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Tracing the Cluster Formation History of Galaxies: the Case of the Large Magellanic Cloud

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Star Clusters :

- Virtually **all** stars in the Universe are born in star clusters
→ they are at the very heart of many astrophysical key issues

  Ø young star clusters tell us about star formation
  Ø star clusters with an age range tell us about the evolution of their host galaxy over this age range

- Most stars are born in star clusters, but observed as field stars.

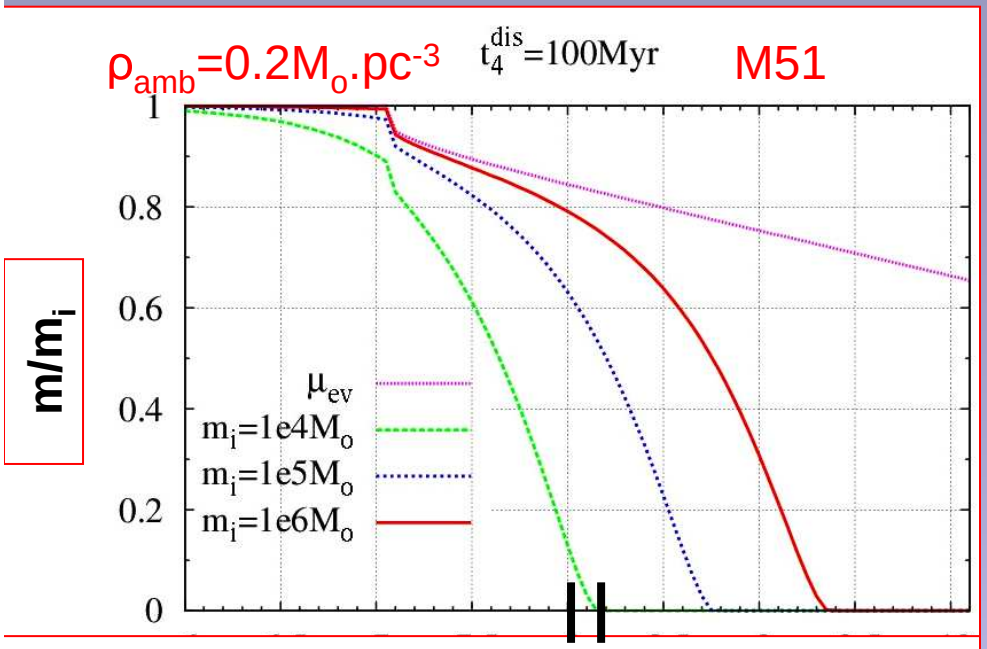
- Star clusters go through a lifecycle: they evaporate, until complete dissolution

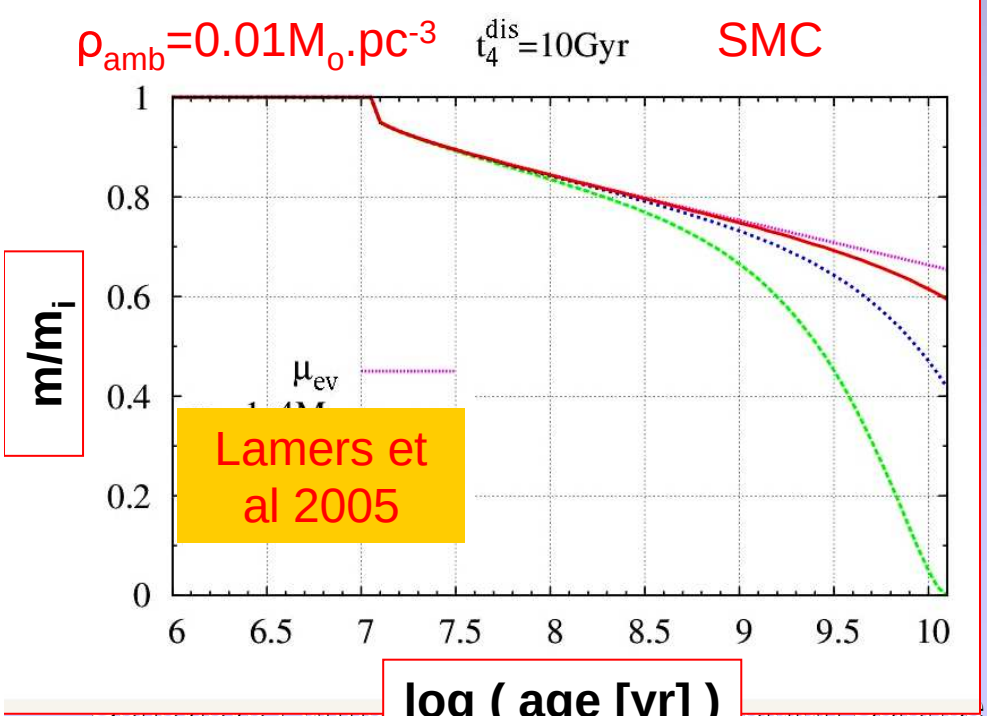
- Cluster lifecycle includes 2 phases:

  Ø gas expulsion and violent relaxation: very short (10-50 Myr),

  Ø secular evolution/gas free evolution

Secular Evolution





$$\frac{m(t)}{m_i} = \left\{ [\mu_{ev}(t)]^{\gamma} - \frac{\gamma\, t}{t_4^{dis}} \left(\frac{10^4 M_o}{m_i} \right)^{\gamma} \right\}^{1/\gamma}$$

with $\gamma \cong 0.62$

$\Rightarrow\ m = 0$ **at** t^{die} **:**

$$t^{die} = \frac{[\mu_{ev}(t^{die})]^{\gamma}}{\gamma} \cdot t_4^{dis} \left(\frac{m_i}{10^4 M_o} \right)^{\gamma}$$

Cluster initial mass

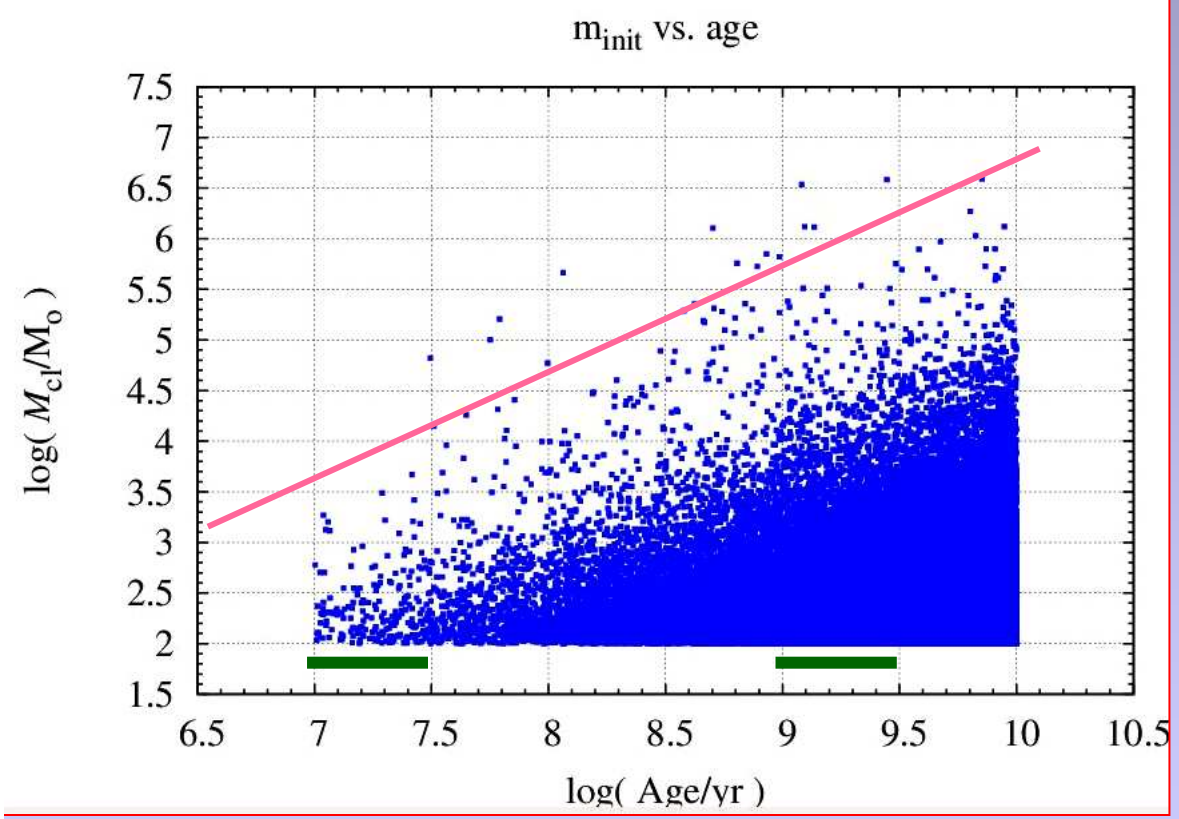
Cluster environment (ambient density, GMCs, …)

$$t^{die}(10^4 M_o) = 1.2 - 1.5\, t_4^{dis}$$

Given $\mathbf{t_4^{dis}}$ **:** $t^{die} \approx m_i^{\gamma}$

$m_i \times 10 \Rightarrow t^{die} \times 4$

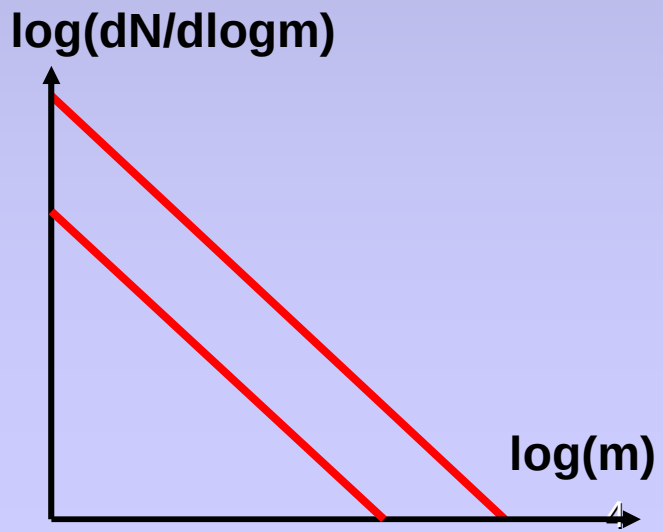
- Cluster Formation Rate (CFR) constant with time,
- Initial Cluster Mass Function (ICMF): $\frac{dN}{dm} \propto m^{-2} \equiv \frac{dN}{d\log m} \propto m^{-1}$



