Planet formation around M dwarfs

linking disk and exoplanet demographics

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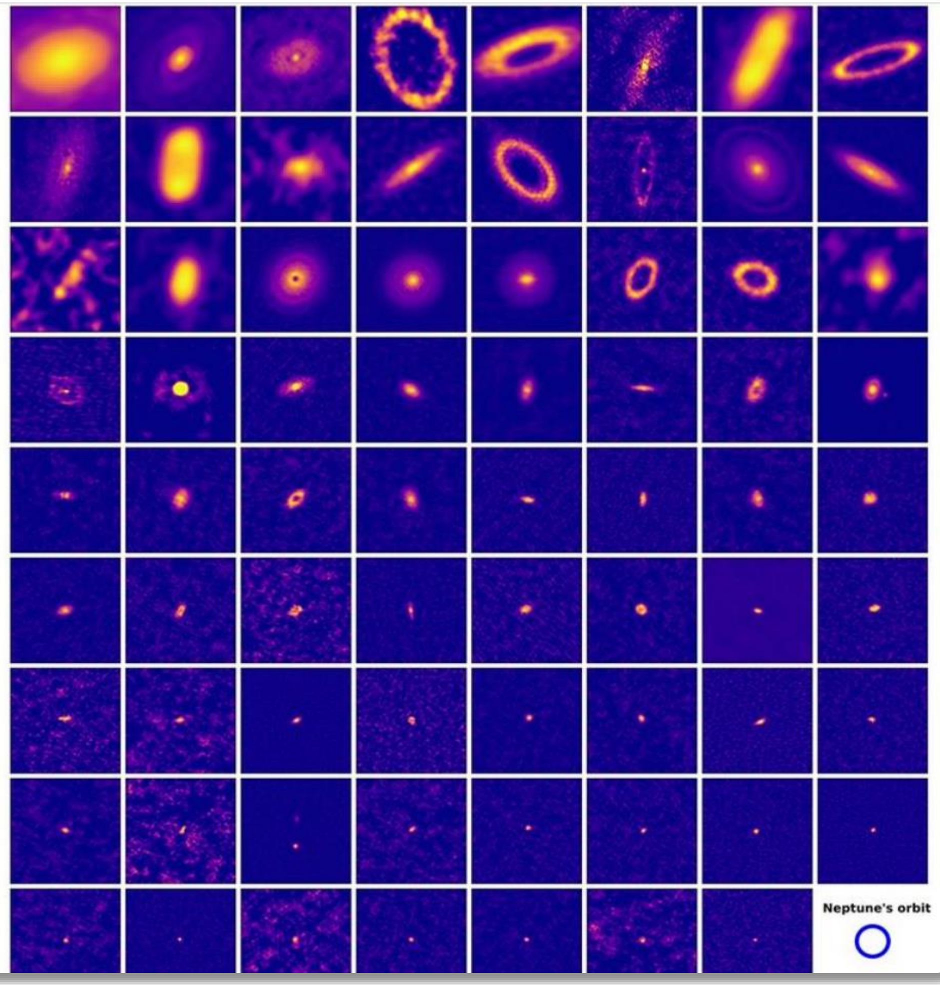
Perspectives of planet and star formation – June 26, 2026

Motivation

- M dwarfs are the most abundant stars in the Milky Way (~70%).
- Close-in, rocky, multi-planetary systems are the most abundant.
- Close-in rocky planets are easier to characterize (JWST, ELT, HWO, LIFE).
- Planets in the habitable zone are easier to detect .
- Giant planet formation remains a challenge...

Protoplanetary disks around M dwarfs

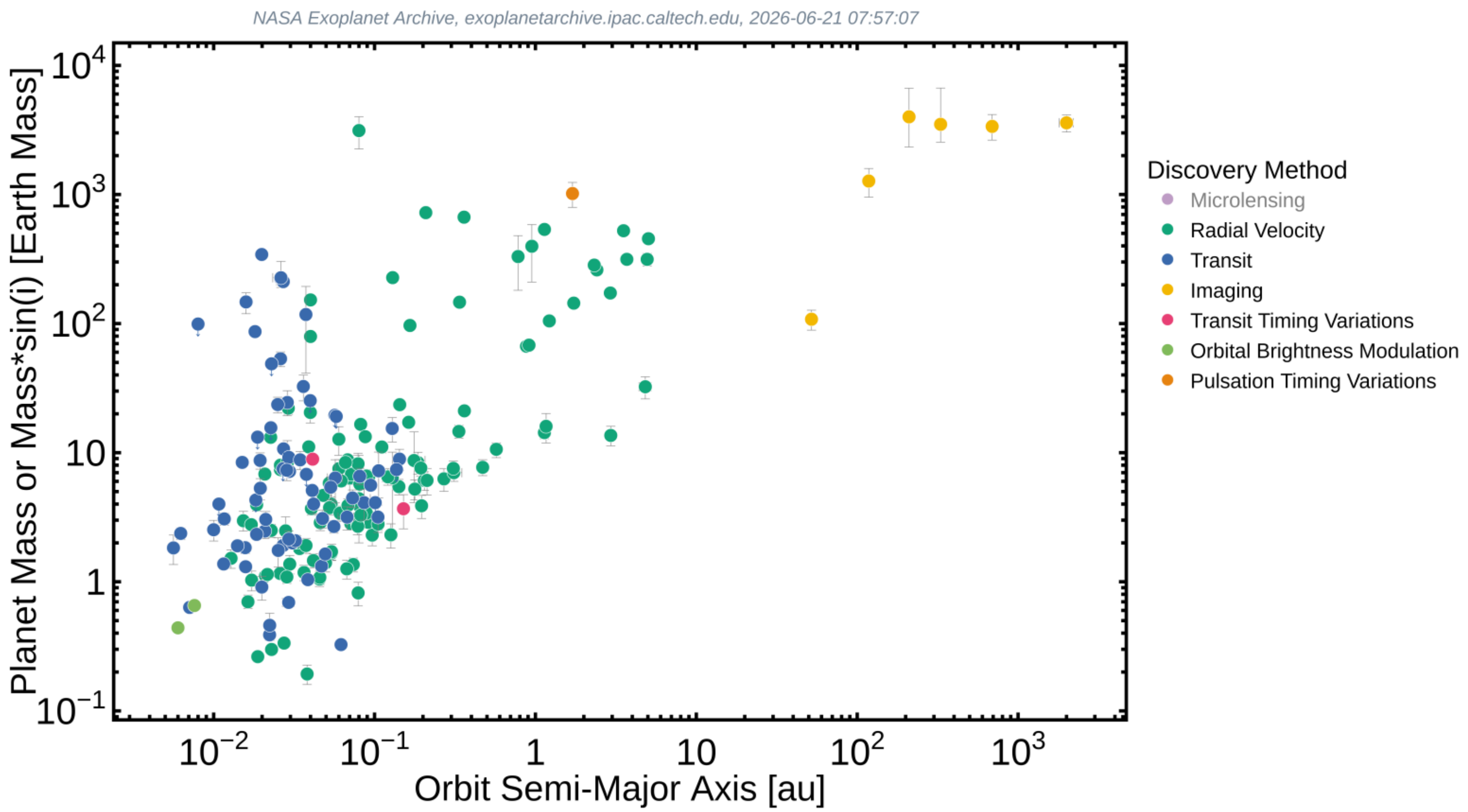


New sample of class II disks in Lupus around M and K dwarfs (high-resolution ALMA data ~4 au)

- 70% compact disks (<30 ua)
- Masses between 0.3-27 M_{Earth}
- More than 50% of them ultra-compact (<5 au)

