Impact of radial migration on the chemical evolution of the local disk

OLD Models

Solar Neighborhood

Constraints:

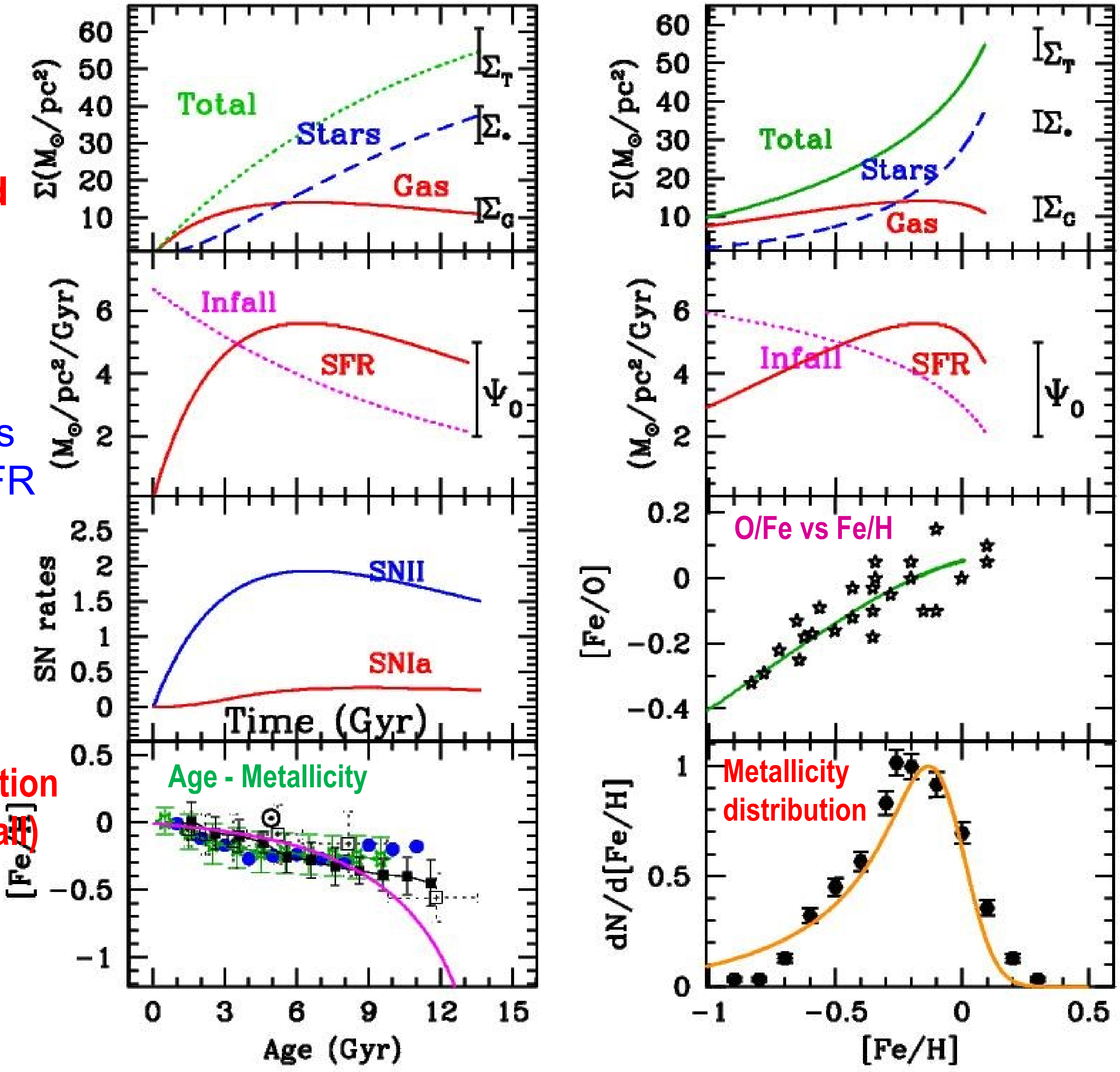
Local
column densities
Of gas, stars, SFR

as well as

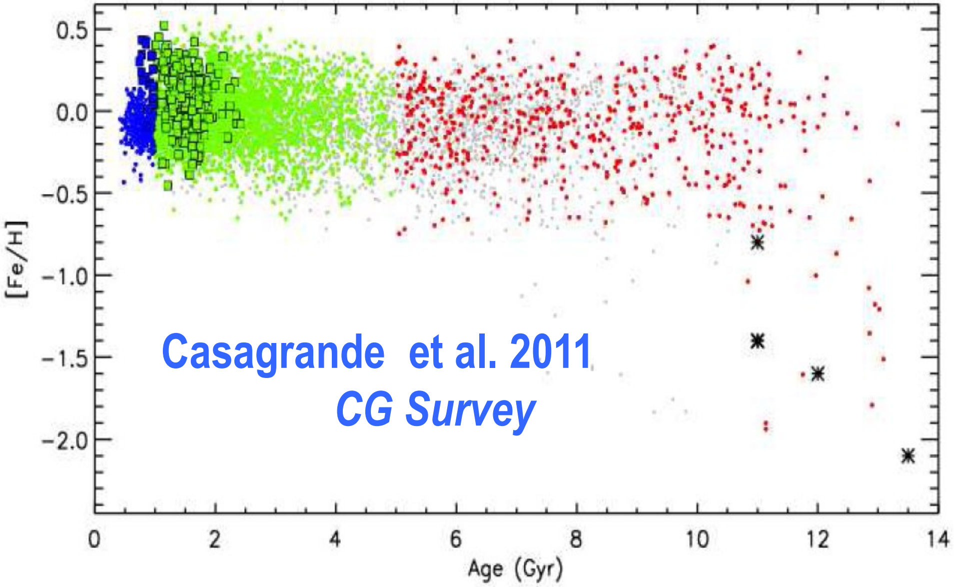
Age – Metallicity (uncertain)

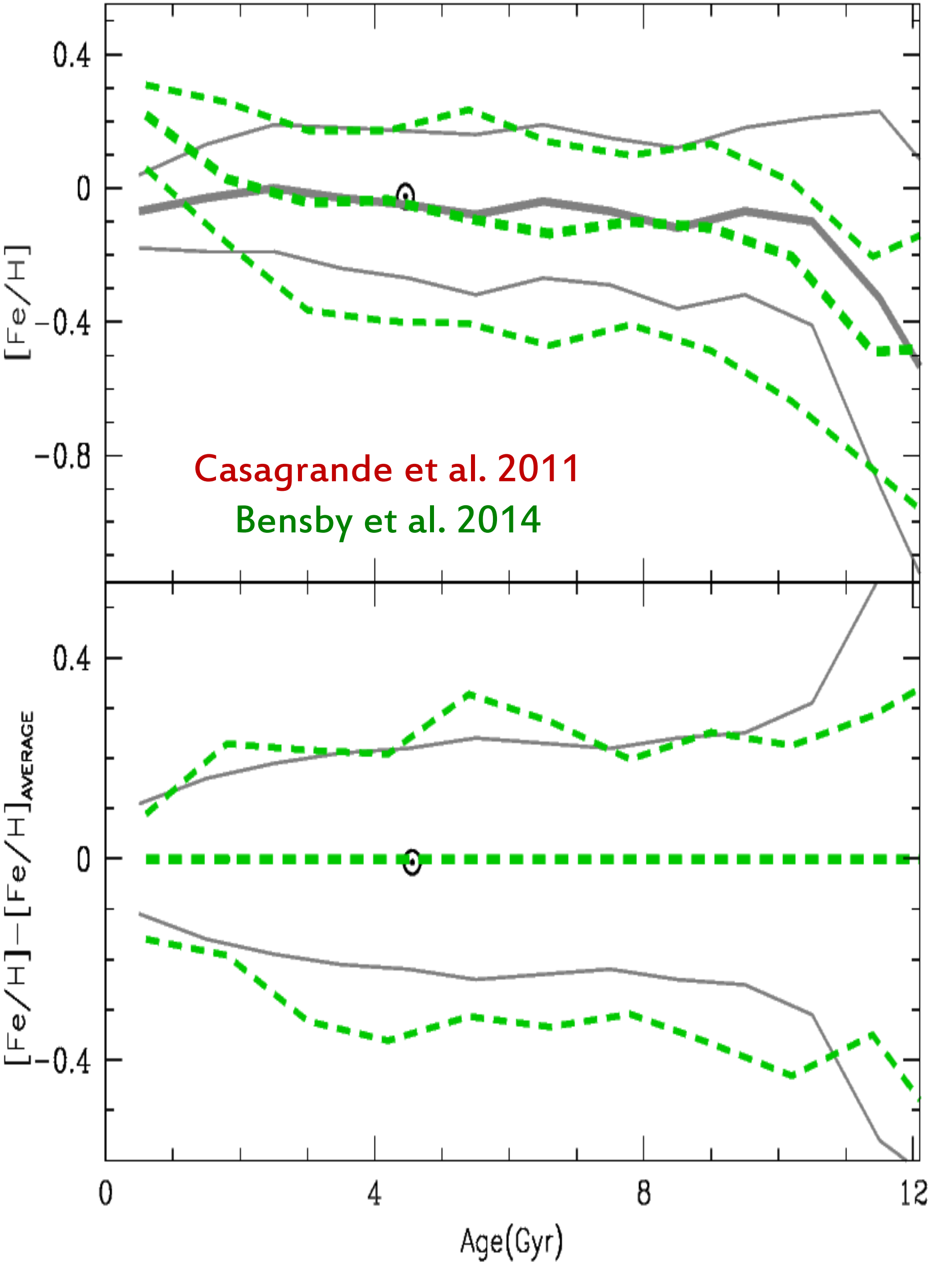
Metallicity distribution (requires slow infall)

O/Fe vs Fe/H (requires SNIa for late Fe)



