The metallicity distribution in the Milky Way disks: Chemical Evolution Models

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- **Chemical abundances can be interpreted within the framework of Galactic chemical evolution models**

- **Schmidt (1959, 1963); ... Tinsley (1980); ... Pagel (1997); ... Matteucci (2001); ...**

ORIGIN AND EVOLUTION OF GRADIENTS

- **<u>Question 1:</u> “How can we obtain abundance gradients along the Galactic disk?”**

Origin and evolution of gradients

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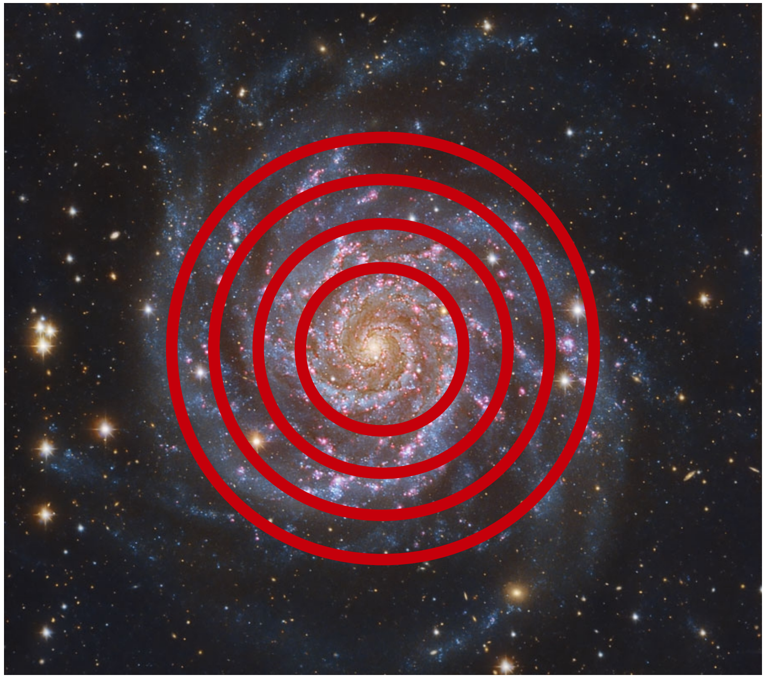

Origin and evolution of gradients

- **Variation in gas fraction along the disk (in a closed-box model; Pagel 1989, following Searle & Sargent 1972)**
- **Variation in stellar IMF (to produce a higher bulk yield in the innermost regions; Güsten & Mezger 1982)**
- **Variation in effective yield (due to ejection of hot gas; Pantelaki & Clayton 1987)**
- **Variation in star formation rate relative to infall rate (Tosi 1988; Matteucci & François 1989)**
- **Variation in star formation efficiency (Prantzos & Aubert 1995)**
- **Metal-dependent stellar yields (Giovagnoli & Tosi 1995; Carigi 2000)**
- **Radial gas flows (Tinsley & Larson 1978; Mayor & Vigroux 1981; Lacey & Fall 1985)**
- **Existence of a gas density threshold for star formation (Tinsley & Larson 1978)**
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The role of gas flows

- **First studies of Milky Way's chemical evolution: closed-box models (no gas or stars can leave or enter the examined region)**

“G-dwarf problem” in the solar neighbourhood

(van den Bergh 1962; Pagel & Patchett 1975)

