Towards a comprehensive method for detecting broadband transmission spectra of exoplanets using high-resolution spectroscopy

Mariana A. F. de Melo e Sousa, marianademeloesousa@gmail.com, Departamento de Fisica e Astronomia, FCUP e Instituto de Astrofísica e Ciências do Espaço/CAUP
Eduardo Cristo, eduardo.cristo14@gmail.com,Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto, CAUP, Rua das Estrelas, 4150-762 Porto, Portugal

Motivation and Objectives

Scientists studying exoplanet atmospheres have made progress, but there are still some challenges, especially when trying to analyze different wavelengths of light from Earth-based telescopes. In 2016, researchers introduced a new technique that uses the way a planet blocks different colors of light as it passes in front of its star. Building on this, we propose chromatic Doppler tomography, using full residual cross-correlation functions. "Residual" CCFs refer to the data that remain after subtracting out the expected or modeled signals, such as the star's light or known patterns, from the observed data. By analyzing these residuals, it's possible to uncover more subtle features, like the composition of an exoplanet's atmosphere, that are not immediately obvious in the original data.

Data

- Exoplanets: HD 209458b, ESPRESSO data
- night:10-08-2021
- 40 fit files: 170 CCFs that correspond to 170 slices + 1 CCF that corresponds to the weighted sum of all (i.i. white-light CCF)

Method

- CCF was shifted to the stellar rest frame via the introduction of an offset in its RV
- Normalize each CCF by its continuum level using Guassian fit
- CCFs were linearly interpolated to the same RV grid
- Master-Out: Mean of interpolated CCFs
- Residual Matrix: Interpolated CCF – Master-Out

