THE DUNHUANG CHINESE SKY: A COMPREHENSIVE STUDY OF THE OLDEST KNOWN STAR ATLAS

Jean-Marc Bonnet-Bidaud
Commissariat à l'Energie Atomique, Centre de Saclay, F-91191 Gif-sur-Yvette, France.
E-mail: jean-marc.bonnet-bidaud@cea.fr

Françoise Praderie
Observatoire de Paris, 61 Avenue de l'Observatoire, F-75014 Paris, France.

and

Susan Whitfield
The British Library, 96 Euston Road, London NW1 2DB, UK.
E-mail: susan.whitfield@bl.uk

Abstract: This paper presents an analysis of the star atlas included in the medieval Chinese manuscript Or.8210/S.3326 discovered in 1907 by the archaeologist Aurel Stein at the Silk Road town of Dunhuang and now housed in the British Library. Although partially studied by a few Chinese scholars, it has never been fully displayed and discussed in the Western world. This set of sky maps (12 hour-angle maps in quasi-cylindrical projection and a circumpolar map in azimuthal projection), displaying the full sky visible from the Northern Hemisphere, is up to now the oldest complete preserved star atlas known from any civilisation. It is also the earliest known pictorial representation of the quasi-totality of Chinese constellations.

This paper describes the history of the physical object—a roll of thin paper drawn with ink. We analyse the stellar content of each map (1,339 stars, 257 asterisms) and the texts associated with the maps. We establish the precision with which the maps were drawn (1.5-4° for the brightest stars) and examine the type of projections used. We conclude that precise mathematical methods were used to produce the Atlas. We also discuss the dating of the manuscript and its possible author, and we confirm the date +649-684 (early Tang Dynasty) as most probable based on the available evidence. This is at variance with a prior estimate of around +940. Finally, we present a brief comparison with later sky maps, both from China and Europe.

Keywords: Chinese astronomy, Dunhuang Star Atlas, star catalogues, Silk Road.

1 INTRODUCTION

The Dunhuang Star Atlas is one of the most spectacular documents in the history of astronomy. It is a complete representation of the Chinese sky, including numerous stars and asterisms, depicted in a succession of maps covering the whole sky (Figure 1). Apart from its aesthetic appeal, this document found on the Silk Road is remarkable, as it is the oldest star atlas known today from any civilization.

This Atlas is unique in the information it gives, which is discussed in more detail below: a) more than 1,300 individual stars are represented, as could be observed by eye from the Chinese Imperial Observatory; b) the sky is displayed as in the most modern charts with twelve hour-angle maps, plus a North polar map; c) the Chinese constellations are indicated with their names; d) the atlas is drawn in two colours on the finest paper and accompanied by complementtary text; e) the document is shown to date from the early Tang period (+618-907), while the next-oldest Chinese star atlases date from the eleventh century.

The manuscript is very often quoted in encyclopaedic and popular publications as an illustration of Chinese astronomical knowledge. However, despite its crucial historical and scientific importance, no extensive description and analysis of the Atlas exists in Western literature. In 1959, Needham (1959: 264) reproduced part of the manuscript and gave only a very short description. Since then it has received only brief mentions in other studies (see Deng Wenkuan and Liu Lexian, 2003: 76; Sun Xiaochun and Kistemaker, 1997: 29).

We decided to undertake a detailed study of the Star Atlas after the exhibition on the Silk Road organised in 2004 by the British Library, where the document was shown and a preliminary analysis was given (Bonnet-Bidaud and Praderie, 2004). In the present paper, we shall first give a full review of the Chinese sources (Section 2), then give a general description of the Star Atlas (Section 3), examine the accuracy and the type of planar projection used and also present a method to give a date from astronomical arguments (Section 4). We then discuss the date of the Star Atlas, compare the Dunhuang Star Atlas with other Chinese atlases, and comment further on the status of these documents (Section 5). In the Appendices, we also include in-depth descriptions of two representative sections of the Atlas. This study was made possible by the use of high-resolution digital copies of the Star Atlas made available to us by the International Dunhuang Project.[1] This is the first publication in a Western language, and is aimed at making available basic information on this important document.

1.1 The 'Discovery' of the Star Atlas

Inscribed on a roll of Chinese paper, the manuscript star atlas is surprisingly well preserved. The conditions in which the document was found are well known and leave no doubt about its antiquity. It was discovered by the British-nationalised but Hungarian-born archaeologist Aurel Stein in 1907 among a pile of at least 40,000 manuscripts (Hamilton, 1986) enclosed in the so-called 'Library Cave' (Cave 17) in the Mogao ensemble, also known as the 'Caves of the Thousand Buddhas', near Dunhuang (Gansu). The Mogao caves are a set of several hundred Buddhist temples cut into a cliff and heavily decorated with statues and murals. The site was active from about +360[2] up to the end of the Mongol period. In about +1000, one cave was apparently sealed (Rong Xinjiang, 1999) to preserve a collection of precious manuscripts and some printed material, including the world's earliest dated complete printed book (Whitfield and Sims-Williams, 2004). The sealed cave was rediscovered by accident and re-opened only a few years before the arrival of Stein in 1907. He was therefore the first European visitor to see the hidden library.

These circumstances, together with the dry desert climate of Dunhuang, contributed to excellent conservation of the cave's contents. Most of the Dunhuang manuscripts are religious texts on Buddhism but there are some socio-economic documents and a few concern medicine, divination and astronomy (Kalinowski, 2003). The astronomical texts are all calendars or almanacs, with the exception of two star charts. One of them contains the representation of the whole sky as it could be observed from a latitude of ~34° N. This is now known as the Dunhuang Star Atlas. The other (which is probably only a fragment) represents part of the polar region, but not the rest of the sky.

After Stein's visit and subsequent visits by other foreigners such as Paul Pelliot, Otani Kozui and Sergei Oldenburg, the cave was cleared by the Chinese Government and the manuscripts were dispersed to England, France, Russia, China and Japan.[3] Stein's collections were transferred to the British Museum, where the Dunhuang Star Atlas received the registration number Or.8210/S.3326 (S. for Stein; hereafter this document is simply referred to as S.3326).[4] The other star chart (DB 76) is preserved in the Dunhuang City Museum in China.

S.3326 did not receive much attention at the time of its discovery. This manuscript, which is in two sections, was catalogued by Lionel Giles (1957). He listed it under the classification 'divination' (cat. no. 6974) for the first section and described the second section as "… 13 star-maps with explanatory text." He did not estimate a date. His catalogue was published in 1957 but it had been ready for publication since 1947.[5] Around this earlier date, Joseph Needham and Chen Shixiang studied the Stein collection of astronomy-related manuscripts when researching their volume on Chinese astronomy (Needham, 1959). In a footnote in the volume, Needham (1959: 264) claims to have been the one to recognize the worth of the star atlas: "I discovered this extremely interesting map in conjunction with my friend Prof. Chhen Shih-Hsiang." Needham is also probably responsible for the initial dating of this manuscript, quoted in most studies thereafter, as he continues (ibid.): "Its probable date makes it about contemporary with the maps in the 'Book of the Fixed Stars' ... (+903 to +986 …) …" and he puts the date at "ca. +940" in his text and captions to the reproduced images (his Figures 99 and 100).

Unfortunately, the Needham archives do not yield any further information about Needham's visit to the British Museum to view the manuscripts, nor his research notes (John Moffett, pers. comm., 9 January 2007). The astronomy volume was published in 1959 but most of the work was carried out between 1949 and 1956, when the manuscript for this volume was completed. It is probable, therefore, that the 'discovery' was in the early 1950s. By this time, Giles had completed work on his catalogue, although it was still unpublished, and could have directed Needham to the astronomy-related manuscripts.

2 THE CHINESE CONTEXT

2.1 Chinese Astronomical Background

Although we know that the sky was carefully observed for at least four millennia in China, India and Mesopotamia, what remains in written or graphical form of these observations is very patchy. China is noticeable, though, since astronomical chapters can be found in every one of the official dynastic historical records, starting in the second century BCE with the *Historical Records* (*Shiji* 史记)[6] of Sima Qian (司马迁) (Chavannes, 1895), generally considered to be the first history of China. The astronomical chapters of the *Shiji* include stellar catalogues, which are copies of older, lost ones composed during the Warring States period (–476 to –221). They are known to result from different schools led by three astronomers of ancient times, Shi Shen (石申), Gan De (甘德) and Wu Xian (巫咸), who composed reference books describing the stars and the different astrological predictions associated with them (Chavannes, 1895; Maspero, 1929). Although Sima Qian himself does not differentiate information from the three schools of astronomers, the three distinct catalogues were maintained through the Han period (–206 to +220) and later combined by the astronomer Chen Zhuo (陈卓) (+220-280). The tradition of attributing each asterism (or Chinese constellation) to a different school survived because of the demands of astrological prediction.

The most complete and detailed description of the Chinese sky, including positions given by coordinates in Chinese degrees, is later found in the *Astrological Treatise of the Kaiyuan Period* (*Kaiyuan Zhanjing* 开元占经), a compilation attributed to the astronomer Qutan Xida (瞿坛悉达) in +729. Part of this information is also present in the astronomical chapters of the *History of the Jin* (*Jinshu* 晋书) and *History of the Sui* (*Suishu* 隋书), both probably written by the astronomer Li Chunfeng 李淳风 (+602–670) (Ho, 1966; Needham, 1959: 197, 201).

Chinese astronomy differs from the ecliptic-based Chaldeo-Greek tradition by its equatorial character, due to the central role of the Pole Star (Biot, 1862; de Saussure, 1930). The celestial region close to the Equator is divided into 28 asterisms (group of stars), called *xiu* (宿), and often translated as 'mansions' or 'lunar lodges' (hereafter referred to as 'mansions'), which can be considered as an equatorial Chinese zodiac.[7] A mansion is defined by an hourly interval corresponding to the meridian passage of two successsive leading stars. The grouping of the stars in China is also totally different from the Greek tradition. Besides the equatorial region, the rest of the sky is divided into very numerous small asterisms (nearly three hundred), most associated with practical objects or persons of the Chinese Empire, leading to astrological predictions. Lists of the Chinese constellations were maintained all through Chinese history and did not change much over time. They form the basis of the Chinese astronomical tradition (Ho, 1966; Sun and Kistemaker, 1997).

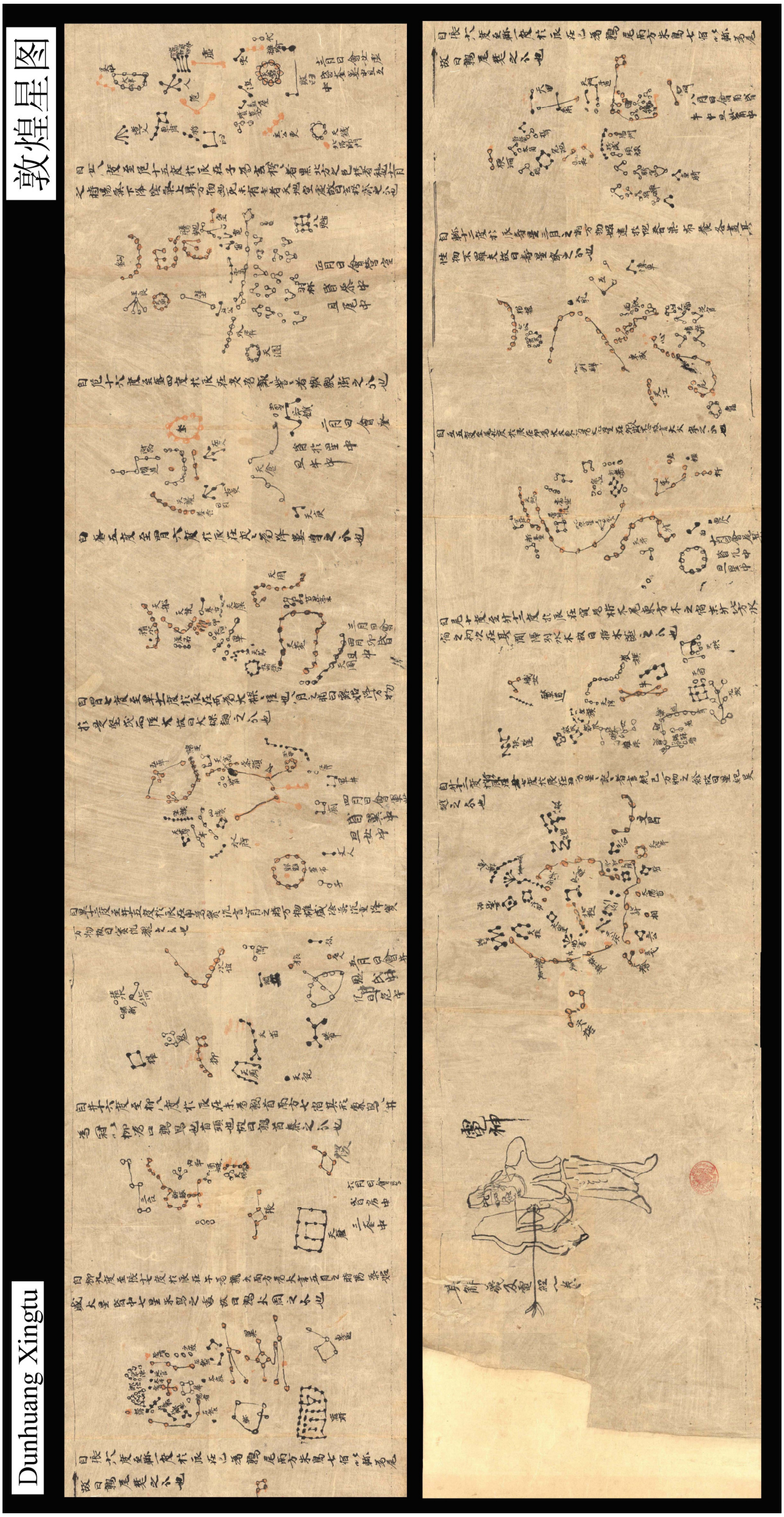

Figure 1: The complete Dunhuang Star Atlas, the last section of the Or.8210/S.3326 British Library manuscript, showing the twelve star maps (as seen above, from top to bottom and left to right), followed by the circumpolar map and ending with the drawing of a bowman in traditional clothes. The total dimensions are 2100 mm in length and 244 mm in width.

