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Escape of Hydrogen from HD209458b

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Abstract

Recent modeling of the atmosphere of HD209458b has been used to interpret the Lyman-α line and other observations during transits. In this presentation, we model the hydrogen exosphere of the short period, Hot Jupiter planet to investigate the dynamics of the extended hydrogen cloud and to determine the observability of relevant physical processes.

1 Introduction

[2] used a hydrostatic density profile in the thermosphere combined with the Voigt profile to estimate the Lyman-α transit depths for an array of model parameters. A detailed photochemical-dynamical model of the thermosphere was developed by [3] and used to again estimate model parameters to fit not only the Lyman-α transits, but also the transits in the O I, C II and Si III lines [4].

Recently, [1] modeled the escape of hydrogen from the extended atmospheres of HD209458b and HD189733b and used the results to interpret Lyman-α observations. They included acceleration of hydrogen by radiation pressure and stellar wind protons to simulate the high velocity tails of the velocity distribution, arguing that the observations are explained by high velocity gas in the system while Voigt broadening is negligible.

2. Modeling

In this work we connect a free molecular flow (FMF) model similar to [1] to the results of [4] and properly include absorption by the extended thermosphere in the transit model (see Figure 1). The solution and absorption are iteratively computed to find a consistent solution. In this manner, we can interpret the necessity of the various physical processes by comparing the simulated line profiles (see Figure 2) to observations [2]). Furthermore, the transit depths of this model can be used to re-evaluate the atmospheric model parameters to determine if they need to be adjusted due to the existence of the extended hydrogen tail.

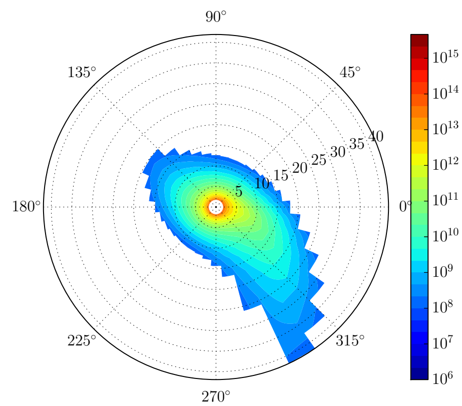

Figure 1: Simulated hydrogen density (m^{-3}) in the rotational plane with ionization due to 2 times solar UV. The orbital direction is up, and the star is to the left.

3. Summary and Conclusions

We have constructed a new model of the hydrogen exosphere of HD209458b. The extended hydrogen tail is formed by escaping atoms in the rotational frame, and modified by solar ionization and acceleration. This model improves our understanding of the exosphere compared to the 1-D escape assumptions of [3, 4], and by comparing the resulting column densities to the transit depths, we suggest improvements to the parameters used in that model. The observability of the solar ionization and acceleration on the hydrogen tail are discussed by looking at the column densities and at the simulated Lyman-α line profiles.

References

[1] Bourrier, V, Lecavelier des Etangs, A.: 3D model of hydrogen atmospheric escape from HD 209458b and HD

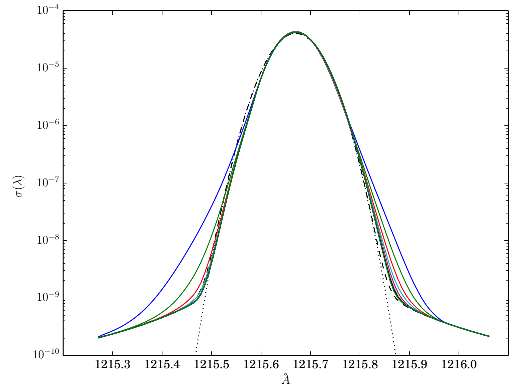

Figure 2: Simulated hydrogen Lyman-α cross section due to simulated velocity distribution and self-broadening for different ionization rates, without considering absorption by interstellar gas.

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[2] Koskinen, T.T., Yelle, R.V., Lavvas, P., Lewis, N.K.: Characterizing the thermosphere of HD209458b with UV transit observations. The Astrophysical Journal (2010).

[3] Koskinen, T.T., Harris, M.J., Yelle, R.V., Lavvas, P.: The escape of heavy atoms from the ionosphere of HD209458b. I. A photochemical-dynamical model of the thermosphere. Icarus (2013).

[4] Koskinen, T.T., Harris, M.J., Yelle, R.V., Lavvas, P.: The escape of heavy atoms from the ionosphere of HD209458b. II. Interpretation of the observations. Icarus (2013).