Allusions to Ancient Indian Mathematical Sciences in an Early Eighth Century Chinese Compilation by Gautama Siddha

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Abstract

Gautama Siddha belonged to one of the three prominent Indian families of expert-astronomers settled in China during Tang dynasty (618-906 AD). Members of this family held important positions in the successive astronomical bureaus of Tang dynasty. Gautama, once President of the bureau, was assigned the task of writing down a compendium *Datang Kaiyuan Zhanjing* (大唐開元占經) since he was very well acquainted with both systems, Chinese and Indian. He devoted one chapter out of hundred and twenty altogether, to Indian calendar-making method, popularly known as the *Jiuzhili* or *Navagraha* method.

At the outset Gautama explained the decimal notation system as employed in arithmetical operations in India at that time. He recorded symbols for numbers one to nine and also zero. He went on to explain the division of earth's orbit into 360 degrees as against more than 365 in the Chinese system and further proposed algorithms for calendar making and prediction of lunar and solar eclipses. Trigonometric functions were also officially introduced to China through this work.

Key words: Ancient Indian astronomy, Calendar making, Eclipse-equinox prediction, Gautama Siddha, *Jiuzhili*, *Navagraha*, Siddhāntic astronomy, Tang China

1. INTRODUCTION

Study of the skies or 'the heavens' was a topic of great interest even to the ancients. It was useful in navigation at night to begin with. Monthly rotation of the moon and yearly rotation of the earth were studied to predict seasons, making accurate calculations of the calendar day and predicting celestial events like equinoxes and eclipses that sometimes had religious significance. Ancients also observed and recorded relative position of the planets as against the sun and distant constellations, to understand their motion. Every ancient culture developed their individual system of celestial observation, recording, calculations and prediction based on their indigenous celestial map with characteristic nomenclature for stars, planets and constellations. Yet, transmission of ideas and techniques were not

infrequent. Babylonian, Greek, Arabian cultures successively influenced both Indian and Chinese astronomy.

Likewise Indian astronomy substantially influenced both Arabian and Chinese astronomy during medieval period.

As Buddhism established itself in China, alongside Buddhist monks, experts of other fields like astronomy, medicine etc often visited the Chinese capital, especially during Tang dynasty. Three Indian families of expert astronomers are mentioned in Chinese historical records. Among them one 'Gautama' family was outstanding in the positions they held in court and their scholarly work in the field of making new calendar system, writing/compiling books. They advised the ruler in astrological matters too. They were highly

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Table 1. Approximate parallels to *Nakṣatras* are listed below

<i>Rohiṇī</i> 畢 Bì	<i>Kṛttikā</i> 昴 Mǎo	<i>Bharanī</i> 胃 Wèi	<i>Aśvinī</i> 婁 Lóu
<i>Puṣya</i> 鬼 Guǐ	<i>Punarvasu</i> 井 Jǐng	<i>Ārdrā</i> 參 Shēn	<i>Mṛgaśīras</i> 觜 Zī
<i>Uttara-Phālgunī</i> 翼 Yì	<i>Pūrva-Phālgunī</i> 張 Zhāng	<i>Maghā</i> 星 Xīng	<i>Aśleṣā</i> 柳 Liǔ
<i>Viśākhā</i> 氏 Dī	<i>Svāti</i> 亢 Kàng	<i>Citrā</i> 角 Jiǎo	<i>Hasta</i> 軫 Zhěn
<i>Pūrva-Aṣādhā</i> 箕 Jī	<i>Mūla</i> 尾 Wěi	<i>Jyesthā</i> 心 Xīn	<i>Anurādhā</i> 房 Fáng
<i>Dhanīṣṭhā</i> 廬 Lú	<i>Śravaṇa</i> 女 Nǚ	<i>Abhijit</i> 牛 Niú	<i>Uttara-Aṣādhā</i> 斗 Dǒu
<i>Revatī</i> 奎 Kuí	<i>Uttarābhadrapadā</i> 壁 Bì	<i>Purvābhadrapadā</i> 室 Shì	<i>Śatātārakā</i> 危 Wēi

respected for their mastery over both Indian and Chinese theories and techniques, and overall contribution they made in transmitting ancient Indian astronomical-mathematical knowledge into China. This article studies contribution by Gautama Siddha in some detail.

2. ANCIENT ASTRONOMY - INDIAN AND CHINESE

Ancient Chinese and ancient Indians both had their separate astronomical theories and practices that were in use long before they developed close contacts through Buddhism from second century AD onwards. These systems were largely similar since they both were studying identical celestial phenomena. Variations were due to dissimilar assumptions and other geographic and cultural factors.

