Modelling the Galactic disc(s) with radial mixing

Madrid, 15.10.2009

Ralph Schönrich (MPA)
with James Binney,
Martin Asplund

What is your personal thick disc?

What is your personal thick disc?

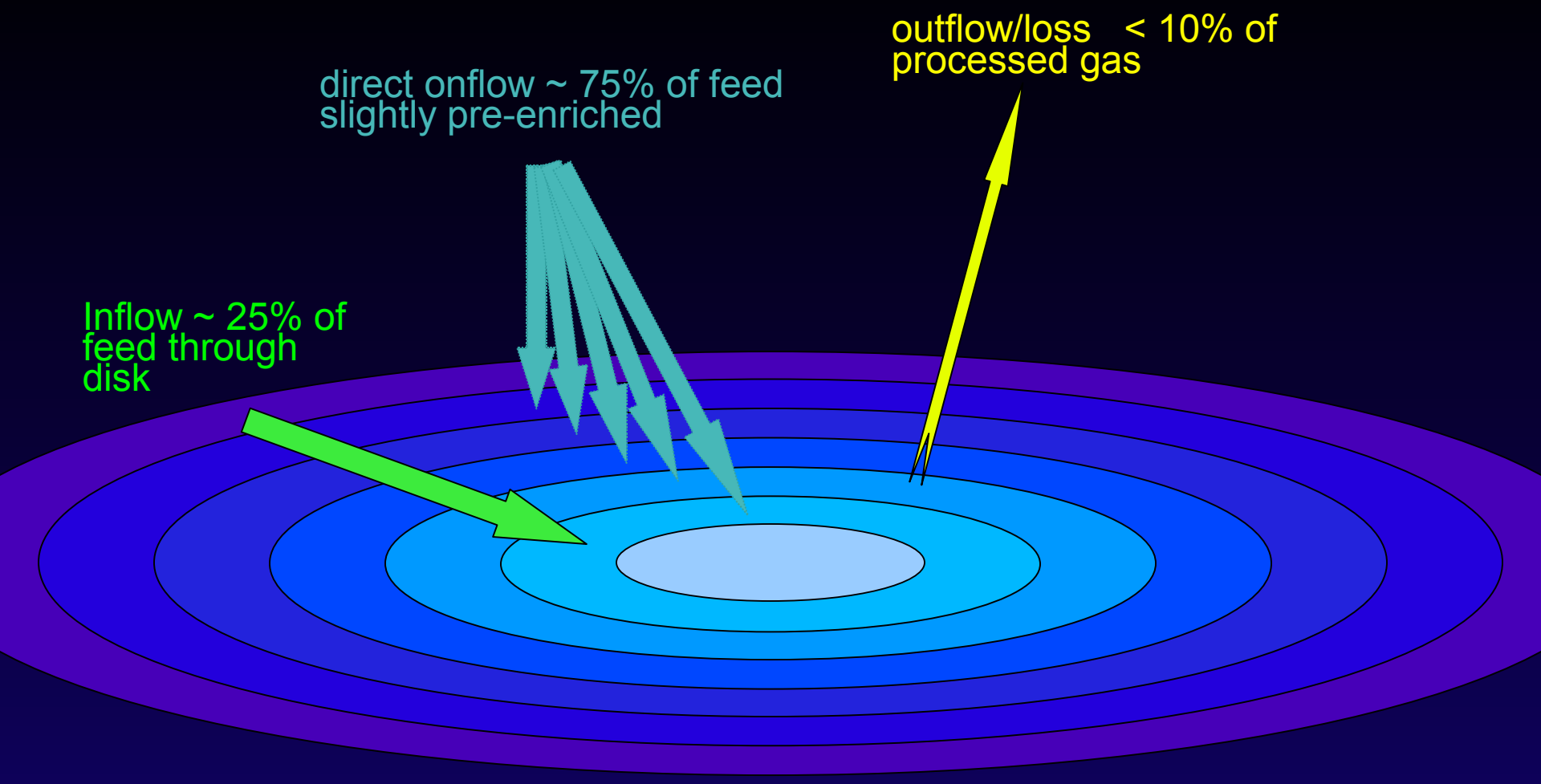
Two-exponential fit of vertical density profile

Bimodal behaviour in [α/Fe]

Asymmetric drift

Full chemo-kinematical representation

Model



radial spacing 0.25 kpc

time spacing 30 Myrs

Basic ingredients

Gas disc:

exponential disc, scalelength *l* = 3.5 kpc $\Sigma_g \propto e^{-R/l}$

cold and warm gas

Star formation law:

Kennicut (1998) law:

$$\frac{d\Sigma_g}{dt} = 1.2\text{x}10^{-4} \begin{cases} \Sigma_g^{1.4} & \text{for} \quad \Sigma_g \geq \Sigma_{crit} \\ C\,\Sigma_g^{4} & \text{for} \quad \Sigma_g < \Sigma_{crit} \end{cases}$$

Initial mass function:

Salpeter IMF: $\frac{dN}{dM} \propto M^{-2.35}$ for $0.1 < M < 100$

Adopted metallicity scale:

$Z_{sun} \sim 0.019$

Basic ingredients

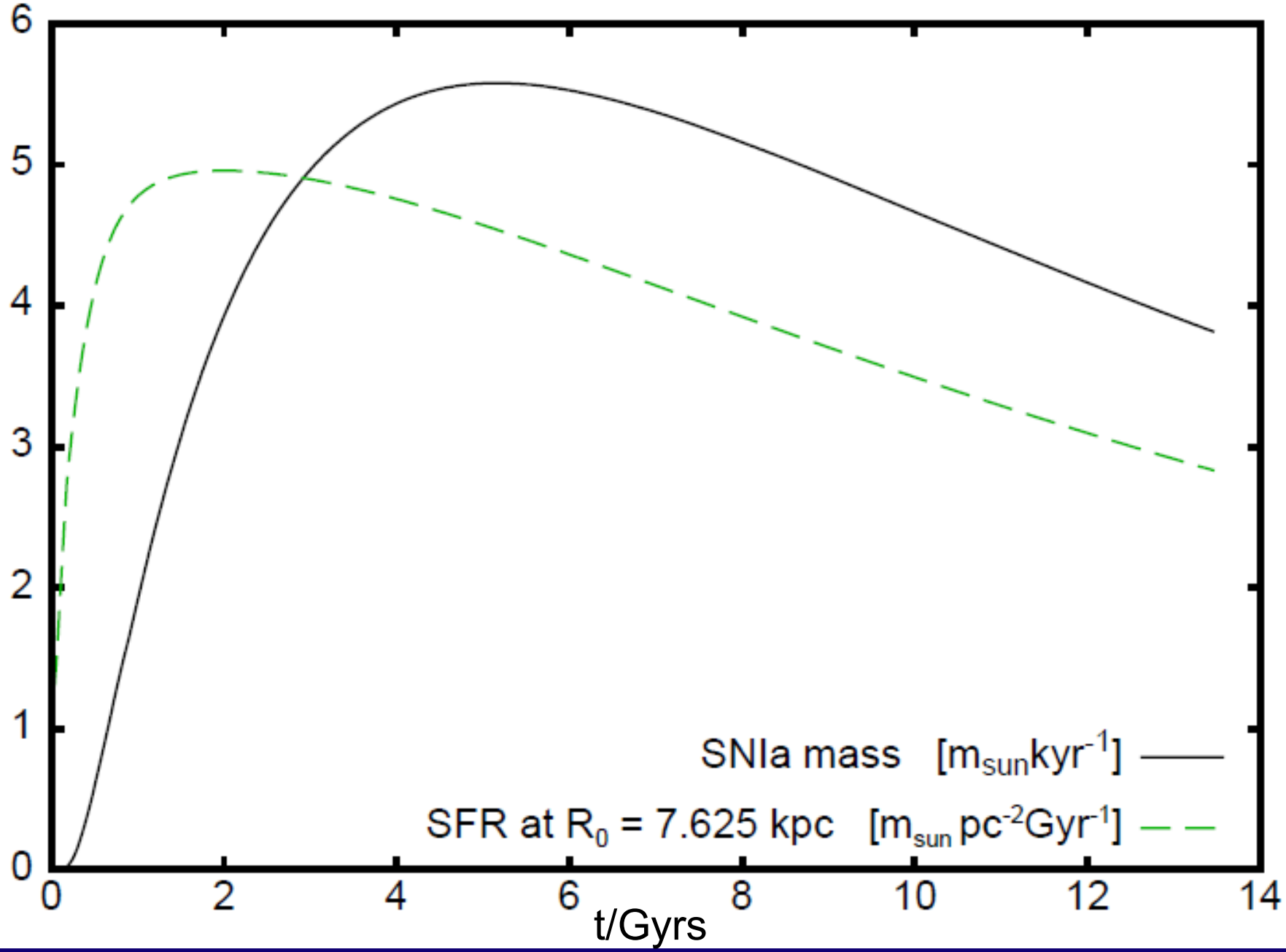
Yields from SNIa

Ascribe 7.5% of remnant mass of stars between 3.5 and 8 Msun to SNIa progenitors.

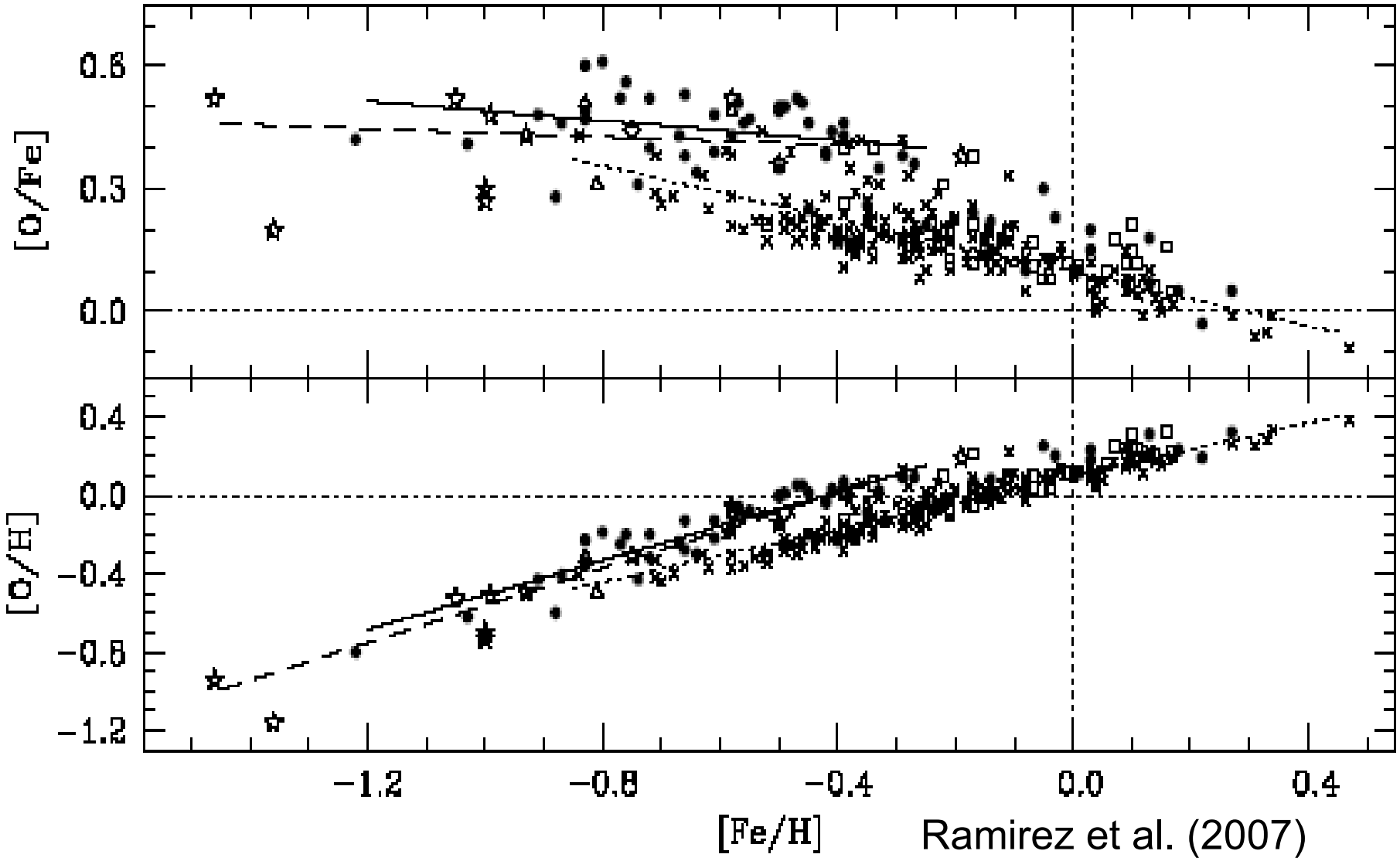
Yields from Iwamoto et al. (2007), W70 model

$$\frac{dM_{WD}}{dt} = \begin{cases} 0 & \text{for} \quad t < 150\,Myr \\ -M_{WD}/1.5\text{Gyr} & \text{for} \quad t \geq 150\,Myr \end{cases}$$

