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A COMPRESSED CLOUD IN THE VELA SUPERNOVA REMNANT

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ABSTRACT

Observations by the *IUE* of stars behind the Vela supernova remnant show that HD 72350 (type B4 III) has exceptionally strong interstellar absorption lines of C I arising from the two excited fine-structure levels. A curve of growth analysis yields column densities for many neutral atomic species and the CO molecule. An analysis of the excited-level populations of C I provides limits on the local temperature and pressure. Auxiliary data on the limit of column density for excited O I and the carbon ionization help to establish that the local temperature is within the limits of 25–100 K and that p/k (where p is the pressure and k is Boltzmann's constant) is at least $10^{4.3}$ cm^{-3} K, despite its small size as indicated by the reddening of only $E_{B-V}=0.14$. We discuss this unusually high pressure cloud in terms of shock compression by the Vela supernova blast wave. High velocity C IV is seen toward HD 72350, and we note that the presence of excited C I is correlated with the appearance of velocity-shifted C IV features for other observed stars in the nebula. We discuss the relationship of this kind of cloud compression to star formation and to the origin of the characteristic filamentary emission arcs seen in Vela and in other supernova remnants.

Subject headings: interstellar: matter — nebulae: individual — nebulae: supernova remnants — shock waves

I. INTRODUCTION

Analysis of interstellar absorption lines toward the Vela supernova remnant demonstrated conclusively that supernova blast waves must generally interact with a highly inhomogeneous interstellar medium (Jenkins, Silk, and Wallerstein 1976*a*, *b*, hereafter JSW). High-resolution X-ray maps have subsequently confirmed this model, both for Vela and other supernova remnants of comparable age. However, the nature of the ambient interstellar clumps has not been clarified. For a very young supernova remnant, the blast wave probably overtakes the clumpy debris consisting of mass-loss ejecta from the massive supernova precursor star. Both the extent of the Vela supernova remnant and the absence of any abundance anomalies indicate that the remnant is well beyond this phase and is now interacting with the ambient medium. Furthermore, perusal of a photograph of the Vela supernova remnant reveals the presence of numerous arclike nebulosities, whose geometry seems inconsistent with emission behind a shock passing through quasi-spherical clumps of interstellar gas. While these arcs could be associated with shock fronts at the clump surfaces, another possible explanation is that the remnant has interacted with dense shells of ambient gas with a characteristic radius of ~5 pc (McCray and Snow 1979).

Our previous interstellar-line survey, carried out with the *Copernicus* satellite, was limited to selected lines in only four bright stars (JSW). Nevertheless, our data revealed the presence of numerous absorbing, predominantly ionized gaseous sheets and filaments that had evidently been shocked, compressed, and accelerated by interaction with the Vela SNR. The significance of the interaction of a supernova with interstellar clouds was first stressed by Öpik (1953), who suggested that star formation would be initiated. More recent studies have supported this view, although direct evidence for the triggering of star formation by supernovae is very tenuous. Herbst and Assousa (1977, 1978) emphasized the location of young stellar associations at the edges of expanding shells of gas: however, such shells are not necessarily old supernova remnants. A more direct connection was sought by Wootten (1977, 1978) who found

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evidence for compression by a factor of ~10, heating, and enhanced line broadening in molecular clouds near the supernova remnants W44 and W28.

Another connection between a supernova and star formation has been inferred from the presence of excess ^{26}Mg in certain inclusions in the Allende meteorite, taken to indicate that the unstable isotope ^{26}Al was injected into the protosolar nebula within $\sim 10^6$ yr of its nucleosynthesis in a nearby supernova (Lee, Papanastassiou, and Wasserburg 1976). Such circumstantial evidence suggests that interaction with the supernova may have both enriched the presolar nebula and possibly initiated the collapse of the interstellar cloud destined to form the Sun and the solar system.

Finally, recent models of spiral structure have utilized supernova-induced star formation as a means of enabling star formation to be self-propagating in the galactic disk (Mueller and Arnett 1976; Gerola and Seiden 1978). To justify this type of theoretical work, one would like to know whether there is any evidence for the extreme degree of compression of ambient gas near a remnant that is necessary in order to initiate star formation.

