"The Base of the Iceberg": A Gigantic Icy Body Reservoir Produced by an Early Rogue Planet. Y. Huang[1] and B. Gladman[1], [1]Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, BC V6T 1Z1, Canada (yhuang.astro@gmail.com)

We are developing a more detailed understanding of a rogue planet scenario [1] as a solution to various puzzles in the outer Solar System addressing the implantation of distant resonant and detached objects [2, and Fig. 1], as well as understanding the emplacement of a gigantic 'iceberg' population (a cone-shaped structure in (a, q) space, Fig. 2) that includes the three most distant trans-Neptunian objects (TNOs) often referred to as as `sednoids': Sedna, 2012 VP_{113} and Leleākūhonua.

A favorable and plausible scenario is that the rogue planet (of an Earth mass or two) would have been initially scattered out by Saturn to a semimajor axis of hundreds of au, and then interacted only with Neptune for ~100 Myr. The rogue would work in harmony with Neptune's slow, grainy, and eccentric migration [3] and adheres to observational constraints derived from OSSOS [4] and other outer Solar System surveys. In this talk, I demonstrate the model's capacity to account for the existence of the iceberg population, which is estimated to comprise approximately 250,000 objects with a diameter greater than 100 km and a total mass of roughly 0.25 Earth masses.

The rogue planet scenario is also compatible with the stability of the cold classical belt, as both analytical estimates and numerical studies confirm its survival despite the rogue planet's traversal [2]. The building of the Oort Cloud is not prevented by the presence of a temporary rogue planet, although the efficiency is somewhat reduced. Finally, the rogue planet, similar to other early scattering disk objects, has a small probability (5%) of being trapped in the Oort Cloud [5]. This study provides additional perspectives into early Solar System dynamics and contributes to our understanding of the formation and evolution of the outer Solar System's icy body reservoirs.

References:

[1] Gladman, B. & Chan, C. *AJ* **643**, L135–L138 (2006).
[2] Huang, Y., Gladman, B., Beaudoin, M. & Zhang, K. *ApJL* **938**, L23 (2022).
[3] Nesvorný, D. *ARA&A* **56**, 137–174 (2018).
[4] Bannister, M. T. *et al. ApJS* **236**, 18 (2018).
[5] Dones, L., Weissman, P., Levison, H. & Duncan, M. *Oort Cloud Formation and Dynamics*. (The University of Arizona Press, 2004).

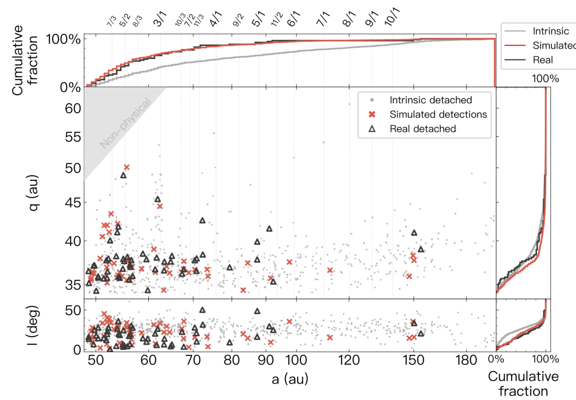

Figure 1, **Comparison with real detections:** *a*, *q*, *i* distributions of the intrinsic detached based on the rogue planet model (gray dots), the simulated detections using the OSSOS survey simulator (red crosses), and the real detached objects discovered by OSSOS (black triangles). This figure shows that the rogue planet model creates a 50 < *a* < 200 au detached population similar to the OSSOS detections.

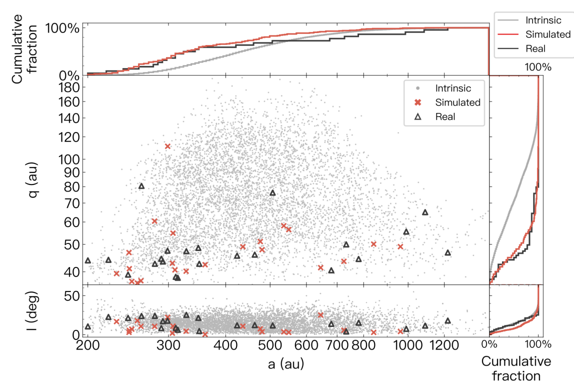

Figure 2: **The iceberg**. *a*, *q*, *i* distributions of the intrinsic 'iceberg' population (gray dots), the simulated detections using the OSSOS survey simulator (red crosses), and the currently-detected TNOs in this region (black triangles). This figure confirms that the iceberg produced by the rogue planet model has same trends as the *a*, *q*, and *i* distributions of the 22 real discoveries, with high-q objects being very hard to detect.