Chemical Evolution Model of Fornax Dwarf Spheroidal Galaxy

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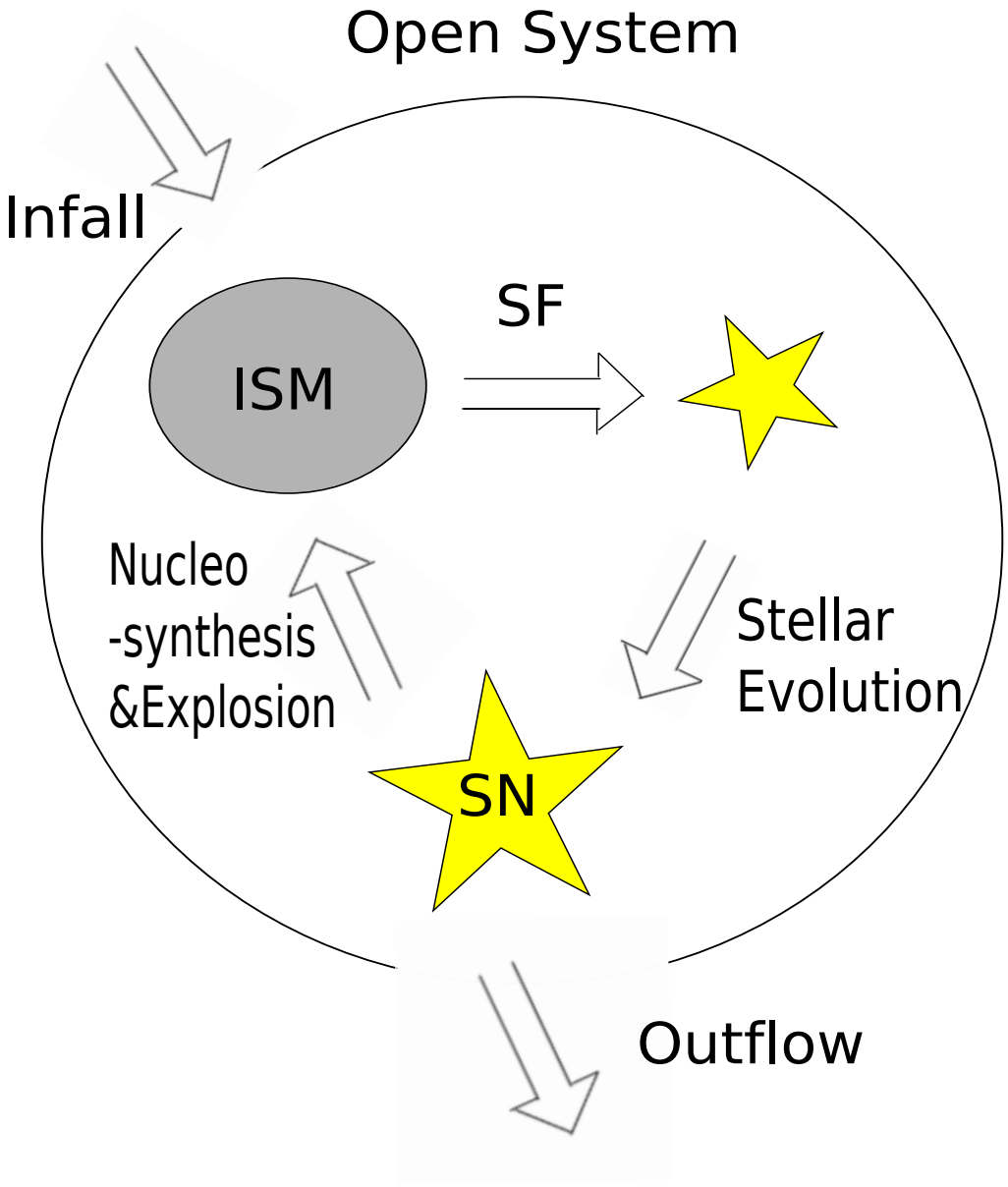
Outline

- Halo model and Gas Dynamics of Fornax dSph
- Analytic Chemical Evolution Model (homogeneous mixing)
- Numerical Chemical Evolution Model (inhomogeneous mixing)


Open System
Infall
ISM
SF
Nucleo
-synthesis
&Explosion
Stellar
Evolution
SN
Outflow

$$\psi = \lambda_* M_g^{1.5}$$

$$\psi \approx \frac{M_g}{\tau}$$

$$\tau \approx \frac{1}{\sqrt{G\rho}}$$

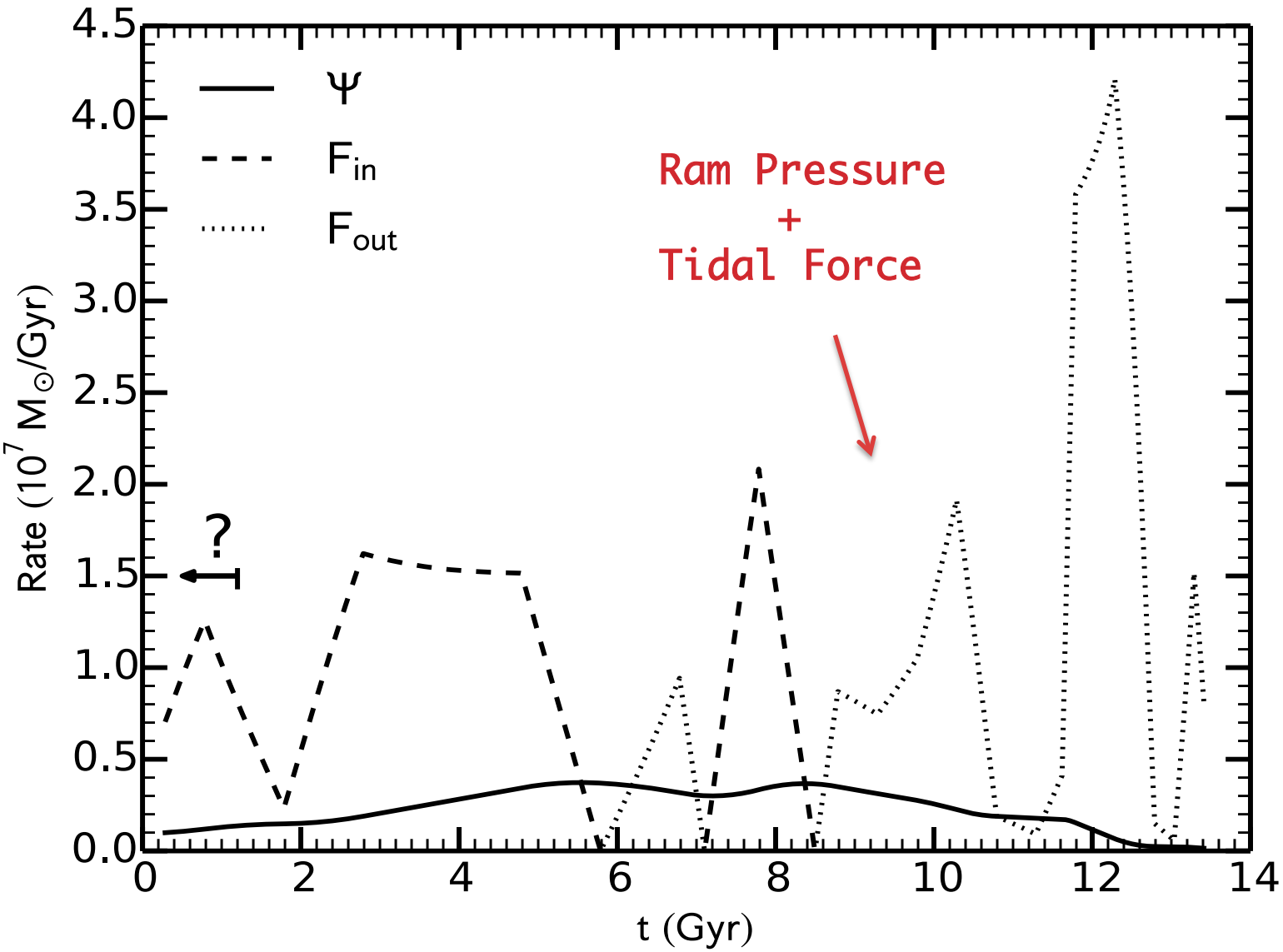
$$\frac{dM_g}{dt} = F_{in} - \psi - F_{out}$$

