The Unusual Stellar Mass Function of Starburst Clusters

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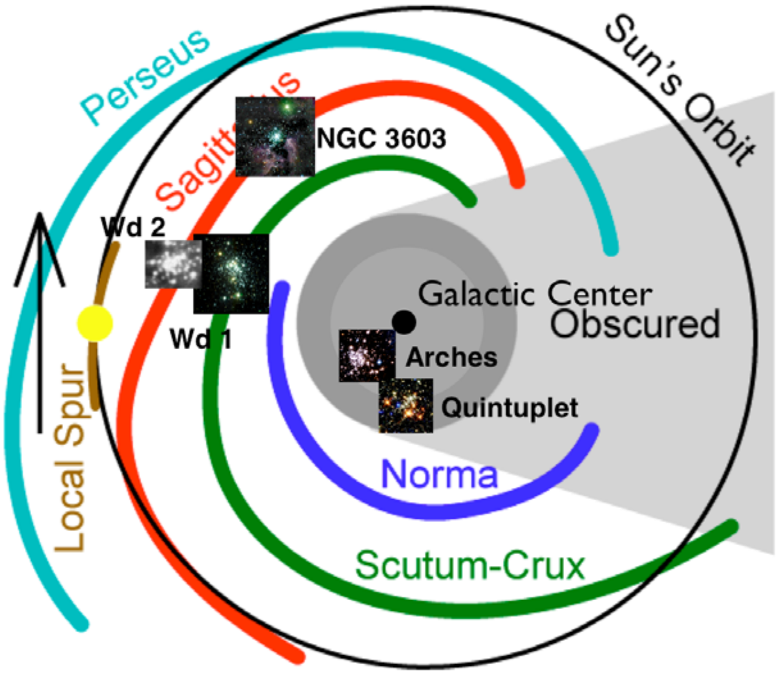
Where are they located and how many are there?



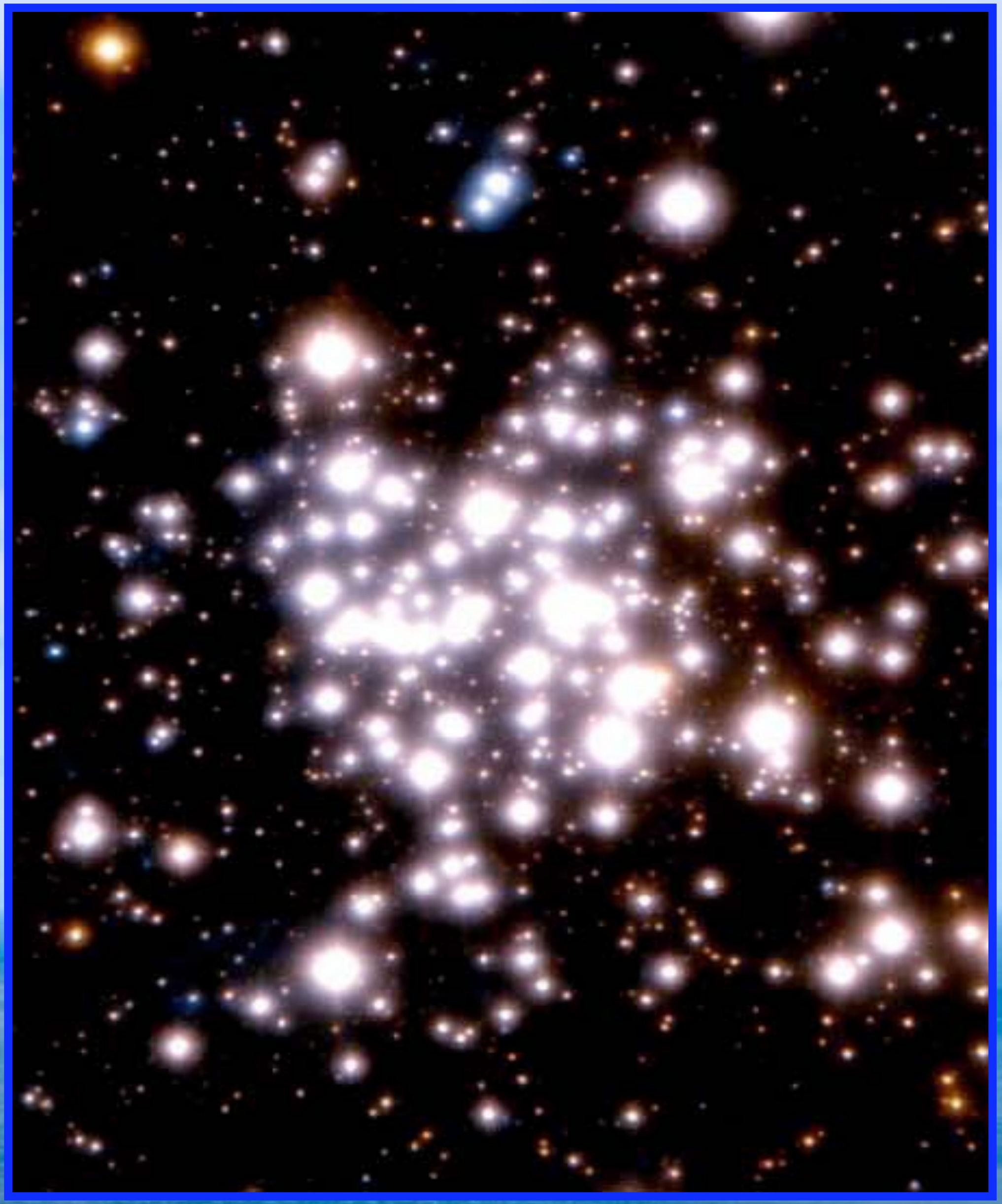
≥3 spiral arm SB cluster:

