Late-stage accretion and stellar pollution

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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, $\Delta[Fe/H] \sim 0.02$, 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 5 Myrs, 10 Myrs
Simulations

- Isolation-mass cores from 0.1 to 2 AU, for 1, 5 and 10 $\Sigma_{\text{min}}$ 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 follows a power law, \( M_{\text{lost}} \sim t^{0.4} \).

Higher-mass disks pollute more, but pollution also ends earlier.

\[
M_{\text{poll}} \sim M_{\text{lost}} (t_{\text{stop}}) - M_{\text{lost}} (t_{\text{ZAMS}} - t_{\text{disk}})
\]
What do we see?

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

Conclusions

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