Because the existent historical records on fiscal income are brief and scarce, and a considerable amount of the income was directly controlled by the Inner Treasury of the imperial court: “Nobody from outside the court knows its amount” (taren mo neng xiao 他人莫能晓),³ it is hard to obtain information on the precise amount of the Northern Song state’s total fiscal income. We can therefore only estimate the total annual fiscal income based on the money received by the Three Bureaus of the State Finance Commission (Sansi 三司).

¹ Qi Xia (1999), pp. 28-33, 205-260.
² Gernet (1985), pp. 319-324.
³ SS, chap. 179, p. 4371.
Table 6. The Northern Song Government’s Fiscal Income

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Annual Fiscal Income (strings)</th>
<th>Sources</th>
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</thead>
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<tr>
<td>979</td>
<td>16,000,000</td>
<td>Jianyan yilai chaoye zaji (JYZJ), chap. 14, p. 289.</td>
</tr>
<tr>
<td>997</td>
<td>22,245,800</td>
<td>SS, chap. 179, p. 4349.</td>
</tr>
<tr>
<td>1021</td>
<td>26,530,000</td>
<td>XCB, chap. 97, pp. 2259-2260. Also: JYZJ, p. 289; SS, p. 4349.</td>
</tr>
<tr>
<td>1041-1048</td>
<td>28,136,000</td>
<td>Gujin yuanliu zhihun houji, p. 209.</td>
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<td>1049-1054</td>
<td>39,000,000</td>
<td>SS, chapter 355, p. 11194.</td>
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<tr>
<td>1056-1063</td>
<td>36,822,541</td>
<td>Cai Xiang quanji, p. 436.</td>
</tr>
<tr>
<td>1064-1067</td>
<td>44,000,000</td>
<td>SS, chapter 355, p. 11194.</td>
</tr>
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<td>1065</td>
<td>60,000,000</td>
<td>Guling ji, p. 549.</td>
</tr>
<tr>
<td>1068-1077</td>
<td>50,600,000</td>
<td>SS, chap. 355, p. 11914. Also: JYZJ, p. 289.</td>
</tr>
<tr>
<td>1078-1085</td>
<td>60,000,000</td>
<td>JYZJ, p. 289.</td>
</tr>
<tr>
<td>1085</td>
<td>48,480,000</td>
<td>Qunshu kaoshuo heji, chap. 63, p. 859.</td>
</tr>
<tr>
<td>1086</td>
<td>48,000,000</td>
<td>JYZJ, p. 289.</td>
</tr>
</tbody>
</table>

Figure 1. Growth of Fiscal Income of the Northern Song
The government's fiscal income grew steadily during the entire Northern Song period, accelerating rapidly from 1060 to 1080, reaching a climax in 1080. This was probably the result of Wang Anshi’s New Policies Reform, since the main aim of Wang’s reform was to improve the imperial state’s fiscal situation.4

While these numbers are just approximations, they clearly indicate the general fiscal context against which to understand the level of the Northern Song government’s financial support for astronomy. We currently have data for the government’s annual expenditure on astronomy for 1057, 1066, 1071, and 1082. In comparison to the total fiscal income for each corresponding year, the Northern Song government’s annual expenditure on astronomy was about 0.07 per cent (see Table 7)—a remarkably strong and consistent figure. Costs of constructing astronomical instruments during the period are not included in our calculation, meaning that the actual expenditure on astronomy comprised an even larger percentage of the state’s total fiscal income. Assuming that expenditure on astronomers’ salaries remained at the same level as in 1082, then the government’s annual financial support for astronomy amounts to 43,792.2 strings (36,248.6 + 7,543.6), or 0.09 per cent of its total fiscal income.

It would be interesting to compare the Northern Song case with that of the earlier Tang dynasty (618-907), during which the imperial astronomical establishments were similar.5 Although it is even more difficult to estimate the Tang government’s expenditure on astronomy due to lack of data, we can still find some information about astronomers’ salaries. From existing sources such as the Tang huiyao 唐會要 (Collected Essentials of the Tang Dynasty), we estimate that the government’s expenditure on astronomical staff salaries for the years 666 and 736 was 1,636 and 3,763 strings of money respectively.6 The available sources often give contradictory numbers about the Tang state’s fiscal income, for instance, for the year 780, one source cites 10,898,000, another gives 30,000,000 strings of money; and historians’ opinions also differ considerably. However, it is safe to say that the income varied from 10 to 30 million strings of money.7 Even if we take the lower estimate, relatively speaking, the Tang government’s expenditure on

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4 Qi Xia (2001), pp. 146-161.
5 For a detailed study of the Tang astronomical establishments, see Wang Baojuan (1989).
6 Here we can only give very rough estimates. Another study would need to be undertaken to obtain more details and more accurate data.
7 For the year 780, Quan Hansheng (1948) cites the lower estimate while Ning Ke (2001, p.66) cites the higher.
astronomy only comprised 0.016 to 0.038 per cent of its overall fiscal income. This shows that the Northern Song government’s financial support for astronomy was much higher than that of the Tang government. During the Northern Song, astronomy received favourable support from the imperial government when compared to other technical sectors such as the Hanlin Academy’s Medical Academy, the Directorate for the Palace Building, the Directorate for Imperial Manufactories, and the Directorate of Waterways. Of course, governmental support took various forms, but we can still compare them by contrasting the rank and salary of the heads of these departments. For instance, in 1057, the astronomical director’s rank was 3b, with an annual salary of 1320 strings of money, while the medical director’s rank was the seventh, with an annual salary of 306 strings of money.

