Accretion of moon(s) around Earth-like planets

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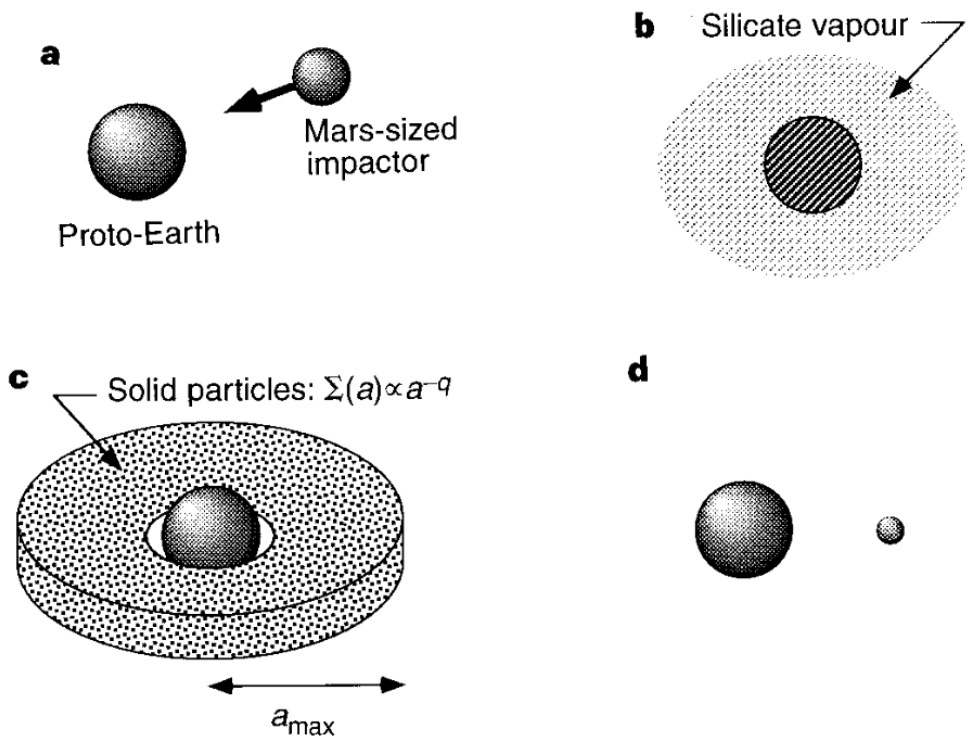
Moon formation from giant impacts via circumplanetary disks is a universal process

1. Growing protoplanets collide in giant impacts
    - Robust outcome of terrestrial planet formation simulations (e.g. Chambers 2000)
2. Giant impacts make circumplanetary disks
    - Verified outcome from SPH simulations (e.g. Canup & Asphaug 2001)
3. Circumplanetary disks make moons
    - Earth's moon (e.g. Ida et al. 1997)
    - Mars' Phobos and Deimos (e.g. Canup & Salmon 2018)



Ida et al. 1997

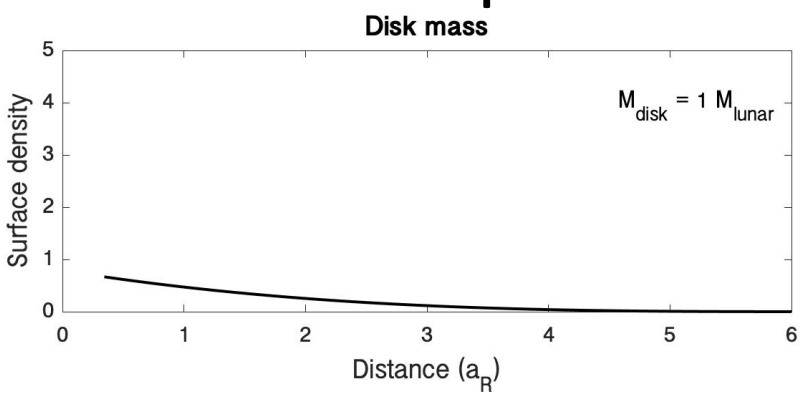
Numerical simulations of moon formation from a circumplanetary disk

