The Methanol Multibeam Survey

J. A. Green (1), R. J. Cohen (1), J. L. Caswell (2), G. A. Fuller (1), S. Breen (5), K. Brooks (2), M. G. Burton (3), A. Chrysostomou (4), P. J. Diamond (1), S. Ellingsen (5), M. D. Gray (1), M. G. Hoare (6), M. R. W. Masheder (7), B. N. McClure-Griffiths (2), M. Pestalozzi (4), C. Phillips (2), L. Quinn (1), M. Thompson (4), C.M. Voronkov (2), A. Walsh (10), D. Ward-Thompson (8), D. Wong-McSweeney (1), J. A. Yates (9), J. Cox (8)

Introduction

A purpose-built 7-beam methanol receiver is being used to survey the Galaxy for newly forming massive stars, pinpointed by strong methanol maser emission at 6.668 GHz. The receiver, jointly constructed by Jodrell Bank Observatory (JBO) and the Australia Telescope National Facility (ATNF), was successfully commissioned at Parkes in January 2006. The Methanol Multibeam Survey (MMB) is surveying the full 360° of Galactic longitude with a ±2° latitude range, and is the first systematic survey of the entire Galactic plane for methanol and excited-state OH masers.

FIGURE 1: The Parkes radio telescope, New South Wales, Australia.

Observing is in blocks of 2° x 4°, scanning at a rate of 0.1 per min, and taking ~11 hours to complete a block. Observations are designed to fully sample the range of velocities demonstrated by the CO emission of Dame, Hartmann & Thaddeus (2001). We incorporate 2048 frequency channels across a 4-MHz bandwidth to give a spectral resolution of ~0.09 km/s. We observe both 6.668-GHz methanol and 6.035-GHz excited-state OH simultaneously in dual circular polarization. For more details of the 6.035-GHz results and data processing and reduction techniques see the accompanying poster by Lyshia Quinn.

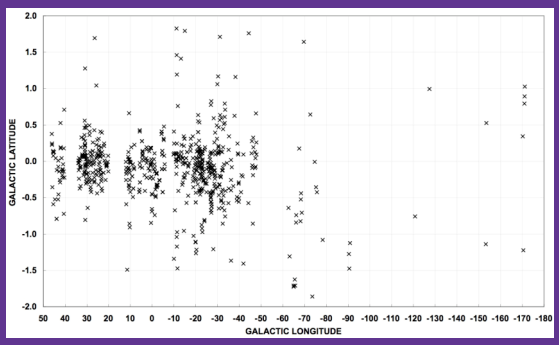

FIGURE 2: Longitude vs. latitude distribution of 6.7-GHz methanol masers detected by the MMB to date.

Methanol Masers

Since its discovery, the methanol 6.7-GHz maser has been recognized as one of the brightest signposts to the formation of massive young stars (Menten 1991). It is the second strongest cosmic maser known, second only to H_2O at 22 GHz, it is widespread and, unlike all other strong masers (OH, H_2O, SiO etc), it is only found close to massive young stars (≥ 8 $M_\odot$). Therefore a 6.7-GHz detection can only indicate a massive young star (Minier et al. 2003). The masers are often associated with Young Stellar Objects with an ultracompact (UC) HII region, but they can also trace earlier hot core phases (e.g. Minier et al. 2005). It seems likely that heating of the hot molecular core, or shock heating from an outflow, liberates methanol from dust mantles and so provides the high column density needed to give strong maser action (Cragg et al. 2002; Codella et al. 2004).

Results

The survey has a 3σ sensitivity of 0.6 Jy. To date the MMB has detected ~700 methanol masers with ~300 of those representing new sources. The distribution of sources is shown in Figure 2. Applying the rotation curve of Brand & Blitz (1993) it is possible to ascertain the Galactocentric distances, and the distribution of these is shown in Fig 3. There is a clear peak at ~5 kpc, tying in with the distance of the molecular ring. Furthermore the distribution of fluxes is given in Fig. 4 and shows a possible peak at about 1-2 Jy.

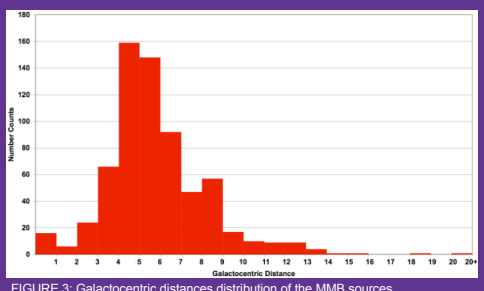

FIGURE 3: Galactocentric distances distribution of the MMB sources.