- NGC 3603: d = 6.0 kpc (A_V = 4.5 mag)
- Westerlund 1: d = 3.5 kpc (A_V = 10 to 13 mag)
- Westerlund 2: d = 2 to 5 kpc

Two "nuclear cluster":

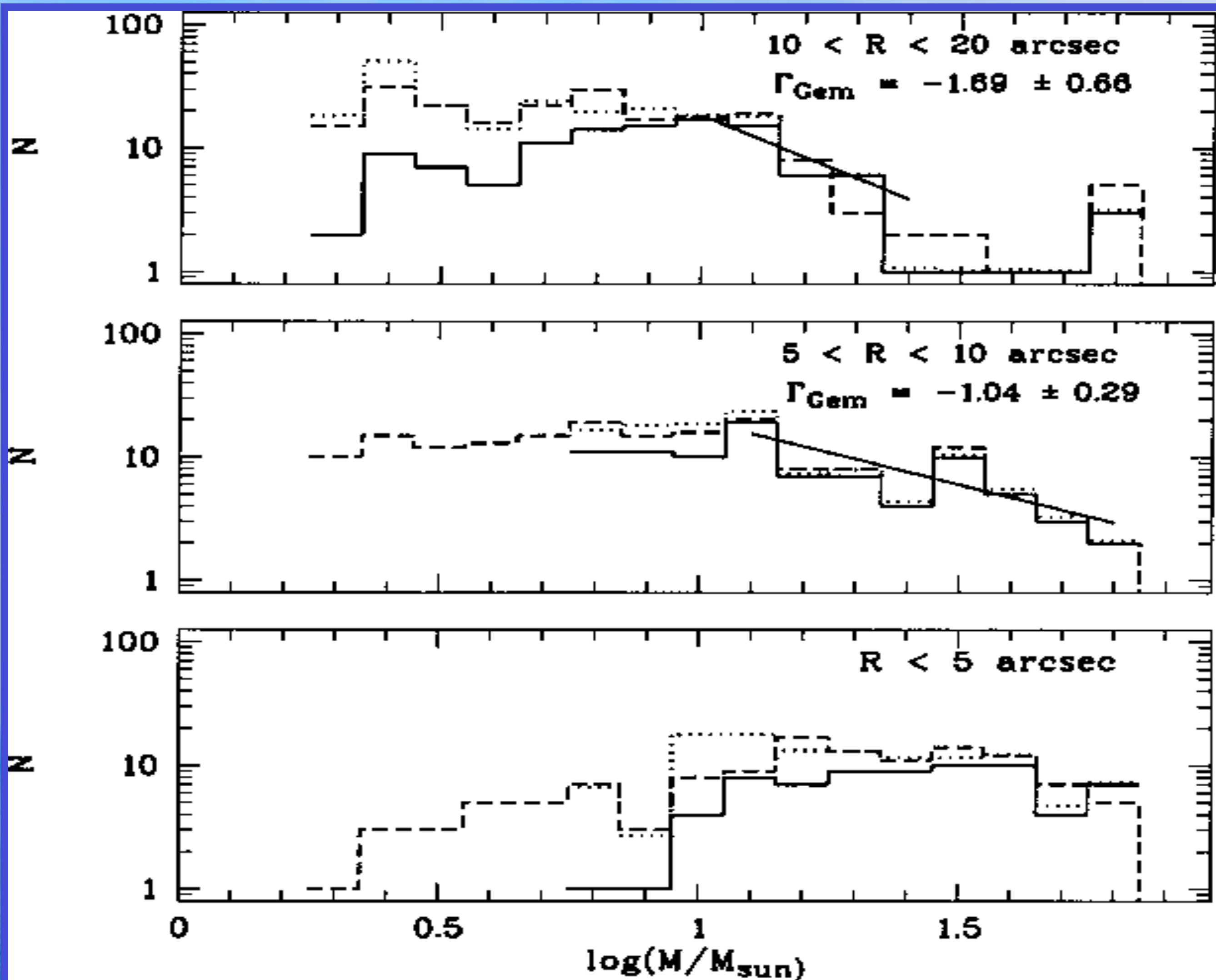
- Arches & Quintuplet: d = 8.0 kpc (A_V = 24 mag)

