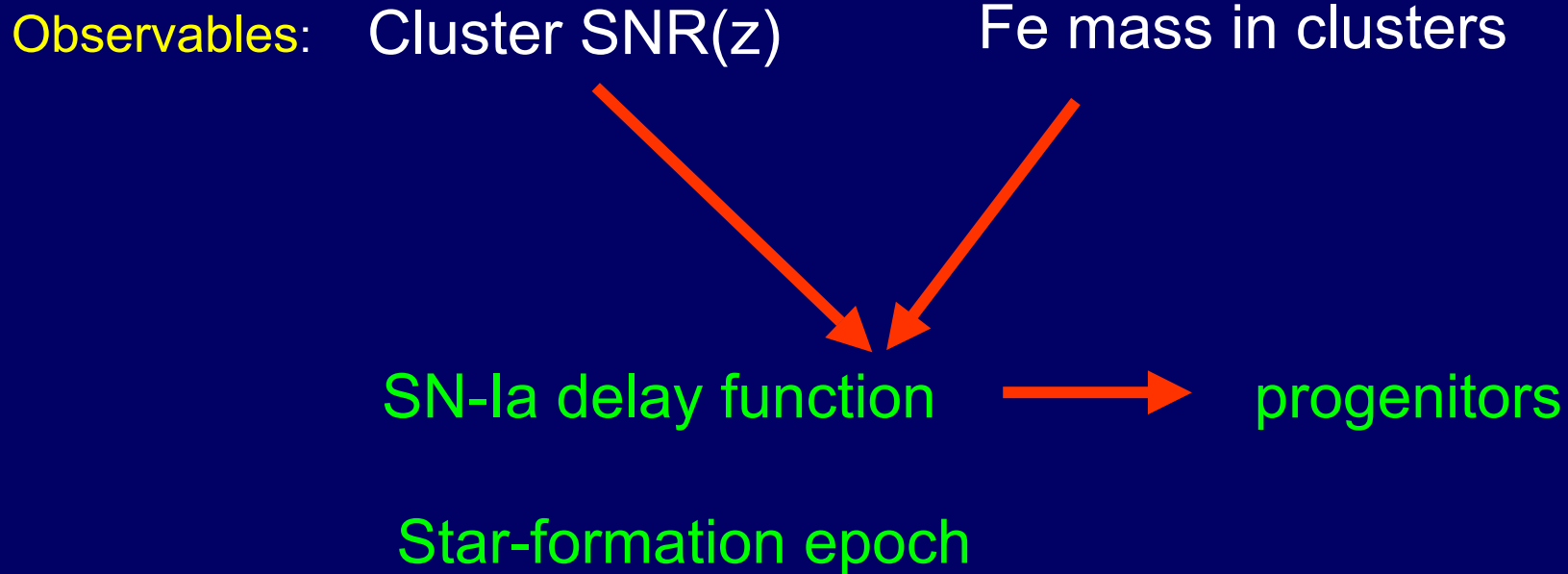


SN-Ia Rates vs Redshift: Implications for Metal Enrichment, SN-Ia Progenitors and SF History

Dan Maoz, Avishay Gal-Yam, Keren Sharon

Clusters = “closed boxes” → good laboratories



The Iron Crisis in Clusters:

In ICM: $Z_{\text{Fe}} = 0.3 Z_{\odot}$

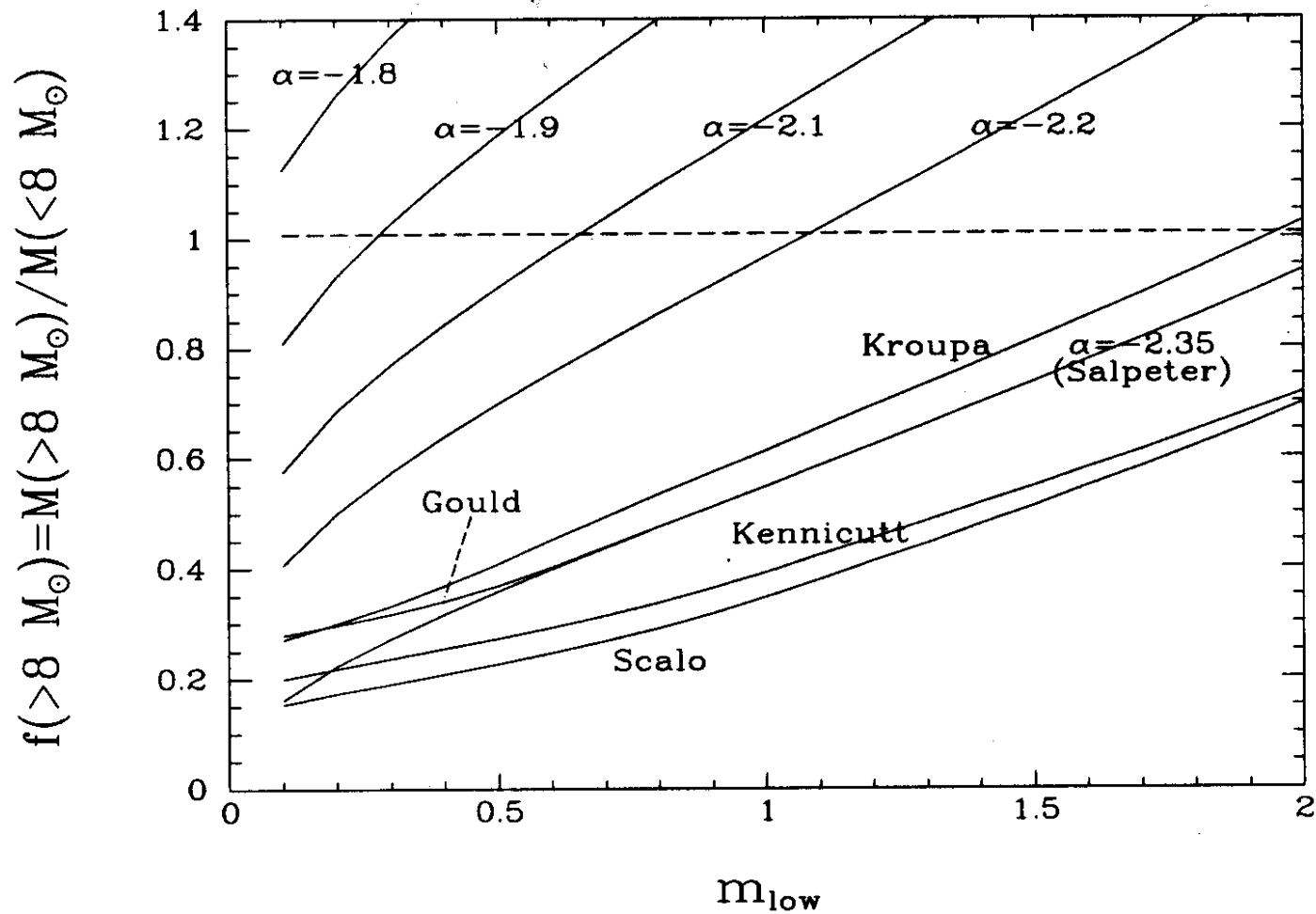
In galaxies: $Z_{\text{Fe}} = 1.2 Z_{\odot}$

 Lots of iron!

$$\frac{M_{\text{Fe-observed}}}{M_{\text{Fe-SNII}}} = \frac{M (f_{\text{gas}} Z_{\text{Fe-gas}} + f_{\text{star}} Z_{\text{Fe-star}})}{M f_{\text{star}} f(> 8M_{\odot}) y_{\text{Fe-SNII}}} = 6$$

Solution 1: Top-heavy IMF

How heavy an IMF is needed?