Results

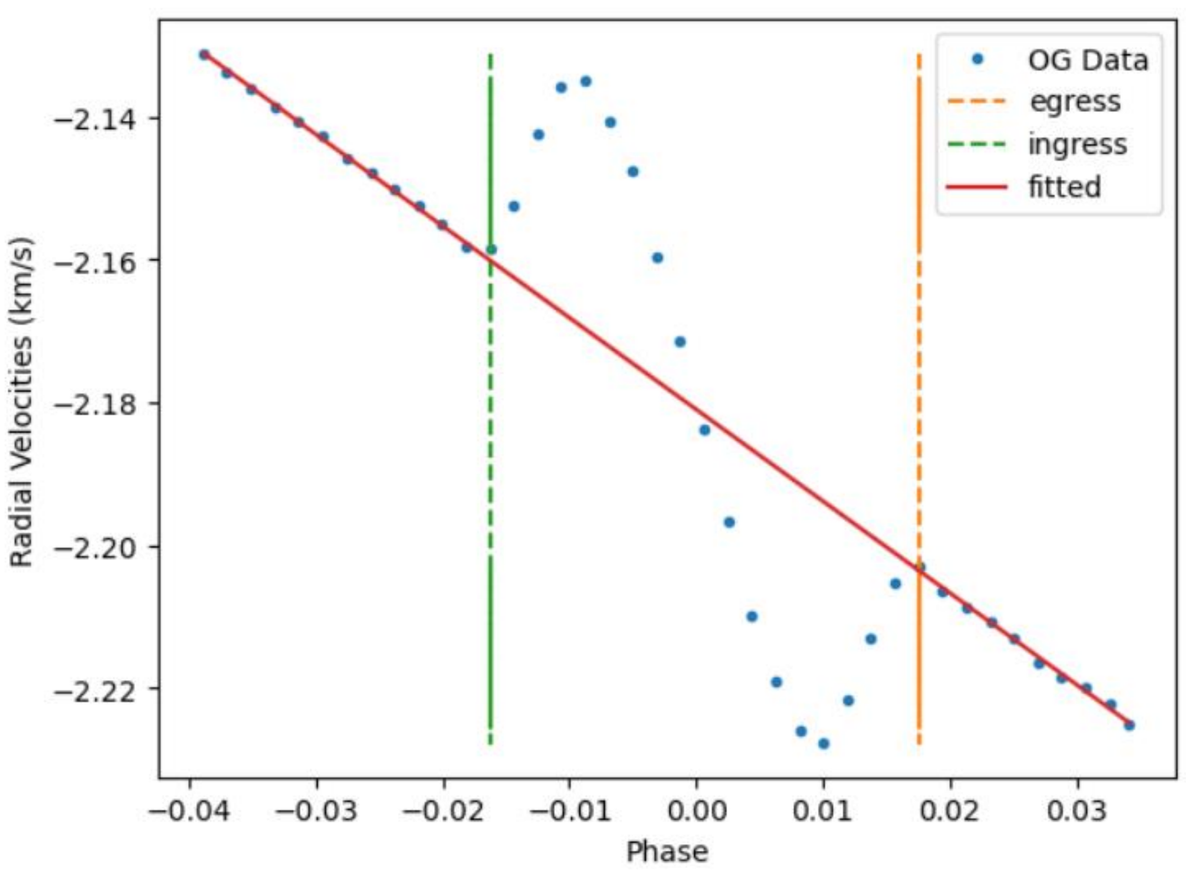

Fig.1: Shift to the stellar frame – white light;

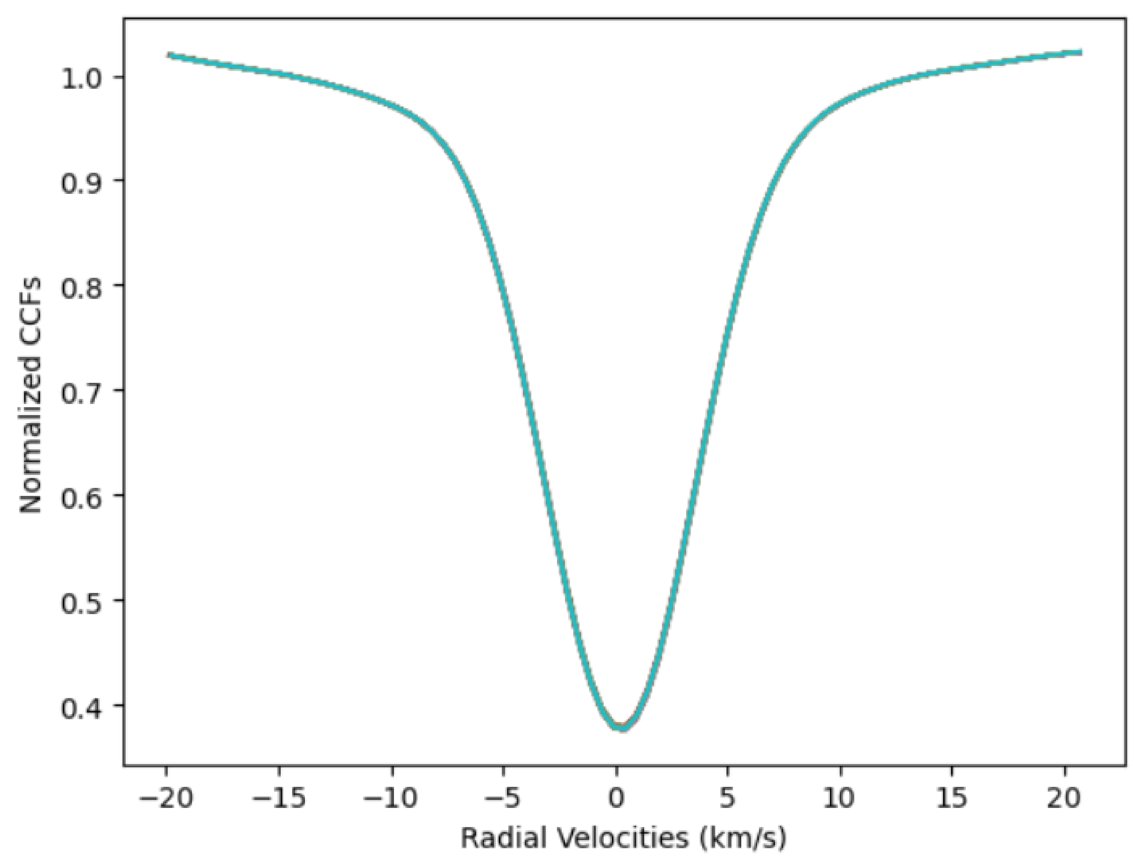

Fig.2: Master-Out CCF – white light;

