A NEW METHOD TO COMPUTE THE CHEMICAL ENRICHMENT FROM MULTIPLE STELLAR POPULATIONS

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Importance of the mass return from Stellar Pop.

- In galaxies, the mass return from evolved stellar pop. (SP) represents a non-negligible fraction of the total baryonic budget (20-30 % for standard IMFs)

Importance of the mass return from Stellar Pop.

Various Examples:

- Generally important for the enrichment of the ISM
- Mass accretion onto super-massive black holes
- Multiple SP in globular clusters

Mass return from a SSP

$\phi(m)$ Is the IMF (in number)

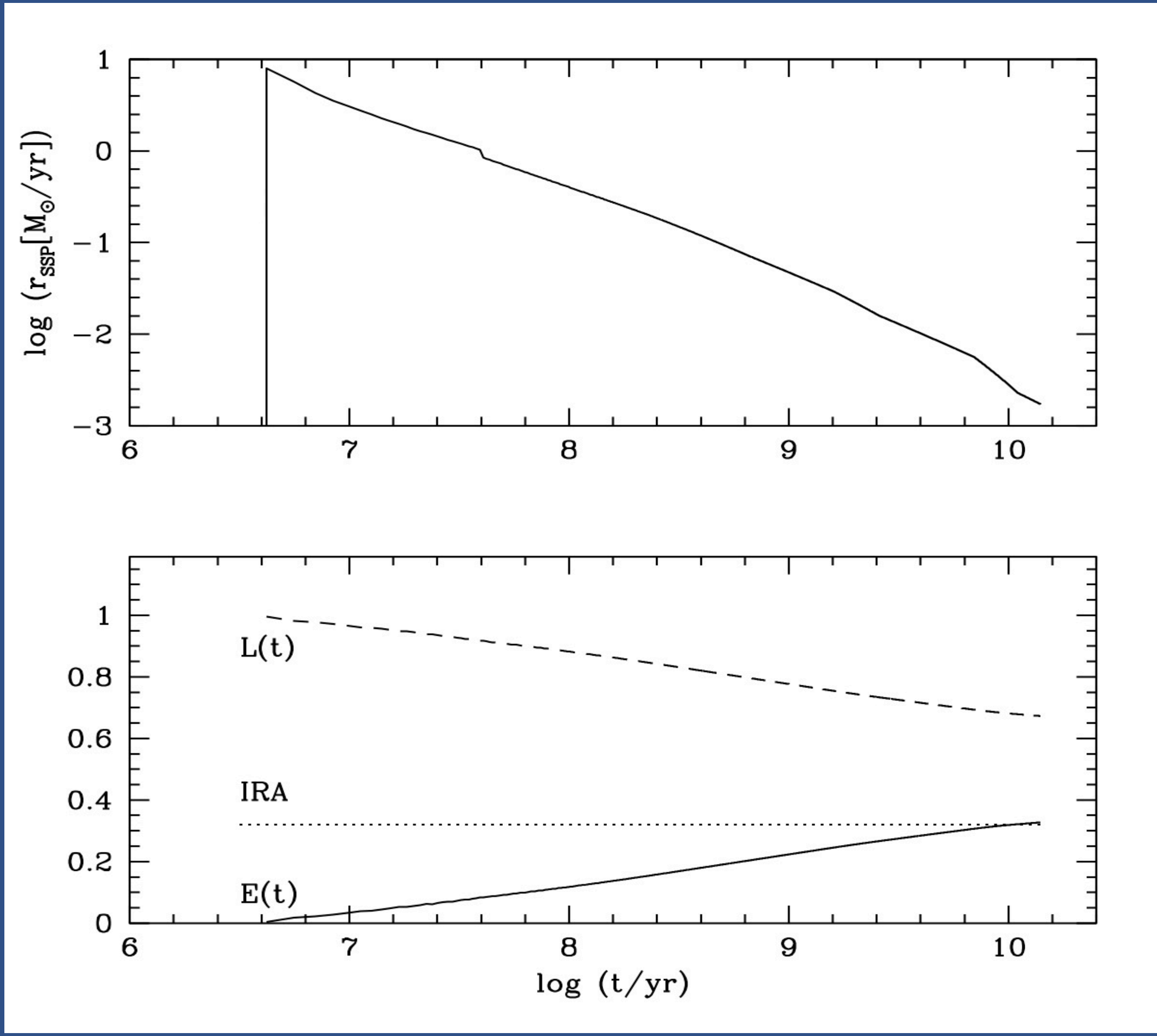
$m(t)$ Is the mass of the star going off the MS @ t

M_{ej} Is the tot. mass ejected by a star of mass m

$$r_{SSP}(t) = \phi[m(t)] \times M_{ej}[m(t)] \times |\dot{m}(t)|$$

(Ciotti et al. 1991)

Mass return from a SSP



(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The mass return from Composite Stellar Populations

- In general, in galaxies we have composite stellar populations, i.e. collections of SSPs of various masses & metallicities
- The evaluation of the MRR requires storing the star formation history and the metallicity of each SSP ever born

