Effects of galactic fountains and metal cooling in the chemical evolution of the Milky Way

Emanuele Spitoni
PhD student
Dipartimento di Astronomia
Università degli Studi di Trieste

(in collaboration with F. Matteucci, S. Recchi, G. Cescutti, A. Pipino)

Outline

- The relaxation of the instantaneous mixing approximation
- The galactic fountain time delay model and results
- The metal cooling delay model and results
- Conclusions

The relaxation of the instantaneous mixing approximation (IMA)

- Most of the chemical evolution models adopt the IMA. In the past there have been only a few attempts to relax the IMA because of:
  - Difficulties in estimating the dispersion time and mixing of the chemical elements (Roy & Kunth 1995)
  - Models which retain IMA provide an excellent fit of the data in the MW (François et al. 2004)

Two possible causes for the relaxation of the IMA:

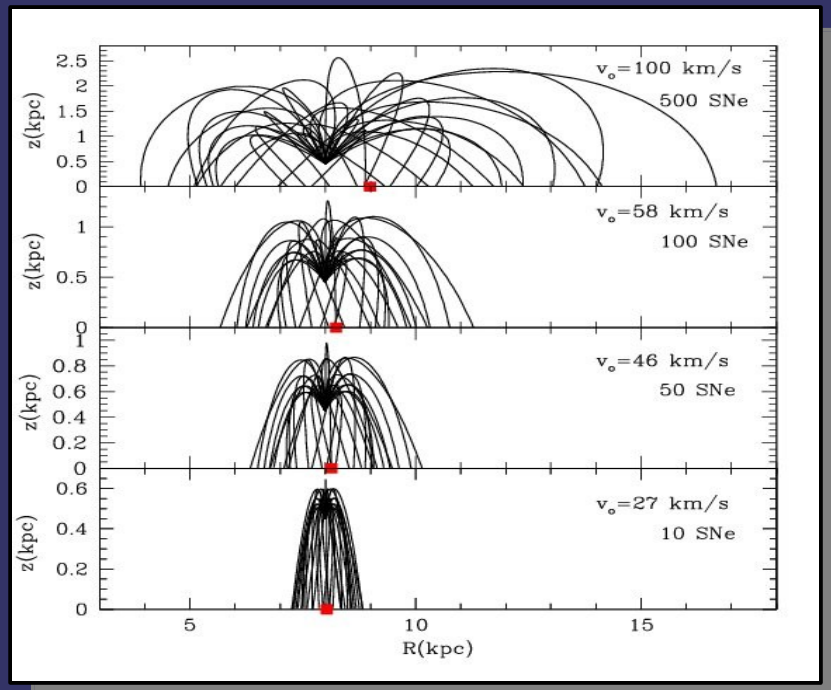
i) Galactic fountain delay model

ii) Metal cooling delay model

The galactic fountain time delay model

- It is unlikely that a galactic fountain can affect abundance gradients (the average landing coordinate differ from the throwing coordinate by at most 1kpc)

- A galactic fountain can affect the chemical evolution in terms of a delay in the mixing of metals in the ISM



Estimate of the delay

$$< t_{total} >= t_{final} + < t_{orbit} >$$

- We refer to the work of Spitoni et al. (2008):

	4 kpc	8 kpc	12 kpc
10 SNe	43	53	75
50 SNe	36	54	87
100 SNe	36	57	96
500 SNe	38	75	133

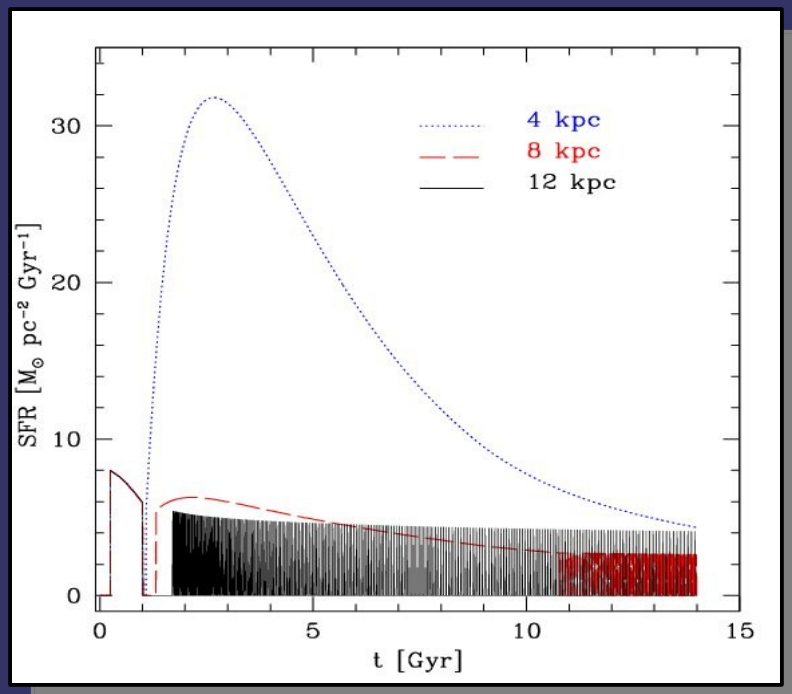
  - Single OB association
  - Kompaneets (1960) approximation
  - Galaxy potential:

    Miyamoto & Nagai (1975) ,
    Hernquist (1990),
    Navarro et al. (1996).

	4 kpc	8 kpc	12 kpc
Maximum delay	48 Myr	114 Myr	245 Myr

Description of the model

- We implemented the time delay on the chemical evolution model of François et al. (2004)
- We considered the delay only for massive stars M> 8 $M_{\odot}$
- We computed this effect only on thin disk stars, e. g. only for stars born after the halo-thick disk transition



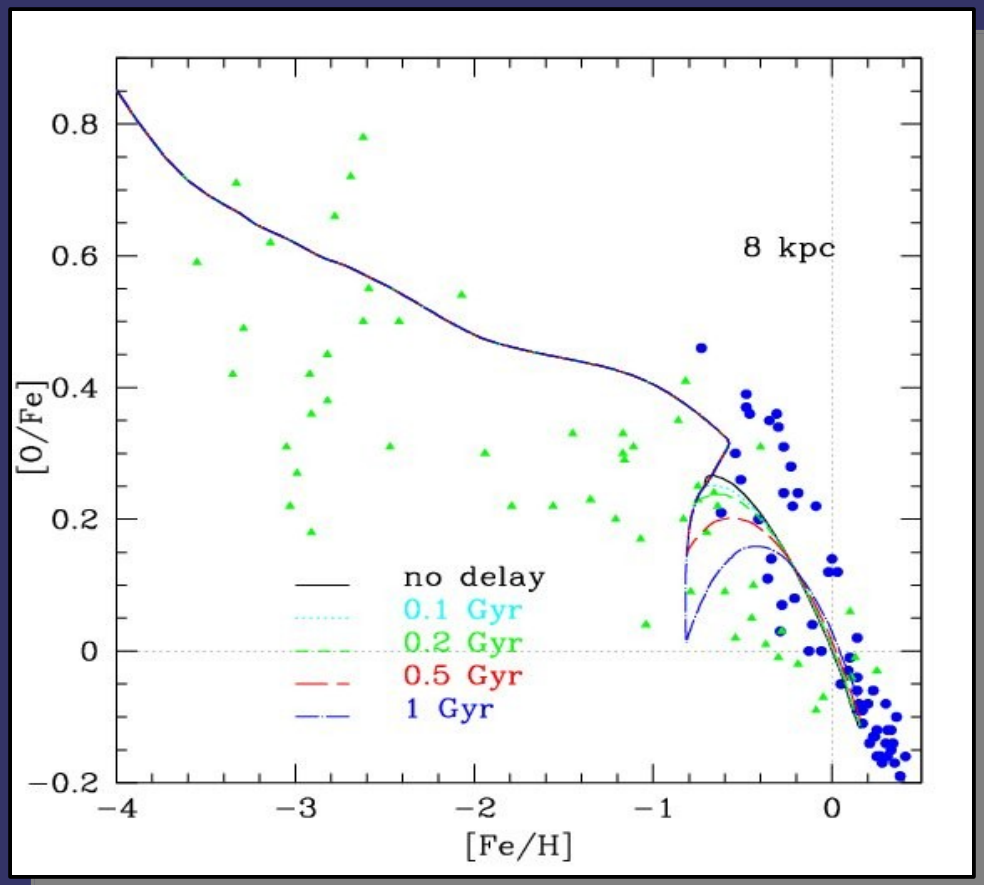
	4 kpc	8 kpc	12 kpc
Beginning of SF in the disk	1.1 Gyr	1.3 Gyr	1.7 Gyr

- Time delay: 0.1, 0.2, 0.5, 1.0 Gyr (… a delay of 1.0 Gyr can be obtained in case of a OB association composed by 10^4 SNe)

