Deriving Star Formation Histories of Galaxies from their Most-Massive Star-Cluster Distributions

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Hoher List
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Star formation histories of galaxies

Usual method for determination: CMD fitting

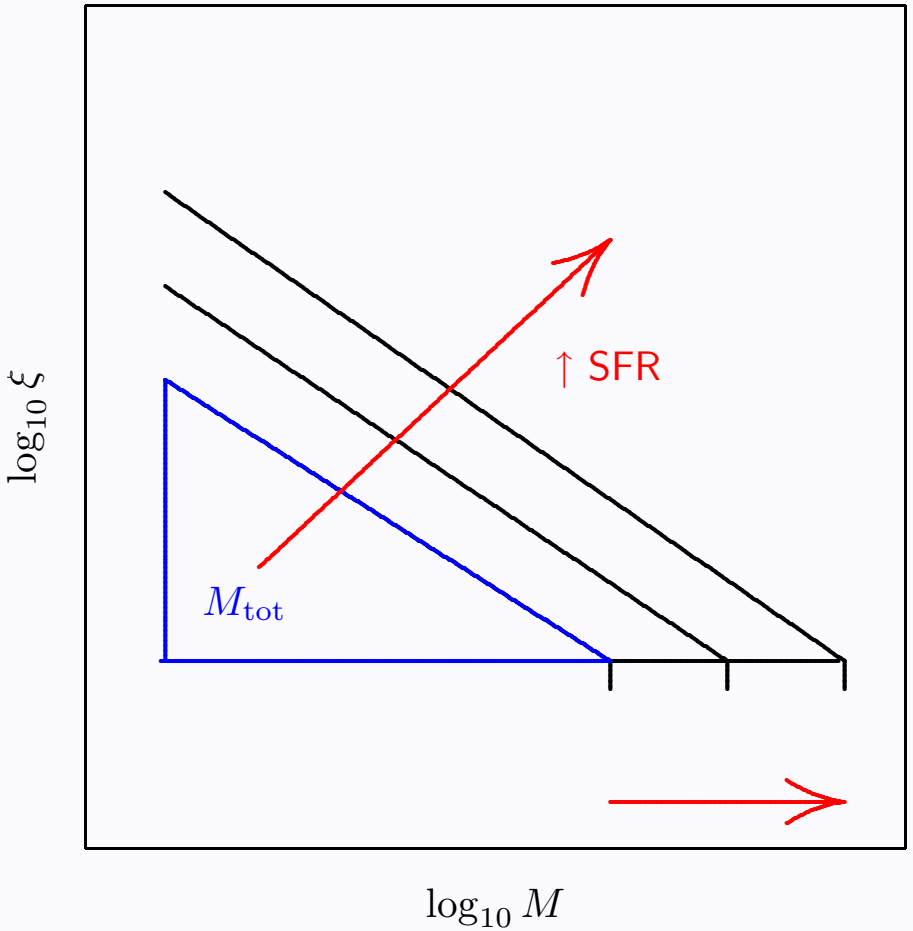
- Resolve individual stars
- Create synthetic CMD using model isochrones
- Fit model to observations

Possible only for distances up to 1 Mpc

But: Stars form in star clusters

Star clusters resolvable to larger distances: 20 to $\approx$ 50 Mpc

Star formation histories of galaxies from their most-massive star-cluster distributions



