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The Extended Methanol Maser Emission in W51

Chris Phillips

Australia Telescope National Facility, CSIRO, PO Box 76, Epping NSW 1710, Australia

Huib Jan van Langevelde

Joint Institute for VLBI in Europe, 7990 AA Dwingeloo, The Netherlands

Abstract. The European VLBI Network (EVN) has been used to make phase referenced, wide-field (several arcminute) spectral line observations of the 6.7-GHz methanol maser emission towards W51. In the W51main region, the bulk of the methanol is offset from an UCHII region. This probably indicates the methanol emission arises at the interface of the expanding UCHII region and not from an edge-on circumstellar disc, as previously suggested. Near the W51 IRS2 region, the methanol emission is associated with a very compact, extremely embedded source supporting the hypothesis that methanol masers trace the earliest stages of massive star formation. As well as these two previously well studied sites of star formation, many previously unknown regions star formation are detected, demonstrating that methanol masers are powerful means of detecting young massive stars.

1. Introduction

Massive stars play a crucial role in the dynamics and evolution of galaxies but their formation is poorly understood because they are rare, evolve rapidly and are heavily embedded. There is increasing evidence that class II methanol masers are associated with with some of the earliest stages of massive star formation. If this is the case, methanol masers can be a powerful probe for finding and studying young massive stars and proto-stars.

W51 is one of the most luminous regions of massive star formation in our Galaxy, and is at a distance of 7 kpc. The W51a field is known to show methanol maser emission and two isolated sources, W51 Main and W51 IRS2, have previously been observed with the EVN at 6.7 GHz (Phillips, 2000) and at 12.2 GHz with the VLBA (Minier et al. 2000). The region was also observed as part of a survey of Northern methanol maser sources with the ATCA. These observations showed that the VLBI imaging had missed a large fraction of the maser emission which was located in 9 separate sites spread over more than 4 arcminutes.

2. Observations

The Northern position of W51 resulted in limited *uv* coverage and observations at low elevation, so good astrometry could not be achieved with the ATCA data.

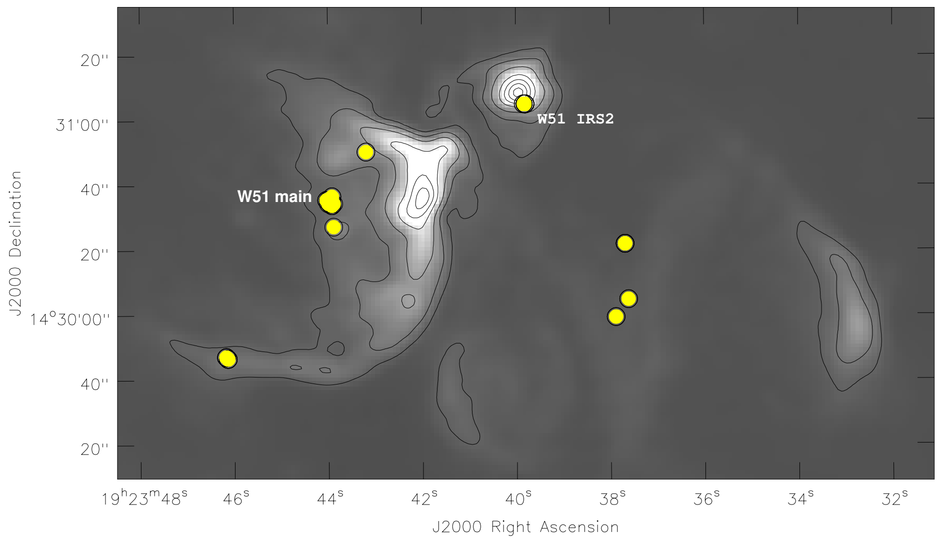

Figure 1. The W51a region observed with the EVN. The white/yellow circles with a black outline indicate the position of the 6.7-GHz methanol masers, while the greyscale and contours show the 4.8 GHz continuum observed with the VLA (Mehringer 1994).