Results

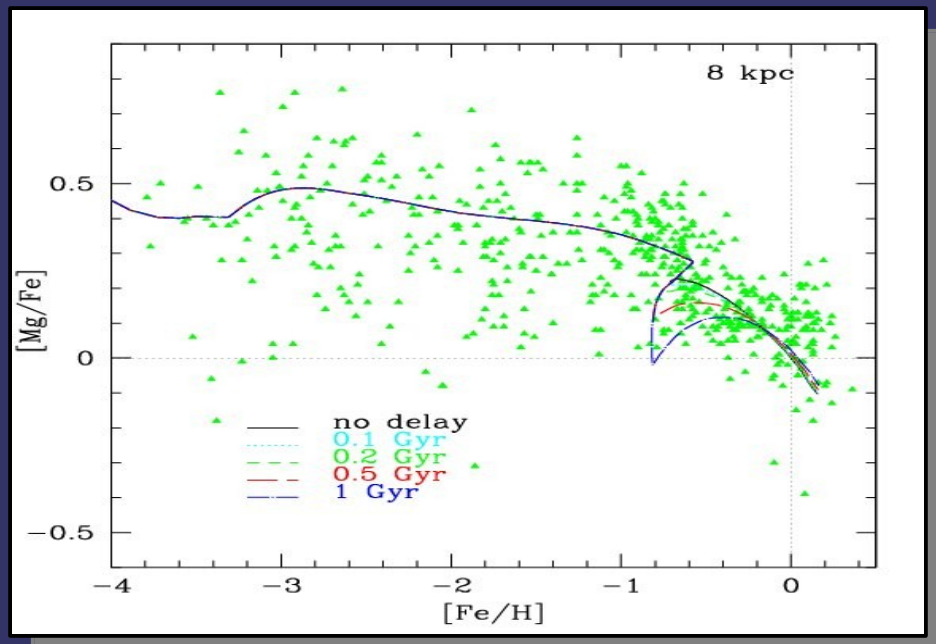
8 kpc

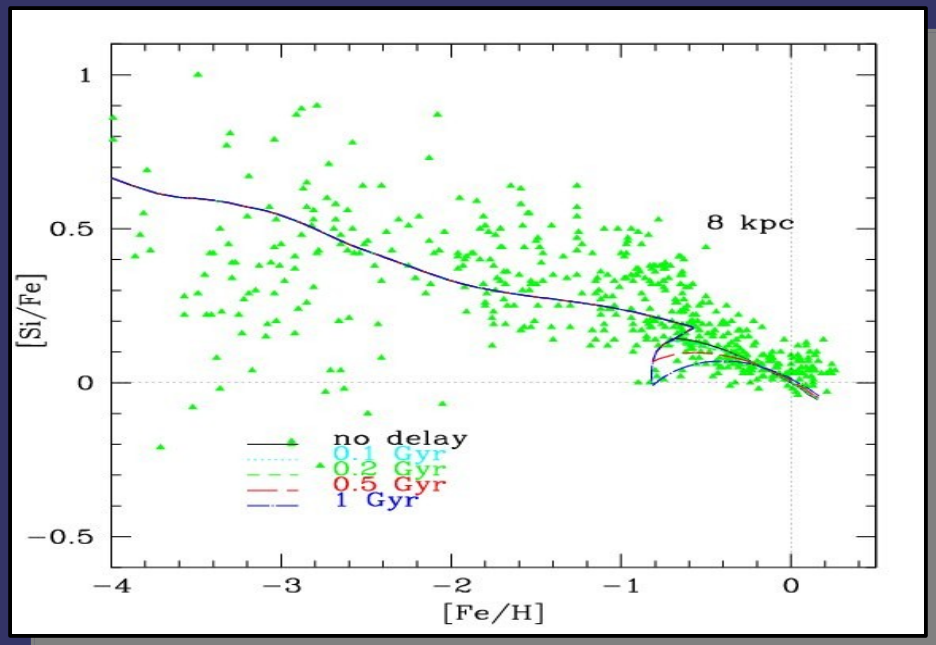
[el/Fe]/ [Fe/H]



Data: Bensby (2004), François et al. (2004)

- The main feature of the galactic fountain is an enhancement of the drop in the [O/Fe] ratio. The galactic fountain delay has the effect of increasing the period during which there is no pollution from type II SNe.
- Type Ia SNe are not affected by the delay
- The maximum possible delay must be lower than 1.0 Gyr

