Unveiling Vela - Time Variability of Na I D lines in the Direction of the Vela Supernova Remnant

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ABSTRACT
High-resolution spectral profiles of Na I D lines from the interstellar medium towards 64 stars in the direction of the Vela supernova remnant are presented. This survey conducted mostly between 2011-12 complements an earlier survey of the same stars by Cha & Sembach done in the 1993-96 period. The interval of 15 to 18 years provides a base line to search for changes in the interstellar profiles. Dramatic disappearance of strong absorption components at low radial velocity is seen towards three stars – HD 63578, HD 68217, HD 76161 – over 15-18 years; HD 68217 and HD 76161 are associated with the Vela SNR but HD 63578 is likely associated with the wind bubble of η Velorum. The vanishing of these cold neutral clouds in the short time of 15 to 18 years needs some explanation. Other changes are seen in high-velocity Na D components.

Key words: Star: individual: ISM: variable ISM lines: Supernova Remnants: other

1 INTRODUCTION
The supernova responsible for the Vela supernova remnant (SNR) exploded about 11000 years ago (Reichley, Downs & Morris 1970). Within the Vela SNR lies a pulsar at a distance of 287±19 pc, as measured by its VLBI parallax (Dodson et al. 2003). This distance is consistent with that determined from a search for high-velocity components in high-resolution Ca II and Na I interstellar absorption line profiles towards OB stars with Hipparcos and spectroscopic parallaxes. These high-velocity components discovered by Wallerstein & Silk (1971) which are attributed to interactions between the local interstellar medium and the SNR were assigned the distance of 290±30 pc (Sushch, Hnatyk & Neronov 2011; Cha, Sembach & Danks 1999).

Various studies have expanded observations of the interstellar components seen in stars in the direction of the Vela remnant with some studies emphasizing searches for variability of high and low velocity components with efforts concentrated on the Ca II K and Na I D lines. This paper reports on a campaign mainly in 2011-2012 to obtain high-resolution profiles of the Na D lines towards many OB stars in the direction of the Vela SNR and to compare profiles with similar data obtained in 1993-1996 by Cha & Sembach (2000) of Ca II K and Na I D lines. As appropriate, we comment on the relationship between our Na I D line profiles and other published observations towards stars behind the Vela SNR.

Na I D lines are important in several respects. They represent the behaviour of neutral gas. It is now clear that the Vela SNR’s expansion proceeded in a cloudy interstellar medium. Earlier studies of the absorption lines towards various stars suggested that the high velocity (> 100 km s−1) components, mainly present in Ca II lines, represent the shocked gas that had interacted with the SNR (Wallerstein, Silk & Jenkins 1980; Jenkins, Silk & Wallerstein 1984). However, as pointed out by Sushch, Hnatyk & Neronov (2011), although the distance to the SNR is 290±20 pc, the high velocity absorption components are present only in stars more distant than 500 pc and stars with distances smaller than 350 pc do not show evidence of 100 km s−1 absorption components. Stars at or immediately behind the SNR show components of intermediate velocity, which are well represented by Na I lines along with the Ca II K lines. Thus, the Na I components might be from the neutral ISM that is interacting with the SNR and surroundings.

The Vela SNR has a diameter of about 7.3 degrees on
Figure 1. Location of the stars observed towards the Vela SNR. This optical image covering a field of 9.3° × 8.5° is from Davide de Martin (WWW.Skyfactory.org)- by permission. Stars are identified by their HD number.

the sky (Aschenbach 1993; Aschenbach, Egger & Trumper 1995). Figure 1 shows the remnant and the locations of most of the stars observed in our Na D survey. The optical image covering a field of 9.3° × 8.5° from Davide de Martin (WWW.Skyfactory.org) is compiled from AAO, UK Schmidt and Digital sky survey images. Cha & Sembach’s (2000) multi-star survey was based on a target list of 68 OB stars observed at high spectral resolution in 1993, 1994 and 1996. A selection of the target list was observed more than once and slightly more than half of the 68 stars observed for Ca II were observed also at Na I. Of the 13 stars observed twice, seven proved to have variable absorption line profiles. Our survey principally from 2011 and 2012 provides only Na I profiles for the majority of Cha & Sembach’s 68 stars and expands their baseline of three years to 15 to 18 years. Whenever possible, other high-resolution profiles in the literature are included in the discussion of variability.

Our observations were obtained with the fiber-fed cross-dispersed echelle spectrograph of the Vainu Bappu 2.3m reflector at the Vainu Bappu Observatory, Kavalur (Rao et al. 2005). The spectral resolving power, $R = \lambda / \Delta \lambda$, employed was 72000. The spectrum covers 4000 to 10000Å with gaps beyond about 5600Å where the echelle orders were incompletely captured on the E2V 2048 x 4096 CCD. The Na D lines are recorded but not the Ca II H & K lines. The wavelength calibration was done using a Th-Ar hollow cathode lamp soon after the stellar exposures. Our spectral resolving power, as determined from the width of weak atmospheric (H₂O) lines, is very close to that ($R \approx 75000$) used by Cha & Sembach (2000) for their spectra and, thus, matching of our line profiles with theirs becomes easy and appropriate. Usually, two exposures of 30 to 45 minutes have been combined for each night. A nearby hot star was observed to remove the telluric lines. Most of our observations were obtained between early 2011 and late-2012 (see Table 1). Limited observations were also obtained during 2007 March-April and in 2008.

We used IRAF routines for spectral reductions (flat field corrections, wavelength calibration and telluric line corrections). All heliocentric velocities are converted to the local standard of rest (LSR) adopted by Cha & Sembach (2000). The Na D profiles are fitted with gaussian components to
Table 1. Observations & Other Parameters

| Star      | α,δ(2000)                  | epoch   | V  | (B-V) | E(B-V) | d(Hip)^a pc | d(Sp)^b pc | (S/N)^b |
|-----------|----------------------------|---------|----|-------|--------|-------------|------------|---------|
| HD 63308  | 07h46m33.4s -49°03′34.2″   |         | 2011.1.7 | 6.57 | -0.13 | 0.11 | 606±108   | 490       | 112     |
| HD 63578  | 07 47 31.5 -46 36 30.5     |         | 2011.1.8 | 5.23 | -0.14 | 0.11 | 481±45     | 480       | 149     |
| HD 65814  | 07 58 50.4 -40 20 34.6     |         | 2011.3.16 | 8.77 | 0.28  | 0.52 | 2590:      | 34        |         |
| HD 68217  | 08 09 35.9 -44 07 22.0     | 2007.1.3 | 5.21 | -0.19 | 0.05  | 383±26     | 340       |         |
| HD 68243  | 08 09 29.3 -47 20 43.0     | 2011.4.2 | 4.27 | -0.24 | 0.02  | 240        | 153       |         |
| HD 68324  | 08 09 43.2 -47 56 13.9     | 2011.4.2 | 5.23 | -0.21 | 0.05  | 339±21     | 520       | 98      |
| HD 69144  | 08 13 36.2 -46 59 29.9     | 2012.4.2 | 5.13 | -0.16 | 0.07  | 417±32     | 300       | 112     |
| HD 72067  | 08 29 07.6 -44 09 37.5     | 2011.12.24 | 5.83 | -0.16 | 0.08  | 439±78     | 360       | 103     |
| HD 72088  | 08 29 12.6 -44 53 05.6     | 2011.3.18 | 9.07 | 0.03  | 0.23  | 1630       | 28        |         |
| HD 72089  | 08 29 07.0 -45 33 26.9     | 2011.3.20 | 8.02 | -0.09 | 0.06  | 1600       | 46        |         |
| HD 72108  | 08 29 04.8 -47 55 44.1     | 2011.2.19 | 5.33 | -0.15 | 0.10  | 653±118    | 380       | 67      |
| HD 7217A  | 08 29 27.5 -44 43 29.4     | 2004.2.14 | 5.20 | -0.18 | 0.10  | 480        |           |         |
| HD 72179  | 08 29 37.7 -44 05 58.0     | 2011.3.20 | 8.14 | -0.12 | 0.04  | 640        | 48        |         |
| HD 72232  | 08 29 45.6 -46 19 54.1     | 2011.3.4 | 5.99 | -0.15 | 0.00  | 177±7      | 290       | 93      |
| HD 72350  | 08 30 39.2 -44 44 14.4     | 2011.3.17 | 6.30 | -0.02 | 0.16  | 606±132    | 390       | 116     |
| HD 72485  | 08 31 10.6 -47 51 59.8     | 2011.3.17 | 6.38 | -0.14 | 0.09  | 365±34     | 101       |         |
| HD 72535  | 08 31 47.6 -42 01 59.7     | 2011.3.20 | 8.20 | 0.07  | 0.31  | 770        | 52        |         |
| HD 72555  | 08 31 39.6 -47 14 27.7     | 2011.3.17 | 6.76 | -0.14 | 0.09  | 439±60     | 470       | 96      |
| HD 72648  | 08 32 19.0 -43 55 53.4     | 2011.3.18 | 7.61 | 0.12  | 0.34  | 909±268    | 1340      | 62      |
| HD 72800  | 08 32 53.8 -43 36 19.8     | 2011.3.17 | 6.64 | 0.12  | 0.12  | 2222±956   | 2260      | 75      |
| HD 73326  | 08 36 02.2 -46 30 05.9     | 2011.3.18 | 7.27 | -0.03 | 0.21  | 800        | 51        |         |
| HD 73478  | 08 36 42.7 -47 59 54.2     | 2011.3.19 | 7.37 | -0.10 | 0.10  | 581±133    | 820       | 103     |
| HD 73658  | 08 37 40.0 -46 16 57.8     | 2011.3.19 | 6.86 | 0.04  | 0.28  | 1515±440   | 1580      | 120     |
| HD 74194  | 08 40 47.8 -45 03 30.2     | 2008.4.21 | 7.57 | 0.21  | 0.50  | 2800       | 16        |         |
| HD 74234  | 08 40 53.4 -48 13 31.8     | 2011.3.19 | 6.95 | -0.17 | 0.07  | 719±141    | 610       | 98      |
| HD 74251  | 08 41 01.6 -48 04 02.9     | 2011.3.19 | 7.76 | -0.11 | 0.09  | 1111±397   | 840       | 43      |
| HD 74273  | 08 41 05.3 -48 55 21.6     | 2011.3.31 | 5.92 | -0.20 | 0.05  | 606±68     | 490       |         |
| HD 74319  | 08 41 34.9 -44 59 30.9     | 2011.3.17 | 6.69 | -0.10 | 0.06  | 538±87     | 320       | 38      |
| HD 74371  | 08 41 56.9 -45 24 38.6     | 2011.3.16 | 5.24 | 0.21  | 0.28  | 2325±787   | 1920      | 45      |
| HD 74436  | 08 42 07.8 -48 14 40.8     | 2011.3.31 | 8.24 | -0.08 | 0.12  | 662±293    | 820       | 51      |
| HD 74531  | 08 42 34.8 -48 09 48.9     | 2011.3.31 | 7.25 | -0.16 | 0.08  | 1351±524   | 1260      | 44      |
| HD 74650  | 08 43 16.6 -47 48 23.8     | 2011.3.24 | 7.35 | -0.05 | 0.01  | 220:       | 75        |         |

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determine the central radial velocity $V_{\text{LSR}}$ and equivalent width of the components. The components listed by Cha & Sembach were taken as starting parameters for the fits and further adjustments were made such that both $D_2$ and $D_1$ profiles are satisfied with the same number of components with the same $V_{\text{LSR}}$ and nearly same half-widths. The fits to the observed profiles are made such that no residuals are seen over the noise level of the surrounding continuum. The signal to noise $(S/N)$ in the continuum near Na D lines is given in Table 1 for each telluric-corrected spectrum. If more than one observation is available then the average of equivalent width and the standard deviation for the components is given in tables.