Guerra-Alvarado+2025

Exoplanet demographic around M dwarfs



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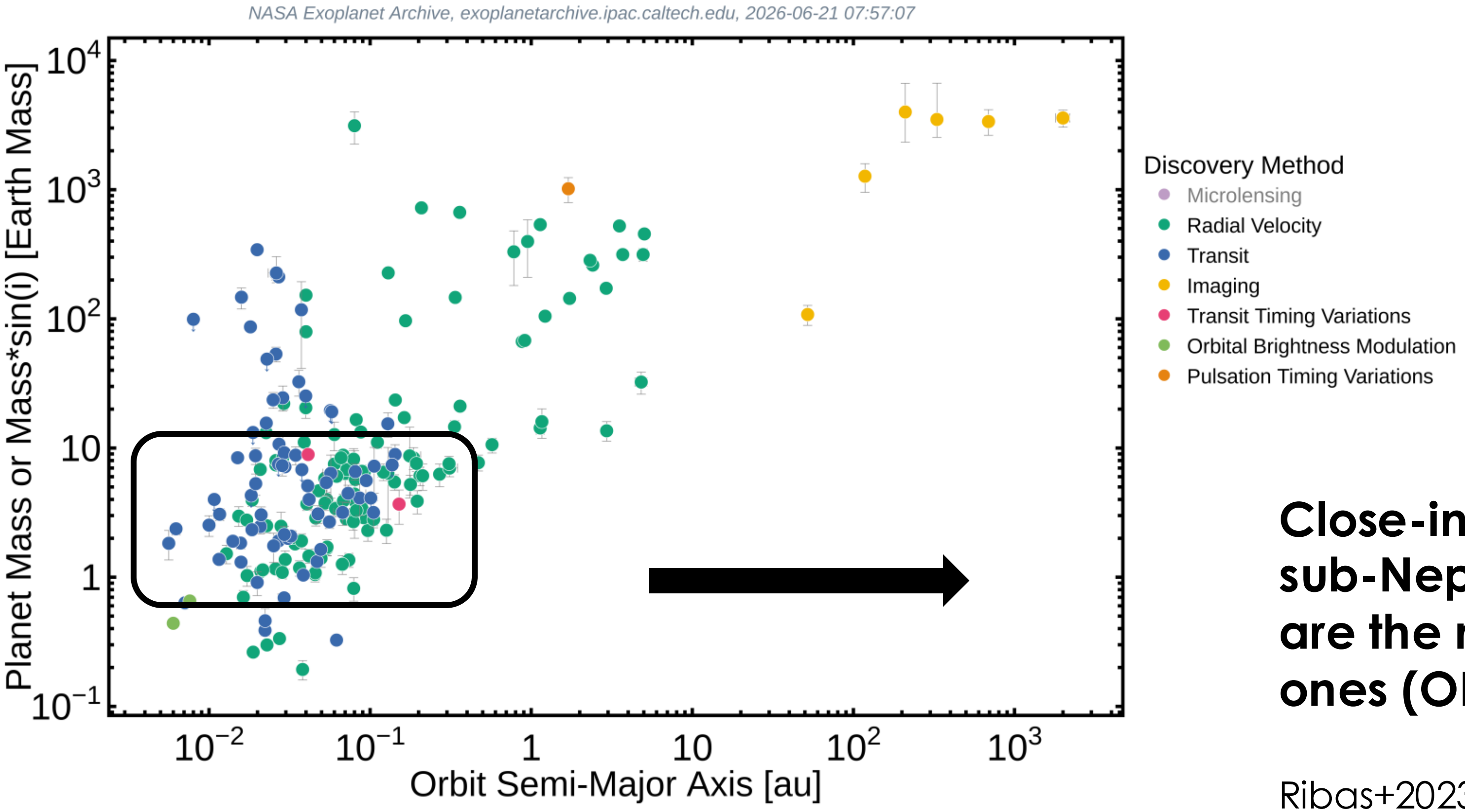
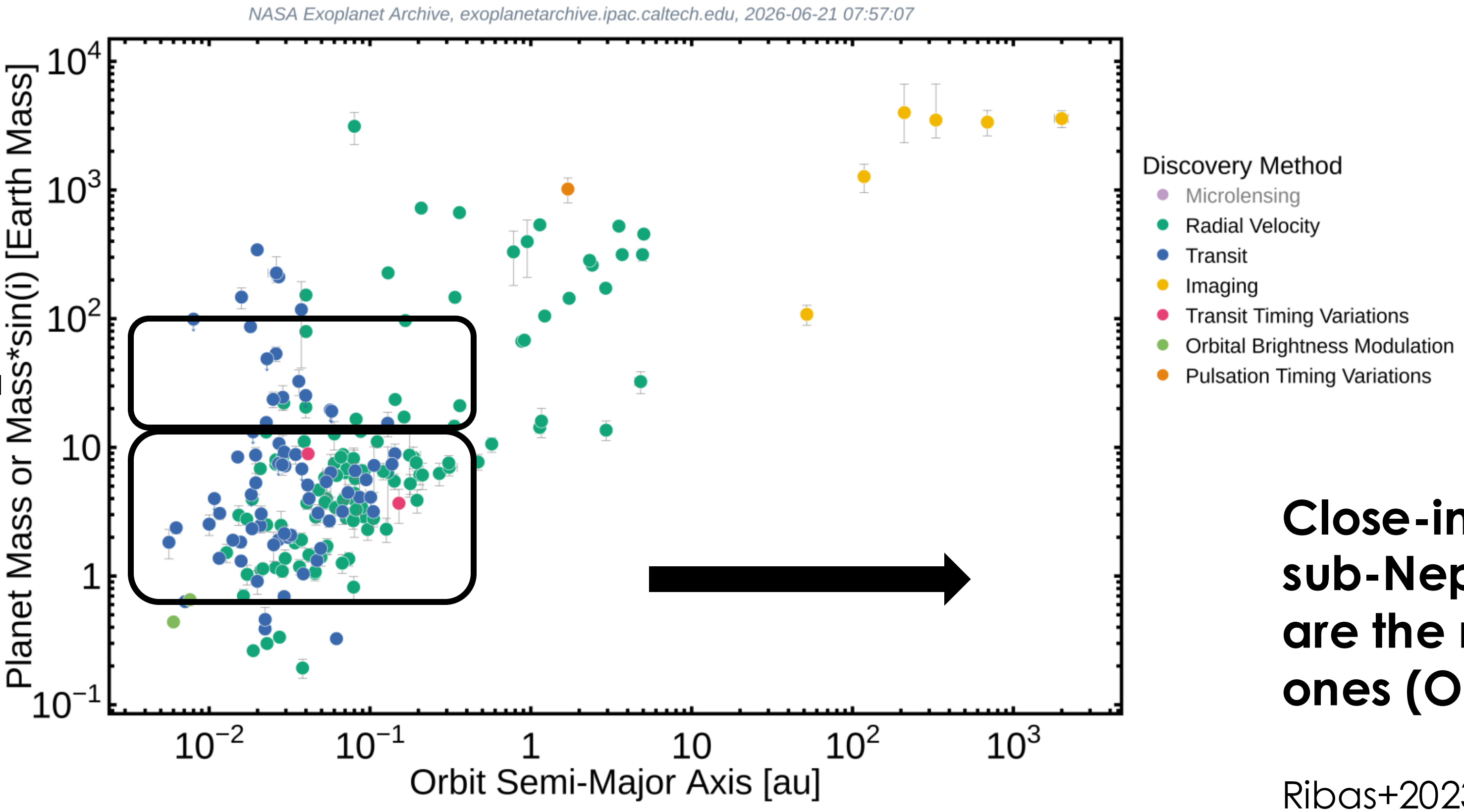


Close-in Super-Earth and sub-Neptunes explanets are the most common ones (OR ~ 70%)

Ribas+2023, Kaminski+2025

Exoplanet demographic around M dwarfs

Close-in giant planets (M_p<100 M_{Earth}) are rare (OR < 10%)



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Ribas+2023, Kaminski+2025

Exoplanet demographic around M dwarfs

Lack of hot and warm Jupiters (OR < 2%)

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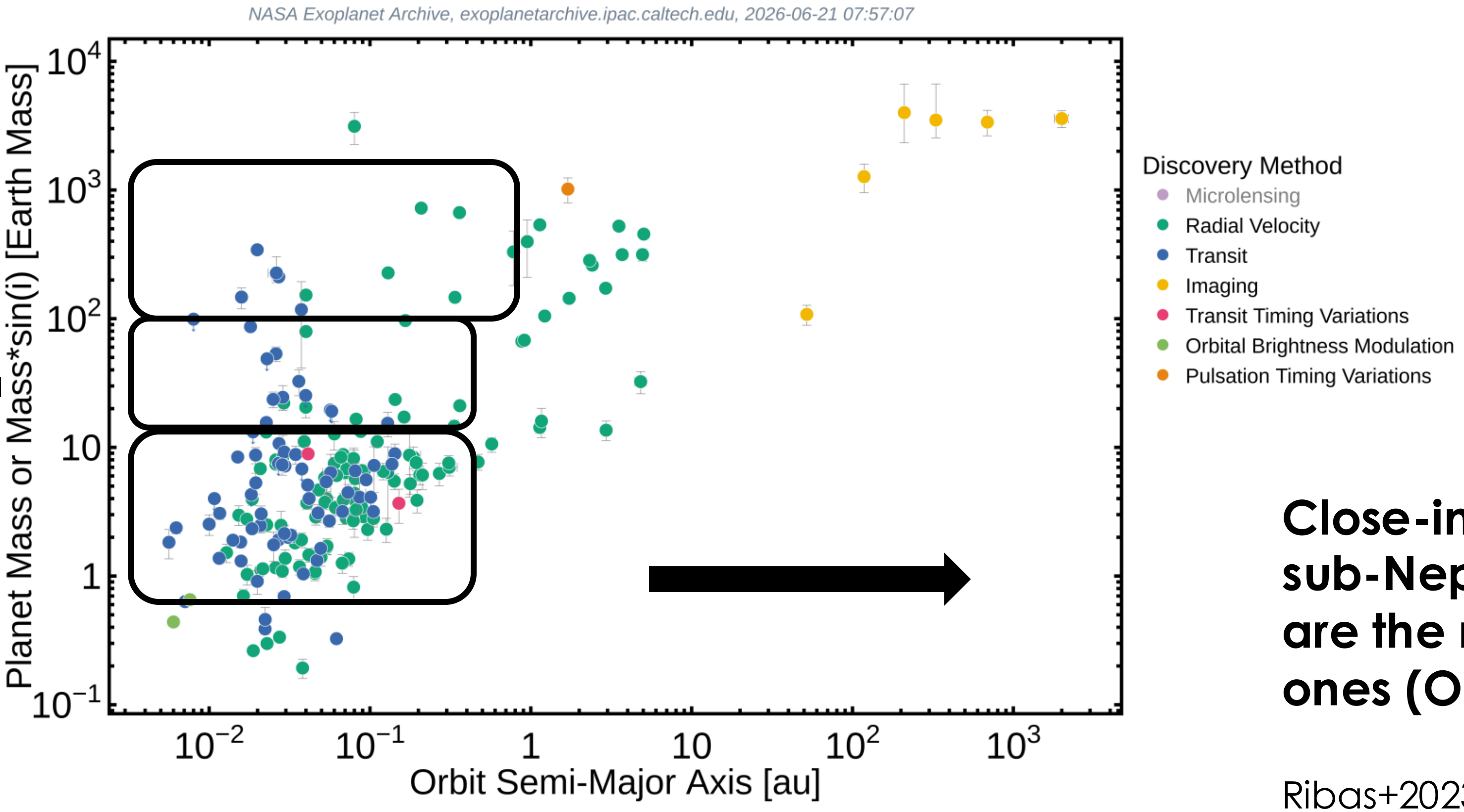

