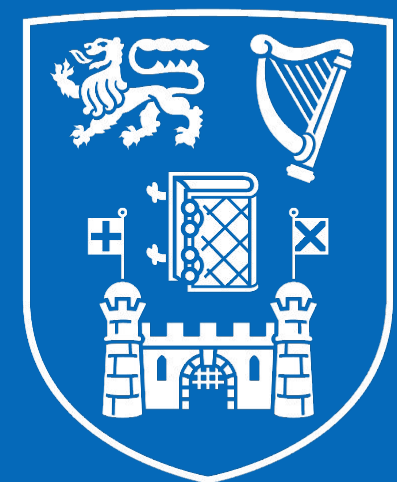




Bridging High- and Low-Resolution Spectroscopy for In-Depth Exoplanet Atmosphere Analysis

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High-Resolution Spectroscopy

- Resolution $\geq 50,000$
- Ground-based facilities (e.g. ESPRESSO or CRIRES+ on ESO VLT or HARPS on La Silla)

Pros:

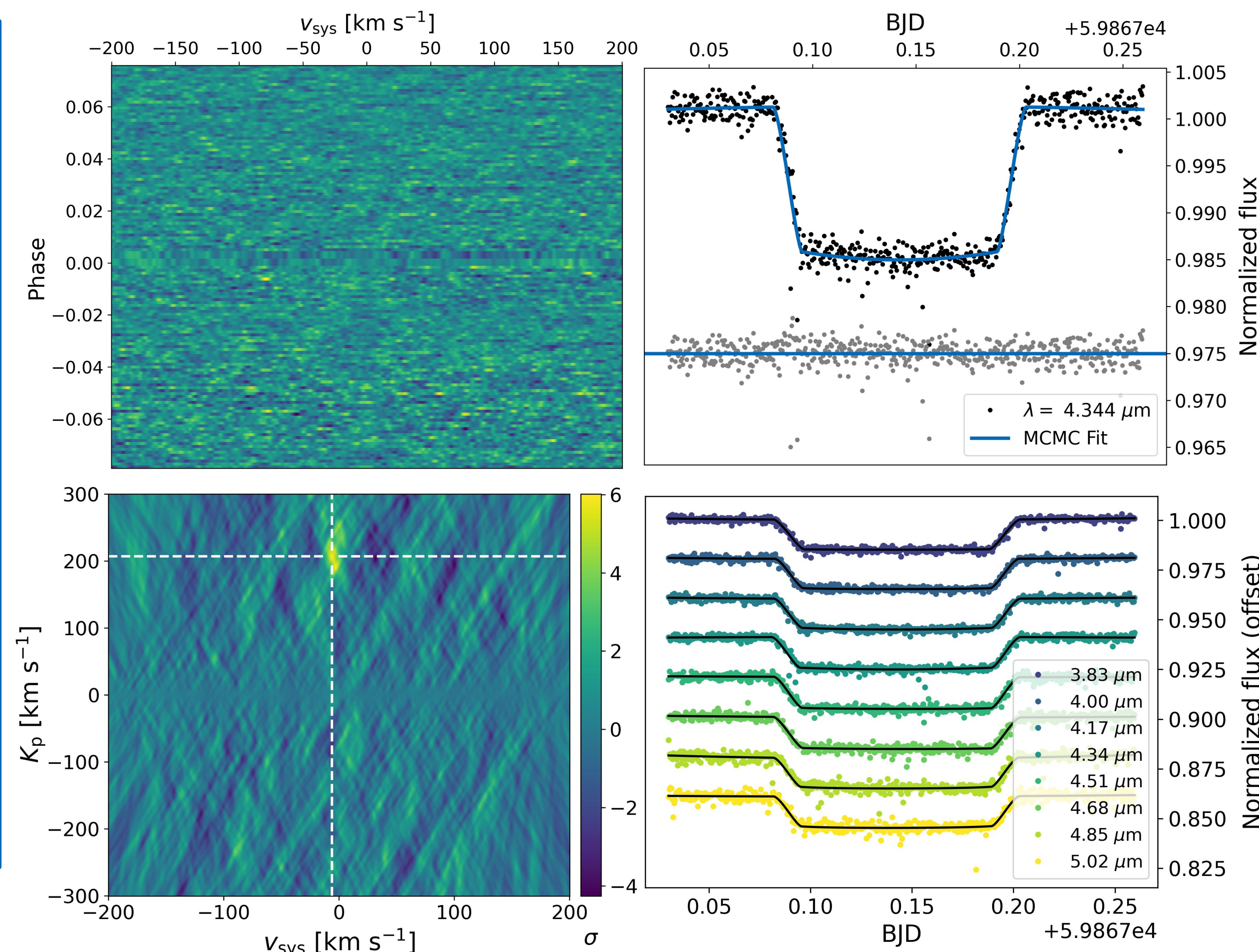
- Ability to resolve individual lines and their Doppler shifts
- Sensitive to line shapes
- Large number of detectable species¹
- Useful for study of atmospheric composition and dynamics, i.e. winds or jet streams²
- Probes higher in the atmosphere

Cons:

- Telluric lines / Earth atmosphere's contamination
- Limited information on continuum
- Exoplanet spectrum cannot be directly inspected

Top left image: Cross-correlation of spectral template at each orbital phase of WASP-121b

Bottom left: Detection of Fe line in WASP-121b spectra using UVES high-resolution spectrograph at VLT



Low-Resolution Spectroscopy

- Resolution usually $\lesssim 1,000$
- Space based observation (e.g. JWST)

Pros:

- Broad spectral coverage (study of the continuum)
- Detection of the most dominant species³
- No telluric lines contamination from space, better sensitive for small planets
- Useful for T/P profile and climate study²

Cons:

- Individual lines are not resolved: subject to confusion of atmospheric species
- Not sensitive to line shapes or positions
- Less sensitive in the optical part of the spectrum

Top right image: Transit curve of WASP-121b at 4.344 μm observed with JWST/NIRSpec

Bottom right: Comparison of transit curves of WASP-121b at various wavelengths (JWST/NIRSpec)

Combining High- and Low-Resolution

High- and low-resolution spectroscopy have both provided spectacular new discoveries in exoplanet atmospheres in recent years. However, they both probe different parts of the atmosphere and are sensitive to different physics.

High-res. spectroscopy is sensitive to weaker spectral lines and their Doppler shift allowing for study of dynamics such as atmospheric winds. Low-resolution spectroscopy offers broad view of spectral continuum, leading to study of thermal structure and exoplanetary climate.

Recent advances in performing high-resolution retrievals have opened up the possibility to simultaneously retrieve parameters from both types of data, in principle allowing us to probe these planets in more detail.

The aim of my PhD project is to create a framework to simultaneously analyze JWST and ground-based high-resolution spectroscopy, with the overall aim of providing better constraints on atmospheric parameters.

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¹Gibson, N.P. et al. 2020, MNRAS, 493, 2215

²Smith, P. C.B. et al. 2024, AJ, 167, 110

³Gapp, C. et al. 2025, AJ, 169, 341

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