SMA Observations of High-Mass Star Forming Region Onsala 1

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Summary

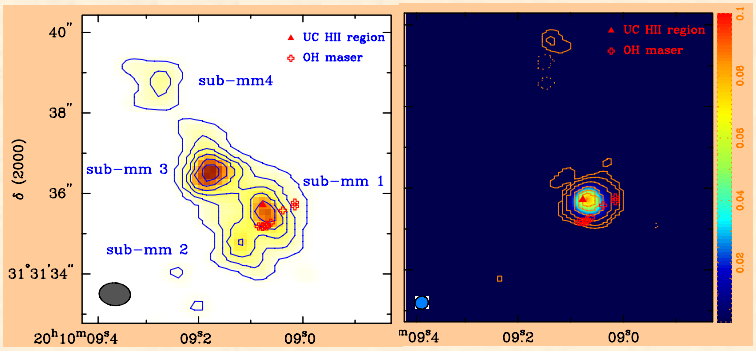
Onsala 1 (ON 1) is one of the smallest, hence possibly youngest ultracompact (UC) HII regions in the Galaxy. Past studies showed that this region exhibited various maser phenomena as well as outflow activities. We report here the preliminary results of SMA 345 GHz (0.85 mm) observations in ***SO***, ***CH_3OH*** and ***continuum*** with sub-arcsecond resolutions to study the dust and molecular gas environments in this region. Four sub-mm continuum components, denoted as sub-mm 1-4, are identified within a field of ~5", with sub-mm 1 closely coincident with the UC HII region ON 1 and the OH maser spots. Both SO and CH_3OH emission show that the UC HII region ON 1 is surrounded by a rotating core of ~2000 AU. The rotating axis is consistent with that seen in the relative large envelope, and is perpendicular to the outflow axis. Sub-mm 2 and 3 appear to be spatially coincident with H_2O maser emission, which likely traces young high-mass stars prior to the phase of UC HII regions. Indeed, our recent deep VLA observations did not identify any ionized gas emission associated with sub-mm 2 and 3.

Background

Due to their rapid evolutions, newly formed massive stars, even when they have reached the stage of main-sequence phase, are still deeply embedded in their natal cloud cores. The initial conditions of high-mass star formation therefore are still very unclear. **ON 1** is a young UC HII region in the Galaxy. The detection of various H_2O, OH, and CH_3OH maser emission (Zheng et al. 1985, and reference therein) gives further support this is a site of massive star formation. Observations in NH_3 and CS revealed a large (~1') rotational molecular core around ON 1, with peaks offset from the UC HII region (Zheng et al. 1985; Shirley et al. 2003). SMA "snapshot" observations previously revealed a secondary (dusty) clumpy in the close vicinity of the UC HII region (Su et al. 2004). From the above-mentioned observational evidence, we speculate that the ON 1 region harbors massive YSOs at *different but extremely young* evolutionary stages, thus providing a very good laboratory for studying the *initial conditions of high-mass star formation regions*.

Results

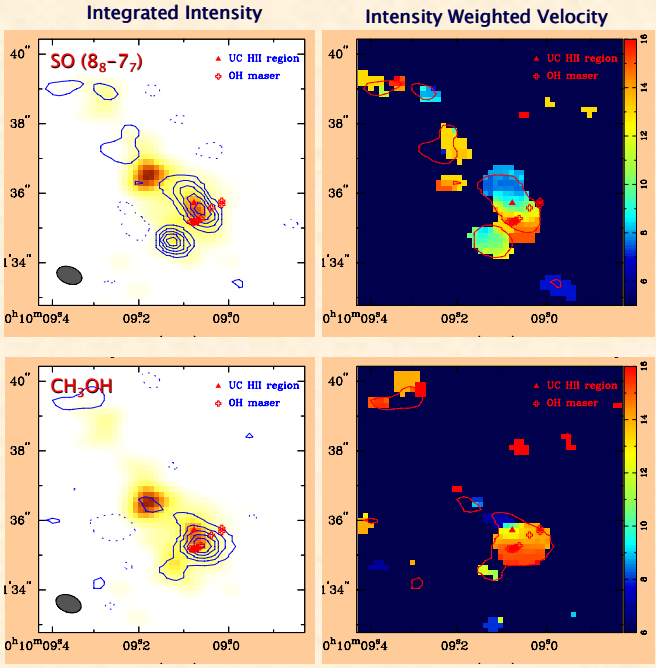
Continuum Emission of 0.85 mm and 1.3 cm



