Constraints on galaxy formation timescales from observed alpha overabundance

Other Conference Item

Author(s):
Greggio, Laura

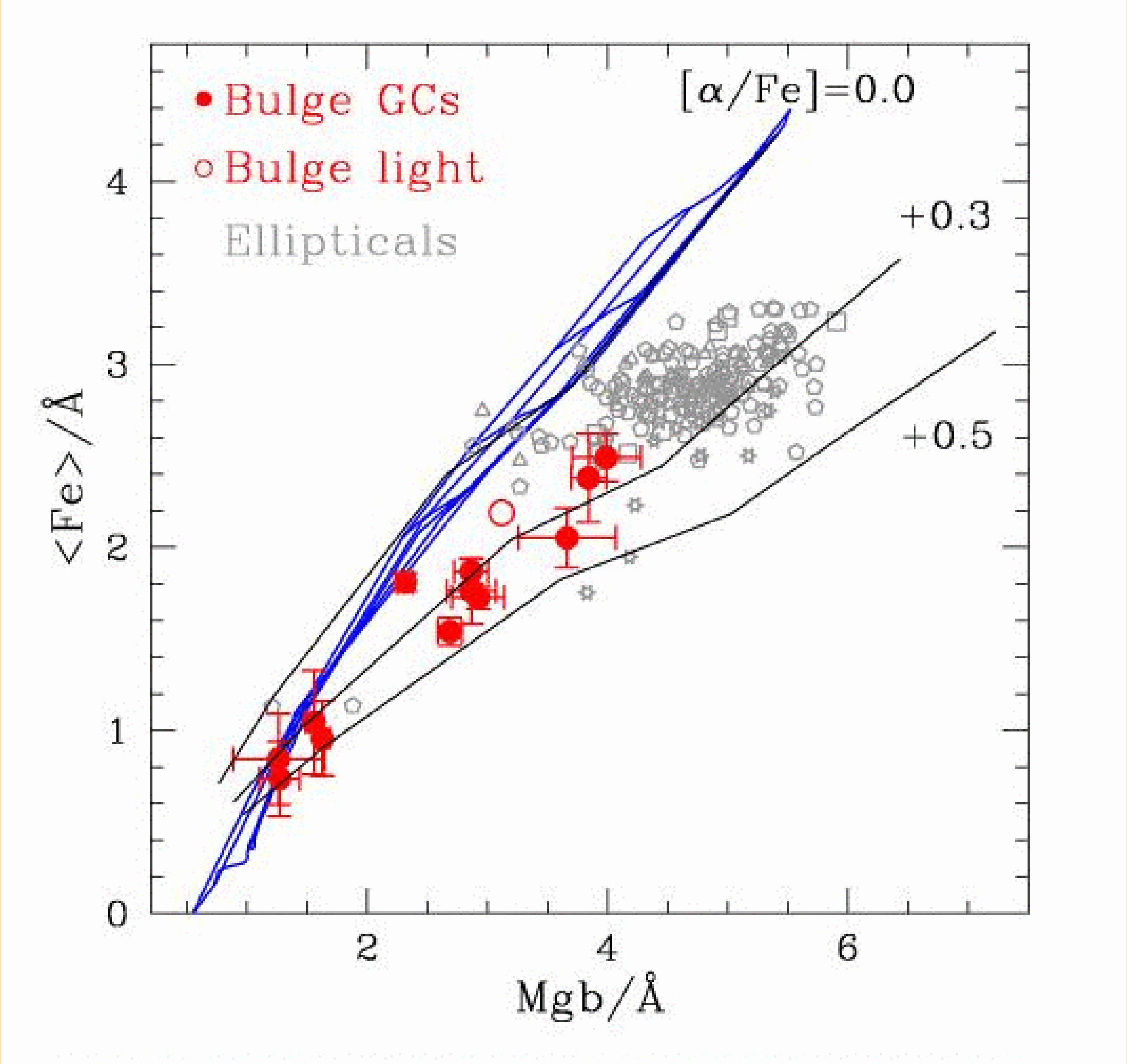
Publication date:
2003

Permanent link:
https://doi.org/10.3929/ethz-a-004584673

Constraints on Galaxy Formation Timescales from observed alpha Overabundance

Laura Greggio, Osservatorio Astronomico di Padova, Italia

Maraston et al., 2003, A&A 400, 823



At given <Fe>, Mgb is strong relative to solar proportions

↓

$(Z_a/Z_{Fe}) > (Z_a/Z_{Fe})_{SUN}$

- SNII provide the α's to the ISM
  m $\gtrsim$ 8 $m_\odot \Rightarrow \tau_{SNII} \lesssim$ 0.03 Gyr