In an attempt to shed light on these issues and to further elucidate the nature of the interstellar medium in the vicinity of the Vela supernova remnant, we have undertaken an extensive study with the *International Ultraviolet Explorer* (*IUE*) of interstellar absorption lines toward 37 stars in the vicinity of the Vela remnant. Observations of interstellar absorption, in particular of C I, toward one of these stars, HD 72350 (type B4 III), are of sufficient interest that we report here a preliminary analysis of these data before the entire survey has been reduced. Our observations are described in § II, the properties of the C I absorption-line region are analyzed in § III, and the implications of our results are discussed in § IV.

II. OBSERVATIONS

In 1979 June we obtained high-resolution *IUE* spectra of 37 stars in the field of the Vela supernova remnant. From the video displays of the short-wavelength echelle spectra, it was clear that HD 72350 showed especially prominent multiplet structures in all of the C I transitions, indicating that the excited fine-structure levels are heavily populated. Two additional short-wavelength exposures of this star were recorded in 1979 September to verify this result and improve the net signal-to-noise ratio. Intensity tracings of several multiplets of C I are shown in Figure 1. Equivalent widths were taken from tracings of the three exposures stacked together. The exposure taken in June was reduced with a flawed intensity transfer function (ITF) (Holm 1979), but the high particle background on this exposure placed all of our flux values above the bad part of the ITF. The September exposures were reduced with a proper ITF.

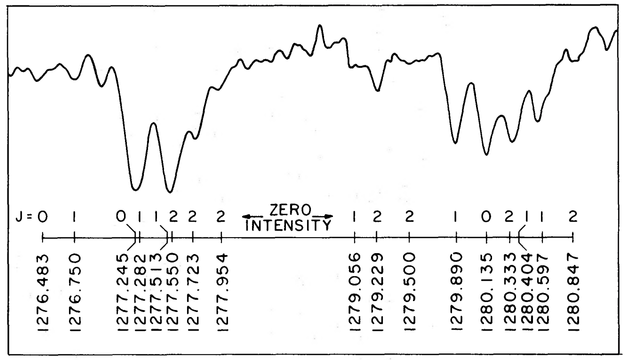

FIG. 1.—Interstellar absorption lines of C I in the spectrum of HD 72350. The *J* values of the substate of the ground configuration from which each line arises are indicated.

The equivalent widths and transition probabilities are listed in Table 1.

a) *Velocity Dispersions and Curves of Growth*

Column densities of various species were derived using curves of growth based on Voigt profiles. For unresolved blends of two or more transitions from a single level of C I, special curves of growth were calculated to derive the total equivalent width of the partially overlapping components. Table 2 lists the derived column densities as a function of the velocity dispersion parameter *b*, averaged from all but the weakest lines. We calculated the standard error of the results for cases where we measured three or more lines, and these dispersions are shown in parentheses after the respective entries.

For our study of cloud compression, our primary objective is to derive column densities of neutral carbon atoms, i.e., N(C I), N(C I*), and N(C I**), in the three levels of fine-structure excitation, $^3P_0$, $^3P_1$, and $^3P_2$ respectively. From the standard errors in Table 2, we see that the best internal consistency for the column densities occurs for $b \geq 10$ km s^{-1}. Within the range $10 \geq b \geq 20$ km s^{-1}, the total column density of neutral carbon varies by a factor of 3, but the *ratios* of C I, C I*, and C I** populations are relatively insensitive to the choice of *b*. Our inability to detect the weakest transitions indicates that the absorptions we have measured do not have heavily saturated cores. In particular, our detection limit for λ1276.48 forces us to conclude that log N(C I) < 14.7 for any *b* greater than 4 km s^{-1}, if $\log f\lambda$ for this transition is about 0.8 (this line strength is based on a preliminary analysis of C I absorption data recorded by Jenkins, Jura, and Lowenstein 1981; see also de Boer and Morton 1979). In addition, Mr. Michael Van Steenberg of the University of Colorado has found that log N(H) = 21.15 from the Lyα profile and 20.5 from the S II lines and an assumed ratio of log N(S/H)