A *nakṣatra* or a lunar mansion in Chinese is the group of stars the moon moves through in twenty four hours. Since the moon revolves round the earth in about twenty eight days, number of *nakṣatras* or mansions is also the same.¹ In fact, apart from the number twenty eight, all other factors are different e.g. number of stars in each

nakṣatra/mansion are different since they depend upon the position of the observer and therefore are defined in a different way in each culture. Again, when the stars in the constellation are not exactly alike, their overall shape, chief star in that constellation differs too.²

The twenty-eight mansions 二十八宿 of Chinese astronomy are divided into four groups of seven each referred to as East or Spring; South or Summer; West or Autumn; and North or Winter. Chinese zodiac is tropical i.e. it relies on sun's position in a particular constellation, and hence mansions are related to specific seasons. Furthermore, the beginning of the year does not change with precession of equinoxes but remains fixed since it is related to particular lunar mansion i.e. a distant constellation. Thus Chinese year begins when the sun enters the lunar mansion *jiao* 角, which is the first mansion in the section 'east' of the lunar mansions. *Nakṣatra Citrā* which means bright, clear or variegated corresponds to Chinese lunar mansion *jiao* which means 'horn'. Both correspond to the star spica in western astronomy. Here correspondence is as regards location which is measured as longitude with respect to the equatorial plane.

¹ The number was revised to 27 in later Indian works from 5/6th century AD onwards. *Nakṣatra* 'Abhijit' was dropped since it was not necessary. The division of the zodiac in 27 *Nakṣatras* was accepted to account for the period of 27.32 days taken by the moon to complete one rotation through the zodiac i.e. 360 degrees.

² Niu weixing. (1997/98), p119-129

Sūtra on Mañjuśrī Bodhisattva and the Sage's Teaching on Auspicious and Inauspicious Times, Days, Good and Evil Constellations and Luminaries 文殊師利菩薩及諸仙所說吉凶時日善惡宿曜經, translated by Amoghavajra (705-774 AD) in 759 and revised in 764 by disciple Yang Jing Feng 楊景風 under his master's guidance.

On the contrary, a major difference lay in calculating angles, since Indians divided the celestial orbit in 360 degrees whereas the Chinese into little more than 365 which is based on their assumption that the sun moves one degree per calendar day of twenty four hours. They divided the whole zodiac by number 365.25 hence their single smallest unit is smaller than a degree.³

3. ANCIENT INDIAN ASTRONOMY IN CHINESE BUDDHIST WORKS

Earliest indication of the entry of Indian astronomy is found in Buddhist canonical works. Ideas related to cosmology, constellations, the sun, the moon, planets; also names and categories of months like lunar, solar, intercalary months, changes in the lengths of day and night, noon shadow method for determining latitude of a place etc. are recorded in these works.⁴

Following three sutras allude to the noon shadow method for determining latitude of a place.⁵

Modengjia jing, Mātāṅgasūtra 摩登伽經 (TT 1300) the Chinese translation of *Śārdūlakarṇa-avadāna*, translated into Chinese in 230 AD,

Fo shuo shi fei shi jing 佛說時非時經 (TT794) – When time was non-time *sūtra* as told by Buddha

Dafang deng daji jing 大方等大集經 (TT 397) - *Mahāvaiṣṭya mahāsamghāta sūtra*

Siddhāntic astronomy appeared in later Buddhist *sūtras*. Buddhist *sūtra Brahma-horānavagraha* written around 751 AD, alluded to *navagraha* defined by the Indian tradition, the

nine heavenly bodies as 九執 *Jiu zhi*, the nine *grahas*, “seizers” or upholders, also written as *Jiu yao* 九曜 or nine luminaries or planets.

The nine luminaries mentioned are: 日 Āditya - the sun, 月 Sōma - the moon, five planets are- 火星 *Angāraka* - Mars, 水 *Budha* – Mercury, 木 *Brhaspati* – Jupiter, 金 *Śukra* – Venus, and 土 *Sanaiścara* - Saturn; also 羅睺 *Louhou* - *Rāhu*, and 計都 *Jidu* - *Ketu*, the demons that were supposed to cause eclipses.⁶

4. ANCIENT INDIAN ASTRONOMY IN CHINESE HISTORICAL RECORDS

Several allusions to ancient Indian astronomy, visiting Indian astronomers and their skills are found in Chinese historical records too. Titles of works related to mathematics and astronomy were also included in the *Polomen* 婆羅門 or Brahmin books listed in the bibliography of Sui dynasty (581-618 AD). These books are no more extant though. Their titles mention Jivaka, Nagarjuna, Brahmins or western sages as their authors suggesting their Indian connection. Among these, one by the name *Polomen tian wen jing* 婆羅門天文經, was probably related to astronomy and calendar science.