2.2 Review of the Chinese Sources on S.3326

Based on different photographic reproductions, Chinese scholars, both historians and astronomers, have produced several papers in Chinese about S.3326 since the 1960s.

Xi Zezong (1966) first published an article with complete images. He probably used facsimile images of S.3326 taken from the microfilm. He emphasizes the progress represented for the first time by the representation of the sky charts not on a circular plan but in a way similar to the Mercator projection, several hundred years before Mercator. He notes that the column texts accompanying each hour-angle map are similar to the ones found in Chapter 64 in the *Kaiyuan Zhanjing* and provides more complete versions based on this text. He then describes the hour-angle maps and the circumpolar map, giving the number of stars by asterism, with asterisms being ordered according to the mansions. He counts 1,359 stars in total and compares it to the Chen Zhuo list giving 1,464 stars following a compilation of the catalogues of Shi Shen, Gan De and Wu Xian (Needham, 1959: 265).

Ma Shichang (1983) paid particular attention to the dating of S.3326. While Needham (1959) mentions, without any justification, a date of ca. +940, Ma Shichang analyzes three elements in the document: a) the style of writing, b) the clothing of the bowman whose drawing ends the manuscript, and c) the taboo characters in the text.[8] He cites the taboo form of the character 民 (*min*) to infer that the manuscript was copied after the reign of Li Shimin (李世民), the personal name of the Taizong emperor (r. +626-649). He argues further that since the character 旦 (*dan*) occurs several times, the manuscript was written before the reign of the Ruizong emperor (i.e. before +710), who had this character as his personal name, Li Dan (李旦). Starting with his reign, the character 旦 should have been replaced. Ma Shichang narrows the time gap further by using the types of clothes worn by the bowman (see also Section. 5.1), saying that this type was in use only since the time of Empress Wu Zetian (r. +690-705). Since the manuscript has no Empress Wu taboo characters, it had to be written after her reign, i.e. after +705. From this evidence he concludes that S.3326 was written in about +705-710. His argument, however, contains inconsistencies (see also Section 5.1).

Pan Nai (1989: 148) also produced a description of S.3326, with a valuable discussion on its date. He is careful to point out the distinction between the original star atlas and copies and he notes that in the section of S.3326 devoted to divination, there is a possible reference to Li Chunfeng. He refutes the claim (made in Li Guohao, 1982) that S.3326 was inspired by *Songs of Pacing the Heavens (Bu Tian Ge* 步天歌) (Iannaccone, 2002; Zhou, 2004), a book dating to +590-600 with verses including some sky illustrations. Pan Nai supports the idea that there was an original star atlas prepared by Li Chunfeng from which S.3326 was copied. Considering the style of writing of the accompanying text, he proposes without any further argument that the copy may date from the tenth century, thus concurring with Needham (see also Section 5.1).

Deng Wenkuan (1996: 58ff), in the context of a study of astronomical texts and calendars found in Dunhuang, reproduces the S.3326 Star Atlas with explanatory notes and punctuated versions of the text. In a more recent book, Deng (2002: 25-37) dedicates a chapter to S.3326 and finds similarity with several other texts such as the astronomical chapters of the *Jinshu*, another text by Li Chunfeng (*Yisi Zhan* 乙巳占), and the *Kaiyuan Zhanjing*.

In a book on ancient Chinese star atlases, Feng Shi (2001: 330) also gives a brief survey of S.3326.

3 GENERAL DESCRIPTION OF S.3326

3.1 Physical Characteristics of the Manuscript

S.3326, now held at the British Library, is a paper scroll of total length 3,940mm and width 244mm. It is in reasonable condition. The thickness of the original paper is about 0.04mm (0.16mm with the modern lining). The manuscript is currently wrapped in a silk wrapper and supported by a wooden roller, both being later additions. The Chinese paper is very fine and a recent analysis revealed that it is made of pure mulberry fibres.[9] The scroll is fully lined with a brown Kraft paper.[10] The lining on the object is a treatment performed in the 1950s, its style and materials being consistent with the type of interventions performed during that period and the following decade at the British Museum. The microfilm provides further evidence. This was shot in 1953 and shows the manuscript already lined. It is possible that the Kraft paper lining was only added to the manuscript after Needham's discovery of it. It is clear that those items in the Stein Collection that received the most attention from scholars were those that received conservation treatment. The remainder were largely left in their original condition.

The scroll is inscribed on one side only. The beginning of the scroll is however missing so that there is no title or names of the authors. The bottom section is also missing at the beginning of the document. In some parts there are traces of replication marks by contact due to the long conservation in a rolled state. The document is divided into two different parts. From right to left, the first section is an uranomancy/ meteoromancy text containing 80 extant columns of text below 26 drawings of clouds of different shapes. In this part there is an interesting citation under column 43 which can be translated as "… according to your servant Chunfeng ..." (Deng and Liu, 2003; Pan, 1989), a possible direct reference to the astronomer Li Chunfeng. Lü Buwei (吕不韋) (ca. –291-235), advisor to the First Emperor of China, Qin Shihuangdi, is also mentioned (Figure 2; see also Section 5.1 below).

The star atlas follows this first section without a break. The atlas is 2,100mm in length and consists of 12 vertical maps, each with accompanying texts in columns on the left, followed by one map of the circumpolar region with no text, and one column at the end, making 50 columns and 13 maps in total. The full star atlas is presented in Figure 1. The very last part of Figure 1 is a drawing of a bowman in traditional clothes shooting an arrow and, judging by the caption to his right, this depicts the god of lightning. He is followed by what appears to be a title (to his left). It is common in Chinese manuscripts to note the title at the beginning and end of the document so it is most probable, therefore, that this title refers to the previous parts. However, the meaning of this title remains a mystery and it has not yet been possible to make sense of it;[11] moreover, a survey of Chinese historical and bibliographical sources failed to reveal a similar title.

3.2 The Astronomical Content

3.2.1 The Star Maps

The twelve star maps are arranged in separate hour-angle sections, beginning with the mansions of *Xu* (虛) and *Wei* (危) and covering the entire sky, namely the 28 mansions and their North and South prolongations, by slots of about 30° in the East-West direction. In each map, the Chinese asterisms with their names are drawn from declination about −40° to about +40°. The stars are shown as coloured dots, the majority of which are encircled in black. All dots are of similar size. Black lines joining the dots indicate the constellations or asterisms. The orientation is such that North is up and West is to the right so that the star right ascensions (or celestial longitudes) increase from right to left in the direction of the document. The Celestial Equator and the Ecliptic are not represented and the Milky Way is not apparent. There is no coordinate grid either. The thirteenth and last map is the North circumpolar region, represented as a planisphere of radius about ~40° (i.e. covering the declination zone from 90° to 50°). Obviously, the 12 maps are limited towards the South by the visibility above the horizon of the night sky from the Imperial Observatory, which might have been in Chang'an (present-day Xi'an) or Luoyang, both of which have a latitude of ~34° N.

Noticeably, S.3326 records however the presence of several very southern objects, hardly observable from Chang'an or Luoyang. On the map corresponding to the fifth lunar month (Map 6), the star *Laoren* 老人 (α Carinae, or Canopus) is displayed, though misplaced towards the north and closer to the Equator than it is in reality. Despite its southern position, the star is also included in Sima Qian's astronomical chapter. He indicates it symmetrically about *Tian Lang* 天狼 (α Canis Majoris, or Sirius) as "… a big star called 'the old man of the south pole' (*Nanji Laoren* 南极老人)." Also shown, are the very southern stars, *Beiluo shimen* 北落柿门 (Map 1 - α Piscis Austrini) and *Nanmen* 南门 (Map 9 - two stars of Centaurus), also reported by Sima Qian. This shows that Chinese astronomers explored the Southern sky and had done so long before the southern expedition of +724-725. This was led by Yi Xing 一行 (+683-727), a Tang astronomer who remeasured the positions of many stars in the Chen Zhuo list and established at least eleven observing stations, down to latitude 17.4° near Hué in present-day Vietnam (Beer et al, 1961).

The individual stars appear to have been taken from a composite catalogue, established by the astronomer Chen Zhuo, by merging the observations of the 'Three Schools' astronomical tradition (see Section 2.1). Although the Chen Zhuo catalogue, which is also said to have contained a star atlas (Ho, 1966: 67), is lost, *Kaiyuan Zhanjing* has preserved the list of constellations of the Three Schools, with 1,464 stars grouped in 283 asterisms. S.3326 contains similar information and is the first known document which shows stars as different coloured dots to differentiate between the astronomers of the Three Schools: Shi Shen (red), Gan De (black) and Wu Xian (white and/or yellow). Here the colour conventions are *grosso modo* followed. There are many changes however, which suggests that this tradition was less rigidly followed at the time S.3326 was drawn. We have counted 1,339 stars grouped in 257 asterisms, although some overlapping and some non-encircled dots prevent an accurate census. For the same chart, Xi Zezong (1966) gives 1,359 stars. We were able to identify all but fifteen asterisms, as their Chinese names are given on the map.

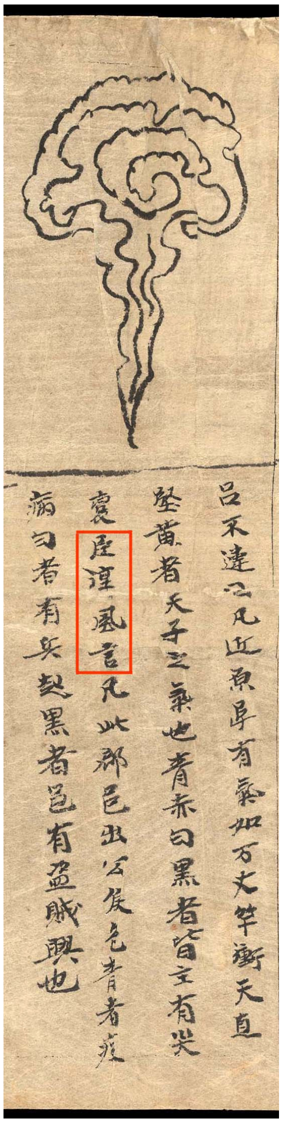

Figure 2: Part of the S.3326 first section (cloud divination texts). Columns 41 to 44 are shown, 41 to the right. The text (fully translated in Section 5.1 in the present paper) includes a reference to the possible author of S.3326, the astronomer Li Chunfeng (text in red frame).