2 OVERVIEW OF THE NA D PROFILES

The VBT Na D profiles were obtained primarily to define their evolution, if any, since similar quality Na D profiles were obtained in 1993-1996 by Cha & Sembach (2000). Cha & Sembach searched for evolutionary changes in both the Ca II K and Na D profiles over their three year baseline but only among the 13 stars observed twice. Of the 13, seven showed variable profiles with Ca II K line variations being generally more prominent than those affecting the Na D lines. Changes were seen both among the low velocity complex of lines (two cases) and at high velocity (six cases). Our Na D observations cover 43 stars out of the 44 for which Cha & Sembach provide Na D profiles. (Our Na D spectra include 22 stars for which Cha & Sembach obtained Ca K line profiles but not Na D profiles.) Remarkable weakening of low-velocity absorption in Na D between 1993-1996 and 2011-2012 is seen in three cases – HD 63578, HD 68217 and HD 76161 – and strengthening in the case of HD 68243. Cha & Sembach reported changes in some high velocity components. In a few cases, cloud accelerations are evident between 1993-1996 by Cha & Sembach.}

Table 1 (continued)

| Star     | α,δ(2000) | $V_{\text{LSR}}$ | $\alpha_{\text{2000}}$ | $\delta_{\text{2000}}$ | Epoch | V  | (B-V) | E(B-V) | d(Hip)$^a$ | d(Sp)$^b$ | $(S/N)^c$ |
|----------|-----------|------------------|------------------------|------------------------|-------|----|-------|--------|------------|-----------|----------|
| HD 74711 | 08h43m47s.5 | -46°47′56″.4 | 2011.3.5 | 7.11 | 0.07 | 0.33 | 1140 | 57    |
| HD 74753 | 08 43 40.3 | -49 49 22.1 | 2012.3.16 | 5.16 | -0.22 | 0.08 | 568±58 | 700 | 118   |
| HD 74773 | 08 44 09.7 | -47 06 58.0 | 2008.4.16 | 7.24 | -0.12 | 0.06 | 1351±524 | 480 | 31    |
| HD 74920 | 08 45 10.3 | -46 02 19.2 | 2011.3.24 | 7.53 | 0.03 | 0.34 | 1500 | 61    |
| HD 74979 | 08 45 47.4 | -40 36 56.1 | 2011.3.24 | 7.24 | -0.05 | 0.00 | 588±129 | 1460 | 77    |
| HD 75009 | 08 45 47.5 | -44 14 52.8 | 2008.4.17 | 6.70 | -0.09 | 0.02 | 362±41 | 230 | 67    |
| HD 75129 | 08 46 19.4 | -47 32 59.6 | 2011.3.23 | 6.87 | 0.26 | 0.35 | 1282±412 | 1980 | 32    |
| HD 75149 | 08 46 30.5 | -45 54 45.0 | 2011.3.5 | 5.45 | 0.27 | 0.40 | 2702±948 | 1600 | 59    |
|          |           |                  | 2012.3.16 |          |      |      |        |       |          |          |         |
| HD 75241 | 08 47 05.4 | -45 04 29.1 | 2008.4.17 | 6.58 | -0.13 | 0.03 | 356±37 | 550 | 69    |
| HD 75309 | 08 47 28.0 | -46 27 04.0 | 2011.3.30 | 7.86 | 0.10 | 0.25 | 2610 | 71    |
| HD 75387 | 08 48 08.8 | -42 27 48.4 | 2011.4.1 | 6.42 | -0.20 | 0.04 | 483±61 | 600 | 63    |
|          |           |                  | 2011.4.1 |          |      |      |        |       |          |          |         |
| HD 75534 | 08 48 44.8 | -47 45 48.1 | 2011.3.30 | 7.82 | 0.36 | 0.55 | 2083±1093 | 2610 | 65    |
| HD 75608 | 08 49 21.3 | -43 22 14.4 | 2011.3.30 | 7.45 | -0.09 | 0.06 | 347±48 | 420 | 61    |
| HD 75759 | 08 50 21.0 | -42 05 23.3 | 2011.4.1 | 6.00 | -0.11 | 0.20 | 769±128 | 860 | 144   |
| HD 75821 | 08 50 33.5 | -45 31 45.1 | 2011.3.31 | 5.11 | -0.23 | 0.07 | 1000±213 | 910 | 107   |
|          |           |                  | 2012.1.16 |          |      |      |        |       |          |          |         |
| HD 76004 | 08 51 50.0 | -44 09 03.4 | 2011.4.1 | 6.35 | -0.17 | 0.03 | 515±74 | 390 | 73    |
| HD 76161 | 08 52 38.6 | -48 21 32.8 | 2011.3.31 | 5.90 | -0.16 | 0.04 | 318±57 | 310 | 32    |
|          |           |                  | 2011.12.25 |          |      |      |        |       |          |          |         |
| HD 76534 | 08 55 08.7 | -43 27 59.9 | 2011.4.1 | 8.02 | 0.13 | 0.37 | 980±485 | 650 | 59    |
| HD 76566 | 08 55 19.2 | -45 02 30.0 | 2011.4.2 | 6.26 | -0.16 | 0.04 | 370±40 | 530 | 70    |
| HD 76838 | 08 57 07.6 | -43 15 22.3 | 2013.3.23 | 7.31 | 0.00 | 0.20 | 336±59 | 480 | 87    |
| HD 77320 | 09 00 22.3 | -43 10 26.4 | 2011.3.5 | 6.02 | -0.14 | 0.09 | 320±24 | 290 | 53    |
|          |           |                  | 2012.3.15 |          |      |      |        |       |          |          |         |
| HD 78005 | 09 04 05.8 | -47 26 29.2 | 2011.3.4 | 6.44 | -0.15 | 0.08 | 358±38 | 550 | 56    |
| HD 79275 | 09 11 33.4 | -46 35 02.1 | 2011.3.4 | 5.79 | -0.22 | 0.02 | 305±23 | 460 | 61    |
|          |           |                  | 2012.2.24 |          |      |      |        |       |          |          |         |

$^a$The distances are Hipparcos revised parallaxes (van Leeuwen 2007) from SIMBAD. The spectroscopic distances are from Cha & Sembach (2000). V, B-V, and E(B-V) values are also from Cha & Sembach (2000) except when they are uncertain (or differ too much from Simbad). In such cases Simbad values are used.

$^b$Signal to noise in the continuum near Na I D lines of the telluric corrected spectrum.

$^c$ Vmag of Simbad is 6.577, B-V = -0.17
Figure 2. Na I D$_2$ profile of HD 63308, HD 69302, HD 70309, HD 71609, HD 72108, HD 72179, HD 72535, HD 72800, HD 73326, HD 73478, HD 74234 and HD 74251 obtained by us in 2011-12 (blue line) is superposed on the Ca II K profile obtained in 1993-94 (black line) by Cha & Sembach (2000).
Figure 3. Na i D₂ profile of HD 74371, HD 74436, HD 74650, HD 74920, HD 74979, HD 75129, HD 75534, HD 75608, HD 76838 and HD 77320 obtained by us in 2011-12 (blue line) is superposed on the Ca ii K profile obtained in 1993-94 (black line) by Cha & Sembach (2000). The prominent emission in the Na D profile of HD 75608 is due to terrestrial Na D airglow: weaker emission is seen in some other Na D profiles in this and Figure 2.
Table 2. Na I(now) and Ca II(then) Absorption Lines

