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ENAs around HD 209458b: Estimations of magnetospheric properties

M. Holmström (1), A. Ekenbäck (1), P. Wurz (2), J-M. Grießmeier (3), H. Lammer (4), F. Selsis (5), and T. Penz (6)

(1) Swedish Institute of Space Physics, Kiruna, Sweden (matsh@irf.se), (2) Physikalisches Institut, University of Bern, Switzerland, (3) Netherlands Institute for Radio Astronomy, Dwingeloo, The Netherlands, (4) Space Research Institute, Austrian Academy of Sciences, Graz, Austria, (5) Laboratoire d'Astrophysique de Bordeaux, Université Bordeaux 1, Floirac, France (6) INAF – Osservatorio Astronomico di Palermo, Italy

Abstract

HD 209458b is an exoplanet found to transit the disk of its parent star. Observations have shown absorption in the stellar Lyman-α line during transit, revealing a large population of high-velocity atomic hydrogen around the "hot Jupiter" HD 209458b. This work expands on an earlier work studying the production of energetic neutral atoms (ENAs) as a result of the interaction between the stellar wind and the exosphere. We present an improved flow model of HD 209458b and use stellar wind values similar to the ones in our solar system. We find that the ENA production is high enough to explain the observations, and we show that – using expected values for the stellar wind and exosphere – the spatial and velocity distributions of ENAs would give absorption in good agreement with the observations. We also study how the production of ENAs depends on the exospheric parameters, and establish an upper limit for the obstacle standoff distance at approximately 4-10 planetary radii.Finally we compare the results obtained for the obstacle standoff distance with existing exomagnetospheric models, and show how the magnetic moment of HD 209458b can be estimated from ENA observations for different exospheric scenarios.

Background

HD 209458b is a Jupiter-type planet for which several transits in front of its parent star were discovered in 2000. Observations with the Hubble Space Telescope (HST) show absorption in the Lyman-α line (at 1215.67 Å) during transit, revealing the occurence of high-velocity atomic hydrogen around HD 209458b [3, 4]. This has been interpreted as hydrogen atoms in the exosphere undergoing hydrodynamic escape, further accelerated by the stellar radiation pressure [3, 5]. Recently an alternative explanation was suggested by [6], showing that energetic neutral atoms (ENAs) created by charge-exchange between the stellar wind and the exosphere can explain the observations. ENAs resulting from the interaction of the solar wind with a planetary environment have been observed at Earth, Mars and Venus, and charge-exchange with stellar wind protons around HD 209458b can explain the high-velocity hydrogen in analogy with these observations in our solar system. Here we study how an improved flow model for the stellar wind will affect the ENA production. In particular, the changes to the flow model are:

1. Stellar wind protons reaching the obstacle boundary are now reflected at the obstacle boundary to model the deflected stellar wind flow around the obstacle. In the earlier model the protons arriving at the obstacle boundary were deleted.

2. The forces on hydrogen atoms in [6] were inaccurate at large distances from the planet since only the Coriolis force from the rotating coordinate system represented the gravity of the star. Star gravity and centrifugal force on the particles are now included.

We also investigate if it is possible to infer properties of the planetary obstacle to the stellar wind from the ENA observation, e.g. if the planet is magnetized or not.

References

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