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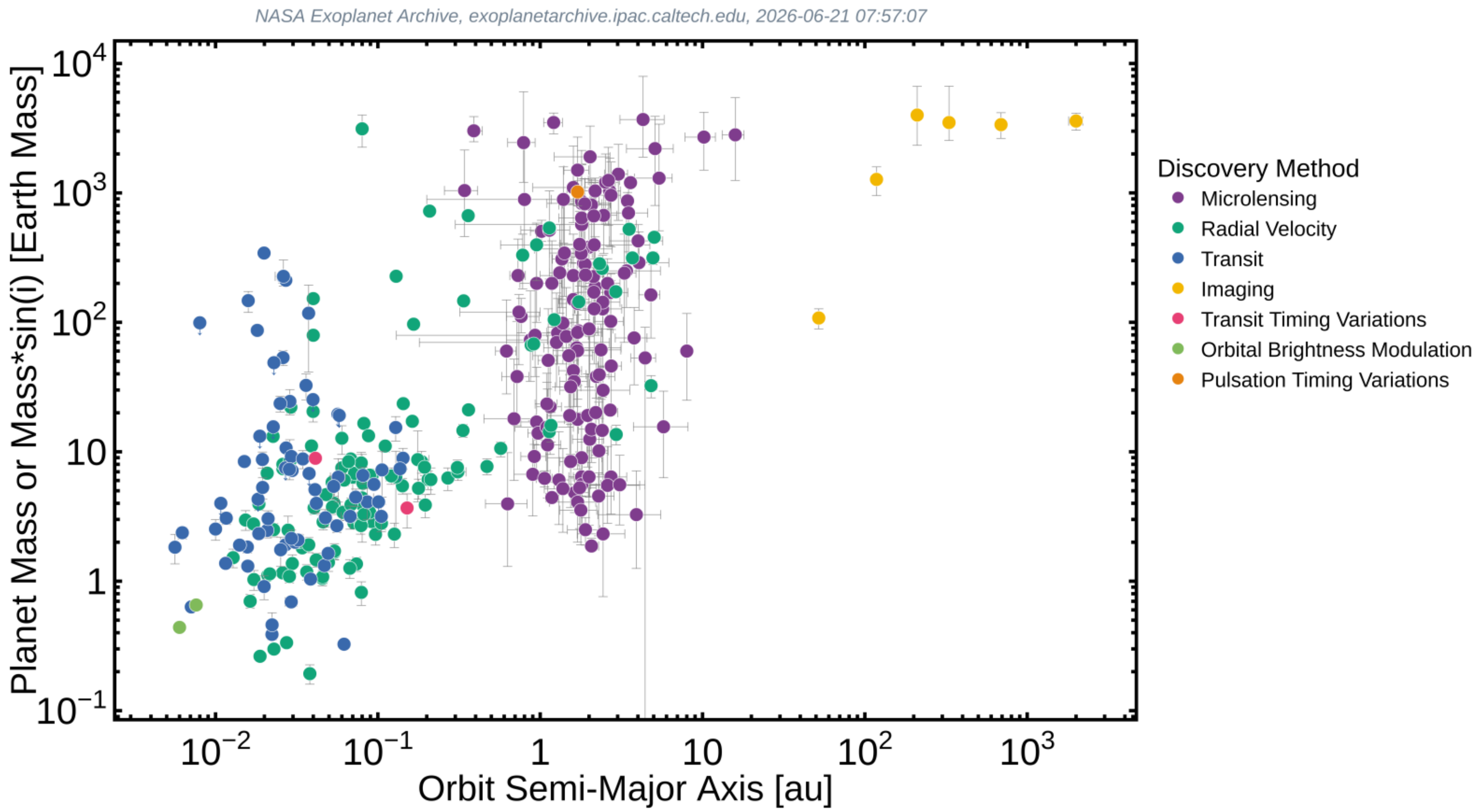

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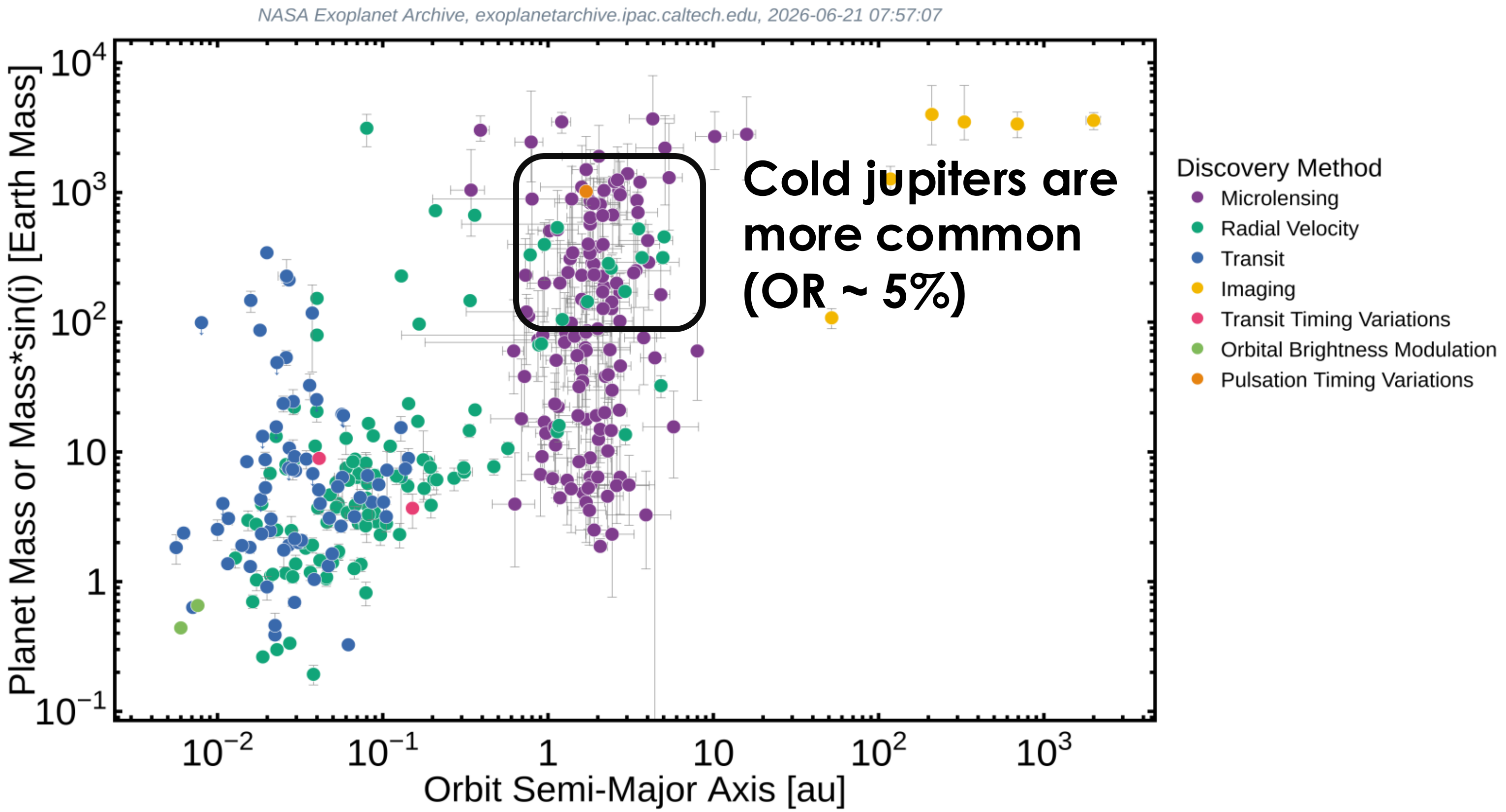
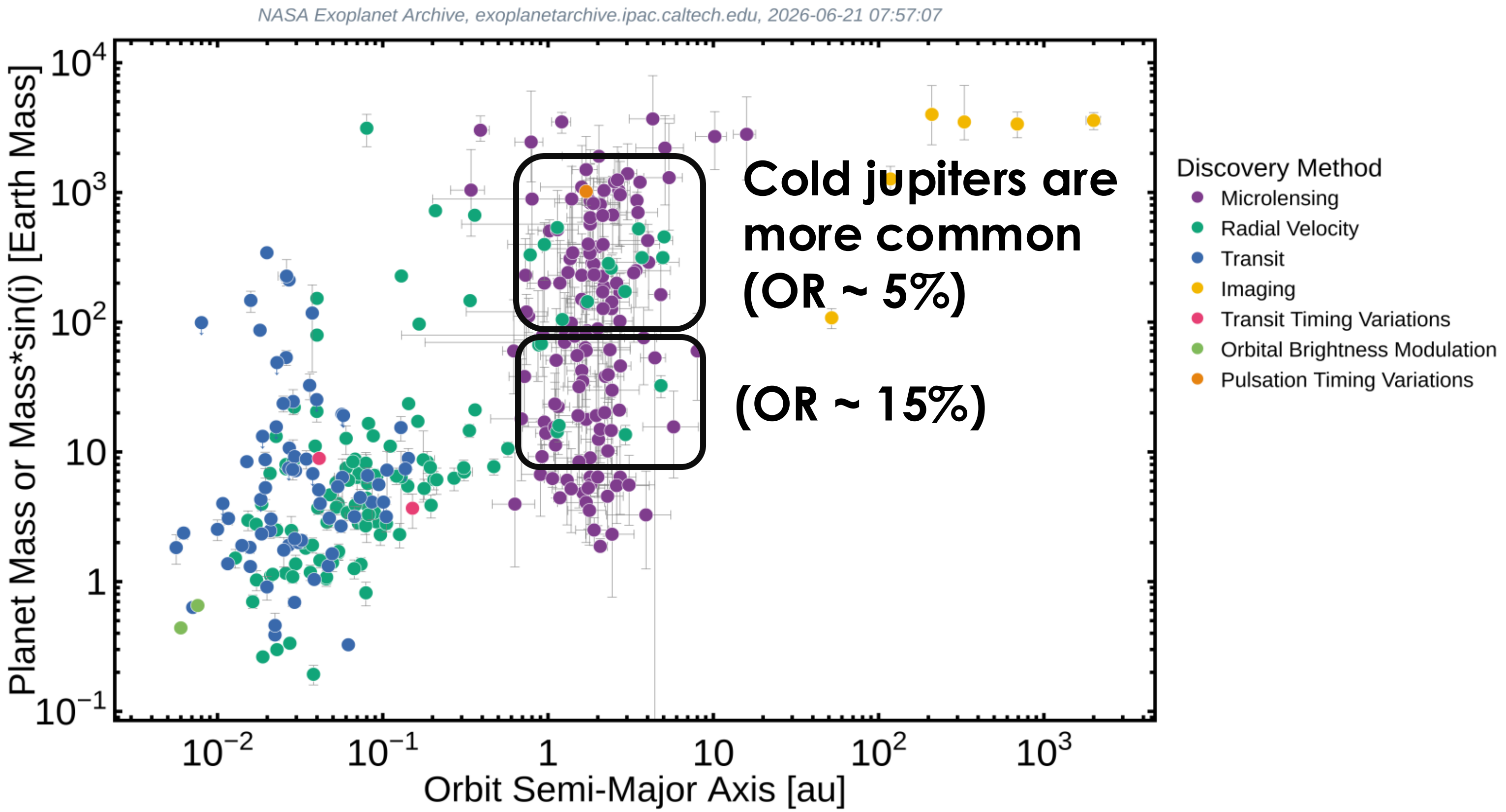


