以尺量天

TO MEASURE THE SKY WITH RULERS

——中国古代目视尺度天象记录的量化与归算

王玉民 著

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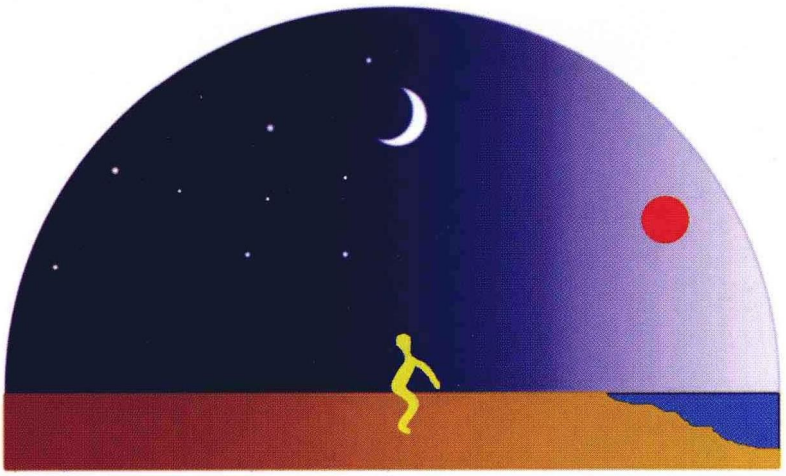
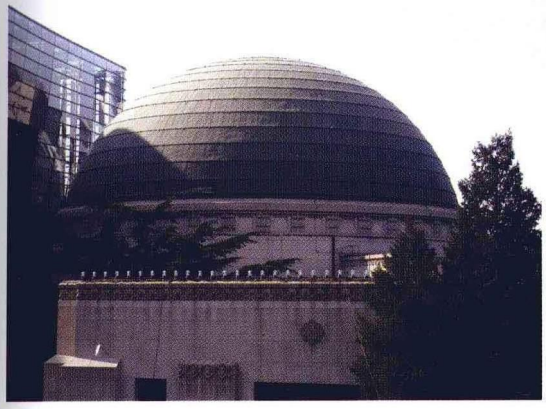
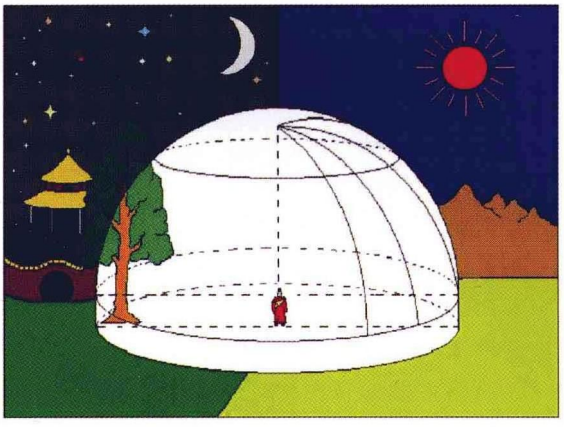


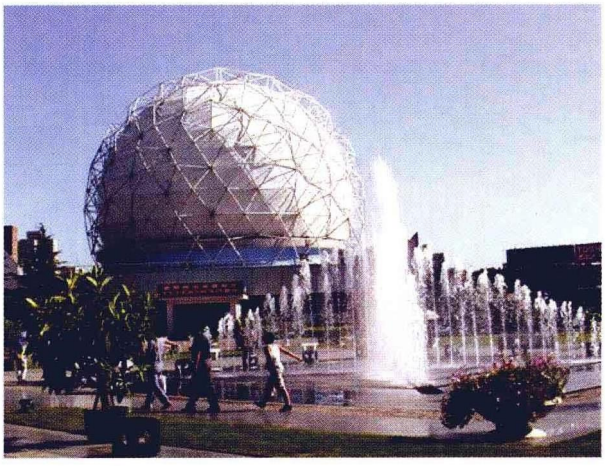
▲“三光者，日月星，三才者，天地人”，该图正反映了中国古代的这种宇宙观念（其中人形用汉字的篆书代表）



