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6668-MHz Methanol Maser Exploration of the W51 SFR Complex beyond W51 Main

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Sandra Etoka*, **Malcolm D. Gray, Gary A. Fuller**
Jodrell Bank Centre for Astrophysics, the University of Manchester – UK
E-mail: Sandra.Etoka@googlemail.com

W51 is one of the most massive giant molecular clouds in the Galaxy. It contains two giant HII regions labelled W51A and W51B which are themselves resolved into smaller components. In W51A, the most luminous sites are the two protocluster regions, so-called IRS2 and e1/e2. These regions, known to harbour maser emission from various species, show clear evidence of embedded young massive forming stellar objects. Our initial investigation of the region through MERLIN observations revealed intense and complex Class-II 6.668-GHz methanol maser activity towards W51 Main, associated with the e1/e2 protocluster. Here we present the second part of the investigation of this SFR complex which revealed the presence of 6.668-GHz methanol maser activity in several regions including W51 IRS2/North. The overall view of the class-II 6.668-GHz methanol maser emission towards W51A indicates that the masers are excited by multiple objects potentially at different stages of evolution.

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*Speaker.

1. Introduction

W51 is located in the Sagittarius spiral arm at 5.4± 0.3 kpc (Sato et al. 2010). It contains W51A (including W51 IRS1/Main and W51 IRS2/North) known to be an active site of massive-star formation. Several radio-continuum compact sources, mainly associated with the IRS1 shell/arc-like HII region were identified in this star-forming-region (SFR) complex (Ginsburg et al. 2016). In W51 IRS2/North, a cometary HII region (W51 d), and an UCHII region (W51d2) were detected (Gaume et al. 1993). Four SMA 870 μm continuum sources were identified towards this region (Tang et al. 2013). W51A shows a rich maser activity: H_2O, OH, NH_3 , CH_3OH and SiO (Genzel et al. 1981; Menten et al. 1990; Eisner et al. 2002; Imai et al. 2002; Phillips & van Langevelde 2005; Fish & Reid 2007; Goddi et al. 2015). Surveys have shown that 6.7-MHz Class-II methanol maser emission traces massive-star forming region processes from the very early stages where the star has not ionised enough its environment to show evidence of HC/UCHII (Hyper Compact / Ultra compact HII) regions to a later stage where these are indeed detected. This makes this maser emission a powerful tool to detect and study a wide range of "early-stage" high-mass young stellar objects (HMYSOs). Here we present the preliminary results of the exploration of the W51A SFR complex through 6.7-MHz Class-II methanol maser emission from MERLIN observations.

2. Results

Figure 1 presents an overview of the findings. The background image is an adapted map and information from Ginsburg et al. (2016, Figs. 1 & 2). The map presents the Ku-Band (14.5 GHz) continuum emission, tracing ionised gas towards W51A along with the identified compact sources relevant for the current study. The overlaid panels present the summary of the Class-II 6.7-MHz methanol maser emission found in this SFR complex.

The bulk of the methanol maser activity is found around the e1/e2 cluster of compact sources (Etoka et al. 2012). Most of the emission is concentrated towards W51 Main, with the centre of the maser activity around e2-E and e2-W (cf. Fig. 1 top-left panel). The methanol masers trace a wide-opening angle structure centred on e2-E, aligned on a PA $\sim$150^{o}, roughly perpendicular to the CO outflow observed in the region (Shi et al. 2010), and showing a clear velocity coherence. The inner part of the emission shows a "loop"/ring-like structure well described by an ellipse with a semi-major axis of $\sim$200 mas (i.e., $\sim$1000 AU), while the west-southwest emission clearly traces filaments which orientations agree with the magnetic field lines as inferred by dust polarimetric information from SMA observations at 0.87 mm (Koch et al. 2012) in the same region. Only two faint methanol masers are found in W51 South, probably associated with e3 and e8. A compact methanol maser region was also detected northern of the most active maser site in the IRS1 shell/arc (cf. Fig. 1 top-middle panel) showing no close association with a compact source.

