"Old" pre-main-sequence stars

and a second chance for planet formation

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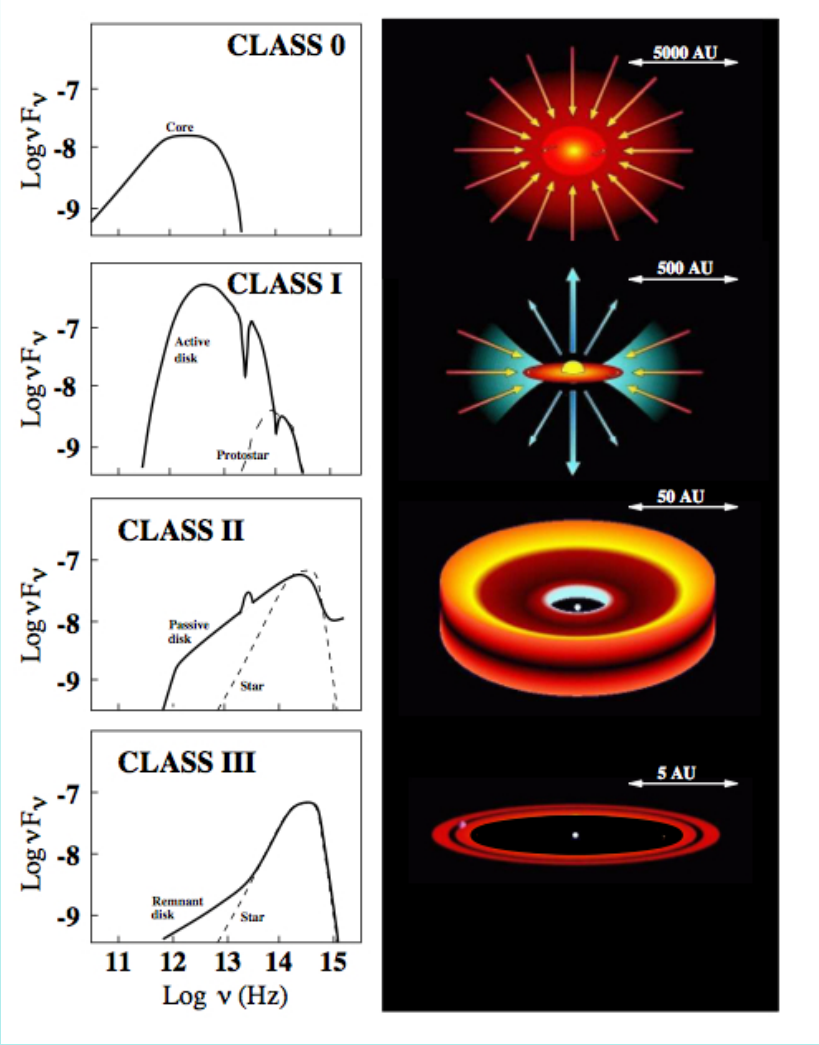
A&A, 566, L3