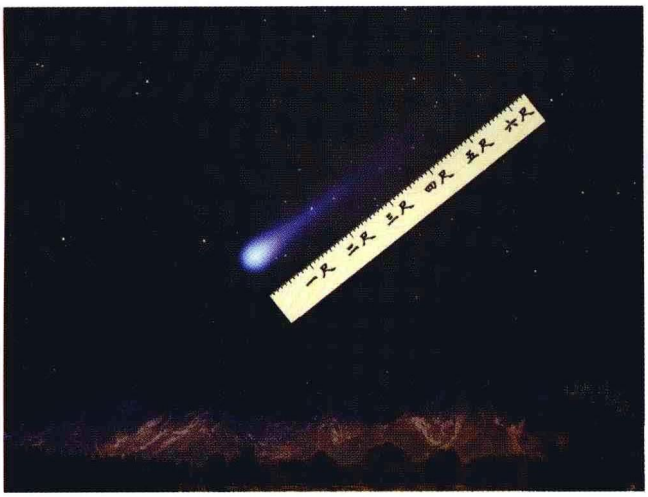
▲北京天文馆光学天象厅，半径近 12 米



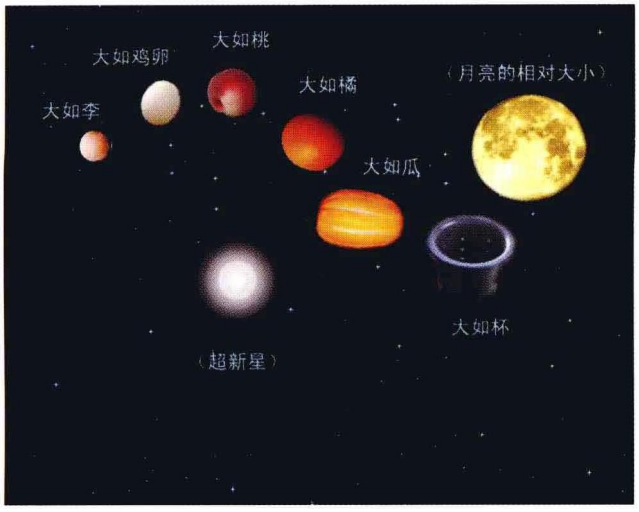
▲古人目视观天时，总把天象投影在以自己为中心、半径约 13 米的假想天球面上去估测它们的长短、大小



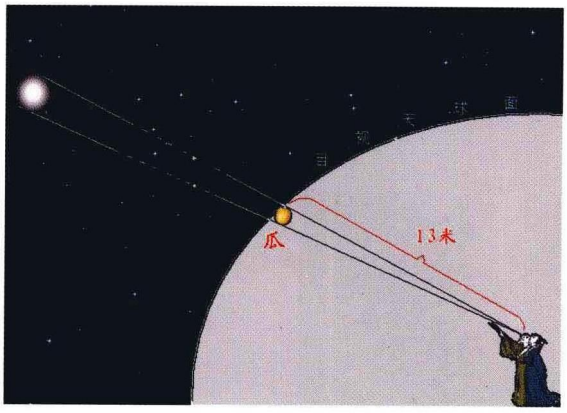
▲中国科技馆穹幕影厅，半径 13.5 米



▲ 以尺量天——我们的祖先常这样用假想的尺子来度量天体的高度、长度、角距等



▲ 古人用多种物体进行假想比较后，会称这颗超新星“大如瓜”



▲“大如瓜”的由来

▲ 如此巨大的火流星，古人会记录为“大如房”

序

玉民学兄自小爱好天文，然而，他实现梦想的道路却比较曲折，跨了数学（本科）、文学（硕士）、科学史三个学科之后才成为职业的天文学史学者，期间还曾做媒体工作。难怪有网友称他比刘翔的跨越能力还强。这样的学历和工作经历倒是使他知识面广博，对学术的追求更加执著。2000年，他考入中国科学院自然科学史研究所，师从科学史家席泽宗院士，攻读博士学位。