TABLE 1

EQUIVALENT WIDTHS OF INTERSTELLAR LINES FORMED IN THE H I REGION IN FRONT OF HD 72350

λ(Å)	Identification	log $f\lambda$	$-\log W/\lambda$
1199.55	N I	2.20	3.69
1200.22	N I	2.03	3.75
1200.71	N I	1.73	3.69
1276.48	C I	0.80	>4.70
1276.75	C I*	0.30	>4.70
1277.53	C I*+C I**	2.09	3.85
1277.72	C I**	1.24	4.19
1277.95	C I**	0.00	4.57
1279.06	C I*	0.30	>4.70
1279.23	C I**	0.70	4.63
1279.50	C I**	0.20	4.89:
1279.89	C I*	1.17	4.10
1280.14	C I	1.55	4.07
1280.36	C I*+C I**	1.41	4.00
1280.60	C I*	0.94	4.22
1280.85	C I**	0.81	4.80:
1302.17	O I	1.80	3.64
1304.86	O I*	1.80	>4.50
1328.83[a] ...	C I	2.04	4.00
1329.10[a] ...	C I*	1.71	3.89
1329.59[a] ...	C I**	1.71	4.02
1419	CO (4-0)	1.37[b]	4.59
1447	CO (3-0)	1.56[b]	4.56
1477	CO (2-0)	1.66[b]	4.71
1509	CO (1-0)	1.62[b]	4.75
1544	CO (0-0)	1.34[b]	4.60
1560.31	C I	2.10	3.90
1560.69	C I*	2.13	3.82
1561.39[a] ...	C I**	2.10	3.89
1656.27	C I*	1.97	3.94
1657.38	C I*	1.75	3.92
1657.91	C I*	1.88	4.00
1658.12	C I**	1.75	4.03
2025.82	Mg I	2.35	4.51
2852.13	Mg I	3.70	3.80

[a] More than one component.

[b] The CO values are from Tarafdar, Swamy, and Vardya 1980.

$=-4.8$. Hence, we are confident that the conspicuousness of the excited lines is attributable to a strong excitation of carbon rather than a large difference in line saturations.

If we assume $\log N(\mathrm{H})=20.9$ from the star's $B-V$ color excess of 0.14 (Ferro and Garrison 1979) and the general gas-to-reddening ratio of 5.8×10^{21} atoms cm^{-2} mag^{-1} (Bohlin, Savage, and Drake 1978), we find that the relative abundances of N I and O I are consistent with the cosmic abundance ratio if b is near 10 km s^{-1}, although uncertainty in the reddening permits a range from 8 to 12 km s^{-1}. The values of the C I, C I*, and C I** column densities show a substantially higher dispersion for $b=8$ than for $b=10$–12 km s^{-1}. Doublet ratios for the Ca II and Na I absorptions in the visible yield b values of 10 and 5 km s^{-1} respectively (Wallerstein, Jenkins, and Silk 1980). The value for sodium appears to be too low, perhaps because the equivalent widths were not very accurate; 8 km s^{-1} would be acceptable, but a larger b value implies the D lines are virtually unsaturated, which is inconsistent with the observed line-strength ratio. Since the sodium plate is underexposed, we will ignore its suggested low b value and assume that the most probable value of b for C I is 10–12 km s^{-1} and that all C I lines have the same b.

In addition to the lines of neutral species listed in Table 1, HD 72350 shows the many interstellar lines commonly seen in stars lying behind interstellar clouds of moderate reddening. For C IV, we observed strong lines at low velocity ($v_{\mathrm{LSR}}=-5$ km s^{-1}) and much weaker lines at an unusually high negative velocity $v_{\mathrm{LSR}}=-129$ km s^{-1}.

Our proposal that we are viewing a cloud compressed by a shock (§ IV) suggests that it may be profitable to look for absorptions from CH^+ (Elitzur and Watson 1978). We could see neither the 4232 Å nor the 3958 Å line on a blue spectrogram (from the survey by Wallerstein, Jenkins, and Silk 1980) at 9 Å mm^{-1} for this star.

