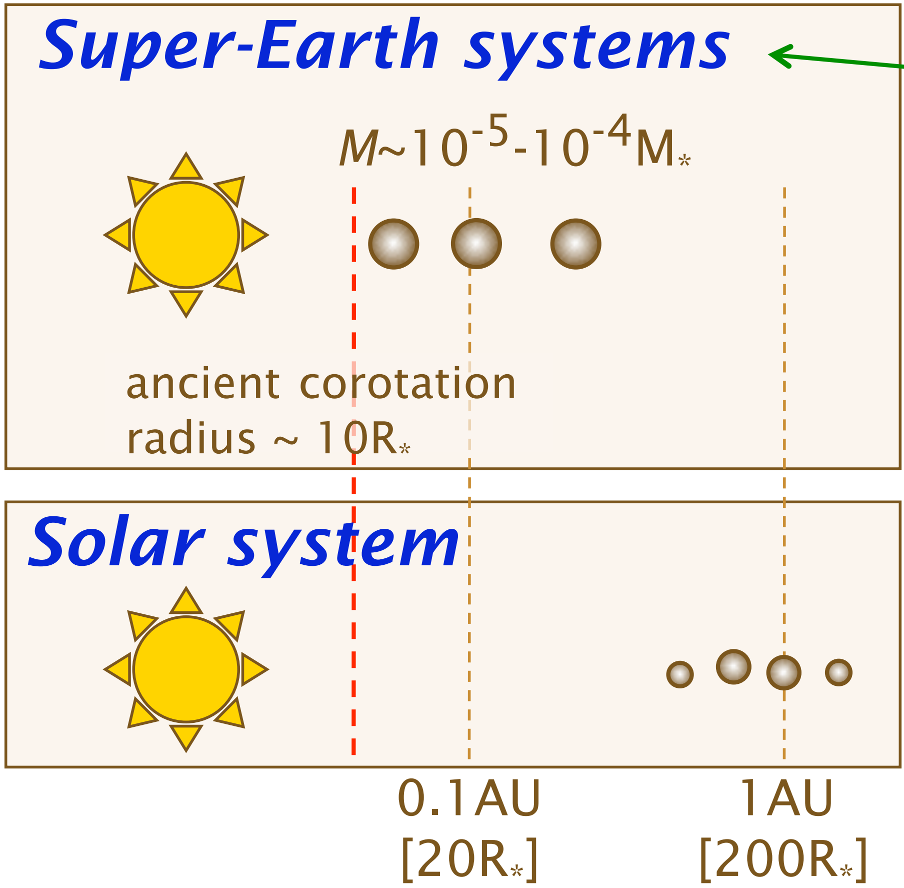
Formation of Non-Resonant, Multiple, Close-In Super-Earth Systems

Shigeru Ida (Tokyo Tech.)



Ida & Lin (2010)

RV survey by Swiss team

(Stephane's talks)

- common
  ~40-60%(?) of FGK dwarfs
  ←→ Solar system
- multiple, non-resonant
  ~70-80%(?)
- $a \sim 0.1$AU
  > HJs' a ; > corotation radius
- no runaway gas accretion?
  some SEs: $M > 10M_{\oplus}$

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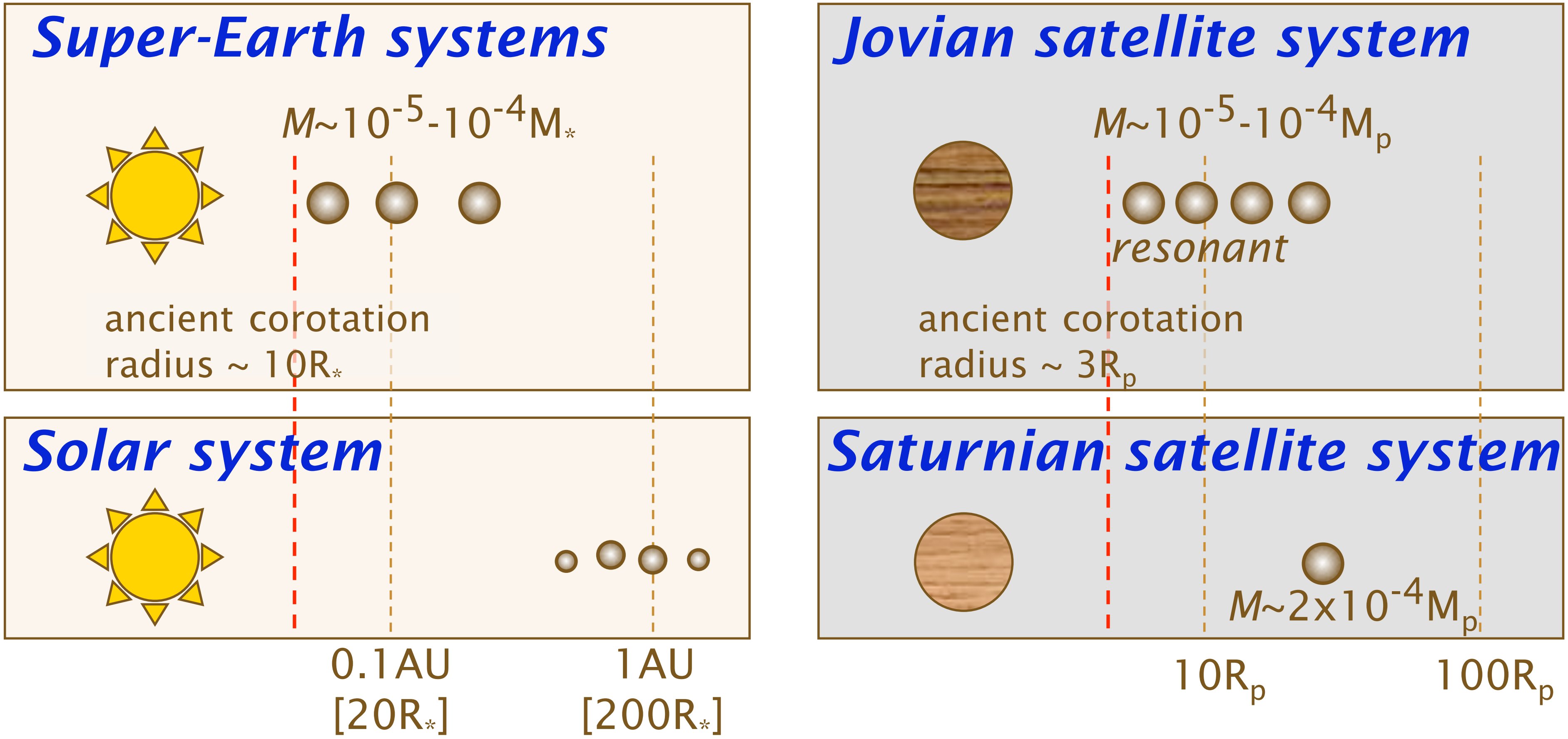

Ida & Lin (2010)

Sasaki, Stewart, Ida (2010)

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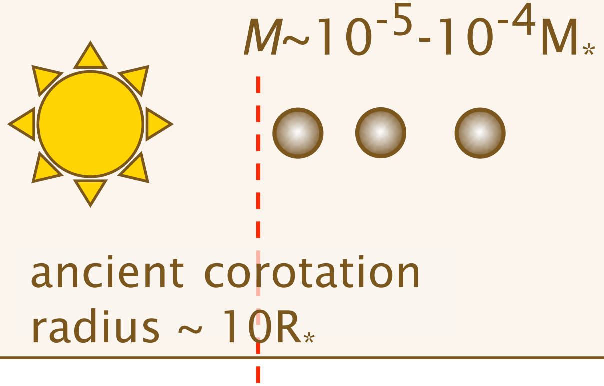
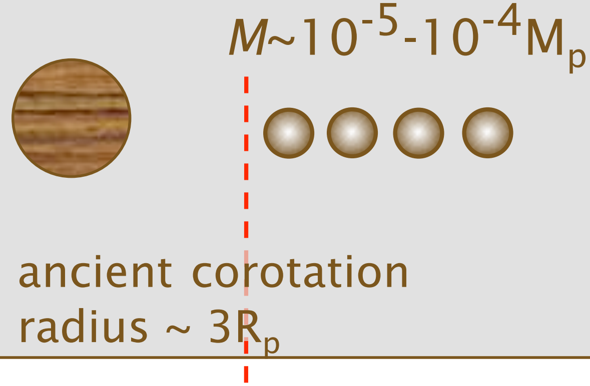
Super-Earth systems



Jovian satellite system



Why > corotation radius ?