$$\frac{dM_g}{dt} + \psi = F_{in} - F_{out}$$

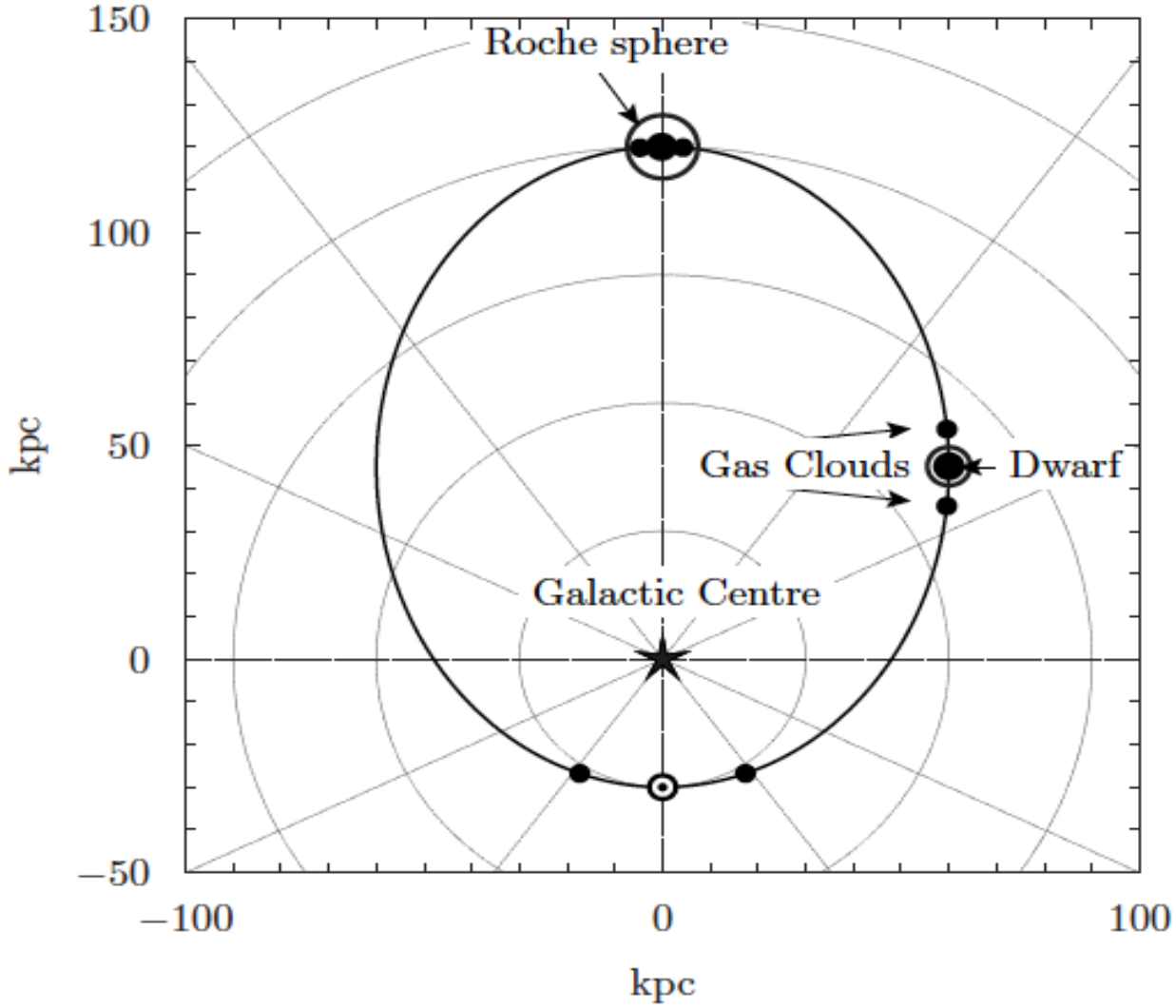
$$F_{out} = 0 \Rightarrow F_{in} = \psi + \frac{dM_g}{dt}$$

$$F_{in} = 0 \Rightarrow F_{out} = -\psi - \frac{dM_g}{dt}$$

Gas Dynamics based on SFH

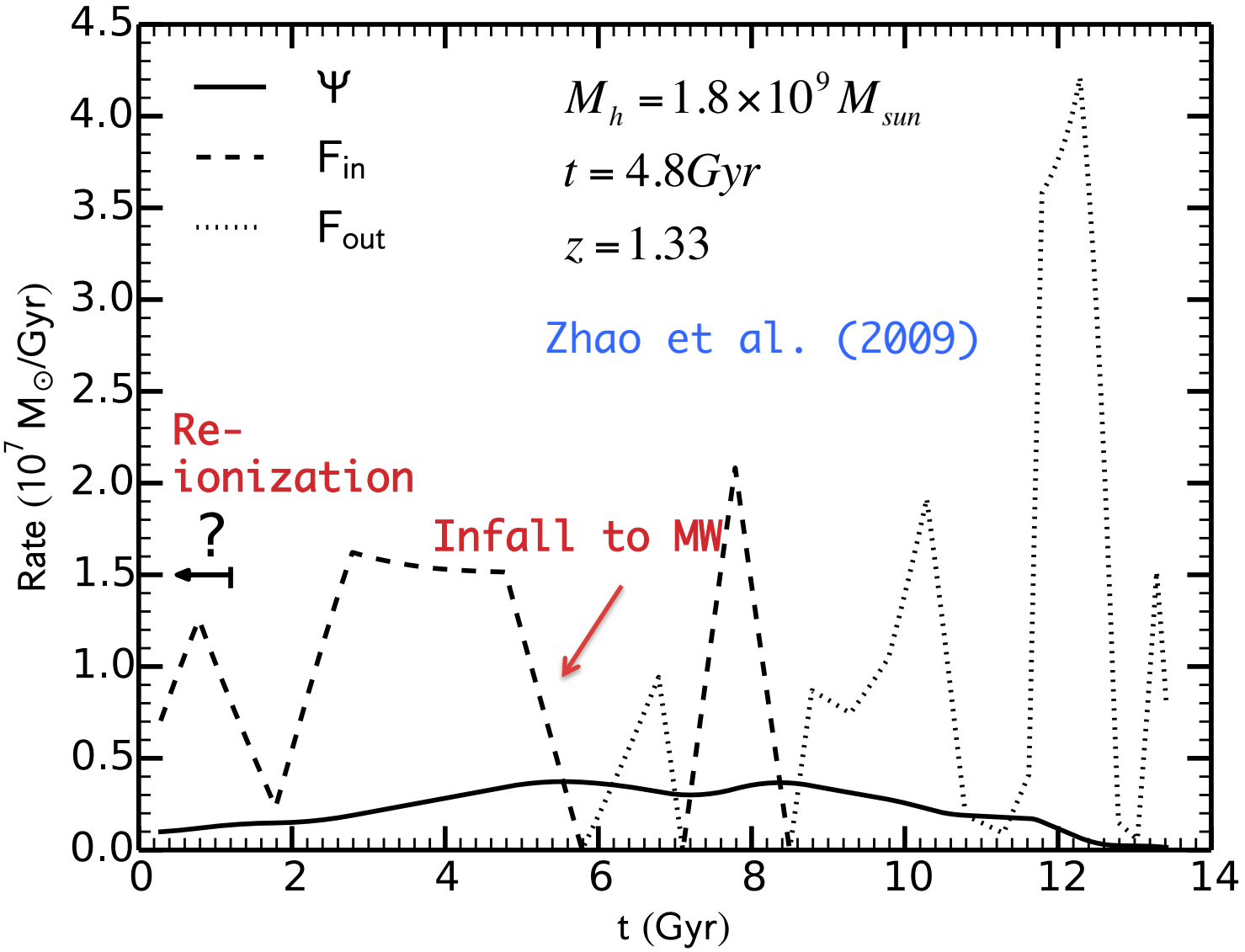


Yuan, Qian, Jing (2014 submitted)

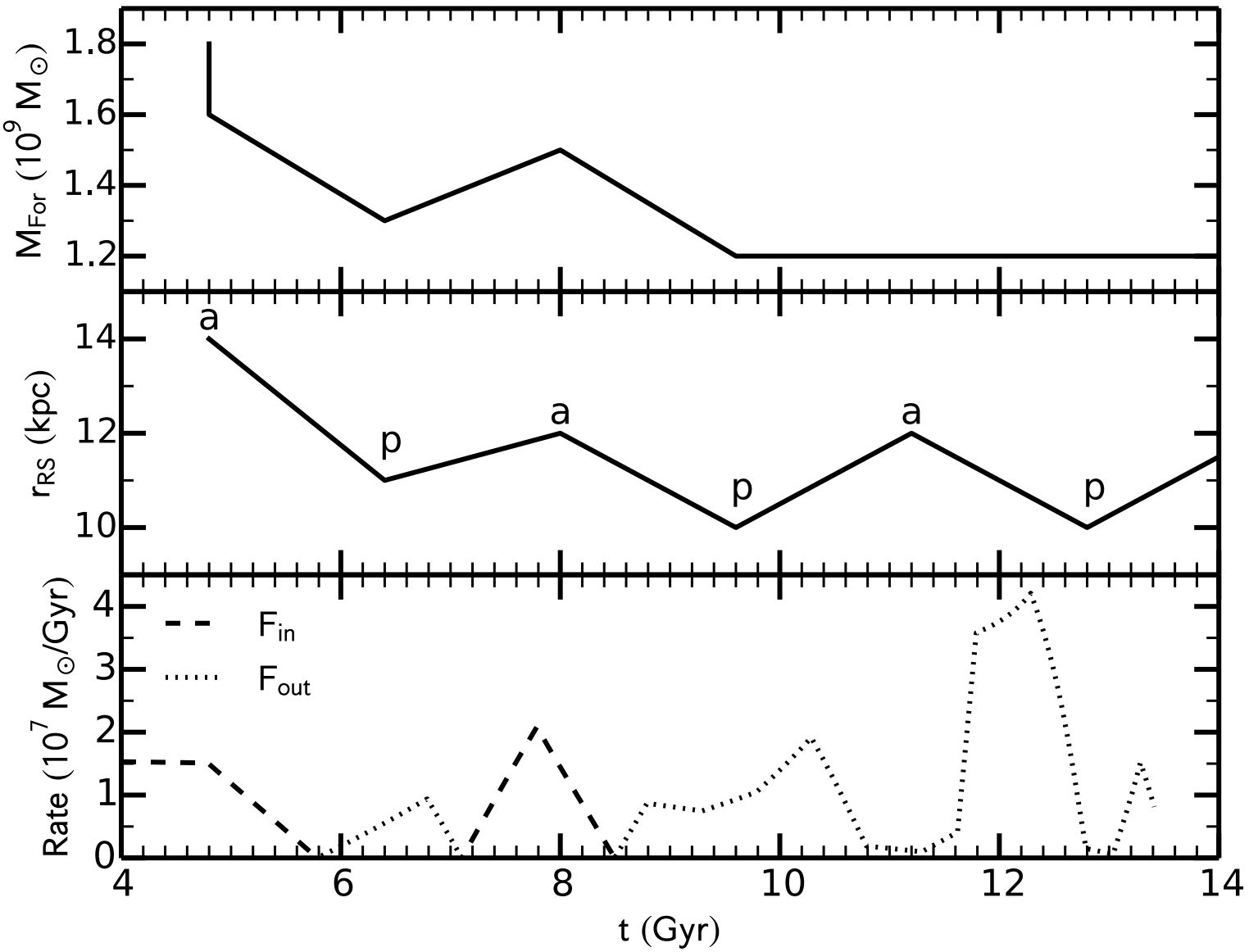


Nichols, M., Lin, D. et al (2012)