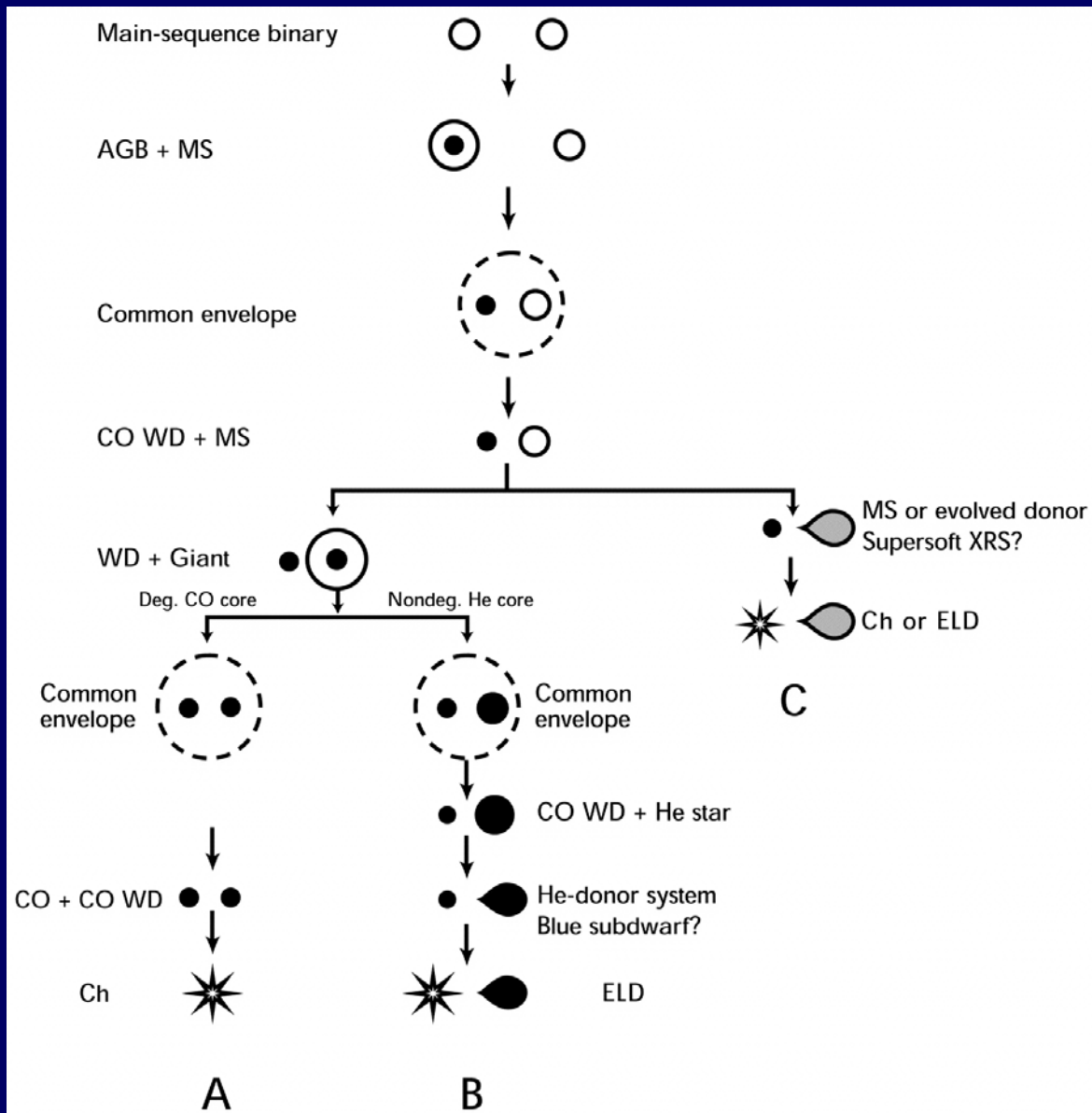
Solution 2: Most of iron is from SNe-Ia

then:

$$\frac{1}{L} \int \text{SNR}_{Ia}(t) dt = \frac{M_{Fe}}{L m_{Fe-Ia}} = 0.04 \frac{\text{SN}}{L_{\odot}} = 40 \text{ SNu Gyr}$$

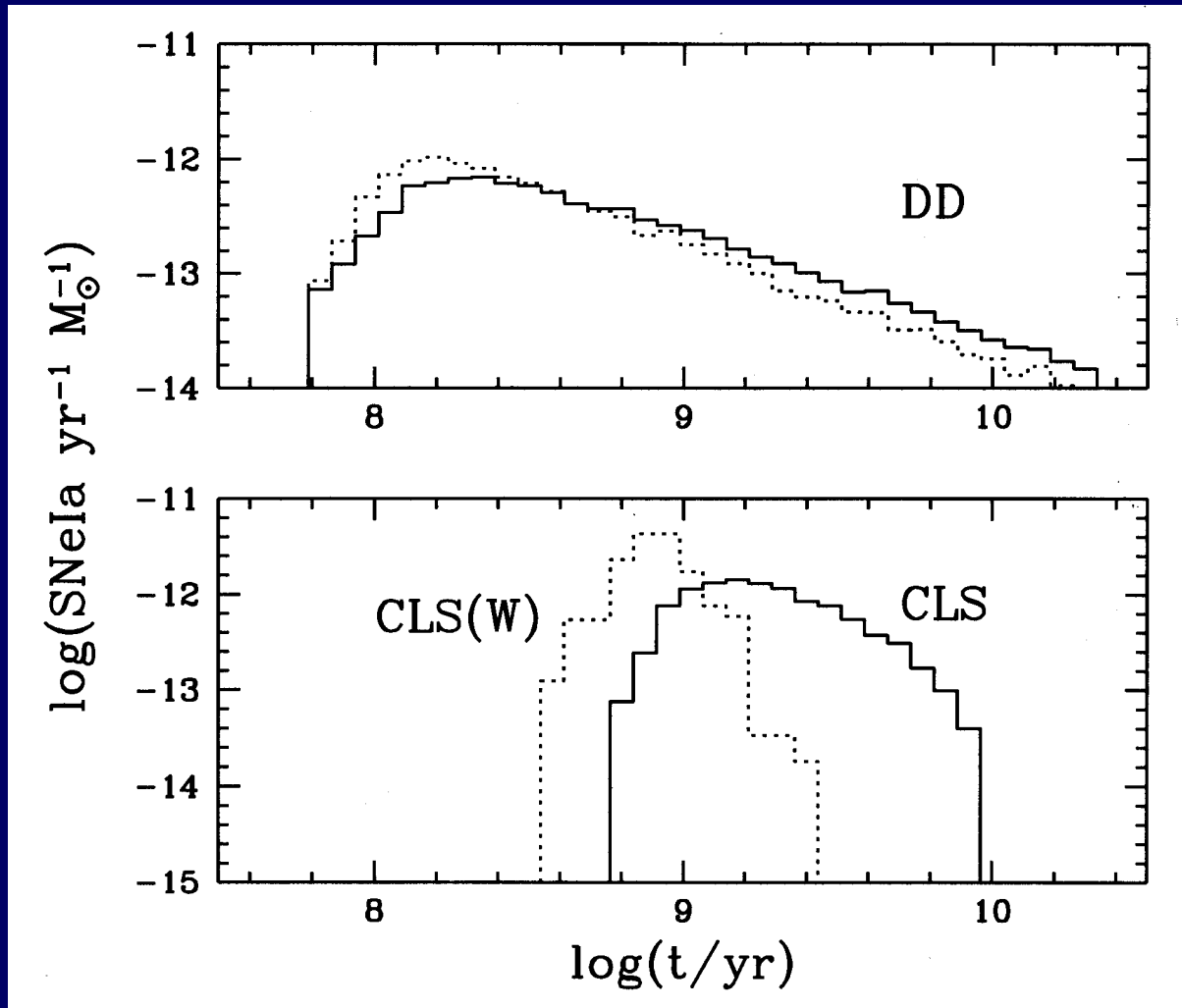
(1 SNu=1 SN/century/10**(10) Lo)

Yungelson & Livio (2000)



Ruiz-Lapuente & Canal (1998)

