# Non-integrable model describing some aspects of celestial bodies' dynamics in first order mean motion resonance

**Sergey Efimov, Vladislav Sidorenko**

*Moscow Institute of Physics and Technology, Dolgoprudny, Russia*
*Keldysh Institute of Applied Mathematics, Moscow, Russia*
efimov.ss@phystech.edu, vvsidorenko@list.ru

Mean-motion resonance (MMR) is the dynamical situation in characterized by commensurability between the orbital periods of two celestial bodies. Effects of bodies' interaction in the resonance are very different from non-resonant case. The study of MMR is very important, in particular, for problems of formation and stability of the solar system.

The commensurability $p+q\colon p$ ($p \in \mathbb{N}$, $q \in \mathbb{Z}$) is referred to as resonance of order $|q|$. Systems with the first order MMR are usually considered to be integrable [1]. However, there is evidence that dynamics of Pluto, which is in $2\colon 3$ orbital resonance with Neptune, is chaotic [2]. In this work, it is shown that integrability of the problem is a consequence of a rough approximation. General non-planar case within the circular restricted three-body problem is considered. The model Hamiltonian describing evolution of the system in the first order MMR more accurately is introduced. Following the technique originated from [3, 4], canonical variables are divided into slow and fast and the averaging method is applied to study long-term evolution of the orbit.

It is shown that the phase space of the system contains a region with adiabatic chaos. Some characteristics of emerging chaos are calculated, classification of all possible long-term evolution scenarios is presented and bifurcations in phase portraits of the system are analyzed.

## References

1. *Sessin W., Ferraz-Mello S.* Motion of two planets with periods commensurable in the ratio 2:1 solutions of the Hori auxiliary system // Celestial Mechanics. 1984. V. 32. P. 307–332.
2. *Wisdom J., Sussman G.J.* Numerical evidence that the motion of Pluto is chaotic // Bull. Amer. Astron. Soc. 1988. V. 20. P. 910.
3. *Wisdom J.* A perturbative treatment of motion near the 3/1 commensurability // Icarus. 1985. V. 63. P. 272–289.
4. *Neishtadt A.I.* Jumps in the adiabatic invariant on crossing the separatrix

and the origin of the 3 : 1 Kirkwood gap // Sov. Phys. Dokl. 1987. V. 32. P. 571–573.