Gas Dynamics based on SFH



Yuan, Qian, Jing (2014 submitted)

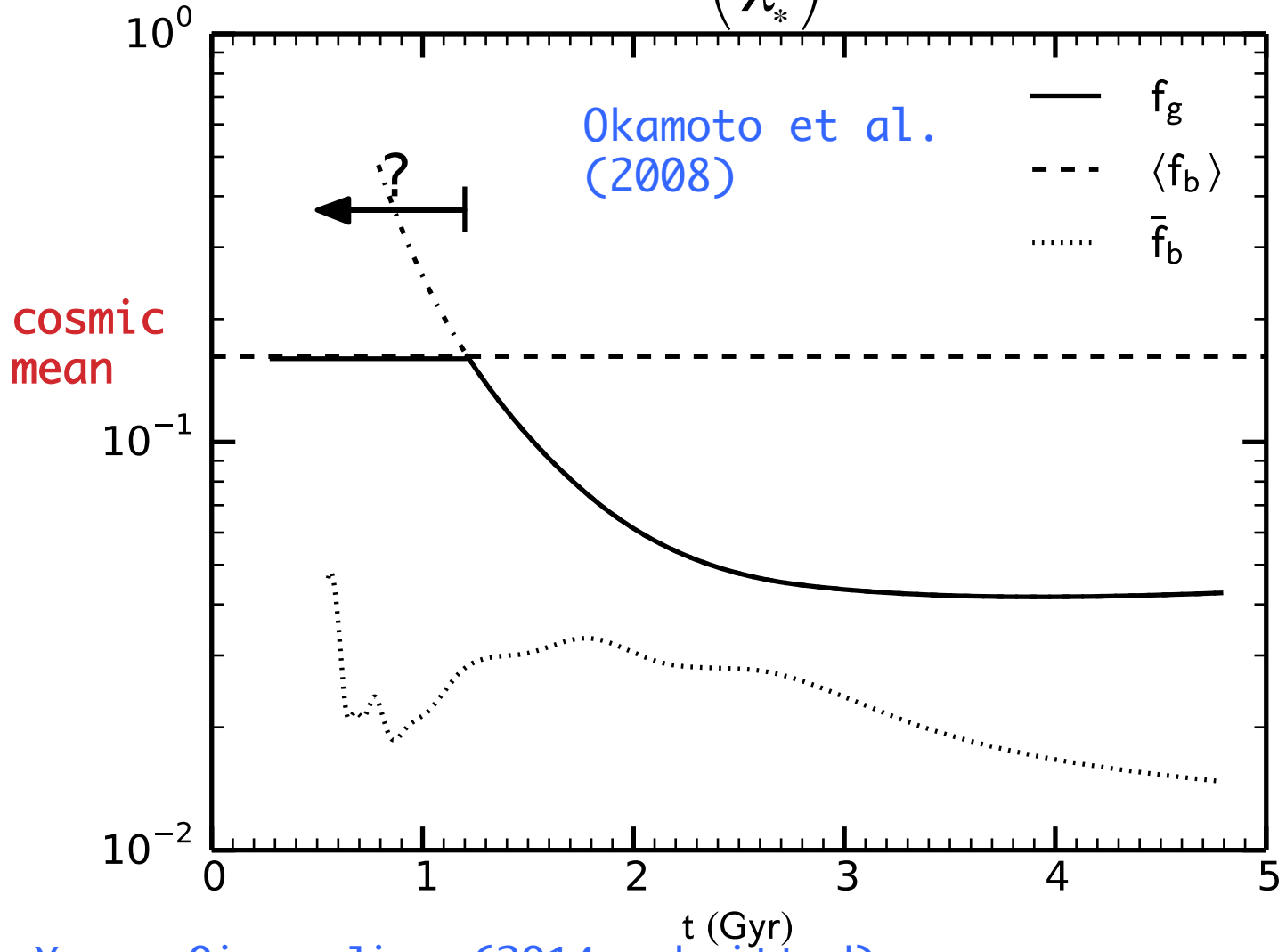


Yuan, Qian, Jing (2014 submitted)

$$f_b = \frac{M_g}{M_h}$$

$$M_g = f_{b,\mathrm{cosmic}} M_h \qquad t < 1.2 Gyr$$

$$M_g = \left(\frac{\psi}{\lambda_*}\right)^{2/3} \qquad t > 1.2 Gyr$$



Yuan, Qian, Jing (2014 submitted)

