The Conditions for Competitive Accretion

Paul C. Clark & Ralf S. Klessen

Institute for Theoretical Astrophysics (ITA)

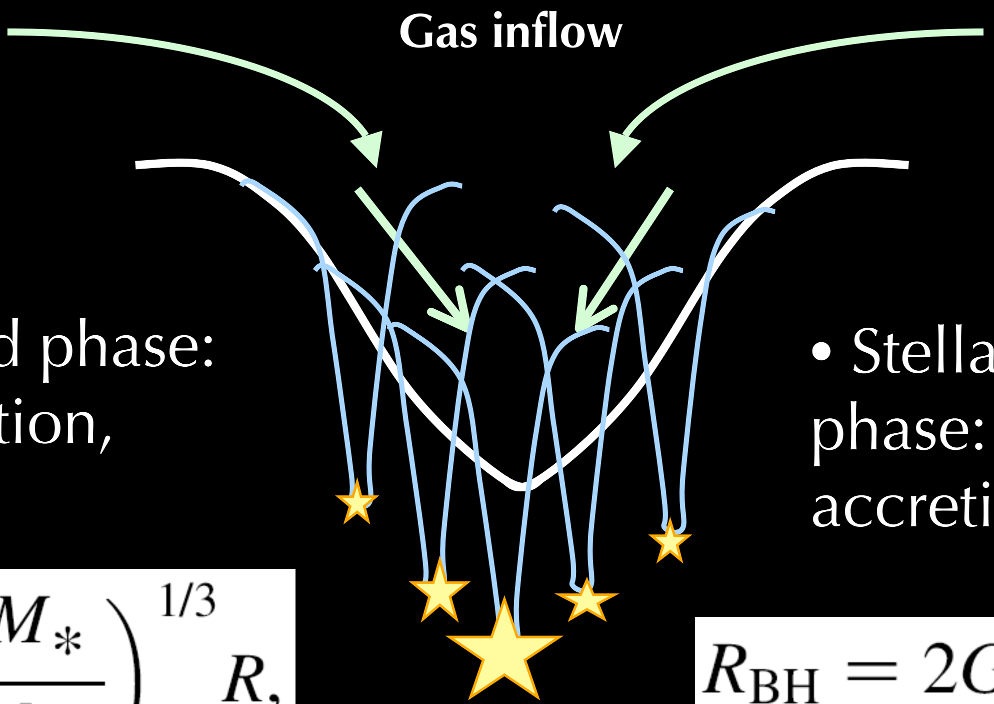
University of Heidelberg

Ian A. Bonnell & Rowan J. Smith

University of St Andrews

Accretion and the IMF…

Accretion rate: $\dot{M}_* = \pi \rho V_{\rm rel} R_{\rm acc}^2$ *Bonnell et al (2001a,b)*



- Gas dominated phase: tidal-lobe accretion,

$$R_{\rm tidal} \approx 0.5 \left(\frac{M_*}{M_{\rm enc}}\right)^{1/3} R,$$

- Stellar dominated phase: Bondi-Hoyle accretion,

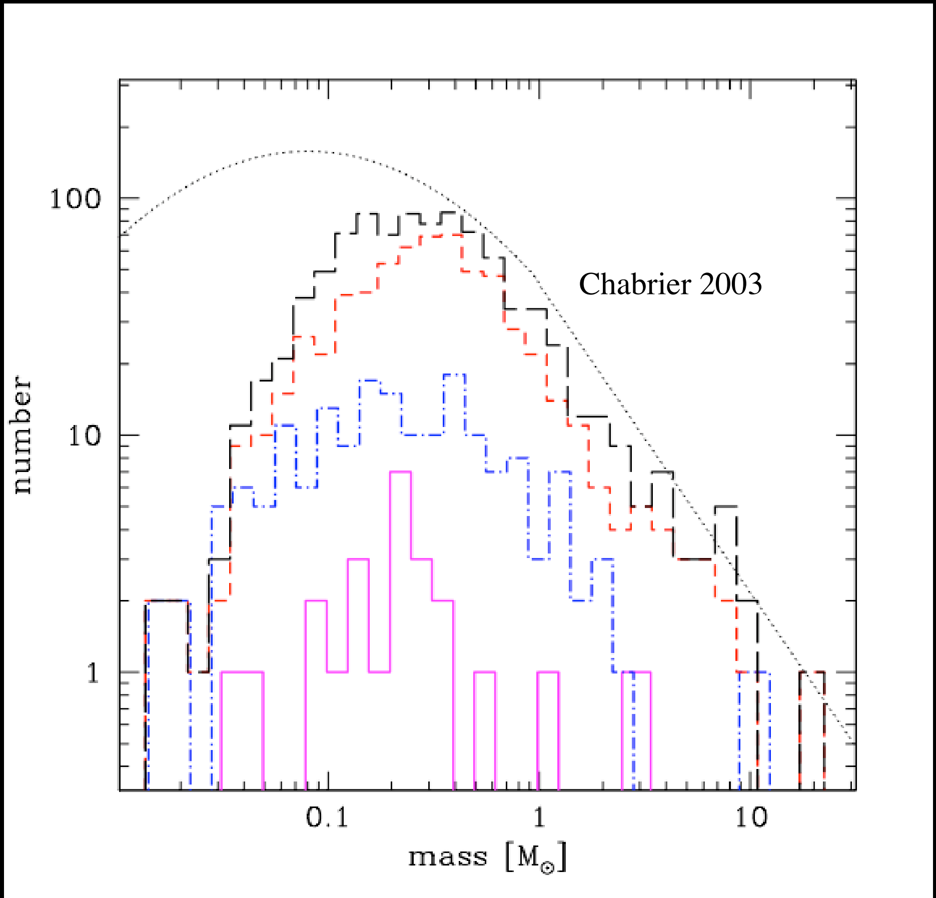
$$R_{\rm BH} = 2GM_*/(V_{\rm rel}^2 + c_{\rm s}^2)$$