| Star       | Ca II K |                     | Na I D |                     | Na I D |
|------------|---------|----------------------|--------|----------------------|--------|
|            | epoch V$_{LSR}$ km s$^{-1}$ | Eq.w (mA) | epoch V$_{LSR}$ km s$^{-1}$ | Eq.w (mA) | Eq.w (mA) |
| HD 63308   | 1993    | -15 29               | 2011-12| -9.7 43 19           |        |
|            |         | 5 71                 |        | 0.6 80 66            |        |
|            |         | 16 123               |        | 6.3 173 141          |        |
|            |         | 28 47                |        | 16.6 83 40           |        |
|            |         | 45 5                 |        | 29.4 43 20           |        |
|            |         |                      |        | 45.5 11 5            |        |
| HD 69302   | 1996    | -23 5                | 1989   | -30.2 9 0.6          | 2011   |
|            |         | -9 14                |        | -22.3 10 4           | -21.1 5 1 |
|            |         | -1 8                 |        | -16.8 9 4            | -8.9 28 14 |
|            |         | 5 15                 |        | -8.5 43 18           |        |
|            |         | 60                   |        | -1.2 29 18           |        |
|            |         | 40 6                 |        | 3.3 52 25            |        |
| HD 70309   | 1996    | -28 14               | 2011   | 0.8 81 46            |        |
|            |         | -13 21               |        | 22.5 8 2             |        |
|            |         | 1 53                 |        | -29.5 6 3            |        |
| HD 71699   | 1996    | -20 35               | 2011   | -12.0 34 17          |        |
|            |         | -8 31                |        | 2.0 73 40            |        |
|            |         | 6 107                |        | -12.0 34 17          |        |
|            |         | 17 34                |        | 23.8 8 4             |        |
|            |         | 32 22                |        | 33.7 24 6            |        |
|            |         | 48 15                |        | 45.2 6 2             |        |
| HD 72108   | 1996    | -111 4               | 1989   | 3.3 160 145          | 2012   |
|            |         | -31 13               |        | -28.3 28 8.5         | -111   |
|            |         | -23 67               |        | -28.3 28 8.5         | <1.7 <1 |
|            |         | -12 35               |        | -21.2 146 132        |        |
|            |         | -1 20                |        | -10.7 87 60          |        |
|            |         | 5 22                 |        | -0.1 91 71           |        |
|            |         | 15.9 12 7            |        | 7.3 39 21            |        |
| HD 72179   | 1996    | -33 6                | 2011   | 15.6 22 13           |        |
|            |         | -12 66               |        | -25.3 6 3            |        |
|            |         | 11 11                |        | -12.1 31 15          |        |
|            |         | 11 117               |        | 1.3 72 33            |        |
|            |         | 29 10                |        | 12.0 88 55           |        |
|            |         | 35 17                |        | 25.6 12 6            |        |
|            |         | 61 26                |        | 34.9 12 5            |        |
|            |         | 71 65                |        | 57.7 2 1             |        |
|            |         | 78 50                |        | 71.6 87 54           |        |
|            |         | 84 15                |        | 78.5 14 7            |        |
|            |         | 127 19               |        | 88.9 10 5            |        |
| HD 72535   | 1996    | -9 8                 | 2011   | 291 12 6             |        |
|            |         | 10 142               |        | -12.7 12 6           |        |
|            |         | 21 44                |        | 7.3 181 164          |        |
|            |         | 29 42                |        | 16.0 172 157         |        |
| HD 72800   | 1996    | -35 26               | 2011   | -20.9 18 9           |        |
|            |         | -10 106              |        | -10.0 60 30          |        |
|            |         | 7 124                |        | 3.0 180 152          |        |
|            |         | 21 90                |        | 11.0 168 147         |        |
|            |         |                      |        | 26.9 32 16           |        |
|            |         |                      |        | 43.7 10 5            |        |
| Star     | Cha & Sembach | Franco/Other | Present Observations* |
|---------|---------------|--------------|-----------------------|
|         | Ca II K       | Na I D       | Na I D                |
|         | epoch V$_{LSR}$ km s$^{-1}$ Eq.w (mA) | epoch V$_{LSR}$ km s$^{-1}$ Eq.w (mA) | epoch V$_{LSR}$ km s$^{-1}$ Eq.w (mA) Eq.w (mA) |
| HD 73326 | 1996 -46 14 | 2011 -11.3 41 | 2011 45.5 5 2          |
|         | -37 18       | -0.7 36      | 164 143              |
|         | -10 50       | 10.1 164     | 156 133              |
|         | 0 7          | 20.3         |                      |
|         | 7 48         |              |                      |
|         | 17 36        |              |                      |
| HD 73478 | 1996 -36 10  | 2011 -19.1 13 | 8.2 170 122          |
|         | -22 44       | -10.0 24     |                      |
|         | -8 73        | -2.8 57      |                      |
|         | 5 70         | 8.2          |                      |
|         | 13 51        |              |                      |
| HD 74234 | 1996 -17 27  | 2011 -19.3 14 | 5.2 180 147          |
|         | -6 18        | -7.6 36      | 15.8 49 26           |
|         | 5 64         | -2.8 57      | 26.0 13 7            |
|         | 28 15        | 8.2          |                      |
|         | 69 47        |              |                      |
|         | 85 6         |              |                      |
| HD 74251 | 1996 -108 8  | 2011 0.2 55  | 22.5 180 132         |
|         | -5 41        | 13.6         |                      |
|         | 6 56         | 190 122      |                      |
|         | 16 40        |              |                      |
|         | 78 5         |              |                      |
|         | 86 9         |              |                      |
| HD 74371 | 1994 -10 42  | 2011-12 -30.5 8  | -19.6 18 9          |
|         | -9 42        | -9.7 98      |                      |
|         | 2 286*       | 3.8 >250     |                      |
|         | 11 96        | 14.6 >189    |                      |
|         | 29 301*      |              |                      |
| HD 74436 | 1994 -7 57   | 2011 -9.0 60  | 6.9 260 185          |
|         | 7 80         | 6.9          | 20.1 35 18           |
| HD 74650 | 1996 -1 8    | 2011 -1.7 8  | 22.5 35 20           |
|         | 6 21         | 14.6         |                      |
| HD 74920 | 1993 -36 23  | 2011 -25.0 11 | 22.5 35 20           |
|         | -23 50       | -11.2 79     |                      |
|         | -9 34        | -3.7 165     |                      |
|         | -3 42        | -3.7 165     |                      |
|         | 2 35         | 6.9 148      |                      |
|         | 10 134       | 13.7 148     |                      |
|         | 21 40        | 22.5         |                      |
|         | 45 14        | 35 20        |                      |
| HD 74979 | 1996 -87 15  | 2011 -84.5 <8 | -8.1 25 13          |
|         | -13 9        | -8.1 25      |                      |
|         | 1 73         | 0.9 35       |                      |
|         | 12 146       | 12.5 312     | 280                  |
| HD 75129 | 1996 -98 26  | 2011 -67.8 10 | -21.4 20 11          |
|         | -67 62       | -8.8 33      | 5.7 146 131          |
|         |              | -8.8 33      | 146 131              |
|         |              | 5.7          | 146 131              |
|         |              | 12.7 138     | 137                  |
|         |              | 19.7 137     | 130                  |
|         |              | 27.9 116     | 97                  |
|         |              | 41.9         | 7 2                  |
Table 2 (continued)

| Star       | Cha & Sembach | Franco/Other | Present Observations* |
|------------|---------------|--------------|-----------------------|
|            | Ca\(\text{II} \text{ K}) | Na\(\text{I} \text{ D}) | Na\(\text{I} \text{ D}) |
|            | epoch | \(V_{\text{LSR}}\) \(\text{ km s}^{-1}\) | Eq.w (mA) | epoch | \(V_{\text{LSR}}\) \(\text{ km s}^{-1}\) | Eq.w (mA) | Eq.w (mA) |
| HD 75534   | 1996   | -46 | 8 | | 2011 | -14.4 | 16 | 9 |
|            |        | -17 | 32 | | | -0.2 | 145 | 120 |
|            |        | -5  | 62 | | | 5.7 | 132 | 118 |
|            |        | 5   | 128 | | | 13.6 | 179 | 164 |
|            |        | 13  | 72 | | | 23.0 | 85 | 50 |
|            |        | 23  | 62 | | | 
| HD 75608   | 1996   | -37 | 8 | | 2011 | -33.9 | 10 | 4 |
|            |        | -27 | 21 | | | 
|            |        | -19 | 14 | | | 
|            |        | -9  | 12 | | | 
|            |        | 4   | 26 | | | 
|            |        | 25  | 12 | | | 
| HD 76838   | 1996   | -18 | 24 | | 2011 | -22.7 | 6 | 3 |
|            |        | 9   | 65 | | | 
|            |        | 17  | 7 | | | 
|            |        | 33  | 7 | | | 
| HD 77320   | 1994   | -20 | 18 | | 2011 | -19.2 | 13 | 7 |
|            |        | -8  | 3 | | | 
|            |        | 3   | 16 | | | 
|            |        | 36  | 4 | | | 

\(a\): The \(V_{\text{LSR}}\) is an average of \(D_2\) and \(D_1\).

We have checked our velocities with telluric lines, which suggest errors around 0.15 km s\(^{-1}\). The agreement of our \(V_{\text{LSR}}\) of the gaussian components for many sight lines with those of Cha & Sembach is good with a mean difference of -0.09±1.25 km s\(^{-1}\) for 31 components. Moreover, when we mention change in velocity of the components they are essentially differential with respect to the low velocity components that remain unchanged.

### 2.1 Na\(\text{D}\) now and Ca\(\text{II}\) then

In this section, we compare the Ca\(\text{II} \text{ K}\) profile from 1993-1996 observations by Cha & Sembach (2000) with our Na D profile for stars for which Cha & Sembach did not have a Na D profile. Figures 2 and 3 show the profiles. As in other directions through the Galaxy, the Ca\(\text{II} \text{ K}\) and Na D interstellar absorption profiles while similar are never exact replicas. In addition, several profiles show high-velocity components, usually exclusively in the Ca\(\text{II} \text{ K}\) profile: see, for example, HD 72179 (Figure 2) with its strong high-velocity components at about +80 km s\(^{-1}\) in both Ca\(\text{II} \text{ K}\) and Na D and a higher velocity and weaker Ca\(\text{II} \text{ K}\) component at about +130 km s\(^{-1}\) with no counterpart (after almost two decades) in Na D.

Table 2 lists the gaussian components of both the Ca\(\text{II} \text{ K}\) profiles obtained by Cha & Sembach in 1993-96 period and the Na D profiles obtained by us mainly during 2011-12. Most of the components in both lines have the same \(V_{\text{LSR}}\) suggesting that the same clouds are present even after about 20 years. Two of the stars in the current sample were observed by Franco (2012) in 1989 April for their Na D profiles at high resolution with the telescope-spectrometer combination used by Cha & Sembach (2000): HD 63902 and HD 72108. Franco’s and our Na D profiles are compared below. Gaussian fits to the profiles and Cha & Sembach’s fit to their Ca\(\text{II} \text{ K}\) profile are summarized in Table 2.