Two methanol maser regions were detected towards W51 IRS2/North separated by $\sim$1 arcsec (cf. Fig. 1 top-right panel). The most redshitfted region is an isolated compact region. The most blueshifted regions in the vicinity of SMA3 central position (Tang et al. 2013) and hence most likely associated with it, clearly show some structure. A closer analysis of the most blueshifted emission as maser components, revealed that they trace a "loop"/ring-like structure of ∼200 mas in diameter (i.e., roughly half the extent of the one observed in W51 Main) where a velocity gradient can be seen.

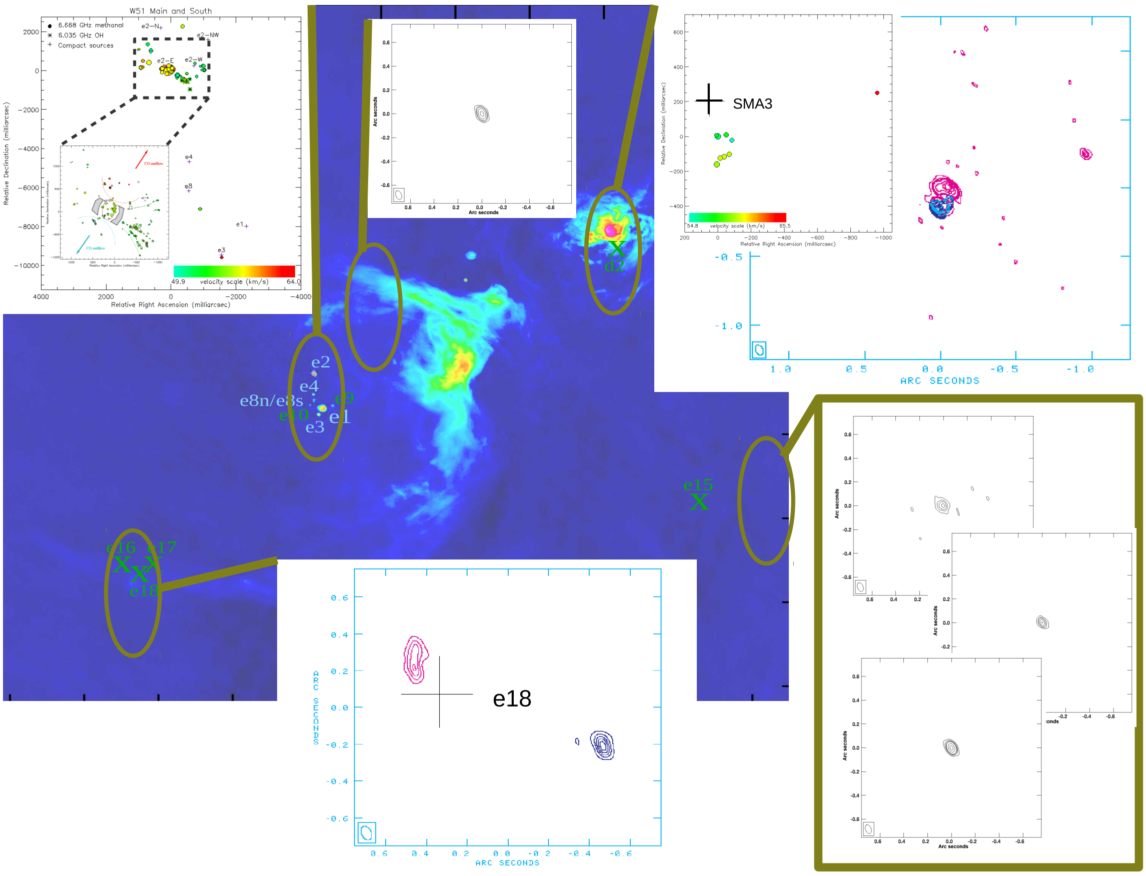

Figure 1: Background: Adapted Ku-Band (14.5 GHz, tracing ionised gas) continuum emission map including the relevant identified compact sources from Ginsburg et al. (2016, their Figs. 1 & 2). **Overlaid panels:** the 5 sites where Class-II 6.7-MHz methanol maser emission was found. *The top-left panel* also shows the 6.035-GHz maser components detected with MERLIN towards W51 Main & south, with the insert showing a magnification of the maser activity around e2-E and e2-W, including the OH maser component detected at 1.665, 1.667 & 1.720 GHz by Fish & Reid (2007) and presenting the various spatial kinematic components identified by Etoka et al. (2012). *The top-right panel* presents a composite image of the methanol maser emission detected towards W51 IRS2/North, with the insert showing the colour-coded maser component distribution along with the relative position of SMA3 from Tang et al. (2013). *The bottom-middle panel* presents a composite image of the methanol maser emission associated with the southeast end of the IRS1 shell/arc along with the position of the closest compact source e18 from Ginsburg et al. (2016). The size of the crosses for SMA3 and e18 corresponds to their positional uncertainty. *The top-middle panel* and *the bottom-right panel* present the compact methanol maser emission detected northern of the e1/e2 cluster and in the west "outskirts" of W51A away from the 2 most active regions respectively.

Beyond W51 e1/e2 & IRS2/North, several methanol maser regions were also detected. In the far southeast end of the IRS1 shell/arc structure, emission is observed most likely associated with e18 (cf. Fig. 1 bottom-middle panel). West of the IRS1 shell/arc, ∼1 arcmin away from e15 hence most likely not associated with it, 3 compact maser regions were detected (cf. Fig. 1 bottom-right panel).

