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On the exospheres of the rocky planets HD219134b and c

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Abstract

We simulate the formation of exospheres around the rocky planets HD219134 b and c. The exospheres are formed by surface particles that have been sputtered by the wind of the host star. The stellar wind properties are derived from 3D simulations driven by observationally-derived stellar magnetic field maps; our simulations are con strained by Ly-α observations of wind mass-loss rates. The interaction between the wind particles and the planets' crust makes the surfaces of planets b and c sputter, similarly to what occurs at Mercury. Due to the proximity of the planets to their host stars and, therefore, the high kinetic energy of the incident stellar wind particles, the sputtering process is sufficiently energetic to build up relatively dense metal-rich exospheres. We show that sputtering is expected to release refractory elements from the dayside surface of the planet, with elements such as oxygen and magnesium creating an extended neutral exosphere with densities larger than 10 cm^{-3}, within several planetary radii. By integrating the particle densities along the line-of-sight, we derive column densities of up to $\sim 10^{14}$ cm^{-2} for O and $\sim 10^{13}$ cm^{-2} for Mg, with higher column densities found ahead of the orbital motion of planets b and c.

1. Introduction

For planets similar to Mercury (i.e., weakly-magnetised and without a thick atmosphere), the stellar wind interacts directly with either their atmosphere or solid surface. Although lacking a substantial atmosphere, bodies like Mercury may hold a tenuous (i.e., non-collisional) gaseous envelope, forming their exospheres. This exosphere is made up of particles sputtered from the surface by precipitating solar wind protons and following ballistic orbits around the planet. Photoionisation of these neutral particles creates an ion population in addition to the ions directly ejected from the surface. Among the interaction processes, sputtering is considered to be the most energetic mechanism, leading to particles with energies of up to several hundreds of eV, distinctly exceeding the escape energies of many species at Earth-like planets. In this work, we start from the assumption that both planets have lost their CO2-dominated atmosphere and do not host a significant magnetic field. We use state-of-the-art models of stellar wind and wind-induced sputtering to investigate the effects that the wind of HD219134 has on building up an exosphere on the two inner-most planets and how the wind interacts with it.

2. Discussion and Conlusion

Our stellar wind model is possibly the most well constrained to date after that of the Sun. We used observationally-derived maps of the stellar surface magnetic field for the inner boundary of our 3D wind model. Additionally, the mass-loss rate derived in our wind model is constrained by Ly-α observations of the stellar astrosphere. We then used the results of our stellar wind model to quantify surface sputtering for the two planets and estimate the density and structure of the planetary exospheres.

Our results can be summarised as follows. The large-scale magnetic field of the planet-hosting star HD219134 can be described as a dipole whose axis is roughly perpendicular to the stellar rotation axis. As a consequence, the stellar wind of HD219134 is highly non-axisymmetric, which implies that planets orbiting in the equatorial plane of the star interact with low and high speed winds in a very short timescale.

The simulations show that sputtering processes release refractory elements from the entire dayside surface with velocities sufficiently high to allow for elongated trajectories of the sputtered particles. In particular, we find that oxygen and magnesium are expected to form an extended neutral exosphere with densities larger than 10 cm^{-3}, within several planetary radii. Because of the close proximity of both planets to the host star, a substantial amount of the neutral atoms will quickly be ionised and picked up by the stellar wind. The simulations suggest the column density of oxygen to be on average up to $\sim 10^{13}$ cm^{-2} close to the day-side of planet b and an order of magnitude smaller for planet c. Further, the column densities are not symmetric, with enhanced densities ahead of the planets' orbits.

3. Equations

Below, you will find examples of two equations. You should use an equation editor of your word-processing program in order to include your equation(s). The equation number should be placed at the right side of the column and all equations should be consecutively numbered.

$$a^2 + b^2 = c^2 \quad (1)$$

$$E = m \cdot c^2 \quad (2)$$

4. Summary and Conclusions

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The Acknowledgements section should not be numbered. Here, you may include all persons or institutions which you would like to thank. We recommend that the abstract is carefully compiled and thoroughly checked, in particular with regard to the list of authors, **before** submission.

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