Later in the year 759 AD Amoghavajra, a well-known Tantrik author and translator of Buddhist canonical works, wrote *Xiu yao jing* 宿曜經 i.e. ‘Lunar mansion and planet *sūtra*’. A commentary to this work by Yang Jingfeng mentioned the three Indian schools of astronomy in following words.

³ Ho Pengyoke (1985)

⁴ ‘Four definitions of month are given in Volume 48 of Great Treatise on the Perfection of Wisdom namely “Solar Month”, “Karma Month”, “Lunation Month”, “Nakṣatra Month”. Therein, “Solar Month” is one-twelfth the length of the tropical year, “Karma Month” is an ideal year (360 days as an ideal year), “Lunation Month” is namely the synodic month and “Nakṣatra Month” is the sidereal month’. See Encyclopedia of India-China cultural contacts, MaXposure Media Group, New Delhi, 2014, part 1, p 74

⁵ Niu weixing – (1997/98), p199-129

Also see, Niu Weixing and Jiang xiaoyun, (1998).

⁶ Niu Weixing (2005) p329.

‘Those who wish to know the positions of the five planets adopt Indian calendrical methods. One can thus predict what *hsiu*⁷ (a planet will be traversing). So we have the three clans of Indian calendar experts, 迦葉 *Chia yeh* (*Jia ye Kāśyapa*), 瞿曇 *Chhu than* (*Qu tan Gautama*) and 鳩摩羅 *Chu mo lo* (*Jiu mo lo Kumāra*), all of them hold office at the Bureau of Astronomy. But now most use is made of the calendrical methods of Master *Chhu than chuan* (*Qutan zhuan*)⁸ together with his Great Art’.⁹

Here the author states that positions of five planets can be determined using Indian methods. Probably they were part of earlier calendars 經緯歷 *Jingweili* and 光宅歷 *Guangzaili* composed by Gautama Rahula, father of Gautama Siddha or in the methods taught by experts of other clans viz. *Kāśyapa* and *Kumāra*.

Also, *Xintangshu*, New History of Tang dynasty (10th century AD) records that Temolo, an Indian transmitted the method of solar eclipse prediction.¹⁰

In order to translate Buddhist works related to astronomy and astrology into Chinese and to express Indian ideas correctly, new terminology was developed in Chinese. It was formulated either by translating Sanskrit words into Chinese or transliterating them using Chinese characters with similar sounds e.g. 阿濕毘羅 *A shi bi ni* for *aśvinī*, 阿失麗沙 *A shi li sha* for *Aśleṣā* and 阿奴邏陀 *A nu luo tuo* for *Anurādhā*. This terminology changed with time as Gautama Siddha specifically mentioned in his work.

In the sub-section no. 4 while calculating the mean longitude of the sun, Gautama Siddha

explains the division of degrees in Indian method as sixty minutes of *fen* making one degree and thirty degrees making one zodiacal sign called *hsiang* and further that, signs filled to twelve should be cancelled. (Naturally, since they complete one circle). Gautama writes,

‘The *hsiang* is called *loshih* (*rāṣī*) in Sanskrit, which means collection. Formerly it was translated as *tz’u*, and now *hsiang* is adopted.’

We can see here that Chinese astronomers before Gautama’s time itself replaced the transliterated word *loshi* to its Chinese counterpart *hsiang*.

Again, in the sub-section no. 7, while calculating the anomaly of the moon 月藏 Gautama Siddha states,

‘Formerly *yuehts’an* (*yuechang*) was sometimes translated as *yueh-sun-i-shuai* 月損益率 (*candra-rṇa-dhana* in Sanskrit)’¹¹

When ideas or substances came from outside, related terminology was transmitted too. As new substances or ideas became familiar their foreign sounding names were dropped for more homogeneous terms. This is observed even in other disciplines like chemistry, alchemy and medicine.¹²

5. GAUTAMA CLAN OF ASTRONOMERS

The long tradition of having Indian scholar-astronomers in prominent positions in the Tang court began in mid sixth century AD and *Jiaye xiaowei* was probably the first among them. *Jiaye* or *Kāśyapa*, *Jiumolo* or *Kumāra* and *Qudan*

⁷ 宿 *Hsiu* or *Xiu* in Pinyin or the modern system of transliteration means ‘(lunar) mansion’.

