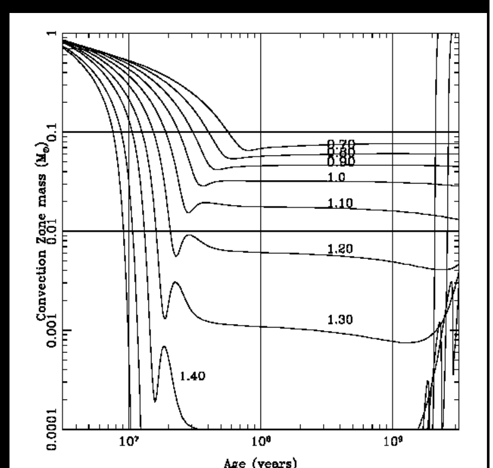
Late-stage accretion and stellar pollution

Ed Thommes (CITA, Toronto)
Doug Lin (UCO/Lick)

Stellar pollution by planets

- Pollution of a small stellar convective envelope could be detected as [Fe/H] enhancement
- Time evolution of convective envelope mass depends on stellar mass
- High-mass stars offer the best chance to detect pollution by planets



Murray et al. 2001

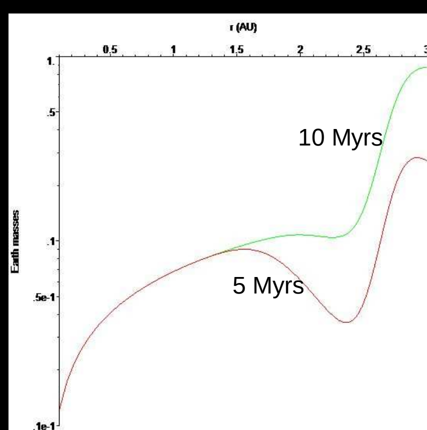
How much pollution?

- Pollution likely small, Δ[Fe/H] <~0.02, during gas disk lifetime (Laughlin & Adams 1997, Murray et al. 2001), and undetectable in stars <1.2 $M_\odot$
- Pollution during late-stage may leave a more noticeable signature
  - Can be recorded in ZAMS envelope even in stars <1.2 $M_\odot$
  - Undiluted by disk gas accreting at the same time

→We perform simulations of **late-stage terrestrial planet accretion** to constrain how much pollution could occur.

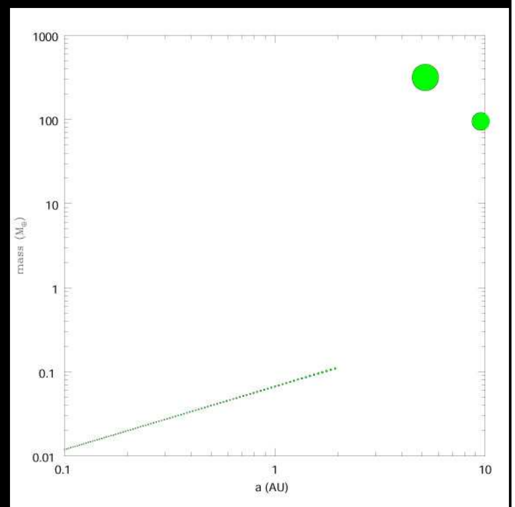
Initial conditions for late-stage accretion

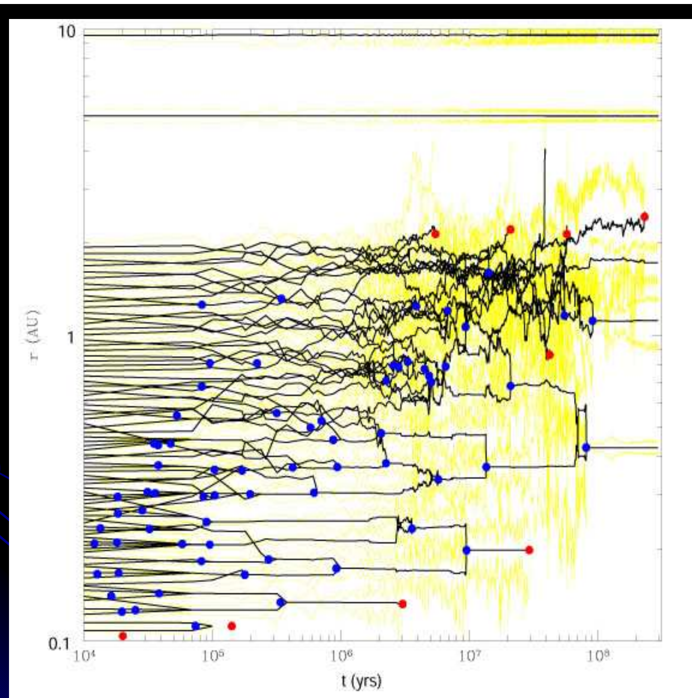
- 3 stages of terrestrial accretion:
  1. Runaway
  2. Oligarchic
  3. Late-stage
- Kominami & Ida 2002: Stage 3 delayed until gas dissipates