- SNIa provide a substantial part of the Fe to the ISM
  m $\lesssim$ 8 $m_\odot \Rightarrow t_H \gtrsim \tau_{SNIa} \gtrsim$ 0.03 Gyr

If SF ends before a large fraction of SNIa has exploded, the stars could not incorporate the Fe from Ias, and their metallicity distribution will be overabundant in α's (underabundant in Fe)

$$\Downarrow$$

$$Z_\alpha / Z_{Fe} \Rightarrow t_{SF}$$

Matteucci (1994) :
Salpeter IMF + model for Ia progenitors $\longrightarrow$ $t_{SF,E} < 0.3$ Gyr

The constraint depends on the model for the Ia progenitors
(Matteucci and Recchi 2001)

Define:

A_{Ia}(t) as the fraction of stars of an SSP which end up as a SNIa
realization probability of the Ia event

$f_{\mathrm{Ia}}(\tau)$ as the distribution function of the delay times normalized to 1
over the whole τ range ($\tau_n \leq \tau \leq \tau_x$)

⇒ The Ia rate at time t is:

$$\dot{n}_{Ia}(t) = k_\alpha \times \int_{\tau_n}^{min(t,\tau_x)} d\tau \cdot \psi(t-\tau) \cdot A_{\mathrm{Ia}}(t-\tau) \cdot f_{\mathrm{Ia}}(\tau)$$

where

ψ is the SFR in $m_\odot$/yr

k_α accounts for the dependence on the IMF:

$$k_\alpha = \frac{\int_{m_l}^{m_s} dm \cdot \phi(m)}{\int_{m_l}^{m_s} dm \cdot m \cdot \phi(m)}$$

$k_\alpha = 2.8, 1.5$ for $\alpha = 2.35$, Kroupa IMF, within $0.1 \leq m/m_\odot \leq 120$

For a burst of SF: $\psi = \psi_0$ in $0 \leq t \leq t_B$
$\psi = 0$ in $t > t_B$

$$\dot{n}_{Ia}(t) = k_\alpha \times \psi_0 \times \int_{t-t_B}^{t} d\tau \cdot A_{\mathrm{Ia}}(t-\tau) \cdot f_{\mathrm{Ia}}(\tau)$$

- SSP : $t_B \ll$

$$\dot{n}_{Ia}(t) = k_\alpha \ \psi_0 \ A_{\mathrm{Ia},0} \ f_{\mathrm{Ia}}(\tau = t) \ t_B = k_\alpha \ \mathcal{M}_B \ A_{\mathrm{Ia},0} \ f_{\mathrm{Ia}}(\tau)$$

For galaxies: assume $A_{\mathrm{Ia}}(\mathrm{t}) = \mathrm{const} = A_{\mathrm{Ia}}$

- Late Type:

$$\dot{n}_{Ia}^{\mathrm{LT}} = k_\alpha \times A_{\mathrm{Ia}} \times \langle \psi \rangle \times \int_{\tau_x}^{min(t,\tau_x)} d\tau \cdot f_{\mathrm{Ia}}(\tau)$$
$$\simeq k_\alpha \times A_{\mathrm{Ia}} \times \mathcal{M}_{\mathrm{LT}} \times \langle f_{\mathrm{Ia}} \rangle_{\tau_x, t}$$

- Early Type:

$$\dot{n}_{Ia}^{\mathrm{ET}} = k_\alpha \times A_{\mathrm{Ia}} \times \psi_B \times \int_{t-t_B}^{t} d\tau \cdot f_{\mathrm{Ia}}(\tau)$$
$$\simeq k_\alpha \times A_{\mathrm{Ia}} \times \mathcal{M}_{\mathrm{ET}} \times \langle f_{\mathrm{Ia}} \rangle_{t-\Delta t, t}$$

OBSERVED RATES (Cappellaro, Evans & Turatto 1999)

★ $\dot{n}_{Ia}^{\mathrm{LT}} \simeq 0.2\ \mathrm{SNu} = \frac{0.2}{100} \times \frac{L_{\mathrm{B}}}{10^{10} L_{\mathrm{B}\odot}} = 0.2 \cdot 10^{-12}\ L_{\mathrm{B}}$ events/yr

$$\dot{n}_{Ia}^{\mathrm{LT}} = k_{\alpha} \times A_{\mathrm{Ia}} \times \langle\psi\rangle \times \int_{\tau_n}^{min(t,\tau_x)} d\tau \cdot f_{\mathrm{Ia}}(\tau) \qquad t \rightarrow \tau_x \quad \mathfrak{I}_{Ia} \rightarrow 1$$

$$\longrightarrow A_{\mathrm{Ia}} \simeq \frac{0.2}{k_{\alpha}} \times \frac{1}{(M_*/L_{\mathrm{B}})_{\mathrm{LT}}} \times \frac{t_{Gyr}}{\mathfrak{I}_{Ia}(t)} \times 10^{-3} \approx 10^{-3}$$