Δt=20Myr

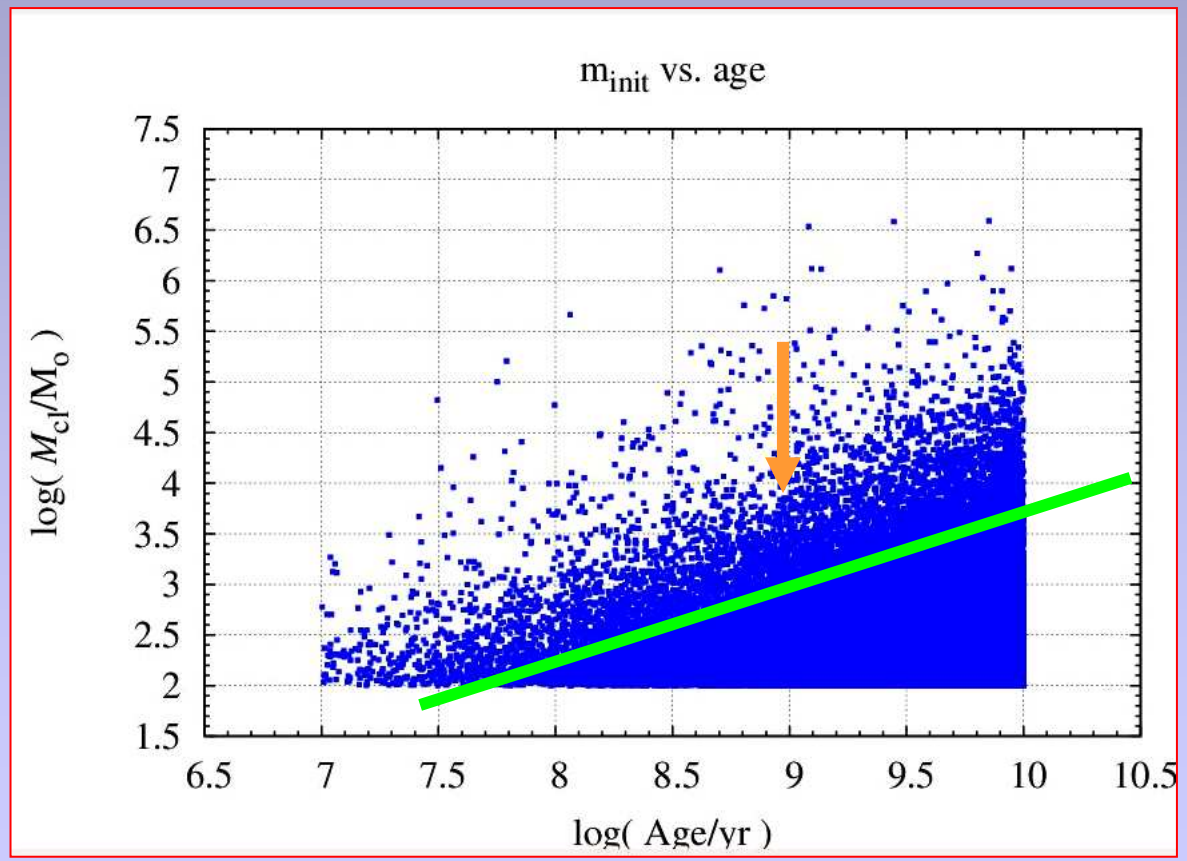
Δt=2Gyr

(100× more SCs if CFR=cst)



These are the initial conditions, not what an observer sees !

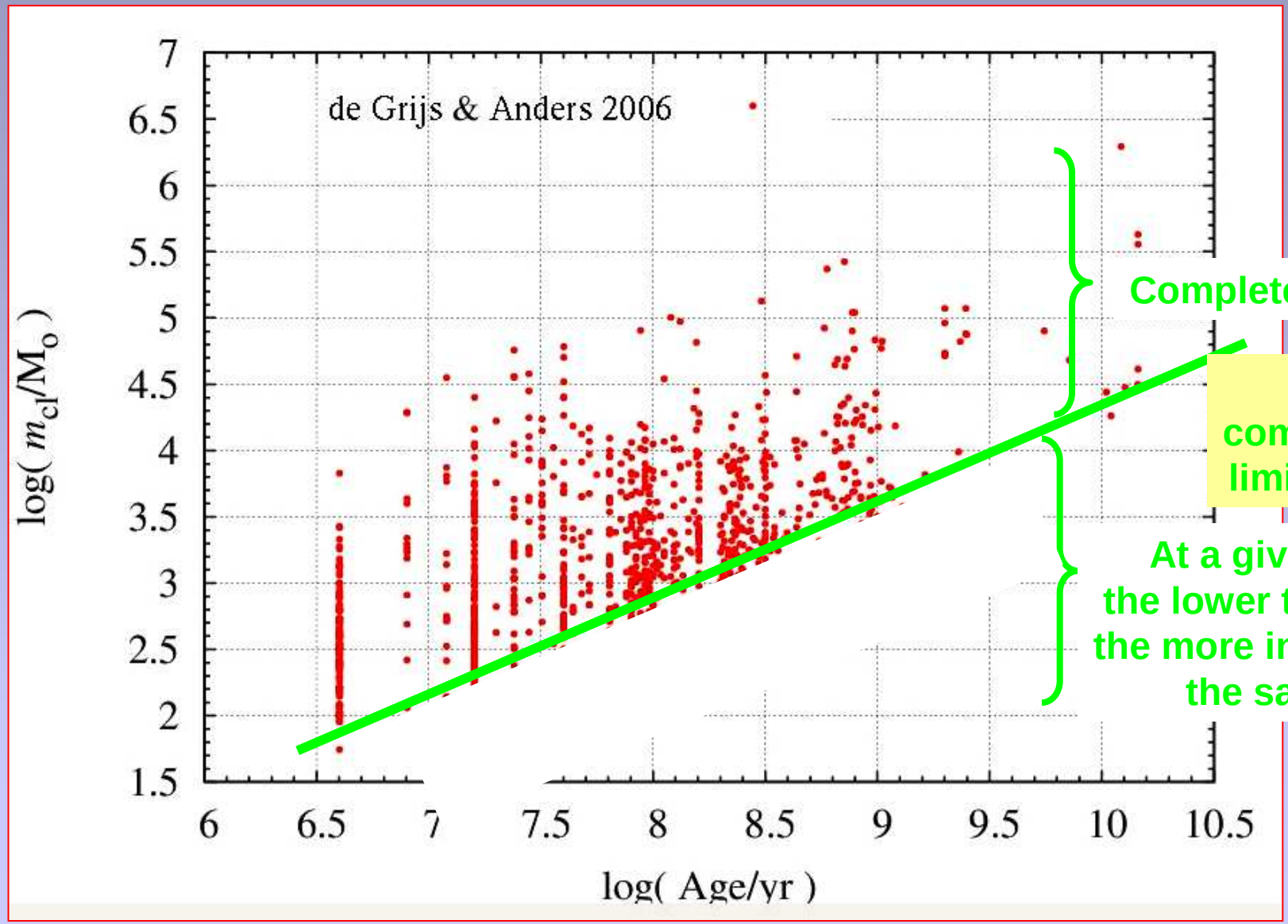
- **SC evolution/evaporation**
- **Inability of detecting all clusters (for any given mass, the older the cluster, the fainter it is)**