⁸ Son of Gautama Siddha

⁹ *Xiuyao jing* p 350, see Sen Tansen (1995) p197

¹⁰ Yabuuti, K. (1979) p2

¹¹ Yabuuti, K. (1979) p 18 (Translation by Yabuuti K.)

¹² *Nao sha* for ammonium chloride or Sal ammoniac was written with different characters in succeeding periods which suggested that it was a transliterated word from some foreign language. The word was in fact derived from Sanskrit *Navasāra*. It was later changed to *Lu hua an* 氯化銨 or Muriate of ammonia.

or Gautama, these three were major astronomical schools of Indian origin at that time. *Qudan xida* or Gautama Siddha belonged to the Gautama clan settled in China.¹³ Four/five generations of this clan were high officers in astronomical bureaus of Tang dynasty. When Gautama family's tomb was excavated in Chang'an in the year 1977, inscriptions therein provided more information about the clan.

Gautama family was originally from Banares. One named *Gautama yi* went to China sometime in the sixth century. He worked as a translator of Buddhist classics. His son Gautama Rāhula 瞿曇羅 was the director of astronomy between 627 to 649 AD. He compiled two calendars viz. 經緯歷 *Jingweili* and 光宅歷 *Guangzaili*. As the family settled down in China they married Chinese women so later generations are not mentioned as 'Indian' in Chinese records.¹⁴

Gautama Siddha 瞿曇悉達 was born sometime after 650 AD. He was the head of the Bureau of Astronomy from 712 to 718 AD. Between 712 and 713 AD he was in charge of repairing the armillary sphere. In 718 AD he translated the *Navagraha Siddhānta* - *Jiuzhili* into Chinese. Being well acquainted with Chinese astronomical development till the time, he was given the task of compiling astronomical works. Gautama Siddha compiled a book named 大唐開元占經 *Datang Kaiyuan Zhanjing* - 'The Great Tang Treatise on Astrology of the Kaiyuan Era' between the years 718 and 728 AD. He

included all earlier rare texts of Chinese astronomy in this compilation thus making the otherwise extinct works available to posterity. For this reason, he is a highly respected figure in the History of Chinese astronomy.

Kaiyuan zhanjing devoted chapter 104 (hereafter KYZJ-104) to the so-called *navagraha* or *jiuzhi* 九執 method of calendar making. It was initially introduced into China through the *Mātāṅgasūtra* translated in third century AD. These *navagraha* or 'Nine upholders' refer to the sun, the moon, five planets and *Rāhu* and *Ketu* that were the terms given to the two nodes, ascending and descending respective of the moon. Scholars believe the contents of (KYZJ-104) as derived from, and not a direct translation of, famous sixth/seventh century Indian astronomical works *Pañcasiddhāntikā* by Varāhamihira and *Khaṇḍakhādya* of Brahmagupta of AD 575 and 665 respectively.¹⁵

Gautama Siddha wrote advanced algorithms in KYZJ-104 for calculations for predicting various astronomical events. *Jiuzhili* or the *navagraha* system did not get much popularity though. Knowing its importance the manuscript was secretly preserved. Therefore it was forgotten over a long period till accidentally in 1616 AD Cheng Mingshan 程明善 discovered the manuscript inside the stomach of a Buddha statue, most probably hidden there for safe keeping by some unknown Buddhist monk-scholar.¹⁶

Tang and early Song names of eye disease pterygium are *Nurou panjing* 翳肉攀睛 'spoilt flesh spreading over the eye', and *Nurou qinjingwaizhang* i.e. 翳肉侵睛外障 'The external obstacle due to the spoilt flesh invading the eye'. They appear to be derived from the Sanskrit term *Prastāri arma* - A spreading (over the eye) spoilt flesh. This was the time when there occurred major transmission of ophthalmic ideas to China from India. Pre-Tang name for the same disease was *Xi rou* or polypus in general. In modern terminology, pterygium is now called *Yizhuang nurou* 翼狀胬肉 or Wing-shaped spoilt flesh. This name is derived from the English name of the disease 'pterygium' which means 'wing-shaped'. It is in turn derived from Greek *pterygion* meaning 'wing'.