Star formation + discs

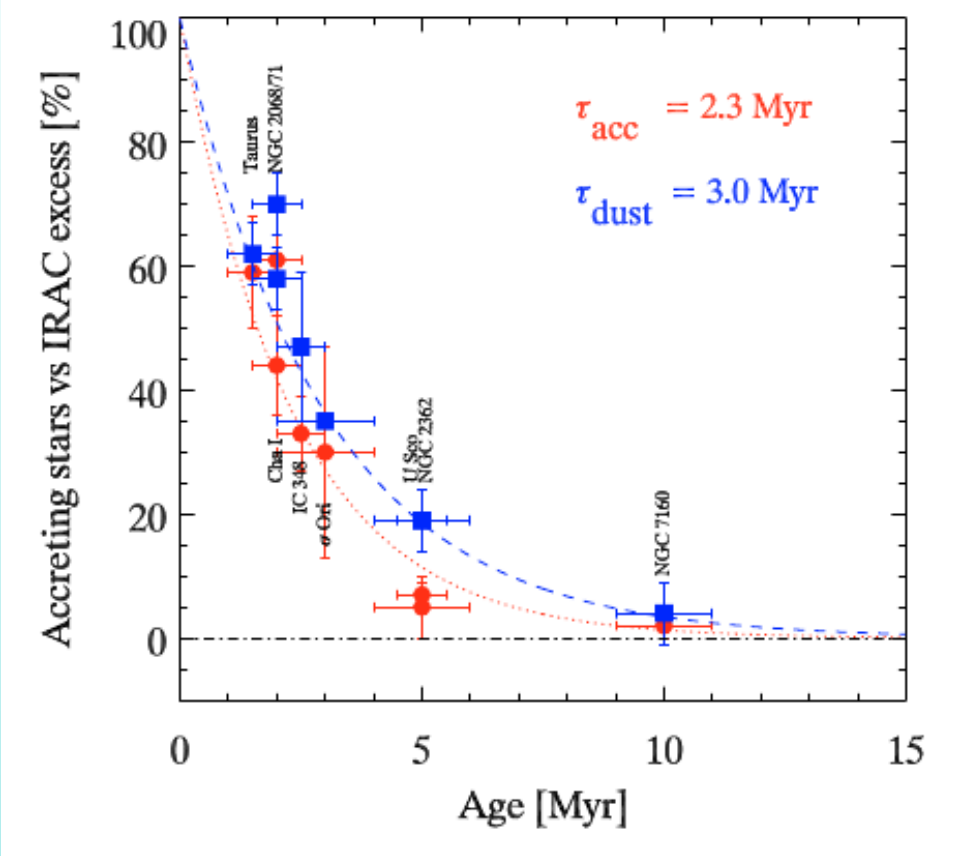
- Stars form in collapsing clouds
- Residual angular momentum $\Rightarrow$ disc formation
- Disc observed indirectly through
  1. IR Excess (stellar flux reprocessed by dust disc)
  2. UV Excess & Spectral lines (accretion region)



Isella (2006)

