1K067 protostars and planets VI @ Heidelberg, July 15-20, 2013

Elemental abundance effects on the CO_2 absorption band at 4.2 μm in Spectra of Brown Dwarfs

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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_2O 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, the observed 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 can not 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.

★ *AKARI*

- Launched in February 2006
- Two instruments : IRC(1.8-26μm), FIS(50-180μm)
- Observation period

- 2006-2007 cold phase (with liquid He) : Phase2
- 2008-2009 warm phase (without liquid He) : Phase3

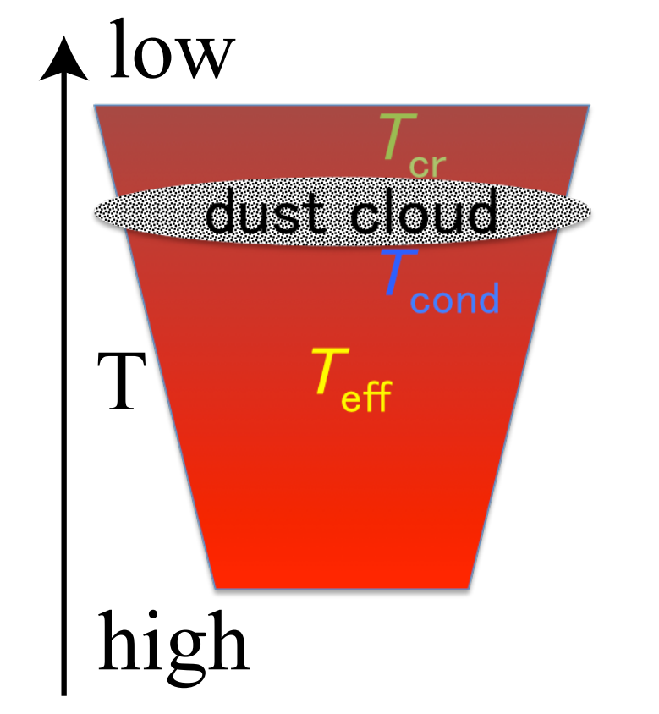
★ Unified Cloudy Model (UCM)

To interpret our spectra, we apply UCM (Tsuji 2002, 2005). In this model, condensation and sublimation/sedimentation of dust species(Fe, Al_2O_3, Mg_2SiO_4) are considered (size: 0.01 μm). We give an additional parameter, namely **the critical temperature T_{cr}**.

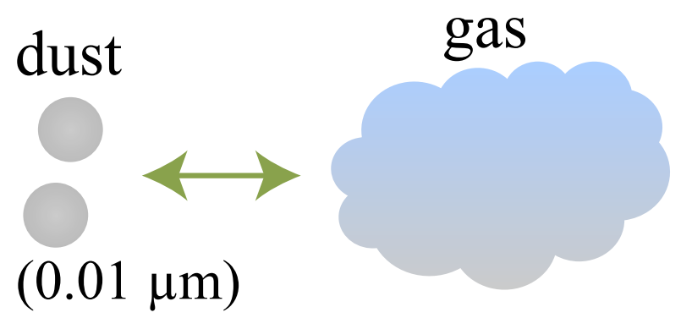
$T_{cr} < T < T_{cond}$: Condensation and sublimation are balanced.
$T < T_{cr}$: Dust settle down because dust grows larger.

UCM parameters:
T_{eff}, log *g*, *metallicity*, *micro turbulent velocity*, T_{cr}

