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Radiative hydrodynamics in exoplanet thermospheres

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Abstract

The thermosphere of a close-in exoplanet is a rarefied medium exposed to the energetic radiation of its host star. In these conditions, the thermospheric plasma is easily driven out of Local Thermodynamic Equilibrium (LTE) by the interactions between radiation, the population of excited states and its flow dynamics. The proper approach to investigate these interactions is a non-LTE (NLTE) treatment that includes both radiative effects and hydrodynamics. We present a NLTE model for the thermosphere of hot-Jupiter exoplanets, and demonstrate previously unexplored insight into: 1) the physical conditions that lead to recent measurements of atoms and molecules in some of these atmospheres; 2) the role of the above processes on the bulk mass loss.

1. Introduction

NLTE effects are potentially significant in the thermospheres of hot Jupiters. Strong stellar radiation together with low atmospheric densities drive the plasma away from LTE. In addition, plasma radiation introduces non-local effects in the atmosphere as photons may be emitted and re-absorbed multiple times. The complexity of these interactions remains largely unexplored save for some exceptions [e.g. 1].

2. The model

We have built a plasma model for hot Jupiter thermospheres that considers the population of excited atom states through the available collisional-radiative channels. It also considers the interaction of the atom states with the stellar and diffuse radiation. The treatment of the population and radiative problems is coupled to the atmospheric escape dynamics through the framework described in [2].

Our NLTE model considers collisional processes for excitation, de-excitation, ionization and three-body recombination. It also includes radiative processes for bound-bound, bound-free/free-bound and free-free transitions. The corresponding rates are drawn from a variety of sources in the plasma and astrophysics literature. For consistency, our treatment solves the radiative transfer equation:

$$\frac{dI_\lambda}{ds} = -\kappa_\lambda I_\lambda + \varepsilon_\lambda$$

with absorption (κ_λ) and emission (ε_λ) coefficients based on the thermodynamic properties and population of excited atom levels at each altitude.

3. Perspective

We will present simulations that demonstrate the interplay between the problem of atomic level population, radiation and hydrodynamics in hot Jupiter thermospheres, and connect them to existing measurements of a few atoms. We will also discuss prospects for future observations.

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References

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