From Wolfgang Brandner



Figer et al. 1999

What is so unusual ? Arches



Stolte et al. 2002

Figer et al. 1999

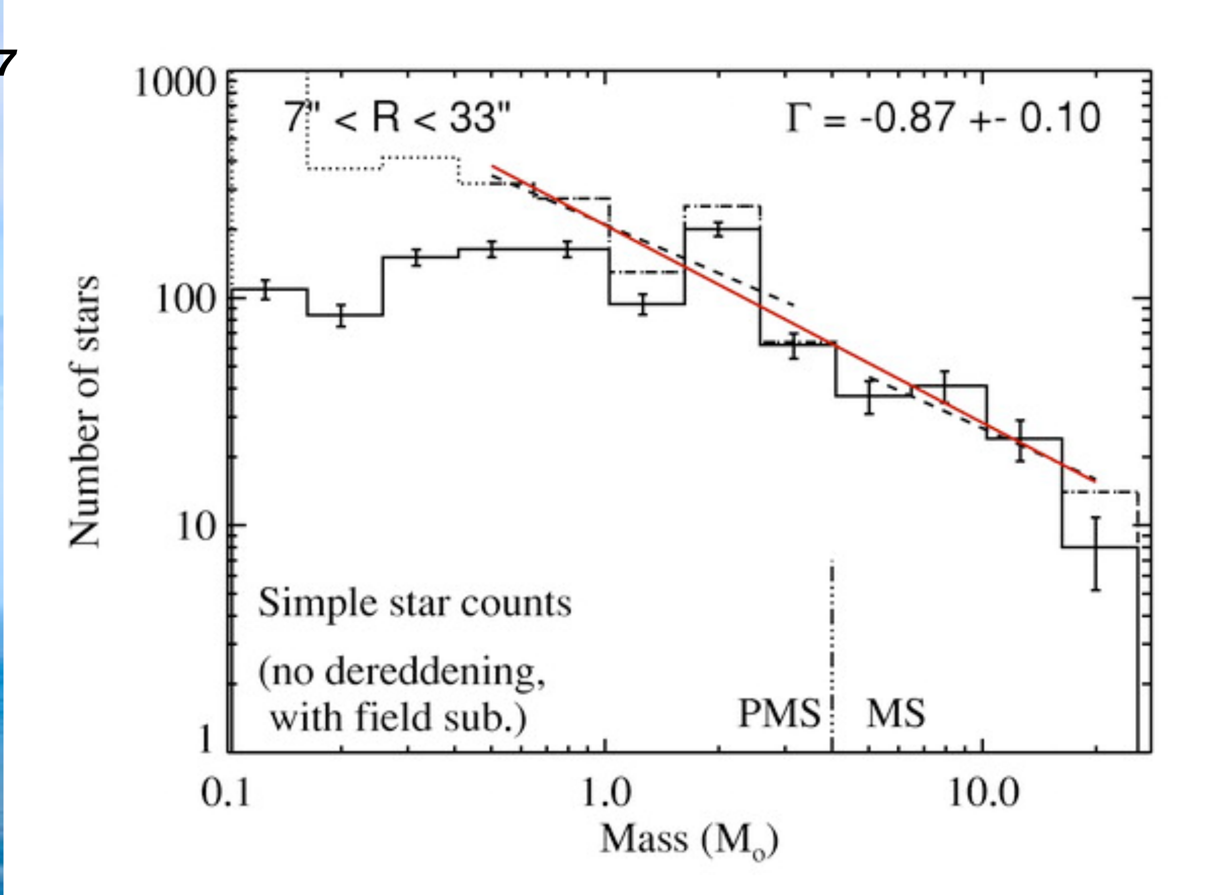
What is so unusual ? Other starburst clusters

Quintuplet , Figer et al. 1999

NGC 3603 Eisenhauer et al. 1998,

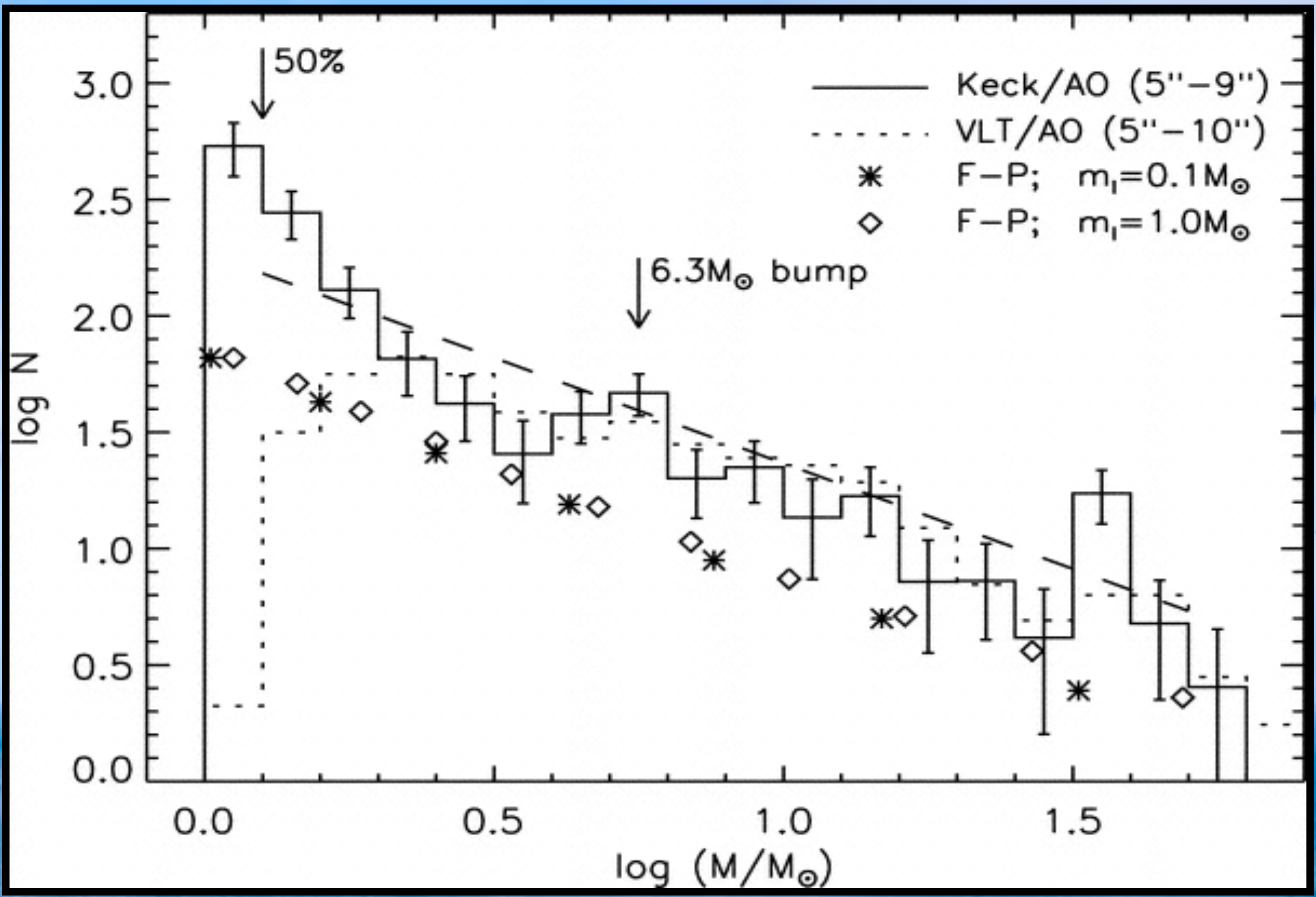
Stolte et al. 2006.Harayama et al. 2007

Westerlund I: Brandner et al. 2007



Stolte et al. 2006

What is so unusual ?



