OPTICAL OBSERVATIONS OF SNRs AND RING NEBULAE IN THE LMC

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The work we have performed on some of the SNRs and ring-shaped nebulae of the LMC refers mainly to: photographic plate Hα and [SII](λλ 6717 Å) imagery and Fabry-Perot (FP) interferometry.

I. THE IMAGERY

The photographic plate imagery has been performed by means of a focal reducer equiped with a 2-stage, magnetically focused, RCA image tube attached to the Cassegrain focus of the 1.52 m telescope of ESO. The photographs were calibrated, digitalized and filtered (Llebaria, 1980). From these we obtained the 2-D [SII]/Hα line-ratios of the nebula. Figure 1 is a plot showing our results on the [SII]/Hα line-ratios of some of the LMC SNRs and ring nebulae.

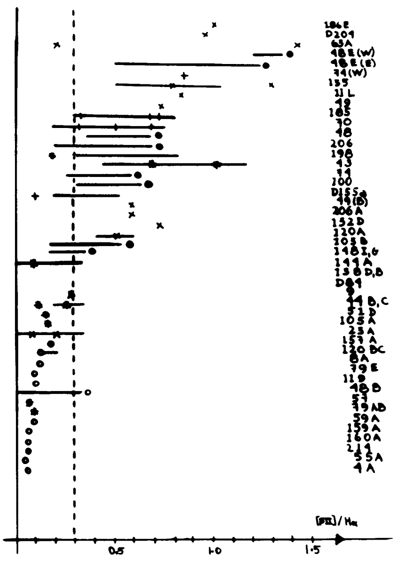

Fig. 1. [SII](λλ6717+6731)/Hα line ratios of nebulae in the LMC obtained from our imagery (straight lines) or from spectroscopic observations of different authors (points). Henize or DEM numbers are given at the right-hand side (DEM numbers are symbolized by a D preceding the number). The different symbols of the points correspond to the different nature of the nebulae (X = SNRs; + = ring nebulae of unknown origin; * = nebulae presumably formed by SSSWs; o = classical HII regions). Encircled symbols are used only to show the nature of the nebula and do not correspond to any observation.

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Figure 2 shows, as a matter of example, the [SII]/Hα line-ratio of the nebula N 23 A which is thought to be an HII region superimposed to the radio and X rays SNR.

Fig. 2. r = [SII](λλ6717+6731)/Hα line-ratio distribution of the nebula N 23. The values are as follows : r < 0.14, weak points: 0.14 < r < 0.26, bright points: 0.26 < r < 0.38, horizontal bars and r > 0.38, vertical bars.

Two facts can be seen directly from the plot shown in Figure 1:

- In general, the nebulae show large internal variations in their [SII]/Hα line-ratios.
- The ring nebulae of unknown origin have, in general, [SII]/Hα line-ratios greater than those of classical HII regions ($\gtrsim$ 0.3).

These assertions have several implications :

- In the case of SNRs, large internal variations on the line-ratios of some galactic SNRs (as the Cygnus Loop filaments (Fesen et al., 1982)) have been also found. These variations are interpreted as indications of non-steady flow situations. Consequently, one must be careful with the interpretation of relations between line-ratios and some other quantities such as diameter or galactocentric distances (the latter used in the study of gradients in abundances) because the internal variations in these line-ratios are, in some cases, larger than either the variations among different SNRs or the dispersion due to the use of different shock models. Thus one must select only the data corresponding to the brightest filaments in order to be sure that the data correspond to radiative shocks.
- The enhanced [SII]/Hα emission of ring nebulae has been frequently interpreted as a consequence of shock emission. However, photoionization models which take into account geometrical effects, such as steps in density, may predict enhanced ratios (Stasinska, 1980). Thus, the large internal variations of the ring nebulae may be interpreted either as deviations to steady flows (if the emission is due to shocks) or as due to differences in the ionization degree of the filaments (if the emission is due to photoionization).
- Because of the geometrical enhancement in the forbidden line-ratios of photoionized nebulae we conclude that the only means of finding shocks from observations at optical wavelengths are:
  i) The knowledge of the radial velocity field of the nebula (in order to see if there are large internal motions)
  ii) The observations of temperature sensitive line-ratios such as the [OIII]λλ 4363/(5007 + 4959) line-ratio.

