PLANETARY PROTECTORS: GIANT PLANETS AND THE OORT CLOUD

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Abstract

We study the influence of outer Solar System architecture on the structural evolution of the Oort Cloud and the flux of Earth-crossing comets. In particular, we seek to quantify the role of the giant planets as ”planetary protectors”. To do so, we have run simulations in each of four different planetary mass configurations to understand the significance of each of the giant planets. We integrate each simulation over the full age of the Solar System, following the evolution of cometary orbits from their starting point in the protoplanetary disk to their injection into the OC to their possible re-entry into the inner planetary region.

Simulations

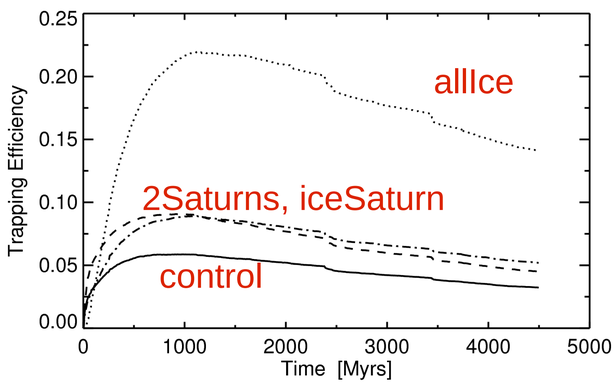
- Start in protoplanetary disk
- Integrate for 4.5 Gyr
- Include passing stars, Galactic tide
- Experiment with the outer planet masses

Outer Planet Configurations

Simulation name	a = 5AU planet	a = 10AU planet	a = 20AU planet	a = 30AU planet
Control	Jupiter	Saturn	Uranus	Neptune
2Saturn	Saturn	Saturn	Uranus	Neptune
iceSaturn	Jupiter	Neptune	Uranus	Neptune
allIce	Neptune	Neptune	Neptune	Neptune

All simulations are run with 4 planets starting in the current orbits of the outer Solar System planets. Planet names in the above table refers to the masses assigned to these planets.

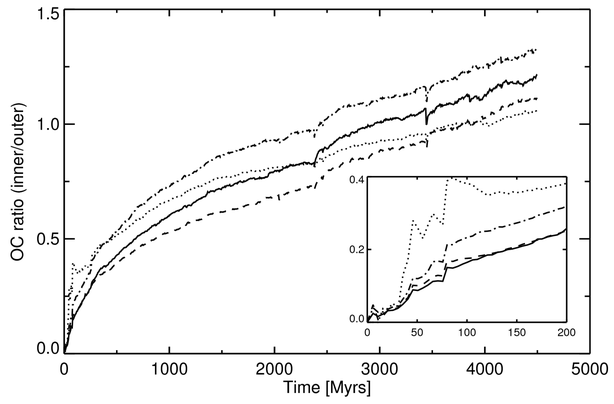
Results: trapping efficiency



The fraction of comets in the Oort Cloud (q > 45 AU and bound) over 4.5 Gyr for the 4 configurations. Both Jupiter and Saturn are effective at ejecting bodies from the Solar System. In all line plots: Solid: control, Dashed: 2Saturns, Dash-dot: iceSaturn, Dotted: allIce