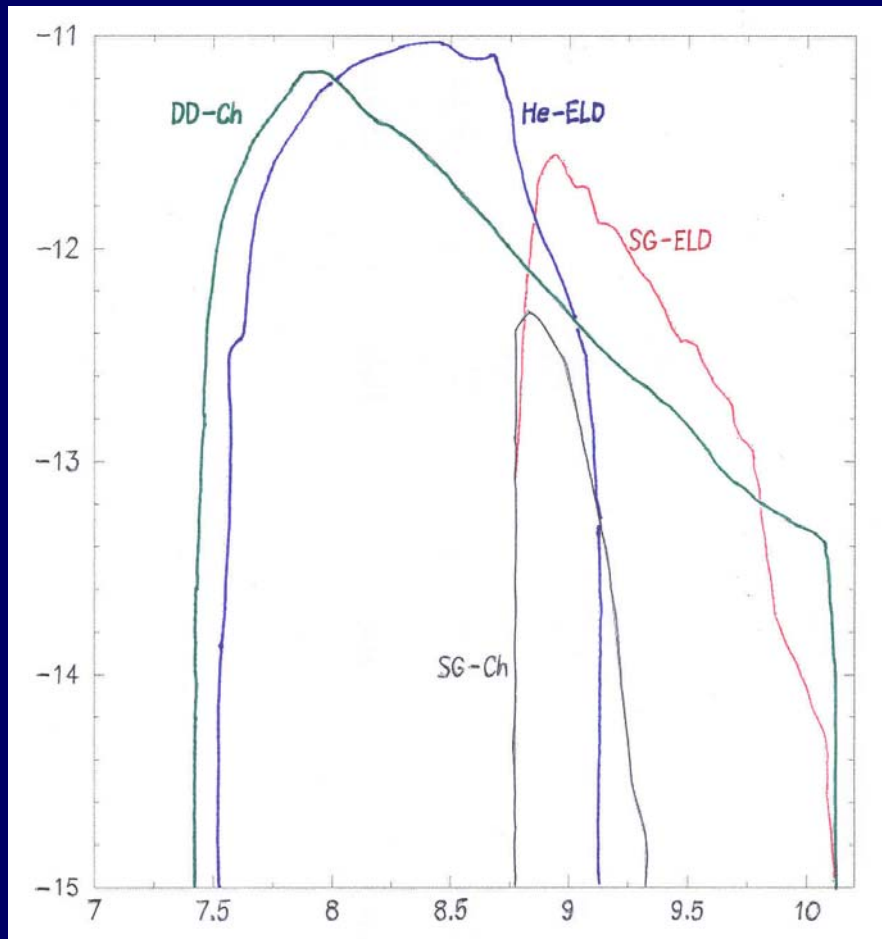
$\log D(t)$



$\log(t/\text{yr})$ since starburst

Yungelson & Livio (2000)

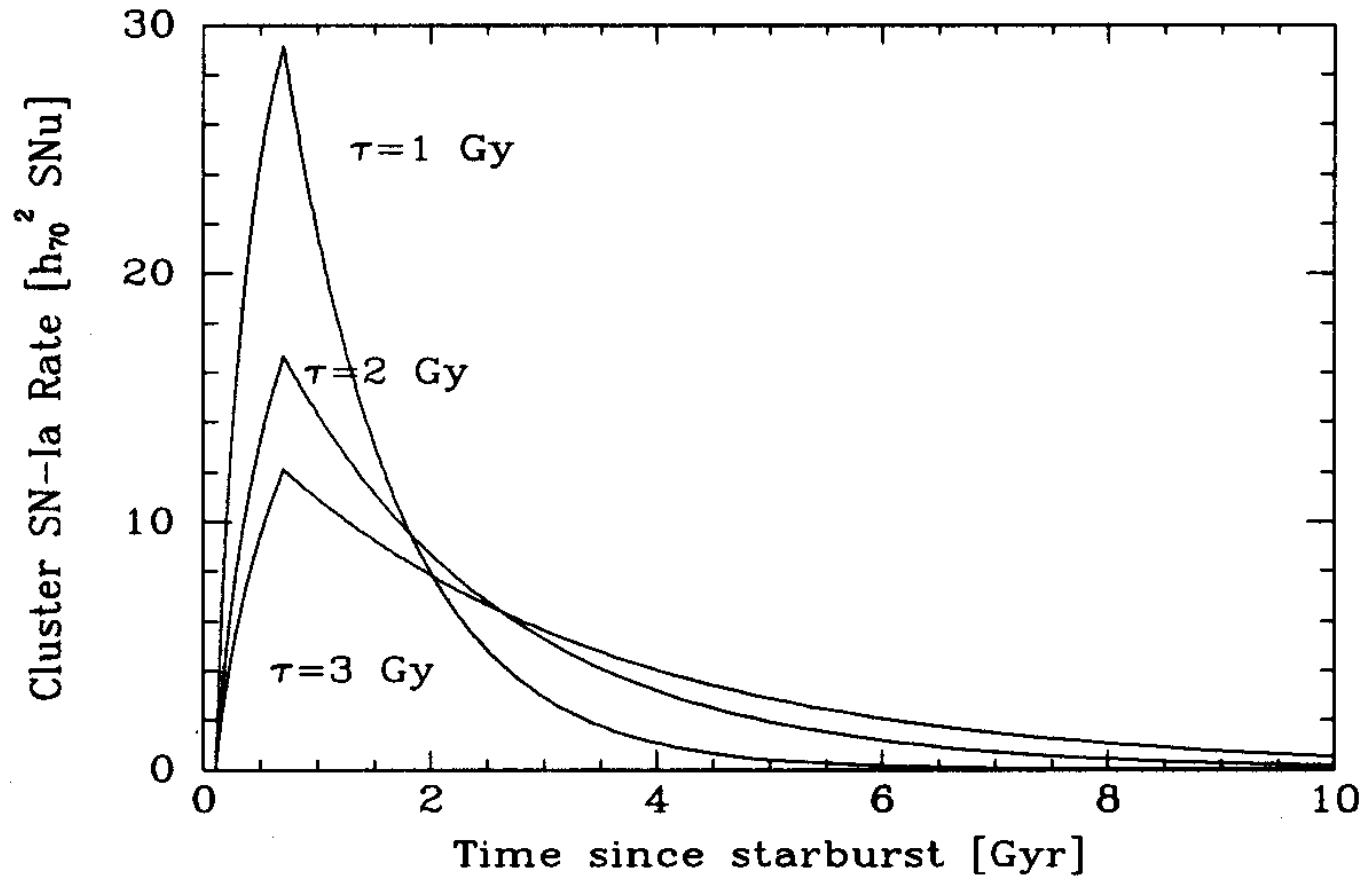
$\log D(t)$



$\log (t/\text{yr})$ since starburst

following Madau, DellaValle, & Panagia (1998)