The role of gas flows

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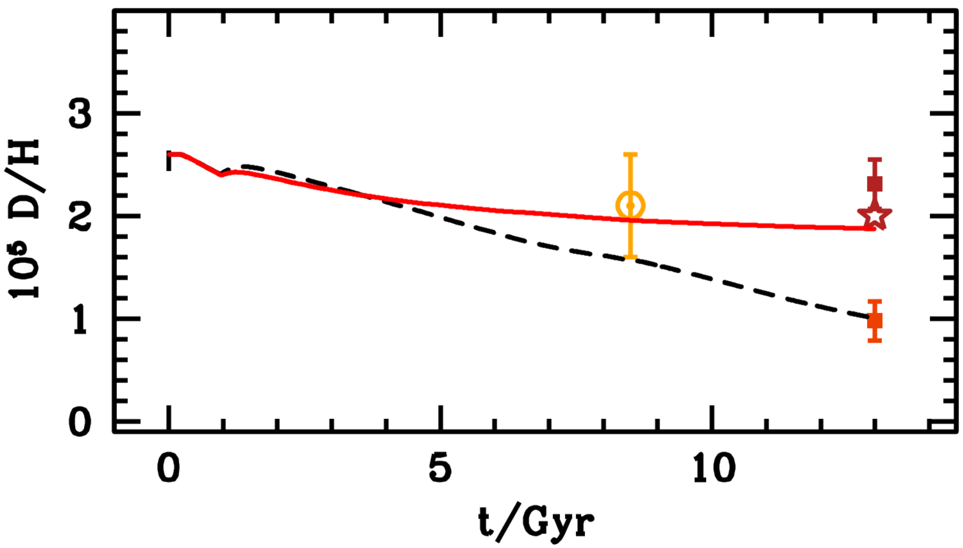
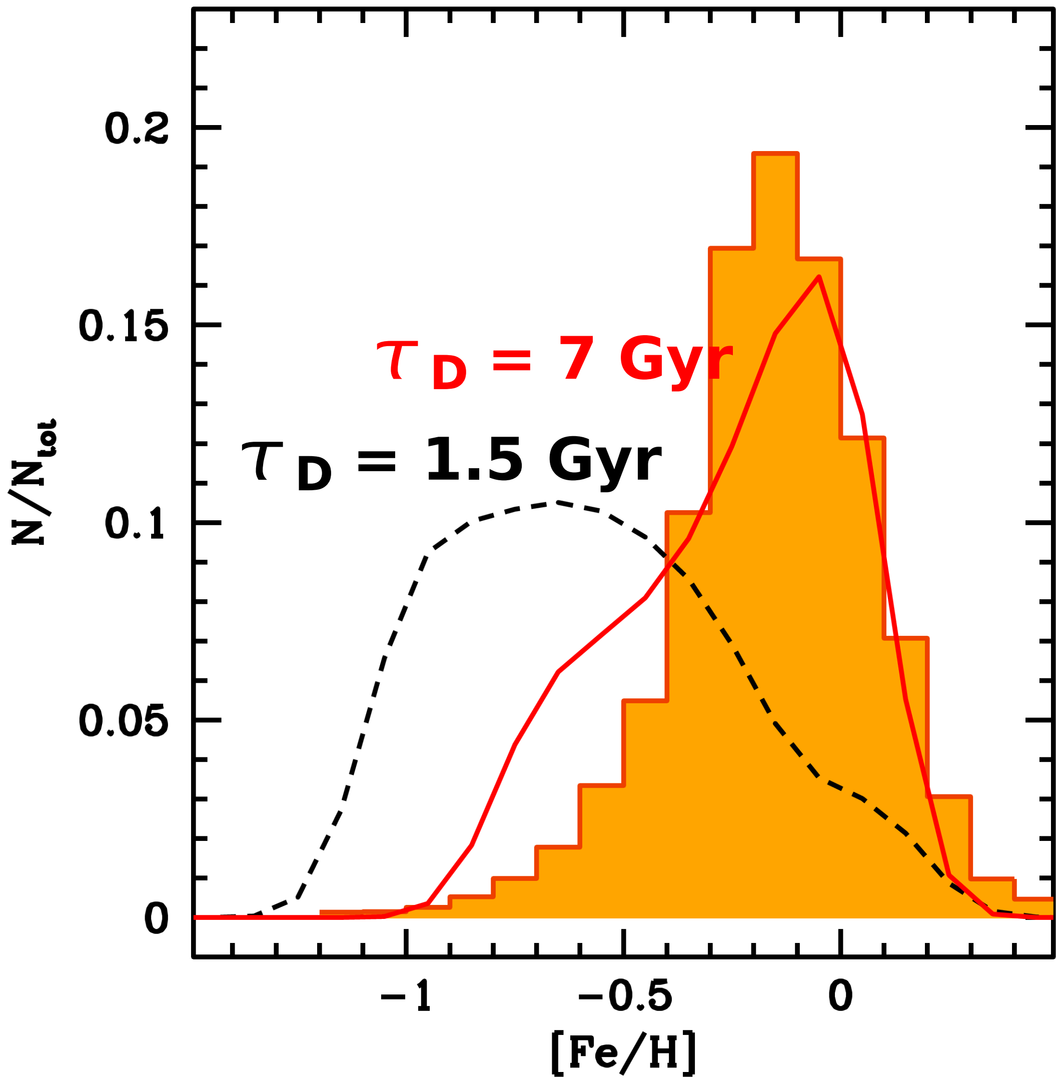
- **Infall of gas (Larson 1972; Chiosi 1980; ...) of primordial or slightly enriched chemical composition. Tosi (1988): $Z_{infall} \leq 0.1\ Z_{\odot}$, in agreement with metallicities of HVCs of likely extragalactic origin (Richter 2006)**