$dn/dm \propto m^{-1.5}$

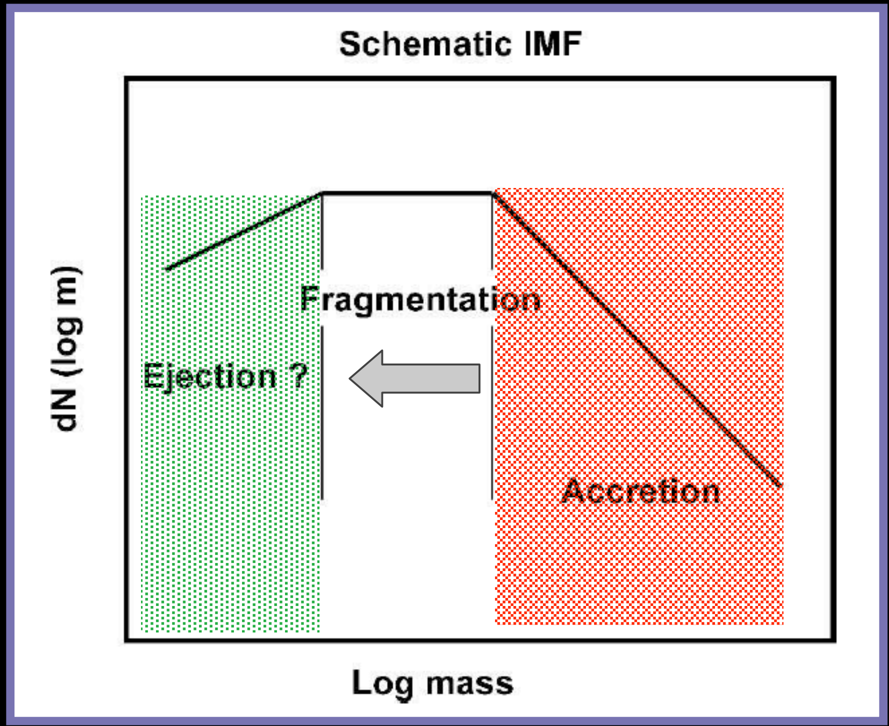
$dn/dm \propto m^{-2.5}$

Features of the CA mass function

Grows in time



All mass bins are related



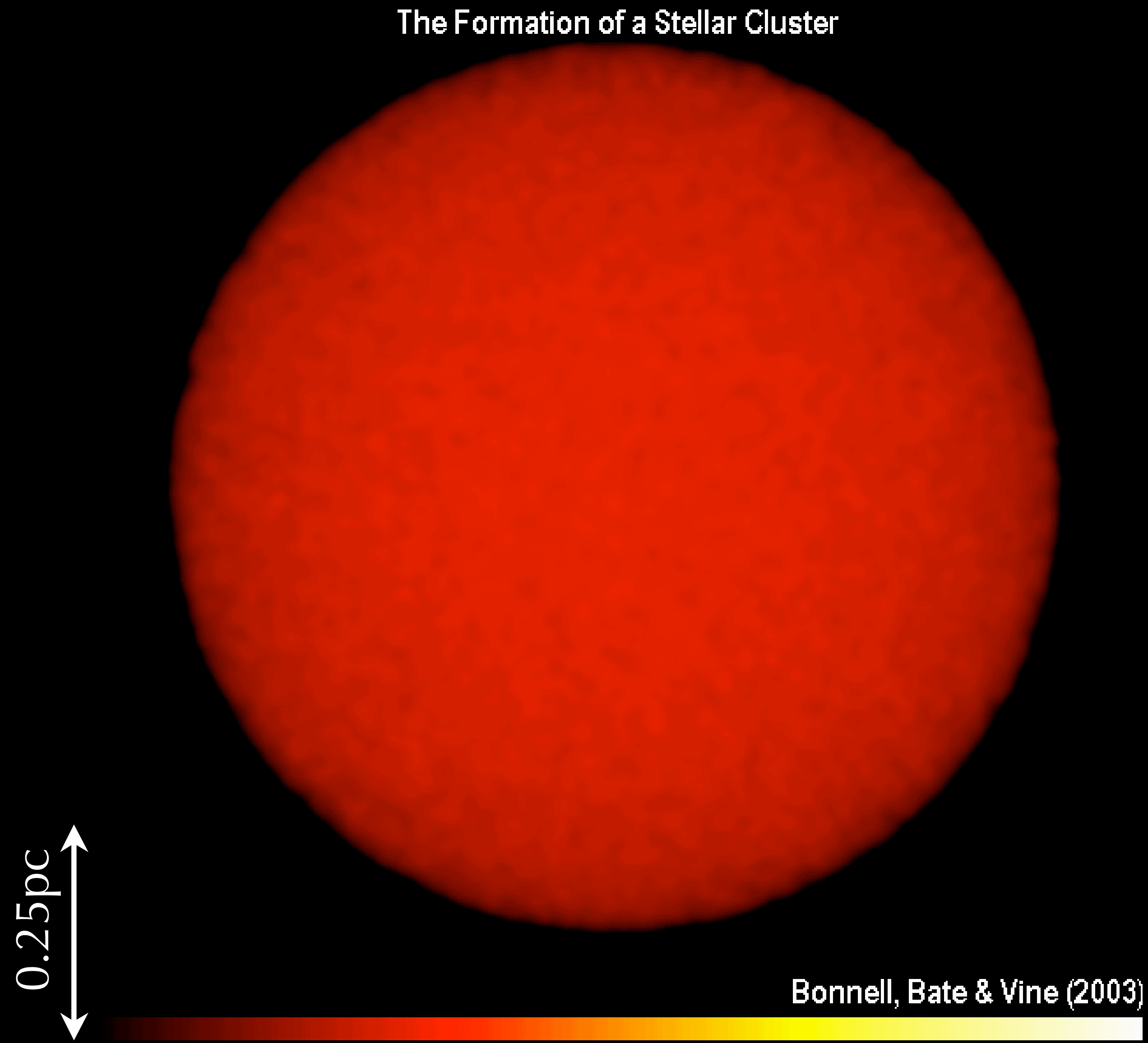
Hierarchical process…

- Hierarchical dissipation of turbulence
- Small scales loose support first:

$t_{disp} \sim t_{cross} \sim L/\sigma(L)$

$t_{cross} \sim L^{0.5}$

- Followed by collapse of progressively larger regions



Conditions for competitive accretion...