Clanton & Gaudi 2014

Exoplanet demographic around M dwarfs



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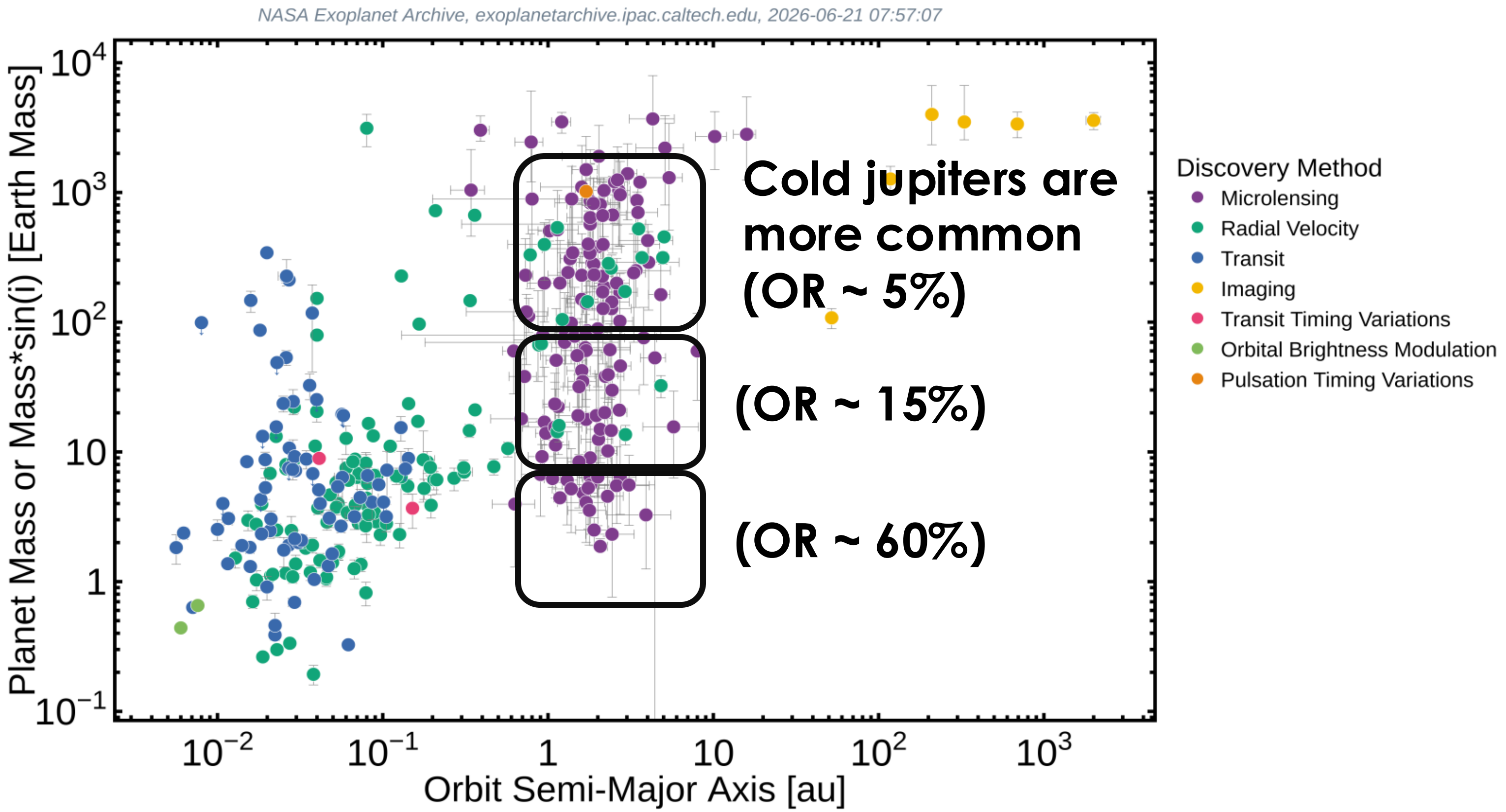
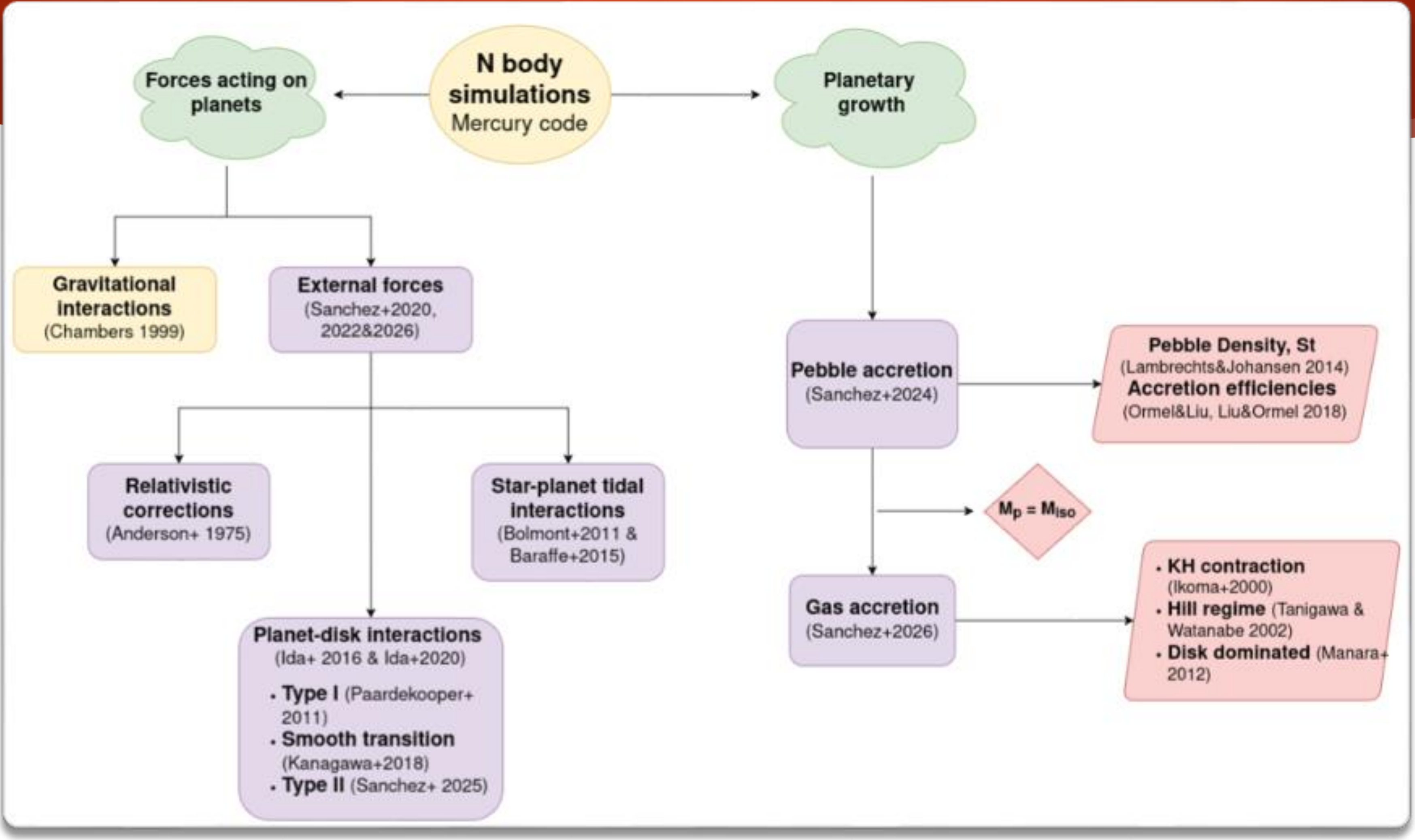