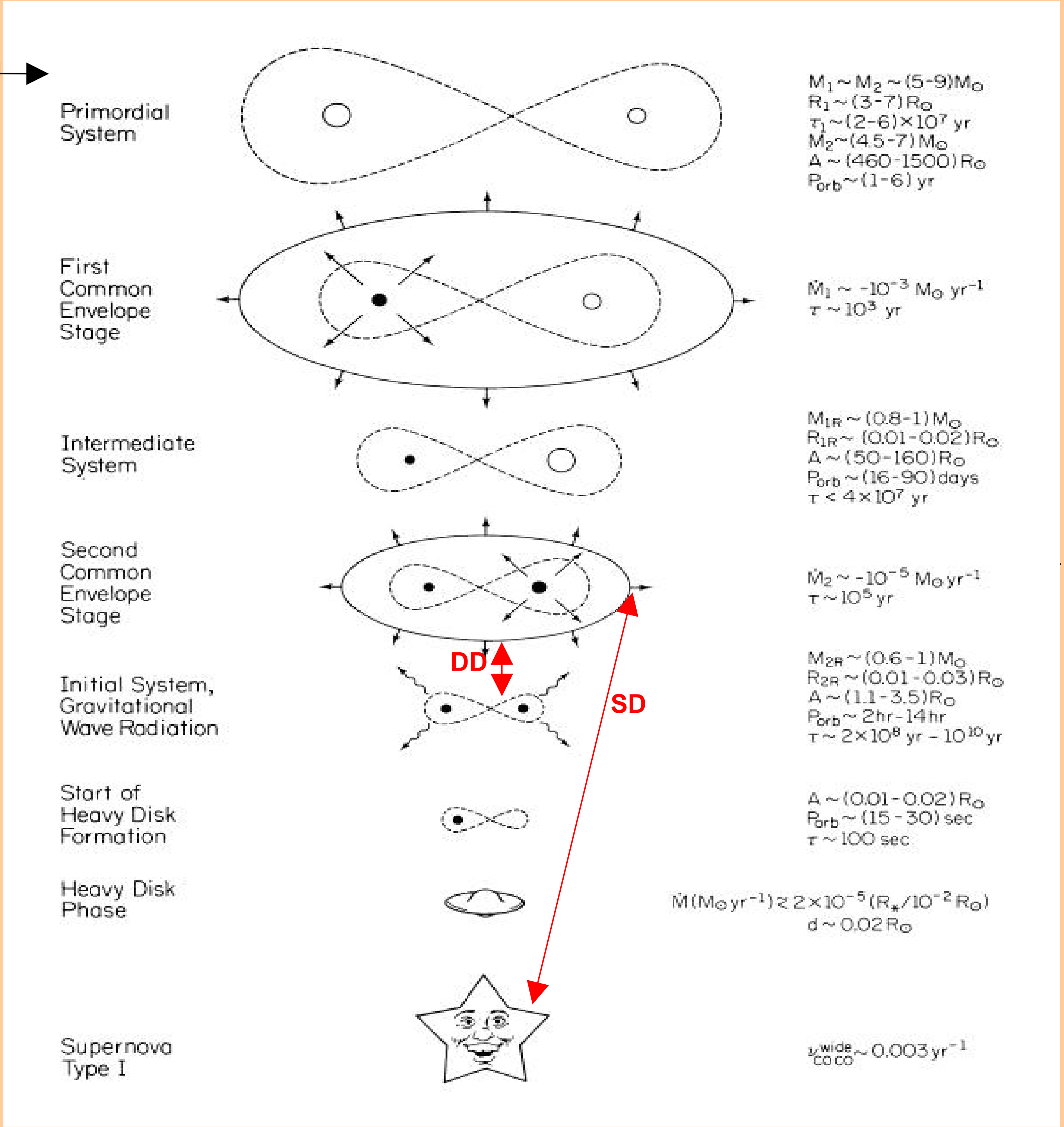
★ $\dot{n}_{Ia}^{\mathrm{ET}} \simeq 0.2\ \mathrm{SNu}$

