The PPOLs Model
Planetary System Architecture & Water Content from Pebble Accretion

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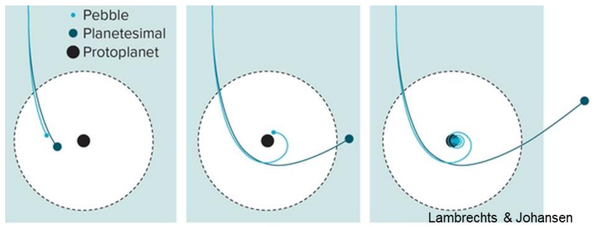
my website & digital poster

What is pebble accretion?

- Pebble accretion: mechanism for protoplanet growth by collecting ~centimeter size solids that coagulate from protoplanetary disk dust and drift inward through disk.
- **"aerodynamically assisted accretion"**: attracted by gravity alone, a planetesimal may scatter instead of accrete. A pebble experiences gravity + gas drag, increasing the collection area for growing protoplanet.



This research develops a model of pebble accretion valid across a range of stellar and protoplanetary disk masses to explore a combination of **mechanisms** often studied independently. By doing so, we identify trends in overall system architecture, particularly bulk water content of planetary embryos.

Spatial scales of planet formation processes:

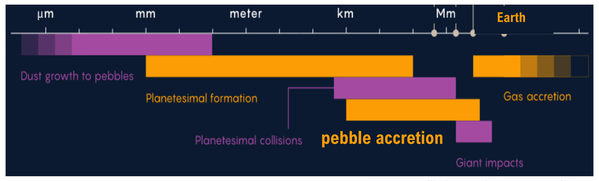
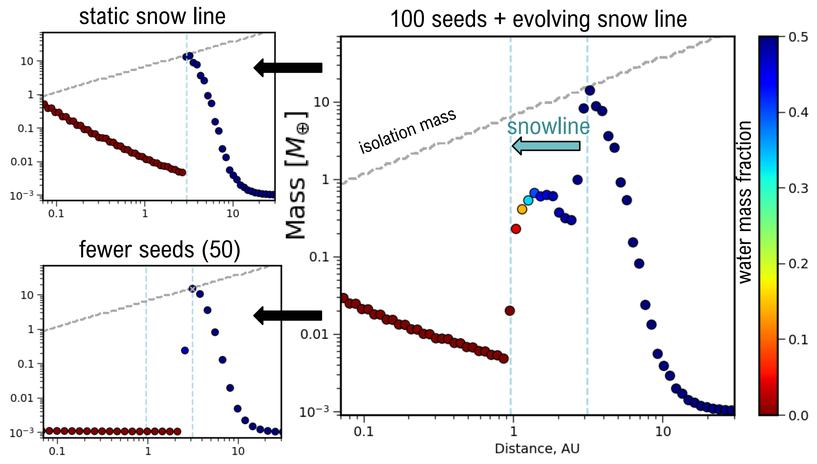


Image: Merrill Sherman/Quanta Magazine

Key PPOLs Mechanisms

- **filtering**: pebbles accreted by an outer seed are removed (*filtered*) from pebble supply inward.
- **pebble isolation mass**: protoplanet mass threshold which creates a pressure bump in the gas disk, halting pebble drift. Effectively quenches growth of interior seeds.
- **snow line & evolution**: the distance at which conditions allow water vapor to condense into ice/icy pebbles. Location evolves as disk dust mass diminishes. Icy pebbles may be larger and enable more efficient growth.

