Multi-Object and Long-slit Spectroscopy of Very Low Mass Brown Dwarfs In Orion Nebular Cluster

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1. Abstract

The characterization of brown dwarfs (BDs) is important for the construction of Initial Mass Function (IMF) because IMF is closely connected with the star formation. We present near-infrared multi-object and long-slit spectra of low-mass BD candidates in the Orion Nebular Cluster (ONC). The MOS spectra were obtained using MOIRCS on the 8.2-m Subaru telescope with HK grism, while the long-slit data were observed in H and K band by using ISLE on the 1.88-m telescope of Okayama Astronomical Observatory (OAO). We determine the effective temperatures for the 14 candidates from \( \chi^2 \) fitting to synthetic spectra and 9 objects show strong water absorption with the effective temperatures < 3000K (SpT > M6). By plotting our sources on HR diagram overlaid with theoretical isochrones of low-mass objects, we find 2 new BDs, and one of them have very low masses (~0.02 M\(_{\odot}\)).

2. The Bottom of IMF

Recent deep surveys have revealed a number of objects whose masses less than 80M\(_{\oplus}\) down to or even below the Deuterium burning limit (13M\(_{\oplus}\)). They are called as brown dwarf or Planetary Mass Object (PMO), respectively. The existence of these objects imply IMF appears to extend well into the planetary mass regime. Then we will think.

What is the bottom of IMF? How common are the BDs and PMOs?

The bottom of IMF is predicted in 1 ~10M\(_{\oplus}\) but NOT confirmed observationally (Low & Lynden-Bell 1976, Bate 2005).

The abundance of M > 30M\(_{\oplus}\) has been found in some star forming regions but IMF below 30M\(_{\oplus}\) has been hardly revealed.

Orion Nebular Cluster is an excellent location to search for BDs and PMOs. The cluster is nearby (~450 parsec) and compact. Lucas et al. (2005) detected a large number of BD and 33 PMO candidates using Gemini south/Flamingos in the south region of the ONC. Some spectroscopic follow-up has been done but many candidates of BDs and PMOs are not confirmed for their cluster membership.

3. Multi-object and Long-slit Spectroscopy

We conducted infrared multi-object and Long-slit Spectroscopy in the south region of ONC. Our observation have a great advantage below our goal.

Multi-object spectroscopy
- MOS can obtain many spectra at one time
- BDs and PMOs are bright in star forming region
- They can NOT burn their hydrogen
- They darken over time
- BDs and PMOs are bright at infrared

We're are proposing to conduct more observations on several telescopes.

4. \( \chi^2 \) -Fitting: Derivation of \( T_{\text{eff}} \) and \( \text{log}(g) \)

We conducted \( \chi^2 \) fitting between the observed spectra and the model spectra given the expected range of the effective temperature and the surface gravity.

Reduction is conducted using IRAF software and MCSRED(MOIRCS imaging package). Dereddening is based on J-H vs H Color-magnitude diagram.

\( \chi^2 \) -Fitting is done using the synthetic spectra BT-Settl model (Allard et al. 2010)
- Effective Temperature \( T_{\text{eff}} \): 2000 ~ 4900K
- BDs have cool atmosphere containing H\(_2\)O. The absorption makes its H-b band shape triangular.
- Surface gravity \( \text{log}(g)\): 3.5 ~ 5.5
- Because YSO are still during the gravitational contraction, they have low surface gravity. In contrast, Field dwarfs have high surface gravity. H\(_2\)O CIA absorption which is sensitive molecule for gravity cause the peak smoothing and moving.

5. HR Diagram: Derivation of Mass

Relative Flux

1Myr

10Myr

50Myr

13 and 75 M\(_{\oplus}\)

13 and 75 M\(_{\oplus}\)

A newly detected very low mass BD candidate

We successfully extracted 14 spectra and determined these physical parameter. But this observation alone is not enough to construct IMF. We’re proposing to conduct more observations on several telescopes.