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Are we ready to characterize exoplanet atmospheres with the James Webb Space Telescope observations ?

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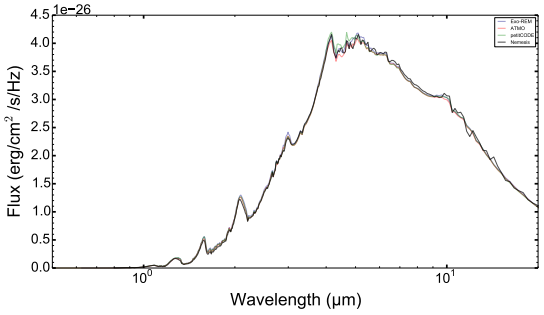

Figure 1: Example of calculated synthetic emission spectra with an imposed temperature profile $T_{\rm eff}$ = 1000 K. Exo-REM is in blue, petitCODE in green, ATMO in red and NEMESIS in black.

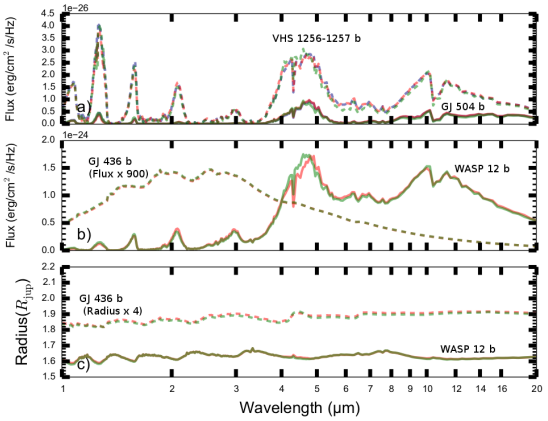

Figure 2: Example of calculated synthetic emission spectra of the two directly imaged planets (a), and for the two transiting planets the emission (b) and transmission (c) spectra. For GJ 436 b the flux is multiplied by 900, and the radius by 4 to put the two cases in the same plot.

Abstract

The James Webb Space Telescope (JWST)will open a new area in the domain of exoplanet atmosphere characterizations and will require accurate models to interpret the observations. In this context, we propose a protocol to compare various atmospheric codes, to identify and discuss the significant differences in the results and to help the codes evolve to become as consistent as possible. We applied this protocol on 3 forward models and one retrieval. We updated them to account for the major differences and we are now able to identify the remaining differences observable with the JWST.

1. Introduction

Launched at the end of the next year, the JWST, thanks to a large collecting area and a large wavelength range coverage (near and mid-infrared) will be a key machine to study the atmosphere of exoplanets. One of the four main topics put forward for this observatory will be the study of exoplanets, mainly through the characterisation of their atmosphere, using transmission and emission spectroscopy. The study of exoplanets will not be only focused on transiting exoplanetes; some modes (such as coronagraphic modes) will allow characterizing exoplanets detected by direct imaging.

Atmospheric models are needed to interpret quanti-

tatively the observations. With the recent and forthcoming improvement of the data quality, the question of comparing the uncertainties in the model predictions with the precision of the observations has to be considered. To investigate the uncertainties in the model predictions, our approach has been to start with the comparison of the results from four models developed independently: the *petitCODE* model [1, 2], the *ATMO* model [3], and the *Exo-REM* model [4] in Baudino et al. 2017 in prep, following by adding the *NEMESIS* model [5].

2. Common model

We define of a common set of parameters and of physical, chemical processes to be taken into account.

The common model considers the opacities from the most important molecules and atoms: NH_3, CH_4, CO, CO_2, H_2O, PH_3, Na, K, as well as the collision-induced absorption for H_2–H_2 and H_2–He. For the alkali metal lines we use the Voigt profile up to 4500 cm^{-1} from line center for all Na and K lines and zero absorption beyond. We have not considered the presence of clouds. We consider an atmosphere with a solar metallicity and solar elemental abundances from [6].

We compute the abundance profiles at chemical equilibrium and spectra for various temperature profiles (Fig. 1). We compare the result without iteration of the models in similar condition (i.e. same imposed temperature profile). Then we apply the iterations needed for the full convergence of a model to radiative-convective equilibrium in four more realistic cases (Fig. 2). At the end, we retrieve resulting spectra to compare the difference in term of resulting temperature and abundances.

3. Summary and Conclusions

We defined a benchmark protocol and used it with success to compare and update 4 models.

We find that the assumed model parameters that have the most major impact on the calculated spectra are: a) Assumed alkali metal line shape; b) the assumed absorption spectrum of PH_3; c) and what correction for sub-Lorentzian line shape is assumed.

All spectra and profiles will be soon available for the community. We encourage the community to compare them to their models in these benchmark conditions and iterate with us to continue to improve our respective models and identify the existing differences.

Acknowledgements

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