High-Resolution View of Luhman 16 Chemistry, Clouds and Gravity

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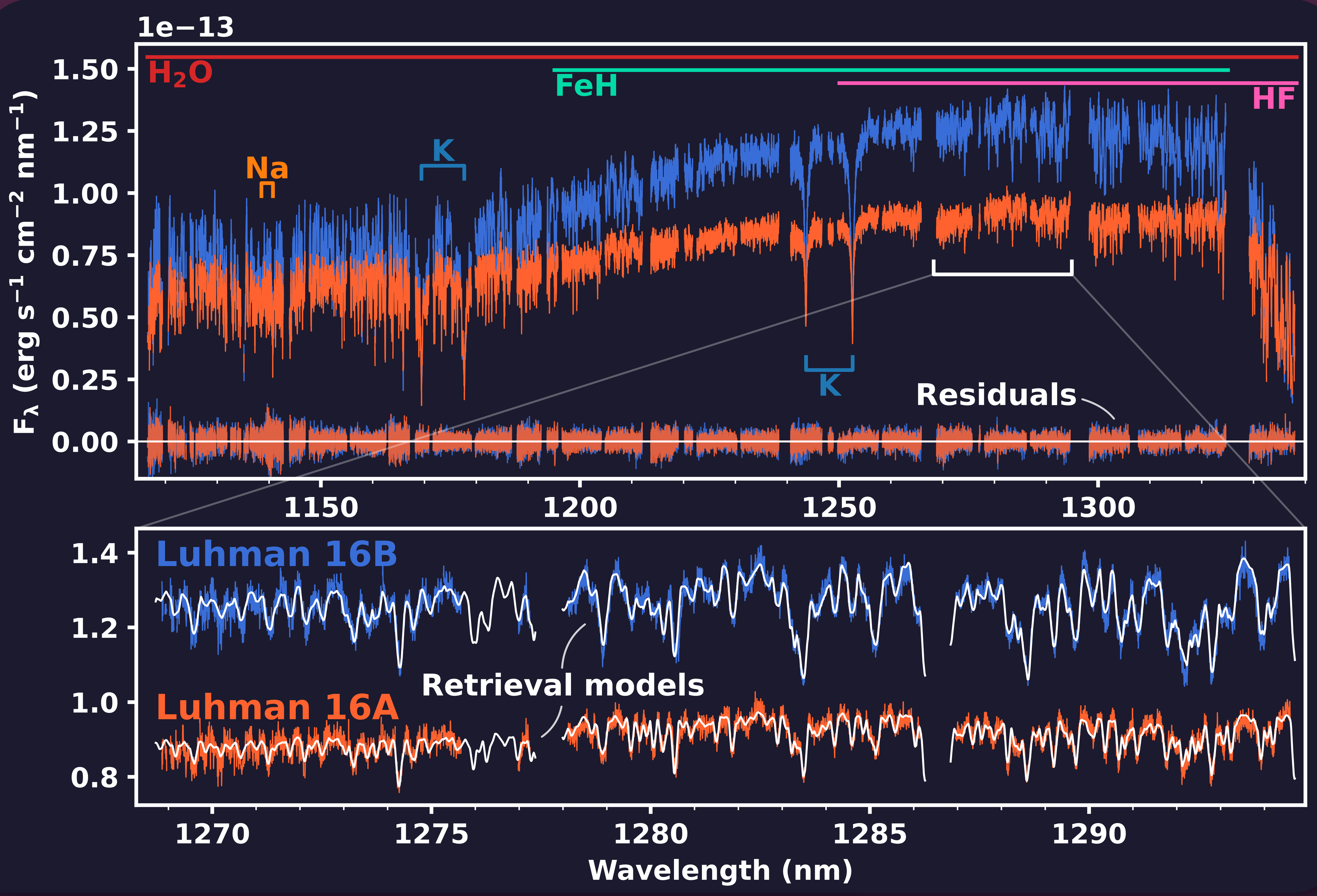


Fig. 1: Observed and modeled spectra of Luhman 16AB with absorption features of molecules or atoms.

The Nearest Brown Dwarfs

Luhman 16AB is the nearest brown dwarf (BD) binary (~2 pc), with spectral types L7.5 and T0.5[1]. At the transition between L- and T-types, sub-stellar objects likely experience a dissipation of clouds in their photospheres. Photometric variability and Doppler Imaging studies indicate that this cloud-clearing happens inhomogeneously, also for Luhman 16AB[2,3].

As part of the *ESO SupJup Survey*[4], we observed the Luhman 16 binary with *VLT/CRIRES+*. These J-band spectra (Fig. 1) are some of the highest quality observations at a spectral resolution of R ~ 65 000.

