KINEMATICS OF THE RING-SHAPED NEBULA N206 IN THE LMC

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Abstract. Preliminary results on the radial velocity field of the ring-shaped nebula N206 in the LMC are given. Several early type stars are located inside this nebula one of them being a WC5-6 star. A discussion about the kinematics of the gas around the WR star is also given.

We have performed direct imagery on the light of Hα (λ_0= 6568, $\Delta\lambda$=9.8Å, t_{exp}= 5 min) and [S II] (λ_0= 6719, $\Delta\lambda$= 16Å, t_{exp}= 15 min) and FP interferometry (p= 1365 and 3000) on the nebula N206 (Henize, 1956) in the LMC. Plate I shows the interference filter photographs. The [S II] (λ6717)/Hα line-ratio ranges from 0.05 to 0.4. The radio information on this nebula reveals a thermal nature (the radio sources 0532-710A and 0531-711C have spectral indexes of +0.03 and +0.00 respectively, (Milne, Caswell and Haynes, 1980)). The non-thermal radio source 0532-710B located at the East of this nebula is identified with the SNR N206A. However, this SNR is seen exterior to the nearly circular shape of the thermal nebula, N206. Its proximity to N206 could be only a projection effect rather than a real association. The 21 cm-line survey of McGee and Milton (1966) reveals that this nebula is engulfed in an HI cloud of mean particle density, $\bar{n}_H \simeq 1.2$ cm^{-3} and radial velocity, v_r= 240±10 km/s. N206 contains several early-type stars (some of them in the LH66 and 69 stellar associations (Lucke and Hodge, 1970). Figure I shows the mean radial velocities and the standard deviations of some regions of N206 obtained from the radial velocity data. The different regions shown in the figure correspond to different optical features but these divisions are quite arbitrary. Figure I also

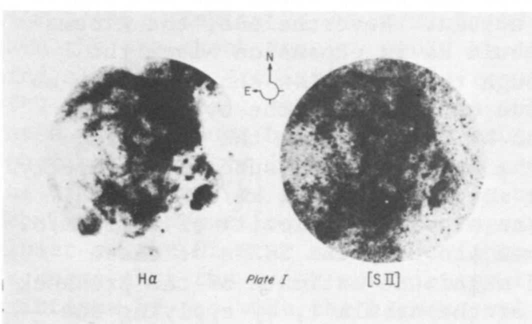

Plate I

C. W. H. de Loore and A. J. Willis (eds.), Wolf-Rayet Stars: Observations, Physics, Evolution, 479–483.

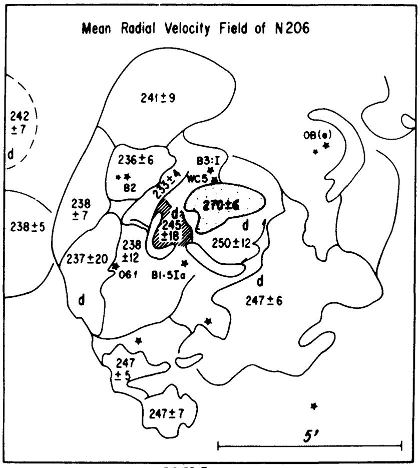

FIGURE I

shows the positions and spectral types of the early-type stars most relevant in this discussion: a WC5+OB star (SR 38-71, Sanduleak, 1969), an Of star (with an O9 fainter companion): R113 (Feast et al. 1960), a P Cygni-type star: R112 (Feast et al. 1960) of spectral type B1.5 Ia, a B3: supergiant (SK 39-71, Sanduleak, 1969) and an OB emission star (SK 34-71, Sanduleak, 1969). The radial velocity field shown in Figure I shows some regions with high velocity dispersions (revealed by their high values of their standard deviations) and with the existence of splittings in the FP profiles. These regions have some common characteristics: they are located quite close to the earliest stars where, in at least two cases, the existence of supersonic stellar winds (SSSWs) has been proved (R112 and R113, Hutchings, 1980). These regions (with the exception of the one near to the Of star) are located in the central parts of the nebula. In addition, the pointed region shown in Figure I, in the neighbourhood of the WC star, has the highest radial velocities relative to the velocities of the remaining regions (about 27 km/s higher than the systematic velocity of the whole nebula). We think that unless the existence of the B3 supergiant, these high velocities are due mainly to the interaction of the ISM with the SSSW of the WC star. The kinematics of this nebula must be quite intrincate because the windy stars are not concentrated in a small region inside the nebula. Nevertheless, the kinematical data seem to show that this nebula is in expansion since the central parts show splitting. Although the expansion should not be so simple, preliminary order of magnitude estimates of the systematic motion and the expansion velocity can be derived from the splitting data of the central regions, under the assumption of spherical symmetry. In this way we obtained a systematic motion of 246±11 km/s, in good agreement with the HI data, and a mean expansion velocity of 18±5 km/s. If we assume that this nebula has been blown by the SSSWs of these stars, then one can have an order of magnitude estimate of the preshock ambient density, n_o, and of the age of the nebula t, by applying the treatment of Castor, Mc Cray and Weaver (1975), since, n_o and t are given by:

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$$n_o = \frac{L_{36}}{3.3\ 10^{-7}\ R^2\ V^3}\ \ cm^{-3}$$

and

$$t = 16/27\ \ R/V\times10^6\ yr$$

where L_{36} is the wind luminosity in units of 10^{36} ergs/s, R, is the nebular radius in pc and V is the shock velocity in km/s.