Simulations

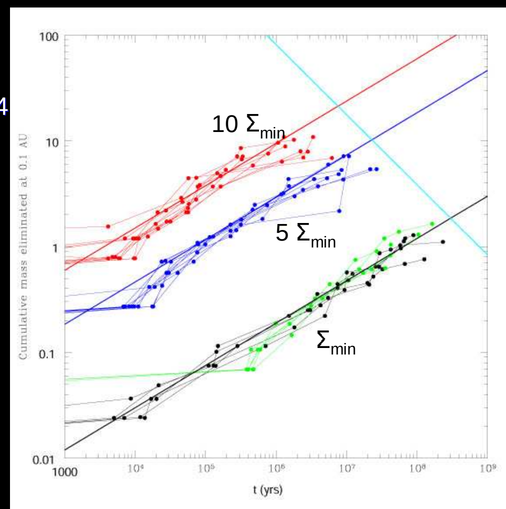
- Isolation-mass cores from 0.1 to 2 AU, for 1, 5 and 10 Σ_{min} disks. Also a “Jupiter” and a “Saturn”
- Evolved until a “stable” terrestrial planet region forms
- Mass crossing inner boundary (0.1 AU) is tracked



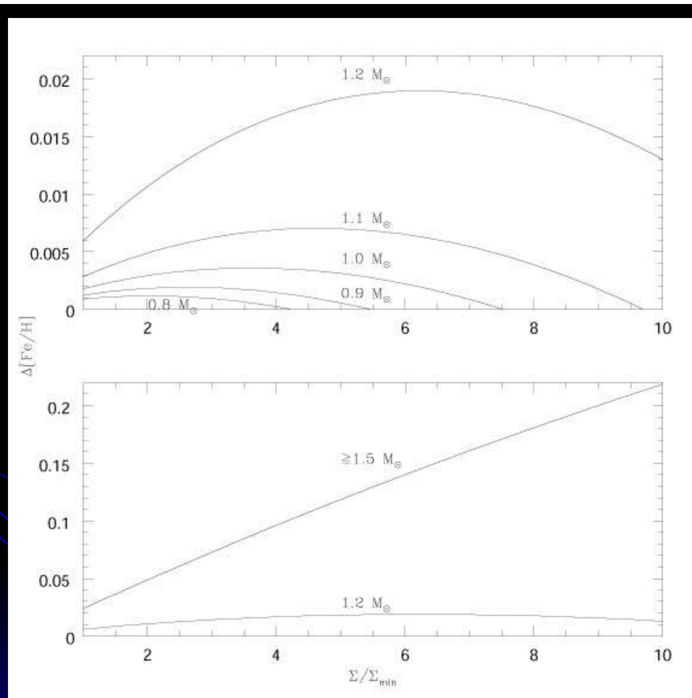


Pollution and disk mass

- Pollution follows a power law, $M_{lost} \sim t^{0.4}$
- Higher-mass disks pollute more, but pollution also ends earlier