Out of the 28 mansions, 27 are shown on S.3326, as a belt roughly following the Celestial Equator, and all show up with their leading star. The only missing one is *Wei* (胃) or belly which may be present in the eastern part of Map 3 but with a character including a mistake. As in the description by Li Chunfeng given in the astronomical chapters of the *Jinshu* (Ho, 1966), the Chinese sky exhibited by S.3326 displays the three *yuan* (垣 enclosures or wall systems), namely *Ziwei* (紫微), *Taiwei* (太微) and *Tianshi* (天市), which encircle different groups of stars. These are regions of the present Pole Star, α Ursae Minoris, and stars in

Draco and Cassiopeia for *Ziwei*; β Virginis and stars in Virgo for *Taiwei*; and ζ Ophiuchi and stars in Ophiuchus for *Tianshi*. All the bright stars visible from latitude 34° N are found on the map. As to the faintest ones, they correspond to naked eye observations of astronomers with very sharp eyesight. It is puzzling, as has been noted for a long time, that Chinese astronomers did not pay attention to visual magnitudes when drawing star atlases. This is the case with S.3326, where we estimate that stars as faint as visual magnitude 6.5 are present.

Figure 3: The Orion star map (Map 5, lunar month 4th). The map shows the recognizable Western constellation, Orion, and includes additional calendar texts (on the left) and culmination texts (at the bottom).

The document, drawn by hand and most possibly a copy, shows the positions of the stars with, in general, good precision (see Section 4.1). In Chinese astronomy, the large number of asterisms (257 as compared to the 88 modern constellations) allows one to specify fairly well the 'co-ordinates' of non-stationary heavenly bodies such as the Sun, Moon and five planets, and unexpected events such as 'guest stars' (comets or novae). None of the latter appears on S.3326.

We have noted some misplacements of stars or asterisms, which are either errors or show lack of attention on the part of the copyist. For instance, on Map 6 the asterism *Liu* 柳 (part of Hydra) should be at the same declination as *Nanhe* 南河 (containing α Canis Minoris) while on the map *Liu* is too far to the North. We also note that the same name appears for different groups of stars, but this is in accordance with Chinese tradition. For instance, *Tiantian* 天田 denotes an asterism south of the mansion *Niu* 牛 (Map 12) as well as an asterism of three stars north of the mansion *Jiao* 角 (Map 9). On Map 13, there are also two groups of three stars with the same name, *Sangong* 三公 (Three excellencies), one to the south of the handle of *Beidou* 北斗 , the other near the star α Ursae Major- is also in *Beidou*, but this appears here to be a faulty duplication. Finally, there is some confusion between left (*zuo* 左) and right (*you* 右) when denoting east and west relative to a given star or asterism. An example is found on Map 3, with *You-geng* 右更 being east and *Zuogeng* 左更 west of *Lou* and on Map 8 with *Youzhifa* east and *Zuozhifa* west of *Taiwei* 太微 (β Virginis). This seems in both cases an error of the author of the S.3326 map, an error which is not repeated on Map 12 where *Youqi* 右旗 is west and *Zuoqi* 左旗 is east.

Two representative maps, the Orion region (Map 5) and the circumpolar region (Map 13) are shown respectively in Figures 3 and 4 and are fully described in the Appendices.

3.2.2 The Calendar Texts (Jupiter Stations)

Each of the twelve hour-angle maps comes with an explanatory text in one or two columns located to the left. The north polar map has no such text.

The texts are a description of the twelve divisions of the Chinese year with their associated astrological predictions. In each map, the equatorial zone (including classically 2 or 3 mansions) is defined precisely by its extension in Chinese degrees,[12] and related to the corresponding station of Jupiter (the so-called 'year star'). The sidereal period of Jupiter being 11.86 tropical years, it was approximated to 12 years in Chinese tradition. The sky was therefore divided in twelve sectors, successively occupied by Jupiter in 12 years, and named Jupiter stations (*ci* 次). Moreover, each column text gives two more indications: the name of each terrestrial branch (one element in the enumeration of days in the Chinese calendar) associated with the Jupiter station, and the name of the state within the Chinese Empire supposedly influenced by that region of the sky (see Table 1).

As an example, the first map refers to the Jupiter station *Xuan Xiao*. The text reads:

> From the 8th degree of *Nü* to the 15[th] degree of *Wei*, associated with [the terrestrial branch] *zi*, is [the Jupiter station] *Xuan Xiao*. The colour of the North direction is black. When *Xu* [appears], [it will be] a bad harvest. At the 11[th] month, the spirit *yang* contracts, the spirit *yin* expands, the ten thousand beings [all creation] disappear into the darkness, there is no life, sky and Earth are without substance, the Sun [goes] into *Xuan Xiao*. This division corresponds to [the state of] *Q*i.

These texts are mainly of astrological use but the scientific notation in degrees reveals that they are based on astronomical observations and have been produced with the attempt to be as precise as possible for this period. Interestingly, a reduced version of similar texts is found in the astronomical chapters of the *Jinshu* with a later redaction commonly attributed to Li Chunfeng. This shortened version includes only the station extensions in degrees, the terrestrial branch and a more detailed association with Chinese states, but without any astrological predictions (Ho, 1966: 113-120). We have checked the S.3326 extensions and found them almost exactly the same as those of the *Jinshu*, with only very minor one-degree variations in three cases (Table 1).

We also note that in five cases (Maps 1, 4, 5, 7 and 9), the texts refer to a lunar month different from the corresponding map, in accordance with the long astrological tradition of considering a 'shadow planet' moving in the opposite direction of Jupiter (see Needham, 1959: 402).

The astrological comments were found by previous authors analogous to texts in the section *Fenye Lueli* (分野略例) of the astronomical treatise (Chapter 64) of the later *Kaiyuan Zhanjing*. Based on this complementary information, a completed version in Chinese of the twelve calendar texts was produced, restoring the punctuation and the missing characters since some of the texts seem abbreviated in S.3326 (Deng, 1996: 58; Xi, 1966). The S.3326 texts appear therefore more developed than those found in *Jinshu*, and may be a somewhat earlier preliminary version of those in the *Kaiyuan Zhanjing*.

Analysis of the stations' equatorial extensions in S.3326 shows that their lengths are approximately equal, with a mean value of 29.0° and a total range from 27.1° to 31.4° (for an Equator at date +700). A major difference occurs, however, for the Jupiter stations *Chun Huo* (month 6) and *Chun Wei* (month 7) with respectively extensions of 36.7° and 19.7° (Table 1). There appears to be an error of 10° in the extension of the mansion *Zhang*, which is given as 18° whereas the mansion's total extension is only 8° (the effect of precession will not vary this value by more than a fraction of a degree even as far back as –500).

Table 1 shows that the correspondence between Jupiter stations and Chinese mansions on the Dunhuang Star Atlas is almost exactly the same as that found on Figure 91 and Table 34 in Needham (1959). Actually the repartition of the mansions with respect to the Jupiter stations is conventional and seems to go back to a very old tradition (de Saussure, 1930). Since these calendar texts are based on Jupiter's cyclic behaviour, they do not provide useful astronomical information on the production date of the document.

3.2.3 The Culmination Texts

At the bottom of the maps, an additional text gives the major annual landmarks associated with the lunar month. Together with the number of the lunar month, one reads the position of the Sun with respect to the mansions present on the map and the culminating constellations at dusk and at dawn during the month. The first map is labelled "12th lunar month". For three maps (8, 10 and 12), these indications are absent or have been erased.

Table 1: The Calendar Texts and Comparison to Needham (1959).

Map[1]	Month	S.3326 Jupiter stations	S.3326 Jupiter Station Extensions	S.3326 Chinese Mansions[2] (from West to East)	S.3326 Month/ Branch/ State[3]	Needham's Jupiter stations[4]	Needham's Lunar mansions[4]
1	12	*Xuan Xiao*	from 8th ° of *Nü* to 15th ° of *Wei*	*Xu*, *Wei* (12)	11 / *zi* / *Qi*	5. *Xuan Xiao*	*Nü*, *Xu*, *Wei*
2	1	*Zou Zi*	from 16th ° of *Wei* to 4th ° of *Kui*	*Shi*, *Bi* (14)	- / *hai*/ *Wei*	6. *Qu Zi*	*Shi*, *Bi*
3	2	*Jiang Lou*	from 5th ° of *Kui* to 6th ° of *Wei*	*Kui*, *Lou*	- / *xu*/ *Lu*	7. *Jiang Lou*	*Kui*, *Lou*
4	3	*Da Liang*	from 7th ° of *Wei* to 11th ° of *Bi*	*Mao*, *Bi* (19)	8 / *yu* / *Zhao*	8. *Da Liang*	*Wei*[5], *Mao*, *Bi*
5	4	*Shi Chen*	from 12th ° of *Bi* to 15th ° of *Jing*	*Zui*, *Shen*, *Jing*	7 / *shen*/ *Wei*	9. *Shi Chen*	*Zui*, *Shen*
6	5	*Chun Shou*	from 16th ° of *Jing* to 8th ° of *Liu*	*Gui*, *Liu*	- / *wei* / *Qin*	10. *Chun Shou*	*Jing*, *Gui*
7	6	*Chun Huo*	from 9th ° of *Liu* to 17th ° of *Zhang*[6]	*Xing*, *Zhang*	5 / *wu* / *Zhou*	11. *Chun Xin*	*Liu*, *Xing*, *Zhang*
8	7	*Chun Wei*	from 18th ° of *Zhang* to 11th ° of *Zhen*	*Yi*, *Zhen*	- / *si* / *Chu*	12. *Chun Wei*	*Yi*, *Zhen*
9	8	*Shou Xing*	from 12th ° of *Zhen* to 4th ° of *Di*	*Jiao*, *Kang*	3/ *chen*/ *Zheng*	1. *Shou Xing*	*Jiao*, *Kang*
10	9	*Da Huo*	from 5th ° of *Di* to 9th ° of *Wei*	*Di*, *Fang*, *Xin*, *Wei* (6)	- / *mao* / *Song*	2. *Da Huo*	*Di*, *Fang*, *Xin*
11	10	*Xi Mu*	from 10th ° of *Wei* to 12th ° of *Dou*[7]	*Ji*, *Dou*	- / *yin* / *Yan*	3. *Xi Mu*	*Wei*, *Ji*
12	11	*Xing Zhi*	from 12th ° of *Dou*[7] to 7th ° of *Nü*	*Niu*, *Nü*	-/ *chou*/ *Wu-Yue*	4. *Xing Ji*	*Dou*, *Niu*

1 The Dunhuang S.3326 maps are numbered 1 to 12, according to their order in the document, with Map 1 corresponding to the Winter solstice.
2 Chinese mansions (*xiu*) with the same pinyin names (such as *Bi* (14) and *Bi* (19)) are distinguished by their order number, as in Needham (1959: Figure 91 on page 243).
3 Lunar month used for predictions and the name of the corresponding state as indicated in the astrological text.
4 Correspondence between Jupiter stations (*ci*) and Chinese mansions (*xiu*) from Needham (1959: Figure 91 on page 243, and Table 34 on page 403).
5 The *xiu Wei* (17) is absent from the S.3326 map.
6 An apparent copyist error, introducing a very unequal station (see text).
7 Between months 10 and 11 the station extension is noted with the same degree on the map (from 12th ° of *Dou*) instead of increasing by one degree as in the other extensions.

Table 2: The Culmination Texts.

Map	1	2	3	4	5	6	7	8	9	10	11	12
Lunar Month	12	1	2	3	4	5	6	7	8	9	10	11
Major Western Constel-lations on S.3326	Cygnus Pegasus Aquarius	Andro-meda Pegasus Pisces	Aries Cetus Andro-meda	Perseus Taurus Eridanus	Auriga Orion Lepus	Cancer Canis Major Gemini	Leo Hydra	Virgo Corvus Canes Venatici	Bootes Virgo Lupus	Serpens Ophiuchus Scorpius	Herculus Ophiuchus Sagittarius	Lyra Aquila Capri-cornus
S.3326												
Chinese mansions (*xiu*)[1] on S.3326	*Xu* *Wei* (12)	*Shi* *Bi* (14)	*Kui* *Lou*	*Mao* *Bi* (19)	*Zui* *Shen* *Jing*	*Gui* *Liu*	*Xing* *Zhang*	*Yi* *Zhen*	*Jiao* *Kang*	*Di* *Fang* *Xin* *Wei* (6)	*Ji* *Dou*	*Niu* *Nü*
Sun con-junction	*Nü* *Xu*	*Shi*	*Kui*	*Wei* (17)[2] *Mao*	*Bi* (19) *Zui*	*Jing* *Gui*	*Xing*	*no text*	*Jiao*	*no text*	*Wei* (6) *Ji*	*no text*
Dusk culmination	*Kui* *Lou*	*Shen*	*Liu* *Xing*	*erased?*	*Yi*	*??Kang*	*Fang*	*no text*	*Niu*	*no text*	*Kang*[3]	*no text*
Dawn culmination	*Di*	*Wei* (6)	*Niu*	*erased?*	*Nü*	*Wei* (12)	*Kui*	*no text*	*Zui*	*no text*	*Xing*	*no text*
Yueling[4]												
Sun conjunction	*Nü*	*(Ying)* *Shi*	*Kui*	*Wei* (17)	*Bi* (19)	*Jing*	*Liu*	*Yi*	*Jiao*	*Fang*	*Wei* (6)	*Dou*
Dusk	*Lou*	*Shen*	??	*Xing*	*Yi*	*Kang*	*Huo* /*Xin*[5]	*JianXing*	*Niu*	*Xu*	*Wei* (12)	*Bi* (14)
Dawn	*Di*	*Wei* (6)	*Dou*	*Niu*	*Nü*	*Wei* (12)	*Kui*	*Bi* (14)	*Zui*	*Liu*	*Xing*	*Zhen*

1 Chinese mansions (*xiu*) in pinyin transcriptions are given from West to East on the maps (right to left). Mansions with the same pinyin names (such as *Bi* (14) and *Bi* (19)) are distinguished by their order number as in Needham (1959: Figure 91 on page 243).
2 *Wei* (17) is the only *xiu* missing graphically in the Star Atlas. A character in the eastern part of panel 3 could be *Wei* but with a mistake.
3 *Kang* does not correspond to a possible astronomical configuration; this is a possible copying error.
4 After Legge (1885); see, also, Couvreur (1913).
5 The term *huo* (火) also designates the *xiu xin* (心).

