Libration amplitude distributions of resonant Kuiper belt objects

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Abstract

We examine the dynamics of observed Kuiper belt objects (KBOs) that have been found to be trapped in various mean motion resonances (MMRs) with Neptune. We present the eccentricity, inclination, and libration amplitude distributions for the Plutinos (members of the 3:2 MMR) and several other occupied resonances. These orbital parameter distributions may provide a useful test of the dynamical mechanisms proposed for the origin of resonant KBOs and may help to constrain the nature and extent of Neptune's orbital migration history.

1. Background

The dynamical structure of the Kuiper belt has led to many discoveries about the dynamical history of the giant planets. The migration history of Neptune is of particular importance in sculpting the resonant structure of the Kuiper belt. There are two different models for giant planet migration that differ in terms of both the smoothness of Neptune's outward migration and Neptune's eccentricity evolution during this migration (see review by Morbidelli et al. 2008 [2]). The nature and extent of Neptune's migration should leave a signature in the resonant KBOs: capture into MMRs via resonance sweeping during smooth migration will result in a distinct distribution of libration amplitudes and eccentricities [1], different than if the resonant KBOs were captured into MMRs via gravitational scattering from an eccentric Neptune.

2. Preliminary Results

In previous work [5] we identified 194 resonant KBOs from the Minor Planet Center database in the semimajor axis range $30 < a < 50$ AU. We performed numerical simulations of their orbital evolution over 10 Myr and 4 Gyr with 10 clones of each observed KBO; the clones sampled the error ellipse of their orbital elements. For each identified q:p MMR with Neptune,
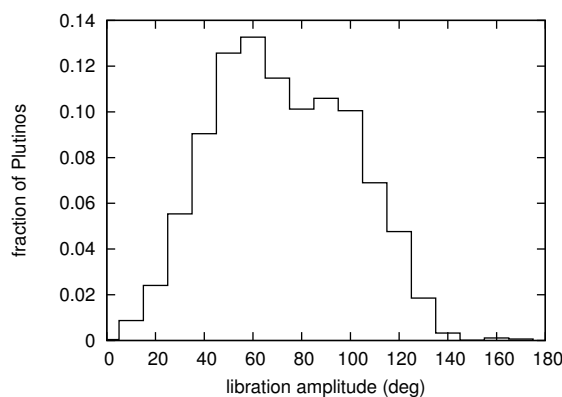

Figure 1: Amplitude distribution for the resonant angle $\phi = 3\lambda_{kbo} - 2\lambda_N - \varpi_{kbo}$ of 108 observed Plutinos.

we analyzed the evolution of the resonance angle

$$\phi = q\lambda_{kbo} - p\lambda_N - (q-p)\varpi_{kbo}. \qquad (1)$$

to determine stability within the resonance as well as the amplitude of the librations of the resonance angle. Figure 1 shows the libration amplitude distribution (determined from the 10 Myr numerical integration) of the 108 Plutinos (members of the 3:2 MMR) within our sample of observed objects. The eccentricity and inclination distributions of these Plutinos are shown in Figures 2 and 3. There are three other MMRs in our sample that contain significant numbers of KBOs: the 7:4 (28 members), the 2:1 (16 members), and the 5:3 (15 members). For each MMR we will present libration amplitude, eccentricity, and inclination distributions from both the 10 Myr and the 4 Gyr simulations. We will compare these results to previous studies of the observed resonant objects (such as Nesvorný & Roig 2000, 2001 [3, 4]), and we will discuss implications of these data for theoretical models of the origin of the dynamical structure of the Kuiper belt.
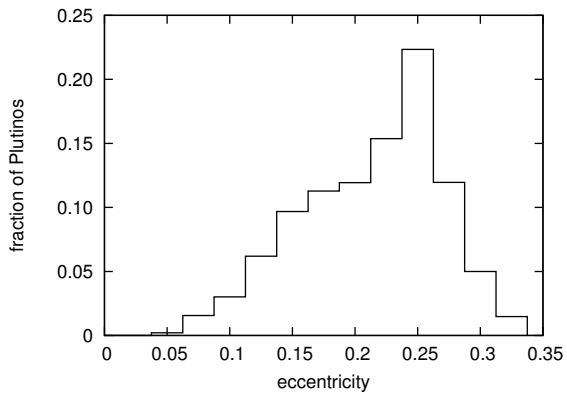
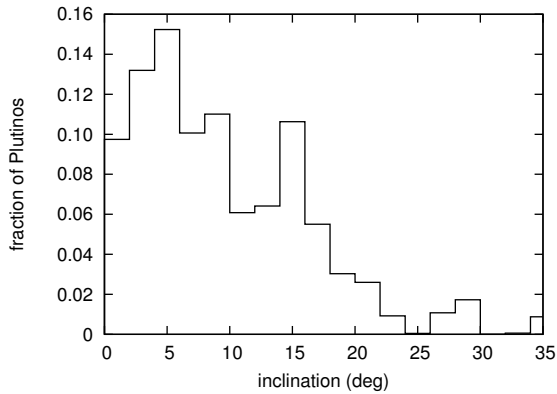Figure 2: Eccentricity distribution of the observed Plutinos.

Figure 3: Inclination distribution of the observed Plutinos.

Acknowledgements

References

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[3] Nesvorný, D. and Roig, F.: Mean Motion Resonances in the Trans-neptunian Region. I. The 2:3 Resonance with Neptune, Icarus, Vol. 148, pp. 282-300, 2000.

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