NEUTRAL GAS AND DIFFUSE INTERSTELLAR BANDS IN THE LMC[1]

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Introduction.

The diffuse interstellar bands have recently become more relevant, due to the recent progress in the laboratory astrophysical measurements, which have begun to identify the carriers of the DIB's as ionized polyatomic hydrocarbons (PAH's), such as naphalene ($C_{10}H_8$), and C_{60}^+, Salama and Allamandola, (1992, 1993) respectively. The observational study of the DIB's has been reviewed by Herbig and Leka (1991) and Krelowski (1988). The differences in abundances of various elements in the LMC, reported for instance by Pagel et al. (1978) is an incentive to establish the presence and behavior of DIB's in the LMC which may also give an indication of the chemical composition of the DIB's. But, the study of DIB's in the LMC has to date has been limited. The first detection in the LMC was reported by Hutchings (1966), who observed the "4430" band towards three stars with a low resolution photographic spectrogram. Blades, and Madore (1979) obtained higher resolution spectra of DIB's for four stars in the LMC and showed previous estimates of the "4430" band to be over estimates due to contamination by stellar lines. Houziaux et al. (1980) obtained an average "4430" feature from the composite of four reddened LMC stars and concluded that the LMC "4430" band strength per unit E(B-V) is consistent with Galactic values. The situation was improved with the observations of 11 LMC supergiant's by Hutchings (1980) and the reported detection of 4430, 5780 and 6284A in 5 of these stars.

The dust environment of the LMC has been observed by Koorneef (1982), who measured a gas/dust ratio of N(HI)/E(B-V) = 2 $\times 10^{22}$, a factor four larger than the Galactic value. Other studies by IUE have observed that the LMC has a deficiency in heavy elements, but less than that reported in Koorneef. Extinction curves in the UV have been obtained by Fitzpatrick, (1985), and Clayton and Martin, (1985) from IUE data and show the LMC to posses a very uniform extinction curve, which is characterized by a weak 2175A bump and a steep rise to the far UV. Our observations were designed to try to increase the sample of stars with [1]Based on data obtained from the European Southern Observatory, Chile.

Table 1.

R	SK		HD	Other	Sp.Type	V	(B-V)
-	-		-	HV821			
RMC51	-67	2	270754	-	B1.5Ia	11.28	+0.10
RMC52	-69	7	268654		B8Iab	10.49	+0.18
-	-69	27	268774		B1	12.27	+0.85
-	-66	19		HV5497	B4Iab	12.79	+0.12
-	-69	108			B6Iab	12.10	+0.27
-	-67	108			B0	12.56	-0.20
RMC103	-68	82	269546		B3Iabp	9.89	-0.03
RMC136	-69	243	38268		WR	9.50	+0.13
-	-68	140			B0	12.74	+0.09
-	-69	250			B6Iab	12.14	+0.39
RMC148	-69	254			B5Iab	12.04	+0.26

measured DIB's. We have tried specifically to detect 5780 and 5797A. In addition our observations include the NaI D lines which are important in order to unravel the gas dynamics along the sightlines.

To date 52 stars have been observed spectroscopically in the LMC, mostly in the K lines of Ca II. The Ca II observations include the surveys of Wayte (1990), Songaila et al. (1986), Songaila and York (1980), Songaila, Cowie and York (1981), Blades and Meaburn (1980), and Blades (1980). The observations of NaI D lines towards the LMC at high resolution include Molaro, Vladilo, Avila and D'Odorico (1989), Dekker at al. (1986), and Ferlet, Dennefeld and Maurice (1985). Surprisingly the NaI D observations are less complete and only 10 stars in the LMC have been observed at high resolution (dv < 15 km/sec).

The results of the spectroscopic observations to date have illustrated the kinematic association of the gas between the LMC and the SMC, and have mapped distinct components of the ISM of the LMC and the Galaxy. By combining HI data and Ca I absorption line data, Wayte (1990) and Sonaila et al. (1986) showed that the majority of the CaII absorption lines were not of Galactic origin, but arose in regions of the LMC spatially distinct from the HI emission. Songaila et al. (1986) also contended that the Magellanic Stream arose from tidal stripping of the LMC and SMC from dynamical arguments. Wayte, (1990) used polarimetry and an inferred magnetic field structure which was shown to be consistent with the line of sight distance to argue for a collision between the LMC and SMC, which is consistent with the Magellanic Stream material being stripped from the LMC by the SMC.

