THE MULTIPLE-PHASE STRUCTURE OF THE INTERSTELLAR MEDIUM IN THE LMC

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Physical properties of the ISM near SNRs in the LMC can be deduced from their very high-resolution, two-dimensional spectra. The ISM around the N49 and N63A SNRs apparently has as many as three different phases of varying density, clumpiness, and spatial distribution.

1. OBSERVATIONS AND RESULTS

The N49 and N63A SNRs were observed with the 4 m echelle spectrograph at Cerro Tololo. The optical emission lines of H I, [O III] , [N II] and [S II] were imaged. Angular resolution was 1".9, and the night-sky line was 10 km s^{-1} wide (HWHM). Further details concerning this and following sections are in Shull (1983) and references therein.

Each emission "line" consists of a sharp spike (at rest in the LMC reference frame) flanked by spectral features called narrow bands and broad bands. N49's features indicate spherically symmetric expansion, while those in N63A show only asymmetrical blueshifting. Characteristic velocity widths, surface brightnesses, and velocity shifts (relative to the spikes) of these spectral features are summarized in Table 1.

TABLE 1. Properties of Spikes and Bands in N49 and N63A.

SNR	Feature	Δv (km s^{-1}, HWHM)	v shift (km s^{-1})	Surf. Brightness
N49	Spike	7-16	0	...
"	Narrow Band	30-60	100-140	Low
"	Broad Band	80-130	20-70	High
N63A	Spike	9-17	0	...
"	Narrow Band	30-50	20-50	High
"	Broad Band	70-110	100-140	Low

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2. INTERPRETATION OF THE RESULTS

N49 and N63A both have round X-ray disks about 1' in diameter (Mathewson et al. 1983). Optically, N63A is much smaller than N49 (which is almost coextensive with its X-ray disk). Since both SNRs are in the "radiabatic" phase, simply meaning that radiative clouds and the adiabatic blast wave simultaneously exist, the first inference is that radiating clouds are less plentiful in N63A than in N49.

The broad and narrow bands are produced by shocked gas, while the spikes are produced by photoionized gas. Therefore it is reasonable to identify the velocity shifts of the bands with the bulk outward motion of gas clouds accelerated by the high-speed SNR blast wave.

Clouds are accelerated by momentum transfer and the pressure change across the shock front. Equations by Cox (1979) indicate that the resulting velocity increase is proportional to (matrix density / cloud density) as measured before the collision, to the blast velocity at impact, and to a geometrical factor. Using measured expansion velocities, it is therefore possible to (1) estimate the density ratio between the intercloud matrix and a given cloud species and (2) to show that the density ratio between various cloud species is inversely proportional to their expansion velocities.

Thus, the second inference for N49 and N63A is that the density ratios for the band and matrix gas are about 100:30:1. For N49, the mean preshock density as determined from X-ray measurements is 1 cm^{-3}, which means that the two cloud populations have mean densities of ~ 30 and ~ 100 cm^{-3}. Interestingly, preshock cloud densities that Dopita et al. (1977) infer from line intensities cluster near 30 and 100 cm^{-3}. Uncertainties in these ratios due to variations in blast wave impact speed, finite cloud acceleration times, velocity projection effects, and cloud deceleration through mass accumulation are small.

Finally, Table 1 shows that surface brightness and velocity width of the bands are correlated differently in N49 than in N63A. Let us assume that cloud brightness is proportional to mean density ρ, and that shocks propagate within clumpy clouds so as to conserve kinetic energy. The third inference is then that the internal rms density fluctuations vary as $\rho^{1.5}$ or more in N49, and less strongly than this in N63A.

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