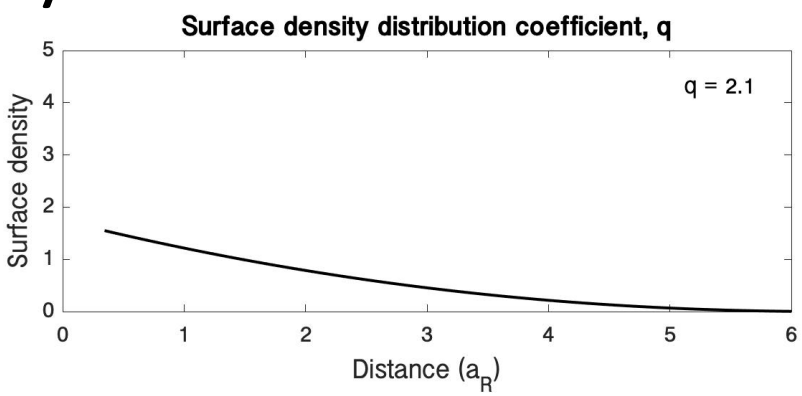
Model Components

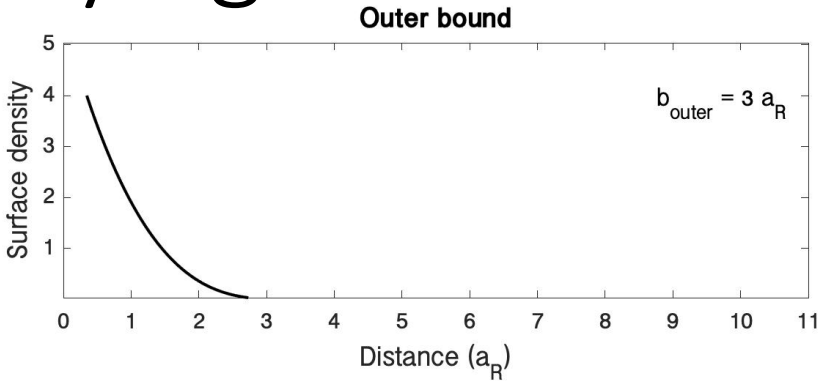
- Inner viscously evolving, fluid-like disk
- Outer moonetesimal n-body disk
- Mass transfer between inner and outer disks
- First-order Lindblad resonances
- Tidal dissipation
- Both bouncing and accretional moonetesimal collisions

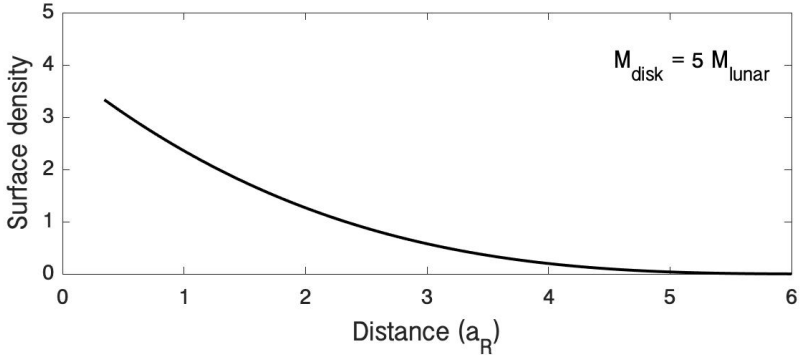
Canup & Salmon 2019

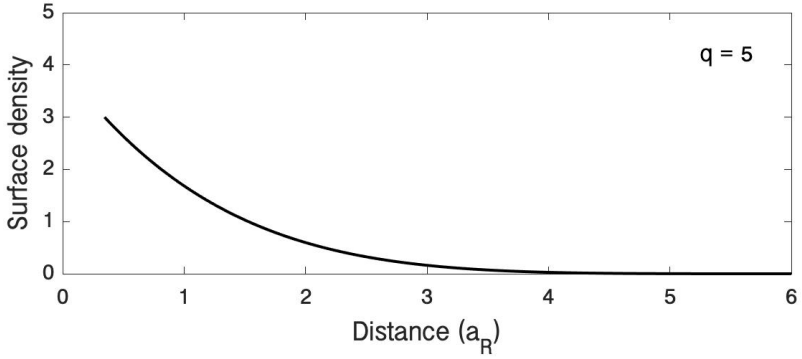
What about moon formation from circumplanetary disks are we studying?

