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Probing the Very Distant Solar System: A Deep, Wide and Uniform Survey for Extreme Trans-Neptunian Objects

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Abstract

We are conducting the largest and deepest survey ever obtained for distant solar system objects. Several of our discoveries are some of the only known objects that have their entire orbits trans-Plutonian, including 2012 VP113, 2015 TG387, 2014 FZ71 and 2015 FJ345. There are several theories as to the origin of the extreme trans-Neptunian objects with high semi-major axes and eccentricities. Our surprising result in 2014 was that these extreme objects are strangely clustered together, suggesting a yet unobserved super-Earth planet is shepherding them into these similar orbits. Our continuing survey has found about 80 percent of all known objects that are currently beyond 60 AU, including the most distant object ever observed in our Solar System at 123 AU: 2018 VG18 (nicknamed Farout). We will discuss our newest findings and update the latitude and longitude clustering trends of the extreme objects first reported in 2014.

1. Introduction

The Kuiper Belt has an outer edge around 48 AU. Objects that have their entire orbits beyond this edge are considered Trans-Plutonian objects (TPOs). The TPOs with semi-major axes above some 150 AU are known as extreme objects and currently have minimal interactions with the known giant planets. In 2014 we showed the extreme objects are clustered together in a sort of latitude space through having similar arguments of perihelion [1]. We detailed how this could not be from observational biases since most extreme object discoveries have not been near the ecliptic. It was also shown that the clustering would only be seen if the mechanism for the clustering was still operating today since any orbital clustering from no longer operating shepherding mechanisms would disperse over much less than the age of the Solar System.

We then showed several simulations we performed with a Super-Earth mass planet beyond 200 AU that would constrain the arguments of perihelia of the extreme objects, arguing that some sort of dynamical interaction with an unknown distant planet that is still in the outer Solar System is likely the cause of the observed clustering of the extreme objects. We further discussed that these extreme objects could also be asymmetric in longitude space, but that unlike the argument of perihelion or latitude spacing, there were strong observational biases in the longitude space requiring further discoveries to be made in order to see if the longitude clustering was statistically significant [1].

In 2016 we announced several more extreme objects, including 2013 FT28 and 2014 SR349 and showed with these new discoveries that the longitude clustering of extreme objects does appear to be real, but still only at a marginal level [2]. We also showed that there were two longitude clustering groups of extreme objects with 2013 FT28 being the first very high semi-major axis object that was 180 degrees opposite of the others in longitude of perihelion [2].

Then in 2018 we announced the discovery of 2015 TG387, being only the third entirely TPO with a large semi-major axis [4]. We showed 2015 TG387 is similar to Sedna, 2012 VP113 and the other known extreme objects and that its orbit is stable to an eccentric distant Super-Earth planet beyond a few hundred AU when the other extreme objects are also stable. In fact, in most simulations 2015 TG387's orbit liberates with the planet, keeping 2015 TG387 away from the planet and thus stable [4].

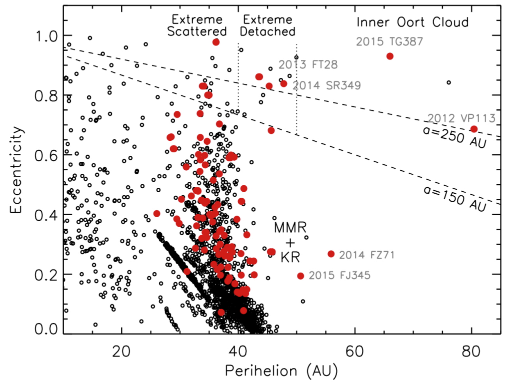

Figure 1: Perihelion versus eccentricity of well observed outer solar system objects. Red circles show the discoveries to date from our survey, which has found two (2012 VP113 and 2015 TG387) of the only three known inner Oort cloud objects or objects that are Trans-Plutonian for their entire orbits. Our survey has also found objects with very high perihelion but more moderate to low eccentricity like 2014 FZ71 and 2015 FJ345. We showed that these lower semi-major axis and eccentricity objects are near strong Neptune Mean Motion Resonances (MMR) and can be explained by a combination of the MMR and the Kozai Resonance (KR) as all these objects also have large inclinations [3].

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