$$\frac{\dot{n}_{Ia,SNU}^{E}}{\dot{n}_{Ia,SNU}^{L}} \simeq \frac{(\mathcal{M}/L_{\mathrm{B}})_{ET}}{(\mathcal{M}/L_{\mathrm{B}})_{LT}} \times \frac{\langle f_{\mathrm{Ia}}\rangle_{t-\Delta t,t}}{\langle f_{\mathrm{Ia}}\rangle_{\tau_n,t}}$$

$$\longrightarrow \frac{\langle f_{\mathrm{Ia}}\rangle_{t-\Delta t,t}}{\langle f_{\mathrm{Ia}}\rangle_{\tau_n,t}} \simeq \frac{(\mathcal{M}/L_{\mathrm{B}})_{LT}}{(\mathcal{M}/L_{\mathrm{B}})_{ET}} \approx 0.1$$

- SNIa rates in Late Type Galaxies can be used to constrain A_{Ia}
- SNIa rates in Early Type Galaxies can be used to constrain f_{Ia}
  The dependence of $\dot{n}_{Ia}^{\mathrm{ET}}$ with redshift reflects $f_{\mathrm{Ia}}(\tau)$

From
Iben and Tutukov, 1984
ApJS 54, 335



SINGLE DEGENERATE

CLOCK IS $\tau_{ev}(M_2)$

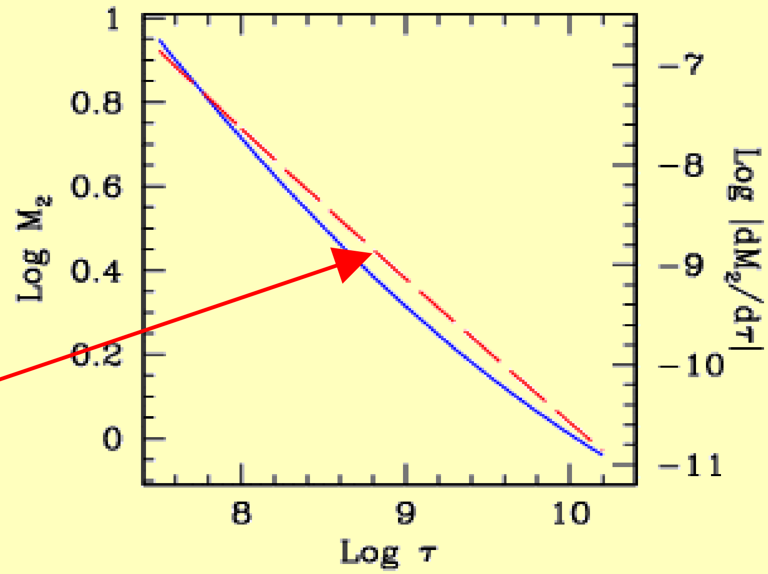
$$|\, f_{\mathrm{Ia}}(\tau)\cdot d\tau\,| \;\propto\; |\, n(M_2)\cdot dM_2\,|$$

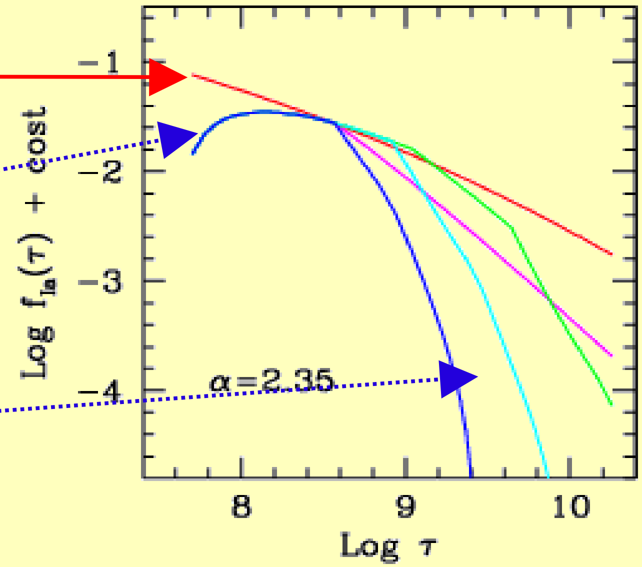
$$f_{\mathrm{Ia}}(\tau) \;\propto\; n(M_2)\times |\, \dot{M}_2\,|$$