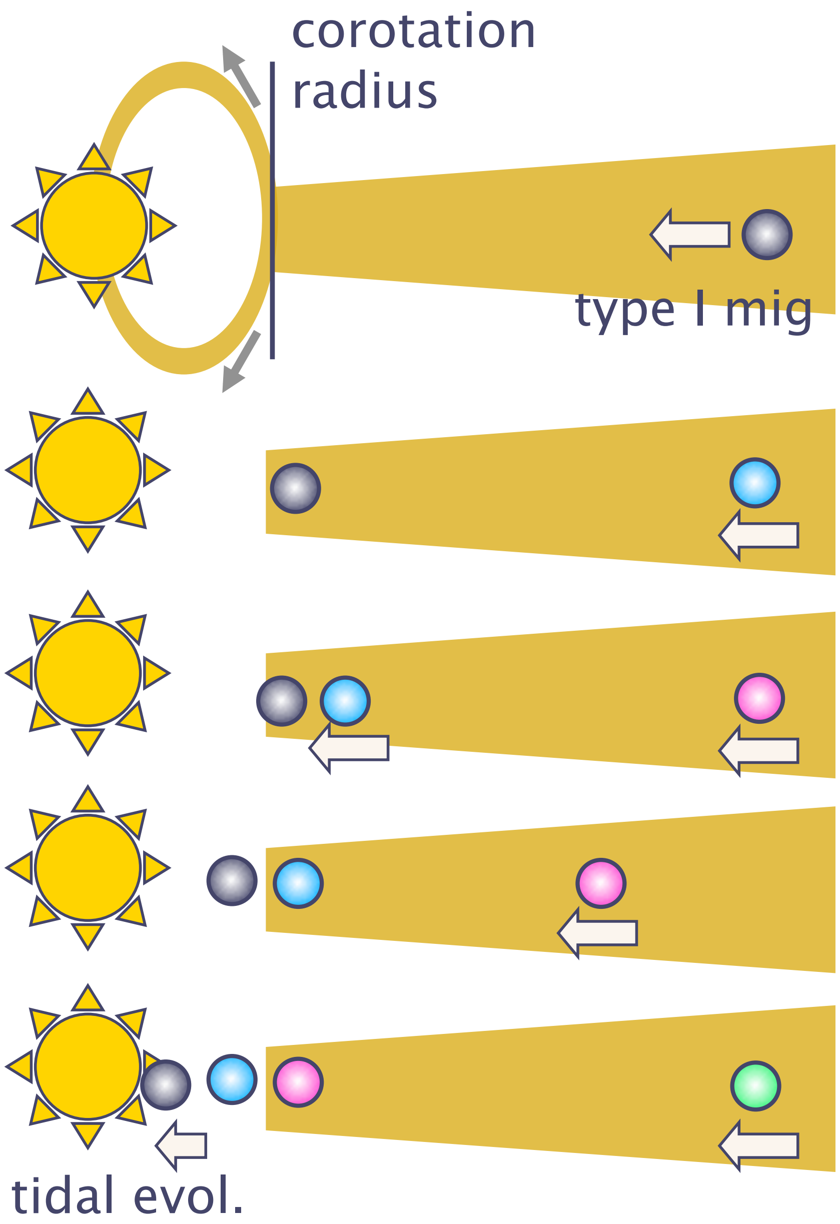
Ogihara, Duncan, Ida (2010)

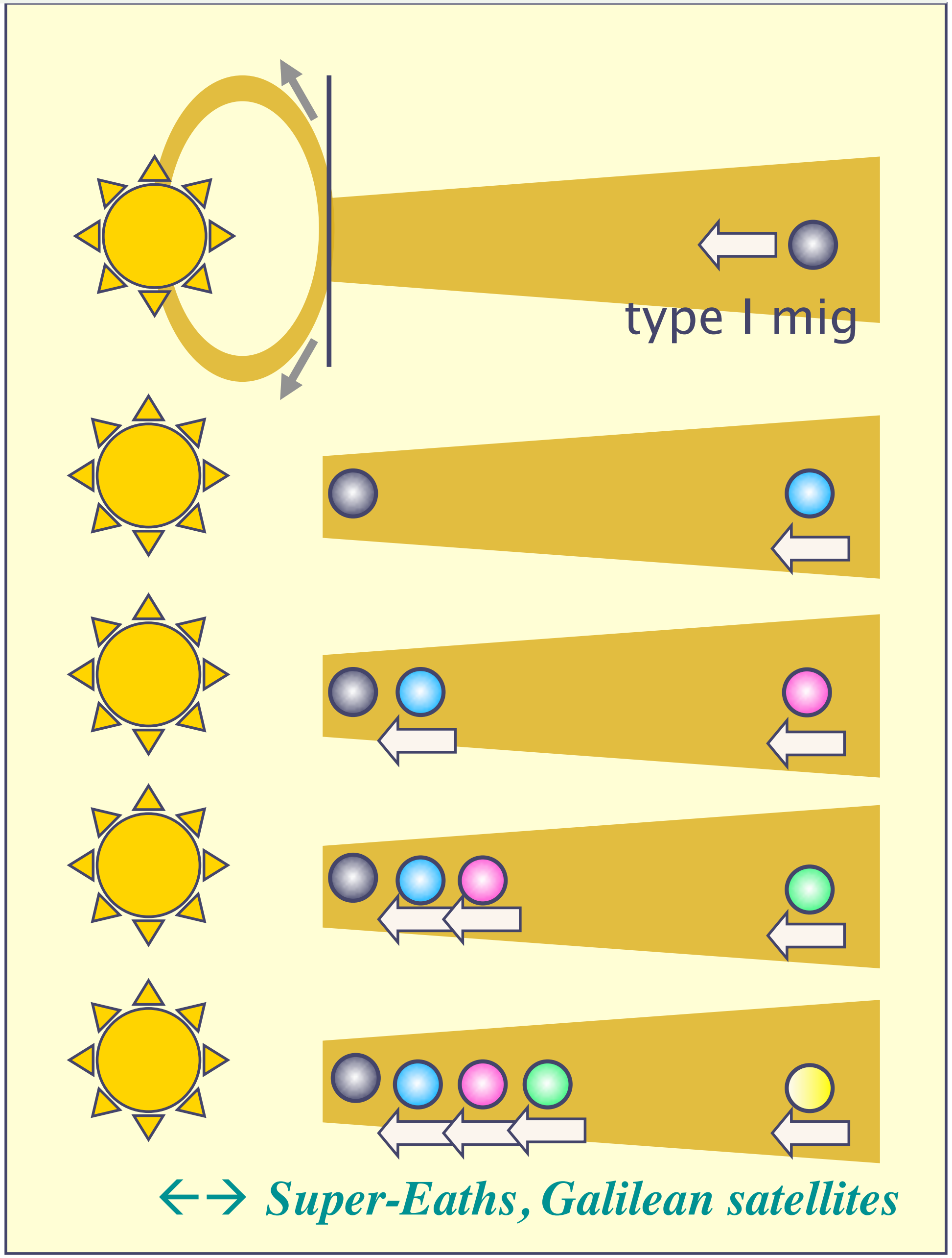
Ogihara & Ida (2009, ApJ)

Ida & Lin (2010)

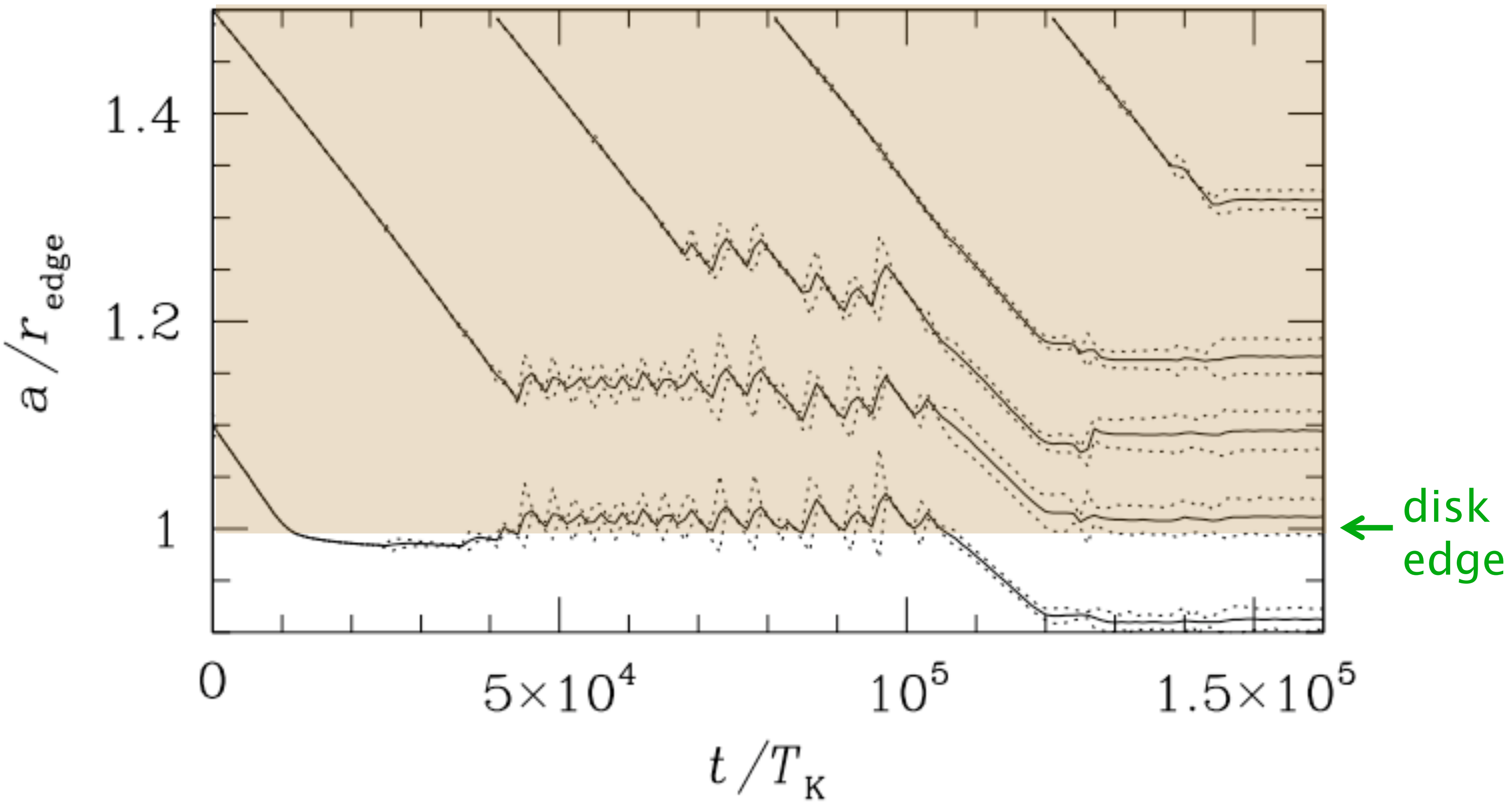
Sasaki, Stewart, Ida (2010)