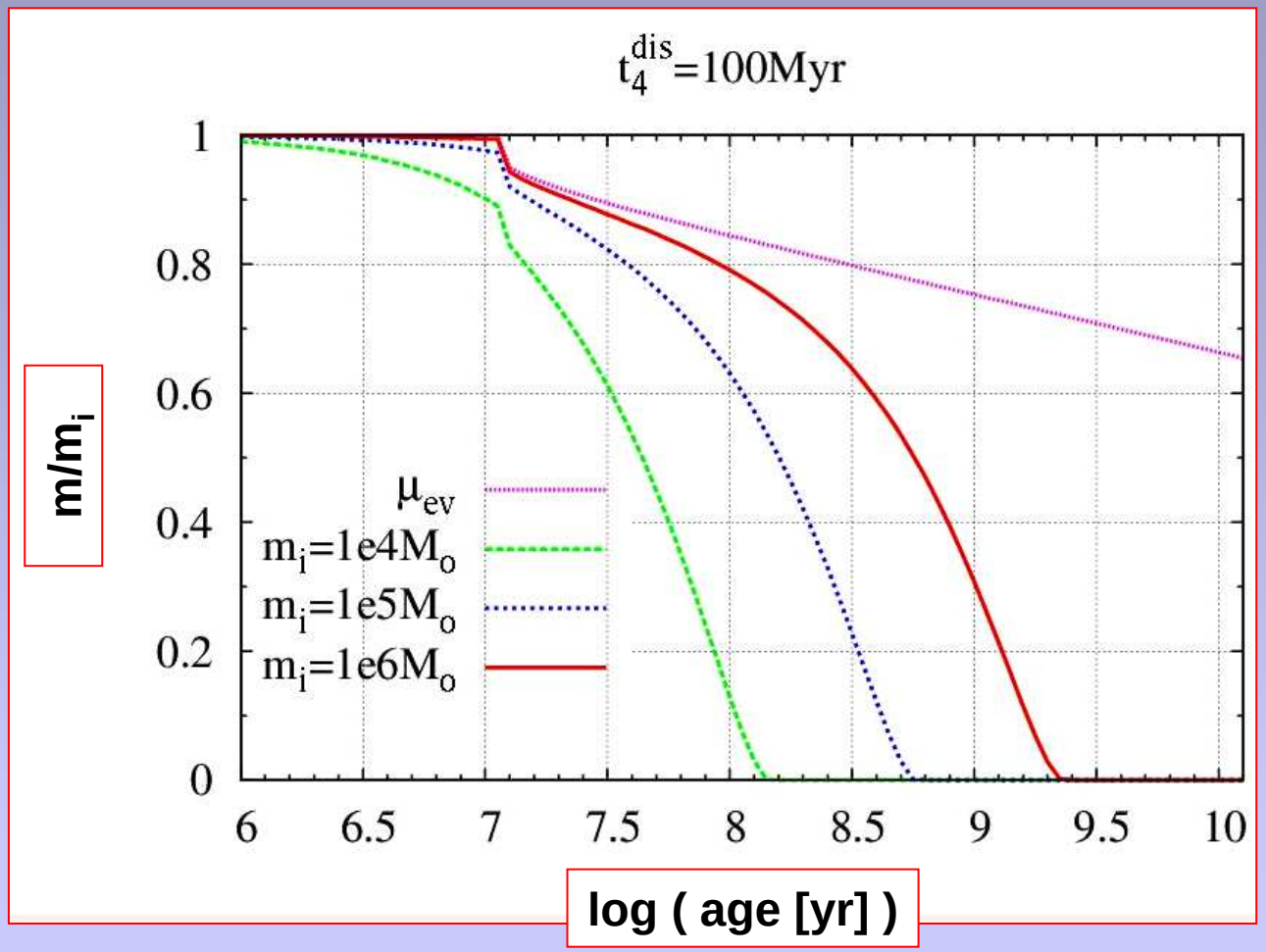
Mv = constant

- **slope ≅ 0.7**

Cluster mass vs cluster age distribution for a sample of ≅1,000 clusters in the **Large Magellanic Cloud**



Phase 2: Instantaneous Disruption Approximation



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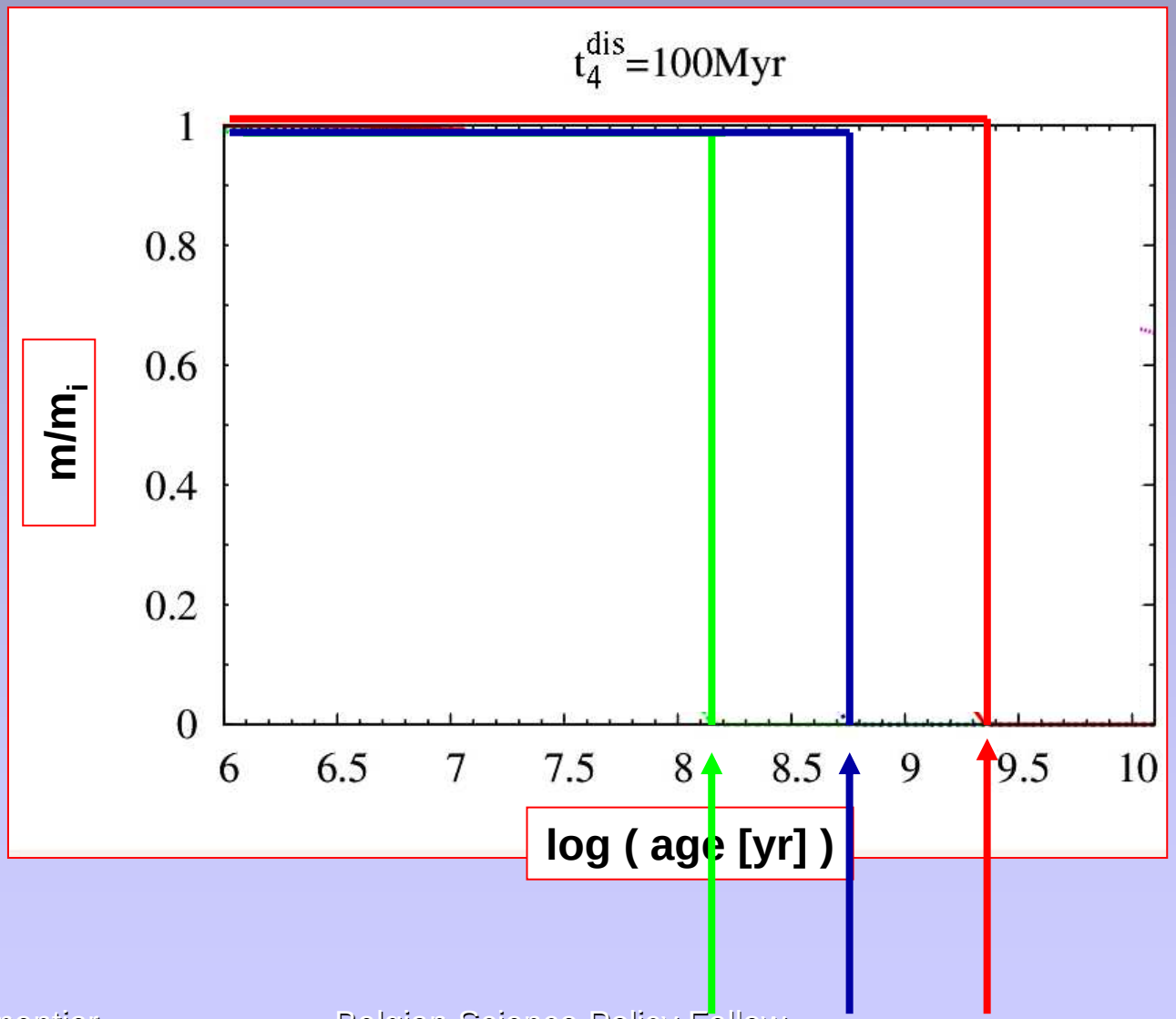
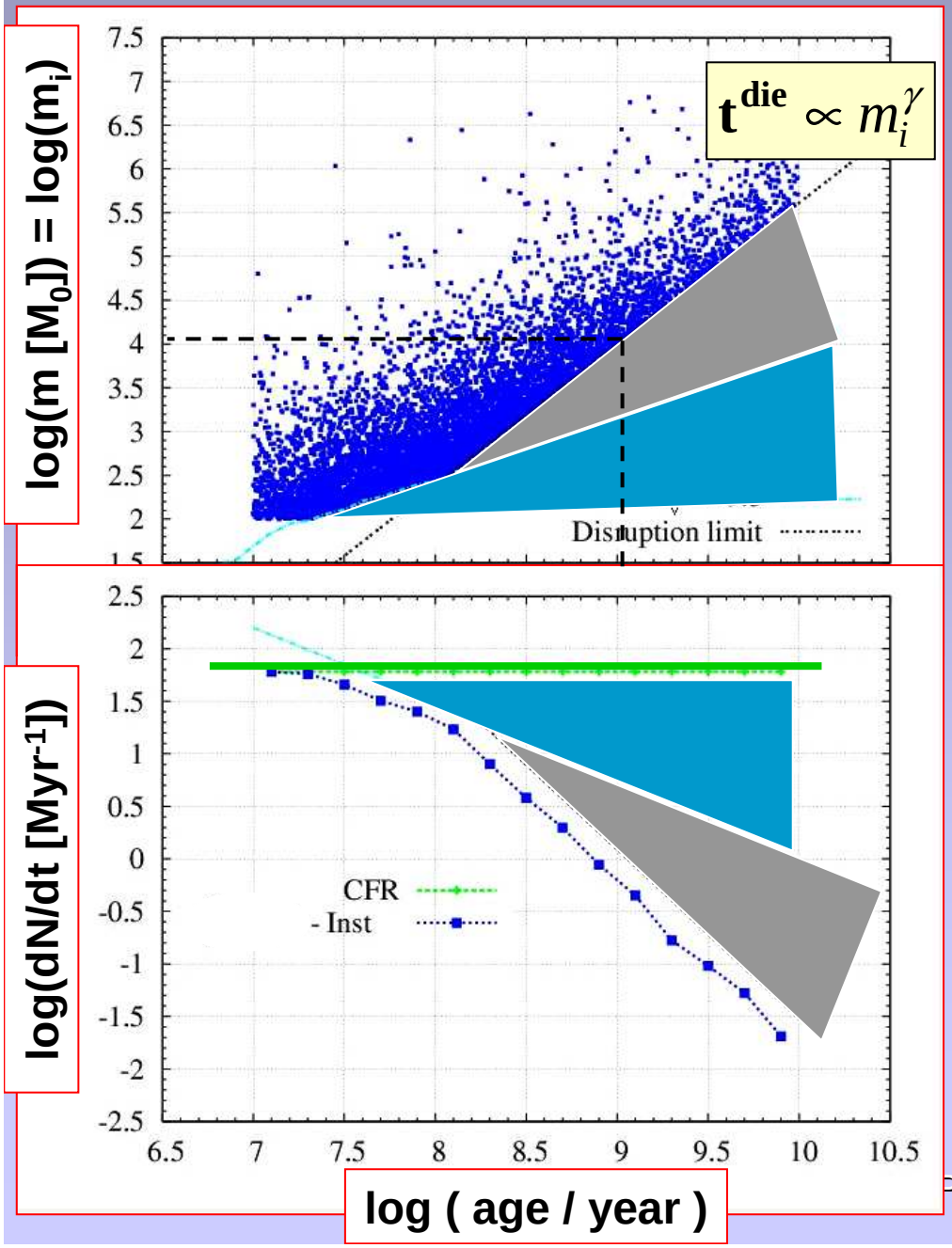