¹³ Sen Tansen (1995)

¹⁴ Jean-Claude Martzloff- Le Calendrier Chinois

¹⁵ Li Hui and Niu Weixing (2014) (2010)

¹⁶ Yabuuti, K. (1979) p 9

5.1 The 'zero' symbol and decimal place value system

In Indian scientific literature from the sixth century AD onwards one frequently comes across the 'zero' symbol and its application in the decimal place value. In the year 498 AD, when Āryabhaṭṭa wrote his *Āryabhaṭīyam*, he introduced the decimal place value system. Even before that time a Jain work *Lokavibhāga* of 458 AD referred to it. In China, however, both these concepts were unknown at the time of writing of KYZJ. The KYZJ -104 clearly mentioned both, the symbol of zero and its use in decimal value system for the first time. The text elaborated the new concepts in following words.

算字法：样一字二字三字四字五字六字七字八字九字点右天竺算法，有上件九个字乘除，其字皆一舉礼而成凡数至十进入前位每空位处恒安一点有间咸记，无由辄错，运筹便眼趁须，先及历度

'Method of the 'Counting symbols':
symbol for 1 - for 2 - for 3 - for 4 - for 5 -
for 6 - for 7 - for 8 - for 9 and a dot. On

the right (i.e. aforesaid) is Indian counting method. Using the above nine symbols, multiplication and divisions are carried. All these characters are single stroked, and are written cursively. While counting when the number reaches ten then it is entered in the front (row). In each vacant place is then placed one dot. In this way there is a mark/symbol in each place so there cannot be any error. The calculation is necessarily easy to the eye, so it is (we have described it) before the calendrical methods.'

Although, perhaps the symbols for the numbers were written by the original author Gautama Siddha, they were dropped by successive copyists and now we have only the mention of them in KYZJ that is preserved in a 18th century compilation that is oldest available source of this work now.¹⁷

KYZJ is available separately too in new editions.¹⁸

¹⁷ Here is the page from 四庫全書 *Siku quanshu*, a eighteenth century collection which contains KYZJ. The column second from left keeps the places of symbols blank. See the page below. It actually says 'character/symbol (for) 1, character (for) 2, and so on, without actually writing symbols. It is followed by the character in Chinese for 'dot' which is *dian* 點 or in the simplified version in modern compilations *dian* 点 as quoted in the passage above.

Fig. 1 See *Siku Quanshu* 四庫全書 *Wen yuan ge si ku quan shu dian zi ban*. [Catalog] [electronic resource] / *Di zhi wen hua chu ban you xian gong si*. 文淵閣四庫全書電子版. [Catalog] [electronic resource] 迪志文化出版有限公司. Hong Kong [1999?]

¹⁸ *Kai yuan zhan jing* (2012)

Other Chinese Buddhist works written around eighth century that refer to Indian numerals may give an idea as to how Gautama Siddha might have had written the numbers.

6. LATER GENERATIONS OF THE GAUTAMA FAMILY AND *DAYANLI* CONTROVERSY

Yi xing 行 (683–727 AD), a contemporary of Gautama Siddha, was a mathematician, astronomer and also a translator-commentator of Buddhist canonical works. He was in charge of the terrestrial astronomical board and under his direction was carried out the gigantic task of measuring shadow lengths and longitude of pole star at thirteen places between latitude 29 to 52 degrees North. These observations were used in a variety of astronomical calculations and eventually in writing a new calendar 大衍历 *Dayanli*. He created an armillary sphere in Chang an. Yi xing was the most prominent Buddhist monk of the time.

Gautama Siddha's son, Gautama Duan (712-776 AD) was a scholar astronomer as well as a soldier. He later held the office of Vice Director of the bureau of astronomy as the post was called in the Tang. Gautama Duan criticized *Dayanli* calendar made by Yi xing in 727 AD after the latter's death, pointing out that portions from *Jiuzhili* calendar were incorporated in *Dayanli*. He accused Yi xing of plagiarism. Since Yi xing was highly respected, and also that Gautama Duan's astrological predictions sometimes failed, he was banished from the court and the kingdom. Later, after the regime change he was reinstated and many honors were conferred upon him.

Some scholars are of the opinion that certain tangent tables documented by Yi xing were most probably an outcome of calculations made using sine tables method stated in *Jiuzhili* than actual observations.¹⁹ Again, some other scholars

do not agree with this but propose an alternative method that Yi xing might have used. In a nutshell, there exists controversy regarding the extent to which Indian methods/theories were incorporated in *Dayanli* but all agree that although Yixing used traditional Chinese methods in his calendar making, he was acquainted with Indians theories and he made use of them too.