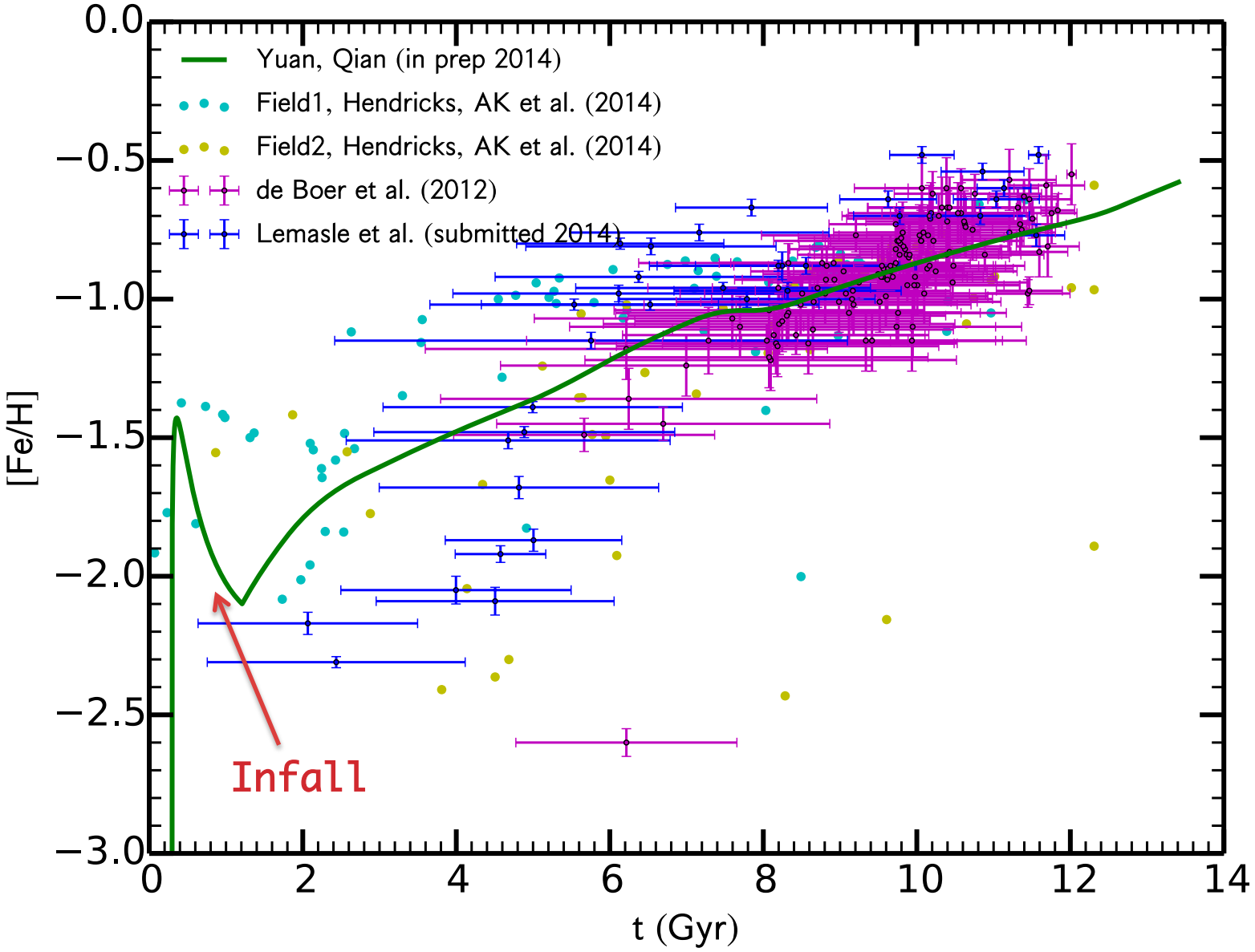
Analytic Model
--- homogeneous Mixing

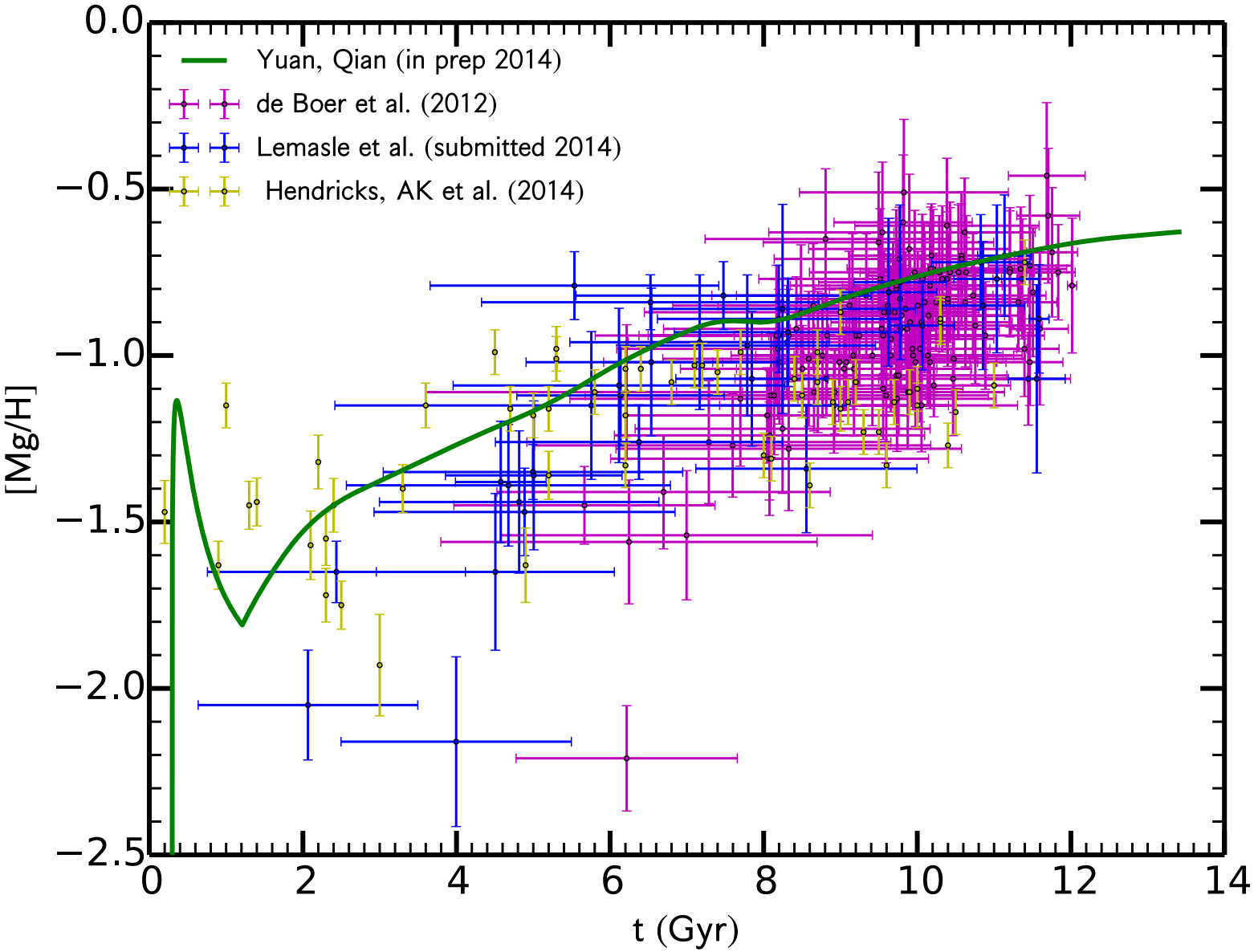
$$\frac{d(Z_{Fe}M_g)}{dt} = P_{Fe}(\psi) - F_{out}Z_{Fe} + F_{in}Z_{Fe,in}$$

$$P_{Fe} = \eta_{Fe}^{cc}\psi + \eta_{Fe}^{Ia}\int_{\tau_{Ia}}^{t}\psi(t-\tau)D(\tau)d\tau$$

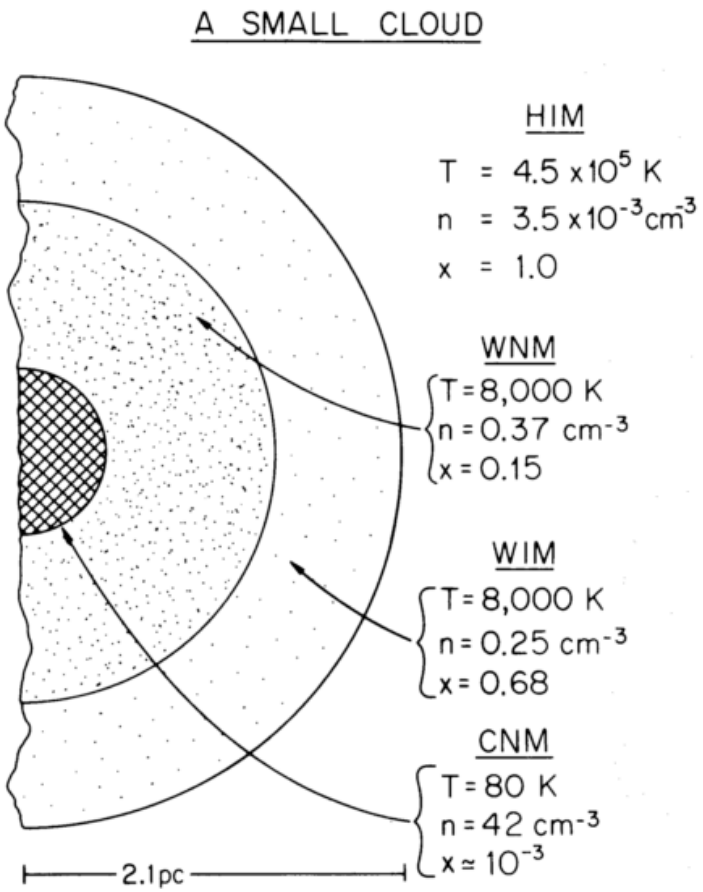
Yields from Heger & Woosley (2008)

Standard Mixing, E=1.2 B, S=4 Piston

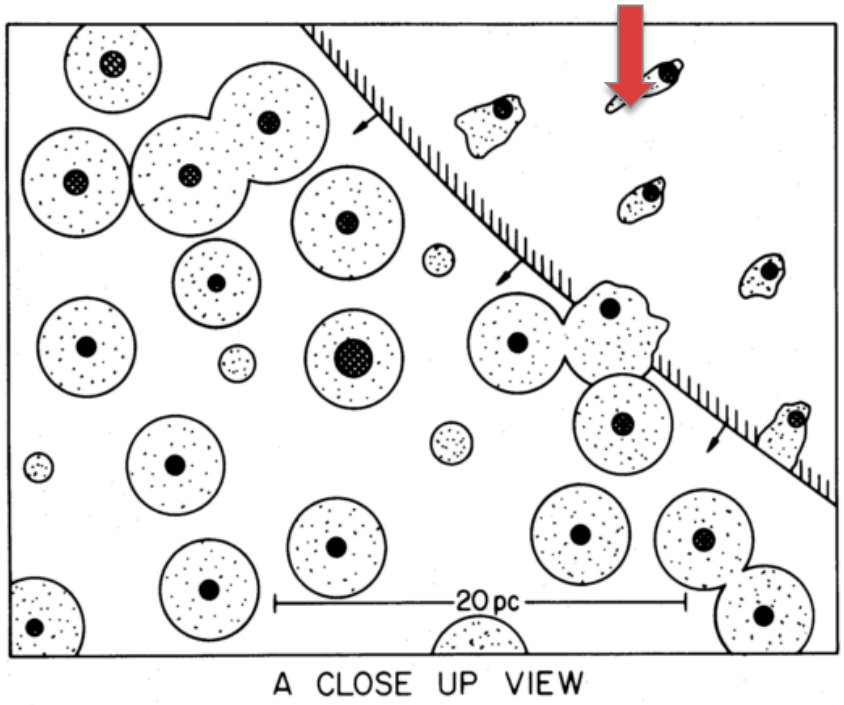

Yuan, Qian (in prep 2014)
Field1, Hendricks, AK et al. (2014)
Field2, Hendricks, AK et al. (2014)
de Boer et al. (2012)
Lemasle et al. (submitted 2014)
Infall
[Fe/H]
t (Gyr)
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
0
2
4
6
8
10
12
14


Yuan, Qian (in prep 2014)
de Boer et al. (2012)
Lemasle et al. (submitted 2014)
Hendricks, AK et al. (2014)
[Mg/H]
t (Gyr)
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
0
2
4
6
8
10
12
14