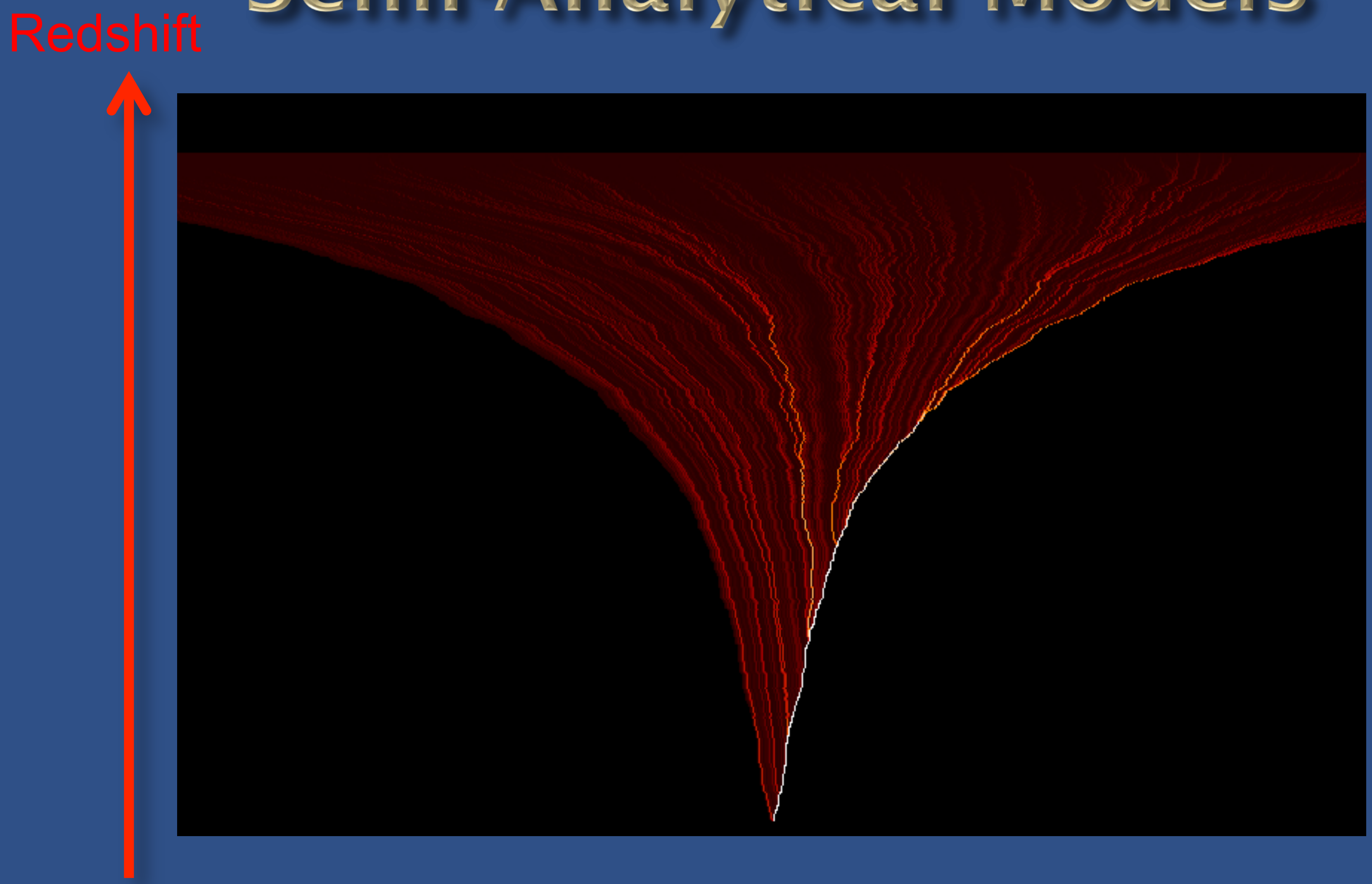
➔ Can be computationally expensive

Mass return from CSPs

$\psi(t)$ Is the star formation rate

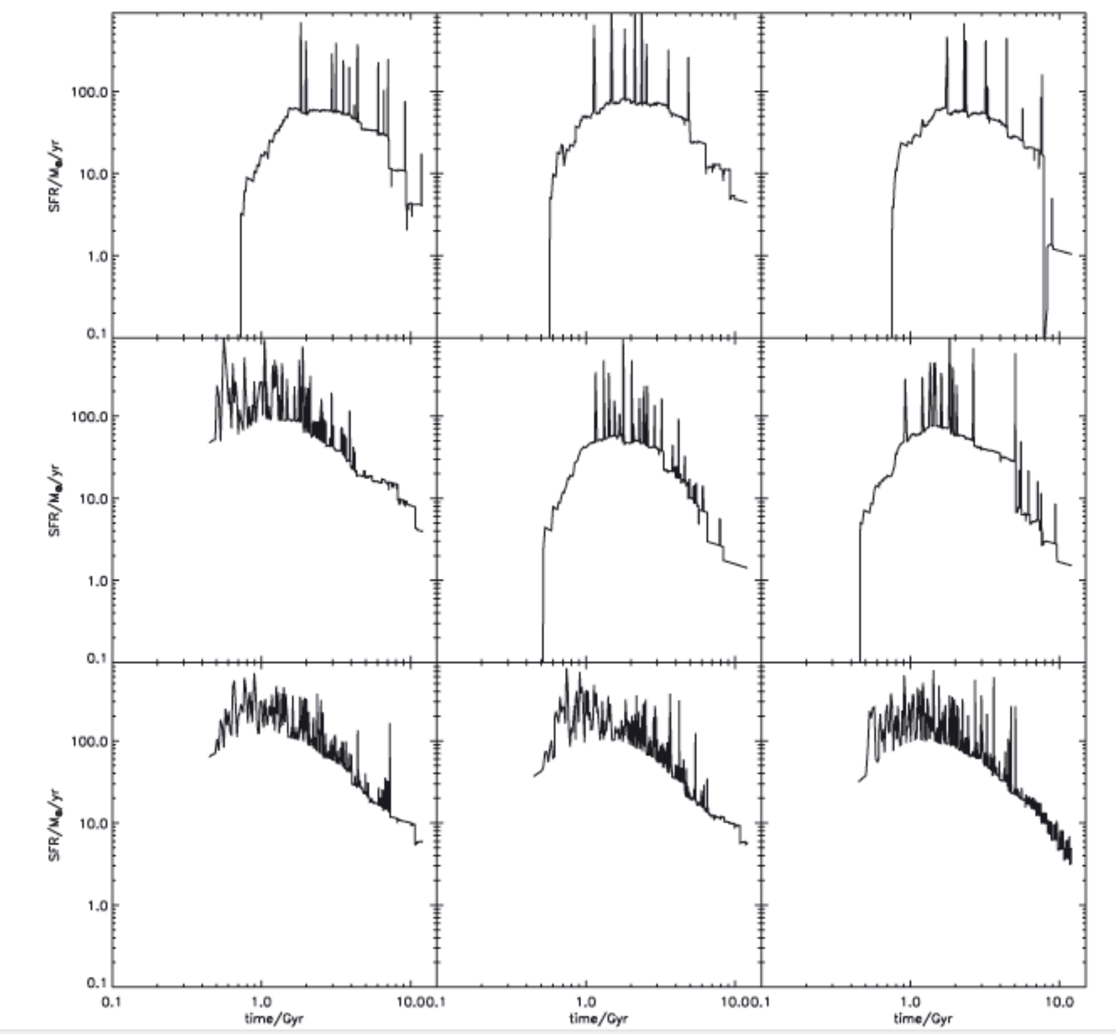
$$R(t) = \int_0^t \psi(\tau)\, r_{SSP}(t-\tau)\, d\tau.$$

Semi-Analytical Models



Example of a complex merger tree (courtesy of N. Menci)

Semi-Analytical Models



FC & Menci 2009

A question since the dawn of Chemical Evolution

Can we compute the MRR from a complex SFH without storing the SFH itself?

Mass return from CSPs

If $R(t)$ is computed by direct sum (i.e. in the discrete, realistic case) , we have

$$T_{CPU} \propto N_{step}^2$$

With our new method, we have

$$T_{CPU} \propto N_{step}$$

The new method

The idea is to use functions with special properties, i.e. functions of the type

$$t^n \cdot e^{\beta \cdot t}$$

to fit the mass return rate of a SSP.

Simplest case: $n = 0$

(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method

Suppose that we can write

$$r_{SSP}(t) = \sum_i^k \alpha_i e^{-\beta_i t}$$

Where α_i, β_i are determined by fitting the exact $r_{SSP}(t)$

(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method

Now we can write

$$R(t) = \sum_i^k \alpha_i I_i^{(0)}(t)$$

Where

$$I_i^{(0)}(t) = \int_0^t \psi(t) e^{-\beta_i (t-\tau)} d\tau$$

(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method

For simplicity, let us drop the subscript index i. It is straightforward to show that, for a generic time interval Δt

$$I^{(0)}(t+\Delta t) = e^{-\beta \Delta t} I^{(0)}(t) + J^{(0)}(t, \Delta t)$$

Computed @ previous timestep

(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method

And

$$J^{(0)}(t,\Delta t) \sim \frac{\Delta t}{2}[\psi(t+\Delta t) + \psi(t)e^{-\beta\Delta t}]$$

Note the dependence on SFR computed at the current-time!

(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method

$$I^{(0)}(t + \Delta t) = e^{-\beta \Delta t} I^{(0)}(t) + J^{(0)}(t, \Delta t)$$

In practice, at time $t + \Delta t$, each term of the sum can be calculated iteratively from the values at time t, plus a contribution $J^{(0)}$ due to the star formation over the last time interval only

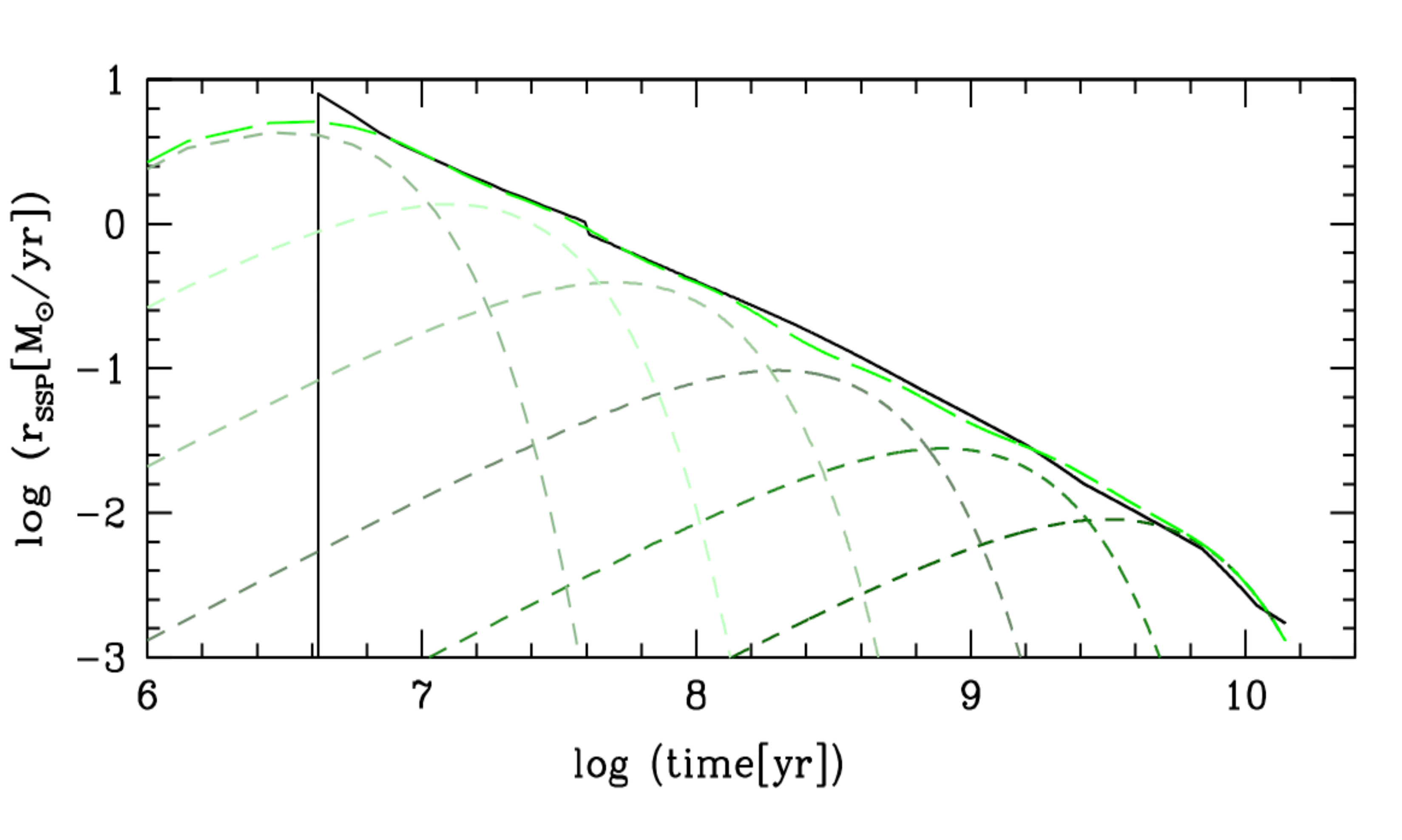
(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