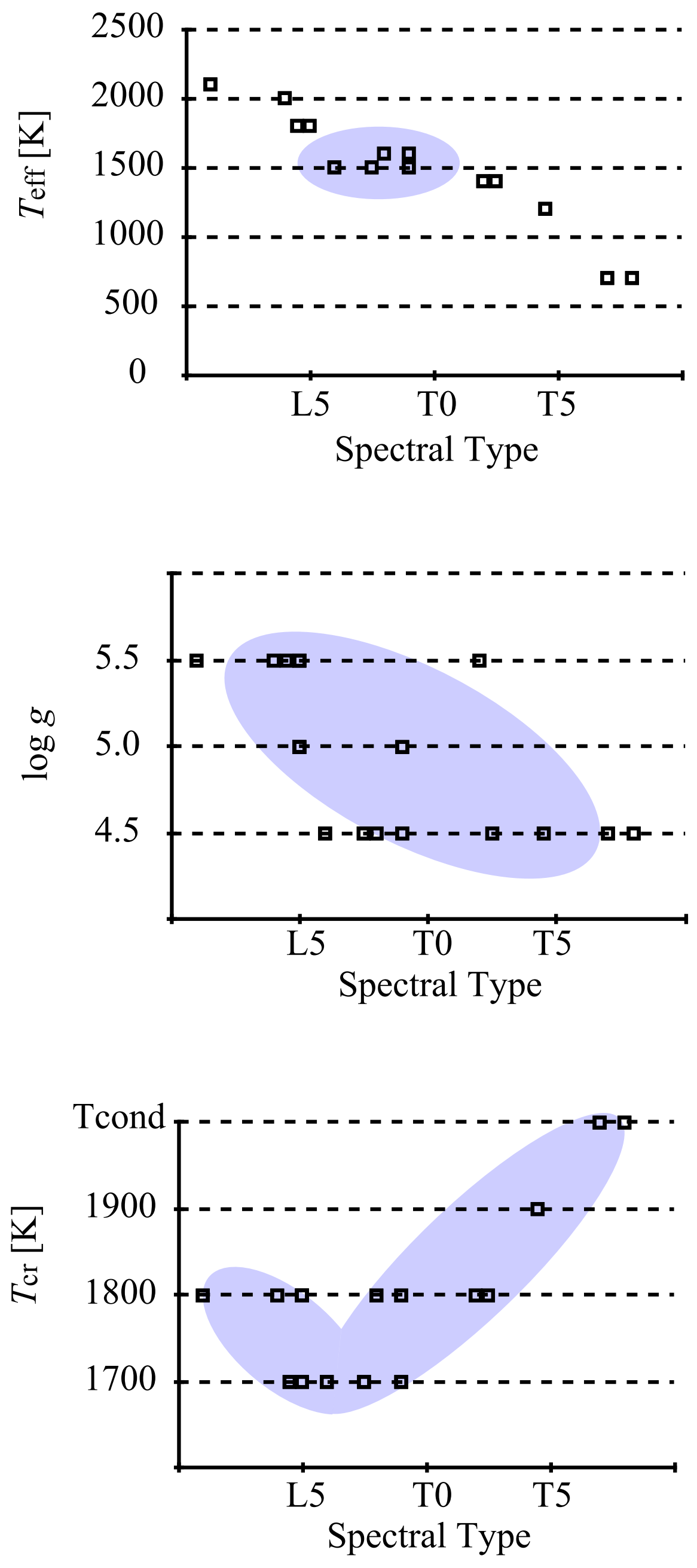
UCM assumes LTE.