中国有悠久的天文学传统，古代典籍中有极其丰富的天象观测记录。然而，天文学史家过去对涉及“丈、尺、寸”和取象比类（“大如X”）的裸眼目视天象观测记录重视不够，已有的研究远不够深入系统，其结论缺乏说服力。玉民敏锐地注意到目视尺度天象记录的重要价值，将《以尺量天——中国古代目视尺度天象记录的量化与归算》作为学位论文选题。由于学术积累扎实，又勤奋钻研学术，他才在导师的指导下出色地完成了学位论文，为学弟、学妹们树立了榜样。

《以尺量天》是近年来中国天文学史研究中的一项重要成果，其主要内容具有开创意义。玉民通过对古代天象记录的完整统计并运用现代天文学方法，论证了古代记录中的一尺等于现代一度的换算标准，给出了“古代天象记录的尺度体系”概念；将天象记录的统计与视觉生理学、人类行为学、知识考古学等学科的研究结果相结合，提出一个约为13米半径的目视观测天象的天球模型假说，由此确定了“丈、尺、寸”天象记录和“大如X”记录的几何意义；详细论证了目视观测天象的视错觉及其校正归算方法；首次提出中国古代存有大量天体亮度记录的观点，并对这类记录都做了系统完整的亮度归算。在此基础上，玉民对中国古代天象记录如太阳黑子、新星、超新星、流星、彗星等天象记录做了视高度、视长度、亮度、视角度或面积的量化归算。玉民把中国古代天象记录中以“丈、尺、寸”和取象比类表示的尺度系统提高到一个重要的高度，得出了令人信服的结论，为古代天象记录的现代应用提供了一种可靠的基础。玉民的部分研究成果在《天文学报》、《自然科学史研究》和国际会议上公布后，得到国内外同行的高度评价。《以尺量天》在2004年被评为中国科学院优秀博士论文，2005年获教育部全国百篇优秀博士论文提名奖。

山东教育出版社正式出版《以尺量天》，使更多的读者方便地阅读玉民的这项系统的研究成果。在此，我愿冒昧地代表同行，感谢山东教育出版社与自然科学史研究所的多年合作，及对科技史事业的支持！

张柏春

2008年1月12日于北京九爷府

本书摘要

在中国古代典籍中，经常可以看到一种奇特的天文记录，它们用长度来表示天象在天球上的视角。比如，以“丈”、“尺”、“寸”为单位来标出天体的长短、大小、地平高度或角距离；另外，还有许多记录在描述天体的视大小时，使用“大如桃”、“如鸡蛋”、“如盘”等以物作比的方式(称“取象比类”)，也包含着长度意义的度量。

与用“度”进行的天体测量工作相比，“丈”、“尺”、“寸”式记录因其不易用现代科学方法解释，在中国古代天文学史研究中一直处于不很受重视的从属地位。但是作者发现，这类记录方式在中国古代天象记录中占有相当大的比例，被古代天文家在各种场合广泛使用，它自身也有着相当丰富的表现形式，这说明它在古代天文观测活动中一直起着不可忽视的作用，理清这个问题，对挖掘中国古代天文遗产将是一件颇有意义的工作。

关于“丈”、“尺”、“寸”式记录与今日度数的换算关系，前人曾做过不少工作，江涛、薄树人、王健民、刘金沂、刘次沅等人求出的尺－度关系均为 1 尺＝1～1.5°。但尚无人对这类记录从整体上进行全面的量化分析，至于“大如 X”形式的取象比类式记录，能否系统量化更一直是个谜。

本书在前人研究的基础上，对中国古代典籍中以“丈、尺、寸”为单位的天象记录以及取象比类式(“大如 X”形式)的记录在按现代科学标准量化、建立体现它们内在联系的几何模型、对目视天穹视错觉的校正方面都进行了较为深入的研究和探索，试图结束人们对这类记录的模糊认识。本书主要提出或解决了以下问题：

1. 古人在目视天象观测时所做的“丈、尺、寸”式记录与“取象比类”式(“大如 X”形式)记录，其数量庞大、分布广泛、历史一贯，有方法、有模型、有传承性，是成系统的，可统称为“中国古代目视天象记录的尺度体系”。本书从记录的数量、记录数据的分布梯度、记录的分布地域、分布朝代等几个方面都进行了完整细致的统计论证。