SFR

$\Updownarrow$

$M_{\rm tot}$

$\Updownarrow$

$M_{\rm max}$

mass of the most-massive star cluster

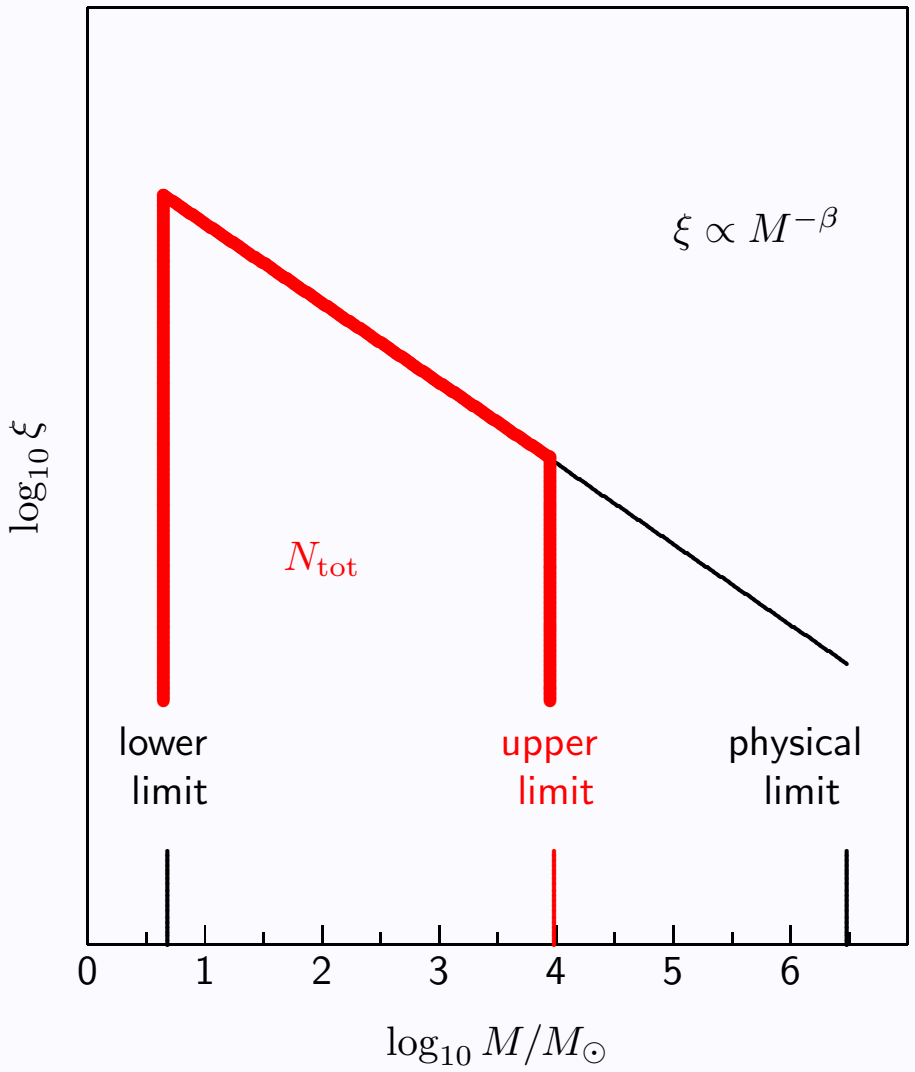
$$\xi = \frac{dN}{dM}$$

Star formation histories of galaxies from their most-massive star-cluster distributions

- How is the star formation history of a galaxy related to the star-cluster population?
  By formation epochs (Weidner, Kroupa & Larsen 2004).
- Why the most-massive star clusters?
  Because they are visible for a long time.
  Because its properties can easily be described.
- How is the most-massive star cluster of a star-cluster population related to the total mass of the population?
  By a distribution function, not by a deterministic law.

$\Rightarrow$ New method

Describing an unevolved $10^4 M_\odot$ cluster population



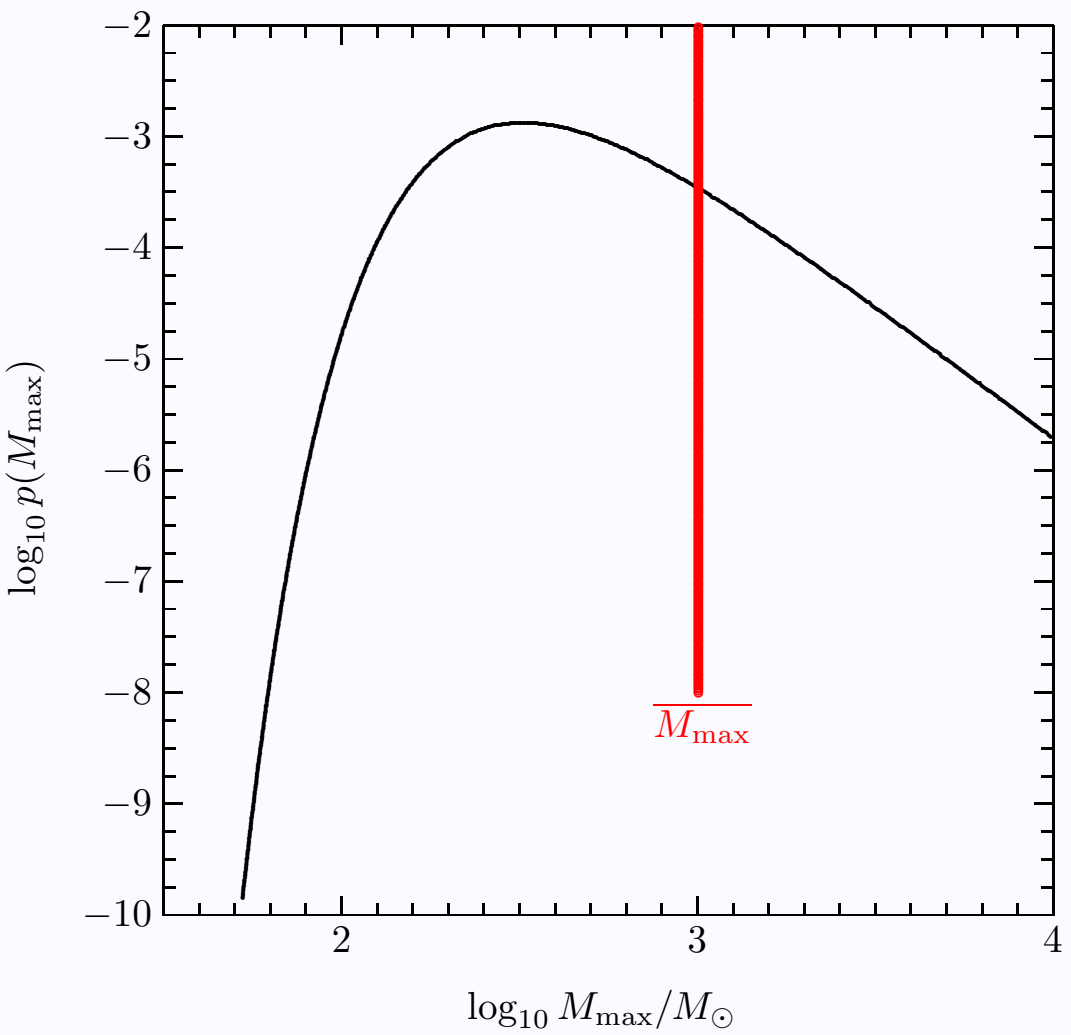
Embedded Cluster Mass Function

$$\xi = \frac{dN}{dM}$$

Ingredients:

- shape: power law $\xi \propto M^{-\beta}$
- physical mass limits: lower: $5 M_\odot$ upper: $10^{6.5} M_\odot$
- total mass: $M_{\rm tot} = 10^4 M_\odot$
- upper mass limit: $10^4 M_\odot$

Distribution of the most-massive star clusters



Analytical formula for $p(M_{\max})$

(cf. Oey & Clarke 2005)

$\overline{M_{\max}}$
expectation value
characterising the distribution of the most-massive clusters