The location of the intermediate velocity absorption components has been studied by Wayte, (1990) who argued that the intermediate velocity components of the CaII absorption's in the LMC belong to the Galactic halo, by observing that the 60km/sec features seen towards the LMC are also present in HI emission beyond the boundary of the LMC. Waytes, (1990) also contends that the 130 km/sec feature arises from the Galactic halo, while Blades et al. (1988) argued that the 130 km/sec feature originates from the LMC on the basis of spectroscopic abundances. Ferlet et al.(1985) have argued that the decreased Ca depletion for the intermediate velocity components may imply a Galactic origin. For absorption at v > 170 km/sec, all authors agree that the spectroscopic observations have constrained the material to belong to

the LMC. The dynamics of the gas is complicated, with the entire LMC apparently undergoing both a translation and a rotation. Clearly our new high resolution data on 11 stars is important in obtaining an accurate picture of the ISM in this direction.

Observations.

The stars observed were selected to sample the 30 Dor vicinity and also include several stars from the outer regions of the LMC to trace the dynamics of the neutral gas. The stars are listed in Table 1. The stars were observed at the 3.6-m telescope at the European Southern Observatory, the 18-19th December 84, using the Cassegrain Echelle Spectrometer with a cooled Thompson 512 x 340 CCD. Details of the spectrograph may be found in Dekker, et al. (1986). The cross disperser allowed for complete wavelength coverage from 5150A to 6170A over 18 orders. The dispersion varied smoothly from 0.16A/pixel at 5200A to 0.18A/pixel at 6000A. The observed resolution at the NaI D lines was 18 km/sec FWHM. For each object a separate Quartz lamp exposure was taken for flat fielding, and a Thorium Argon comparison lamp exposure was taken for wavelength calibration. Each star was observed for about 1 hour to obtain S/N values of 50 to 70 for most stars. The data were reduced using IRAF. The stellar continuum was fitted with a low order spline which preserved the DIB features, stellar and interstellar lines, and the wavelength was converted to LSR velocity scale for spectral plots in the Figs.

Discussion.

The region of 5780 and 5797A is shown in Fig. 1 with small triangles illustrating where the lines should appear. The most convincing detection is in SK-69 250, and weaker cases in SK-67 108 and R 148. These spectra have not yet been fully analyzed in detail and equivalent widths for the lines and upper limits for the other stars have not yet been calculated.

In Figs. 2 and 3 the region of the NaI D2 lines are shown for all stars. The importance of these lines to obtain the probable velocities of the weaker DIB's becomes clear. The arrows below showing the components detected. The velocity components and equivalent widths are given in table 2. Since this data was obtained in 1984, they represent a snapshot of the neutral material near 30 Dor prior to the 1987 supernova. For SK-69 250 and R 136 the velocity structure appears to contain blended components ranging in velocity from 210 to 340 km/sec with a peak absorption at 280 km/sec and 310 km/sec respectively. The R 136 sightline has been studied previously by Blades (1980) and Walborn (1980). The higher resolution used by these authors resolved these NaI features into 3 components about a central velocity of 280 km/sec, consistent with our observations. Both R 136 and SK-69 250 sightline profiles mirror very closely the Ca II lines of Sonaila et al. (1986). The NaI absorption profile has a much steeper decent on the blue wing, and cuts off at a velocity of 215 km/sec, unlike the CaII absorption which continues to 150 km/sec. A similar effect has been reported by Ferlet et al. (1985) for star R 127, which has a minimum NaI velocity of 240 km/sec. Combining our NaI observations with the CaII profiles from Waytes and Songaila, suggests that the CaII profiles from R 136-140 are tracing intermediate velocity gas from the LMC, the values of the

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N(NaI)/N(CaII) are rapidly changing, suggesting the existence of an ionized and shocked halo about 30 Dor.

The weak absorption line system toward R 148 and the lack of absorption lines towards SK-68 140 are most probably due to the fact that these stars lie in front of the 30 Dor region.