Most of the Na D profiles are unchanged in equivalent width between 1993-1996 and 2011-2012. If it is assumed that the Na D components are unchanged, the ratio of column densities of Ca\(\text{II}\) to Na\(\text{I}\) could be estimated from the ratio of equivalent widths. As emphasized by Wallerstein et al. (1980) a high ratio of column densities of Ca\(\text{II}\) to Na\(\text{I}\) for high-velocity components is a sign of shocked gas, presumably resulting from the SNR interacting with interstellar clouds. This conclusion is supported by our larger sample. Stars in the direction of the Vela SNR offer the opportunity to examine the number density ratio \(R_{\text{(Ca,Na)}} = N(\text{Ca}\text{II})/N(\text{Na}\text{I})\) in clouds of higher velocity than those in the undisturbed diffuse interstellar low-velocity medium where an increase in \(R_{\text{(Ca,Na)}}\) with radial velocity was long ago noted by Routly & Spitzer (1952) over the approximate velocity range of ±60 km s\(^{-1}\). For the highest velocity clouds in the Vela survey spanning ±190 km s\(^{-1}\), one might expect differences in physical conditions – densities and ionizing radiation – as well as destruction of grains with appreciable release of Ca (relative to Na); Ca in quiescent interstellar gas is much more severely depleted onto/into grains than Na. An analysis of \(R_{\text{(Ca,Na)}}\) in high-velocity components along seven Vela SNR sight lines was reported by Danks & Sembach (1995) using a subset of the line profiles assembled
and discussed by Cha & Sembach (2000). Our extension of their analysis uses the full dataset provided by Cha & Sembach (2000) with new information on the Na D profiles for stars observed by them at the K line but not the Na D line. Additional information on high-velocity gas is modest because high-velocity components are rarely observed in the Na D profiles.

Our evaluation of $R(\text{Ca,Na})$ is made for about 40 stars for which equivalent widths are available for both the Ca II K and the Na I D lines. All of the K line profiles are taken from Cha & Sembach (2000). For those K line profiles for which Cha & Sembach did not provide a D line profile that profile is taken from the VBT observations with the assumption that the profile that has not changed in the 15-18 year interval. We limit the study to components with LSR peculiar velocities greater than $\pm 20$ km s$^{-1}$ to avoid the strong (saturated) foreground clouds, a limit close to that suggested by Cha et al. (1999) as a representative (minimum) velocity for clouds shocked by the SNR. For the stronger Na D lines (equivalent width greater than 100 mÅ) we used the doublet method to derive column densities. Almost all the K line equivalent widths are less than 100 mÅ and were assumed to be optically thin, the same assumption was adopted by Cha & Sembach (2000). The plot of $R(\text{Ca,Na})$ versus $|V_{\text{LSR}}|$ from 20 to 200 km s$^{-1}$ not surprisingly is similar to that (their Figure 3) provided by Danks & Sembach (1995).

At the ‘low’ velocities from $|V_{\text{LSR}}|$ of 20 to about 50 km s$^{-1}$, $R(\text{Ca,Na})$ increases steeply from about unity to about 20 with a large scatter all velocities. At higher velocities, $R(\text{Ca,Na})$ appears to attain an approximately constant value of 10 with a large scatter and with many lower limits arising from the non-detection of the Na D lines. The observed scatter at low and high velocities most probably exceeds the measurement errors. With the possible exception of the $R(\text{Ca,Na})$ values at the lowest considered velocities, all values are greater than values reported by Sembach & Danks (1994) for diffuse interstellar clouds for which $R(\text{Ca,Na})$ does not attain a value of 10 until peculiar velocities exceed about 50 km s$^{-1}$. Danks & Sembach (1995) suggest that although (incomplete) dust destruction in shocked gas may explain high $R(\text{Ca,Na})$ values, clouds with low $R(\text{Ca,Na})$ values may be found in gas which is in process of being compressed and accelerated. Testing this suggestion will require high-resolution ultraviolet spectra and thus access to more diagnostic lines.

Interstellar absorption line studies towards a few other SNRs have been reported in the literature but no study approaches the richness achieved for the Vela SNR and, in particular, no other SNR has been exposed to precision spectroscopy at more than a single epoch. The studied SNRs with a range of ages are all older than the 11000 year old Vela SNR and, thus, comparisons may shed light on the evolution of the interaction between a SNR and its interstellar environment. The SNRs for which Na D and Ca K observations are available include the Cygnus Loop at 20000 years (Welsh et al. 2002), IC 443 at 30000 years (Welsh & Sallmen 2003), Shajn 147 at 100000 years (Silk & Wallerstein 1973; Sallmen & Welsh 2004), and the Monoceros Loop at 150000 years (Wallerstein & Jacobsen 1976; Welsh et al. 2001) where the ages are those given in the cited references.

In the case of the Cygnus Loop, Welsh et al. (2002) observed nine OB stars with distances of 2500 to 2300 pc with the SNR at a distance of about 440 pc. There is strong interstellar absorption at low velocity ($V_{\text{LSR}} \approx 1$ km s$^{-1}$) with the negative $R(\text{Ca,Na})$ ratio representative of the diffuse interstellar medium. Components at 9 and 20 km s$^{-1}$ are present for a majority of the sight lines and a component at 30 km s$^{-1}$ is seen at the Na D lines but not the Ca K line for one star. These latter components appear for stars at distances beyond the Cygnus Loop. However, Welsh et al. are ‘unable to definitely associate these components with an interaction between the expansion of the SN shock wave and the ambient interstellar medium’ and suggest the alternative origin with the ‘an old pre-cursor SN neutral gas shell’.

For the IC 443 SNR, Welsh & Sallmen (2003) describe Na D and Ca K absorption profiles towards four early-type stars, three probably beyond the SNR and one in the foreground. Two of the more distant stars show high-velocity components extending to $-100$ km s$^{-1}$ and $+50$ km s$^{-1}$ with $R(\text{Ca,Na})$ values which, as Welsh & Sallmen write, are ‘consistent with appreciable levels of dust grain destruction due to interstellar shocks caused by interaction of the expanding SNR blast-wave with the ambient interstellar medium.’

Interstellar gas in the direction of the Shajn 147 SNR has been subject to limited exploration: Na D and Ca K lines were measured off photographic spectra for seven stars by Silk & Wallerstein (1973) and Na D and Ca K line profiles from CCD spectra of three stars (plus FUSE spectra of two stars) were obtained by Sallmen & Welsh (2004). High-velocity gas in one star - HD 36665 - first noted by Silk & Wallerstein is discussed in detail by Sallmen & Welsh. FUSE spectra of a second star - HD 37318 - show a high-velocity red-shifted component in ions such as N$^+$ and Fe$^+$ which is not seen in Na D and Ca K. The various high-velocity components ‘can be associated with the expansion of the SNR that has disrupted the surrounding interstellar gas’ (Sallmen & Welsh 2004).

A photographic spectroscopic survey of 25 sight lines towards the Monoceros Loop by Wallerstein & Jacobsen (1976) yielded one star – HD 47240 – showing high-velocity components. This star was subsequently reobserved at Na D and Ca K by Welsh et al. (2001) who also discuss FUSE spectra. Components at $V_{\text{LSR}} \approx +65$ km s$^{-1}$ show $R(\text{Ca,Na})$ values indicative of some release of Ca from grain destruction, a result in line with measurements of Fe, Si and Al column densities from FUSE.

Studies of these four SNRs, all older than the Vela SNR, show that high-velocity gas linked to the SNR can persist for at least 150000 years. An impression is suggested that gas at the highest velocities seen in the Vela observations is less common among the older SNRs. No information is available about the evolution of the high-velocity components. Reobservation at Na D and Ca K would seem now warranted in order to constrain evolution over about a decade.

2.2 Na D then and now

Thirty three stars are judged to have Na D$^2$ profiles which appear to be unchanged between 1993-1996 and 2011-2012 (Figures 4, 5, 6, and 7). Na D profiles for six stars observed in 1989 with the same telescope-spectrometer combination used several years later by Cha & Sembach were published by Franco (2012). Two of these six stars were observed neither by Cha & Sembach nor by us. Two were observed by
Figure 4. The Na\textsc{i} D\textsc{2} profile of HD 68324, HD 65814, HD 69144, HD 70930, HD 71302, HD 71459, HD 72014, HD 72067, HD 72088, HD 72127A, HD 72232, and HD 72350 obtained by us in 2011 (red line) is superposed on the Na\textsc{i} D\textsc{2} profile obtained in 1993 (black line) by Cha & Sembach (2000). For HD 72127A, VBT profiles from 2004 and 2007 are shown with Cha & Sembach’s profile from 1994.
Figure 5. The Na I D$_2$ profile of HD 72485, HD 72555, HD 72648, HD 73658, HD 74194, HD 74273, HD 74455, HD 74531, HD 74711, HD 74753, HD 74773 and HD 75009 obtained by us in 2008 or 2011 (red line) is superposed on the Na I D$_2$ profile obtained in 1993, 1994 or 1996 (black line) by Cha & Sembach (2000).
Normalised Intensity

Figure 6. The Na\textsuperscript{i} D\textsubscript{2} profile of HD 75149, HD 75241, HD 75309, HD 75387, HD 75759, HD 76004, HD 76534, HD 76566, and HD 78005 obtained by us in 2011-12 (red line) is superposed on the Na\textsuperscript{i} D\textsubscript{2} profile obtained in 1993-94 (black line) by Cha & Sembach (2000). The VBT spectrum of HD 75241 was obtained in 2008.

Cha & Sembach at Na D and one of the pair (HD 68217) shows changes in the low velocity Na D absorption (see next subsection). Three of the six and also HD 68217 were observed with the VBT. Comparison of Franco’s (2012) and the VBT profiles for the three common stars is given in Figure 8. The bulk of the Na D absorption is at low velocity and likely produced by the intervening spiral arms: here, low velocity corresponds to within ±25 km s\textsuperscript{-1} of \(V_{\text{LSR}} = 0\) km s\textsuperscript{-1} (Cha, Sembach & Danks 1999). Of the illustrated stars, eight have high velocity Ca\textsuperscript{ii} components. Of this octet, three were judged to have variable high-velocity components by Cha & Sembach. Similar profiles in 1993-1996 and 2011-2012 should not be taken to mean that differences at high velocity did not occur in the intervening years; several of the observed changes in high-velocity components occur with a short half-life (see below).

Inspection of Figures 4-8 shows examples where the profiles from then and now are essentially indistinguishable pixel by pixel across the low velocity complex of blends. In some cases, small differences occur in the deep line cores and/or wings. Other apparent differences occur at high velocity but none are appreciably greater than expected from signal-to-noise ratio differences; in general, the VBT spectra are of a lower (but high) S/N ratio than Cha & Sembach’s spectra. Additionally, subtle differences in spectra will arise from differences in the instrumental profiles, reduction techniques and correction for the telluric H\textsubscript{2}O absorption lines. Table 3 summarizes the breakdown of the Na D\textsubscript{2} profiles into gaussian components. In Figure 9, equivalent widths of low
velocity components measured by Cha & Sembach or Franco are compared with values from the VBT spectra. With the exception of the low velocity components for the four stars discussed below (and not plotted in Figure 3), Figure 9 shows that components have maintained a constant equivalent width over the multi-year baseline. The not unexpected constancy of the majority of the Na D absorption profiles from 1993-1994 to 2011-2012 contrasts sharply with the dramatic and rare examples of strong low velocity absorption which disappeared almost completely between 1993-1994 and 2011-2012, as discussed next. Changes in high-velocity absorption components were discovered by Cha & Sembach and are commented upon below.

