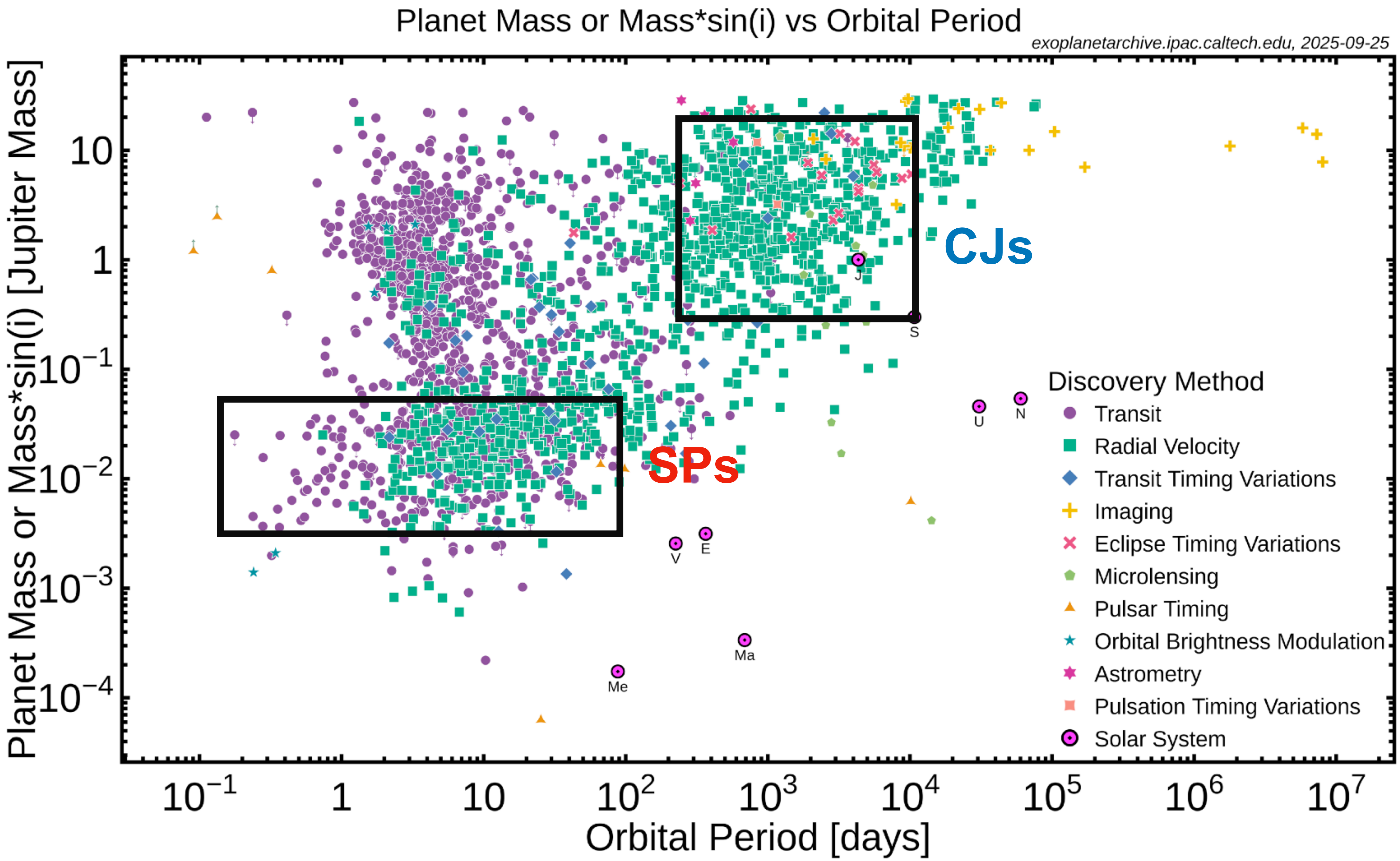
Introduction to the session on cold Jupiters and close-in small planets