Stolte et al. 2005, Kim et al. 2006

Constraints on models

A successful model has to explain

a) Slope for M > 10-15 M_sol

b) Slope for 1 M_sol < M < 3 M_sol

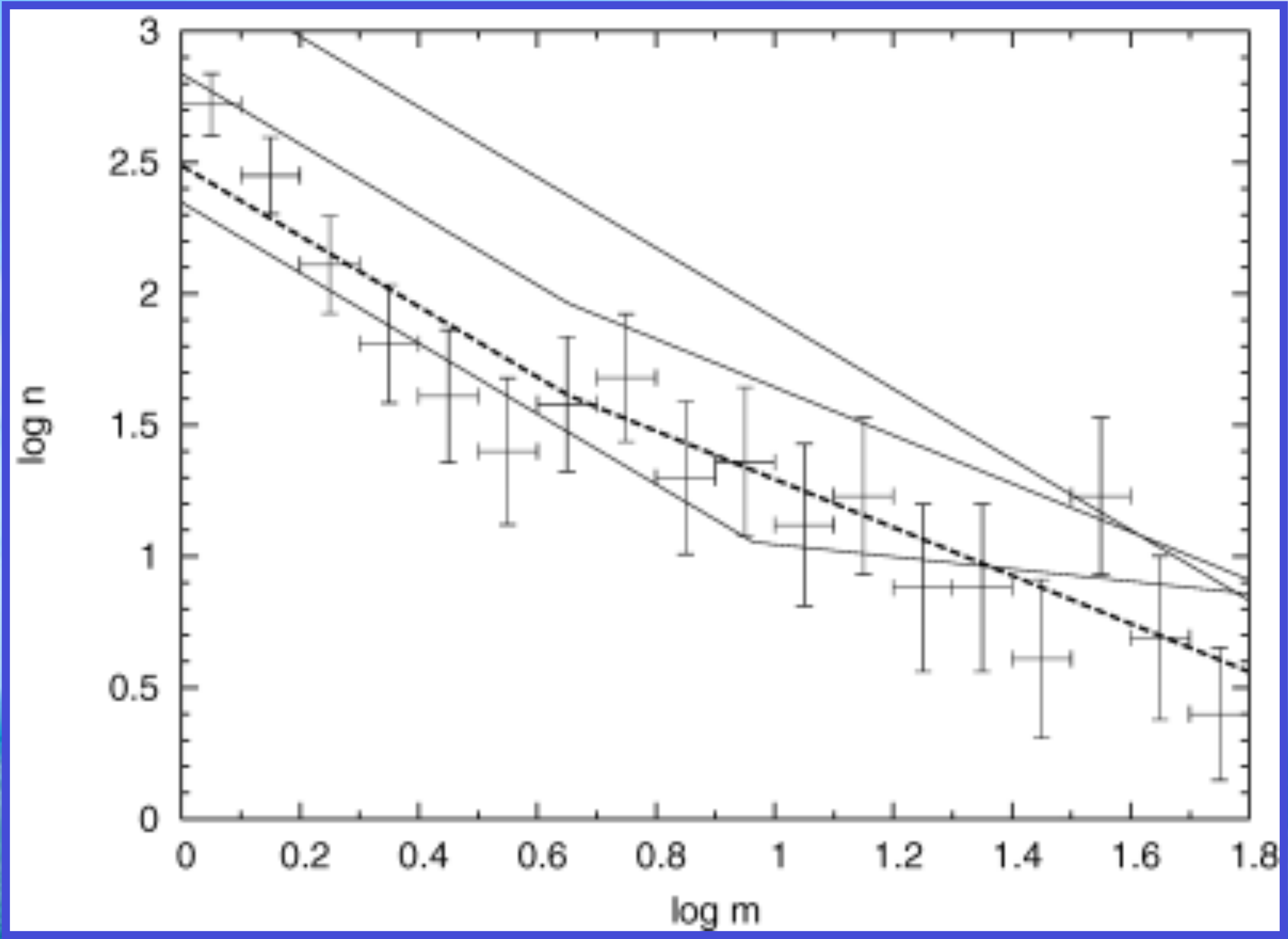
c) Position of the bump at 6 M_sol

and

d) Eventually form low-mass stars first

Another approach :