The $M_{\max}$(SFR) relation

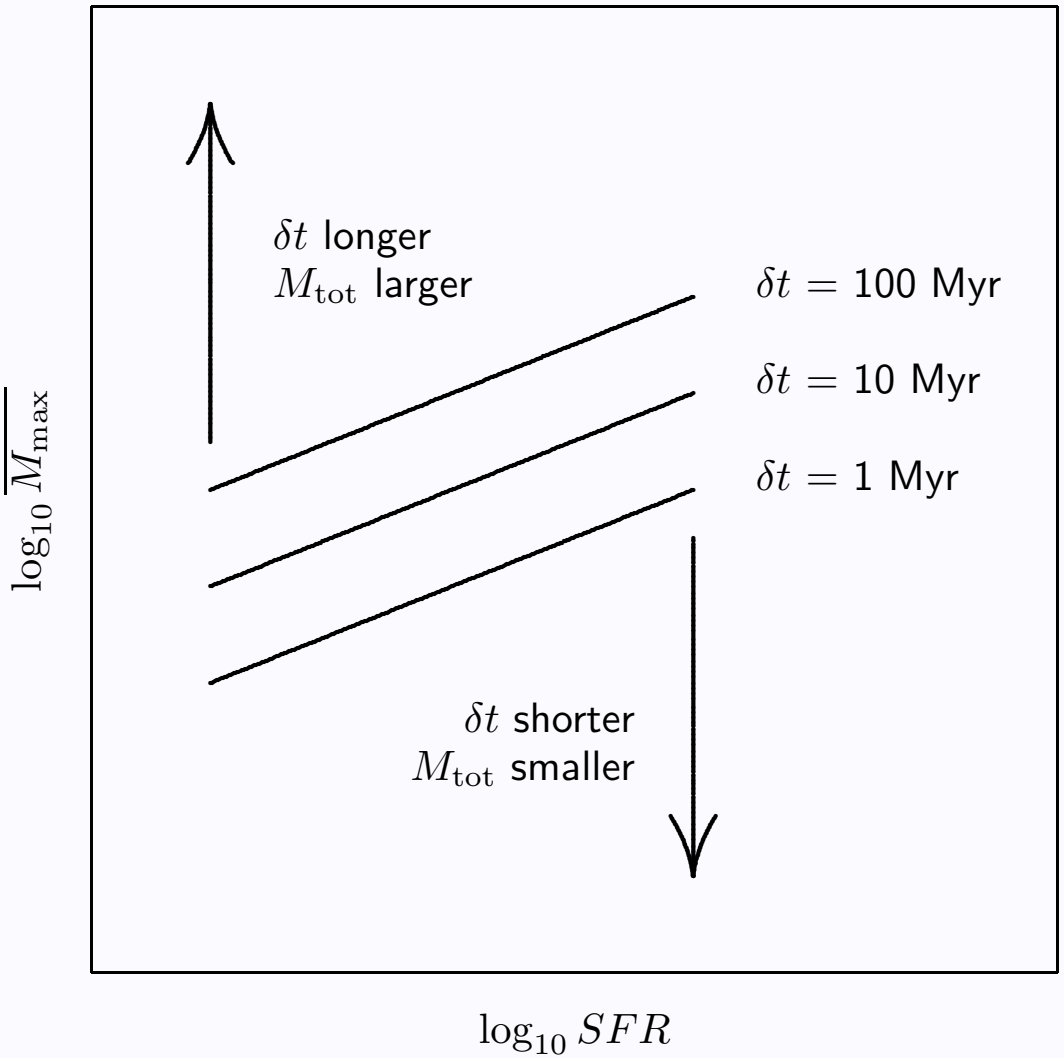
How long does it take to form a complete population of star clusters?

$M_{\rm tot}$ = SFR $\times$ length of formation epoch

$\Rightarrow$ Observable relation:
Brightest clusters in galaxies with different SFR.

Brightest cluster usually the most massive one
of the recent formation epoch.