type I migration vs. disk inner edge





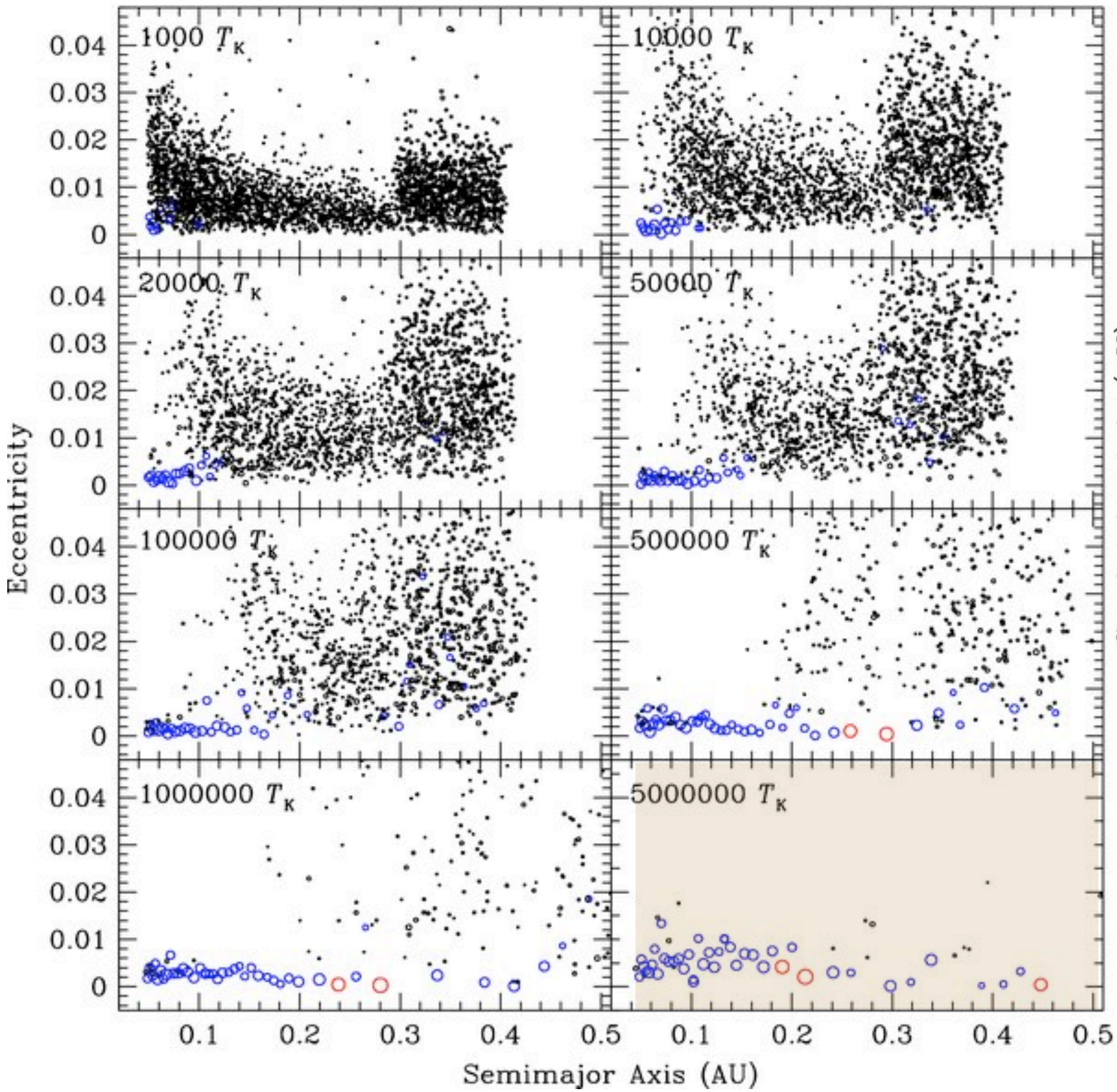
Eccentricity trap



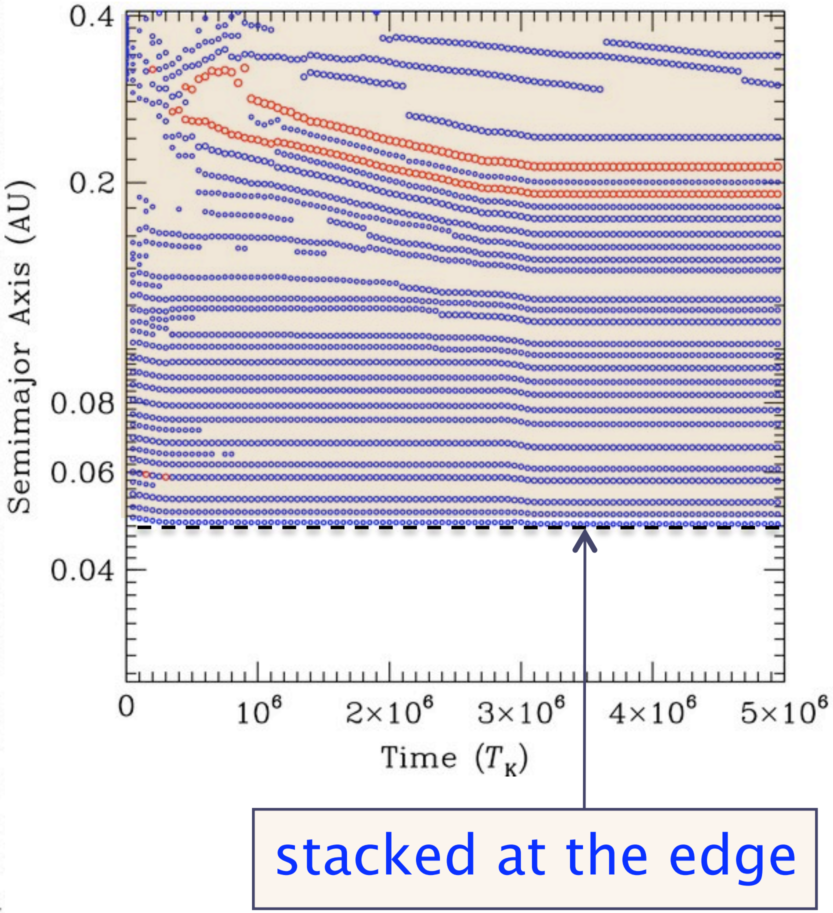
N-body + type-I drag (*fast* migration)
Ogihara, Duncan, Ida (2010)

Eccentricity trap

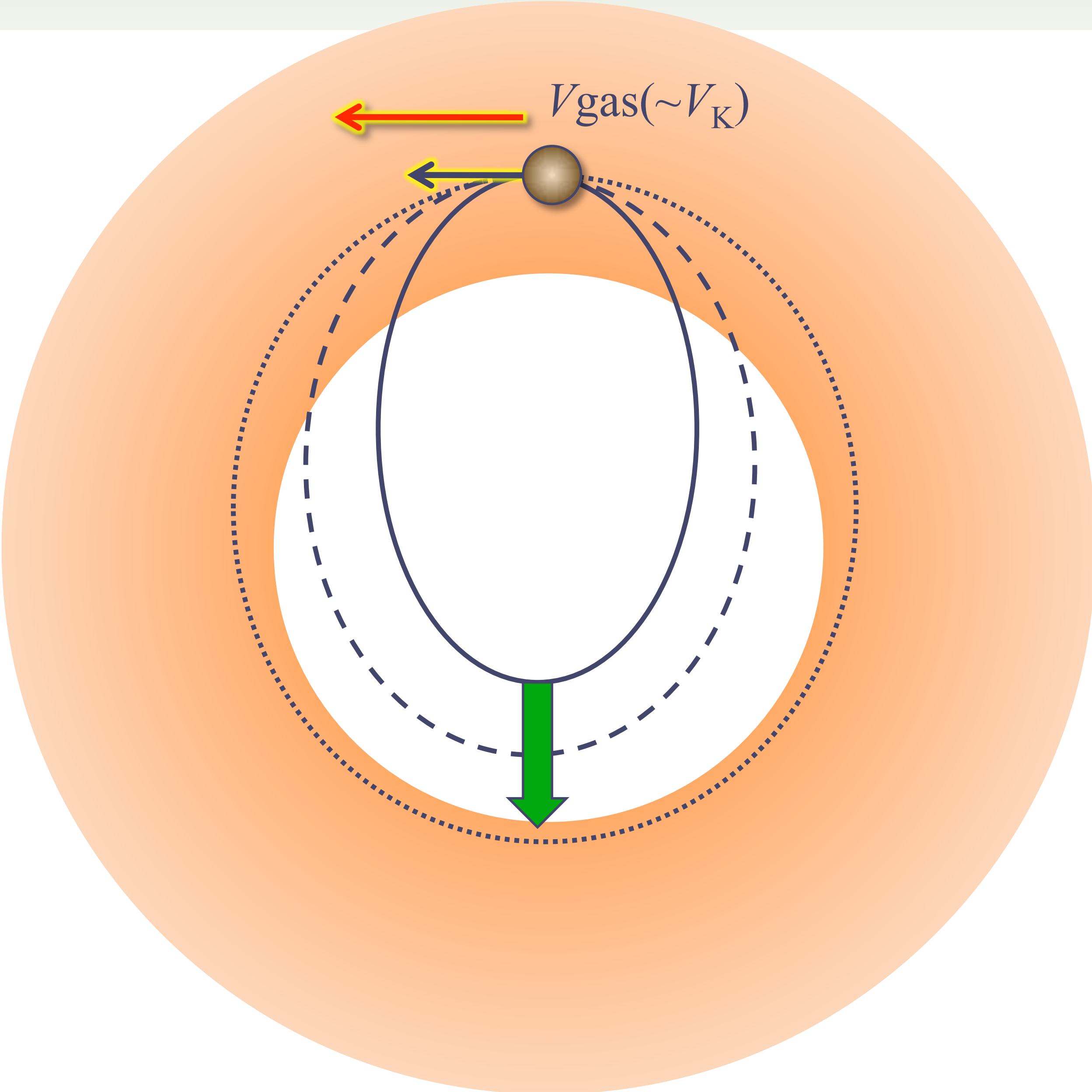
Ogihara & Ida (2009, ApJ 699, 824)