ORIGIN AND EVOLUTION OF GRADIENTS

Infall rate ∝ e^{-t/τ_D}

(Better in a cosmological context? See Calura's talk)





Models: Romano et al. (2006)

ORIGIN AND EVOLUTION OF GRADIENTS

- **Conclusion: in the solar neighbourhood, the Galactic disk must have assembled on long time scales from accretion of metal-poor gas**

... what about disk formation at different radii?

Origin and evolution of gradients

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- **Early dynamical models of the formation of disk galaxies by Larson (1976) suggest a more rapid formation of the inner disk relative to the outer one**

“Inside-out” formation of the Galactic disk

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“Inside-out” formation of the Galactic disk

- **Now commonly adopted in GCE models (e.g., Chiappini et al. 1997, 2001; Portinari et al. 1998; Boissier & Prantzos 1999; Carigi et al. 2005; Magrini et al. 2009):**

$$\tau_D(R) = a \times R - b$$

Origin and evolution of gradients

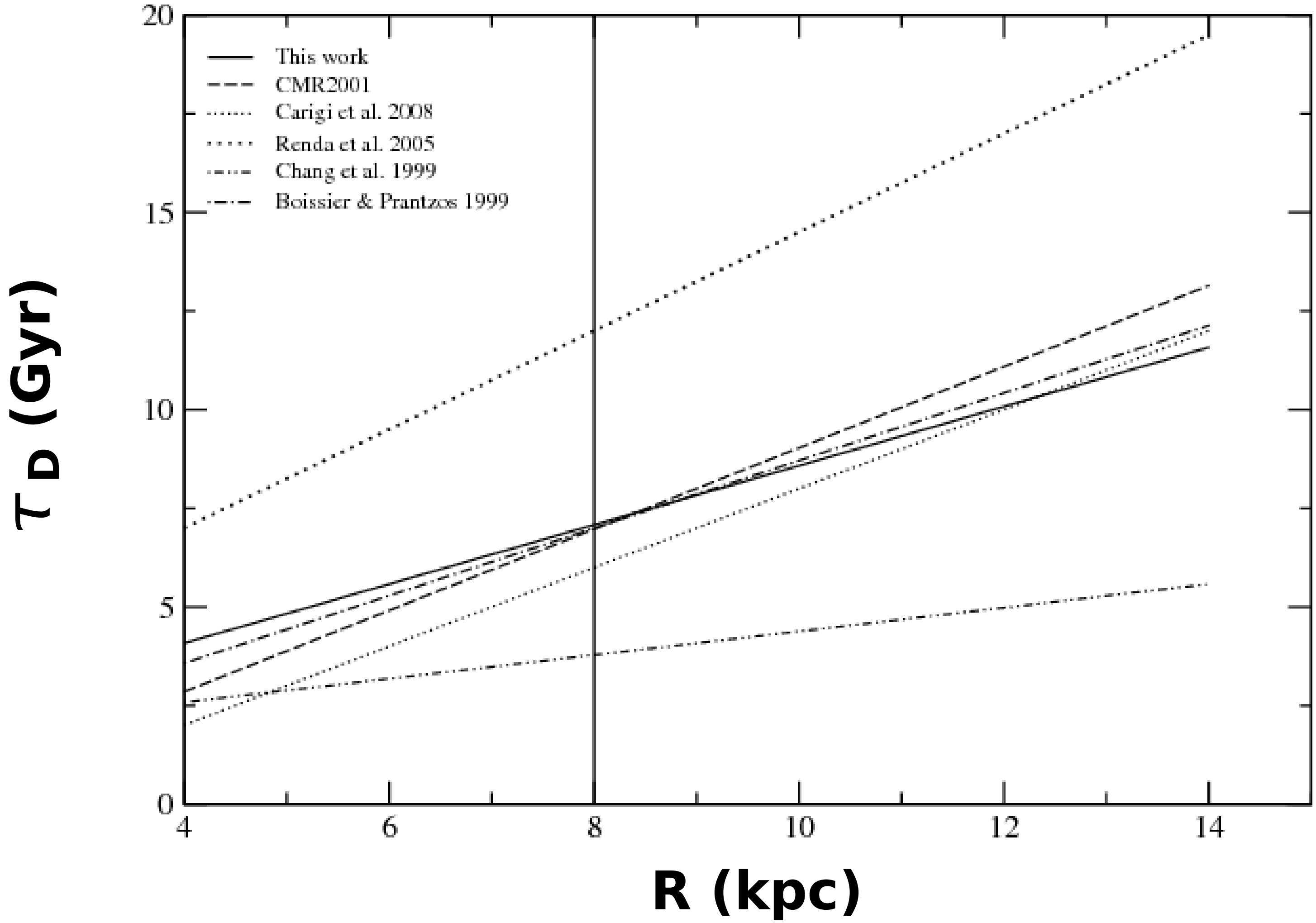


Figure from Marcon-Uchida et al. (2010)

Origin and evolution of gradients

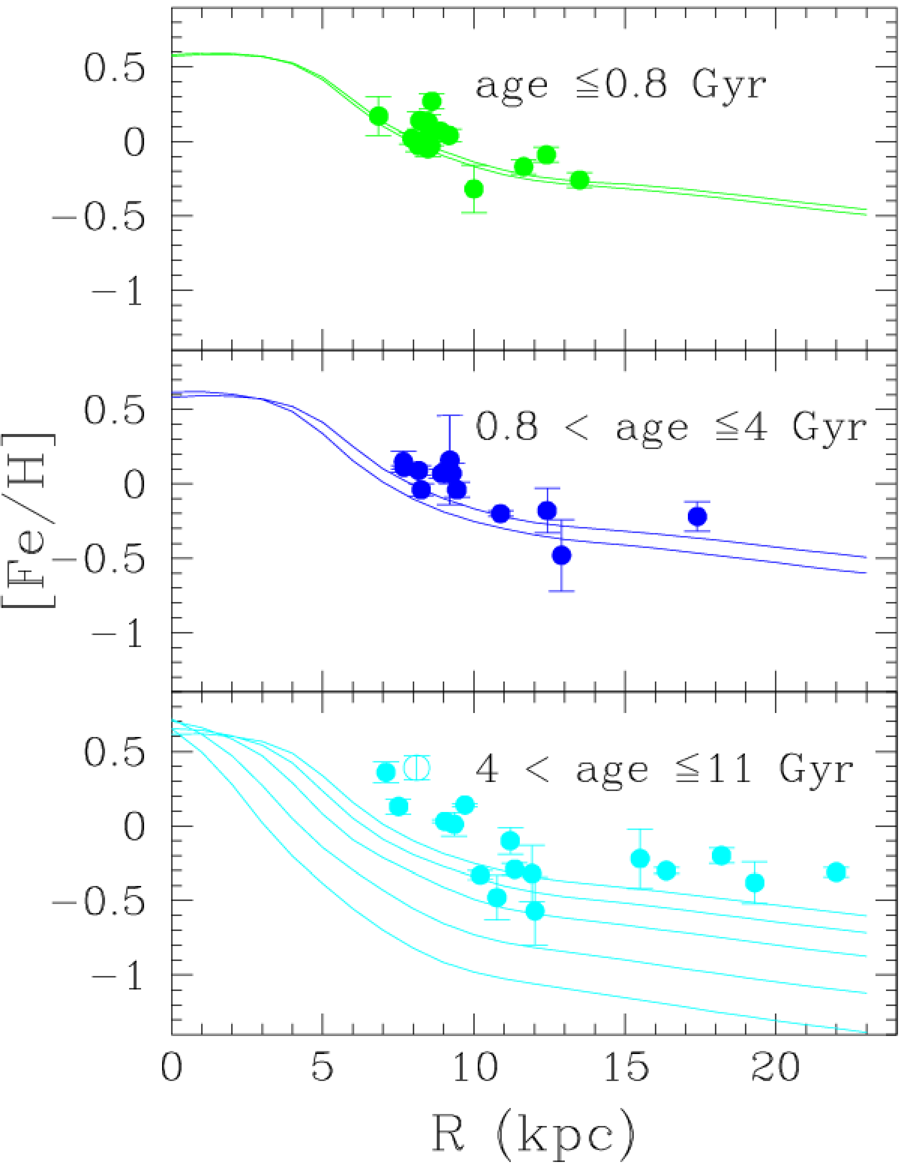
- **The inside-out formation of the disk is an important mechanism to produce abundance gradients (Matteucci & François 1989)**
- **Different GCE models can all reproduce the present-day observed gradient along the disk**

