Abstract: We present possible elemental abundance variations among brown dwarfs based on the CO$_2$ absorption band at 4.2 µm. We obtained a continuous brown dwarf spectral data set for a new wavelength range of 2.5 to 5.0 µm with AKARI. Such spectra are the most powerful tools for obtaining physical and chemical information on brown dwarf atmospheres because they sample various molecular bands: H$_2$O at 2.7 µm, CH$_4$ at 3.3 µm, CO$_2$ at 4.2 µm, and CO at 4.6 µm. These are fundamental and non-blended bands so they are suitable for analysis with relatively low-resolution spectra.

We observed the CO$_2$ absorption band at 4.2 µm for the first time. This detection of this band has made it possible to discuss CO$_2$ molecular abundances in brown dwarf atmospheres. In our study, we observed the CO$_2$ absorption band in some late-L and T dwarfs is stronger or weaker than predicted by atmosphere models with solar metallicity under LTE. These unusual CO$_2$ abundances cannot be explained by vertical mixing, which was suggested by previous studies.

As our first trial for improving the Unified Cloudy Model (UCM) for brown dwarf atmosphere, we focus on the elemental abundances of brown dwarfs to account for the observed CO$_2$ band strengths. We construct a set of models of brown dwarf atmospheres with various elemental abundances, and investigate the variations of the molecular composition and thermal structure and their effects on near-infrared spectra between 1.0 and 5.0 µm. We find that the CO$_2$ band is better reproduced by the model with revised C & O abundances than the solar elemental abundance model, except for very late-T dwarfs. This indicates that the CO$_2$ band strength is especially sensitive to the combination of C and O abundances. On the other hand, changing only the C or O abundance does not fit the observed spectra. These results indicate that both C and O abundances should increase and decrease simultaneously.

We observed the CO$_2$ absorption band at 4.2 µm in Spectra of Brown Dwarfs. We observed the CO$_2$ absorption band at 4.2 µm in Spectra of Brown Dwarfs. We observed the CO$_2$ absorption band at 4.2 µm in Spectra of Brown Dwarfs. We observed the CO$_2$ absorption band at 4.2 µm in Spectra of Brown Dwarfs.

References
Burrows et al., 2001, RvMP, 73, 719

Future work
Our analysis confirms that brown dwarf atmospheres cannot be explained simply by LTE theoretical models. We have to consider physical and chemical processes associated with increasing CO in late-L to middle-T dwarf photospheres, and increasing or decreasing CO$_2$ in late-T dwarfs. In future work, we will thus improve the UCM brown dwarf atmosphere model. Our analysis of elemental abundances can be applied to exoplanet atmospheres. Since metallicity is important to understand planet formation, we will gain insight into the origin of planets.

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