The $M_{\rm max}$(SFR) relation



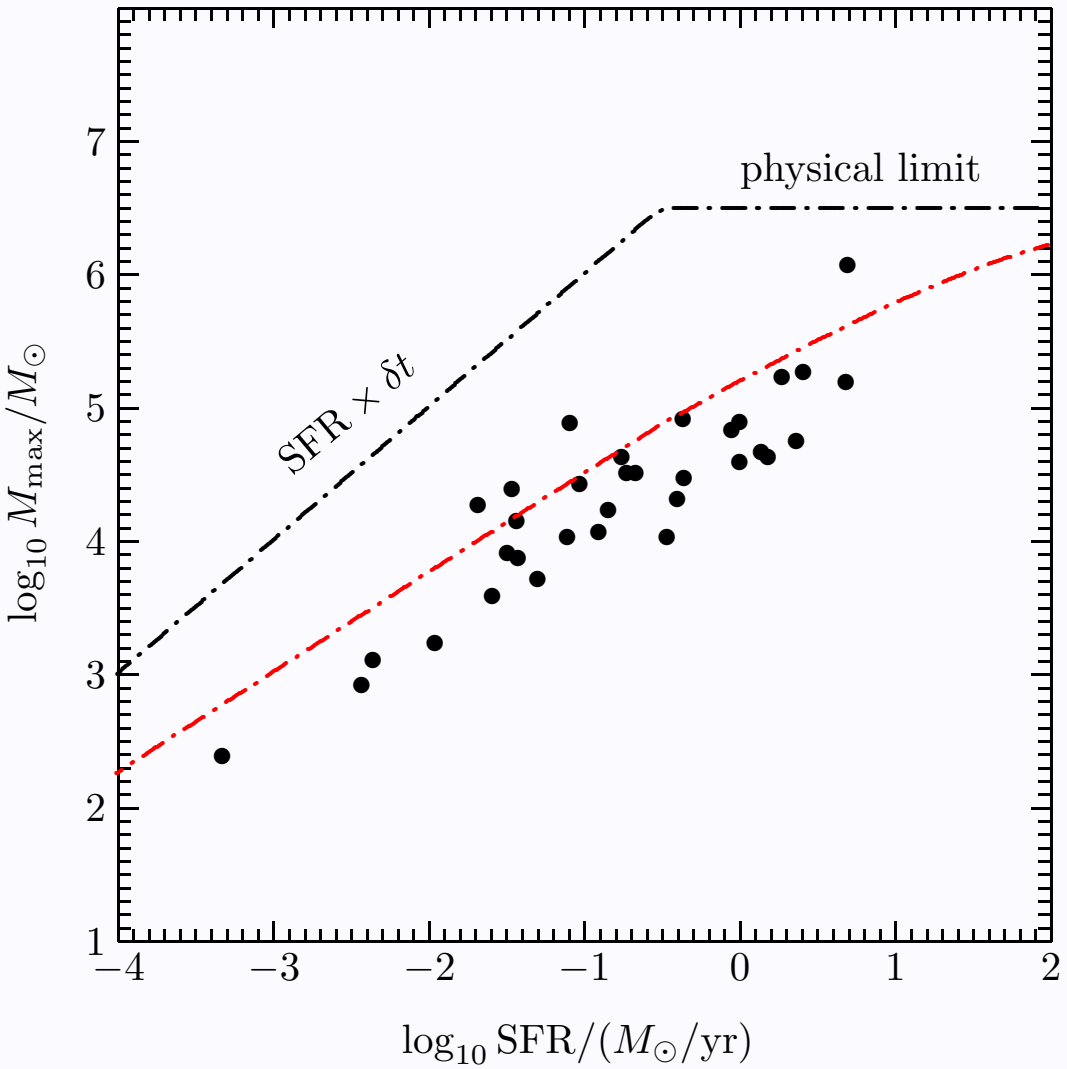
$$M_{\rm tot} = SFR \times \delta t$$

$$p(M_{\rm max}) = f(M_{\rm tot})$$

$$\Rightarrow \overline{M_{\rm max}} = f(M_{\rm tot})$$

$$\Rightarrow \overline{M_{\rm max}} = f(SFR \times \delta t)$$

The $M_{\max}$(SFR) relation



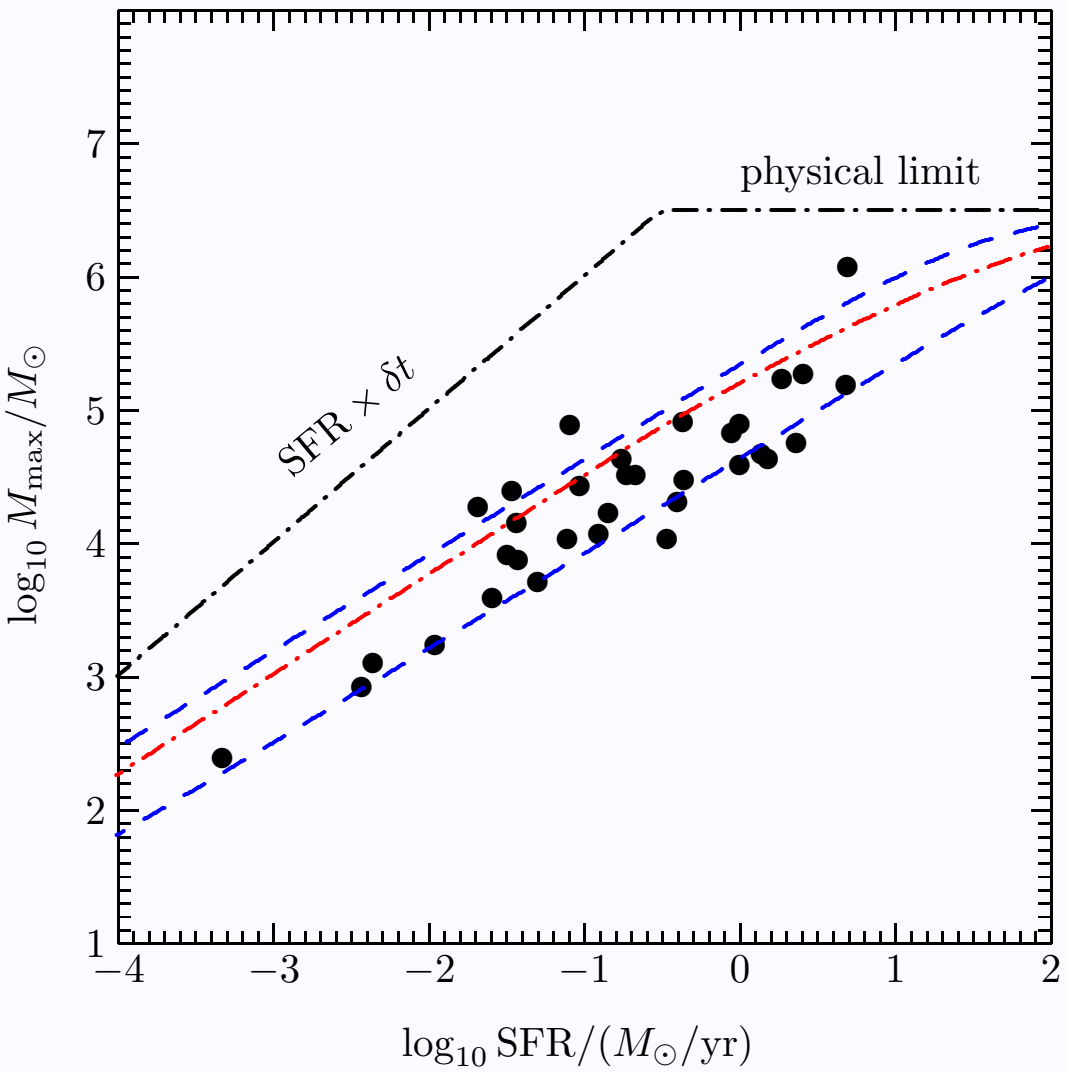
Data from Larsen(2002)
SFR determined independent of $M_{\max}$
Masses by Weider, Kroupa & Larsen (2004)

$\overline{M_{\max}}$ Expectation value

not fitting?