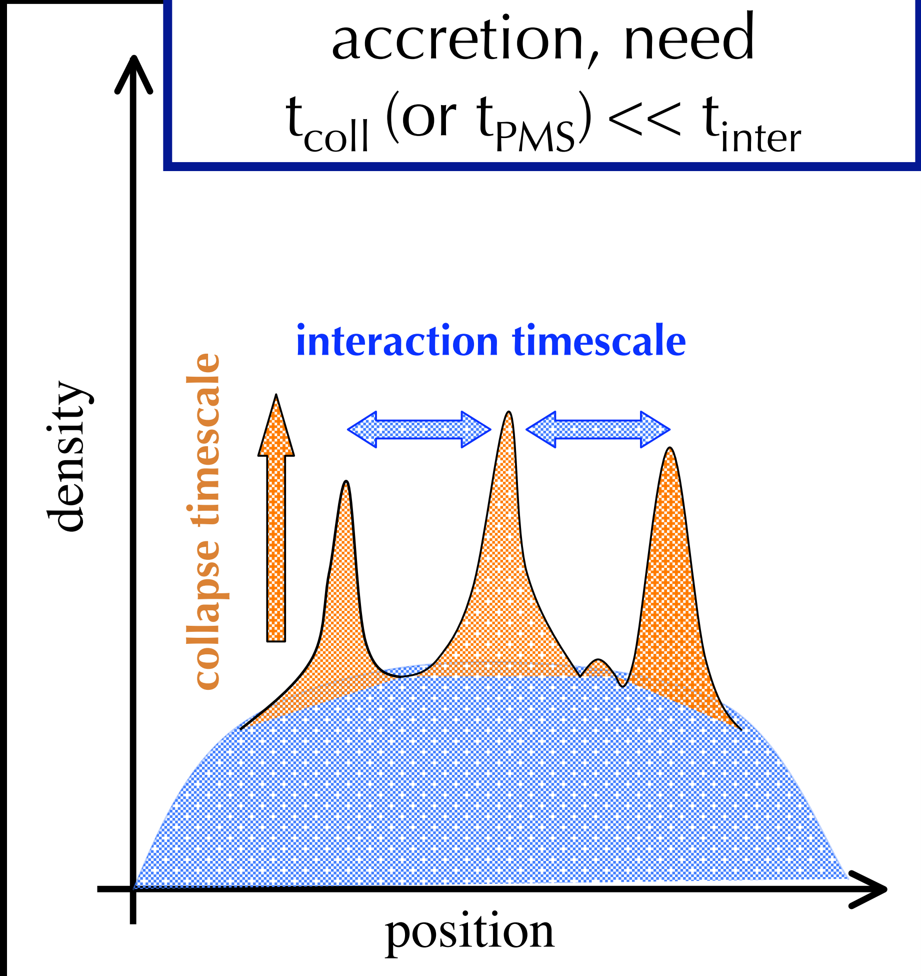
- Competitive accretion requires a region in which the collapse timescale and interaction timescale are similar.

- If the clump densities and cloud density are roughly equal, then:

$$t_{inter} \sim t_{acc} \sim t_{ff,\, local}$$

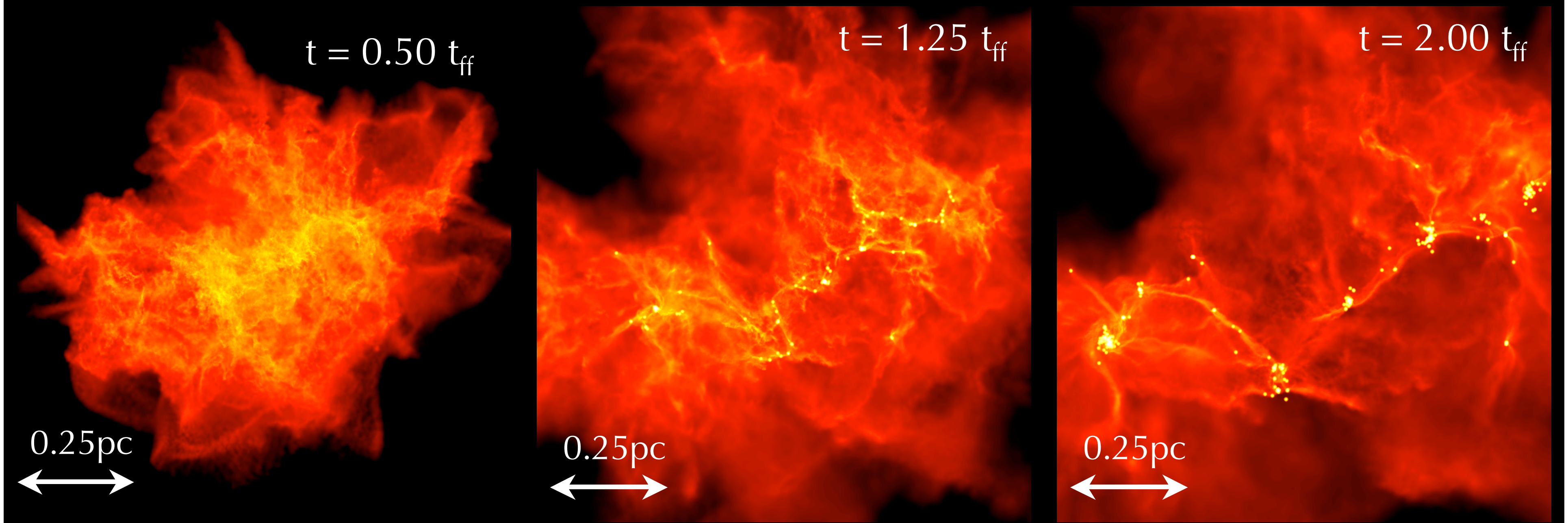
- Any region with multiple Jeans masses automatically satisfies this requirement.