$$n(M_2) \;\propto\; (M_2)^{-2.35}$$

$$M_1, M_2 \leq 8M_\odot$$

$$M_{WD} + \epsilon\cdot M_{2,env} \geq 1.4M_\odot$$

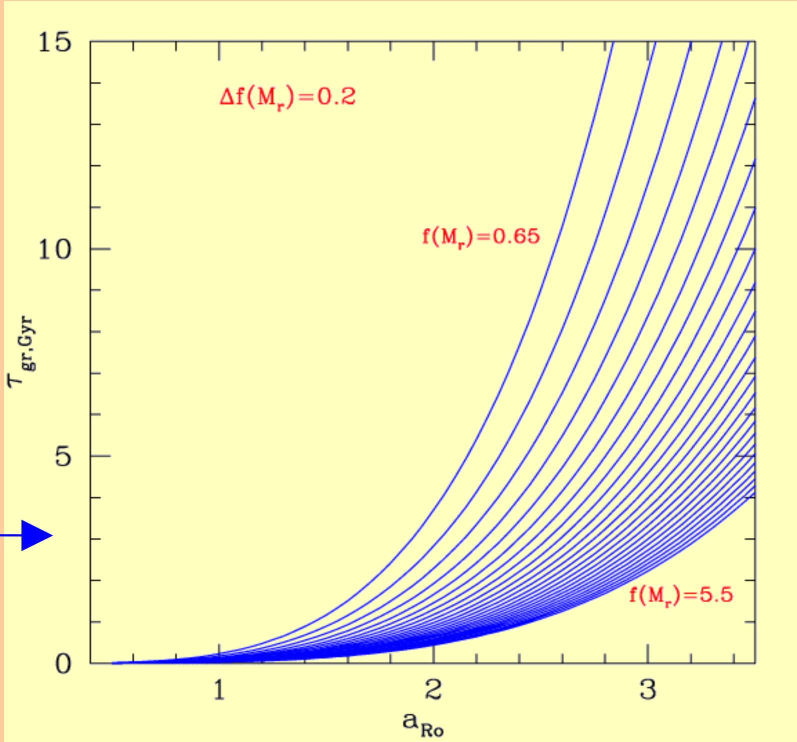




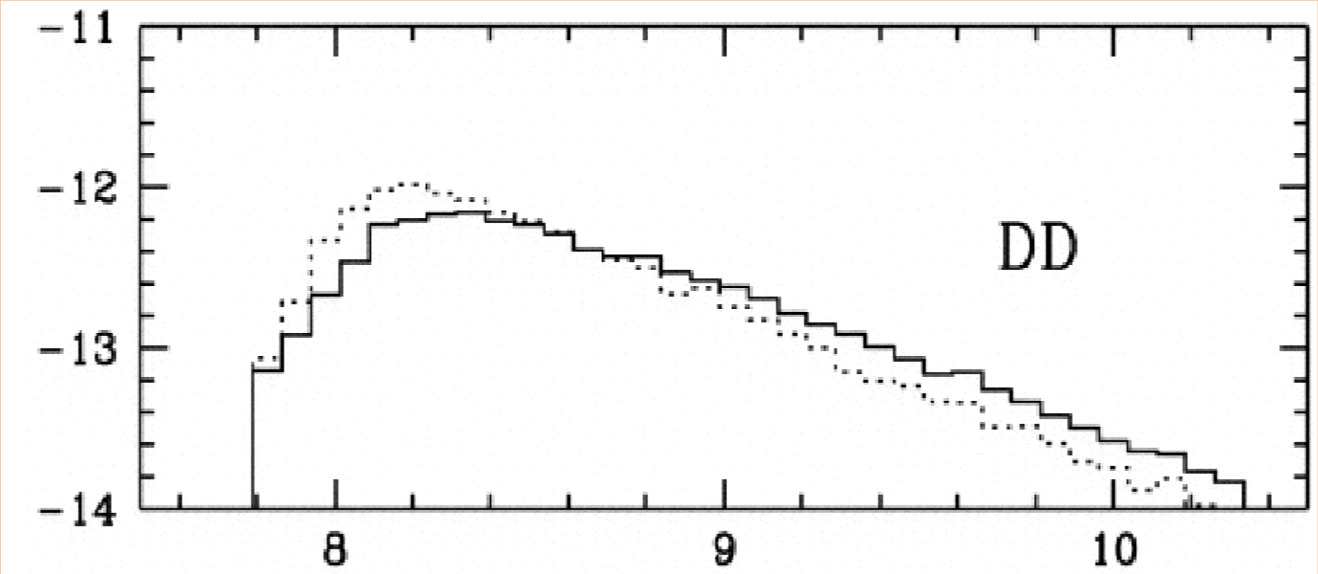
DOUBLE DEGENERATE

CLOCK IS $\tau_{ev}(M_2) + \tau_{gr}$

$$\tau_{gr} = \frac{0.15 \times (a_{ff}/R_\odot)^4}{M_{1_r} M_{2_r} (M_{1_r} + M_{2_r})}\, Gyr$$