TABLE 2

COLUMN DENSITIES (log N) FOR LIGHT ELEMENTS IN THE H I REGION IN FRONT OF HD 72350

Elements	No. of Lines	b (km s^{-1}) 8	10	12	15	20	Notes
C I	3	15.3(0.4)	14.8(0.2)	14.6(0.2)	14.4(0.2)	14.4(0.2)	
C I*	9	15.5(0.5)	15.1(0.3)	14.8(0.2)	14.7(0.2)	14.6(0.2)	
C I**	8	14.8(0.2)	14.6(0.1)	14.5(0.1)	14.4(0.1)	14.3(0.1)	
C I (total) ...	22	15.8	15.4	15.1	15.0	14.9	1
N I	3	17.6(0.3)	17.1(0.4)	16.3(0.4)	15.5(0.3)	15.0(0.2)	
O I	1	18.0	17.7	17.2	16.2	15.4	
O I*	1	<13.9	<13.9	<13.8	<13.8	<13.8	
Mg I	2	13.3	13.2	13.2	13.2	13.2	
CO	5	13.9(0.1)	13.9(0.1)	13.9(0.1)	13.9(0.1)	13.9(0.1)	
Na I	2	12.8	12.4	12.3	12.3	12.3	2
Ca II	2	13.2	12.9	12.8	12.7	12.7	2

NOTES.—(1) Includes two blends of C I* and C I** features; (2) from optical spectra (Wallerstein, Jenkins, and Silk 1980).

Upper limits for the equivalent widths of these lines are about 20 mÅ; assuming no saturation, the absence of the stronger line (4232 Å) implies $N(\mathrm{CH}^+) \leq 10^{13.3}$ cm^{-2} if its f value is 0.0065 (Yoshimine, Green, and Thaddeus 1973). The apparent lack of CH^+ can probably not be blamed on an absence of H_2 needed for the reaction suspected for producing it, since we see a reasonable amount of CO (§ III*c*). On the other hand, the high temperatures needed for the reaction to proceed may have happened long enough ago that the CH^+ has been destroyed by photodissociation or dissociative recombination with electrons.

III. THE C I ABSORPTION-LINE REGION

a) Can the C I *Populations be Affected by the Star's Radiation Field?*

Prior to discussing the implications of the C I populations in Table 2, we must demonstrate that the anomalously large fine-structure excitation is not a result of the material being very close to HD 72350. We would expect to find an H II region immediately adjacent to the star, but the total column density of C I should not exceed a few times 10^{11} cm^{-2} for a B4 III star (Jenkins and Shaya 1979, hereafter JS), an amount which is about three orders of magnitude below the observed N(C I) in any of the fine-structure levels. This estimate should be insensitive to the density of gaseous material near the star or its radial distribution.

One might envision that, just outside the Strömgren sphere, there could be a significant accumulation of H I gas which is exposed to a radiation field strong enough to populate the excited levels primarily by optical pumping rather than by collisions. We propose that this is not a reasonable interpretation for our observations toward HD 72350 for the following reason. With electrons coming from carbon and the metals, the ionization equilibrium for a local hydrogen density n gives us

$$N(\mathrm{C\,I}) \leq \alpha_c \xi_c^2 N(\mathrm{H}) n \Gamma_c^{-1}, \qquad (1)$$

where α_c is the recombination coefficient of neutral carbon, ξ_c is its fractional abundance, and Γ_c is its local photoionization rate. (The inequality becomes an equality when $\Gamma_c/\alpha_c \gg n\xi_c$, i.e., most of the carbon is ionized; see eqs. [12] and [13] of JS.) If the ionizing radiation from the star is greater than that of the general interstellar medium by a factor $(\Gamma_c/\Gamma_{c,\mathrm{ism}})$, we find that equation (1) is numerically equivalent to

$$n \geq 200(\Gamma_c/\Gamma_{c,\mathrm{ism}})\ \mathrm{cm}^{-3}, \qquad (2)$$

if $\log N(\mathrm{H}) \leq 20.9$, ξ_c is the cosmic abundance ratio, $T = 100$ K, $\Gamma_{c,\mathrm{ism}} = 2 \times 10^{-10}$ s^{-1}, and $\log N(\mathrm{C\,I_{total}}) \geq$ 15.0. If the increase in the local flux of UV photons which can pump C I is greater than the general interstellar value by a factor comparable to $(\Gamma_c/\Gamma_{c,\mathrm{ism}})$, the above inequality and the results of JS show that collisional excitation always dominates optical pumping.