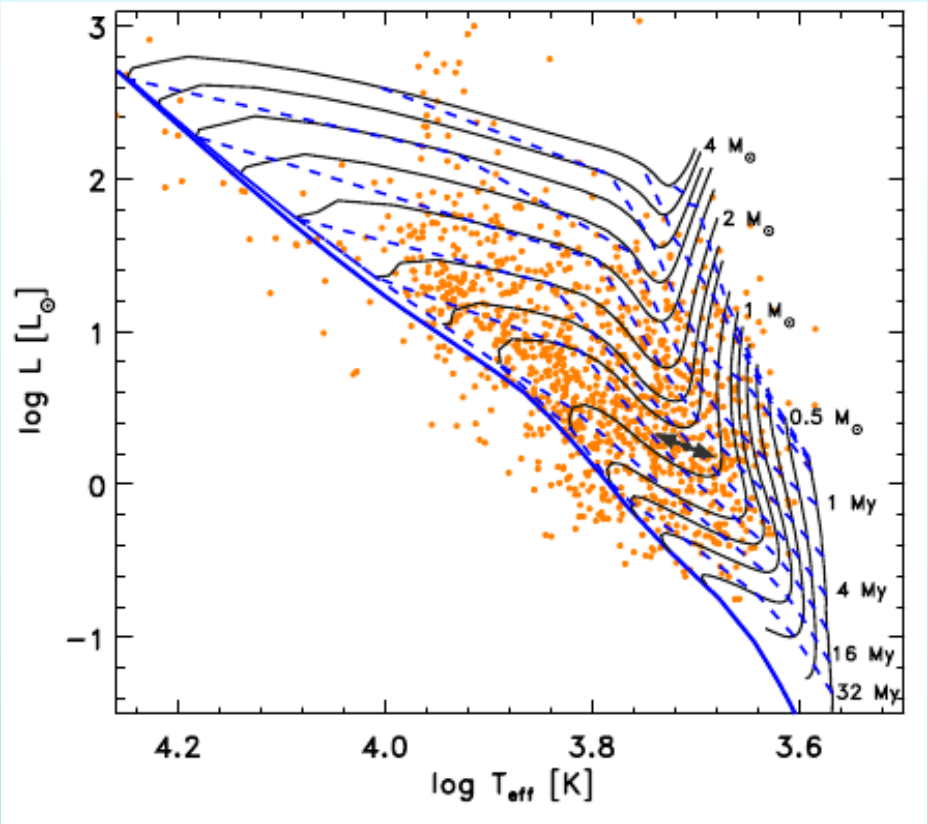
Timescales - Disc dissipation

- $\tau_{\rm disc} \sim 2 - 3$ Myr
- (Caution: Bell et al. (2013) suggest $\tau_{\rm disc} \sim 5$ Myr!)
- Strict constraint on planet formation!



Fedele et al. (2010)

"Old" accretors



de Marchi et al. (2011a)

- Large SFRs (Galactic, SMC, LMC) contain population of "Old" (> 10 Myr) accretors

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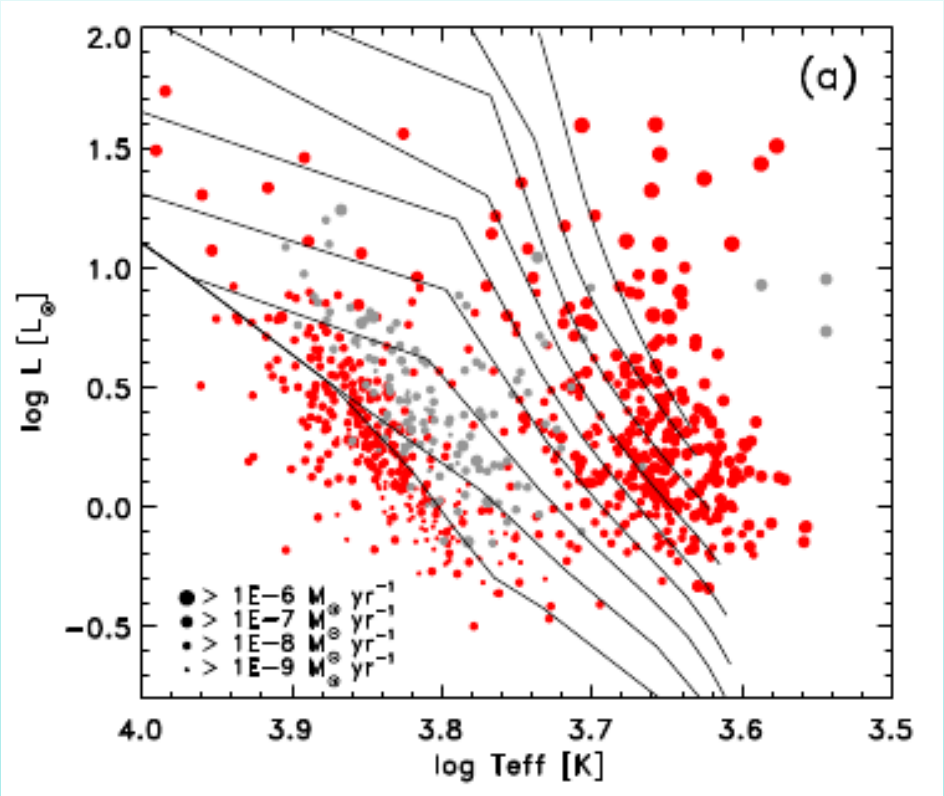

de Marchi et al. (2011b)

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- Accrete at similar rates to "young" PMS
- Also show NIR excess