A.S. Bonomo on behalf of all the speakers of the session

51 Peg b - Cool giant planets and their systems

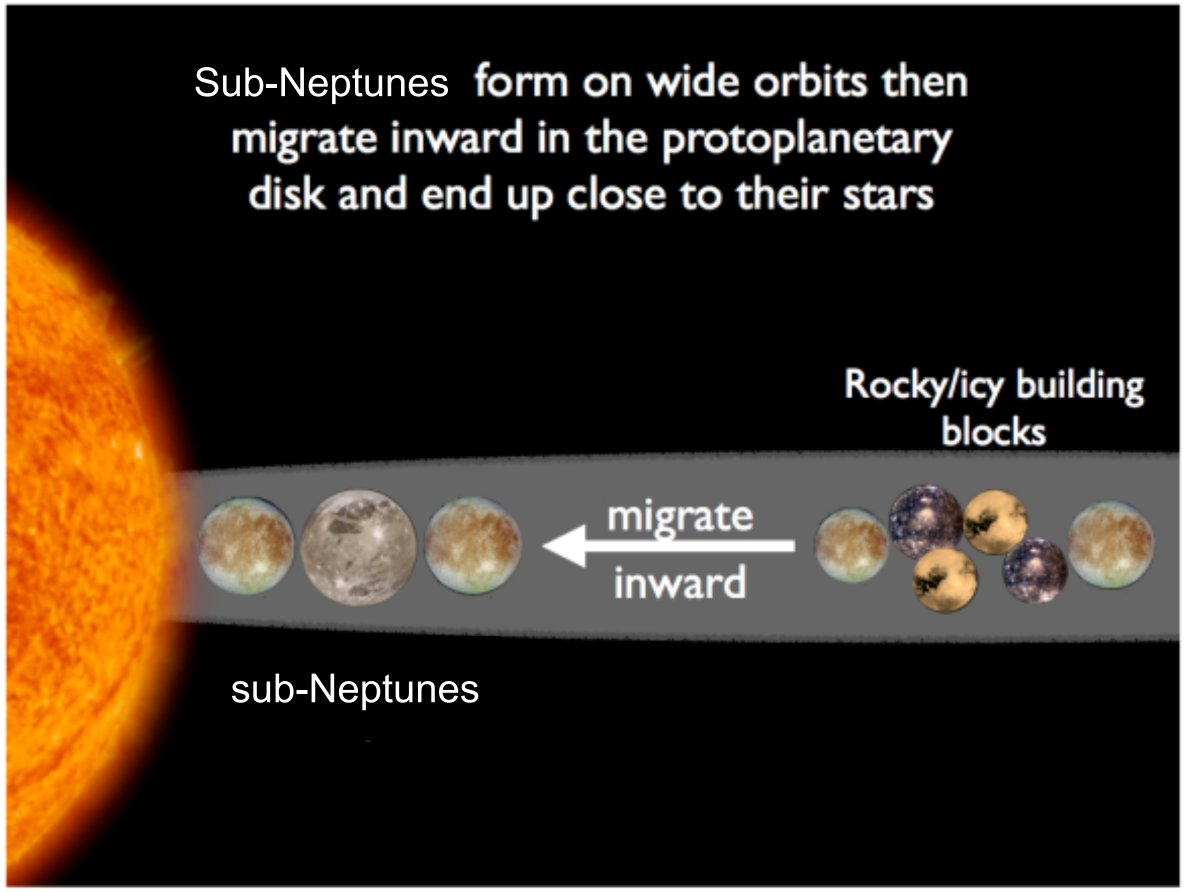
Observatoire de Haute Provence (6-10 October, 2025)

