ANCIENT GUEST STARS AS HARBINGERS OF NEUTRON STAR FORMATION

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1. INTRODUTION

It was just after the discovery of neutrons in 1932, Landau suggested the possibility of compact stars composed of neutrons.In 1934 Baade and Zwicky proposed the idea of neutron stars independently and suggested that neutron stars would be formed in supernova explosions.

It is a pity that no any supernova explosion has been observed in our Galaxy since the invention of telescope. We have had no opportunity to catch the formation of neutron stars for these several hundreds of years. It naturally leads to the search for the ancient Guest Stars. "Guest Star" is a term that the ancient Chinese and the people in Far-East used to describe a new star. i.e. a star that suddenly appeared remarkably for some time and then gradually disappeared as if a guest in the sky. For example, the well-known AD 1006, 1054, 1572, and 1604 were all described as Guest Stars by Chinese, Japanese and Korean. In most cases, we might thus expect a Guest Star to be a term of supernova or nova.

There are a lot of records concerning ancient Guest Stars (AGS) in Chinese historical books. Two catalogues were compiled by Xi (1955) and Xi and Bo (1965, 1966) that listed 90 probable novae or supernovae observed between 1400 BC and AD 1700 Clark and Stephenson (1977),Ho(1962) and Kanda (1935) collected more or less similar records. Among all the historical records more than 80% are from China. Our following discussion are based on them.

2. THE FAMOUS CHINESE ANCIENT GUEST STAR AD 1054 AND THE CRAB

The Crab Nebula is the most fascinating object in our Galaxy (Fig.1) It is a very strong source over all the frequences. A rapidly spinning pulsar lies near its center and emits pulsating radiation with a period of 33 ms from the radio to the γ-ray frequencies. Many massages about synchrotron radiation, the origin of neutron stars, the sources of cosmic rays, the manufacture of heavy elements, the strange dense matter, the strong magnetic field and gravitation are comming from

D. J. Helfand and J.-H. Huang (eds.), The Origin and Evolution of Neutron Stars, 305–318.

the crab. It is no surprising that the Crab Nebula, as a cosmic laboratory, is an interesting topic at a lot of international scientific conferences and gives a good account of itself in the modern astrophysics.

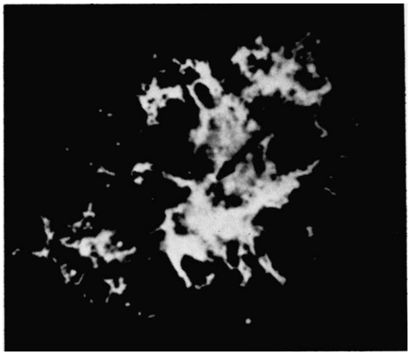

Fig.1. The Crab Nebula. The arrow marks the position of the Crab pulsar

Now it is well-known that the Crab Nebula is the remnant of the supernova explosion that occured in the constellation of Taurus on July 4th,1054 and observed by ancient Chinese astronomers. Some of the historical records of AD 1054 Guest Star are as follows:

1. 至和元年五月己丑客星出天关东南可数寸，岁余消没

《宋史》

"1st year of Zhi-ho reign period, 5th day of Ji-chou,* a Guest Star appeared approximately several inches to the south-east of Tian-guan. After a year and more it gradually vanished"

'Sung-Shi'

*i.e. July 4, 1054

2. 嘉祐元年三月辛未司天监言：'自至和元年五月客星晨出东方，守天關，至是没'

《宋史仁宗本纪》

"1st year of the Jia-hu reign period, 3rd month, day of Xin-wei,* the Director of the Astronomical Bureau reported that since the 5th month of the 1st year of the Zhi-ho reign period a Guest Stay had appeared in the morning in the east guarding Tian-guan and had only now become invisible"

'Sung-Shi-Ren-Zong-Ben-Ji'

*i.e. April 17, 1056

3. 至和元年七月二十二日守将作监致仕杨惟德言："伏觀客星出現，其星上微有光彩，黄色。"

《宋會要》

"1st year of the Zhi-ho reign period, 7th month, 22nd day ···. Yang Weide said:'I humbly observe that a Guest Star has appeared, above the star in question there is a faint glow, yellow in colour.'"