Asymmetry!

The $M_{\max}$(SFR) relation



Data from Larsen(2002)
SFR determined independent of $M_{\max}$
Masses by Weider, Kroupa & Larsen (2004)

$\overline{M_{\max}}$ Expectation value

Region, in which 2/3 of all $M_{\max}$ are expected

$\beta = 2.4$
$\delta t = 10$ Myr

Star formation histories - Method I

Length of a star forming epoch: $\delta t = 10\ \mathrm{Myr}$

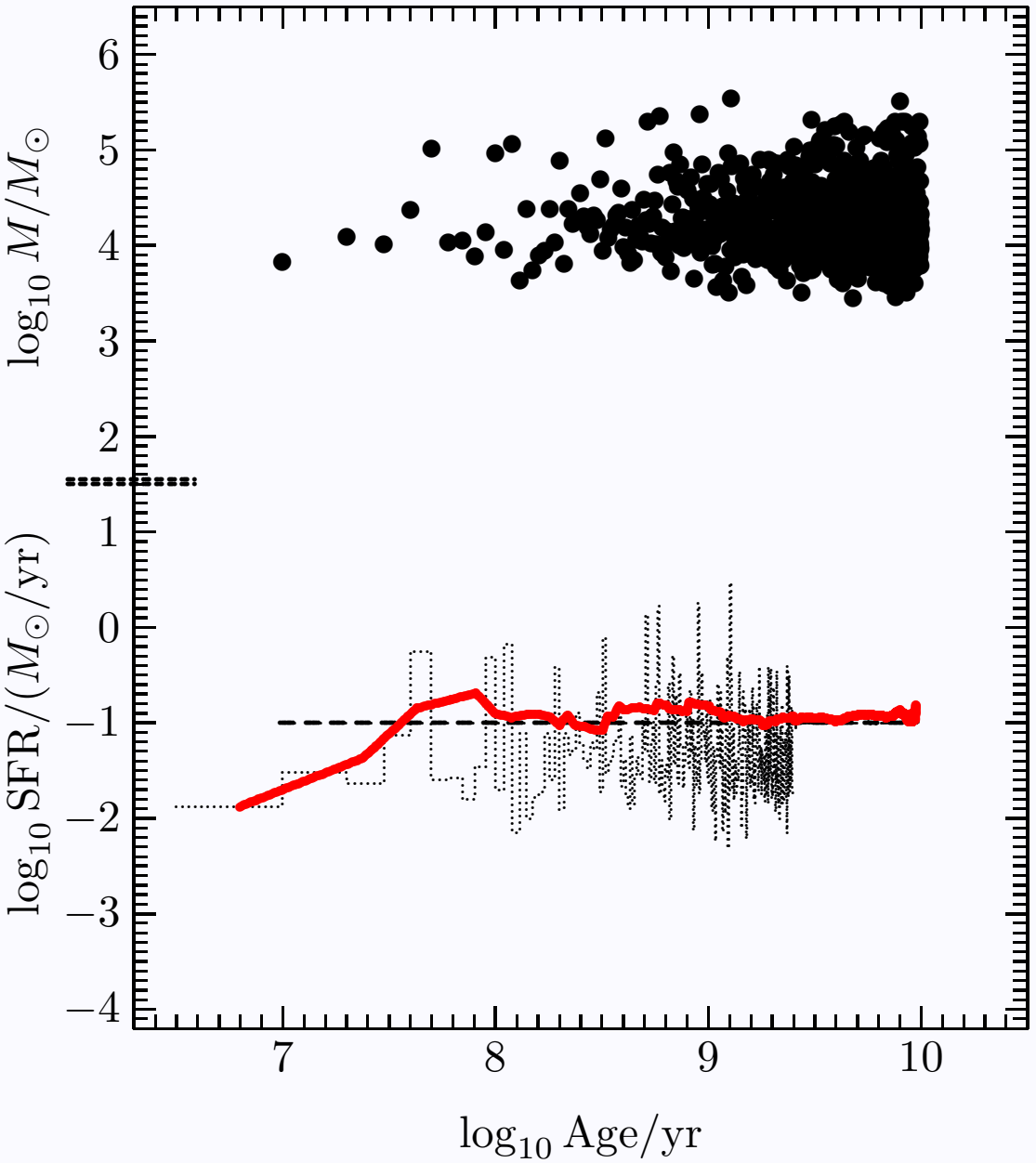
- Determine $M_{\max}$ in each formation epoch
- Calculate SFR

$$\mathrm{SFR} = \left(\frac{M_{\max}}{M_\odot}\right)^{1.37} \times 10^{-7.14} M_\odot/yr$$

But:

$M_{\max}$ is distributed
$\Rightarrow$ Calculate average over 0.5 dex
Solves age uncertainties:
Typical age error 0.4 dex

