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ASTEROIDS AND TERRESTRIAL PLANETS IN MULTIPLANETARY SYSTEMS

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Abstract. Most of the extrasolar planetary systems discovered seem to harbor only one big planet orbiting the host star. This is for sure just an artifact of the observations which are not precise enough to deduce from the available data correct orbital elements of other planets which we expect in such systems. To look for possible additional smaller bodies on stable orbits like terrestrial planets and asteroids these 'simple' systems can be treated in the framework of the restricted three body problem. Although from theory no qualitative analysis is possible there exist a detailed stability catalogue for additional celestial bodies in the restricted three-body problem which was compiled with the aid of very detailed numerical integrations. Being aware that in multiplanetary systems it is out of question to accomplish such a catalogue because of too many parameters to describe it properly we show how one can use this simple catalogue also for multiplanetary extrasolar systems.

1. INTRODUCTION

The race to find the first earth-like planet in extrasolar planetary systems (EPS) led to the finding of super-earth planets with several earth-masses like in the system Gl581. The stability of the systems can be directly checked by integrating the orbits with an appropriate n-body integrator for sufficiently long time. We stress this fact because quite often orbital elements of planets in EPS with more than one planet are published which seem to be on unstable orbits (Ferraz-Mello et al)! In addition to this problem we ask another question: how can we then check whether additional planets may move in systems where more than one gas giant is known? There exist several studies for specific systems (e.g. Asghari et al, Dvorak et al, Érdi et al) but no global study for 2 planet systems exist. For such a study one has to vary the published elements of these planets according to the error bars given by the observers (e.g. Ji et al, Jones et al, Menou & Tabachnik, Noble et al). But when we check the parameterspace we can see that it is hopeless to cover the whole parameter range: for a two planet system one has to take into account the mass ratios of the two planets with respect to the host star μ_1 and μ_2, the two different semimajor axes of the planets a_1 and a_2, furthermore the two orbital eccentricities e_1 and e_2, and in addition the two perihelions ω_1 and ω_2.

One quite often ignores the inclination, because they are unknown and cannot be determined from radialvelocity measurements where more of the up to known more than 300 planets have been detected in EPS. Also the masses for these kind of observations are only minimum masses and – something which one can see from numerical experiments and also from the catalogue which we use for our study – this makes a big difference for stability considerations.

2. THE EXOCATALOGUE FOR THE ELLIPTIC RESTRICTED THREE BODY PROBLEM

When we check the stability of an additional terrestrial planet or an asteroid, in a EPS with one big giant its mass with respect to the large planet can be ignored. Consequently the elliptic restricted three body problem as dynamical model applies, which is defined as follows:

Two primary bodies move in keplerian orbits around their common barycenter and the motion of a third, massless body moves in the same plane of the two massive bodies.

In hundreds of plots which were computed with the aid of the RLI [1] for different massratios star-planet and also different eccentricities of the primaries orbits the stability character of a massless body starting in the region inside (but also outside the large planet) [2].

3. TESTS FOR 2-PLANET EXOPLANETARY SYSTEMS

Different investigations were undertaken to ensure that this approach is valid:

1. A first test was for two Jupiter-like planets: we put one planet in 5 AU and another one in 15 AU, both with almost circular orbits. We show the graph of the comparison of direct numerical integrations for 1 million years. The 5 stability windows for this model are well represented when one uses only the elliptic problem (the largest one between $8.5AU \leq a \leq 9.5AU$. Consequently the Exocatalogue can be used for determining stable regions.

2. Because we know that between the orbits of Jupiter and Saturn all asteroids escape sooner or later we used the appropriate pictures of the Exocatalogue: one time for orbits outside Jupiter and another time for orbits inside Saturn. The respective results showed that none of the massless test-planets (asteroids) survived.

4. RESULTS FOR HD11964

As an example we show the results for the planetary system in HD 11964 consisting of a a Sun-like star (spectral type G5) and two planets of minimum masses (0.11 and 0.7 $M_{Jupiter}$), semimajor axes of 0.229 AU and 3.167 AU with relatively large eccentricities (0.15 and 0.3). From the respective plots one can see that only between 0.4 AU $\leq a \leq$ 0.8 AU a terrestrial planet would survive.