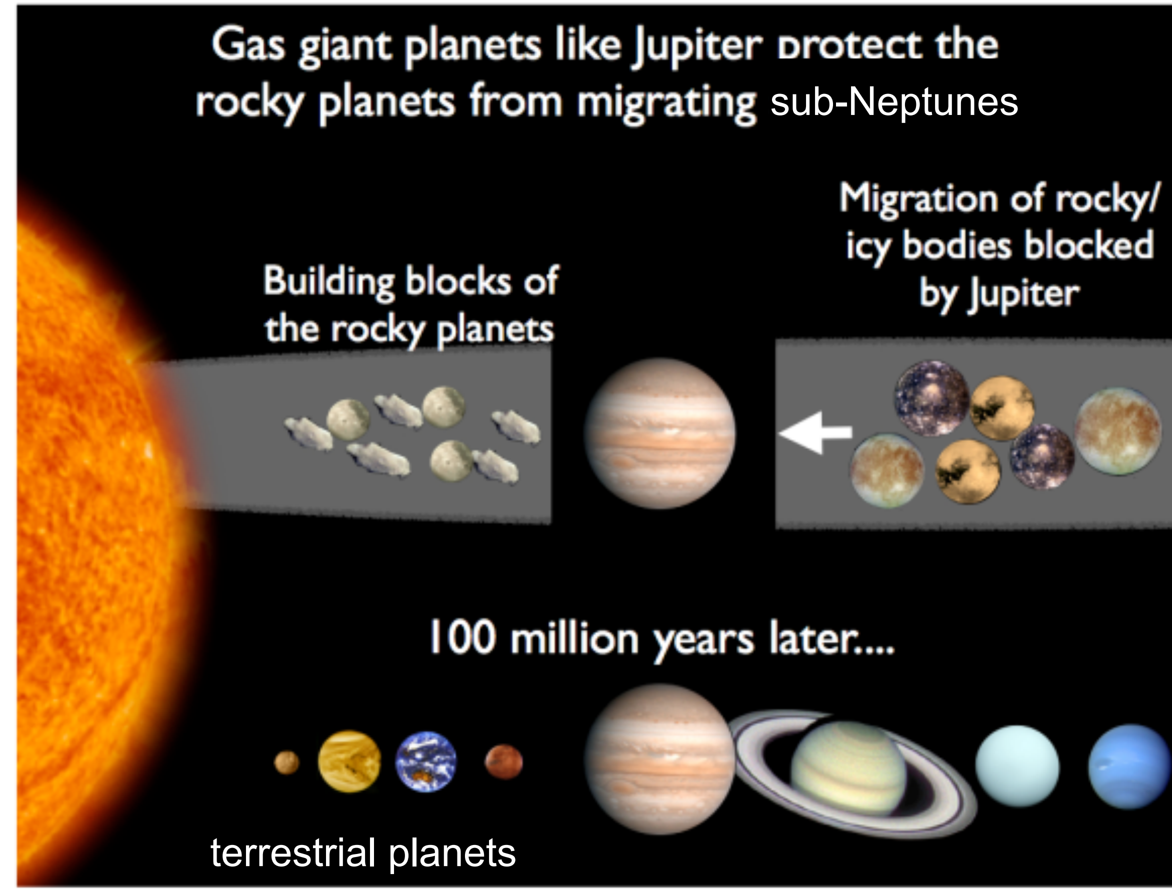
Definition of cold Jupiters and close-in small planets



- Cold Jupiters (CJs) [Jupiter and Saturn analogs]:
  a = 1-10 AU and M_p = 0.3-13 M_{Jup} (or 0.3-20, 0.5-20, 0.1-13 M_{Jup})
- Close-in small (low-mass) planets [SPs, i.e. super-Earths and sub-Neptunes]:
  a≲0.4 AU (or ≲1 AU) from P<100 d (or <400 d) and $1 < R_p < 4\ R_\oplus$ | $1 < M_p < 20\ M_\oplus$
- "Mixed systems": systems with close-in SP & close-in giant planets (e.g., WASP-47)

Theoretical small planet (SP) vs cold Jupiter (CJ) anti-correlation and the lack of small planets in the Solar System





courtesy: S. Raymond

CJs as dynamical barriers to sub-Neptune inward migration (Izidoro et al. 2015)

- Jupiter may have prevented the icy-rocky nuclei of Saturn, Uranus and Neptune from migrating inward and thus becoming a compact system of sub-Neptunes like those observed by Kepler, K2 and TESS.

- It assumes sub-Neptunes form beyond the water snowline (~1-3 AU) and are thus ice-rich