Finally, many of the stars that lie very close to SN 1987A which was reported by Molaro et al. (1989) seem to have a weaker simpler Na I absorption profiles that those of stars -69 250 or R 136. This is probably due to a combination of z distance for stars near SN 1987A and the SN 1987A progenitor which puts them above the majority of neutral gas from 30 Dor, and also increased ionization of the region due to stellar winds from the SN 1987A progenitor.

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Fig.2
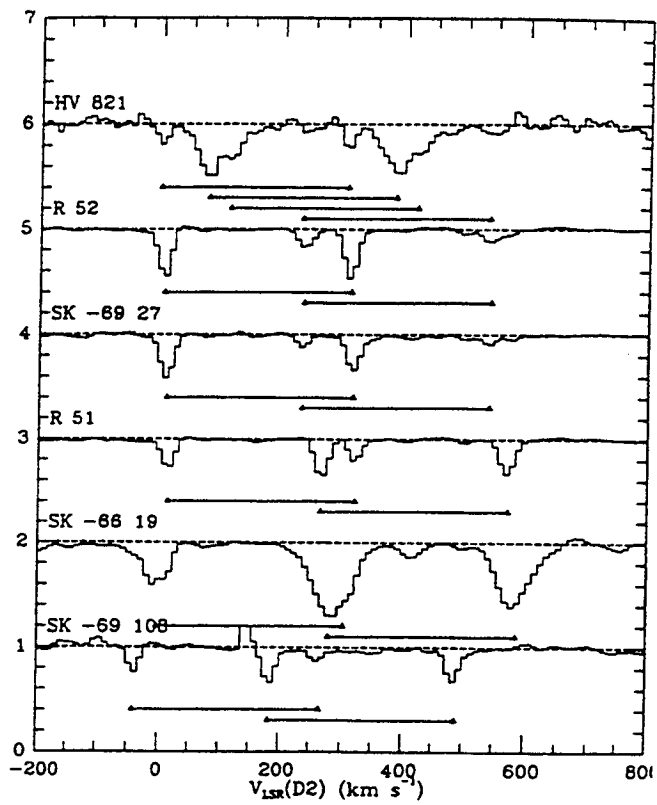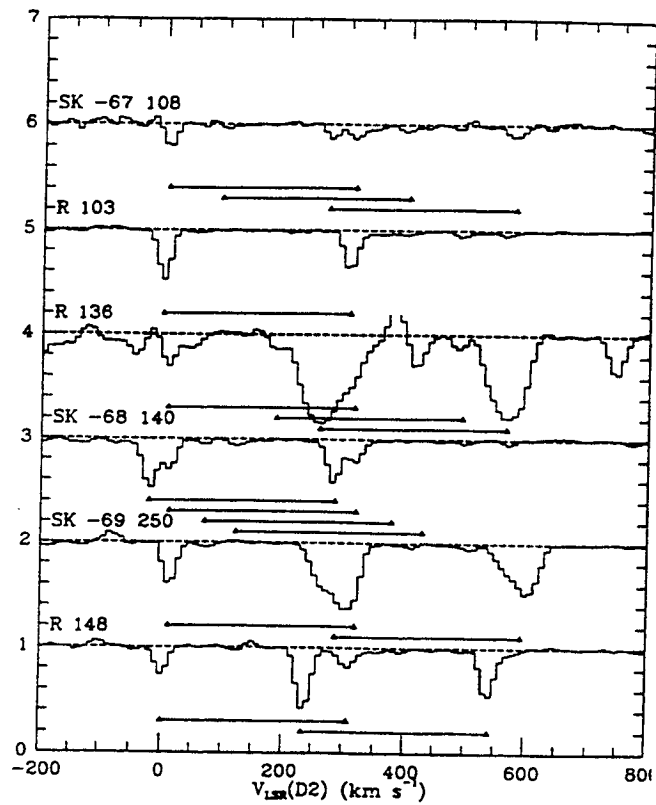NaI velocities
in LMC stars.