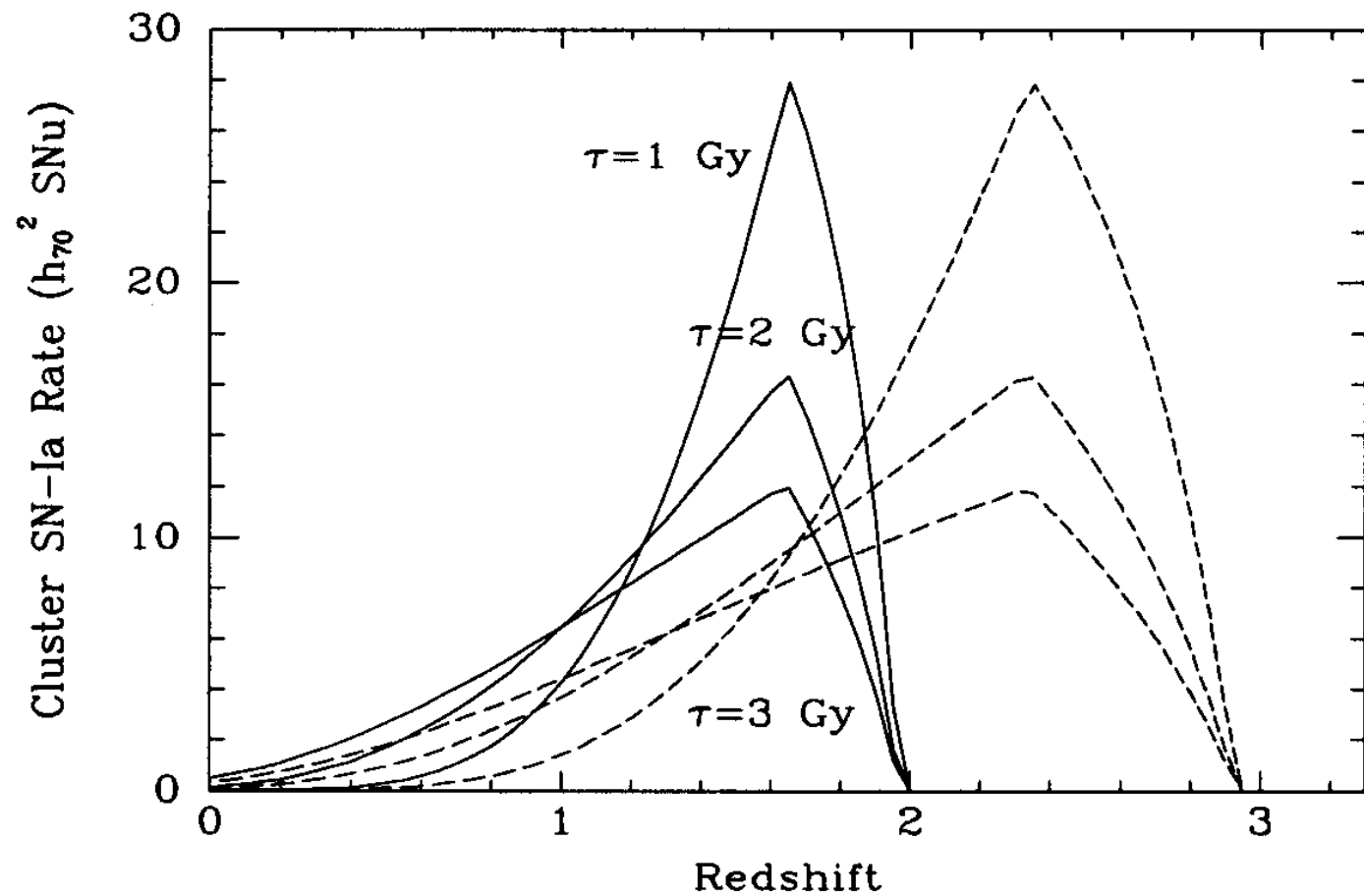
$D(t)$

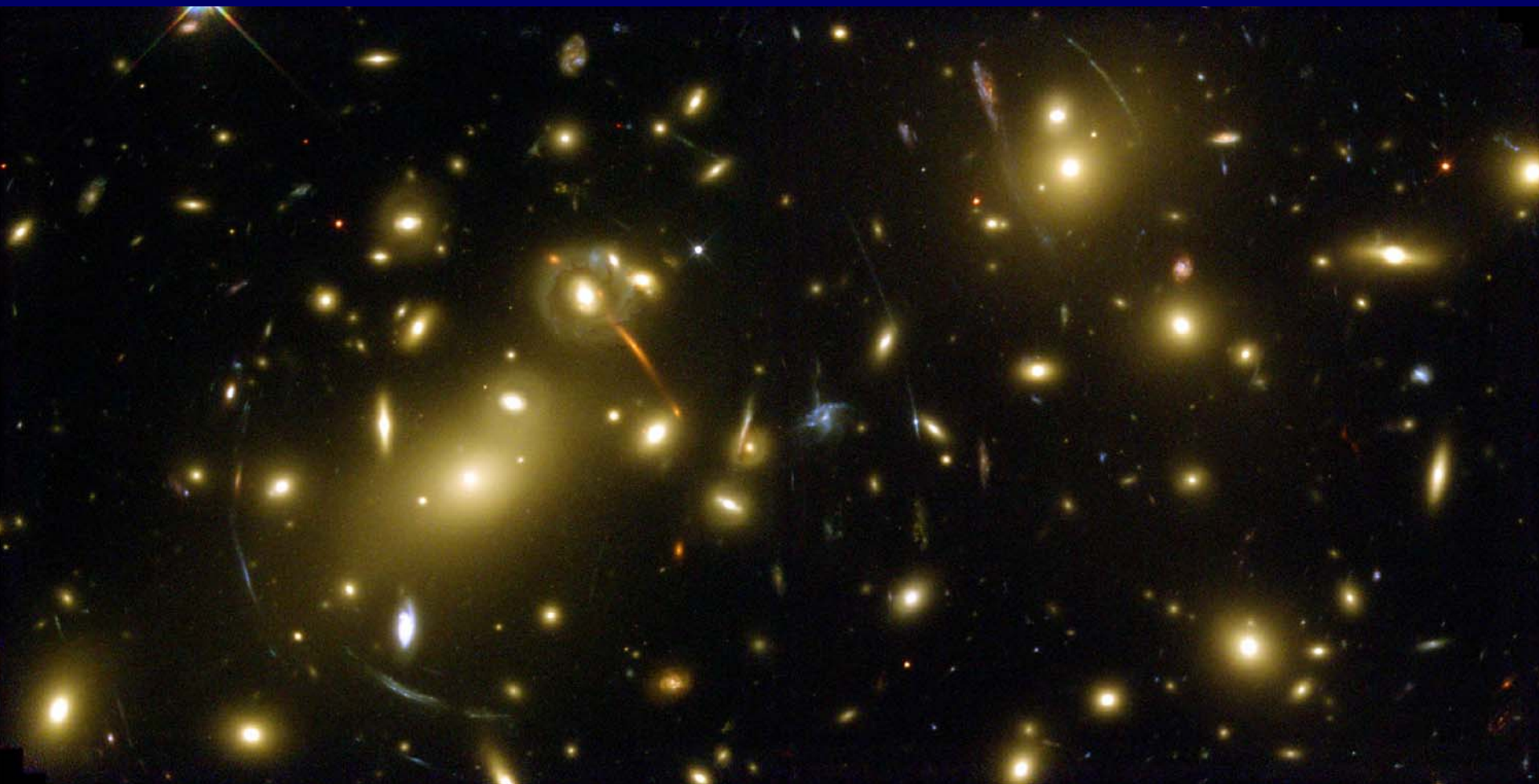


t

Cluster SN-Ia rates vs. z depend on two parameters:

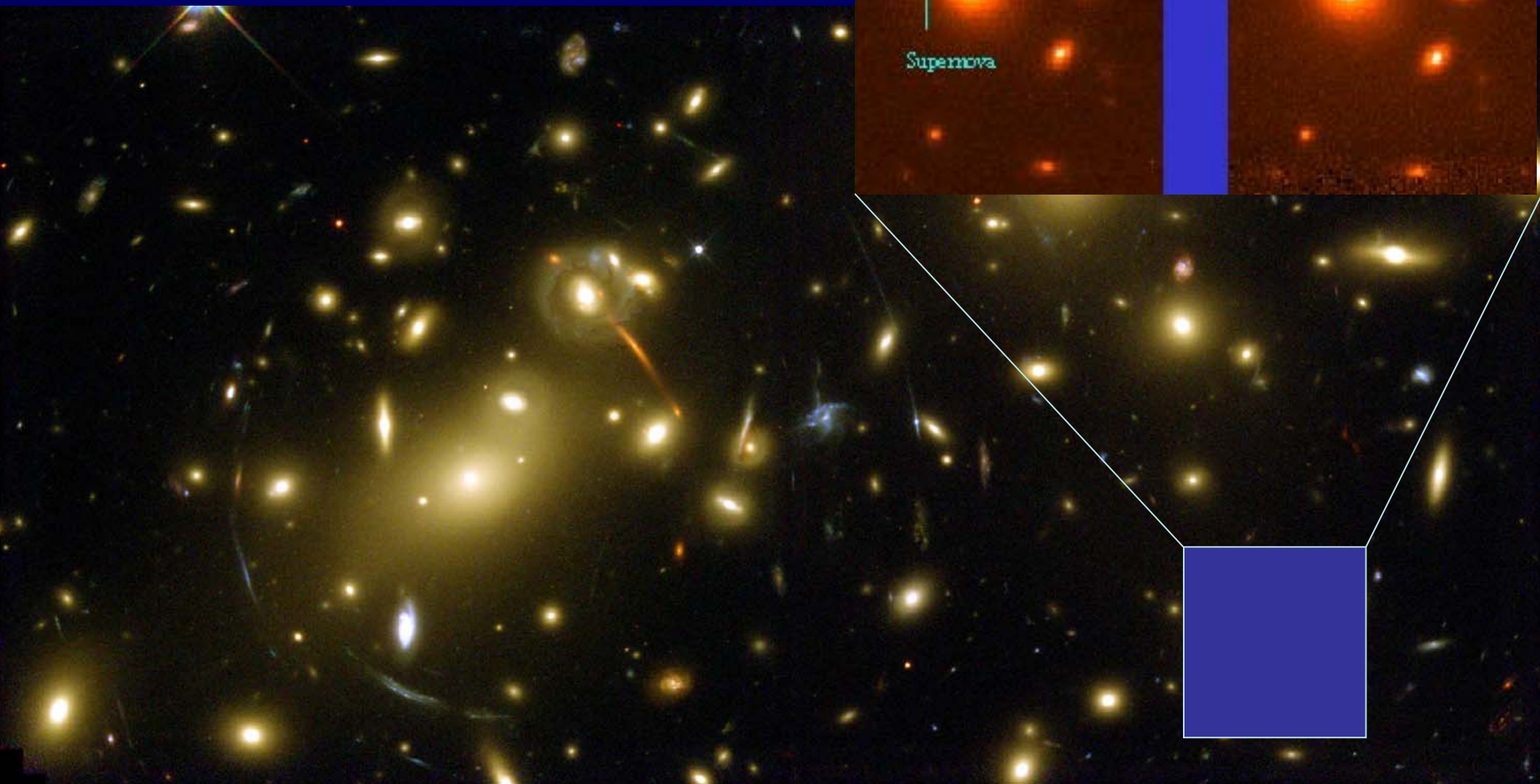
$z_{\text{formation}}$ and τ



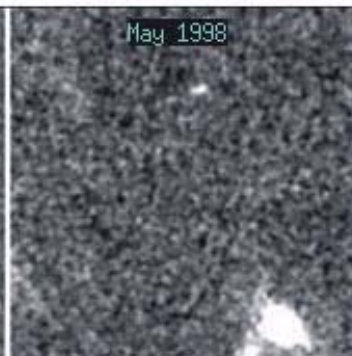
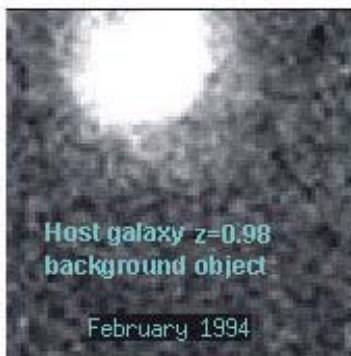


Cluster SN-Ia rates $0 < z < 1$

Gal-Yam, Maoz, & Sharon (2002)

