The Formation and Retention of Gas Giants around Stars with Different Metallicities

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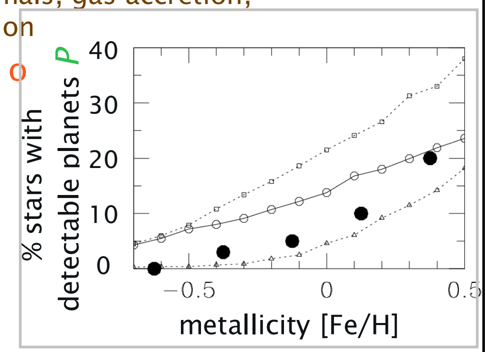
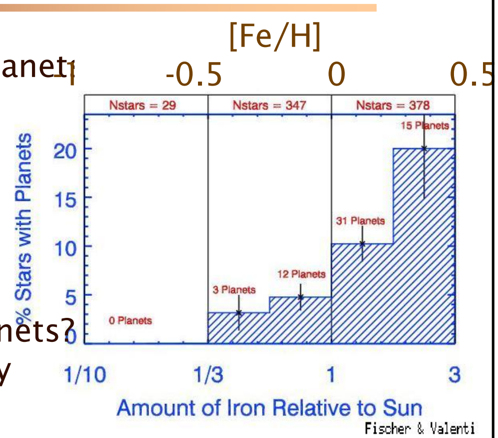
- a deterministic planet formation model *Ida & Lin (ApJ, in press)*
  - core accretion from planetesimals, gas accretion, gap formation, type-II migration
  - predict deficit of planets of $10\text{-}100 M_\oplus$ inside 3AU
- metallicity dependence *Ida & Lin (submitted)*
  - predict that *P* increases with metallicity



Motivation

observation of extrasolar planets metallicity dependence (Fischer & Valenti)

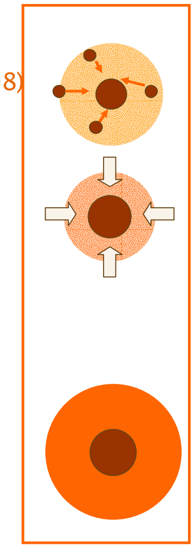
(1) pollution by infall of planets?
(2) high formation efficiency in metal-rich disks?



We consider the possibility of (2) with a theoretical model based on **core accretion scenario.**

Model

- core accretion from planetesimals
  - rate: two-body approx. (Safronov 1969)
  - isolation: oligarchic growth (Kokubo & Ida 1998)
    giant impacts after gas depletion are also included
- gas accretion (Kominami & Ida 2000)
  - critical core mass $M_{\rm crit} \approx 10 \left(\frac{dM_{\rm core}/dt}{10^{-6} M_\oplus/{\rm y}} \right)^{1/4} M_\oplus$ (Ikoma et al. 2000)
  - KH contraction $\tau_{\rm KH} \approx 10^9 \, (M/M_\oplus)^{-3}$ yr (Pollack et al. 1996, Ikoma et al. 2000)
  - type-II migration:
    - *start: planetary torque > viscous torque*
    - *rate:* $\tau_{\rm mig} \approx 10^6 f_{\rm gas}^{-1} \left(\frac{M}{M_{\rm J}} \right) \left(\frac{\alpha}{10^{-4}} \right)^{-1} \left(\frac{a}{1{\rm AU}} \right)^{1/2}$ yr
    - *halt:* a=0.04AU (Lin & Papaloizou 1985,1993)
  - termination:
    - *Hill radius > 1.5 x disk scale height*
    - *disk gas depletion*



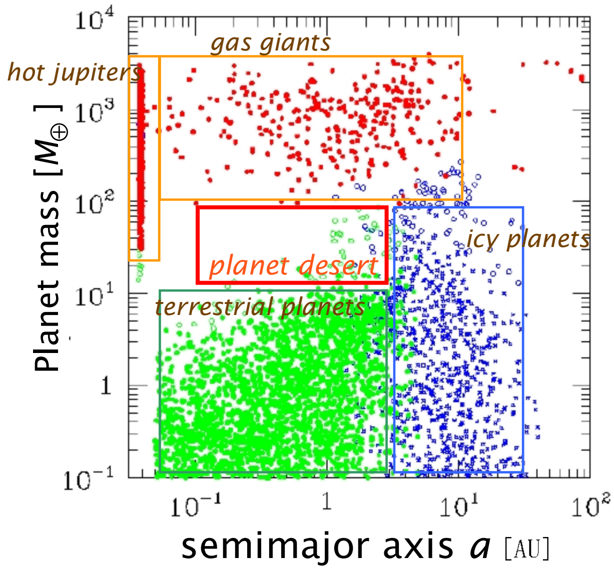
Monte Carlo simulation: initial conditions