slow **migration case**



Eccentricity trap

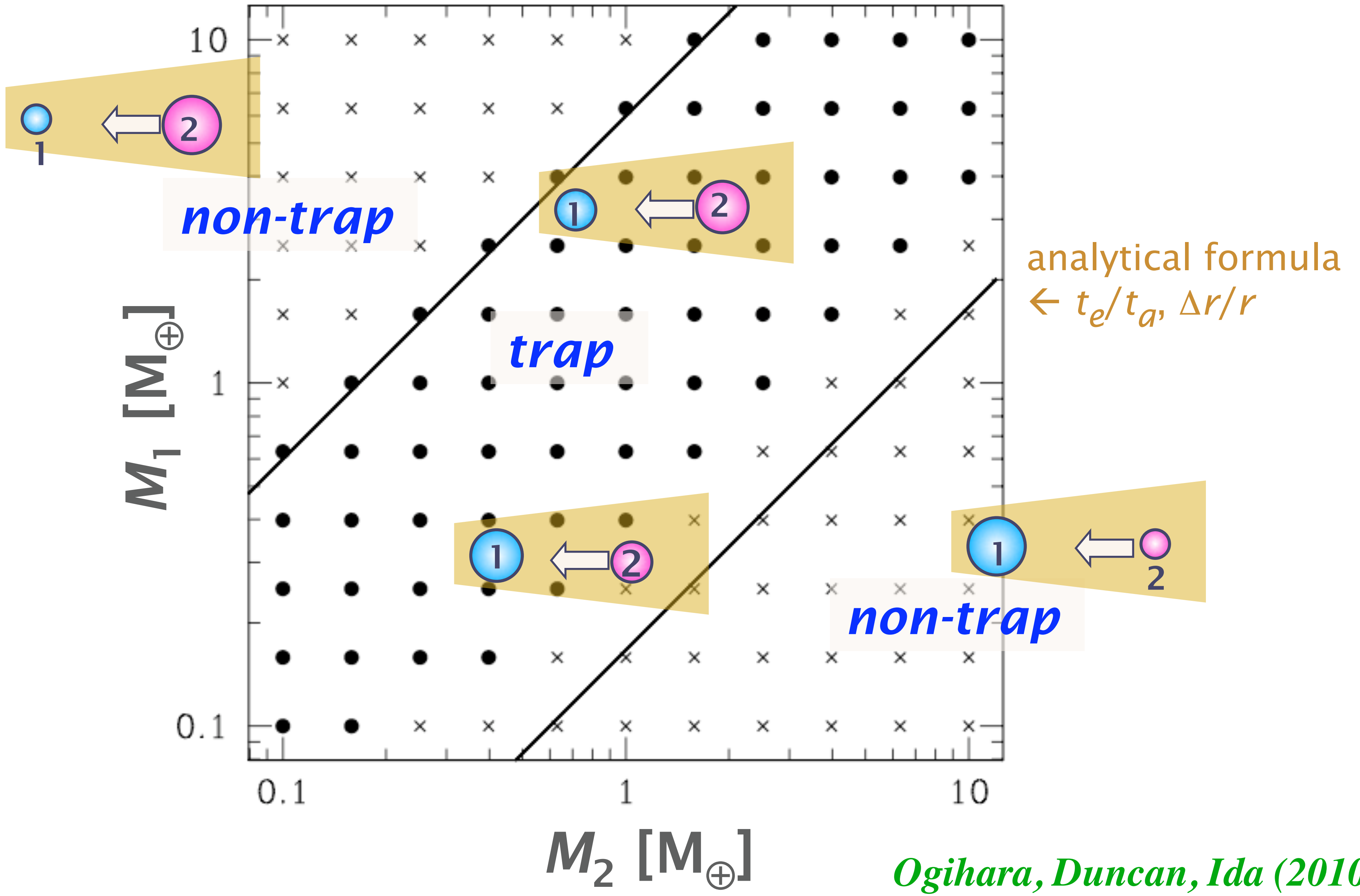


Tidal e-damping
(+ resonant e-excitation)
↓
outward migration !
very fast:
$t \sim (c_s/v_K)^2\, t_{type\text{-}I\ mig}$

much stronger than reverse type-I mig. near disk edge (Masset et al. 2006)

