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 χ^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_{SUN}).

2.The Bottom of IMF

Recent deep surveys have revealed a number of objects whose masses less than $80M_{Jup}$ down to or even below the Deuterium burning limit ($13M_{Jup}$). 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 -$10M_{Jup}$ but NOT confirmed observationally (Low & Lynden-Bell 1976, Bate 2005).

The abundance of M > $30M_{Jup}$ has been found in some star forming regions but IMF below $30M_{Jup}$ has been hardly revealed.

Orion Nebular Cluster is an excellent location to search for BDs and PMOs. The cluster is nearby (~450pc) 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

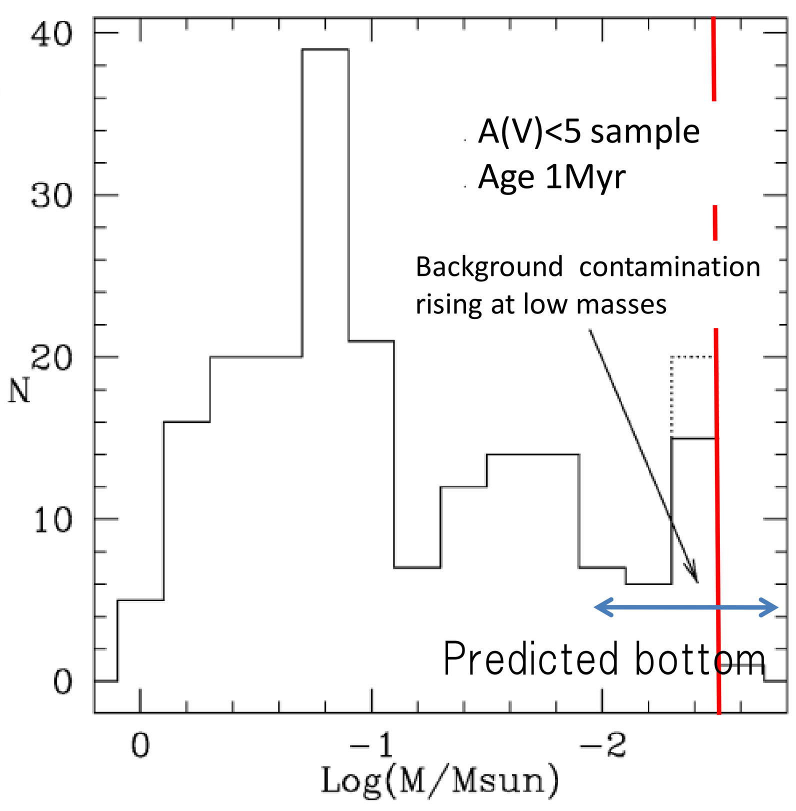

Fig1. The histogram of Lucas et al. (2005) Red line shows completeness limit ($5M_{Jup}$) with assumed age of 1Myr for A(V)<5 samples .

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 for 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
- They are very cool objects (T_{eff} < 3000K)
- Embedded YSOs are affected by reddening

	Obs 1	Obs 2
Telescope	8.2m-Subaru MOIRCS	1.88m-OAO ISLE
Date	Nov 2007	Dec 2010
Mode	Multi-Object Spectroscopy	Long-Slit Spectroscopy
Band& Resolution	1.3-2.5μm R~500	H(R~350) K(R~400)
Integration Time	1hour	10min(H) 40min(K)
Number	10	4

Relatively high galactic latitude (b=-19°)
Dense background cloud
Low contamination of background star
(Lucas et al. 2006)
Fainter nebulosity makes follow-up easier

