1B056

Observation of Massive Star Forming Regions at 30 Microns

M. Uchiyama[1], T. Miyata[1], S. Sako[1], T. Kamizuka[1], K. Asano[1], K. Okada[1],
T. Nakamura[2], T. Yamashita[3], T. Fujiyoshi[3], Y. Yoshii[1], and TAO team

[1]*Institute of Astronomy, Graduate School of Science the University of Tokyo, Japan*
[2]*Department of Astronomy, Graduate School of Science, the University of Tokyo, Japan*
[3] *National Astronomical Observatory of Japan*
E-mail: uchiyama@ioa.s.u-tokyo.ac.jp

MAX38
Mid-infrared Astronomical eXplorer

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 been carrying out mid-infrared observations of nearby massive star forming regions **at MIR including 31 and 37 microns** 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 accreting 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.

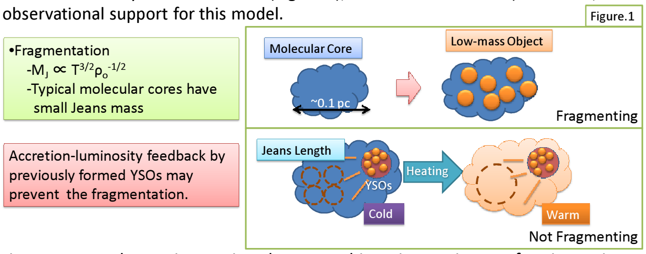


Figure.1

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.*

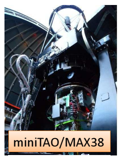
Observations

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 micron from the ground (Yoshii 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.2012).*

Table.1

Telescope's aperture	1.0m
Telescope's site	Co. Chajnantor, Atacama, Chile
Altitude	5,640m
Observable wavelengths	8-38 micron
Spatial resolution	~ 8" at 30 micron


miniTAO/MAX38

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.

Table.2

Object name	Distance	Observing band
M8E	1.5 kpc	18,25,30,37 micron
RAFGL 6366S	2.0 kpc	8.9,12,18,30 micron
IRAS 18317-0513	3.2 kpc	12,18,30 micron

0.1 pc separation is equal to ~ 10 arcsec at 2.0 kpc

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 2,3, and4).

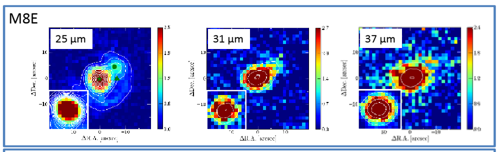


Figure. 2. The images of M8E region. The position of star mark represents the known MYSO(IR) and circle represents the known UCHII(radio) and triangle represents the third MIR source.

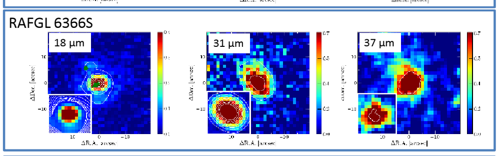


Figure. 3. The images of RAFGL 6366S region. The position of star mark represents the known MYSO(IR1) and circle represents the known UCHII(IR2) and triangle represents the known bright NIR source(IR1 unresolved).

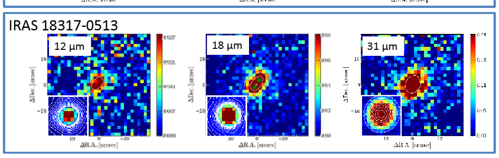


Figure. 4.The images of IRAS 18317-0513 region. The position of star mark(IR1) and circle mark(IR2) represent the known MYSOs.

In all images, the North is upside and scale unit is $Jy/arcsec^2$. The left-bottom box in each image shows a PSF star image.

If you are interested in observations at 30 microns, please contact us!
Our developing MIR instrument is also presented at 2B058.

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.

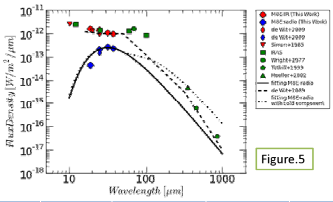


Figure.5

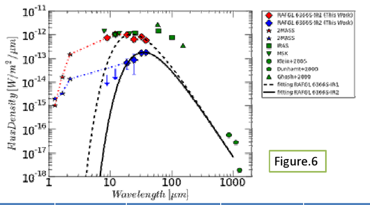


Figure.6

Object	Evolutional stage	Luminosity ($L_\odot$)	Spectral type	Mass ($M_\odot$)
M8E-IR	MYSO	6-8*10^3	B0.5-1	11-12
M8E-radio	UCHII	1-2*10^3	B2.5-3	6-7

Object	Evolutional stage	Luminosity ($L_\odot$)	Spectral type	Mass ($M_\odot$)
RAFGL 6366S-IR1	MYSO	3-5*10^3	B0.5-1.5	9-11
RAFGL 6366S-IR2	UCHII	1.0-1.5*10^3	B2.5-3	6-7

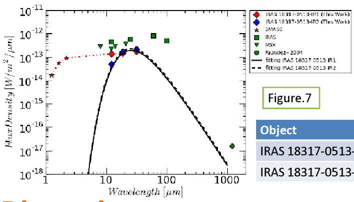


Figure.7

Table. 3. Derived SED of each objects in each region. Red and blue marks represent resolved fluxes of each object in the region and green marks represent unresolved fluxes. Fitting lines are used for calculating the total luminosities.

Object	Evolutional stage	Luminosity ($L_\odot$)	Spectral type	Mass ($M_\odot$)
IRAS 18317-0513-IR1	MYSO	3-4*10^3	B1-2	8-9
IRAS 18317-0513-IR2	MYSO	3-4*10^3	B1-2	8-9

Discussion

As listed in table. 3, the masses of the MYSOs are larger than those of the UCHIIs 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.

•The typical gas-fall timescale in massive star forming regions is ~ 1*10^5 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 this way, the derived masses suggest that UCHIIs started to collapse earlier than MYSOs by ~ a few *10^5 yr in M8E and RAFGL 6366S region.* In IRAS 18317-0513, differences of evolutional stage between two MYSOs are unknown due to unresolved radio observations.
These two results suggest that the less massive objects began to collapse earlier.

We also searched the previous works which spatially resolved the objects in massive star forming regions (~0.1pc) at multi-band and derived the luminosities and masses of the objects via SED. Then, the results of the works are checked weather the less massive objects began to collapse earlier in the regions or not as shown in table.4.

Name of region	UCHII Mass ($M_\odot$)	MYSO Mass ($M_\odot$)	Trend	Reference
M8E	6	12	Yes	This Work
RAFGL 6366S	6	10	Yes	This Work
ISOSS J18364-0221	-	18*, 12	Yes	Hennemann et al. 2009
Mon R2	17	10	?	de Wit et al. 2009; Massi et al. 1985
AFGL 437S	8, 8	9, 7	-	de Wit et al. 2009; Kumar & Anandarao 2010

Table. 4. * Mark represents the youngest objects among MYSOs in the region.
"Trend" means that the less massive objects began to collapse earlier.
? Mark means that we cannot determine which object began to collapse earlier.
- Mark means that all objects' masses are almost same and they are not suitable for discussion.

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 *10^5 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.**

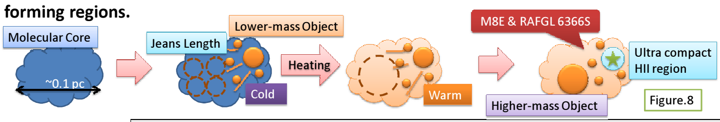


Figure.8

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