- In principle, one can use more complex functions for the fit
- In this case, the scheme is different (see our work). Here, we choose *n=1,* i.e. we fit $r_{SSP}(t)$ as a combination of functions

$$t \cdot e^{-\beta t}$$

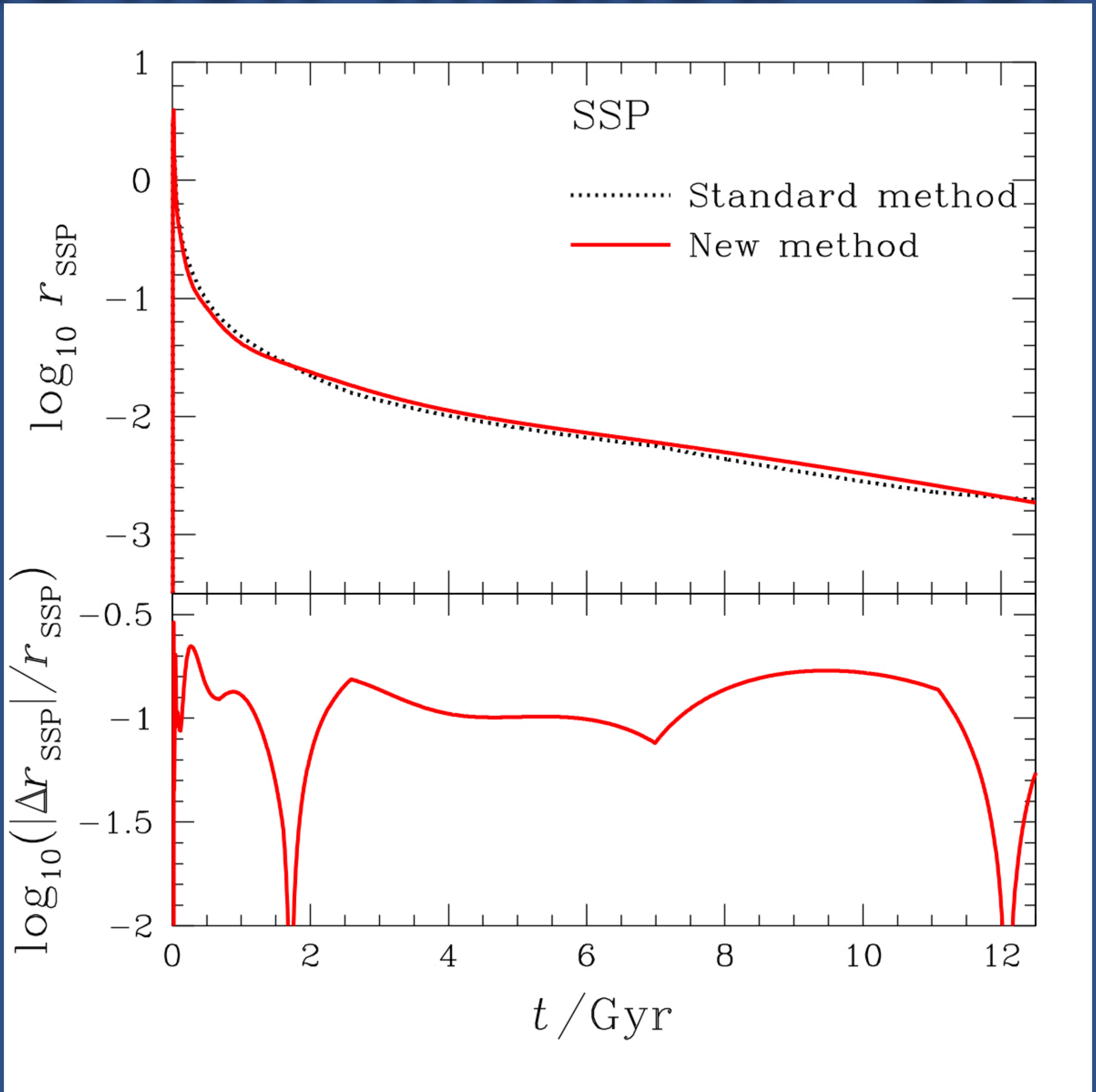
(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method – SSP case



(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method – SSP case



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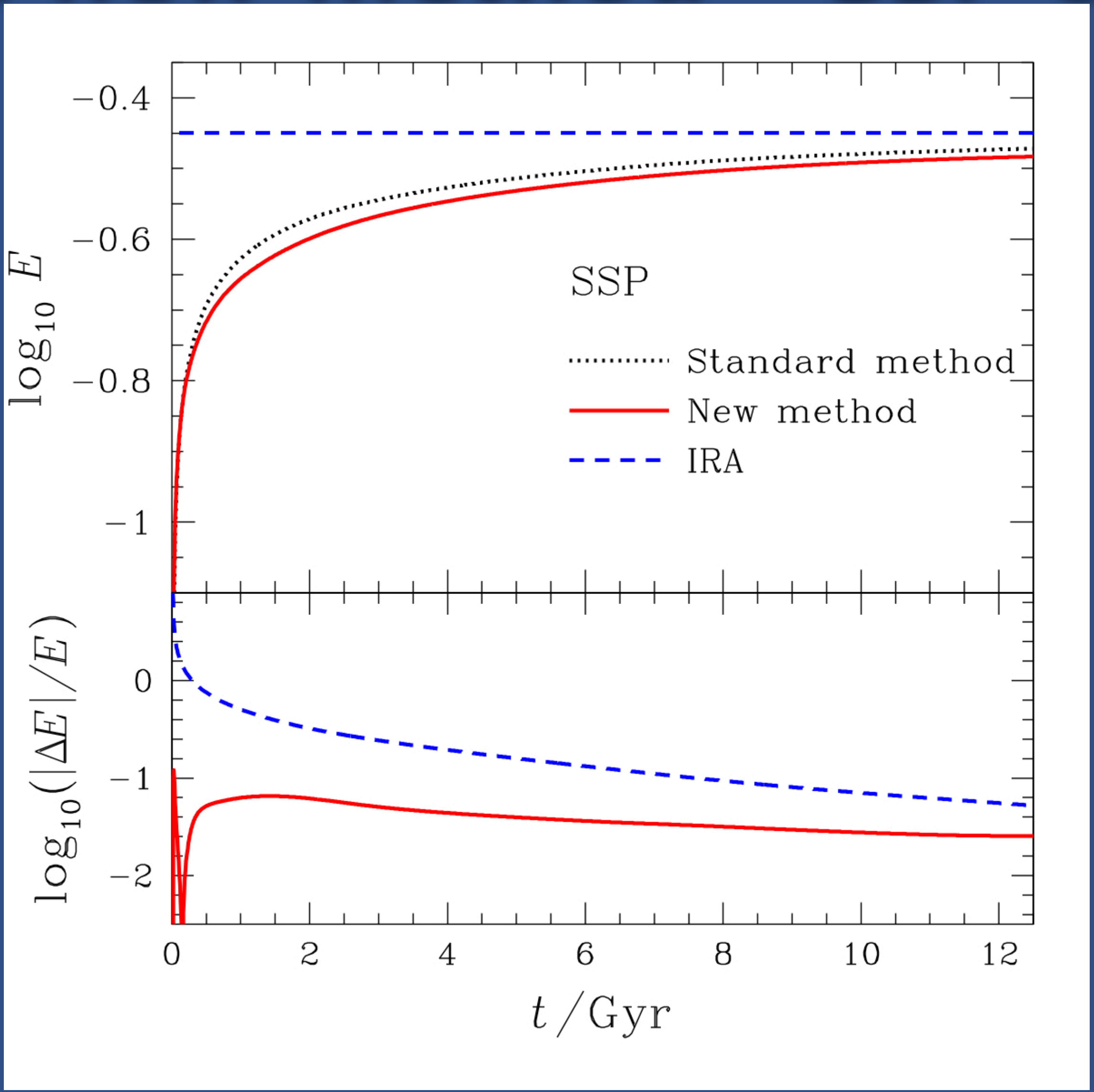
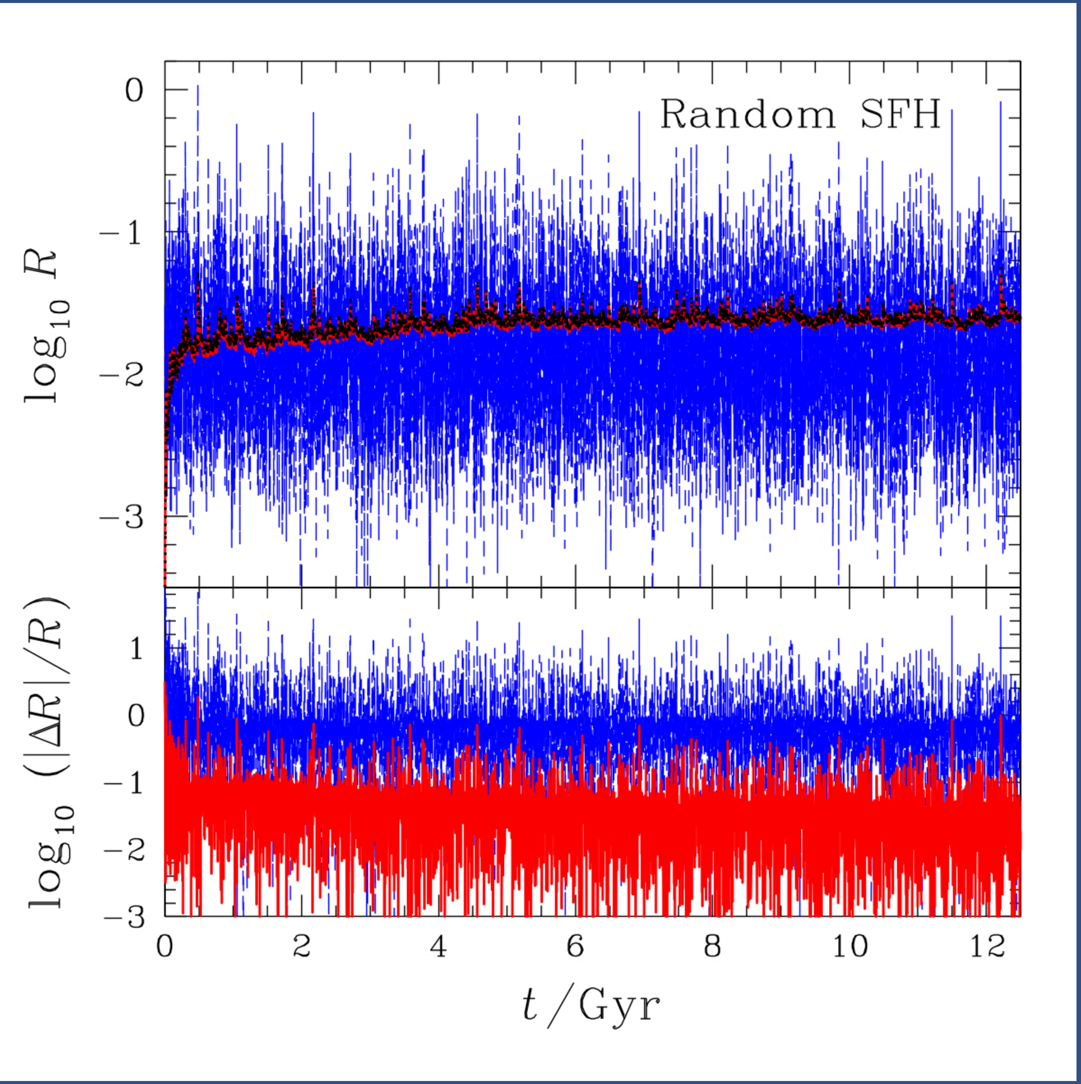