Clanton & Gaudi 2014

Objectives

- Could compact protoplanetary disks be the birthplace of close-in super-Earths?
- Which are the Initial solid and gas mass budgets required for the formation of giant planets?
- Can a single formation model explain planet formation around M dwarfs?

Planet formation model



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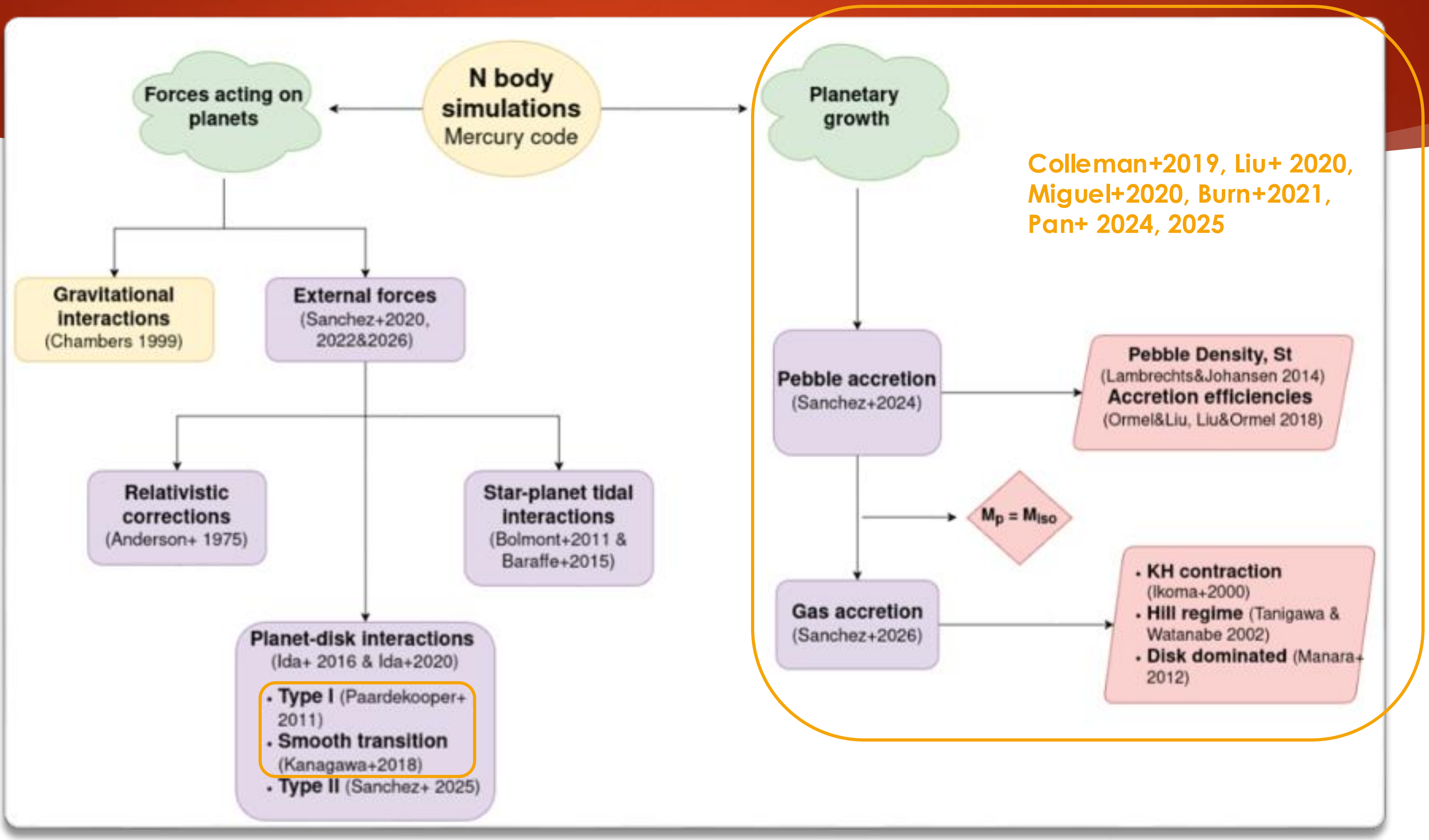