Structure of ISM

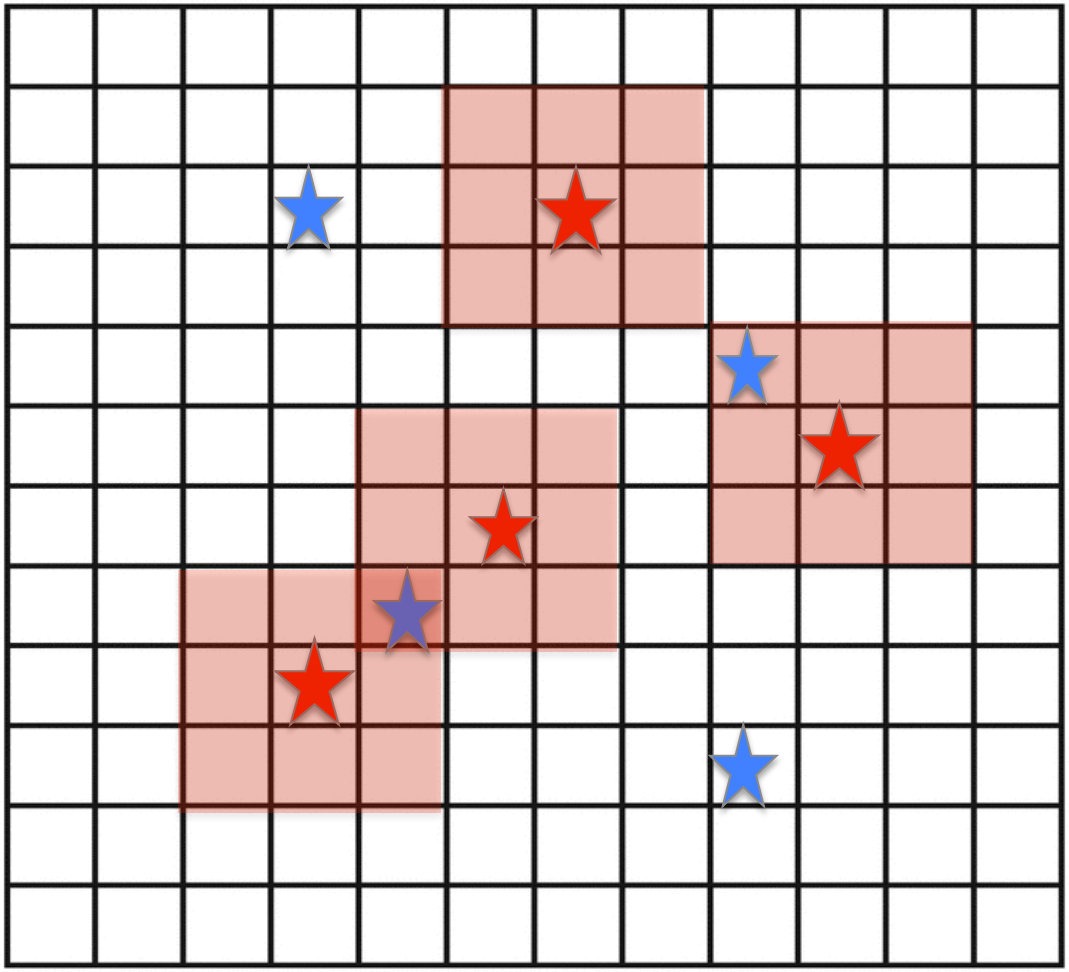


SN hot bubble



McKee & Ostriker (1977)

Numerical Model
--- Inhomogeneous Mixing



$$N = 2000^2$$

$$\Delta t = 0.25 Gyr$$

$$m_{0,i} = \frac{M_{g,i}}{N}$$

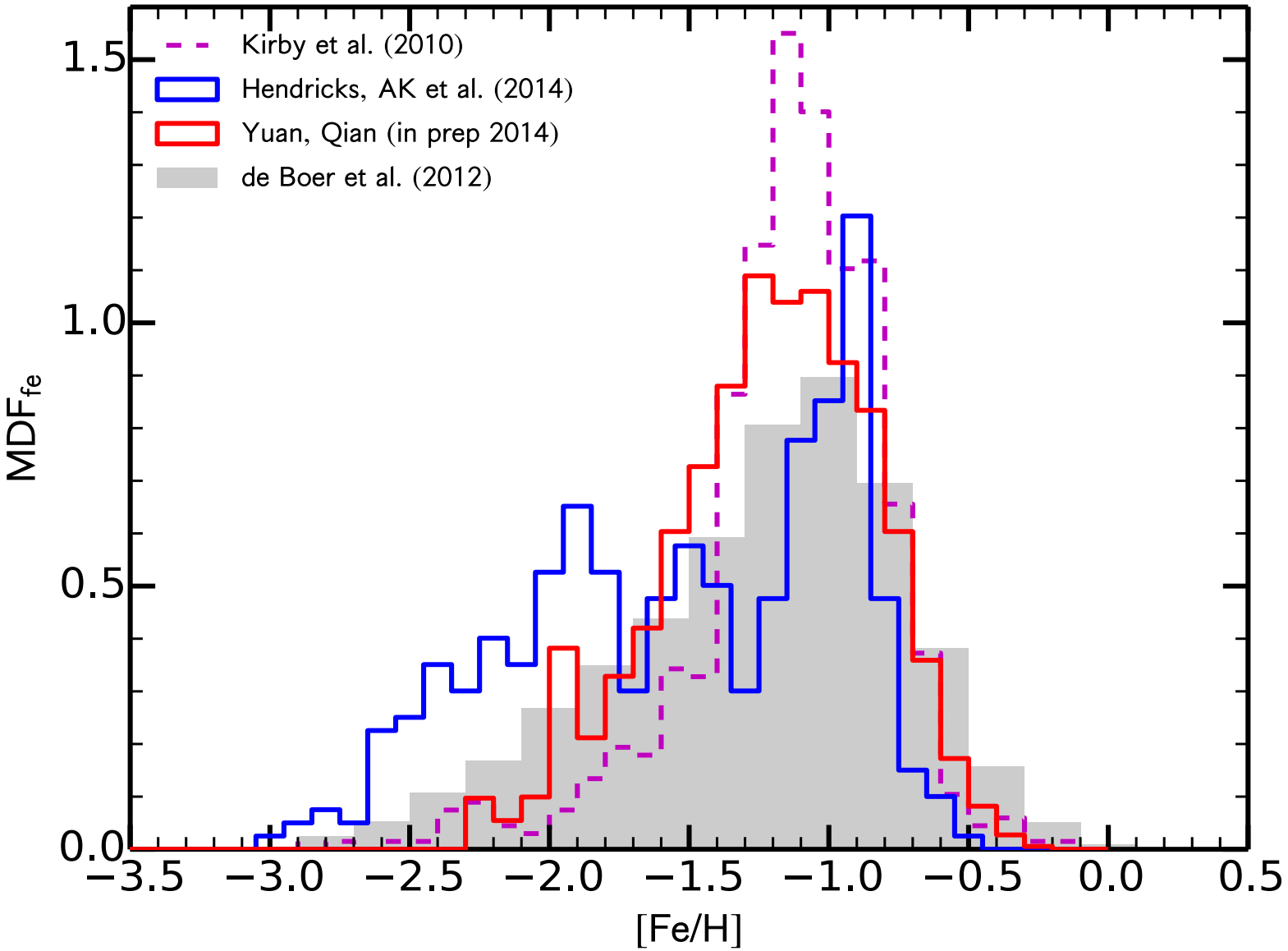
$$Z_{Fe,i,(x,y)} m_{0,i} = m_{0,i-1} Z_{Fe,i-1,(x,y)}$$

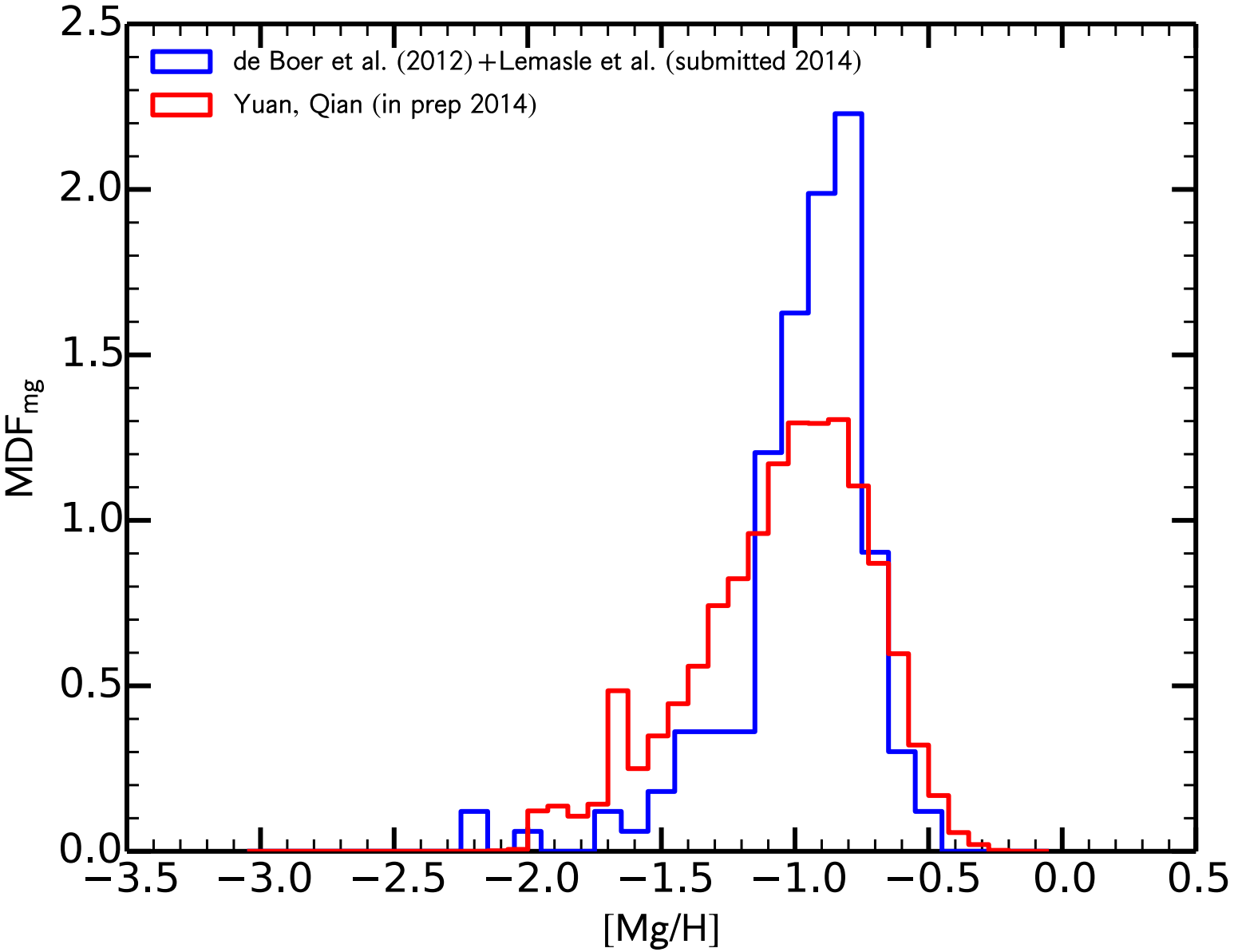
$Z_{Fe,0,1}$	$Z_{Fe,0,2}$	$Z_{Fe,0,2}$
$Z_{Fe,1,0}$	$Z_{Fe,1,1}$	$Z_{Fe,1,2}$
$Z_{Fe,2,0}$	$Z_{Fe,2,1}$	$Z_{Fe,2,2}$

$$n_{mix,i} = \frac{M_{mix}}{m_{0,i}} \qquad \delta Y_{Fe,i} = \frac{Y_{Fe}}{n_{mix,i}}$$