'Sung-Hui-Yao'

"During the 3rd month of the 1st year of the Jia-hu reign period the Director of the Astronomical Bureau said:

4. 嘉祐元年三月，司天监言："客星没，客去之兆也。"初，至和元年五月，晨出東方，守天關，昼見如太白，芒角四出，色赤白，凡見二十三日

《宋會要》

'The Guest Star has vanished.'Earlier, during the 1st of the Zhi-ho reign period the Guest Star appeared in the morning at the east, guarding Tian-guan. It was visible in the daytime, like Venus. It had pointed rays on all sides and its colour was reddish-white and visible for 23 days."

'Sung-Hui-Yao'

5. 天喜二年四月中旬以后，丑時客星出觜参度，見东方，孛天關星，大如歲星

《明月记》

"2nd year of the Tenki reign period, 4th month, after the middle decade, at the hour Chou (i.e. 1-3am) a Guest star appeared in the degree of Tsue and Shen. It was seen in the east and flared up at Tian-guan. It was as large as Jupiter.'

'Meigetsuki'

Hundreds of years later, a nebula in the constellation of Taurus was discovered by English amateur astronomer Bevis and the expression "Crab Nebula" was used for the first time by Rosse. In 1921 Lundmark first noted that its position is close to the location of the AD 1054 Guest Star and suspected that they were related. Lampland, Duncan and Hubble discovered and detected its expansion. In 1942 Ort and Duyvedark first identified the Crab Nebula as the remnant of the AD 1054 Guest Star. The discovery of the Crab pulsar in 1968 greatly strengthened this identification. The magnetic dipole model of rapidly rotating neutron stars put forward by Gold, Pacini, Goldreich, Ostriker and others successfully accounted for the energy source of the Crab Nebula. The deduced age parameter of the Crab pulsar approximately coincides with the explosion time of the Guest Star AD 1054. Hence, the Crab pulsar is an excellont sample for a neutron star formed in an event of supernova explosion.

Now we know that there are about 425 radio pulsars. The Crab pulsar is the only radio pulsar whose harbinger has been found in the historical records. This is because most of the radio pulsars are too old (10^4-10^7 yr) compared with the several thousand years of the civilization history of mankind, and are thus not possible to leave historical records.

Are there any other neutron stars except radio pulsars formed in the events of Guest Stars? From the data of hundreds of pulsars and the succesful magnetic dipole model, we know that "pulsar" is only such kind of neutron stars which have a definite range of the rotating period and the magnitude of the magnetic field as well as a certain structure of magnetic field and a limitation on the directions of radiation beam. It is obvious that there should be many neutron stars not detected as pulsars just because of the above physical or geometrical factors beyond the certain range or the limited sensitivity and counts of observation up-to-date. The most apparent example of them are those that exist as the central energy sources of supernova remnants like those in Crab-like SNR and composite SNR (Weiler 1985). In the next three paragraphs. our interests turn to the Guest Stars related to such central sources.

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3. THE GUEST STAR AD 1181 AND 3C 58

3C 58 was first suggested as a Crab-like SNR (Weiler & Seielstad, 1971)because of its center-filled morphology, flat spectra and strong linear polarization. The compact and extended X-ray emission was first discovered by Becker,Helfand and Szymkowiak(1982) from Einstein observation.

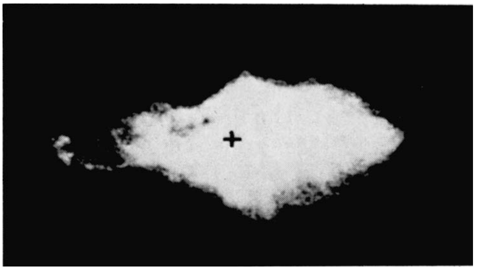

Figure 2. 3C 58 at 2.7 GHz (Green and Gull 1983). The cross marks the position of the X-ray point source.