b) Properties of the C I *Cloud*

Since it is now clear that the peculiarity of the gas bearing C I cannot be attributed to the fact that it is near the target star, we can adopt the viewpoint that it is normal interstellar material subjected to unusual physical conditions. From the fine-structure population ratios $f_1 \equiv \mathrm{C\,I^*/C\,I_{total}}$ and $f_2 \equiv \mathrm{C\,I^{**}/C\,I_{total}}$, we may arrive at permitted combinations of pressure and temperature using the diagrams for collisional equilibria in H I regions given by JS. The curves (a) in Figure 2 show the combinations of pressure and temperature in a single region which are consistent with our population ratios, allowing for 2 σ errors in all three column densities and allowing b to vary between 10 and 15 km s^{-1} (but with all levels having the same b).

However, there are two additional constraints, shown in the figure, which we may impose on the conditions. First, we can require that a solution for the ionization equilibrium between C I and C II (eq. [1]) not give a computed value N(C I) less than the observed value, assuming $\log N(\mathrm{H}) = 20.9$ (see § II*a*), a cosmic abundance ratio for C/H, and an ionization rate $\Gamma_c = 2 \times 10^{-10}$ s^{-1} for the general interstellar medium. (This argument is only a limiting case because the computed

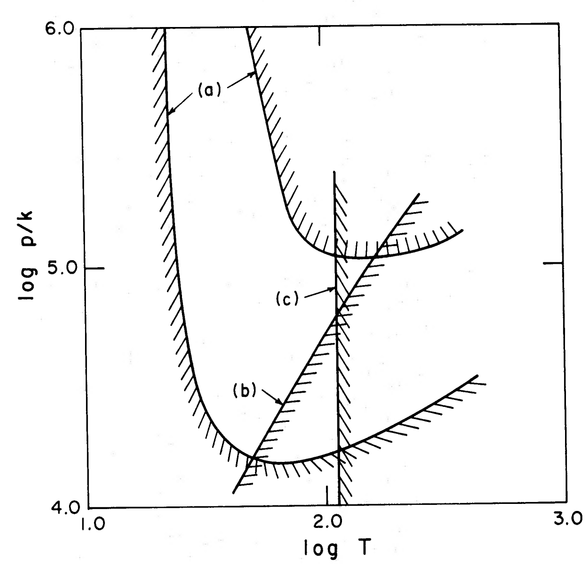

FIG. 2.—Pressures and temperatures for the C I cloud. Excluded areas (on shaded sides of lines) are from (a) fine-structure excitations of C I, (b) the relative abundance and ionization equilibrium of carbon, and (c) a lack of observed absorption from O I*.

value could greatly exceed the observed $N(\text{C I})/N(\text{H})$ if much of the reddening were not associated with the C I region.) This constraint may be even stronger than shown here, since there is a good chance that Γ_c in the Vela region is higher than the usual interstellar value and that some of the free carbon atoms are depleted onto grains.

The second constraint comes from our upper limit for $N(\text{O I}^*)$. If we solve for the collisional equilibrium for the O I fine-structure levels, assume a cosmic abundance ratio for C/O, and compute the total carbon density from the ionization equilibrium (see above), we obtain $\log T<2.05$. This result is independent of $\log p/k$ (where p is the pressure and k is Boltzmann's constant) because the computed ratios O I*/O I and C I/C both scale approximately linearly with pressure.

c) The Carbon Monoxide Column Density

The carbon monoxide column density is at least an order of magnitude less than the total column density of neutral carbon. For $b=10-12$ km s^{-1}, the ratio is from 1/30 to 1/16. These ratios are in good agreement with the outer layers of the model cloud of de Jong, Dalgarno, and Boland (1981) where $A_V \lesssim 1.0$, because CO is radiatively dissociated at such small optical depths. The visual absorption in the HD 72350 cloud cannot be more than the total visual absorption toward the star, 0.42 mag, and the radiation field in the Vela remnant is surely greater than one-half of the interstellar radiation field in the solar vicinity as assumed by de Jong, Dalgarno, and Boland. In addition, the observed ratio of CO/C I in this cloud is similar to the ratio elsewhere in diffuse clouds (Federman *et al.* 1980).