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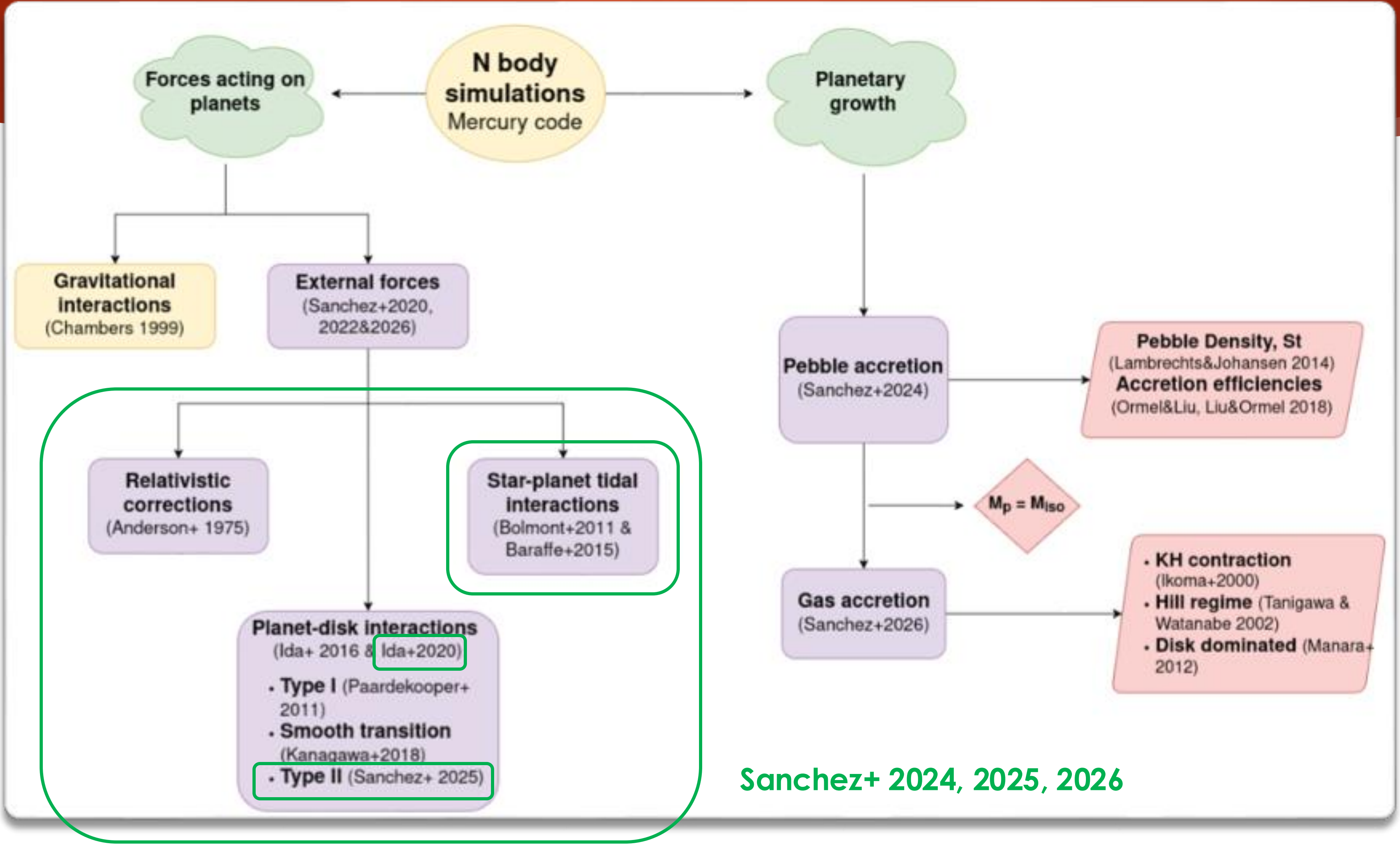
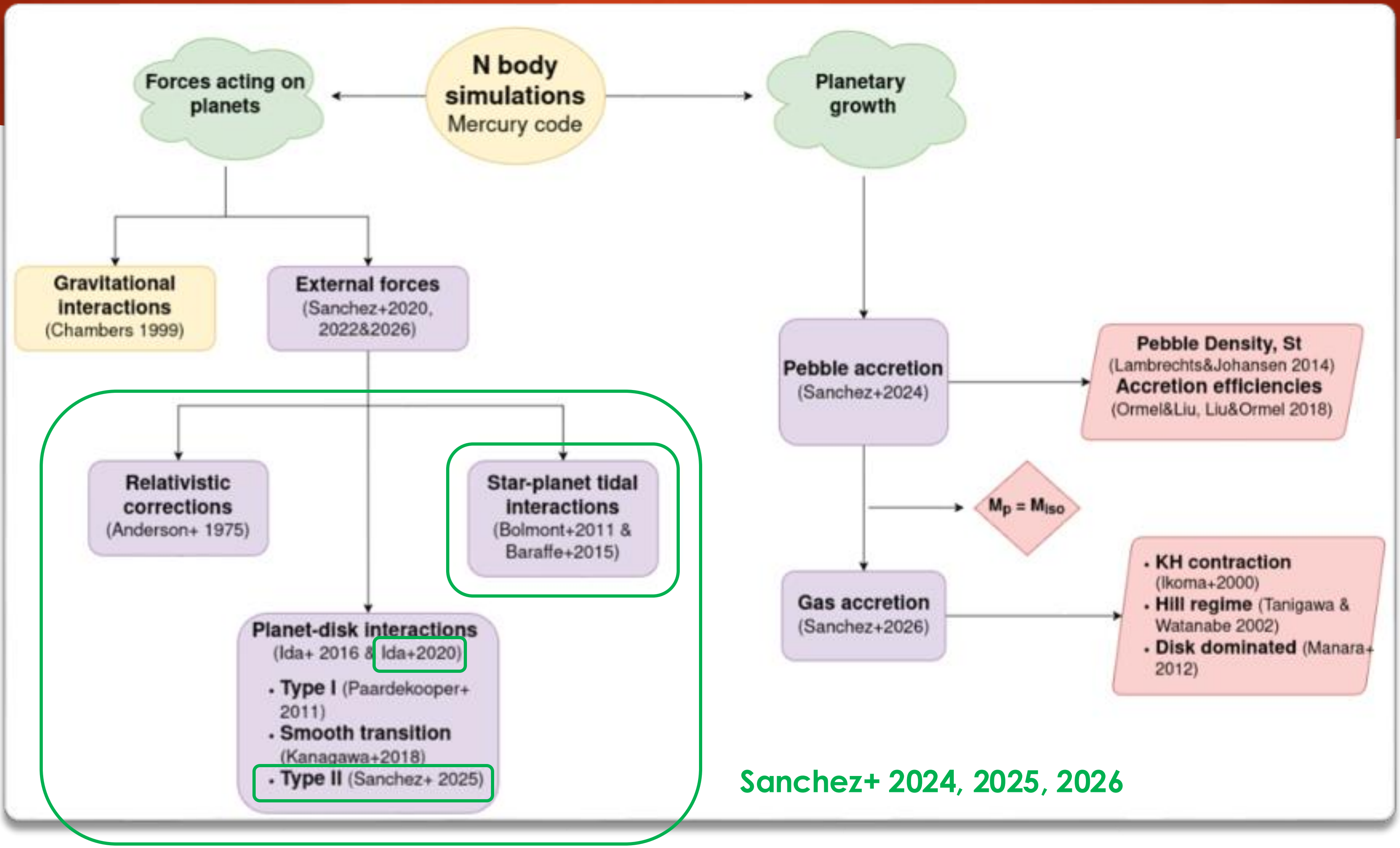


Sanchez+ 2024, 2025, 2026

Planet formation model



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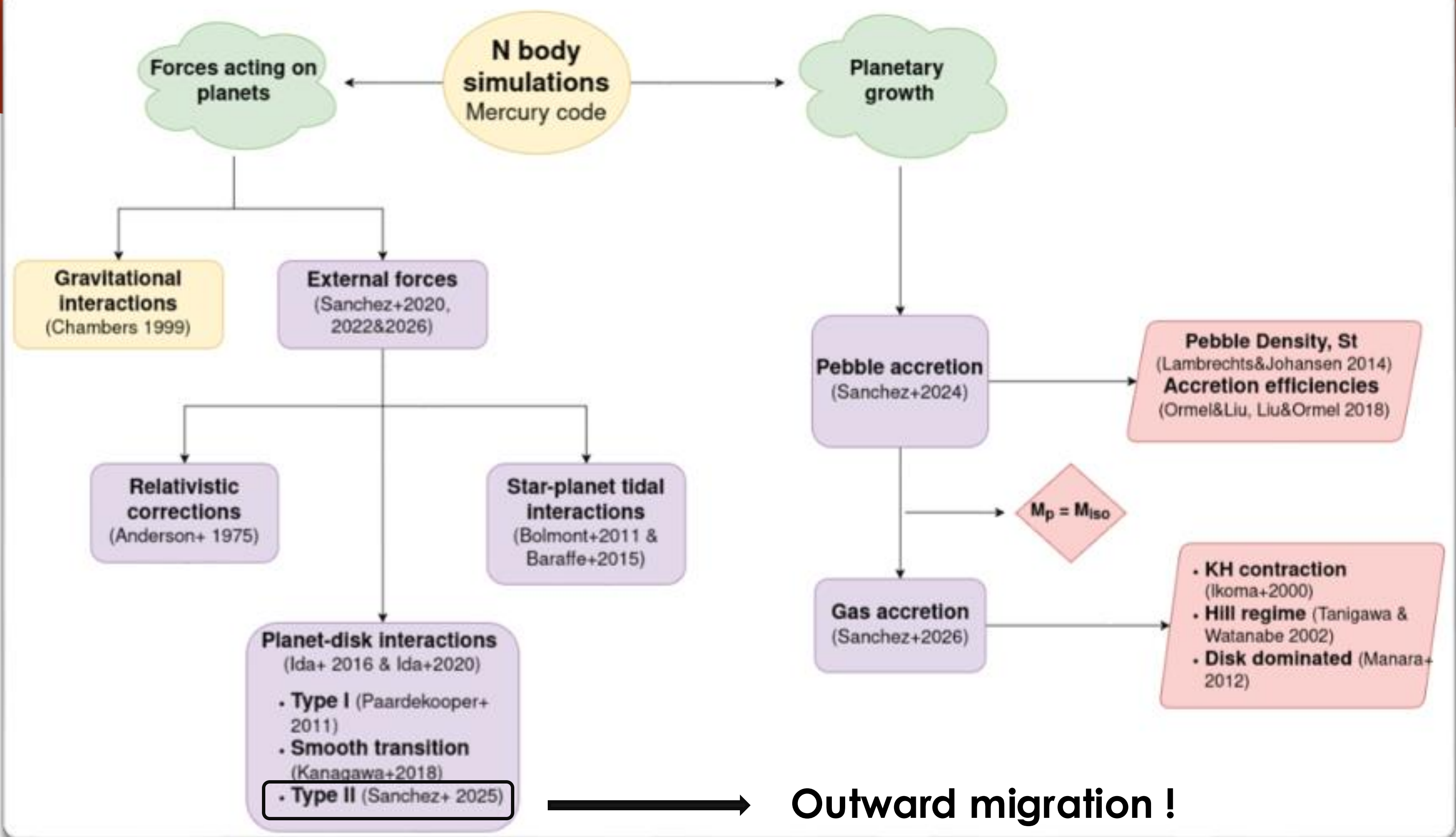


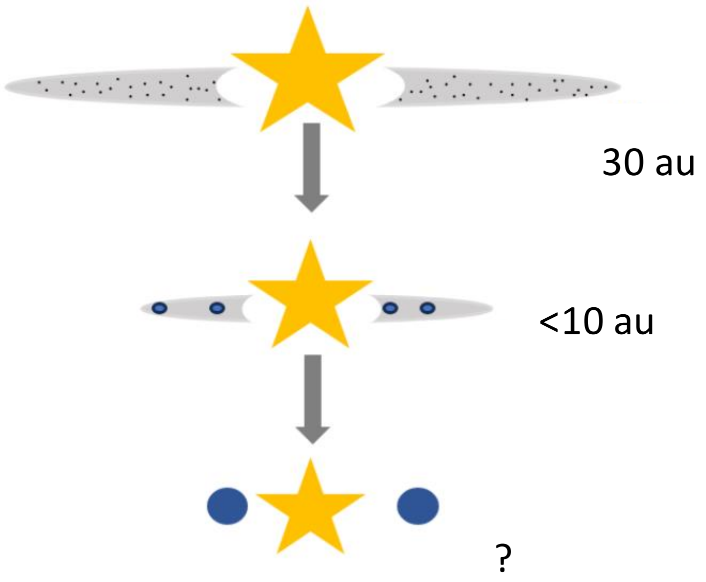
Outward migration !