Stephenson (1971), Wilson and Weiler (1976), Clark and Stephenson (1977) and Liu (1983) have suggested 3C 58 being the remnant of the Guest Star AD 1181. The historical records about it are as follows:

1.(宋)淳熙八年六月己巳客星出奎宿，犯传舍星，至明年正月癸酉，凡一百八十五日始灭

《宋史》

"On the day Ji-si in the 6th month of the 8th year of the Chun-xi reign peroid* a Guest Star appeared in Kui-su and invading Chuan-she until the day Gui-you of the 1st month of the following year**. Altogether 185 days, only then was it extinguished."

'Sung-Shi'

*i.e. August 6, 1181

**i.e. February 6, 1182

2.(金)大定二十一年六月甲戌客星见于华盖，凡一百五十有六日灭

《金史》

"On the day Jia-xu in the 6th month of the 21st year of the Da-ding reign period a Guest Star was seen at the Hua-gai altogether for 156 days, then it was extimguished."

'Jin-Shi'

3.(宋)淳熙八年六月己巳客星出奎宿，犯传舍……甲戌，客星守传舍第五星，九年正月癸酉客星始不见……

《文献通考》

"On the day Ji-si in the 6th month of the 8th year of the Chun-xi reign period, a Guest Star appeared in Kui-su and invading Chuan-she······ On the day of Jia-xu,the Guest Star guarding the 5th star of Chuan-she. It disappeared on the day Gui-you of the 1st month of the 9th year, altogether it

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4. 養和元年六月廿五日庚午
客星出北方，近王良，守
傳舍

《明月记》

appeared for 185 days since the day Ji-si of the 6th month last year, then it disappeared."

'Wen Hsien Thung Khao'

"On the day Geng-wu, the 25th day of 6th month of the 1st year of the Yang-he period* a Guest Star appeared at the north near Wang-Liang and Guarding Chuan-she."

'Meigetsuki'

* i.e. August 7, 1181

5. 治承五年六月二十五日庚午，
戌刻客星見艮方，(大如)
鎮星，色青赤，有芒角，是寬
弘三年(1006)出現之后无
例云云.

吾妻镜

"At the hour Xu, on the day of Geng-wu, the 25th day of the 6th month of the Zhi-Cheng period* a Guest Star was seen in the north-east. It was like Saturn and its colour was bluish-red and it had rays. There had been no other example since that appearing in the third year of Kuan-Hong (AD 1006)"

'Azuma Kagami'

The appearance of SN 1181 was also shown on the star map of Su-Zhou carved stone in China contributed by Huang Chang in AD 1190 with one more Star (than maps in other era) at the position where 3C 58 locates (Liu 1983).

The compact source in 3C 58 is likely to be a neutron star formed in the event of AD 1181 and was detected as a compact X-ray source by Einstein observation 800 years after the event.

4. THE GUEST STAR AD 1408 AND SNR CTB 80

CTB 80 is an unusual SNR.It has a bright core embeded in a very large three-lobed structure in radio (Angerhofer et al 1981). An optical ring of nebulosity is coincident with the central radio core from which some optical filaments extend (Van den Bergh 1980, Blair et al, 1984). a compact X-ray source was discovered by Becker, Helfand and Szymkowiak (1982).Its X-ray structure appears more jet-like than shell-like (Wang and Seward 1984). The compact X-ray source contributes 31% to the total X-ray luminosity.Strom et al (1980) have first suggested that CTB 80 may be the remnant of the Guest Star AD 1408. The ancient records about it are as follows (Li 1978, 1979):

"永乐六年冬十月庚辰，夜
中天，輦道东南有星如盏，
黄色光润，出而不行，盖
周伯、德星也" (《明实录》)

"Reign Ying-le, Year 6, winter, month 10, day Geng-chen*, at night, near the meridian, to the south-east of Niandao (13, η, θ, Lyr; 4, 17 cyg), there is a star like a lamp, its colour is yellow and its lustre smooth, it shows up and does not move,it is a Zhou-bo, a virtuous star."

