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20 Pairs of Real Pulsar/Supernova Remnant Associations

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Abstract. We trace all pulsar/SNR associations proposed in the literature, and find that 20 pairs of associations are highly likely real because the pulsar wind nebulae around the pulsars have been detected.

1. Methods to Judge Pulsar/Supernova Remnant Associations

At least three kinds of methods are used to judge if there possibly exists an association between a pulsar and a supernova remnant (SNR): (a) The simplest method taken by many authors to judge the relation is to check whether a pulsar and an adjacent SNR lie along similar lines of sight. The method has to be carefully considered because they could be possibly physically unrelated; (b) A widely-used method is to check whether a pulsar and a SNR have compatible ages and distances and whether a transverse velocity derived for the pulsar is reasonable. This method's key is how to get convincing measured parameters, because an independently reliable measure of the age and distance for both SNRs and pulsars is usually difficult to obtain; (c) A very powerful method to confirm an association is by observing the interaction between pulsar and SNR, because when a pulsar is still inside its parent SNR, the high pressure of the surrounding plasma can confine the pulsar's relativistic wind generating synchrotron emission observable as a pulsar wind nebulae (PWN).

2. 20 Pairs of Associations Accompanying PWNe

So far, about 20 PWNe are known unambiguously around pulsars which are associated with SNRs: J0205+6449 / 3C 58, B0531+21 / Crab Nebula, J0537–6910 / N157B, J0538+2817 / S147, B0540–69 / 0540–69.3, B0833–45 / Vela SNR, J1124–5916 / G292.0+1.8, B1338–62 / G308.8–0.1, B1509–58 / G320.4–1.2, B1643–43 / G341.2+0.9, B1706–44 / G343.1–2.3, B1757–24 / G5.4–1.2, J1811–1925 / G11.2–0.3, J1846–0258 / G29.7–0.3, B1853+01 / G34.7–0.4, J1930+1852 / G54.1+0.3, B1951+32 / CTB 80, J2229+6114 / G106.3+2.7, B2334+61 / G114.3+0.3. As is known, there are at least two morphological types of PWNe: those with so-called filled-center morphology, in which the PWN is confined by

the gas pressure of the surrounding medium (e.g., the Crab), and those with a bow-shock morphology, where the PWN is confined by ram pressure resulting from the pulsar's motion with respect to its environment (e.g., B1757–24/G5.4–1.2).

PSR B1757–24/SNR G5.4–1.2: Pulsar B1757–24 is surrounded by a compact flat-spectrum nebula and is powering at least some of the radio emission of SNR G5.4–1.2. Manchester et al. (1991) first confirmed that the pulsar was associated with SNR G5.4–1.2 from the location of the pulsar relative to the SNR, and the agreement of the pulsar's characteristic age, 15.5 kyr, and the DM-based distance of 4.4 kpc with the age ∼14 kyr and distance ∼5 kpc of the SNR, respectively. By using HI absorption data, Frail et al. (1994) determined a lower distance limit of 4.3 kpc to the SNR, and further confirmed the association by determining the distribution of radio spectral index across the bright western side of G5.4–1.2. Gaensler & Frail (2000)'s multi-epoch VLA observations countered the above conclusions concerning the true age and proper motion velocity of the pulsar, and showed that the pulsar's true age should be 39–170 kyr. But this conclusion is doubted by direct interferometric proper-motion measurements of the radio pulsar (Thorsett et al. 2002).

PSR J0538+2817/SNR G180.0–1.7: The association was suggested for the positional coincidence and an acceptable similarity of distances and ages of PSR J0538+2817 and SNR G180.0–1.7 (S147). The estimated distance to S147 is uncertain and ranges from 0.8 kpc, as deduced from interstellar reddening measurements, to ∼1.6 kpc, based on the surface brightness–diameter relationship. The age for S147 is estimated between 80 and 200 kyr. Pulsar J0538+2817, located $\sim 40'$ west of the center of S147, i.e., about one third of the SNR radius, was discovered by Anderson et al. (1996) with a characteristic age 6×10^5 yr and a DM-based distance of 1.2 kpc. The association is more convincing due to the recent discovery of a faint PWN surrounding the pulsar in *Chandra* imaging (Romani & Ng 2003). Recent timing observations (Kramer et al. 2003) imply that the transverse velocity of the pulsar is 255–645 $\mathrm{km\,s^{-1}}$, and a real age for the association should be 30 ± 4 kyr.

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