To prevent competitive accretion, need t_{coll} (or t_{PMS}) << t_{inter}



Unbound clouds

KE = 2 × PE (initially), 1000 solar masses, 0.5pc



No global collapse:

local t_{ff} < global interaction time-scale

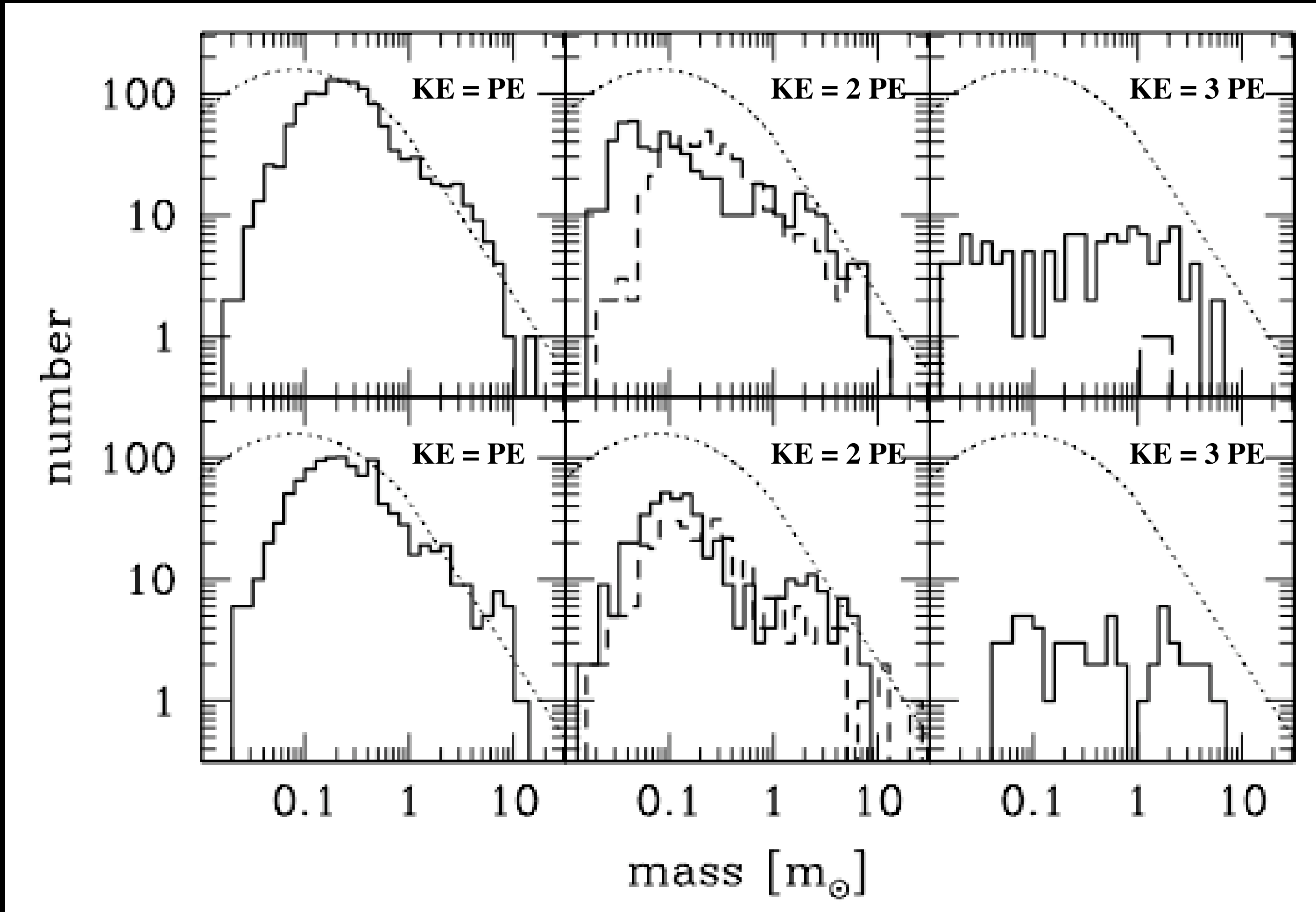
$t_{ff} \sim 2 \times 10^5$ years

Clark, Bonnell & Klessen (2007)

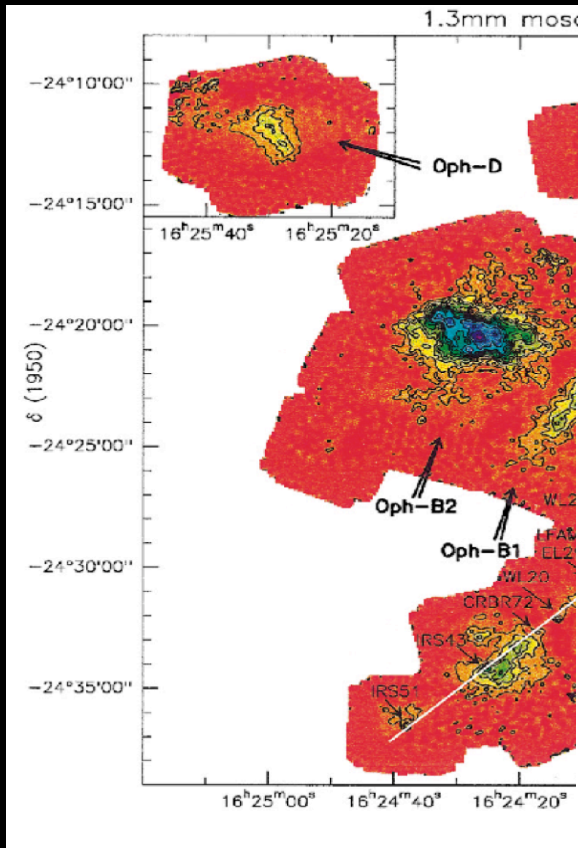
Mass functions?