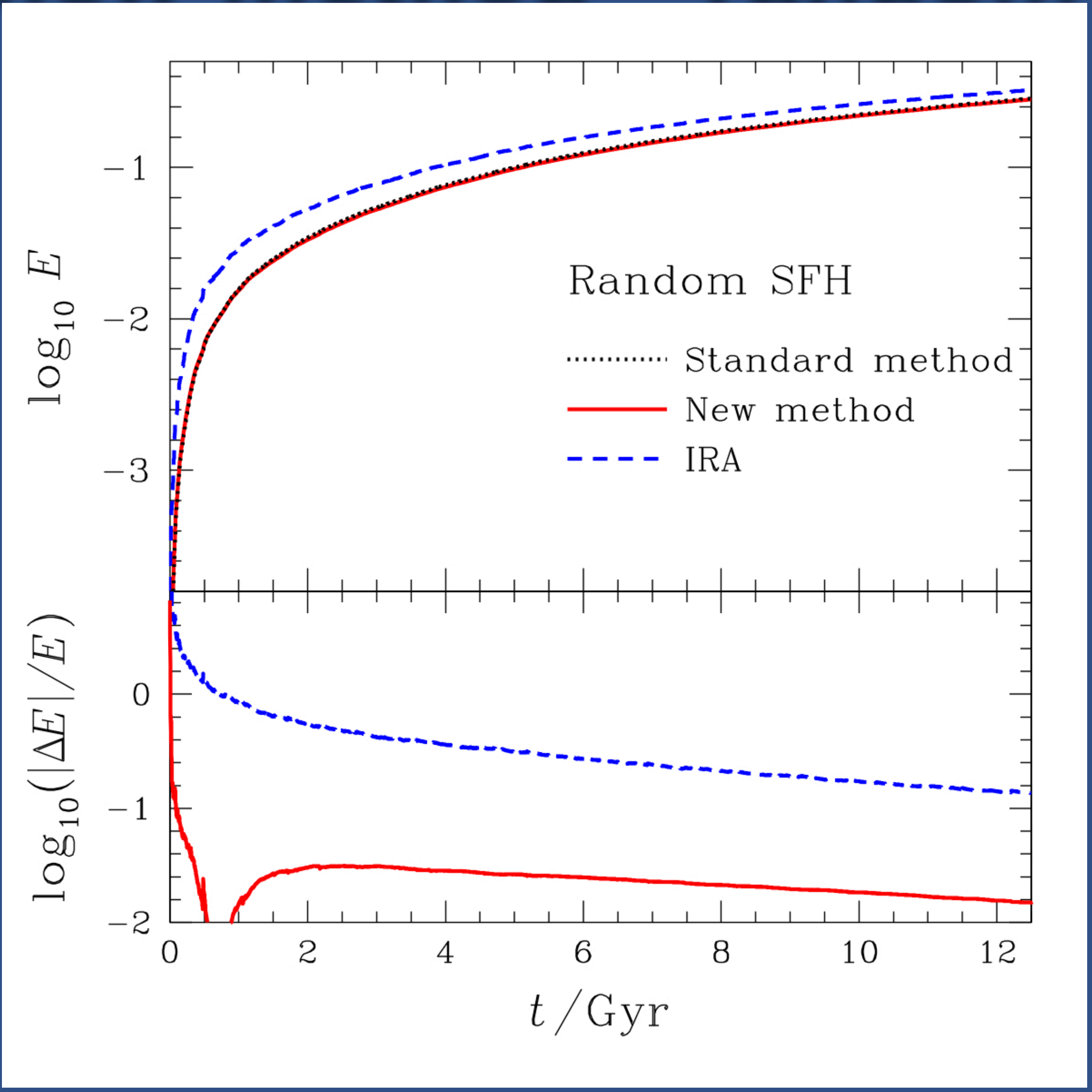
(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method – random SFH