As an example, at the bottom of Map 1 (12th lunar month), one reads:

> The twelfth (lunar) month, the Sun meets the mansions *Nü* and *Xu*; at dusk the mansions *Kui* and *Lou* culminate; at dawn the mansion *Di* culminates.
> 十二月 - 日會女虛 - 昏奎婁中 - 旦氐中

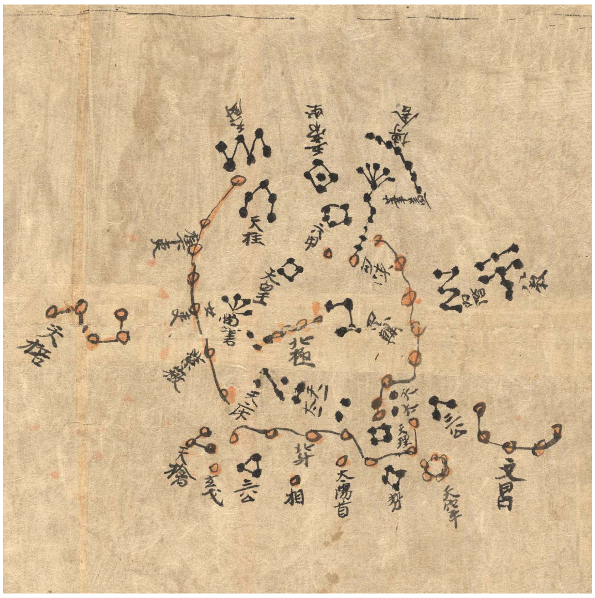

Figure 4: The North circumpolar region (Map 13). The map displays from the polar region down to a celestial latitude of about +50°.

The astronomical content of these texts is summarized in Table 2. According to different authors (Deng, 2002; Pan, 1989), these monthly texts are identical to those found in an early text, the *Monthly Ordinances* (*Yueling* 月令), that can be found both in the historical text *The Spring and Autumn Annals* (*Lüshi Chunqiu* 呂氏春秋), dated –240, and in a chapter of the *Classic of Rites* (*Liji* 礼记), dated approximately to the third or second century before the modern era. For comparison, the corresponding information from the *Yueling* texts is also given in Table 2, according to Legge's translation (Legge, 1885; see, also, Couvreur, 1913). Despite an overall similarity, there are notable small differences between *Yueling* and S.3326. For the culminations of mansions at dusk and dawn, the differences only affect months 2, 6 and 10 (out of the 9 months for which these texts are present in S.3326), with at least one obvious copying error (see Table 2).

Interestingly enough, for the solar conjunction with the mansions, the months 3, 4, 5, 10 and 12 are given with two mansions instead of one, the second one always with a higher right ascension than the mansions in *Yueling*. If interpreted as corrections to take into account the effect of precession for a period later than that of the *Yueling*, this is opposite to what would be expected. The culmination texts on the maps can however be dated by comparing them with known astronomical configurations (see Section 4.2).

3.3 The Pole Star

The circumpolar map is fully described in the Appendices (see Section 10.2) and is shown in Figure 4. As was usual in the Chinese sky representations, the north polar region features the central Purple Palace with the Celestial Emperor at the Pole, surrounded by his family, servants, military officers and the corresponding housing.

According to Gaubil (1819), and also quoted by de Saussure (1930), the star β Ursae Minoris was adopted as the Pole Star by the Chinese about –1000, and named *Di* (the first ancestor), but it was distant by 6° 30′ from the real Pole. Due to the precession of equinoxes, the astronomical North Pole describes a circle around the Ecliptic Pole in 25,800 years. Recognising the North Pole Star would therefore be a means of dating the sky map. On S.3326 the asterism *Beiji* is clearly drawn, with four red stars encircled by a black line (γ Ursae Minoris, β Ursae Minoris, 5 Ursae Minoris, and 4 Ursae Minoris). Another star is red and pale, not encircled in black, and is located near 4 Ursae Minoris. It is not easily identifiable in modern terms. The Pole Star is not indicated as such on the map. It could be that red pale spot, but it would be strange that the star figuring the supreme ruler should be so inconspicuous on the map. Quite different to the Suzhou sky map (see Section 5.2), on S.3326 the Pole Star cannot be seen within the asterism *Sifu* (the four advisors). We therefore conclude that for some reason the Pole Star is not shown on S.3326. However, the type of projection used to represent the polar region in S.3326 allows us to date the map, even if there is no graphical representation of the Pole itself (see Section 4.1).

4 SCIENTIFIC EVALUATION OF S.3326

4.1 Accuracy and Projection Study

S.3326 is a unique document as it presents a display of the full sky in a very 'modern' way, including a set of hour-angle maps in cylindrical-type projection, combined with a circumpolar map in azimuthal projection. This is the way most geographical maps are still presented today. Unlike most other ancient astronomical artefacts (i.e. the Denderah Zodiac or the Farnese Globe, see Section 5.2) which only show constellations figures without individual stars, it also provides a large number of star positions, grouped in asterisms each clearly labelled so that only a few ambiguities remain. In this sense, it can be considered as a scientific document and its accuracy can be tested.

To evaluate the accuracy of the star positions in the maps we made use of only the brightest stars (i.e. $m_v < 3$). Identifications were made using mainly the list provided from the study of the Han catalogues (Sun and Kistemaker, 1997: 44), but other traditional compilations (e.g. Ho, 1962) were also used as a check. We have further selected only the stars for which no ambiguity exists as to their identification by name, though in some cases slightly different positions are still possible, thereby adding probable systematic errors. The star positions on the maps were measured from the high-resolution scans provided by the British Library. A ruler is present in each scan that allows conversion to the physical size. The scan scale (204.8 pixel/cm) yields a precision an order of magnitude better than the size of the symbols on the maps. The typical size of the dots marking the stars (~0.2 cm) is indeed the limiting factor, so that the accuracy of the measurements can therefore be estimated to be <0.1 cm.

The star positions on the maps were compared to the stars' equatorial coordinates (right ascension and declination), corrected for proper motion and precessed to the date +700 (using ESA, 1997, for proper motions). As no absolute references are present in the document, the effect of precession is not fully relevant here (see, however, below for the position of the North Pole).

To evaluate the maps' accuracy, some assumption has to be made on the projection used. We tested the hour-angle maps with the two simplest versions of the cylindrical projection (pure-cylindrical and Mercator) and the circumpolar map with two azimuthal projections (equidistant and stereographic). In each case, the accuracy in the two coordinates (right ascension and declination) was evaluated separately to judge for the effect of different scales.

The best parameters of the projections consistent with the measured positions (X, Y) were determined by least-square fits with fitted function as:

For the hour-angle maps:

Pure-cylindrical projection:-

$$RA = a + b.X \text{ and} \quad (1)$$

$$DEC = c + d.Y \quad (2)$$

Cylindrical-Mercator projection:-

$$RA = a + b.X \text{ and} \quad (3)$$

$$DEC = c + d.\ln\left[tg\left(\frac{\pi}{4} + \frac{Y}{2}\right)\right] \quad (4)$$

For the circumpolar map:

Azimuthal equidistant:-

$$RA = a + b^{*}\text{arctg}(Y/X) \text{ and} \quad (5)$$

$$\frac{\pi}{2} - DEC = c + d.\left(X^2 + Y^2\right)^{\frac{1}{2}} \quad (6)$$

Azimuthal stereographic:-

$$RA = a + b^{*}\text{arctg}(Y/X) \text{ and} \quad (7)$$

$$tg\left(\frac{\pi}{2} - DEC\right) = c + d.\left(X^2 + Y^2\right)^{\frac{1}{2}} \quad (8)$$

where (RA and DEC) are the star's predicted position, (X and Y) the star's measured position, and (a and c) and (b and d) respectively the zero points and scale factors for each projection.

Table 3 gives representative results of the fits for three selected hour-angle maps (Maps 1, 2 and 5) and for the circumpolar map (Map 13).

The general quality of the document is illustrated by the mean residuals (in degrees) and values of R, the associated correlation coefficients.[13] For the hour-angle maps, the regression factor is always quite good, ranging from 0.91 to 0.99, with a markedly better correlation in the vertical (declination). The residuals are of the order of a few degrees only, with the best accuracy (~1.6°) achieved in Map 5. One notices also a significant difference between the horizontal (right ascension) and the vertical (declination) scales, the latter always being larger. This means that the projection is not strictly conformal (equal scales), but the scales are consistent from one map to another. The typical scale is ~4.5°/cm (horizontal) and ~5.5°/cm (vertical). The extensions and the geometrical centre of the maps have been computed from the star extreme fit positions. From one map to the other they are very similar (~50°) in right ascension but more variable in declination (70° to 100°), though more or less centred at the Equator. The comparison of the different types of projection, 'pure cylindrical' vs 'Mercator', does not yield a significant difference in the quality of the fit, as shown by the corresponding similar regression factors. Within the uncertainties, both projections are therefore in equal agreement with the maps. For illustration, Figures 5 and 6 give the correlation results for Map 5, as well as the reconstructed positions using the fitted scales.

Table 3: The Projection Results.

	Map 1	Map 2	Map 5	Map 13
Input stars[1]	19	12	17	22
Selected stars[2]	16	10	15	19
Right Ascension (RA) fit	*Horizontal*	*Horizontal*	*Horizontal*	*Azimuthal*
Scale factor (°/cm)	4.40	4.24	4.56	1.05
Mean residuals (°)	3.54	4.63	2.26	1.67
Correlation coefficient[3]	0.947	0.957	0.907	0.995
Declination (DEC) fit	*Vertical*	*Vertical*	*Vertical*	*Radial*
Scale factor (°/cm)	5.40	7.66	5.28	5.10
Mean residuals (°)	3.57	4.07	1.61	3.29
Correlation coefficient	0.974	0.975	0.996	0.919
Correlation coefficient Mercator	0.972	0.974	0.994	-
Correlation coefficient Stereographic	-	-	-	0.932
Map Dimensions				
Map centre (RA)	308°	344°	73°	-
Map limits (RA)	284 to 332°	321 to 366°	49 to 97°	-
Map extension (RA)	48°	45°	48°	-
Map centre (DEC)	+0.3°	+10°	+8°	+87.6°
Map limits (DEC)	−44° to +45	−41° to +61°	−27° to +43°	+90° to +52°
Map extension (DEC)	89°	102°	70°	48°
Geometrical centre (DEC)	–14°	–8°	+5°	

1 Input stars selected according to their magnitudes.
2 Selected stars for the fit after rejection of the largest deviations.
3 The correlation coefficient, R, is the Pearson least-squares fit parameter where R = 1 is a perfect fit and R = 0.76 and 0.68 for a random probability of 0.01% and 0.1% respectively.

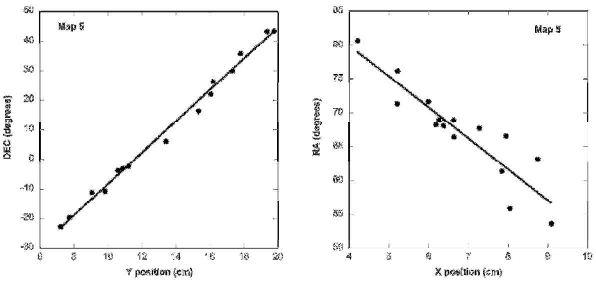

Figure 5: The regression factors and residuals (Orion, Map 5). Least-square fit of the measured *X-Y* positions with a pure cylindrical-projection. Note the very good correlation in the vertical scale (*Y*-declination).

