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A New Method for Calculating Exoplanetary Spectra from 3D Simulations

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Abstract

The atmospheres of hot Jupiters are three-dimensional, non-linear entities and understanding them requires the construction of a hierarchy of models of varying sophistication. I report on a recently completed computational setup, of intermediate sophistication, which couples three-dimensional atmospheric dynamics with dual-band radiative transfer and convective adjustment. The relative simplicity of the setup allows for a more efficient sampling of the broad parameter space of hot Jupiter atmospheres. I also discuss work in progress in further coupling this setup with two approaches for predicting synthetic spectra. This three-way coupling between dynamics, radiation and the resultant spectra will allow us to systematically study the interplay between them and is key towards preparing for the theoretical interpretation of exoplanetary spectra which will be obtained by future space-based missions such as JWST and EChO.

1. Introduction

Much of the previous work on hot Jupiters has either focused on the 3D atmospheric dynamics (e.g., Cho, Rauscher) or coupled 3D dynamics with sophisticated, multi-band schemes for radiative transfer (e.g., Showman). As the atmospheres of hot Jupiters are 3D, non-linear entities, the way forward is to construct a hierarchy of 3D models of varying sophistication (Held 2005). Therefore, a reasonable approach is to combine the treatment of 3D dynamics with dual-band radiative transfer, where the assumption is that the stellar irradiation and re-emitted (infrared) radiation from the exoplanet are at distinct wavelengths.

Here, I report on the successful implementation of such a computational setup (Heng, Frierson & Phillipps 2011). I will demonstrate how we can self-consistently compute temperature-pressure profiles on both the day and night sides of a hot Jupiter, as well as the zonal-wind profiles, circulation cell patterns and the angular/temporal offset of the hot spot from the substellar point. In particular, the hot spot offset should aid us in distinguishing between different types of hot Jupiter atmospheres.

2. Work in Progress

Much of my current research effort is in elucidating a new method for predicting synthetic spectra of hot Jupiters and exoplanets in general. I will report on the progress made in the following two approaches:

a. the "forward" approach is where broad-band opacities are computed from standard opacity tables, fed into the 3D simulations and spectra is computed from the resultant temperature-pressure profiles. This is the traditional approach taken so far by groups capable of computing synthetic spectra from 3D simulations (e.g., Showman, Fortney).

b. the "reverse" approach uses the abundance retrieval method pioneered by early studies of the terrestrial atmosphere and recently applied to exoplanets by Madhusudhan & Seager, where the elemental abundances are derived, with error bars, from observations. The derived abundances are then converted into broad-band opacities as before. The advantage of this method is that one can use opacities specific to each case study (e.g., HD 209458b) and that the range of opacities used improves with time as the observations get better.

3. Summary and Conclusions

The ability to thoroughly, efficiently and systematically explore the interplay between atmospheric dynamics, radiation and the resultant, synthetic spectra is an important step forward, as it prepares us for the theoretical interpretation of exoplanetary spectra which will be obtained by future space-based missions such as JWST and EChO.

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