Age-metallicity relation in the solar neighborhood

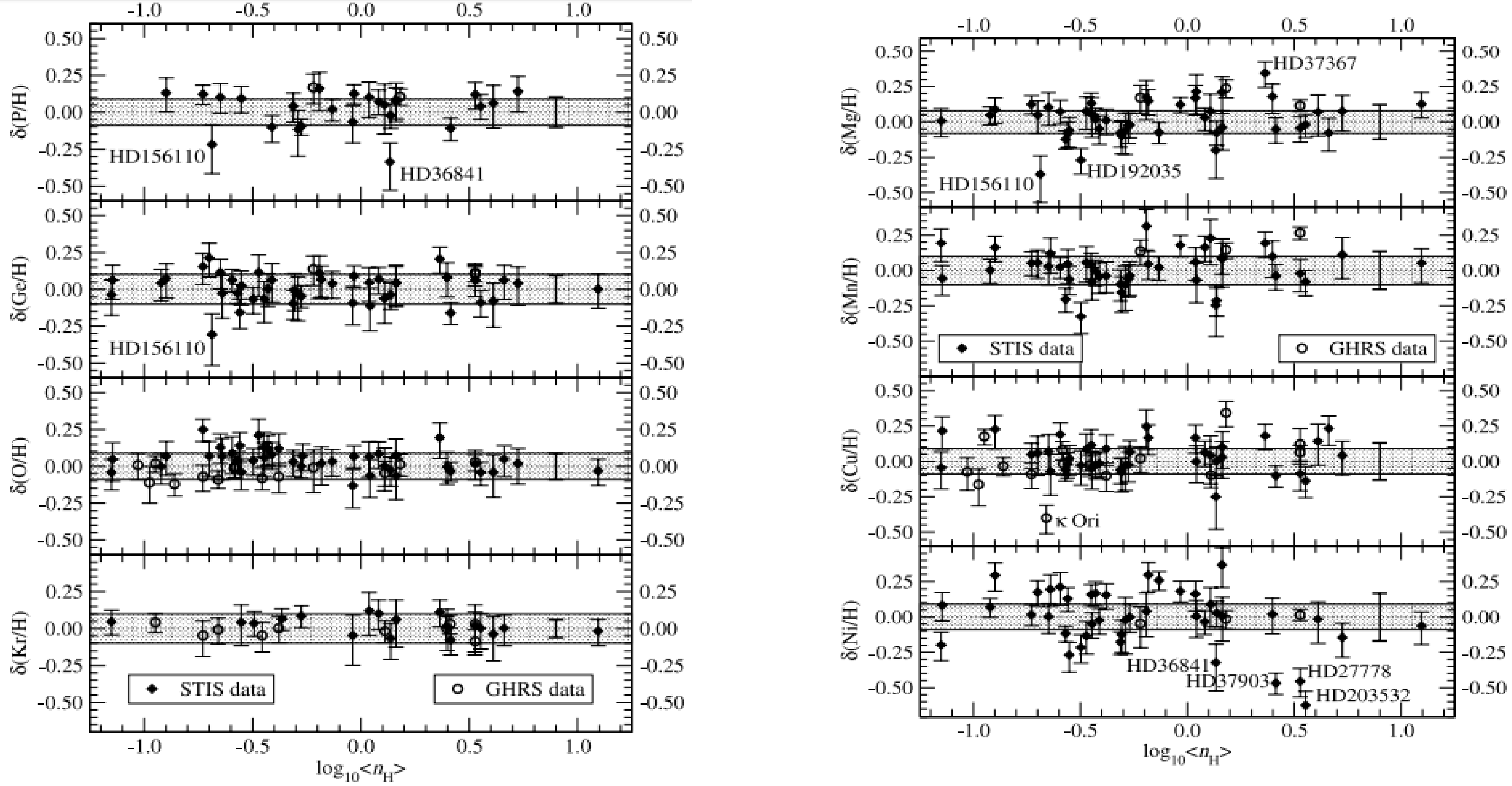


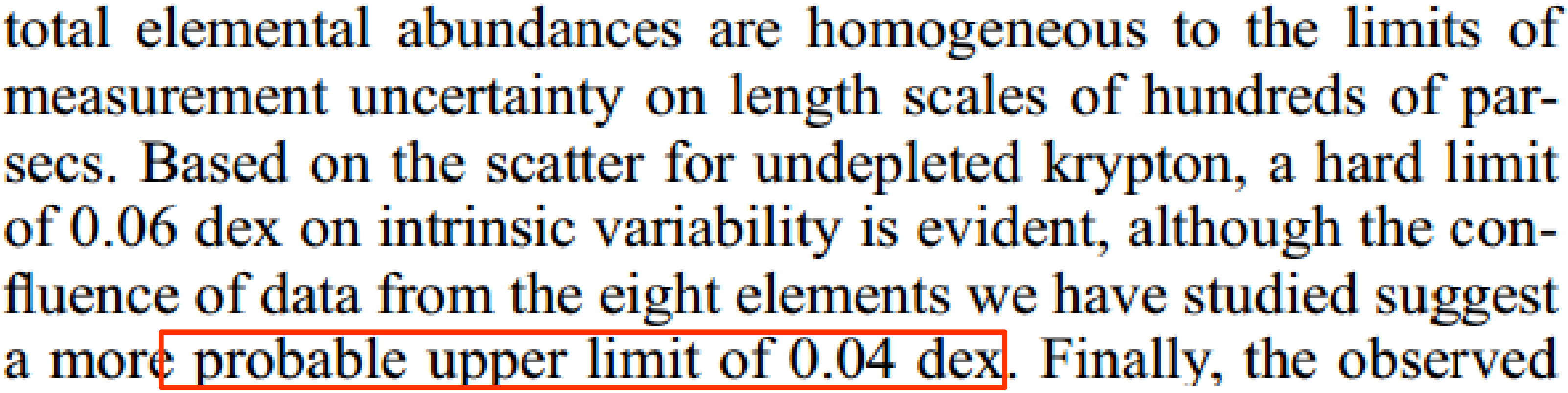


-Little metallicity evolution in the past 10 Gyr

- **Sizeable dispersion ± 0.2 dex (~60% at 1 σ) at all ages**

Cartledge et al. 2006 : local ISM appears well mixed





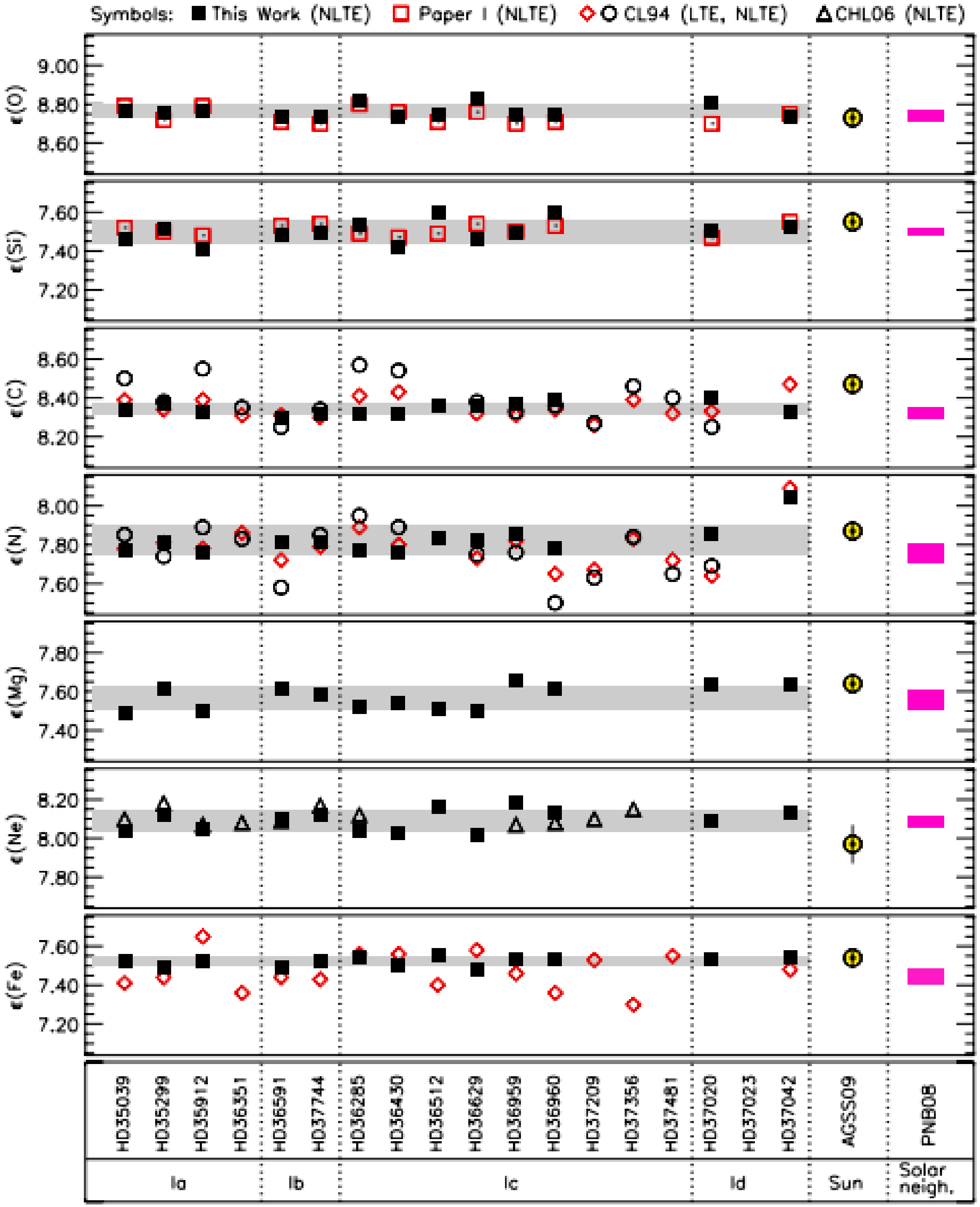
total elemental abundances are homogeneous to the limits of measurement uncertainty on length scales of hundreds of parsecs. Based on the scatter for undepleted krypton, a hard limit of 0.06 dex on intrinsic variability is evident, although the confluence of data from the eight elements we have studied suggest a more probable upper limit of 0.04 dex. Finally, the observed

Nieva and Simon-Diàz (2011)
11 OB-stars in Orion

Young stars have
~solar abundances,
after 4.5 Gy
of chemical evolution

Either
Chemical evolution was
locally inefficient
in the past 4.5 Gy

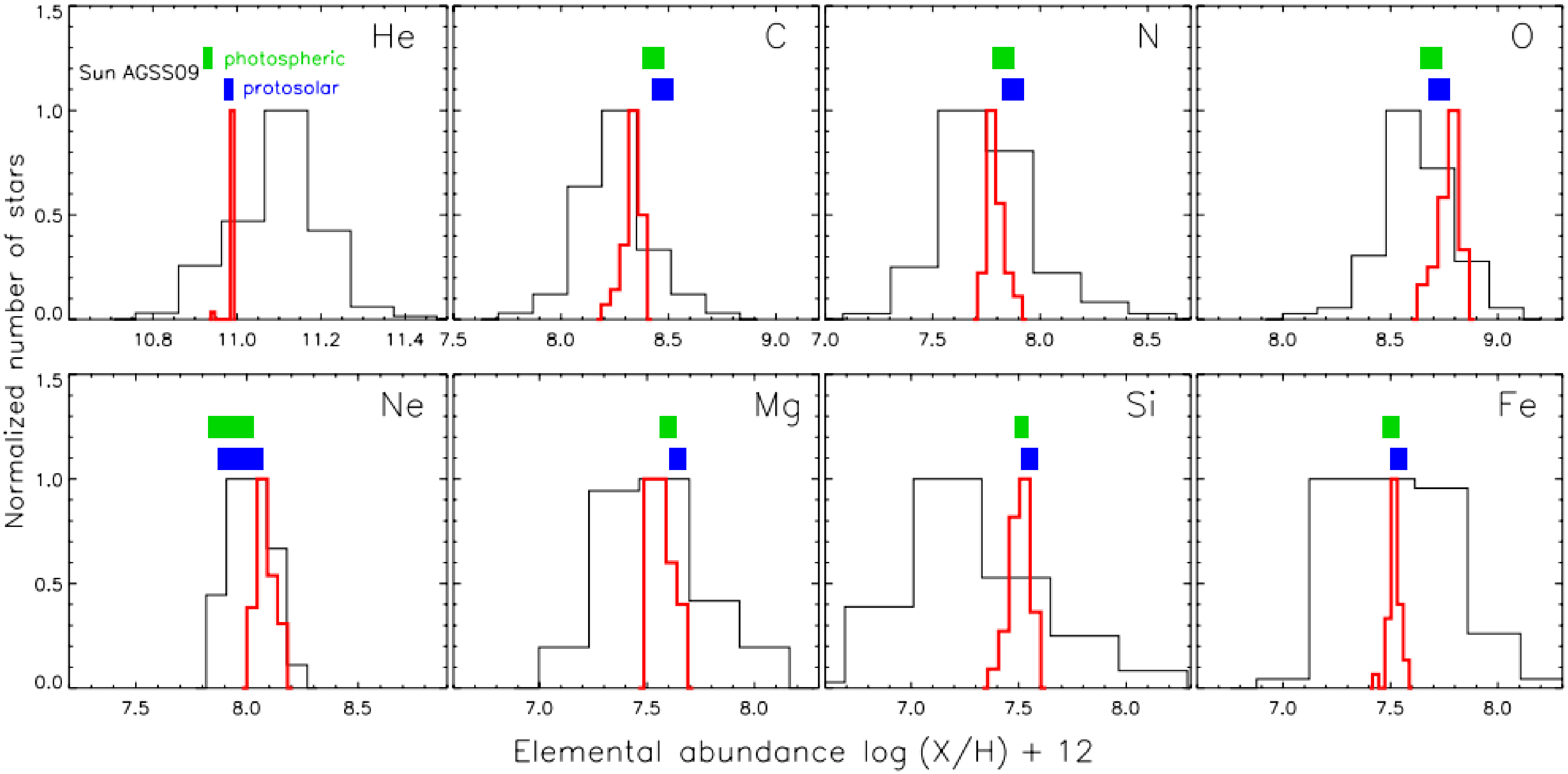
Or
The Sun was formed
in the inner disk
which had metallicity Z☉
4.5 Gy ago