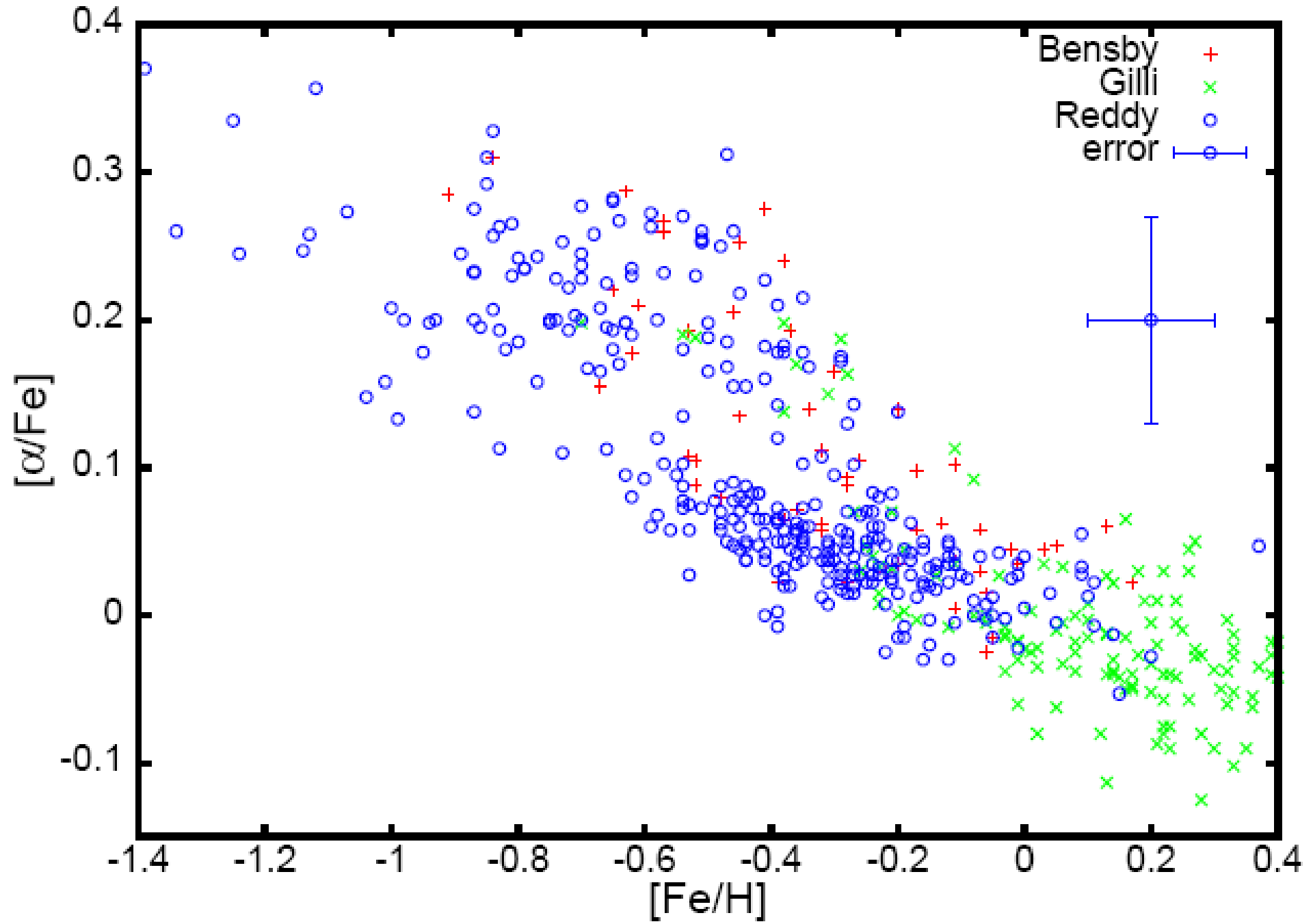
(cp. Förster et al., (2006))

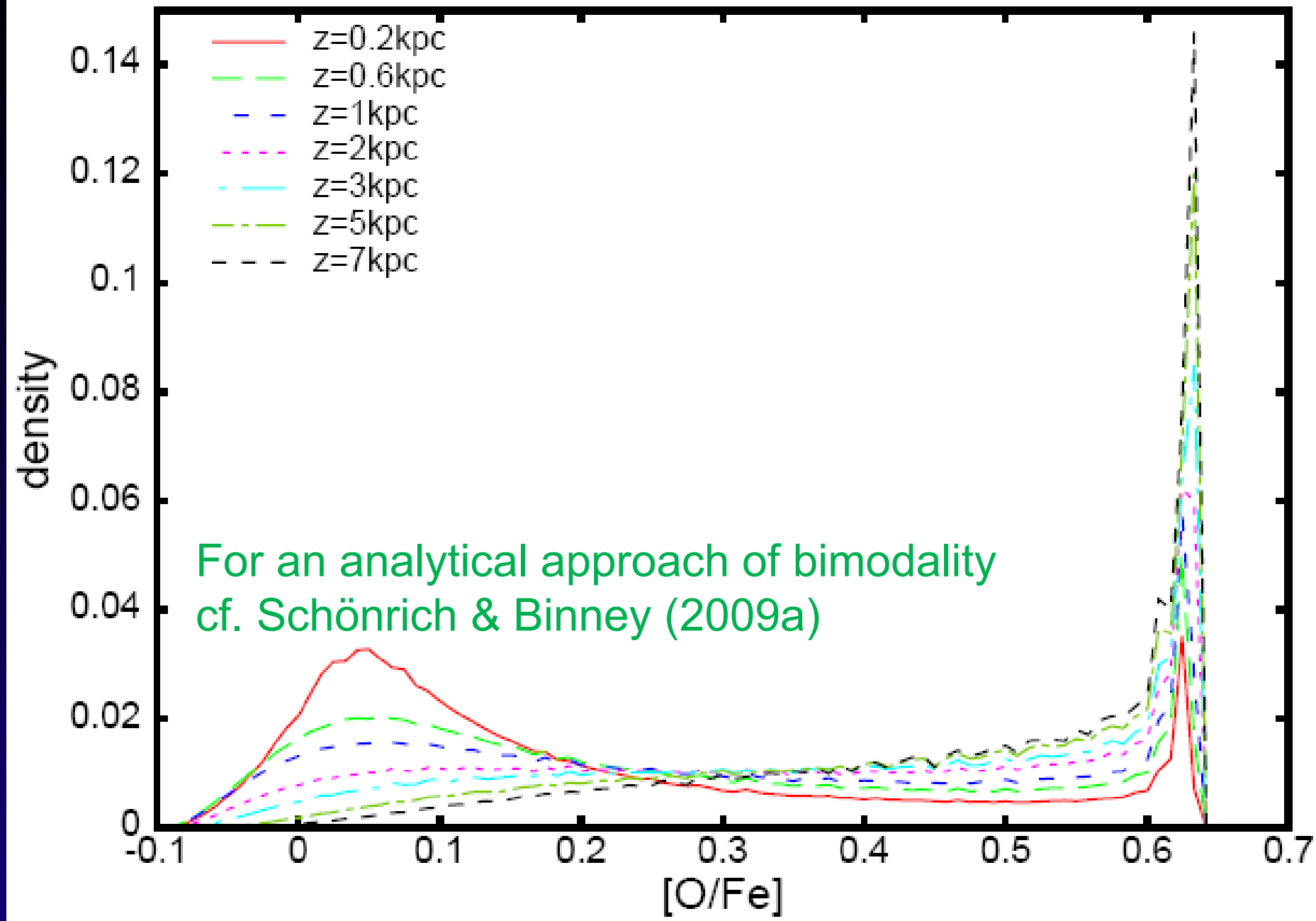

6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
t/Gyrs
SNIa mass [$m_{sun}kyr^{-1}$]
SFR at R_0 = 7.625 kpc [$m_{sun}\,pc^{-2}Gyr^{-1}$]

O/Fe ratios

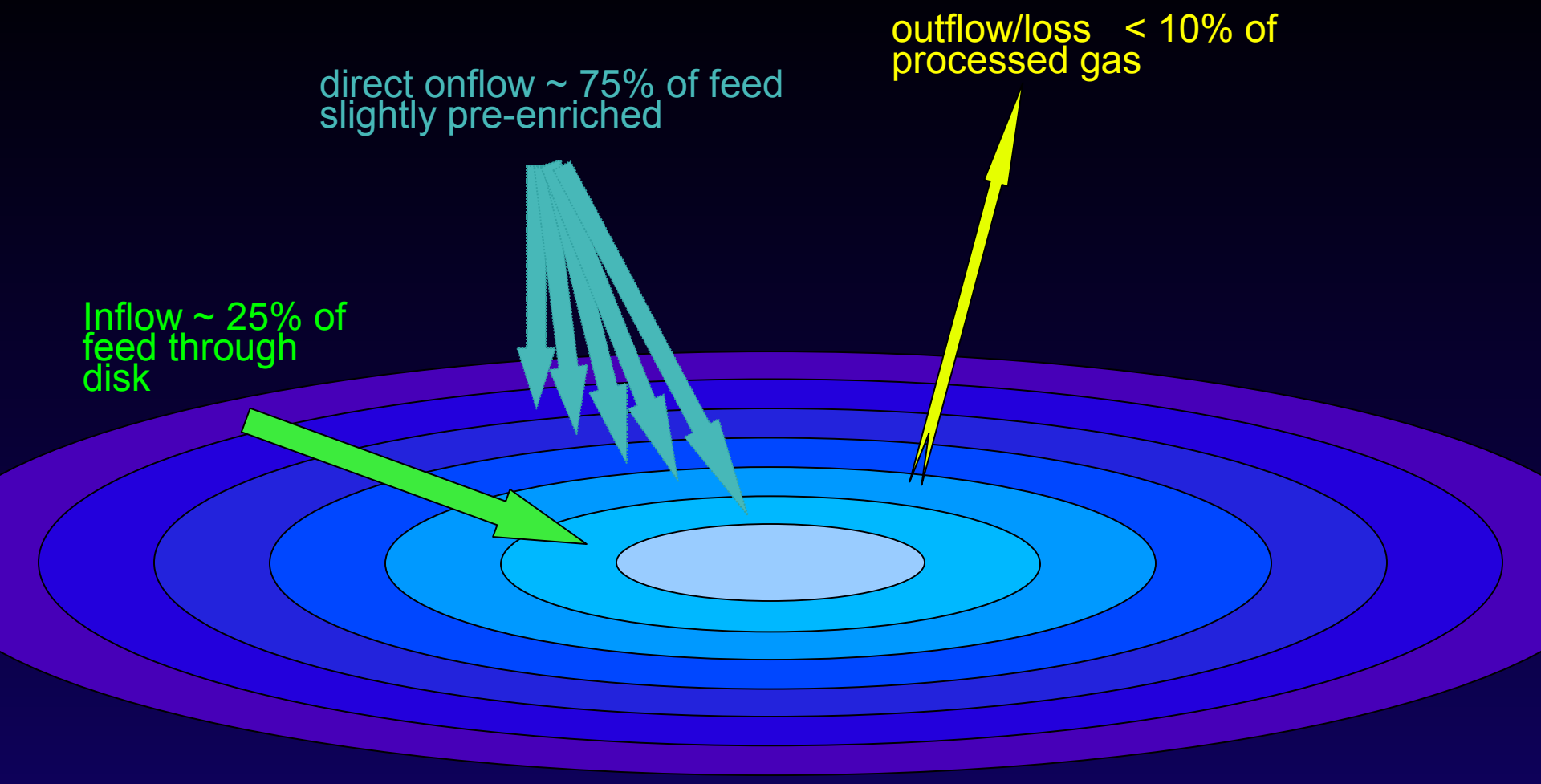


Ramirez et al. (2007)


Bensby
Gilli
Reddy
error
[α/Fe]
[Fe/H]
0.4
0.3
0.2
0.1
0
-0.1
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4


z=0.2kpc
z=0.6kpc
z=1kpc
z=2kpc
z=3kpc
z=5kpc
z=7kpc
density
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
[O/Fe]
For an analytical approach of bimodality
cf. Schönrich & Binney (2009a)

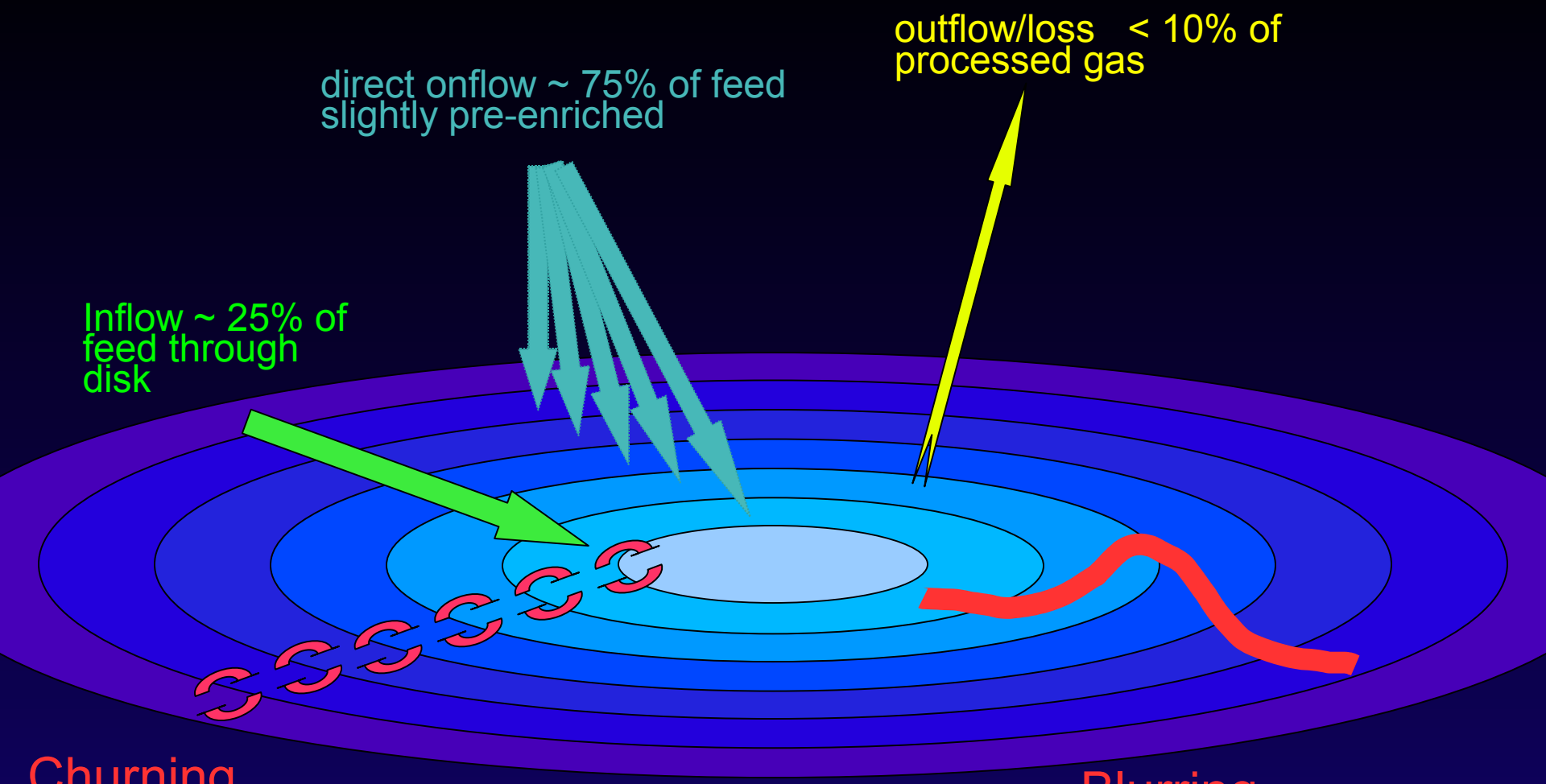
Model



radial spacing 0.25 kpc

time spacing 30 Myrs

Model



Churning

-mass exchange between neighbouring rings
-cold gas and stars
-no heating of the disc
- cf. Sellwood & Binney (2002)