Test: constant SFR

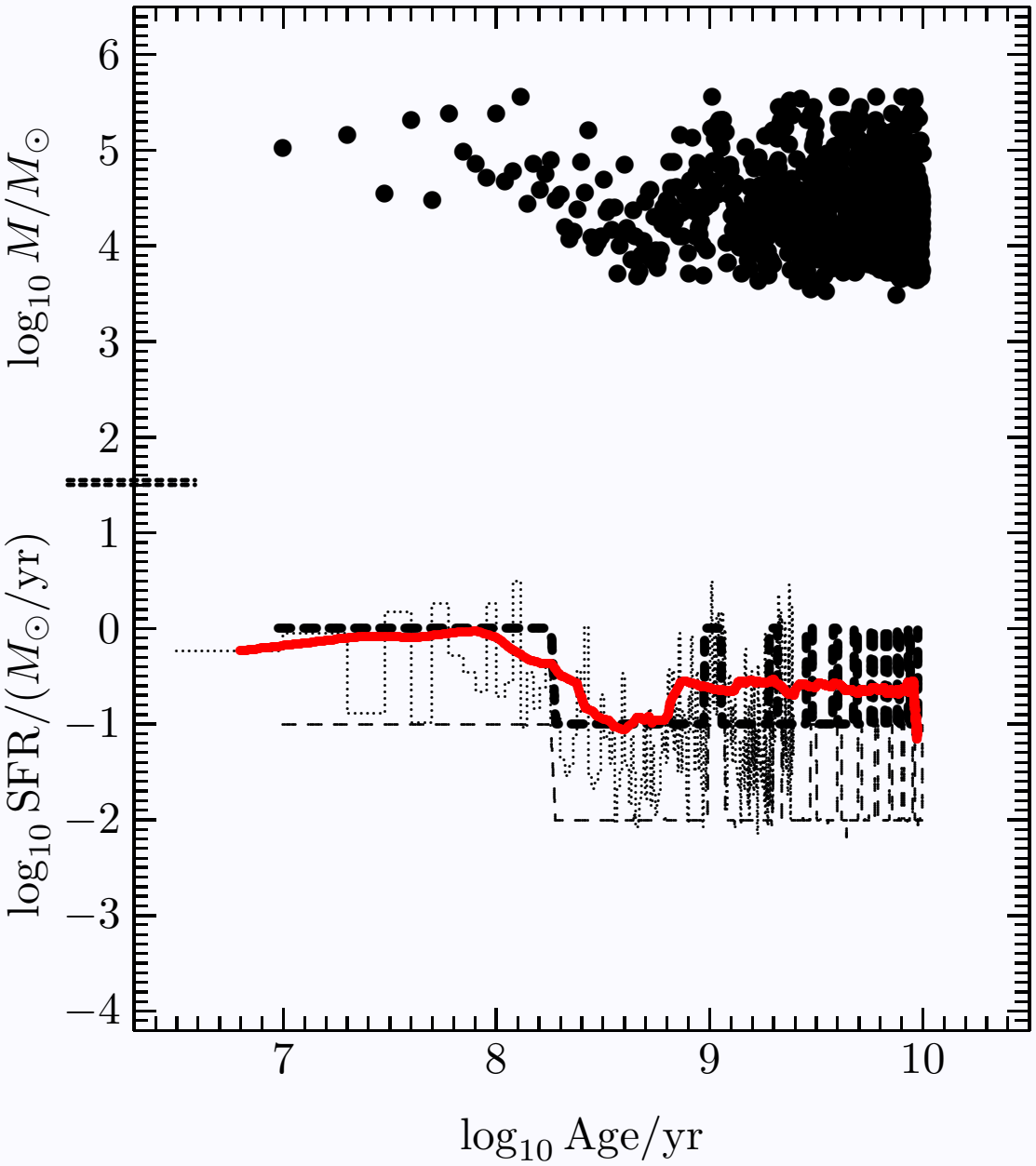


Most massive clusters

Derived SFH

$\Rightarrow$ Method works if over enough epochs is averaged

Test: bursting SFR



$\Rightarrow$ Short time variations cannot be resolved due to averaging

Possible traces in short-time SFH

Cluster evolution

"Real data":

- Stellar evolution:
  30 % of total mass loss in $\approx$ a few 100 Myr
  Corrected in age- and mass-fitting.
- Dynamical evolution:
  important over the whole lifetime of a cluster.
  Depending on unknown orbit and tidal field.
  $\Rightarrow$ Analytical model by Lamers et al. (2005)
  only one parameter for the tidal field