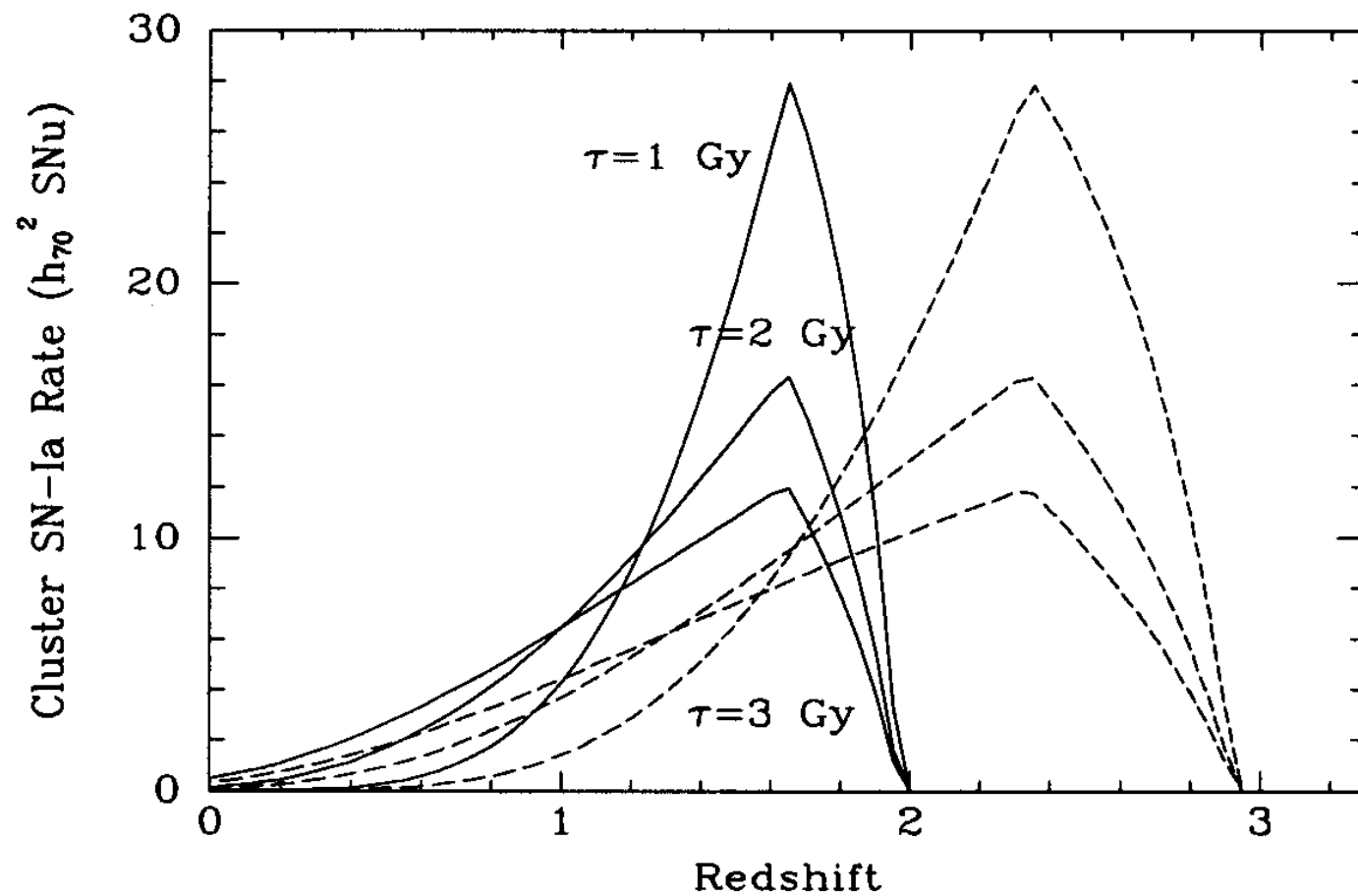


SNe candidates

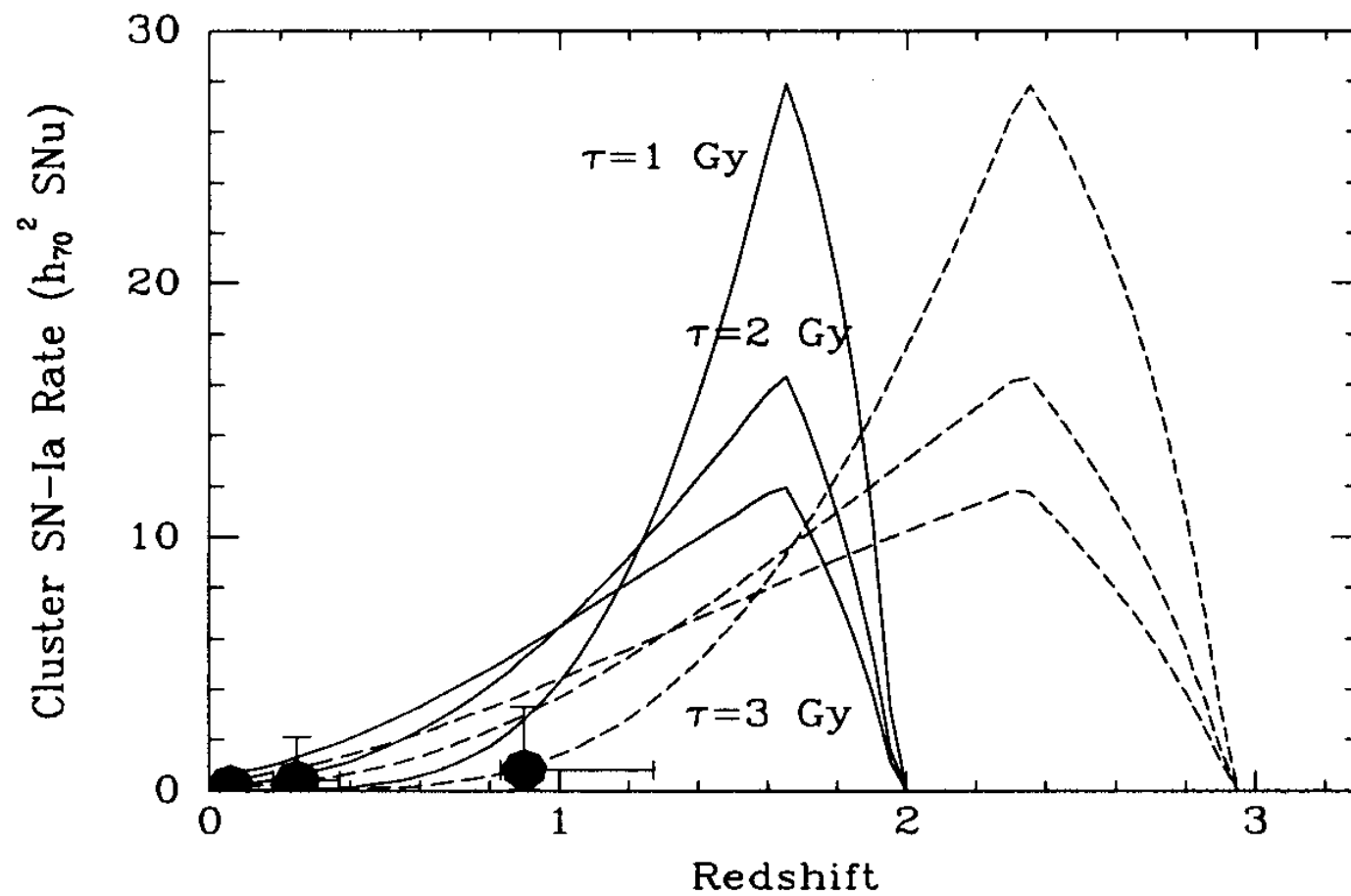


SNe in cluster fields

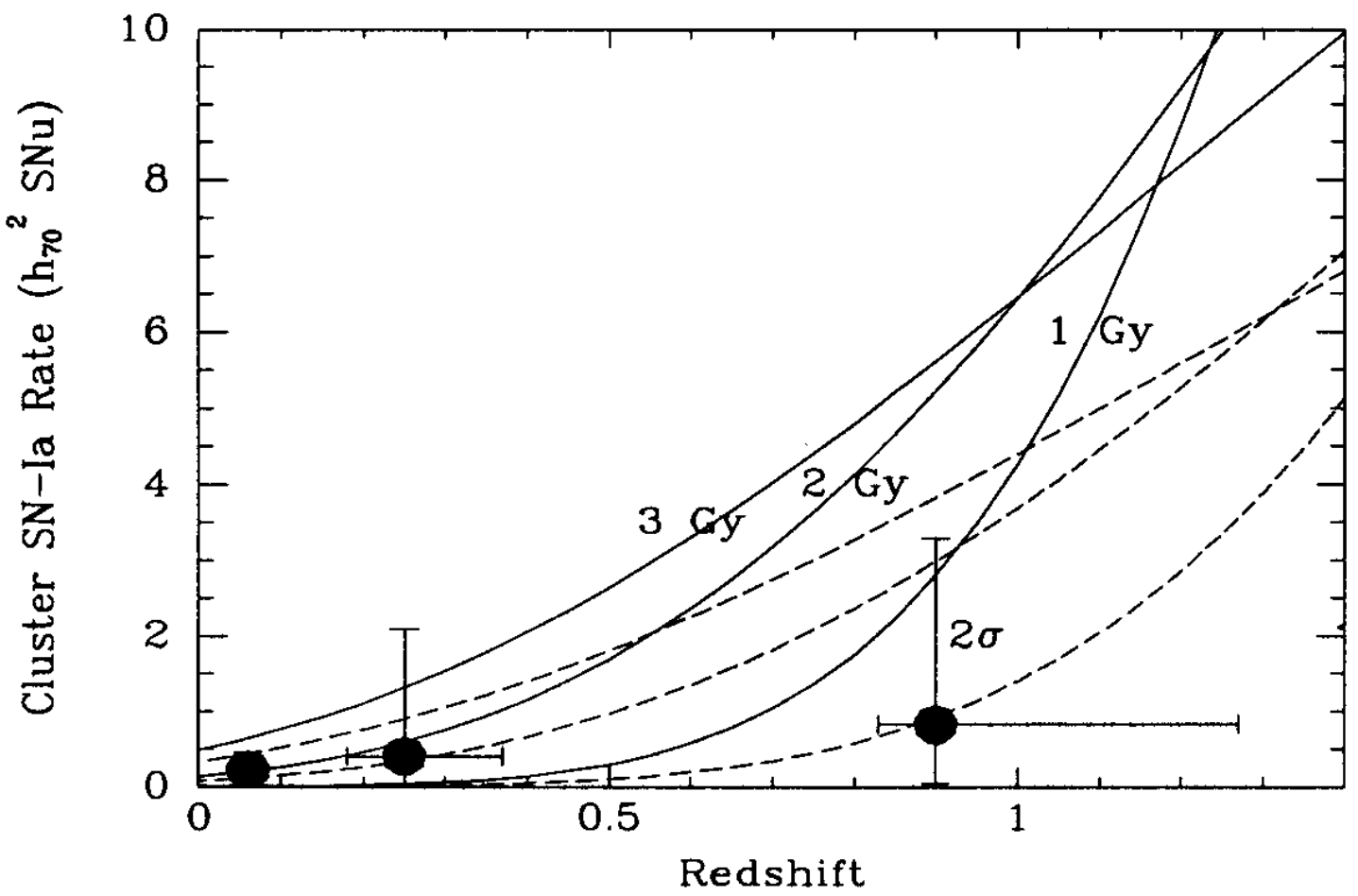
Predictions vs. SNR(z) measurements



Predictions vs. SNR(z) measurements



Predictions vs. SNR(z) measurements

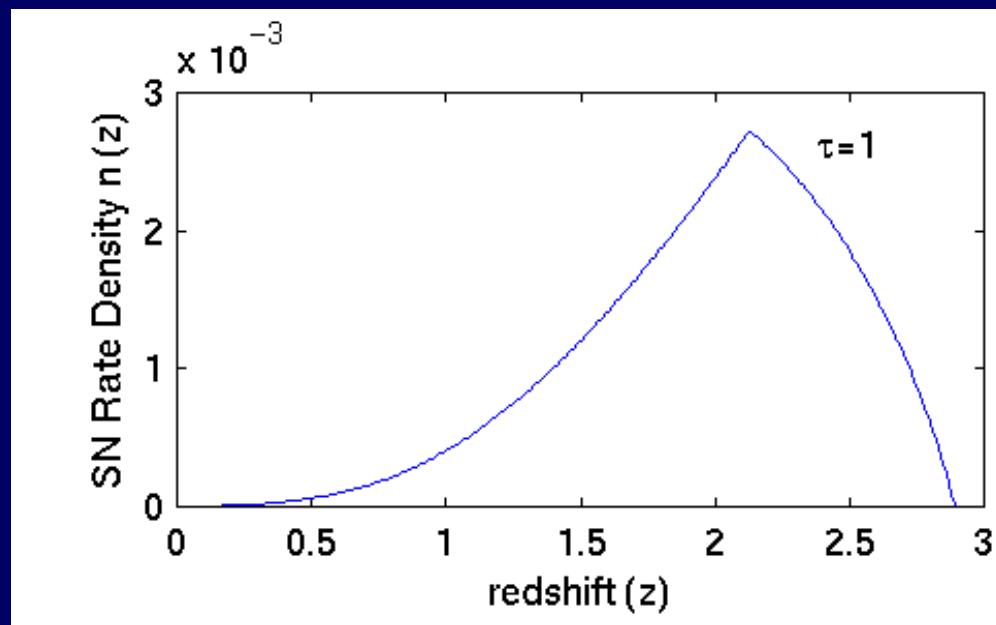


Similarly for...