Instantaneous Disruption Approximation



- Initial conditions:
  - CFR constant with time,
  - ICMF: PL(-2)
- Fading: all SCs detected if brighter than Mv ≅ -3.3
- SC evaporation: $t_4^{die} = 1Gyr$

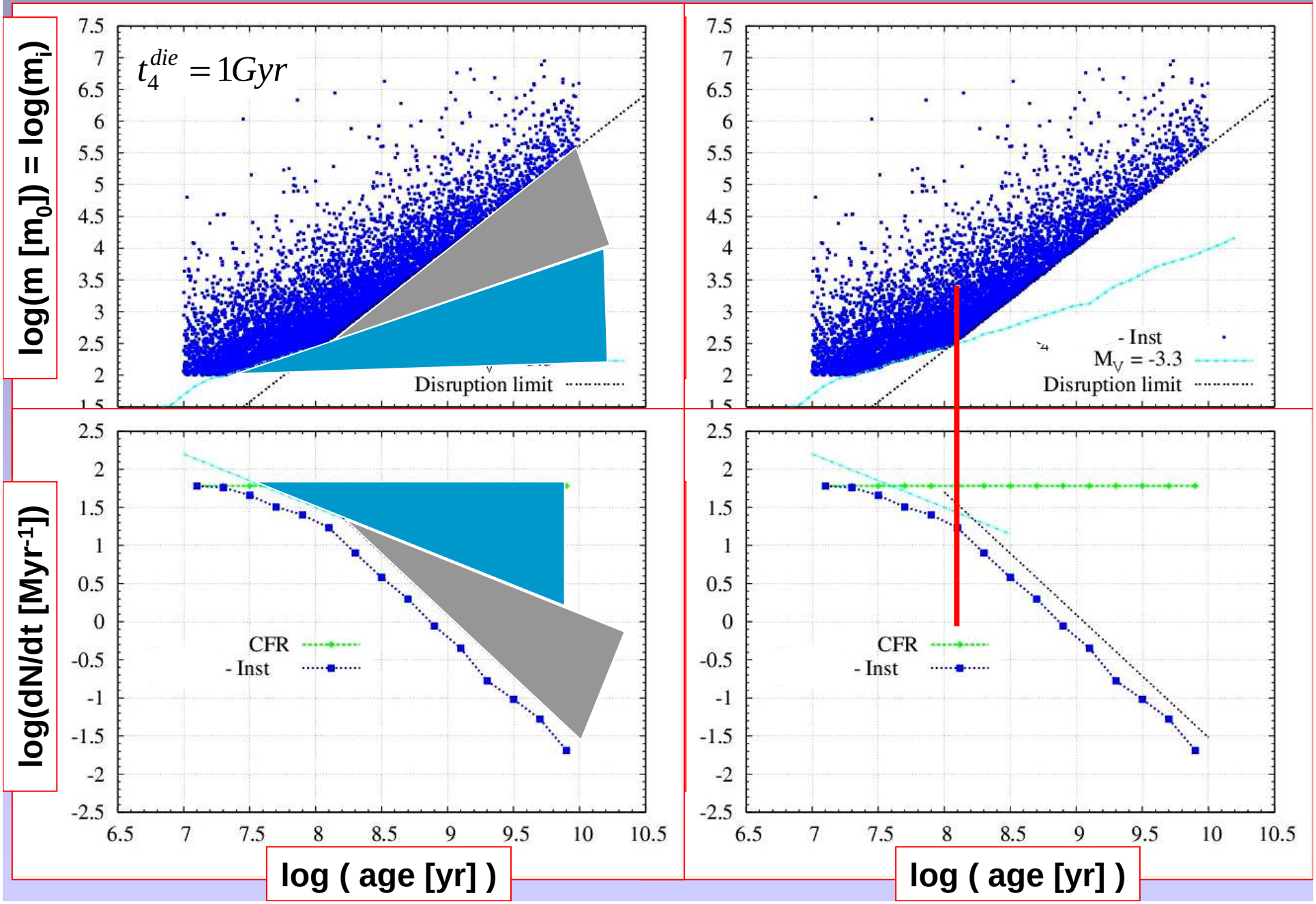
Fading :

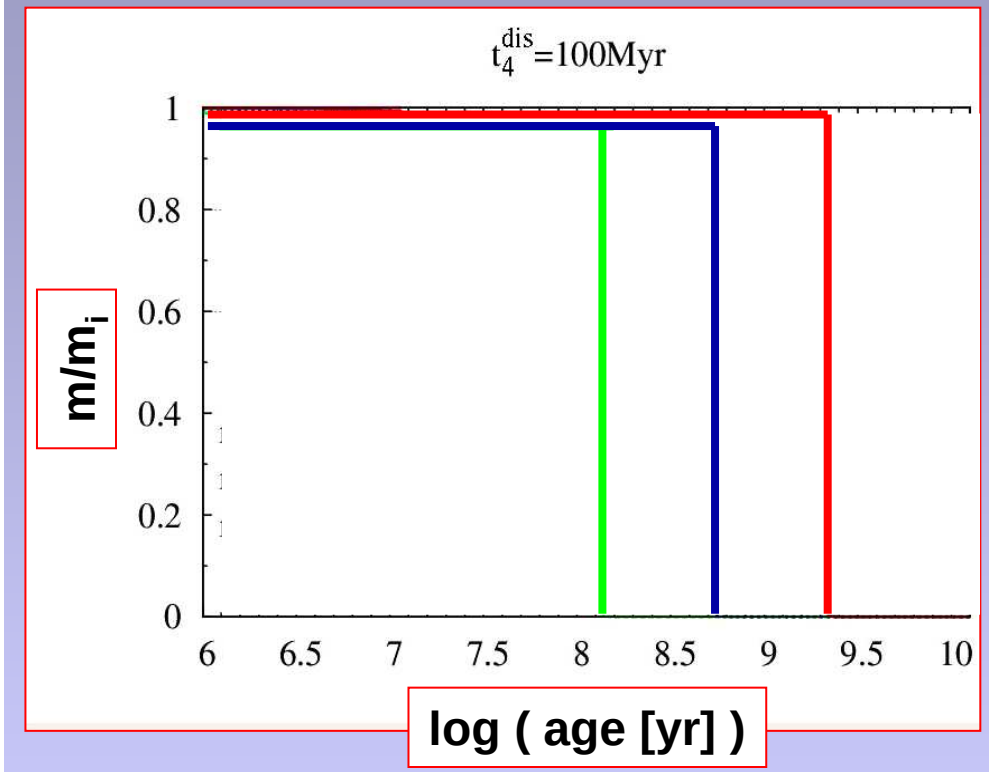
$slope \approx -0.7$

Disruption :

$$slope \approx -\frac{1}{\gamma} = -1.6$$

Phase 2: Instantaneous Disruption Approximation

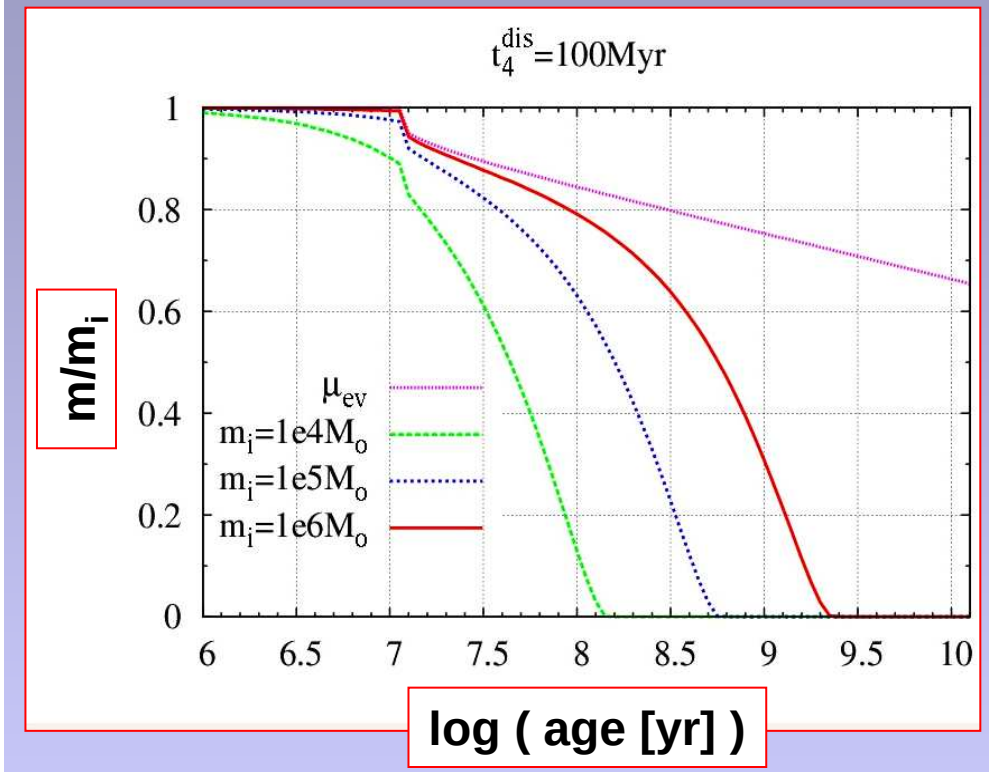




- Clusters are
  - instantaneously disrupted
  - steadily losing mass (evaporation)

