Deep 3 micron Photometry of Substellar Mass Objects around a Massive Star in S106

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Abstract

Many "accretion-aborted" low-mass and substellar mass YSOs could be born due to the UV radiation from a nearby massive star. To investigate the formation process of substellar objects under the influence of the UV radiation from a massive star, we have carried out JHK photometric survey of the S106 region, which is one of the nearest massive star forming regions. From this survey, hundreds of substellar YSO candidates have been identified, and there exists a number of faint red sources detected at HK-bands or only K-band in the western region of the massive star. To examine their characteristics, we have carried out a deep L'-band photometric survey of the west region in S106. From the JHKL' survey, 64 YSOs were identified and the YSO fraction and the K-L' excesses increase toward the west. This indicates that the central O-star evaporates the disks around nearby low-mass YSOs, or that star formation propagates from the central O-star to the west.

Introduction

Substellar mass objects may form from contracting cloud fragmentation by itself just like low-mass stars (Masunaga 1999), or removal of accretion envelops from low mass contracting cores due to photo-evaporation through a nearby O-type star (Kroupa & Bouvier 2003).

[Substellar Mass Object]

Brown Dwarf (0.013~0.08Msun)

- Effective Temperature (T_{eff}): < 3000K
  → Not start the fusion reaction due to low T_{eff}
- Shining by gravitational contraction energy

Free-Floating Planet (<0.013Msun)

- The mass corresponds to that of giant planets, but this object does not orbit a star.
  → Not a brown dwarf and not a planet → new type object

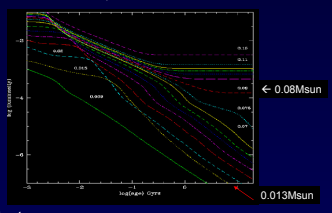


Fig 1; An evolutionary track of very low-mass objects (Burrows et al. 1997).

Luminosities of substellar mass objects decreases with ages (Fig 1).

An O-star evaporates the disks around nearby low-mass YSOs

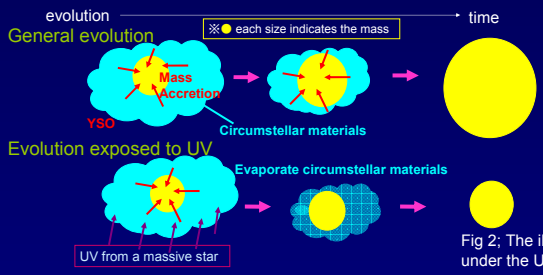


Fig 2; The illustration of the star formation under the UV from a massive star.

The UV radiation generated by the Trapezium OB stars evaporates the disks around nearby low-mass stars, and low-mass stars may terminate their pre-main sequence evolution (Robberto et al. 2004).
→ The number of intermediate-mass stars could be deficient in the initial mass function and many "accretion-aborted" low-mass and substellar YSOs could be born.

Purpose **This study is to investigate the formation process of substellar objects under the influence of the UV radiation from a massive star.**

[S106]

(RA, Dec)=(20h27m, +37° 21')

- S106 is one of the nearest massive star forming regions (~ 600 pc).
- A central O-type star (IRS4) makes prominent bipolar nebulae and an HII region.

[Previous Study]

JHK photometry (Fig 3; 5'x5')

- Each limiting magnitude exceeds 20 mag.
- About 600 YSO candidates were identified.
- There appears to be a substantial substellar population, some members of which possibly have planetary masses at ages of ~ 1Myr.

→ **They are concentrated to the western region of IRS4.**

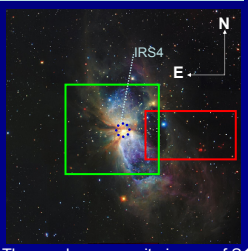


Fig 3; Three-color composite image of S106 obtained with SUBARU/CISCO (J: blue, H: green, K: red). The field of view is ~ 5'x5'. The red and green boxes correspond to the regions observed at Subaru and at UKIRT, respectively.

L'-band (~3.8 um) Observations

We have carried out a deep L'-band photometric survey of the west regions of S106 where low-mass and substellar YSOs are concentrated.

→ **• Identify substellar YSOs**
• Search the distribution of YSOs

SUBARU Observation

Date: 2005/5/4
Instrument: IRCS
Exposure time: 0.096s, 0.118s
Integration time: 500s ~ 1000s
FOV: 1'x2' (red box of Fig 3)
Seeing: ~0.5"

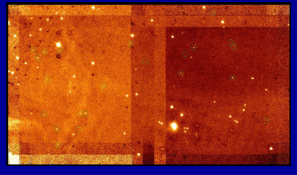


Fig 4; L'-band image of the S106. This region corresponds to the red box of Fig 3. The field of view is 1'x2'.