2. FP INTERFEROMETRY OF RING-SHAPED NEBULAE

Figure 3 shows the splitting distribution of two ring shaped nebulae of unknown origin: N 185 and N 70. These were derived from our FP interferometry performed at the Cassegrain focus of the 3.60 m telescope of ESO (Rosado et al., 1982, 1981 respectively). For N 70 we have also plotted the splittings observed by Blades et al. (1980) in their spectroscopic work. The spectroscopic observations of Dopita et al. (1981) are not shown but, in general both the spectroscopic and the interferometric data agree and complement themselves.

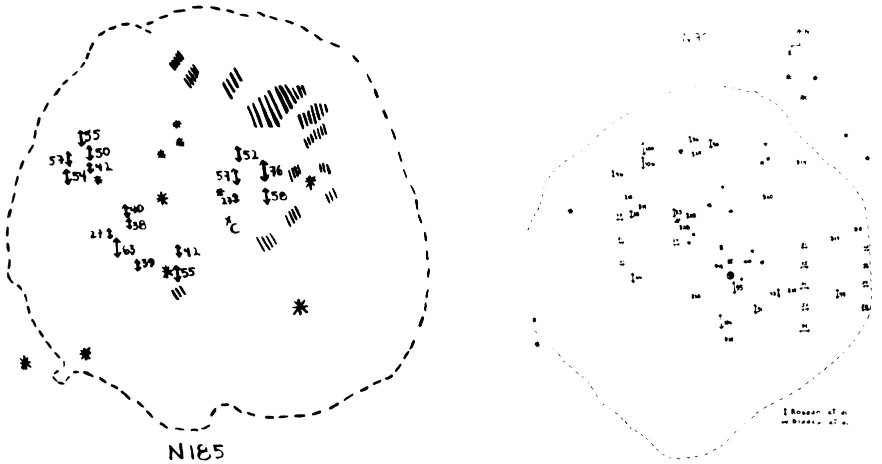

Figure 3. Distribution of splittings in N 185 (left) and N 70 (right). The numbers give the differences in radial velocities (in km s^{-1}) between the two components. The hatched zones correspond to splittings found in low surface brightness filaments but difficult to evaluate accurately.

Three models are the most favoured in explaining the origin of these ring nebulae:

- The fossil SNR model.
- The supersonic stellar wind (SSSW) driven nebula model (Weaver et al., 1977; Dyson and de Vries, 1972).
- The confined bubble (CB) model (Dopita, 1981).

The models predict differences in the kinematics which can be verified by the observations. Some of these differences are:

- The first two models may predict non-spherical shapes if the event occurs in a large scale inhomogeneous medium such as a medium with a gradient in density. Consequently, the faintest filaments must be correlated with the highest velocities (the strongest splitting). On the other hand, the CB model predicts a non-spherical shape due to the asymmetry in pressures of the collapsing cloud material when the star is not located at the center of accretion. This model may predict that the strongest splittings occur near the brightest filaments.
- The CB model predicts also, a lack of splittings in the central

band (due to the refraction of the stellar wind at the oblique shock front).

- The angular variation of the filaments located at the boundaries might be explained by the three models in their non-spherical modalities.

In the case of N 185, the splitting pattern indicates an expansion. Its density, energetics and stellar content are more compatible with the fossil SNR model (Rosado et al., 1982).

The case of N 70 is more complicated:

- The pattern show strong splittings in the central band.
- The splittings are, in the mean, of the same strength in both the faint and bright sides of the nebula (however, the strong splittings found in the weakest filaments are difficult to evaluate accurately and consequently we have an observational selection effect).
- The radial velocities of the boundaries show an angular variation.
- There are strong splittings in the bright filaments located at the boundaries.

The latter point makes these observations incompatible with any of the mentioned models. It is important to establish if there is a correlation between the brightness of a filament and the splitting strength. In any case, in a time comparable to the cluster age, a SN explosion could occur.

In conclusion, at the moment, optical observations are the only means in the discrimination of old SNRs.

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DISCUSSION

RAYMOND: Did you find the same small splitting in the center of N70 which was seen by Dopita et al.?

ROSADO: We find large and small splittings in the central band of N70 depending on the position. The advantage of FP interferometry is that it gives a 2-D view of the radial velocities over the entire nebula necessary in order to survey the zones of splittings. It seems that the slit position in Dopita's spectroscopy did not fall at the place of strong splittings. It is in this sense that the interferometric and spectroscopic observations are complementary.