Theoretical SP vs CJ anti-correlation and the lack of SPs in the Solar System

courtesy: P. Armitage

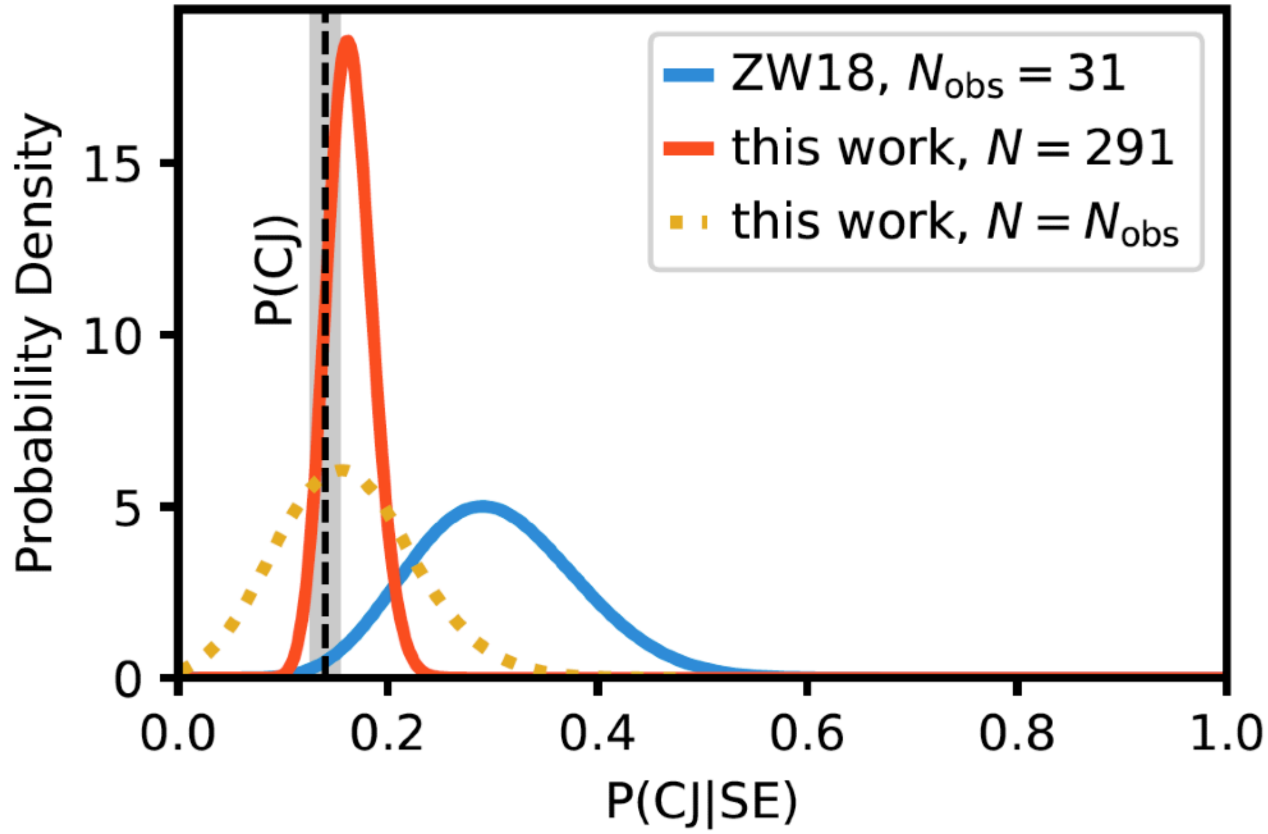
CJs as a hindrance to SP formation inside the water snowline (Lambrechts et al. 2019)

- Jupiter may have opened a gap by reducing the inward flux of material (pebbles) required to form planets bigger than the terrestrial planets

- It assumes SPs form within the water snowline (~1-3 AU) and are thus dry (rocky with possible H/He envelopes)

but only in some cases (Danti et al. 2025)