A **Starting with 100 seed masses around a 1 solar mass star…**



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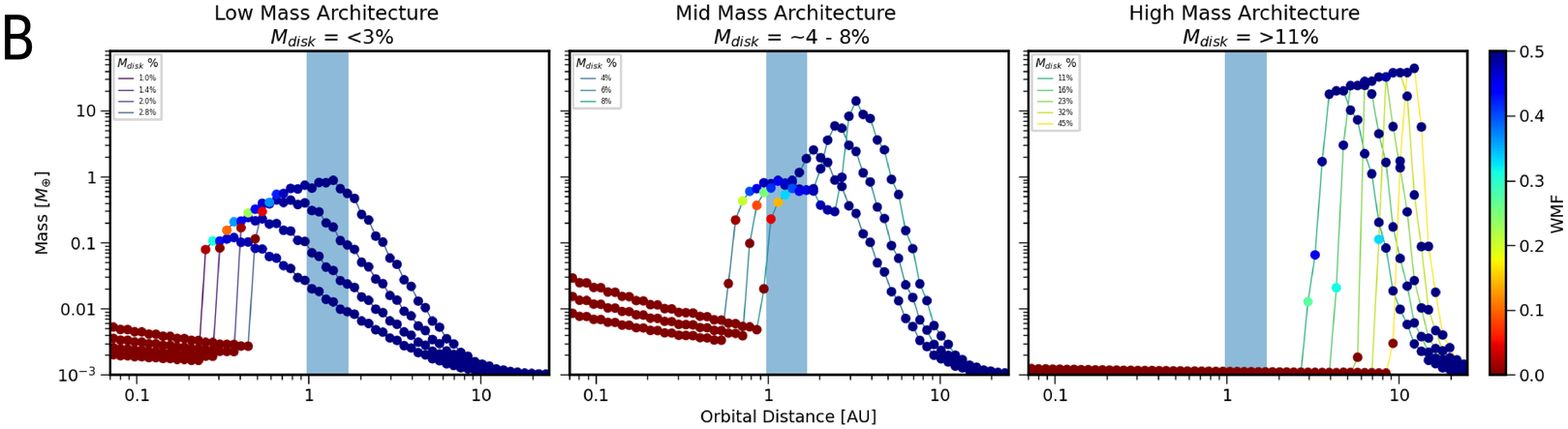

Credit to the PPOL

The PPOLs Model is developed from "pebble-predictor" (Drazkowska et al. 2021) and pebble accretion recipes by Ormel & Liu (2018), from whom the model is named as a combination of "pp" and OL". This research is supported by a fellowship from the North Dakota Space Grant Consortium.

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Mulders, G. D., O'Brien, D. P., Ciesla, F. J., Apai, D., & Pascucci, I. (2020). Earths in Other Solar Systems' N-body Simulations: The Role of Orbital Damping in Reproducing the Kepler Planetary Systems. *The Astrophysical Journal*, *897*(1), 72.

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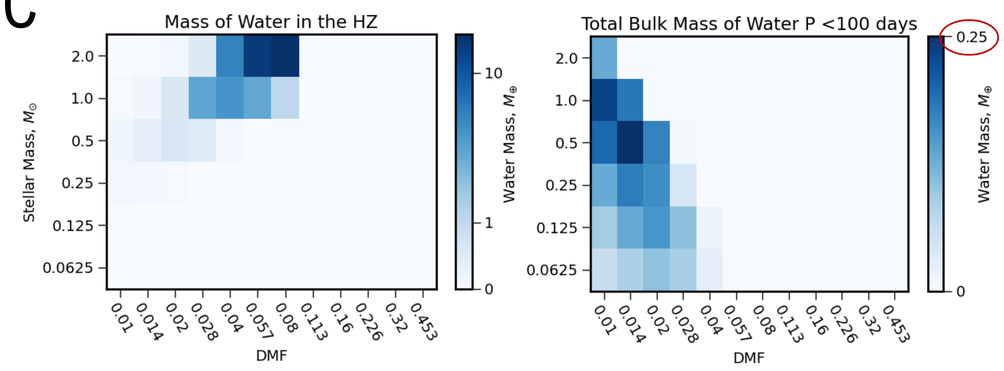
Architectures Determined by Disk Mass

A – Cumulative filtering from 100 seeds + evolving snow line significantly alter outcome of system after 10 Myr. Snow line position shown by vertical dashed line, evolving inward. Compared to fewer seeds or a static snowline, the combined effects allow Earth-like and gas giant cores to form, and limited water delivery to some inner planets. Filtering prevents a proto-Jupiter from growing too efficiently and quenching the pebble flux for this disk mass fraction, 8%.

B – Planetary systems determined by disk mass into low-, medium-, high-disk mass architectures, with planet water mass fraction (WMF) shown by dot color, conservative HZ shown by blue region. Low disk mass fraction yields only peas-in-a-pod similarity (left). High disk mass yields only outer gas giant cores (right). Medium disk mass contains ~Earth-like and ~Jupiter-like planets together, with range of WMF (middle).

C – Bulk water content across grid of all stellar and disk masses in regions of interest: HZ and for P < 100 days.

C



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