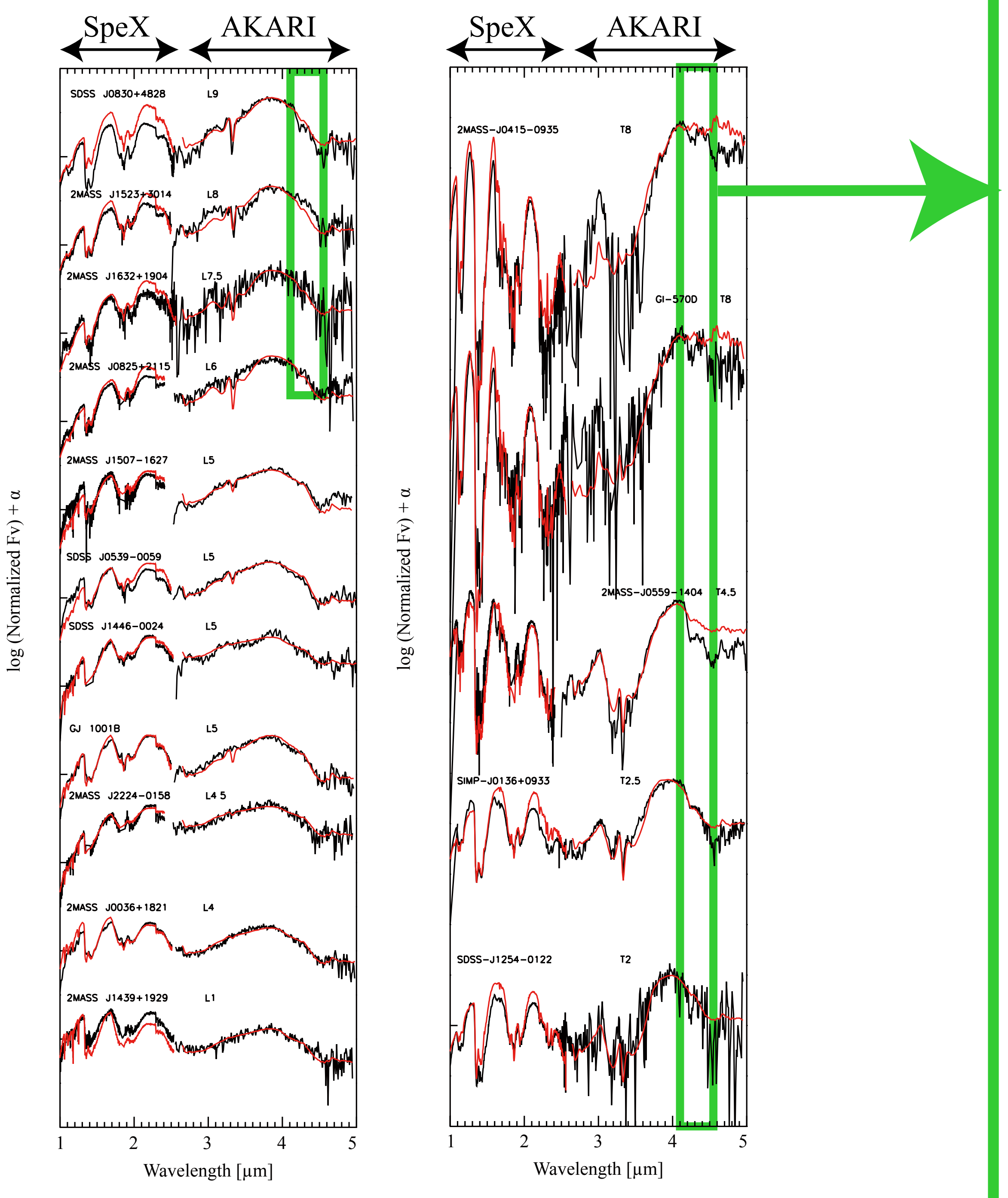
There are rapid phase changes between the gas and dust states. The time scale of the chemical (phase) reaction is smaller than that of convection, so a dust layer can be sustained.



★ Results: How do the parameters correlate with spectral types?



We confirm that the spectral types of late-L dwarfs are not a sequence of T_{eff}, but a sequence of dust effects.