3. Conclusion

We have presented the preliminary results of the 6.7-MHz Class-II methanol maser emission observed towards W51A. Emission was found in 5 sites with a wide range of complexity. By far the most complex region is towards W51 Main, followed by W51 IRS2/North and the far southeast of the IRS1 shell/arc which are all found in close association with a compact source. Velocity-coherent methanol "loop"/ring-like structures are observed in the two most "maser active" regions: namely W51 e1/e2 and W51 IRS2/North. This is reminiscent of the ring-like structure observed by Bartkiewicz et al. (2009) towards other SFR sites. These sites most likely probe the environment of "older" HMYSOs. Comparison with the compact sources currently known in this SFR complex have revealed that the most likely association for the methanol masers in W51 IRS2/North is SMA3 and that for the far southeast masers in the IRS1 shell/arc is e18. The remaining methanol regions detected, northern of the e1/e2 cluster and in the west "outskirts" of W51A, do not show any close association with a compact source. Their compactness and overall structural simplicity along with the lack of other {species} maser activity hints to possibly association with objects in an earlier stage of the formation process.

References

[1] Bartkiewicz et al., 2009, A&A, 502, 155

[2] Eisner et al. 2002, ApJ, 569, 334

[3] Etoka S., Gray M.D., Fuller G.A., 2012, MNRAS 423, 627

[4] Fish V.L. & Reid M.J., 2007, ApJ, 670, 1172

[5] Gaume R.A., Johnston K.L., Wilson T.L., 1993, ApJ, 417, 645

[6] Genzel et al. 1981, ApJ 247, 1039

[7] Ginsburg et al., 2016 A&A 595, A27

[8] Goddi et al., 2015, A&A 573, A109

[9] Imai et al. 2002, PASJ 54, 741

[10] Koch P.M., Tang Ya-Wen, Ho P.T.P., 2012, ApJ 747, 79

[11] Menten K.M., Melnick G.J., Phillips T.G., Neufeld D.A., 1990, ApJ 363, L27

[12] Phillips C. & van Langevelde H., 2005, ASPC, 340, 342

[13] Sato M., Reid M.J., Brunthaler A., Menten K.M., 2010, ApJ, 720, 1055

[14] Shi H., Zhao J.-H., Han J. L., 2010, ApJ, 718, L181

[15] Tang et al., 2013, ApJ 763, 135

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