Our 0.85 mm continuum observations at ~0.6" resolution with the SMA revealed at least four components (denoted as sub-mm 1, 2, 3, & 4) within a field of ~5" (i.e., 0.05 pc at 2 kpc). However, our VLA observations at rms levels of ~0.1 mJy detected only one component (i.e., the UC HII regions ON 1) with marginally resolved structure in this region. Because the turn-over frequencies of most UC HII regions are smaller than 100 GHz, the non-detection of cm-wave free-free emission at ~0.1 mJy levels suggests that the 0.85 mm continuum of sub-mm 2, 3, & 4 are produced by dust.

Molecular Line Emission

— SO (8_8–7_7) & CH_3OH ($13_{7,6}$ A⁻ – $13_{7,7}$ A⁺)



Both SO and CH_3OH emissions are concentrated on the UC HII region ON 1, with velocity gradients roughly along the axis of PA=40°. Sub-mm 2, 3, & 4 have quite different chemistry — sub-mm 2 shows strong SO but weak CH_3OH emission, while sub-mm 3 appears to exhibit weak CH_3OH emission only. Neither SO or CH_3OH is detected in sub-mm 4.

Discussions

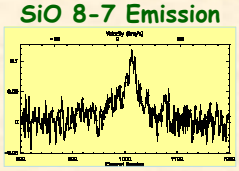
Properties of the Sub-mm Components

	Emission mechanism	Core Mass ($M_\odot$)	Maser activities	Molecular line emission
Sub-mm 1	ionized gas + dust	6	OH	strong SO & CH_3OH
Sub-mm 2	dust	2	H_2O	strong SO & weak CH_3OH
Sub-mm 3	dust	6	H_2O	weak CH_3OH
Sub-mm 4	dust	4	—	—

Outflow Activities

ON 1 region exhibited outflow activities revealed in SiO (J = 2-1) and near-IR H_2 emission (Kumar et al. 2004). Recently SiO (J = 8-7) emission toward ON 1 region was detected with the 10-m Sub-Millimeter Radio Telescope. The high-J SiO lines have been demonstrated to be good tracers of energetic molecular outflows around YSOs, and likely providing information on outflow process. Imaging the SiO (J = 8-7) line with the SMA will help us to understand the outflow driving agents/mechanisms.

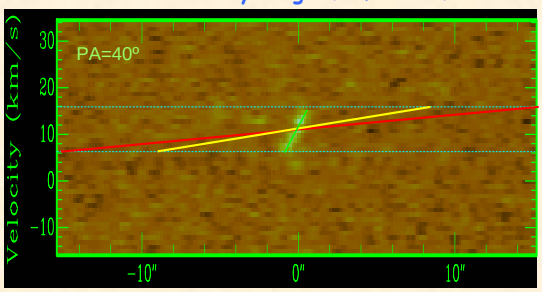
SiO 8-7 Emission



Rapid Rotating Core surrounding the UC HII Region ON 1

The position-velocity diagram of SO emission shows a linear relationship. Such a linear position-velocity relation is also seen in other tracers (e.g., $C^{18}O$) toward this region, but with different velocity gradients. The P-V diagrams of $C^{18}O$ at 10" (red line) and 3" (yellow line) resolutions show relatively flat linear relations, with velocities spanning similar to that of SO emission. The dynamical mass of SO core and central YSO is 20 $M_\odot$ approximately; the core mass therefore is consistent with that inferred from 0.85 mm continuum. Assuming a flatten structure, the P-V relations inferred a density profile of $n \propto r^{-1}$ at scale ranging from 2000 AU to ~0.1 pc. While the envelopes of deeply embedded massive young stars have $n \propto r^{-\alpha}$, α = 1.0-1.5 (van der Tak et al. 2000).

Position-Velocity Diagram of SO Emission



Color scales show the P-V diagram of SO emission along the axis of PA = 40°. The P-V diagrams of $C^{18}O$ emission at ~10" and ~3" resolutions (Lim et al. 2002) were represented by red and yellow line respectively.

Reference

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