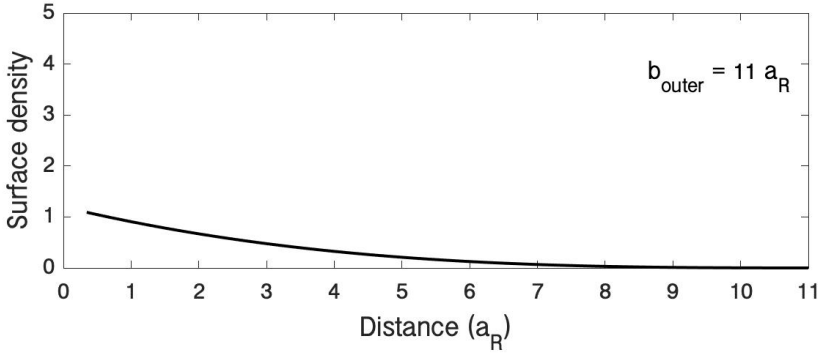








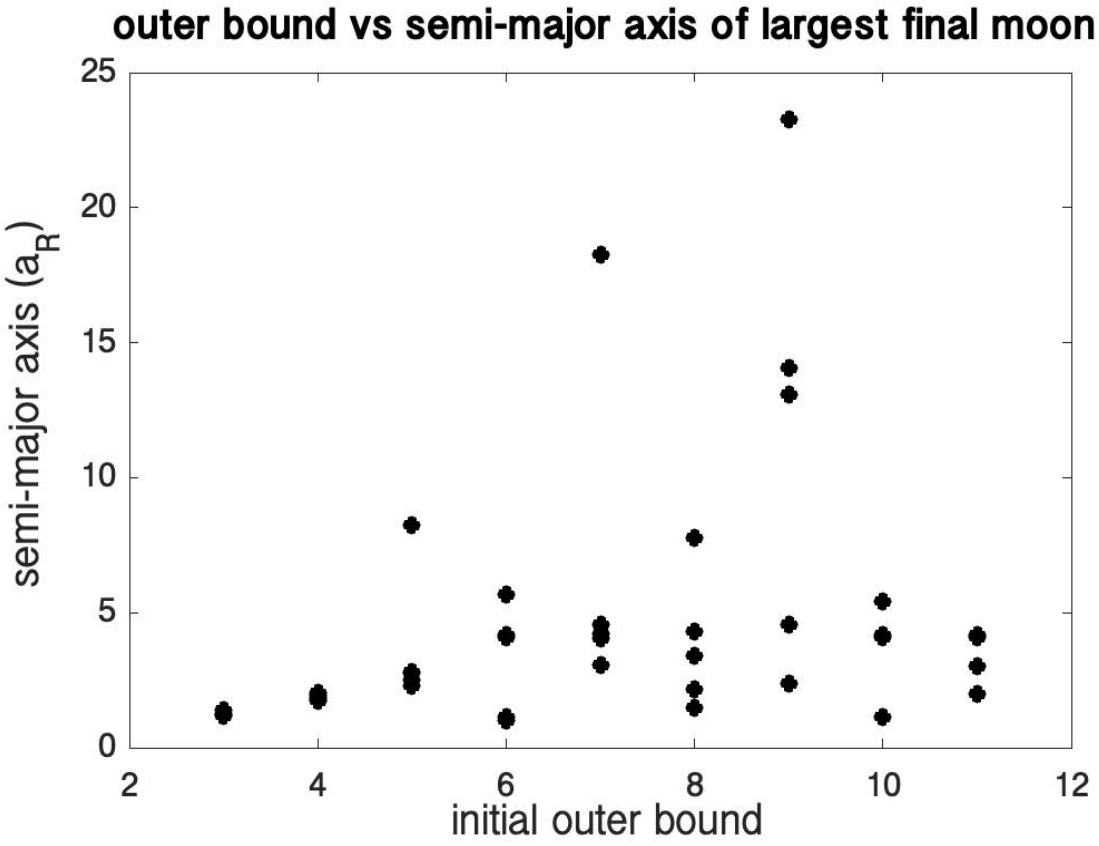




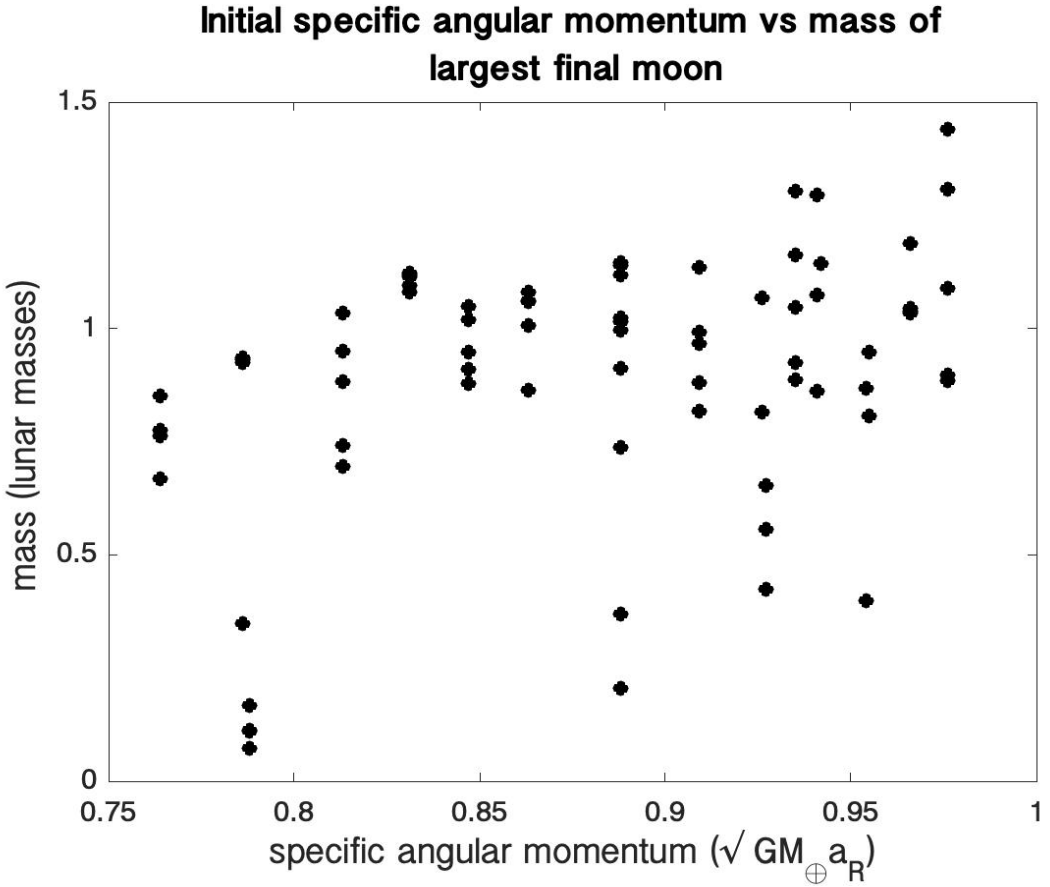
In what ways do the above parameters affect the resulting system?

- Which conditions yield our Earth-moon system?
- Which conditions yield two-moon systems?