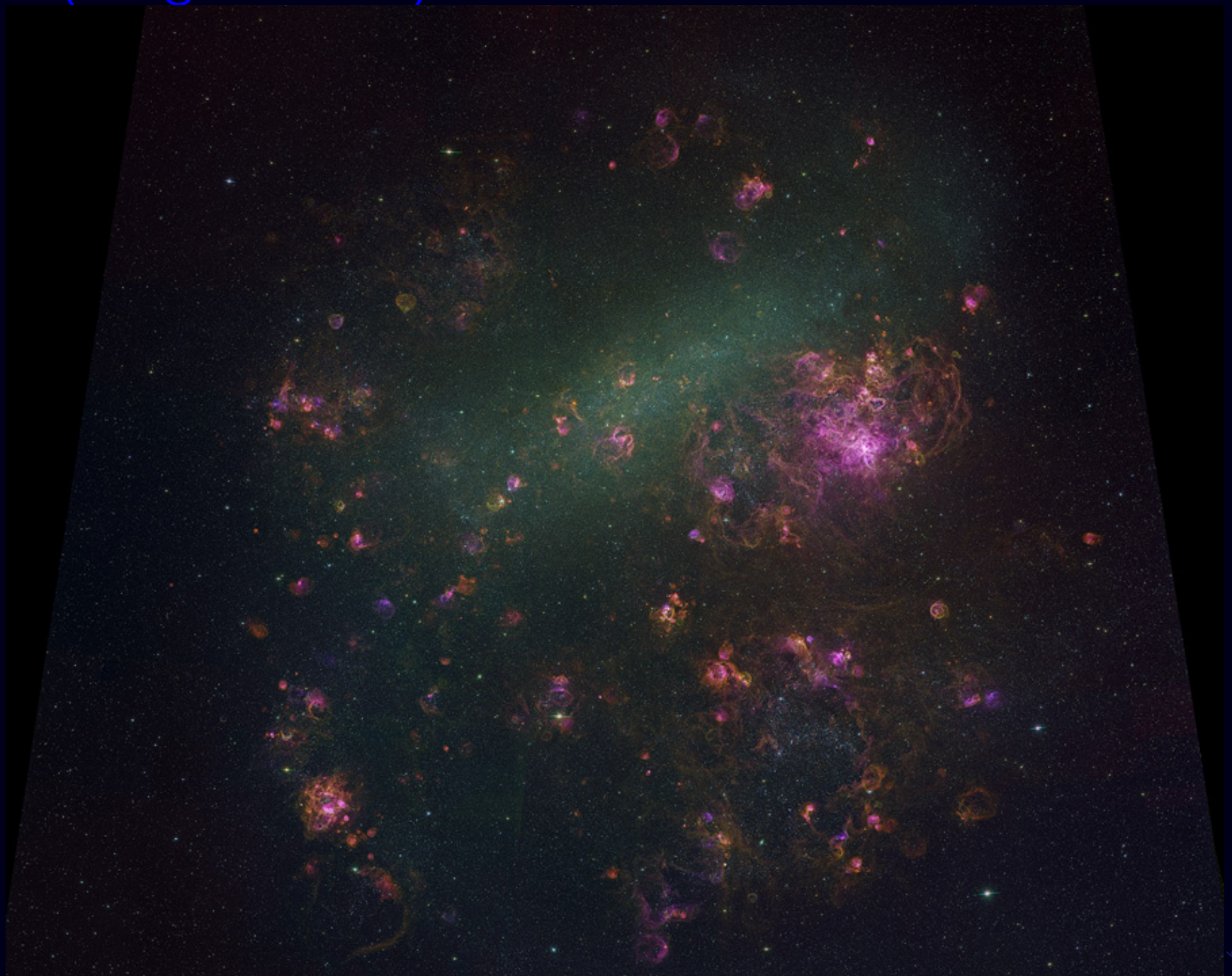
Star formation histories - Method II

- Determine $M_{\max}$ in each formation epoch
- Correct for dynamical evolution
- Calculate SFR
- Average over 0.5 dex

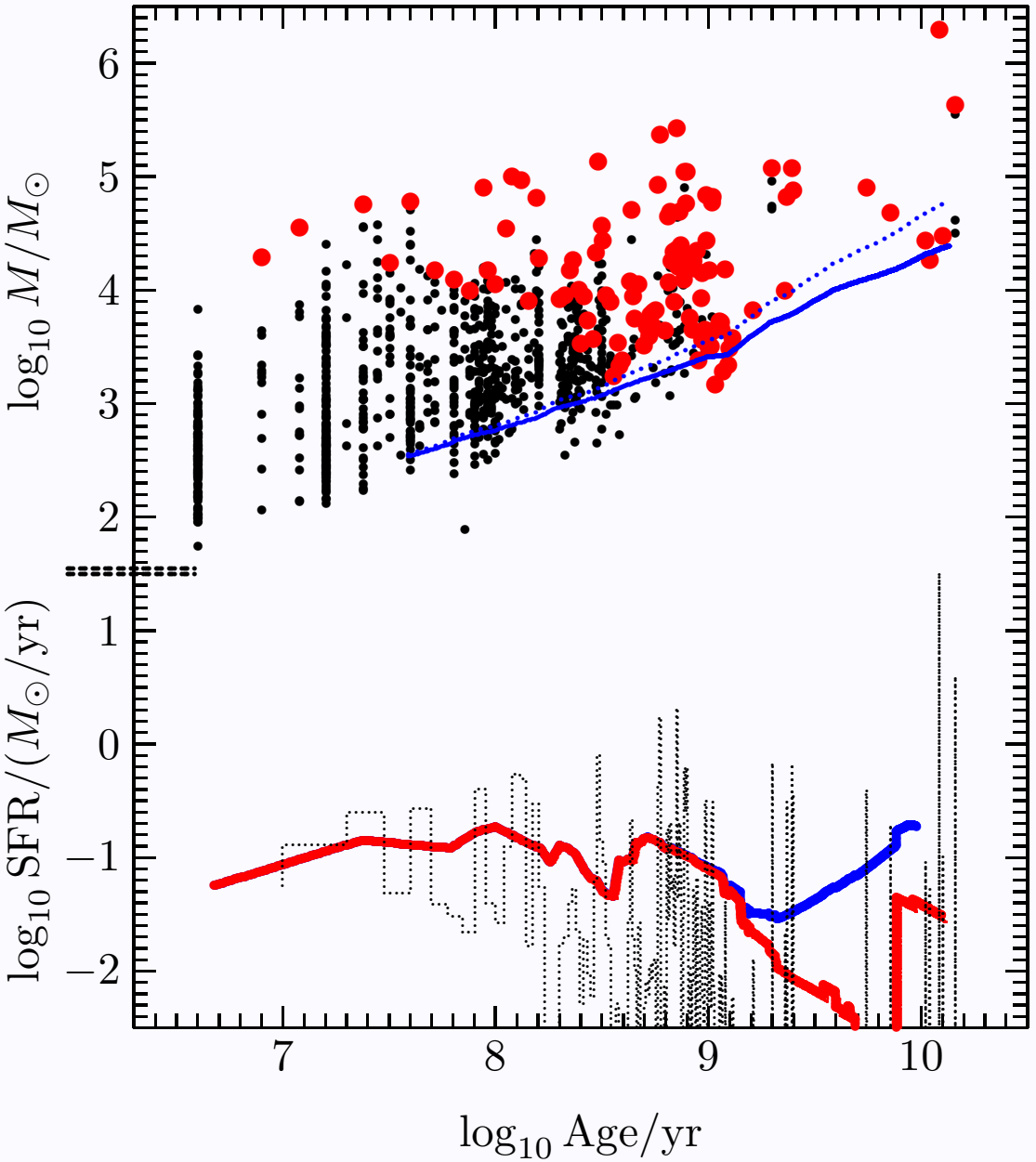
But:

Not all 10 Myr bins contain a cluster
$\Rightarrow$ Lower limit for the SFH

LMC (Image: NOAO)



LMC: SFH from 922 clusters



Stellar content:
$M_{\rm gal} = 2 \times 10^9 M_\odot$
(Kim et al. 1998)

SFH with back-evolved fading limit masses used in gaps
Upper Limit
${}^{UL}M_{\rm gal} = 2.6 \times 10^9 M_\odot$
SFH with gaps:
Lower Limit
${}^{LL}M_{\rm gal} = 5.8 \times 10^8 M_\odot$

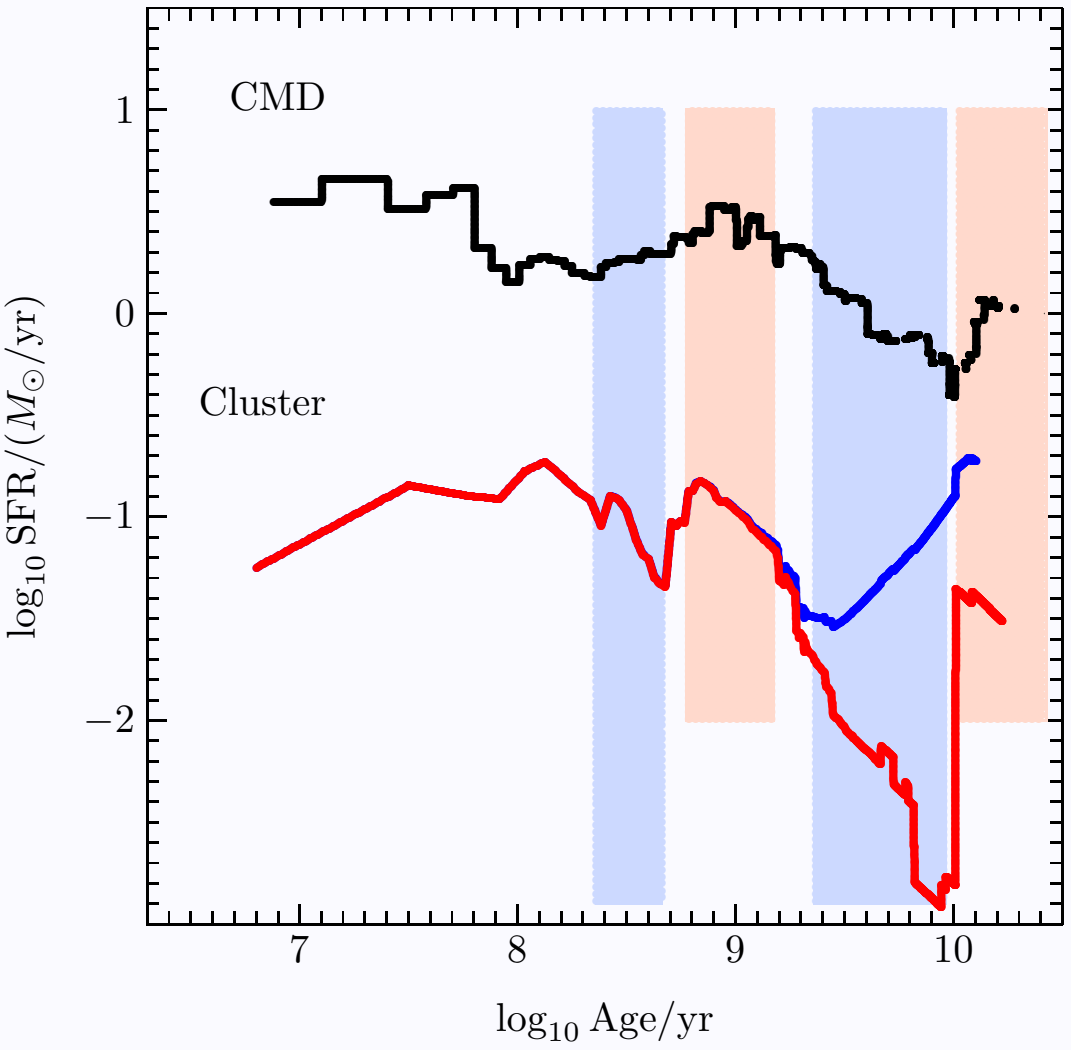
Cluster data from de Grijs & Anders (2006)

LMC: Fields with SFH from CMDs

28 Fields:
6 - Olsen (1999)
3 - Holtzman et. al (1999)
2 - Dolphin (2000)
4 - Harris & Zaritsky (2001)
2 - Smecker-Hane et al. (2002)
6 - Subramaniam (2004)
6 - Javiel et al. (2005)

For Averaging:
Normalise each field $\int SFR\ dt = 1$

LMC: SFH from clusters and CMDs



SFH from CMDs for 28 fields on an arbitrary scale

Common structures:
log age

- 8.4 - dip
- 9 - peak
- 9.2 -9.8 - "age gap"
- 10 - peak

log age younger 8:
averaging effects?

Summary

- $M_{\max}$ is distributed
- Distribution of $M_{\max}$ characterised by average
- Formation epochs of $\approx$ 10 Myr
- New method to derive SFHs
- LMC: SFH from star clusters and CMD show similar features