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Models of cloudy exoplanetary atmospheres

M. D. J. Hollis, G. Tinetti
(1) University College London, Gower Street, London, WC1E 6BT, UK (mdjh@star.ucl.ac.uk)

Abstract

We present a code to model one-dimensional radiative transfer in exoplanetary atmospheres, in the primary transit, or terminator, geometry [3]. This code is designed to be able to produce a first order estimate of the transmission spectrum that one may expect to observe from an object, given a modelled atmospheric temperature structure and molecular composition, and has been used for previous studies of hot-Jupiters such as HD189733b [6] and WASP-12b [5]. Also presented is the application of this code to assess the effects of clouds and hazes in characterising exoplanet atmospheres, as part of the effort to evaluate the stability of potential retrievals of important atmospheric properties and to quantify possible errors in the interpretation of the available observations. This is an important and timely inclusion given the current focus of the atmospheric retrieval field.

1. Introduction

With the increased interest in observational and theoretical study of extrasolar planets in recent years, atmospheric retrieval and the ability to characterise such objects have become prominent areas of current research. To this end the TAU code [3] has been developed to produce models of the transmission spectra that one may expect to observe from an exoplanet in primary transit, given a modelled atmospheric temperature structure and molecular composition. This code has been used for previous studies of hot-Jupiters such as HD189733b [6] and WASP-12b [5] in order to test novel ground-based detection and data reduction procedures and to probe the extreme environments of highly-irradiated atmospheres.

In particular, the recent developments in the field have led to consideration of the effects that the presence of atmospheric hazes and cloud layers may have on the observations of exoplanets [2, 4, 1], and recent discussions concerning the interpretation of exoplanetary spectra have brought these issues to the fore. Hence this code has been extended to include a simple scheme to estimate the effects of additional opacities due to scattering particles and cloud layers. These modifications have been applied in studies of the best-observed exoplanets, over a broad wavelength range, in order to look at the effects of varying cloud and atmospheric properties, and to hence assess and quantify the possibilities for the retrieval of key atmospheric parameters.

2. Figures

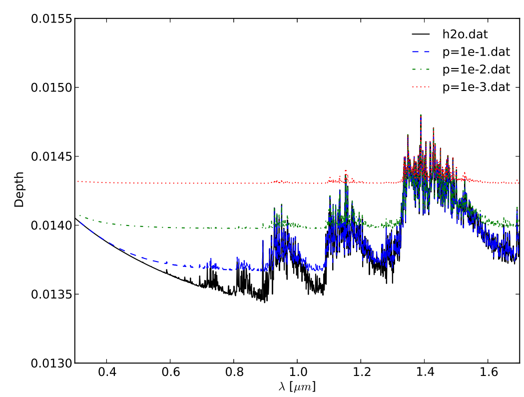

Figure 1: A modelled transmission spectrum, illustrating the effect of changing the pressure level (i.e. altitude) of the top of a potential cloud deck in the atmosphere, where p is the pressure in bar.

3. Summary and Conclusions

Presented here is the TAU code, which produces transmission models of the atmospheres of extrasolar planets. This has been validated and applied in previous studies, testing data reduction procedures and characterising atmospheres of exoplanets in extreme environments. It also has the capacity to estimate opacities due to haze particles and clouds decks; comparing models including such effects leads to an assessment of the stability of detections of likely absorbing molecular species, in terms of the ability to accurately estimate abundances and other vital atmospheric parameters.

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