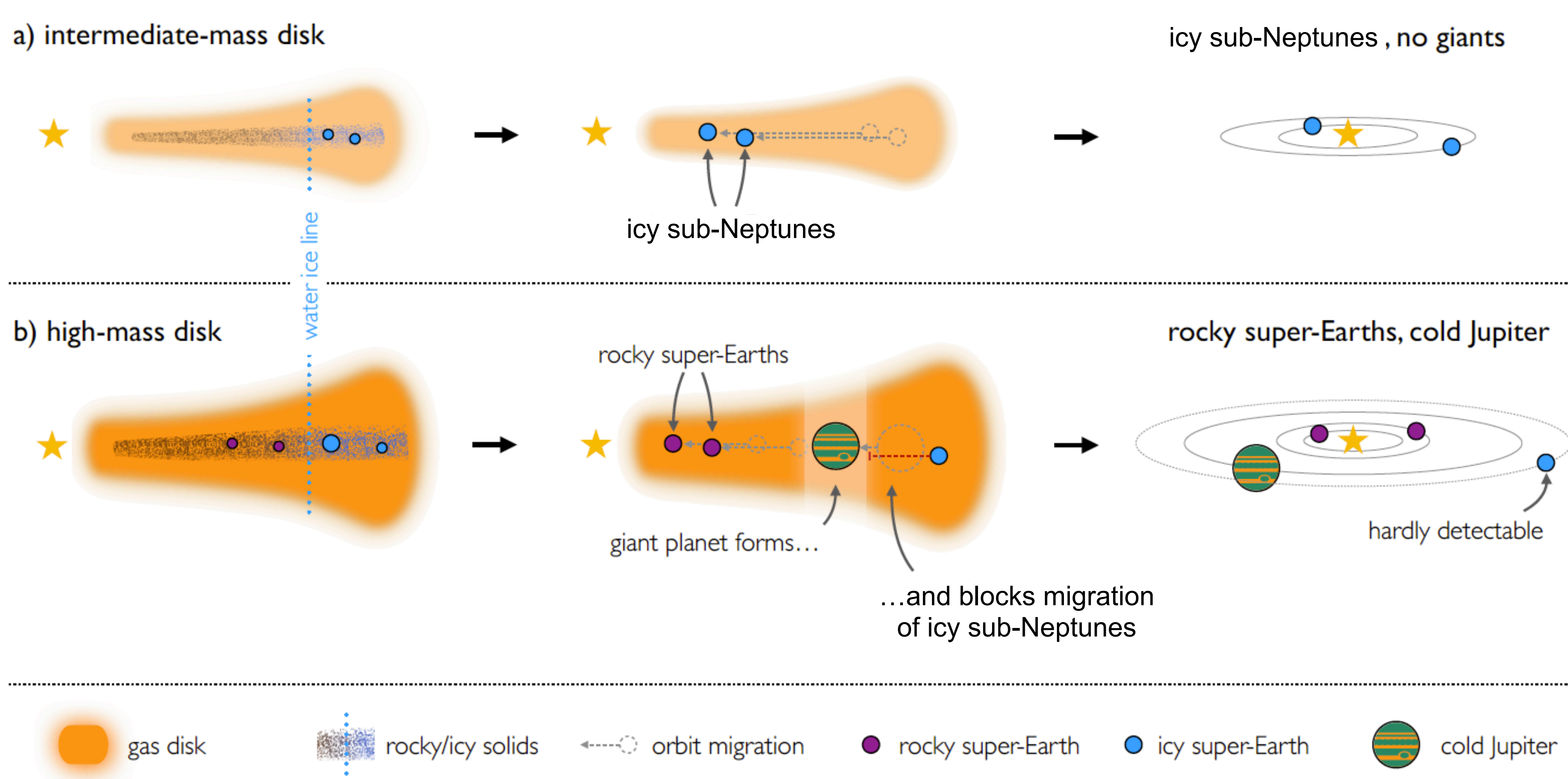
Pebble filtering due to outer giants would be efficient only if some mechanisms of delaying inner disk growth (i.e., efficient viscous heating of the inner disk or the presence of an iceline) are at work, otherwise it is quite limited



Theoretical weak (or no) SP vs CJ correlation

Classical planetesimal accretion with Gen 3 Bern Planet Population Synthesis (Schlecker et al. 2021)