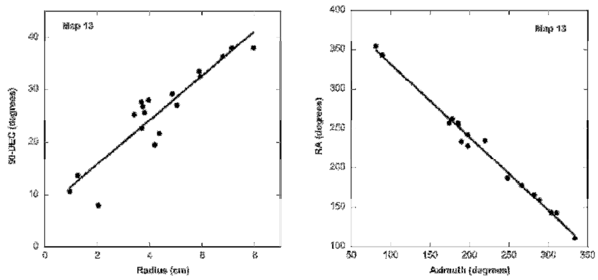

Figure 7: The regression factors and residuals (North polar region, Map 13). Least-square fit of the measured polar distance (radius) and azimuth with an azimuthal equidistant projection. Note the good azimuth correlation.

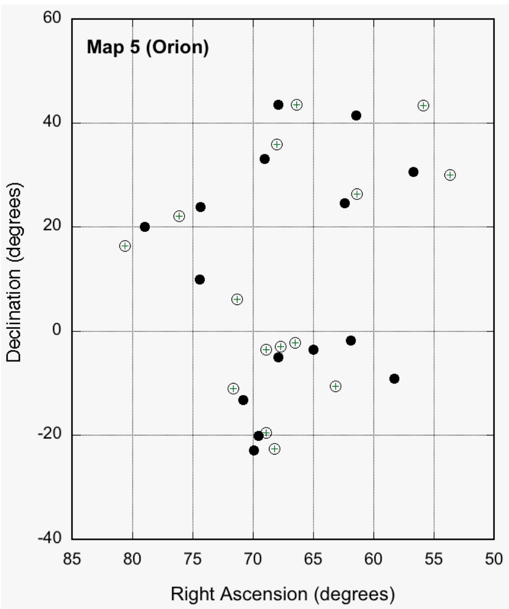

Figure 6: Computed vs measured positions (Orion, Map 5). The measured positions from the best fit cylindrical projection (filled circles) are compared to star positions for +700 (open circles with crosses). Note the good accuracy in declination.

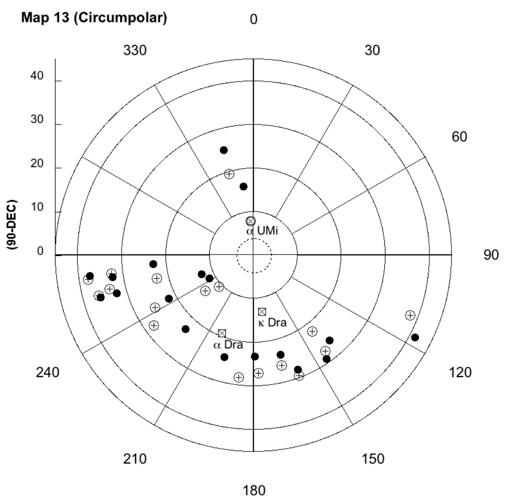

Figure 8: Computed vs measured positions (polar region, Map 13). The measured positions from the best fit azimuthal projection (filled circles) are compared to star positions for +700 (open circles with crosses). Also shown is the measured uncertainty in the Pole position from the best fit (dotted circle) and the different positions of the Pole (open squares with crosses) at dates of about +2000 (α Ursae Minoris), –1000 (κ Draconis) and –2500 (α Draconis).

For the circumpolar map (Map 13), the results are also given in Table 3 in terms of the azimuthal fit (hour-angle) and radial fit (polar distance). The azimuthal fit is extremely good, with a correlation coefficient of 0.995 and mean residuals of 1.7°. With a scale factor of 1.05 ± 0.03, there is also no significant distortion from the theoretical value (1.0) for the azimuthal projection. Comparatively, the radial fit is notably poorer (R = 0.92) with mean residuals of 3.3° and significant distortions in the polar distances (see Table 3 and Figure 7). The comparison of the 'pure equidistant' projection with the 'stereographic' projection gives a slightly better fit for the latter (R = 0.93), but strictly speaking this is not statistically significant. Although some distortions obviously exist (Figure 8; see, also, Section 10.2 in the Appendices), the overall accuracy of the projection is well preserved.

Interestingly, the correlation study also provides an indication of the expected position of the Pole on the map with respect to the reference position at date +700. The measured shift in polar distance of the Pole reference point (0,0 in Figure 8) between the S.3326 map and the sky at date +700 is only marginally significant with a difference of (3.9 ± 2.9)°. This position and the associated uncertainty is compared in Figure 8 with stars that were close to the Pole at different dates, namely α Ursae Minoris (~ +2000), κ Draconis or β Ursae Minoris (~ –1000) and α Draconis (~ –2500). Within the above uncertainties, the Pole is fully consistent with a +700 date.

The numerical study of the S.3326 document yields important results. The atlas is not a simple hastily hand-made reminder but was established according to precise geometrical rules. The projection methods used are consistent with either a pure-equidistant or the Mercator projection for the rectangular maps and with the azimuthal-equidistant or stereographic projection for the circular one. This is in line with similar results obtained on two later Song period maps, the Suzhou 苏州 Planisphere and the *Xin yixiang fayao* 新仪象法要 rectangular map (see Miyajima, 2002).

In all cases, the correlations are very good, which eliminates any random coincidence. Based on the brightest stars, the general positional accuracy of the maps is of the order of 1.5°-4°. The layout of the rectangular maps is reasonably good with similar scales from one to another, but with ±5° variation in the location of the Equator. The maps appear therefore as probable hand copies of a previous more accurate document, although the method of reproduction is not clear. The fineness of the original paper might have allowed for the maps to be traced from a clear original. It has nevertheless preserved a remarkable accuracy. It should be noted, however, that this accuracy study is based on selected bright stars only. The overall accuracy is well preserved, but there are local significant differences in the positions of some individual stars (e.g. β Canis Majoris in Map 5 and α Carinae (*Laoren*) in Map 6). In some parts, the geometrical shape of numerous asterisms appears also highly approximate and even fanciful.

4.2 Analysis of the Culmination Texts : An Attempt at Dating

Temporal information can also be extracted from the Dunhuang maps using the culmination data contained in the texts added to at least eight out of the twelve maps. In these texts, the given information is the number of the month, the name of the mansions through which the Sun passes during that month, and the names of the mansions which culminate (i.e. cross the meridian) at dusk and dawn during the month. This information does not change appreciably from one year to another, but over a longer time-scale the slow effect of the precession of the equinoxes introduces a significant shift in the position of the stars defining the mansions with respect to the Sun.

We have calculated the effect of precession in a period ranging from –500 to +900, which corresponds to the most likely interval when the information could have been produced. The definition of the mansions and more precisely their leading stars, have been taken from the list by Needham (1959: 234-237, Table 24). Standard precession has been applied without introducing proper motion, which is negligible for this list of stars.

The Sun's position along the Chinese zodiac formed by the mansions was computed for each chart at mid-month, and a common Chinese year starting on 5 February was assumed. This is the exact middle date for the variable Chinese luni-solar calendar (see Aslaksen, 2003: 27). For each month, the equatorial solar coordinates (right ascension and declination) were computed from astronomical formulae as well as using planetarium software (Voyager v. 4.0.3), and three different indicators were computed.

The Sun's position indicator, $H_{\rm sun}$, was defined as the difference in right ascension between the Sun and the leading star of the mansions indicated in the map. In the case when two mansions are indicated in the map, the mean right ascension of the two mansions was used. Two other parameters, the rise ($H_{\rm rise}$) and set ($H_{\rm set}$) indicators, are defined as the difference in right ascension between the culminating right ascension and the mansions indicated respectively for the rising and setting time in the maps.

The culminating right ascension is simply the sidereal time (*ST*) at sunrise and sunset, and can be computed using standard formulae:

$$ST_{rise} = 24 - \frac{1}{15}\arccos\left[-tg\phi.tg(DEC)\right] + RA \qquad (9)$$

$$ST_{set} = \frac{1}{15}\arccos\left[-tg\phi.tg(DEC)\right] + RA \qquad (10)$$

where *RA* and *DEC* are the Sun's equatorial coordinates on the date and φ is the observer's latitude. In these equations a latitude of 34° was used, corresponding to the city of Chang'an (present-day Xi'an) but also compatible with Luoyang, the eastern capital of China. For each epoch, from –500 to +900 in 100-year steps, the indicators were computed for each month and their mean value and standard deviation for each epoch were evaluated.

The $H_{\rm sun}$ mean value is plotted in Figure 9 against time. Due to the effect of precession, it shows a continuous decrease, from +0.25 hr at –500 to –0.27hr at +900. A best date for a minimum shift can therefore be interpolated and is computed to be +85 with an interval (−40 to +220) according to the mean statistical errors. An important dispersion around the mean value is present from month to month (up to 0.5hr), which is reflected in the significant error bars.

Some caution has to be voiced about this absolute dating of the chart texts since there is no clear indication that our basic assumptions that the Sun's position is considered at mid-month and that the mansions are given by their leading stars (the starting points of the mansion*s*) are correct. If the mansion positions were identified with their mid-extensions or the Sun was considered at the beginning of the month, the absolute dates will be shifted in the past by quite a large amount, not consistent with the supposed period.

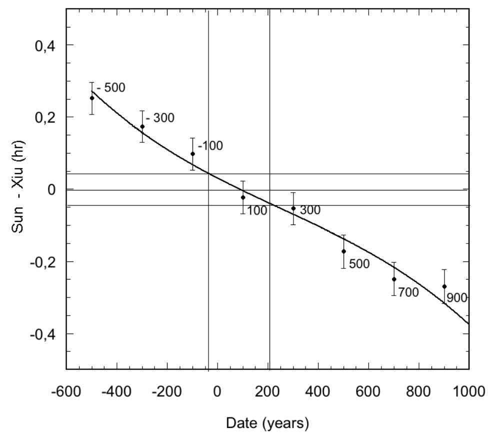

Figure 9: Dating from the culmination texts. The time difference between the Sun's position and the mansion (*xiu*) indicated in the culmination texts as a function of time. Shown is the mean Sun position indicator, H_{sun}, an average value over the 12 months for each epoch. Note the large error bars reflecting the important dispersion of the monthly values around the mean value. From a polynomial interpolation (thick line), the minimum difference is found at date ~+85 with an interval (−40 to +220) according to the mean errors (shown by vertical lines).

5 THE STATUS OF S.3326

5.1 Dating the Document

The exact dating of S.3326 is a difficult task. It is necessary to distinguish between the following factors:

(a) The date of the paper support itself. The nature of the paper makes it similar to those used in China up to and including the Tang Dynasty (+618-907), although its extreme thinness and long pure mulberry fibres make it an expensive paper, not an everyday paper. Such paper was almost certainly made in Central China and probably under Imperial order in the capital, Chang'an. More precise dating by means of radioactive carbon (C^{14}) should be possible but has not been attempted yet.

(b) The date indicated by its possible author. The scroll S.3326 lacks its original front cover that could have guided us for this purpose. However, there is a phrase in the initial uranomancy section which reads: "chen Chunfeng yan …" (臣淳风言). This translates literally as "your servant Chunfeng says …" It is a part of a paragraph (see Figure 2) which reads:

> Lü Buwei said that, as a general principle, when you approach a mound on a plain and there are air vapours in the shape of a staff reaching high up into the sky, straight and firm; if it is yellow, it is the colour of the Son of Heaven (i.e. the Emperor). Blue, red, white and black all mean the presence of tears and grief. Your servant Chunfeng says that as a general principle such prefectures and cities produce dukes and knights. With regard to colours, blue means deliverance from sickness, white that an army is being raised, black that robbers and thieves are increasing in the city.[14]

This is an argument for considering Chunfeng as a possible author of either the S.3326 manuscript itself or the original (if it is a copy). The only person mentioned in historical records at this time who had the right expertise with this name was Li Chunfeng, an outstanding figure in astronomy and mathematics. The phrase "Your servant … says …" is formulistic and the absence of the family name is a sign of modesty when referring to oneself in company with a famous man, here Lü Buwei, but it obviously makes the attribution to Li Chunfeng less certain. Moreover, this statement is extremely similar to the one used to introduce the commentaries by Li Chunfeng in the mathematical treatise *The Nine Chapters on the Mathematical Art* (Jiuzhang Suanshu, 九章算术).[15] As Li Chunfeng was also a highly-skilled mathematician, it is quite reasonable to think that he had the necessary expertise to design the projection methods used in the chart. The mention of Li Chunfeng would therefore put the period the document at about +650-670, when he was active.