'Ming-Shi-Lu'

* i.e. October 24, 1408

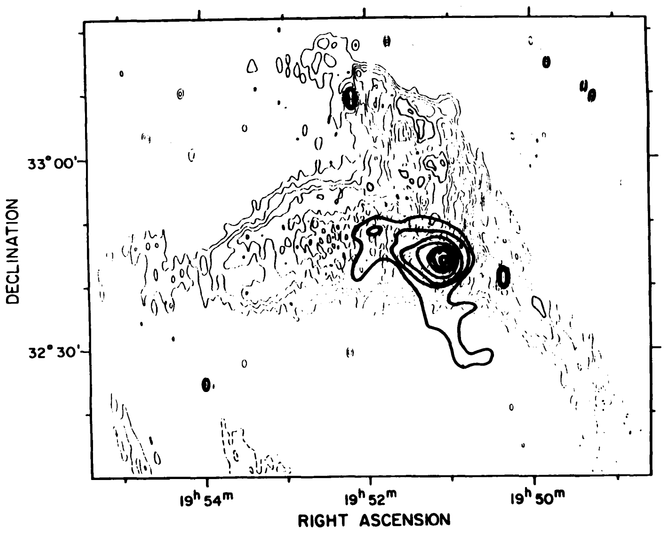

Figure 3. The Einstein IPC image of CTB 80 (Wang and Seward 1984). The thin contours are from 49 cm radio observation of Angerhofer et al. (1981)

Two difficulties have been advanced to this identification. One is about its too large radio size and the other is about its too small ratio of X-ray luminosity to radio luminosity L_x/L_R (Van den Bergh 1980, Dickel et al. 1981 and Becker et al. 1982).Our reanalyses of its Einstein observation (Wang and Seward 1984) showed the ratio of $L_x/L_R \sim 60$ for the whole source and $\sim$150 for the core-plateau region. This is to the advantage of CTB 80 being a very young SNR. Paying attention to the alignment of the X-ray jet-like structure with the projected magnetic field lines, the size of both radio and X-ray can be explained by the relativistic beam with 0.16c and its synchrotron radiation since the explosion in AD 1408. Strom and Blair (1985) compared its optical image in H_α +[NII] with one taken 28 years before also strongly support CTB 80 to be the remnant of SN 1408. Therefore the compact source in CTB 80 with $L_x = 1.0 \times 10^{34}$ erg s^{-1} (Wang and Seward 1984) is probably a neutron star formed in the event of AD 1408.

5. SOME OTHER POSSIBLE IDENTIFICATIONS BETWEEN AGS AND CRAB-LIKE SNRs OR COMPOSITE SNRs

Our discussion is based on the following principal of identification suggested by us (Wang et al. 1986). For an event of SN explosion, it should be described by the place where it occured and the time when it occured. A reliable identification should be made on the basis of agreement in visual position, distance and age between AGS and SNR. Let us first discuss the visual position. The visual position is exactly known for a known SNR, but is only approximately known for an AGS (e.g.