Origin and evolution of gradients

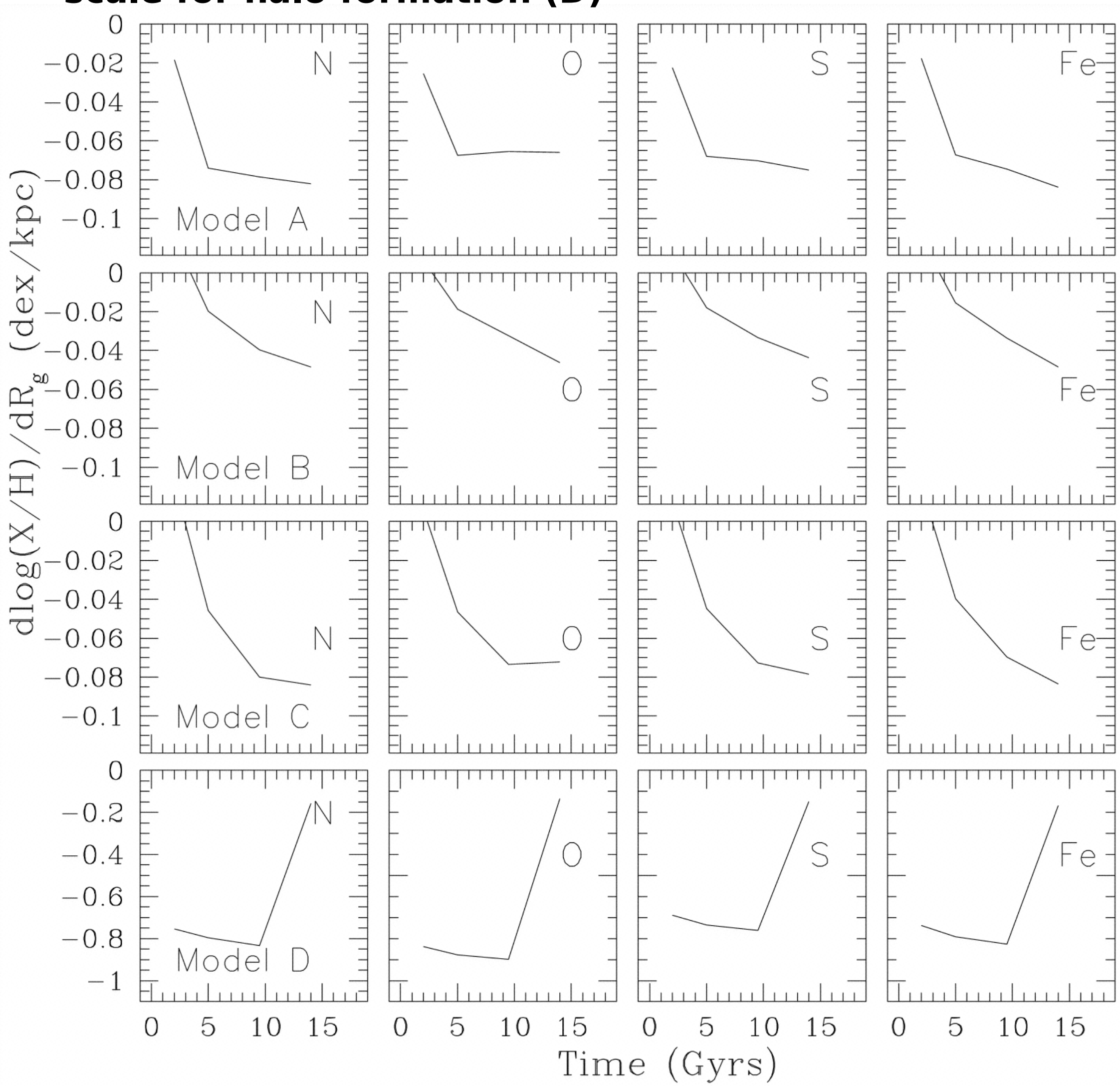
- **The inside-out formation of the disk is an important mechanism to produce abundance gradients (Matteucci & François 1989)**
- **Different GCE models can all reproduce the present-day observed gradient along the disk**
- **However, different evolution: the gradients either steepen or flatten with time!**
- **This is due to the different assumptions about star formation and/or infall rates (see Tosi 1996)**