Analysis

All data were reduced using Image Reduction and Analysis Facility (IRAF). Fig 5 shows the image mosaic. Total 102 objects were detected with the limiting magnitude of about 15.5 mag (10 sigma detection).

Results

[Color-Color Diagram]

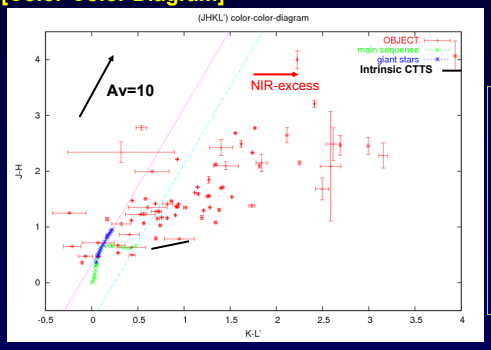


Fig 5; JHKL' color-color (CC) diagram. The stars which have JHKL' mag are plotted (77 objects).

From JHKL' and HKL' CC-diagrams, 64 YSOs with NIR-excesses were identified. (JHKL': 50/77, HKL': 14/15)
Comparison of the JHK CC-diagram with JHKL' one, demonstrate that majority (70%) of sources lie in the K-L' excess region.
Combined with their J_0 mag and evolution model (Baraffe et al. 2002), 24 substellar YSO candidates were identified.
(J_0 [mag] = Absolute J [mag] – A_J [mag])

[Spatial Distribution of YSOs]

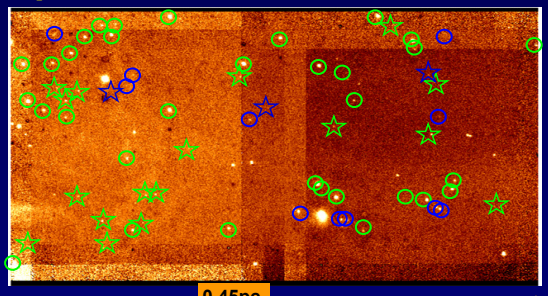
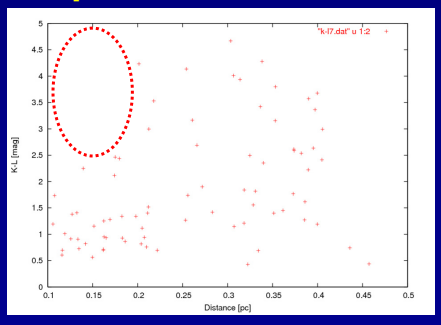


Fig 6; Spatial distribution of YSOs. Green and blue marks show YSOs identified from the JHKL' and HKL' CC-diagrams, respectively. Circles and stars show YSOs and substellar YSO candidates, respectively.

The YSOs are concentrated close to IRS4, and the substellar YSO candidates are concentrated to the left region (near IRS4), too.
This indicates that star formation propagates from the central O-star to west, or that the central O-star evaporates the disks around nearby low-mass YSOs.

[K-L' Excesses vs Distance from IRS4]

Fig 7; K-L' excesses as a function of the distance from IRS4.



There are no objects with large excesses near (< 0.2 pc) IRS4 (red ellipse).
This also indicates that star formation propagates from the central O-star to west, or that the central O-star evaporates the disks around nearby low-mass YSOs.

Conclusions

From this study, we propose the two mechanism of the formation of substellar objects; substellar YSOs of S106 formed due to propagation from O-star to the west, or due to disk-evaporation by the UV radiation of O-star.

Future Perspective

To search the mechanism of the formation of substellar objects around IRS4, we have carried out a deep L'-band imaging survey of the central and eastern 2'x2' region (green box of Fig.3) of S106 (in analysis).

UKIRT Observation

Date: 2008/8/2-3
Instrument: UIST
Exposure time: 0.175s
Integration time: 4.42h
FOV: 2'x2' (green box of Fig. 3)
Seeing: ~0.5"

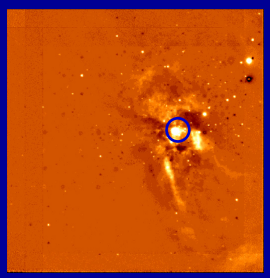


Fig 8; L'-band image obtained with UKIRT/UIST. The field of view is ~ 2'x2'. The blue circle corresponds to the position of IRS4.