To get high precision absolute and relative astrometry of the maser emission, we used the EVN in phase referenced mode to make large field of view observation of the region. The observations were made on 7 Feb 2002, using 4 EVN antennas which can observe at 6.7 GHz. The data were correlated with the EVN MarkIV data processor at JIVE. Because the maser emission is spread over a region larger than the primary beam of the Effelsberg telescope, the observations had to be made using two separate pointings.

3. Results and Discussion

Figure 1 shows the measured position of the methanol masers overlayed on an 4.8-GHz VLA continuum image of the region. Although a few sources are associated with known centres of activity, the majority of the masers do not show any obviously compact radio continuum. However, the presence of the methanol masers means that these are the locations of some sort of activity, presumably massive star formation. Interestingly, 800 μm observations made by Ladd et al. (1993) using the JCMT, show a compact continuum source at the same position of the masers in the South-East. The whole region has been surveyed for main line OH maser emission using the VLA (Argon et al. 2000) and most of sites of methanol maser emission do not show any OH maser emission either. VLA observations of H_2O masers and thermal NH_3 do not detect any emission towards most of the methanol masers, but given the relatively small primary beam at 22 GHz, this is probably not surprising without targeted observations.

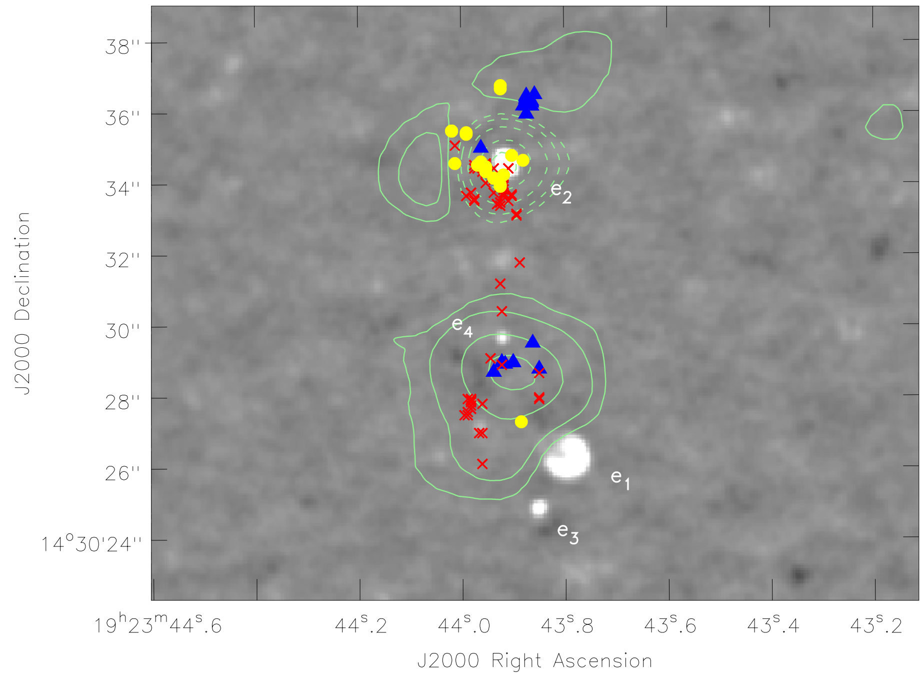

Figure 2. Detail of the W51 Main region. The white/yellow circles indicated the position of 6.7-GHz methanol masers, the position of OH and water masers are indicated by (red) crosses and (blue) triangles (Argon et al. 2000; Imai et al. 2002). The greyscale shows the 8.4 GHz continuum emission observed using the VLA A array (Gaume et al. 1993) while the (green) contours show the integrated NH_3 (1,1) emission also observed with the VLA (Zhang & Ho 1997).

We suggest that the newly detected methanol masers represent either very young or very embedded (possibly both) massive stars or proto-stars. Follow-up observations using instruments such as BIMA and the VLA at 20 GHz will be needed to understand the origin of these sources.

