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A Search for OB Stars in Supernova Remnants

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Abstract. A massive binary, in which the primary becomes a supernova, should leave a luminous secondary near the centre of its remnant. Contrary to expectation no statistically significant excess of OB stars is, however, found near the centres of optically visible galactic supernova remnants.

Key words: Supernovae—supernova remnants—binaries

1. Introduction

Recently van den Heuvel, Ostriker and Petterson (1980) have presented a model in which SS 433 is considered to be a binary system consisting of an evolved early-type star and an old neutron star. Since many massive early-type stars are binaries a major fraction of all Supernovae of type II should leave early-type stars near the centres of their remnants. Even if these left over OB stars become runaway objects (Blaauw 1961; Zwicky 1957) they will still remain close to the centres of the supernova remnants in which they are located. This is so because the ejection velocity of a runaway star ($\sim 10^2$ kms^{-1}) is so much lower than the initial expansion velocity ($\sim 10^4$ km S^{-1}) of supernova remnants. A search for OB stars near the centres of supernova remnants therefore seemed promising.

2. Expected number of OB stars in SNR's

From data collected by Tammann (1974) it is seen that Supernovae of type II outnumber those of type I by factors of 4/3 and 21/13 in Sb and Sc galaxies respectively. Since the Galaxy is generally considered to be of morphological type intermediate between types Sb and Sc ~ 60 per cent of all galactic SNR's should have been produced by SN II. Of the 34 presently known optical SNR's in the Galaxy ~20·4 should therefore have been formed by the explosion of the massive (*cf.* Maza and van den Bergh 1976) precursors of SN II. According to Garmany, Conti and Massey (1980) ⩾ 37 per cent of all O stars are, on the basis of their radial velocities, certain or probable binaries. If it is assumed* that all primaries *and* secondaries become SN II then a fraction ⩾ 37/(63 + 37 + 37) = 0·27 of all galactic SN II remnants were produced by primaries and should still contain OB secondaries. On the basis of this assumption ⩾ 5·5 of the optically visible galactic SNR's should contain an OB star near their centres. The real number of OB stars in SNR's will be even greater than this because a large fraction of all OB stars are known to be members of wide physical double or multiple systems (Salukvadze 1979) such as the Orion Trapezium.

Since both OB star surveys and searches for optical SNR's extend to similar distances† it seemed worthwhile to undertake a search for OB stars near the centres of supernova remnants. Such objects would be particularly valuable because they might provide accurate distance determinations for supernova remnants.

3. Search for OB stars in SNR's

The O star catalogue of Cruz-González *et al.* (1974) was used to search for O-type stars located within 1·5 R_m (in which R_m is the larger of the optical and radio semi-

Table 1. Identified galactic supernova remnants.

Designation	Name	R_m (arcmin)	Designation	Name	R_m (arcmin)
G 004·5 + 6·8	Kepler	1·5	G 180·3 − 1·7	S 147	100
G 006·5 − 0·1	W 28	15	G 184·6 − 5·8	Crab	7
G 039·7 − 2·0	W 50	44	G 189·0 + 3·0	IC 443	27
G 053·6 − 2·2	3C 400·2	10	G 205·6 − 0·1	Monoceros	105
G 065·3 + 5·7	S 94	120	G 206·9 + 2·3	PKS 0646+06	40
G 068·8 + 2·6	CTB 80	20:	G 260·4 − 3·4	Puppis	40
G 074·3 − 8·5	Cygnus Loop	120	G 263·4 − 3·0	Vela	150
G 078·2 + 2·1	DR 4	31	G 284·2 − 1·7	MSH 10–5$\underline{3}$	25
G 111·7 − 2·1	Cas A	2·1	G 292·0 + 1·8	MSH 11–5$\underline{4}$	2·7
G 116·9 + 0·2	CTB 1	22	G 296·1 − 0·7	...	8
G 119·5 + 9·8	CTA 1	45	G 296·5 + 10·0	PKS 1209–52	40
G 120·1 + 1·4	Tycho	4	G 315·4 − 2·3	RCW 86	28
G 130·7 + 3·1	3C 58	5	G 320·4 − 1·0	RCW 89	5
G 132·7 + 1·3	HB 3	70	G 326·3 − 1·8	MSH 15–5$\underline{6}$	18
G 160·4 + 2·8	HB 9	78	G 327·6 + 14·5	Lupus	17
G 166·1 + 4·4	OA 184	45	G 332·4 − 0·4	RCW 103	5
G 166·3 + 2·5	VRO 42·05·01	38	G 342·0 + 0·1	Kes. 45	15

*Some support for this assumption is provided by the work of Bohannan and Garmany (1978) who find a real lack of low amplitude binary systems. Taken at face value their results indicate that O-type close binaries tend to have similar masses.

