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Thermal Emission Spectra of Earth-like Extrasolar Planets and the Effects of cloud layers

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Abstract

We present first results on the impact of multi-layered clouds in the atmospheres of Earth-like extrasolar planets orbiting different types of central stars on the planetary thermal IR emission spectra at low resolution.

1. Introduction

The climate of Earth-like planets results from the energy balance between absorbed starlight and radiative losses of heat from the surface and atmosphere to space. Since clouds reflect sunlight back towards space, reducing the stellar energy available for heating the atmosphere (albedo effect), but also lowering radiative losses to space (greenhouse effect), they evidently influence e.g. the surface temperature and thereby also the (potential) habitability of a planet. Clouds also have a large impact on the IR emission spectra of planetary atmospheres, by either concealing the thermal emission from the surface or dampening the spectral features of molecules, which is, of course, also true for biomarkers (e.g. O_3).

2. Computational details

A one-dimensional steady state radiative-convective atmospheric climate model is used here to study the effects of clouds on the climate and emission spectra of Earth-like planets orbiting different types of central stars (see [Pavlov et al.(2000)], [Segura et al.(2003)], [Segura et al.(2005)], and [Kitzmann et al.(2010a)] for details of the model). In particular, the influence of two different cloud layers (low-level water and high-level ice clouds) are included in the model. The model uses the measured value of the Earth surface albedo. In clear sky model calculations of Earth-like planets the surface albedo has to be tuned to mimic the climatic effects of clouds by prescribing the resulting surface temperature (see e.g. [Segura et al.(2003)], [Segura et al.(2005)]). In contrast, the surface temperatures are direct results of our atmospheric model calculations including the effects of clouds. Details about the developed cloud description and the calculation of the particle size and wavelength dependent optical properties of both cloud types are given in [Kitzmann et al.(2010a)]. The chemical composition of the atmospheres is chosen to represent the modern Earth atmosphere and was calculated using a photochemical model (cf. [Grenfell et al.(2007)]). Four different types of central stars are considered in this study: F2V, G2V, K2V, and M4.5V-type stars. The incident stellar fluxes are scaled by varying the orbital distances, such that the frequency integrated energy of each stellar spectrum at top of the atmosphere of the corresponding Earth-like planet equals the solar constant.

3. Results

Due to enhanced cloud absorption and scattering of the outgoing radiative IR flux, the presence of clouds generally results in an overall decrease of IR emission compared to the respective clear-sky conditions. These results have been confirmed by measurements of the emission spectra of Earth published by [Hearty et al.(2009)]. However, assuming clear sky conditions, the calculated planetary surface temperature differs for all four central stars from the measured mean Earth surface temperature of 288.4 K. Consequently, the mean Earth surface temperature can only be reached by implicating different combinations of low and high-level cloud coverages for each stellar type. Fig. 1 shows four different computed low-resolution IR emission spectra for 60% low-level clouds with the required high-level cloud cover, for which the planets reach a surface temperature of 288.4 K. Besides the overall decrease of IR emission, the individual spectral features of molecules are also dampened by the presence of clouds (see also [Kitzmann et al.(2010b)] for a more detailed discussion). The spectral absorption band feature of the biomarker ozone (at ≈ 9.6 μm) is especially affected by the high-level cloud. Even though the atmospheric profile of ozone is considered to be the same for all atmospheres, the absorption feature of ozone can disappear due to the effects of clouds (e.g. for the F-type star case). In general, the depths of the molecular IR features decrease with increasing high-level cloud cover.

4. Summary

The detectability of molecular absorption signatures in the IR spectral region is strongly influenced by the presence of clouds and may become impossible at low resolution for high cloud coverages. This is especially apparent in case of the F-type star, where for high ice cloud coverages no molecular absorption features at all are visible in the calculated low-resolution spectrum of an Earth-like planet.