- Major message to be kept in mind: the observed distribution of cluster masses vs cluster ages bears clues about the evolutionary rate of clusters

- Limitations to address:
  - CFR is assumed to be a constant
  - completeness limit must be known



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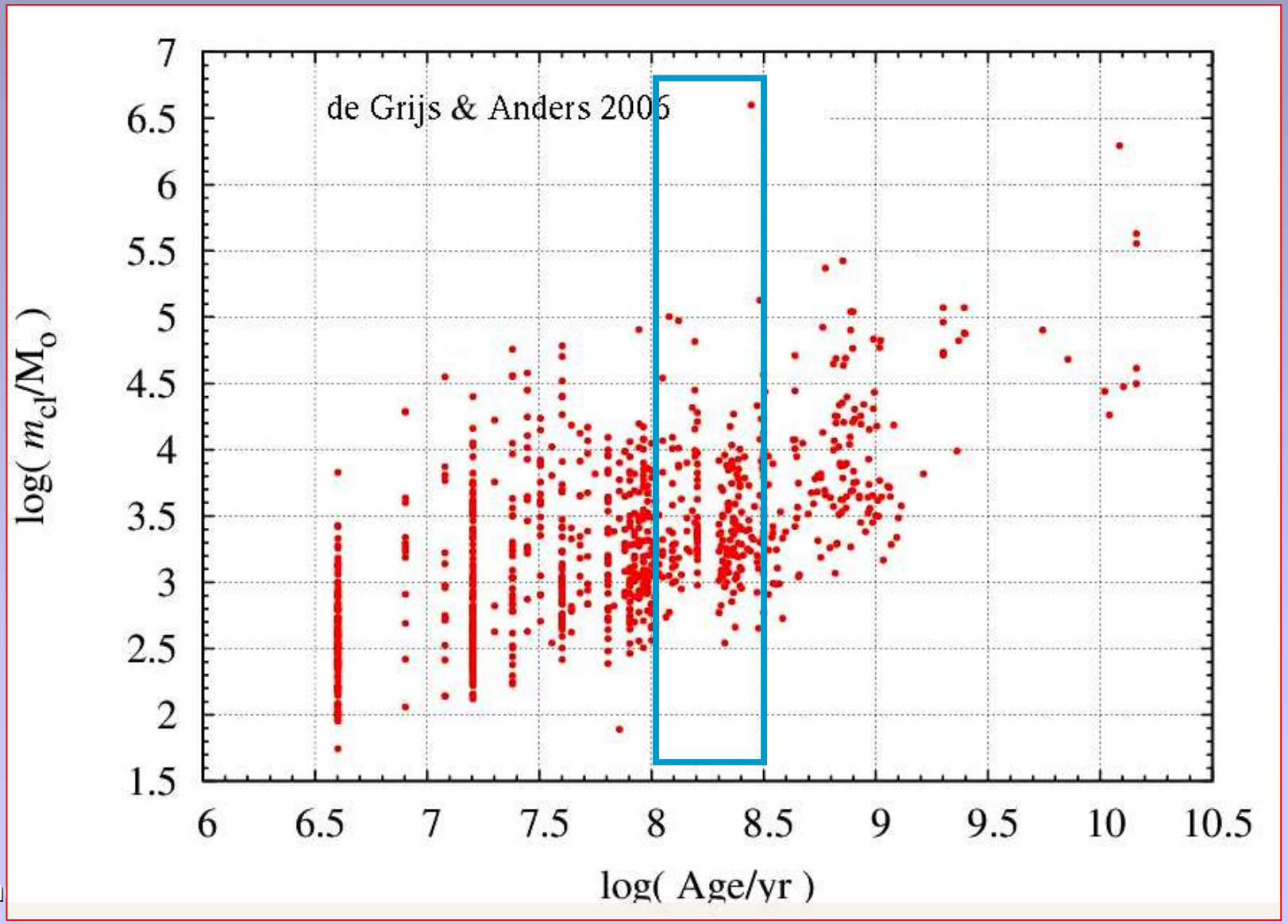
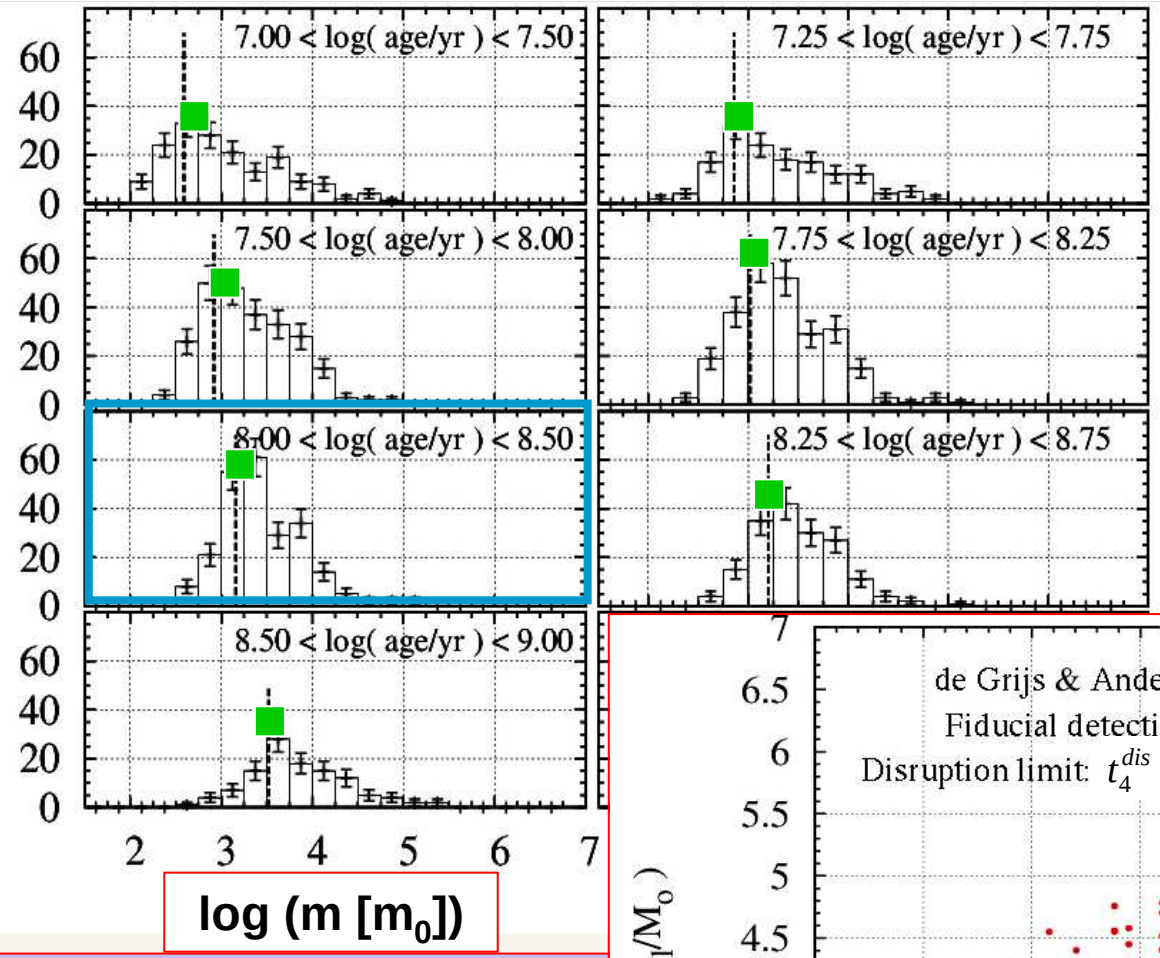
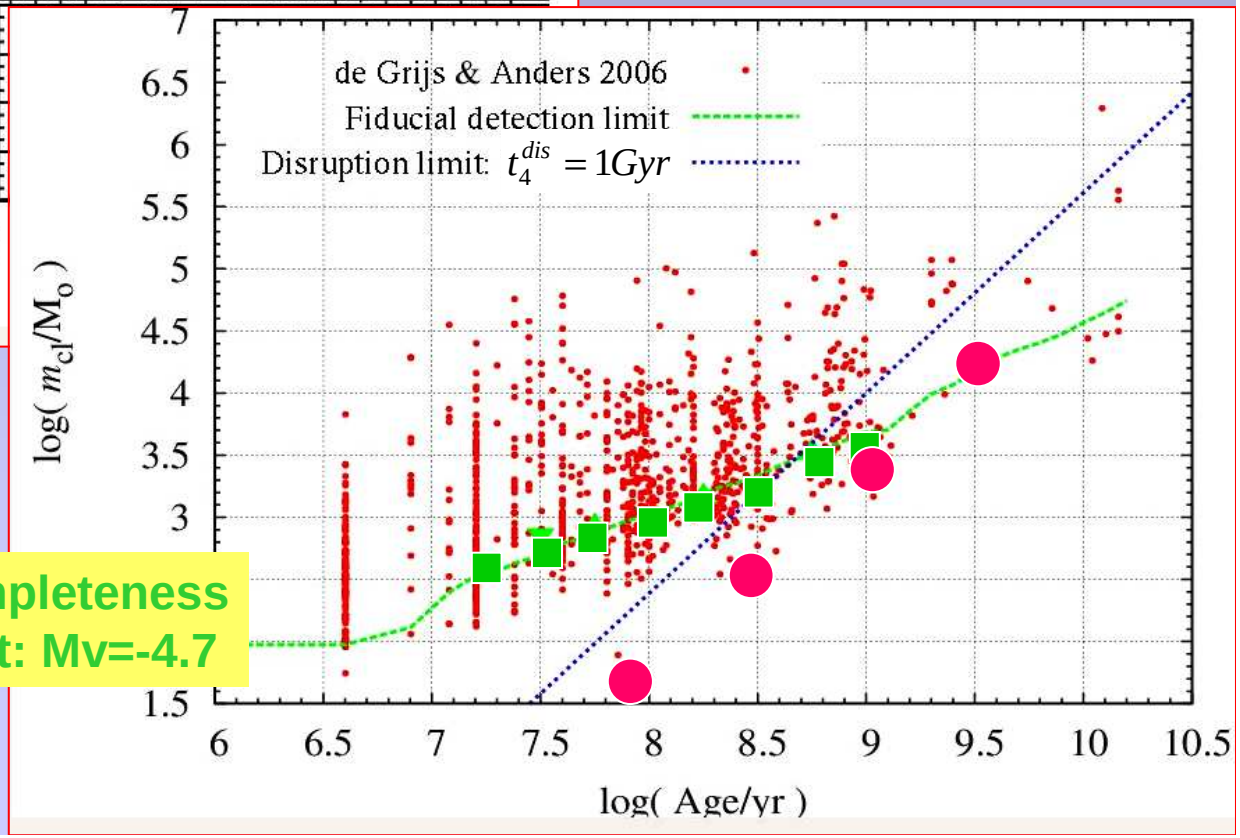
Cluster mass vs cluster age distribution for a sample of ≅1,000 clusters in the **Large Magellanic Cloud.** Addressing the completeness limit issue