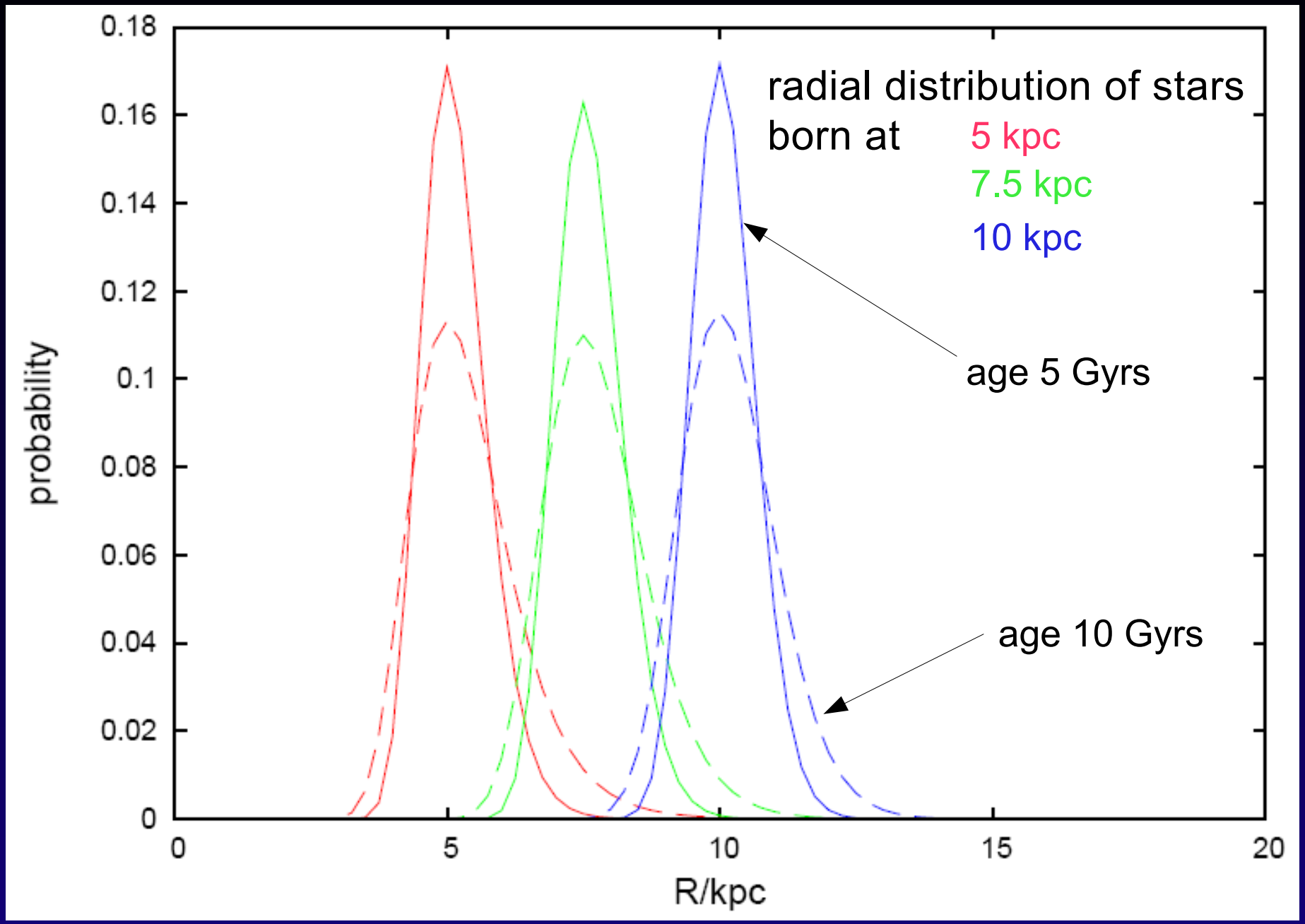
radial spacing 0.25 kpc

time spacing 30 Myrs

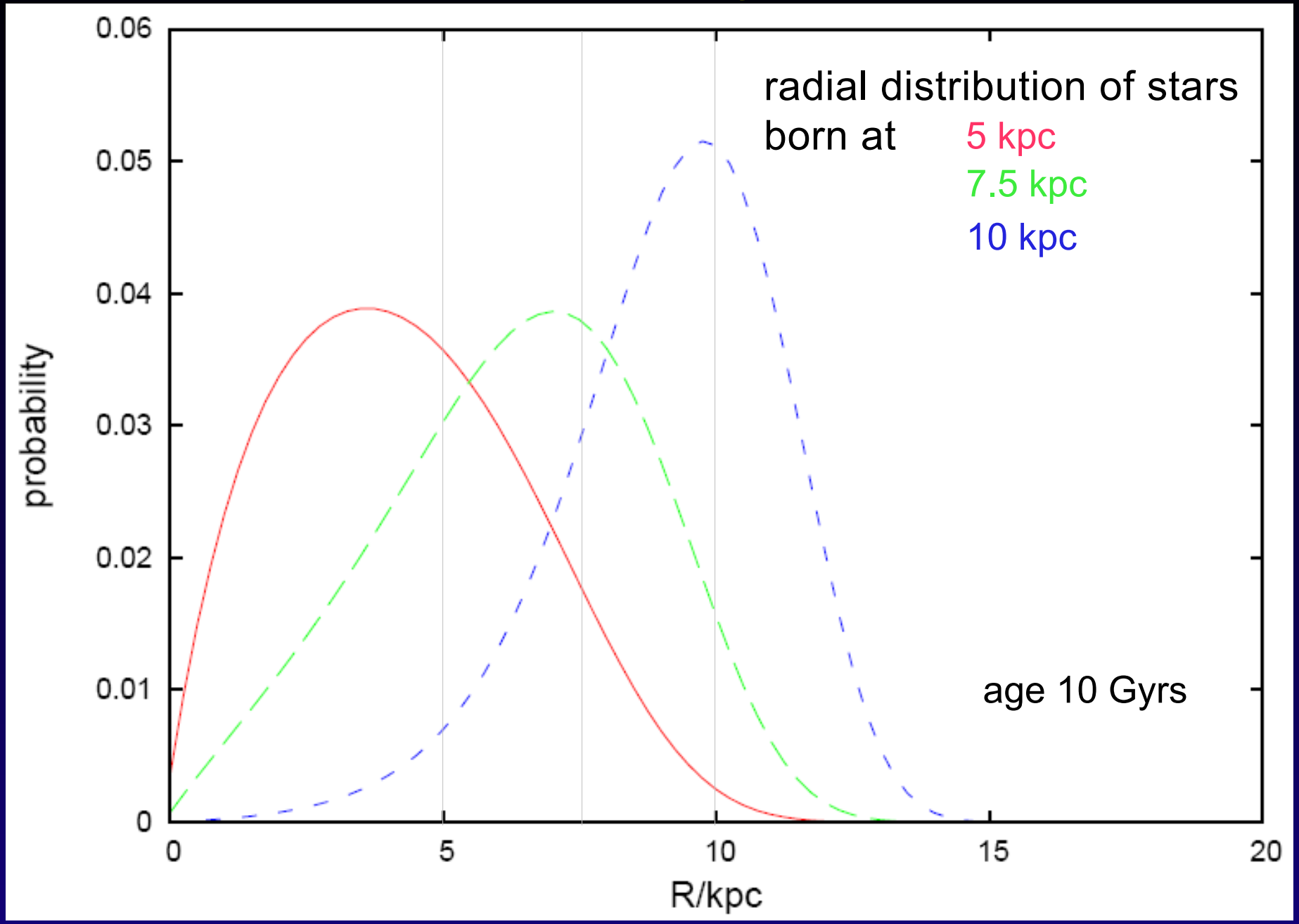
Blurring

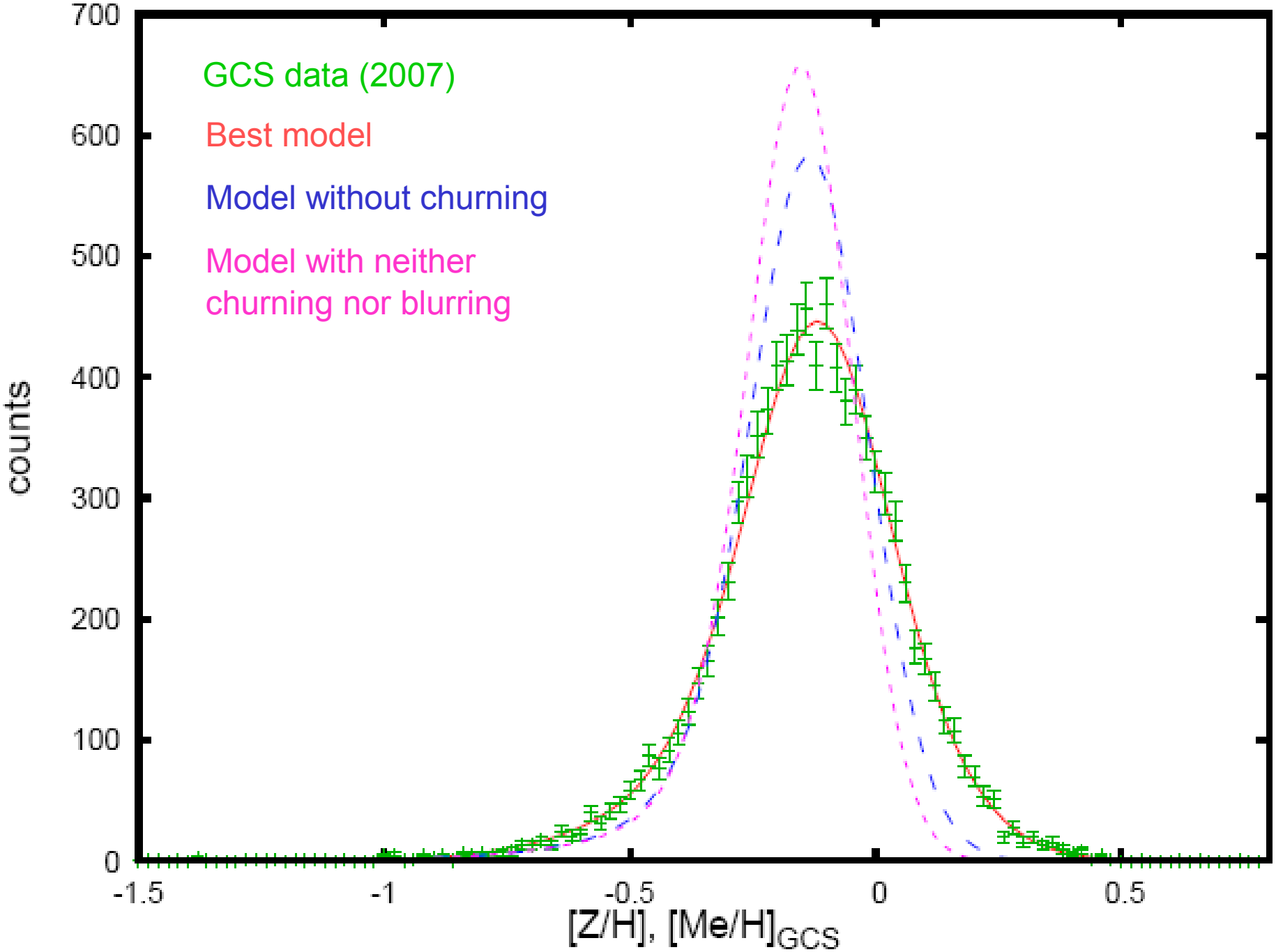
-stars on increasingly excentric orbits (heating of the disc)
→broadening of the disc and increasing scale height