confirmed by hydro - Crida, Baruteau

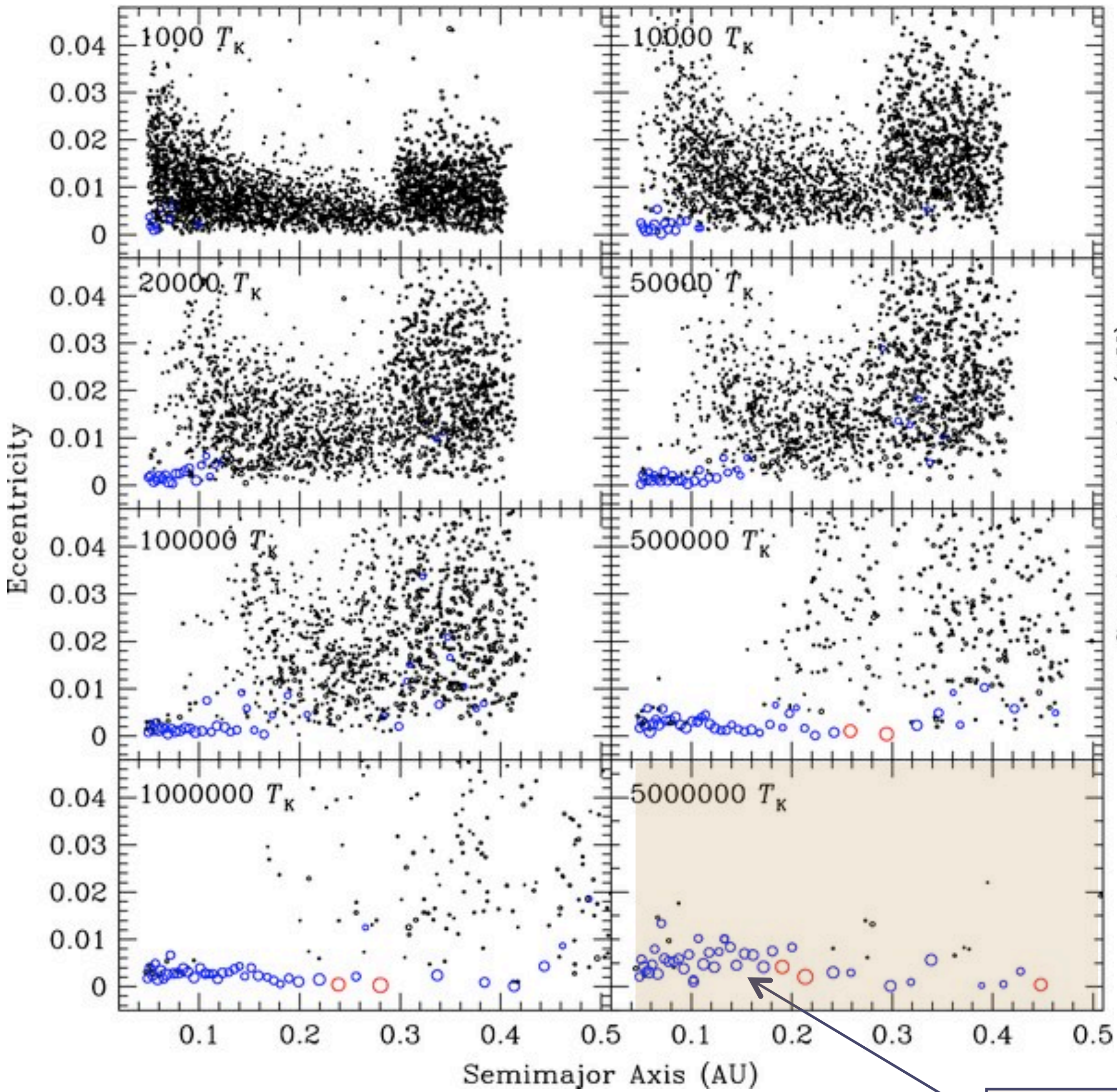
Eccentricity trap



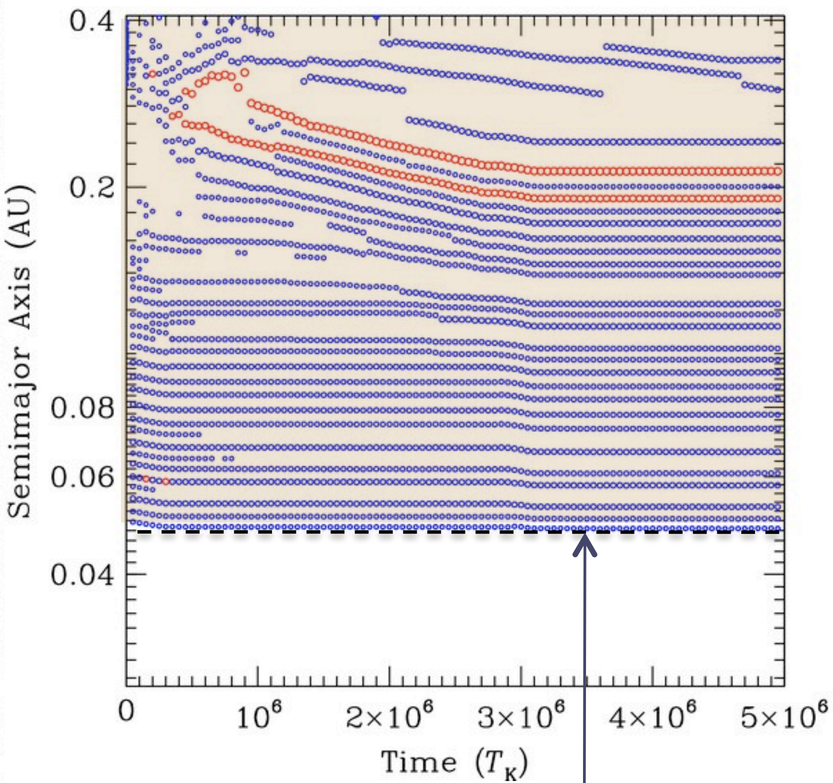
Ogihara, Duncan, Ida (2010)

N-body simulation (3D)

Ogihara & Ida (2009, ApJ 699, 824)



slow **migration case**



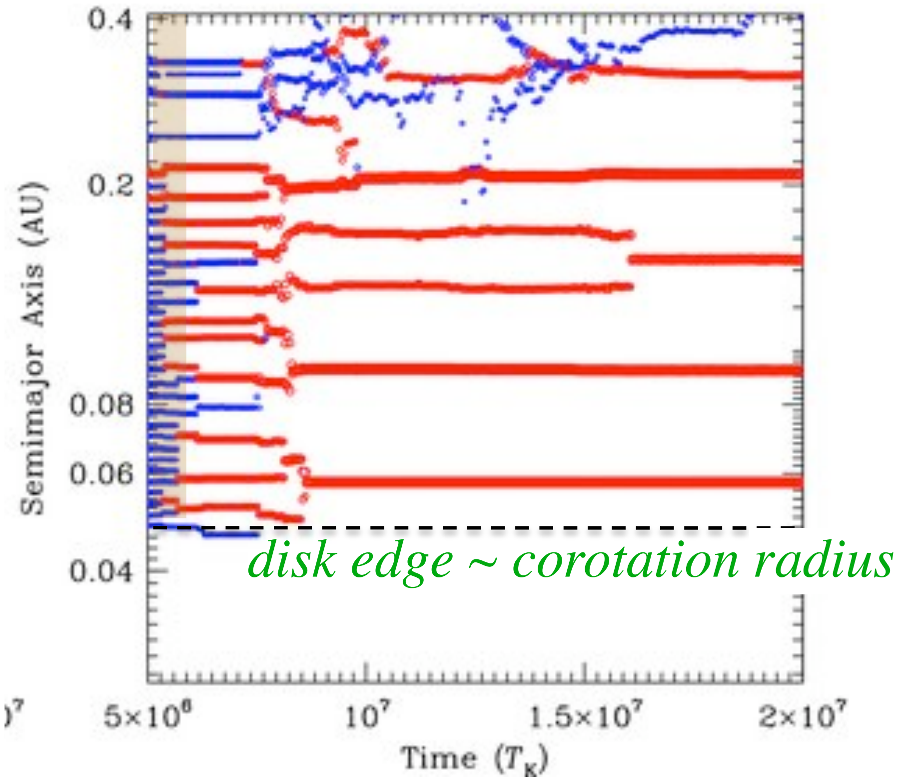
stacked at the edge

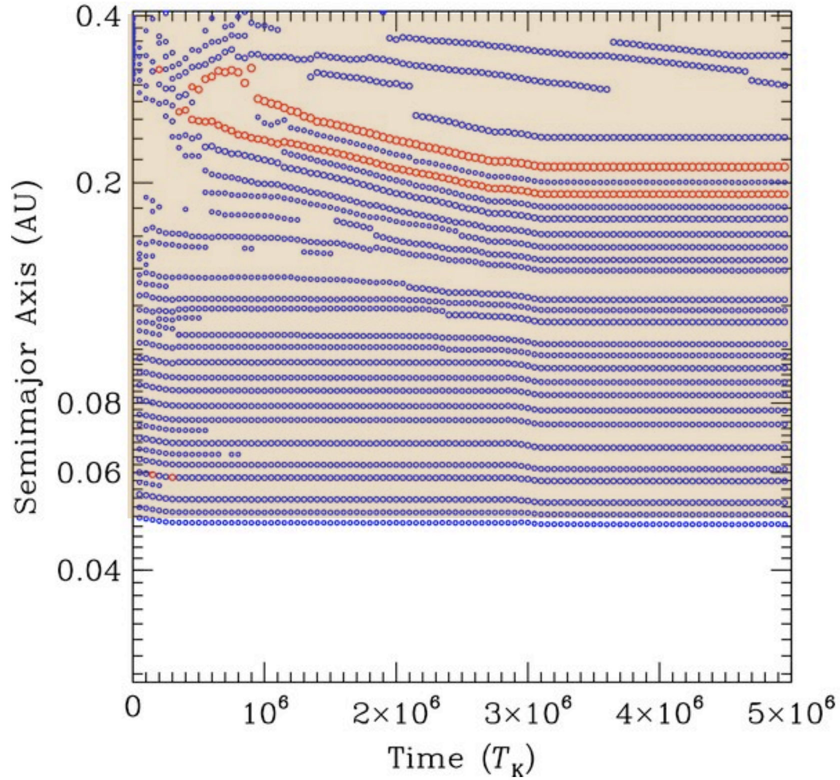
similar $M \leftarrow t_{mig} \sim t_{acc}$

N-body simulation (3D)

Ogihara & Ida (2009, ApJ 699, 824)