(c) The date suggested by the style and form of the writing. Just as for European manuscripts, the style of the handwriting can be used to help date Chinese manuscripts. Pan (1989), in the article discussed above, suggested that the manuscript is a tenth-century copy, but I. Galambos (pers. comm., 2008) believes that the handwriting is more typical of an earlier period, fitting with a seventh or early eighth century date, and Ma (1983) in the article discussed above also follows this view. The handwriting is not that of a professional scribe, who would have written in a much neater and more regular hand and might, if required, have copied an earlier style. It is individualistic, and this suggests that the writer was using his own hand and was following the conventions of his time. This is relevant to the use of taboo characters, which are another clue to dating (see below).

(d) The date suggested by the taboo form or 'spelling' of the Chinese characters. Taboo characters are peculiar to Chinese texts (see Note 8). As discussed above, Ma (1983) points out the use in the Star Chart of the taboo form of '*min*', one part of emperor Taizong's personal name, confirming a date after the end of his reign (i.e. +649 onwards). He also points out that the character '*dan*', forming emperor Ruizong's personal name, is in its standard, non-taboo form. This suggests a date before this emperor came to the throne. Ma gives this as +710. However, Ruizong also ruled briefly in +684 (e.g. see Fairbank and Twitchett, 1979), and the taboo form should have been in effect from this earlier date. There are no other characters from later emperors' or empresses' names appearing in the manuscript in either standard or taboo form. This is fairly strong evidence that the manuscript dates from between +649 and +684. The individualistic style of the handwriting supports this conclusion: it is not the handwriting of a scribe paid to make an exact copy of an earlier manuscript. These two pieces of evidence seriously challenge Needham's +940 date.

(e) The date suggested by the drawing, which Ma Shichang argues is a style common during Empress Wu Zetian's reign. The clothing is fairly generic, but the official hat does provide some useful supporting evidence (see Figure 10). From the tenth century it became common for officials to starch their hat flaps so that they stuck out horizontally. This image shows unstarched hat flaps, also suggesting an earlier date.

(f) The date of the sky epoch as it is graphically represented in the maps. This is provided by the astronomical analysis presented here. The sky configuration may be dated using (a) the location of the Celestial Equator in the stellar maps, and (b) the position of the Pole in the circumpolar map. On the short stretch of each hour-angle map, the location of the Celestial Equator is too imprecise to be a useful constraint (see Table 3). However, the projection analysis of the circumpolar chart gives a meaningful constraint on the position of the Pole (Figure 8). The configuration is fully consistent with a date around +650.

(g) The date corresponding to the additional culmination texts. The analysis of the Sun's position among the mansions as indicated in the maps, points to a configuration at dates −40 and +220, which puts these texts at an earlier epoch than the maps. This suggests that the texts in the document may be a compilation from different sources.

From our analysis, it is likely that both the original document and its possible copies were produced in the interval +649-684, at the beginning of the Tang Dynasty, a period rich in significant works on astronomy. This precise date range is provided by the 'taboo characters' and is consistent with all other estimates. This date range encompasses a time contemporary with Li Chunfeng, and is earlier than the period when the important astronomical text *Kaiyuan Zhanjing* was produced. It also corresponds to the full apogee of the Tang domination in the Gobi region where the manuscript was found. The preliminary date of about +940 initially suggested by Needham—but on grounds that we were unable to trace—is certainly not confirmed by our analysis, although it is still compatible with the date at which the Dunhuang library was sealed (c. +1000). At this time China was divided and so the conditions were certainly less favourable for production of such a sophisticated scientific document.

5.2 A Comparison with Other Sources

It is outside the scope of this paper to review all the different sources where a pictorial representation of the sky is included, but what we will do here is consider S.3326 in relation to other important early artefacts with similar contents.

In China, before the Dunhuang Map, only a few documents or artefacts had graphical depictions of the sky, and none showed it in its entirety. Among the oldest such artefacts is a lacquered box found in 1978 in Sui County (Hubei), in the tomb of the Marquis of Yi. Dated from −430 (Warring States period), it is decorated with the first-known representation of the 28 mansions encircling the central *Bei Dou* (Ursa Major), but has no other detail on the sky (Li Changhao, 1987: 45; Rawson, 1997). Later sky representations were also found in the ceilings of different tombs such as the Jiatong Tomb, dated −25 (Stephenson, 1993) and the Luoyang Tomb, dated +526 (*Album of Ancient Relics …*, 1980), but all contain a very limited fraction of the sky. The closest comparable document to S.3326 is the already-cited *Bu Tian Ge* (Iannaccone, 2002; Zhou, 2004). This book, dating from +590-600, includes sky illustrations with stars and asterisms comparable to the Dunhuang Map, but limited only to the mansions at the Equator and the North circumpolar region. Although it may be considered as a preliminary version, it is by no means as complete and accurate as S.3326.[16]

Figure 10: The last section of the S.3326 document showing the image of a bowman in traditional clothes shooting an arrow. Judging by the caption to the right of the image, the figure is the god of lightning (Dian Shen 电神). The drawing is followed by what appears to be a title (to the left). The clothing is typical of an Imperial functionary and the official hat provides some evidence of the epoch. After the tenth century it became common for officials to starch their hat flaps so that they stuck out horizontally. This image shows unstarched hat flaps, which suggests an earlier date.

Later, i.e. after +700, the production of star atlases continued in China, Korea and finally in Europe, and different Chinese maps immediately followed S.3326. They of course largely benefited from the improvement in observational methods during the Song Dynasty (960-1279). Two outstanding Chinese star charts with a complete coverage of the observable sky are mentioned by Needham (1959: 277-279), and are still the only available ones from the Song period.

The Su Song Atlas, included in the book *Xin Yixiang Fa Yao* (新仪象法要, *New Design for an Armillary Clock*) by the astronomer Su Song, is dated to +1092 by Needham. It is a set of five maps, more elaborate and more complete (1,464 stars) than S.3326, and comprises two (instead of twelve) rectangular maps (where the mansions, the Celestial Equator and the Ecliptic are conspicuously drawn), one circumpolar map and two North and South polar projection maps. All five maps are reproduced in *Zhongguo Heng Xing Guance Shi (History of the Observation of Fixed Stars in China)* (Pan, 1989: 436-438).

The Suzhou Map (*Suzhou Tian Wen Tu* 苏州天文图) is a planisphere which was engraved in stone in +1247 and is still visible in a temple in Suzhou (Jiangsu). The astronomer Huang Shang prepared it in +1193 for the instruction of a future Emperor of the Song Dynasty. It is remarkable since it is accompanied by an explanatory text which is a full astronomical treatise. This text has been translated by Chavannes (1913). The Suzhou Planisphere is more elaborate than S.3326 in the sense that it shows radial grids converging on the North Pole and corresponding to the equatorial mansions. It also displays the Celestial Equator, the Ecliptic and the Milky Way. Like S.3326, it extends up to the declination limit beyond which stars are no longer visible from the observing site.

Those two star atlases allow an assessment of the astronomical quality of S.3326, which is 400 and 500 years earlier, respectively. It is interesting that all three maps are based on the same 'Three Schools' list of stars and asterisms. Progress in celestial observation under the Song—but within the context that the same objects were observed as before the Han—originates from documents like S.3326. It is a valuable witness to the advance of ancient Chinese astronomy.

In Western civilisations there are no known extant sky charts before the early Islamic work by the Persian astronomer, Al-Sufi (+903-986), the *Book of Fixed Stars*, illustrated with constellation pictures with stars (see Hafez, 2009). Unfortunately, apart from a unique copy kept in Oxford which possibly dates to +1009-1010 (Brend, 1994; Wellesh, 1959), no contemporary examples survived, and the earliest other copies are from the twelfth century. In these, the sky is displayed through independent panels showing stars in separate constellations, but without any indication of the constellations' relative positions. Among the other related works in Europe, only the Farnese Globe is older than the above documents. It is considered to be a Roman copy from the second century AD of a Greek original dating from before the modern era (Duke, 2006; Schaefer, 2005). Although the major constellations of the Greek sky are carved on marble, no individual stars are positioned on the sphere; therefore it is hardly comparable to a full star atlas such as S.3326. Similarly, the other famous source, the Denderah Zodiac, dating to –50 (Aubourg, 1995) and preserved in the Louvre Museum, shows only constellations, with no identifications and no individual stars. In the same way, a Carolingian manuscript (dated +818), drawn according to Aratus, and sometimes referred as the earliest European star atlas, shows only naïve drawings of a few constellation figures, without stars (Whitfield, 1995).

The tradition of representing the sky finally came to Europe during the early Renaissance. The oldest true star atlas in Europe is probably the Vienna manuscript (Oesterreichische Nationalbibliotek MS 5415) dating to ca. +1440, which contains the main northern constellations and a limited number of stars. It is plotted in a polar projection from the ecliptic pole (Whitfield, 1995), and dates some seven centuries after the Dunhuang Star Atlas.

An extensive compendium of astronomical maps, mostly from the Western world, can be found in Gingerich (1983). Meanwhile, Chinese star atlases are listed by Feng Shi (2001).

5.3 The Purpose of S.3326

S.3326 lacks its cover and introduction which might have guided us as to its purpose. The first section of the extant document is concerned with uranomancy. The star atlas follows and completes the manuscript. The scroll also lacks its end sheet so we have no way of knowing whether it originally consisted of only these two texts or more. What could be the use of the star atlas which follows this first section of the manuscript? We can only make conjectures.

Dunhuang was an important strategic town for the Chinese during much of the first millennium and was administered by Imperially-appointed officials, the senior ones from Central China. The administrative office kept archives of important documents. It is hypothesized that, because of the shortage of paper during the Tibetan rule of Dunhuang (ca. +781-868), documents from the Chinese administrative archive were recycled—with Buddhist *sutras* being inscribed on the backs or versos. At other times, the backs of Buddhist texts were used. Such documents came to be stored in the Library Cave, a Buddhist library. Documents like S.3326, with no Buddhist text on the back, could have been kept there for future use.

A manuscript such as S.3326, however, contains very important and valued official knowledge. Astronomy in China was an essential Imperial science as divination based on events taking place in the celestial mirror image of the Empire was the way to rule the state. S.3326 was either copied in Dunhuang or originally produced at the Imperial Observatory and brought to Dunhuang. There is no evidence that Li Chunfeng, a possible author of the original version of S.3326, ever went to Dunhuang. As a high official during the early Tang Dynasty he would have lived in Chang'an, the capital. He remained in office at the Imperial Observatory until at least +664, occupying from about +648 the position of *Taishiling*, (太史令) i.e. Director of the Astrological Service (Chemla and Guo Shuchun, 2004; Deng Kehui, 2007).

We can also focus on the portable character of the document. It is possible that we have in hand not a scientific text intended for scientists only but a product of more popular use which existed in the form of several copies for several users. This would suggest that such texts could have been multicopied and that the version found in Dunhuang is merely one example from among others that were copied from the original. As we have noted, the calligraphy is not of Imperial standard. Since the manuscript found in Dunhuang has two consecutive sections on the same paper support, the purpose of such a scroll could have been for travellers or warriors on the Silk Road who needed predictions of the future to assist them with their travels, both with respect to clouds (hence the weather) and aspects of the night sky. But the high quality of the paper and the importance and sensitivity of the subject-matter argues against this. S.3326 is a mystery and, unless we discover similar documents, we might never know its original purpose.

6 CONCLUSION

At the end of this paper it is legitimate to again underline the importance of the Dunhuang Star Atlas, S.3326.

It has a special position in the history of astronomy, as it is the oldest extant graphical star atlas known from any civilisation. There is no equivalent either in Western Europe or in any other civilisation. Although it was found at the edge of the central Chinese Empire, a region open to different influences and not always controlled by the Chinese, this precious document was conceived in the purest Chinese astronomical tradition. It is probably a synthetic document that encompasses information of different origins for the use of scientific astronomy as well as divination purposes.

S3326 is the earliest known pictorial presentation of the traditional Chinese constellations. Individual stars, more numerous than in Ptolemy's catalogue, are represented and grouped into constellations. This star atlas gives us a full representation of the Chinese sky in strict accordance with all previously-known catalogues, retaining the old tradition of using different colours to identify asterisms named and described by the three earlier schools of the Chinese astronomy. The information on the star positions is delivered using a careful systematic method that makes use of accurate projection methods. This is unique considering the period of the document, and in all points is similar to present-day techniques. The overall accuracy (of the order of a few degrees) is surprising for a document from an early epoch and considering the relatively small dimensions of the paper roll.

