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# NEW INSIGHT ON BROWN DWARF ATMOSPHERES REVEALED BY AKARI

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## ABSTRACT

We present the latest results from the Mission Program NIRLT, the NIR spectroscopic observations of brown dwarfs using the IRC on board AKARI. The near-infrared spectra in the wavelength range between 2.5 and 5.0 $\mu$m is especially important to study the brown dwarf atmospheres because of the presence of non-blended bands of major molecules, including $CH_4$ at 3.3 $\mu$m, $CO_2$ at 4.2 $\mu$m, CO at 4.6 $\mu$m and $H_2O$ around 2.7 $\mu$m. Our observations were carried out in the grism-mode resulting in a spectral resolution of $\sim$ 120. In total, 27 sources were observed and 18 good spectra were obtained. We investigate the behavior of three molecular absorption bands, CO, $CH_4$ and $CO_2$, in brown dwarf spectra relative to their spectral types. We find that the $CH_4$ band appears in the spectra of dwarfs later than L5 and CO band is seen in the spectra of all spectral types. $CO_2$ is detected in the spectra of late-L and T type dwarfs.

*Key words:* brown dwarfs; stars: atmospheres; stars: low-mass

## 1. INTRODUCTION

Brown dwarfs are objects that are too light to maintain hydrogen fusion in their cores. They are classified into spectral types L and T. Photospheres of brown dwarfs are cool ($600 < T_{\rm eff} < 2{,}200$ K) and dense ($\log P_g \sim 6.0$), thus dominated by molecules and dust. Since almost all carbon atoms are transferred from CO to $CH_4$ in the photosphere of T dwarfs with $T_{\rm eff}$ less than about 1,300 K under thermochemical equilibrium, it had been expected that CO absorption band did not appear in the spectra of the coldest dwarfs. However, several observations made from the ground showed 4.6 $\mu$m CO band in spectra of T dwarfs against theoretical prediction (e.g. Oppenheimer et al., 1998). On the other hand, Noll et al. (2000) reported detections of $CH_4$ 3.3 $\mu$m fundamental band in dwarfs as early as L5 and L8 of type. In addition, Yamamura et al. (2010) showed that the $CO_2$ absorption bands at 4.2 $\mu$m of several brown dwarfs were also inconsistent with the theory. These discrepancies between observations and theoretical prediction are a critical problem for the study of brown dwarf atmospheres. However, few data does not allow to assess its validity.

In this paper, we report the result of investigating the validity of these discrepancies by more spectroscopic data in the wavelength range of 2.5–5.0 $\mu$m obtained by the IRC (Onaka et al., 2007) onboard AKARI (Murakami et al., 2007).

## 2. SPECTRA OF 18 AKARI OBJECTS

Spectra of 18 brown dwarfs (12 L dwarfs and 6 T dwarfs) observed by AKARI are of high quality, with signal-to-noise ratio (S/N) averaged over the spectra higher than or about 3.0. We include 2MASS J1553+1532 (T7) in our sample, despite of its relatively low quality (S/N $\sim$ 2) to complete the T-type sample. Known binaries are excluded. Figure 1 shows

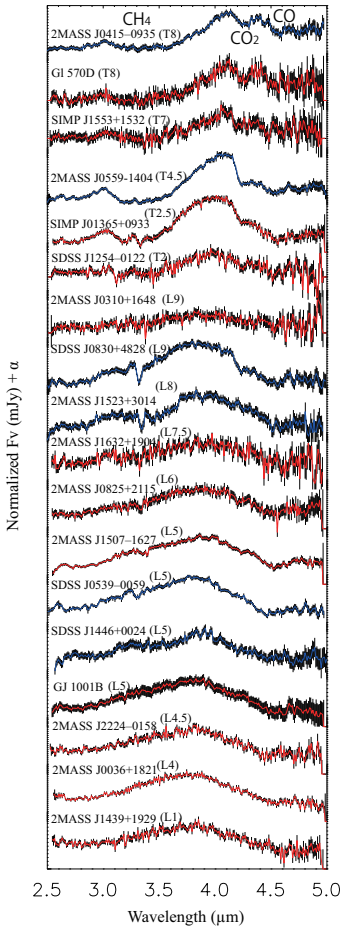


**Fig. 1.** AKARI spectra of brown dwarfs with errors in black. 12 L-dwarfs and 6 T-dwarfs are successfully observed. Data taken in Phase 2 are drawn in blue line and these in Phase 3 are drawn in red. The Phase 2 data are generally in better quality than the Phase 3 data. The spectra are normalized at 4.0 $\mu$m flux values.

the spectra of the brown dwarfs in the sequence of their spectral types from T8 (top) to L1 (bottom).

### *2.1. CO Fundamental Absorption Band at 4.6 $\mu$m*

The CO 4.6 $\mu$m band appears in the spectra of all spectral types including late-T dwarfs. The result confirms that CO generally exists in the atmospheres of any spectral types against the prediction by the Unified Cloudy Model (UCM; Tsuji, 2005). However, we have not yet succeeded to understand this phenomenon. We will investigate these CO excess in a future work.

### *2.2. $CH_4$ Fundamental Absorption Band at 3.3 $\mu$m*

The $CH_4$ 3.3 $\mu$m band appears in spectra later than L5. This result indicates that $CH_4$ already exists and plays a role in the photosphere of middle-L dwarfs. The band is seen in only two of four L5 dwarfs. We confirm that the appearance of $CH_4$ band in two L5 dwarfs is associated with dust presence from model fitting with the UCM.

### *2.3. $CO_2$ Absorption Band at 4.2 $\mu$m*

We detect the $CO_2$ absorption band at 4.2 $\mu$m in the spectra of late-L and T type dwarfs. We find that the $CO_2$ molecule is generally in the atmosphere of T dwarfs. We also find that the observed $CO_2$ bands in some spectra are stronger or weaker than the prediction by the UCM. We suggest that a possible reason is the higher or lower C and O elemental abundances than the solar values in the dwarfs (Tsuji et al., 2011; Sorahana et al., in prep).

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