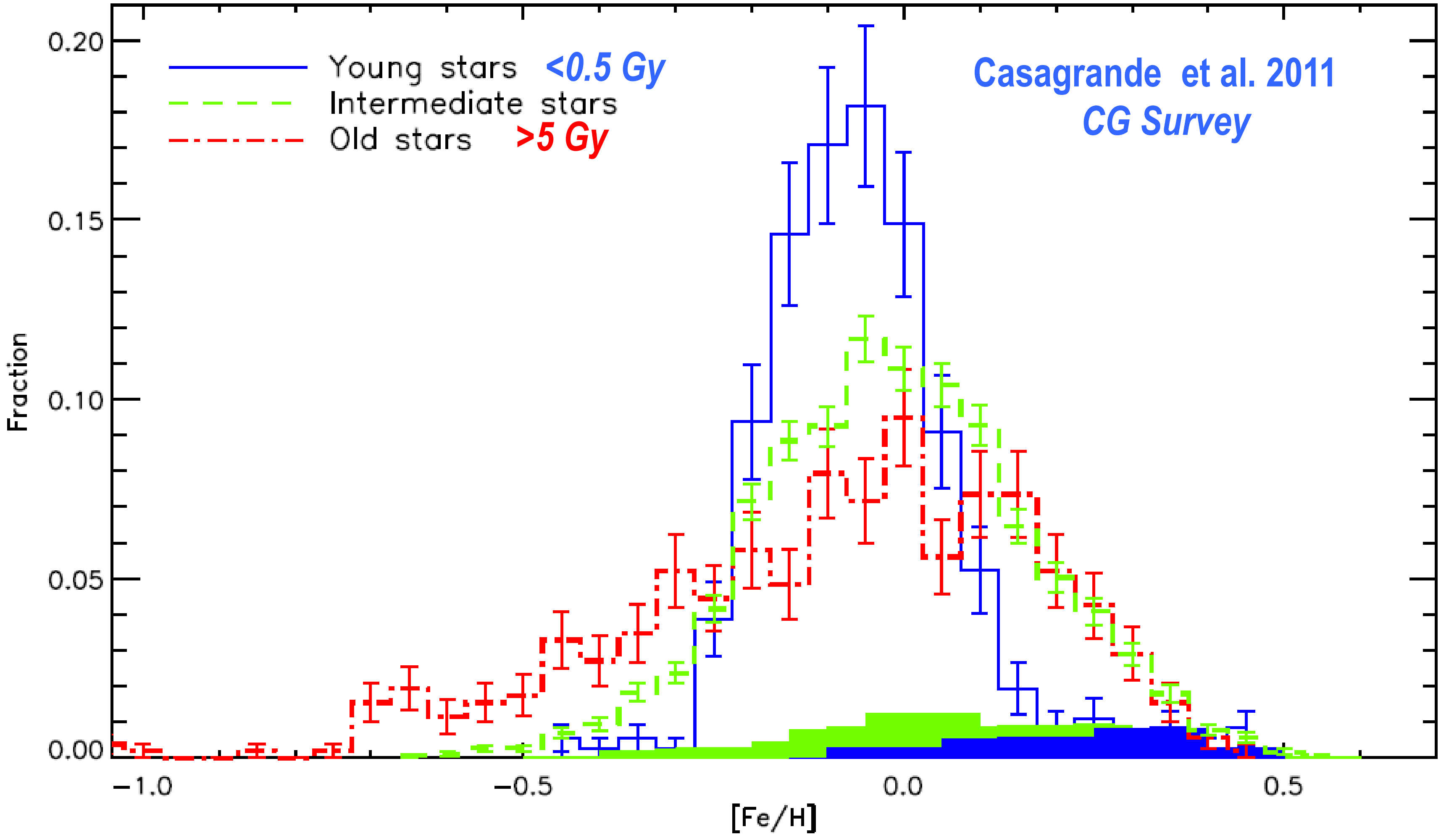
Nieva and Przybilla(2012)

Similar conclusions from a high resolution NLTE analysis of 29 nearby B-stars in the field (within a few hundred pc from the Sun)

Fluctuations of less than 10% (0.04 dex) from the mean



Inadequacy of the simple models for the solar neighborhood

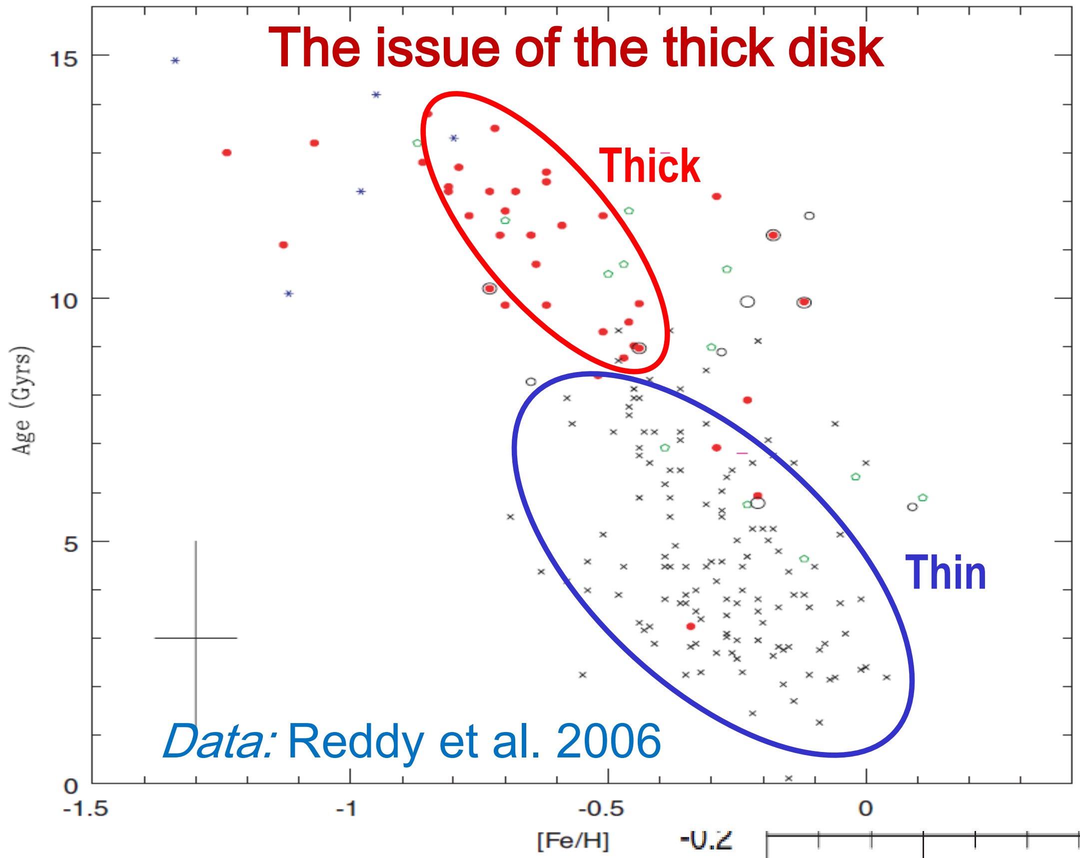


Old *AND* young stars of both *high* and *low* metallicities

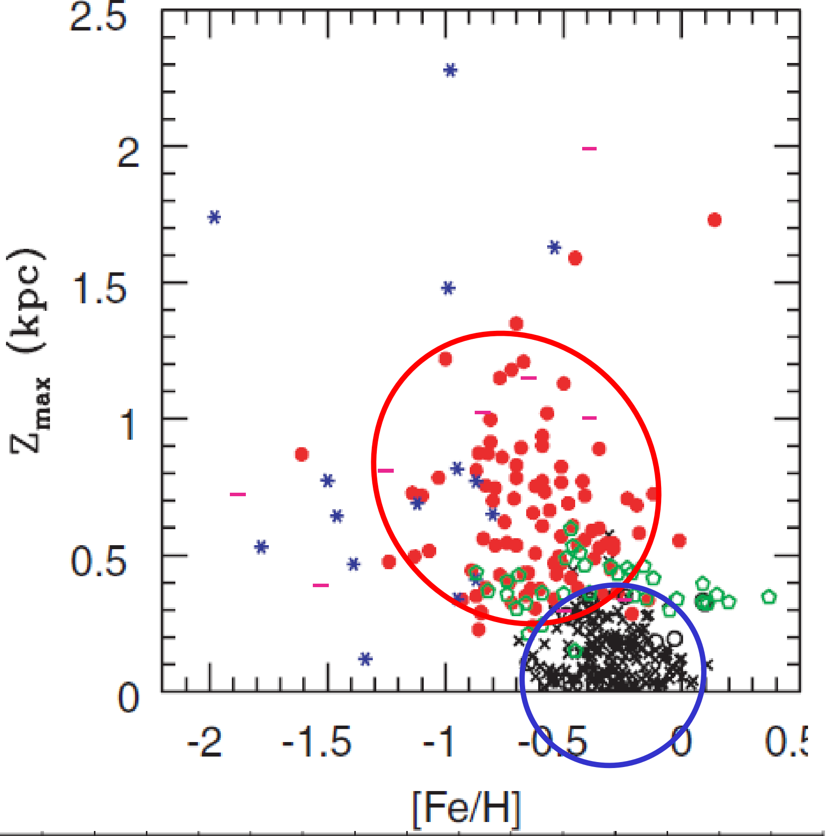
- **the most metallic stars (2-3 Z☉) CANNOT be LOCAL**