d) The Cooling Time Scale

Since the abundance of molecules is not especially large (see § III*c*), the primary heat loss for the compressed gas is collisional excitation of C I and C II interacting with the neutral hydrogen (Dalgarno and McCray 1972). We have a direct measure of the C I cooling rate from our observations of the C I* and C I** column densities, but the amount of C II* present must be inferred from calculations of collisional excitation because the C II* absorption line at 1335.7 Å is too heavily saturated and probably arises chiefly from other material along the line of sight, such as the star's H II region. The radiation rate per unit volume is given by

$$\frac{dQ}{dt}=n_{\mathrm{H}}\left\{\left(\frac{\text{C I}}{\text{H}}\right)(f_1A_1\Delta E_1+f_2A_2\Delta E_2)+\left[\xi_c-\left(\frac{\text{C I}}{\text{H}}\right)\right]f_{3/2}A_{3/2}\Delta E_{3/2}\right\}, \quad (3)$$

where f_J, A_J, and ΔE_J denote the fractional populations, decay rates, and energies of the excited states ($J=1$ and 2 for C I and $J=3/2$ for C II). The fractional populations f_1 and f_2 of C I are observed to be about 0.45 and 0.23 respectively (see § III*b*), and that of C II should be

$$f_{3/2}=\left[1+\tfrac{1}{2}\exp\left(\Delta E_{3/2}/kT\right)+\left(A_{3/2}/C_{3/2}n_{\mathrm{H}}\right)\right]^{-1}, \quad (4)$$

where $C_{3/2}$ is the (temperature-dependent) excitation-collision rate for C II (cf. Table 4 of Dalgarno and McCray). The calculations of carbon recombination which give (C I/H) were performed using equation (12) of JS (approximated by eq. [1] of this paper). For $T\gtrsim 50$ K, the loss rates for C I and C II are nearly equal, which means that the calculated dQ/dt is insensitive to the adopted value of (C I/H).

We calculated the cooling time,

$$t_c=\frac{T}{dT/dt}=\frac{(5/2)kTn_{\mathrm{H}}}{dQ/dt}, \quad (5)$$

for all of the pressures and temperatures in the permitted region of Figure 2 and found that t_c ranges from 1500 yr at the lowest pressures down to about 250 yr for conditions near the top of the figure. Fortunately, these times are longer than $\Gamma_{c,\mathrm{ism}}{}^{-1}=160$ yr, which means that the time-independent calculations of the carbon ionization should be nearly valid.

IV. DISCUSSION

a) Shock Compression

The high pressure and short cooling time of the C I absorption region suggest that it indeed has been compressed recently by the Vela SNR. Our data describe a central region that is far denser than any previously analyzed by us in JSW. It is possible to construct a simple model which accounts for the density, thickness, and pressure of the C I absorption-line region.

Consider a clump of density n_c in an ambient medium of density $\langle n\rangle \approx 0.1$ cm^{-3} and exposed to the supernova blast wave moving at velocity $v_b \approx 400$ km s^{-1} (JSW). A shock will traverse the clump at velocity $v_c \approx v_b(\langle n\rangle/n_c)^{1/2}$, which, for the C I region, is $\lesssim 10$ km s^{-1}. This implies that $n_c \gtrsim 200$ cm^{-3}. After the shock has passed, the pressure at the clump surface equals the ambient postshock thermal pressure, which is of order

$$p/k=\tfrac{3}{4}\langle n\rangle v_b^2\mu/k \approx 10^{5.9}\ \mathrm{cm}^{-3}\ \mathrm{K},$$

where $\mu=0.61\ m_{\mathrm{H}}$ is the mean mass per particle. Note that the inferred preshock pressure within the clump $p/k \gtrsim 10^4$ cm^{-3} K and exceeds the characteristic pressure in the Gum Nebula (Wallerstein, Jenkins, and Silk 1980). The C I region hydrogen column density amounts to $\sim 10^{20\pm1}$ cm^{-2} from a consideration of carbon-ionization equilibrium and the observed pressure. This is consistent with the column density traversed by a shock that interacted with the clump some 10^4 yr ago (JSW).