It would be simplistic to suggest that the more money invested in the salaries of Astronomical Bureau staff, the more astronomical research was carried out. On the contrary, during the Northern Song era, there were numerous complaints that too many members of the Astronomical Bureau held sinecure posts, being happy to receive salaries without doing any actual astronomical work. Indeed, at one point, Shen Kuo complained that the staff in one of the two establishments did not undertake any work of their own, but simply copied the other group’s reports. Nevertheless, the money spent on the astronomical staff salaries clearly indicates the government’s support for astronomy. Putting the question of efficiency aside, we can see that the Northern Song government gave astronomy ample and sustained financial support, which was unprecedented at that time.

During the Northern Song era, the Imperial Astronomical Bureau carried out nine astronomical reforms, each producing a new computational system, with improvements and innovations in both astronomical prediction and calendrical computation. It undertook at least eight projects

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8. A comparison with contemporary China illustrates how high this figure was. In 2009, China’s fiscal income was 6,266.5 billion RMB. The state investment in science and technology was 258 billion RMB, with support for astronomy comprising about 1 billion RMB, or just 0.016 percent of the state’s annual fiscal income. See [http://www.sts.org.cn/zlhb/2010/hb3.1.htm](http://www.sts.org.cn/zlhb/2010/hb3.1.htm) (accessed on September 18, 2011).


10. We are grateful to an anonymous reviewer for pointing this out. For Shen Kuo’s complaint about works at the Imperial Astronomical Bureau, see [Mengxibitan](http://www.sts.org.cn/zlhb/2010/hb3.1.htm), pp. 384-385.
for constructing astronomical instruments, with Su Song’s 蘇頌 (1019-1101) Water-Powered Astronomical Clock Tower being a high point of the development of mechanical engineering. It combined an armillary sphere for measurement, a celestial globe for demonstration, and devices for telling the time. With these instruments, astronomers at the Imperial Astronomical Bureau recorded frequently measured star positions, improving the accuracy of such measurements to an unprecedented level. The star catalogues and star maps of the Northern Song demonstrate the accuracy of measurements. There were also important innovations in the main time-keeping device, the clepsydra. Yan Su’s 燕肅 (961-1040) ‘Lotus Clepsydra’ (lianhua lou 蓮花漏) incorporated a new design that led to greater accuracy. Shen Kuo further discussed the water clock and improved it considerably. Without the Northern Song state’s sustained support, such astronomical achievements are unlikely to have been possible.\textsuperscript{11}

\begin{table}[h]
\centering
\caption{Northern Song Annual Expenditure on Astronomy as a Percentage of its Annual Fiscal Income}
\begin{tabular}{|c|c|c|c|}
\hline
Year & Expenditure on Astronomy (strings) & Fiscal Income (strings) & Percentage \\
\hline
1057 & 21,365.0 & 36,822,541 & 0.058\% \\
1066 & 36,605.0 & 44,000,000 & 0.083\% \\
1071 & 39,533.0 & 50,600,000 & 0.078\% \\
1082 & 36,248.6 & 48,480,000 & 0.075\% \\
1086-1092 & 43,792.2 & 48,480,000 & 0.090\% \\
\hline
\end{tabular}
\end{table}

\textsuperscript{11} Sun Xiaochun (2007), pp. 21f.
Conclusion

Our investigation reveals that the Northern Song government spent a considerable amount of its fiscal income on astronomy, much more than the previous Tang dynasty had done. This helps to explain why astronomy achieved great developments and innovation during the Northern Song period. The Northern Song state was characterized by its well-organized bureaucratic system, and astronomical activities were exclusively organized and paid for by the state. The Imperial Astronomical Bureau had, at times, more than 100 staff. The state’s patronage of astronomy was mainly made as salary payments to the many people employed at the Imperial Astronomical Bureau and the Hanlin Academy’s Astronomical Bureau. In addition to this expenditure, the government also frequently invested large amounts of money in astronomical instrument making. The water-powered astronomical clock tower constructed in 1086-1092, for instance, cost more than 45,000 strings of money, accounting for about one-thousandth of the imperial state’s total annual fiscal income. Such an undertaking would have been impossible without the state’s robust financial support. Astronomy was considered an important science for the Northern Song state, it was a state enterprise and was managed as a bureaucratic system. This article has shown how state support for astronomy during this period made it possible to maintain research teams and to carry out major astronomical projects.

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