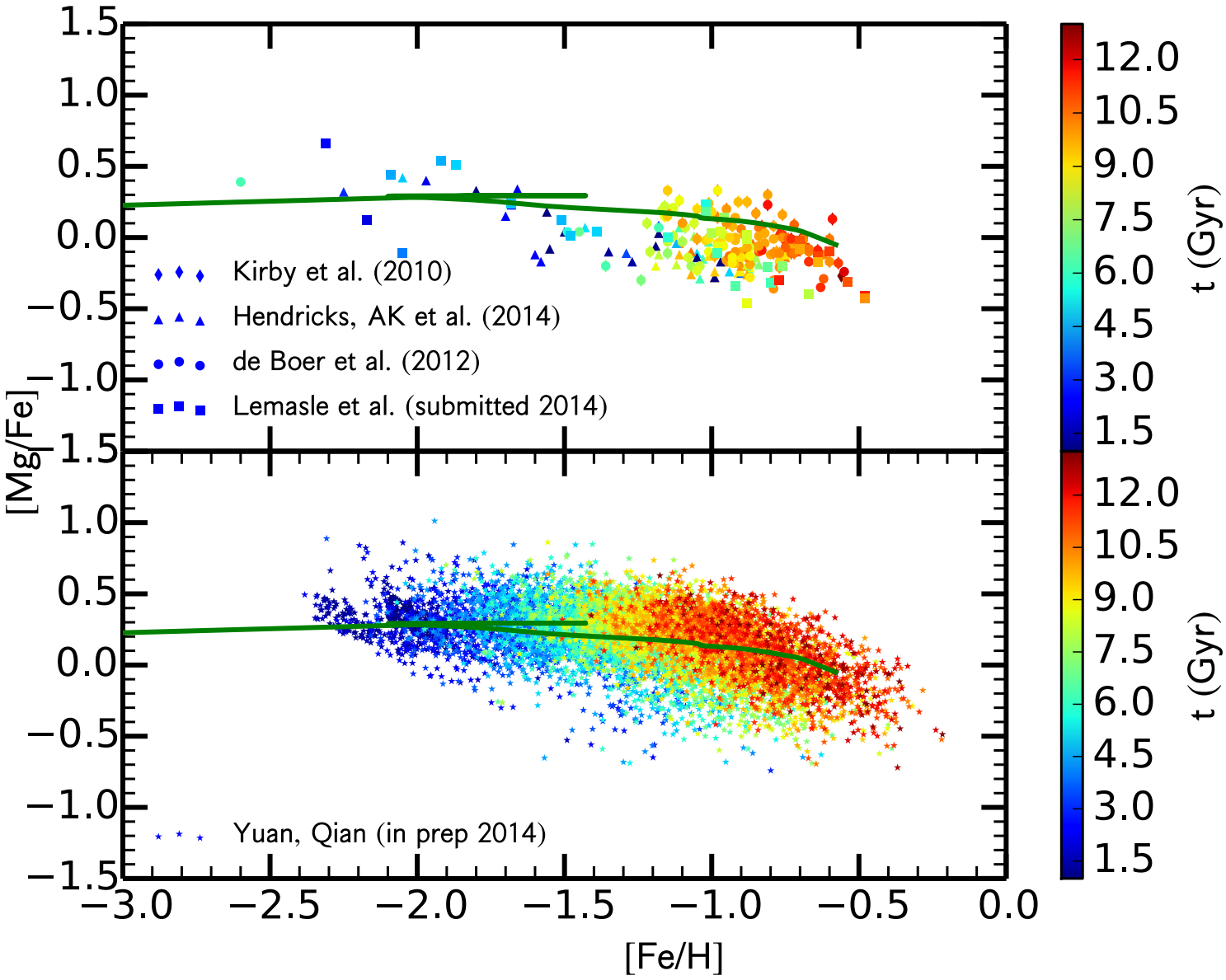
$$Z_{Fe,i,(x,y)} = Z_{Fe,i-1,(x,y)} + \delta Y_{Fe,i}$$