What can we infer about the origin of this clump? It may be related to the prominent emission arcs, of characteristic radius $\sim 30'$ or ~ 5 pc that are evident on visual inspection of a print of the Vela SNR. The line of sight to HD 72350 passes within about 3 pc of the center of one such arc. Other SNR of age comparable to that of Vela, such as S147 (van den Bergh, Marscher, and Terzian 1973) have a similar appearance. The SNR interaction with the ambient medium is evidently exciting these dense shells.

Inspection of the Vela region indicates that winds from massive main-sequence stars cannot account for the formation of these shells since the shells are not centered on stars of type B0 or earlier. Since the main-sequence turn-off in the Vela OB association corresponds to an age of about 3×10^6 yr, we may speculate that the formation of dense shells in this region could be associated with mass loss from pre–main-sequence stars in a region of active star formation.

b) *High-Velocity* C IV *and Excited* C I

The presence of high-velocity interstellar C IV in HD 72350 led us to investigate a possible correlation between high-velocity C IV and excited neutral carbon toward other stars in the Vela remnant. We have classified our *IUE* spectra of 32 stars as to whether or not we could see evidence of excited C I and high-velocity C IV. The results are shown in Table 3. Twenty-one out of 27 stars show the correlation of excited C I with high-velocity C IV with five stars showing doubtful features. The distance moduli and reddening of the stars with both features are no greater than those which show neither; hence we are not looking at a distance effect. A contingency table analysis of all of the cases, excluding the five uncertain ones, gave $\chi^2 = 8.6$, which means the correlation has a statistical significance at the 99.5% level. The high-velocity clouds themselves never show excited C I, which is only seen in dense clouds that have been shocked and compressed but have not been significantly accelerated. A similar correlation between high-velocity C IV and excited C I is indicated for field stars observed with the *IUE* by one of us (E. B. J.) (Heisler 1981). The most plausible interpretation of this correlation can be found in the detailed interaction of the supernova blast wave with inhomogeneous filaments and clouds. As discussed in JSW and by Ostriker and McKee (1977), denser cloud cores or clumps acquire lower velocities leading to a correlation of the observed form.

TABLE 3

PRESENCE OR ABSENCE OF EXCITED C I AND HIGH VELOCITY C IV (number of cases)

HIGH VELOCITY C IV	EXCITED C I		
	Present	Uncertain	Not Present
Present	10	0	2
Uncertain	3	0	1
Not Present	4	1	11

c) *Concluding Remarks*

We believe that the detailed data for HD 72350 combined with the strong statistical correlation of excited neutral-carbon with high-velocity gas show that shock compression is a common phenomenon when a supernova explodes into a cloudy interstellar medium. Whether or not such interactions initiate star formation must depend upon the initial mass and density in the shocked cloud as well as the presence of shielding dust. There is very little dust associated with the Vela remnant or even with the entire Gum Nebula. No heavily, or even moderately, reddened B stars are seen in the area except for background objects. Hence, molecule formation will be strongly inhibited by the local interstellar radiation field. The whole B association in the Gum Nebula contains no molecular cloud such as the ρ Ophiuchi cloud associated with the Scorpio-Centaurus association or the Orion molecular cloud in its association. Nevertheless, a dust cloud containing two Herbig-Haro objects has been found by Schwartz (1977) in the Gum Nebula.

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Note added in proof.—Echelle spectra taken by Dr. E. Hu of 2.1 Å mm^{-1} at Ca II and 3.1 Å mm^{-1} at Na I show three components of Ca II whose velocities are +1, 17, and 36 km s^{-1} and two components of Na I at −3 and +14 km s^{-1} (with respect to the LSR). The velocities of the interstellar lines of C I and other low-ionization species in HD 72350 are $+11\pm2$ km s^{-1} (internal standard error). This makes it difficult to tell whether our C I lines should be identified with the Na I component at +14 km s^{-1} or with a blend of both components. In any case, the low turbulence as derived from the blended Na D lines should not be taken too seriously until a reanalysis of the separate line intensities has been completed.

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