[1] A chaos indicator developed by Sándor et al

[2] http://www.univie.ac.at/adg

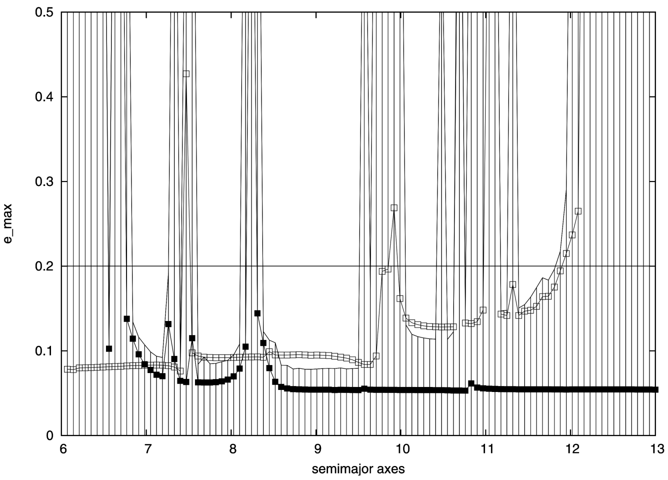

Figure 1: Region of possible motion for terrestrial planets in a exosystem with 2 Jupiter-like planet in 5 AU and 15 AU. Comparison of results of direct numerical integrations for the full problem with two massive bodies (impulses) and one model with the Jupiter inside and one with Jupiter outside in the elliptic restricted problem.

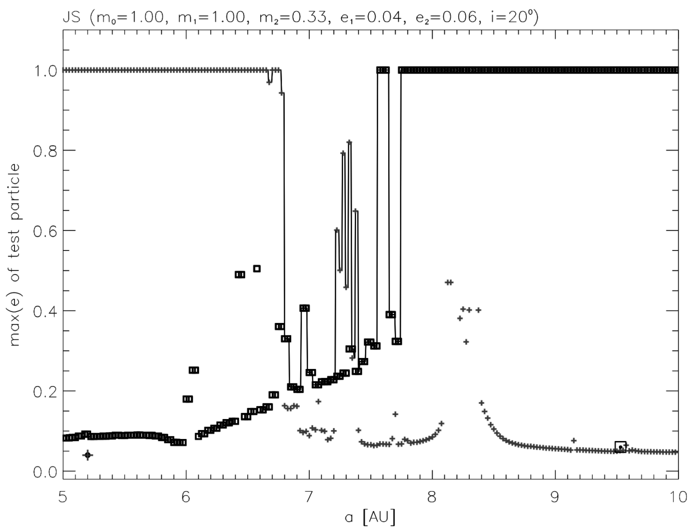

Figure 2: Region between Jupiter and Saturn in the Solar system maximum eccentricity versus the semimajor axes. Results derived by using the Exocatalogue.

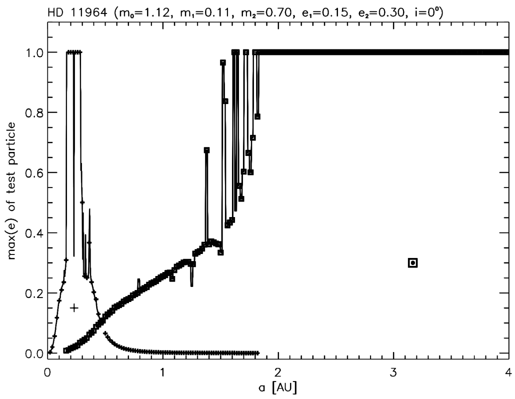

Figure 3: Region between Jupiter and Saturn in the Solar system maximum eccentricity versus the semimajor axes. Results derived by using the Exocatalogue.

5. CONCLUSIONS

We showed how one can use the results of an existing survey of the stability of terrestrial planets for exoplanetary systems hosting more than one giant planet. The big advantage is that for any new discovered system we can use the results from the exocatalogue to estimate immediately whether an additional Earth-like could be on stable orbits. Also we can – without new computation – do this estimate of a stable zone for a system where new observations provide better orbital elements of the planets involved. To finish we need to say that we have results for all known exoplanetary systems with two planets; this is the subject of a paper which is in preparation.

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