Multi-modal Atmospheric Characterization of β Pictoris b : Adding High-Resolution Continuum Spectra from GRAVITY

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Abstract

The characterization of giant exoplanets such as β Pic b is now routinely performed with multiple spectrographs and imagers exploring different spectral bandwidths and resolutions, allowing for atmospheric retrieval of spectra with or without the conservation of the planet spectral continuum. The accounting of data multi-modality in the analysis can provide a more comprehensive determination of the planets physical and chemical properties and inform on their formation history. As both data and models are becoming increasingly complex, new analysis techniques are being developed to better characterize these objects. We present the first VLTI observations at R 4000 of β Pic b, the first obtained on an exoplanet with GRAVITY at such resolution. We upgrade the forward modelling code ForMoSA to account for the data multi-modality, including low- medium- and high-resolution spectroscopy both based on direct model-data comparison and the analysis of cross-correlation signals. We use ForMoSA to refine the constraints on the atmospheric properties of the exoplanet and evaluate the sensitivity on the retrieved values to the input dataset. We obtain four high signal-to-noise (S/N 20) spectra of β Pic b at K-band with GRAVITY conserving both the pseudo-continuum and the pattern of molecular absorptions. We use ForMoSA with four grids of self-consistent forward models (Exo-REM, ATMO, BT-Settl, and Sonora) exploring different $T_{\rm eff}$, $\log g$, metallicity, C/O, and ^{12}CO/^{13}CO ratio. We then combine the GRAVITY spectra with published 1-5 μ photometry (NaCo, VisAO, NICI, SPHERE), low- to medium- resolution (R 700 broad band, 0.9-7 μ) spectra, and echelle spectra covering narrower bandwidths (R 100000, 2.1-5.2 μ).