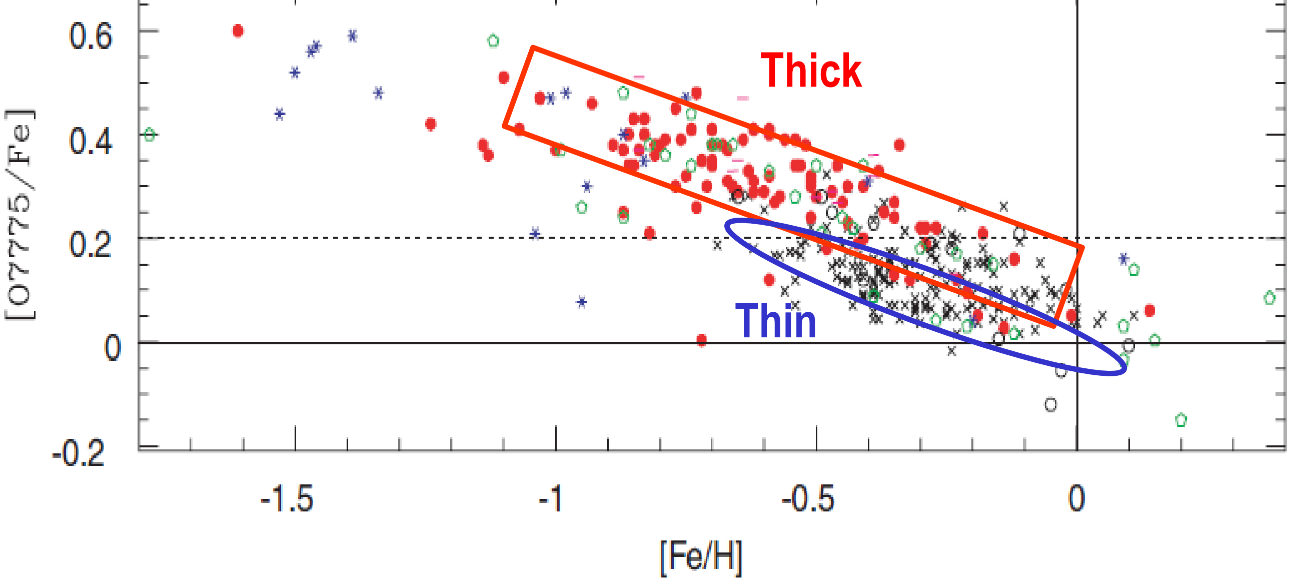
- they are NOT the youngest

The issue of the thick disk



Data: Reddy et al. 2006



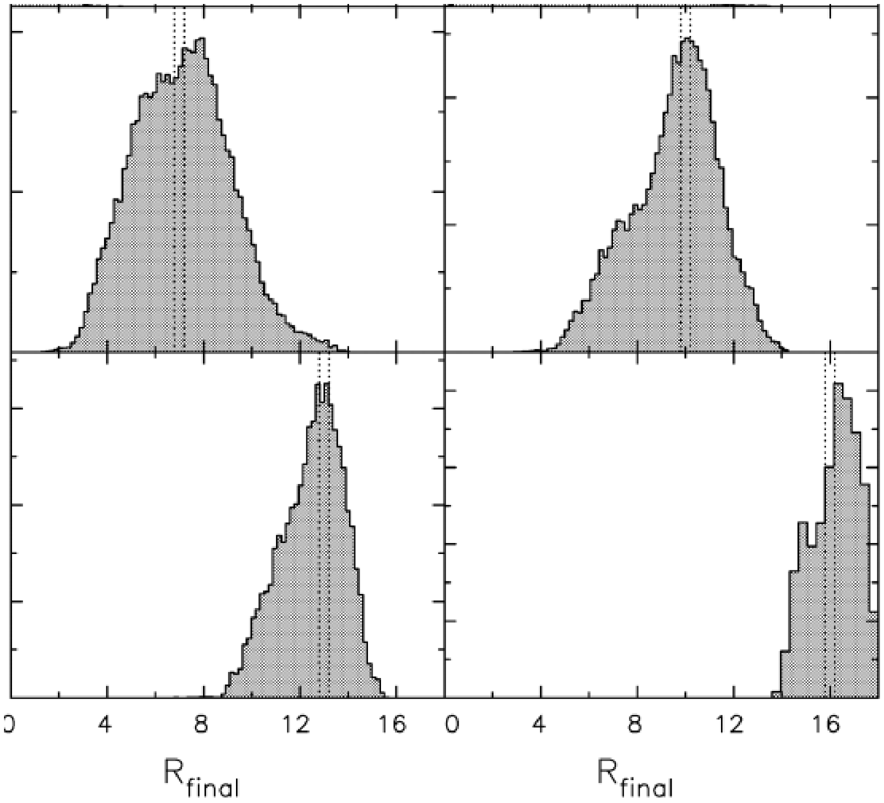


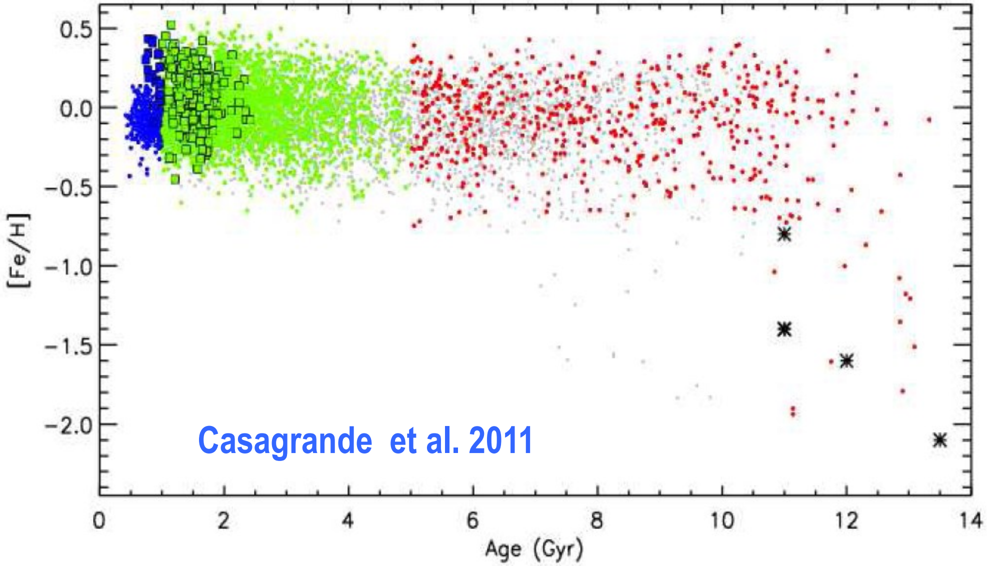
Old (>8-9 Gyr) stars,
have larger scaleheight
and **higher O/Fe ratio**
than thin disk stars
of the **same metallicity**

EFFECT OF TRANSIENT SPIRALS
(Sellwood and Binney 2002)

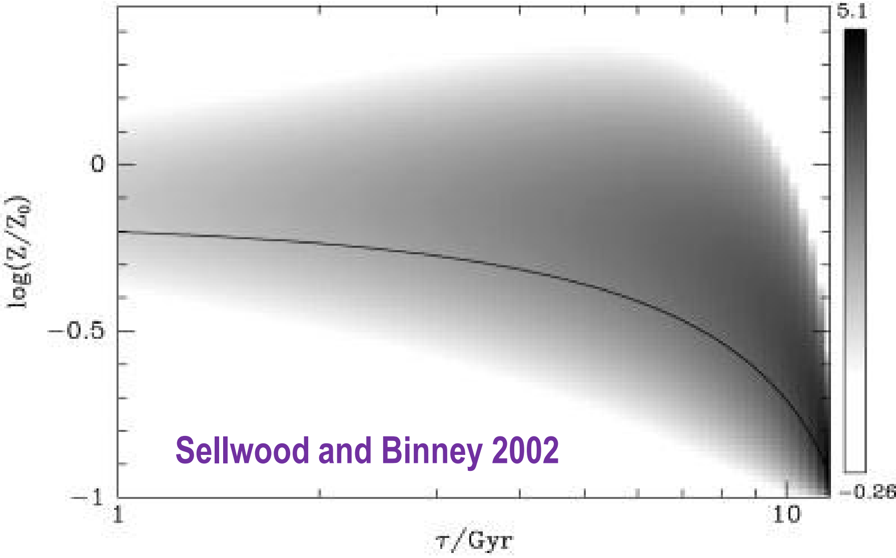
Stars just inside corotation with spirals swap places with those just outside it;
Radial migration (churning)
without heating radially the disk

It can « naturally » explain
(assuming **a disk metallicity gradient)**
the observed *dispersion* in
local age-metallicity relation