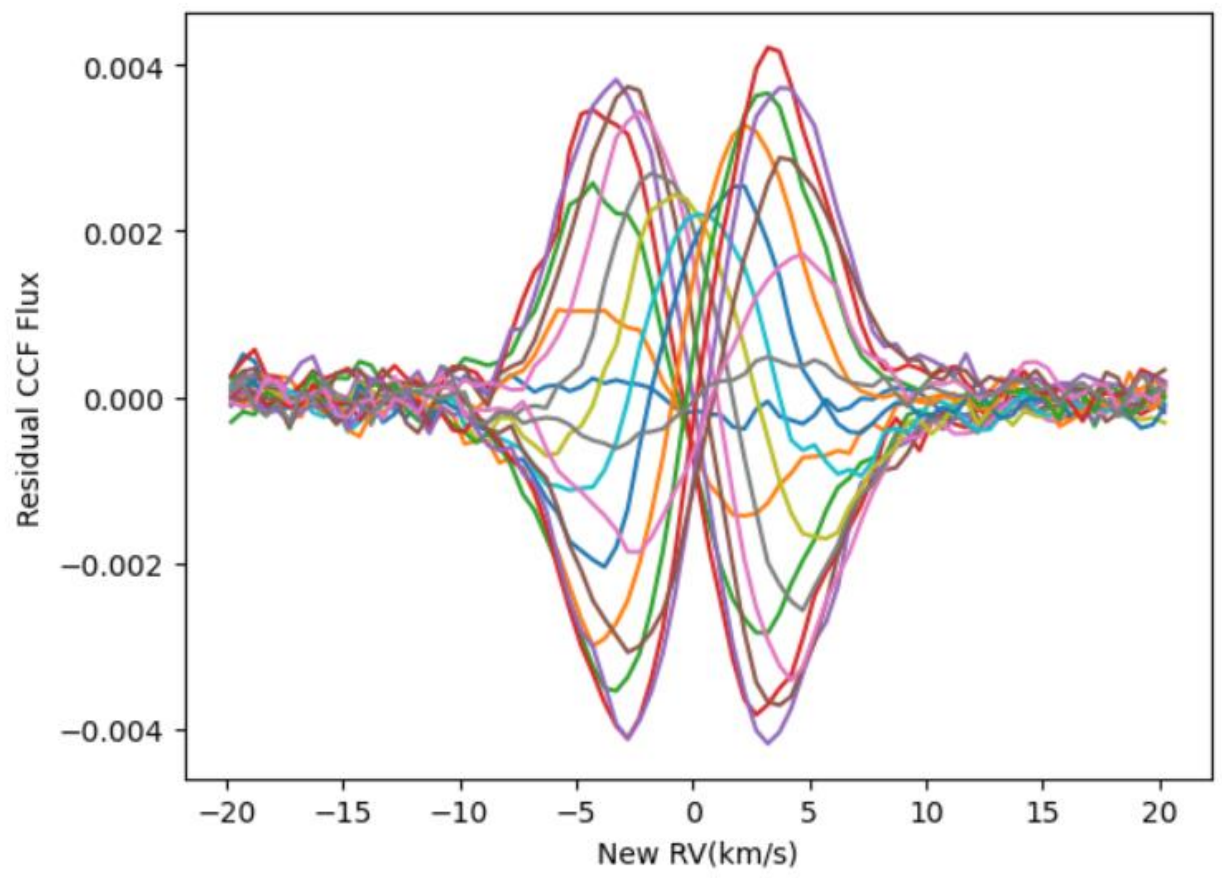

Fig.3: 1D Residual CCF in transit– white light;