- surface density distribution
  - gas $\Sigma_{\rm gas} = f_{\rm gas,0} \, e^{-t/\tau_{\rm dep}} \times 2400 \, (a/1{\rm AU})^{-1.5}$ g/cm^2
  - dust $\Sigma_{\rm dust} = f_{\rm dust} \, f_{\rm ice} \times 10 \, (a/1{\rm AU})^{-1.5}$ g/cm^2

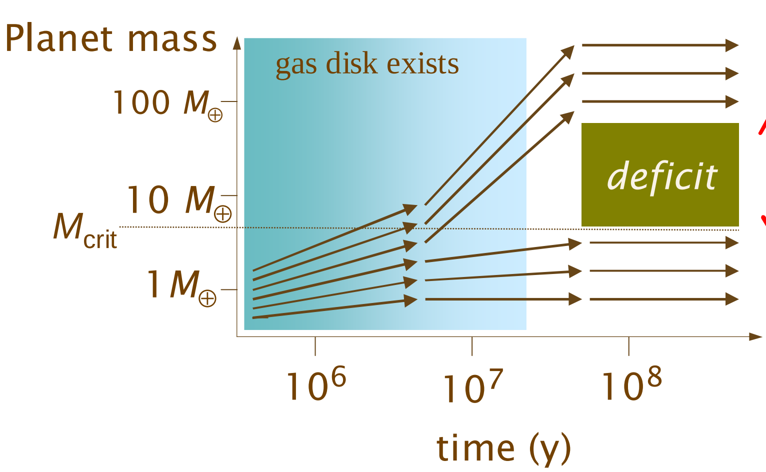
$f_{\rm dust} = f_{\rm gas,0} = 1$: min. mass solar nebula
observations: $M_{\rm disk} = (0.1-30) M_{\rm solar\ nebula}$

- $\log_{10} f_{\rm gas}$ - distribution: $\propto \exp(-(x-0.25)^2)$
- $\log_{10} f_{\rm dust}$ - distribution: $\propto \exp(-(x-0.25)^2)$ ($Z_* - Z_\odot$)
  Z_* : metallicity [Fe/H] of a host star ($=Z_{\rm disk}$)
- a - distribution : uniform in log scale
- disk lifetime: $\tau_{\rm dep}=10^6$-10^7 y
- stellar mass: $M_* = 0.7$-$1.4 \, M_\odot$ → $a_{\rm ice} = 2.7 (M_*/M_\odot)^2$

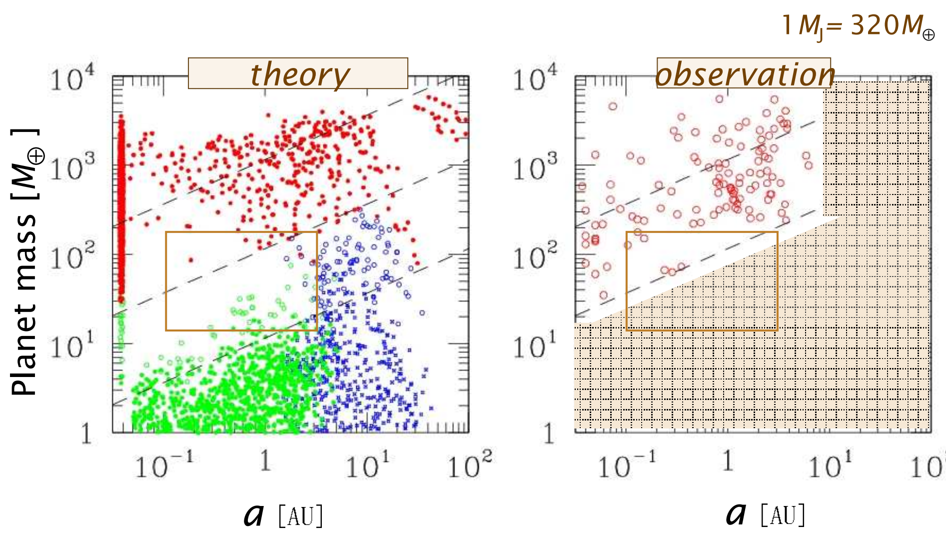
Results: $\triangle Z = Z_* - Z_\odot = 0$