Lunar Mansion, Yuan or some other Chinese Asterisms). The agreement in visual position means that the visual position of a SNR is just in the region described for an AGS by the ancient records. As to the agreement in distance, we use the well-known relation:

$$M = m + 5 - 5 \times \text{LOG}\ d - A_V \qquad (1)$$

to an Ancient Guest Star at its observation time. Obviously m was its visual magnitude, probably around its maximum luminosity, and could be estimated for an AGS from its historical records. d and A_V should be its distance and absorption correction. It is sure that the ancient people could not know about its distance and absorption. But we can get them from its possible identified candidate of a SNR. Usually, d can be obtained from the neutral hydrogen observation or other method and A_V can be got from the following relation (Gorenstein 1975):

$$A_V = 4.5 \times 10^{-22}\ N_H(\text{ mag. }) \qquad (2)$$

or

$$A_V = 3.0E(B-V) \qquad (3)$$

Where N_H is the column density of neutral hydrogen, E(B-V) is the colour excess, If the value of the absolute magnitude M obtained from eq. (1) is approximately satisfied with the following relation (Trimble 1982)

$$M = -18^m \pm 2^m\!.5 \qquad (4)$$

the agreement in distance is set up. Finally we discuss the agreement in age-t. t is known for an AGS, and we can get t for a SNR from some theoretical considerations. We demand the age of both SNR and AGS is almost the same for a reliable identification or we demand a reasonable velocity for a SNR from its size and the age of its identified AGS. Using the principal of identification to 90 AGS(Xi and Bo 1965) and >130 SNR(Van den Bergh 1983, Green 1984). We find that the identification in the complete four-dimensions (two dimensions for the visual position and the other two for its distance and age) is a very crucial principal. It gives the identification with a very serious confinement and can exclude effectively some accidental coincidence (Wang et al. 1986). Obviously, the identifications for the Crab, 3C 58 and CTB 80 are satisfied with the principal. Now let us only talk about some other possible identifications related to Crab-like or composite SNRs.

G 332.4-0.4 (RCW 103) -----Guest Star BC 134

RCW103 is a composite SNR with a filament shell (Van den Bergh 1978) and a central compact X-ray source (Tuohy and Garmire 1980) that may be associated with the γ-ray source CG333+0 (Lamb and Markert 1981). It is considered as a young SNR owing to its small diameter (9 pc) and the high velocity of its optical filament and is estimated to be an order of magnitude younger than the Vela (Tuohy et al.1979), approximately

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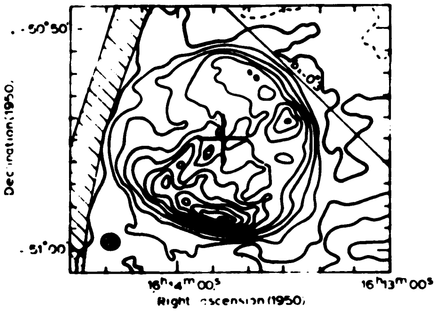
1-2x10^3yr old. According to the principal of identification, it should be the remnant of the Guest Star BC 134.



Figre 4. G 332.4-0.4 (RCW 103) at 1.4 GHz (Caswell et al. 1980).The position of the X-ray source is marked with a cross.

The ancient records of the Guest Star BC 134 are as follows:

汉"元光元年六月客見于房"
班固撰，约公元100年，汉书·天文志26卷
徐天麟等撰，约12世纪，西汉会要29卷

"During the 6th month of the 1st year of the Yuan-Kuang reign-period (22nd June to 21st July, BC 134), a Guest Star appeared at the Fang"
Ban Gu, AD 100, Han-Shu, Chapter of Astronomy, Vol.26
Xu Tian-ling, 17th Century, Hsi-Han-Hui-Yao, Vol.29

The Guest Star appeared at the Fang, the sky region of RA between π Sco and α Sco. RCW 103 is just in the Lunar Mansion of Fang. The Guest StarBC 134 was discovered by Chinese and Greek astronomer Hipparchus. We estimate its visual magnitued m=-3 around its maximum. Taking its distance d = 3.3kpc (Caswell et al. 1975), neutral hydrogen column density N_H=4.8 x 10^{21} (Tuohy et al. 1979) and absorption correction A_V to be 2.2 from eq.(2). An acceptable value of absolute magnitude for its maximum M =-17.8 is obtained. From its diameter and age, a reasonable average expansion velocity 2x10^3km.s^{-1} is obtained. So the central compact source sith L = 10^{34} erg.s^{-1}(Seward 1985) is probably a neutron stau formed in the explosion of SN BC134.