$M_{poll} \sim M_{lost}(t_{stop})$
$- M_{lost}(t_{ZAMS}-t_{disk})$

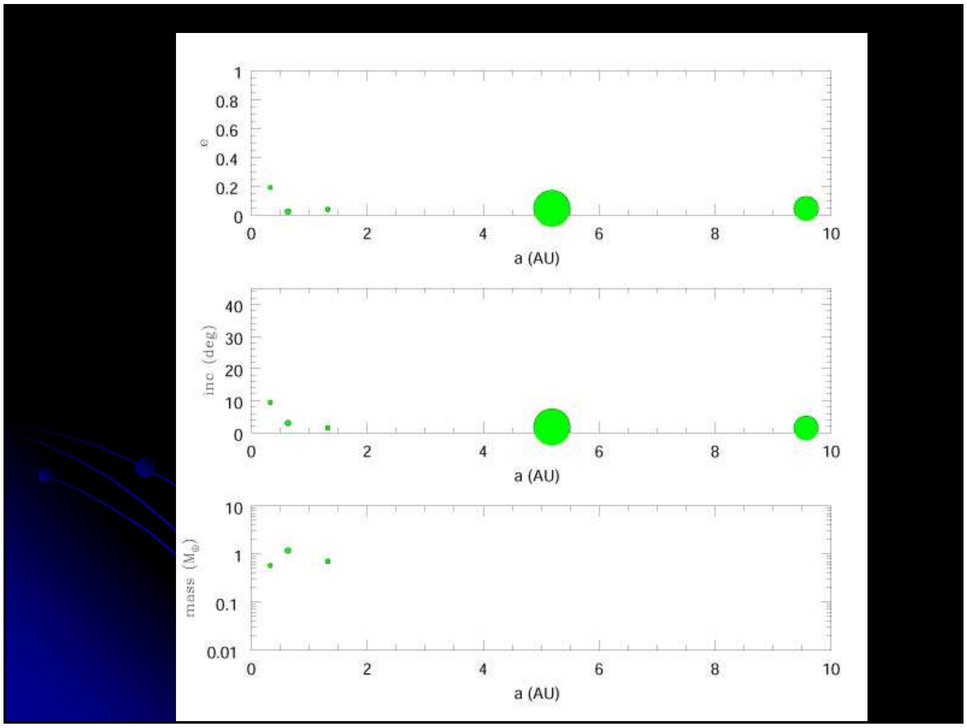


What do we see?

- Does [Fe/H] increase with stellar mass?
  - **Yes**: Murray et al (2001), Murray & Chaboyer (2002); consistent with accretion of 0.5 – 5 $M_\oplus$ of Fe.
  - **No**: Pinsonneault et al (2001), Fischer et al (2004)
- Clusters provide a good “laboratory”
  - Same age, initial [Fe/H]; can construct HR diagrams
  - Δ[Fe/H] constrains pollution
    - Pleiades, Solar-type: Δ[Fe/H] <~ 0.02 (Wilden et al 2002)
    - Hyades, incl. F stars: Δ[Fe/H] <~ 0.03 (Quillen 2002)

Conclusions

- More massive disks pollute more but finish sooner
- Δ[Fe/H] from terrestrial pollution < 0.02 in stars <1.2 $M_\odot$; consistent with observations
- Δ[Fe/H] increases monotonically with disk mass for stars <1.5 $M_\odot$; obs. limit of Δ[Fe/H] <~ 0.03 suggests terrestrial regions not much more than a few Σ_{min}
- Caveat: Pollutants could punch through F star envelope.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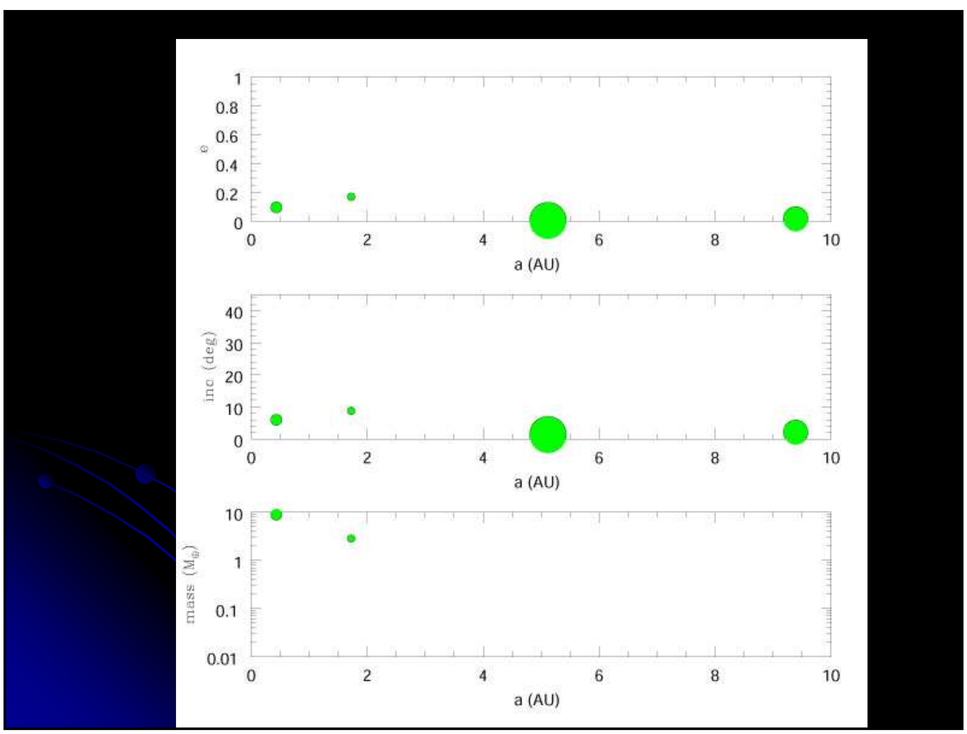
a (AU)
inc (deg)
a (AU)
mass ($M_\oplus$)
a (AU)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Stellar Pollution