Strong architecture-composition link

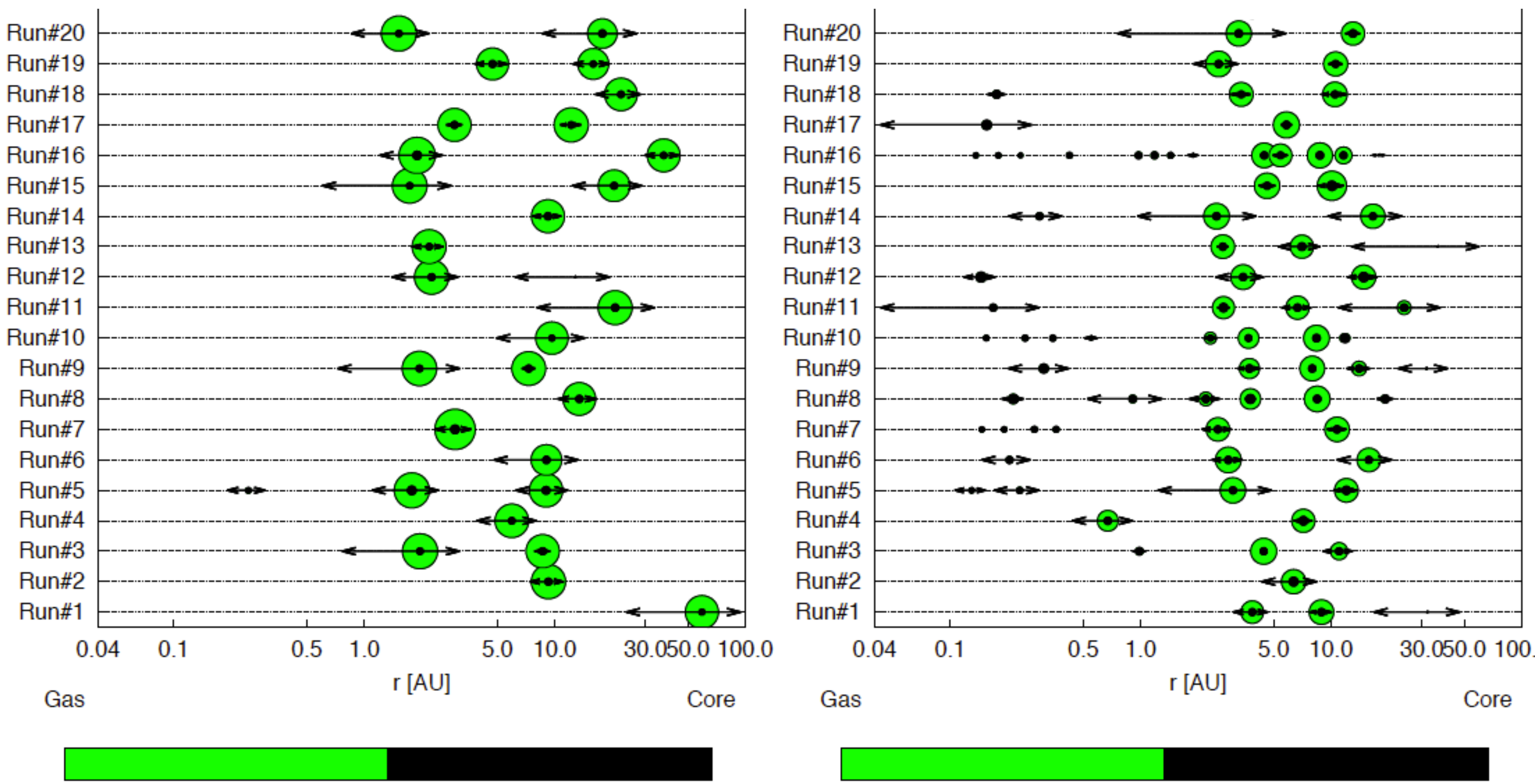


Theoretical SP vs CJ correlation

Low efficient gas contraction rates allow for a more efficient formation of systems with inner SPs and outer CJs: the cores that form in the inner disk are too small to effectively accrete large envelopes, and only cores growing in the outer disk can become giants. These outer giant planets are enough away not to necessarily destroy the inner systems of SPs.