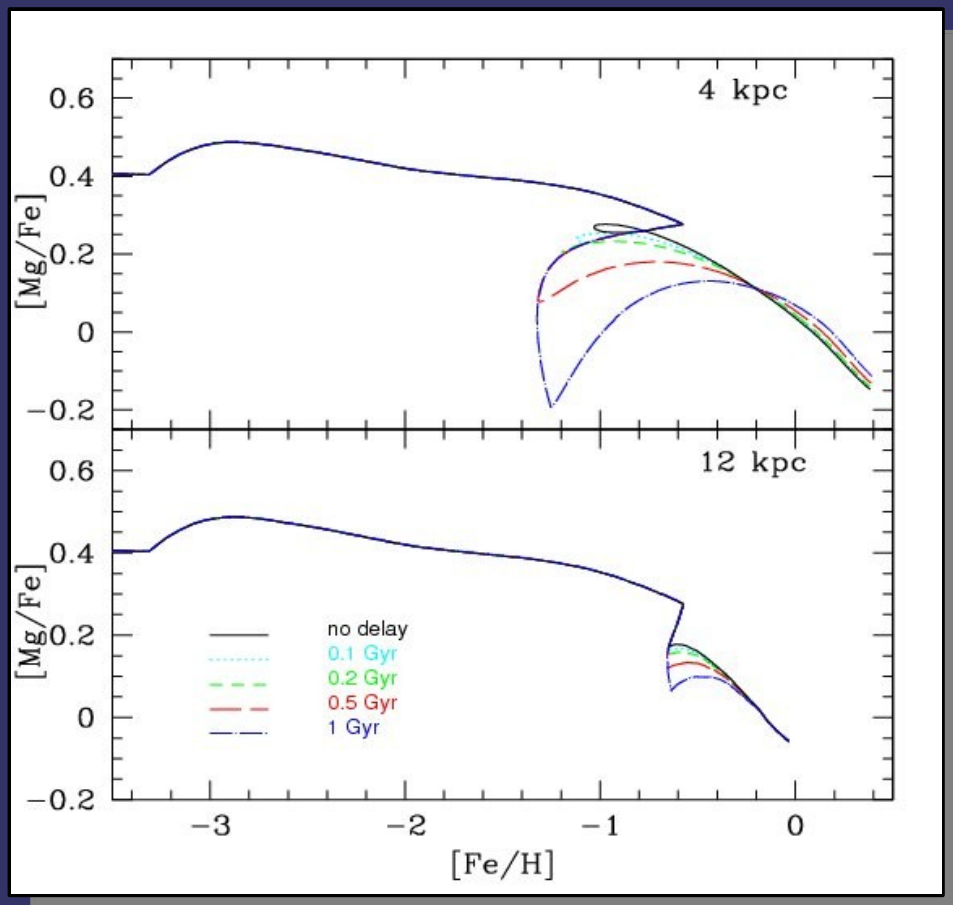


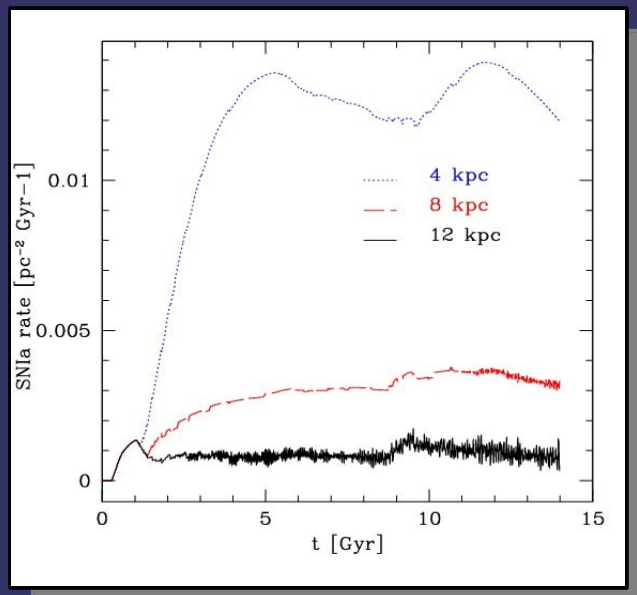


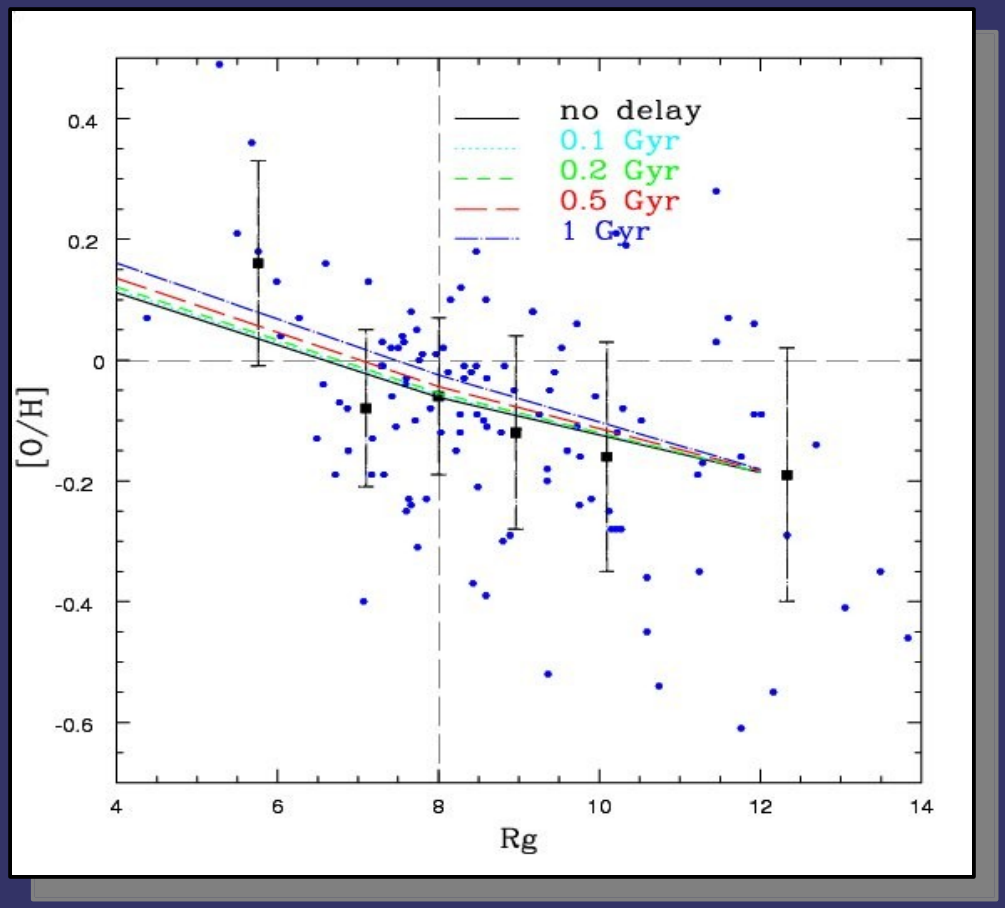
- The effect of the galactic fountain depends on the considered element. Si, which is also produced by type Ia SNe in a non negligible amount, shows a smaller drop of the [Si/Fe] quantity compared to O and Mg.

Results at 4 kpc and 12 kpc

- The effect depends on the galactocentric distance: The rate of type Ia SNe depends on the galactocentric distance







Data from Cescutti et al. (2007)

The time delay produced by a galactic fountain has a negligible effect on the abundance gradient in the Galaxy disk

The metal cooling delay model

- Malinie et al. (1993) claimed that re-mixing and star formation may be delayed by $10^{8\text{-}9}$ yr.

Thomas et al. (1998) proposed a chemical evolution model including the relaxation of the IMA by splitting the gas component into two different phases *: active* and *inactive phases.*