slow **migration case**

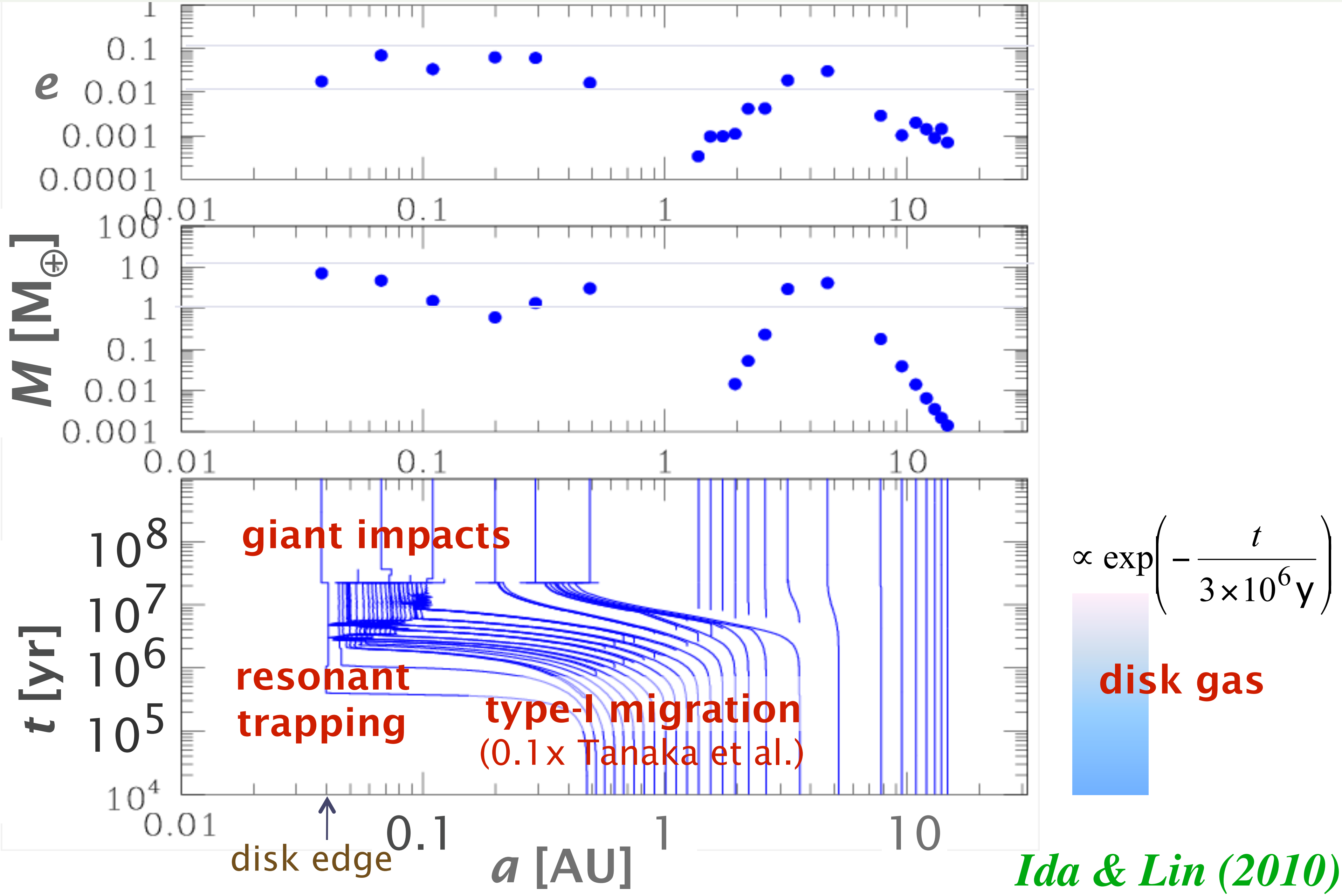




instability after gas depletion
→non-resonant multiple planets
at relatively large *a*
→ *population synthesis calculation*

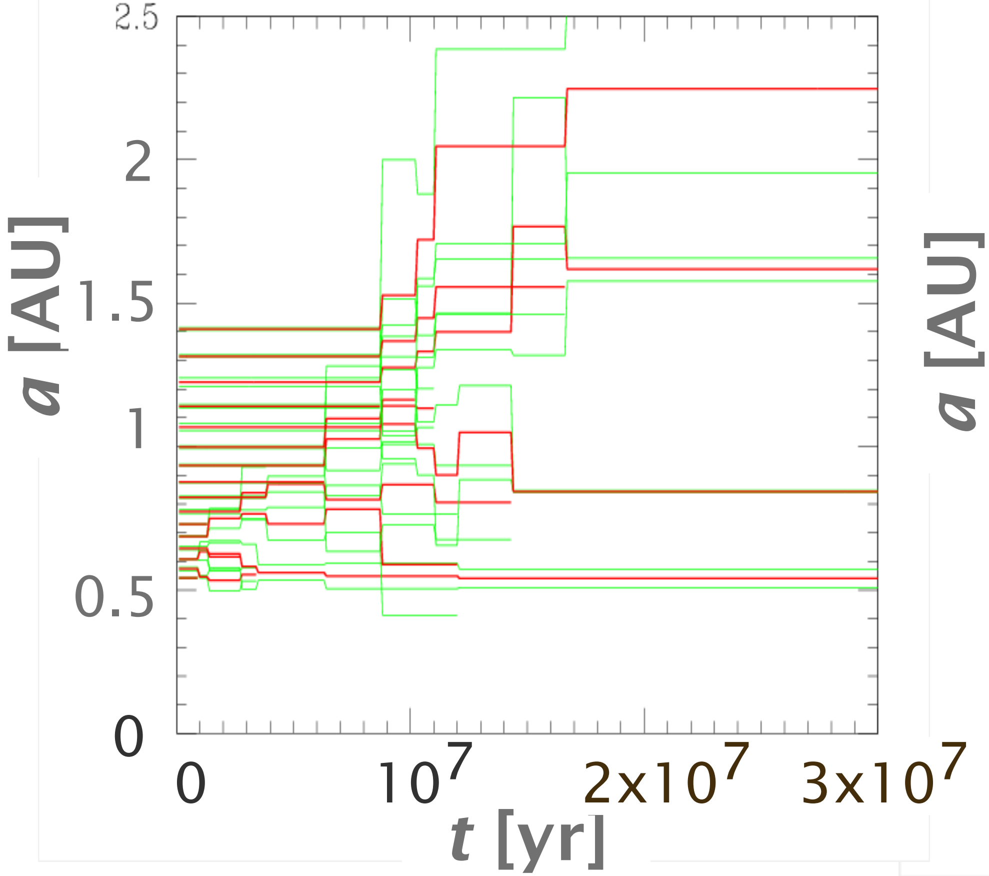
depends on N

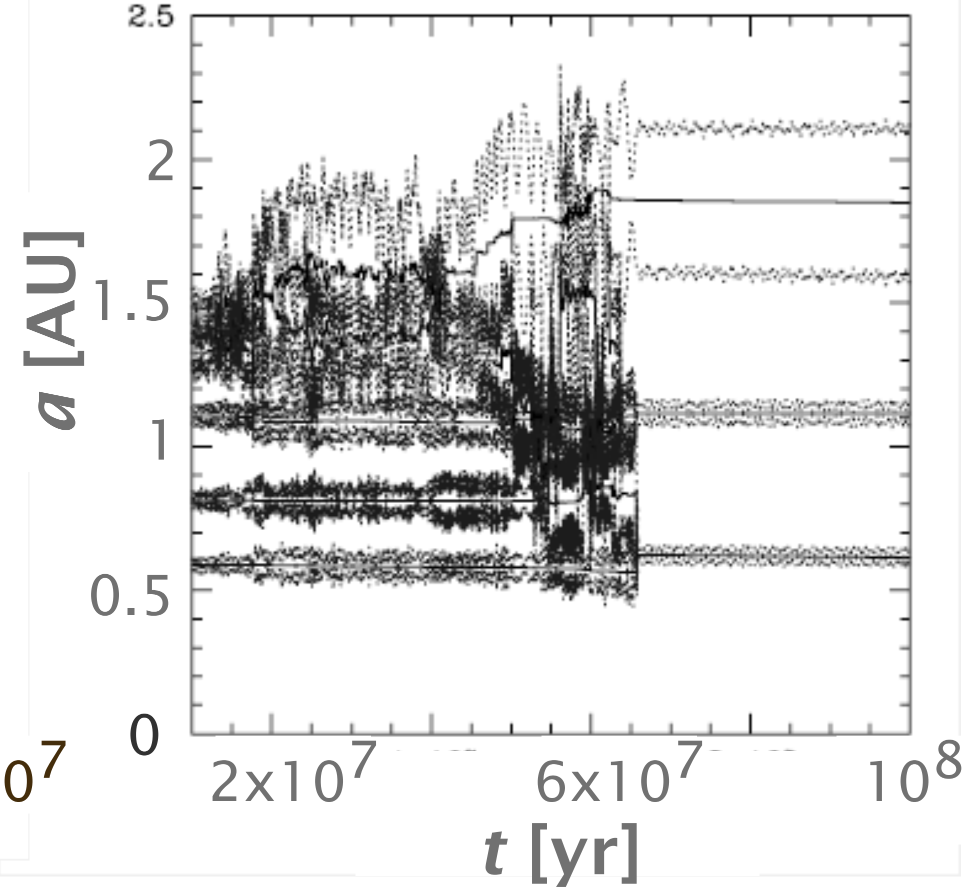
Semi-analytical calculation of accretion & migration of solid planets



Ida & Lin (2010)

Modeling of giant impacts





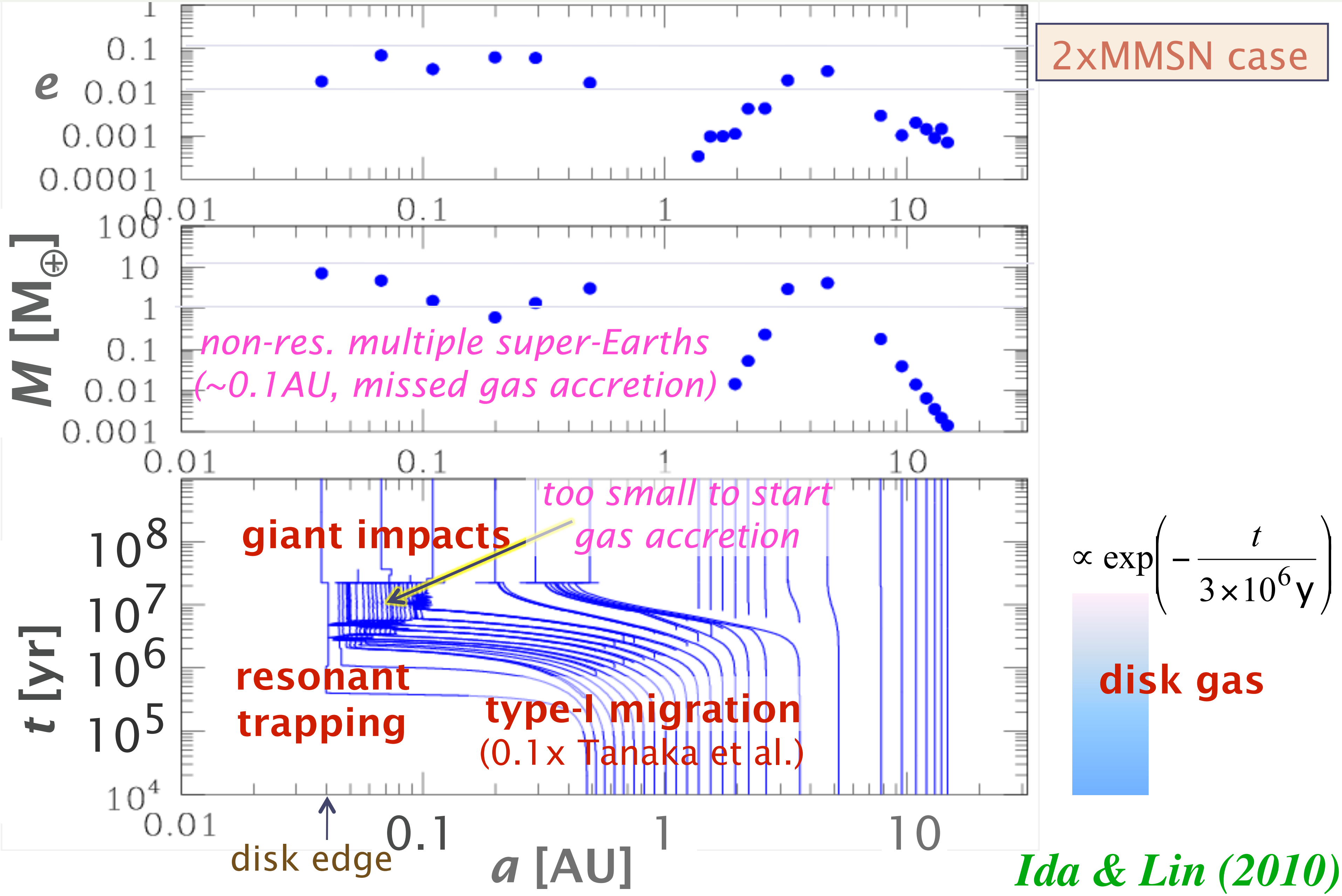
Monte Carlo Model :

