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On the Io-type plasma source in Hot Jupiters systems

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Abstract

We discuss the possibility of the existence of Io-type plasma source in the exoplanetary systems from the stability point of view. We point out that close-in exoplanets possibly have no or only very small moons because of the small Hill radii defined by their proximity to the host stars. For close-in Hot Jupiters, the Hill radius is of the order of only several planetary radii. Some exoplanets, e.g. WASP-12b, are so inflated, that they are believed to fill their Roche lobes with the expanded atmosphere only. For stability reasons, the orbits of the moons have to be within the Hill sphere of their planets, this makes the very existence of the Earth- and even Io-size moons in such systems questionable, and, thus, probably also the Io-type plasma source. However, one can not exclude plasma producing exomoons orbiting in or near the Lagrange points L4 and L5. We discuss also the outgassing rates of such an exomoon in comparison to Io.

1. Introduction

WASP-12b is a planet which showed a significant early ingress in UV observations [1]. This result was later confirmed [2]. The following sources for the absorption were suggested: the optically dense material in the vicinity of a planetary bow shock [1, 2] and a plasma torus outgassed by an exomoon of the size of Io, assuming the same outgassing rate [3]. The same plasma torus hypothesis was also applied to HD 189733b.

In this work, we compare the Jupiter satellite system to those suggested at Hot Jupiters WASP-12b and HD 189733b. We study potential orbits of these satellites from the dynamical point of view and discuss possible outgassing rates a satellite may have in a Hot Jupiter system compared to Io.

2. Method

We study the stability of the satellites by means of numerical simulations using a Bulirsch-Stoer integration method with adaptive stepsize. In addition to the orbit, we calculate the variation equations for the tangent vectors whose evolution defines the orbital behavior via the FLI (Fast Lyapunov Indicator), a chaos indicator which was introduced in an earlier study [4]. Taking into account the architecture of the considered Hot Jupiter systems and assuming different orbital parameters and mass of the satellites, we analyse the extension of the stability zones around L4 and L5 in the circular restricted and in the three body problem. Our results are in agreement with an earlier study [5].

3. Results

Fig. 1 shows the dependence of the maximal possible separation between an exoplanet and its satellite on the planet's orbital distance assuming three different mass ratios between the planet and the star.

4. Summary and Conclusions

Considering small possible masses of the exomoons in Hot Jupiters systems, one has to reinvestigate the possible outgassing rate a small moon can produce in comparison to Io. Also, one has to take into account the small orbital separation between an exomoon and a Hot Jupiter needed for the stability of the exomoon orbit and/or its possible short life time. These factors together make the explanation of the early egress observed at WASP-12b by plasma outgassing from an exomoon rather unrealistic.

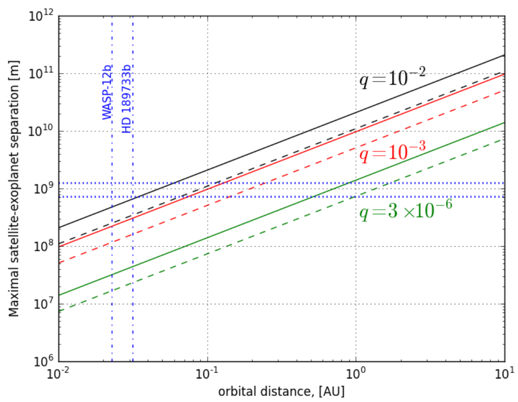

Figure 1: Maximal possible separation for retrograde (solid lines) and prograde (dashed lines) satellites depending on the orbital separation for three possible values of planet-star mass ratio $q = 10^{-2}; 10^{-3}; 3 \times 10^{-6}$ (black, red, green lines, respectively).

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