active phase: assumed to be cool and well-mixed

inactive phase: component hot and non homogeneously distributed

Our Model

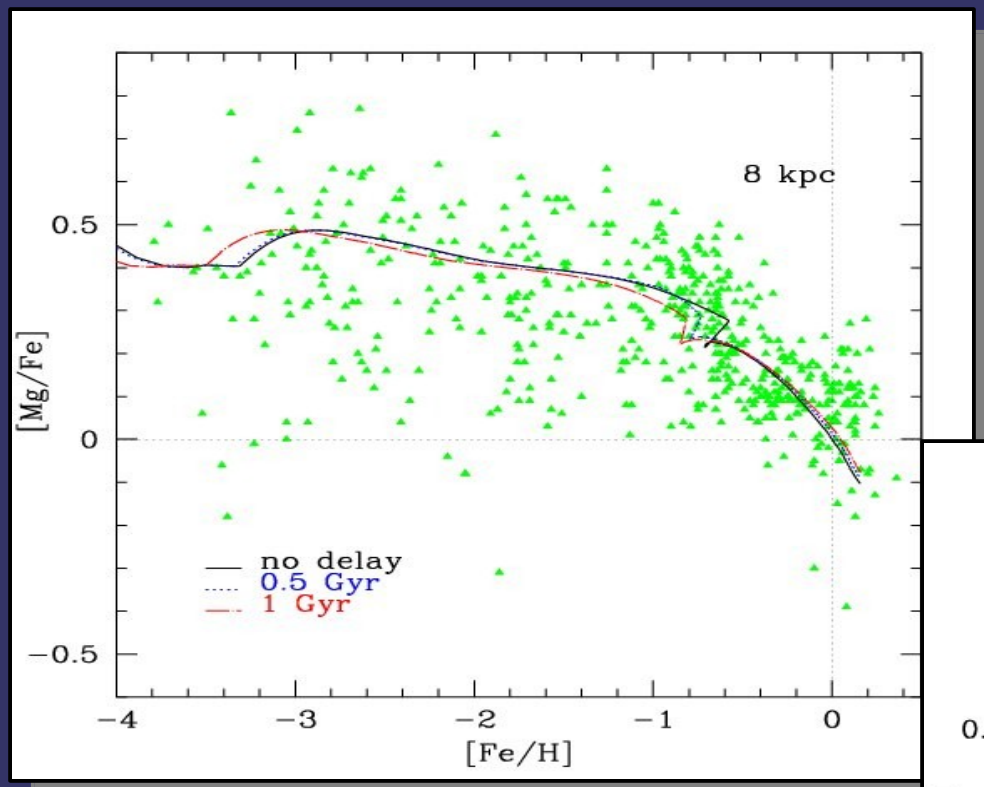
- We implemented the time delay on the chemical evolution model of François et al. (2004)

- We considered the delay *i*) ***for all stars*** (both type II and type Ia SNe)