2. 通过对前代学者关于尺－度换算关系结论的全面分析比较，并在史书中寻找案例进行重新论证、利用新天文软件 SkyMap Pro8 对正史中有关行星位置的记录重新进行了比较统计，证实 15 年前刘次沅做出的 1 尺＝1°的论断是最为可靠的。因此结论是：1 尺＝1°。书中又通过大量例证的分析进一步证实：这个结论是可以外推的，即 1 丈＝10°……36.5 丈＝一周天，等等。

3. 首次提出，古代裸眼目视观测天象的记录中，包含着一种未见古人说出的观测基准知识，它相当于球面天文学中的天球投影。根据这种“意会知识”，按 1 尺＝1°的换算标准，可建立人们裸眼目视观测天象的天球模型，由此可以明确确定“丈、尺、寸”天象记录的几何意义。通过对尺寸系统起源的分析，得出了古人裸眼目视观测时的天球半径约为 13 米左右。本书还从人本心理行为渊源、天文馆天象厅的直径、航海牵星术等多方面进行了详细的论证。

4. 建立古人裸眼目视观测天象的天球模型后，又通过外国、现代的许多例子进一步论证了，人类有一种共同的知觉现象：在不借助仪器目视观天时，总是将星象、大气光象想像为是投影在距人眼 13 米半径的半球状天幕上，然后去估测其视大小、长度，并在想像中与日常

生活中的尺度、物体相对照。现代人仍保留着这种能力。

5. 古代天象的取象比类式("大如X"形式)记录,过去常被认为是一种修辞性的描述,用语因人而异、表述非常模糊。但作者发现,它们并不是单纯的比喻,而是一种科学的记录,属中国古代特有的科学思维方法——取象比类。通过目视观测天象13米半径的天球模型,作者找到了这种记录方法的参考距离,进而证明了:取象比类式记录并非异类,它就是"丈、尺、寸"记录的另一种表现形式,两类记录可以统一在一个系统中。因此,取象比类式记录也可以按"丈、尺、寸"记录的标准进行尺度或亮度的量化。

6. 人们裸眼目视观测天象时,有一个与仪器观测的重大不同点:人直接观天时,会对天穹形状做错误的估计,由此必然会导致对天体的长度、高度、角直径等的估算误差。这是古今人人共有的一种视错觉现象,是一种系统误差,在一定程度上可以按其固有规律进行量化和校正。此种效应在天象记录中的影响,过去几乎无人提及,但作者认为,视错觉是我们在对古代目视尺度天象记录进行量化与归算时(特别是研究目视估测天体的视高度、视长度、视大小时)必须考虑的因素。否则我们对记录的理解将是不完整的,也难以做到准确。

这种误差是人眼将天穹视为扁平状造成的。其扁平程度已有初步的数学模型,前人通过实验已得知:在不同的天空照度与气象条件下,目视天穹的扁平程度是有所不同的,可以量化。但前人尚无完整的量化校正结果。为对古代天象记录的可能误差进行校正,作者首次完整求出了在各种状况下(昼、夜、阴、晴、有月、无月)裸眼观测时,天体"视"(带误差的)高度、"视"(带误差的)长度与其真实尺度(视角)的校正归算表。

7. 中国古代典籍中存有大量关于流星、新星、超新星"大如鸡子"、"大如碗"、"大如瓮"等等的记录。由于这些星体大都是点光源,所以此处记录的不是星体的"发光直径",而是古人对星像主观视面大小的一种估测。人们裸眼直接观察星体时,由于光线通过眼球造成的漫射、大气的扰动以及视觉中的光渗作用等,会使本来是点光源的星体在感觉中形成一个扩散开的面,结果人们在观察星体亮暗的同时,也感知到了它们的"大小"。正是对这种特殊感知现象的分析,作者发现,古籍中对流星、新星、超新星"大如X"形式的描述其实质是亮度的分级记录。以目视天球模型为标准可对它们进行视大小(角直径)的量化,进而以一些已知亮度的流星、新星记录为"标准点"可以将其全部归算为亮度。作者将古籍中流星"大如X"形式的4 582次记录中的133种比体均做了亮度的归算,得出了意义重大的流星亮度归算表。对(超)新星的取象比类式记录也做了亮度的归算。

