Constraining Planetary Parameters with a photometric and spectroscopic fit

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1. Abstract

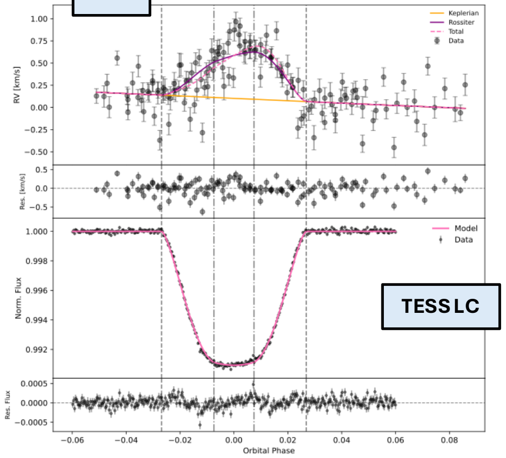
Within the framework of the **BRIDGES** Large Program (**GAPS** collaboration), we present a methodology to self-consistently model the intertwined effects of a planet's **atmospheric transit** and the **Rossiter-McLaughlin (RM) effect**. Our approach is based on the joint analysis of four observables: the photometric **TESS light curves**; the Least-Squares Deconvolution (**LSD**) stellar line profiles; the LSD residuals—which contain the direct atmospheric absorption and the Doppler shadow—and the in-transit radial velocities, which trace the stellar reflex motion modulated by the **atmospheric RM effect**. By modelling these physically connected signals simultaneously, we **break geometric degeneracies** and achieve robust, independent constraints on orbital parameters and planetary mass. While this technique is currently applied to ultra-hot Jupiters using **HARPS-N**, the leap in sensitivity provided by **ANDES** at the **ELT** will extend our detailed dynamical framework to the atmospheres of smaller, potentially rocky planets.

2. Datasets and joint fit

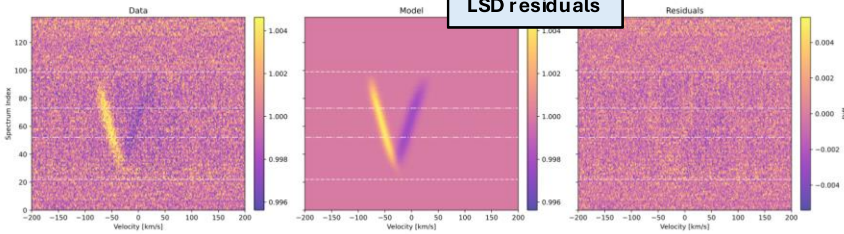
Observables: Simultaneous analysis of photometric light curves and high-resolution HARPS-N spectroscopic data.
Modeling Framework: Transit photometry modelled via batman.
Classic and Atmospheric Rossiter-McLaughlin (Borsa+21) effects modelled via PyAstronomy.
Bayesian Retrieval (emcee): Fits a unique, shared set of geometric parameters: orbital inclination i, projected obliquity λ, and core radius ratio Rp/Rs.
Independently constrains the stellar K, and planetary Kp, radial velocity semi-amplitudes. Directly measures the fraction of the occulted stellar disk.

RVs

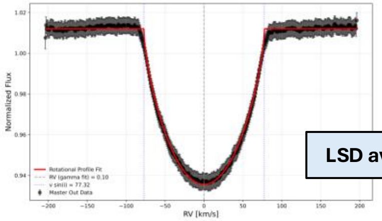
TESS LC



LSD residuals

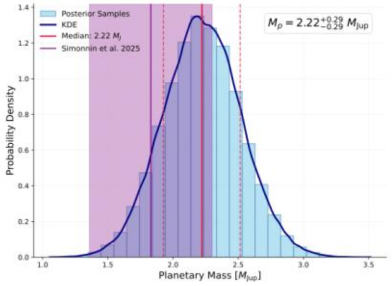


LSD average profile

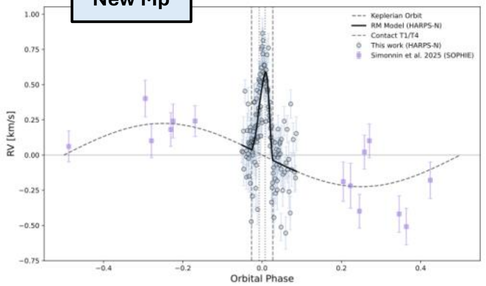


3. TOI-1518 b mass refinement

Applying our joint framework to the Ultra-Hot Jupiter TOI-1518 b (Cabot+21), we achieved a significant refinement of the system's orbital parameters and a much tighter constraint on the planetary mass:
Mass Precision: By independently anchoring the orbital kinematics, the joint fit effectively halved the uncertainty on the planetary mass ***Mp* = *2.22* $\pm$ *0.29 Mj*** respect to Simonnin+25.
Dynamical Architecture: The models accurately captured the Doppler shadow, confirming a highly misaligned, near-polar orbit $\lambda \sim 235°$.
Atmospheric RM Detection: The framework robustly isolated the atmospheric extension in the RVs, providing an independent kinematic validation for the chemical detections found via transmission spectroscopy.

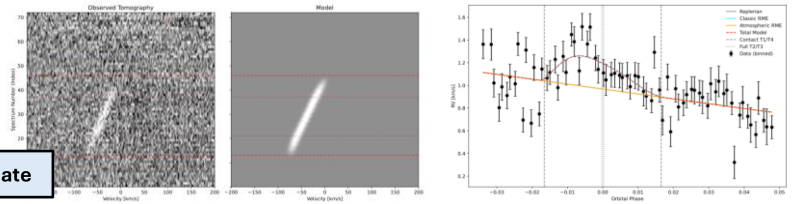


New Mp



4. Prospects

Expanding the Sample: Validating TESS Planet Candidates and conducting preliminary atmospheric investigations.
The ELT Era: While currently applied to hot giants using HARPS-N , the leap in sensitivity provided by ANDES at the ELT will allow us to extend this dynamical framework to smaller, potentially rocky planets. This advancement is driven by the massive collecting area of the ELT providing a significant boost in S/N, and by the extension into the Near-Infrared (NIR) allowing us to target colder stars (e.g., M-dwarfs), enabling the study of planets orbiting in cooler and potentially habitable environments



TOI Planet Candidate