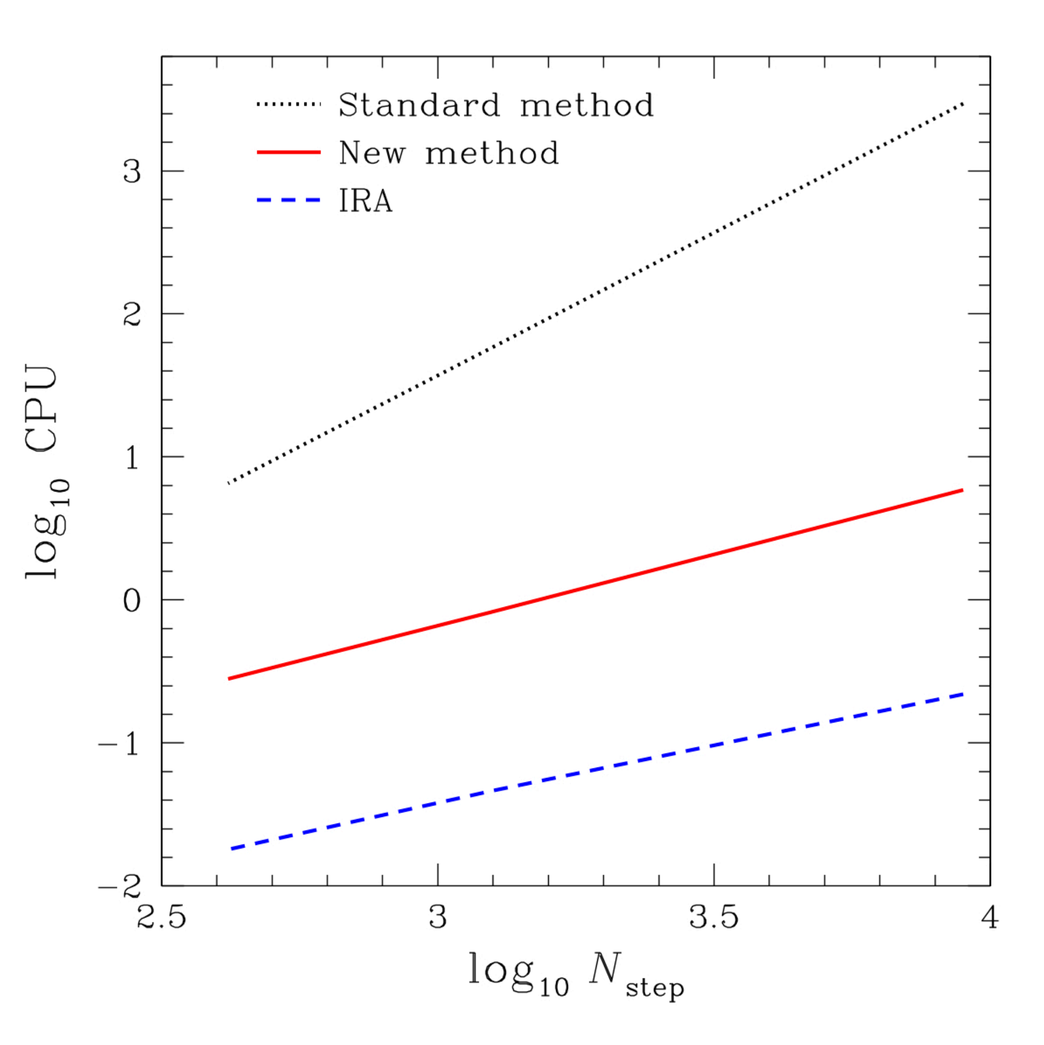
(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

The new method – random SFH



(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

Computational advantages of the new method



(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

Computational advantages of the new method

A step forward in terms of CPU time…

(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

Computational advantages of the new method

With the standard method, we have:

$$T_{CPU} \propto N_{step}^2$$

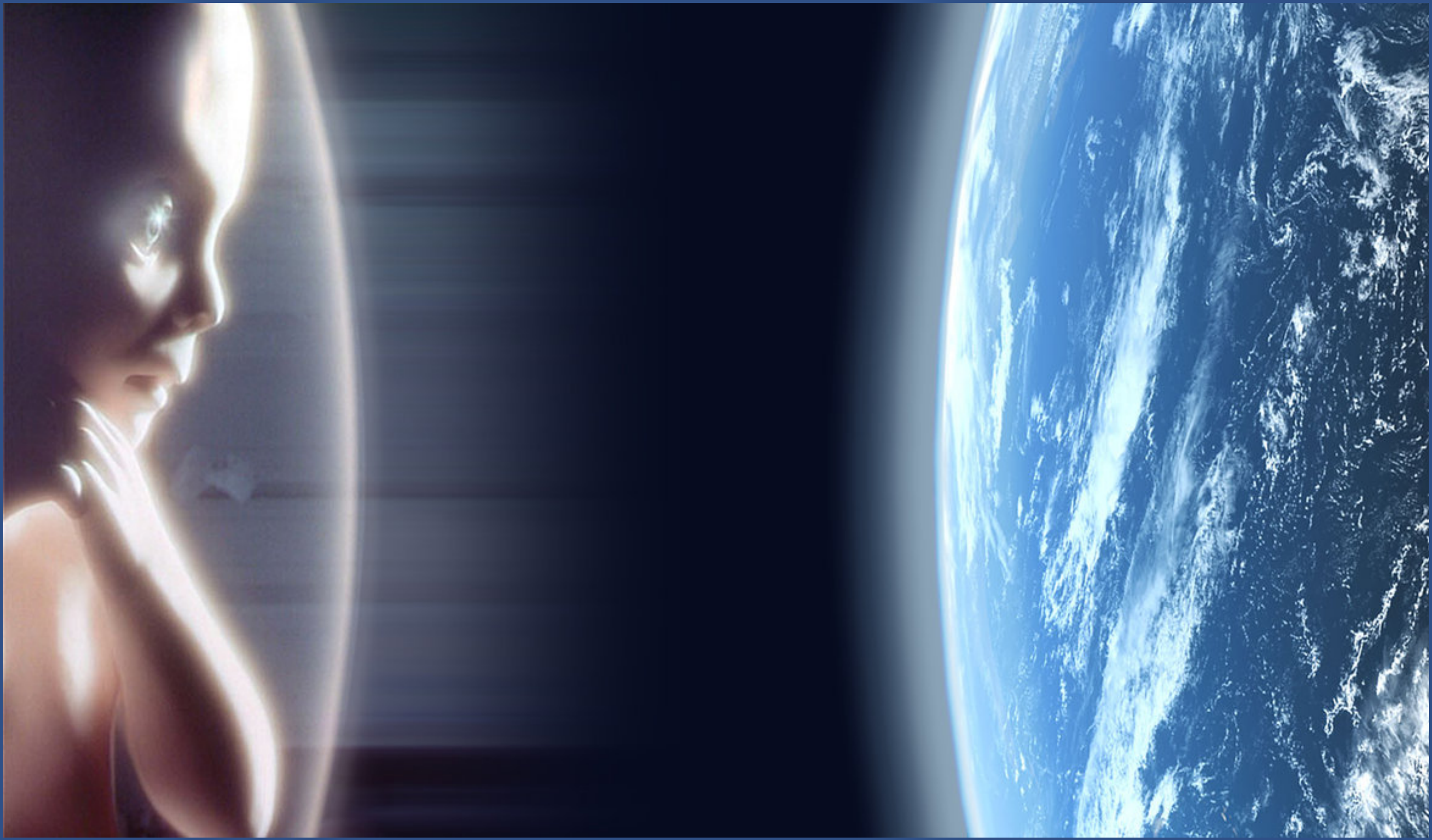
With our new method, we have

$$T_{CPU} \propto k\,(n+1)\,N_{step}$$

k functions for the fit, *n* integrals *J(0)….J(n)*

(FC, Ciotti, Nipoti, 2014, MNRAS, 440, 3341)

Future applications



Type Ia Sne in Semi-analythical models

$$R_{SNe\,Ia}(t) \propto \int_0^t \psi(\tau)\, DTD(t-\tau)\, d\tau.$$

(Greggio 2005; FC & Matteucci 2006)

- Chemical feedback (most of all important for Fe production)
- Energetic feedback

Feedback in SAMs

- Type II SN feedback:

$$\Delta E = \epsilon_0 \, E_{SN} \, \eta \, \psi(t) \, dt$$

$\epsilon_0 \quad \sim 0.01$ Transfer efficiency into ISM

$\eta \sim 7 \cdot 10^{-3} 1/M_{\odot}$ (Depends on IMF)

$$E_{SN} = 10^{51} erg$$

Feedback in SAMs

- Type Ia SN feedback:

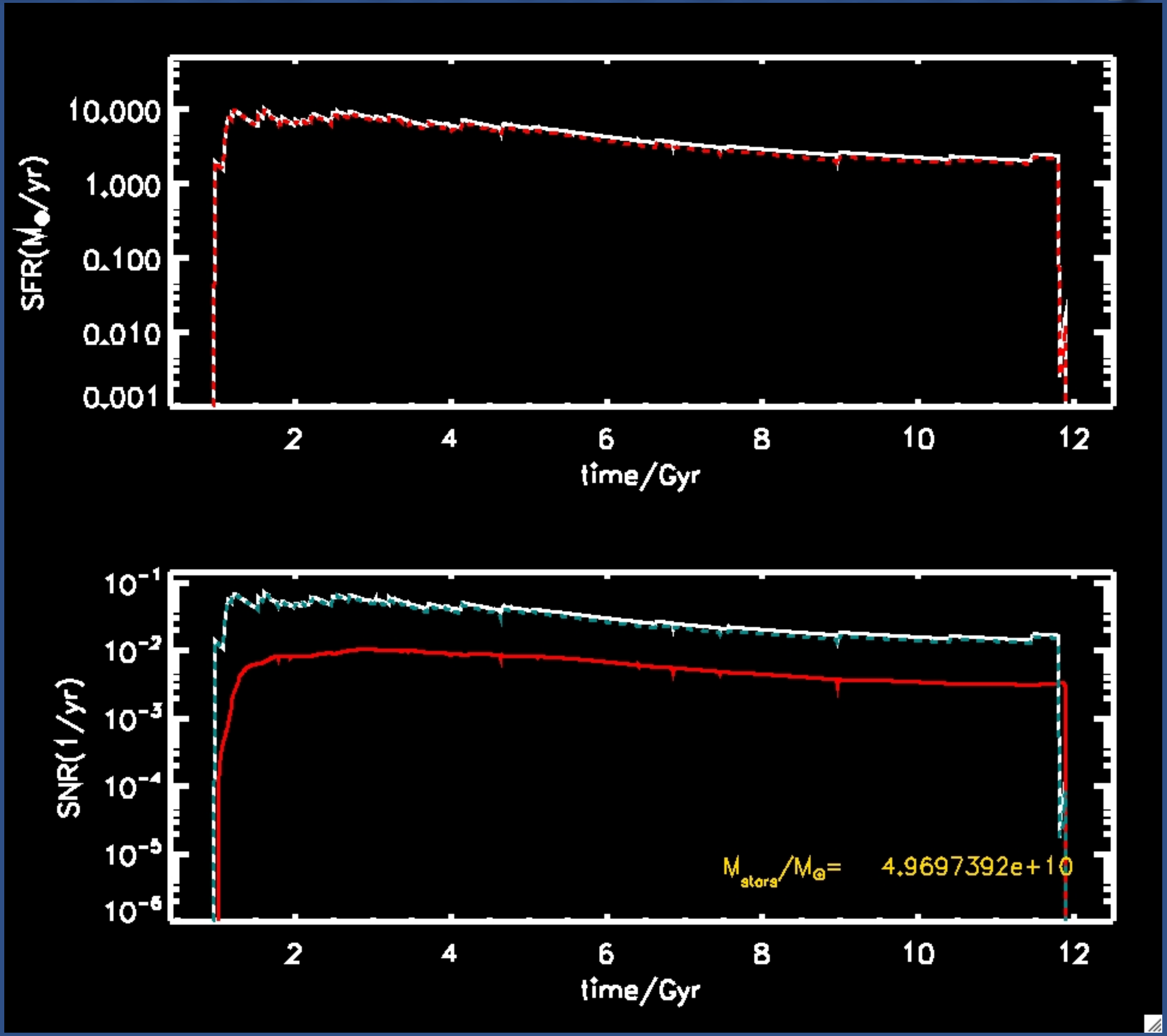
$$\Delta E = \epsilon_0 \, E_{SN} \, R_{SNe\,Ia} \, dt$$

$\epsilon_0 \;>> 0.01?$ Radiative losses may be much less significant (hot, tenuous ISM)

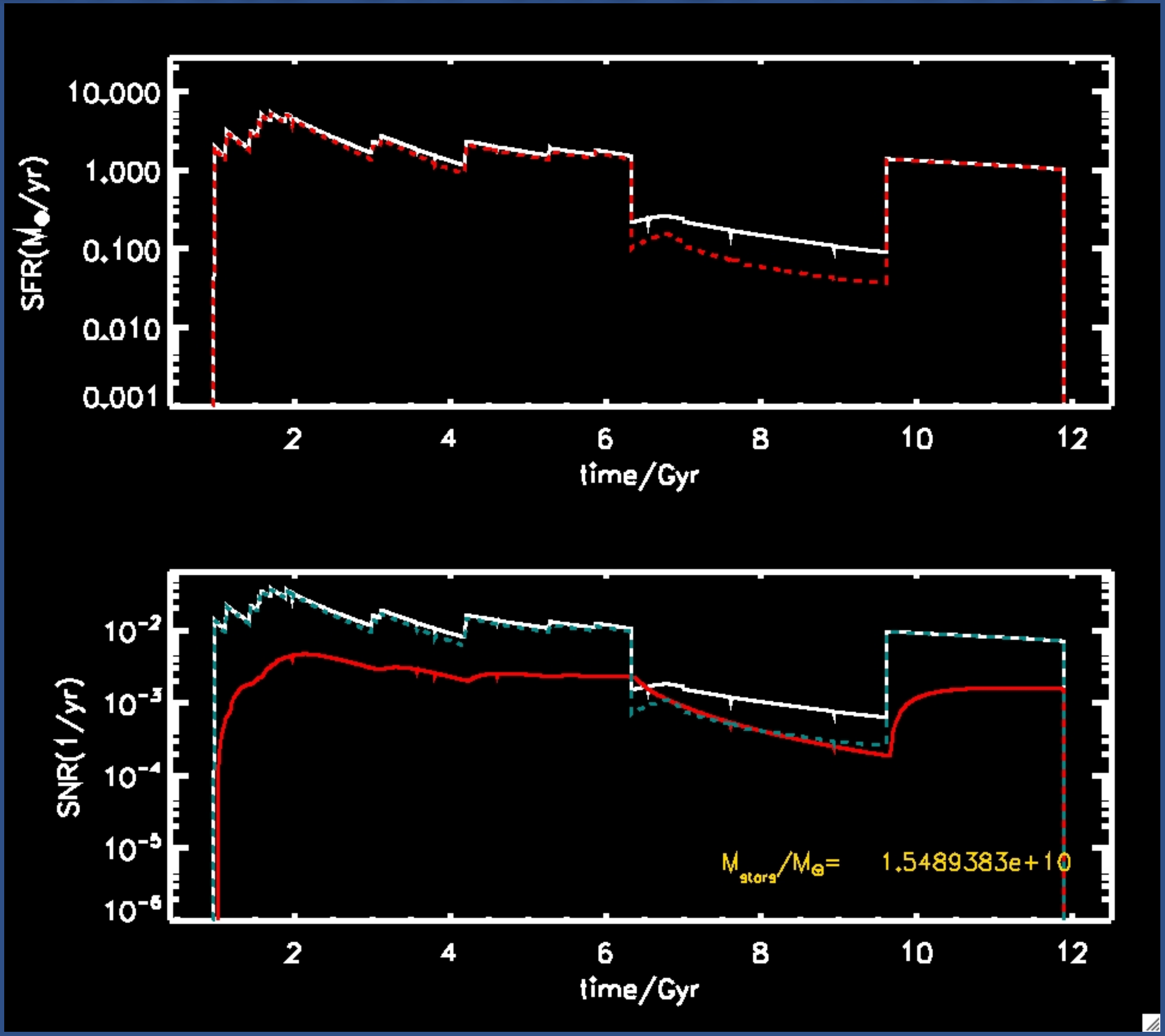
$R_{SNe\,Ia}$ Cannot be computed with I.R.A.!

$$E_{SN} = 10^{51} erg$$

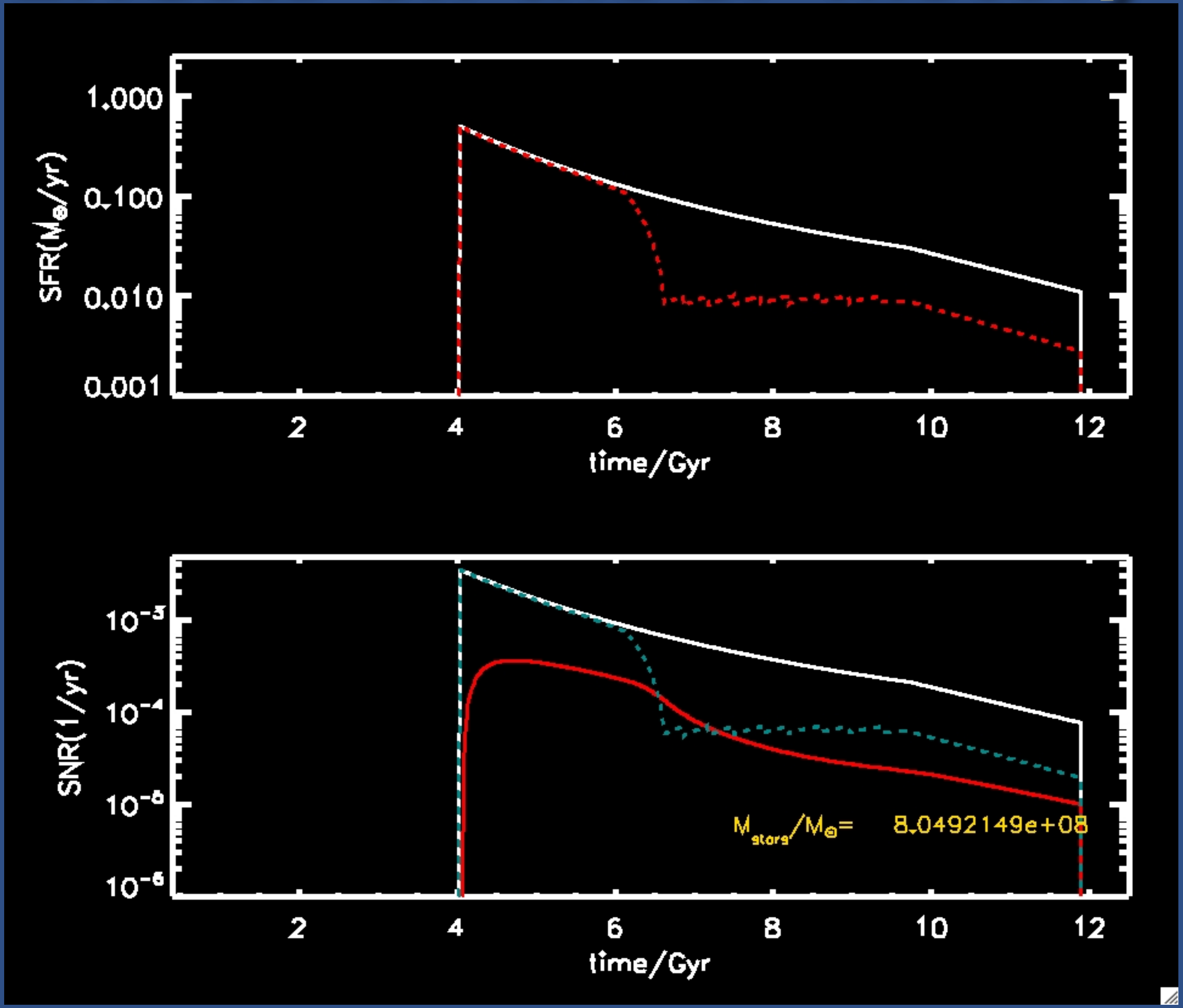
Type Ia SN feedback
Effects on the SF history



