# 博 士 論 文 公 聴 会

# ご 案 内

下記の要領で博士論文公聴会を開催します。皆様のご来聴をお待ちしております。

記

日　時　：　２０２６年２月５日（木）13：30 ～ 15：00

場　所　：　Ｆ６０８号室

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　　　　　　大阪大学大学院理学研究科宇宙地球科学専攻　後期課程

題　目　：Toward Accurate Spectroscopic Characterization of Exoplanetary Atmospheres: A Retrieval Study of the Benchmark Brown Dwarf Binary Luhman 16AB

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論文題目 ： Toward Accurate Spectroscopic Characterization of Exoplanetary Atmospheres: A Retrieval Study of the Benchmark Brown Dwarf Binary Luhman 16AB

論文要旨 ：

More than 6000 exoplanets have been discovered to date, and in recent years, observational studies aimed at characterizing the physical and chemical properties of their atmospheres have rapidly progressed. Advances in extreme adaptive optics combined with near-infrared high-resolution spectrographs on ground-based large telescopes have enabled high-resolution spectroscopic observations of exoplanets, allowing for detailed atmospheric characterization. In particular, atmospheric retrieval analyses—an inverse problem framework that infers atmospheric physical states from observed spectra—enable not only the detection of molecular species but also the estimation of their abundances and the atmospheric temperature pressure structure (*T*-*P* profile). Such retrieval techniques are now widely used as a standard approach for characterizing exoplanetary atmospheres.

Elemental abundances inferred from molecular compositions provide important clues for understanding the formation processes of giant gas planets. In particular, the atmospheric carbon-to-oxygen (C/O) ratio has been suggested to exhibit different behaviors depending on the dominant formation pathway, such as the core (or pebble) accretion scenario or the gravitational instability scenario, which is analogous to star formation. However, existing observational results have not yet led to a unified understanding of whether differences in gas-giant formation processes are clearly reflected in atmospheric C/O ratios.

In this context, brown dwarfs, which possess atmospheres similar to those of giant gas planets, serve as important comparative benchmarks. Brown dwarfs are thought to form through processes analogous to star formation and, owing to their higher intrinsic brightness compared to exoplanets, yield spectra with higher signal-to-noise ratios. Consequently, their atmospheric C/O ratios can provide a reference for gas planets formed via gravitational instability. Nevertheless, the number of brown dwarfs with measured C/O ratios remains limited. Furthermore, systematic uncertainties arising from differences in atmospheric models used in retrieval analyses—such as molecular line lists employed in opacity calculations and parameterizations of the *T*-*P* profile—have not yet been thoroughly investigated, despite being critical for robust comparisons of C/O ratios.

In this work, we present atmospheric retrievals of the benchmark brown dwarf binary Luhman 16AB, based on high-resolution near-infrared spectra obtained with VLT/CRIRES and the differentiable retrieval framework ExoJAX. Owing to its proximity and brightness, high-S/N data are available, and extensive external constraints exist, making the system not only a

key anchor for C/O but also a valuable testbed for evaluating model systematics and trialing new methodologies, as pursued here.

We first perform retrievals with a power-law *T-P* profile and assess the sensitivity of inferred molecular abundances and C/O ratios to different CO line lists. We then introduce a flexible Gaussian process-based *T-P* profile, allowing a non-parametric characterization of the thermal structure and a more conservative treatment of uncertainties. For both components, we infer C/O ratios of about 0.67, slightly above solar, with line list systematics at the 7 percent level emerging as the dominant source of uncertainty, whereas assumptions about *T-P* parameterization or photometric variability play a lesser role. The retrieved *T-P* profiles and molecular abundances are broadly consistent with atmospheric models and equilibrium chemistry. Our results establish Luhman 16AB as a key anchor for substellar C/O measurements, demonstrate the utility of flexible *T-P* modeling in high-resolution retrievals, and highlight the importance of systematic tests particularly line list uncertainties—for robust comparisons between brown dwarfs and giant exoplanets.