Formation of "Planet Desert"



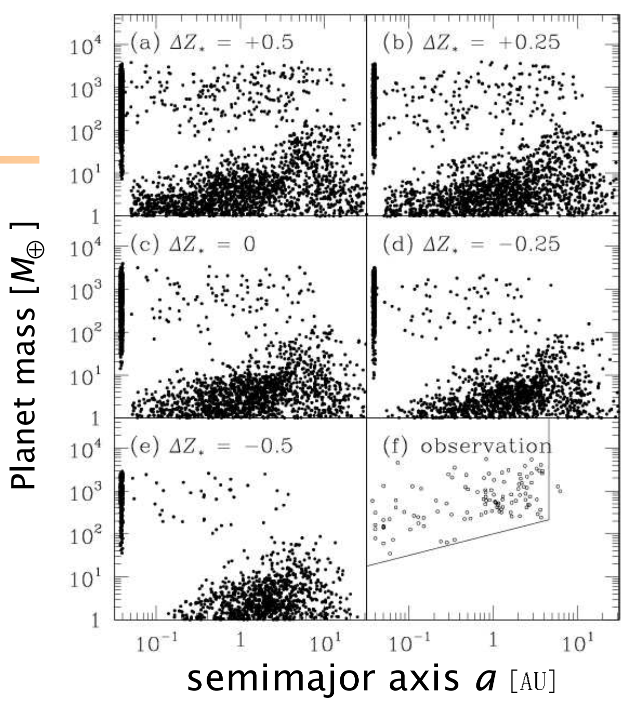
comparison with observation



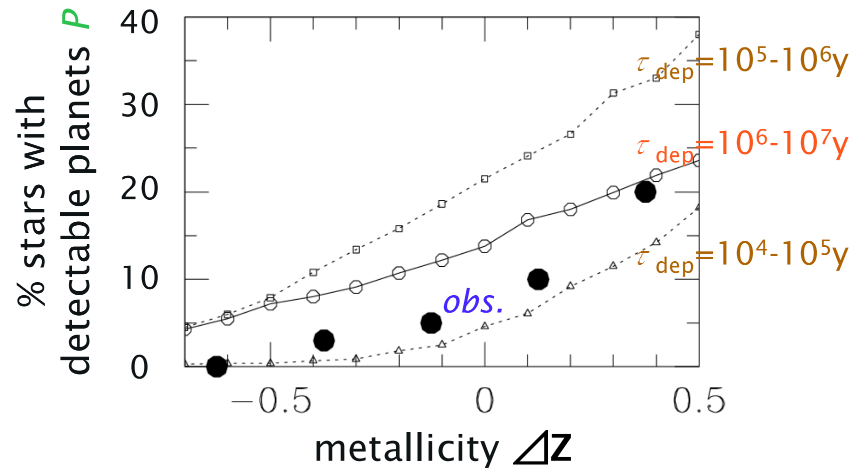
Results: ⊿Z -dep.

$M_{core} \propto f_{dust}{}^{3/2}$

Kokubo & Ida 1998



Results:⊿Z –dependence



** absolute values change with α*

core accretion model reproduces the dependence
⇔ self-grav. instability model

Summary

- We constructed a deterministic planet formation model
  - core accretion from planetesimals, gas accretion, gap formation, type–II migration
- predictions [consistent with observations]
  - deficit of planets of 10-100$M_\oplus$ at a < 3AU (Planet Desert)
  - *P* increases with metallicity
- future issues
  - jumping jupiter
  - type-I migration

  (random-walk type is already included
  - effects near disk inner edg
    - *truncation*