Origin of Scattered Disk Resonant TNOs: Evidence for an Ancient Excited Kuiper Belt of 50AU Radius

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A myriad of bodies orbit beyond Neptune (semimajor axes *a* beyond 30AU) representing the remnants left after planetary formation. These trans-Neptunian objects (TNOs) offer important clues on the origin and evolution of the solar system. We investigated TNOs dynamical properties by performing computer simulations using long-arc orbits (622 TNOs) plus several clones, totaling thousands of particles. We identified 196 TNOs locked in resonance with Neptune in the trans-Neptunian belt (or Edgeworth-Kuiper belt) and the scattered disk (typically at *a* greater than 48AU). Occupied resonances sorted by distance from the Sun are: 1:1 (Neptune Trojans), 5:4, 4:3, 11:8, 3:2, 18:11, 5:3, 12:7, 19:11, 7:4, 9:5, 11:6, 2:1, 9:4, 16:7, 7:3, 12:5, 5:2, 8:3, 3:1, 4:1, 11:2, and 27:4. Particularly, the most populated sites are the 3:2, 7:4, 2:1 and 5:2 resonances. Detailed general features for the resonant populations are also given (i.e., libration amplitude angles, libration centers, Kozai resonants, Kozai libration amplitudes, etc.).

In the scattered disk, we examined the long-term evolution of 27 resonant TNOs (in the 9:4 resonance and beyond) by integrating their orbits plus several clones over 4Gyr. The origin of long-term 9:4, 5:2, and 8:3 resonant TNOs (median ˜4Gyr) was investigated using static (i.e., giant planets at their current positions) and planetary migration dynamical models. All the simulations were evolved to 4Gyr and compared with observations. We found that the Gyr-resident populations of 9:4, 5:2, and 8:3 resonant TNOs are well explained through adiabatic resonance capture by a migrating Neptune over a dynamically excited ancient trans-Neptunian belt. Therefore, this suggests that the primordial planetesimal disk had at least 47-50AU in radius, and suffered a dynamical perturbation leading to 0.1-0.3 or greater eccentricities and a range of inclinations up to ˜20 degrees during early stages of the solar system existence, before planetary migration.