Observation of Massive Star Forming Regions at 30 Microns

M. Uchiyama1, T. Miyata1, S. Sako1, T. Kamizuka1, K. Asano1, K. Okada1, T. Nakamura2, T. Yamashita3, T. Fujiyoshi3, Y. Yoshii3, and TAO team
1Institute of Astronomy, Graduate School of Science the University of Tokyo, Japan
2Department of Astronomy, Graduate School of Science, the University of Tokyo, Japan
3National Astronomical Observatory of Japan
E-mail: uchiyama@ioa.s.u-tokyo.ac.jp

Summary
How to prevent a massive molecular core from fragmenting into low-mass cores before it grows up to massive young stellar objects (MYSOs) is an important issue. To search this, it is important to observe interactions between objects in massive star forming regions with high spatial resolution in the long-MIR wavelengths. We have carried out high-resolution observations of three massive star forming regions and successfully obtained the first resolved images of three regions. The observation results suggest that the less massive objects began to collapse earlier in these three regions. If the accretion-luminosity feedback works well and prevents fragmentation of cores, the less massive objects begin to collapse earlier. This agrees with the results of our observations. Therefore, our results supports that the accretion-luminosity feedback works efficiently in the massive star forming regions.

Introduction
How to prevent a massive molecular core from fragmenting into low-mass cores before it grows up to massive young stellar objects (MYSOs) is an open question of massive star formation. A recent model predicts that a massive core grows up to a MYSO if it is heated by accretion radiation from less massive stars formed previously around the core (accretion-luminosity feedback model (Figure 1). Krumholz & Tan 2008). However, there is no observational support for this model.

It is important to observe interactions between objects in massive star forming regions. High spatial resolution is essential because these regions exist far from us and are crowded. MYSOs are heavily obscured and their radiation is mainly emitted in the mid to far infrared wavelength. Therefore, the mid to far infrared observations are important to measure total fluxes and estimate luminosity and mass accurately.

Observations
miniTAO/MAX38
We have been carrying out mid-infrared observations of nearby massive star forming regions at 31 and 37 microns with the mid-infrared camera MAX38 installed at the University of Tokyo Atacama 1.0-m Telescope (table 1). The miniTAO/MAX38 is the only instrument that can observe up to 38 microns from the ground (Yoshi et al. 2010; Miyata et al. 2010). The MAX38 achieves high spatial resolutions of 8 arcsec at 31 micron which are better than those of the previous space telescopes (Nakamura et al. 2010; Miyata et al. 2013).

Observation targets
The massive star forming regions which is suitable to search the evidence of the accretion-luminosity feedback scenario have been selected. The selection criteria is below and three massive star forming cores have been chosen (table 2).

- Nearby massive star forming regions.
- There are at least 2 bright MIR objects in compact (~ 0.1 pc) regions.

Results
Images
Three massive star forming regions have been observed and the first resolved images at 31 and 37 microns have been successfully obtained (figure 2, and 3).

Deriving luminosities and masses
The SED of each MIR-bright object in each region including photometry at 30 microns has been got (figure 5, 6, and 7). The total luminosities were then estimated using NIR and MIR flux and black body fitting of SED up to 1mm (table 3). Note that the estimated luminosities are minimum values in MYSOs. The luminosities of MYSOs increase monotonically through the evolution until reaching at the ZAMS (Hosokawa & Omukai 2009). The spectral type and mass assuming that each object is at the ZAMS are listed table 3. In the same way as discussed above, the estimated masses are minimum values in MYSOs.

Discussion
As listed in table 3, the masses of the MYSOs are larger than those of the UC-HII in observed regions.

In addition, we focus on the sequential order of star formation in each observed region in this study. The formation timescale is approximately estimated by the sum of gas-fall timescale and the Kelvin–Helmholtz timescale (contracting timescale) of the object’s mass.

In this way, the derived masses suggest that UC-HHs started to collapse earlier than MYSOs by ~ a few *10^{1} yr and this timescale is almost independent of the final mass of the star (McKee & Tan 2002). The Kelvin–Helmholtz timescale getting shorter with increasing the mass of MYSO. The calculation from Zinnecker and Yorke 2007 which assume typical massive star forming regions was used for estimation.

In three of five regions, the less massive objects began to collapse earlier. Therefore, this trend may be universal in massive star formation.

If the accretion-luminosity feedback works well, the less massive objects begin to collapse earlier (figure 8). This scenario agrees with the results of our observations and the previous works. In addition, the gap of ~ a few *10^{1} yr is consistent with the time that accretion-luminosity feedback works well in the parent core (Krumholz & Tan 2008). Therefore, our results supports that the accretion-luminosity feedback works efficiently in the massive star forming regions.

References
Krumholz, M., McKee, C. F., 2006, Nat, 441, 1081

If you are interested in observations at 30 microns, please contact us!
Our developing MIR instrument is also presented at 20058.