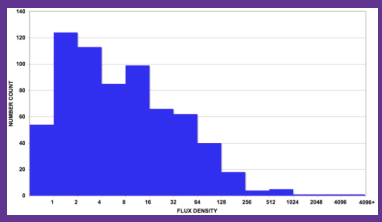

FIGURE 4: Flux density distribution of the MMB sources.

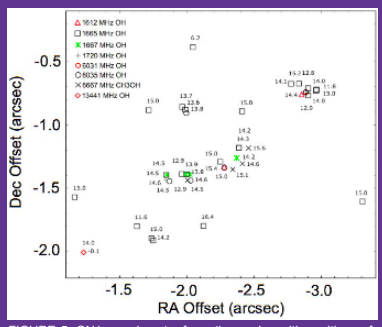

FIGURE 5: ON1 massive star-formation region with positions of known masers in the region. These are: Ground-state OH from Nammahachak et al. (2006), 4.765-GHz OH from Baudry & Diamond (1991), 13.4-GHz OH from Baudry & Desmurs (2002), H_2O maser positions from Downes et al. (1979) and 44-GHz methanol from Kurtz et al. (2004); together with the new excited-state OH and methanol features of Green et al. (2007, submitted). Offset positions on the right are given relative to the MSX point source at RA (J2000) = 20°10'09ˢ.23628, Dec (J2000) = 31° 31' 36".3784. LSR velocities are listed next to the maser positions.

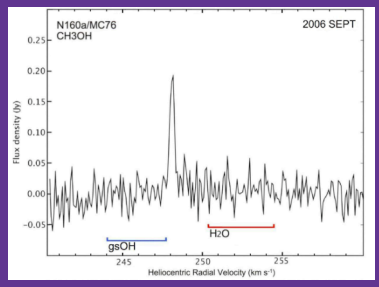

FIGURE 6: New 6.7-GHz methanol maser detected in the LMC towards N160a. gsOH and H_2O represent the velocity ranges of maser emission for ground-state OH and H_2O respectively (Green et al. in prep.)

High Resolution Follow-up

The Parkes detections can readily be positioned to an accuracy of the order of 30 arcsec, which is adequate for Galactic distribution studies, but it is not enough to determine the characteristics of massive star-formation. Therefore the positions of the Parkes detections are observed with MERLIN and the Australia Telescope Compact Array (ATCA) to refine the positions to the sub-arcsec accuracy achievable with these instruments. An example of what is possible is given in Fig. 5 for the star-forming region ON1 from Green et al. (2007, submitted) where the location of each maser species is pinpointed and the structure of the region is evident, with the methanol possibly tracing a shock front ahead of the ground-state OH maser emission.

Magellanic Clouds

In addition to the Milky Way, the MMB is also surveying the Large and Small Magellanic Clouds (to respective 3σ limits of 0.27 Jy and 0.39 Jy). A new 6.7-GHz methanol maser has been found in the star-forming region N160a in the LMC (Fig. 6). There were no detections in the SMC. Analysis of the populations of OH, H_2O and methanol star-formation masers show the LMC populations to be deficient by a factor of up to ~45, with the methanol populations showing the largest discrepancy (Green et al., In prep.).

Conclusion

The MMB survey with Parkes is due to finish mid-2008, at which point the receiver will move north to complete the survey on the Lovell Telescope at Jodrell Bank Observatory. With the detection of ~700 sources from ~70% of the Galactic plane, the predictions of 1000-1200 masers (Caswell 1996a,b; van der Walt al. 2005) appear feasible. Multi-frequency follow-up work has already begun.

On completion of the southern sky survey we will present survey statistics and establish the Galactic distribution of 6.7-GHz methanol masers and thus massive star-formation.

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1 Jodrell Bank Centre for Astrophysics, The University of Manchester, Oxford Road, Manchester, M13 9PL;
2 Australia Telescope National Facility, CSIRO, PO Box 76, Epping, NSW 2121, Australia;
3 School of Physics, University of New South Wales, Sydney, NSW 2052, Australia;
4 Centre for Astrophysics Research, Science and Technology Research Institute, University of Hertfordshire College Lane Hatfield Herts AL10 9AB;
5 School of Mathematics and Physics, University of Tasmania, Private Bag 37, Hobart, TAS 7001, Australia;
6 School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT;
7 Astrophysics Group, Department of Physics, Bristol University, Tyndall Avenue, Bristol BS8 1TL;
8 Department of Physics and Astronomy, Cardiff University, 5 The Parade, Cardiff CF24 3YB;
9 University College London, Department of Physics and Astronomy, Gower Street, London WC1E 6BT;
10 James Cook University, Townsville, QLD 4811, Australia