2.3 Sight lines with a large change of neutral sodium column density

Interstellar clouds providing the low velocity Ca II and Na D components are part of the diffuse interstellar medium and generally associated with the spiral arms between us and the target star. Clouds close to the Vela supernova may be expected to have their physical conditions altered by the supernova and its remnant by radiation or collisions. At Na D, Cha & Sembach found no example of a star exhibiting large changes at low velocities and only two examples (HD 72127A and HD 73658) of modest changes in the Ca II K line profiles. Now, four examples of unprecedented change in the interstellar Na D profiles in less than two decades may be drawn from our sample. This quartet—three examples of a dramatic weakening and one of a modest strengthening of a Na column density between 1993-1994 and 2011-2012—surely indicate the affected clouds’ close proximity to the supernova or another source of an energetic outflow.

**HD 63578:** The Na D profile in 2011-2012 is strikingly different from that obtained by Cha & Sembach in 1993 (Figure 10): a component at −4 km s⁻¹ and a second and weaker component at −25 km s⁻¹ in 1993 are considerably weakened by 2011. Four observations between 2011 January 8 and 2012 November 14 provide identical Na D profiles. The 1993 Ca II K profile (Cha & Sembach 2000) consists of two components with the stronger one coincident in velocity with the Na D component at +6 km s⁻¹ and the other at
### Table 3. Na I Absorption Gaussian Components towards Some Sight Lines

| Star     | Cha & Sembach | | | Franco/Other | | | Present Observations$^a$ | | |
|----------|---------------|-------|-------|---------------|-------|--------------------------|-------|
|          |               | Na I D |       |               | Na I D |       |               | Na I D |
|          | epoch | $V_{\text{LSR}}$ | Eq.w | Eq.w | epoch | $V_{\text{LSR}}$ | Eq.w | Eq.w | epoch | $V_{\text{LSR}}$ | Eq.w | Eq.w |
| HD 65814 | 1993      | 1      | 267  | 138  | 2011      | 0.2   | 258  | 138  |       |       |       |       |
|          |           | 14     | 354  | 304  |            | 15.7  | 340  | 307  | 31.5  | 90    | 90    |       |
|          |           | 31     | 128  | 104  |            | 31.5  | 90    | 90   |       |       |       |       |
| HD 68243 | 1994      | -8     | 23   | 10   | 2011-12   | -11.5 | 24   | 10   |       | 2     | 56    | 33    |
|          |           | -2     | 33   | 25   |            | 7.6   | 12   | 7    |       |       |       |       |
| HD 70930 | 1993      | -10    | 131  | 66   | 1989      | -12.9 | 129  | 65   | 2011  | -9.4  | 105   | 48    |
|          |           | 9      | 138  | 84   |            | 0.8   | 17   | 11   |       | 1.9   | 8     | 7     |
|          |           | 13.4   | 29   | 19   |            | 7.3   | 102  | 75   |       | 10.1  | 129   | 85    |
|          |           | 36.1   | 8    | 5    |            | 13.4  | 29   | 19   |       | 18.0  | 24    | 17    |
| HD 71302 | 1994      | -23    | 61   | 24   | 2011      | -23.4 | 50   | 27   |       | -7.1  | 10    | 6     |
|          |           | 3      | 58   | 46   |            | 2.9   | 63   | 46   |       | 10.4  | 10    | 5     |
|          |           | 30.1   | 12   | 6    |            | 30.1  | 12   | 6    |       | 45.4  | 17    | 7     |
| HD 71459 | 1993      | -14    | 24   | $\leq 6$ | 2011-12   | -11.5 | 18   | 8    |       | 5.6   | 60    | 33    |
|          |           | 6      | 60   | 32   |            |       |       |       |       |       |       |       |
| HD 72067 | 1994      | -23    | 17   | $\leq 6$ | 2001      | -22   | 13   | 6    |       | -23.2 | 8     | 5     |
|          |           | -10    | 27   | 16   |            | -11.2 | 20   | 10   |       | 1.1   | 9     | 4     |
|          |           | 1      | 100  | 46   |            | 0.1   | 85   | 50   |       | 8     | 12    | 6     |
|          |           | 31     | 23   | 13   |            | 8     | 12   | 6    |       | 31    | 23    | 12    |
| HD 72089 | 1993      | -10    | 127  | 76   | 1996      | -10   | 118  | 70   | 2011  | -10.0 | 121   | 76    |
|          |           | 2      | 89   | 47   |            | 2     | 68   | 42   |       | 2.0   | 90    | 50    |
|          |           | 11     | 51   | 34   |            | 11.0  | 50   | 28   |       | 20.4  | 65    | 39    |
|          |           | 20     | 77   | 43   |            | 20.4  | 65   | 39   |       | 71.6  | 8     | $\leq 6$ |
|          |           | 75     | 12   | 6    |            | 75    | 14   | 6    |       | 107.9 | 7     | $\leq 4$ |
|          |           | 104    | 56   | 30   |            | 106   | 23   | 9    |       |       |       |       |
| HD 72232 | 1994      | -29    | 11   | $\leq 6$ | 2011      | -29   | 4    | 2    |       | 0.1   | 80    | 62    |
|          |           | 1      | 84   | 58   |            |       |       |       |       | 8.7   | 11    | 6     |
| HD 74773 | 1994      | -17    | 43   | 16   | 2008      | -16.9 | 20   | 8    |       | -9.4  | 36    | 18    |
|          |           | -8     | 37   | 18   |            | -0.5  | 61   | 40   |       | 7.7   | 38    | 22    |
|          |           | 2      | 63   | 39   |            | 16.9  | 60   | 36   |       | 26.3  | 66    | 45    |
|          |           | 9      | 31   | 16   |            |       |       |       |       |       |       |       |
|          |           | 18     | 53   | 36   |            |       |       |       |       |       |       |       |
|          |           | 27     | 47   | 38   |            |       |       |       |       |       |       |       |
| HD 79275 | 1994      | -29    | 18   | $\leq 6$ | 2011-12   | -31.4 | 11   | $\leq 3$ |       | 15.2  | 125   | 76    |
|          |           | -14    | 129  | 72   |            |       |       |       |       | -8.0  | 10    | 6     |
|          |           | -2     | 95   | 50   |            |       |       |       |       | -1.7  | 100   | 45    |
|          |           | 102    | 12   | $\leq 6$ |            |       |       |       |       | 97.9  | $\leq 2$ |       |

$^a$ The $V_{\text{LSR}}$ is an average of $D_2$ and $D_1$.

$^b$ The feature seems to be superposed on a stellar line of C ii at 5891.59 Å. The stellar as well as the ISM features are assumed to have gaussian profiles for estimating the equivalent widths.

$-14 \text{ km s}^{-1}$ may be coincident with the Na D components which decreased greatly in strength between 1993 and 2011 (Table 4). The Ca ii K line appears not to have been reobserved since 1993. The 1993 Ca ii K profile is quite similar to that reported by Wallerstein, et al. (1980) from observations between 1971 and 1977. Na D observations of Wallerstein et al. include the stronger component in the 1993 and 2011-2012 spectra but are probably of inadequate quality to determine if the blue-shifted 1993 component was present between 1971 and 1977. In summary, HD 63578 is an example where the largest change in Na D profile occurs among the low velocity clouds. Neither the available Ca ii K nor the Na D profiles have shown high-velocity components.

**HD 68217:** This star’s profiles of interstellar Ca ii K and Na D, as illustrated by Cha & Sembach (2000), resemble those of HD 63578 and, in addition, there is a close par-
Figure 9. Equivalent widths of low-velocity components of the Na\textsubscript{i} D\textsubscript{2} profiles obtained by Cha & Sembach (2000) or Franco (2012) versus the equivalent widths for the same components provided by VBT spectra (see Table 3). The line corresponds to equal equivalent widths. Dashed lines represent a 10 percent variation. Red dots refer to HD 70930 (Franco 2012), and cyan dots refer to HD 65814.

Figure 10. The Na\textsubscript{i} D\textsubscript{2} profile of HD63578 obtained by us in 2011 (red line) is superposed on the Na\textsubscript{i} D\textsubscript{2} profile obtained in 1993 (black line) by Cha & Sembach (2000). Note the absence of the blue-shifted absorption components in the 2011 spectrum (red line) that were present (marked with arrows) in the 1993 spectrum.

Table 4. HD 63578 Ca K and Na\textsubscript{i} Absorption Lines

| Epoch | $V_{\text{LSR}}$ km s$^{-1}$ | $W_{\text{eq}}$ (mA) | Epoch | $V_{\text{LSR}}$ km s$^{-1}$ | $W_{\text{eq}}$ (mA) | Epoch | $V_{\text{LSR}}$ km s$^{-1}$ | $W_{\text{eq}}$ (mA) | $W_{\text{eq}}$ (mA) |
|-------|-----------------------------|---------------------|-------|-----------------------------|---------------------|-------|-----------------------------|---------------------|---------------------|
| 1993  | -14                         | 24                  | 1993  | -4                          | 223                 | 2011-12| -13.2                      | 31                  | 15                  |
|       | 6                           | 34                  |       | -6                          | 39                  |       | -6.4                        | 39                  | 24                  |
|       | 11                          | 325                 |       | 5.8                         | 232                 |       | 5.8                         | 232                 | 191                 |
|       |                              |                     |       |                              |                     |       | 22.0                        | 5                   |                     |
allel in the Na D profile’s changes between 1993-1994 and 2011-2012. Figure 11 compares the Na D 2 profiles from the two epochs. An additional data point on the Na D variations is provided by the 1989 April Na D profiles shown by Franco (2012) which shows that the blue-shifted components at about −18 and −8 km s$^{-1}$ were slightly weaker in 1989 than in 1994. A VBT spectrum of lower quality obtained in 2007 February is similar to those from 2011 and 2012. Thus, the prominent −8 km s$^{-1}$ component which had strengthened between 1989 and 1994 had largely disappeared by 2007. Table 5 summarizes the results of Gaussian decomposition of the Na D profiles. The Ca II profile closely resembles that for HD 63578 except that the blue-shifted component for HD 68217 is the stronger than the red-shifted component but the reverse is found for HD 63578. For both stars, there is an absence of high-velocity components in the Ca II K and Na D profiles.