Isothermal EOS

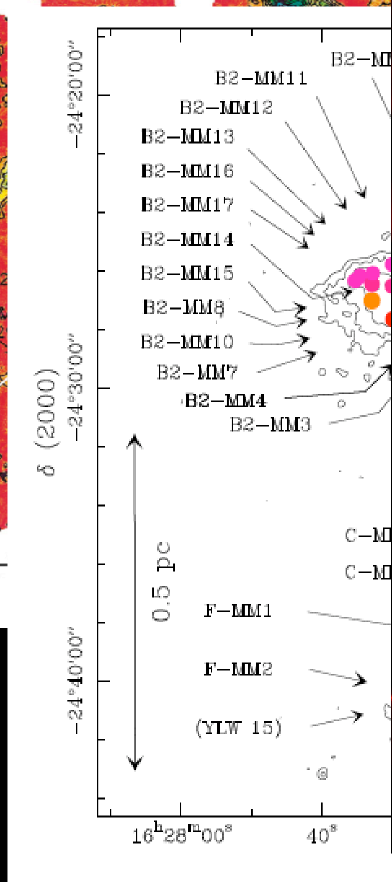
Barotropic,
Larson (2005),
Style EOS



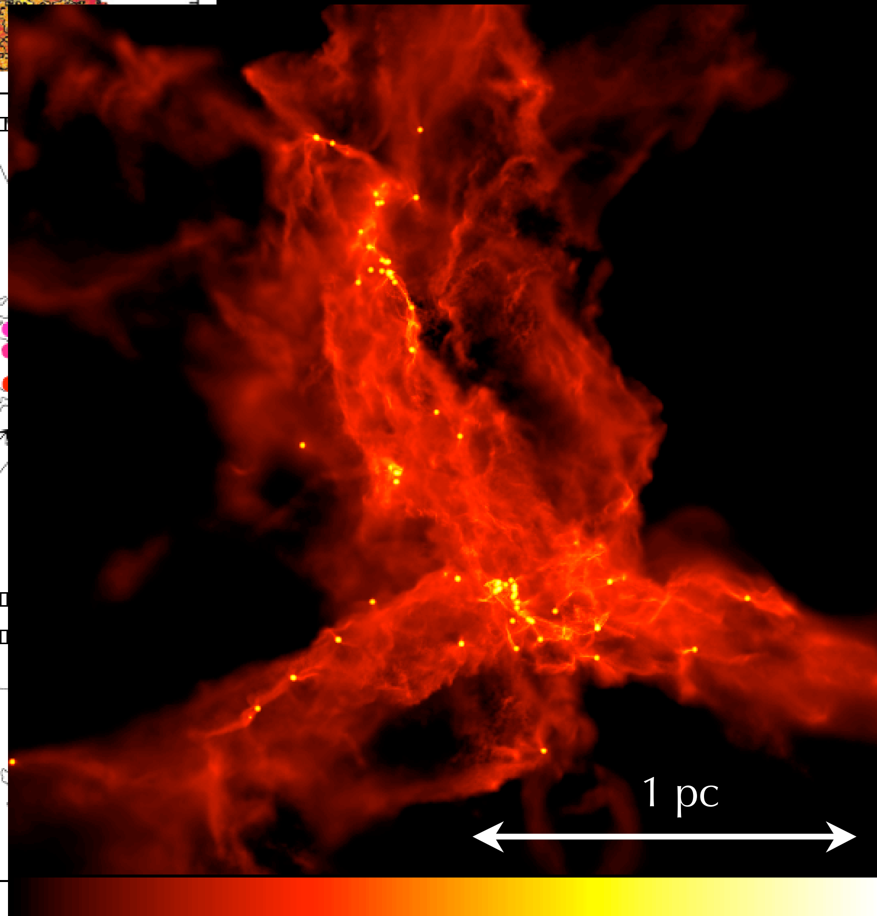
Observational tests?



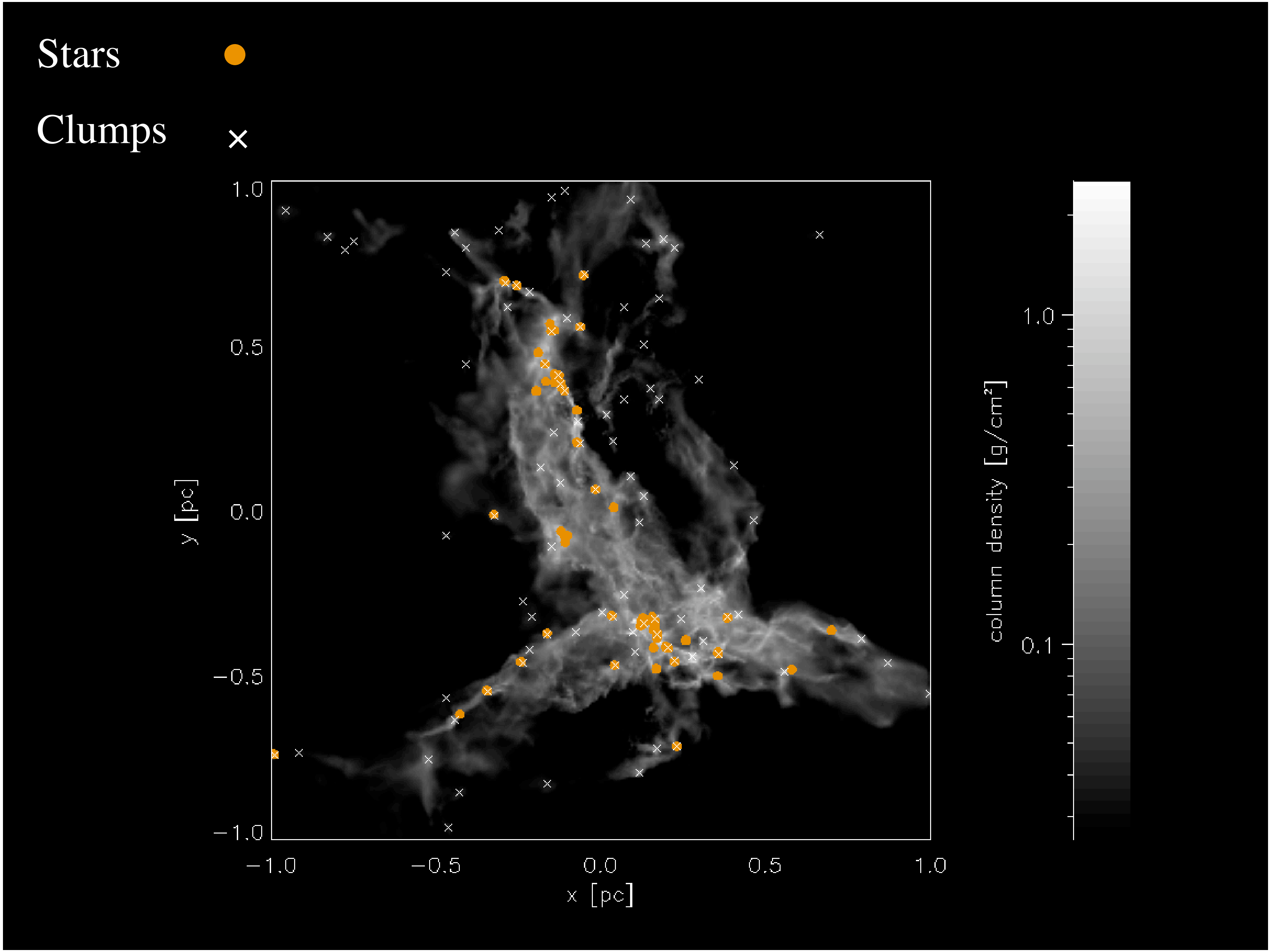
Motte, André & Neri (1998)