The Dunhuang Star Atlas also includes additional texts with information relating to a conventional calendar (the position of each lunar month in the seasons and within the Jupiter cycle), as well as some specific astronomical conjunctions within each month. These texts are also part of the ancient Chinese astronomical tradition as they are only slightly different versions of known earlier sources, namely the *Yueling* (not older than –240), the *Jinshu* (with a redaction around +635), and probably the later source, *Kaiyuan Zhanjing* (dated +729).

The source of S.3326 is probably the early Chinese lists of stars such as those included in the third century Chen Zhuo catalogue. Based on different arguments, the dating of the star atlas (+649-684) shows that it could originally have been drawn by Li Chunfeng around +650, although the lack of a front cover and other evidence does not allow us to confirm this.

Nonetheless, the Dunhuang Star Atlas, as we have it today, was preserved by chance in a hidden cave for almost a millennium and this makes it a unique witness to the sky as it was seen during the Tang Dynasty.

7 NOTES

1. The International Dunhuang Project (IDP) was started in 1994 "… to promote the study and preservation of the archaeological legacy of the Eastern Silk Road through international cooperation." Its directorate is based at the British Library (see http://idp.bl.uk).
2. The dates in this paper are given in the so-called astronomical system where year –1 corresponds to 2 BC (or 2 BCE) and year +1 to AD 1 (or 1 CE).
3. The Chinese Government removed only the Chinese manuscripts leaving the remaining Tibetan manuscripts behind, and they are now in collections throughout Gansu Province. The Stein Collection was divided between the British Museum and the Government of India, co-sponsors of his expedition, and part of the Dunhuang Collection is in India's National Museum in New Delhi. The Japanese collections were dispersed and a large part is now in the National Museum of Korea in Seoul.
4. The manuscripts in the British Museum became part of the British Library collection with the establishment of the latter institution in 1972. S.3326 is now preserved in the Asian, Pacific and African Collections of the Library.
5. Re Giles's retirement in 1940, and the initial offering of the manuscript for publication in 1947, see Wood (1996).
6. Chinese characters are given here in their simplified form together with their standard 'pinyin' transcription in Latin letters (marked in italics).
7. Their precise origin is still an enigma and their relation to the Moon is not documented. However, these constellations were constantly used throughout Chinese history as precise markers of the positions of heavenly bodies during the seasons.
8. For those not familiar with the convention, during the reign of any emperor, characters that made up the emperor's personal name were not allowed to be used in their standard form. The characters were changed slightly—usually by omitting or adding a stroke. This is known as the 'taboo' form of the character. After the emperor's death, the 'taboo' forms of any of the characters in his name—not just his whole name—were used until the end of that dynasty. The consistent use of the taboo characters in *all* documents is not absolutely certain, but the fact that a taboo form is used in this document suggests that the rule was being followed.
9. From a study carried out by Anna-Grethe Rischel (National Museum of Denmark) who remarks that the fibres are "… particularly long and fine." Images of the manuscript and fibres are shown on IDP direct link http://idp.bl.uk/database/oo_loader.a4d?pm=Or.8210/S.3326
10. "The roller has been lined with acid-free Japanese tissue paper to protect the object from acid migration. The Kraft lining extends to both end maps. Due to the lack of written surviving documentation it is impossible to trace the history of conservation of the object, so our remarks can only be based on transmitted knowledge and visual observation. Using transmitted light it is possible to observe a long patch running along the whole length of the scroll. This patch has an irregular shape with non-defined margins. This might suggest that the patch is contemporary with the object, and was obviously not removed when the lining was applied. Other evidence to support this is represented by the fold lines, which can be observed in some areas. This fold runs through the patch and along the object in a continuous manner suggesting that the patch has indeed been in place for a long time although not conclusive in respect to a precise dating. There is evidence of other small patches along the manuscripts although some were removed as we could only observe their shape in the imprint they left in the paper." Description by Barbara Borghese, IDP UK and European Project Manager (private communication).

11. This title has been transliterated in some recent Chinese publications as "Qi jie meng ji dian jing yi juan", with the suggested translation of "Interpreting Dreams and Book of Lightning in One Chapter" (Deng and Liu, 2003). However, this interpretation is problematic. Firstly, it ignores the first character *'qi'*, which makes no sense in this context. Secondly, it reads the third character, which is in a non-standard form, as '*meng*' (= dreams) even though this is not an attested variant of '*meng*'. A more probable reading would be 蔑 or '*mie*' (= scorn, villify). And two titles like this joined with '*ji*' (and) is not a form seen in China.
12. The Chinese degrees are defined according to the mean year duration (325.25 days) and therefore 365.25 Chinese degrees corresponding to 360 European degrees.
13. The correlation coefficient, R, is the Pearson least-squares fit parameter with the value of R = 1 for a perfect fit and R = 0.76 and 0.68 for a random probability of 0.01% and 0.1% respectively.
14. Translation by Imre Galambos (British Library). He also notes that the first part of the compilation of *Lushu Chunqiu,* sponsored by Lü Buwei in the mid-third century BC, is concerned with the correlation of colours and the workings of the Universe.
15. The mention found here only differs from the one in *The Nine Chapters* by the use of '*yan*' (says) instead of '*an*' (comments) and the absence of 'with respect'. (K. Chemla, pers. comm.).
16. There is also a star catalogue forming part of Shi Shen's works which contains illustrations of asterisms within the Chinese mansions. A copy is preserved in Kyoto. We have not seen this manuscript and can merely cite Fung Kam Wing's (2003) paper.
17. An early discussion of ancient North Pole stars can be found in de Saussure (1930: 494-525).
18. No mention is made in the *Jinshu* (Ho, 1966) nor in the Han catalogues (Sun and Kistemaker, 1997).

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10 APPENDICES

10.1 The Orion Stellar Region (Map 5)

The sky region displayed on Map 5 (fourth lunar month) extends from −30° to +40° in declination (Figure 3 and Table 4). Right ascension increases from ~50 to 100°, right to left, i.e. west is to the right of the map, east to the left. This particular map is different from most of the other maps in that a major constellation can be recognised: *Shen* 参, or Orion, is a rare case where a constellation seen by the ancient Chinese is similar to what we are used to in the Western world.

The map contains 109 stars, grouped in 20 Chinese asterisms (see Table 4). The northern features are *Wuche* 五车 and *Sanzhu* 三炷, both forming Auriga. The two mansions *Zui* 觜 and *Jing* 井 are easily found south of it. *Shenqi* 参 旗 and, further South, *Shen* (also a *xiu*), comprise the brightest stars in Orion. Three not encircled, hazy, red stars form the group named *Fa* 伐, but here no label is present; they represent the multiple star θ Orionis, and maybe also M42 (The Great Orion Nebula), which is visible to the naked eye. To the southeast of *Shen*, but located too far north by about 10°, one finds the star *Yeji* (β Canis Majoris), surrounded by a crown of 11 stars. It is noticeable that this crown (asterism *Junshi* 军市) is formed of faint stars that a modern naked eye could hardly distinguish (visual magnitude around 6). However, the very bright star *Lang* 狼 (α Canis Majoris, or Sirius) is not related to *Yeji* and is found on Map 6. The modern constellation Lepus is here spread into several small asterisms, all at about the same declination, which is not correct. Finally two groups of two stars (*Zi* 子 and *Zhangren* 丈人) are identified as belonging to the constellation of Columba, but in this case they are also drawn too far north as compared to *Ce* 厕, *Junjing* 军井 and *Ping* 屏.

This chart, the drawing of which is quite clear, shows nevertheless that the author had difficulties positioning the southernmost stars of the zone. The constellations which are best represented are those along the Celestial Equator (declination 0°). Several stars and asterisms which are described in the *Jinshu* are absent from this map: within *Wuche* the asterisms *Tianhuang* 天潢 and *Xianchi* 咸池; south of *Wuche* the star *Tianguan* 天关; and the asterisms *Siguai* 司怪 and *Wuzhuhou* 五渚候.

Calendar text (2 columns, left)

From the 12th degree of *Bi* to the 15th degree of *Jing*, the astral position is *Shen*. It is *Shichen*, the sinking (or fructification). It is said that at the 7th lunar month, ten thousands creatures are full of force and blossoming, the yin spirits deepen and are heavy; the ten thousands creatures fructify. For this, it is called *Shichen*. It is part (of the state) of *Wei*.
自毕(?) 十二度 至井十五度

Culmination text (3 columns, bottom)

The fourth (lunar) month, the Sun meets the mansions *Bi* and *Zhu*, at dusk the mansion *Yi* culminates, at dawn the mansion *Nü* culminates.
四月 - 日會畢觜 - 昏翼中 - 旦女中

10.2 The Circumpolar Map (Map 13)

The circumpolar map (Figure 4) is a rich one in that it displays 144 stars. This indicates the attention with which Chinese astronomers observed this northern part of the sky, which was supposed to be the seat of the Emperor, his family, the court and the officials. On the Dunhuang maps, the names of all asterisms are easily read therefore identification is not dubious, inasmuch as the author of the map is correct.

The map extends over 40° in declination (from about 50° to 90°). A major role is played by the Pole (or pivot) Star, around which the sky seems to revolve. On the S.3326 map, this star is not specially indicated. A red hazy spot, not encircled in black, could be it. The asterism *Sifu* 四辅, a group of four stars representing the four advisors to the Emperor, is close to this spot, on its western side, but does not surround it. The Emperor sits in the Purple Palace (*Zigong*). The Palace is surrounded by an eastern wall (7 stars, left on the map) and a western wall (8 stars, right on the map) constituting *Ziwei*, one of the three enclosures (*yuan*) of the Chinese sky. A number of high officials, commodities such as grains, or rooms such as kitchens or bedrooms, are also represented in the sky (see Table 5). Of the three asterisms named kitchen (*chu*) in the Chinese sky, two are found on the circumpolar map: *Tianchu* 天厨 and *Neichu* 内厨 (but the latter is without a name on the map; see below).

Table 4: Content of Map 5 (The Orion Region).

Map: 5
Month: 4 (*wu yue*)
Xiu: *Zhi*, *Shen*, *Jing*
(The fourth lunar month), the Sun meets with the mansions (*xiu*) *Bi* and *Zhi* (*Zui*); at dusk the mansion *Yi* culminates; at dawn the mansion *Nü* culminates.
Totals: 20 asterisms and 109 stars.

	Asterism[1] (pinyin) by RA and from N to S	Asterism (common Chinese name)	IAU[2] Constel -lation	Identifi-cation in SXC[3]	Colour (R, B, W)[4] on map	Nb[5] of *[6] (SXC)	Nb of * on map	Ident. of one star (SXC)	Remarks (between quotes are comments by SXC)	Conf. Index[7] (ident.)
1	*Wuche* + *Sanzhu*	Five chariots+ three poles	Aur	I 37	R	14	14	ι Aur		5
2	*Zhuwang*	Several princes		II 60	R	6	5	τ Tau	"6 * S of *Wuche*."	5
3	*Zuoqi*	Left banner	Aur	II 62	B	9	8	κ Aur	"9 * NE of *Siguai*."	5
4	*Tian zun*	Celestial wine cup	Gem	II 59	B	3	3	δ Gem	"3 * N of *xiu Jing*, E of *Zuoqi*."	1
5	*Tiangao*	Celestial high terrace	Tau	II 63	W	4	4	97 Tau	"4 * close to *xiu Bi*." Note that *Bi* is on S 3326 Map 4.	4
6	*Jing*	Eastern well	Gem	I 114	W	8	8	μ Gem		5
7	*Shenqi*	Shen banner	Ori	I 82	R	9	6	π Ori		5
8	*Zui*	Bird beak	Ori	I 112	W	3	3	ϕ Ori		5
9	*Shuifu*	Water palace	Mon	II 106	B	4	4	ν Ori	"4 * S of *xiu Jing*." Labels are inter-changed for *Shuifu* and *Sidu*.	4
10	*Sidu*	Four rivers	Ori	II 107	B	4	4	ε Mon	"4 * S of *xiu Jing*." Labels are inter-changed for *Shuifu* and *Sidu*.	4
11	*Shen*	Warrior-hunter	Ori	I 113	R circled black and red alone	10	10	δ Ori	No label for *Shen* on the map. The three hazy red stars are *Fa*, the dagger (no specific label).	5
12	*Jiuliu*	Nine flags	Ori	I 104	B	9	9	54 Eri?	"9 * SW of Yujing." No label on the map.	5
13	*Yujing*	Jade well		I 83	R	4	4	β Eri	A circle of stars close to β Ori.	5
14	*Yeji*	Pheasant cock	C Ma	I 88	R	1	1	β C Ma		5
15	*Junshi*	Soldiers market	Lep	I 87	R	13	11	17 Lep	Surrounds *Yeji*.	5
16	*Ping*	Toilet screen		I 84	W	2	2	μ Lep	The group is labelled but not at its place; should be S of *Junjing*.	2
17	*Junjing*	Soldiers well	Lep	II 105	B	4	4	κ Lep	"4 * SE of *Yujing*."	2
18	*Ce*	Toilet with a shed	Lep	I 85	W	4	4	β Lep		5
19	*Zhangren*	Husband man	Col	II 110	B	2	2	ε Col	"2 *SW of *Junshi*." *Zhangren* and *Zi* should be more S of *Ce* and *Junjing*.	5
20	*Zi*	Son	Col	II 111	W	2	2	β Col	"2 * E of *Zhangren*." *Zhangren* and *Zi* should be more S of *Ce* and *Junjing*.	5

1 Asterisms are listed from North to South and from West to East (i.e. in increasing right ascension).
2 IAU = International Astronomical Union.
3 The lists, labelled I, II and III, are found in Sun Xiaochun and Kistemaker (1997). This book name is abbreviated as SXC.
4 R = red, list of Shi shi (I); B= black, list of Gan shi (II); W = white, list of Wu Xian shi (III).
5 NI = Unidentified.
6 * means star.
7 Confidence index: from 1 to 5; 5 = very good, 1 = bad.