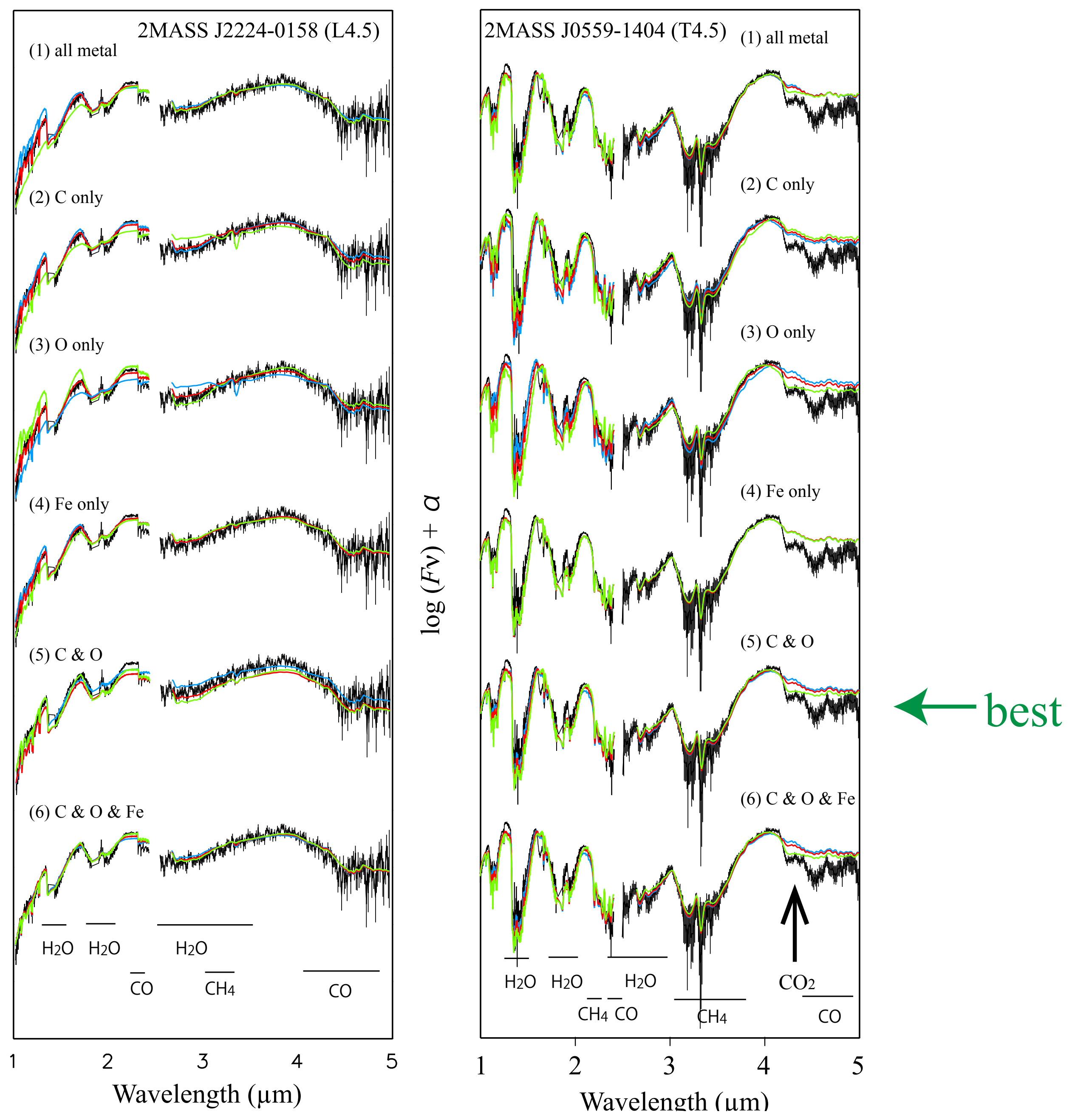
Spectra of observation (black) and the best fit model (red) derived by model fitting.