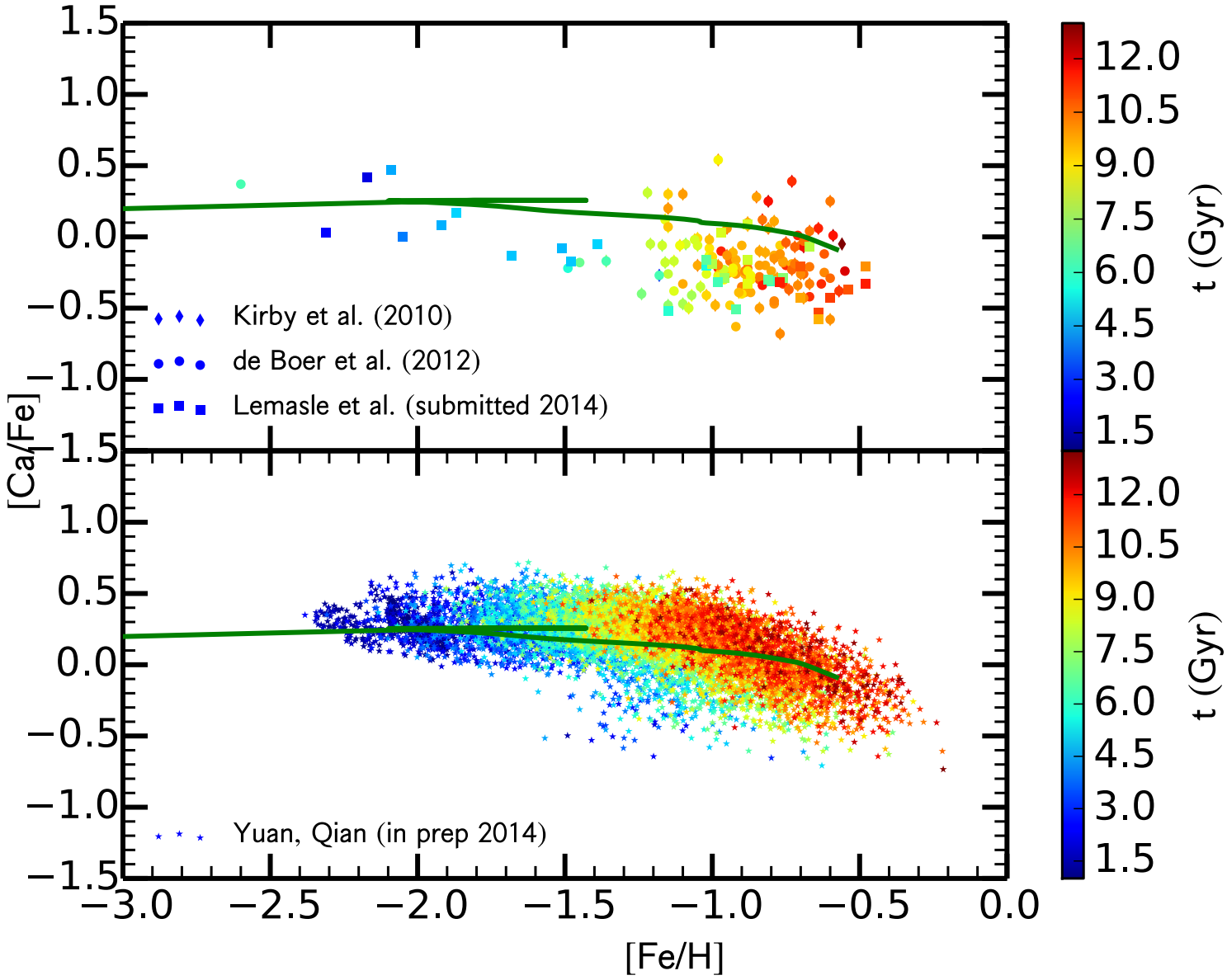
Comparison with Observation

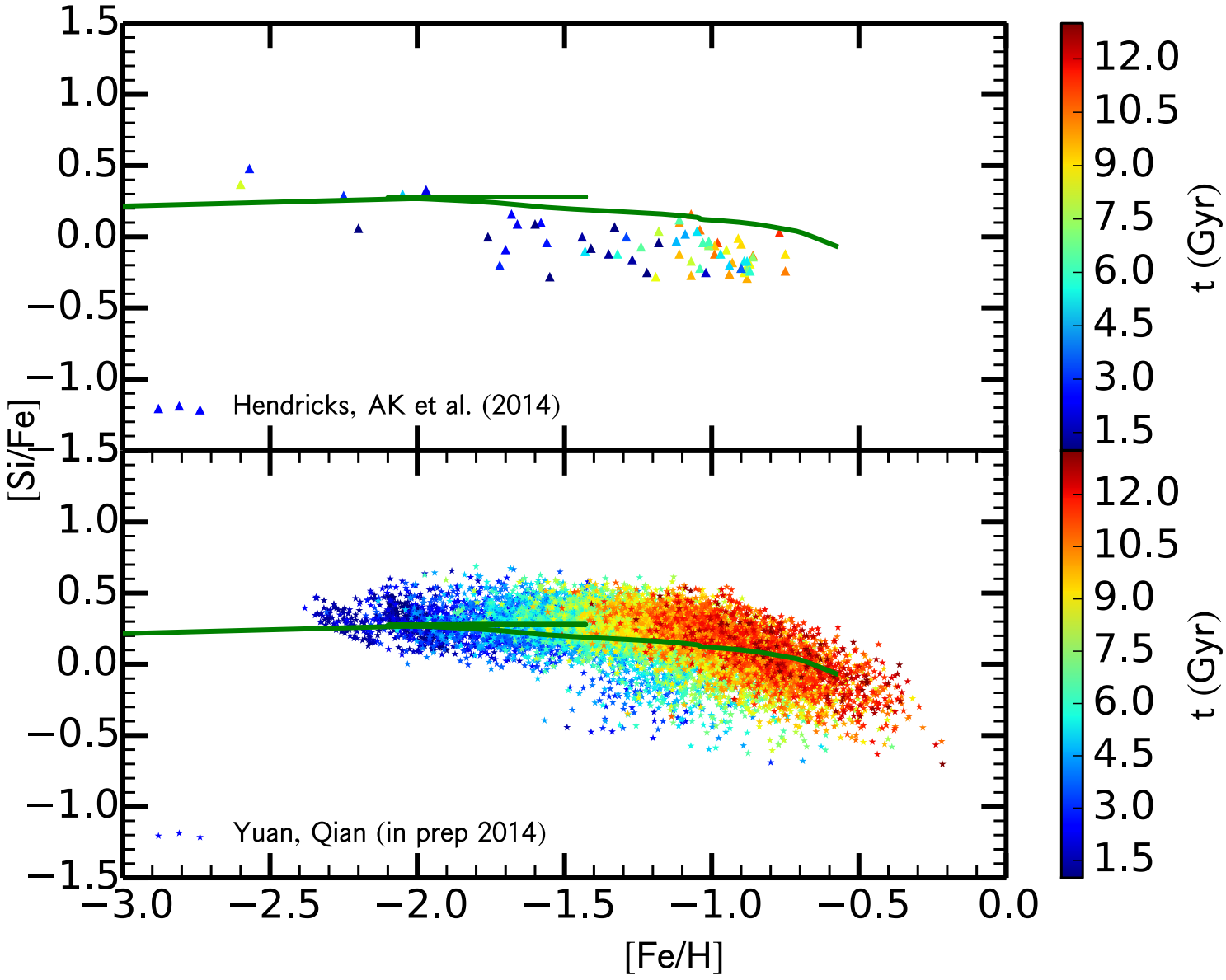


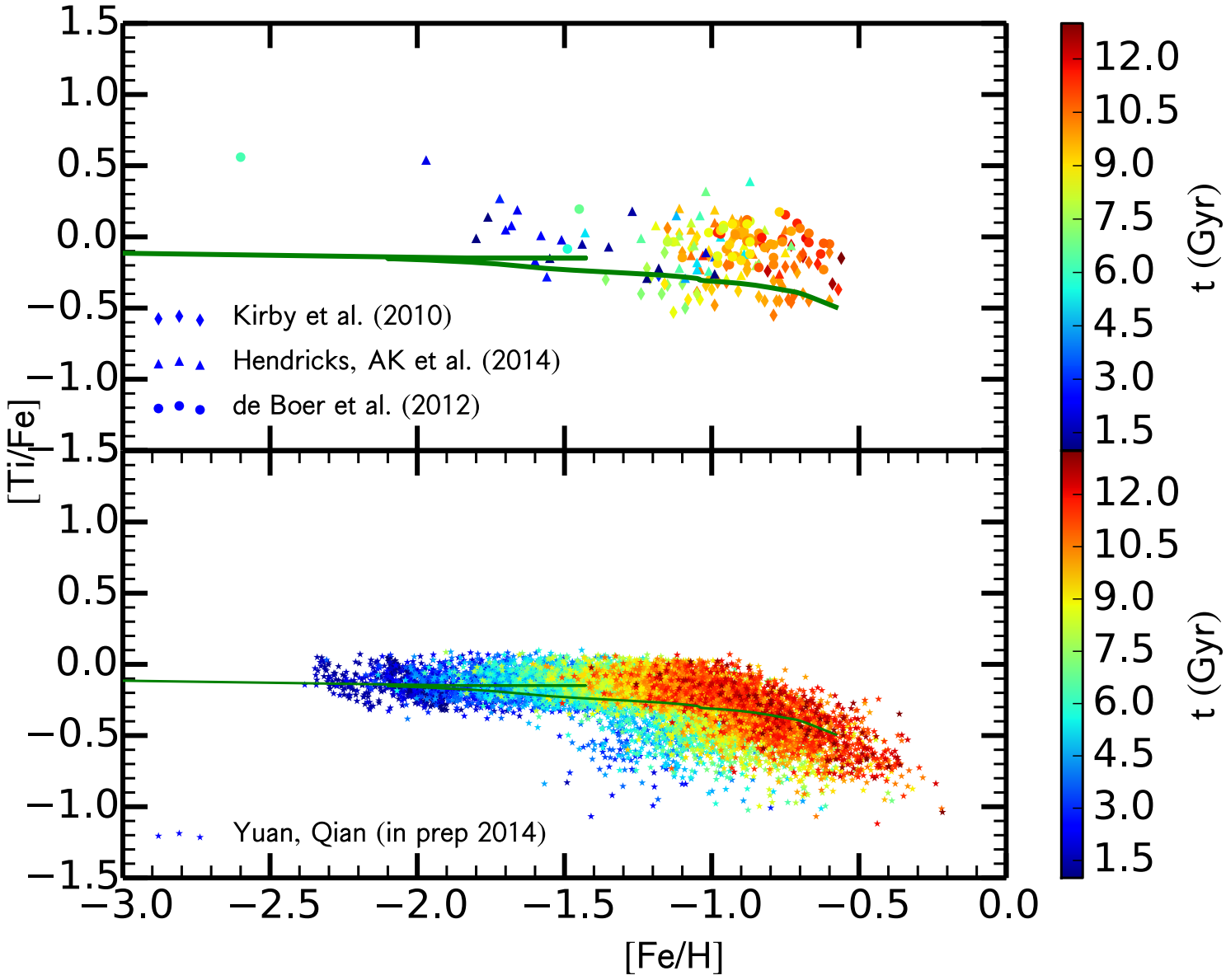

de Boer et al. (2012)+Lemasle et al. (submitted 2014)
Yuan, Qian (in prep 2014)
MDF$_{mg}$
[Mg/H]
2.5
2.0
1.5
1.0
0.5
0.0
−3.5
−3.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5

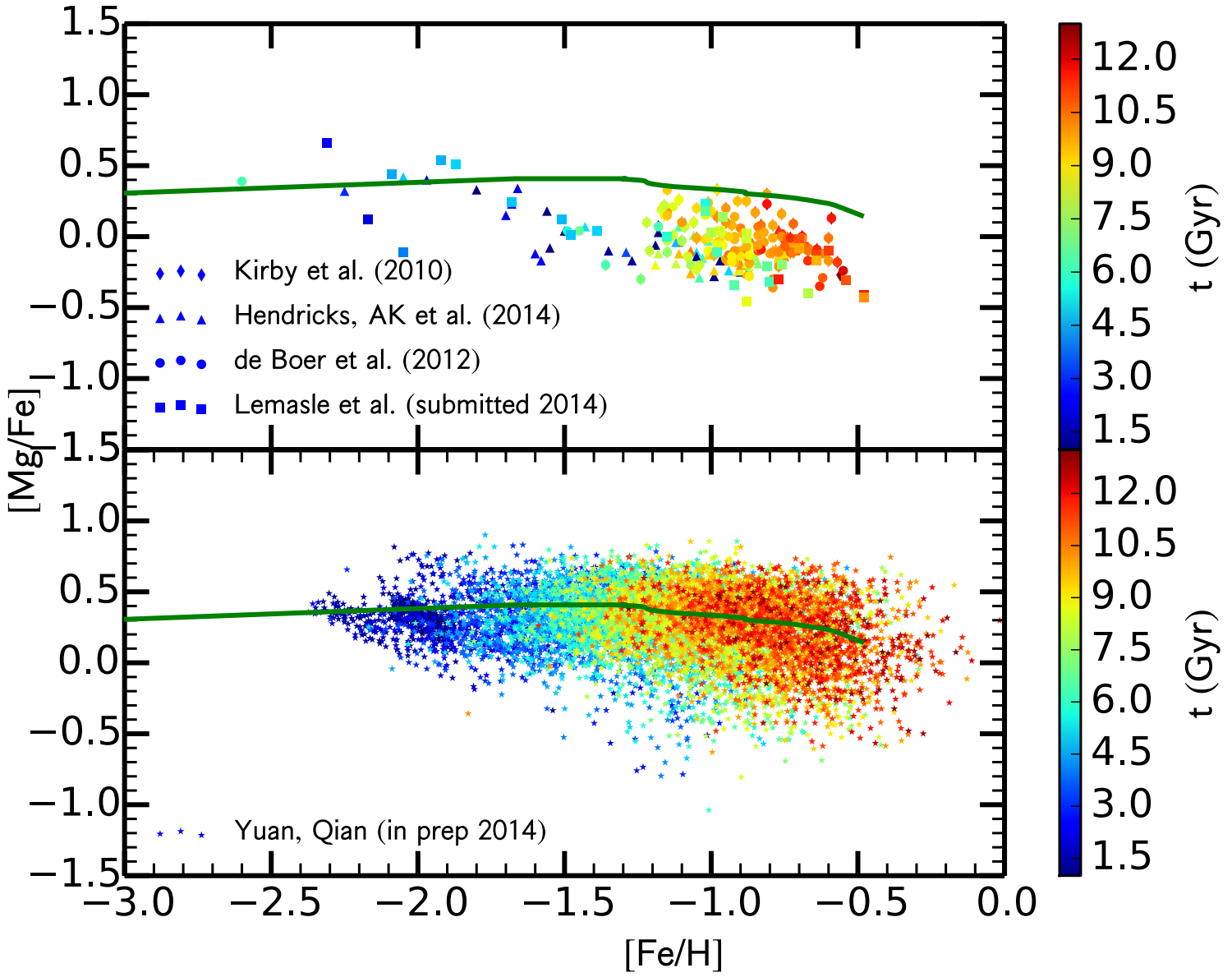
Scatter comes from astrophysical sites !