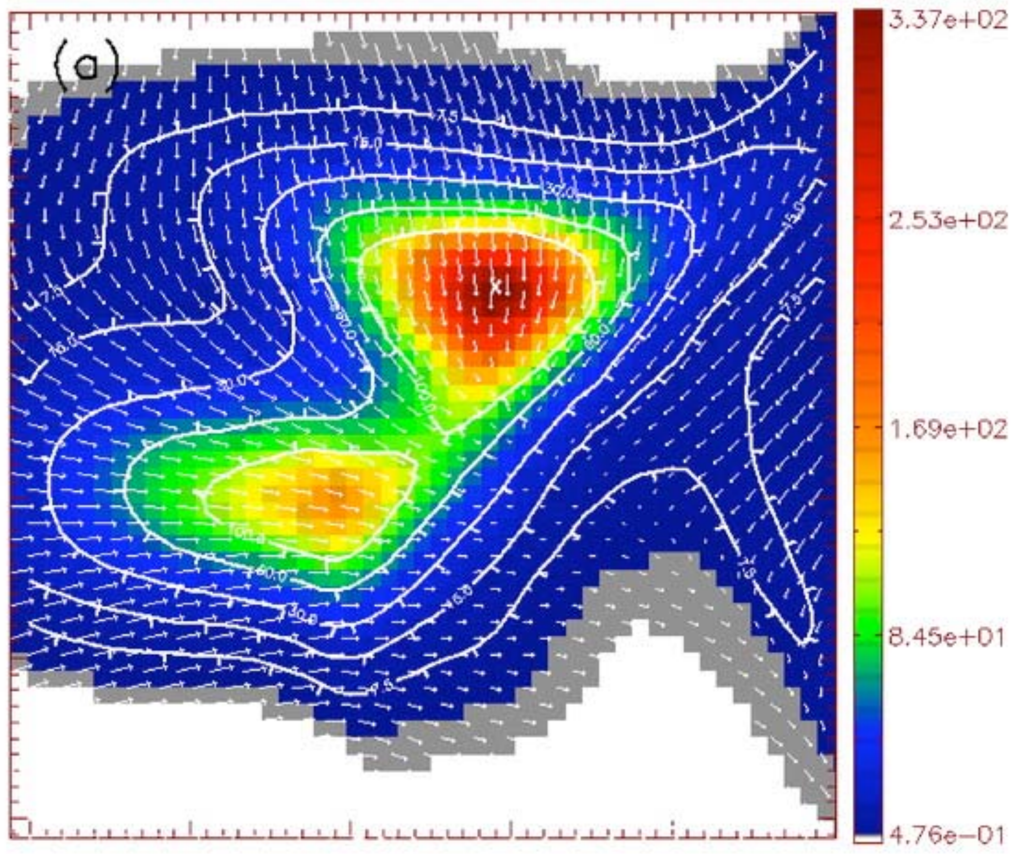
“Mass segregation by dynamical friction”



Portegies-Zwart et al. 2007

And another : A coalescence-collapse model of PSCs

Initial pre-stellar cores mass function + evolution ⇒ primordial IMF + evolution (?)



Dib et al. 2007a

The coalescence-collapse model

- *Protocluster cloud model : $\rho_{cloud}(r) \propto$ flat inside+ r^{-2}, $\sigma = \sigma_0 r^{\alpha}$, T=cte=10 K*
- *Pre-stellar cores model $\rho_{PSC}(R) \propto$ flat core+ R^{-4}*
- *Initial distributions of cores populations at different r*
- *Time evolution*

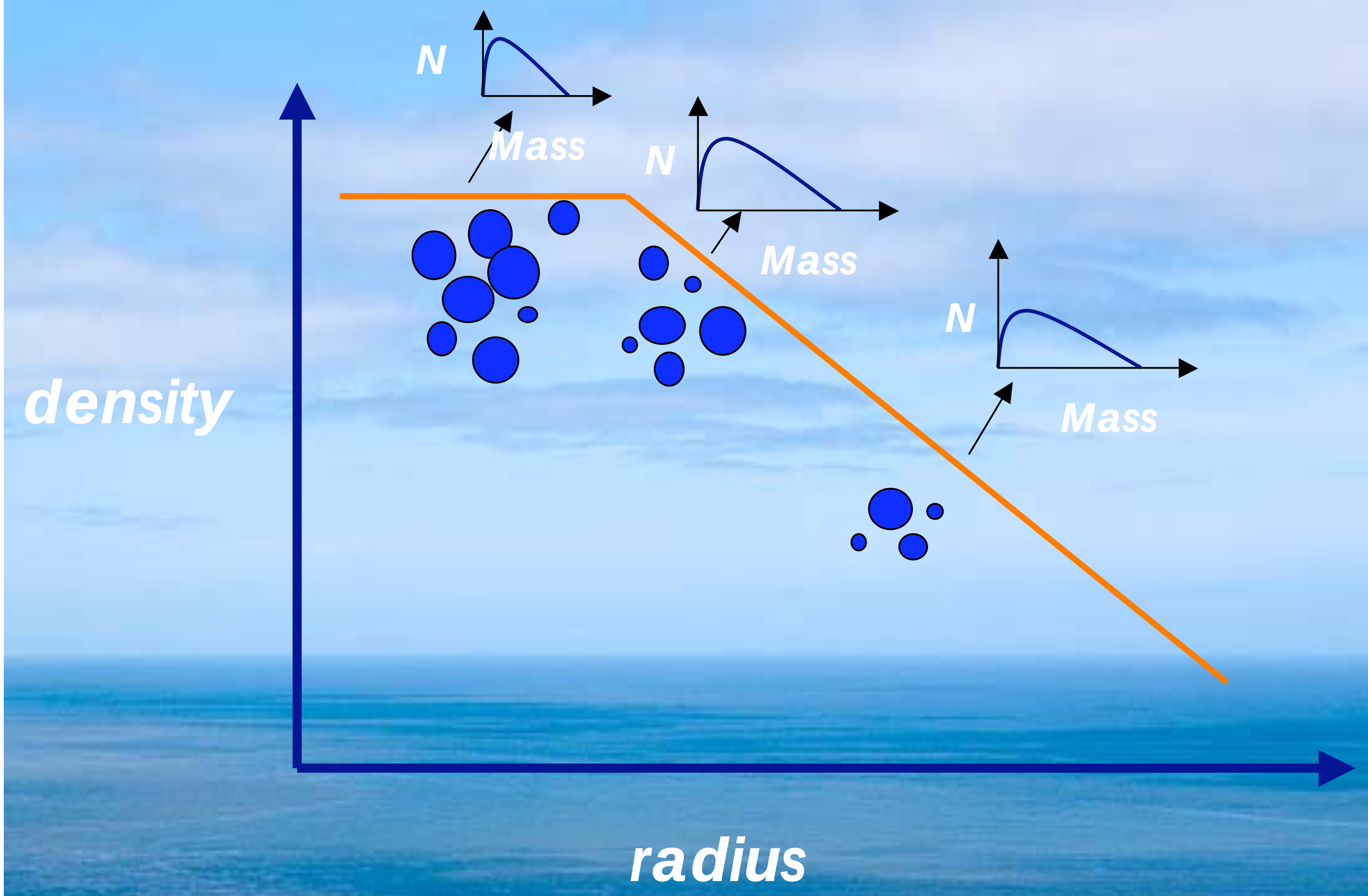
  cores contraction (R decreases with times)

  cores coalescence

- *Transition to stars, when: $t_{collapse} < t_{coalescence}$*

  mass loss (outflows)