8. 黑子的"大如瓜"、"大如桃"、"大如钱"之类的记录,也不像前人说的那样,仅是"书其形状",而是古人对黑子面积大小的一种估测。在现代的太阳黑子研究中,黑子的面积大小是一项极为重要的指标,所以分析古代黑子记录中面积的大小,对现代研究很有帮助。作者按照视觉生理学原理,利用统计方法,参照扁平天穹归算模型,对古籍中96条黑子"大如X"形式记录中的17种比体进行了面积的归算。

9. 另外,书中对中国古代典籍中彗头、极光的尺度,彗尾、流星尾迹的长度记录也按目视天球模型进行了视角的量化。为进一步说明目视观测天象的天球模型,以及"丈、尺、寸"式和取象比类式记录的量化在古代目视观测天象记录研究中的重大意义,作者对典籍中的若干典型案例做了量化归算方面的综合分析。

通过多方位、异角度、跨学科的综合研究,本书意在重构中国古代目视尺度天象记录的现代意义上的科学成分,为天文学史工作发掘出一条新的"量天尺",为古代目视天象观测史料,如星体掩犯、新星、超新星、彗星、流星、黑子、极光记录及某些奇异天象记录、气象记录的研究提供更多的量化依据,从而也为今日的天体力学、天体物理、大气现象研究提供更可靠的古代数据。

TO MEASURE THE SKY WITH RULERS

The Quantification and Reduction of the Records of Astronomical Phenomena Observed with Naked Eyes in the Scale System in Chinese Annals

ABSTRACT

We can often see many peculiar records of astronomical phenomena in Chinese annals which used length to record the apparent angle of the astronomical phenomena. For example, celestial body's length, size, apparent height and angle distance which were recorded by "zhang, chi and cun". And we can also see many records using phrases such as "big as a peach""big as an egg"" big as a plate" to describe the astronomical phenomenon's apparent size which implied that they were measurements of length.

Compared with the unit "degree", it is difficult to explain the records about "zhang, chi and cun" with modern scientific method. So these records have often been neglected in the research of the history of Chinese astronomy. But the author finds, as there were so many records and they were widely distributed, that they played an important role which can't be ignored in the ancient astronomy. It is a beneficial work in utilizing our ancient astronomical heritage to clear up this problem.

How should "zhang, chi and cun" be converted into modern degrees? Kiang T, Bo Shu-ren, Wang Jian-min and Liu Ci-yuan have all done a lot of research work on it. They worked out 1 chi $=1\sim1.5$ degree. But no one has quantified these records systematically. As for the records of "big as X" , it has been a big mystery whether they can be quantified or not.

This dissertation researches deeply the quantification and reduction of the records of astronomical phenomena measured by "zhang, chi and cun" and the ones described as "big as X" in Chinese annals. This dissertation also sets up a new geometric model that shows interconnection between these records and researches deeply the correction of false impression about plane hemisphere. The author here wants people to end their confused idea in this field. The dissertation mainly resolves the questions as follows:

1. The author holds the view that there were many records of these two kinds stated above and they were widely distributed and permeated through Chinese annals. There were some methods and a model of celestial sphere. They were carried on from generation to generation. So they were systematic and therefore can be named "the Scale System of the records of ancient astronomical phenomena". This dissertation entirely expounds and proves this view by the quantity of the records, the rank of the records, the distribution and time of the records.

2. This dissertation entirely analyses the conversion results about chi and degree made by former scholars. The author then makes a conclusion that it's reliable that 1 chi = 1 degree. The author uses the newest astronomical software SkyMap8 to compare the

planetary distance records in official historical books, and proves Liu Ci-yuan's result is true, i. e. 1 chi =1 degree. This result can be pushed forward, e. g. 1 zhang =10 degree, one sky circumference = 36 zhang, and so on.