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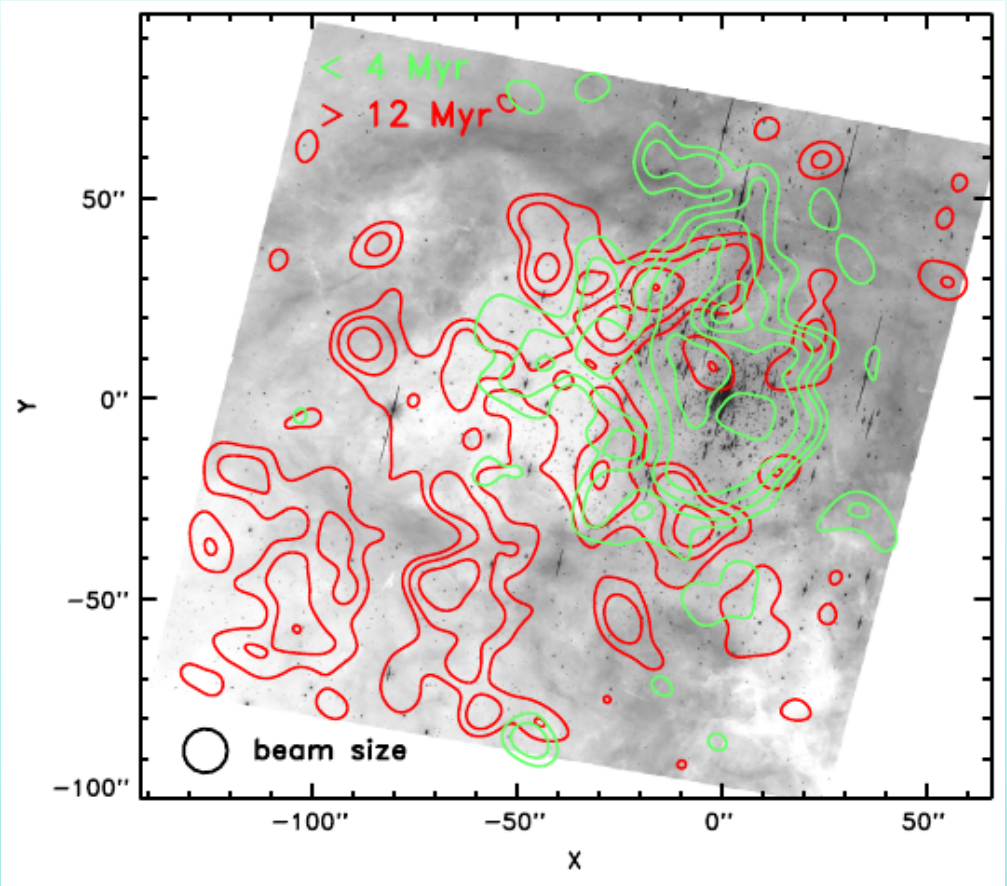

- Large SFRs (Galactic, SMC, LMC) contain population of "Old" (> 10 Myr) accretors
- Accrete at similar rates to "young" PMS
- Also show NIR excess
- Different spatial distribution to "young" stars
- Lower X-ray luminosities $\rightarrow$ old

de Marchi et al. (2011a)