Two of the sites of methanol maser emission in this region are well known sources and have been studies extensively at many wavelength; W51 Main and W51 IRS2.

3.1. W51 Main

Figure 2 shows a close up of the W51 main region, with the methanol positions from the current data overlayed on 8.4 GHz continuum emission as well as OH and water masers and NH_3 (1,1) emission. The astrometry shows that the bulk of the methanol emission is offset to the edge of a bright, unresolved, UCHII region which shows deep NH_3 absorption, indicating that the object is still embedded in dense molecular material. Most of the methanol components lie in an elongated structure which has previously been interpreted as the masers delineating an edge on disc around a young massive star (Phillips et al. 2000). Linear structure of the methanol emission is seen in many other methanol maser

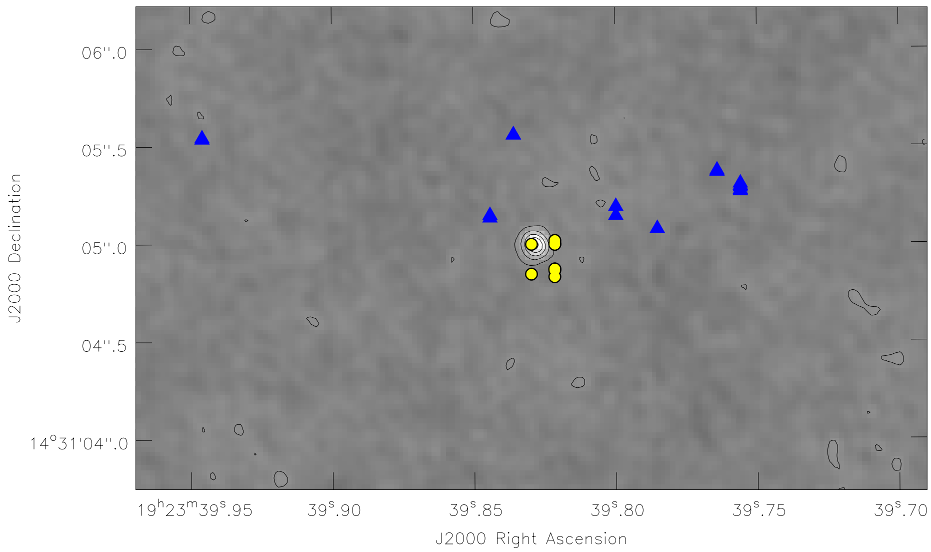

Figure 3. Methanol masers towards the W51 IRS2 region (IRS2 is slightly to the east of viewable region). Position of methanol masers are shown by white/yellow circles with a black border. Black/blue triangles indicated the position of H_2O masers (Eisner et al. 2002). The greyscale and contours show the 22 GHz continuum observed with the VLA-A array (Gaume et al. 1993).

sources, and the disc hypothesis is often used to explain the morphology and velocity gradient along these sources (Phillips et al. 1998; Norris et al. 1998). The relative position of the methanol emission with respects to the UCHII region found by the current observations, and the fact that the methanol is highly mixed with the OH emission, suggest that in fact the methanol emission in this source is not associated with a disc, but is at the interface of the expanding HII region and the molecular envelope.

3.2. W51 IRS2

Figure 3 shows the methanol emission towards W51 IRS2. The methanol masers are not associated with the infrared source but are offset to the South-West and are associated with an isolated UCHII region (Gaume et al. 1993). The HII region has a spectral index of is 2.1, a physical size <300 AU and its emission measure infers a central star of spectral type of B0.5. This shows that the methanol is associated with a very young, highly embedded massive star. Interestingly, the UCHII region is also associated with an $(J, K) = (9, 8)$ NH_3 maser. It seems likely that the newly detected methanol masers are associated with objects similar to this one with, and either have a lower mass or are younger so no UCHII region is present or detectable.

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