André et al. (2007)



Bonnell, Clarke & Bate (2006)



Stars
Clumps
1.0
0.5
0.0
−0.5
−1.0
y [pc]
−1.0
−0.5
0.0
0.5
1.0
x [pc]
1.0
0.1
column density [g/cm²]

Clump mass functions

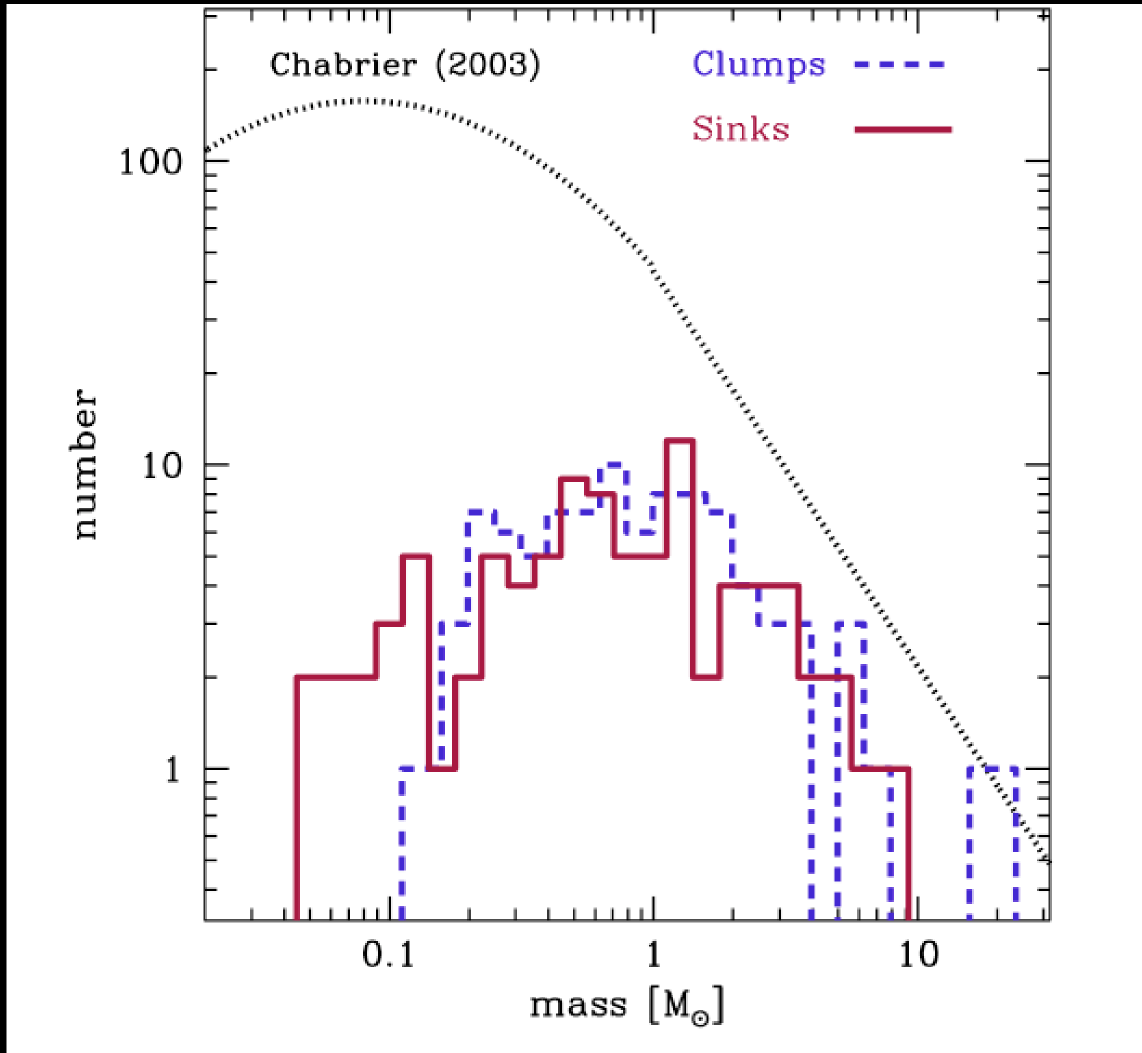
88 sink particles

SPH data mapped to a 2D grid with resolution ~1000 x 1000 au

Column densities limited to range 0.02- 2.00 cm^{-2}

Clumps required to have a density contrast of a factor 2 in column density

91 “sink-less” clumps



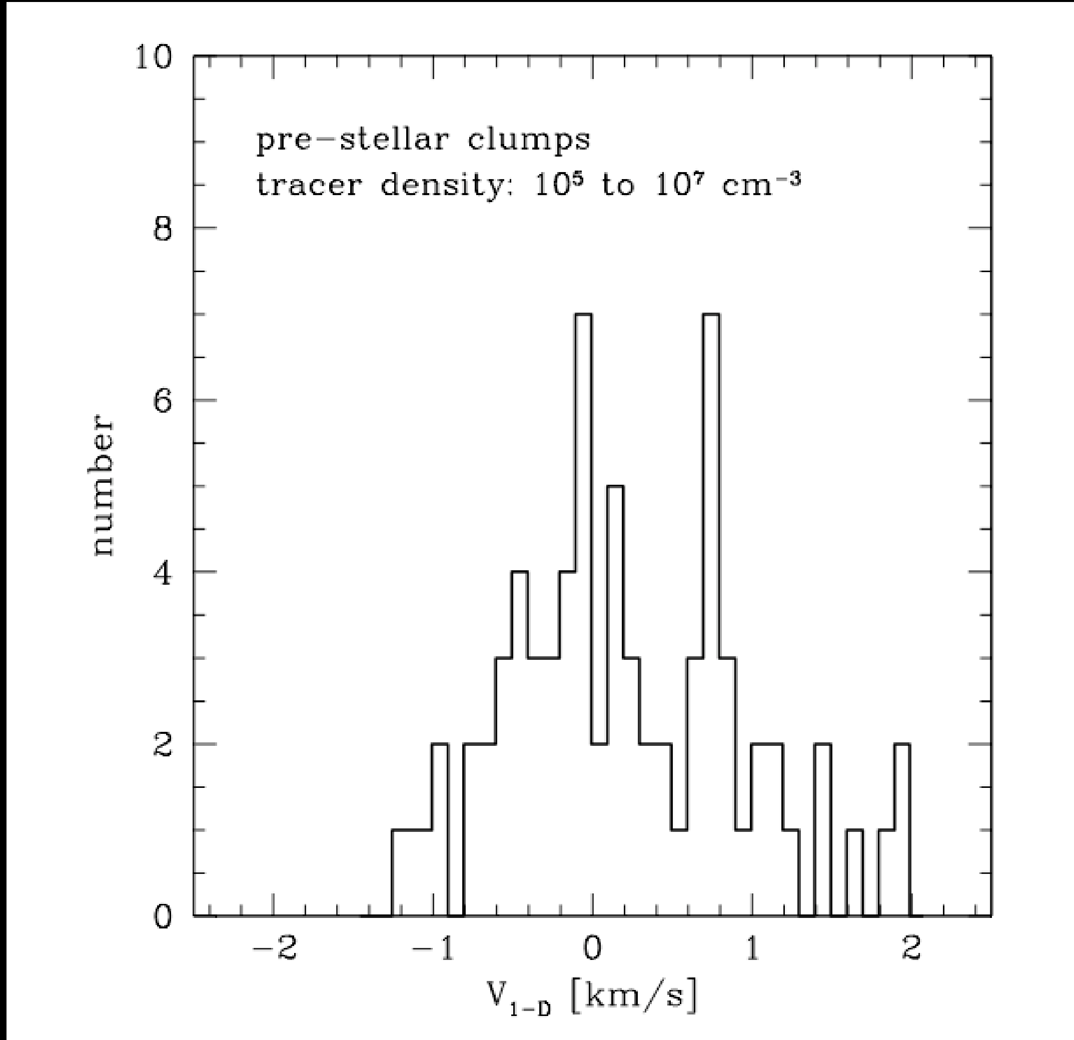
Clump velocity dispersions

Each cluster has it's own central velocity

Distribution around this velocity is ~ 0.25km/s, and the mean is only ~0.7 km/s for the whole region.

Typical of turbulent stagnation points (e.g Padoan et al 2001)

Similar velocities to *André et al (2007)*



Can you see competitive accretion?

André et al (2007):

• Used the clu
to estimate th
