# “The origin of the Kuiper Belt high-inclination population” by Rodney S. Gomes [1]

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## 1 Abstract

The Kuiper Belt has been a source of some of the most puzzling questions in planetary science. Among these is the question of the origin of the structure of the belt. The Kuiper belt is usually broken down into the classical belt and the scattered disk. The classical belt extends from the 2:3 to the 1:2 resonances with Neptune, roughly 40 to 50 AU from the sun. The orbits in the classical belt have fairly low eccentricities. The scattered disk extends out much further than the classical belt and is made up of much more eccentric orbits. Further, the classical belt has been found to be composed of two distinct populations. [2] The first is a relatively high inclination population of larger bodies, dubbed the “hot” population, while the second, “cold” population, has lower eccentricities and smaller bodies.

One of the most successful theories to explain the Kuiper Belt structure was put forward by Renu Malhotra [3]. This theory is that during the late stages of solar system evolution, the giant planets migrated outwards due to energy and angular momentum exchange with a primordial disk of planetesimals. As the giant planets migrated outwards, they swept mean motion resonances across the disk, trapping planetesimals into those resonances. This is particularly true for Neptune. However, this mechanism did not correctly predict the large number of highly inclined orbits observed in both the classical belt and the scattered disk.

The paper by Gomes [1] attempts to remedy the deficiency in the model put forward by Malhotra [3] by examining integrations with far more but lower mass planetesimals than in previous attempts. Gomes uses a 2 part disk, with the inner disk extending from about 15 AU to 30 AU and the outer, less massive, disk extending from the outer edge of the inner disk out to 50 AU. Using this setup, and integrating for $10^8$ years, Gomes is able to achieve an inclination distribution similar to that observed in the real Kuiper Belt. The main mechanism for this is that a fraction of the objects in the inner disk are perturbed by close approaches from Neptune as it migrates outwards, are then trapped into a resonance, and finally escape the resonance at a low eccentricity so that they don’t have another close encounter. Some of these resonances, including the Kozai mechanism, can cause increased inclinations. Thus this mechanism produces a stable, moderately eccentric, relatively highly inclined population of Kuiper Belt Objects (KBO’s) as observed.

I propose to continue this line of investigation using the code PKDGRAV. My first order of business would be to see if I can reproduce the high inclination population of KBO’s. In order to make the integrations feasible I may need to make the planetesimals massless and have the giant planets migrate due to an artificial force as in some of Gomes’ simulations. If the integration time

is still too great, I may need to instead reproduce at least a few examples of KBO's escaping close approaches to Neptune. Once I have reproduced the essential result I would like to expand upon it by examining the effect of altering the distribution of planetesimals, as suggested by Gomes in section 2. This may or may not significantly effect the distribution of inclinations.

## References


[1] Gomes, Rodney S. 2003"The origin of the Kuiper Belt high-inclination population'", Icarus, 161, 404

[2] Levison, H.F. & Stern, S.A. 2001, Astronomical Journal, 121, 1730

[3] Malhotra, R. 1995, Astronomical Journal, 110, 420