G21.5-0.9-------Guest Star BC48

G21.5-0.9 is a Crab-like SNR with a small linear size (1.7x2.9pc) and low brightness (Wilson and Weiler 1976). The ratio of L_X/L_R=15. It seems to be a young SNR but older than Crab (Becker and Szymkowiak 1981) Its brightest center shown in its Einstein HRI observation implies that a neutron star will be expected by the future X-ray observation with higher resolution and sensitivity. According to the principal of identification. G21.5-0.9 should be the remnant of the Guest Star BC 48. The ancient record about the Guest Star BC 48 is as follows

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"汉初元元年四月客星大如瓜,色青白
在南斗第二星东可四尺"
班固和班昭, 100年, 汉书 天文志

"During the 4th month of the 1st year of Chu Yuan reign period(May 3 to May 31, BC 48), a Guest Star as big as a melon with bluish-white colour was seen about four feet east of the second star of Nan-Tou."
Ban Gu and Ban Zhao, AD 100, Han-Shu, Chapter of Astronomy.

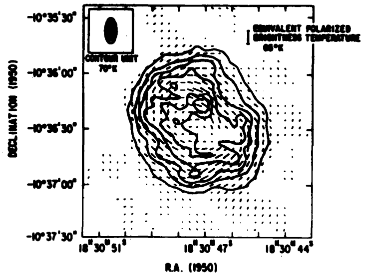

Figure 5. G21.5-0.9 at 5 GHz (Becker & Szymkowiak, 1981)

G21.5-0.9 is just located several degrees north-east to Sgr (the 2nd star of Nan-Tou) and close to the position described in the ancient record. We estimate m=-3 at its maximum. Taking d=4.8 kpc(Caswell et al. 1975), $N_H=10^{22}$(B ecker and Szymkowiak 1981), $A_V=4.5$ from eq. (2), then M=-20.9, also an acceptable value for a supernova at its maximum. From the size (3pc) and its age, an average velocity v=700 $km \cdot S^{-1}$is obtained, slightly lower than the others, perhaps due to its circumferentially oriented magnetic field. The expected neutron Star in G21.5-0.9 is likely to be formed in BC 48.

G74.9+1.2------- New Star BC532

G74.9 +1.2 is a very large Crab-like SNR in both radio and X-ray. It seems to be an older, more evolved remnant and was estimated as $3x10^3$ yr old(Weiler & Panagia 1980). Its X-ray is faint but is clearly brightest at the center(Seward 1985). Hence a compact neutron star will be expected in the future X-ray observation. Our following identification suggests that G74.9+1.2 Should be the remnant of the New Star BC 532. The ancient record about BC 532 is as follows:

"周景王十三年春有星出婺女"
作者不明, 公元前295年, 竹书纪年

"During the spring of the 13th year of Chau-Ching Wang, a star was seen at the Wu-Nu"
Unknown author, BC 295 Zhu-Shu-Ji-Nian

The New Star BC 532 was in Wu-Nu, a Lunar Mansion at the sky region of R A between ϵ Aqr and β Aqr. Considering the effect of precession for more than $2.5x10^3$ yr (Wu and Liu 1983), the circle of RA at 550 BC is shown as an inclination line in the star map of 1950. G 74.9+

1.2 is just in the Lunar Mansion of Wu-Nu. We estimate $m=1^m$ at its maximum. Taking d=12kpc(Kazes and caswell 1977, Sato 1977), $N=10^{22}$ (Wilson 1980) and $A_V=4.5$ From eq.(2). An expected value M=-18.9 is obtained at its maximum. From the size of G74.9+1.2 and its age, an acceptable $v=5.3x10^3 km.s^{-1}$ is obtained. The expected neutron star in G 74.9+1.2 is likely to be formed in BC 532.

