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The dependence of the stability of hierarchical triple systems on the orbital inclination: preliminary results

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Abstract: We study the effect of the orbital inclination on the stability of hierarchical triple systems by means of numerical simulations. The aim of this work is to investigate the possibility that the stability boundary may be independent of the orbital inclination for certain mass ratios and initial orbital configurations. We start with hierarchical triple systems which are on initially circular orbits.

1 Introduction

In a recent paper [2], it has been suggested that the Hill stability boundary of a hierarchical triple system with a low mass inner binary is independent of the mutual inclination of the two orbits for certain orbital configurations. Thus, an interesting question to answer is whether that holds for general stability as well, i.e. whether there are certain values of the mass parameters and certain initial orbital configurations for which the stability boundary is independent or almost independent of the mutual inclination of the two binaries. Here, we attempt to get an answer to the above question by integrating numerically the equations of motion of inclined hierarchical triple systems.We investigate the stability of triple systems over a wide range of mass ratios and we deal at the moment with systems that are on initially circular orbits.

2 Method

We integrate numerically the equations of motion of hierarchical triple systems with initially circular orbits. The bodies are treated as point masses and no other effects than Newtonian gravity are taken into consideration. In order to perform our experiment, we use a symplectic integrator with time transformation [3], which calculates the relative position and velocity vectors of the two binaries at every time step. We introduce two mass parameters, $M_1 = m_2/(m_1 + m_2)$ and $M_2 = m_3/(m_1 + m_2)$, where m_1 and m_2 are the masses of the inner binary. For our simulations $M_1 = 0.5, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}$ and $M_2 = 10^{-7+i}, \quad i = 1, 2, ..., 13$. Hence, we have 91 different triple systems in terms of the masses. Each system is integrated for eleven values of the mutual inclination angle, i.e. $I = 0°$, 20°, 40°, 60°, 80°, 90°, 100°, 120°, 140°, 160°, 180°. For each inclination value, the system is started at eight different positions, i.e. $\phi = 0°$,45°, 90°, 135°, 180°, 225°, 270°, 315°, where ϕ is the initial relative phase of the two binaries. Regarding the initial period ratio X, we start from an appropriate value and we move down to X=1 by steps of 0.05.

A system is considered to be unstable when there is change in the hierarchy of the system, ejection of a body or escape of at least one member of the system during the integration time, which is set, for most of our systems, to 10000 outer orbit periods. For systems with smaller M_2 ($M2 = 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}$), whenever is necessary, the integration time is extended in a way to cover the secular period of the system at least a few times. For a given pair of the two mass ratios and for a specific value of the inclination and the initial orbital period ratio X, we define four stability categories: category one - the system is stable at all starting positions, category two - the system is unstable at one, two or three starting positions, category three - the system is stable at one, two or three starting positions, category four - the system is unstable at all starting positions.

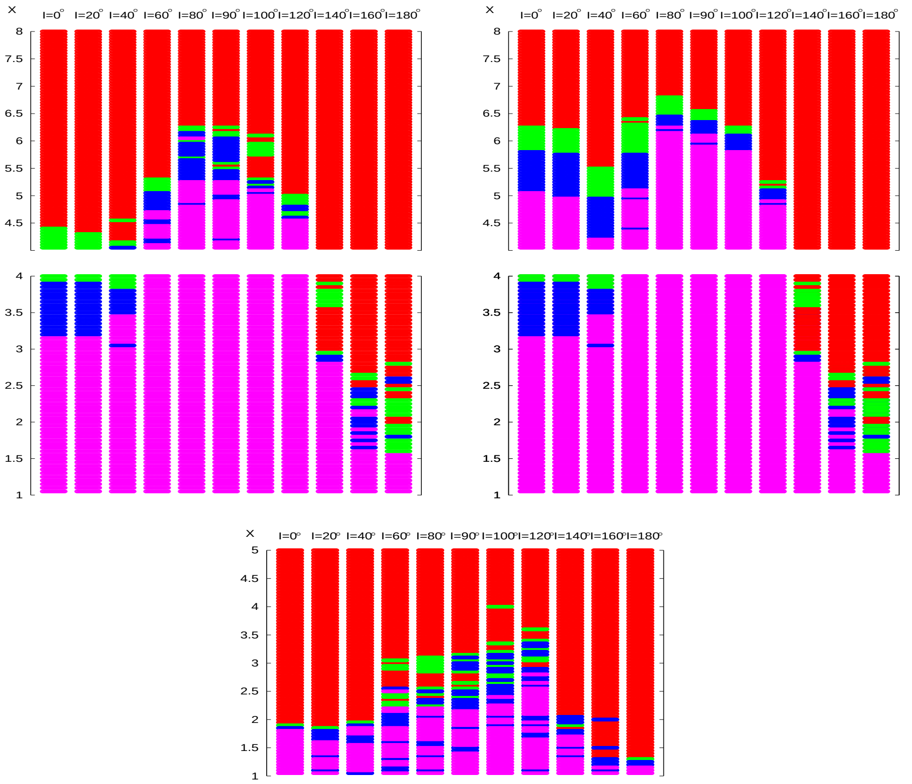

Figure 1: Stability plots for systems with $M_1 = 0.5$ and $M_2 = 1$ (left side), $M_1 = 10^{-5}$ and $M_2 = 10^3$ (right side), $M_1 = 10^{-3}$ and $M_2 = 10^{-2}$ (bottom). Each colour corresponds to one of the stability categories we defined earlier (first category: red, second category: green, third category: blue, fourth category: magenta). The columns in the graphs correspond to different mutual inclination angles.

3 Results

As we have stated, our main interest is to see whether there are areas in parameter space, where the stability boundary for a hierarchical triple system is (almost) independent of the mutual inclination of the two binaries. So far, the results from our simulations are more less as expected, i.e. a rather complicated stability boundary, highly inclined systems tend to be less stable that the rest due to the Kozai effect [1] and retrograde orbits appear to be more stable that prograde orbits. Figs. 1 present some results from our simulations.

4 Discussion

So far, our simulations found no evidence that the stability boundary of a hierarchical triple system could be insensitive to the variation of the mutual inclination of the system orbits. In order to complete this experiment, we still need to obtain results for smaller mass ratios ($M_2 < 10^{-2}$), as most of those systems require a much longer integration time than the 10000 outer orbit periods. As the current simulations deal with triple systems on initially circular orbits, our future aim is to extend our simulations to systems which have non-zero initial eccentricities.

References

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