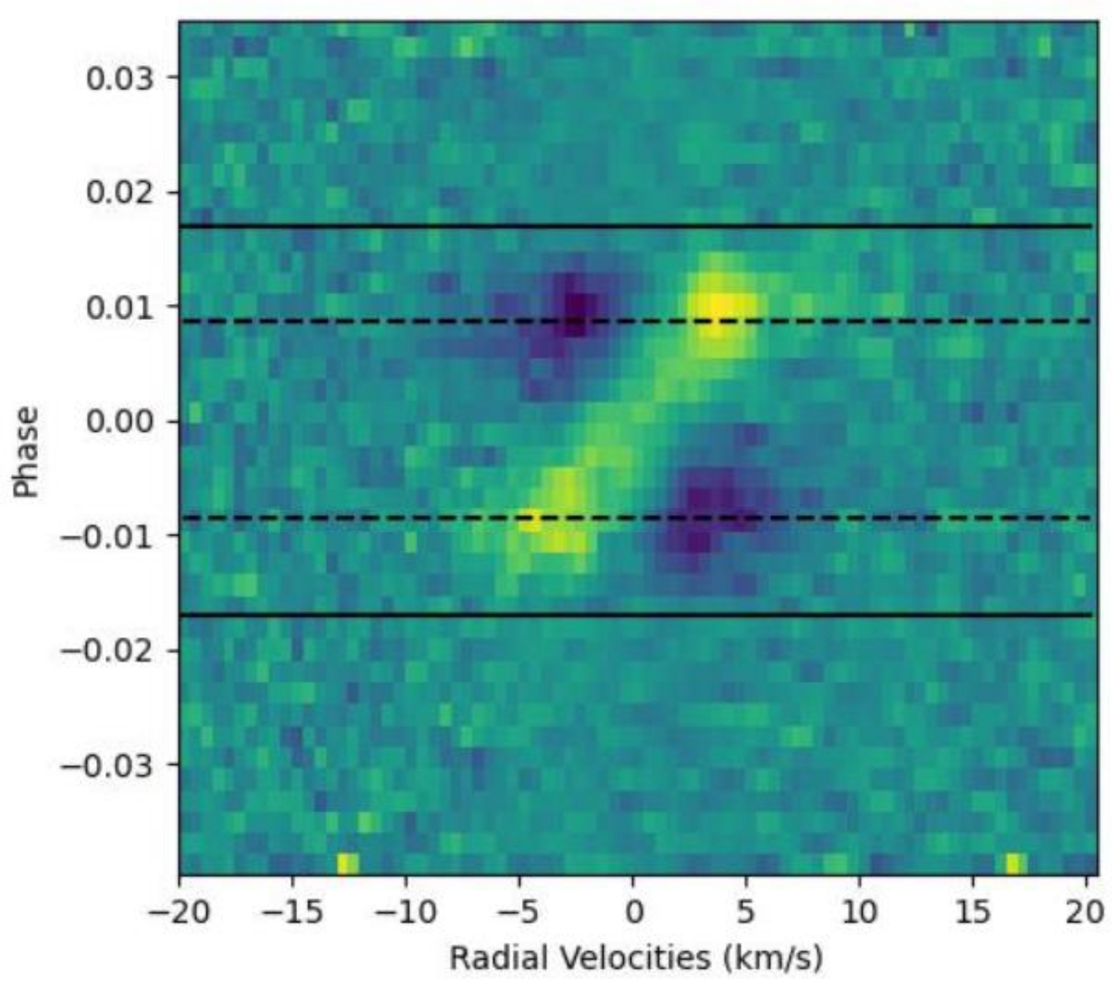

Fig.4: 2D Residual Matrix – Hα interval (~656.28 nm);