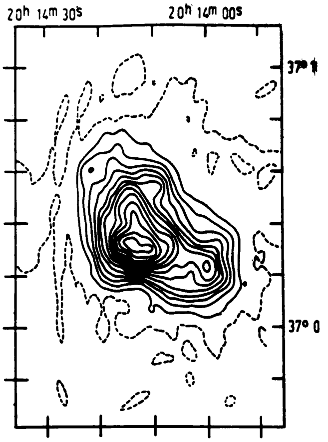

Figure 6. G 74.9+1.2 (CTB 87) at 1.4 GHz (Weiler & Shaver. 1978)

G 29.7=0.3 (Kes 75)----New Star AD 1523

Kes 75 is considered as a composite SNR in radio. X-ray observations showed only the central region ~20" (Seward 1985). A central neutron star will be expected from the future X-ray observation owing to its brightest center. Becker et al. (1983) suggsted an identify crisis for Kes 75 and comsidered it as an extremely young object because of its extremely high ratio of L_X/L_r~500, tripe that of the Crab.

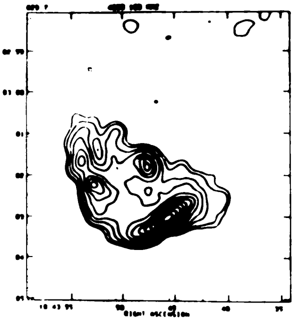

Figure 7. G29.7-0.3 (Kes 75) at 5 GHz (from Van Gorkum,Weiler 1985). The position of the X-ray emmision is marked with a cross.

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Our following identification shows that Kes 75 is probably the remnant of the New Star AD 1523. The historical records about the New Star AD 1523 are as follows:

明"嘉靖二年六月有星孛于天市"
張廷玉等撰, 1739年, 明史·天文志27卷
王圻著, 1586年, 续文献通考, 20卷
龙文彬撰, 约17世纪, 明会要, 68卷

"During the 6th month of the 2nd year of the Chia-Ching reign-period (July 13 to August 10,1523) a po star appeared at the Thieh-Shih (Enclosure of Heavenly Market."
Zhang Ting-yu, AD 1739, Ming-Shih, Chapter of Astronomy, Vol.27·Wang Yi. AD 1586, Xu-Wen-Hsien-Thung-khao, Vol 20
Long Wen-bing, 17 AD, Ming-Hui-yao, Vol.68

Kes 75 is located at the position where three constellations Serpens, Aquil and Scutum meet. It is at the Thieh-Shih. One of the three Yuan in the Chinese ancient division of the sky. As it was considered as a po star $m=5^m$ should be reasonable. Taking d=7kpc (Caswellet al. 1975), $N_H=3\times10^{22}$ (Becker et al. 1983) and $A_V=13.5$ from eq. (2), $M\simeq-22$ is obtained, slightly brighter than that expected from eq. (4). From its size(5pc) and age 460yr, $v=5\times10^3 km.s^{-1}$ is obtained and is reasonable and acceptable for a SNR. The expected neutron star in G29.7-0.3 is likely to be formed in AD 1523.

6. 2 CG 195+4 (GEMINGA)------GUEST STAR AD437

Geminga is a high-energy (>50 Mev) γ-ray source first discovered by SAS2 satellite in 1973 and then confirmed by COS B in 1975. Bignami et al. (1984) analysed the Einstein data and the new Exosat observation and discovered a period of $\gtrsim$59 sec with a high value of period derivative $\dot{P}$. They also summarized the following available data, two satellite (SAS2 and COS B)>50 Mev γ-ray observation, two ground-based $>10^{12}$ev r-ray measurement, three sets of Einstein observation and two sets of Exosat observation. They discovered that the very high $\dot{P}(2\times10^{-9} s.s^{-1})$ between 1973 and 1979 seems to become higher between 1979 to 1983 ($\dot{p}=4.68\times10^{-9}$). Considering the secular change of its period and period derivative, they estimate its age about 1.5×10^3yr and sugested that it may be related to the Guest Star AD 437 observed by the ancient Chinese. The ancient record of the Star AD 437 is as follows:

魏太延三年正月壬午, 有星晡前昏见东北, 在井左右, 色黄, 大如桔
魏收, 572年, 魏书, 105卷

元嘉十四年正月, 有星晡前昏见东北维, 在井左右, 黄赤色, 大如桔.
沈约, 500年, 宋书, 26卷

"On a Ren-wu day in the 1st month of the 3rd year of Tai-yan reign period (Feb.2, 437), a star appeared in the afternoon at the north-east near the Tung-Ching (Gem.). It was yellow in colour and as large as an orange"
Wei Shou, AD 572, Wei-Shu, Vol. 105
Shen Yue, AD500, Sung-Shu, Vol. 26

The identification is reasonable in three dimensions (visual position and age). Except that its distance is unknown and it is therefore difficult to complete the four-dimension identification. If we assume that Geminga is in the same distance as the Guest Star AD 437, then Geminga is likely to be a neutron Star formed in AD 437.

7. CONCLUSION

In the seventies, only two neutron stars----the Crab pulsar and the one in 3C 58 were known to be born at the events of Guest Stars. Or more exactly to say, it is only the Crab pulsar, because the compact source in 3 C 58 had not been detected and the concept of central energy sources was not very clear at that time. Now, our analyses show that the above 8 neutron stars were formed at the events of Guest Stars in history. If it is true, it will increase the birth rate of neutron stars or the frequency of Typw II SN explosions estimated only from the historical events. This result may also settle the difference between the birth rate of neutron stars and the frequency of Type II SN explosions to a certain degree. If we consider the much shorter lifetime of SNRs than that of pulsars and the incompleteness of samples of both historical enents and the observed SNRs with centeral energy sources, a better settlement could come out. Our above discussion can offer meaningful clues to the origin and evolution of both neutron stars and SNRs from historical facts and gives contemporary value to the ancient records of Guest Stars.

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DISCUSSION

KULKARNI: 1. I noticed that you in a few cases you use 21cm absorption to get A_V. However at low latitudes the HI column density provides only a lower limit to Av. This can be seen from CTB 87 where you obtain A_V= 4.5 but distance is 12 kpc. On the average one gets 1 magnitude per kpc at low latitudes.

2. The association of AD 437 event with Geminga is hard to understand given the absence of a nebula either in radio or optical(see Djorgovski & Kulkarni, 1986, Astron. J. 91, 90)

WANG: 1. It is sure that in a few cases A_V is obtained by 21cm observation. The values of N_H or Av here are obtained by some researchers individually. I think that it is better than the crude estimate of 1 magnitude per kpc. For example, Tycho SNR (G120.1+ 1.4) is also at the low galactic latitude similar to CTB 87 (G74.9 + 1.2), Clark and Stephenson (1977) took its absorption as 0.2 magnitude per kpc for identification, very different from your estimate. In our case of CTB 87, we take the value of N_H from Wilson (1980). He gave a range of value for N_H (1.o---1.6)$\times10^{22}$, then the value of Av will be 4.5---7.2 magnitude. It is just at the middle value between your estimate and the estimate of Clark and Stephenson. I think that the value of N_H given by Wilson for CTB 87 is probably the best choice for it.

2. The association of AD 437 event with Geminga is based on Geminga probably being a neutron star with a pulsating period and a period derivative reported by Bignami et al. (1984) and the agreement in both position and age between Geminga and the AD 437 event. The absence of a nebula might be caused by some unknown reasons which wait to be explored. Perhaps it was another new type of SN explosion which cause the remnant to disappear in a much shorter time. e.g., the explosion material with low mass and very high velocity or with relativistic velocity in a special structure of magnetic field would disappear soon.