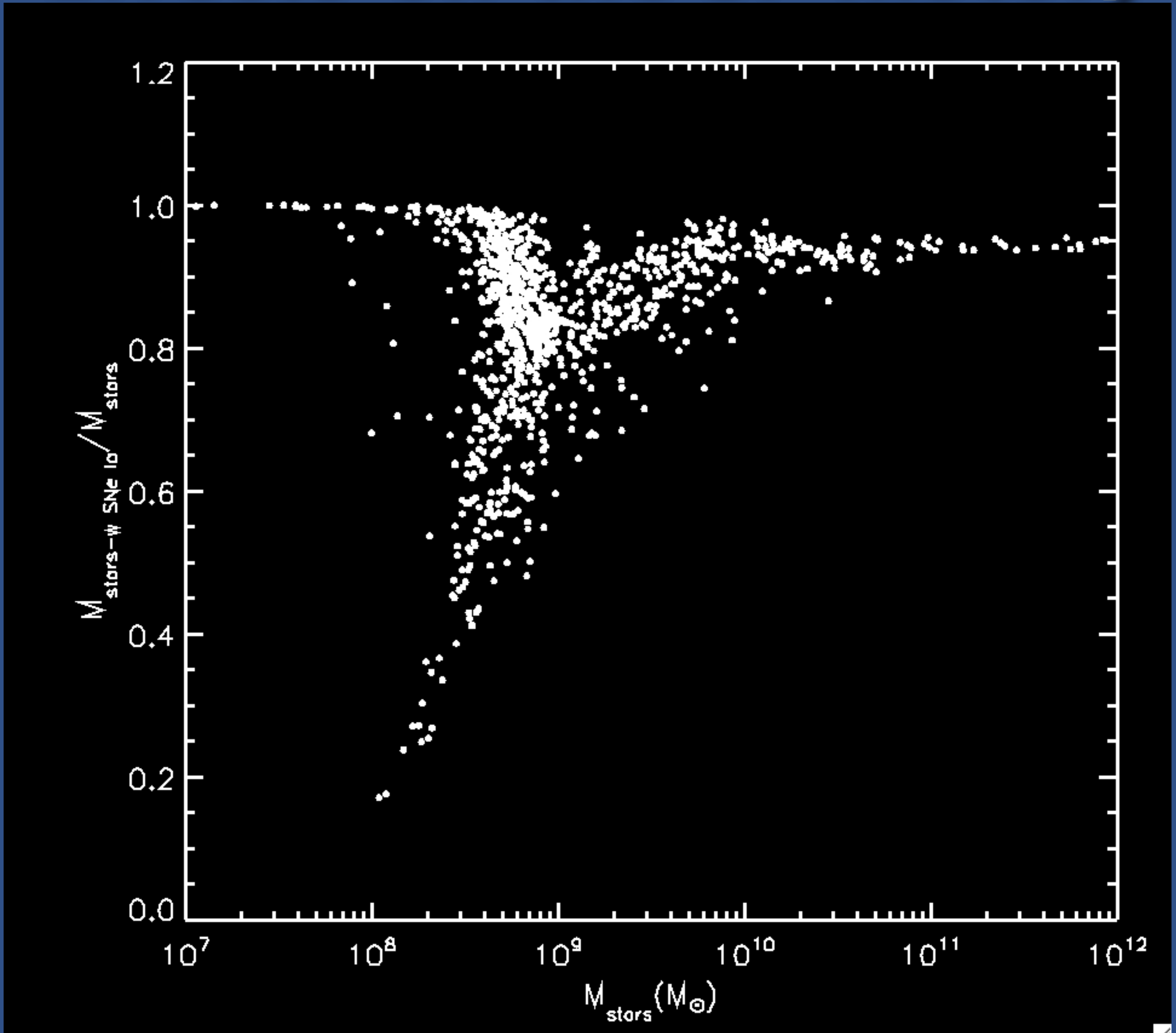
Type Ia SN feedback
Effects on the SF history



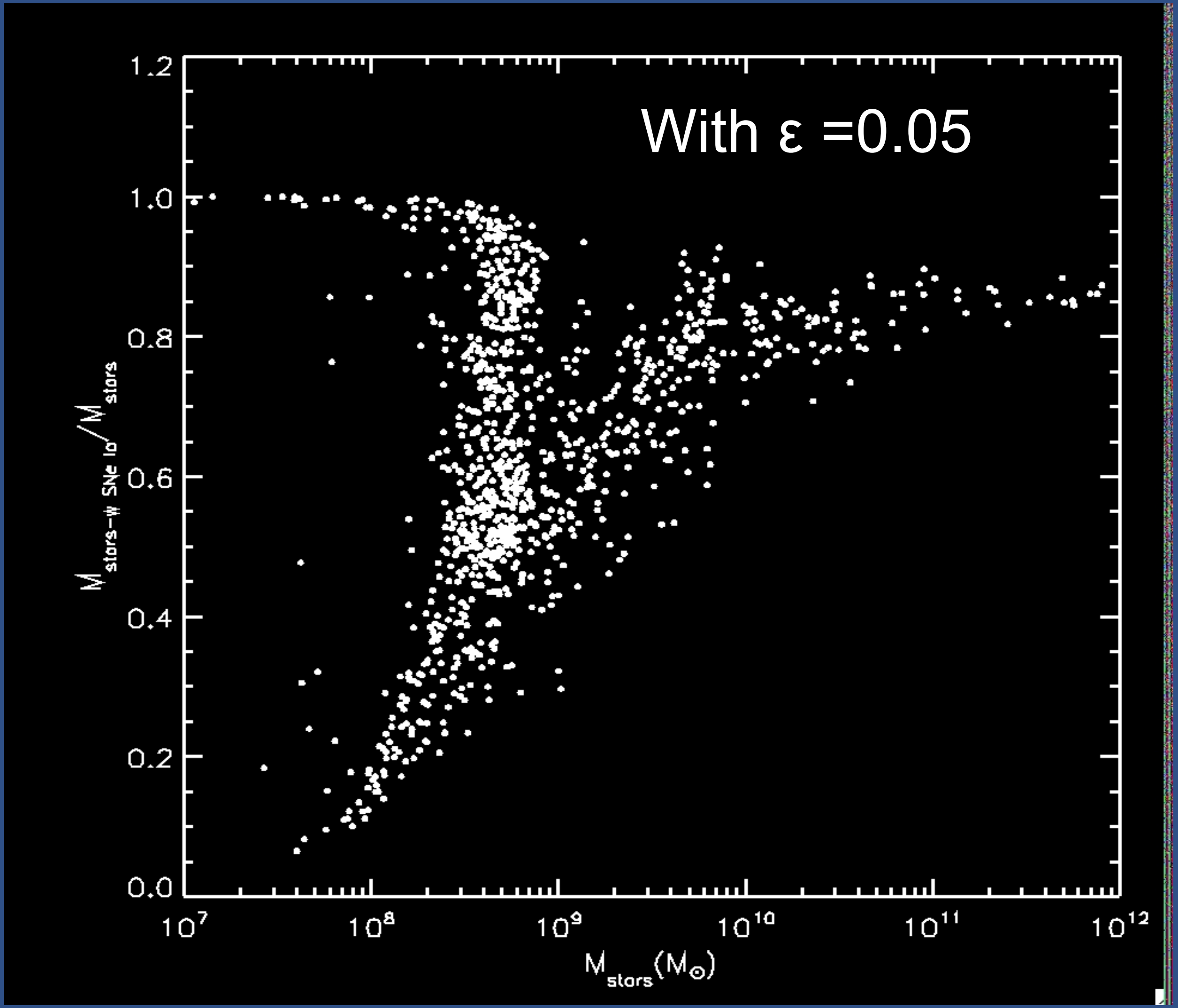
Type Ia SN feedback
Effects on the SF history