interaction tin

• From Binney
(1987),

$$\frac{t_{coll}}{t_{cross}} = \frac{1}{2}\sqrt{\frac{\pi}{3}} \times \frac{R^2}{N_{cond}\, r_{cond}^2} \times \frac{1}{1+\Theta}$$

where,

$$1+\Theta \equiv 1 + GM_{cond}/(\sigma_{1D}^2 r_{cond})$$

For the Bonnell et al (2006) cloud:

t_{cross} ~ 1.7Myr

t_{coll}/t_{cross} ~ 13.5

• Using (for L1688):

55pc

= 57

m/s

R_{cond} ~ 2500 AU

M_{cond} ~ 0.4$M_{\odot}$

t_{cross} ~ 1.78Myr

• Get time-scale ratio:

t_{coll}/t_{cross} ~ 9

Why doesn't it work?

• Need to take the large-scale dynamics into account

• Regions themselves grow through competitive accretion:

Instantaneous measurements don't / can't account for this!

Neglects the self-gravity of the surrounding region.

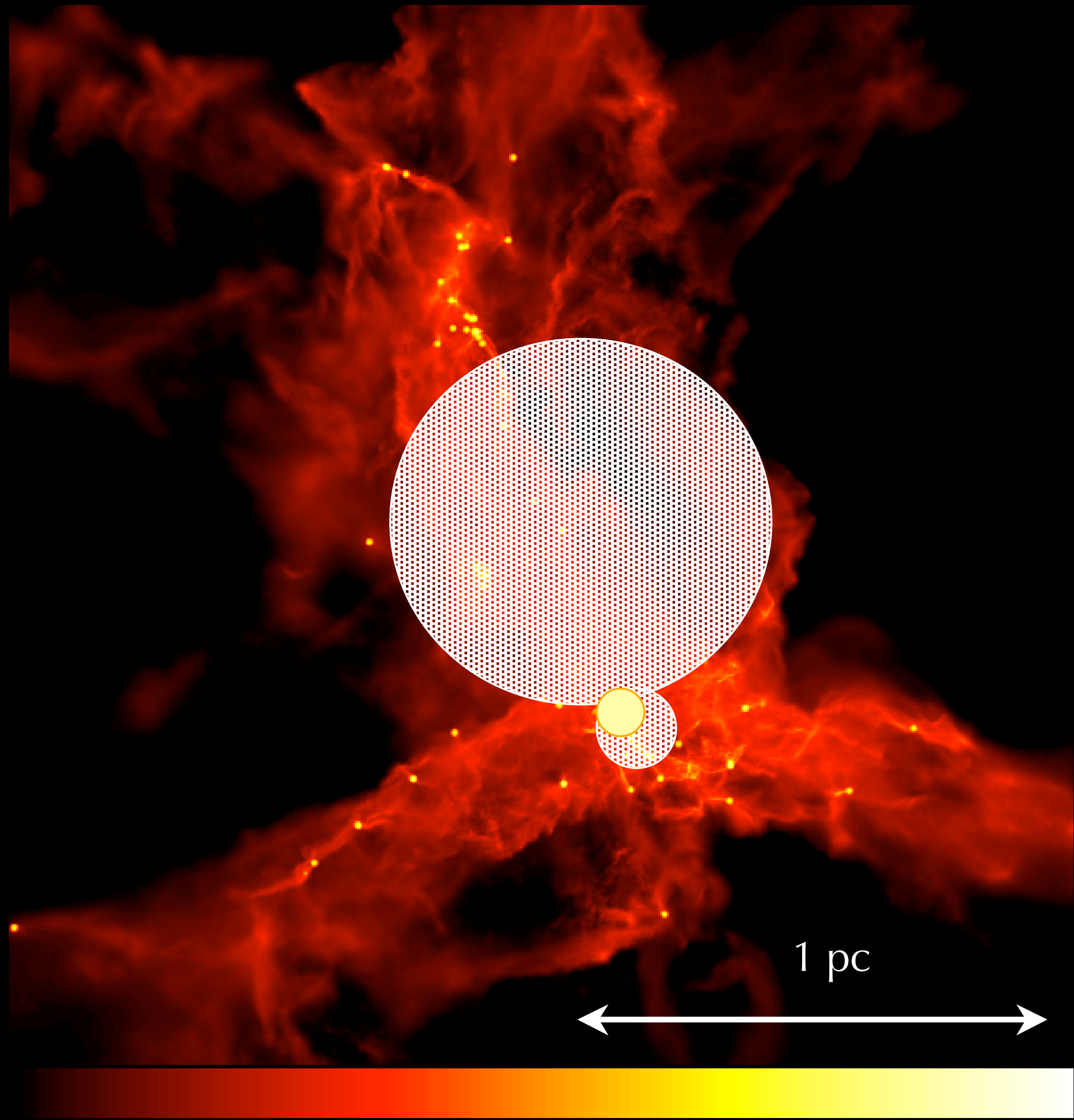
• Using globally averaged properties also results in the 'wrong' answer (Krumholz et al 2005; Bonnell & Bate 2006)