II. Field SNe

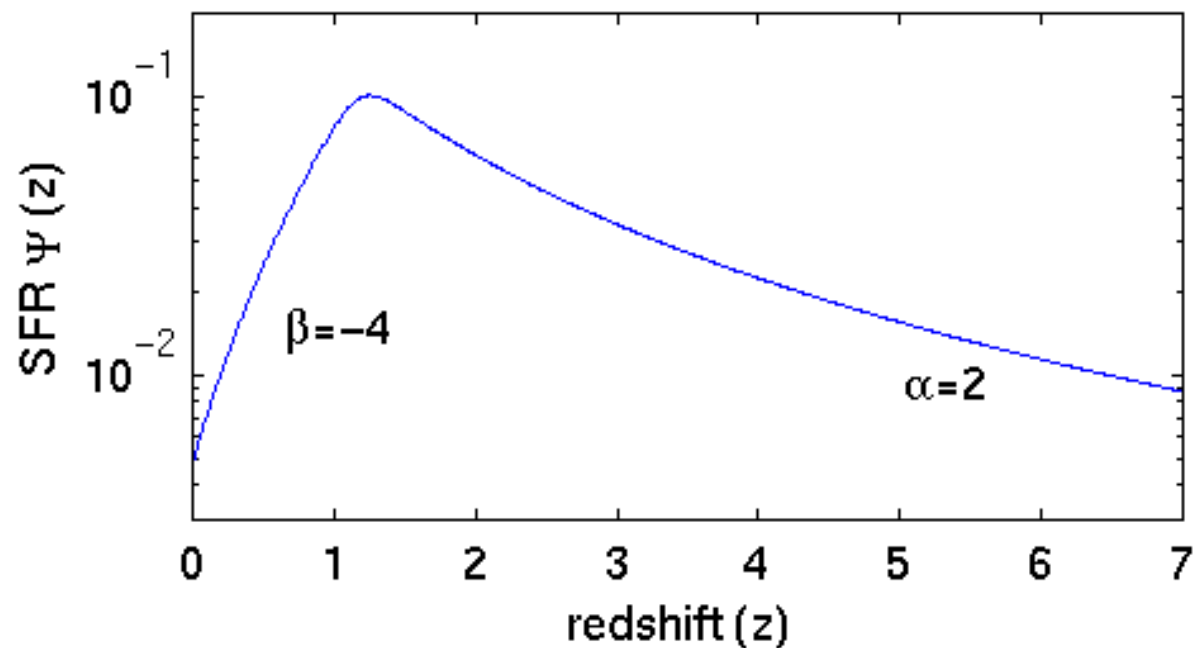
SN delay
function

*

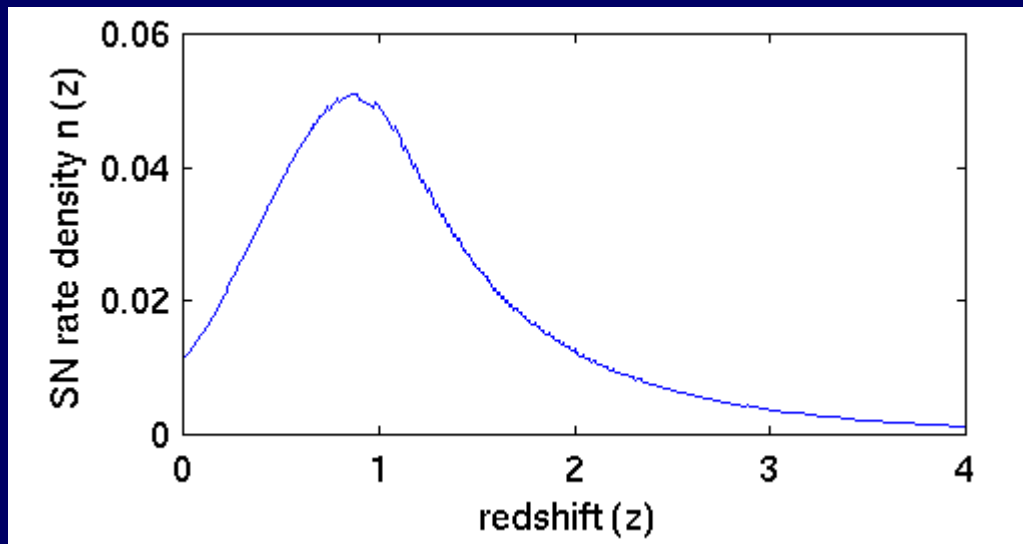


Star-formation
history (z)

(“Madau plot”)

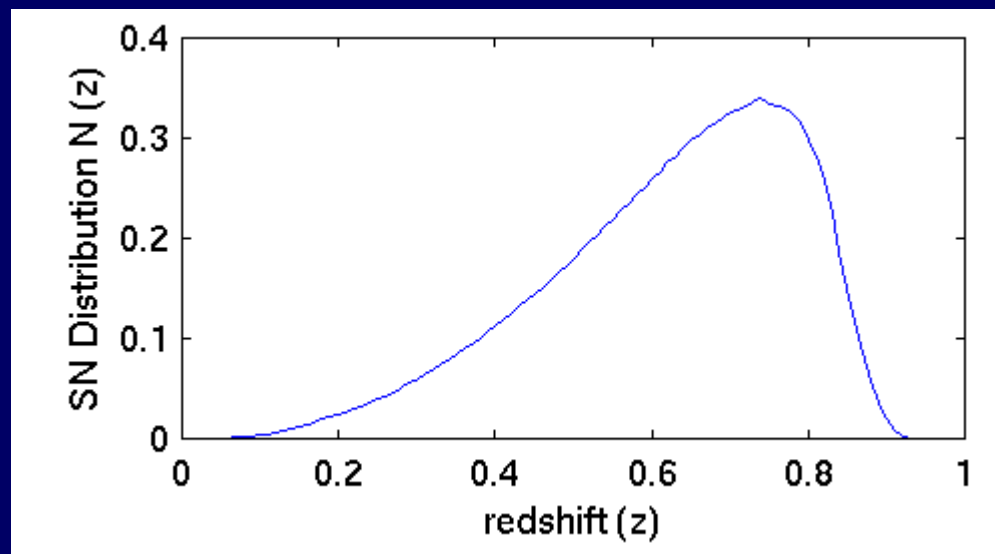


≡ SN rate $n(z)$



X $t(m_{lim}, z)$
visibility time

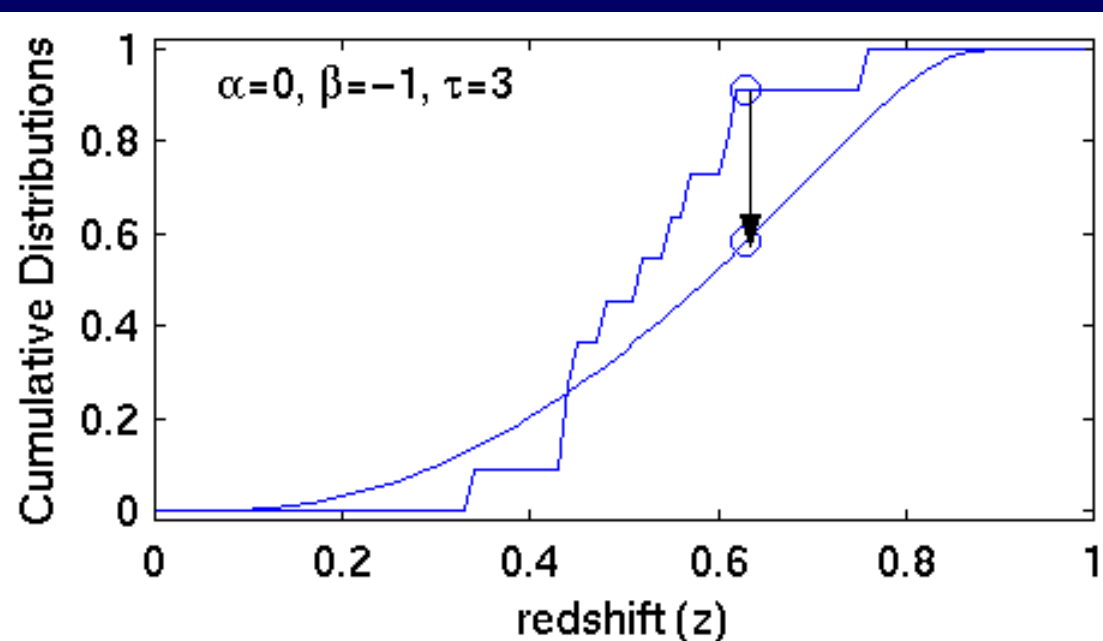
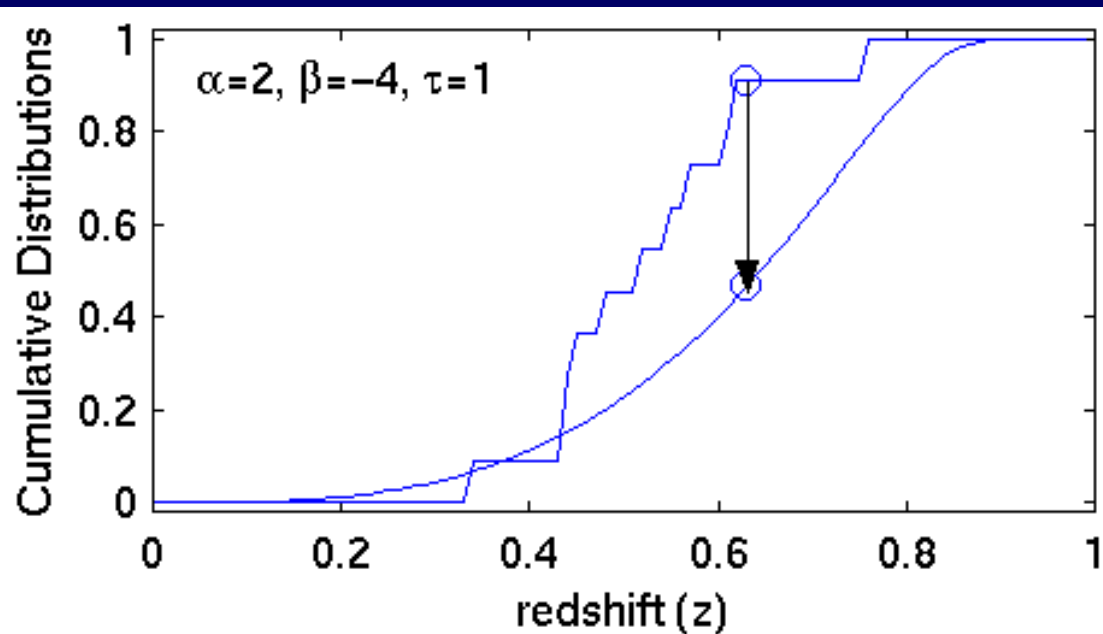
≡ SN number
distribution $N(z)$