Preliminary Results: General Findings

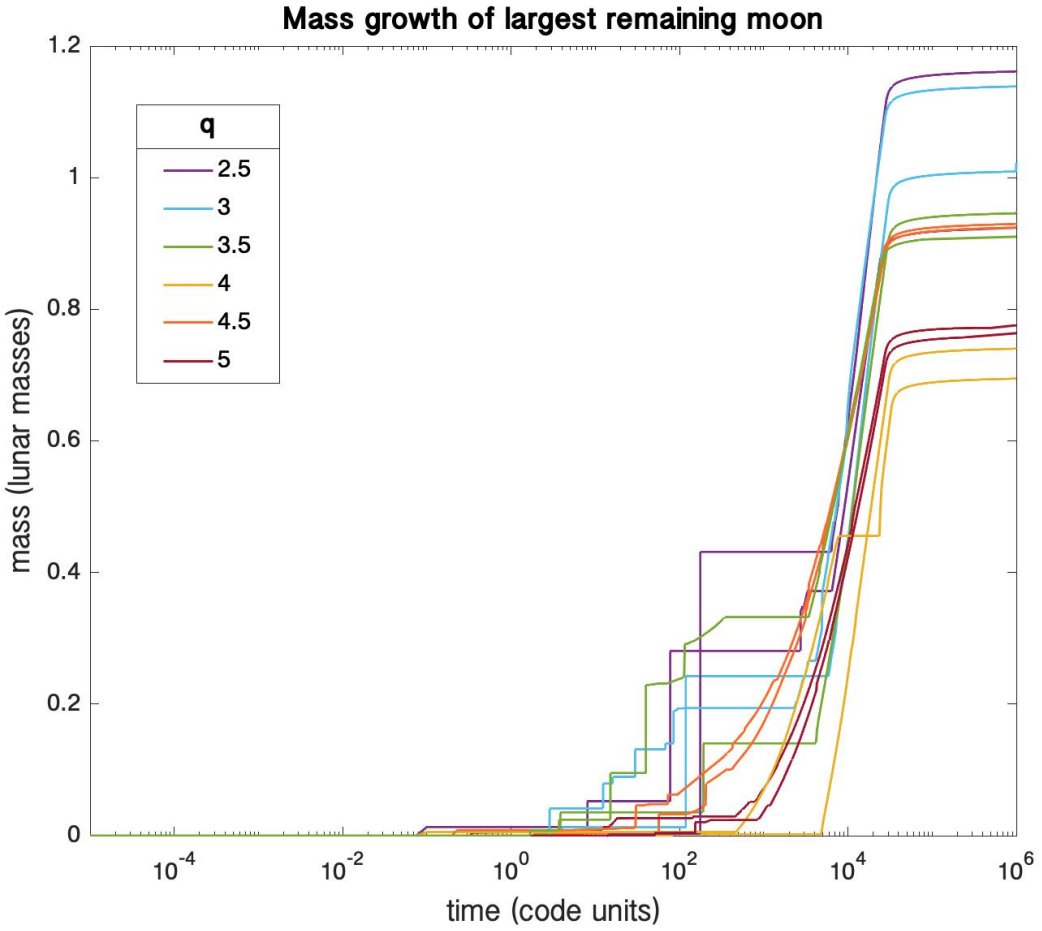


Larger b_{outer} values lead to larger semi-major axes in resulting moon(s)

