Astron. Astrophys. 318, L59–L61 (1997)

ASTRONOMY AND ASTROPHYSICS

LETTER

Letter to the Editor

Is RX J1713.7-3946 the remnant of the AD393 guest star?

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Received 12 August 1996 / Accepted 19 December 1996

Abstract. A new supernova remnant RX J1713.7-3946 in the constellation Scorpius is suggested to be the remnant of the AD393 guest star. The available historical records of the AD393 guest star are introduced in this letter. According to the ROSAT observation of RX J1713.7-3946 and the historical records of the AD393 guest star, the visual position, distance, and age of both RX J1713.7-3946 and the AD393 guest star are in agreement.

Key words: history and philosophy of astronomy – stars: supernovae: individual: AD393 – ISM: supernova remnants

Pfeffermann & Aschenbach (1996) discovered a new supernova remnant (SNR) RX J1713.7-3946 in the constellation Scorpius at the position $\alpha(2000) = 17^{\rm h}13^{\rm m}42^{\rm s}$, $\delta(2000) = -39°46'27''$. It is one of the brightest soft X-ray SNR in our Galaxy with an X-ray flux density of 4.4×10^{-10} erg cm^{-2} s^{-1}.

Pfeffermann & Aschenbach (1996) made very careful spectral fits to various parts of the remnant. They derived kT = 4.8 keV and a distance of 1.1 kpc as a favourable fit for the remnant. This result is consistent with the EXOSAT observation of GPS 1710-396 at the same position (Warwick et al. 1988). Using the Sedov solution, they found the age of RX J1713.7-3946 to be 2100 yr.

Stimulated by this exciting ROSAT observational fact indicating a very young SNR, we have searched for a young historical supernova (SN) at its position. The AD393 guest star is a very favourable candidate. The historical records of the AD393 guest star now available were published in Jin Shu (Official History of Jin Dynasty) by Fang (AD635); in Sung Shu (History of Sung Dynasty) by Shen (AD500); and in Wen Xian Tong Kao (Historical Investigation of Public Affairs) by Ma (AD1254). The contents of these three historical records are the same. We copy only one of its ancient records from Sung Shu in Figure 1. Its English translation is as follows:

"A guest star appeared within the asterism Wei during the 2nd lunar month of the 18th year of the Tai-Yuan reign period (February 27 — March 28, AD393), and disappeared during the 9th lunar month (October 22 — November 19, AD393)."

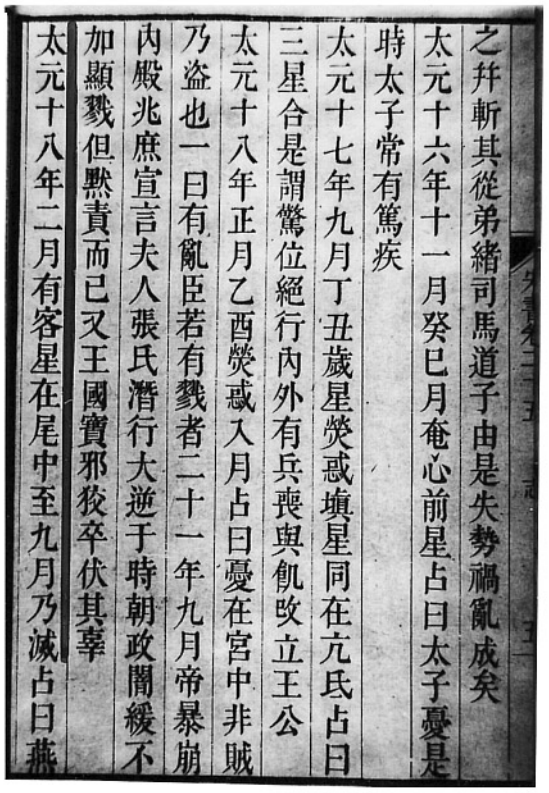

Fig. 1. The historical record of the AD393 guest star in Sung Shu (Shen AD500) — copied from its thread-bound edition in the Qing dynasty

The AD393 guest star was also mentioned by Biot (1846), Lundmark (1921), Xi (1955; 1983), Ho (1962), Xi & Bo (1965), Clark & Stephenson (1977), Chen (1987), and Zhuang et al. (1988) respectively in the 19-20th century.

