PRE–SHOCK AND POST–SHOCK ABUNDANCE RATIOS OF ATOMIC CARBON TO CO IN IC 443 G

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1. Introduction

IC 443 is a prominent, well-studied supernova remnant. Optical pictures show multiple filaments through the midst of which runs a lane of extinction. Bright H_2 emission marks the region of interaction between the SNR and the foreground cloud. Clump G is at the western side of the SNR and is heavily obscured. At its position the velocity of supernova shock is nearly in the plane of the sky and the radial velocity of the shocked material is displaced very little from that of the ambient foreground material.

We have mapped clump G of IC 443 in the $^3P_1 - {}^3P_0$ line of atomic carbon (C I) with the CSO, as well as in ^{12}CO lines from $J = 2-1$ up to $6-5$, ^{13}CO $2-1$ and $3-2$, and have obtained a few C^{18}O $2-1$ spectra (Figs. 1 & 2). The ^{12}CO lines all exhibit strong wide lines which emanate from the shocked region and, up to ^{12}CO $4-3$, strong absorption by very cold foreground gas. The C I lines are much stronger than the ^{13}CO $2-1$ lines, which is unusual. The C I and CO isotopomeric lines also show the wide lines from the shocked region, but, rather than exhibiting absorption by cold gas, they have narrow strong emission lines at the same velocity as the ^{12}CO absorption, evidently emanating from warm pre–shocked gas. Because of the low temperature of the foreground gas, it does not strongly absorb the ^{12}CO $6-5$ line, so at most map positions (but not at the CO peak position with spectra shown in Fig. 2) the CO $6-5$ line also shows the narrow emission line in addition to the wide emission from the shock.

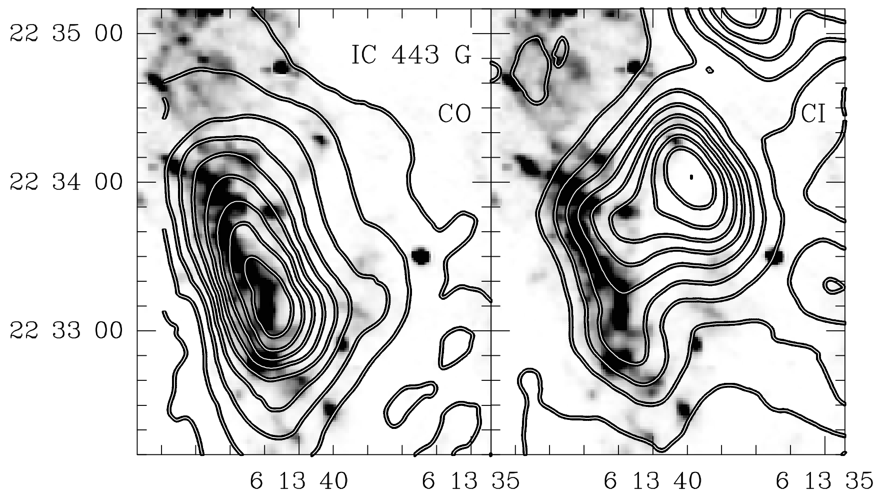

Figure 1. *left*) Contours of integrated ^{12}CO $2-1$ emission superposed on an image of the 2.12 μm H_2 emission (Merrill, Gatley, & Probst 1995, in preparation). *right*) Contours of peak C I temperature superposed on H_2 image. The direction of shock propagation is from east to west.

The ^{12}CO lines up to $J = 4$ peak strongly near the shock front as delineated by the H_2 emission (Fig. 1, left). However, the C I emission shows a more complex behavior – while the broad-line emission has a similar distribution to that of ^{12}CO, the narrow-line emission peaks well to the west of the front, *upstream* from the shock (Fig. 1, right). The same distribution is seen in the ^{12}CO $6-5$ line and the CO isotopomeric lines.