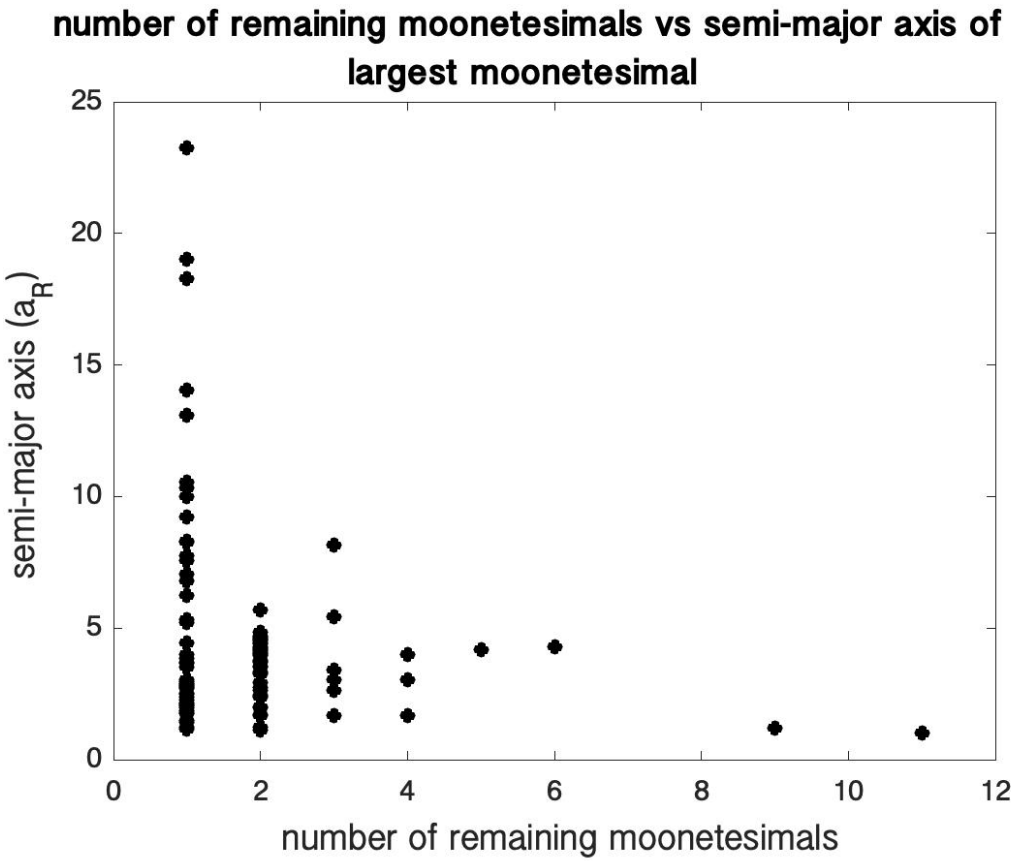


Final mass and semimajor axis of the most massive moon directly vary with initial specific angular momentum (i.e. Ida et al. 1997)

