Methanol Masers in Galactic Center Region Supernova Remnants

Y.M. Pihlström[1,2], B. McEwen[1], & L.O. Sjouwerman[2]

[1]University of New Mexico, [2]National Radio Astronomy Observatory

Introduction

Methanol masers can be used to constrain densities and estimate kinematical distances to supernova remnants (SNRs), important parameters in cosmic ray acceleration models. With the goal of testing those models both for SNRs inside and outside the Galactic Center (GC) region, we have used the Very Large Array to search for 36 GHz and 44 GHz methanol lines in Galactic SNRs. We report on the overall results of the maser search, and in particular the results of the GC SNR G1.4-0.1 in which more than 40 masers were found. They may be due to interactions between the SNR and at least two separate molecular clouds. Methanol masers were also detected in W28 and in SgrAEast.

Project description and overall results

50 hours of VLA time has been awarded for this project, funded by NASA grant grant NNX10A055G. The new VLA Ka band receiver is used to search for 36 and 44 GHz methanol masers in a sample of 21 SNRs showing evidence for an interaction with a molecular cloud. In particular we wanted to learn if methanol masers are found more frequently in SNRs than 1720 MH OH masers.

Our observations target both the 36 and 44 GHz lines, since they trace different density regimes. The small high frequency field-of-view relative to the SNR size presents a challenge for the survey. Our solution was to target the majority of the methanol survey pointings toward the positions of previously known hydroxyl (OH) masers. This strategy was used to good effect in our initial methanol detections in Sgr A East.

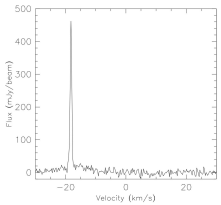

Figure 1: *An example of a maser feature detected in pointing position E in G1.4−0.1.*

Over 100 detections were made in Sgr A East, and in W 28 two detections were made at 36 GHz and four at 44 GHz. 41 detections in G1.4−0.1 are all at 36 GHz. All emission is detected as unresolved point sources, and with the single exception of a pointing position in G1.4−0.1 the lines are narrow consisting of a single spectral feature. An example of a spectral feature is plotted in Fig.1. The relatively large synthesized beam of the VLA configurations yield lower limits of the brightness temperatures of 300−500 K. Such temperatures are certainly consistent with thermal emission since the corresponding thermal linewidth would be 0.8 km/s and thus consistent with many of the detections. On the other hand several linewidths are narrower than 0.8 km/s and since thermal emission tends to be more widespread spatially and our detections are very compact and spot-like, we find it likely that most of the detections are masers.

Methanol and OH velocity and spatial comparison

The SNR G1.4-0.1

The SNR G1.4−0.1 contains a large number of methanol masers. Figure 2 shows the angular distribution of the masers on a 1.4 GHz gray scale continuum map. Less than 8% of the SNR extent is covered by our observations, implying that more masers may be associated with this object. The mean velocities of the masers at each pointing position, indicated in Figure 2, differs significantly from the velocity of the single 1720 MHz OH maser at +2km/s. The methanol is found over the full 60km/s velocity range observed, from about −30km/s to +30km/s. Since many masers were detected close to either edge of that range, it is possible that additional masers at higher negative and positive velocities exist.

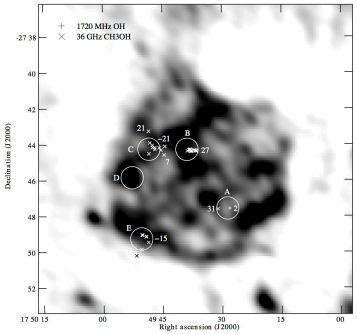

Figure 2: *The 36 GHz methanol masers detected in SNR G1.4−0.1 are plotted with crosses, and the single 1720 MHz OH maser is plotted with a plus symbol (in A) on a grey scale 1.4 GHz continuum map of the SNR. Numbers indicate the mean velocities of the masers in their respective regions. Big circles labeled A through E show the primary beam field-of-view for the methanol maser search observations.*

The line-of-sight toward G1.4-0.1 is covered by at least two molecular clouds, observed in both CO and CS (Oka et al. 1999; Tsuboi et al. 1999). The negative velocity methanol masers observed at the Eastern side of the SNR agree well with the −40 km/s cloud, and similarly, the positive velocity methanol masers at the Western side agree with the +40 km/s molecular cloud. It is not clear whether these molecular clouds do interact with the SNR, although there appears to be a molecular cavity encompassing the SNR, especially well outlined in the CS data presented by Tsuboi et al. (1999), similar to the one observed in CO lines in the SNR 3C397 (Jiang et al. 2010). With the published data it is difficult to find more detailed evidence for the