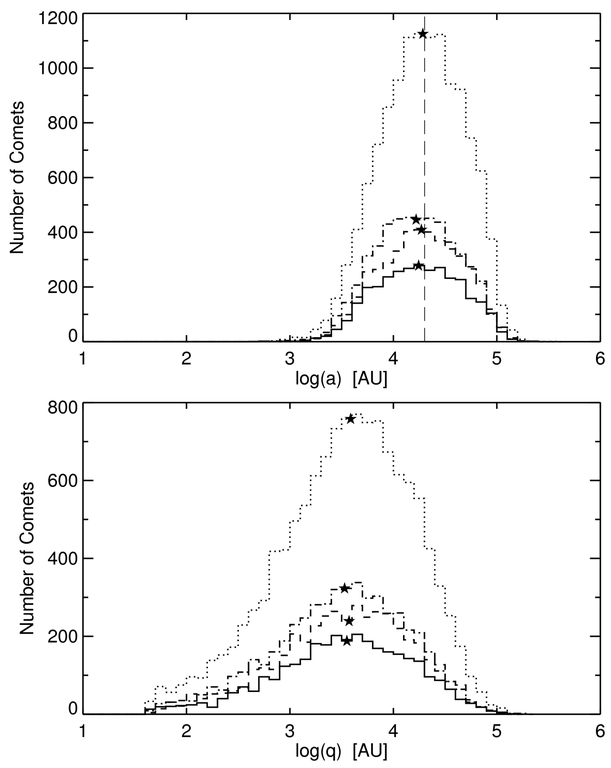
Results: Oort Cloud structure

Inner OC/Outer OC



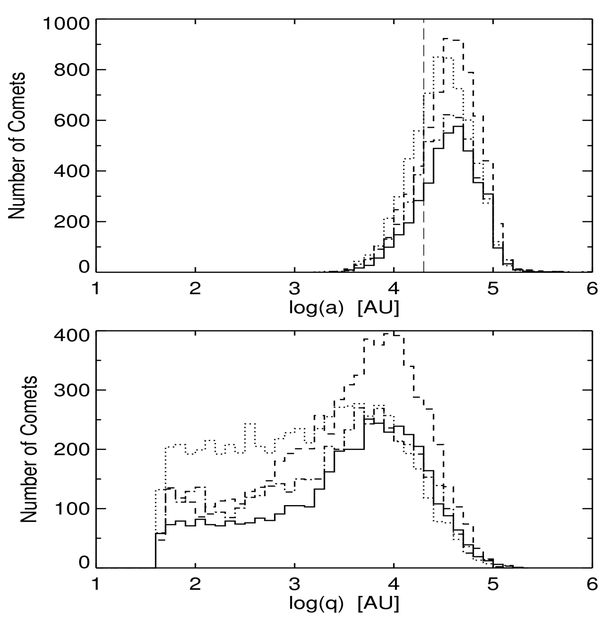
Ratio of the number of inner (a < 20,000 AU) to outer (a > 20,000 AU) OC objects over time. Inset shows the first 200 Myr.

Orbit distribution at 4.5 Gyr



Distributions in semi-major axes (top) and perihelion (bottom).

Orbit distribution at 200 Myr



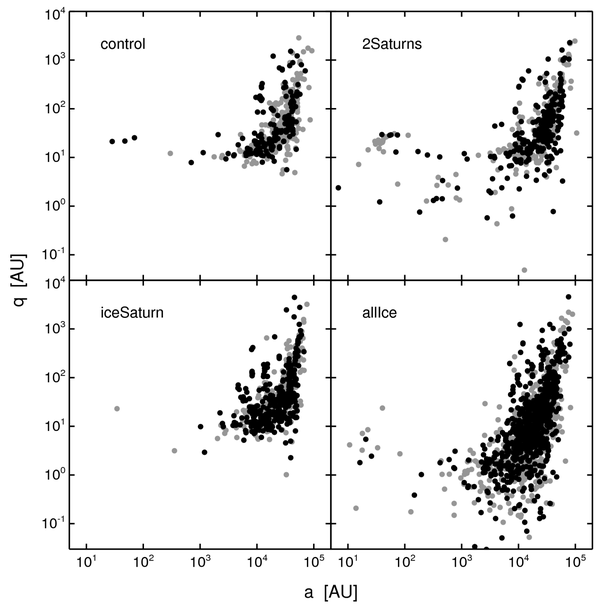
Same as above, but at 200 Myr. AllIce has many small q comets at this time.

Results: Comet Fluxes

Simulation	Rel. Flux @ 1 Gyr	Rel. Flux @ 4.5Gyr	Fraction of OC @ 1 Gyr	Fraction of OC @ 4.5Gyr
Control	241	93	0.15%	0.09%
2Saturn	290	120	0.18%	0.12%
iceSaturn	242	126	0.14%	0.11%
allIce	570	288	0.33%	0.26%

The table shows the number of comets coming inside 2 AU over a 250 Myr interval at 1Gyr and 4.5 Gyr. The numbers are also expressed as fractions of the total OC population. The presence of a Saturn or Jupiter decreases the flux by a factor of 2 to 3. Jupiters and Saturns have a similar effect.

Orbit distributions of visible comets



Perihelion vs semi-major axis is plotted for comets 10 Myr before they become visible (r < 2 AU) for the 1 Gyr population (gray) and the 4.5 Gyr population (black). The lack of a Jupiter barrier means that more visible comets can come from smaller semi-major axes and evolve more slowly in perihelion.

Conclusions

- Presence of Jupiter OR Saturn reduces inner Solar System comet flux.
- Flux at 4.5 Gyr is reduce by less than an order of magnitude
- Presence of Jupiter OR Saturn reduces trapping efficiency into Oort Cloud.
- Structure of Oort Cloud (Inner/Outer) is not changed with changed planetary masses: little difference in intensity of “comet showers”
- Evolution over 4.5 Gyr is needed to understand planetary roles in OC structure.

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Details: Lewis, Quinn, Kaib, 2013. The Influence of Outer Solar System Architecture on the Structure and Evolution of the Oort Cloud. AJ 146, 16.