- *Ida & Lin (2010)*

N-body :

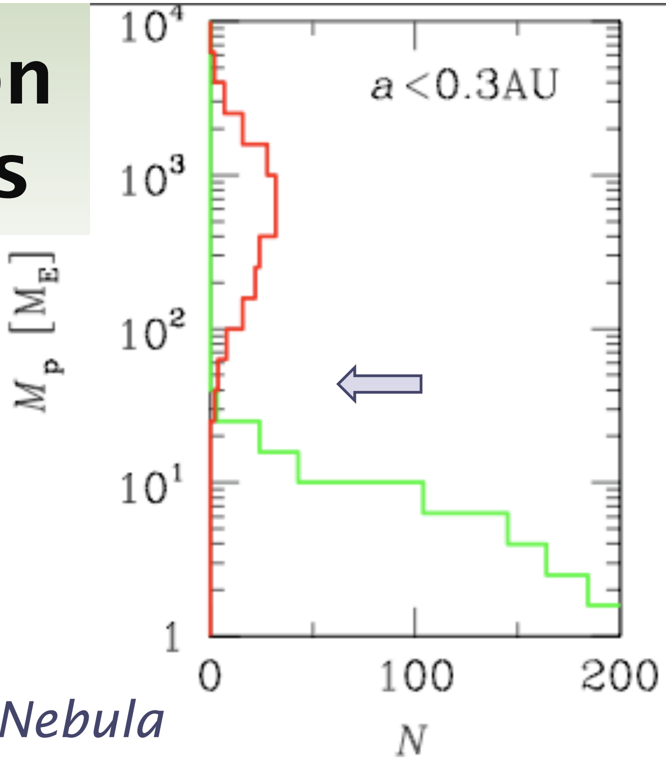
- Kokubo, Kominami, Ida (2006)

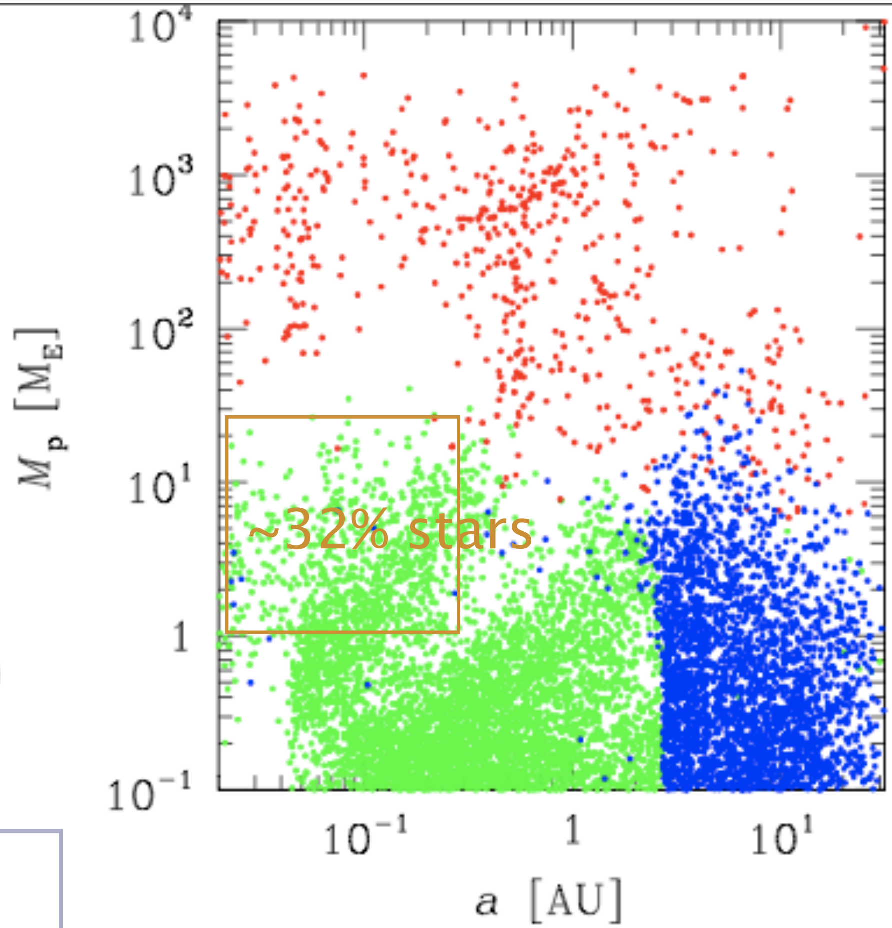
Semi-analytical calculation of Accretion & migration of Solid planets

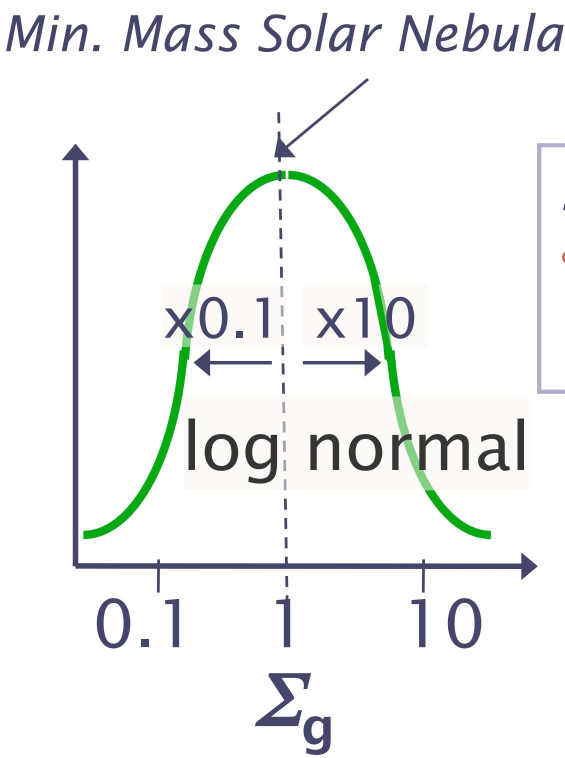


Ida & Lin (2010)

