Cosmic Masers - from OH to H_0
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Molecular outflows toward methanol masers: detection techniques and their properties.

Helena M. de Villiers[1], M. A. Thompson[1], A. Chrysostomou[1,2] and D. J. van der Walt[3]

[1]Centre for Astrophysics Research, University of Hertfordshire,
College Lane, Hatfield, AL10 9AB, United Kingdom
email: `lientjiedv@gmail.com`

[2]Joint Astronomy Centre, Hilo, Hawaii, U.S.A., [3]USSR, North West University, South Africa

Abstract. Class II methanol masers are thought to trace the brief phase in the evolution of a massive YSO, where outflows are expected to occur. Molecular line maps of the CO isotopes of a subset of 6.7 GHz sources from the MMB catalogue were observed with the JCMT telescope. Utilising optically thick ^{12}CO, a search was done to detect broadened line wings (initially only on the source G20.08-0.13). The physical parameters of these detected lobes were then calculated.

1. Introduction

Class II methanol masers show strong emission at 6.7 GHz and are found in the vicinity of massive young stellar objects (YSO's), uniquely associated with high mass star formation regions (e.g., Menten 1991). These masers are thought to trace the stage immediately before the UC HII region in the development of a massive YSO (e.g., Minier *et al.* 2005). Methanol masers are thus likely to be associated with a high mass star's evolutionary phase when outflows occur (Codella *et al.* 2004). In order to test this hypothesis, we observed a subset of 67 6.7 GHz methanol masers from the MMB survey (Green *et al.* 2009) in ^{13}CO$(3-2)$ and C^{18}O$(3-2)$ using the JCMT, HARP. Matching ^{12}CO$(3-2)$ maps for every methanol maser were obtained from the JCMT HARP ^{12}CO Galactic Plane Survey (Dempsey *et al.* 2012, in prep.).

2. Outflow detections

Two detection methods for one dimensional broadened line wings were applied: (1) the technique followed by Hatchell *et al.* (2007) (called HATCHELL) using fixed velocity limits and (2) a combined method from the techniques used by Codella *et al.* (2004) and van der Walt *et al.* (2007) (called VDWC). In VDWC, the C^{18}O profile was scaled to the same peak temperature of ^{12}CO. A Gaussian profile was then fitted to the scaled C^{18}O peak and overlaid on the ^{12}CO spectrum. All temperature emission $> 3\sigma$ (on the noise level) and outside of the fitted peak were defined as respectively blue or red wings. The results are shown in the top row of Fig. 1. This initial study was only applied to G20.08-0.13, with a fairly good correspondence between the two methods. Repetition on more sources will follow. The integrated emission (intensity) were then calculated over the blue and red wing ranges respectively and shown as contour plots in Fig. 1.

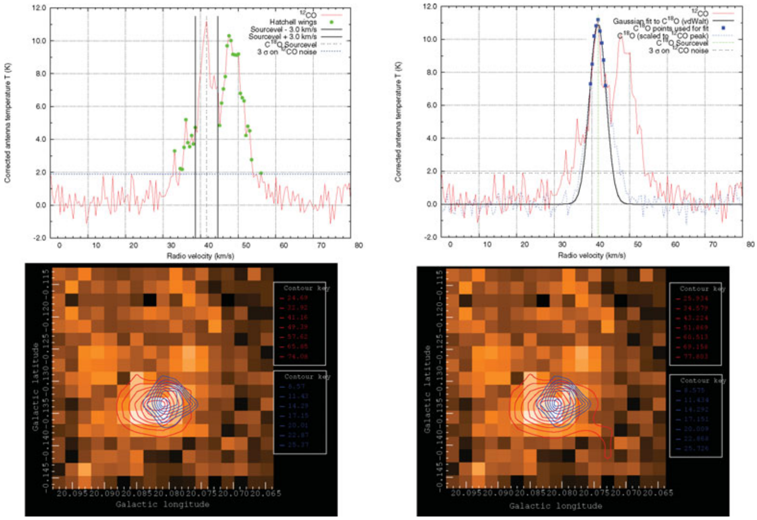

Figure 1. Top: Wing range classification according to (a) HATCHELL and (b) VDWC method for the ^{12}CO emission map associated with maser G20.08-0.13. Bottom: Red and blue wing contours as determined by respectively HATCHELL and VDWC methods.

3. Physical parameters

The contour plots and outflow velocity ranges as determined by method (1), were used to calculate the physical parameters of the outflows associated with G20.08-0.13, following Beuther *et al.* (2002). The H_2 column density were calculated using the approach by Hatchell *et al.* (2007). The resultant parameters were: column density $N_b = 4.9 \times 10^{20}$ and $N_r = 18 \times 10^{20} cm^{-2}$; total mass: $M_{out} = 114 M_\odot$, momentum: $p = 1120\ M_\odot kms^{-1}$; energy $E = 1.35 \times 10^{46}$ erg; characteristical time scale $t = 3.29x10^4$ yr; mass entrainment rate of each molecular outflow: $M_{out}/t = 3.46 \times 10^{-3} M_\odot/yr$; mechanical force: $F_m = 3.71 \times 10^{-2} M_\odot kms^{-1}/yr$; mechanical luminosity: $L_m = 3.37 L_\odot$. Although these listed physical parameters are only preliminary results, all were of the same order as those calculated by Beuther *et al.* (2002) for their 26 high-mass star-forming regions at early stages of their evolution. That is consistent with the hypothesis that methanol masers trace high mass star forming regions in an early evolutionary state. Should the outflow detection methods presented here be refined and the parameter results be expanded for the rest of the available data associated with methanol masers (at least 100 more methanol masers), a more complete picture of the properties of massive young stars in their very early stages of evolution, associated with methanol masers will be obtained.

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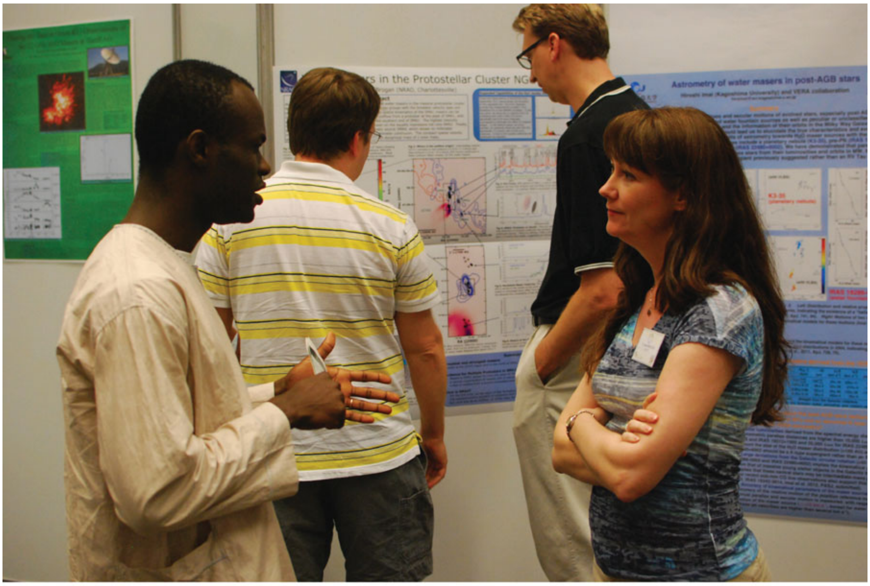

Sharmila Goedhart (bottom left) made sure the conference ran smoothly

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