**HD 76161:** This star provides the third example in which very strong Na D low velocity absorption seen in 1993 had very greatly weakened by 2011 - see Figure 12: the 1993 saturated absorption at about 9 km s$^{-1}$ has almost completely vanished by 2011. Weaker absorption at about −9 km s$^{-1}$ seems unchanged over the 1993-2012 baseline. A weaker component at +27 km s$^{-1}$ in 1993 also weakened considerably by 2012. The 1993 Ca II K profile is almost identical to that of the Na D 2011 profile. The Ca II K profile reported by Wallerstein et al. (1980) was very similar to that seen in 1993 by Cha & Sembach (2000). Table 6 summarizes the Gaussian fits. High-velocity features are absent from all 1993 and 2011 spectra.

**HD 68243:** This star is the one example in our survey where Na D components are obviously stronger in 2011-2012 than in the spectrum obtained by Cha & Sembach (Figure 13). Cha & Sembach’s observations show an asymmetric Na D profile which they modeled with components at LSR velocities of −8 and −2 km s$^{-1}$. This asymmetry is also shown by their Ca K line profile. We observed the star on 2011 April 02 and 2012 February 14. Both observations show additional absorption at about +8 km s$^{-1}$ with a strengthening of the −2 km s$^{-1}$ component (Table 7). The assumption here is that changes in the D line profile reflect changes in the interstellar absorption along the line of sight to the star. However, HD 68243 is a spectroscopic binary (Pourbaix et al. 2004; Mason et al. 2009) and there is a possibility that the changes are the result of ejections of gas from one or both of the orbiting stars but the implied low ejection velocity and narrow line width suggest this is a remote possibility.

**Other lines of sight:** Cha & Sembach noted two stars with changes among the low velocity interstellar components: HD 72127A and HD 73658 (see below).

**High velocity components were not present in spectra of the K and D lines obtained by Cha & Sembach** in 1994. Our spectra from 2011 March 16 and December 24 show no high velocity components for the Na D lines. The sole report of a high velocity component among the limited observations of this star is by Hunter et al. (2006) who found a weak K line component with an equivalent width of 2.8±0.6 mÅ at a LSR velocity of 102 km s$^{-1}$ in a high S/N ratio VLT/UVES spectrum. Hunter et al. illustrate the profiles of the very weak subordinate Na I 3303Å lines but not the Na D lines but our inspection of the archived spectra shows that the high velocity component in the K line is not present in the D lines. The D lines have not changed their low-velocity profiles over the 1994-2011 interval.

The velocity resolution of the VLT observations is 3.75 km s$^{-1}$ not too different from that of Cha & Sembach (2000)’s observations. The absence of high velocity component in Cha & Sembach (2000)’s Ca II K profile is intriguing. The signal to noise limitation does not appear to be the reason since Cha & Sembach’s observations are claimed to have S/N ≥ 100 (equivalent widths greater than 1 mÅ). It is likely it was not present in 1994.

**HD 72088:** A 1994 spectrum of the K line showed a 20 mÅ line at $V_{LSR} = +108$ km s$^{-1}$ and no accompanying component in the D lines. Our Na D profiles confirm the absence of this high velocity component and the close sim-
Figure 11. The Na\(\text{i}\) D\(_2\) profile of HD 68217 obtained by Cha & Sembach in 1994 (black line) superposed on the profile of D\(_2\) obtained by us on 2012 January 16 (red line). Note the strong absorption component at V\(_{\text{LSR}}\) -9 km s\(^{-1}\) present in 1994 is greatly weakened in our 2012 profile. In the righthand two panels, Na\(\text{i}\) D\(_2\) and D\(_1\) profiles obtained in 1989 April by Franco (black lines) are compared with our 2012 January 16 profiles (magenta -D\(_2\); red =D\(_1\) ). Note the presence of a strong absorption component at -8 km s\(^{-1}\) in the 1989 and 1994 profiles that is missing in the 2012 profiles.

Table 5. HD68217 Na\(\text{i}\) Absorption Lines

| Epoch  | V\(_{\text{LSR}}\) km s\(^{-1}\) | Eq.w (mA) | Eq.w (mA) | Epoch  | V\(_{\text{LSR}}\) km s\(^{-1}\) | Eq.w (mA) | Eq.w (mA) | Epoch  | V\(_{\text{LSR}}\) km s\(^{-1}\) | Eq.w (mA) | Eq.w (mA) |
|--------|----------------|-----------|-----------|--------|----------------|-----------|-----------|--------|----------------|-----------|-----------|
| April  | -17.7          | 6.2       | 4.4       | 1994   | -18           | 17        | \(\leq 6\) | 2011-12| -18.9          | 9          | 5          | comp 1 |
|        | -9.0           | 19.9      | 10.9      |        | -8            | 30        | 20        |        | -8.4           | 9.5       | 4.6        | comp 3 |
| 0.8    | 42.1           | 24.5      |           |        | 2             | 43        | 12        |        | 1.5            | 41        | 21.5       | comp 2 |
| 8.5    | 17.8           | 10.9      |           |        | 9             | 20        | 16        |        | 9.0            | 21        | 10         | comp 1 |

\(\text{a}\) Average of four nights observations obtained on 2011 January 7, 2011 February 19, 2012 January 16 and 2012 November 14. The V\(_{\text{LSR}}\) is an average of D\(_2\) and D\(_1\).

Figure 12. The Na\(\text{i}\) D\(_2\) profiles of HD 76161 obtained on 2011 December 25 (red line) superposed on the profile obtained by Cha & Sembach (2000) (black line) in 1993.
Table 6. HD76161 Na i and Ca K absorption Lines

|            | Cha & Sembach | Cha & Sembach | Present Observations$^a$ |
|------------|--------------|---------------|--------------------------|
|            | Ca ii K      | D$_2$ D$_1$   | D$_2$ D$_1$              |
| epoch V$_{LSR}$ km s$^{-1}$ | epoch V$_{LSR}$ km s$^{-1}$ | epoch V$_{LSR}$ km s$^{-1}$ | |
| 1993 -8 16 32 | 1993 -6 94 32 | 2011 -8.9 6 3 3 | comp 1 |
| 2 38 1.0 60 | 9 395 365 | 1.0 60 32 | comp 2 |
| 9 395 365 | 27 61 32 | 12.6 8 4 | comp 3 |

$^a$: Observations obtained on 2011 December 25. The v$_{LSR}$ is an average of D$_2$ and D$_1$.

Figure 13. The Na i D$_2$ profiles of HD 68243. The profile obtained by Cha & Sembach in 1994 (black line) is superposed on the profile obtained by us on 2012 February 14 (red line). Note the strengthening of the line in 2012 due to an extra absorption component in the red wing.

Figure 13. The Na i D$_2$ profiles of HD 68243. The profile obtained by Cha & Sembach in 1994 (black line) is superposed on the profile obtained by us on 2012 February 14 (red line). Note the strengthening of the line in 2012 due to an extra absorption component in the red wing.

HD 72089: This star’s Ca ii K profile showed strong high-velocity components in 1993 and 1996 at +74, +87, +92 and +105 km s$^{-1}$ with records of this velocity gas extending back to before 1983 (Jenkins, Wallerstein & Silk 1984; Wallerstein & Gilroy 1992). In the Na D lines, these components are much weaker with the +76 km s$^{-1}$ component having the same equivalent width in 1996 as in 1993 but the +105 km s$^{-1}$ having a much smaller equivalent width in 1996 than in 1993. No earlier record of high velocity Na D appears to exist. Our 2011 spectrum shows that the +105 km s$^{-1}$ component is undetectable (Figure 15) with the D$_2$ component having an equivalent width of less than 7 mA but in 1996 23 mA was measured. The +75 km s$^{-1}$ component with an equivalent width of 12-14 mA in 1993-1996 is not seen in 2011 (equivalent width of less than 7mA). HD 72089 is a fine example of short-term variability (1993-1996) in the interstellar K and D$_2$ lines with a longer term decline in the Na D lines. New observations of the K line would be of great interest.

HD 72179: The 1996 Ca ii K line profile showed high-velocity components at +61, +71, +78, +84 and +127 km s$^{-1}$. Cha & Sembach did not obtain a matching Na D observation. The K line components around +80 km s$^{-1}$ were unusually strong (Figure 2). Our 2011 Na D profile (Figure 2) shows differences in the low-velocity and high-velocity components relative to the 1996 Ca ii K line profile. In particular, the K line high-velocity component at +84 km s$^{-1}$ is very weak in the D line and the +127 km s$^{-1}$ line is not present in the D line. High velocity absorption around 72 km s$^{-1}$ in the D lines is exceptionally strong for such a component suggesting that neutral clouds do occur at high velocity. It possibly might suggest a shocked and recombined gas cloud.

HD 72997: This star provided Cha & Sembach with one of their seven examples of high-velocity variations in interstellar line profiles with a high-velocity component strong at the K line and weaker in the D lines and both exhibited an approximately 2 km s$^{-1}$ shift to higher velocity over the interval 1991-1996 with little or no change in equivalent width. The 1991 K line profile was from Danks & Sembach (1995).
Table 7. HD68243 Na\textsc{i} Absorption Lines

| Epoch | $v_{\text{LSR}}$ km s$^{-1}$ | Eq.w (mA) | Eq.w (mA) | Epoch | $v_{\text{LSR}}$ km s$^{-1}$ | Eq.w (mA) | Eq.w (mA) |
|-------|----------------|-----------|-----------|-------|----------------|-----------|-----------|
| 1994  | -8             | 23        | 10        | 2011-12 | -11.5         | 24        | 9.5       |
|       | -2             | 33        | 25        |        | -2.1          | 56        | 32.5      |
|       |                | 7.6       | 12        |        |                | 7         | 7         |

* Average of two nights observations obtained on 2011 Apr 2, 2012 Feb 14, 2012. The $v_{\text{LSR}}$ is an average of both $D_2$ and $D_1$.

