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A Hydrodynamic Modelling of Atmospheric Escape and Absorption Line of WASP-12b

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Abstract. Self-Consistent 2D modelling of stellar wind interaction with the upper atmosphere of WASP-12b has been performed. The two case-scenarios of the planetary material escape and interaction with the stellar wind, namely the 'blown by the wind' (without the inclusion of tidal force) and 'captured by the star' (with the tidal force) have been modelled under different stellar XUV radiations and stellar wind parameters. In the first scenario, a shock is formed around the planet, and the planetary mass loss is controlled completely by the stellar radiation energy input. In the second scenario, the mass loss is mainly due to the gravitational interaction effects. The dynamics of Mg_{II} and related absorption were modelled with three sets of different stellar wind parameters and XUV flux values.

Keywords. Dynamical evolution and stability, gaseous planets, hot Jupiters, etc.

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1. Introduction

WASP-12b is a close-orbit, short period hot Jupiter for which Fossati *et al.* (2010) have detected an extra absorption in the Mg_{II} resonance line cores. Because of the close orbital distance of WASP-12b, XUV radiation and stellar wind (SW) result in the escape (Khodachenko *et al.* 2007) of the ionized planetary atmosphere and associated mass loss. The main objective of the present work is to analyse the two scenarios namely the formation of bow-shock (scenario 1) and diffused cloud or torus (scenario 2) due to the planetary material escape to simulate the extra absorption in Mg_{II} resonance line (Fossati *et al.* 2010) and mass loss.

2. Multi-fluid Simulation results

A 2D model developed in (Shaikhislamov *et al.* 2014, Shaikhislamov *et al.* 2018) is adopted for the specific case of WASP-12b. The summary of the modelling parameters used for the simulations of the scenarios 1 and 2 as well as the calculated upper atmosphere mass loss rate are given in Table 1. Figure 1 illustrates the density distribution of the main interacting constituents and figure 2 shows simulated Mg_{II} absorption line, respectively for both scenarios.

3. Summary

The simulation results demonstrate that in the 'blown by the wind regime' when a slow SW condition and no tidal force are considered in the model, we observe a very strong

Table 1. Adopted parameters and mass loss rate.

Scenario	F_{XUV} $[ergcm^{-2}s^{-1}]$	n_{sw} $[cm^{-3}]$	V_{sw} $[kms^{-1}]$	T_{sw} $[MK]$	Mass loss rate $[10^{10}gs^{-1}]$
Blown by the wind	5	$1 \cdot 10^6$	226	1.4	9.91
Blown by the wind	10	$1 \cdot 10^6$	226	1.4	11.91
Blown by the wind	20	$1 \cdot 10^6$	226	1.4	20.49
Captured by the star regime	5	$1 \cdot 10^4$, $3 \cdot 10^4$	417	3.17	145.38, 222.98
Captured by the star regime	10	$1.5 \cdot 10^4$, $3 \cdot 10^5$	417	3.17	169.95, 197.64
Captured by the star regime	20	$1.5 \cdot 10^4$, $3 \cdot 10^5$	417	3.17	186.53, 225.29

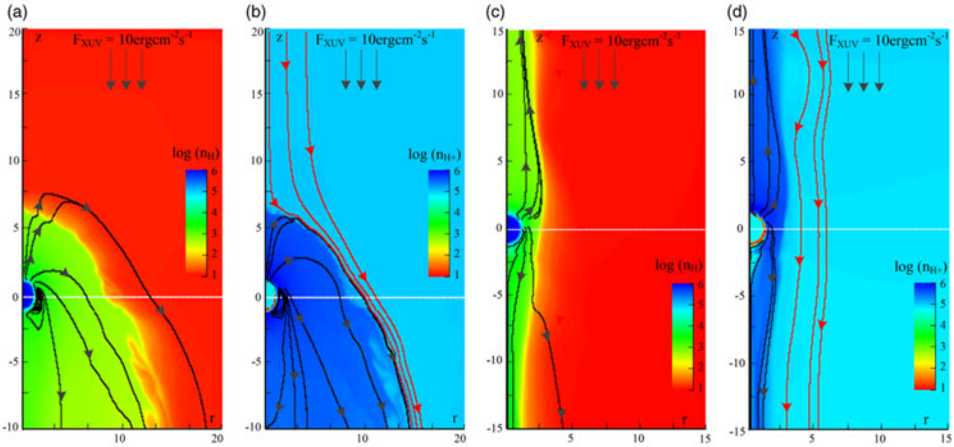

Figure 1. The density distribution of planetary atoms (a, c), ions and stellar protons (b, d) respectively in 'blown by the wind (a, b)' and 'captured by the star (c, d)' regimes.

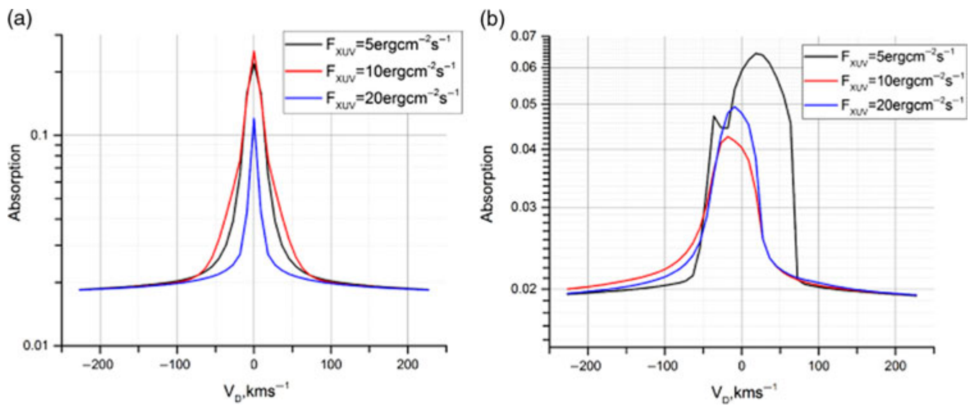

Figure 2. Absorption line profile of the Mg_{II} h line, respectively in 'blown by the wind (a)' and 'captured by the star (b)' regimes.

absorption of Mg_{II}. However, in the 'captured by the star' regime, we found that the change in the XUV radiation fluxes does not make a significant change in the absorption profile of Mg_{II} line. In the case of 'captured by the star' regime, the calculated absorption shows a good agreement with the observed value of absorption in Mg_{II} line which is 3–4 percent.

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