Before Yixing there were astronomers like Cao Shikui of mid-Tang dynasty who developed their own methods and algorithms to calculate astronomical events. In his *Futianli* calendar Cao Shikui used the terms or concepts like *Louhou* – *Rāhu* and *Jidu* – *Ketu* but stuck to the measure of Sun's rotation as one degree a day, again an integration of two systems.

Yabuuti Kiyosi translated KYZJ – 104 i.e. *Jiuzhili* or the *Navagraha* calendar into English. He wrote an article based on his studies in the year 1963.²⁰ Later in the year 1979 he revised the translation with Michio Yano and published an article that included a commentary to Yabuuti's translations by Yano who is an expert of ancient Indian astronomy.²¹ Yano explained Gautama Siddha's algorithms in terms of *Siddhāntic* astronomical methods of calculations, simultaneously elucidating parallel terms from Sanskrit. Together Yabuuti and Yano translated and discussed all 37 sub-sections of the KYZJ-104 which are,

1. Numerals
2. Degrees in Astronomical System
3. Chapter on the *chijih* 积日 (*jiri*), sum of days from the epoch, *dyugana* or *ahargana* in Sanskrit and the *hsiaoyu* 小馀 (*xiaoyu*), its fraction
4. Chapter on the Calculation of the *chungjih* - 中日 (*zhongri*) mean latitude of the sun *madhyasūrya* in Sanskrit

¹⁹ Cullen, Christopher (1982)

²⁰ Yabuuti, Kiyosi. (1963)

²¹ Yabuuti, K. (1979)

5. Chapter on the Calculation of the *chungyueh* 中月 (*zhongyue*), mean longitude of the moon, *madhyacañdra*
6. Chapter on the Calculation of the *kaoyueh* 高月 (*gaoyue*), longitude of the lunar apogee, *cañdra-ucca* in Sanskrit
7. Chapter on the Calculation of the *yuehtsang* 月藏 (*yuecang*), anomaly of the moon, *cañdrakendra* in Sanskrit
8. Chapter on the Calculation of the *jihtsan* 日藏 (*jicang*), anomaly of the sun, *sūryakendra* in Sanskrit
9. Chapter on the Calculation of the *tingjih* 定日 (*dingri*), true longitude of the sun in Sanskrit
10. Chapter on the Calculation of the *tingyueh* 定月 (*dingyue*), true longitude of the moon, *sphuṭacandra* in Sanskrit
11. Chapter on the Calculation of the Daytime and Night
12. Chapter on the Computation of *yuehyu* 月域 (*yueyu*), moon's boundary i.e. true daily motion of the moon
13. Chapter on the Calculation of the *jihyu* 日域 (*riyu*), difference between the daily motion of the moon and the sun
14. Chapter on the Calculation of the *hsio-ko* 小刻 (*xiaoke*), *nakṣatra-kāla* in Sanskrit: a time interval since moon's entrance into the current *nakṣatra* to its present position at midnight
15. Chapter on the Calculation of the *hsiutuan* 宿斷 (*suduan*), *nakṣatra*-cutting i.e. time when moon enters the *nakṣatra*, *nakṣatra-ccheda* in Sanskrit
16. Chapter on the Calculation of the *chiehko* 节刻 (*jieke*), time of joint i.e. time interval between syzygy and midnight before and after, *parvakāla* in Sanskrit
17. Chapter on the Calculation of the *chiehtuan* 节斷 (*jieduan*), joint cutting, *parva-ccheda* in Sanskrit
18. Chapter on the Calculation of the *chunfen* 均分 (*junfen*), longitude of the moon and the sun at syzygy, *samalipta* in Sanskrit
19. Chapter on the Calculation of the *ahsiu* 阿修 (*axiu*), the moon's node, *asura* in Sanskrit
20. Chapter on the Calculation of the *chienliang-fu* 间量府 (*jianliangfu*), longitude of an eclipsed body counted from moon's node
21. Chapter on the Calculation of the *yueh-chienliang-ming* 月间量命 (*yuejianliangming*) half the cord of the *chienliang-fu* 间量府 (*jianliangfu*) i.e. sine table
22. Method on the calculation of the *yueh-chienliang* 月间量 (*yuejianliang*), moon's latitude
23. Method on the calculation of the *yuehliang* 月量 (*yueliang*), apparent diameter of the moon
24. Method on the calculation of the *ahsiu-liang* 阿修量 (*axiuliang*), diameter of the earth's shadow
25. Method on the calculation of the *chuanwei* 全位 (*quanwei*) or *panwei* 半位 (*banwei*) of the *ahsiu* 阿修 (*axiu*) and the moon (sum of the diameters of the earth's shadow and of the moon)
26. Method on the calculation of the Duration of a (lunar) Eclipse
27. Method on the calculation of the *yueh-kuei* 月規 (*yuegui*), moon's disc i.e. magnitude of a lunar eclipse
28. Method on the calculation of the *shihshen* 蝕甚 (*shishen*), middle of eclipses i.e. *vimarda* in Sanskrit
29. Method on the calculation of the *shihhsiang* 蝕行 (*shixing*), direction of the obscuration
30. Method on the calculation of the *jih-liang* 日量 (*jiliang*), apparent diameter of the sun