Observational difficulty!

Tidal lobe accretion:

$$R_{\mathrm{tidal}} \approx 0.5 \left(\frac{M_*}{M_{\mathrm{enc}}} \right)^{1/3} R,$$

Hierarchical,
time-dependent,
problem!



Bonnell, Clarke & Bate (2006)

What can you tell?

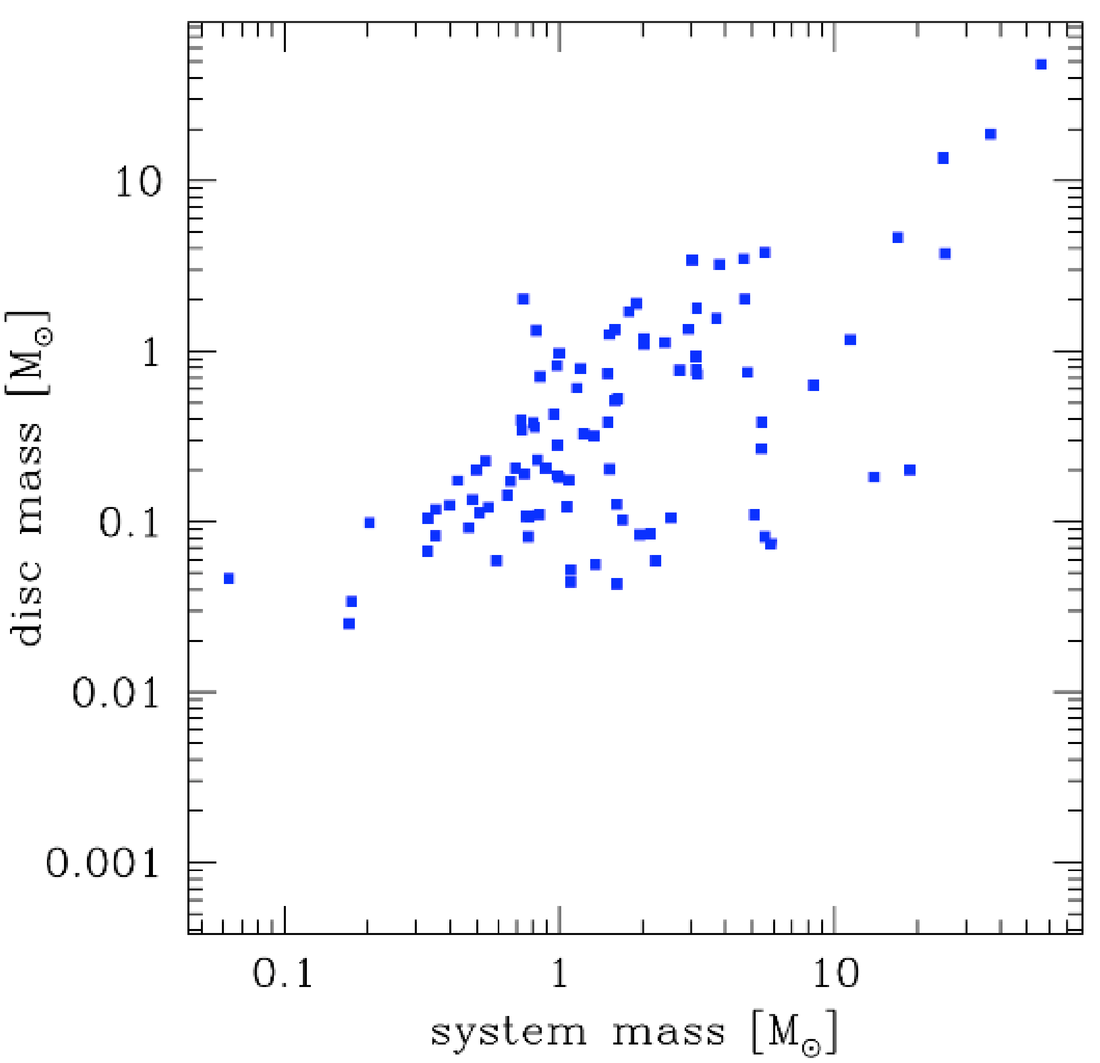
- Region needs to have multiple Jeans masses and be in a state of collapse: gravity dominates over internal support.
- The scale over which the collapse is seen is likely to be the scale over which competitive accretion is dominating, but only for 'now'!
- Observations suggest this is true (André et al 2007):

e.g. ρ - Oph, L1688 (Encrenaz et al 1975)

NGC 2264 (Peretto et al 2006)

NGC 1333 (Walsh et al 2006, 2007)

Discs?



- Relationship between disc mass and protostellar system mass:

$$m_{disc} \propto m_{sys}^{1.5 - 2}$$

- Note that discs come and go!
- Angular momentum vector can change!

Bonnell, Clarke & Bate (2006) *Clark, Bonnell & Klessen, in prep*

Summary

- Competitive accretion requires bound, collapsing regions to produce the ‘correct’ IMF.
- Difficult to use observed interaction time-scales to estimate the competitive accretion rates: tend to neglect the changing potential which plays a crucial role.
- Need to look at global properties and ask ‘can competitive accretion be avoided’ => local reduction of timescales
- Disc observations may help to determine importance of interactions.