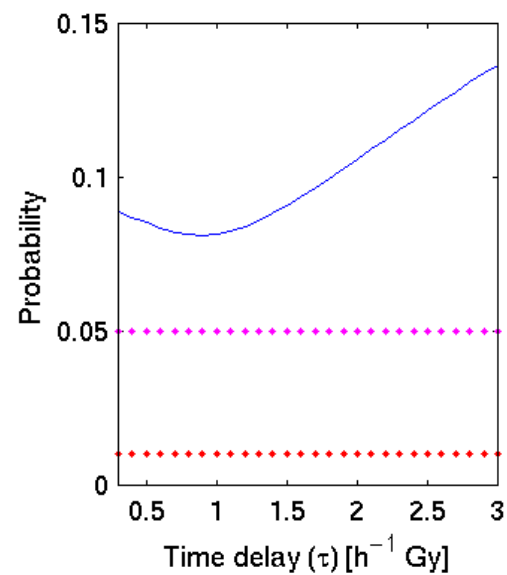
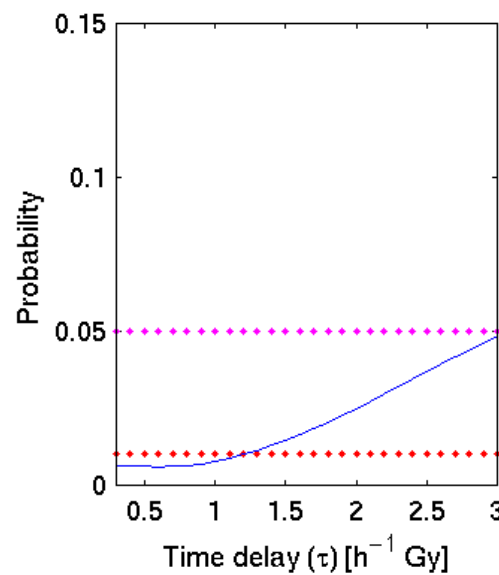
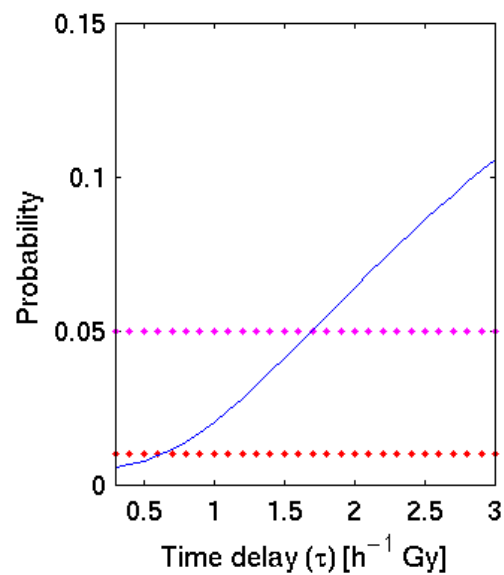
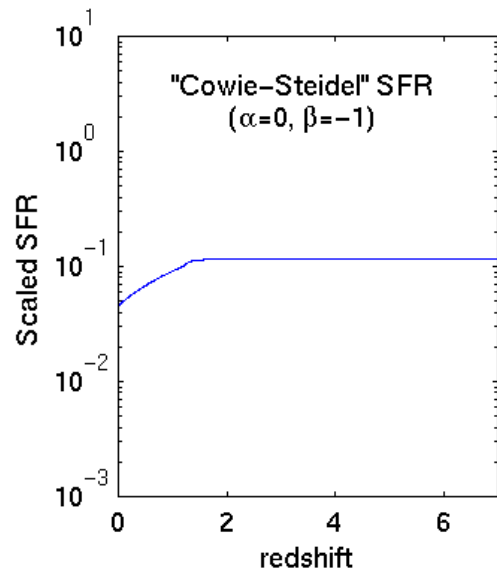
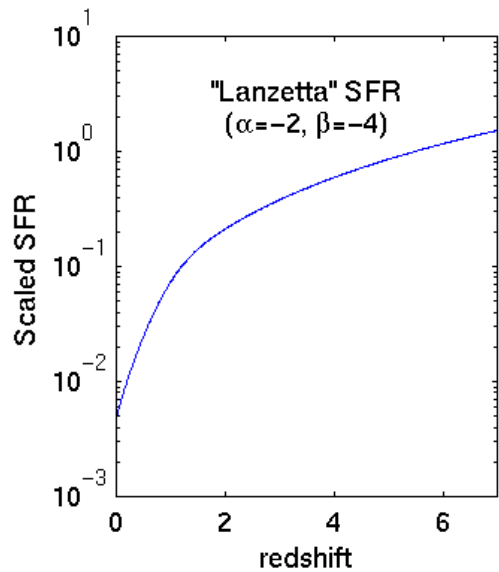
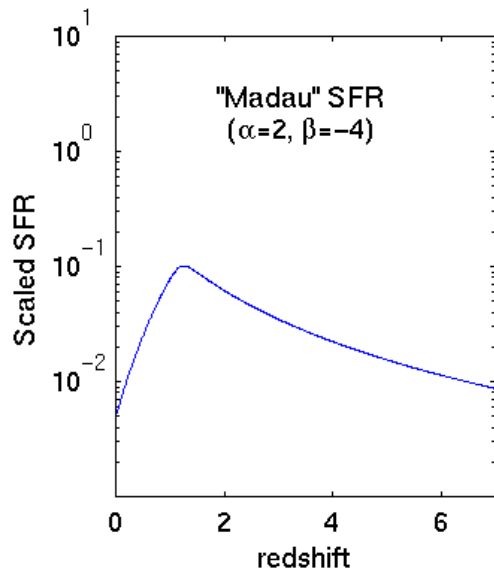


Comparison to data:

SCP SNe from

Pain et al. (2003)





CONCLUSIONS

IN CLUSTERS: observed SN-Ia Rate(z)

1. Cluster IMF is top-heavy

or

2. Cluster Fe is from SNe-Ia; low observed rates imply early star formation and/or short delay times, e.g.:

a. if $z_f < 3$, $\tau < 5$ Gyr

b. if $z_f < 2$, $\tau < 2$ Gyr

IN FIELD: observed SN-Ia z distribution

3. If strong SFH evolution, $\tau > 4$ Gyr

4. Larger number statistics \rightarrow powerful probe of SN-Ia nature, SFH, and metal enrichment.