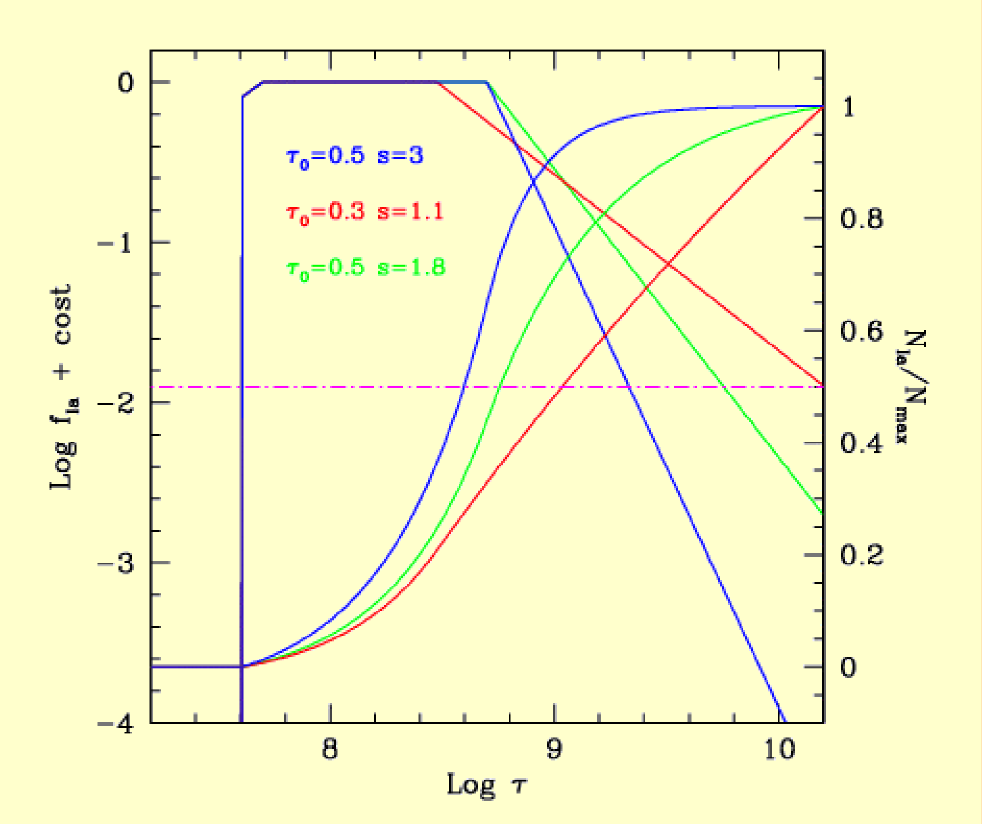


Ruiz Lapuente & Canal 1998, ApJ 497, L57



A useful parametrization:

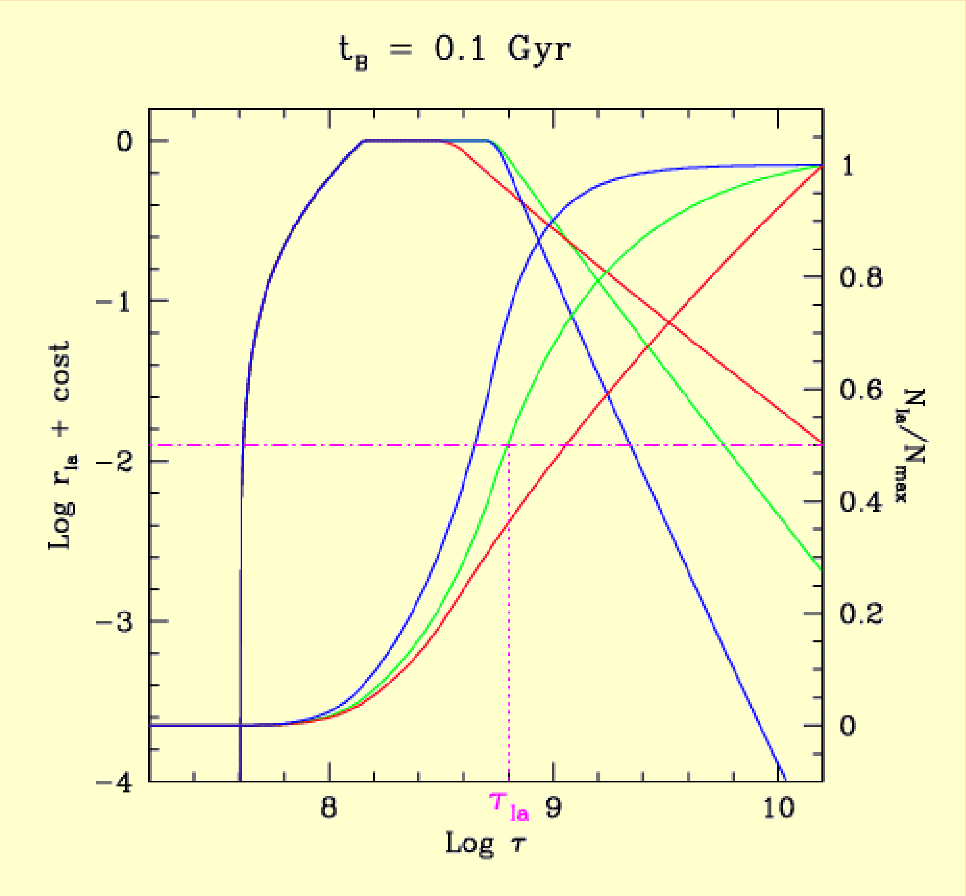
$$
f_{Ia}(\tau) \propto \begin{cases} (\tau/\tau_1)^m & in \quad \tau_n \leq \tau \leq \tau_1 \\ 1 & in \quad \tau_1 \leq \tau \leq \tau_0 \\ (\tau/\tau_0)^{-s} & in \quad \tau_0 \leq \tau \leq \tau_x \end{cases}
$$