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According to the historical records of the AD393 guest star, its position was within the asterism Wei. The asterism Wei includes nine stars: ε, μ, ζ, η, θ, ι, κ, ν, and λ in the constellation Scorpius (see Fig.2). The word "Wei" means that it looks like the tail of a dragon (Clark & Stephenson 1977; Chen 1987). Hence, "within the asterism Wei" means that the guest star appeared within the arc formed by the above nine stars. It is obvious that the position of SNR RX J1713.7-3946 ($17^{\rm h}13^{\rm m}42^{\rm s}$, $-39°46'27''$) is clearly within the asterism Wei. So, this remnant and the AD393 guest star are in good positional coincidence. The explosion of the AD393 guest star occurred about 1.6 thousand years ago, which is nearly consistent with the estimated age of the SNR RX J1713.7-3946 from its X-ray spectral fit and a Sedov model (Pfeffermann & Aschenbach 1996).

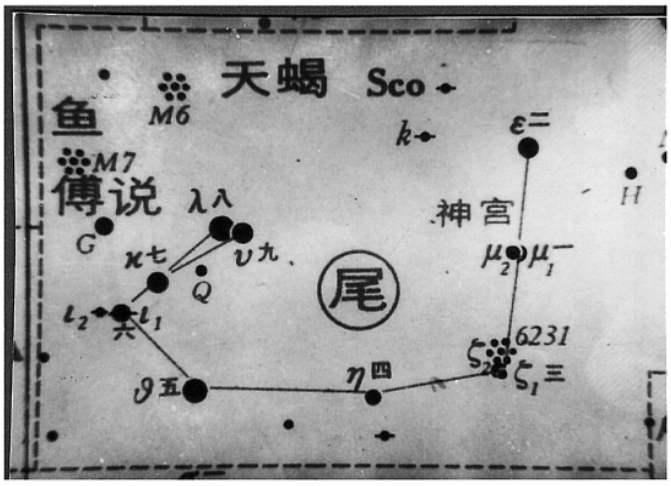

Fig. 2. The asterism "Wei" (taken from Chinese Encyclopedia, Astronomical Volume, 1980). The Chinese character in the circle is "Wei (tail)".

The ROSAT observation provides an estimate for the value of N_H, the column density of neutral hydrogen, throughout the whole remnant. If we take the N_H value in the center of the remnant as $\sim 4.5 \times 10^{21}\,{\rm cm}^{-2}$ (Pfeffermann & Aschenbach 1996), its absorption correction $A_V = 2^{\rm m}$ was estimated by the following relation (Gorenstein 1975)

$$A_V = 4.5 \times 10^{-22} N_H \ {\rm mag}.$$

This AD393 event was described as a guest star, which is a term used by ancient Chinese to discribe the brightest kind of new stars. Usually, the visual magnitude of a guest star is around $0^{\rm m}$ by estimation. There was no special description of the visual brightness for the AD393 guest star in its ancient records, unlike SN 1572, for example, that was described as bright as Venus ($-4^{\rm m}$) in the Chinese historical record. We consider that the visual magnitude of AD393 guest star at its maximum light was probably in the range of ($-2^{\rm m}$, $0^{\rm m}$). The reason is as folows: If the AD393 guest star had been brighter than $-2^{\rm m}$, the ancient Chinese astronomers would have described it as bright as Mars or Jupiter, but no such description exists now for it; on the other hand, if its maximum light had been fainter than $0^{\rm m}$, it would not have been visible by naked eye for 7-8 months, the 5th longest visible duration among all the guest stars. The argument regarding its position near the Sun when it disappeared (Clark & Stephenson 1977) should strengthen this point. Our consideration is consistent with the estimation of $-1^{\rm m}$ by Xi (1983). According to the well-known relation $M = m{+}5{-}5\log d{-}A_V$ and its distance $d \sim 1.1$ kpc (Pfeffermangn & Aschenbach 1996), its absolute magnitude at maximum light was probably between ($-14^{\rm m}$, $-12^{\rm m}$). This peak luminosity seems too low compared with SNIa, the M_{max} value of which is $\sim -20^{\rm m}$, but it is reasonable for SNIb/SNIc, especially for SNIc. If we compare the luminosity of the typical examples of SNIc, such as SN1994I and SN1987M, with that of SNIa, we find that the luminosity of SNIc is only 1% of SNIa (Nomoto et al. 1994, 1995). This means that the maximum absolute magnitude of SNIc is about 5 magnitudes dimmer than that of SNIa.