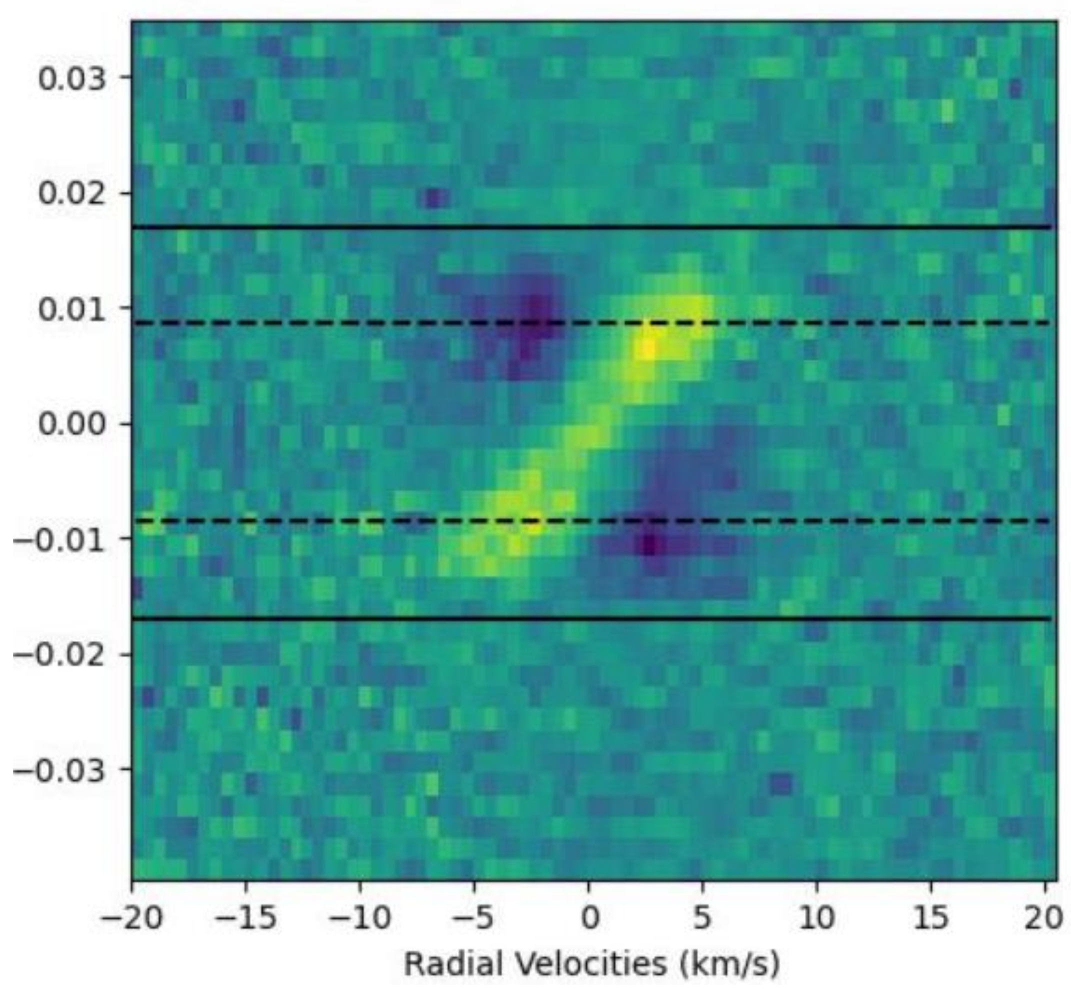

Fig.5: 2D Residual Matrix – Sodium interval (~589.0 nm);