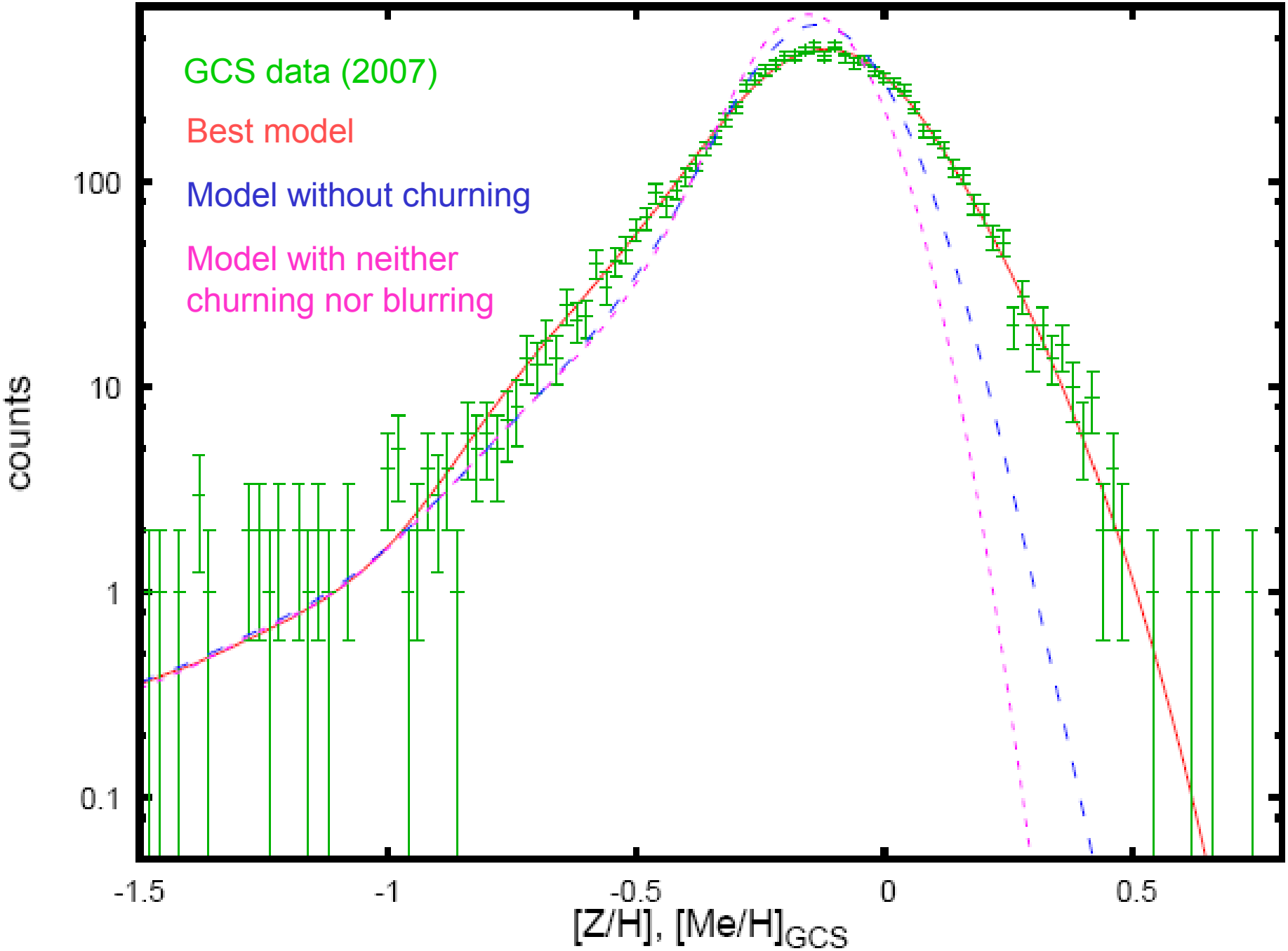
Blurring

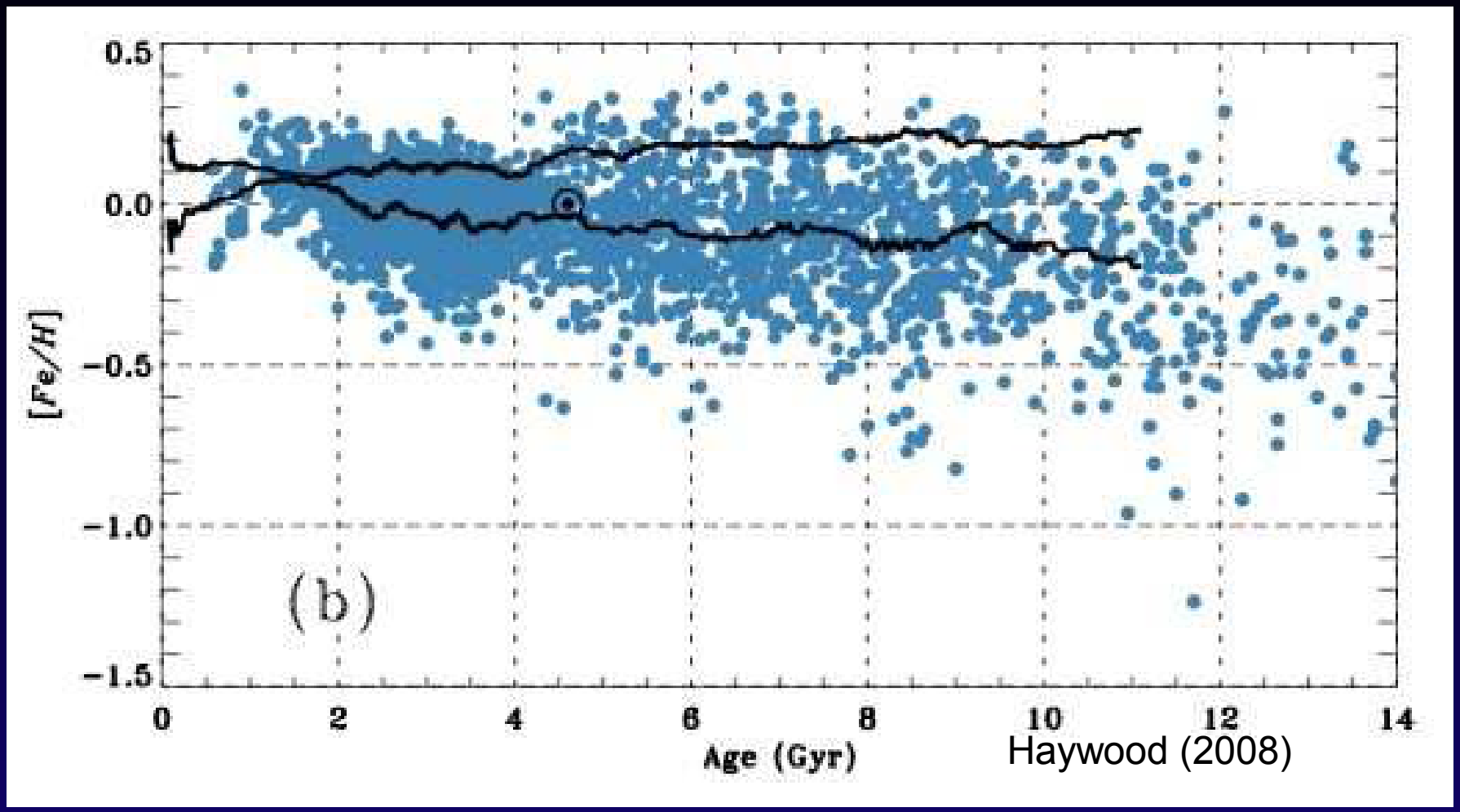

radial distribution of stars
born at
5 kpc
7.5 kpc
10 kpc
age 5 Gyrs
age 10 Gyrs
probability
R/kpc
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20

Churning

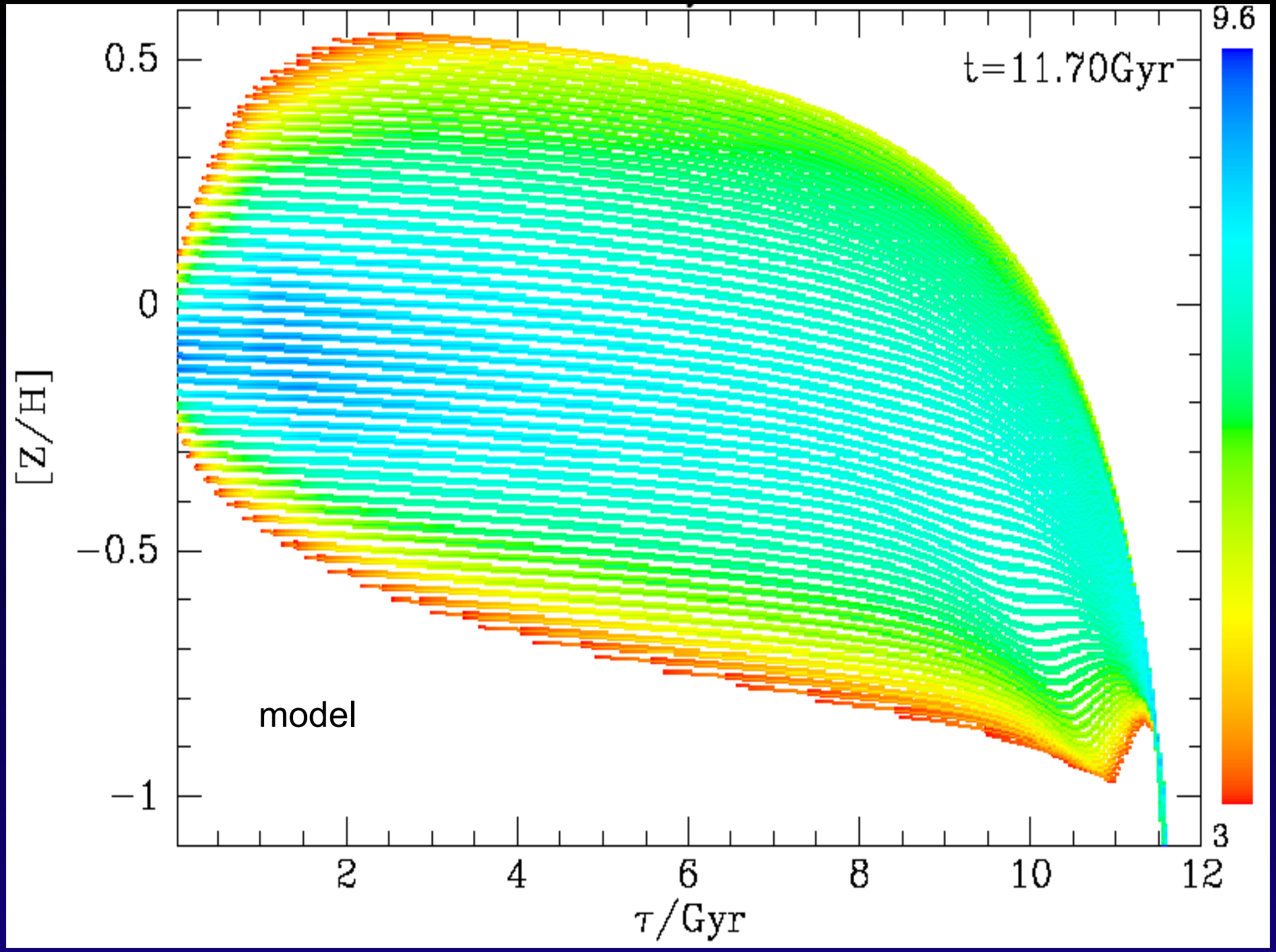

radial distribution of stars
born at
5 kpc
7.5 kpc
10 kpc
age 10 Gyrs
probability
R/kpc
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20

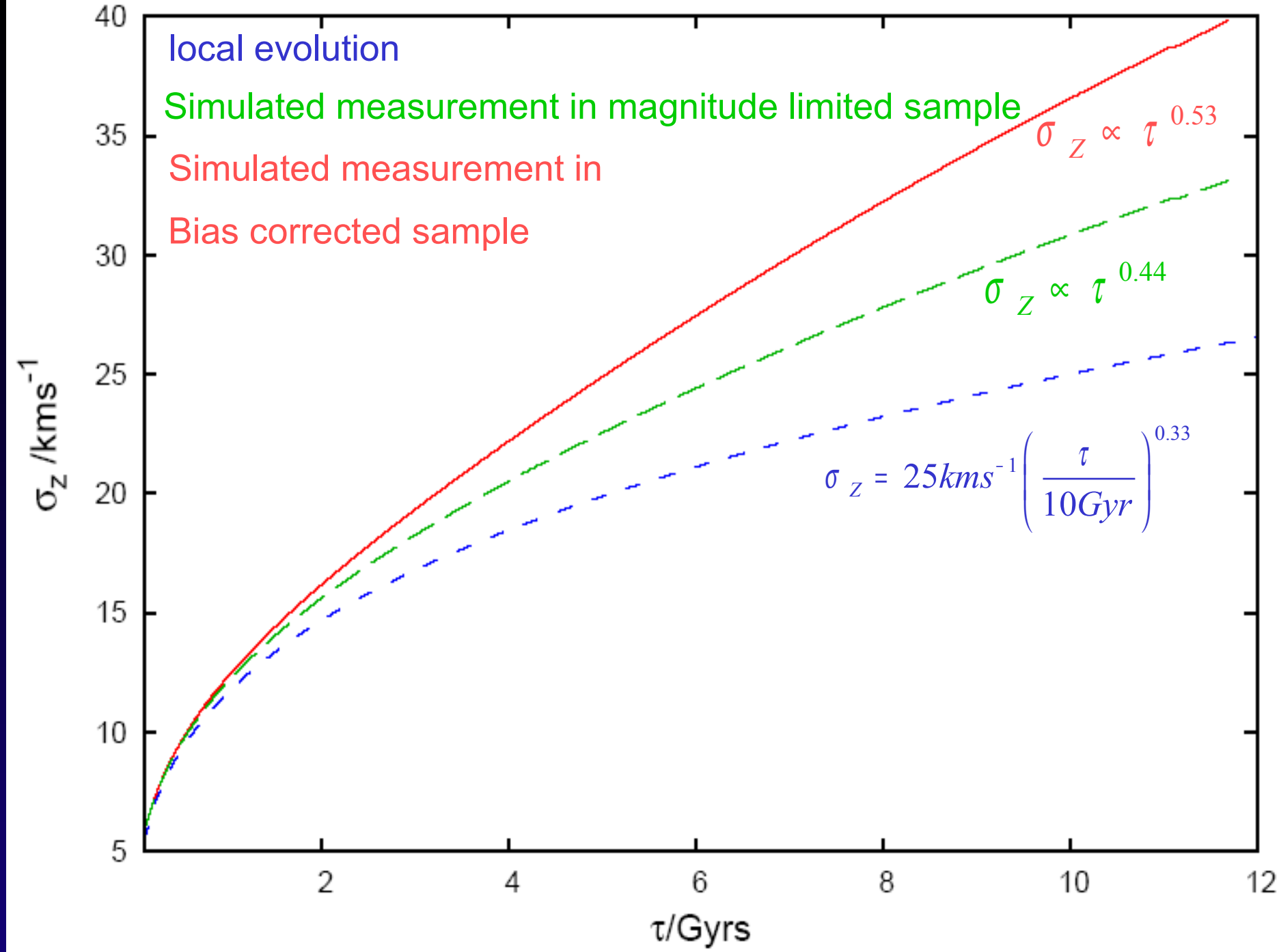

GCS data (2007)
Best model
Model without churning
Model with neither churning nor blurring
counts
700
600
500
400
300
200
100
0
-1.5
-1
-0.5
0
0.5
[Z/H], [Me/H]GCS


GCS data (2007)
Best model
Model without churning
Model with neither churning nor blurring
counts
100
10
1
0.1
-1.5
-1
-0.5
0
0.5
[Z/H], [Me/H]GCS



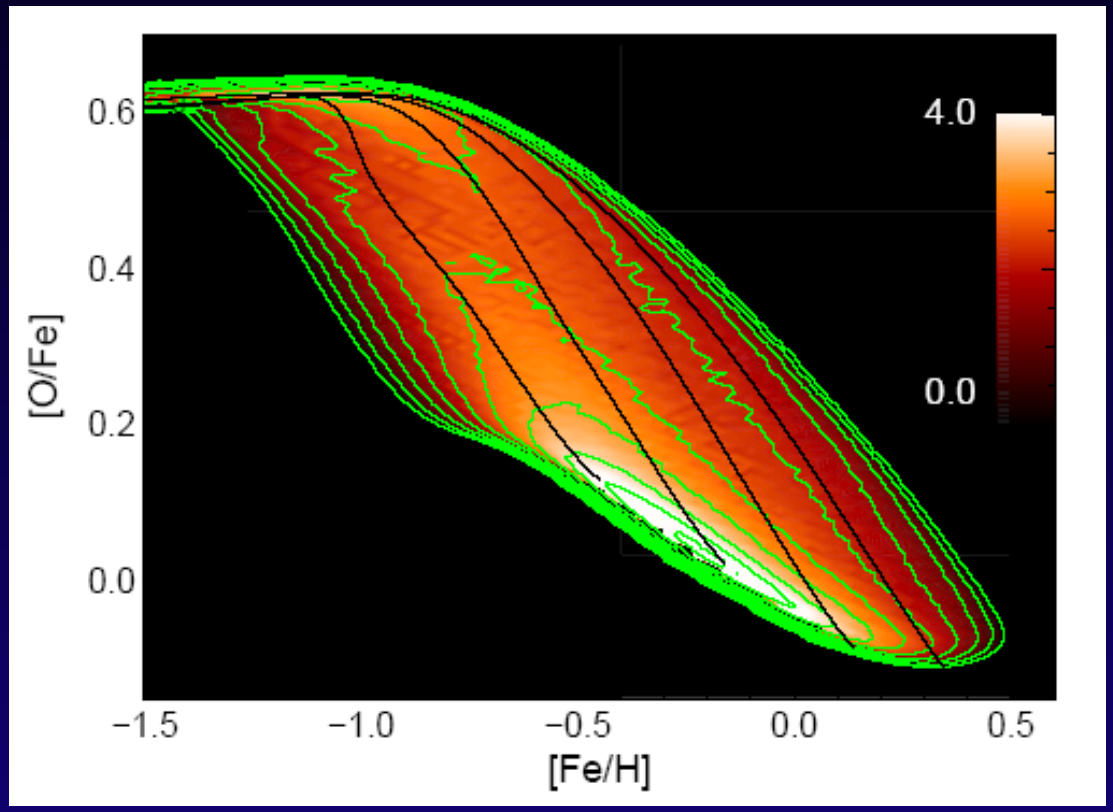
Haywood (2008)


t=11.70Gyr
model
[Z/H]
0.5
0
−0.5
−1
2
4
6
8
10
12
τ/Gyr
9.6
3


local evolution
Simulated measurement in magnitude limited sample
Simulated measurement in
Bias corrected sample
$\sigma_z \propto \tau^{0.53}$
$\sigma_z \propto \tau^{0.44}$
$\sigma_z = 25 kms^{-1} \left(\frac{\tau}{10Gyr} \right)^{0.33}$
σ_z /kms^{-1}
τ/Gyrs
40
35
30
25
20
15
10
5
2
4
6
8
10
12

Divide and conquer

How can we divide the disc?