  ii) both halo and disk stars are affected by this delay

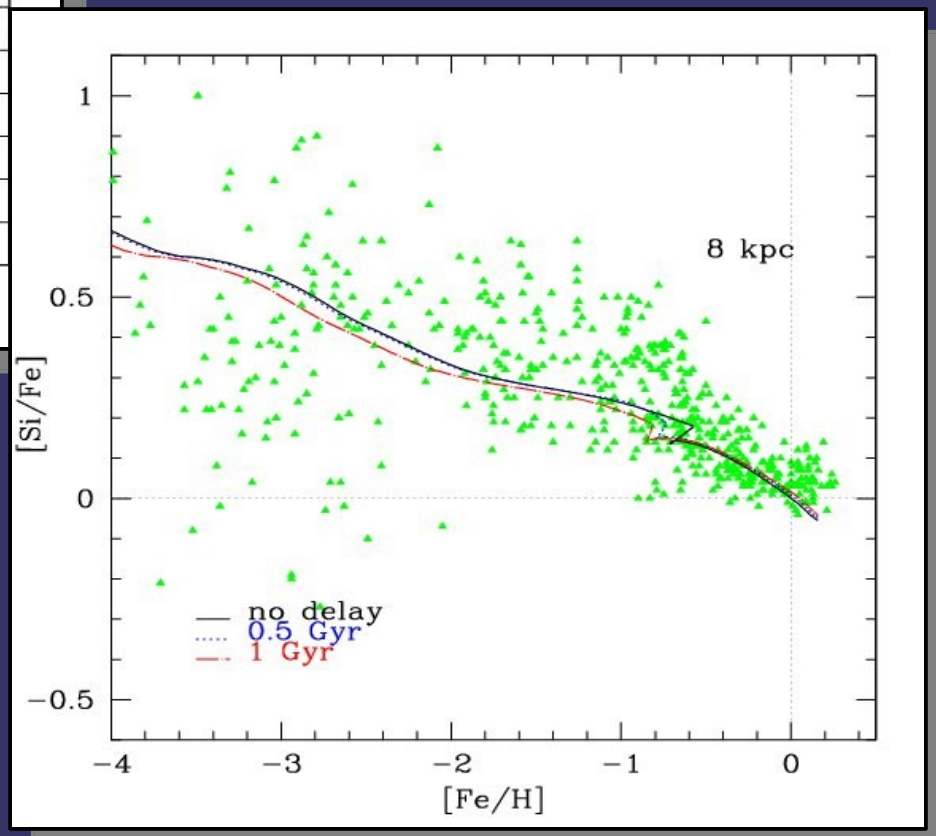
- Time delay: 0.5 Gyr and 1.0 Gyr

Results

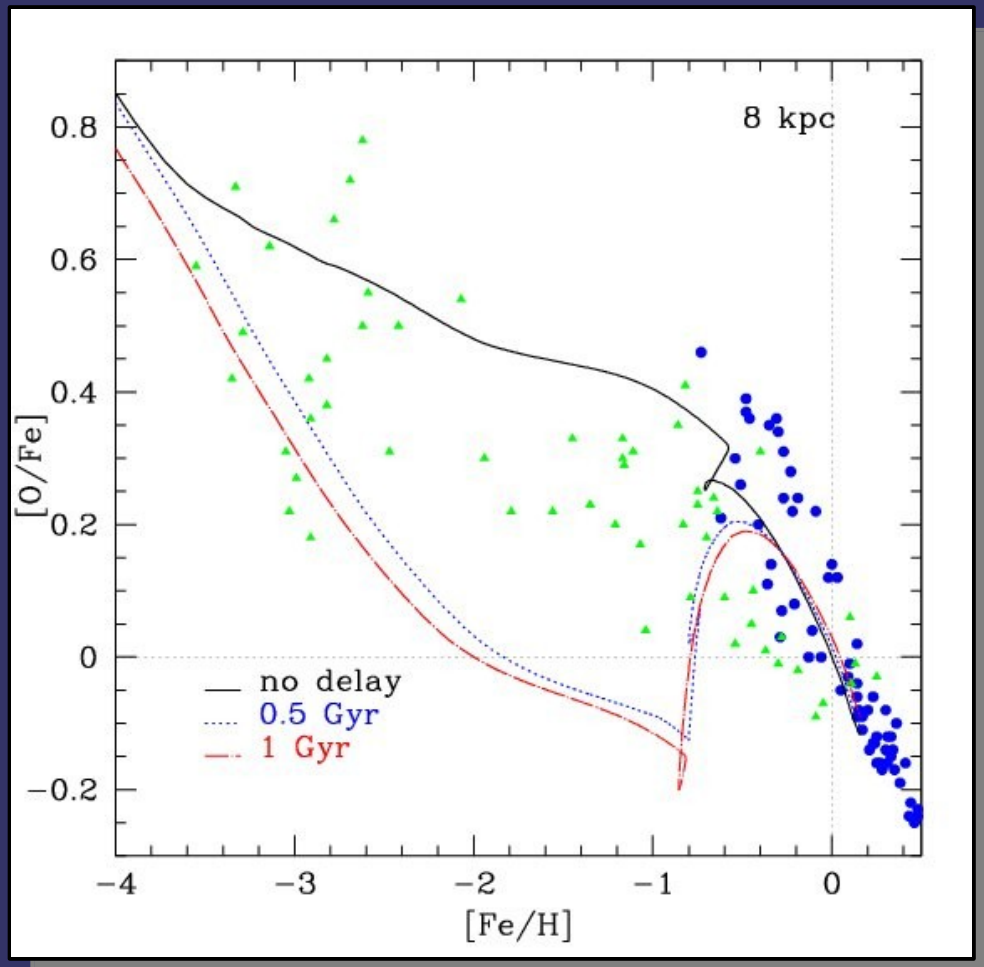