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- Not really old?
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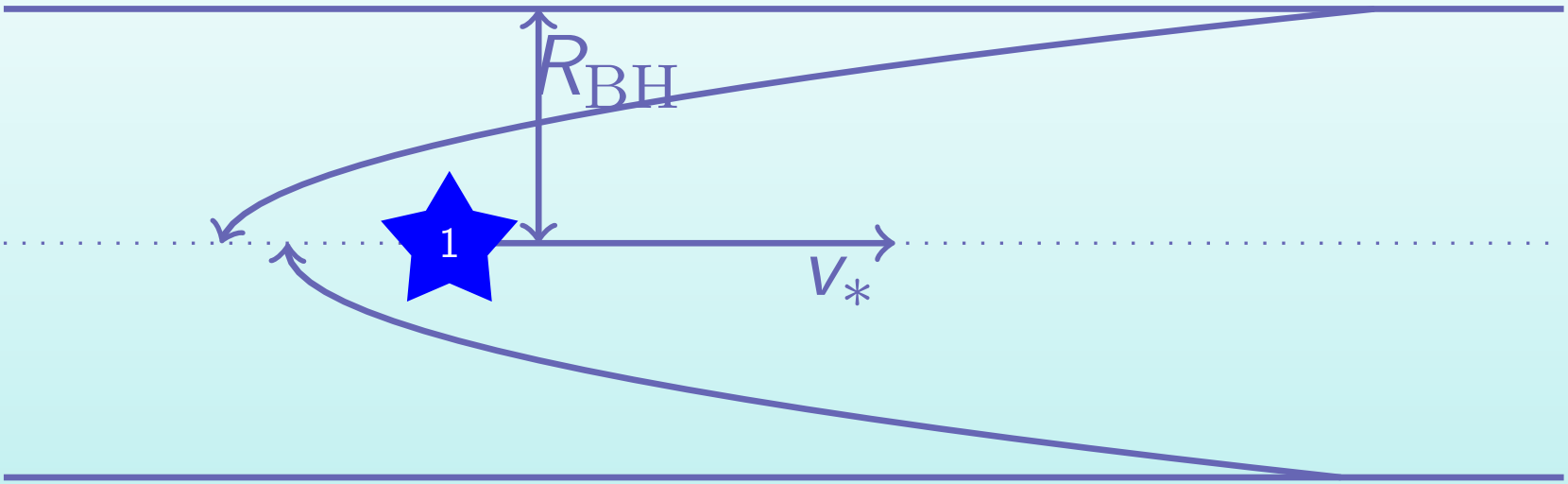
- Not the original disc?

Bondi-Hoyle Accretion?



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- Accretes material

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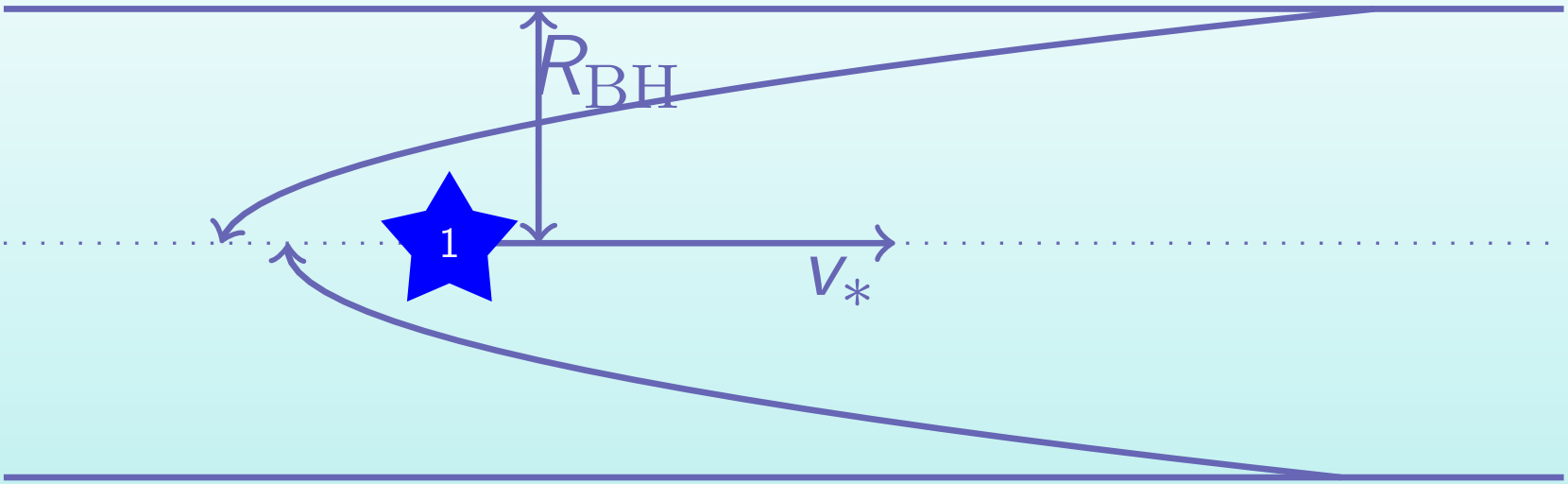

- Star moves through medium
- Accretes material
- $\rightarrow$ UV, lines, but no disc