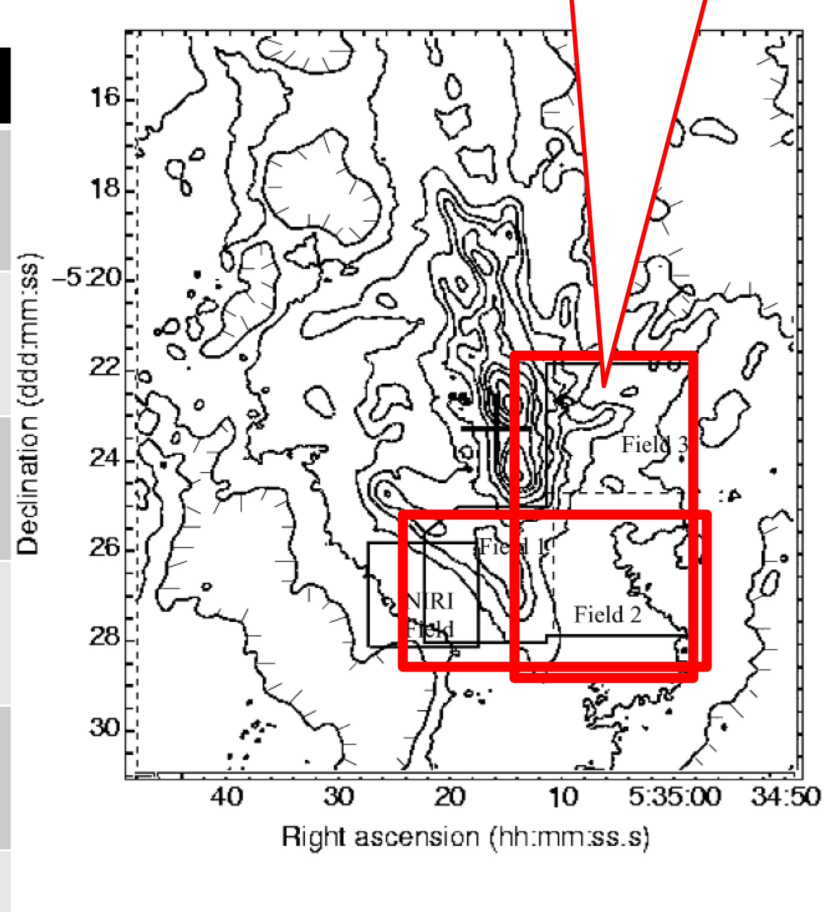

Fig 2. Target field (red square) on 850μm dust contour (Lucas et al. 2005)

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

We conducted χ^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-HvsH Color-magnitude diagram.

χ^2-Fitting is done using the synthetic spectra BT-Settl model (Allard et al. 2010)
•Effective Temperature T_{eff}:2000-4900K
→BDs have cool atmosphere containing H_2O. The absorption makes its H-band shape triangular.
•surface gravity 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_2CIA absorption which is sensitive molecule for gravity cause the peak smoothing and moving.

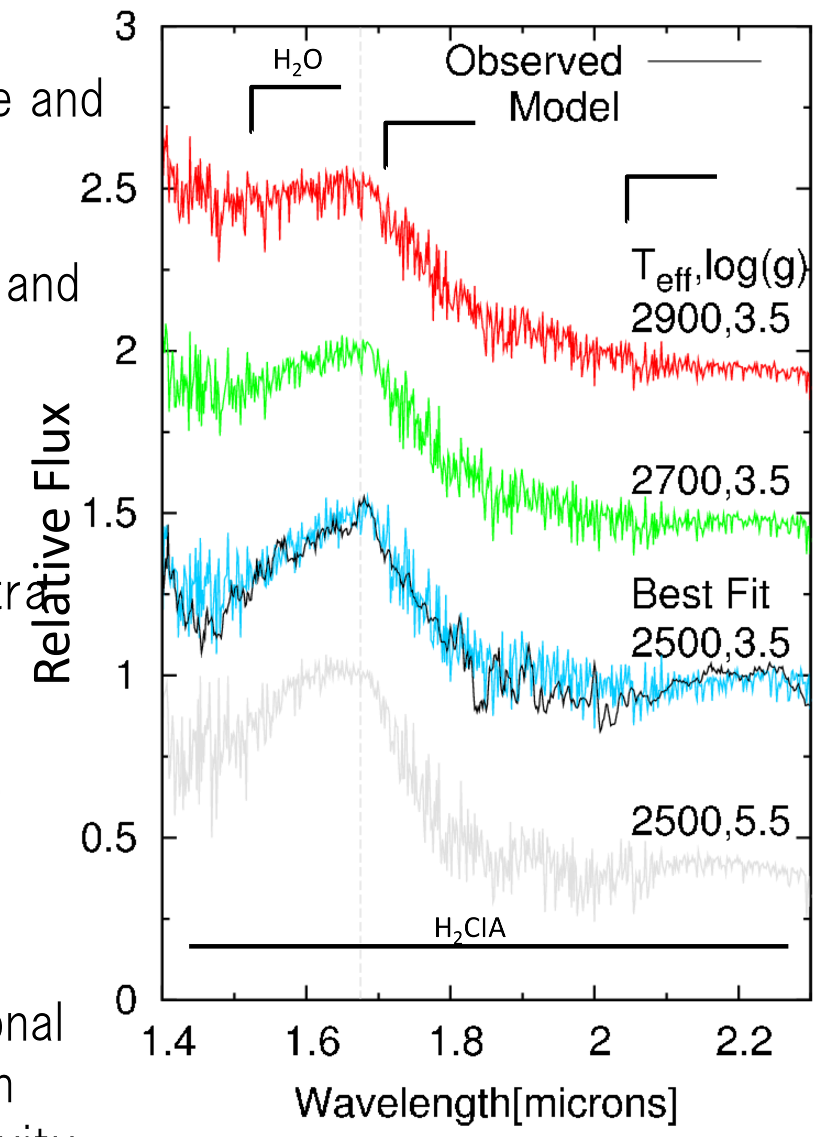

Fig 3. Comparison the observed spectra with the synthetic spectra. Best fit is T_{eff}=2500 and log(g)=3.5.

