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The Environment of Tycho: Possible Interaction with Molecular Clouds

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Abstract. We have conducted ^{12}CO observations with the Nobeyama 45-m telescope in the area of Tycho's supernova remnant. These high-resolution (16″) data show that the molecular cloud surrounds the SNR along the northeastern boundary. We suggest that Tycho's SNR and the molecular cloud are located at comparable distances within the Perseus arm and that they are physically interacting. We also discuss the possible connection between the molecular cloud and the Balmer-dominated optical filaments and propose that the preshock gas may be accelerated within the cosmic-ray and/or fast neutral precursor.

1. Tycho's SNR in ^{12}CO

There are a wide range of observations showing evidence that Tycho's SNR is interacting with an ambient dense cloud toward its northeast direction (Reynoso et al. 1997; Douvion et al. 2001). From the FCRAO ^{12}CO survey of the outer Galaxy (Heyer et al. 1998), we have identified a patch of molecular cloud which could be associated with Tycho and conducted high-resolution ^{12}CO ($J = 1-0$) line observations. Observation was carried out for a total of 20 hours during 2003 Jan 11–13 using the Nobeyama 45-m radio telescope (HPBW $\sim 16''$). The BEARS multi-beam receiver system was used to cover a $12' \times 12'$ area centered at Tycho whose diameter is $\sim 8'$. There is virtually no ^{12}CO emission at $V_{\rm LSR} > -54$ km s^{-1} (except from the gas in the local arm) and most of the emission is between -67 km s^{-1} $< V_{\rm LSR} < -60$ km s^{-1} with some emission at $V_{\rm LSR} = -58 \sim -55$ km s^{-1}. The emission is generally from regions surrounding Tycho. In particular, at velocities between -63.5 and -61.5 km s^{-1}, the emitting area appears to be in contact with the remnant along its northeastern boundary (Figure 1).

2. Discussion

Most distance estimates on Tycho seem to agree on the distance of ~ 2.3 kpc, with Tycho being located just behind the spiral density wave shock in the Perseus arm. The estimate based on H I absorption experiments is confusing (Schwarz

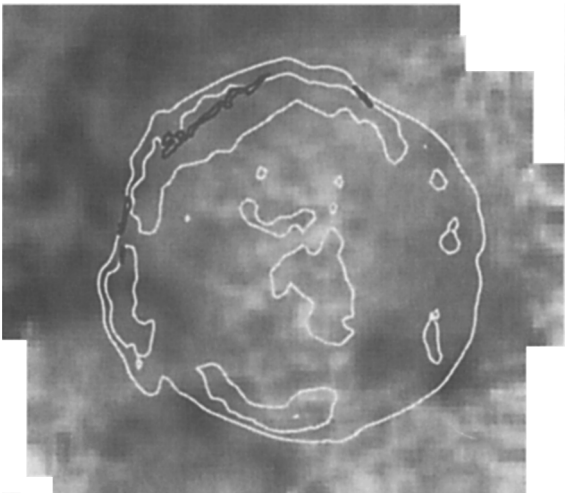

Figure 1. Integrated image of $V_{\rm LSR} = -60 \sim -63$ km s^{-1}. The white contours indicate radio continuum emission, the black contours show the Hα filament.

et al. 1980), but we have found that if b-dependent behavior of the velocity field is carefully accounted for, it is consistent with the above estimates. The distance to the molecular cloud is comparable, supporting its interaction with Tycho.

Balmer-dominated optical filaments, which are characterized by broad and narrow emission components, are observed along the northeastern boundary of Tycho. High resolution spectroscopy (Ghavamian et al. 2000) of this filament gives velocity information for the shock structure. The central velocity of the narrow component (~ -54 km s^{-1}) should represent the velocity of the gas just before the shock, but this is redshifted with respect to that of observed ^{12}CO (~ -62 km s^{-1}). We propose that this velocity difference is due to gas acceleration within the cosmic ray and/or fast neutral precursor. The amount of acceleration from the observed velocity difference is about 150 km s^{-1}. The fact that the acceleration is small compared to the assumed shock velocity of 2000 km s^{-1} indicates that the SNR shock in Tycho is not considerably modified by cosmic rays.

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