Preliminary Results: General Findings

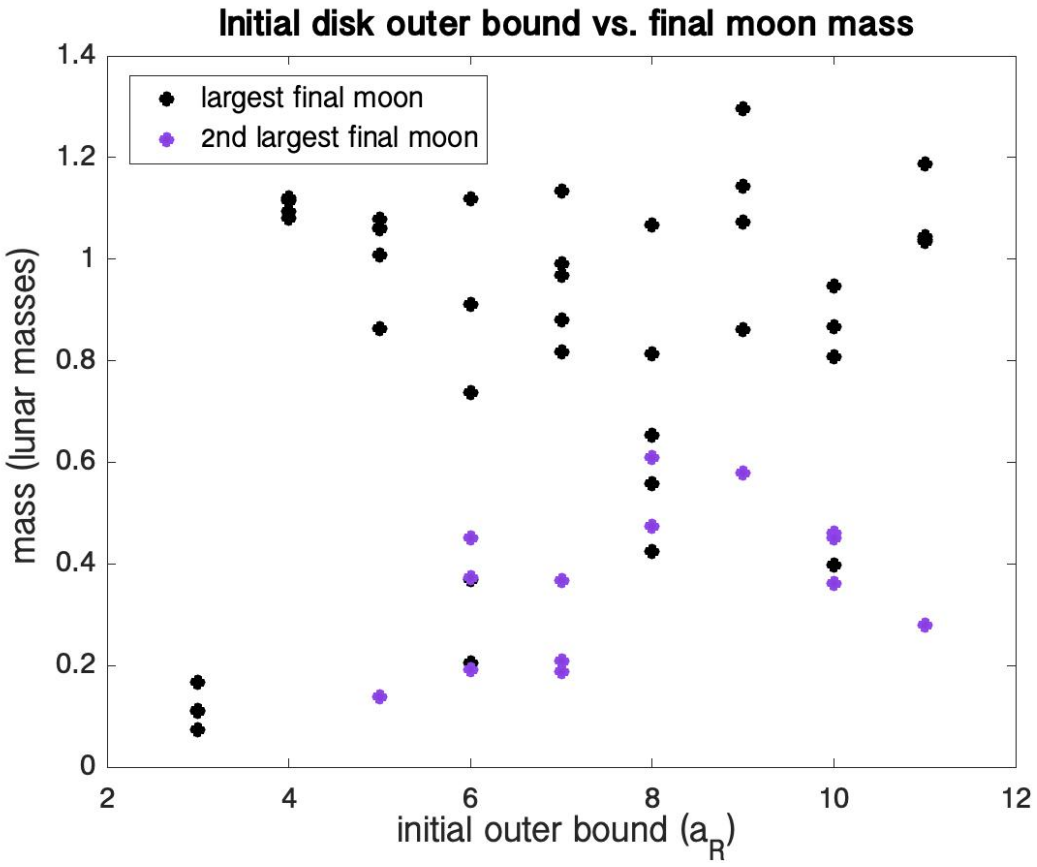


The largest final moon often grew sporadically at first, then smoothly, sometimes with two distinct growth phases

