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Mean-motion and secular resonances in the triple asteroidal system 87 Sylvia

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Abstract

The triple system 87 Sylvia consisting of two small satellites (Romulus and Remus) orbiting around an asteroid in nearly circular orbits is studied. We model it using a four-body system Sylvia-Romulus-Remus-Sun with a spherical harmonics expansion up to the 4th degree and order for the gravitational potential of Sylvia. We integrate the equations of motion in two ways in order to study short and long periods; a complete one with an imposed fixed rotation rate for Sylvia on its principal moment on inertia, and an averaged one over the mean longitudes. We find that the semi-major axis of the satellites are bounded by mean-motion resonances (between the mean longitudes of the satellites) and by evection resonances (between the longitude of pericenter of Romulus and the longitude of the Sun).

1. Introduction

Nowadays a lot of asteroids have been identified as multiple in different populations. In 2005, Marchis et al. [4] discovered a second moon rotating about the asteroid 87 Sylvia (one of the larger of the Main Belt, already identified in 2001 as a binary). It is the first triple asteroid discovered and the one that we study here. The two satellites (named Romulus and Remus) are much smaller and evolve in nearly circular orbits. The satellites are sufficiently small and distant from Sylvia to be considered as point mass satellites. A first study was done on this system in [5]. Secular resonances were found when Sylvia is modeled by a sphere but disappeared when a 2nd degree gravity field for Sylvia is added. Our work show that other resonances are present in the non-spherical case.

2. Model

The gravitational potential of Sylvia is modeled by a spherical harmonics expansion up to the 4th degree and order. The coefficients of this developpement are computed by the software SHTOOLS developped by Mark Wieczorek (see [7]) and using the convex model of Sylvia available on DAMIT [6]. We use two different numerical models to integrate the motion of the satellites; the first one uses the complete equations of motion, taking into account the rotation of Sylvia, and the second one uses averaged equations of motions. Numerical simulations were made thanks to the local computing resources (Clusters ISCF and URBM-SYSDYN) at the University of Namur (FUNDP, Belgium).

Table 1: Orbital elements of the satellites ([4])

	a (km)	e	i (deg)
Romulus	1356 ± 5	0.001 ± 0.001	1.7 ± 1.0
Remus	706 ± 5	0.016 ± 0.011	2.0 ± 1.0

3. Mean-motion resonances

We first look for mean-motion resonances between the two satellites in a Sylvia-Romulus-Remus-Sun system. The rotation of Sylvia is supposed to be constant and its axis of rotation corresponds to its principal axis of inertia. Some orbital elements of the satellites are given in Table 1. For this analysis, we use the MEGNO chaos indicator, designed by [1]. On Fig.1, we compute the mean MEGNO related to the orbit of Remus for different values of the semi-major axis of the satellites (equivalent results are obtained by computing the one of Romulus). For stable quasi-periodic orbits, the mean MEGNO converges towards 2 and for chaotic motion, tends towards infinity. For orbits really close to a stable periodic orbit, the mean MEGNO converges towards 0. The resonances causing chaos on the map are clearly mean-motion resonances.

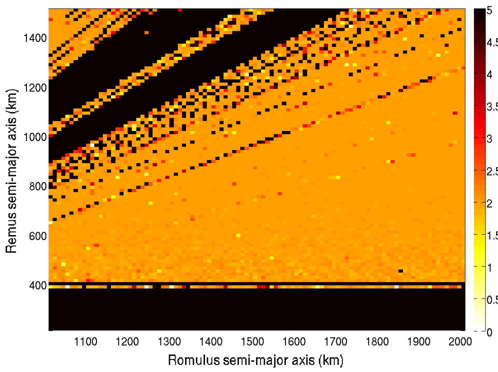

Figure 1: MEGNO map related to Remus. Integration time is 10 years.

4. Secular resonances

Aside from mean motion resonances, secular resonances can be found close to the satellites. These resonances involve the precession angles of the satellites and the mean longitude of the Sun. The averaged equations allow to clearly differentiate the secular dynamics of the satellites and are much faster to numerically integrate than the complete ones. We then check the chaotic diffusion of the orbits by computing the change of their frequencies over time, using frequency analysis [3]. In particular, we found near Romulus low-order secular resonances that can induce a strong chaos. These are evection resonances [2] between the longitude of pericenter of Romulus and the longitude of the Sun ($\varpi_{Ro} - k\lambda_{\odot}$) where k is an integer. They are shown in Fig.2, where the chaotic diffusion of the orbit of Romulus is shown in function of its semi-major axis. These evection resonances are able to increase the eccentricity of Romulus over 0.25 in less than 2.10^4 yr.

5. Summary and Conclusions

We have studied the short-term and secular dynamics of the satellites of 87 Sylvia. To this aim we used very precise numerical integrations taking into account a realistic gravitational potential of the shape of 87 Sylvia, as well as averaged equations describing the long-term motion of the satellites. Results show the web of mean-motion resonances which are present close to

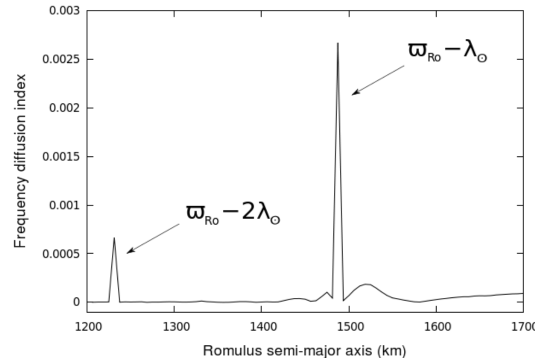

Figure 2: Chaotic diffusion of Romulus in function of its semi-major axis. Integration time is 6700 years.

the actual position of the satellites. The present orbits of the satellites are located in a quasi-periodic zone and show a very regular behavior over 5.10^4 yr. The same conclusion can be drawn from the study of the secular resonances acting close to the actual orbits of the satellites. The localisation of the major resonances and the chaotic regions are very important when drift of the orbital elements due to tides are taken into account. Indeed the satellites can potentially have to cross very powerful chaotic zones.

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