2025 SAGAN SUMMER WORKSHOP

PHYSICAL-CHEMICAL CHARACTERISATION OF THE GJ 3470 EXOPLANETARY SYSTEM

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HIGH-RESOLUTION NEAR-IR SPECTROSCOPY OF AN M2 DWARF

To investigate the chemical composition of the M1.5-type star GJ 3470, we analyzed 107 individual spectra obtained with SPIRou, a high-resolution (R ≈ 70000) near-infrared spectropolarimeter (0.98-2.35 μm) at the Canada-France-Hawaii Telescope (CFHT). SPIRou (Donati et al. 2020) is optimized for studies of cool stars and exoplanets, making it ideal for a detailed characterization of GJ 3470. Also, the APOGEE stellar spectrum from the Sloan Digital Sky Survey (SDSS)-IV (Blanton et al. 2017) was used for abundance data comparison.

SPECTRAL PROCESSING PIPELINE

Step 1: Telluric correction
We used spectra already corrected for telluric lines from APERO Data Reduction Software (Cook et. al 2022).

Step 2: Blaze correction and continuum normalization
Each spectrum was corrected for the blaze function and normalized using the Specutils Python library. Smooth spline fits were applied to selected spectral windows to isolate the continuum.

Step 3: Spectral alignment
Spectra were restricted to the 15,000 - 17,000 Å region and aligned to a reference using χ^2 minimization to calculate optimal wavelength shifts ($\Delta\lambda$).

Step 4: Stacked master spectrum
We co-added all aligned spectra using sigma-clipped averaging (3σ) with a wavelength match tolerance of 0.02 Å. A Savitzky-Golay filter was then applied to reduce residual noise while preserving line features.

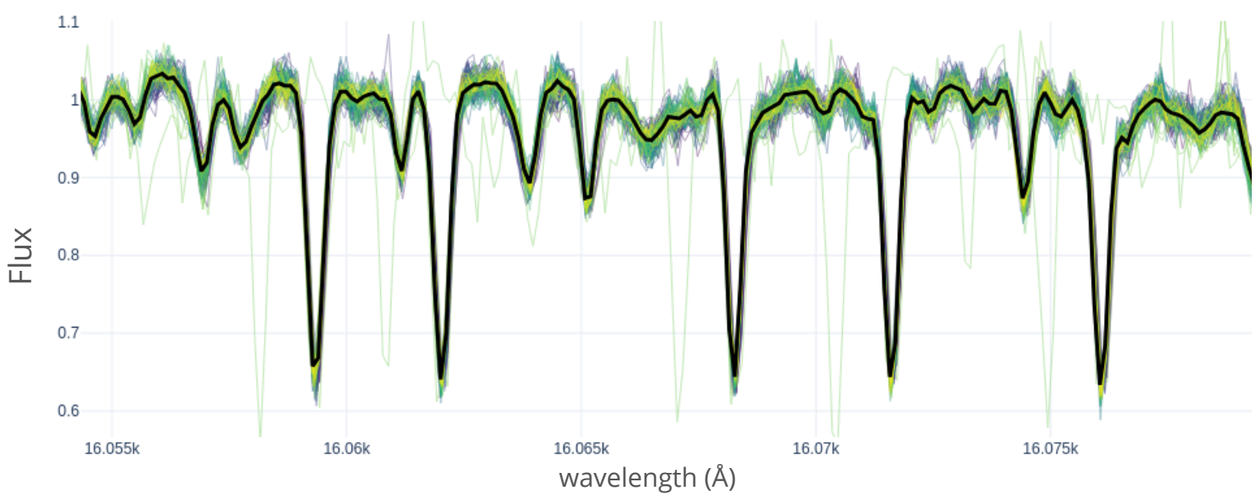

Figure 1: Spectrum of GJ 3470 in the 16055–16085 Å range. Lines are dominated by molecular H_2O absorptions in the near-infrared. Black trace: combined spectrum; colored lines: individual observations.

STELLAR PARAMETERS AND ABUNDANCES OF GJ 3470 HOST-STAR

We used the Souto et al. 2020 methodology to derive stellar parameters and individual abundances for C, O, Mg, Al, Si, K, Ca, V, Cr, Mn, and Fe (Table 1).
The effective temperature (Teff) was estimated using two diagnostics:

- OH and H_2O molecular lines → Teff-A(O)
- Fe I and FeH lines → Teff-A(Fe)

We computed a final temperature: Teff = 3694 K
Note: Fe-based diagnostics consistently yield higher temperatures, as also noted in Souto et al. (2020).