The coalescence-collapse model



The initial conditions:

Analytical model of Padoan & Nordlund (2002). Gravo-turbulent Fragmenation

β Slope of the turbulent velocity power spectrum

If one makes the following assumptions:

a) Density field is a log-normal distribution

b) The power spectrum of the turbulent velocity field is a power low: $E(k) \propto k^{-\beta}$ (β=2α+1)

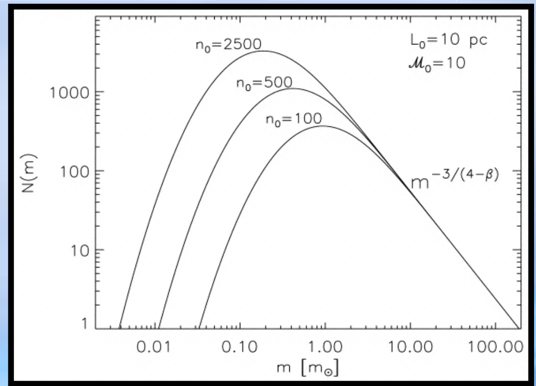
c) Size of cores $\propto$ thickness of the post-shock gas layer

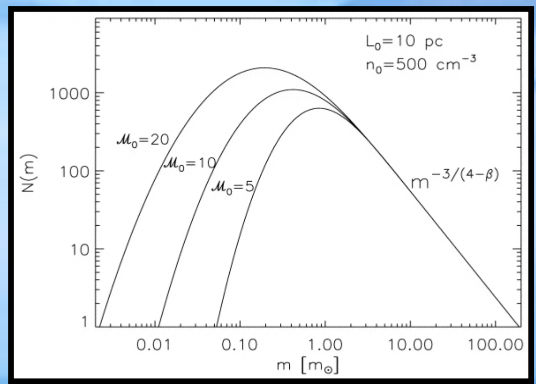
Then:

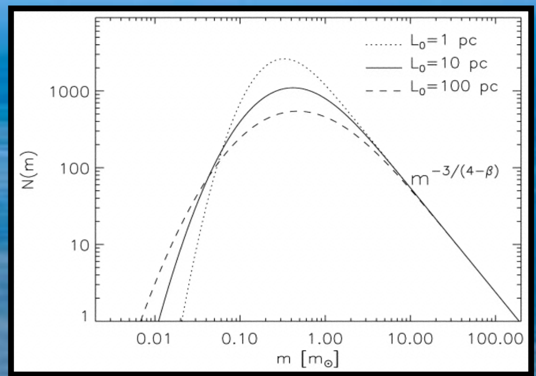
$$N(M)d\log M \propto M^{-3/(4-\beta)} d\log M$$

And the grav. Unstable cores are

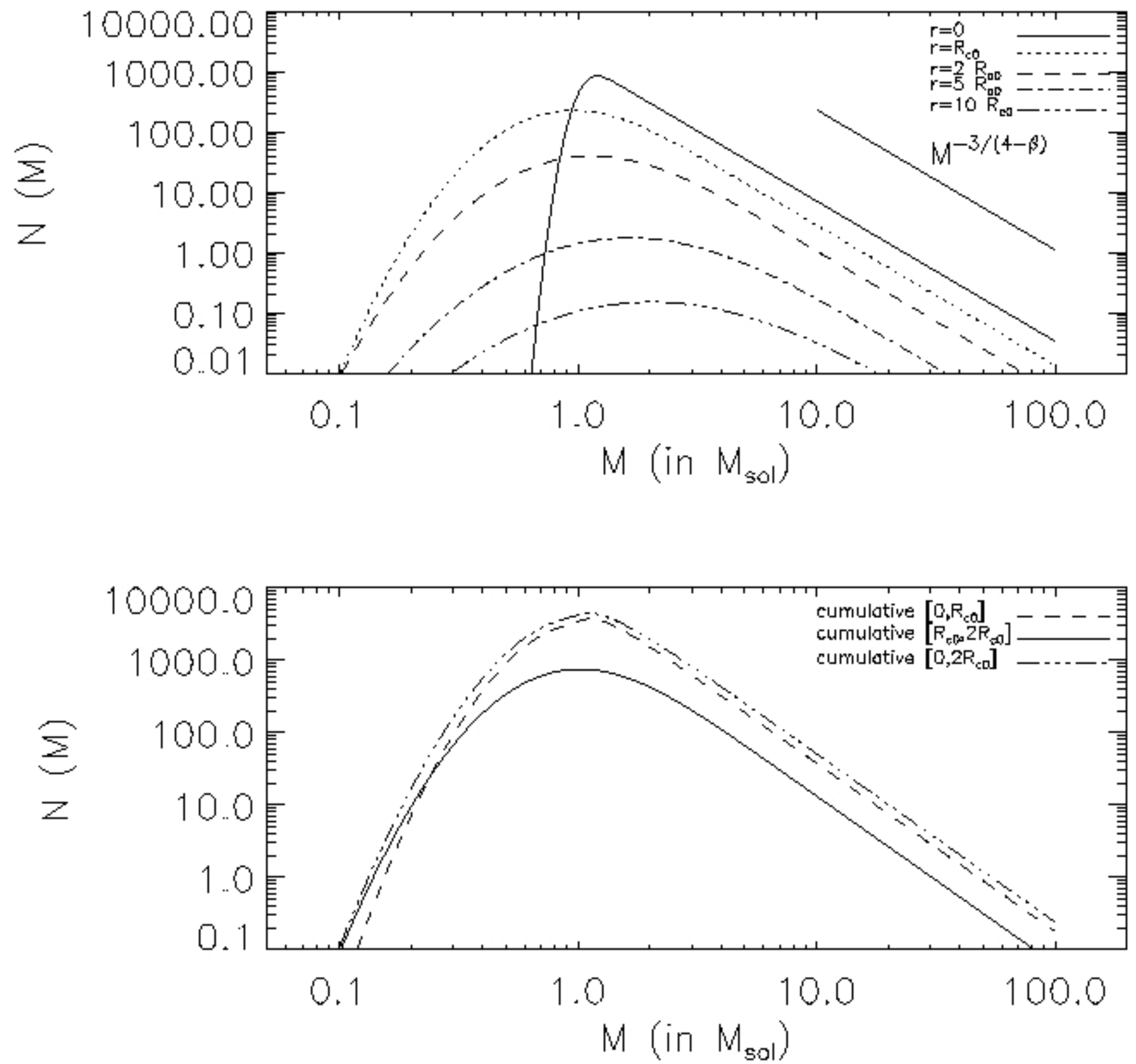
$$N(r,M)d\log M = f(r)M^{-3/(4-\beta)}\left[\int_0^{\infty} P(M_J)dM_J\right]d\log M$$