for Mp > 65 MEarth, Mstar = 0.1 MSun

Sanchez+2025

Initial conditions

- Initial pebble reservoir in a 30 au compact dust disk (Guerra-Alvarado+2025)



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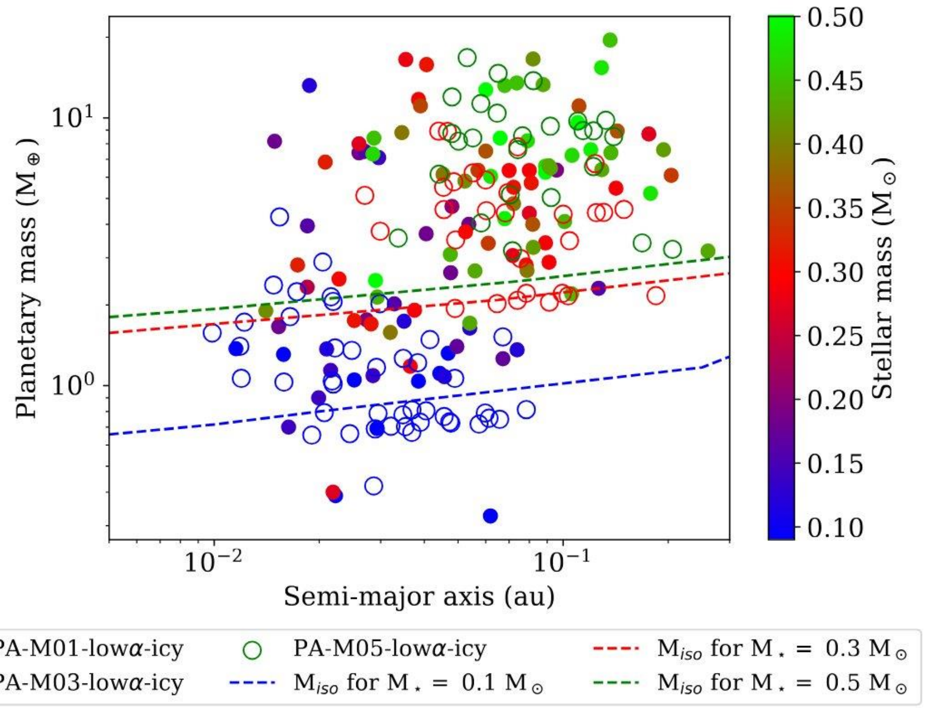
- Gas-disk turbulent viscosity: $\alpha_t = 0.0001$ (Rossotti+2023, Sanchez+2024)

Close-in Super Earth formation can take place in compact dust disks with efficient radial drift

Sanchez+ 2024



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- New prescription for the evolution of the pebble flux: $M_{\mathrm{flux}} = M_{\mathrm{flux,in}} \exp\left(-t/Myr\right)^2$

6, 10, 15, 20 & 30 M_{Earth} (Tychoniec+2020, Guerra-Alvarado+2025, Michel+2021)

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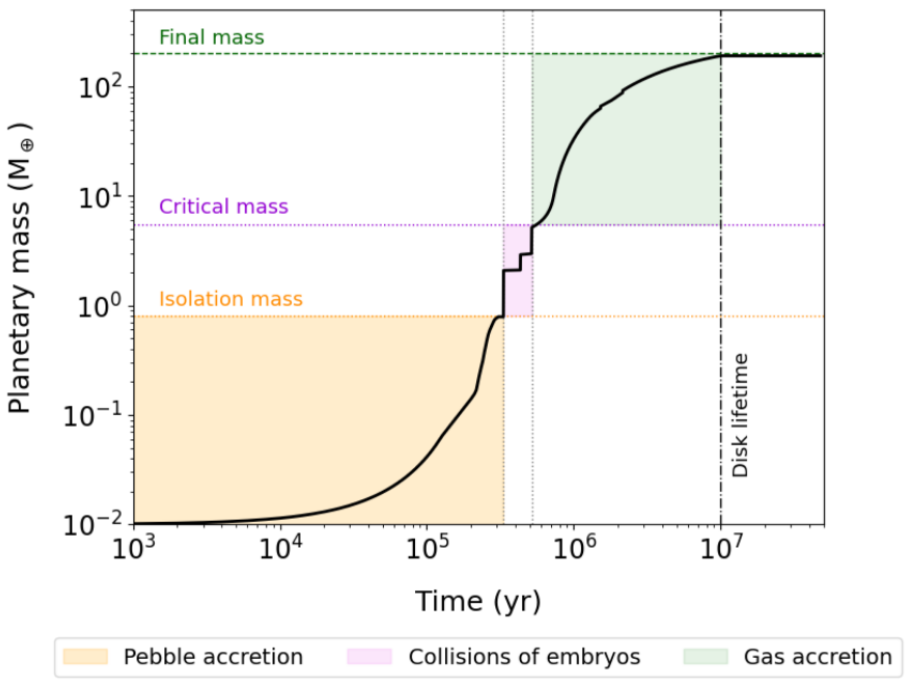
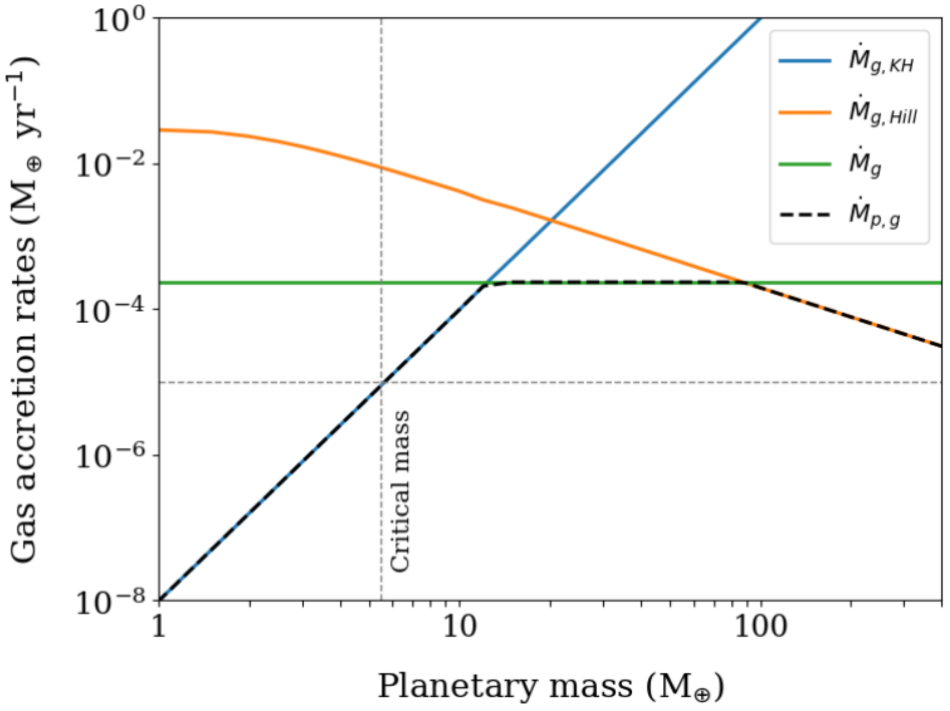
- Gas mass: 1, 5 y 10 M_{jup} (α_g: 0.001, 0.0005, 0.0001)
- Planetary embryo distribution: up to 2, 5 & 10 au
- Stellar mass: 0.1 M_{Sun}
- Disk lifetime: 10 Myr (e.g. Downes et al 2015, Pfalzner et al. 2022)
- Integration time: 100 Myr

Result I: How to form cold Jupiters?