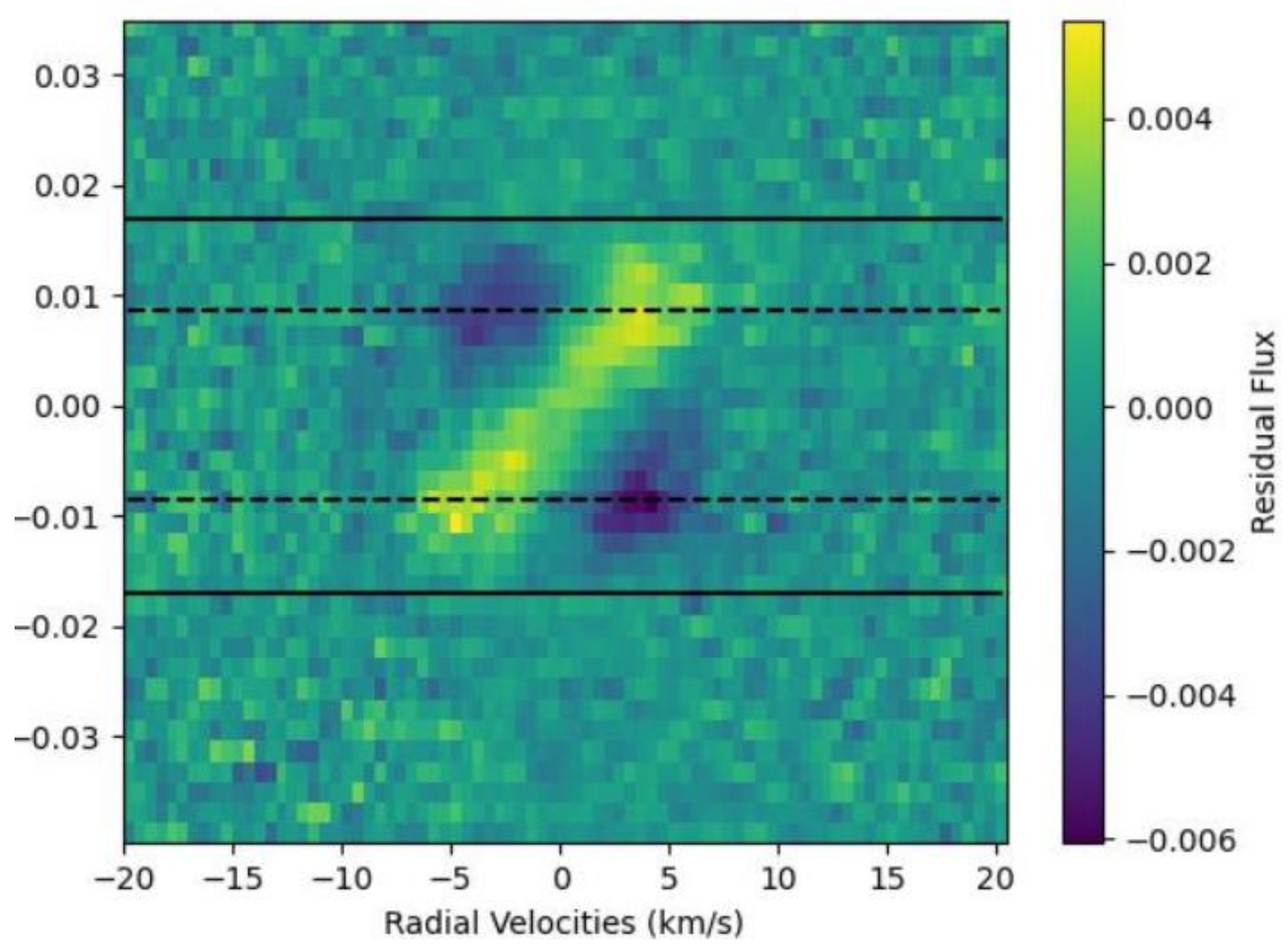

Fig.6: 2D Residual Matrix – Calcium interval (~422.7 nm);

Funded/Co-funded by the European Union (ERC, FIERCE, 101052347). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council. Neither the European Union nor the granting authority can be held responsible for them. This work was supported by FCT - Fundação para a Ciência e a Tecnologia through national funds and by FEDER through COMPETE2020 - Programa Operacional Competitividade e Internacionalização by these grants: UIDB/04434/2020; UIDP/04434/2020.

Conclusion

With these results, we now aim to reproduce and improve upon the methodology outlined in Esparza-Borges (2022). By generalizing the chromatic Doppler tomography method and developing the necessary adaptations for its integration with CaRM, we will apply the technique to ESPRESSO data for HD 209458b and HD 189733b. Future work will focus on investigating the simulated impact of stellar activity on chromatic Doppler tomography.