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- Accrete while passing through clump
- Residual angular moment $\rightarrow$ disc formation?
- $\Rightarrow$ accretion observable for longer

Implementation

- Simple Monte Carlo model, realistic SFR parameters

Table: Parameters for Monte Carlo models

Parameter	Values
$f_{\rm V}$	$10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}$
$\sigma_{\rm v}$	1 km s^{-1}
$c_{\rm s}$	0.3 km s^{-1}
$R_{\rm cl}$	0.1 pc
$n_{\rm cl}$	10^4 cm^{-3}

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- Derive fraction of observable accretors

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- Also no
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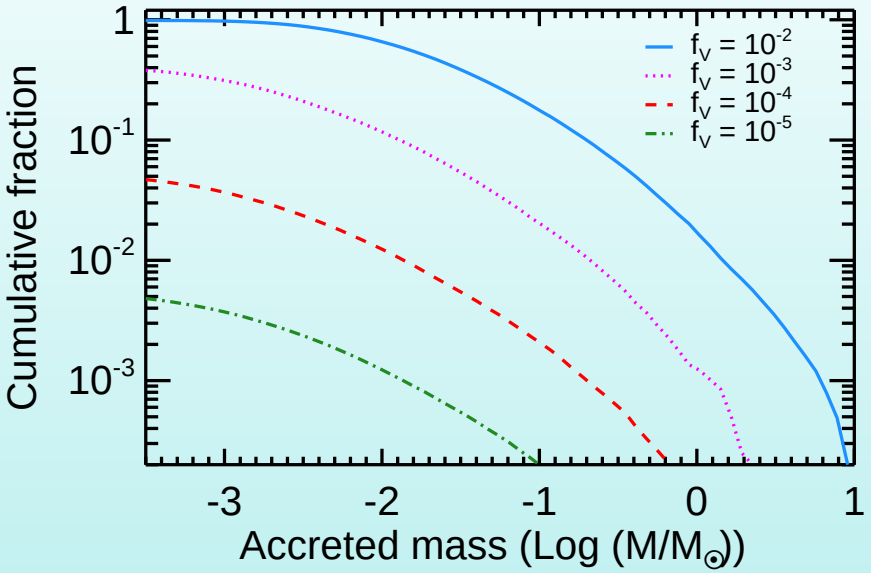
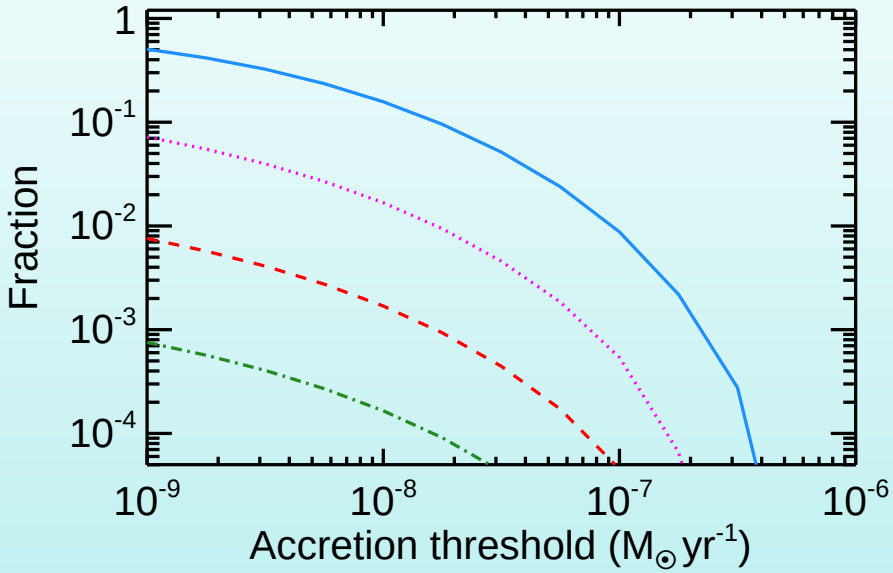
  - ...
- $f_{\rm V}$ & viscosity parameters highly uncertain

