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Identification of asteroids in two-body and three-body mean motion resonances

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Introduction

The resonance represents a commensurability between the mean frequencies of the orbital motions of an asteroid and two planets (e.g., Jupiter and Saturn):

$$m_{\mathrm{J}}\dot{\lambda}_{\mathrm{J}} + m_{\mathrm{S}}\dot{\lambda}_{\mathrm{S}} + m\dot{\lambda} \approx 0, \qquad (1)$$

where $\dot{\lambda}_{\mathrm{J}}$, $\dot{\lambda}_{\mathrm{S}}$, $\dot{\lambda}$ are the time derivatives of the mean longitudes of Jupiter, Saturn, and asteroid, respectively, and m_{J}, m_{S}, m are integers.

In order to distinguish between resonant and non-resonant motions, the *resonant argument* is introduced:

$$\sigma_{p_{\mathrm{J}},p_{\mathrm{S}},p} = m_{\mathrm{J}}\lambda_{\mathrm{J}} + m_{\mathrm{S}}\lambda_{\mathrm{S}} + m\lambda + p_{\mathrm{J}}\varpi_{\mathrm{J}} + p_{\mathrm{S}}\varpi_{\mathrm{S}} + p\varpi, \qquad (2)$$

where λ_{J}, λ_{S}, λ, ϖ_{J}, ϖ_{S}, ϖ are the mean longitudes and longitudes of perihelia of Jupiter, Saturn, and an asteroid, respectively, and m_{J}, m_{S}, m, p_{J}, p_{S}, p are integers satisfying the d'Alambert rule:

$$m_{\mathrm{J}} + m_{\mathrm{S}} + m + p_{\mathrm{J}} + p_{\mathrm{S}} + p = 0. \qquad (3)$$

- If resonant argument (2) librates, the system is in resonance.
- If it rotates, the system is out of resonance.

Identification of resonances

As a first stage of the identification process we build an "identification matrix". It consists of two basic columns. The first one contains designations of resonances (in the notation $m_{\mathrm{J}}m_{\mathrm{S}}m(q)$), and the second one contains the resonant values of the semimajor axis.

At a second stage each asteroid's orbit from the adopted set of 249567 objects (from AstDyS catalog) is computed for 10^5 years (taking into account the perturbations of all planets and Pluto). Each argument σ_{res} is then analyzed on the subject of libration/circulation. We distinguish two types of resonant libration: pure and transient. The libration is pure, if it lasts during the whole time interval of integration (see Fig. 1). The libration is transient, if circulation appears at any time during this interval (see Fig. 2).

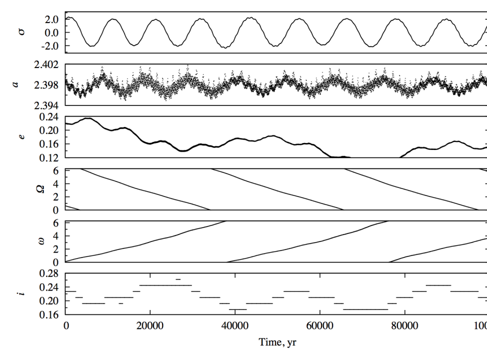

Figure 1: The resonant argument and orbital elements for 463 Lola, resonance $4-2-1$.

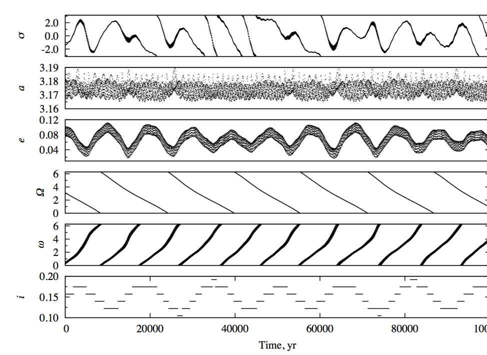

Figure 2: The resonant argument and orbital elements for 490 Veritas, resonance $5-2-2$.

Table 1: An extract from the identification matrix for three-body resonances

m_J	m_S	m	q	a_{res} (AU)
4	-2	-1	1	2.3981
5	-2	-2	1	3.1746
3	-2	-1	0	3.0801
3	-1	-1	1	2.7530
2	2	-1	3	2.6151

Results of identification

Table 2: Asteroids in three-body resonances, statistics

	NM98 [5]	This study $q_{max} = 6$
Studied set of objects	5400	249567
Objects with integrated orbits	836	249567
Pure-resonant objects	—	2516
Transient+pure-resonant objects	255 (4.6%)	11295 (4.5%)
Objects in two-body pure resonances *	—	3213
Objects in two-body transient+pure resonances *	—	4537

* Including Trojans and Hildas.

Conclusions

- The fraction of asteroids in three-body resonances (transient plus pure) turns out to be $\approx 4.5\%$ of the total studied set of 249567 asteroids. The fraction of asteroids in pure three-body resonances turns out to be $\approx 1.0\%$ of the total studied set.

- The top three most populated three-body resonances are: 4 -2 -1 (692 resonant asteroids), 5 -2 -2 (674), 3 -2 -1 (620).

- Except resonances 1/1 (Trojans) and 3/2 (Hildas), the top three most populated two-body resonances are: 11/5 (389 resonant asteroids), 2/1 (274), 8/3 (233).

References

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