Figure 14. Left panel: The Na\textsc{i} D$_2$ profile of HD 72127A obtained in 2007 (magenta) and in 2004 (red) superposed on the Na\textsc{i} D$_2$ profile obtained by Cha & Sembach in 1994 (black lines). Note the appearance of the redward component at 22 km s$^{-1}$ in our spectrum that was not prominent in 1994 spectrum. Right panel: The Na\textsc{i} D$_1$ and D$_2$ profiles (red) of HD 72127A obtained by us in 2004 are coincided with Na\textsc{i} D$_2$, D$_1$ profiles by Welty, Simon & Hobbs (2008) observed in 2003 November (black lines).

Figure 15. Superposition of the Na\textsc{i} D$_2$ (red) profile of HD 72089 obtained on 2011 March 20 is superposed on Na\textsc{i} D$_2$ profile obtained in 1993 (black dashed) and 1996 (black line) by Cha & Sembach (2000). Note the weakening of and increased redshift of the high velocity component (marked R) from 1993 to 1996 and its absence in 2011.
Unfortunately, a VBT Na D spectrum is not available to constrain evolution of the D line.

**HD 73658:** This star qualifies as having variable interstellar line profiles. Changes have been seen in low velocity but not high-velocity absorption components. The K line varied between 1993 and 1996 (Cha & Sembach 2000, their Figure 7): the variable components were at velocities of $-32$ and $-15$ km s$^{-1}$ and, in this respect, the variability might be more appropriately linked with the prominent changes seen for HD 63578, 68217 and 76161. The Na D$_2$ profile in 2011 closely resembles that from 1993 (Figure 5). In 1993 and 1996, the only evidence for high-velocity interstellar gas was a weak (5 mÅ) K line component at $-126$ km s$^{-1}$. This did not then or in 2011 appear in the D line profiles.

**HD 74194:** This star was observed at the VBT in 2008 April. The star showed several high-velocity blue-shifted components in the 1993 and 1996 K line spectra obtained by Cha & Sembach. Velocities and equivalent widths were considered unchanged over the three year interval and the star was not listed by them as having variable interstellar components. Their Na D observations did not show these high-velocity components. The VBT spectrum of the Na D$_2$, although noisy, is a good match to Cha & Sembach spectrum (Figure 5) suggesting no variations.

**HD 74234:** Cha & Sembach (2000) found high-velocity components in their 1996 K line observations but did not obtain D line observations. Our D line 2011 observation and the 1996 K line observation are compared in Figure 2. The D line shows high-velocity components at $+72$ km s$^{-1}$ which may be closely related to the 1996 K line components at $+69$ km s$^{-1}$ (Table 2) suggesting, perhaps, mild acceleration of the cloud.

**HD 74251:** This line of sight in 1996 provided Cha & Sembach with weak K line components at $+78$ and $+86$ km s$^{-1}$. Lack of a D line observation precluded comment on whether these components appeared also in the D lines. Our 2011 observation shows nothing at this (or other high velocities) in the D lines (Figure 2).

**HD 74455:** K line observations in 1994 and 1996 showed blended high-velocity components at $-166$, $-173$ and $-183$ km s$^{-1}$ and a 28% decrease in equivalent width between 1994 and 1996 allowed Cha & Sembach to label this as a line of sight with variable interstellar components. These blue-shifted components appear neither in D line profiles from the same years nor in our profile from 2012 (Figure 5).

**HD 74531:** This line of sight is similar to that towards HD 74455. A blue-shifted K line component at $-141$ km s$^{-1}$ was seen not only in 1994 and 1996 but also earlier in 1973 (Wallerstein et al. 1980). The equivalent width is reported as 34±1 mÅ for 1994 and 25±1 for 1996, a decreases of 26% but apparently insufficient for Cha & Sembach to deem it a variable component. This blue-shifted component was not detectable in the D lines in 1994 and it was similarly absent in our 2011 spectrum (Figure 5).

**HD 75129:** The 1996 K line profile showed high-velocity components at $-67$ and $-98$ km s$^{-1}$ flanking stronger low-velocity absorption near 0 km s$^{-1}$. A Na D profile was not obtained by Cha & Sembach. Our 2011 March D line profile shows no high-velocity components but this cannot be taken as an evolutionary trend because high-velocity components generally appear weaker in the D than the K line.

**HD 75309:** This line of sight has, perhaps, the most interesting K line profile of those presented by Cha & Sembach from their 1993 and 1996 observations. High-velocity components were seen to the blue at $-120$ and $-74$ km s$^{-1}$ and to the red at $+81$, $+89$ and $+123$ km s$^{-1}$. The blue-shifted components strengthened between 1993 and 1996 while the $+81$ and $+89$ km s$^{-1}$ components vanished between 1993 and 1996 and the $+123$ km s$^{-1}$ component appeared unchanged between 1993 and 1996. The 1993 D line profile shows none of these high-velocity components and their absence and the absence of all high-velocity absorption in the D lines is confirmed by our 2011 observation (Figure 6). Of especial interest are the interstellar line profiles for HD 75309 obtained by Pakhomov, Chugai & Iyudin (2012) in 2008 March at a resolving power $R \approx 88600$. These observations confirm the presence in 2008 of the $-120$ and $+123$ km s$^{-1}$ K line components. Pakhomov et al. combine the 1993, 1996, and 2008 profiles to claim that the blue- and red-shifted high-velocity components are increasing their velocity separation at about 0.7 km s$^{-1}$ yr$^{-1}$ as though the centre of expansion were between their locations. The D line in 2008 was devoid of high-velocity absorption.

**HD 75821:** This star provides the rare example of a line of sight in which high-velocity components are seen in both the K and the D lines. HD 75821 was one of the stars for which Cha & Sembach identified variable i high-velocity absorption among a complex of K and D lines at velocities of $-99$ and $-85$ km s$^{-1}$. These D line components are detected in VBT spectra from 2007, 2011 and 2012. The trends seen from 1993 to 1996 continue; the $-85$ km s$^{-1}$ line almost disappears by 2007 while $-99$ km s$^{-1}$ line gets stronger and is apparently accelerated by 2007. Figures 16 and 17 show the high-velocity component for the D$_2$ line from 1993, 1996, 2007 and 2012 with Figure 17 showing that this component is being accelerated from $-98$ km s$^{-1}$ in 1993 to 102 km s$^{-1}$ in 2012. A weak feature at $-28$ km s$^{-1}$ seems to be present in the D$_2$ line from 1993 to 2012 and to move to more negative velocities with time. Thus, not only high velocity features but even low velocity features are accelerated.

**HD 76534:** This line of sight provided a component at $-86$ km s$^{-1}$ in a 1994 K line observation with nothing detectable at this velocity in the D lines. Our D line profile (Figure 6) confirms the absence of absorption at around $-86$ km s$^{-1}$. However, there may be a weak component about -150 km s$^{-1}$ in both the Cha & Sembach’s and VBT profiles.

In a simple interpretation, high-velocity components are associated with the rim of the expanding SNR with blue-shifted lines originating from the nearside and red-shifted lines from the far side. Combining the SNR distance of 287 pc with the 7.3 degree angular size, one obtains a SNR radius of about 18 pc. Figure 18 shows the velocities of high and low velocity components seen in stars at different distances. The striking feature of Figure 18 is the absence of high-velocity components in stars at about the distance of the SNR, as indicated by the location of the pulsar, and their first appearance in stars at distances of about 600 pc, an observation made earlier by Sushch et al. (2011). The nearly 300 pc difference between the location of the pulsar and closest stars showing high velocity components is an unexplained puzzle.
2.5 Other lines

The spectral region covered at the VBT includes other possible interstellar lines including the Li I 6707 Å resonance doublet and the K I resonance lines at 7685 and 7698 Å.

The lithium lines are of interest because energetic particles in the SNR might produce Li - both $^6$Li and $^7$Li - by spallation reactions. Lithium isotopic ratios indicative of spallation have been reported for lines of sight near the SNR IC 348 and IC 343 (Knauth et al. 2000, 2003; Taylor et al. 2012). The resolving power and S/N ratio of the VBT spectra are inadequate for useful determinations of the lithium isotopic ratio. Visual inspection of the spectra does not indicate lines of sight with Li I absorption of unusual strength. In light of the fact that regions within and near the SNR may have greater than average ionization rates for neutral lithium, analysis of the 6707 Å should be made relative to the strength of a K I line.

Regarding the K I lines at 7665 and 7698 Å, Pakhmov et al. (2012) suggested that interstellar K I lines in the direction of the Vela SNR are not detected for stars with distances $d < 600$ pc and then become sharply stronger for stars with distances $d > 600$ pc. They interpret this as due to an underpopulation of dense interstellar clouds until a distance of 600 pc. They go on to say that this 'hollow' in the distribution of K I clouds might be due to the dynamical evolution of Gum nebula. Apparently, the Gum supershell is known to be depopulated by neutral gas clouds between 350-570 pc (Woermann, Gaylard & Otrucek 2001). This assertion is contradicted by our observations, for example, the Hipparcos distance to HD 76838 is $336 \pm 59$ pc yet the sight line shows fairly strong K I lines (Figure 19). The distance to the star is about that of the Vela pulsar and our observation...
Figure 18. $V_{LSR}$ of Ca II K components, positive (red) and negative (blue) plotted with respect to Hipparcos distances (solid symbols). When Hipparcos distances are not available spectroscopic distances are used (denoted with circles -magenta and cyan for positive and negative velocities, respectively). The horizontal lines denote $V_{LSR}$ of $\pm 50$ and $\pm 100$ km s$^{-1}$. The location of the pulsar in the SNR is indicated by the arrow at 287 pc.

suggests cold dense clouds are not uncommon at distances of less than 600 pc. We have detected the K i 7698 Å line in eight stars out of 31 that are within a Hipparcos distance of 600 pc in our survey and in two out of 21 below 500 pc. We plan to discuss our observations of the K i and Li i lines and diffuse interstellar bands (DIBs) in a later paper. For the present, existence of cold dense clouds in the Vela SNR region is shown to be a reality.

3 CONCLUDING REMARKS

Interstellar lines seen in spectra of stars lying behind the Vela SNR differ in two principal respects from interstellar lines produced by the diffuse interstellar gas along the typical of line of sight through the Milky Way. These two differences, which are exhibited by the Na D lines whose evolution over nearly two decades was the focus of this paper, suggest that the key to understanding the two differences is to be found in interactions between the SNR remnant and the gas now embedded in the remnant. Such gas may be part of the remnant, circumstellar gas earlier ejected by the star or interstellar gas swept up by the expanding remnant.