- The metal cooling delay model with the assumed delays has a very small effect.

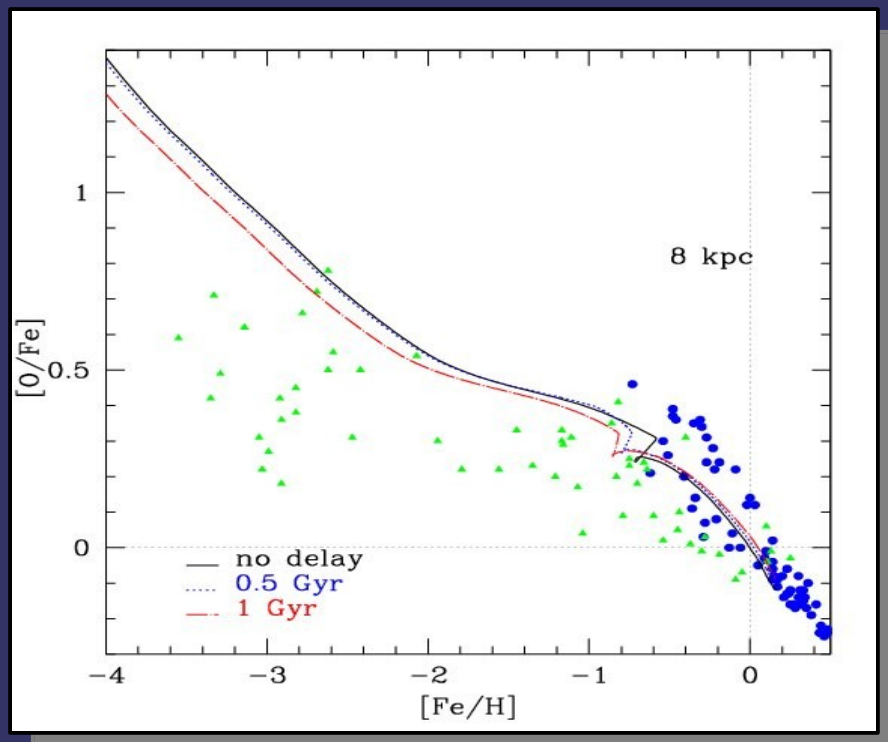
- François et al (2004) nucleosynthesis prescriptions: Mg, Si, Fe yields are not depending on metallicity



