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FUSE Analysis of the Cyg OB1 Superbubble

J. Nichols and P. Mendygral

Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138

Abstract. FUSE observations of four stars in the line of sight to the Cyg OB1 IR-detected superbubble have been analyzed for high-velocity features in the O VI interstellar lines, which might be attributed to the shock structure of the superbubble. Multiple components were detected in the spectra of all four stars, with a velocity range of –85 km/s to +29 km/s. As many as four separate velocity components were identified in each spectrum, implying multiple shock structures in the superbubble. Derived column densities of the O VI components indicate shock velocities of 160-190 km/s according to steady state shock theory.

1. Background

The Cyg OB1 superbubble is an elongated structure that overlaps the boundaries of the associations Cyg OB1, OB3, and OB9 (Saken et al. 1992). The size is 2 $\times$ 4.5 degrees; at an estimated distance of 1.5 kpc the physical size is 52 $\times$ 118 pc. This superbubble is not the same as the well-known Cygnus superbubble which is much larger and includes the association Cyg OB2, but it may be an extension or "blister" of this larger superbubble.

The Cyg OB1 superbubble is best identified in the infrared (Saken et al. 1992; Nichols-Bohlin & Fesen 1993), although evidence of portions of this superbubble have been detected in the optical (Lozinskaya & Repin 1990). Several theories have been proposed to explain the elongated shape of this superbubble. It could be due to non-coeval evolution of the Cyg OB1 association (Saken et al. 1992), or possibly multiple superbubbles that have merged.

The Cyg OB1 superbubble is believed to be in the early stages of evolution (Saken et al. 1992). Nichols-Bohlin and Fesen (1993) estimated the total energy output of Cyg OB1 and, assuming the superbubble is a result of the winds of the member stars and the estimated 4 supernovae that would have occurred during the 2 million year lifetime of Cyg OB1, calculated that the superbubble is about 2×10^6 yr old and has an expansion velocity of about 80 km/sec.

Of the 22 stars in the direction to the Cyg OB1 superbubble having IUE high dispersion observations available, 18 show high-velocity components in both low and high ionization interstellar lines (Nichols-Bohlin & Fesen 1993). The velocity of the components detected in the IUE spectra span the range +/- 90 km/sec, although negative velocities predominate the detections. The multiple components to the interstellar lines, coupled with the lack of geometric velocity gradient across the superbubble, imply that there are several overlapping superbubbles in this line of sight, including a probable multi-association superbubble.

2. Observations

Four stars in the line of sight to the Cyg OB1 superbubble have been observed with FUSE. The observations were made using the LWRS in TTAG mode. The data were reprocessed with CalFUSE 3.0.2 and smoothed with a 3-point median filter. Only the LiF1A spectra were included in this analysis in order to obtain the best spectral resolution. Gaussian profiles were fit to the components of the O VI absorption line at 1031 A. The four stars observed are all members of the Cyg OB1 association, at an estimated distance of 1.5 kpc. Two of the stars (HD 192639 and HD 193077) are near the center of the superbubble, and the other two are near the northern and southern edges of the superbubble, as mapped in the infrared data. Figure 1 shows the smoothed FUSE spectra in the O VI region, with the high-velocity features marked.

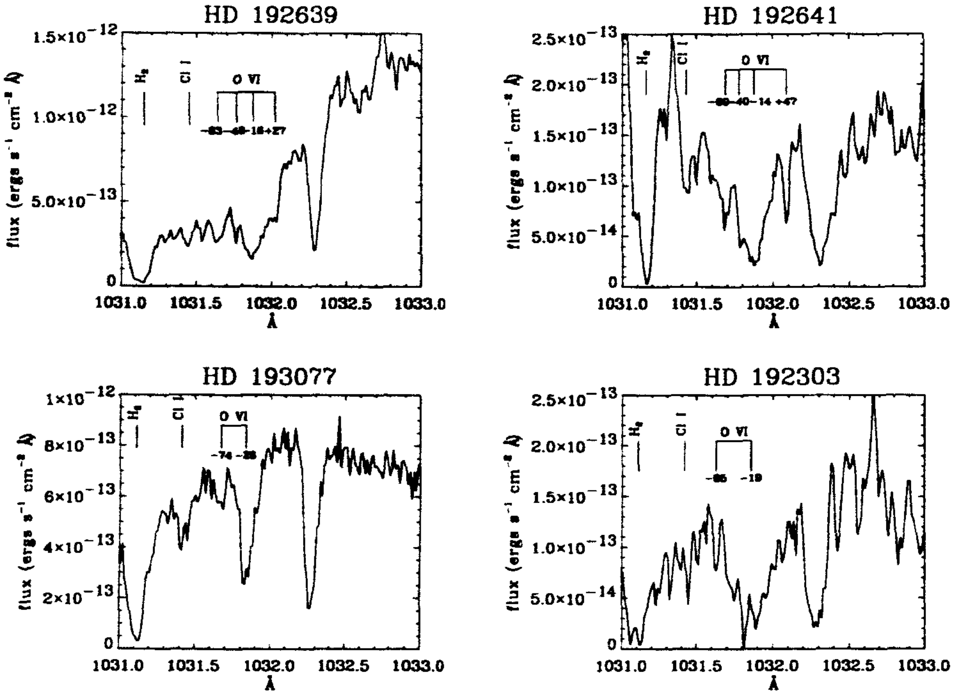

Figure 1. FUSE spectra of four stars observed in the line of sight to Cygnus OB1 superbubble, with indications of the high-velocity components in the O VI interstellar lines

3. Comparison to Shock Models

The O VI column density is very sensitive to shock speed in the steady state shock models in the range of 140-190 km/sec. By comparison of the O VI column density to the steady state shock model predictions, we can evaluate the consistency of each component, both low- and high-velocity, to the expected column density. Table 1 lists each component detected in the O VI line for each star, spectral type, radial velocity, and equivalent width of the components, the derived column density, and the model prediction of the shock speed.

Table 1. O VI Column Densities

Star	Sp. Type	Velocity of Component (km/sec)	Equivalent Width (mA)	N(O VI)	Model Shock Speed (km/sec)
HD 192639	O7.5 IIIf	-83	103	8.23×10^{13}	169
		-48	43	3.43×10^{13}	159
		-16	211	1.68×10^{14}	185
		+27	57	4.60×10^{13}	162
HD 192641	WC7	-69	98	7.83×10^{13}	169
		-40	22	1.76×10^{13}	154
		-14	189	1.51×10^{14}	184
HD 193077	WN6+abs	-74	88	7.03×10^{13}	169
		-28	123	9.82×10^{13}	171
HD 192303	B1 III	-85	62	4.95×10^{13}	188
		-19	253	2.02×10^{14}	166

4. Results

- High-velocity components in the O VI lines have been found in all four stars observed toward the Cygnus OB1 superbubble
- As in the IUE data, no clear geometric effects are apparent in the data between stars projected near the edge of the superbubble and stars projected near the center. Further analysis may reveal such a gradient.
- Steady state shock theory predicts shock speeds of 160-190 km/sec for the O VI column densities we have measured. These shock speeds are plausible if the Cyg OB1 association as a large differential galactic velocity, as has been proposed.
- Multiple components to the O VI lines imply multiple shocks along the line of sight to Cyg OB1.

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