The first difference between Na D absorption along sight lines through the Vela SNR and typical sight lines in the Milky Way concerns the presence of high-velocity components. Many of the observed lines of sight crossing the Vela SNR show high-velocity absorption components. When multiple observations are available, such components prove to be variable on a timescale of a few years (Cha & Sembach 2000). High-velocity absorption is particularly well seen in ions such as Si iv and C iv through their ultraviolet resonance lines (Jenkins, Silk & Wallerstein 1976; Jenkins et al. 1981; Jenkins, Wallerstein & Silk 1984). As Jenkins et al. (1984) remark "The velocity distribution of the triply ionized gas is probably representative of the kinematics of the Vela remnant since gas at such a high ionization is not commonly seen in the general interstellar medium." Unfortunately, a general lack of repeat observations of high resolution ultraviolet spectra means that reports of the variability of the high velocity absorption are limited to scarce repeat observations of the Ca II K line (Cha & Sembach 2000) and of the Na D line but the latter almost never shows strong components at high velocity (Cha & Sembach 2000; this paper). The high velocity components are considered to arise from the passage of the supernova’s blast wave through an inhomogeneous medium—see Jenkins et al. (1984), Jenkins & Wallerstein (1995) and Sushch et al. (2011). Destruction of grains by the blast wave likely accounts for the lower depletion of nonvolatile elements and, hence, the high ratio of N (Ca ii) to (Na i). However, it is still unclear why high velocity components (in Ca II K) occur only in stars more distant than 600 pc when the SNR is at a distance of 290 ± 30 pc (Figure 18).

The second example of a distinct characteristic of interstellar lines, specifically Na D lines, through and near the Vela SNR is that four of the sightlines observed both with the VBT and by Cha & Sembach show dramatic changes in the Na D profiles at low velocity. Across the extensive literature on interstellar Na D lines there are no reports of such large changes in Na D profiles from the quiescent diffuse interstellar medium. The closest example may be the sightline to the halo star HD 219188 (galactic latitude of −50 degrees) which showed a factor of three growth in Na D column density of the high-velocity gas from 1997 to 2000 but no detectable change in several low velocity Na D components (Welty & Fitzpatrick 2001; Welty 2007). In addition to the few examples of sightlines near the Vela SNR with large changes in Na D equivalent widths, some sightlines show small changes in equivalent widths of low velocity compo-
Figure 19. The VBT Na I D profiles (red = D1, blue=D2) and K I 7698 Å interstellar profiles of HD 76838 obtained on 2011 March 23. The line across the top of the figure marks the locations of telluric O 2 absorption lines around the K I line.

Figure 20. ROSAT All-Sky survey image (0.1-2.4 Kev) of the Vela SNR (Aschenbach et al. 1995). A-F are extended features outside the boundary of the remnant (‘bullets’). Light blue to white contrast represents a contrast in surface brightness of a factor of 500. The location of three of the stars that showed strong variable Na absorption in their ISM spectra. The blue stripe in the lower left hand corner is unrelated to SNR- apparently due to unremoned scattered solar X-rays.
three of these stars – HD 68217, HD 76161 and HD 68243 – pass close to the edge of the ROSAT 0.1-2.4 keV image (Aschenbach et al. 1995). HD 68217 may located behind a Vela SNR X-ray bullet, the extension E as shown in Figure 20. The Hipparcos distances of 383±30, 318±50, and 240 pc respectively of this trio suggests a physical connection with the SNR (distance of 290 ±30 pc). The strong Na D lines present in 1993-94 period imply large column densities: N(Na i ) of about ∼1.6x10^{15} cm^{-2} for HD 76161 (Welsh et al. 2010) and a N(H i) column density of ∼1.5x10^{21} cm^{-2}, assuming the relation between N(Na i) and N(H i) for an average ISM cloud (Welty 2007). For the size of a neutral cloud, as estimated by Pakhomov et al. (2012) in the vicinity of HD 76161 in Vela of 0.85 pc would suggest a density of N(H) of 580 cm^{-3}. Destruction of such a cloud by supernova blast wave as pictured in Vela SNR by Bocchino, Maggio & Sciortino (1999) and Pakhomov et al. (2012) seem to require several thousands of years. The time scale of 17 to 18 years, as observed, for the disappearance of the clouds appears to be too short for a supernova shock. Some other rapid cloud destruction mechanisms seem to be operative. However, one is tempted to argue that physical conditions in these particular low velocity clouds were affected by the SNR remnant: increased photoionization of Na by X rays or removal of neutral Na atoms?

The sightline to HD 63578, the fourth star with a large change in Na D strength, does not pass near the SNR and its X ray emission. At the distance of 481 pc, HD 63578 is located behind the wind swept bubble of γ 2 Vel. It is well known that high velocity winds from Wolf-Rayet stars and, in particular, γ 2 Vel are clumpy (Lepine, Eversberg & Moffat 1999) and strong with wind velocities of 1500 km s^{-1} (De Marco, Schmutz & Crowther 2000). Perhaps, a clump was crossing the line of sight at the time of the VBT observations.

Continued pursuit of variations in the interstellar lines along sightlines through and near the Vela SNR is to be encouraged. To expand the insights into the principal variations described here it will be helpful to obtain high-resolution optical spectra over a broad wavelength range such that Ca ii K and Na D lines are both recorded along with a host of weaker atomic and molecular lines. These spectra will serve to follow up the principal discovery of this paper, namely large variations – increases and decreases – in low velocity components of Na D lines and, in particular, provide the first opportunity to map out long term changes in the Ca ii K line profiles relative to the 1993-1996 baseline established by Cha & Sembach (2000). More difficult to obtain but more insightful about the high velocity components and their variations will be high-resolution ultraviolet spectra. In this case, the start of the baseline would appear to be the series of IUE spectra obtained in 1979-1981 and discussed by Jenkins et al. (1984).

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REFERENCES

Aschenbach, B., 1993, Adv. Space. Res., 14, 45
Aschenbach, B., Egger, R., Trumper, J., 1995, Nature, 373, 587
Bocchino, F., Maggio, A., Sciortino, S., 1999, A&A, 342, 839
Cha, A.N., Sembach, K.R., 2000, ApJS, 126, 399
Cha, A.N., Sembach, K.R., Danks, A.C., 1999, ApJ, 515, L25
Danks, A.C., Sembach, K.R., 1995, AJ, 109, 2627
De Marco, O., Schmutz, W., Crowther, P.A., 2000, A&A, 358, 187
Dodson, R., Legge, D., Reynolds, J. E, McCulloch, P. M., 2003, ApJ, 596, 1137
Franco, G.A.P., 2012, A&A, 543, A39
Hobbs, L.M., Ferlet, R., Welty, D.E., Wallerstein, G., 1991, ApJ, 378, 586
Hobbs, L.M., Wallerstein, G., Hu, E.M., 1982, ApJ., 252, L17
Hunter, L., Smoker, J.V., Keenan, F.P., Ledoux, C., Jehin, E., Cabanac, R., Melo, C., Baguolo, S., 2006, MNARS, 367, 1478
Jenkins, E.B., Silk, J., Leep, E.M., Wallerstein, G., 1981, ApJ, 248, 977
Jenkins, E.B., Silk, J., Wallerstein, G. 1976, ApJS, 32, 681
Jenkins, E.B., Wallerstein, G., 1995, ApJ, 440, 227
Jenkins, E.B., Wallerstein, G., Silk, J., 1984, 278, 649
Knauth, D.C., Federman, S.R., Lambert, D.L., 2003, ApJ, 586, 268
Knauth, D.C., Federman, S.R., Lambert, D.L., Crane, P., 2000, Nature, 405, 656
Lauroesch, J.T., Meyer, D.M., 2003, ApJ, 591, L23
Lepine, S., Eversberg, T., Moffat, A.F.F., 1999, AJ, 117, 1441
Mason, B. D., Hartkopf, W. I., Gies, D. R., Henry, T. J., Helsel, J.W. 2009, AJ, 137, 3358
Pakhomov, Yu. V., Chigual, N.N., Iyudin, A. F., 2012, MNARS, 424, 314
Pourbaix, D., Tokovinin, A.A., Batten, A.F., Fekel, F.C., Hartkopf, W.I., Levato, H., Morrell, N. I., Torres, G., Udry, S., 2004, A&A, 424, 727
Rademaker, K., Hodgins, G., Moore, K., Zarrillo, S., Miller, C., Bromley, R.M., Leach, P., Reid, D.A., Alvarez, W.Y., Sandweiss, D.H., 2014, Science, 346, 466
Rao, N.K., Sriram, S., Jayakumar, K., Gabriel, F., 2005, JApA, 26, 331
Reichley, P.E., Downs, G.S., Morris, G.A., 1970, ApJL, 159, L35
Routly, P.M., Spitzer, L., 1952, ApJ, 115, 227
Sallmen, S., Welsh, B. Y., 2004, A&A, 426, 555
Sembach, K.R., Danks, A.C., 1994, A&A, 289, 539
Silk, J., Wallerstein, G., 1973, ApJ, 181, 799
Sushch, I., Hnatyk, B., Neronov, A., 2011, A&A, 525, A154
Taylor, C.J., Ritchey, A.M., Federman, S.R., Lambert, D.L., 2012, ApJ, 750, L15
van Leeuwen, F. 2007, A&A, 474, 653
Wallerstein, G., Gilroy, K.K., 1992, AJ, 103, 1346
Wallerstein, G., Jacobsen, T.S., 1976, ApJ, 207, 53
Wallerstein, G., Jacobsen, T.S., 1976, ApJ, 207, 53
Wallerstein, G., Silk, J., 1971, ApJ, 170, 289
Wallerstein, G., Silk, J., Jenkins, E.B., 1995, ApJ, 440, 227
Welsh, B.Y., Lallement, R., Vergely, J.-L., Raimond, S., 2010, A&A, 510, 54
Welsh, B. Y., Sallmen, S., 2003, A&A, 408, 545
Welsh, B.Y., Sallmen, S., Sfeir, D., Lallement, R., 2002, A&A, 391, 705
Welsh, B.Y., Sfeir, D. M., Sallmen, S., Lallement, R., 2001, A&A, 372, 516
Welty, D.E., 2007, ApJ, 668, 1012
Welty, D.E., Fitzpatrick, E.L., 2001, ApJ, 551, L175
Welty, D.E., Simon, T., Hobbs, L.M., 2008, MNRAS, 388, 323
Woermann, B., Gaylard, M.J., Otrupcek, R., 2001, MNRAS, 325, 1213