3. The author puts forward firstly that in the records of the ancients' observation of the sky with naked eyes, there was a basic knowledge that had not been spoken out by the ancients. This knowledge is similar to the projection on the celestial sphere in modern astronomy. According to the "sensed knowledge" and the conversion standard of "1 chi = 1 degree", we can set up the celestial sphere model of observing astronomical phenomena with naked eyes and then make out the geometric meaning of the records of "zhang, chi and cun". Through the analysis of the origin of the Chi System, the author obtains that the semi-diameter of the celestial sphere is about 13 meters. This dissertation also proves the existence of this celestial sphere in many fields, for example, psychological behavior factor, the radius of planetariums, the records of weather in Chinese ancient annals and nautical "Qian Xing Method".

4. After setting up the celestial sphere model, the author further proves that it is people's common consciousness that makes them image the astronomical phenomena on the celestial sphere of 13 meters semi-diameter and then they estimate the apparent size or length of the astronomical phenomena when they observe the sky with naked eyes. Nowadays people still have this ability.

5. The records of comparison with image ("big as X") were often thought to be some rhetorical descriptions which were vague, varied in their standards. But the author finds that they are not merely rhetoric but scientific records which belongs to a peculiar Chinese scientific method of thinking—comparison with image. Referring to the celestial sphere model of 13 meters, the author finds out the reference distance and proves that it is another form of the records of "zhang, chi and cun". We can unite them with the celestial sphere model when observing astronomical phenomena with naked eyes. So the records of comparison with image can be reduced to the apparent diameter or magnitude by the standard of the records of "zhang, chi and cun".

6. As people always regard the vault of heaven as a plane hemisphere, they have the common effect of false impression in their minds on what they have observed with naked eyes. Therefore the ancient observational data contained such systematic errors. The author thinks this false impression must be considered when we quantify and reduce the records of astronomical phenomena in Chinese annals. Or our explanation about these records will not be complete.

Under various illuminations and weathers, the vault of heaven has different plane degrees. Here we can define "the angle of apparent plane degrees" and quantify them now. In order to correct the errors, the author calculates a series of reduction tables about daytime, nighttime, clear days, cloudy days, moonlight nights, and moonless nights. We can use these tables to change the apparent heights or sizes to the true heights or sizes.

7. The records of "big as X" of meteors and (super)novae in Chinese annals were the values that the ancients had estimated the scale of visible surface of the stars' images. In fact, the visible surface is a special sensation that derives from the diffraction, diffusion of light and the effect of irradiation when we observe stars with naked eyes. In substance,

"big as X" are the records of brightness. These records can be quantified to apparent scales (angular diameter) according to the models of the celestial sphere. Therefore we can reduce the meteors' records "big as X" to the brightness on the bases of some "standard points" that are now known to us. The author here counts up 133 objects by comparison with image from 4 582 times on the records of meteors such as "big as X" in Chinese annals and reduced them to brightness. The records of (super)novae as "big as X" were reduced to brightness too.

8. The records of "big as X" of sunspots were estimation and measurement of the areas of sunspots by ancients. The areas of sunspots are very important data in modern astronomic research, so our analysis of the areas of sunspots recorded by ancients can promote the modern research of sunspots. The author uses the principle of visual physiology and statistical method and the model of the plane vault of heaven to reduce to the areas of the scale of the 17 comparison objects that come from 96 records of "big as X" of sunspots in Chinese annals.

9. According to the models of the celestial sphere, this dissertation quantifies the scales of the cometary heads and aurora, the lengths of the cometary trails and the wake of meteors. The author researches synthetically some typical cases recorded in Chinese annals so as to explain again the important meaning of the celestial sphere model of observing astronomical phenomena with naked eyes, and to quantify the records of scale and comparison with image.

Through synthetic research of various directions and disciplines, this dissertation means to reconstruct the modern scientific factor about the scale astronomical phenomena in Chinese ancient, supplies a "ruler of measuring sky" for researchers of history of astronomy, and finds out more quantitative basis about records of astronomical phenomena observed with naked eyes in Chinese ancient, for example, the star's covering, (super) novae, comets, meteors, sunspots, aurora and some special weather records, so as to supply more reliable ancient data for today's research of astromachanics, astrophysics and meteorology.

Key Words: the records of astronomical phenomena observed with naked eyes, the scale system, "big as X", the celestial sphere, quantification and reduction

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