31. Method on the calculation of the Solar Eclipses
32. Method on the calculation of the *jih-shangsussu* 日上虛驪 (*jishangxusi*)
33. Method on the calculation of the *chiehtuan-cho* 节段刻 (*jieduanke*), the ecliptic point on the eastern horizon at the time of a solar eclipse, *parvakālalagna* in Sanskrit
34. Method on the calculating the *jih-chienliang-ming* 日间量命 (*jijianliangming*)
35. Method on the calculation of *houming* 后命 (*houming*)
36. Method on the calculation of the *jih-chienliang* 日间量 (*jijianliang*), moon's parallax in latitude
37. Calculation of a solar eclipse

7. CONTRIBUTION OF GAUTAMA SIDDHA TO CHINESE ASTRONOMY

Gautama Siddha must have faced enormous difficulties when he compiled KYZJ and particularly when he wrote the chapter on *Jiuzhili*. It was not an easy or straightforward task to write this chapter for several reasons. For that matter, the task of translating Buddhist works in general into Chinese must have been challenging in itself. It either involved word to word translations, or in the case of scientific texts when basic concepts were unfamiliar to the Chinese, the author either explained or simplified them. While dealing with topics like astronomy and medicine, the writer who would be a subject expert as well as linguist just as Gautama Siddha was, essentially wrote a new book altogether. The outcome typically would be a simplified version of original Indian work and an integration of two systems to some extent.

An analogous phenomenon was observed when Nagarjuna's ophthalmic works were written in Chinese between ninth and twelfth century AD. Although these works are based on *Suśrutasamhitā* and *Aṣṭāṅghṛdaya*, they essentially depict an integration of ancient Indian and Chinese ophthalmology.²²

Following factors must have made the writing of KY-104 tricky.

1. Different methods for the division of circle into degrees
2. New concepts introduced e.g. trigonometric concepts and the sexagesimal system for division of degrees, i.e. a degree is divided into 60 minutes
3. Dissimilar epochs used in Chinese and Indian calculations²³
4. Sanskrit terminology unknown to the Chinese and its forever changing Chinese parallels as seen in section 4.
5. Changing the standard latitudes to those of the Chinese capital Chang an for further calculations (see sub-section 11)²⁴
6. Theoretical considerations behind the construction of these algorithms were difficult to comprehend for the Chinese since they knew neither language nor tradition,

All this must have made writing of KY-104 very complex. Yet for the fact that predictions made on the basis of actual observations as done in the Chinese system were found to be more accurate than those using Indian methods, the foreign system was ignored; irrespective of the fact that they were based on genuine scientific theory. A paragraph from the New history of Tang dynasty quoted by Cullen (1982) makes the whole

²² Deshpande Vijaya Jayant with Fan Ka Wai (2012),
Also see Deshpande Vijaya Jayant (1999), (2000)

²³ - 'first day of the second month in the second year of Hsiench'ing reign period, March 20th of 657AD, Julian calendar') and Indian- March 20/21, 505 A.D. or Saka 427/428)

²⁴ Yabuuti, K.(1979) p25

scenario apparent.²⁵ Leaving aside the veracity of their judgment we surmise that *Jiu zhi li* was officially judged to be less precise and ignored.