Casagrande et al. 2011



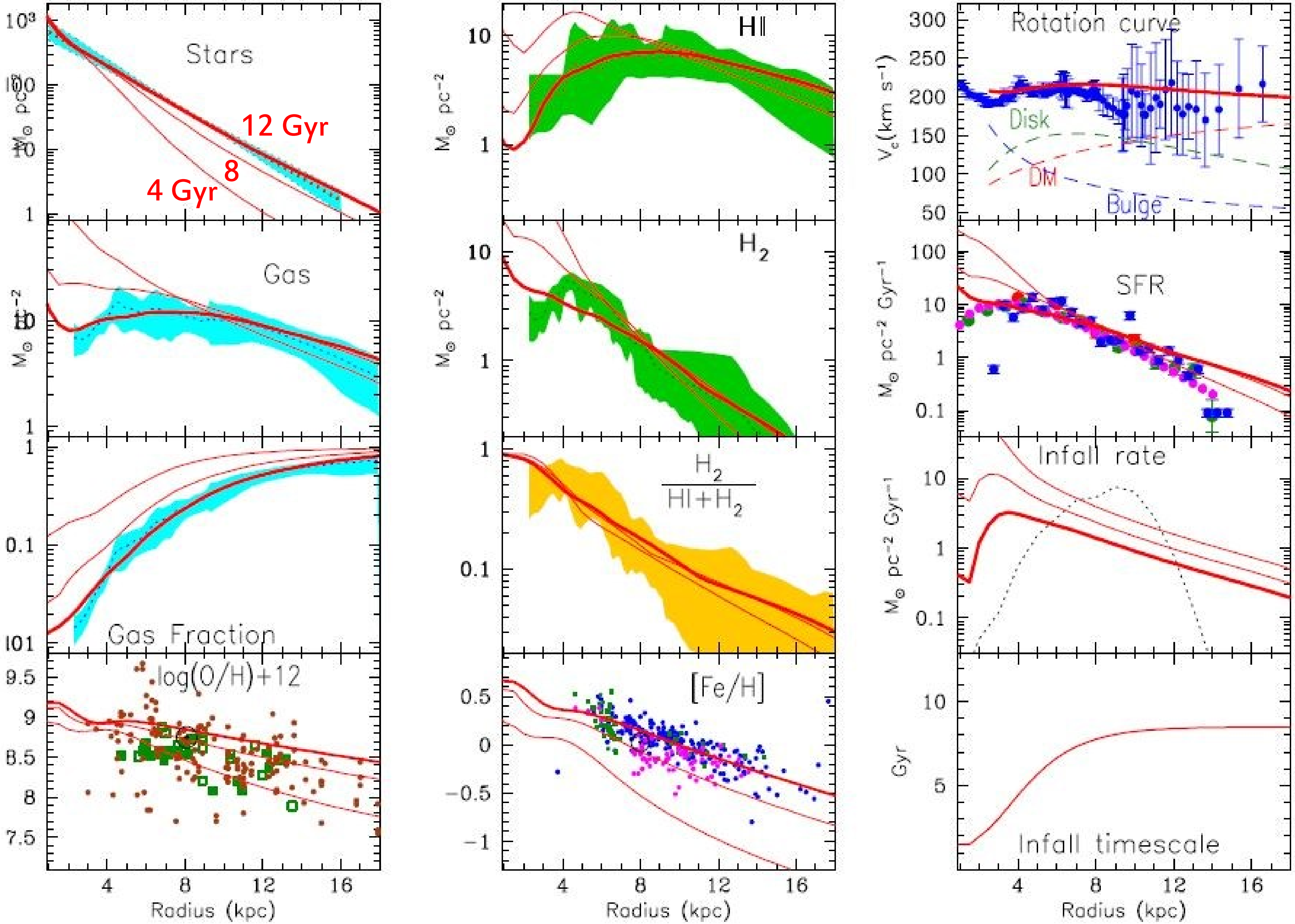
Sellwood and Binney 2002

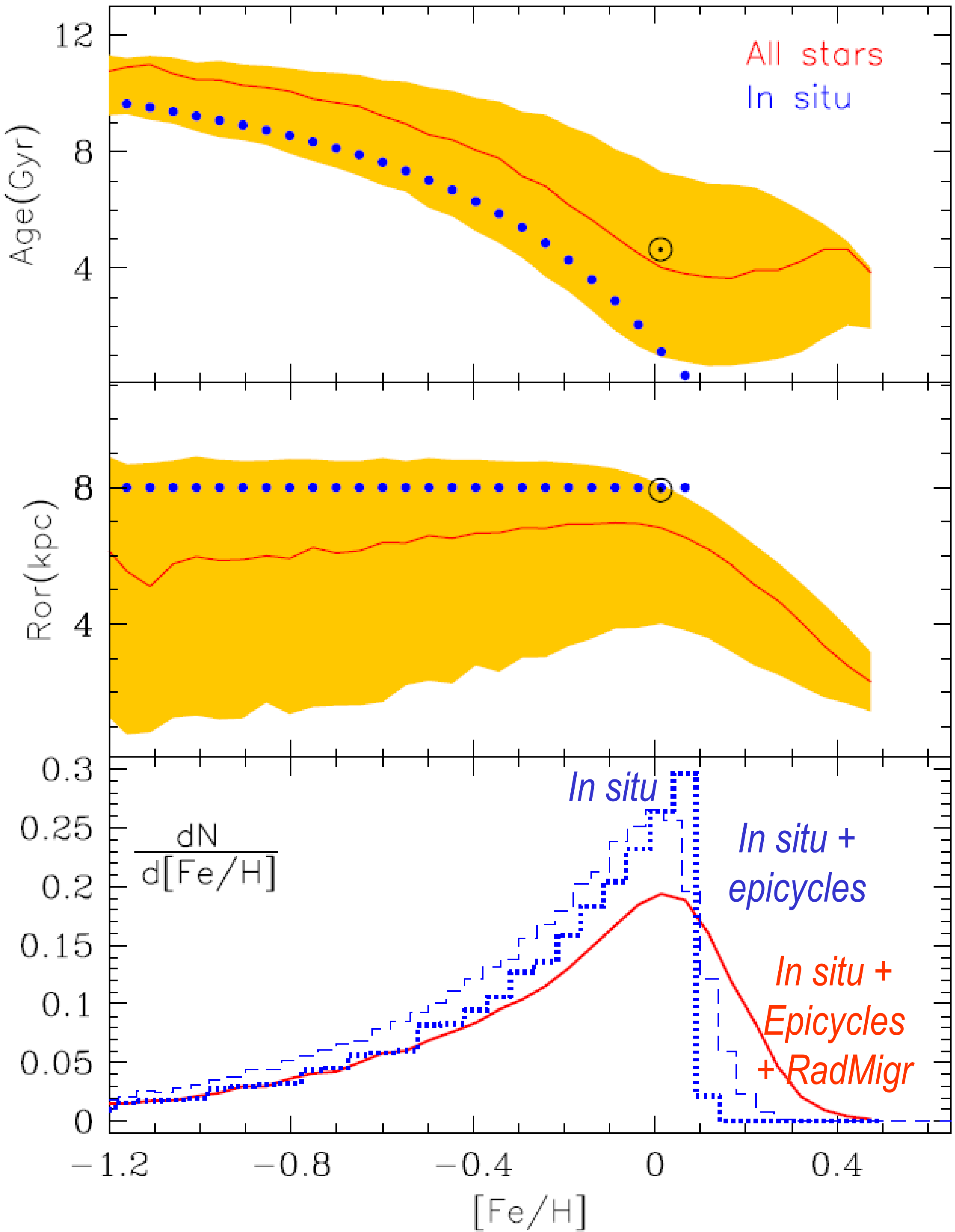
(*Kubryk, NP, Athanassoula AA 2015a,b*)

1D semi-analytical model
with parametrized infall in a DM halo,
SFR from H2,
detailed chemical evolution
(H to Zn, with 2013 yields from both
massive and LIM stars)
with non-IRA
and observed DTD for SNIa rate

and radial motions of gas (parametrized radial inflow)
and stars (with separate treatment of
blurring : analytical
and *churning*: inspired from N-body simulation,
properly re-scaled)

Comparison to present-day profiles of MW disk





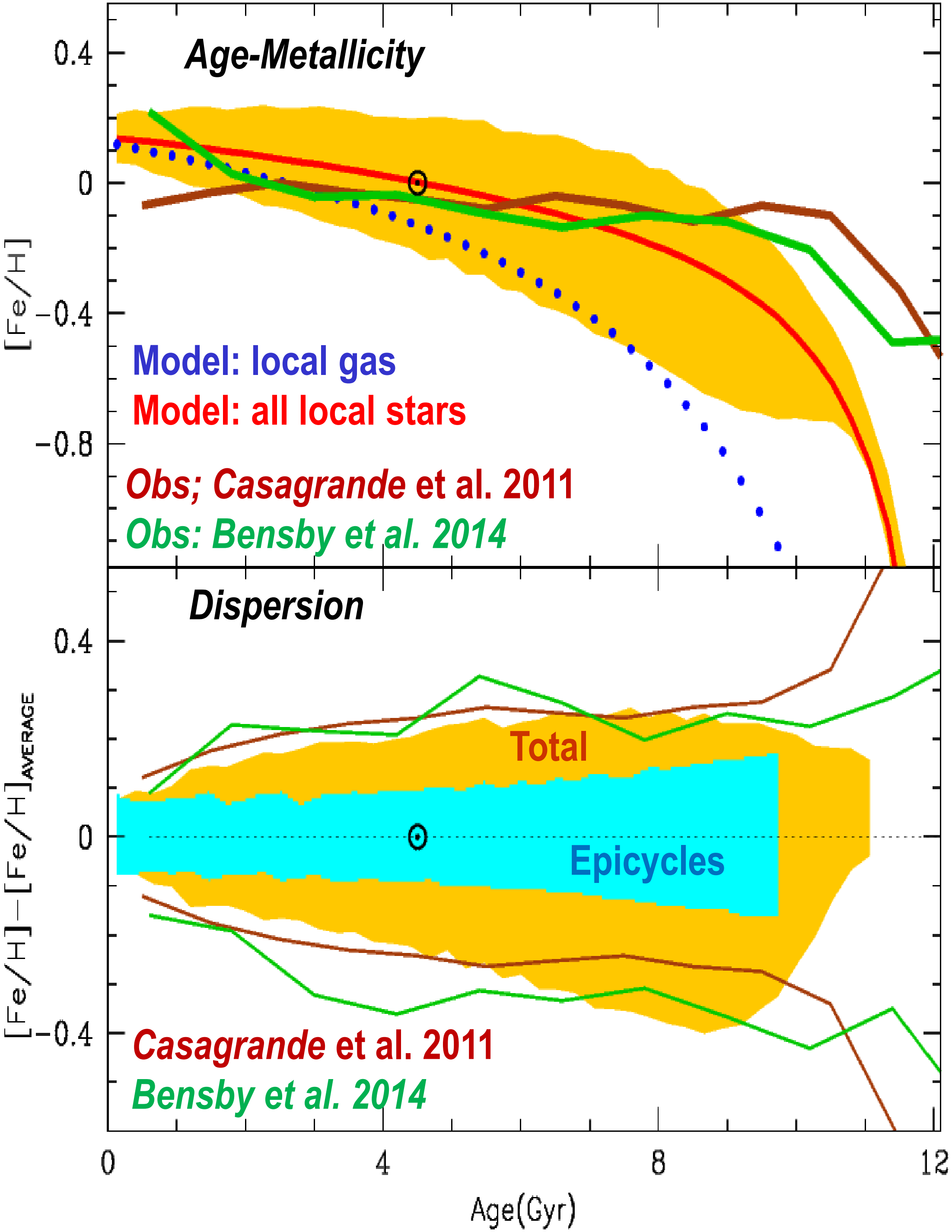
Solar Neighborhood

Radial Migration

1. Increases the average stellar age by ~1 Gyr

2. … and brings locally stars from ~1.5 kpc inwards (on average)

3. The most metal-rich local stars come from several kpc inwards and are ~4 Gyr old



Solar Neighborhood
Radial Migration

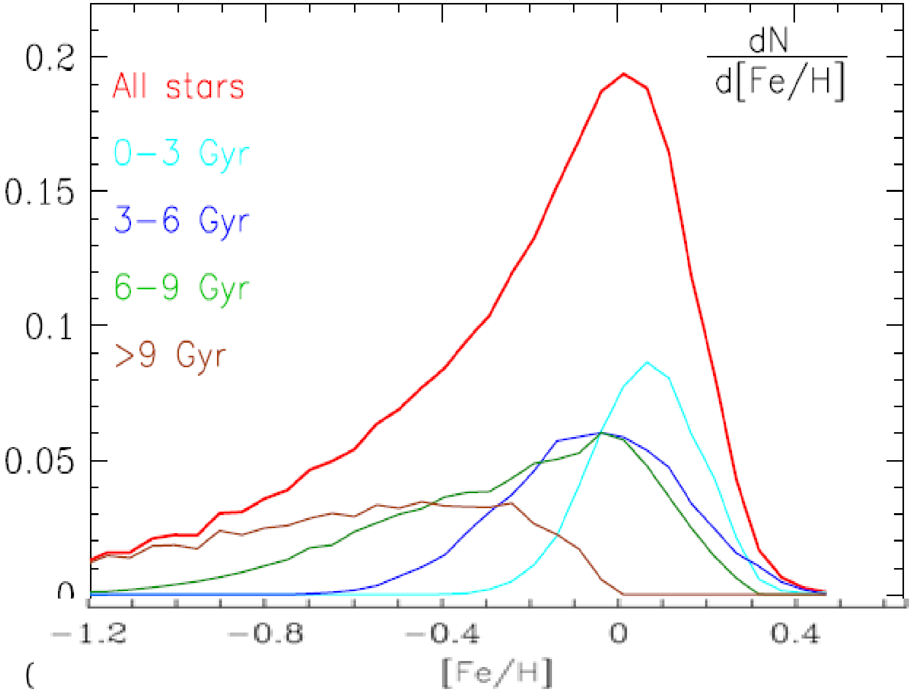
1. Modifies the apparent local SFR *(Röskar et al. 2008)*

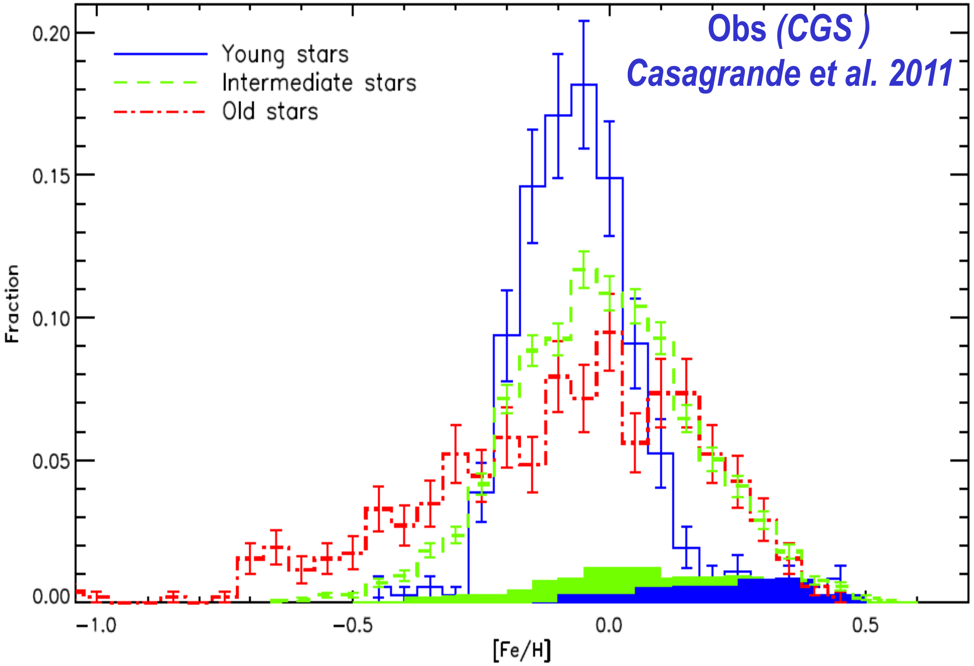
2. Creates dispersion in the age-metallicity relation… *(Sellwood and Binney 2002)*