The following table shows some of the properties (spectrum, luminosity class and visual magnitudes) of the early-type stars located inside,together with some typical values of their mass-loss rates ($\dot{M}$) and the number of ionizing photons (N_L). (These latter values assume that the LMC stars behave as the galactic ones)

TABLE I

Characteristics of the stars interior to N206 probably undergoing SSSWs

Name	Spectrum	m_V(mag)	$\dot{M}(M_\odot/yr)$	N_L[3](ph/s)
SK 38-71	WC5+OB[1]	12.83[1]	4×10^{-5} [2]	4×10^{47}
R112	B1.5Ia[4] (P Cygni-type star)[6]	11.16[4]	3×10^{-6} [5]	1.5×10^{46}
R113	Of (fainter O9 companion)[6]	11.36[4]	$(2-8)\times10^{-6}$ [5]	2.3×10^{49}
SK 39-71	B3:I[4] (composite Sp)	12.56[4]	$(0.6-1.7)\times10^{-6}$ [5]	3.7×10^{45}

1) Breysacher (1980); 2) Typical mass-loss ratios of galactic WC stars derived by Barlow, Smith and Willis (1981); 3) Derived from Panagia's (1973) table of supergiants stars having the same effective temperatures; 4) Rouseeau et al. (1978); 5) Typical mass-loss ratios of galactic O and B supergiant stars derived by Barlow and Cohen (1977); 6) Hutchings (1980).

By assuming a wind velocity of 2000 km/s, these values give: L_{36}= 57-66. Taking V≃ 20 km/s, R= 63 pc as typical values of N206, then the pre-shock density would be of about 4 cm^{-3} (that, having in mind all the uncertainties, this result is in rather good agreement with the HI data); the age of this nebula is of the order of 1.7×10^6yr. These values must be taken with caution because of the assumption of spherical symmetry involved in the computations. According to Table I, the Of star must be the responsible of the photoionization of the whole nebula; an inspection of the photographs shows that the regions closer to the Of star are the brightest indeed. Also from Table I, it seems that the major contributor to the winds is the WC star. The existence of gas with the highest velocity near the WC star goes in favour of this statement. However, while the WC appears to be the more evolved object inside the nebula, the derived age of this nebula is somewhat longer than the characteristic times of core He-burning predicted by the models of stellar evolution.

There appear to be at least three possible explanations to this fact: (1) the nebula has been blown by another pre-ocupant. This is supported by the fact that the stellar association LH69 (Lucke and Hodge, 1970), which contains R112, R113 and the WC star, has an age of a few 10^6 yrs, which is of the same order of magnitude than the dynamical age of the nebula. However, in this case we cannot explain in a simple way why the zones in the neibourhood of the windy stars have high velocity dispersions. (2) The mass-loss of the WC star has started in the star well before the appearance of the WR stage. The value of this primary mass-loss rate being smaller than the value of the actual WR mass-loss rate but in a sufficient amount in order to blow the bubble. If this case holds, then, the pre-shock density estimated before should be only an upper limit. (3) Finally, if one drops the assumption of spherical symmetry, one can think that the bubble was formed by the interaction of the SSSW shocks of several stars lying inside. In this case, it is necessary to have a detailed model of the interaction of these shocks in order to extract the shock velocity from the analysis of the radial velocity field.

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DISCUSSION FOLLOWING ROSADO et al.

Hogg: The problem with the age you deduce is the old one, namely, that the mass lost by the WC star is 70 $M_{\odot}$. That seems to be very high.

Rosado: First of all, these results are highly uncertain as I said in this talk, because they are based on the assumption of spherical symmetry which is not a very good assumption in this case. In any case, there are several possibilities: either the star has undergone a variable mass loss (smaller during its first stages that last longer) and in that case, the L36 would be smaller and consequently, the ambient density must be smaller too. Either you have the interaction of several shocks formed by the winds of the different early-type stars and then there is no spherical symmetry (as one can see from the radial velocity field) and the dimensions of the nebula and the radial velocities are not related directly with the wind luminosity as in the spherical symmetric case. A treatment similar to that developed by Jones et al. (1979) for the interactions of SNR's should be employed in order to have the energetics if that is the case. In any case, it seems important to explore all these possibilities in a more quantitative way.
(Jones et al.: Ap.J. 232, 129 (1979)).

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