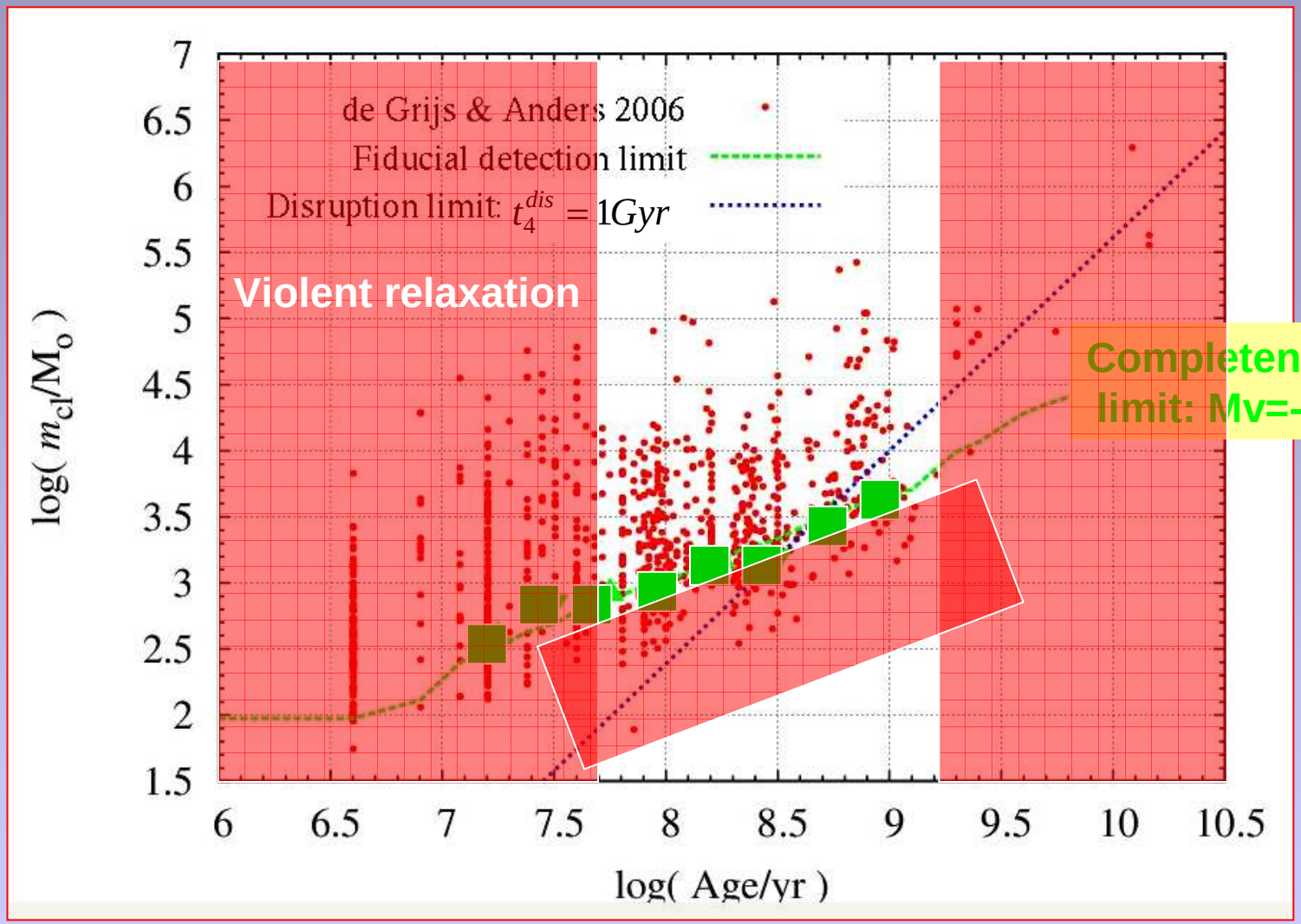


Large Magellanic Cloud
cluster sample:
Fading limit

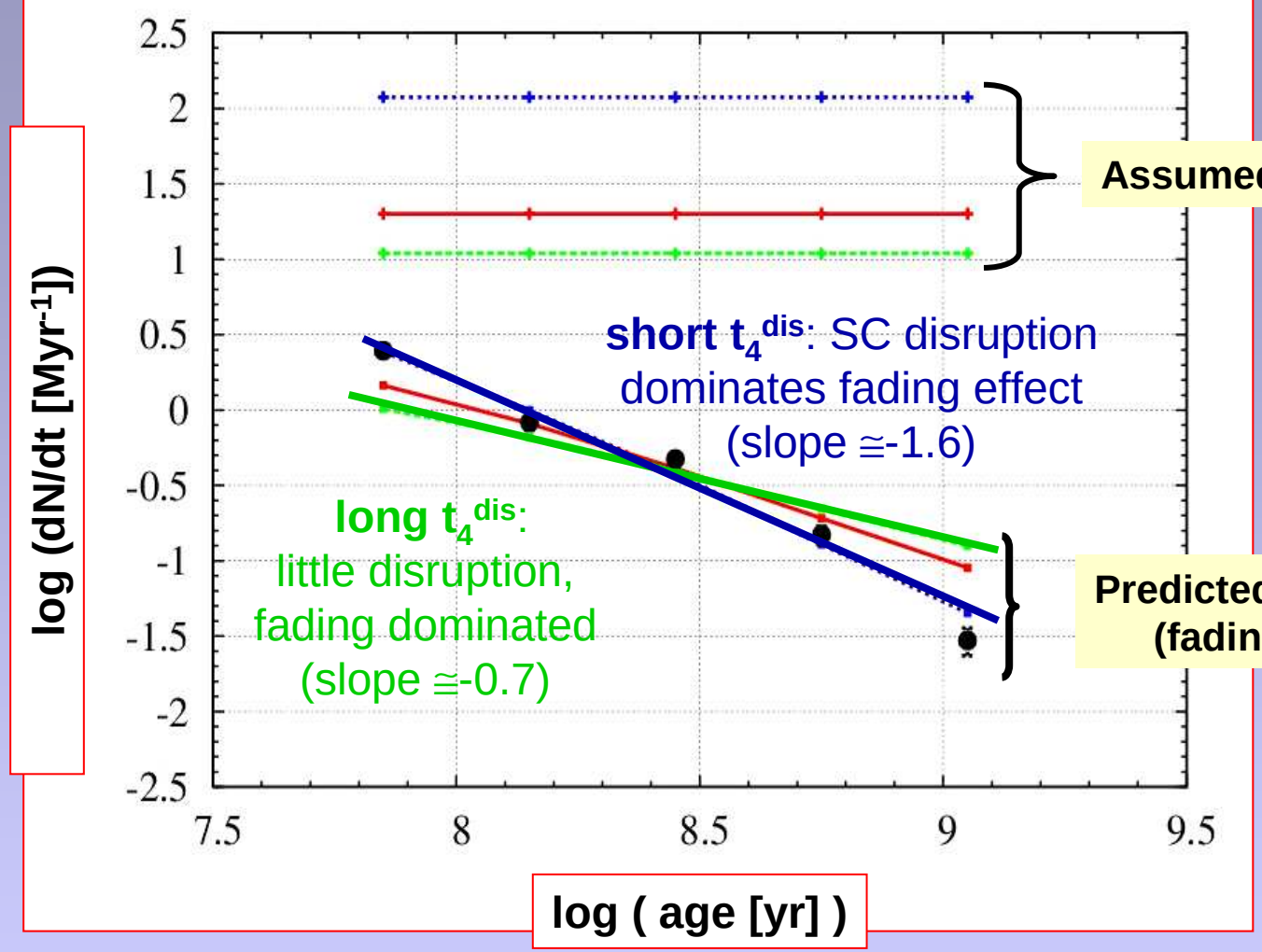




Completeness limit: Mv=-4.7


de Grijs & Anders 2006
Fiducial detection limit
Disruption limit: $t_4^{dis} = 1Gyr$
Violent relaxation
Completeness limit: Mv=-4.7
log(m_{cl}/M_o)
log(Age/yr)
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5

