Complex Planetary Systems II: Latest Methods for an Interdisciplinary Approach
Proceedings IAU Symposium No. 382, 2024
A. Lemaitre & A.-S. Libert, eds.
doi:10.1017/S1743921323004805

Multi-planet systems explored: the case of the HD34445 system revisited

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Abstract. HD34445 is a system that consists of a star and six planets. In some previous work, we investigated the dynamical stability of the system by means of numerical simulations. Here, we explore the system further by carrying out additional numerical experiments. A total of 100000 simulations confirm previous findings of the stability status of the system at the 1σ and 99% c.i. level. We find that only 2.7% of the systems with parameters varied within 1σ from the mean were unstable, while that percentage rose to about 28% for systems with parameter values taken within the 99% c.i. These preliminary results are presented and discussed herein.

Keywords. chaos, methods: numerical, techniques: radial velocities, celestial mechanics, planets and satellites: dynamical evolution and stability

1. Introduction

HD34445 is a system that hosts six planets. The first planet, a sub-Jupiter mass body, was discovered a while ago by Howard *et al.* (2010). A few years later, Vogt *et al.* (2017) revised the orbital solution for HD34445b and announced the detection of another five planets in the system. In some previous work Georgakarakos & Dobbs-Dixon (2019) tested the validity of the solution proposed in Vogt *et al.* (2017) by investigating the dynamical stability of the system. Here, we extend that work by exploring further aspects of the problem.

2. Method

The dynamical stability of the system is investigated by means of numerical simulations. Contrary to what was done in Georgakarakos & Dobbs-Dixon (2019), where the stability of the system was mainly investigated by varying only one parameter at a time and for a rather limited number of cases, here, we create a pool of initial conditions for the masses, eccentricities, semi-major axes, mean anomalies and longitudes of pericentre of all planets drawn from normal distributions with means and standard deviations given in Vogt *et al.* (2017). The parameter ranges are within 1σ or within the 99% credibility interval. Then, we simulate 50000 systems per case. As previously, stability means no hyperbolic orbits with respect to the star and no orbit crossings. We first investigate the system assuming that all bodies lie on the same plane of motion. For the simulations we used the Gauss - Radau integrator in Eggl & Dvorak (2010). We have set the code to stop the integration when any planet becomes hyperbolic.

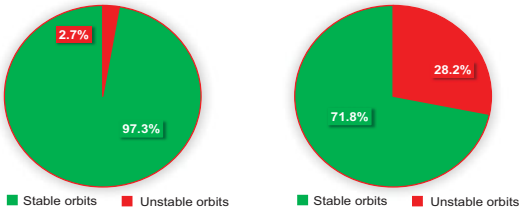

Figure 1. Stability pie charts for the 1σ (left) and 99% c.i. (right) cases.

3. Preliminary Results

Here, we present some results from the 1σ and 99% c.i. simulations. The 1σ results appear pretty stable with only 2.7% unstable orbits (1334 out of 50000), while the 99% c.i. group demonstrates a rather significant percentage of unstable systems (28.2%; 14102 out of 50000). Figure 1 is a graphical representation of these preliminary findings. In most of the unstable cases, it is the smallest planet, HD34445e, that gets ejected from the system. Regarding the initial conditions leading to instability, a quick inspection of them did not reveal any clustering around specific values or any significant difference compared to the initial conditions of the stable orbits. That was the conclusion when inspecting the parameters one by one or in pairs of two, e.g. mass against eccentricity. The only difference we noticed was when we looked at the eccentricities of HD3445d, HD3445c and HD3445f (i.e. the second, third and fourth planet as we move away from the star). It appears that there were more values near the high end of the range that led to unstable orbits than to stable ones. The difference, however, was not significant. It is likely though that as we proceed to grouping three or more parameters at a time, more evident patterns may emerge.

4. Outlook

The analysis on our current results will be extended and additional aspects of the dynamical stability of the system are going to be investigated such as for example the effect of General Relativity, three dimensional orbits and the importance of the presence of the outermost planet HD34445g.

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https://doi.org/10.1017/S1743921323004805 Published online by Cambridge University Press