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CO J=2–1 observations toward the OH 1720 MHz maser in Kes 69

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Abstract. We present CO J=2–1 observations made with the 12 Meter Telescope of NRAO using the On-The-Fly technique, towards the OH 1720 MHz maser detected in direction to the supernova remnant (SNR) Kes 69. OH 1720 MHz masers associated to SNRs are strong evidence of shocked molecular gas, and are proposed to be tracers of SNRs kinematical distances. In our images, the most conspicuous feature positionally coincident with the maser is a cloud at $\sim +41$ km s^{-1}. The difference between the velocity of the OH 1720 MHz maser and this cloud is ~ 30 km s^{-1}. At the systemic velocity of the OH 1720 MHz maser, we detected a weak, small clump with the maser lying at its edge, in agreement with previous findings in other SNRs. We suggest that this small clump has been shocked by the expanding SNR, and the $\sim +41$ km s^{-1} component probably corresponds to gas accelerated by the shock front. We do not discard, however, that the $\sim +41$ km s^{-1} component be just a quiescent, foreground cloud unrelated to Kes 69.

1. Introduction

OH masers in the satellite line at 1720 MHz are a powerful probe of SNR-molecular cloud interactions (Frail et al. 1996; Green et al. 1997; Koralesky et al. 1998). It has been proposed that these kinds of masers are produced when shocks are strongly transversal, since in such cases the velocity dispersion is minimized and hence the maximum coherence is reached (e.g. Claussen et al. 1997). This property would turn OH 1720 MHz masers into excellent tracers of SNRs systemic velocities, and then kinematical distances would be accurately determined.

Molecular line surveys carried out in order to detect the shocked interstellar clouds where OH 1720 MHz masers are being excited, show a close correspondence between the velocities of the masers and of the associated clouds (Frail &

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Mitchell 1998; Reynoso & Mangum 2000). Masers are preferentially distributed along the edges of molecular clumps.

In this paper, we report on the most salient results of a CO J=2–1 study conducted toward the OH 1720 MHz maser detected by Green et al. (1997) in projection to the SNR Kes 69. A more detailed description of this work can be found in Reynoso & Mangum (2001).

2. Observations

Observations of the CO J=2–1 line were performed with the NRAO[1] 12 Meter Telescope using the On-The-Fly (OTF) technique. The surveyed region is sketched by the inner frame in the upper map of Figure 1. Three difrerent spectrometers were employed: two filter bank spectrometers with 128 channels and resolutions of 1 MHz and 500 kHz, respectively, and a 768-channel autocorrelator with a resolution of 98 kHz. The beam size is 27″. An efficiency factor of 0.85 was applied to sources with sizes in the range 20″ – 40″. Data processing was performed using the AIPS package. The final images have an rms of 0.8 K.

3. Results and discussion

An average profile towards the surveyed area, shows a broad (FWHM $\simeq$ 12 km s^{-1}) feature at +66.5 km s^{-1}, not detected earlier in absorption. We suggest that this feature, which corresponds to the far side of the Sagittarius arm, is related to Kes 69. In the direction of the OH 1720 MHz maser, these observations show two clumps at different velocity ranges: one between $\sim$ +39.8 and +41.7 km s^{-1}, and the other between +68.9 and +71.5 km s^{-1}. In Fig. 1, we show an integrated image of the CO J=2–1 emission in this latter velocity interval. In the upper frame, radio continuum emission is also plotted as solid lines, while in the lower, the contours of the CO feature observed between +39.8 and +41.7 km s^{-1} are added as grey solid lines, in which two components are distinguished: *A* and *B*. The clump at $\sim$ +70 km s^{-1} is labelled as *C*. Features *A* and *B* are bright enough to be readily seen with the present data, while to recognize feature *C* it was necesary to improve the signal-to-noise ratio by convolving the data to a 40″ × 40″ beam.

Assuming a distance of 11.2 kpc to Kes 69 (Green et al. 1997), these clumps have sizes of a few parsecs, while masses and H_2 densities are estimated to be 2,000, 3,000, and 200 $M_\odot$, and 120, 70, and 225 cm^{-3} for features *A*, *B* and *C* respectively. The spectral width of feature *C* is twice as broad as features *A* and *B*. We propose that the clump *C*, which has a systemic velocity compatible with that of the OH 1720 MHz maser (+69.3 km s^{-1}; Green et al. 1997), is at the same systemic velocity as the SNR.

