

Puzzling Pulsars and Supernova Remnants

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Abstract. The fact that the majority of the youngest radio pulsars are surrounded by expanding supernova remnants is strong evidence that neutron stars are produced in the supernovae of massive stars. In many cases, the pulsar appears significantly offset from the geometric centre of the supernova remnant, indicating that the neutron star has moved away from the site of the explosion with a substantial space velocity since birth. Here we show that these offsets show an overwhelming preference for one sign in terms of Galactic longitude, a result that has important implications for the number of genuine associations. The origin of this statistically significant effect may lie in a differential Galactic rotational velocity between stars and gas in the interstellar medium.

An outstanding question in pulsar statistics is what fraction of proposed pulsar-supernova remnant associations are genuine as opposed to chance line-of-sight alignments. In attempting to answer this question, Gaensler & Johnston (1995) noted that the distribution of positional offsets shows a clear excess at small values compared to that expected by chance. These analyses suggest that between 7 and 17 of the 30 presently proposed pairs are genuine (Lorimer et al. 1998). Resolving the offsets into Galactic coordinates we find an important and unexpected twist in this story.

The positional data for 27 pulsar-supernova remnant pairings presented in Fig. 1 are the result of a cross-correlation of the publicly-available pulsar and supernova remnant catalogues (Taylor et al. 1995; Green 1998). For each pairing we computed the positional offset defined as the difference between the position of the pulsar and the geometric centre of the remnant. Following Shull et al. (1989) we normalised each offset to the angular size of the respective remnant. Although pulsar positions are known to within an arc second from timing measurements, positions of remnant centroids are more difficult to determine. We carefully searched the available literature to check the positions listed in the catalogue and obtain conservative estimates of their uncertainty.

It is immediately apparent that the distribution of offsets shown in Fig. 1 is not uniform. This is easily quantified by counting the number of pairs N within a given angular radius r . For a uniform distribution, $N(< r) \propto r^2$ so that the number expected within $2r$ should be $4N$. This is clearly not the case, with 10 and 18 pairs lying within half and one remnant radii respectively. What is most remarkable is the *sign* of the offsets. Whilst the signs in Galactic latitude

show no preference for positive or negative values, we see that 20 out of the 27 pairs have negative offsets in Galactic longitude. A simple binomial calculation suggests that this has only a 0.7% likelihood of happening by chance. All the 10 pulsars that lie within half a remnant radii have negative longitude offsets.

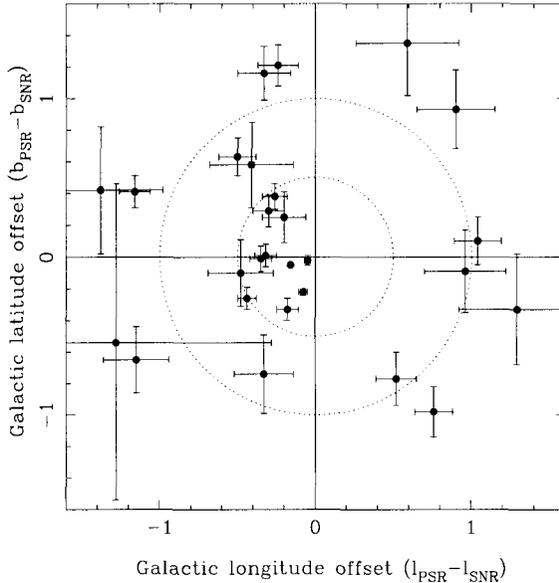


Figure 1. The distribution of normalised position offsets for pulsar-supernova remnant pairs. All offsets have been normalised to the angular size of the parent remnant. The normalisation allows us to display all the offsets relative to the size of the remnant shell (the circle of unit radius). Characterising the pairs in this way is extremely powerful since it does not rely on the distances to individual pulsars or supernova remnants, quantities that are often difficult to obtain reliably.

We have no reason to suspect that this highly significant effect is a result of measurement uncertainties which do not explain the absence of any trends in the latitude offset distribution. We conclude that the data are showing an intrinsic effect common to both the pulsars and supernova remnants. Although the physical origin of this effect is unclear, one possibility is that it is due to a differential velocity between stars and gas in the interstellar medium. We are presently investigating this more carefully using Monte Carlo simulations.

References

- Gaensler, B. M. & Johnston, S. 1995, *MNRAS*, 275, L73
 Green, D. A. 1998, <http://www.mrao.cam.ac.uk/surveys/snrs/>
 Lorimer, D. R., Lyne, A. G. & Camilo, F. 1998, *A&A*, 331, 1002
 Shull, J. M., Fesen, R. A. & Saken, J. M. 1989, *ApJ*, 346, 860
 Taylor, J. H. et al. 1995, <ftp://pulsar.princeton.edu/pub/catalog>