Divide and conquer

How can we divide the disc?

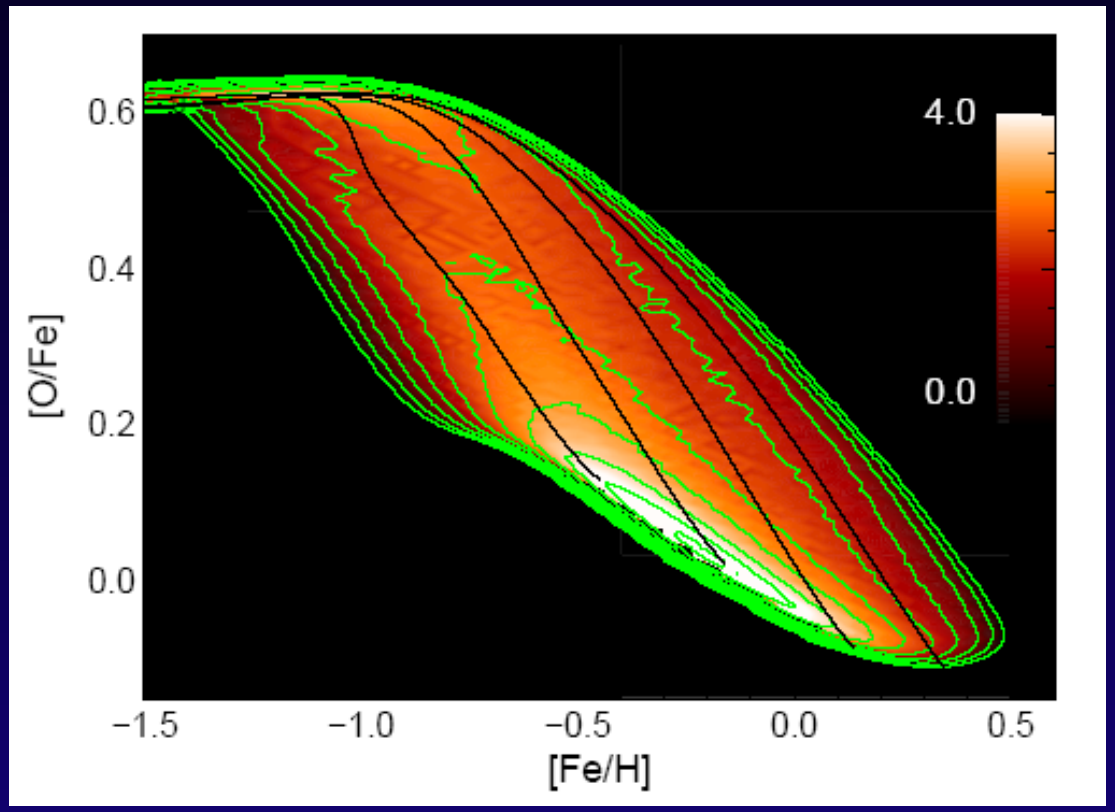
-density

-ages

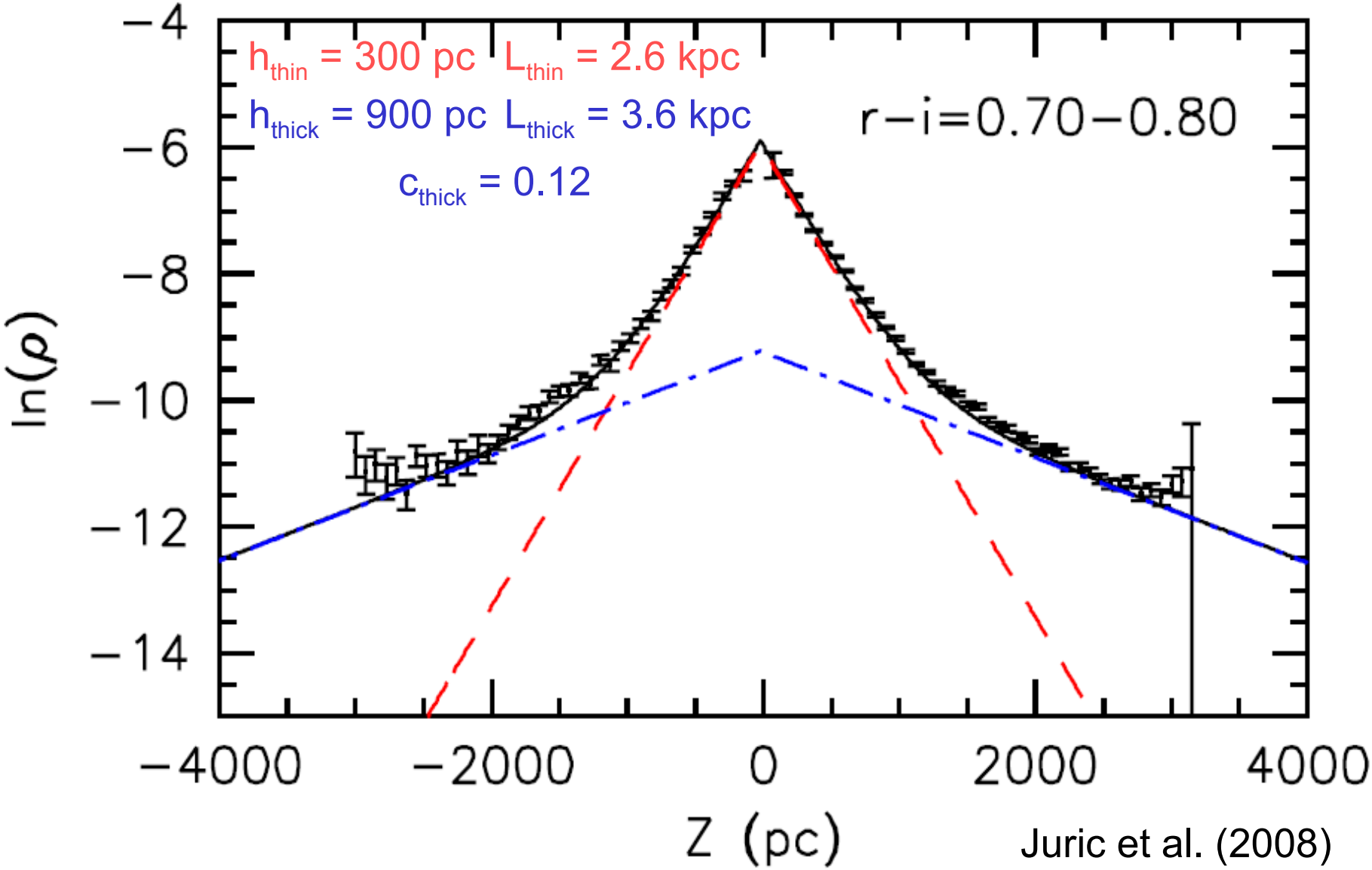
-abundance ratios

-metallicity

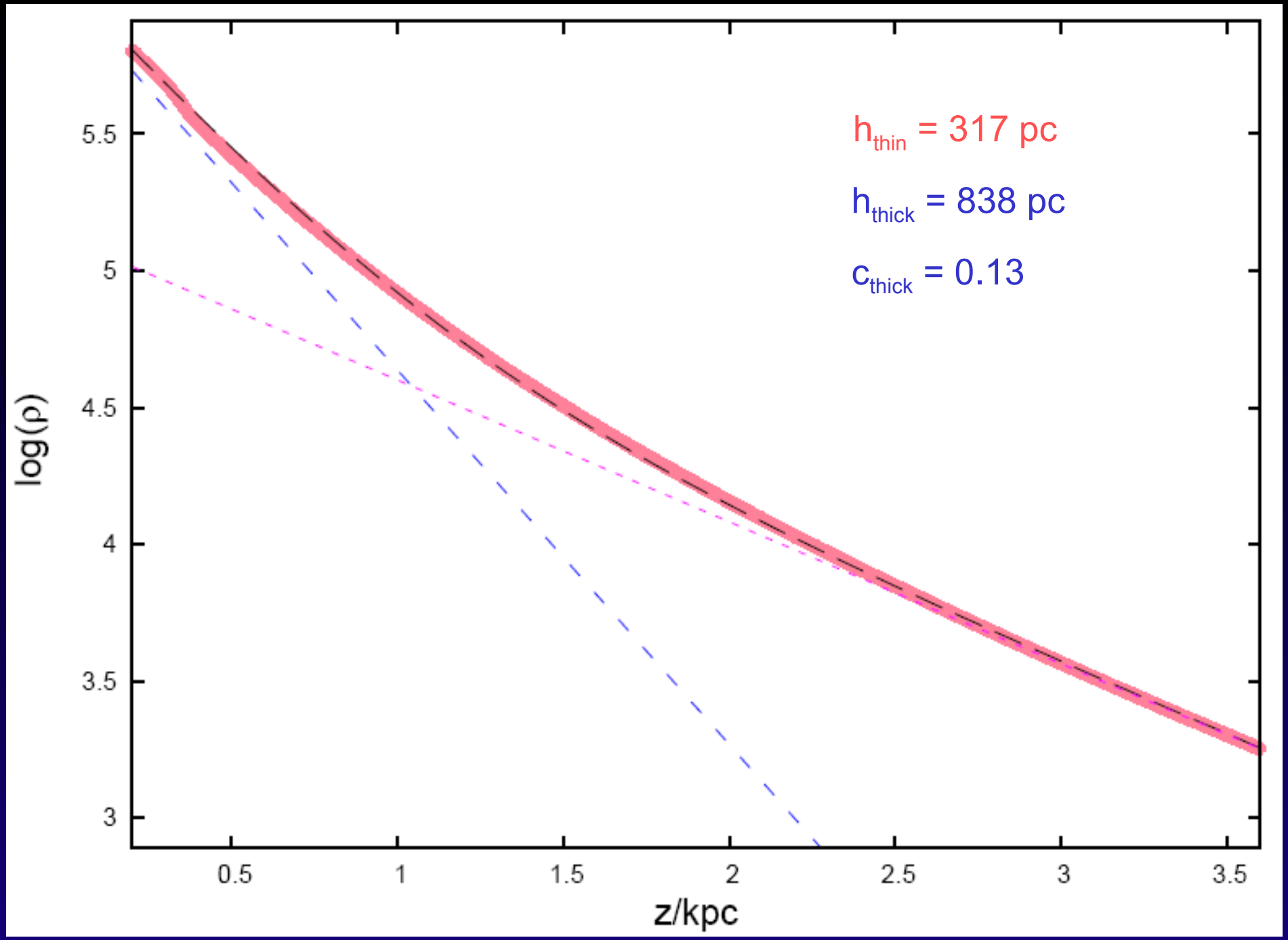
-kinematics

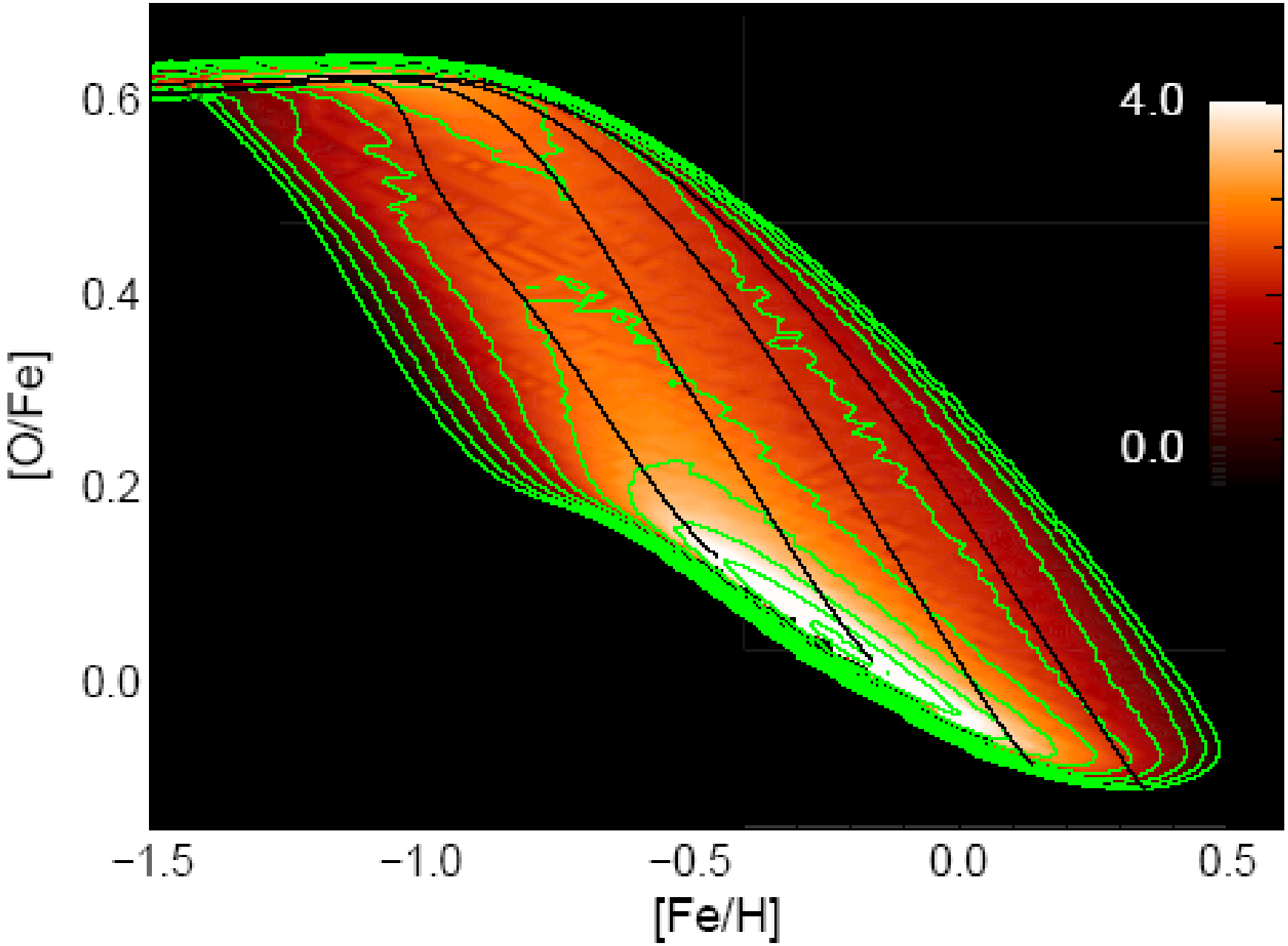