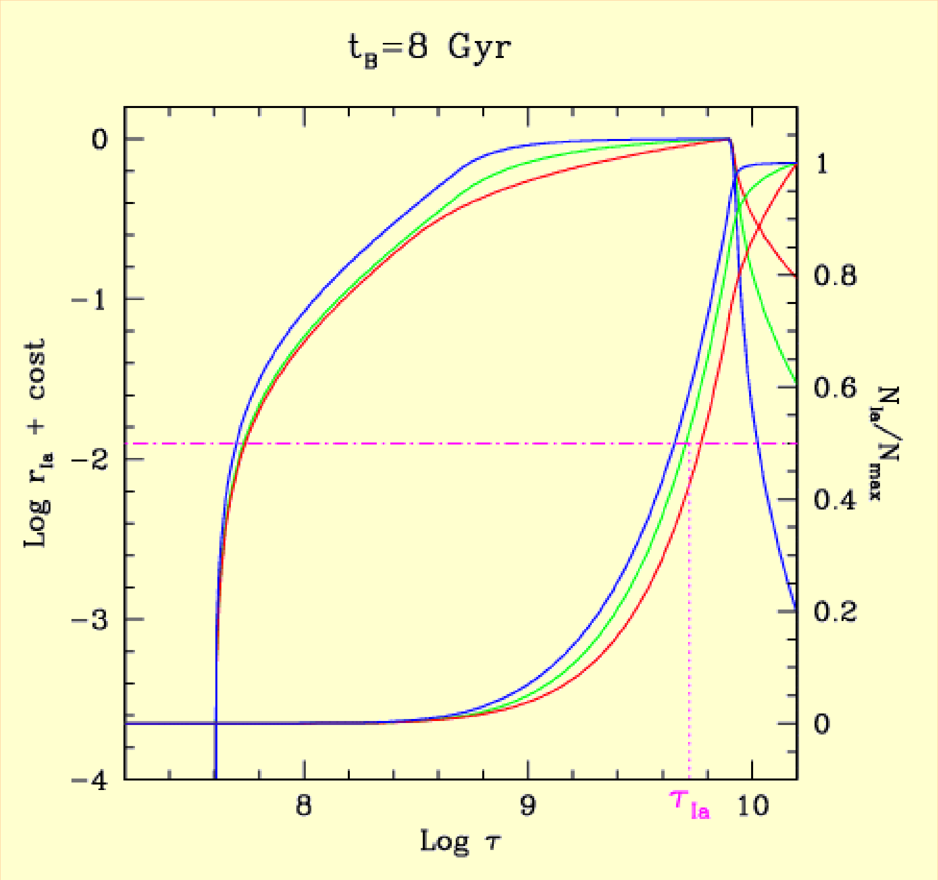


model	τ_1(Gyr)	τ_0(Gyr)	s
SD (GR83)	0.05	0.5	1.8
SD (G96)	0.05	0.8	3
DD (TM86)	0.1	0.25	1.5
DD (RC98)	0.1	0.3	1.1
SD (RBC95)	0.1	1.5	1.6

For a burst of SF:

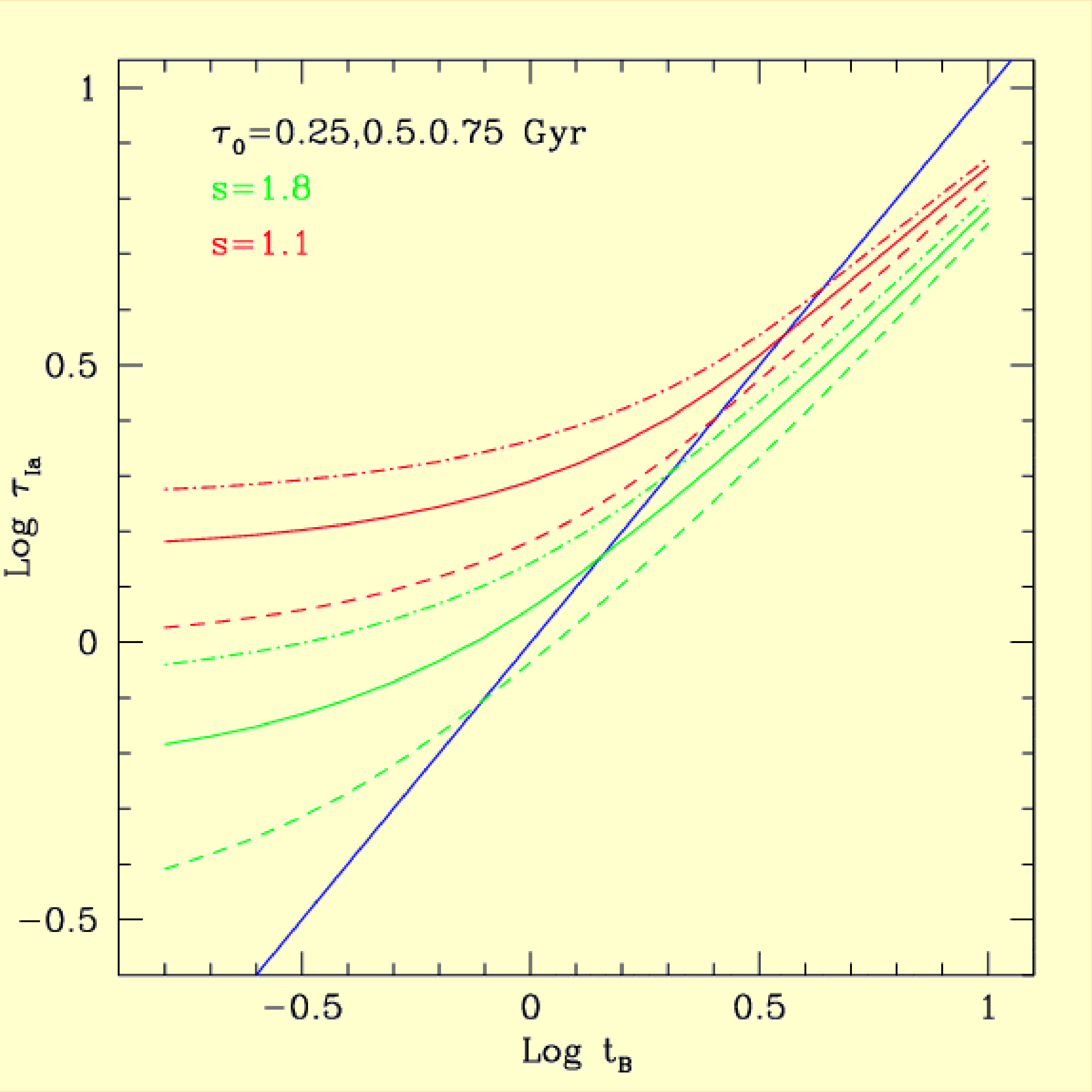
$$\dot{n}_{Ia}(t) = k_\alpha \times A_{Ia} \times \psi_0 \times \int_{t-t_B}^{t} d\tau \cdot f_{Ia}(\tau)$$





ISM pollution occurs on longer timescales for longer Burst duration

A Salomonic Criterion:
The overabundance is realized when about ½ of SNIa explode after the burst ends



Greggio, Recchi, Matteucci, in preparation

CONCLUSIONS

- τ_{Ia} is sensitive to both τ_0 and the late epochs decline slope s

- τ_{Ia} is longer for longer durations of the SF episode

  but for sufficiently large t_B the condition $\tau_{Ia} < t_B$ becomes verified

$\rightarrow$ abundance ratios DO yield info on t_B

- the constraint on t_B depends on the SNIa model

Models in the literature correspond to t_B in the range $1 \div 4$ (Gyr) to accomodate an α overabundance