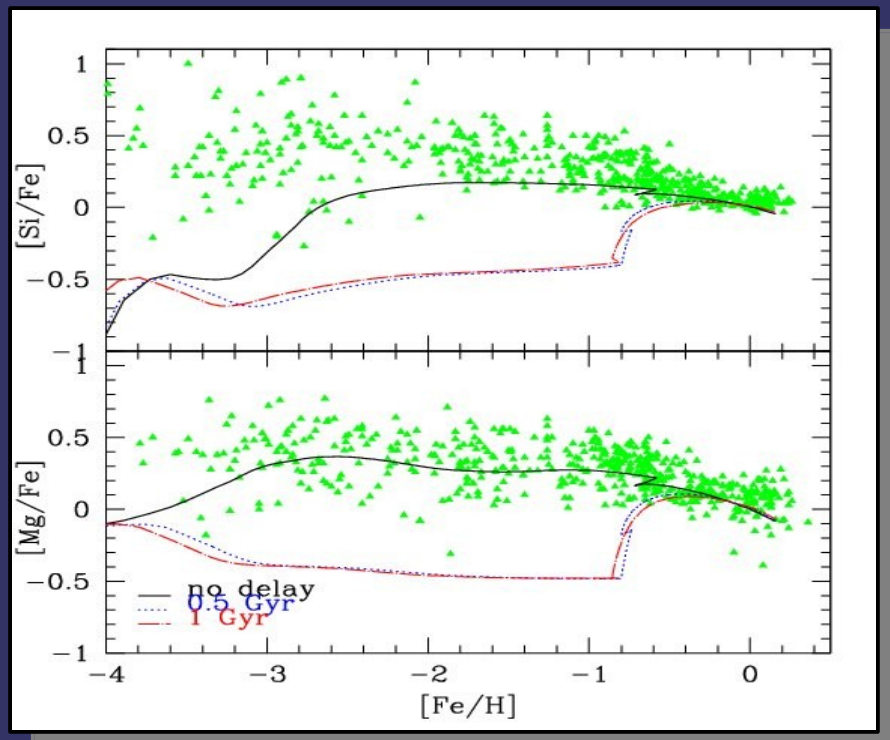
Metallicity dependent oxygen yields of WW95



- The delay induces a situation where the yields for $Z \sim 0$, which are lower than for the other metallicities, act for a longer time.
- As a consequence the [O/Fe] drops to very low values during the whole halo phase



- [O/Fe] using the yields at the solar metallicity given by WW95.



- [el/Fe] for the Si and Mg using for these two elements the metal dependent yields given by WW95.

The metallicity-dependent yields of WW95 are not compatible with a delayed enrichment of the halo.

Conclusions

- We showed that in the solar neighbourhood the delay produced by a galactic fountain has a negligible effect on the chemical evolution of all α elements we studied.
- In [el/Fe] versus [Fe/H] relations, the main feature of the galactic fountain is an enhancement of the drop in the [el/Fe] ratios. The galactic fountain delay has the effect of increasing the period during which there is no pollution from type II SNe.
- *The time delay produced by a galactic fountain originated by an OB association has a negligible effect on the abundance gradients in the galaxy disk.*
- The metal cooling delay model with the assumed delays has a very small effect on the chemical evolution in the solar neighborhood if yields not depending on metallicity are used.
- On the other hand, in the case of the metal dependent yields of WW95 the results differ substantially from the reference model of F04 and do not fit the observations.