Thin and thick disc

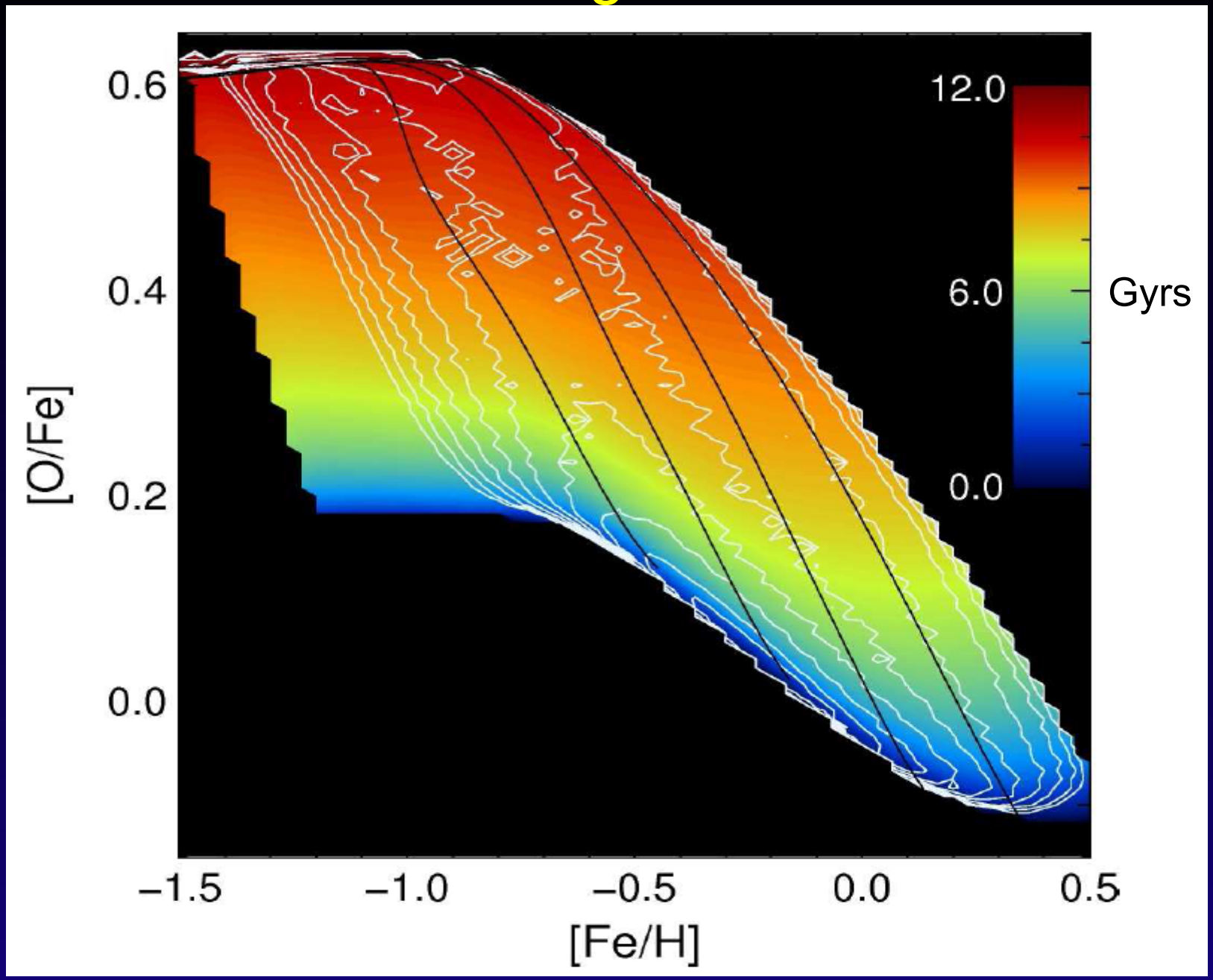


Juric et al. (2008)

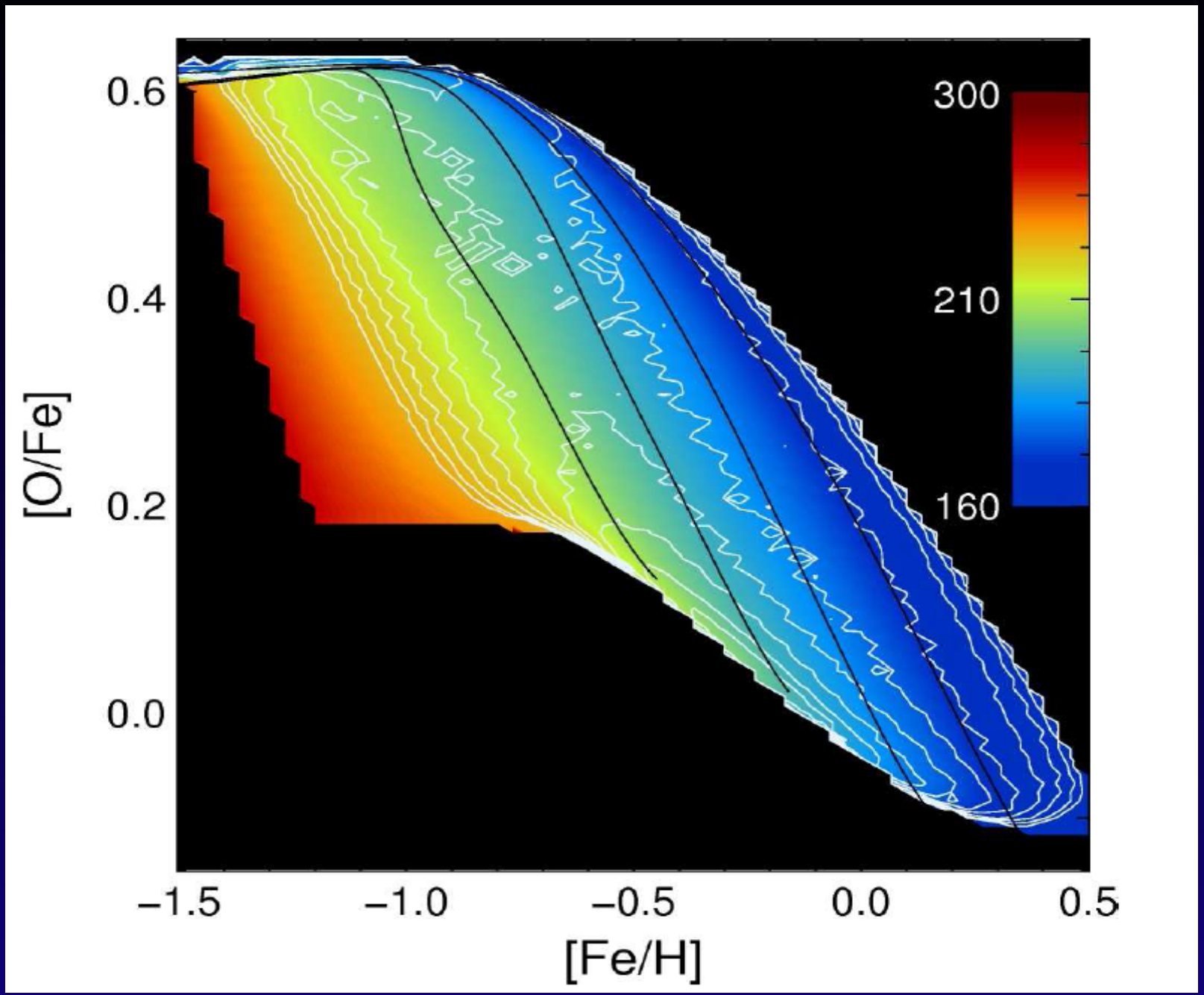

h_{thin} = 317 pc
h_{thick} = 838 pc
c_{thick} = 0.13
log(ρ)
5.5
5
4.5
4
3.5
3
0.5
1
1.5
2
2.5
3
3.5
z/kpc