Table 5: Contents of Map 13 (The Northern Circumpolar Region).

Map: 13
Month: North cicumpolar zone
Xiu:
Totals: 34 asterisms (1 of which is unidentified) and 142 stars (+ 3 in *Beiji*). All stars on this circumpolar map belong to *Shi Shi* or *Gan Shi*.

	Asterism[1] (pinyin) by RA and from N to S	Asterism (common Chinese name)	IAU[2] Constel -lation	Identifi-cation in SXC[3]	Colour (R, B, W)[4] on map	Nb[5] of *[6] (SXC)	Nb of * on map	Ident. of one star (SXC)	Remarks (between quotes are comments by SXC)	Conf. Index[7] (ident.)
1	*Tianchu*	Celestial kitchen	Dra	II 15	B	5	6	δ Dra	"5 * outside the NE wall of *Ziwe*i."	5
2	*Wudizuo*	Seats of five *Di*	Cep	II 4	B	5	5	γ Cep?	"5 * inside *Ziwei* below *Huagai*; rather E of *Huagai*."	5
3	Chuanshe	Guest rooms		II 17	B	9	7	3947 Cam	"9 * above *Huagai*."	5
4	*Tianzhu*	Celestial pillars	Dra	II 6	B	5	5	? Dra	"5 * inside *Ziwei* close to the Eastern wall."	5
5	*Liujia*	Six *jia*	Cam	II 5	B	6	5	? Cep	"6 * inside *Ziwei* near the handle of *Huagai*."	5
6	*Huagai*	Canopy of the Emperor	Cas	II 3	B	7	7 (+ 6)	? Cas	"7 * above *Tianhuang*." What is 6? Is it *Gang*? But character for *Gang* is absent; see also below.	4
7	*Gouchen*		U Mi	I 60	R	5	6		Classified with *Beiji* by SXC; could be the handle of U Mi in modern terms, ending with α U Mi, or the handle of *Huagai*.	5
8	*NI 1*		U Mi		R		1		1 * without character East of *Gouchen*; could be δ U Mi.	
9	*Tianhuang*	High God of Heaven	U Mi	II 1	B	1	4	? U Mi	"1* inside *Gouchen*"; here 4 * two of which belonging to U Mi.	3
10	*Ziwei*	Celestial Purple Palace wall	Dra	I 59	14 R, 1 B	15	15	κ Dra	Two walls, E and W, just as for *Taiwei*.	5
11	*Zhuxiashi*	Officer in charge of communi-cation	Dra	II 7	R	1	1	χ Dra	"1 star inside *Ziwei* N-E of *Beiji*."	5
12	*Nüshi*	Woman officer	Dra	II 8	R	1	1	φ Dra	"1 * N of *Zhuxiashi*"; it is rather W of *Zhuxiashi*.	5
13	*Tianpei*	Celestial flail	Dra	I 7	5 R, 1B?	5	5 or 6	ι Her	Asterism to the extreme left (E) of the map.	5
14	*Shangshu*	Secretary	Dra	II 9	B	5	5	15 Dra	"5 * in the SE of *Ziwei*."	5
15	*Beiji*	North Pole Office	U Mi	I 60	R	5	4	β U Mi	*Beiji* continues with 3 * drawn in B, without characters. Moreover a R non-encircled star slightly erased could be the Pole star.	4
16	*Sifu*	Four advisors	Cam and U Mi	II 2	B	4	4	? U Ma	"4 * surrounding the N Pole"; is the N. Pole visible?	5
17	*Neijie*	Inner steps	U Ma	II 14	B	6	6	2 Dra	"6 * N of *Wenchang*"; asterism outside *Ziwei* to the right of the map (W).	5
18	*Bagu*	Eight species of grains	Cam	II 65	B	8	8	β Cam	"8 * N of *Wuche*"; the character after *Ba* is not easily read; *Wuche* is not on this map.	3

19	*Tianchuang*	Celestial bed	Dra	II 11	B	6	4	? Dra	"6 * outside the doors of *Zi gong* (= *Ziwei*)"; SXC likely include the 2 * which we identify as *Taiyi* and *Tianyi*. The latter may be located further right, just above δ U Ma.	3-4
20	*Taiyi*	Supreme unity		I 62	B	1	1	8 Dra	Unambiguous character. But may be wrong position. Star discussed by de Saussure (1930).	3-4
21	*Tianyi*	Heavenly unity		I 61	B	1	1	7 Dra	Unambiguous character. But may be wrong position. Star discussed by de Saussure (1930).	3-4 cf supra
22	*Tai*			Not in SXC	B		1	?	1 character, 1* near the S border of the W part of *Ziwei*.	
23	*Tian*			Not in SXC	B		1	?	On the *Suzhou* map, these two stars are *Taiyi* and *Tianyi*.	
24	*Sangong(2)*	Three excellencies	U Ma	Not in SXC	B		3	?	East of Wenchang. Unambiguous character.	5
25	*Tianqiang*	Celestial spear	Boo	I 6	R	3	3	κ Boo		5
26	*Beidou*	Northern Dipper	U Ma	I 58	R	8	7	α U Ma		5
27	*Tianli*	Great Judge for Nobility	U Ma	II 12	B	4	4	? U Ma	"4 * inside the scoop of *Beidou*."	5
28	*Wenchang*	Administra-tive center	U Ma	I 57	R	6	5	o U Ma	Note: o U Ma is not on the map.	5
29	*Xuange*	Halberd	Boo	I 5	R	1	1	λ Boo	Small problem of declination on the map between η et ξ U Ma.	5
30	*Sangong(1)*	Three excellencies	C Vn	II 39	B	3	3	24 C Vn	"3 * S of the handle of *Beidou*."	5
31	*Xiang*	Prime Minister	U Ma	I 54	R	1	1	χ U Ma	Identification as χ U Ma not correct; should be S of γ U Ma.	5
32	*Taiyang-shou*	General in charge of the *yang valve*	U Ma	I 55	R	1	1	ψ U Ma	Identification of SXC as ψ U Ma dubious, ψ U Ma should be S of β U Ma.	?
33	*Shi*	Eunuch official	U Ma	II 55	B	4	4	? U Ma	"4 * N of *Taiyangshou*"; this star is not N of *Taiyangshou*, but W.	5
34	*Tianlao*	Celestial prison	U Ma	I 56	R	6	6	44 U Ma		5

1 Asterisms are listed from North to South and from West to East (i.e. in increasing right ascension).
2 IAU = International Astronomical Union.
3 The lists, labelled I, II and III, are found in Sun Xiaochun and Kistemaker (1997). This book name is abbreviated as SXC.
4 R = red, list of Shi shi (I); B= black, list of Gan shi (II); W = white, list of Wu Xian shi (III).
5 NI = Unidentified.
6 * means star.
7 Confidence index: from 1 to 5; 5 = very good, 1 = bad.

The Northern Dipper (*Beidou,* 北斗) is well recognised at the bottom of the map. Contrary to the situation corresponding to the present epoch, the alignment between α and β Ursae Majoris does not point to the Pole Star and does not even enter the *Ziwei* region. Some ambiguity also exists for the one-star asterisms *Xiang* 相 and *Taiyangshou* 太陽首, which are not located accurately south of the Dipper if they are identified with χ and ψ Ursae Majoris respectively, as suggested by Sun & Kistemaker (1997). They are better identified respectively with 5 Canum Venaticorum and χ Ursae Majoris, as proposed by Ho (1966).

Near the Southern Gate of *Ziwei*, a group of six stars raises a question: they are labelled *Tianyi* (天一) and *Taiyi* (太一), *Tian* (天) and *Tai* (太), plus two unnamed stars just 'above' δ Ursae Majoris which we identify with *Neichu* (内厨). The stars *Tianyi* and *Taiyi*, North of ε Ursae Majoris, translated literally as "celestial unique or celestial unity" and "great unique or supreme unity" respectively. Their names refer to a supreme quality, indicating they were once Pole Stars.[18] Two stars, *Tai* and *Tian*, northeast of ε Ursae Majoris, are not mentioned in previous catalogues.[17] Is the confusion on the Dunhuang atlas a copying error? Suggestions have been made of an inversion with two other asterisms, and also of a misinterpretation with two different positions of the Pole in the past (Maeyama, 2002).

An unnamed asterism is located between *Tianhuang* 天皇 and *Gouchen* 狗陈 (in the upper part of the map); it is red and circled in black. Thus it may belong to the Shi Shi Catalogue, and is likely δ Ursae Minoris. The name *Gouchen* on the map refers to a single star (in red), α Ursae Minoris (the present-day Pole Star) and not, as usual, to an asterism of five stars. Within *Beiji* 北极 (an important asterism since it represents the North Pole office) the second red star, named *Di* (Emperor) by the Chinese, but without a name on the map, is identified with β Ursae Minoris, which was also once approximately the Pole Star (together with κ Draconis) around –1000.

Altogether, the S.3326 circumpolar map is well documented. There are, however, several imperfections:

(a) The shape of *Beidou* with respect to the *Ziwei* walls differs from that displayed on the Suzhou Map or on any modern map of the sky. The largest displacements affect the extreme stars, η Ursae Majoris and α Ursae Majoris (see Figure 6b). It is because of this wrong position that the alignment α - β Ursae Majoris is poorly oriented.

(b) The asterism *Gouchen* is not represented in full, and the star that we identify with α Ursae Minoris is here the bottom star of the handle (Gang) of *Huagai* 華蓋 instead of being the brightest star of *Gouchen*. Some asterisms (*Wudi* 五帝, *Zhaofu*) also listed in the *Jinshu* are absent on S.3326.

Jean-Marc Bonnet-Bidaud is an astrophysicist in the Astrophysical Department of the French Atomic Energy Commission (C.E.A.), and specialises in high energy astrophysics and in the study of highly condensed stars in the Galaxy. He is also deeply interested in the history and popularization of astronomy. He is currently the scientific adviser of the French astronomy magazine *Ciel et Espace* and has published numerous articles in different magazines and newspapers. He is mainly interested in the history of modern cosmology and in the roots of ancient astronomy in China and Africa.

Dr Françoise Praderie, an outstanding European astronomer, passed away on 28 January 2009, before this paper was published. Prior to that she was an Honorary Astronomer at the Paris Observatory. She was a former Vice-President of the Paris Observatory and former Editor of *Astronomy and Astrophysics*. She contributed to the creation of the trans-disciplinary European association 'Euroscience', where she served as its first Secretary General. Her main research interests are in stellar seismology, and she was the author of the book *The Stars* (which was co-authored with E. Schatzman).

Dr Susan Whitfield is Director of the International Dunhuang Project at the British Library and an historian and writer on China and the Silk Road. She is interested in cross-disciplinary research, combining history, archaeology, art history, the history of religions and science in her study of manuscripts and artefacts from the eastern Silk Road. She has published extensively, lectures worldwide and also has curated several exhibitions, including a display of historical star charts in the collections of the British Library.