Addressing the issue of the time-variations of the CFR



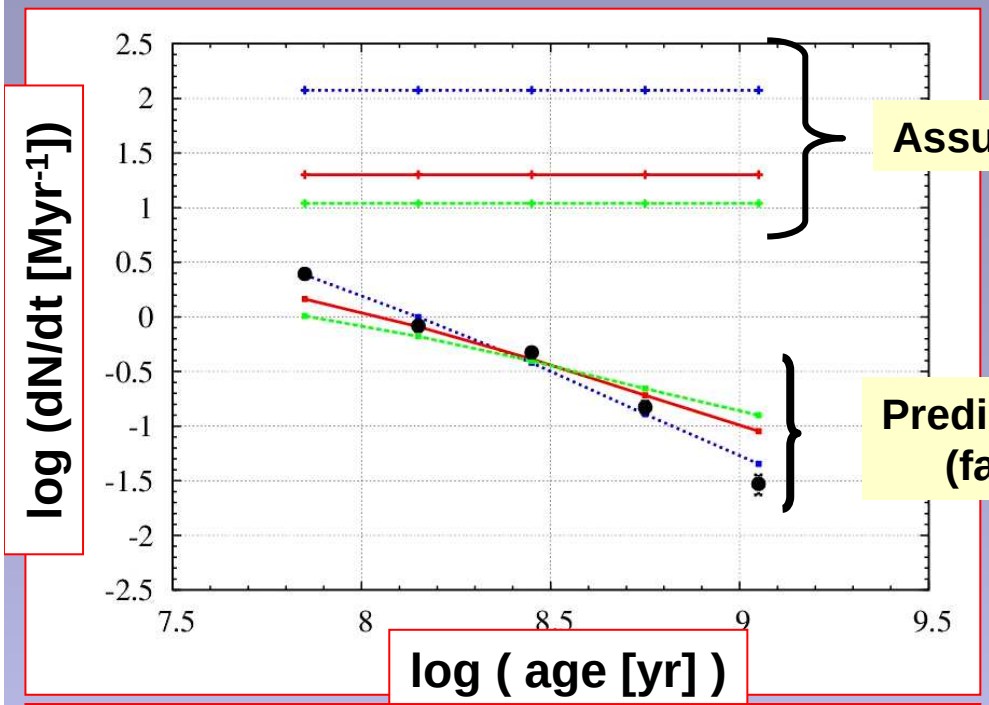
Assumed constant CFRs

t_4^{dis} = 100Myr

t_4^{dis} = 1Gyr

t_4^{dis} = 8Gyr

Predicted age distributions (fading+evaporation)



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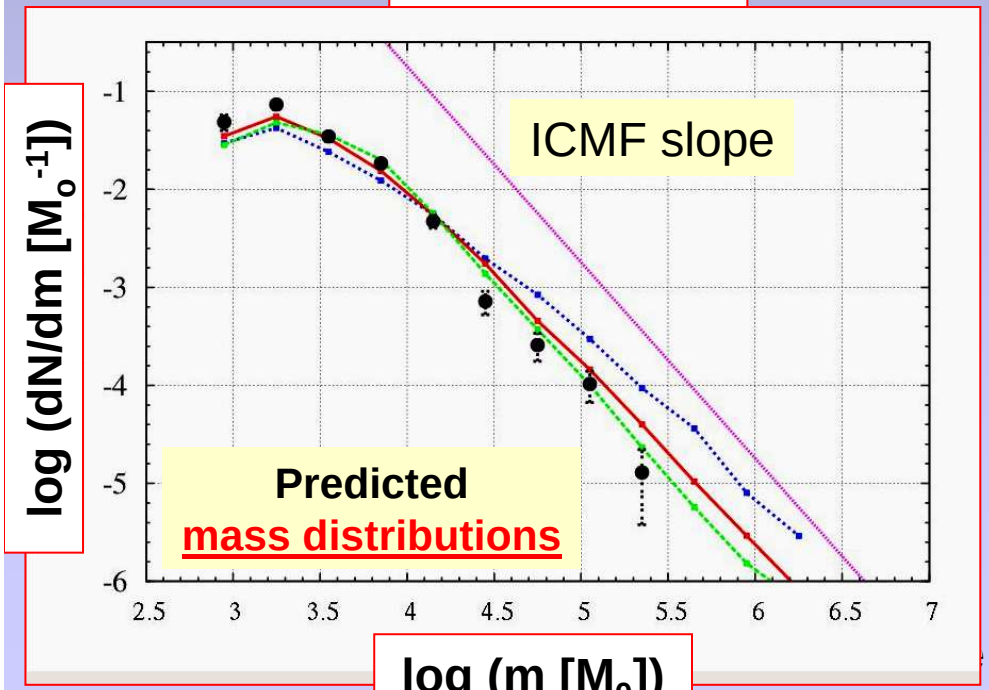
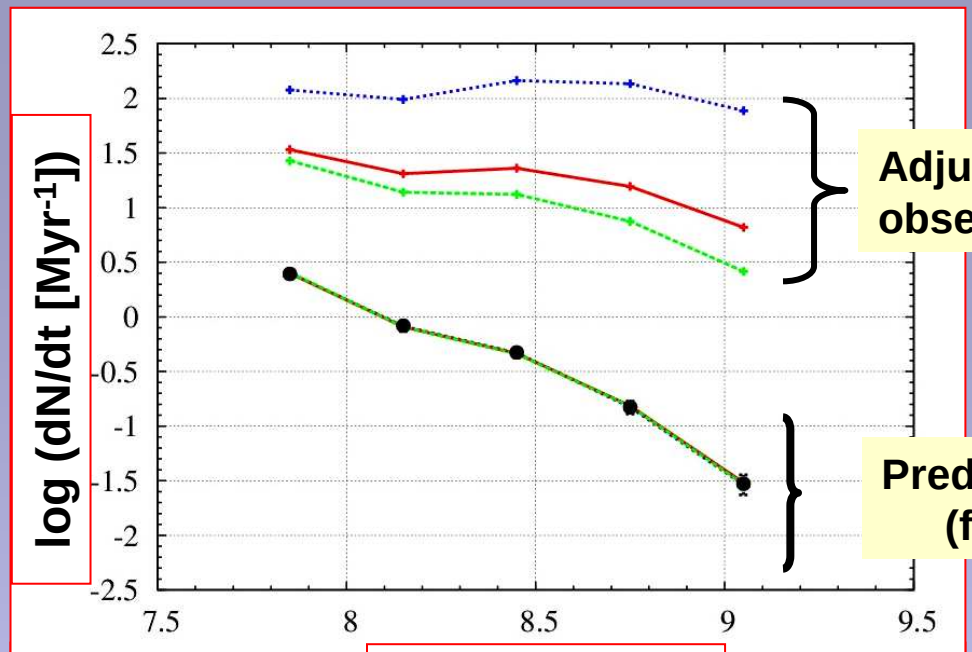


