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Spectroscopic characterization of the atmosphere of potentially habitable planets: GL 581 d as a model case study

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Abstract

The spectral characterization of potentially habitable planets is a major task for the exoplanet community and of prime interest for the search of extraterrestrial biospheres. Currently, one such potentially habitable planet is known outside the solar system, namely GL 581d.

Based on different model atmospheres of GL 581d and resulting synthetic spectra, we will show how the possible investigation of potentially habitable planets could be used to infer atmospheric and surface conditions. In the considered case of GL 581d-like planets, we find that the presence of an atmosphere could be inferred from broad absorption bands of water and carbon dioxide in the spectra. The characterization of surface conditions and distinguishing different atmospheric scenarios is however difficult.

A very interesting challenge is the possibility of a false-positive detection of so-called biomarkers such as ozone in the spectra due to the presence of carbon dioxide absorption bands close to the position of the main ozone band.

1. Introduction

Currently, more than 500 exoplanets are known. For more than 30 of them, spectroscopy or photometry (either from ground or from space) has been attempted to characterize the chemical composition of their atmospheres, the vertical temperature structure or the strength of the atmospheric circulation. Among these planets are also two transiting super-Earths, CoRoT-7b and GJ 1214b. These planets are however far too hot to be considered habitable in the classical sense.

The super-Earth candidate GL 581d [1] is the first potentially habitable exoplanet discovered so far (e.g., [3, 4]). Hence, it is taken as an illustrative example for discussing the spectral characterization of habitable planets, even if GL 581d itself is not a transiting planet.

2. Models

We use model atmospheres of GL 581d simulations to calculate synthetic spectra of GL 581d.

The atmospheric profiles of the model atmospheres have been calculated with a 1D radiative-convective model [3]. This model takes into account energy transport via radiation and convection for the calculation of atmospheric temperature profiles. The condensing species for a potential wet adiabatic lapse rate and the species used for estimating the greenhouse effect are water and carbon dioxide. Additionally, molecular nitrogen is considered in the atmospheres as a filling gas.

With the results of the 1D model, emission and transmission spectra are calculated with a high-resolution line-by-line radiative transfer model [2]. Based on these spectra, the possible characterization of the respective atmospheric scenarios is discussed.

3. Scenarios

We considered three different atmospheric scenarios, with low (355 ppm), medium (5%) and high (95%) CO_2 concentration. For each of these scenarios, the surface pressure is varied between 1 and 20 bar. The planetary and stellar parameters are taken from [1] and [3].

Spectra have then been calculated for the IR, considering a spectral range from 1-25 μm.

4. Summary and Conclusions

The spectral characterization of the potentially habitable super-Earth GL 581d and its atmosphere via emission and transmission spectroscopy was modeled as an example of possible future spectroscopic investigations of candidate habitable planets.

Water and carbon dioxide could be clearly seen in the calculated spectra due to prominent absorption bands, indicating the presence of an atmosphere. However, it was shown that emission spectroscopy is not very well suited to discern the different atmospheric scenarios or to assess surface conditions, hence habitability. Transmission spectroscopy allows for a much better characterization.

Results also indicate that the search for biomarkers in GL 581d-like atmospheres, hence the confirmation of the presence of life, suffers from the possibility of false-positive detections. This is due to absorption bands of CO_2 which occur close to main biomarker absorption bands. However, if the main CO_2 IR bands are observed simultaneously, such false-positive detections could be avoided.

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References

[1] Mayor, M., Bonfils, X., Forveille, T. et al. 2009, Astron. Astrophys., 507, 487

[2] Schreier, F. & Böttger, U. 2003, Atmospheric and Oceanic Optics, 16, 262

[3] von Paris, P., Gebauer, S., Godolt, M., et al. 2010, Astron. Astrophys., 522, A23

[4] Wordsworth, R., Forget, F., Selsis, F., et al. 2010, Astron. Astrophys., 522, A22