0.6
0.4
0.2
0.0
[O/Fe]
−1.5
−1.0
−0.5
0.0
0.5
[Fe/H]
4.0
0.0

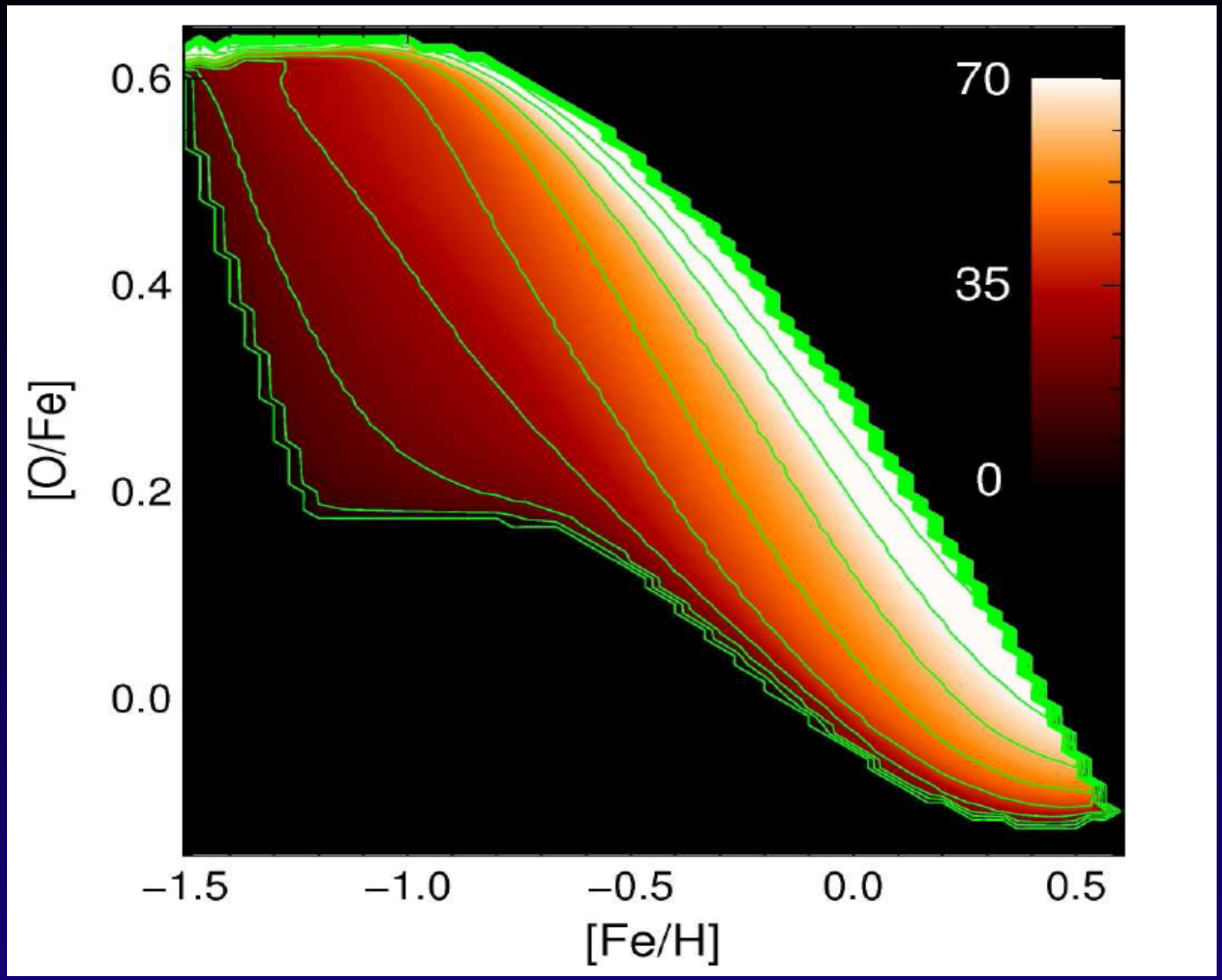
age



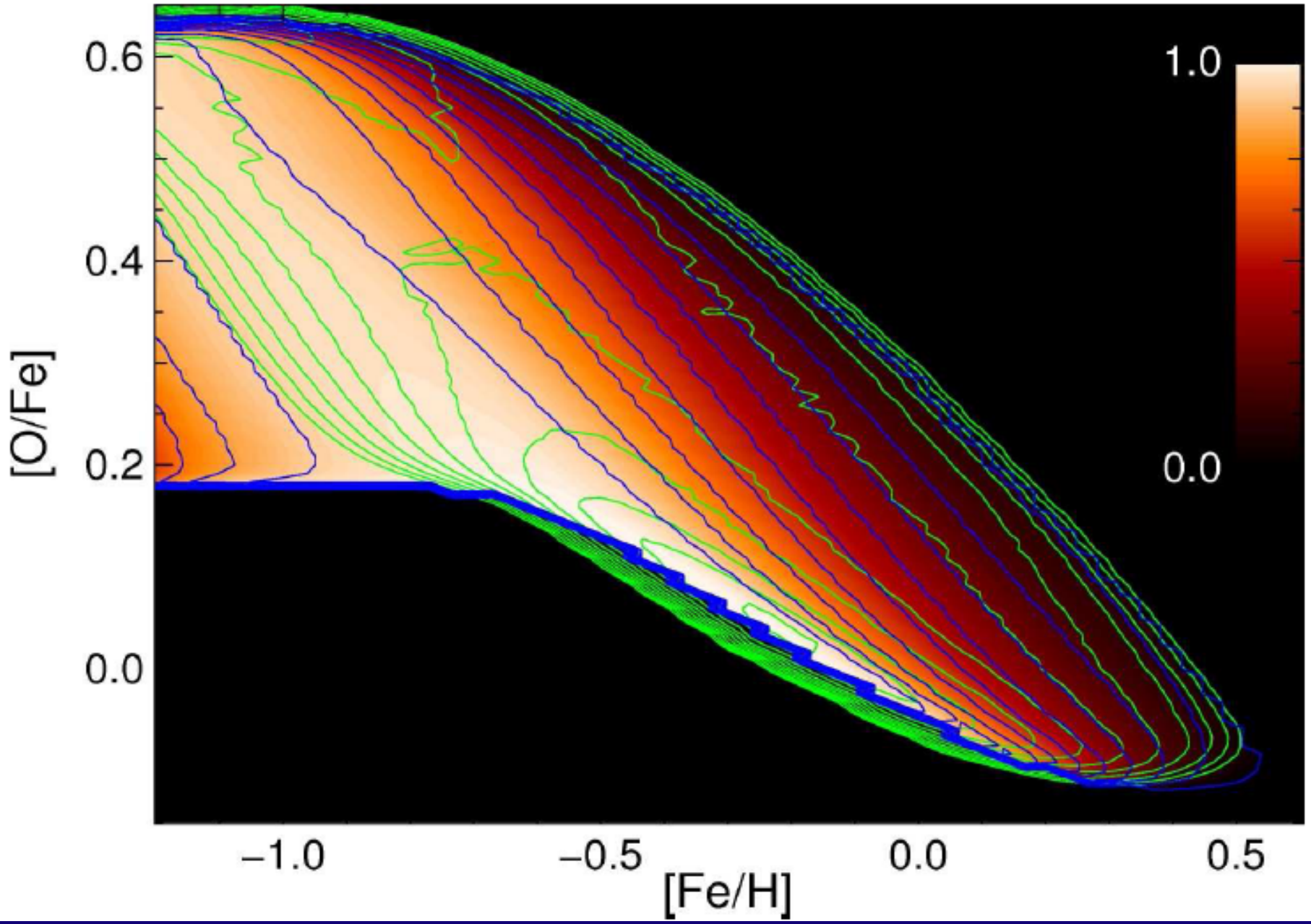
V



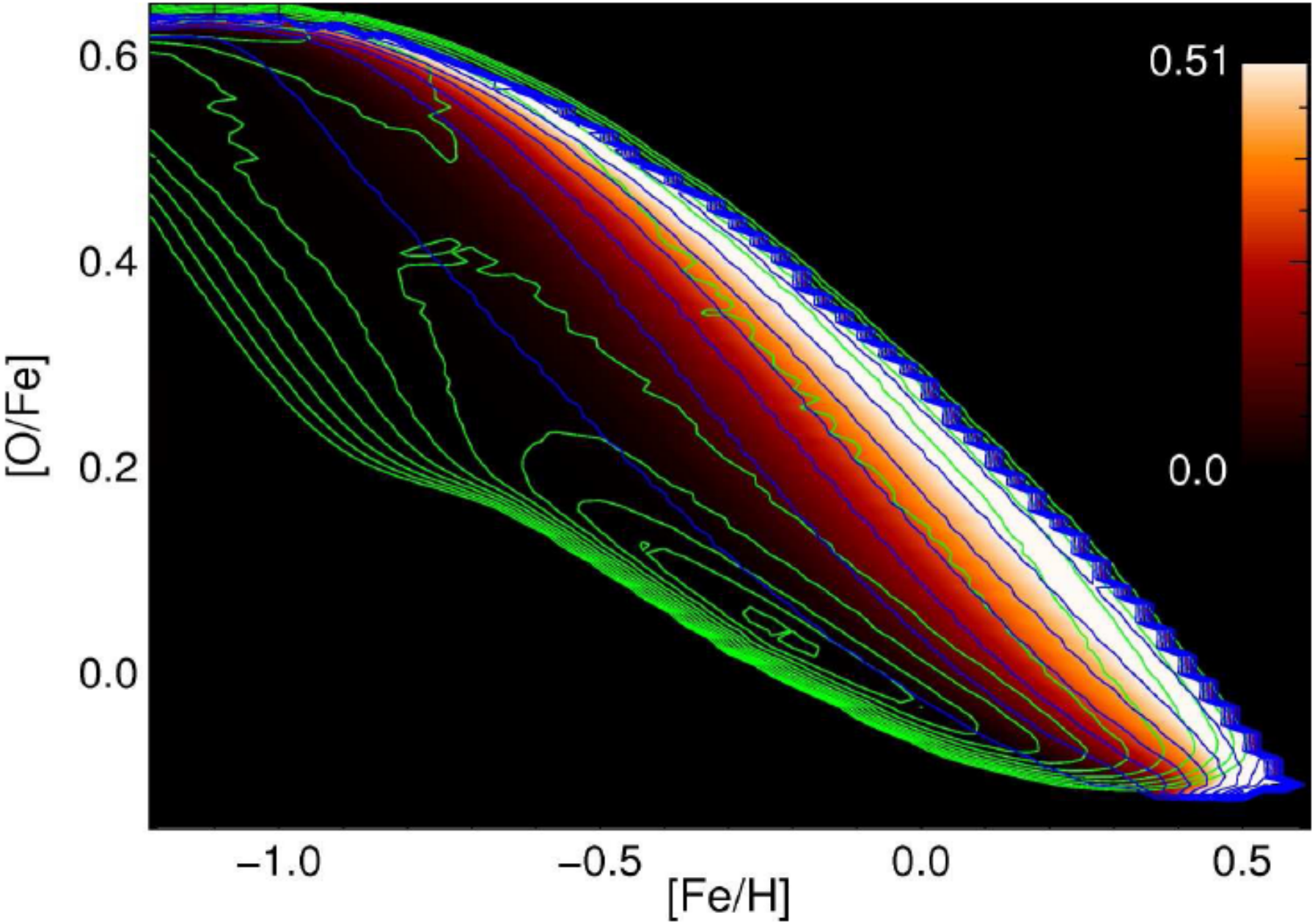
Velocity dispersion



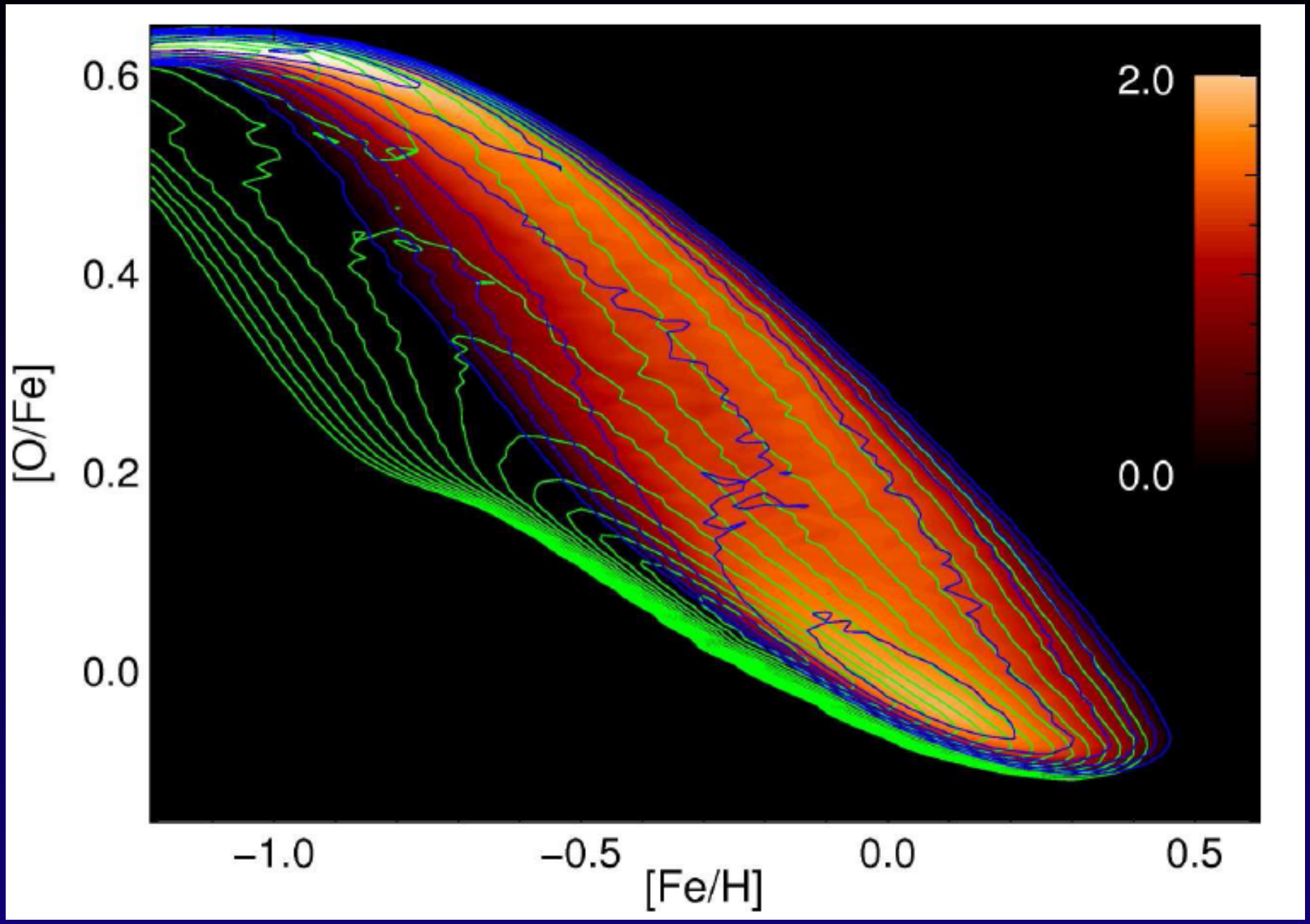
Kinematical selection – thin disc



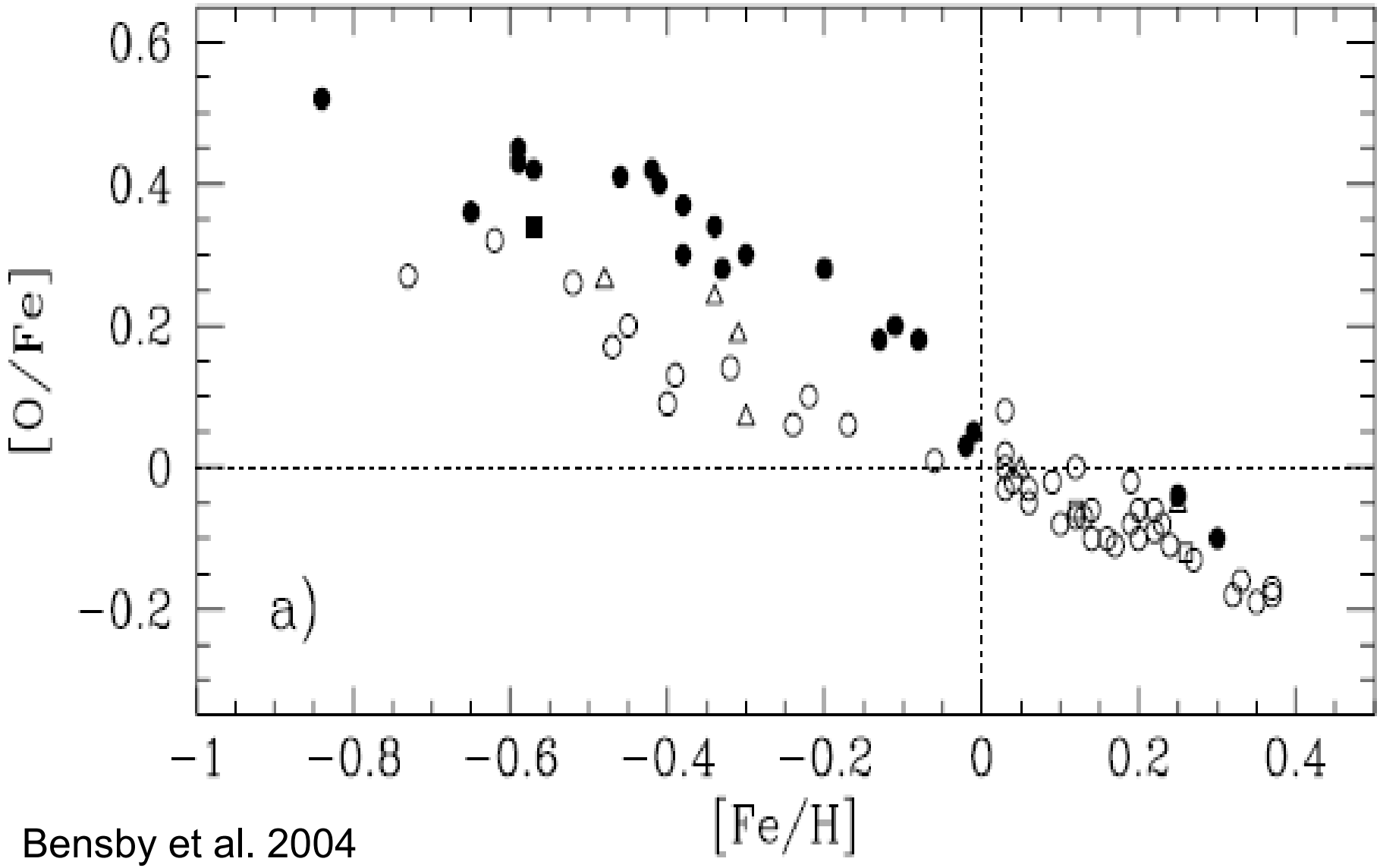
Kinematical selection – thick disc



The kinematic thick disc

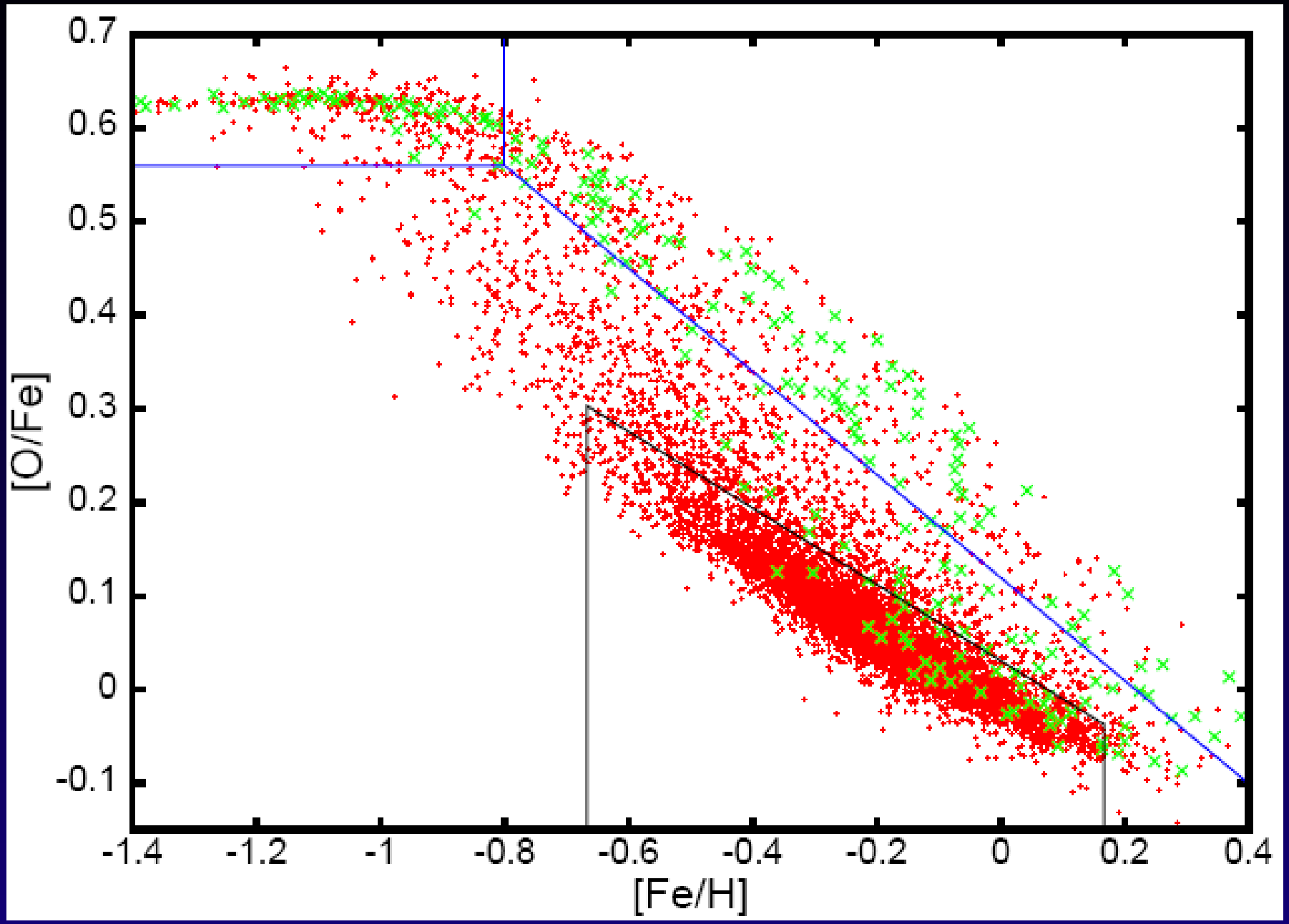


The kinematic thick disc

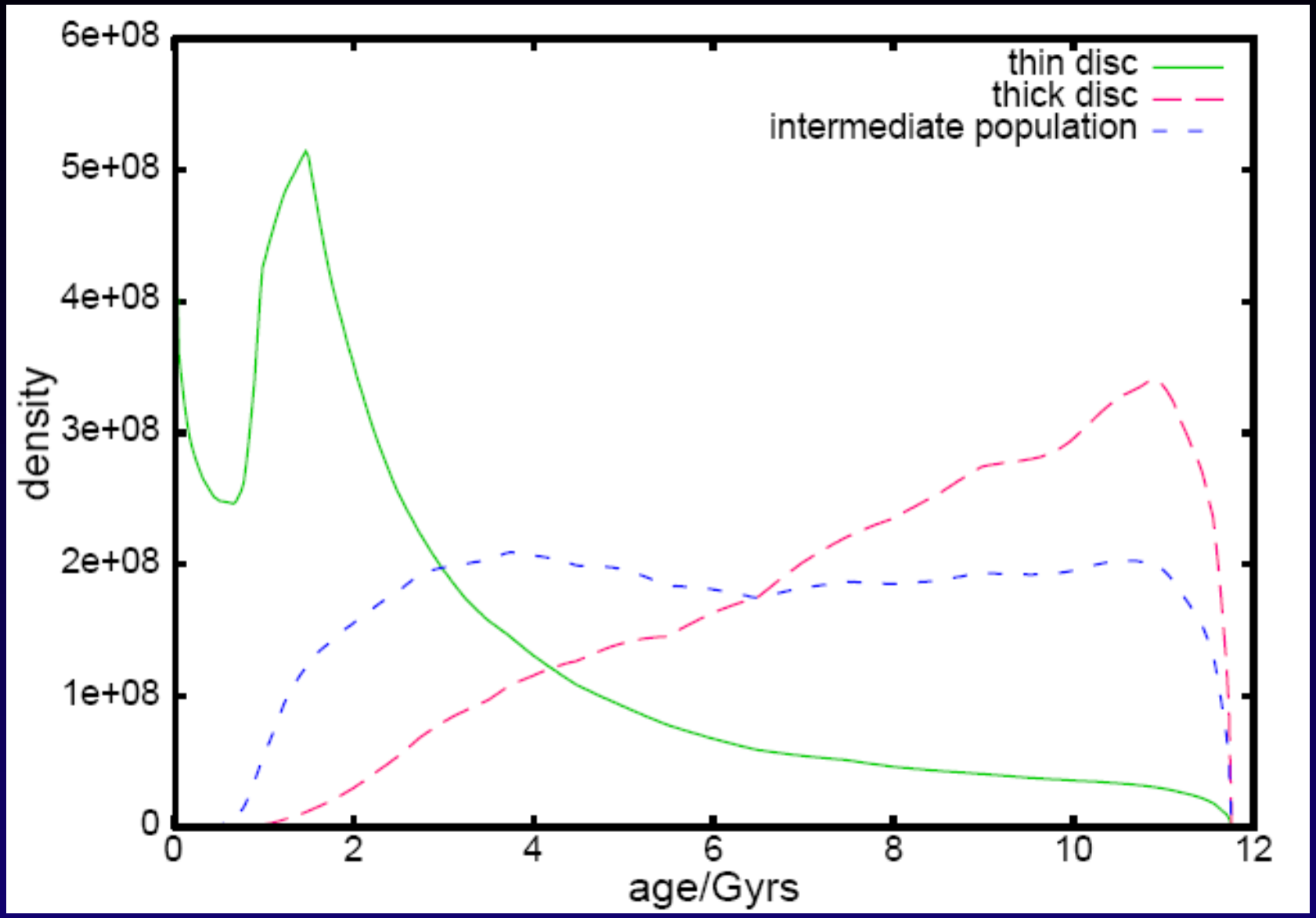


Bensby et al. 2004

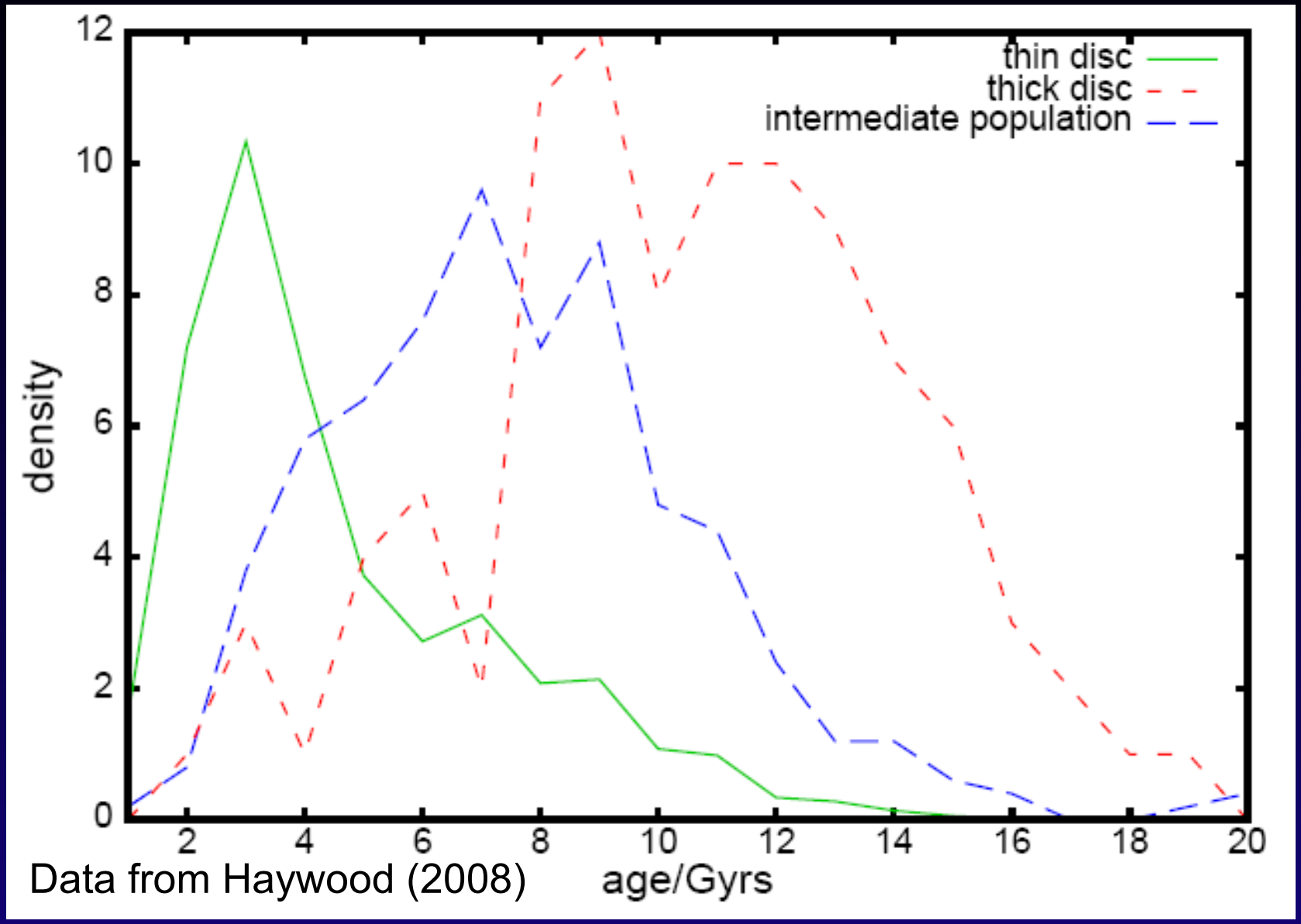
Chemical dissection



Age distributions

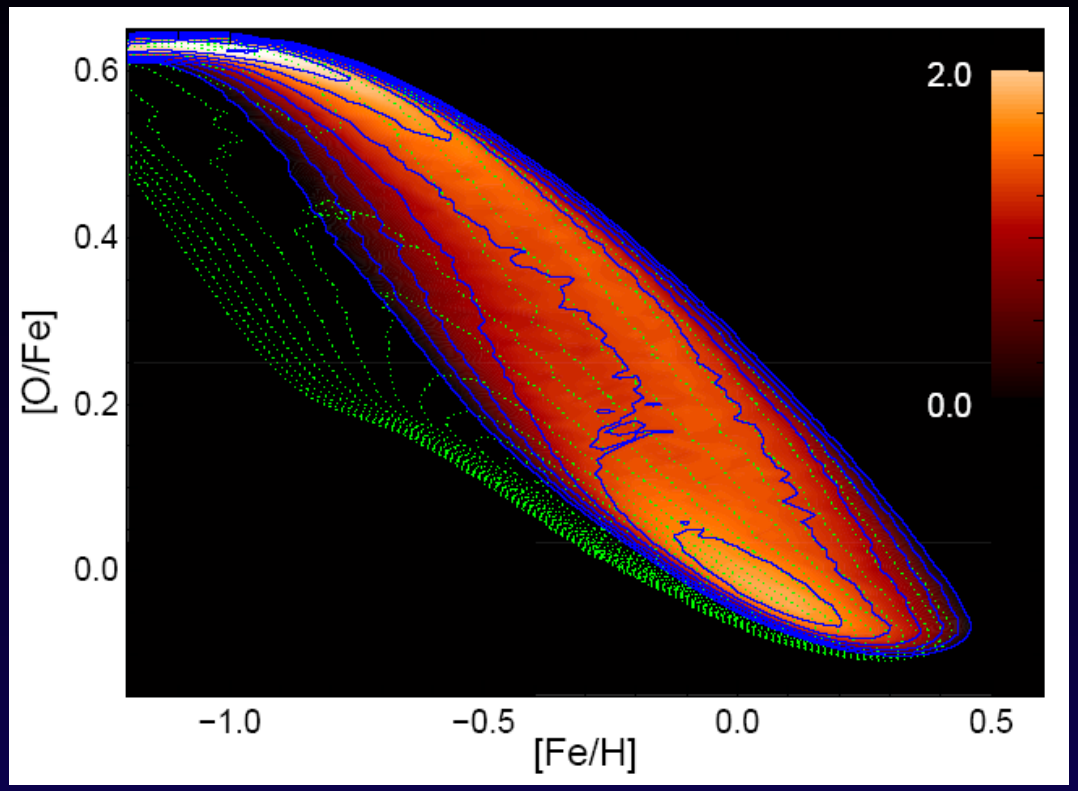


Age distributions



Data from Haywood (2008)

The kinematical thick disc



Ratio of components:

thin:intermediate:thick

Haywood (2008): 1:0.085:0.029

GCS (2007): 1:0.095:0.029

model: 1:0.099:0.025

Thick disc properties

Pluralitas non est ponenda sine necessitate (Ockham, ~1300)

Two-exponential fit of vertical density profile — yes

Bimodal behaviour of in [alpha/Fe] — model and analytical approach

Asymmetric drift — by construction

Full chemo-kinematical representation — fulfilled

Are we really allowed to treat it as a separate entity?

Summary I

Open problems

very crude galactic structure

- no bulge
- no ring/bar(s)

inside-out formation?

crude treatment of mixing

infall/inflow and outflows weakly constrained

exact observational gradients still an open question

SNIa delays weakly constrained

Summary

- Including radial mixing is compulsory from a theoretical point of view

- Classical models of chemical evolution might imply wrong Galactic histories

- The scatter in abundance ratios and in the age-metallicity relationship is fully explained by radial mixing processes

- Clean kinematic selection on a disc component is not possible

- The model can explain/replicates the chemo-dynamical structure of the solar neighbourhood and challenges the separate history of the thick disk