Origin and evolution of gradients

Magrini et al.'s (2009) model vs OC data



Chiappini, Matteucci & Romano (2001) models with different prescriptions on halo density (A, B), gas density threshold for star formation (C) and time scale for halo formation (D)



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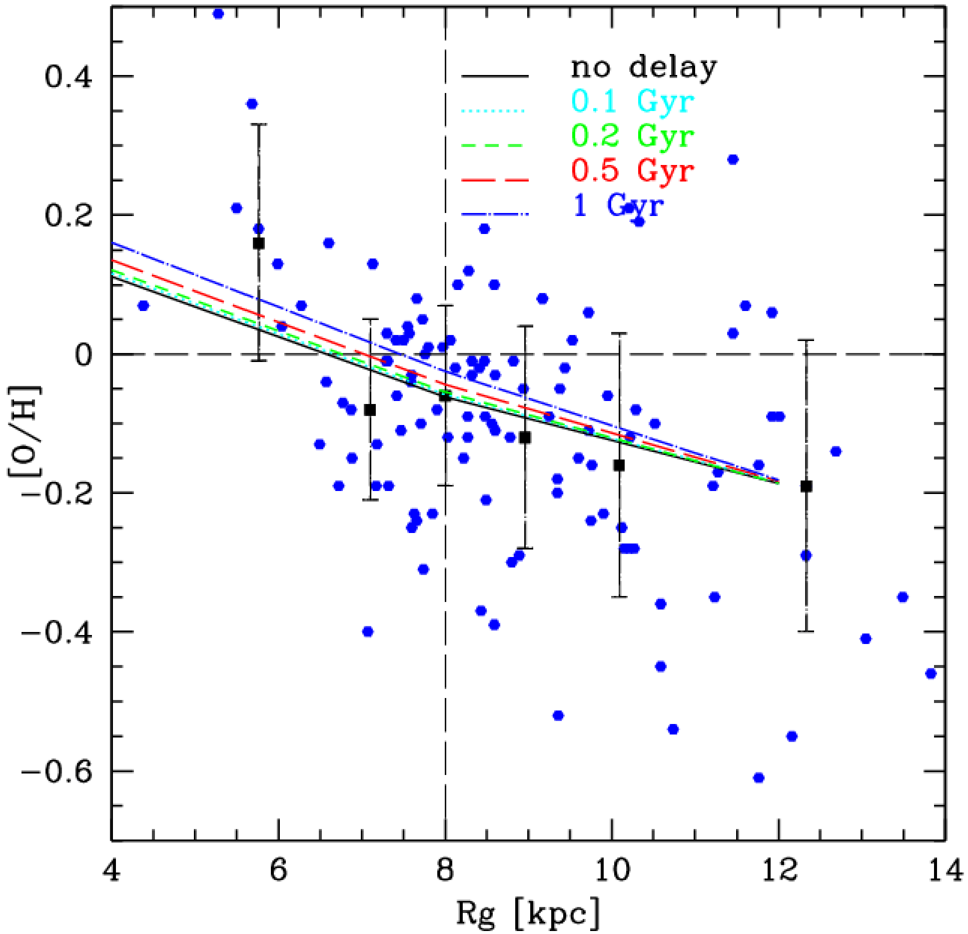
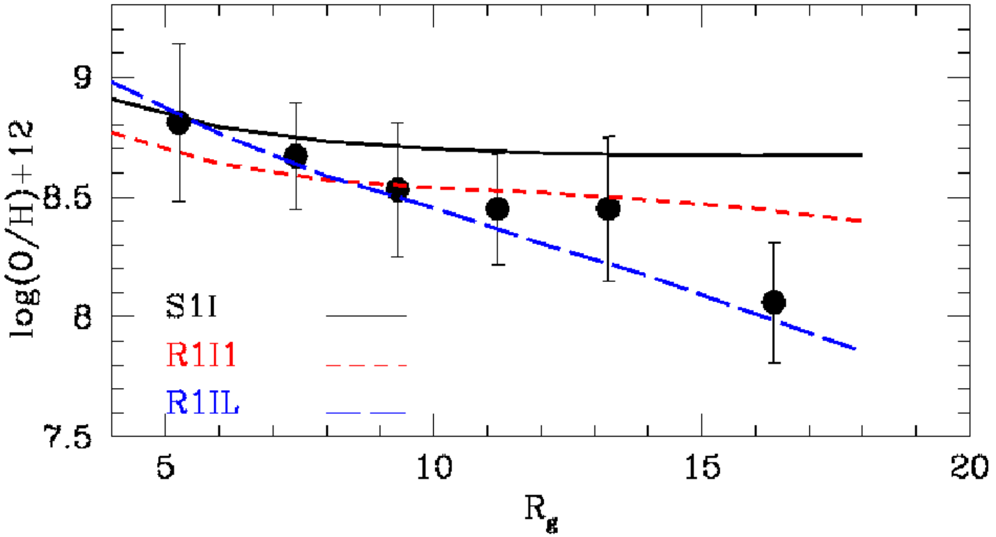
Origin and evolution of gradients