Importance of the Indian system was acknowledged by certain Arab travelers in Tang China. Needham writes, 'Contemporaries such as Sulaimān al - Tājir recorded the impression that Indian astronomy was more advanced than the Chinese.' Sulaimān al - Tājir states, 'Physic and Philosophy are cultivated among the Indians, and the Chinese have some skill in medicine, hot irons or cauteries, they also have some smattering of astronomy; but therein the Indians surpass the Chinese.'²⁶

It was Yabuuti who recognized the true contribution of ancient Indian astronomy. Yano, Michio states, 'Indian astronomy represented by *Jiuzhili* was not highly regarded in China. Chinese records often refer to the *Jiuzhili* as a 'crude' calendar in comparison with Chinese calendars.'²⁷ Yabuuti, however, correctly pointed out importance of the very theoretical nature of Indian astronomy even though it was not very accurate from the practical point of view. For instance the decimal notation system with the symbol of zero, the sine function, spherical astronomy with

graphical representation, and parallax computations for solar eclipses were all recorded in this book'.²⁸ Yano further quotes Yabuuti Kiyosi, 'Such theoretical methods are far more advanced compared with the calendars in the Tang dynasty that used so called experimental methods, in other words, methods of induction exclusively from the ancient records.'²⁹

Li Hui summarized the contribution made by *Siddhāntic* astronomy in following words,

'In terms of astronomical calculation, *Jiuzhi* Calendar, at least, introduces six western (Indian) astronomical elements to China:

1. 360° circumference division
2. Counting method for 60 binary
3. Ecliptic coordinates system
4. Definition of distinctions between perigee and winter as well as between apogee and summer solstice
5. Method for calculating the visible diameter change of the Moon
6. Sine function calculation method and sine-function table.³⁰

²⁵ Cullen (1982), p 30-33)

The author quotes from *Xin tang shu* 新唐书 (New history of Tang dynasty of 1060 AD

'In the twenty-first year (of Kaiyuan era i.e. 733 AD) he (*Qutan zhuan*) memorialized jointly with Ch'en Hsuan-ching (Chen Xuan-jing) "The *Ta Yen li* (*Da yan li*) plagiarizes the *Chiu Chih li* (*Jiu zhi li*), and its methods are incomplete." A similar condemnation came from Nan-Kung Yueh (Nan-gong Yue), the Right Guardian of the Heir Apparent. The Imperial Clerk Li Lin and the Astronomer Royal Huan Chih-Kuei (Huan Zhigui) were then instructed to check the register of observations of the Imperial Observatory. It was found that the *Ta yen li* (*Da yan li*) was correct seven or eight times out of ten, the *Lin te li* (*Lin de li*) three or four times, and the *Chiu Chih li* (*Jiu zhi li*) once or twice only. Thus Nan-Kung Yueh (Nan-gong Yue) and others were seen to be in the wrong, and the dispute was settled." *Hsin T'ang Shu* (*Xin tang shu*) (28A, 587). Again, a brief note on the *Chiu Chih li* (*Jiu zhi li*) follows the full description of the *Ta yen li* (*Da yan li*). It concludes, 'The methods of *Chiu Chih li* (*Jiu zhi li*) were overelaborate, and although they were sometimes fortuitously correct they could not be taken as standard. The terms and quantities employed were strange, and at first no one could make sense of them. Ch'en Hsuan-ching (Chen Xuan-jing) and others took advantage of this to deceive their contemporaries, saying that I-hsing (Yi xing) has plagiarized (the *Jiu Zhi li*) and that the methods (of *Da yan li*). This was nonsense." *Hsin T'ang Shu* (*Xin tang shu*) 28B:692).

²⁶ Needham Joseph, Wang Ling. (1959), p 203

Also see, Al-Sīrāfi, Abū Zayd \$asan ibn Yazīd, (1733)

²⁷ See FN 24 above.

²⁸ Yano Michio (2001)

²⁹ Yabuuti Kiyosi. (1944)

7.1 Planetary Motion

The translated contents of *Jiuzhi* Calendar include the motions of the Sun and the Moon and calculations of magnitude and durations of lunar and solar eclipses, but are not related to planetary motion.³¹ Again, in an earlier quote an eighth century author states that positions of five planets can be determined using Indian methods. These methods are not found in KY-104. To investigate whether they were part of earlier calendars *Jingweili* and *Guangzaili* will again make an interesting and worthwhile study.

8. CONCLUDING REMARKS

Gautama Siddha was a scholar, a linguist and a historian. He stands high in the list of ancient Indian scholars who carried out the task of introducing ancient Indian scientific thought to the new land, thus enabling it to take root there and develop thereafter. It was not possible to translate Indian texts verbatim. Therefore the scholars studied corresponding Chinese systems and modified Indian material so as to make it digestible to the Chinese palate. Gautama was instrumental in the comparative study of two systems and their integration to some extent.

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³⁰ Li Hui and Niu Weixing (2014) p 96

Also see, Duan Yao-Yong and Li Wen-Lin (2011) p 45-54

³¹ Lu hui (2014) part 1, p 82

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