SECULAR AND RESONANT EFFECTS GENERATED BY THE HYPOTHETICAL PLANET 9.

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The hypothesis of the existence of a planet with high eccentricity and inclination, not yet discovered, beyond the orbit of Neptune (called Planet 9), was developed by the authors Batygin y Brown (2016), to explain a series of anomalous dynamic behaviors in trans-Neptunian objects (TNO), such as the existence of objects grouped in their perihelion longitude ϖ, the distance of their perihelions from the Neptune region, or the existence of objects with a high inclination.

Viera 2023 (MSC Thesis) analyzes the validity and potential of using semi-analytical models for the study of secular and resonant dynamics generated by a disturber with high eccentricity and inclination, and its application to the Planet 9 hypothesis. We present here some of the relevant results.

Using a semi-analytic model the secular dynamics without limitations in (a, e, i) are studied, demonstrating that a disturber with high eccentricity and inclination is capable of reproducing the clusters in ϖ reported by Batygin y Brown (2016), for TNO with $a \geq 250$ ua. The parameters used for Planet 9 were: $m_9 = 10m_\oplus$, $e_9 = 0.6$ and $i_9 = 10°$.

By using a semi-analytical model for resonant dynamics, developed by Gallardo (2020), the characteristics of the resonances generated by Planet 9 are studied, the areas where they interact with the resonances of Neptune, and the generation of chaotic zones. The results are verified using dynamic maps (see Fig. 1).

We find that the resonances generated by an eccentric perturber are broad and depend weakly on the eccentricity of the particle (see Fig. 1) .

Using numerical integrations, the secular dynamics within resonances for a period similar to the age of the Solar System are studied. It is verified that the resonant dynamics is capable of generating groupings in ϖ for the same values as the secular dynamics. It is shown that secular dynamics within resonances is capable of generating particles with high inclination for $a > 250$ au. The best observation conditions for these objects, that means lower q, occur for $\Delta\varpi \sim 90°$ y $270°$ and $i \sim 90°$.

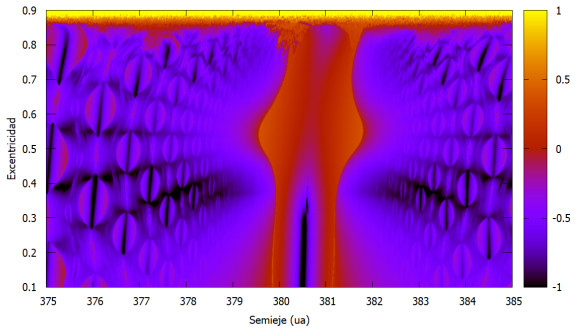

Fig. 1. Dynamic map for test particles with 375 au $< a <$ 385 au and $0.1 < e < 0.9$ generated, including Neptune and P9. The main structure is the resonance 5:2 with Planet 9. The color indicates the variation of the semimajor axis on a logarithmic scale.

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