- **Effects of Galactic fountains and radial flows recently reassessed by Spitoni et al. (2009) and Spitoni & Matteucci (2011)**





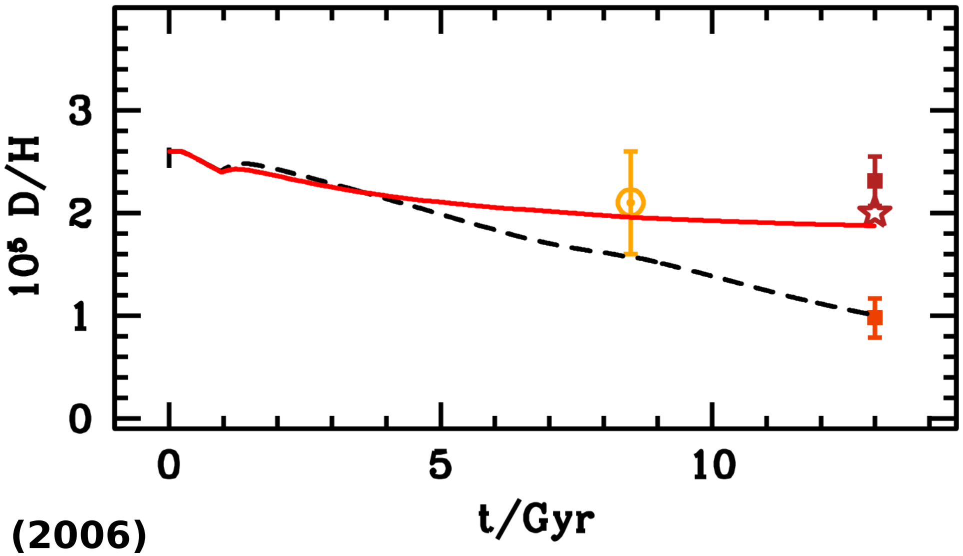
Conclusions and future work

- **Galactic chemical evolution models can reproduce current abundance gradients along the (thin) disk**
- **Either a steepening or a flattening of the gradients with time is obtained, depending on model assumptions**
- **The ESA *Gaia* mission and follow-up surveys (GES, APOGEE, HERMES) will soon allow to test different formation scenarios, by providing fiducial samples of thick and thin disk stars at different R_G → MDFs, AMRs, and [X/Fe] vs [Fe/H] trends**
- **Highly desirable to have detailed SFHs from CMDs!**
- **Absolutely needed (i) coupling with dynamical models and (ii) formation in a cosmological context (some attempts can be found in the literature)**


That's all Folks!

Origin and evolution of gradients

- **Indirect argument in favour of a continuous infall of nearly primordial gas: evolution of deuterium**
- **Deuterium is produced only during Big Bang nucleosynthesis and destroyed in stars**
- **Straightforward evolution: D abundance decreases in time**



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