Bitsch & Izidoro 2023

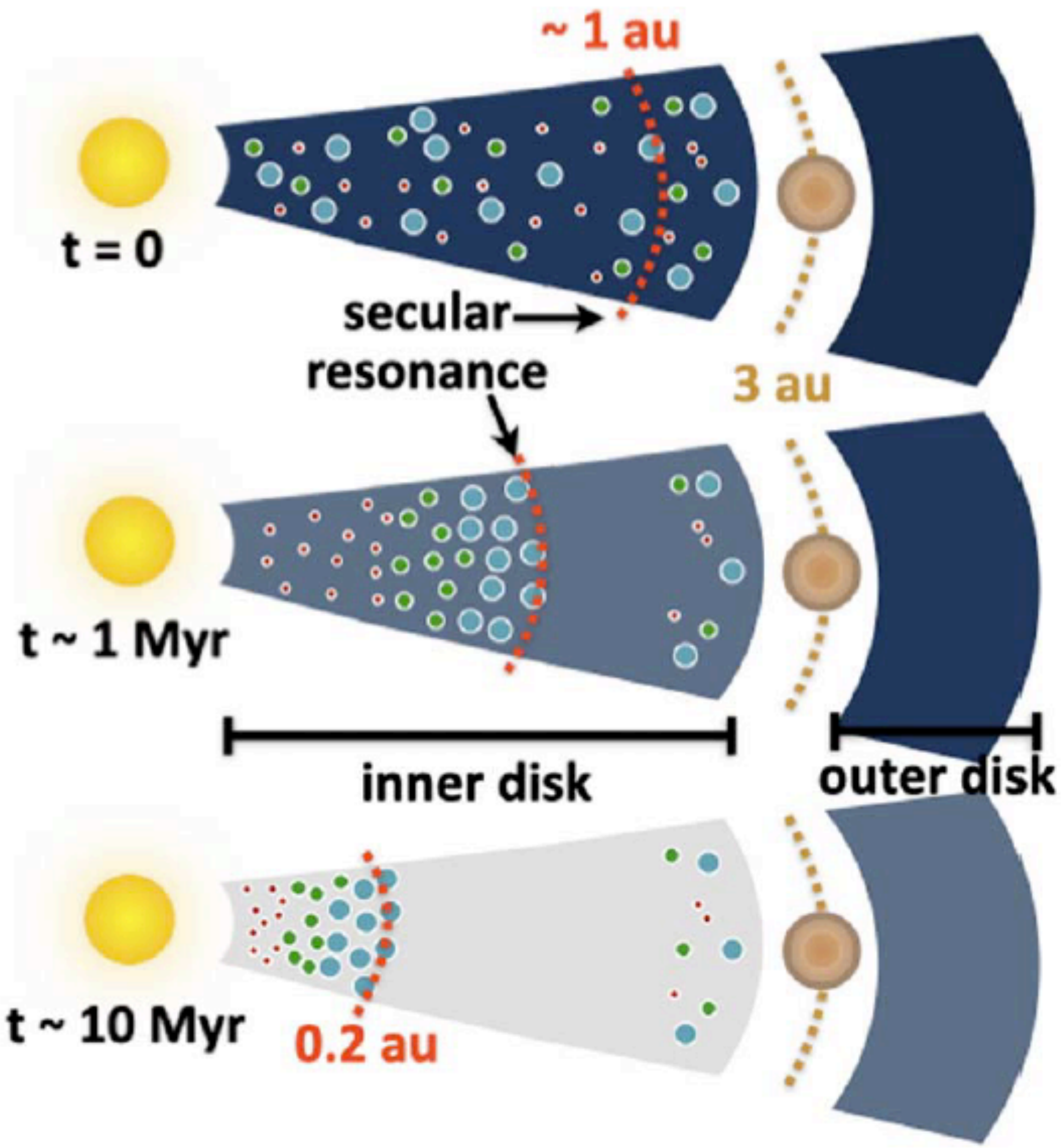
k_{env}=0.1 cm^2/g (high gas contraction rate) k_{env}=0.4 cm^2/g (slow gas contraction rate)



Theoretical SP vs CJ correlation

Snowplow-like process due to a secular resonance sweeping inwards through the disk can efficiently form SPs by accumulating large concentrations of size-segregated planetesimal rings. This redistribution of planetary building blocks would cause SP systems in the presence of CJs to depart from the "peas-in-a-pod" architecture.

Best et al. 2024, 2025



Testing theoretical scenarios

Theory can predict either ***anti-correlation*** (Izidoro+2015, Lambrechts+2019) or ***weak/no correlation*** (Schlecker+2021, Danti+2025) or ***strong correlation*** (Bitsch & Izidoro 2023, Best et al. 2024, 2025) between inner SPs and outer CJs.

Can we test these theoretical predictions? How?

High-precision radial-velocity (RV) monitoring with ground-based high-resolution spectrographs + space-based Gaia astrometry

Inside-out approach

Search for CJs in SP systems

Talks by J. Van Zandt, A. S. Bonomo, L. Naponiello, L. Weiss

Outside-in approach

Search for SPs in CJ systems

Talks by J. Faria, A. Ruggieri

And that's not all: the statistics of CJs in systems with bigger (Neptune- and Jupiter-size) close-in planets is also very interesting! Talk by L. Parc