Results



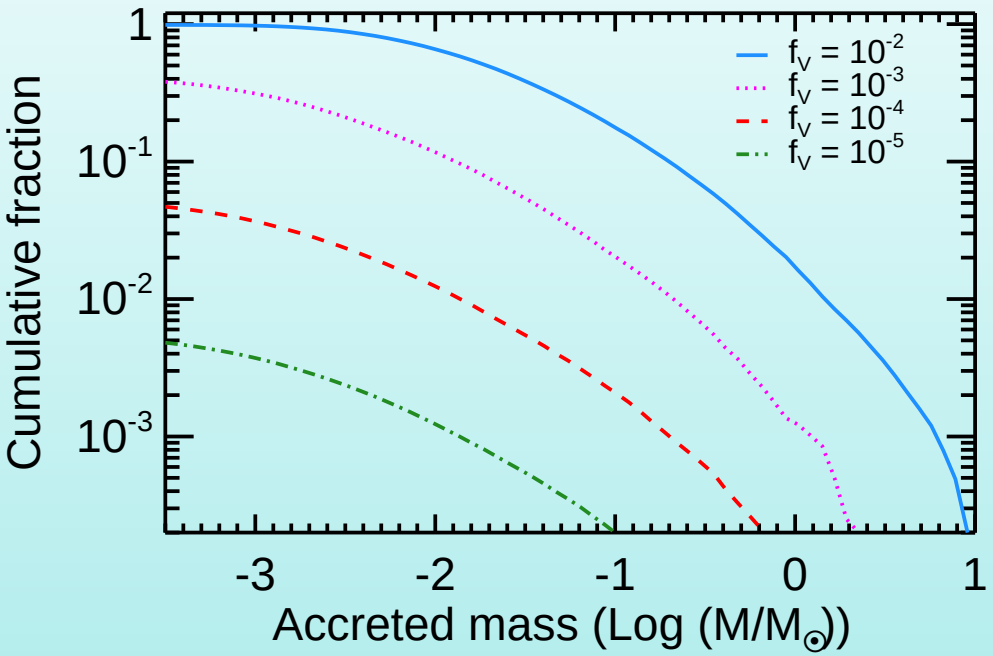


$\Rightarrow$ significant fraction of stars re-accrete

Accretion observable

$\sim$ right numbers of "Old" accretors

A Second Epoch of Planet Formation?



- Significant fraction accrete > 1 MMSN
- New planets?
- Different composition?

...or Destruction?

- What if planets already exist?
- Planet/disc interactions could
  - trigger migration
  - alter eccentricity/inclination
- $\rightarrow$ potential chaos

(Credit: James Garry, Fastlight)

Summary

- Large SFRs have multiple populations of accreting stars
- Ages appear older than allowed in canonical model
- Simple model based on Bondi-Hoyle accretion qualitatively explains observations (size and distribution of populations)
- Potential consequences for planet formation and evolution are manifold and unpredictable

Implementation - Monte Carlo + Viscous Evolution

- Draw random stars from IMF ($n(M) \propto M^{-\alpha}$, $0.7\mathrm{M}_{\odot} < M < 3.2\mathrm{M}_{\odot}$)
- Each step check for encounter with dense clump ($P \propto f_{\mathrm{V}}$)
- Calculate $\dot{M}_{\mathrm{BH}}(t)$ and $\Delta M_{\mathrm{BH}}(t)$
- Pass to viscous evolution model
- Simple treatment of disc formation & evolution
- $\rightarrow \dot{M}_{*}(t)$ for many stars
- Integrate over t to get observable fractions

Table: Parameters for Monte Carlo models

Parameter	Values
f_{V}	$10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}$
N_{stars}	$10^{5}, 10^{5}, 10^{6}, 10^{7}$
α	2.35
σ_{v}	1 km s^{-1}
c_{s}	0.3 km s^{-1}
R_{cl}	0.1 pc
n_{cl}	10^{4} cm^{-3}