Element	ΔA(X) SPIRou [dex]	ΔA(X) APOGEE [dex]	Difference (SPIRou − APOGEE) [dex]
Mg	−0.011	−0.073	0.062
Si	0.098	0.004	0.094
Ca	0.254	0.248	0.006
C	0.06	0.120	−0.06
O	−0.031	−0.023	−0.008
K	0.049	0.026	0.023
Al	−0.036	−0.007	−0.029
Cr	0.238	0.358	−0.120
Fe	0.096	0.117	−0.021
Mn	0.045	0.054	−0.009
V	0.017	−0.076	0.093

Table 1: Comparison of elemental abundances for GJ 3470 from SPIRou and APOGEE spectra analyzed with BACCHUS. The third column shows the difference (SPIRou − APOGEE).

APPLY THE FIT MODELS TO DATA WITH PICASO

The observed JWST transmission spectrum of GJ 3470 b (Beatty et al. 2024) was fitted with a grid of PICASO models (S. Mukherjee et al. 2022, 2023a). The best-fit solution (Figure 2) includes clouds, with retrieved parameters: Tint = 200 K (intrinsic temperature), heat redistribution = 0.4 (day-night energy transport), log Kzz = 9.0 (vertical eddy diffusion coefficient), [M/H] = 0.1, C/O = 0.229, fsed = 1.0 (cloud settling efficiency).

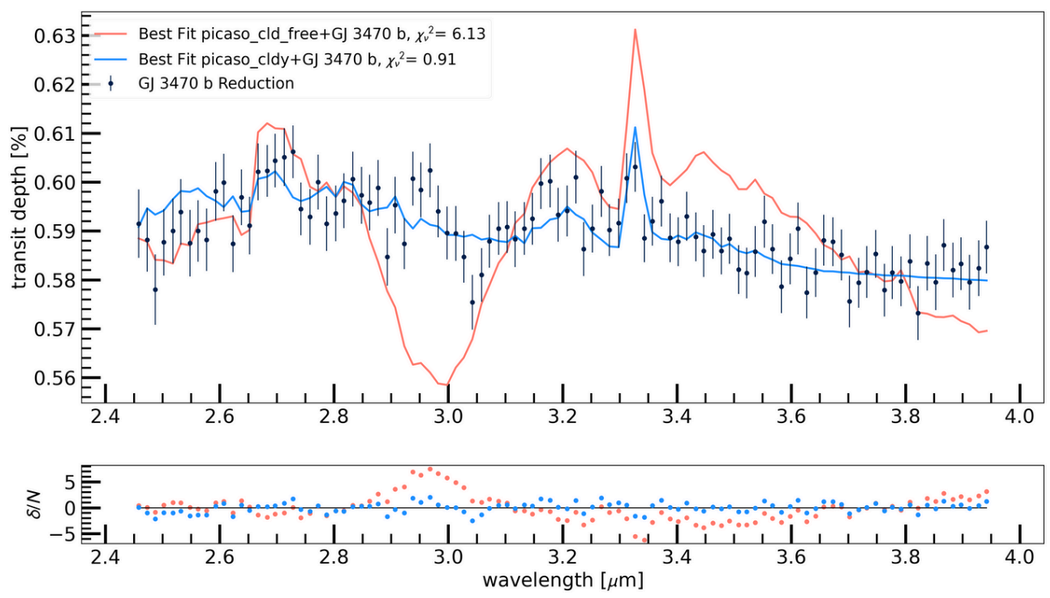

Figure 2: Spectral fitting of GJ 3470 b using PICASO models. JWST observations (black points) are compared to cloud-free (red) and cloudy (blue) models. The cloudy model yields a better fit (reduced chi-squared =0.91).

NEXT STEPS

- Use the physical and chemical parameters of the host star as input for modeling the atmosphere of GJ 3470 b.
- Perform spectroscopic characterization of the planet's atmosphere using JWST data, reduced with the Eureka! pipeline.
- Apply the PICASO code (N. E. Batalha et al. 2019) to simulate the planet's atmospheric structure.

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