Chevalier (1999) has modelled the evolution of a SNR interacting with a molecular cloud, and proposes that a slab of molecular material is accelerated by the SNR shell during the initial interaction. We suggest that feature *A* could

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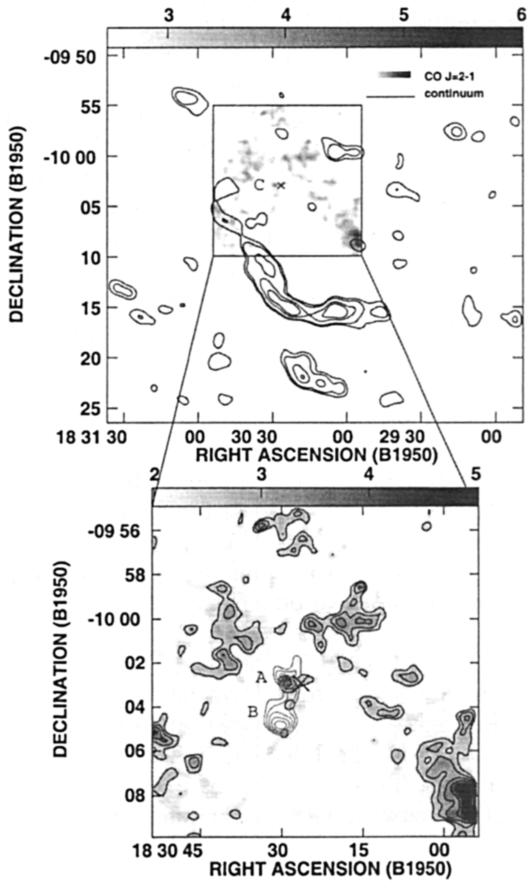

Figure 1. CO J=2–1 emission integrated between +68.9 and +71.5 km s^{-1}. The upper frame includes a region wider than the area covered in this survey in order to show the continuum emission towards Kes 69. The continuum data are extracted from the NVSS and plotted with solid lines. Kes 69 is the arc open to the northwest. The CO J=2-1 data are plotted in greys in both frames, and also in contours in the lower frame. The greyscale is indicated on top of both images, in units of K km s^{-1}. The cross shows the location of the OH 1720 MHz maser. The letter *C* labels the CO clump discussed in the text. The CO J=2–1 data have been convolved to a 40″ × 40″ beam. In the lower frame, the contours of the CO J=2–1 emission integrated between +39.8 and +41.7 km s^{-1} are superimposed as grey solid lines.

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be the accelerated slab. Under this assumption, it can be inferred that the shock driven into the molecular gas is of C-type. The measured H_2 densities are coincident with pre-shock densities expected for these kinds of shocks (Draine & Roberge 1984). Therefore, the present observations would not be tracing shocked gas but the unperturbed interstellar material into which the SNR is evolving. On the other hand, shocked gas should probably have an H_2 density of the order of 10^5 cm^{-3} (Lockett et al. 1999). Moreover, if this gas occupies a region as small as 0.6 pc, as in the case of 3C 391 (Reach & Rho 1999), which is equivalent to an angular extension of 11″, then the lack of signatures due to strongly shocked molecular gas could be attributed to beam dilution.

It is likely, however, that the $\sim +41$ km s^{-1} clump be a quiescent, foreground cloud, since the only argument to suggest a physical connection with the +71 km s^{-1} cloud is the perfect coincidence in position. Whether this coincidence is or not incidental, should be investigated through higher resolution observations in higher transitions, in search for spectral line broadenings or wings, characteristic of shocked gas.

The present result provides further support to the efficiency of OH 1720 MHz masers associated with SNRs as tools for distance determinations. When added to previous results (Reynoso & Mangum 2000), the difference between the velocities of OH 1720 MHz masers and the systemic velocities of CO clouds interacting with SNRs, turns out to be 0.6 km s^{-1} in average, with a dispersion of 1.7 km s^{-1}.

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