

HOW WOULD PLANET 9 (IF IT EXISTS) AFFECT THE DISTRIBUTION OF PEBBLES AND PLANETESIMALS IN THE SOLAR SYSTEM? S. M. Lawler¹, ¹NRC-Herzberg, Victoria, BC (lawler.astro@gmail.com).

Introduction: Planet 9 is a hypothetical distant super-Earth in the outer Solar System that has been invoked to explain observed clustering of orbital angles in distant Kuiper Belt Objects (KBOs; [1, 2]). In [3], we performed detailed dynamical simulations of the distant Kuiper Belt with and without Planet 9 (Figure 1), and find that the distant Kuiper Belt should have a distinct configuration if a Planet 9 is present. However, using a survey simulator for four well-characterized surveys, [3] shows that these very distinct predicted Kuiper Belts are currently indistinguishable in observations.

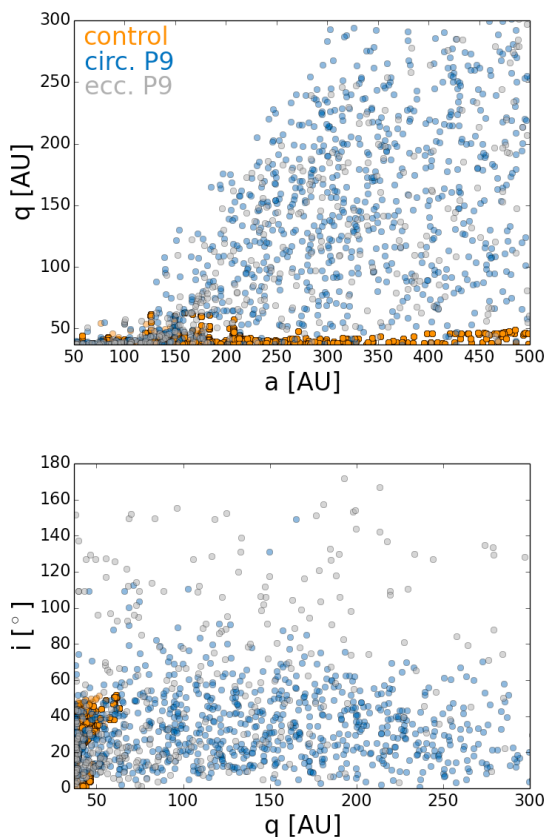


Figure 1: The semimajor axis (a), pericenter distance (q), and inclination (i) distributions of the distant Kuiper Belt (KBOs with $q > 37$ AU and $50 < a < 500$ AU) after 4 Gyr of integration with the known Solar System (orange), and including a circular orbit Planet 9 (blue), or an eccentric Planet 9 (gray). Including a Planet 9 lifts many KBOs onto high pericenter, high inclination orbits (Figure from [3]).

Planet 9 Formation scenarios: The N-body integrations in [3] did not include any planetary migration or capture, but instead emplaced and integrated the distant Kuiper Belt in the presence of Planet 9 on its current (hypothesized) orbit.

There are three possibilities for the formation of a large planet on a distant orbit like Planet 9: in-situ formation, scattering from the inner Solar System, or capture from a passing star.

In-situ Formation. [4] found that it is possible to create Planet 9 by pebble accretion over very long timescales. In this scenario, the distant planet could still be accreting, as formation times range up to Gyr timescales. If this was the case, the signature of Planet 9's presence would be growing stronger with time, and the high- q , high- i signature in the distant Kuiper Belt wouldn't be as pronounced as the simulations presented in [3].

Scattering. [5] showed that, if the scattering occurred before dispersal of the Solar System's gas disk, it would be possible to capture a large planet onto a distant orbit similar to that proposed for Planet 9. If this were the case, there should be a strong signature of Planet 9's passage through the region of the Kuiper Belt.

Capture. [6] and [7] present simulations of Planet 9 being captured from a passing star. Both find that it is possible to capture a planet with an orbit similar to the proposed Planet 9, though [6] finds that it is also likely that such a distant planet would be stripped off by later stellar flybys. [7] specifically models the Kuiper Belt and finds that it is possible to capture a Planet 9 and not disrupt the Classical Kuiper Belt.

Planetesimals and Pebbles: These three formation scenarios present widely different possibilities for the initial orbits of pebbles. I discuss each in turn.

In-situ Formation requires a massive disk at very large distances from the Sun. While not unheard of in protoplanetary disks or debris disks, there should be a signature of such an initial configuration in the orbits of distant KBOs: many more KBOs would have started on orbits with similar semimajor axes to Planet 9 and been scattered, and many should still be on very distant Planet 9-scattering orbits.

Scattering Planet 9 to a distant orbit from within the Solar System would be difficult without disrupting the Classical Kuiper Belt, and any remaining pebbles would be dispersed at this point and unable to form

more planetesimals. Recent papers such as [8] and [9] have simulated similar configurations in detail.

Capturing Planet 9 perhaps provides the best chance for belts of planetesimals and pebbles to survive. However, the simulations in [10] show that even initially tightly clustered KBO orbits will diverge sharply over Gyr timescales due to the perturbations from Planet 9, which may provide a time constraint on when in the Solar System's early history Planet 9 could be captured without disrupting planetesimals and pebble belts in the Kuiper Belt.

Conclusions: Planet 9's origin is difficult to explain, and even its dynamical signature would be currently unobservable [3]. The formation timing of the Kuiper Belt taken together with dropping likelihood of passing stars may provide some additional constraints on when and how Planet 9 could have formed in our Solar System, and whether or not there are any unexplained dynamical signatures of its presence today.

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