The initial conditions: i.e., cores distribution in the protocluster cloud



α=0.4

β=1.8

3/(4-β)=1.33

The coalescence cross-section

calculate instanteneous cross section of collision between objects of Masses M_i and M_j And integrate over the mass spectrum.

$$\sigma(M_i, M_j, r, t) = \pi\left(R_i(t) + R_j(t)\right)^2 \left[1 + \frac{2G\left(M_i + M_j\right)}{2v^2\left(R_i(t) + R_j(t)\right)}\right]$$

..and then solve

$$\frac{dN(r,M,t)}{dt} = \frac{1}{2}\eta(r)\int_{M_{\min}}^{M-M_{\min}} N(r,m,t)N(r,M-m,t)\sigma(m,M-m,r,t)v(r)dm$$

$$-\eta(r)N(r,M,t)\int_{M_{\min}}^{M_{\max}} N(r,m,t)\sigma(m,M-m,r,t)v(r)dm$$

Parameters of the model

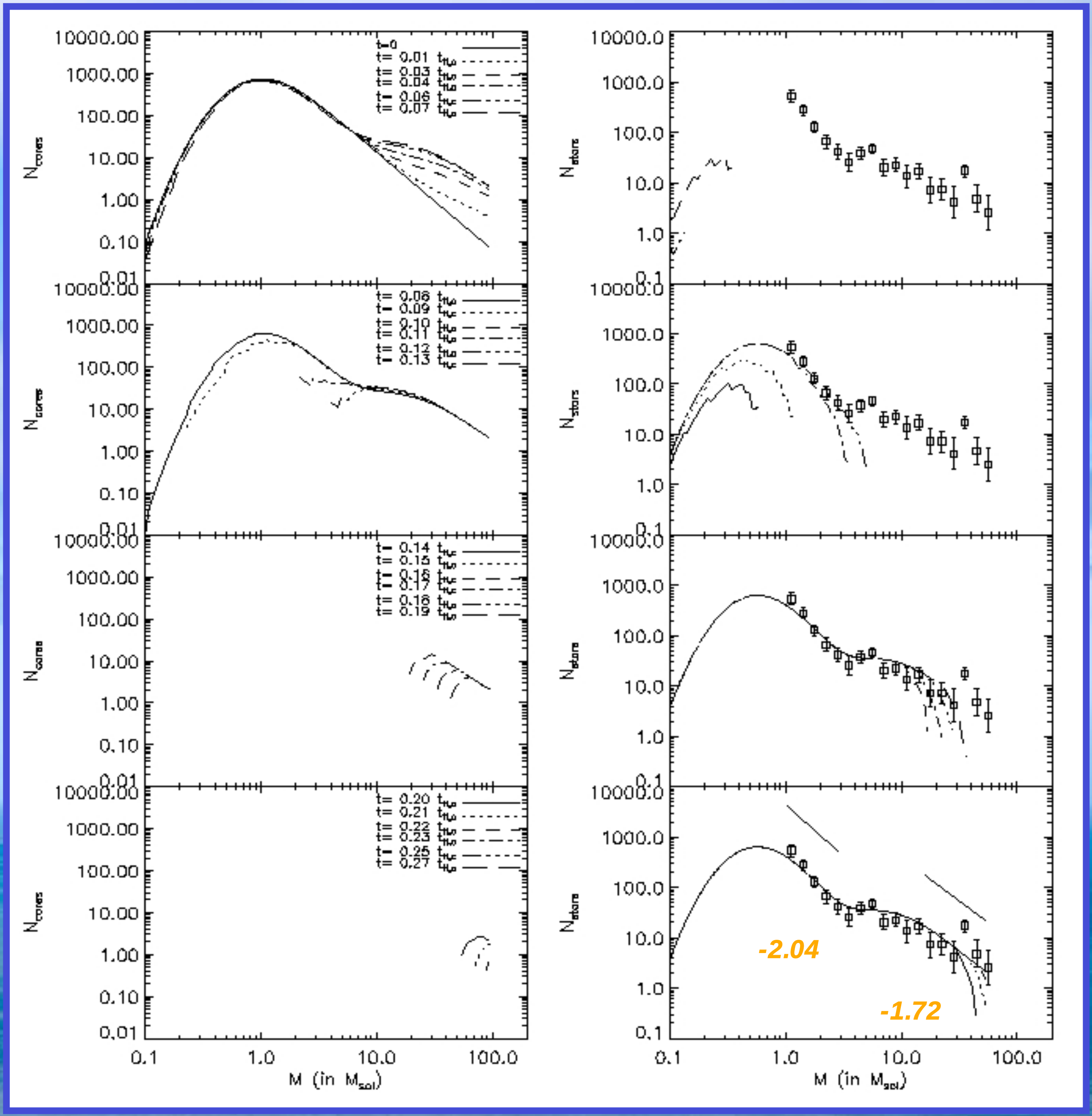
- **coalescence efficiency $\eta=\eta(r)$ (~0.5)**
- **contration timescale t_cont = n t_ff (~10)**
- **Mass cloud = M_c=5x10^5 M_sol,**
- **Radius and core Radius R_c=5 pc, R_c0=0.2 pc**
- **fraction of mass in clumps ε=0.5**
- **Larson relation exponent α=0.37**
- **Cores initial peak density n_p0= 10^7 cm^-3**
- **Mass fraction lost in outflows $\Psi=\Psi(M)$ (~0.60)**