Chemistry and Clouds

We performed atmospheric retrievals using *petitRADTRANS*[5] and obtained excellent model fits for both BDs (Fig. 1). Cloud decks near ~10 bar were found to suppress the line depths. We constrained the abundances of five species, including H_2O, Na, and K. Cross-correlation (Fig. 2) confirmed the presence of FeH and—for the first time in the J band—hydrogen fluoride (HF).

The presence of gaseous FeH is surprising, as chemical equilibrium models predict a depletion into iron clouds (Fig. 2). Its reappearance at the L-T transition may be explained by a patchy cloud deck, where thinner regions expose warmer layers. Confirming this scenario with a two-column model proved challenging due to the limited wavelength-range.

Fig. 2: Detection of HF and FeH, and chemical abundance constraints.

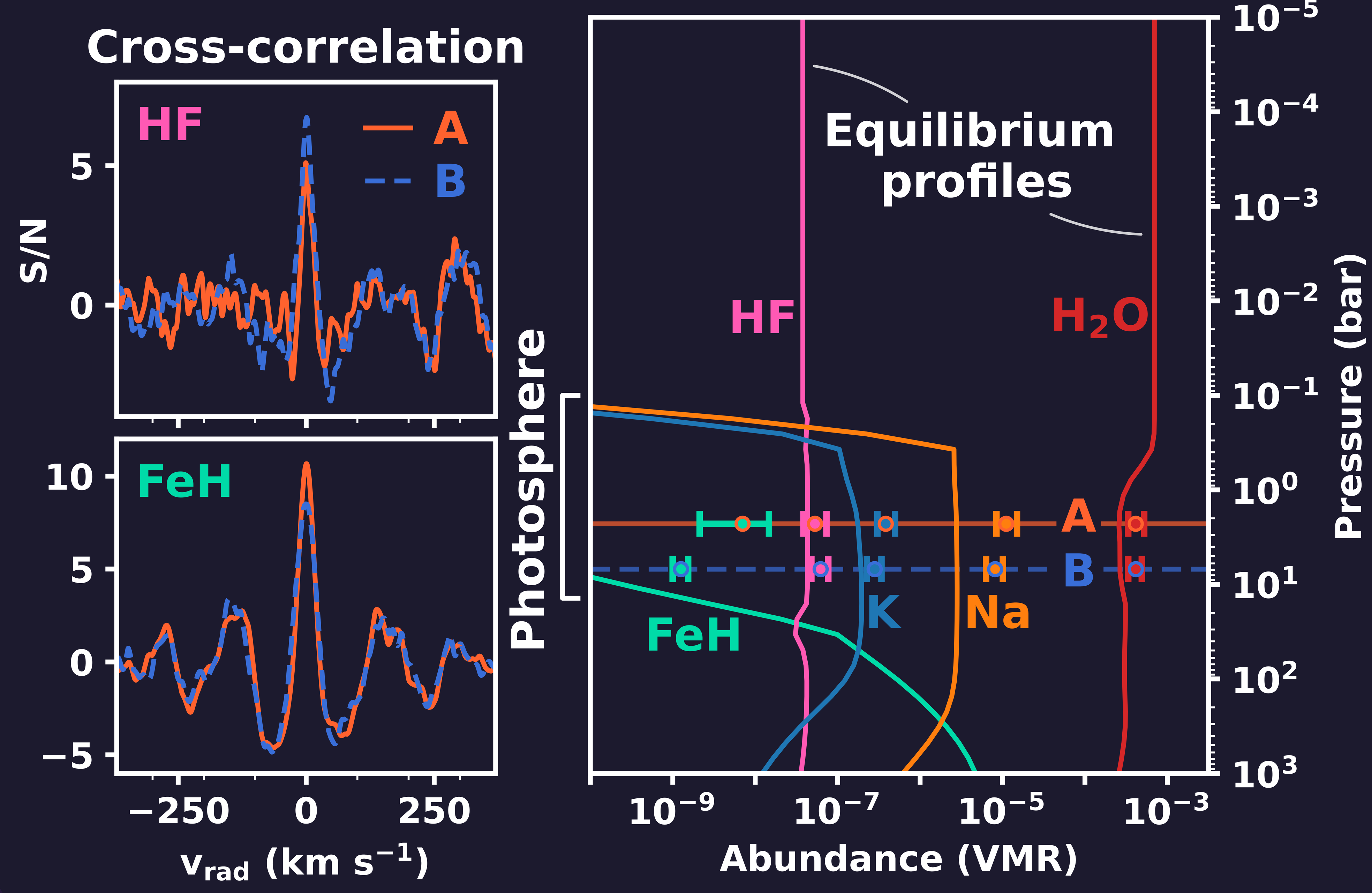
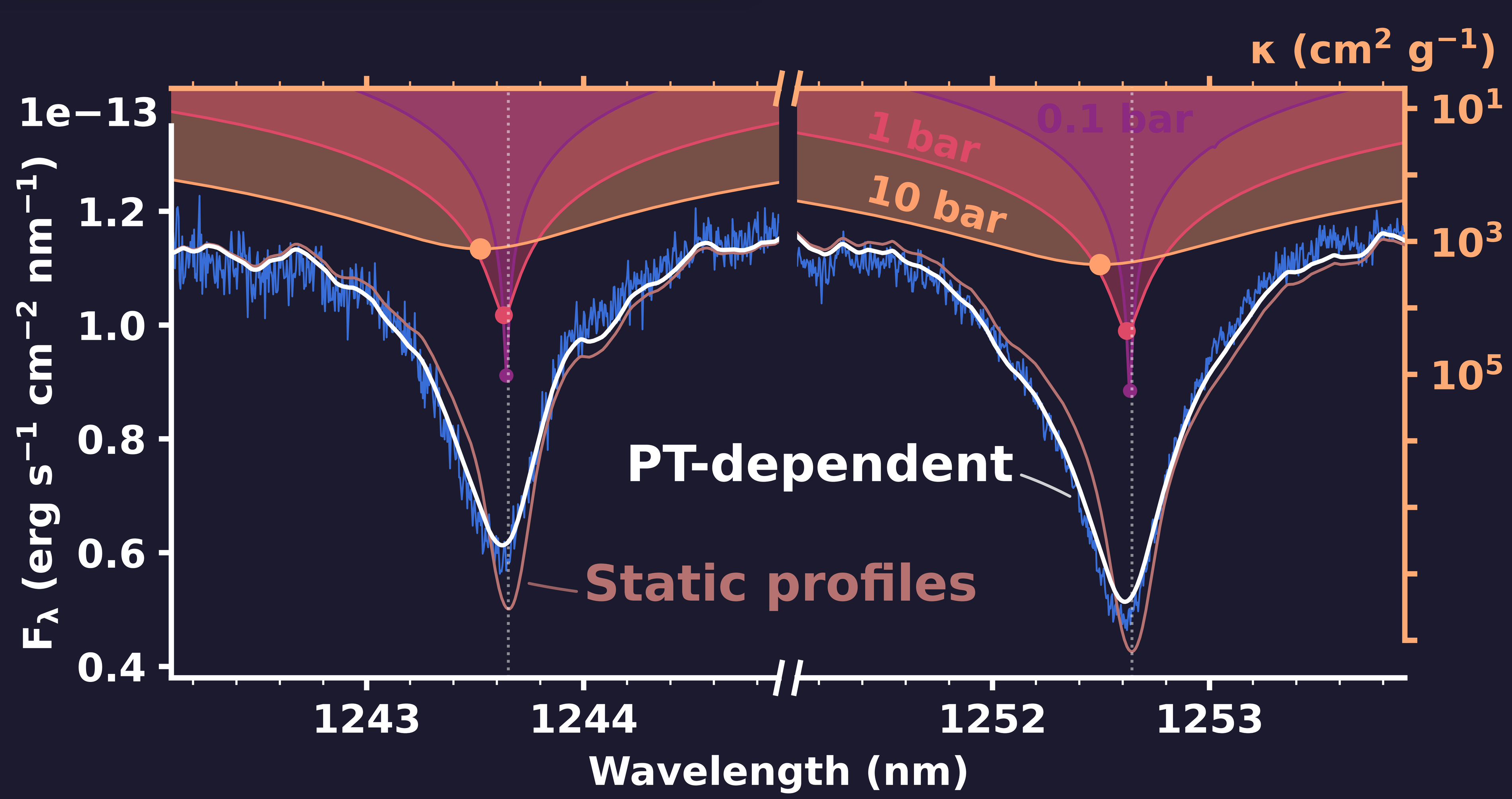


Fig. 3: Asymmetric K doublet and pressure-dependent opacities.



High-Pressure Line Shifts

J-band spectra probe high pressures, causing strong collisional broadening of the K doublet (Fig. 3). The broad lines indicate the high surface gravities of Luhman 16AB.

Collisions with H_2 and He also shift the K energy levels, producing pressure- and temperature-dependent wavelength shifts. Integrated over the photosphere, these appear as asymmetric absorption—detected here for the first time in BDs at high spectral resolution. We improved the fit by modeling this effect with a PT-dependent line core based on unified line shape theory[6] (Fig. 3).

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