2 diagnostic tools,
2 opposed conclusions,
obviously one inconsistent hypothesis



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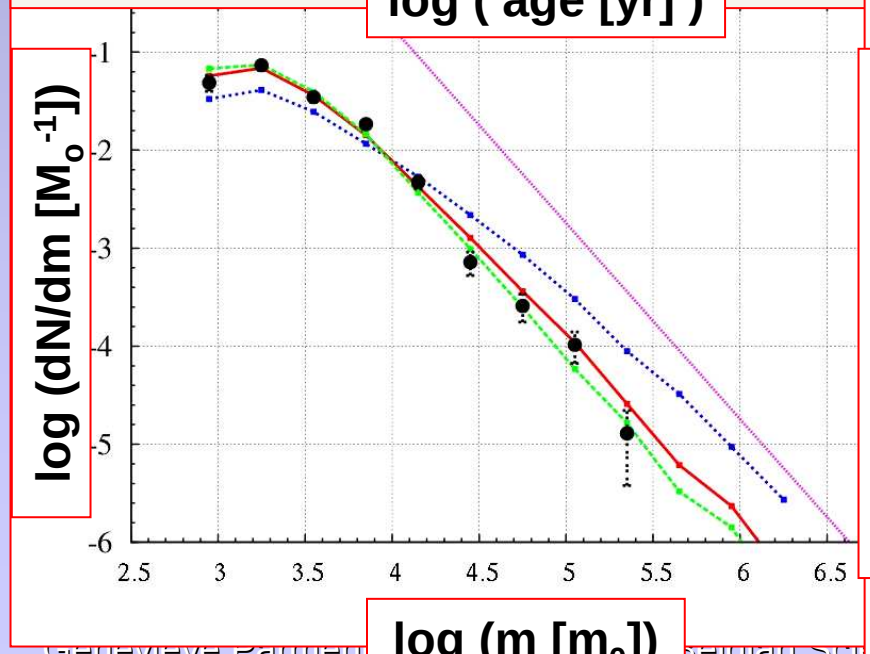
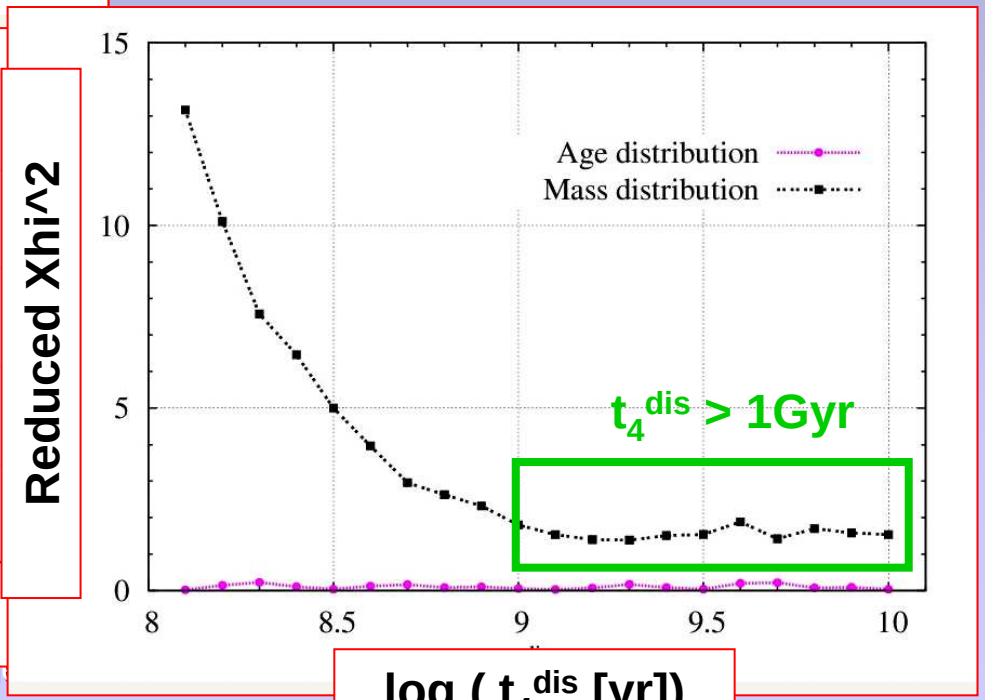
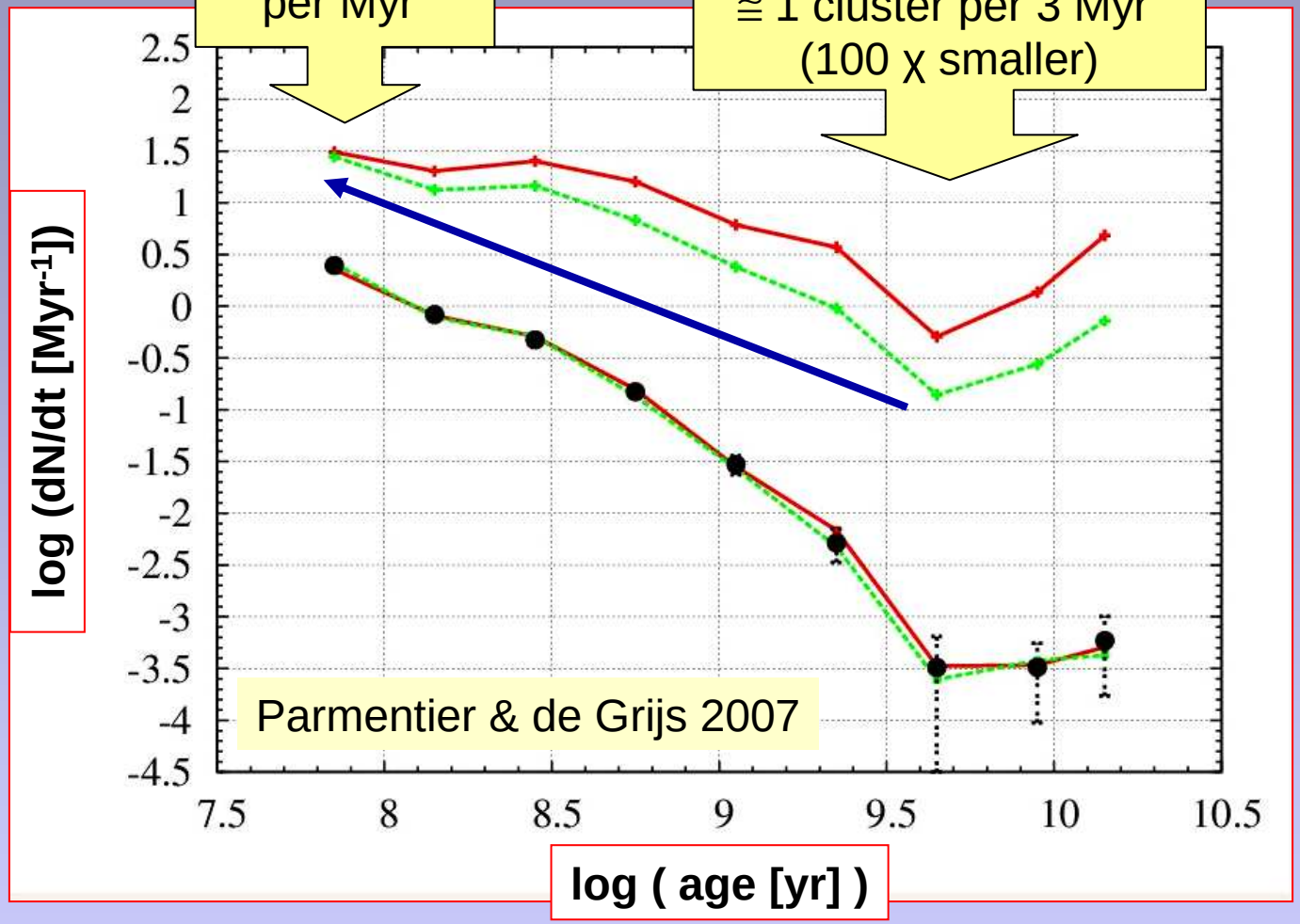
Parmentier & de Grijs 2007





≅ 30 clusters per Myr

LMC cluster age gap: ≅ 1 cluster per 3 Myr (100 χ smaller)

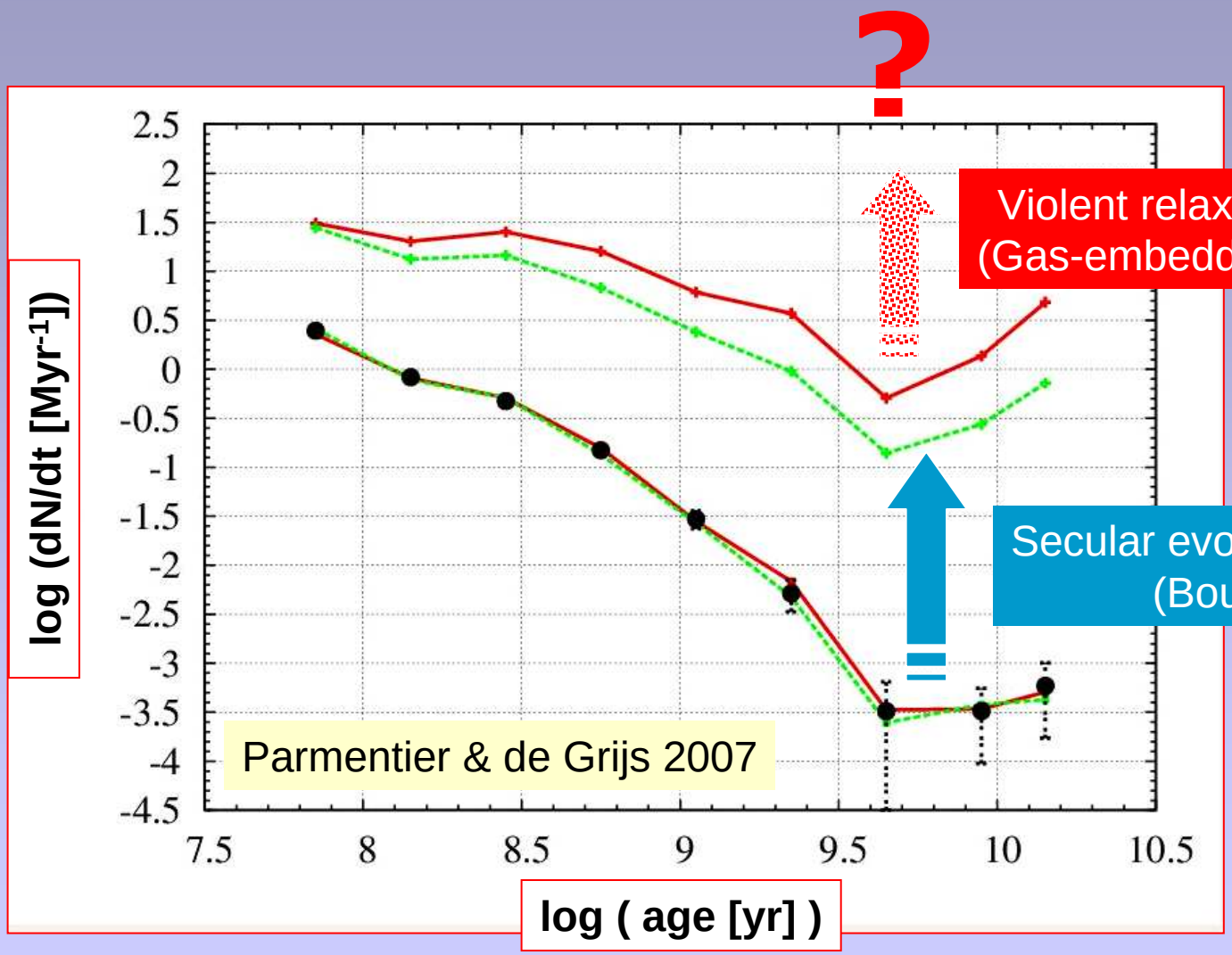


t_4^{dis} = 1Gyr

t_4^{dis} = 8Gyr

The CFR of a galaxy reflects its interactions with its neighbours and, thus, its orbital history - Besla et al.(2007): the LMC is closing its first perigalactic passage about the Milky Way and the Milky Way gravitational influence upon the LMC is mounting

Observed age distribution and predicted bound CFR in the LMC



Hoyle Committee Room - Today – 4PM

What age, mass and size distributions of young star clusters can tell us about their formation

- probing the local SFE with age/mass distributions
- possible tests on the mass-radius relation of cluster forming gas cores
- impacts of observational biases
- mass-independent infant mortality: a concept to be handled with care …