3. …more than the epicyclic motion (~0.08 dex)

and comparable with observations

Solar Neighborhood : stars with different ages and from different regions *at all metallicities*



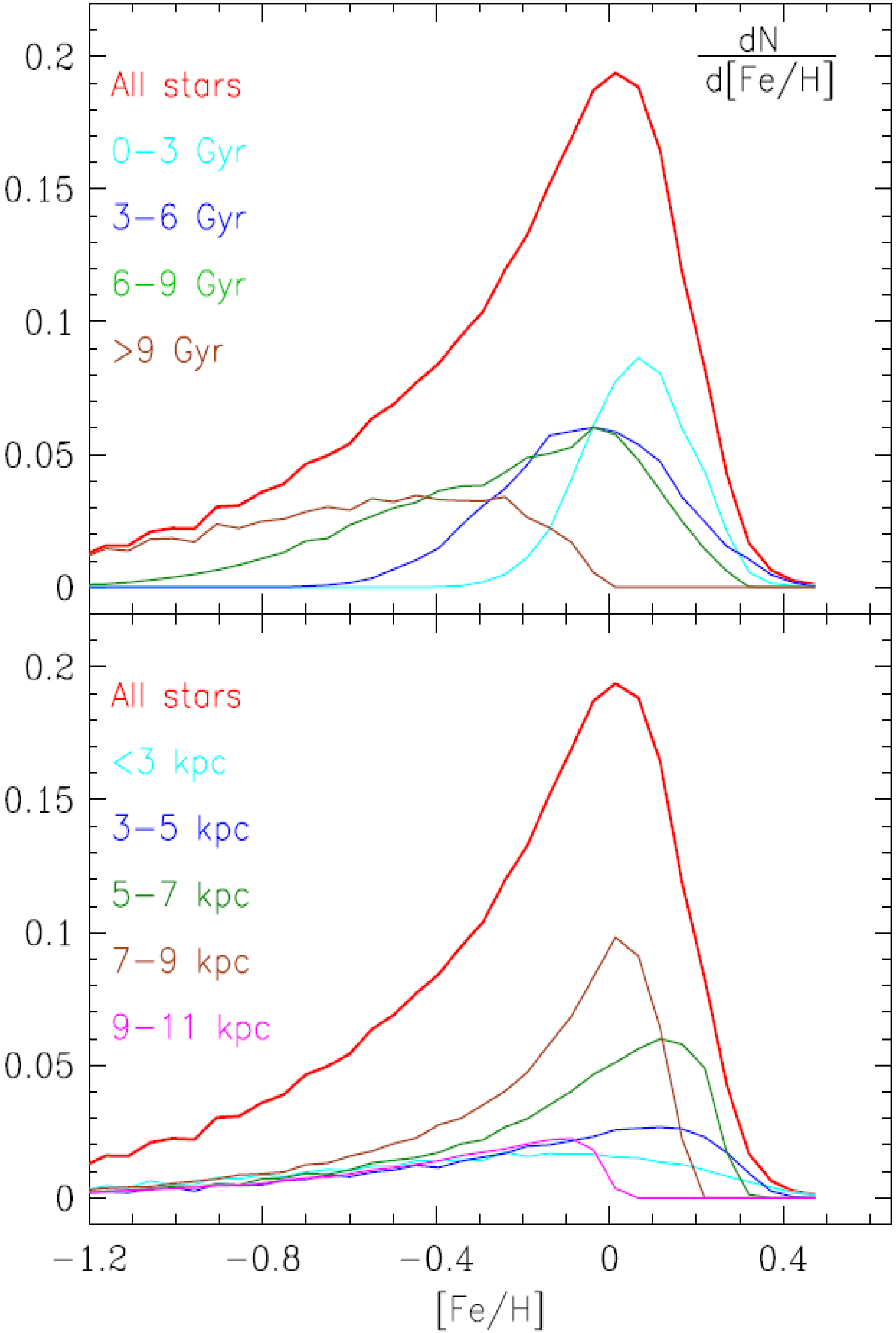


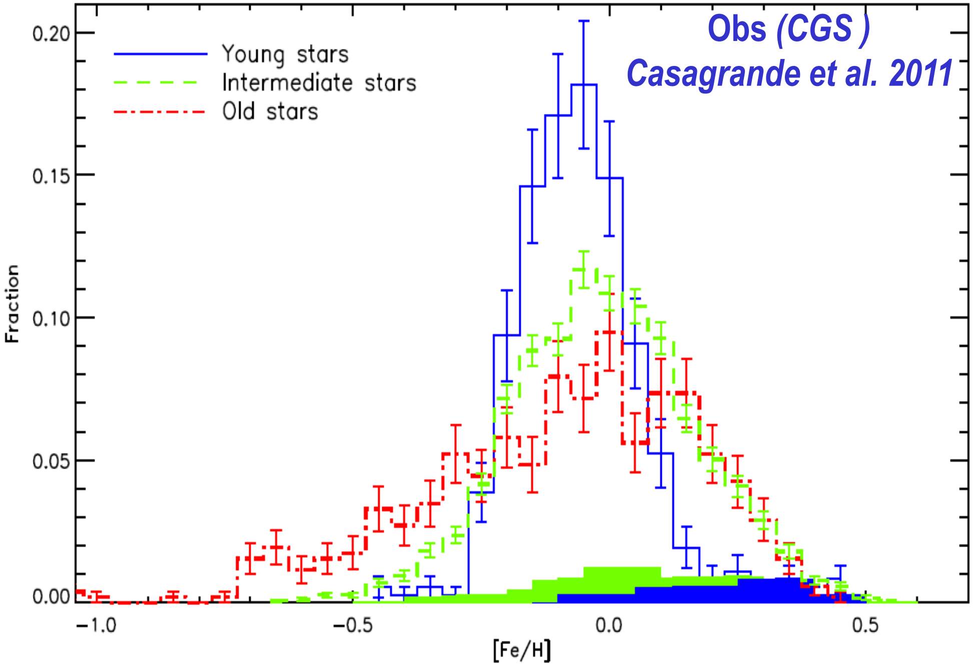
Obs *(CGS)*
Casagrande et al. 2011

The most metallic stars (2-3 Z⊙)

- **are not the youngest**

Solar Neighborhood : stars with different ages and from different regions *at all metallicities*





Obs *(CGS)*
Casagrande et al. 2011

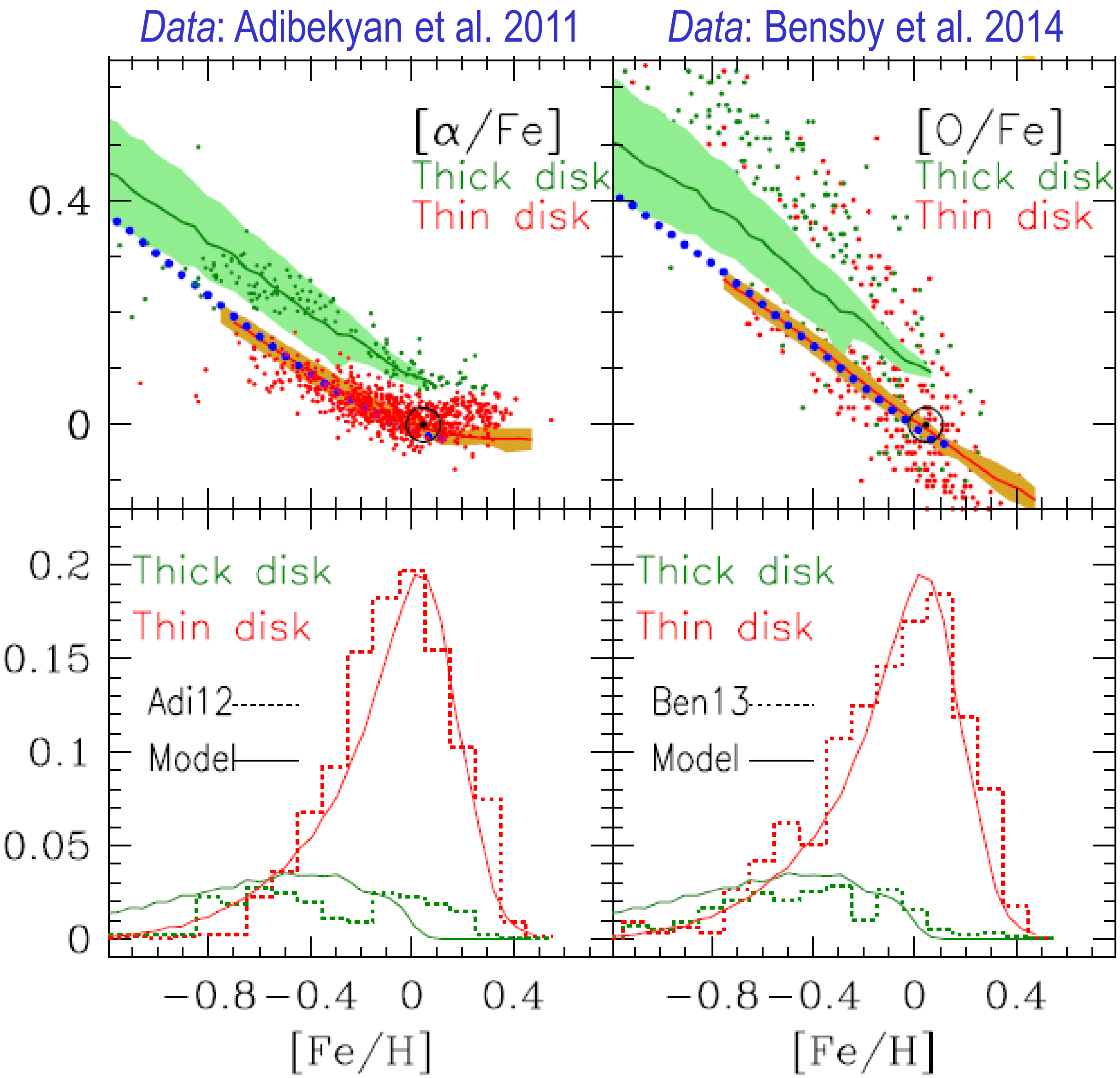
The most metallic stars (2-3 Z⊙)

- **are not the youngest**
- **are not local**

Assuming that
the thick disk is
the old disk (>9 Gyr)