Sanchez+ 2026

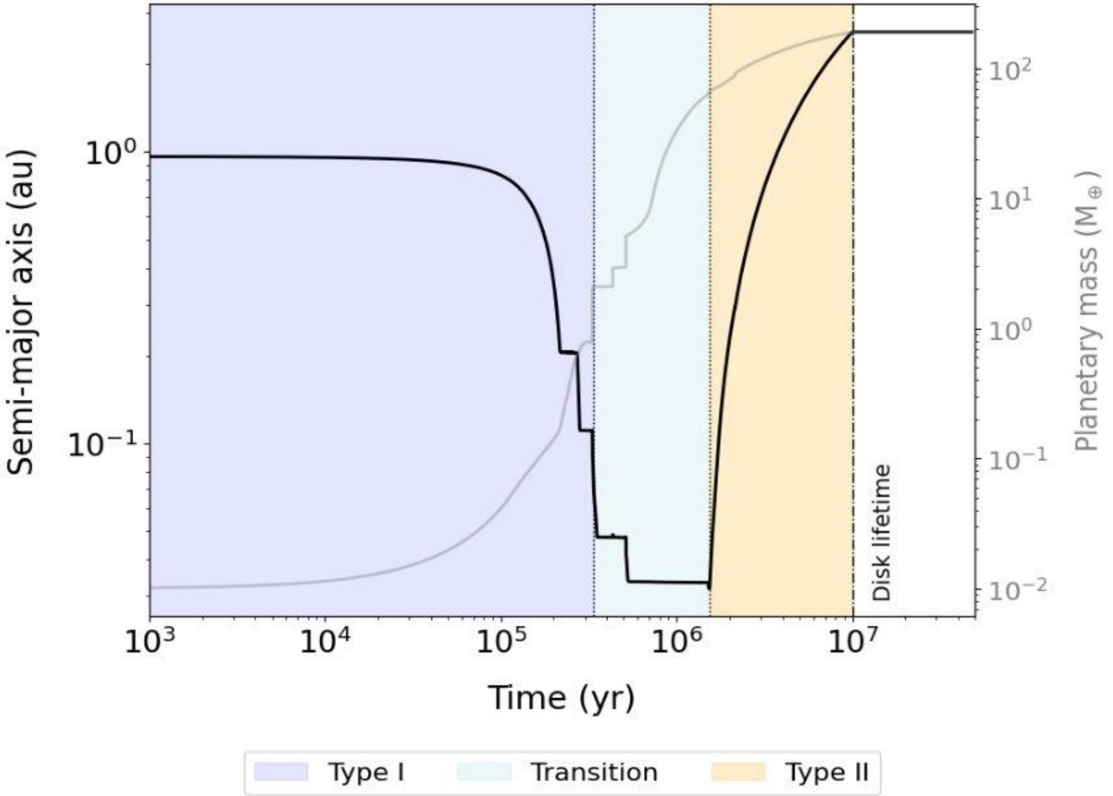
Formation path: mass evolution

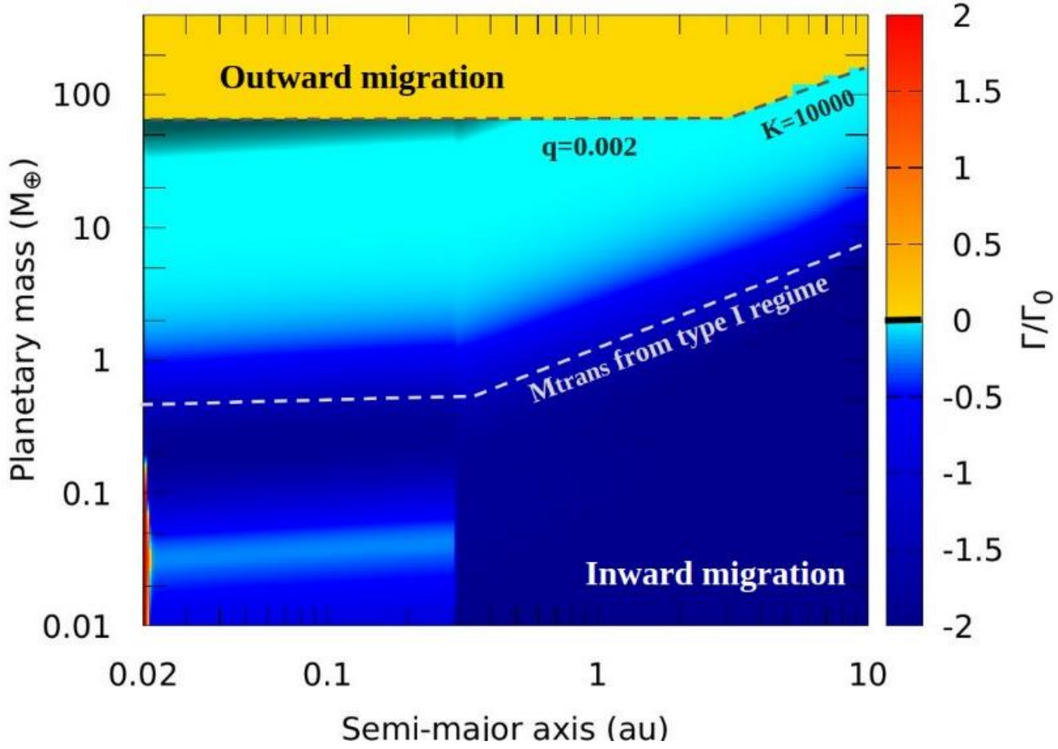




Sanchez+ 2026

Formation path: semi-major axis evolution





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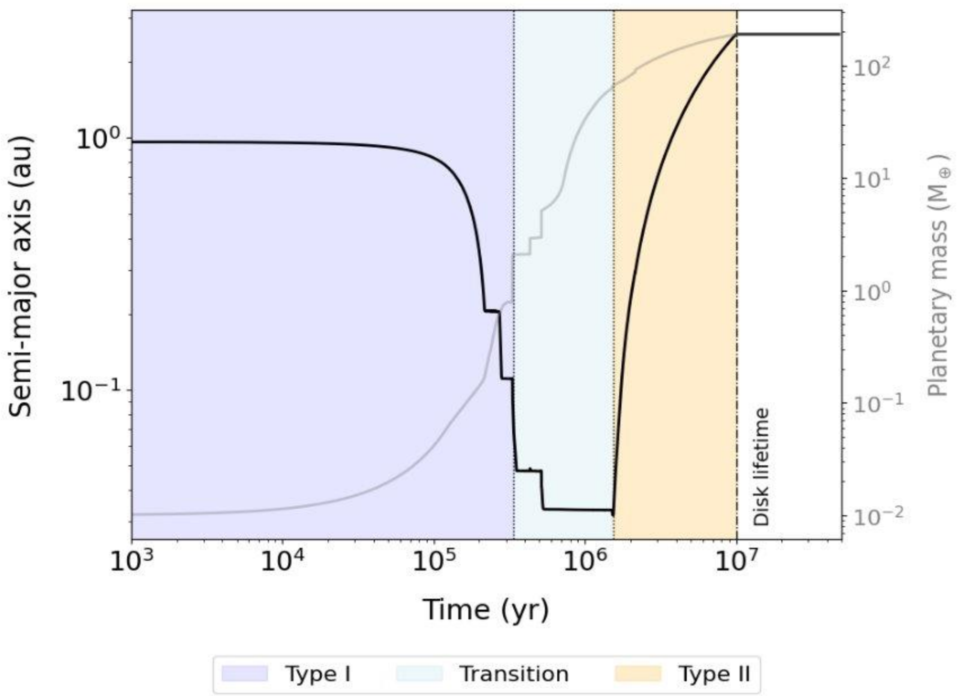

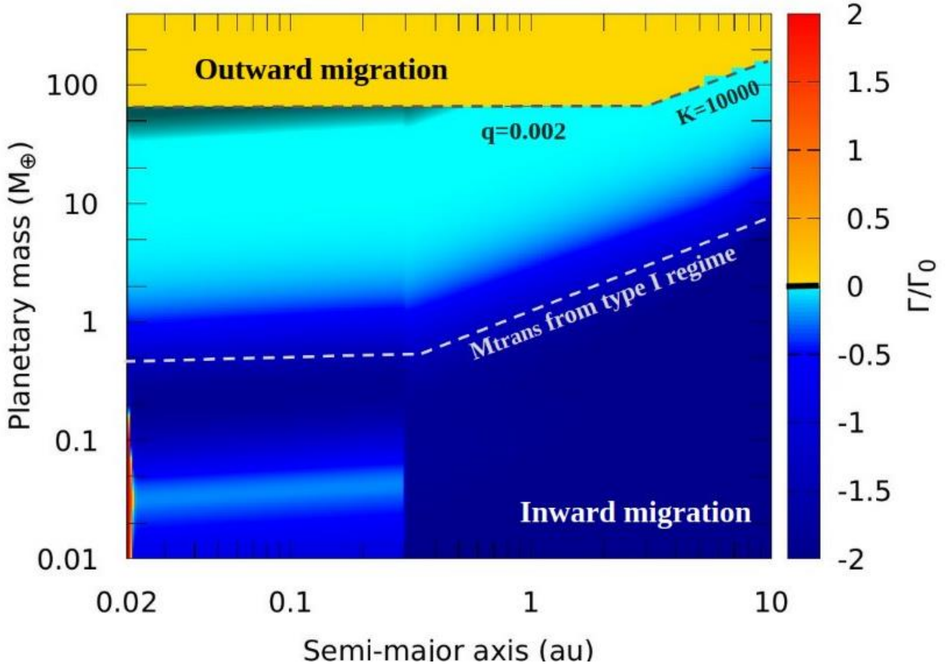

Initial pebble mass = 6 MEarth & Initial gas mass = 10 Mjup !

Sanchez+ 2026

Result II: Match with exoplanet demographic

Sanchez+ subm

Conclusions & ongoing work

- Cold giant formation can take place in compact disk with planetary cores forming close to the star, ending up at wider separations (1-5 au) due to outward migration.
- Good match with the close-in planet population $M < 30\ M_{Earth}$ (in agreement with the outward migration threshold), in terms of mass, semi-major axis, and OR.
- Dust compact disks (<30 au) and low viscosity gas disks (α_t=0.0001, M_{gas}>1 M_{Jup}) could be the origin to the close-in planet population (a<0.1 au) and cold giants around late M dwarfs.
- Potential habitability of planets that retain a thick atmosphere (=10%Mp) during gas-disk phase.
- Overproduction of close-in planets with masses greater than 30 M_{Earth}. Fragmentation role?
- Lack of low-mass planets at wider distances. Formation pathways?
- Application of our model to more massive stars.


THANK YOU !