Type Ia SN feedback
Effects on the SF history

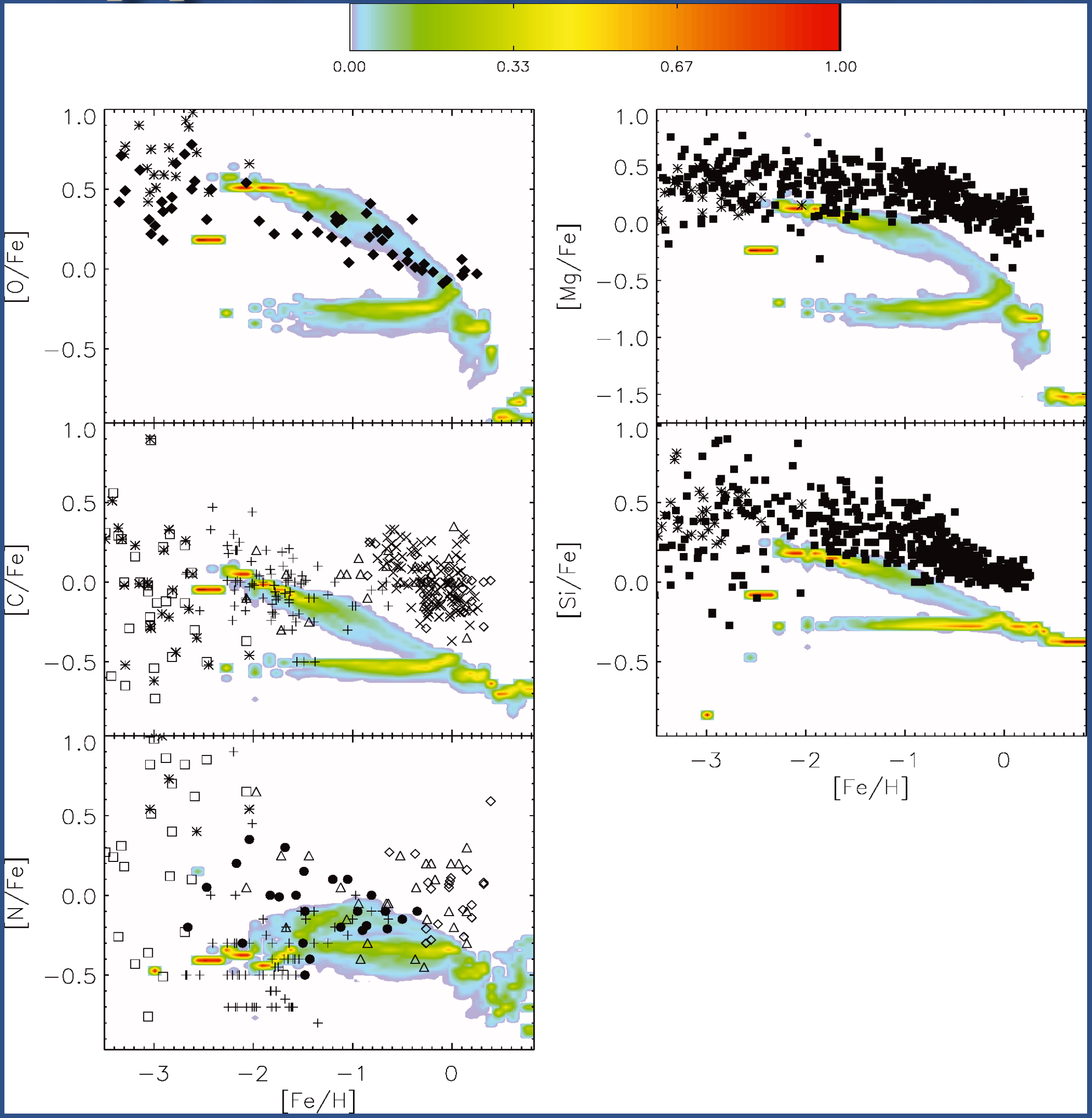


Type Ia SN feedback
Effects on the SF history



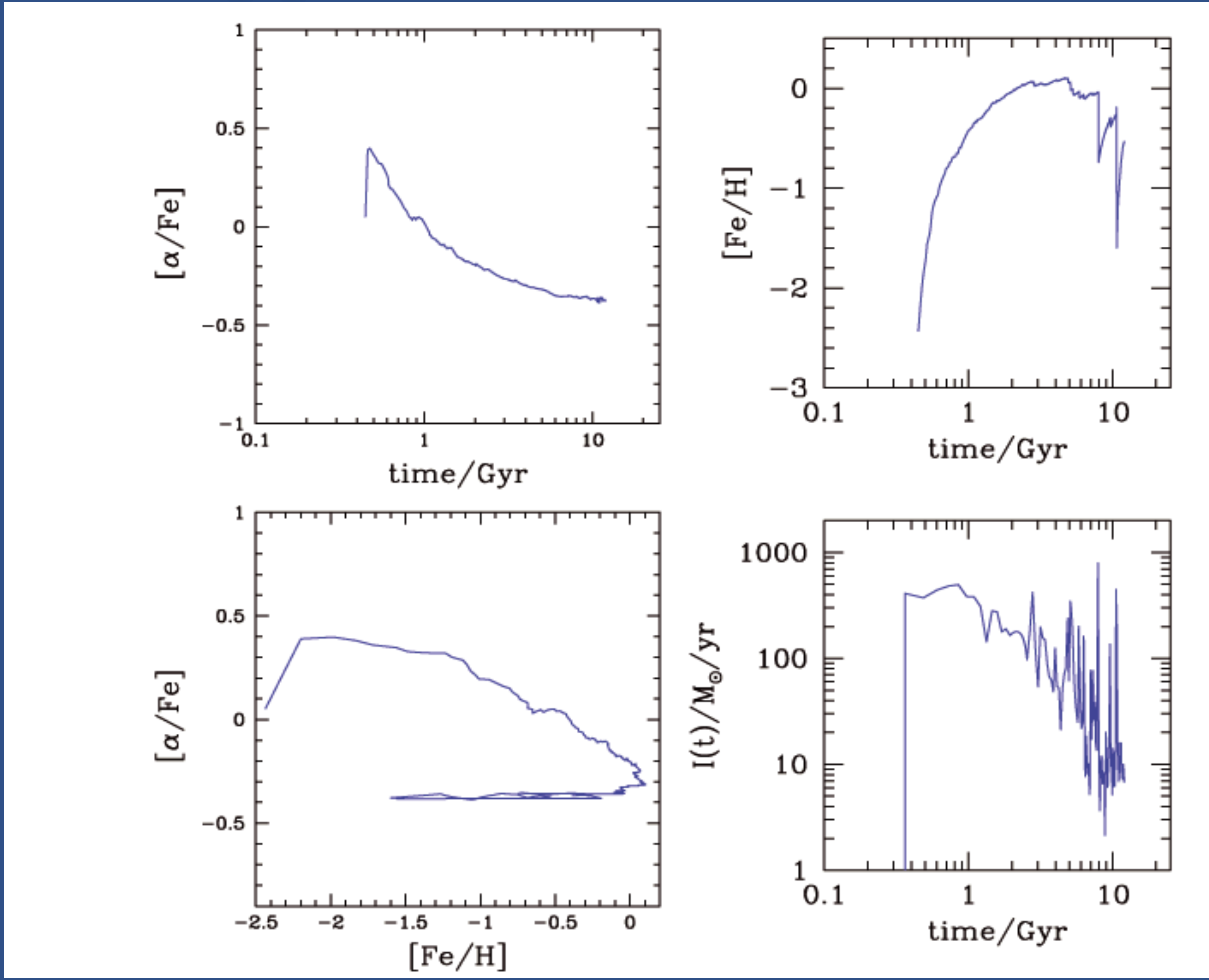
Abundance ratios in the disc

Type Ia SNe in SAMs



Calura & Menci, 2009, MNRAS, 400, 1347

Type Ia SNe in SAMs



Calura & Menci, 2009, MNRAS, 400, 1347

Conclusions

- Important to take into account mass loss from evolved stellar pop. in models
- Our new method to implement GCE allows one to save some CPU time
- Type Ia SNe may produce non-negligible feedback
- Our method useful also for type Ia SNe