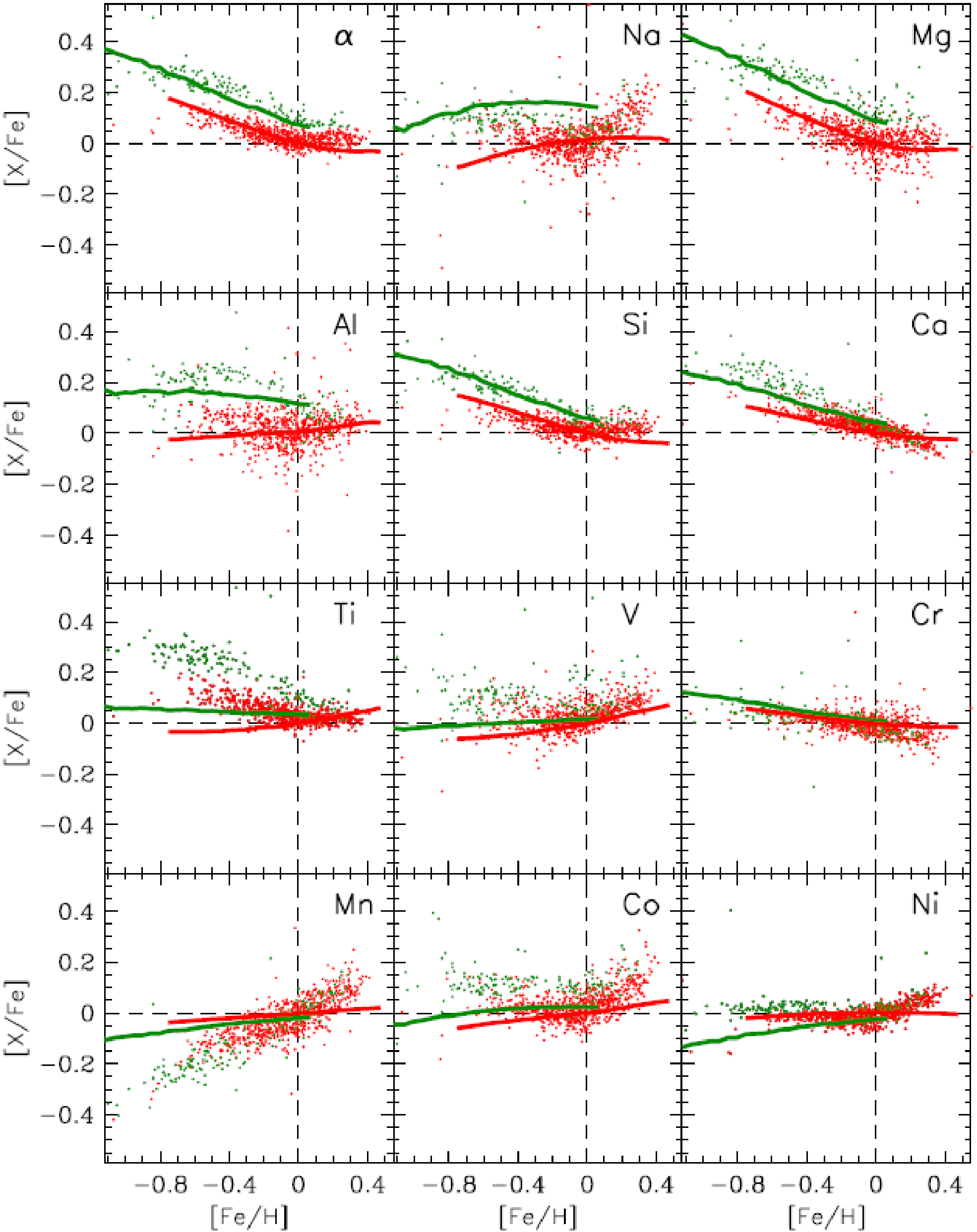
we recover the
[a/Fe] vs Fe/H behaviour
and the
metallicity distributions
of both
the thick and thin disks

(Schoenrich and Binney 2009)

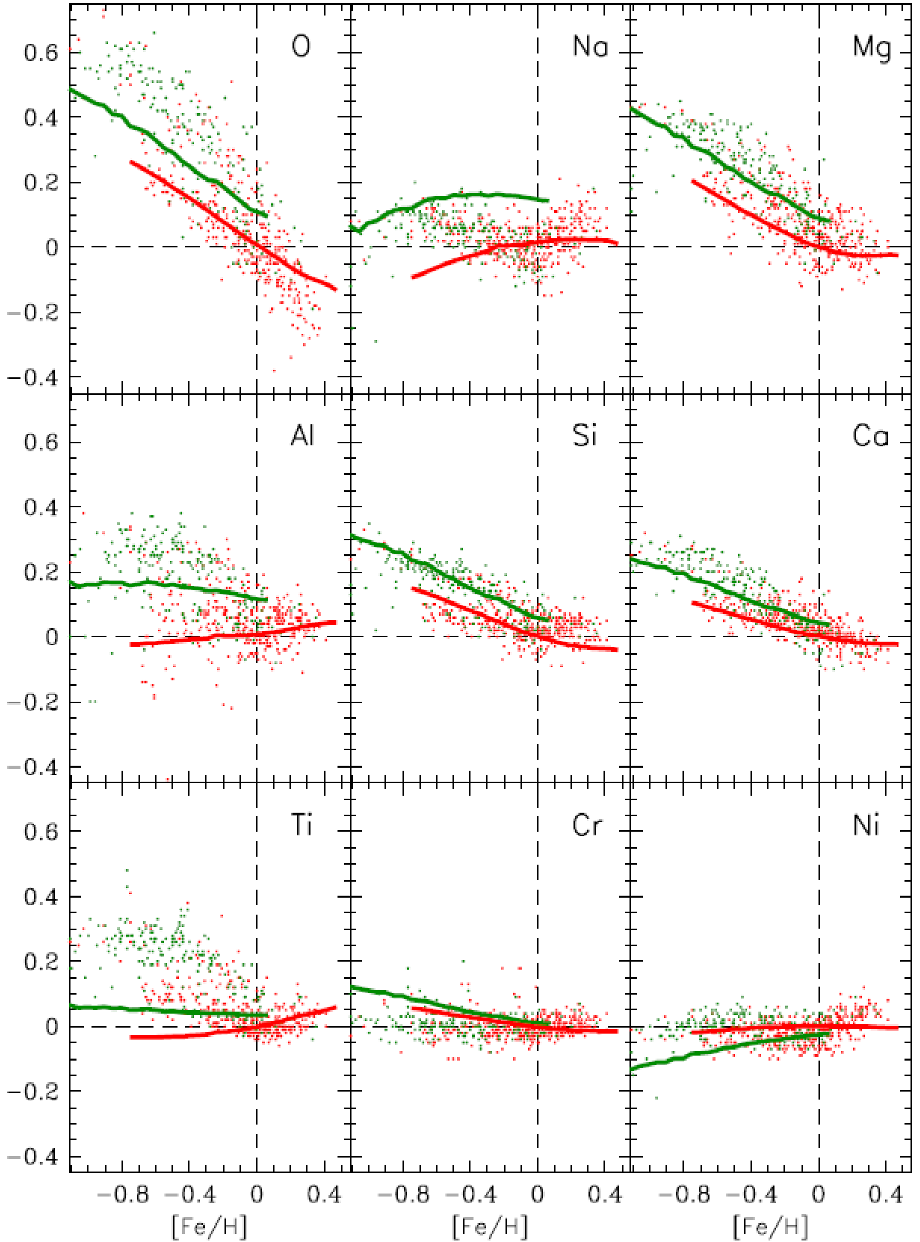


Evolution of thin (<9 Gyr) and thick (>9 Gyr) disks
with yields NORMALISED to solar for AVERAGE LOCAL (8 kpc) STAR 4.5 Gyr old

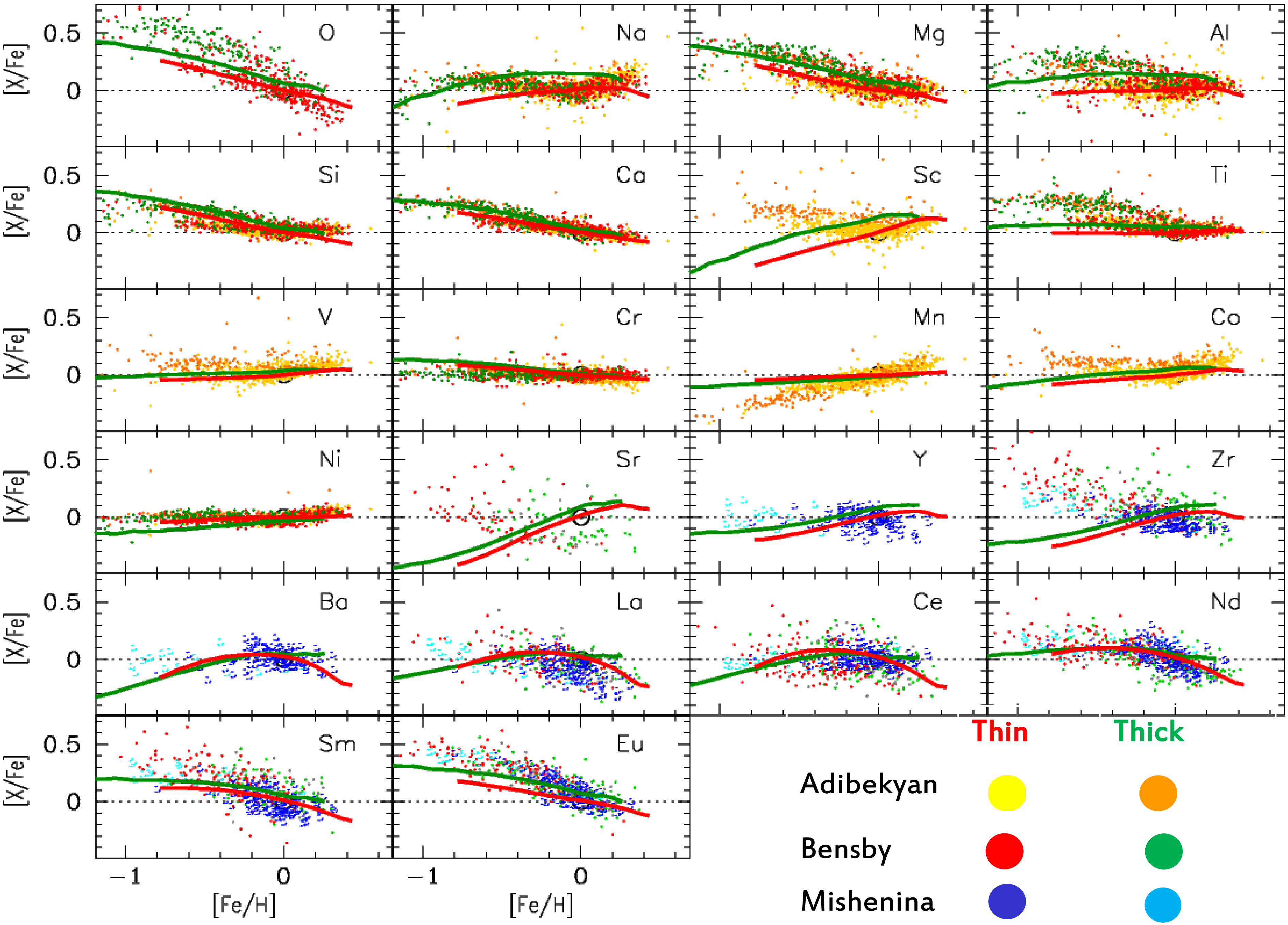
Data: Adibekyan et al. 2011



Data: Bensby et al. 2014



Calculations with new yields (Roma) for massive and LIM stars for all isotopes up to Pb (including s-nuclei)



The evolution of Li in the thin and thick disks

At least three sources of Li:

Big Bang

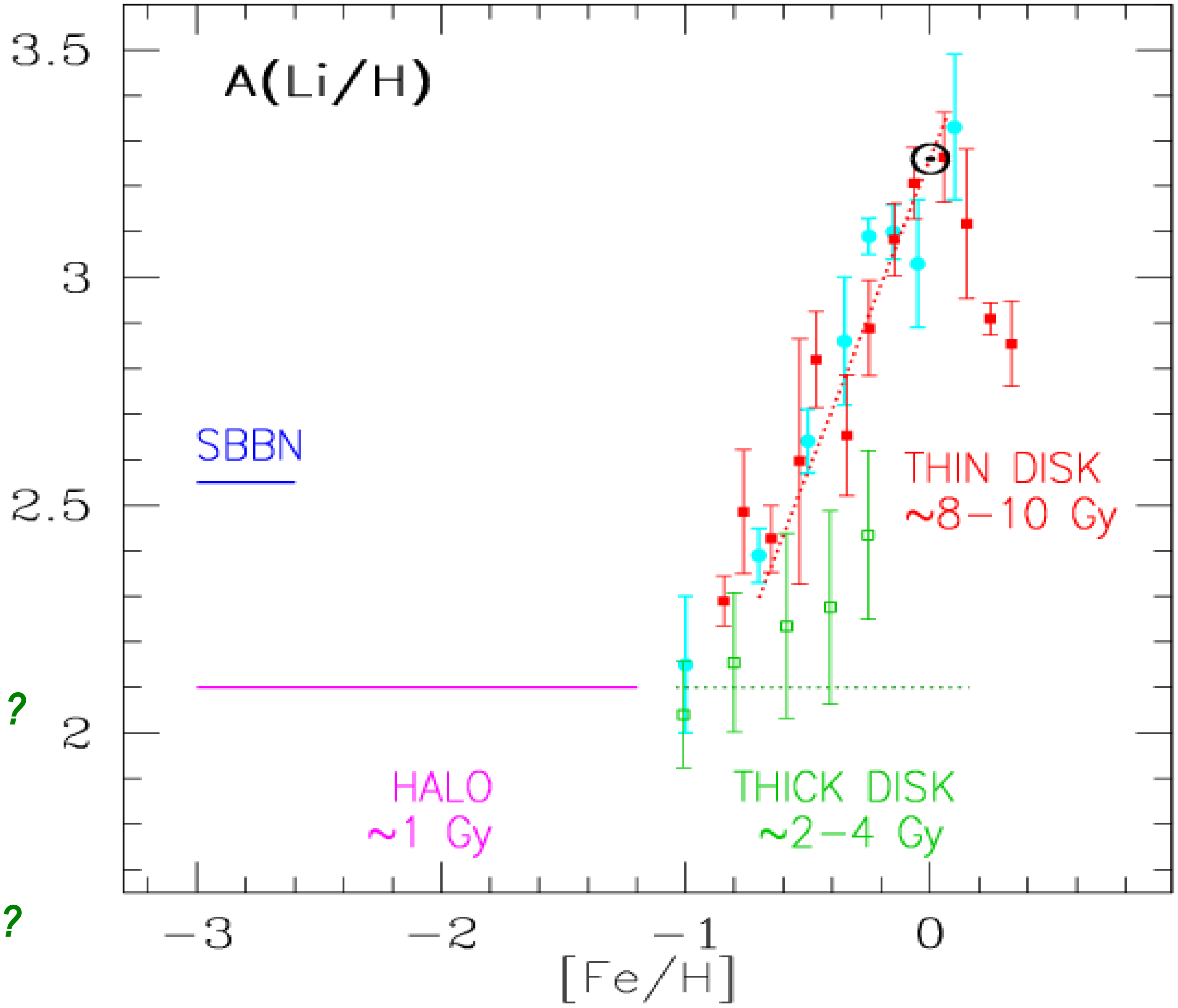
Cosmic rays

Stellar (>60% of solar Li)
Delayed ([Fe/H]>-1) ⇒
Timescale > 1 Gy

2 important problems

1. ***What is the primordial Li ?***
   SBBN vs Spite plateau ?

2. ***Which stellar source ?***
   Novae , Red giants or AGBs ?



AMBER data suggest different sequences of evolution for the thick and thin disks

Double sequence explained by radial migration, for

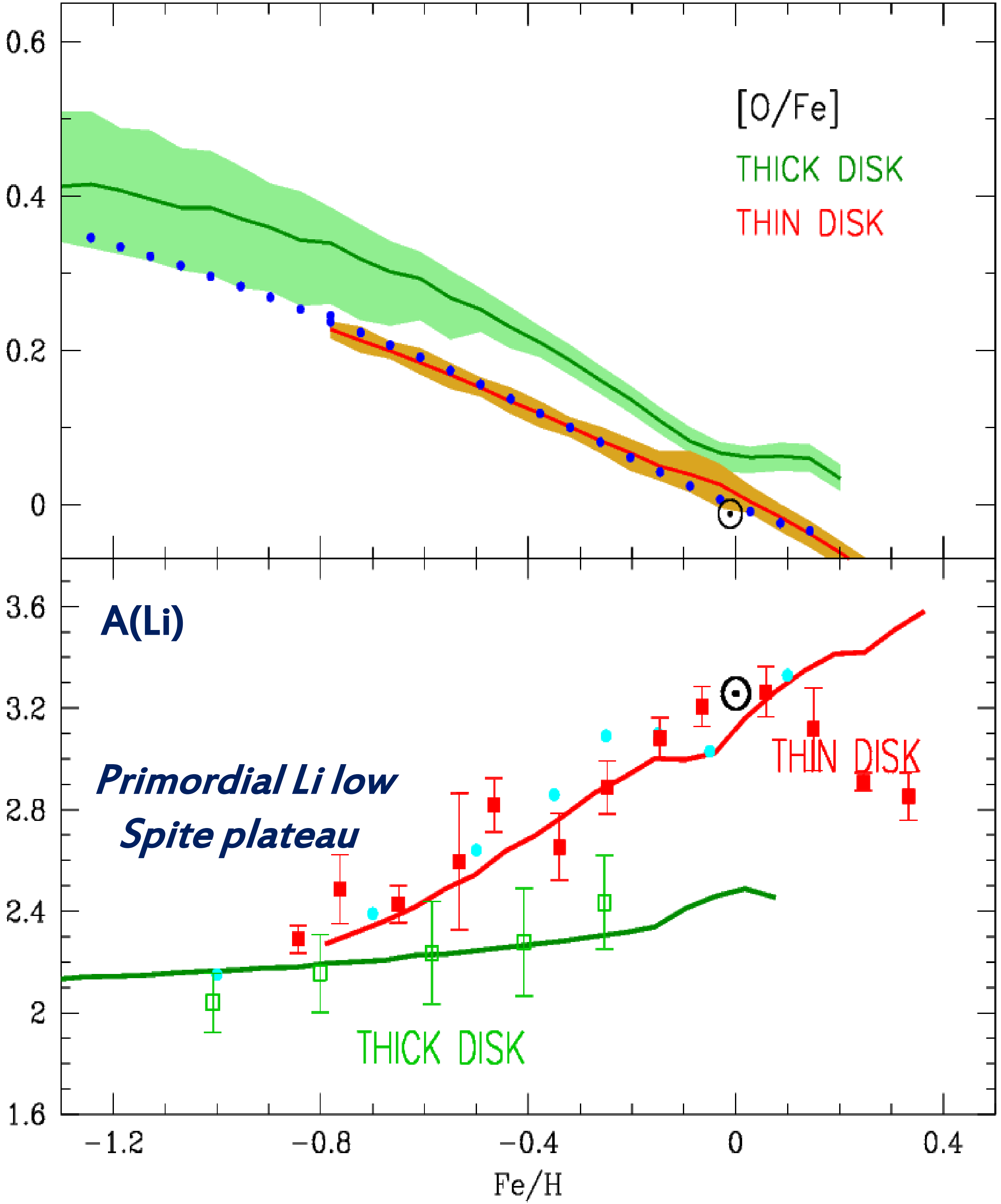
Thin disk <9 Gy
Thick disk >9 Gy

and long lived Li source
(M<1.6 M⊙, τ>2 Gy)

Starting with low primordial Li
(Spite plateau)

no Li depletion in stellar atmospheres is required

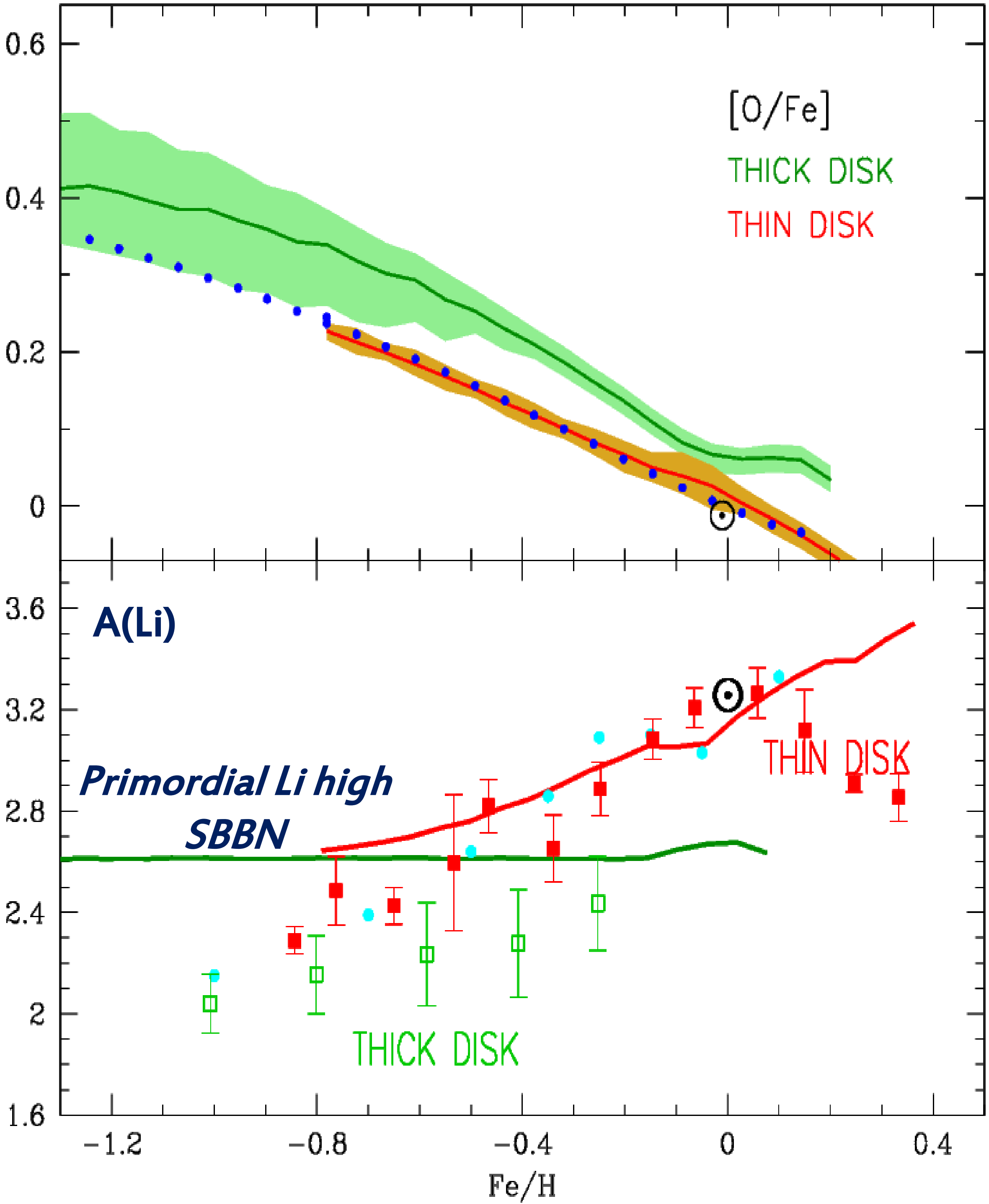
to explain the upper envelope of observations



Starting with high primordial Li *(SBBN)*

important Li depletion in stellar atmospheres is required

to explain the upper envelope of observations



Radial migration in MW disk may explain

1. Dispersion in local age-metallicity

2. Presence of metal-rich stars locally

3. Presence of old metal-rich and young metal-poor stars locally

4. Double sequence of O/Fe in local thin and thick disks

5. Double sequence of Li/H in thin and thick disks *(new)*

Also : different evolution of X/Fe in thin and thick disks will help constraining stellar nucleosynthesis for -1< [Fe/H]<1

Preliminary: s/Fe not expected to behave (very) differently because of similarity in evolutionary timescales