Fig.3
NaI velocities
in LMC stars

Table 2: Spectroscopic Observations of Na I D Absorption

Star	S/N	V_{LSR}(km s^{-1})[1]	N(NaI)(cm^{-2})[2]	V_{Hel}(D1)	Eqw(D1)	V_{Hel}(D2)	Eqw(D2)
HV 821	30	0.5	8.87E11	17.8	110	17.2	81
...	...	81.6	5.50E12	101.4	549	95.9	485
...	...	114.9	1.70E12	132.8	168	131.0	214
HV 821	45	-1.1	1.07E12	16.4	105	15.4	120
..	...	78.3	5.27E12	98.1	520	92.4	498
...	...	113.6	1.64E12	134.5	162	126.7	280
R 52	70	5.7	2.43E12	22.4	240	23.0	245
..	...	236.2	8.17E11	253.2	81	253.2	102
SK -69 27	60	10.7	1.86E12	28.8	184	26.7	231
..	...	235.1	5.80E11	252.8	57	251.3	57
R 51	60	15.0	9.79E11	32.4	96	31.5	155
..	...	266.9	1.91E12	283.3	189	284.4	190
...	...	233.7	.....	250.7	...	250.7	31
SK -66 19	70	-2.6	...	14.4	...	14.4	352
..	...	280.5	7.20E12	297.5	711	297.5	...
SK -69 108	50	-40.7	8.04E11	-25.2	79	-22.2	106
..	...	183.1	1.78E12	197.9	176	202.3	159
R -67 108	40	5.25	7.70E11	22.4	76	22.1	92
..	...	93.8	3.57E11	106.5	35	115.1	17
..	...	270.5	7.45E11	285.7	73	289.3	61
R 103	70	-1.3	1.85E12	15.9	181	15.6	249
R 136	30	8.4	...	25.4	...	25.4	162
..	...	186.4	7.35E11	198.8	72	207.9	109
..	...	260.1	1.08E13	279.6	1074	274.5	127
SK -68 140	75	-21.6	2.19E12	-5.2	216	-4.0	286
..	...	12.0	8.76E11	30.8	86	27.2	122
..	...	71.3	<7.5E10	88.7	<70	87.8	37
SK -69 250	60	11.9	3.76E12	28.9	371	28.9	210
..	...	287.1	5.37E12	306.6	530	301.6	765
SK -69 250	60	-1.8	2.48E12	15.2	245	15.2	...
..	...	290.4	5.31E12	307.4	525	307.4	...
R 148	50	1.8	1.93E12	20.1	118	17.5	133
..	...	235.2	2.64E12	251.7	261	252.7	334

[1] V_{LSR} is based on an average between the D1 and D2 components.
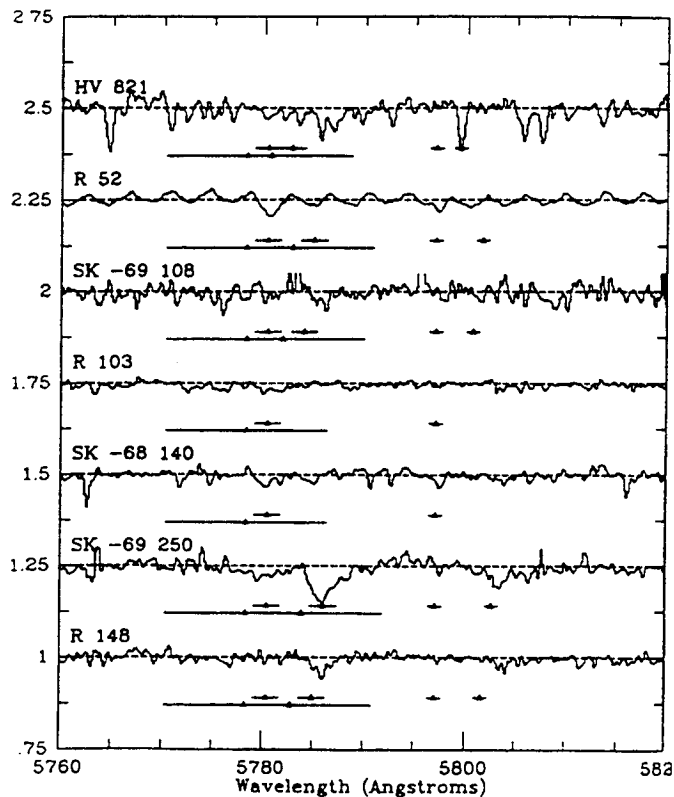[2] N(NaI) Column densities are lower limits, based on the D1 line strength.

Fig. 1 Identification of 5787 and 5789A.