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References

[Grenfell et al.(2007)] Grenfell, J. L., Stracke, B., von Paris, P., et al. 2007, Planet. Space Sci., 55, 661

[Hearty et al.(2009)] Hearty, T., Song, I., Kim, S., & Tinetti, G. 2009, ApJ, 693, 1763

[Kitzmann et al.(2010a)] Kitzmann, D., Patzer, A.B.C., von Paris, P., et al. 2010, A&A, 511, A66

[Kitzmann et al.(2010b)] Kitzmann, D., Patzer, A.B.C., von Paris, P., et al. 2010, A&A, submitted

[Pavlov et al.(2000)] Pavlov, A. A., Kasting, J. F., & Brown, L. L. 2000, J. Geophys. Res., 105, 11 981

[Segura et al.(2003)] Segura, A., Krelove, K., Kasting, J. F., et al. 2003, Astrobiology, 3, 689

[Segura et al.(2005)] Segura, A., Kasting, J. F., Meadows, V., et al. 2005, Astrobiology, 5, 706

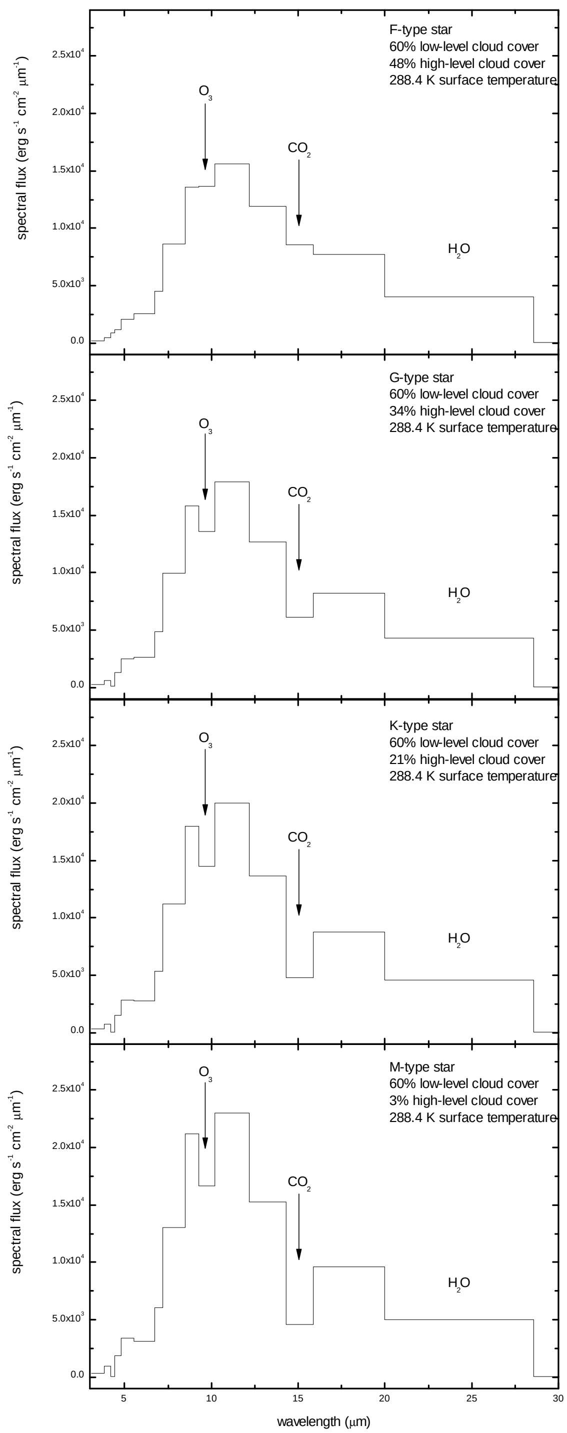

Figure 1: IR emission spectra of Earth-like planets with cloudy atmospheres orbiting different types of stars ([Kitzmann et al.(2010b)]).