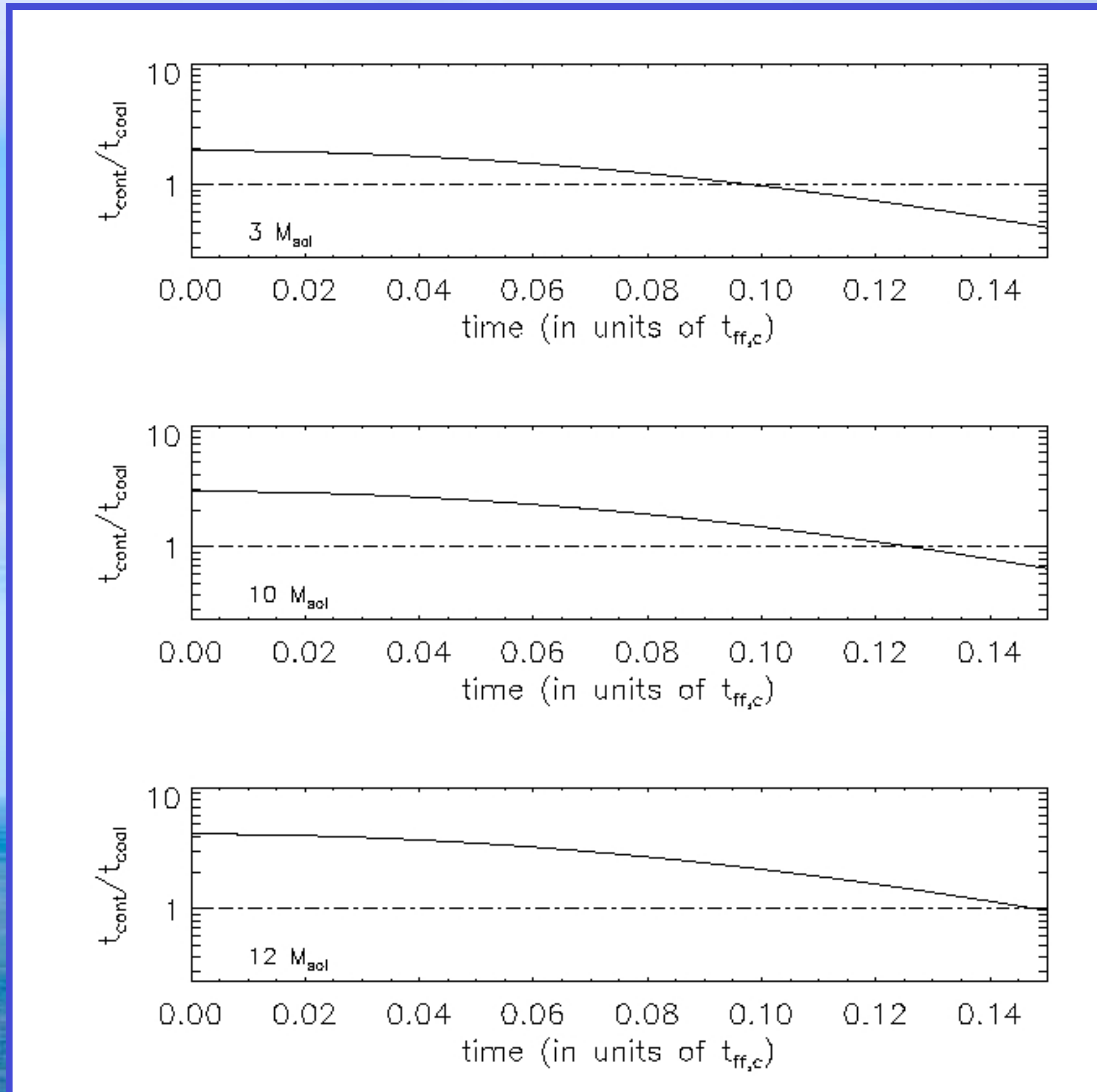
Time evolution

SFE ~ 30%

==> arches is bound

Dib et al. 2007b





10
1
t_{cont}/t_{coal}
3 M_{sol}
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14
time (in units of $t_{ff,c}$)
10
1
t_{cont}/t_{coal}
10 M_{sol}
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14
time (in units of $t_{ff,c}$)
10
1
t_{cont}/t_{coal}
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0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14
time (in units of $t_{ff,c}$)

Conclusions

@ The Coalescence-Collapse model is able to reproduce local slopes, bumps and order of star formation

@ The IMF of the Arches stellar cluster is primordial

(same conclusion should/could apply for other starburst clusters)