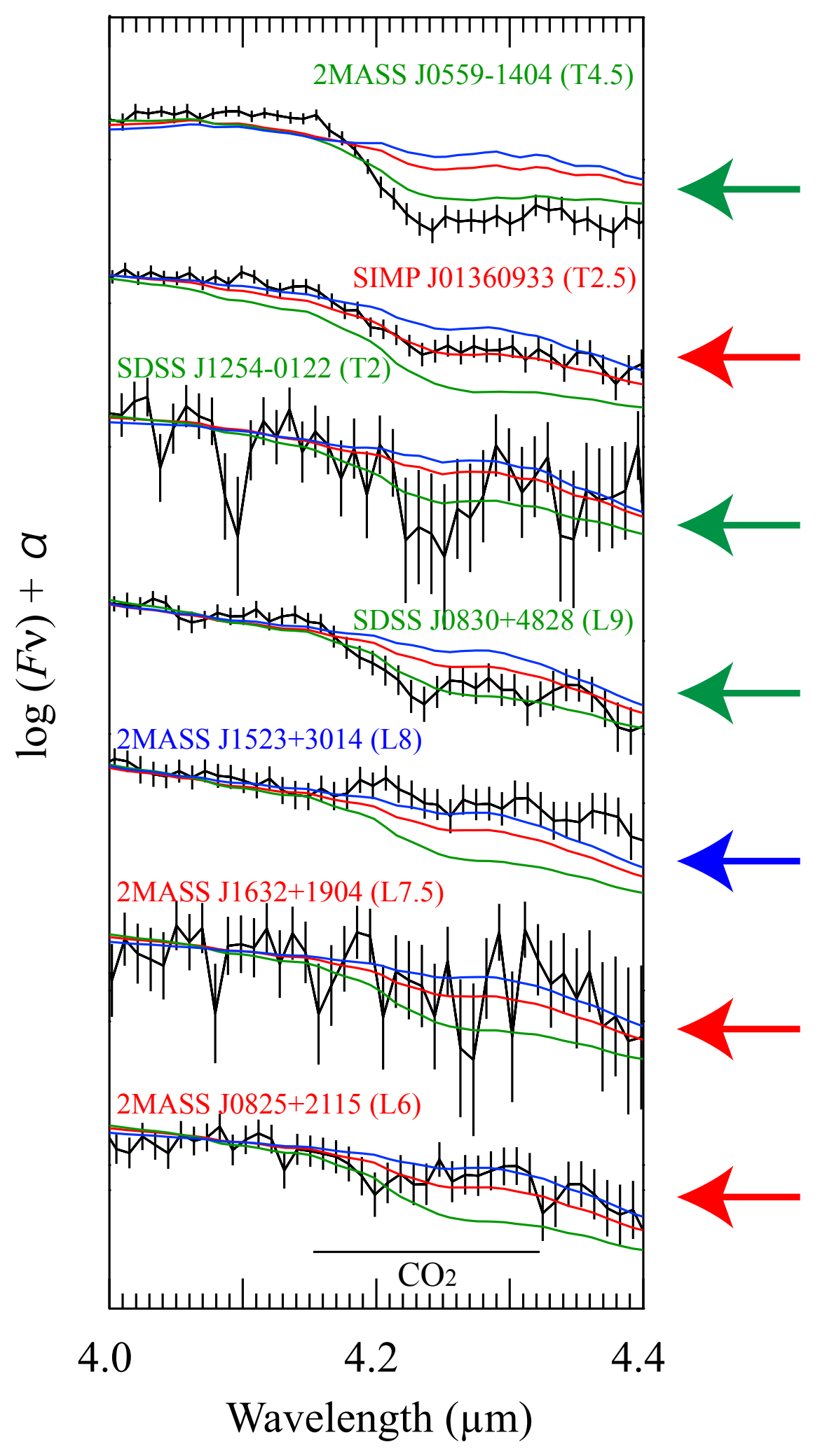
(Sorahana & Yamamura 2012)

★ CO_2@4.2μm (Sorahana et al. in prep.)

The observed CO_2 absorption bands in some objects are stronger or weaker than predicted by model atmospheres. We discuss the metallicity variation among brown dwarfs. We suggest the possibility that C and O elemental abundances are different in every object (see also Tsuji et al. 2011).

We constructed the models by varying (1) all elemental abundances, (2) C abundance only, (3) O abundance only, (4) Fe abundance only, (5) C & O abundances, and (6) C & O & Fe abundances. Model spectra of changing elemental abundances are compared with observed spectra.





Red: model spectra with solar abundance, green: +0.2dex, and blue: -0.2dex.

Observed spectra and models around the 4.2μm CO_2 band. Three are fitted by the model with solar metallicity, Three are better fitted by the model with increasing C and O abundances, and one is better fitted by the decreasing abundances.

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.

★ Acknowledgment

This research is based on observations with *AKARI*, a JAXA project with the participation of ESA. We acknowledge JSPS (PI: S. Sorahana) and JSPS/KAKENHI(C) No.22540260 (PI: I. Yamamura). We thank Prof. Takashi Tsuji for his kind permission to access UCM and helpful suggestions. Dr. Adam Burgasser, Dr.Michael Cushing, and Dr. Dagny Looper generously provided me (S. Sorahana) with observational data.

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