From the ROSAT observation (Pfeffermann & Aschenbach 1996), the morphology of the SNR RX J1713.7-3946 belongs to the shell-type. Especially it looks like a center-brightened shell-type SNR. ROSAT has observed some center-brightened shell type SNRs similar to RX J1713.7-3946, such as G299.2-2.9 (Busser, Egger, & Aschenbach 1996). In these SNRs, the brightest positions are not exactly in their centers, but near and around the centers, just like central rings. Theoretically, this kind of central-ring-brightened SNR can be expected to have originated from SNIb/Ic evolving in an inhomogeneous stellar wind bubble (Chen, Liu, & Wang 1995; Wang 1996). The progenitor of SNIb is a massive star without hydrogen envelope (Wheeler & Levreault 1985; Chevalier 1986). The progenitor of SNIc may be a bare C+O star which has lost its H-rich envelope and most of the He envelope (Nomoto et al. 1994, 1995). Because of the evaporation of the dense clumps of the circumstellar medium in the hot gas behind the blastwave, the thermal X-ray emission of the remnant has a central-ring-brightened morphology (Chen et al. 1995). Therefore it is reasonable to think that RX J1713.7-3946 might be a remnant of SNIb/Ic. The estimation of the absolute magnitude at the peak of the AD393 guest star around ($-14^{\rm m}$, $-12^{\rm m}$) in the above paragraph also implies that the RX J1713.7-3946 may be a remnant of SNIb/Ic and the distance of the AD393 guest star is in agreement with that of RX J1713.7-3946.

Considering that there are several new discoveries of subluminous SNIa recently (Phillips 1993), the AD393 guest star could have been a subluminous SNIa. The central-ring-brightened morphology of its remnant could also possibly have been produced by a SNIa exploding in an intercloud medium (White & Long 1991). If the distance of 1.1 kpc is correct for RX J1713.7-3946, SNIb/c is a favourable type for the AD393 guest star. If RX J1713.7-3946 is a more distant object, SNIa may also be possible.

Clark & Stephenson (1977) discussed the candidate SNRs for the AD393 guest star in detail. They first considered seven SNRs located within the asterism "Wei", then eliminated five of them, and finally suggested the following two SNRs,

G348.5+0.1 and G348.7+0.3, as the possible SNRs associated with the AD393 guest star. Since the distances of these two SNRs are both about 10.2 ± 3.5 kpc (Caswell et al. 1975; Green 1993), and they are both located at the Galactic plane, it is hard to consider a supernova at the Galactic plane as distant as ~ 10 kpc to be visible on earth by naked eye for eight months long. Hence Clark & Stephenson (1977) did not consider G348.5+0.1 or G348.7+0.3 as the certain or probable association of the AD393 guest star, but only as a possible one. It seems very difficult for the two SNRs, G348.5+0.1 or G348.7+0.3, to be in agreement with the AD393 guest star in distance.

Based on the positional, spectral, and morphological observation of SNR RX J1713.7-3946, the four dimensional agreements — two dimensions for the visual position, one for the distance, and one for the age — are suggested between the AD393 guest star and RX J1713.7-3946 in this paper.

Acknowledgements. Z.-R. Wang would like to express her gratitude to Mr. Y. Zhao in Nanjing University for his help in looking for the historical literature, and also to Dr. R. Strom for his valuable and helpful comments and suggestions. This work was carried out on the SUN workstation at the Laboratory for Astronomical Data Analysis of the Department of Astronomy, Nanjing University. This work was supported by the Ascent Project of the State Scientific Commission of China, the National Natural Science Foundation of China, and a grant from the State Education Commission of China.

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