2. Interpretation

We have employed a Monte–Carlo radiative–transfer code (Bernes, 1979, A&A, 73, 67) to model the data. We have found that the emission regions can be satisfactorily represented as a superposition of three layers: 1) an extremely cold ($T_K < 10$ K) and/or low density foreground cloud of normal abundances (N_1[C I]/N_1[CO] ≈ 0.1), 2) an intermediate narrow–line layer of extremely carbon–rich material (N_2[C I]/N_2[CO] ≈ 10) with $25 < T_K < 60$ K and moderate density ($n \approx 10^4$ cm^{-3}), the presence of which indicates that most of the CO molecules have been dissociated *before* the arrival of the shock front, and 3) a background carbon–rich (N_3[C I]/N_3[CO] ≈ 1) shocked region with $T_K \approx 100$ K and high density ($n \approx 10^5$ cm^{-3}) in which molecule re–formation must be taking place. Table 1 gives the calculated column densities and abundance ratios for the position of the ^{12}CO emission peak with the observed and model spectra shown in Fig. 2.

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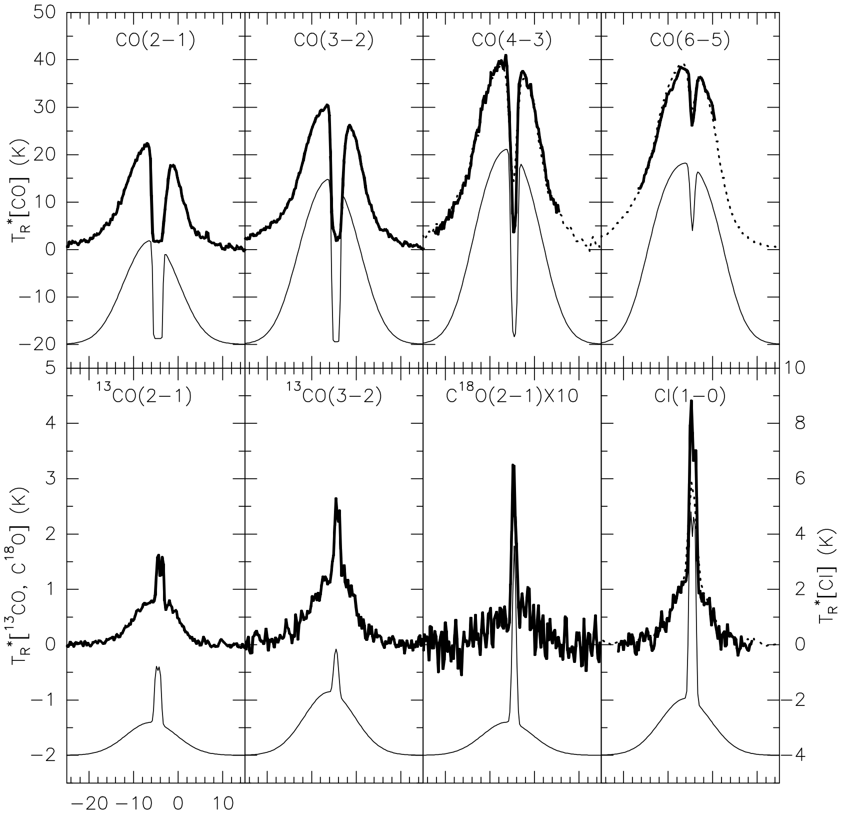

Figure 2. C I and CO spectra at the ^{12}CO peak [6:13:40.9 +22:33:10 (1950)]. Below the observations (heavy lines) are spectra calculated from the three–layer Monte Carlo model (light lines). Low spectral–resolution observations are shown with dotted lines.

TABLE 1. Pre– and Post–shock C I and CO Column Densities at the CO Peak

	1) Cold Pre–shock	2) Warm Pre–shock	3) Post–shock
N[C I]	0.3 (17) cm^{-2}	6.0 (17) cm^{-2}	3.0 (17) cm^{-2}
N[CO]	2.0 (17) cm^{-2}	0.5 (17) cm^{-2}	3.3 (17) cm^{-2}
N[C I]/N[CO]	0.15	13	0.9

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