Population Synthesis

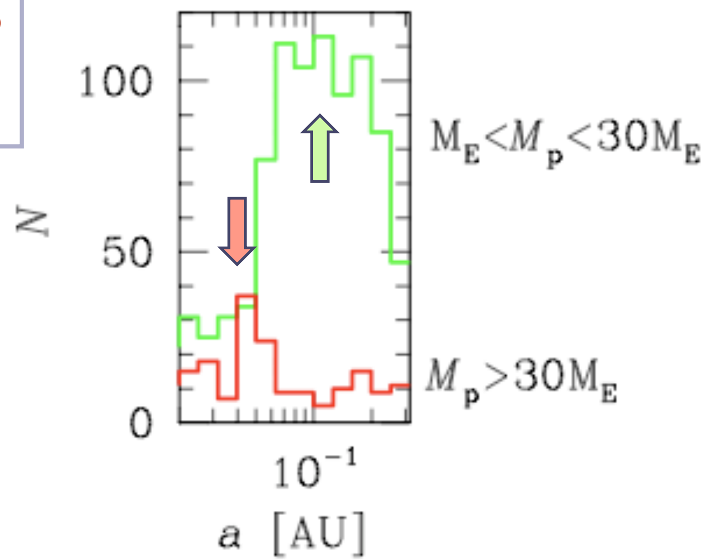




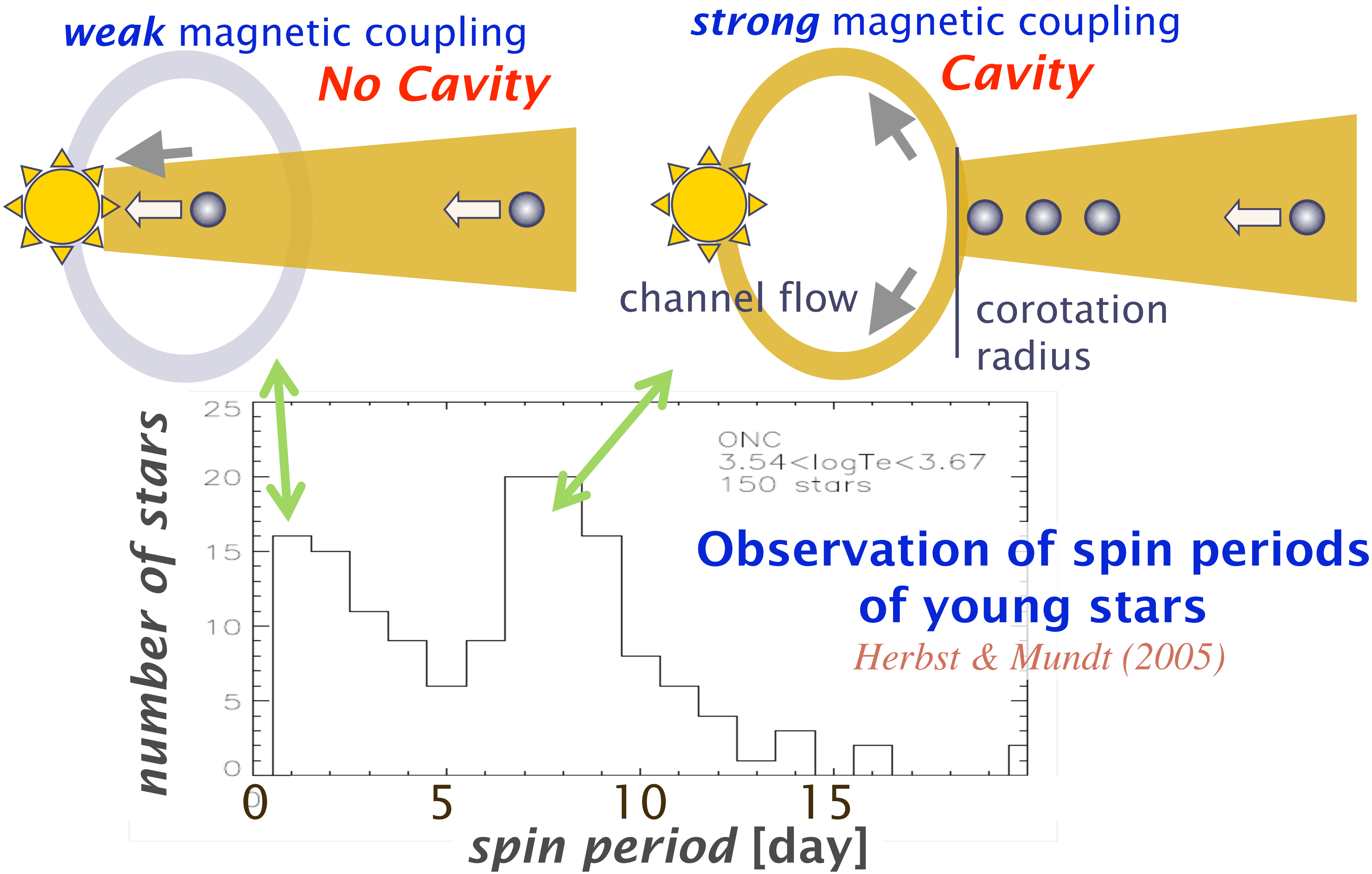


Solar-type stars

- various mass disks (1000 systems)

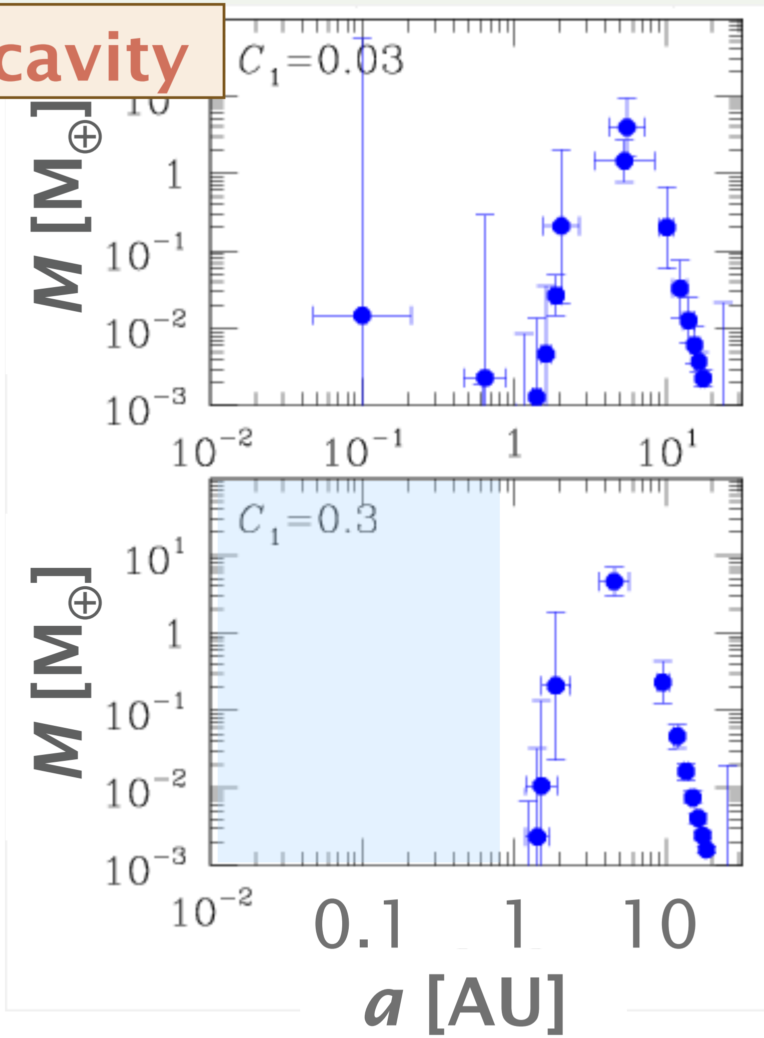


Solar system vs. Super-Earth systems

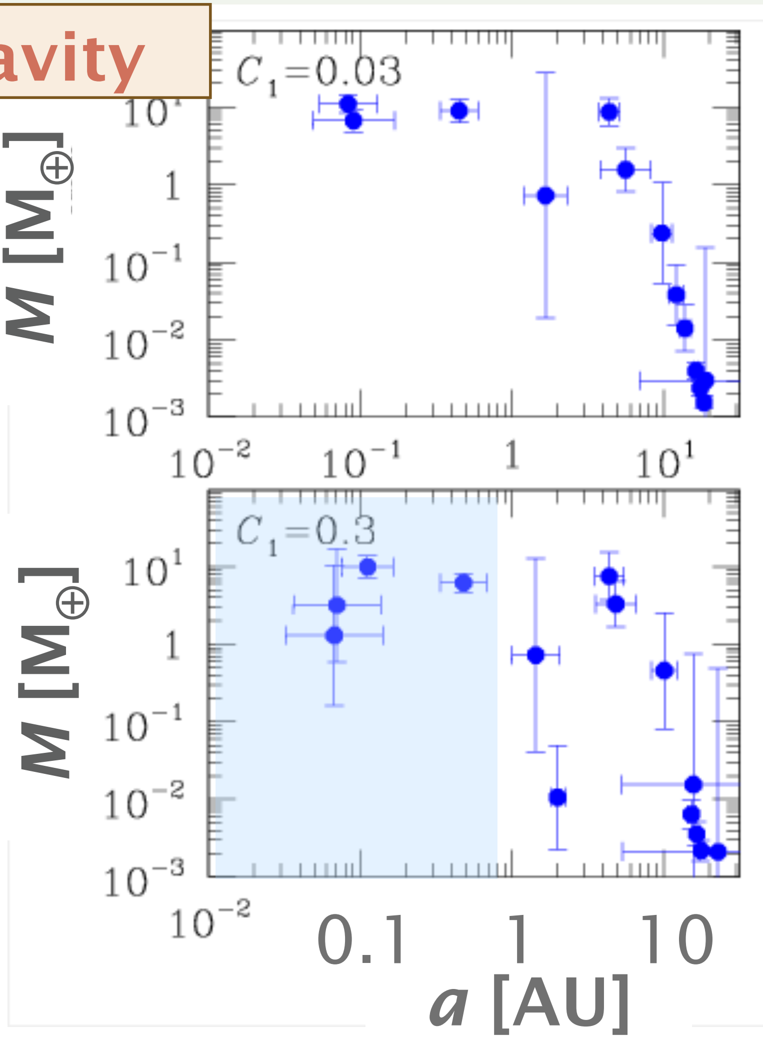


Diversity of short-*P* terrestrial planets

no cavity



cavity



Solar system
Saturnian satellite system?

Short-*P* super-Earths
Jovia satellite system?

Summary

- N-body simulations +
  Synthetic planet formation model including
  disk cavity, "eccentricity trap," resonant trapping,
  giant impacts
  → Non-resonant, multiple, short-*P* Earths/super-Earths
- Diversity of short-*P* rocky planets
  (Solar system: no close-in planets)
  ← diversity/evolution of disk inner boundary?
    1) cavity or non-cavity
    2) condition of eccentricity trap

→ implications for satellite systems around giant planets