52. WOLF-RAYET STARS, RING-TYPE HII REGIONS, AND SPIRAL STRUCTURE

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At the Prague IAU meeting (Isserstedt and Schmidt-Kaler, 1967) we presented some results of investigations on stellar rings, a new kind of stellar association and powerful spiral tracer. We have since kept looking for similar features of gas or dust which might be early stages in the evolution of stellar rings.

We have found about a dozen regular ellipsoidal HII shells with very sharp filamentary outer boundaries (appearing as ring nebulae), and about half a dozen ring-type dark clouds for which a distance estimate was possible (Schmidt-Kaler, 1968, 1969). The minor diameter of the ring-type dark clouds is on the average about 6.5 pc. The exciting stars of 8 sharp HII ring nebulae are Wolf-Rayet stars. All of these are broad-lined, definitely single stars of the classes WN 5, 6, 8 – sequence B (following the definition of Hiltner and Schild, 1966). This is remarkable since WR-stars are a very rare class of stars, and about half of them are binaries. The minor diameter of the HII rings is in the average 6.8 pc. Only one object (NGC 7635) is definitely deviating from the average; it is peculiar also regarding the filaments, the exciting star WN4 p or 07 f, and its location on the rim of the HII filaments rather than near the centre. The observations of the other HII rings are compatible with the assumption of a unique minor diameter of 7.3 pc.

We decided to study the ring nebula NGC 6888 around HD 192163 in detail since a slight concentration of stars inside and particularly on the rim of the nebulae is apparent. Star counts confirmed that the density of stars brighter than $B=17^m$ is about 30% higher inside and about twice as high on the rim (the shape of the rim is completely determined by gas filaments, and *not* by the stars lined up along the edge). Photographic UBV photometry down to $V=16^m$, based on a photoelectric sequence set up in NGC 6888, has been obtained. Preliminary results for the stars on the rim show the colour-magnitude diagram of a very young cluster. The position of the ZAMS as defined by the reddening and distance modulus of the two high luminosity stars in the area with known MK class, HD 192163 WN6-B and BD+37° 3827 F3 Ib, gives a perfect fit to the distribution of the fainter stars in the colour-magnitude diagram. The distance is 1.9 kpc, the minor diameter 6.3 pc. If the supergiant is a member, it should be a contracting star. Cooperating with Mr. Schwartz (Bonn) continuum measurements of the northern ring nebulae at 2.7 GHz have been obtained, measurements at 1.4 and 11 GHz are under way. The results confirm the HII rings as purely thermal sources.

In a recent survey (with Dr. Haupt) of the 23 well-established X-ray sources on the Palomar and the Ross Calvert Milky Way Atlas we found again a connection with

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gaseous shells appearing as rings. Excluding one extragalactic radio source and three well-known supernovae remnants there are 15 X-ray sources for which charts were available. In four cases an X-ray star has already been identified:

GX3+1 lies on the rim of an HII ring, the geometric distance estimated from the ring diameter agrees exactly with the completely independent distance estimate of Freeman *et al.* (1968).

Sco X-1 lies on the outer edge of a ring-type dark cloud, the geometric distance estimate puts it at 300 pc to be compared with the distance of approximately 500 pc given by Westphal *et al.* (1968).

Cen X-2 lies again on the outer edge of a ring-type dark cloud, its geometric distance of 170 pc would relate it to the immediately adjoining coal-sack. For Cyg X-2 no conspicuous optical feature has been noted on the photographs. In the remaining 11 cases where no X-ray star has yet been identified the error circle contains in 4 cases a ring-type dark cloud and in 6 cases a schmetterling HII region (filamentary nebulae of a typical butterfly shape like NGC 6302, often containing elliptical ring filaments).

Cyg X-3 lies in the same region as Cyg X-2 and no optical feature can possibly be associated with it. In the neighbourhood of the schmetterlings always dark cloud rings are seen.

The distances of the X-ray sources have been estimated either by assuming a unique minor diameter of the associated ring type feature and/or from the photometric distance modulus of the associated schmetterling. They are located in the spiral arms as defined by early-type clusters and HII regions (Becker and Fenkart, 1970) or stellar rings (Isserstedt, 1970). The HII ring nebulae are also located in the spiral arms.

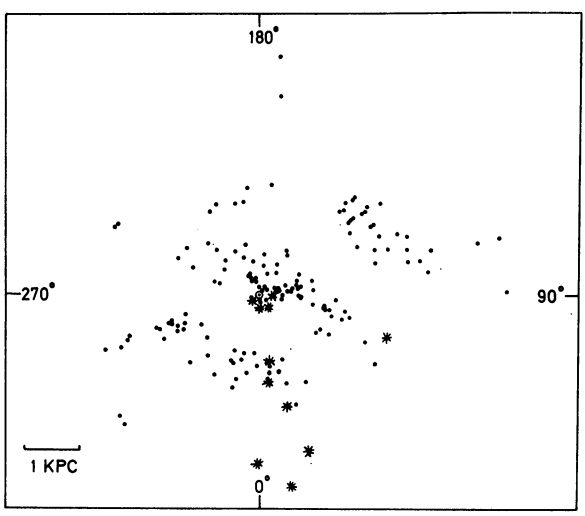

Fig. 1. Distribution of X-ray sources projected on the galactic plane (stars) and early-type clusters and HII regions (dots) according to Becker and Fenkart (1970).

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In conclusion I would like to summarize:

(1) Star formation seems to be going on in dense filamentary shells of gas of ellipsoidal shape, connected with non-binary WR-stars.

(2) The galactic X-ray sources which may be called non-synchotron may be very young objects showing signs of heavy mass loss, and are associated to ring-type dark clouds or HII regions.

(3) The characteristic diameter of these shells is about 6.9 pc.

(4) The X-ray sources are located on the spiral arms; the X-ray sources and the WR-stars (Smith, 1968) seem to be the farthest-reaching spiral tracers of the Galaxy, apart from the stellar rings.

A detailed paper will appear elsewhere.

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