†Twelve of the SNR's listed in Table 1 have distances determined by Clark and Caswell. For these objects the mean and median distances are 2·7 and 2·0 kpc respectively. For a random sample of O stars in the catalogue of Cruz-González *et al.* (1974) the mean and median distances are 2·4 and 2·2 kpc respectively. There may, however, be some bias in favour of distance determinations for the nearer SNR's in the Clark and Caswell compilation. For the 12 SNR's in Table 1 with distances $\langle R_m \rangle$ =45' compared to $\langle R_m \rangle$ =35' for the 22 SNR's without distances.

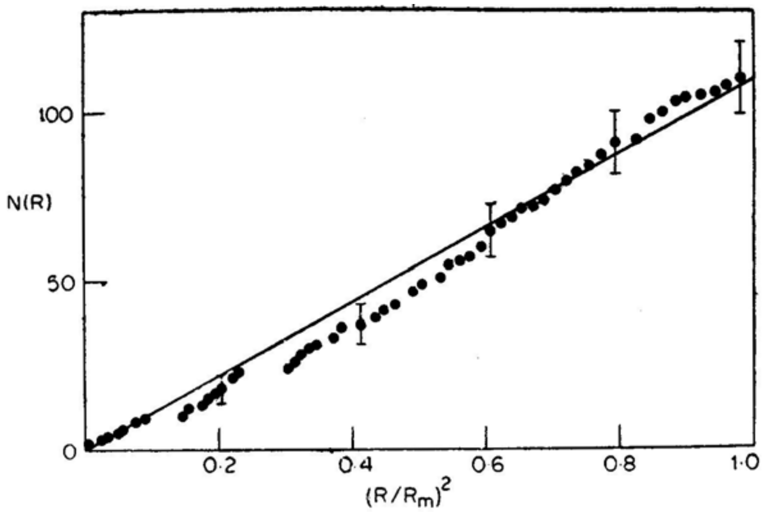

Figure 1. Comparison of the observed and expected (uniform) distribution of R/R_m values. The observations show no significant deviation from a uniform distribution.

major axes) of the centres of optical SNR's. Data on the adopted positions and R_m values of all 34 presently known optical supernova remnants are collected in Table 1. A total of 23 O stars were found to be located within 1·5 R_m of the centres of these SNR's. The distribution of these objects, as a function of their distance R from the centres of the remnants, is compiled in Table 2. The data in this table show that the observed distribution of R/R_m values does not differ significantly from that expected for a uniform distribution of O stars out to R/R_m = 1·5. Note in particular that only one O star has R/R_m < 0·25 compared to 0·6 expected for a uniform distribution. This star is the O 7·5 IIIf star HD 47125 (Plaskett's star), which is located 20′ from the centre of the Monoceros SNR. The fact that this star (Abhyankar 1959; Hutchings and Cowley 1976) is a double-lined spectroscopic binary shows that it is *not* the secondary surviving member of a close binary system.

Possibly the majority of ' missing ' central stars in SNR's are B stars or evolved early-type supergiants rather than O stars. The Hamburg/Warner and Swasey catalogue of *Luminous Stars in the Northern Milky Way* was therefore checked for objects with R/R_m < 1·0. The distribution of the R/R_m values of the 110 objects in volumes I, II, IV, V, VI of this catalogue, that are located in supernova remnants,

Table 2. Distribution of O stars within supernova remnants.

R/R_m	N (Observed)	N (Predicted)
0·00–0·25	1	0·6
0·26–0·50	2	1·9
0·51–0·75	3	3·2
0·76–1·00	4	4·5
1·01–1·25	9	5·8
1·26–1·50	4	7·0

is shown in Fig. 1. The observed distribution of R/R_m values within SNR's is seen to be indistinguishable from a uniform distribution. In particular only four stars are observed to have $R/R_m < 0{\cdot}20$, compared to 4·4 expected for a uniform distribution. In addition to Plaskett's star the following objects are found to have $R/R_m < 0{\cdot}20$:+42° 1286(B 0·5V)in HB 9and +27° 828, +27° 830(OB₋) in S 147.

The Hamburg/Warner and Swasey identification charts show that spectral classification is still possible in the brightest part of the Cygnus Loop. This shows that the observed distribution of OB stars within SNR's is probably little affected by emission nebulosity.

No plausible explanation, other than the perversity of small-number statistics presents itself for the unexpected lack of OB stars at or near the centres of galactic supernova remnants.

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