5.HR Diagram: Derivation of Mass

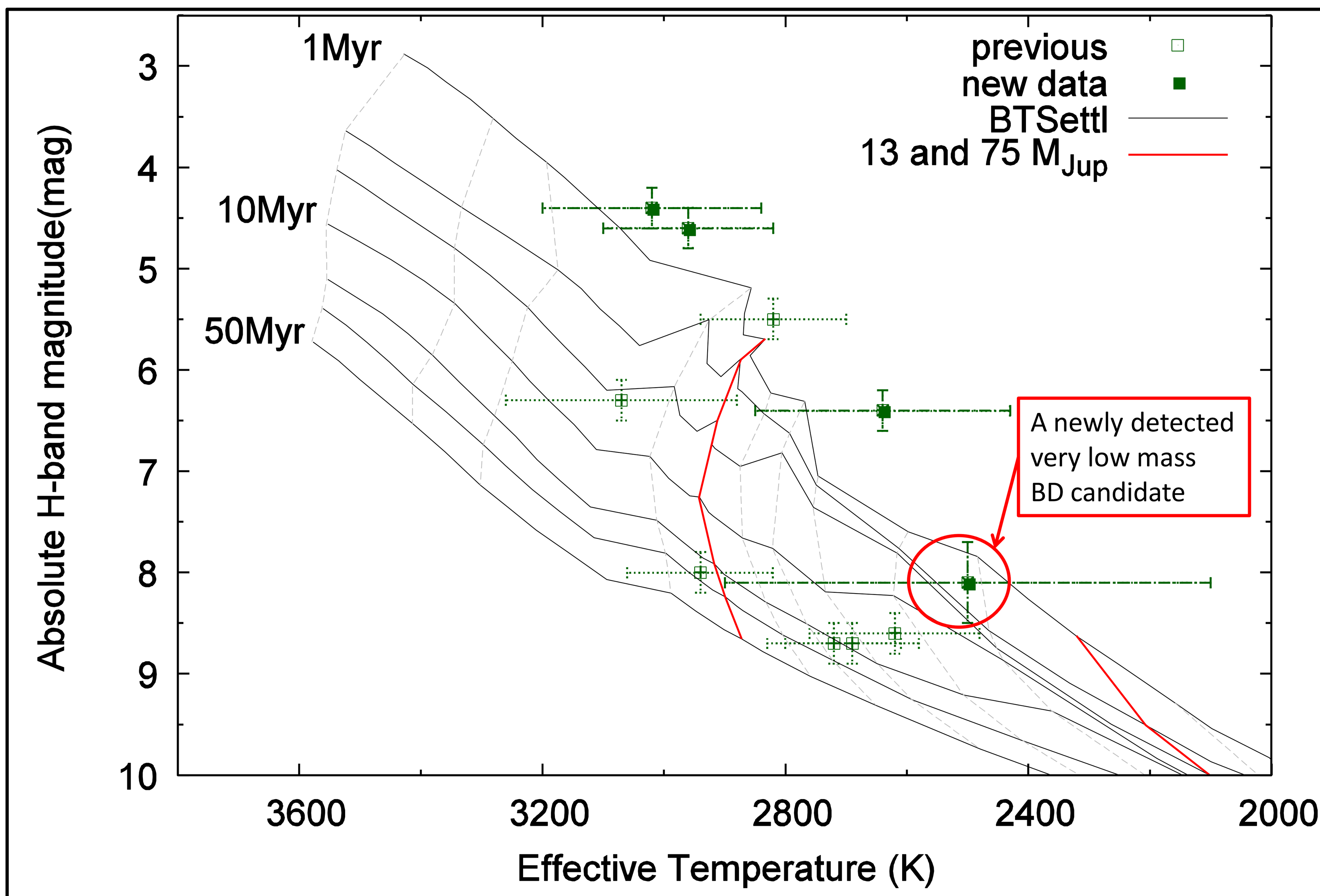

Fig 4. Green filled squares are newly detected by MOIRCS and ISLE.
Open squares show previous observed sources.
Black solid lines are BTSettl model (1,3,5,10,20,30,50Myr).
Black dashed lines indicate mass evolution and red solid lines mean 13 and $75M_{Jup}$.

6.Result

Source	M_H[mag]	T_{eff}[K]	Mass[M_{Jup}]
ONC-YBDC 1	8.1	2500±400	10-75
ONC-YBDC 2	6.4	2640±210	20-65

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