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Star And Planet's Characterisation Through High Spectral Resolution

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The study of exoplanets atmospheres is one of the most intriguing challenges in exoplanet field nowadays and the High Resolution Spectroscopy (HRS) has recently emerged as one of the leading methods for detecting atomic and molecular species in their atmospheres. In terms of numbers, if we define the resolution power R, where λ is the wavelength and Δλ is the spectral resolution:

$$R = \lambda/\Delta\lambda$$

then, "High Resolution Spectroscopy" means R > 50 000.

Nevertheless extraordinary results have been achieved (Birkby, 2018), High Resolution Spectroscopy alone is not enough. 1D models of the host star have been coupled to HRS observations, but they do not reproduce the complexity of stellar convection mechanism (Chiavassa & Brogi, 2019). On the contrary, 3D Radiative Hydrodynamical simulations (3D RHS) take it into account intrinsically, allowing us to correctly reproduce asymmetric and blue-shifted spectral lines due to the granulation pattern of the stellar disk, which is a very important source of uncertainties at this resolution level (Chiavassa et al. 2017).

However, numerical simulations have been computed independently for star and planet so far, while the acquired spectra are an entanglement of both the signals. In particular, some molecular species (e.g, CO) form in the same region of the spectrum, thus planetary and stellar spectral lines are completely mixed and overlapped.

Therefore, a next step forward is needed: computing stellar and planetary models *together.*

With our work, we aim at upgrading the already-in-place 3D radiative transfer code Optim3D (Chiavassa et al. 2009) —largely used for stellar purposes so far — to taking into account also the exoplanetary contribution. We propose to use simultaneously 3D RHS, performed for stars, and the innovative Global Climate Model (GCM), drawn up for exoplanets, in order to generate unprecedented precise synthetic spectra. As a springboard to test the code, we are carrying out the analysis of CO and H2O molecules on the well-know benchmark HD189733. Indeed, to disentangle those star's and its companion's signals due to the same molecules is one of the most challenging problems. In the end, we will be able to compute a complete dynamic characterisation: on one side, a precise knowledge of the stellar dynamic (i.e. convection-related surface structures) would allow to extract unequivocally the planetary signal; on the other one, a well-modelled dynamic of the planet (i.e. depth, shape, and position of spectral lines) would provide us with considerable information about the planetary atmospheric circulation.