Kirby et al. (2010)
de Boer et al. (2012)
Lemasle et al. (submitted 2014)
Yuan, Qian (in prep 2014)
[Ca/Fe]
[Fe/H]
t (Gyr)
t (Gyr)

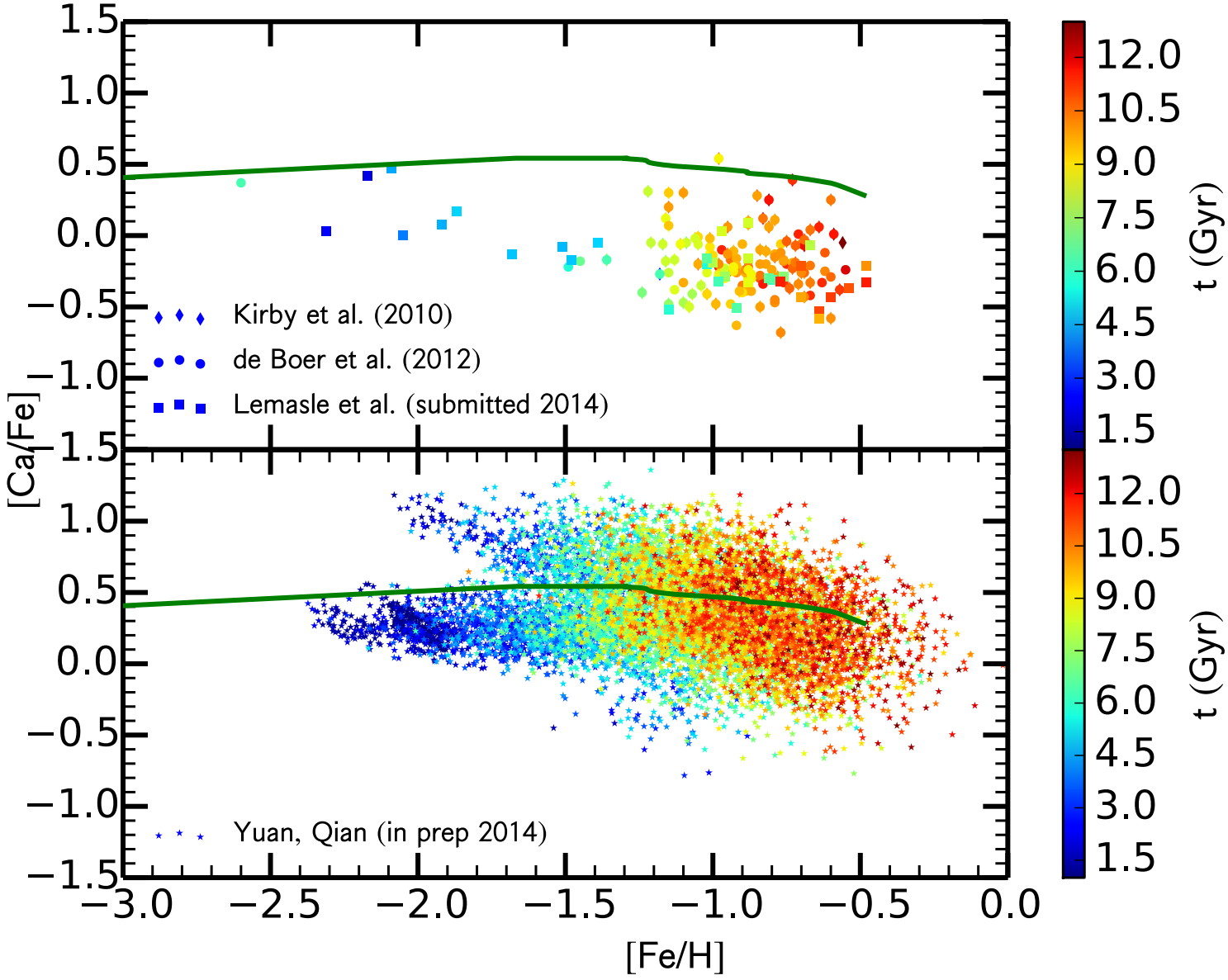

[Si/Fe]
[Fe/H]
Hendricks, AK et al. (2014)
Yuan, Qian (in prep 2014)
t (Gyr)
t (Gyr)


[Ti/Fe]
[Fe/H]
Kirby et al. (2010)
Hendricks, AK et al. (2014)
de Boer et al. (2012)
Yuan, Qian (in prep 2014)
t (Gyr)
t (Gyr)



Yields from Heger & Woosley (2008)

80 Msun – 100 Msun, Standard Mixing, E=5.0 B, S=4 Piston


Kirby et al. (2010)
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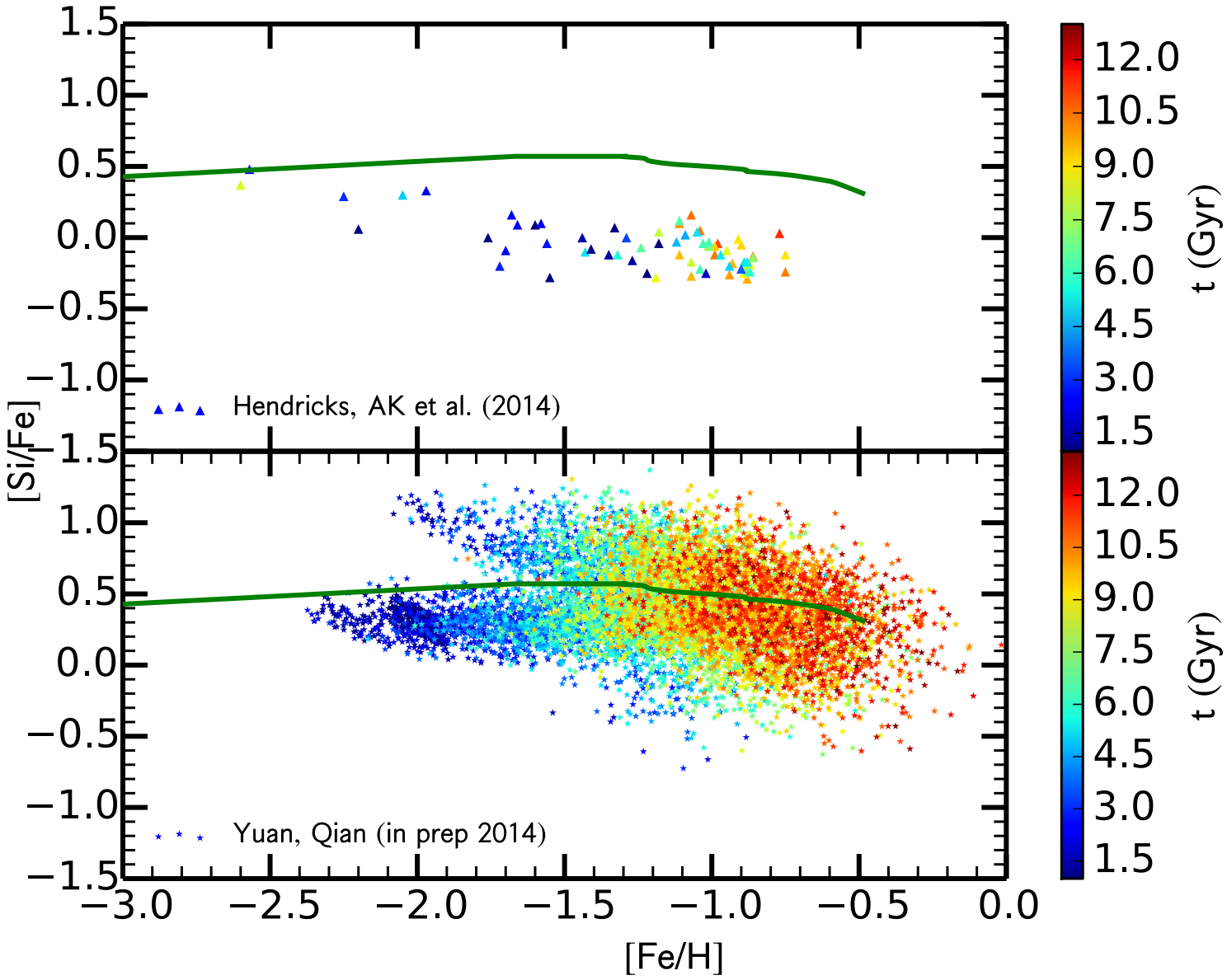
Yuan, Qian (in prep 2014)
[Ca/Fe]
[Fe/H]
t (Gyr)
t (Gyr)


[Si/Fe]
[Fe/H]
Hendricks, AK et al. (2014)
Yuan, Qian (in prep 2014)
t (Gyr)
t (Gyr)

Future work

- SN Model with different E, mixing ?
- 1D, 2D, 3D?
- Motivation from Observations?
- Other dSph: Sculptor, Carina, etc
- r-process/s-process elements

- Hydro-simulation of gas dynamics and chemical evolution in dSph
- Dark Matter Halo Model for Fornax