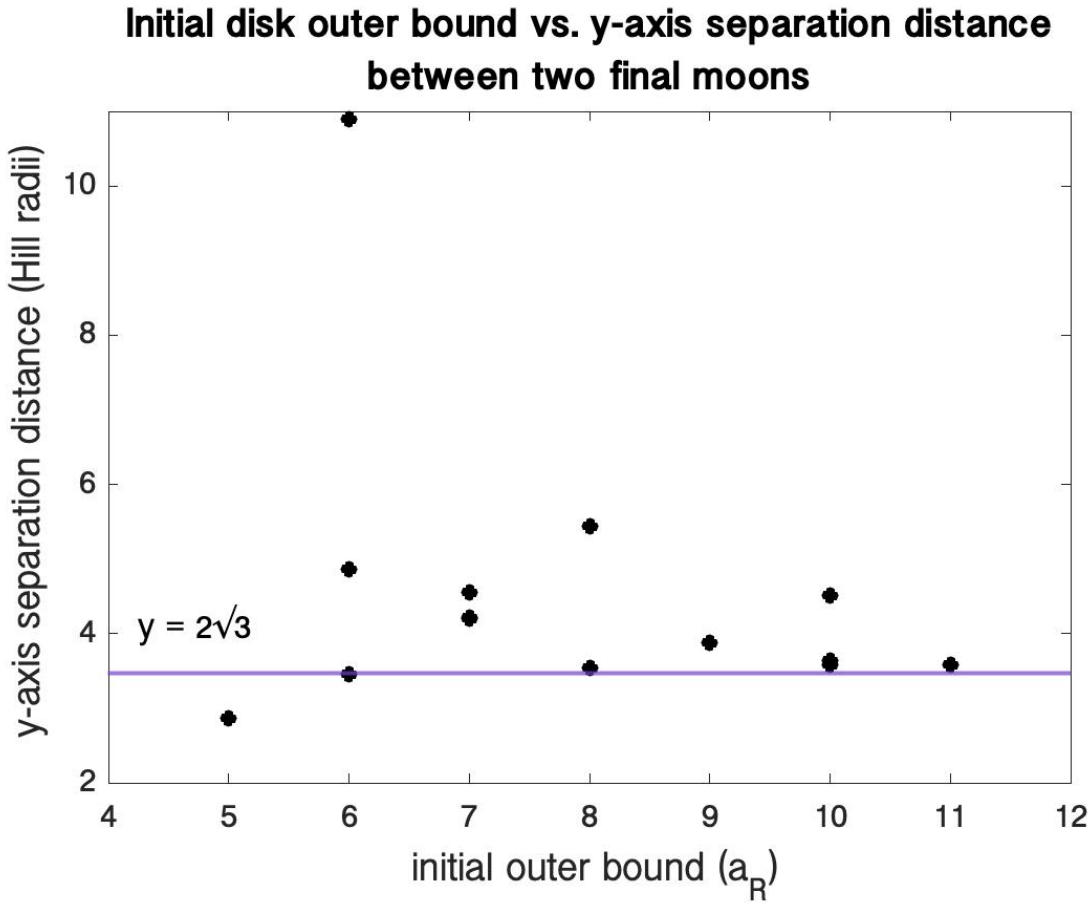


Larger semi-major axes appear more frequently when there are fewer final moonetesimals

Preliminary Results: Two-Moon Systems



Do not occur often when $b_{outer} < 6$

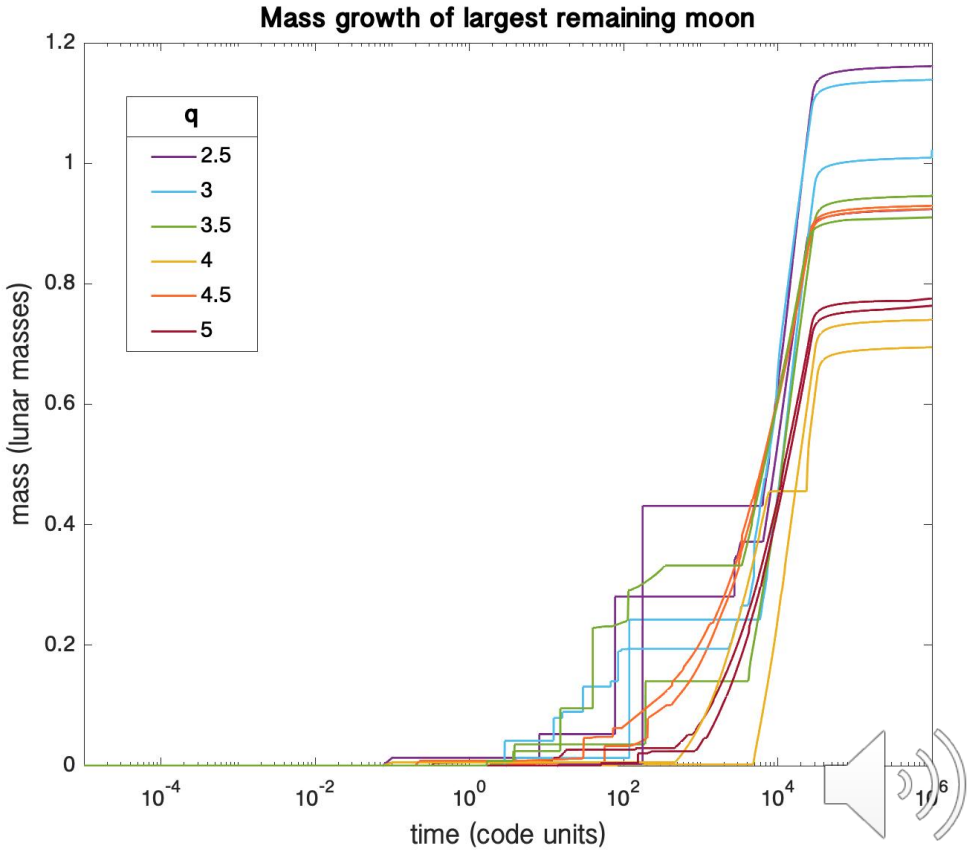


After 800 years, remaining two-moon systems appeared stable

- Stability criterion (Gladman 1993)

Summary

- Results were like those of J. Salmon and R. M. Canup
- A circumplanetary disk with an outer bound of at least 6 a_R from Earth's center is more likely to produce multi-moon systems, most of which are stable
- Systems with fewer final moons tended to have larger semi-major axes
- Results suggest two mass growth phases: perhaps collision-driven and inner-disk driven



Going Forward

- What mass growth patterns do the final moons follow given different parameter values?
- When do much smaller circumplanetary disks form moon(s)?