Atomic diffusion and lithium processing in old metal poor stars

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Plan

- atomic diffusion in stellar modeling,
- atomic diffusion at work in population II stars:

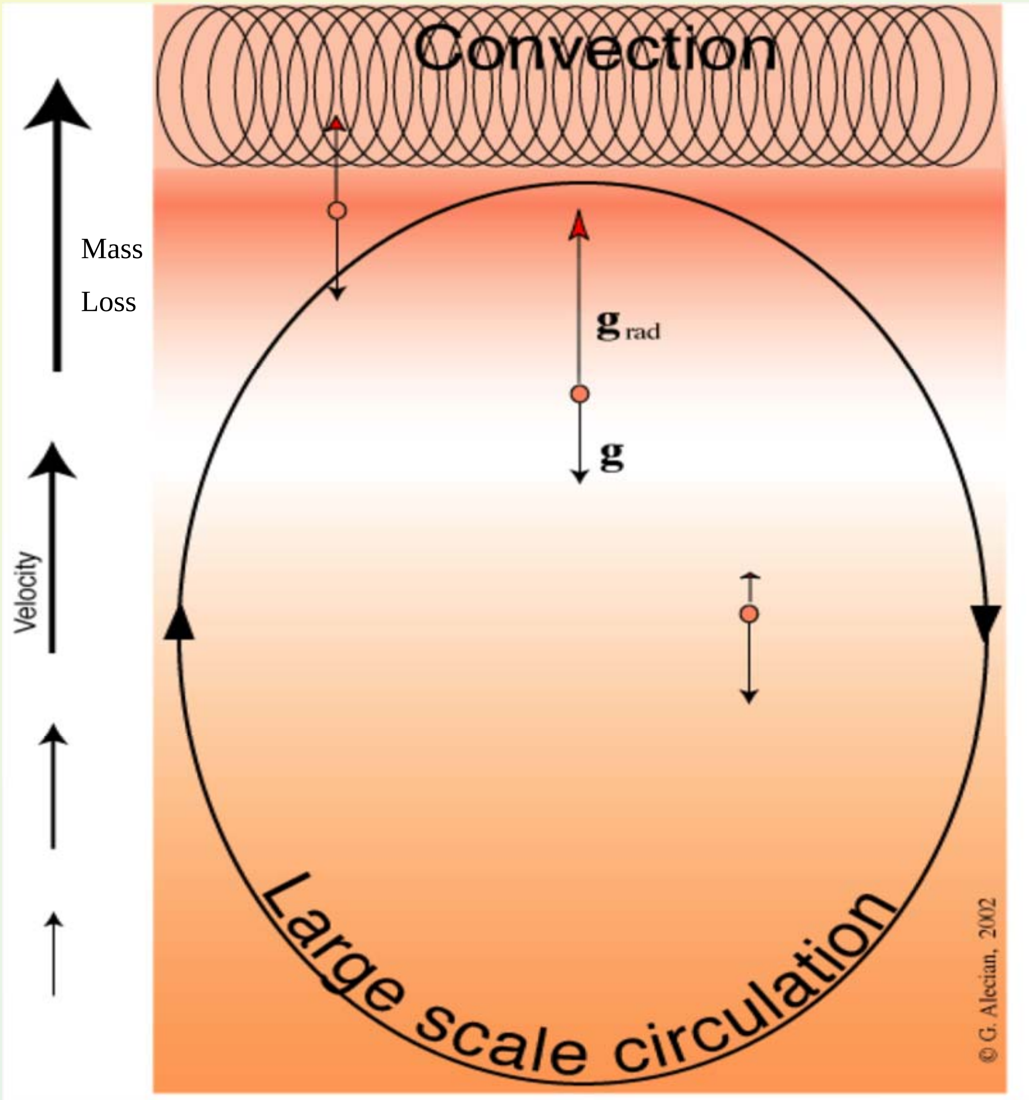
  Effects in the center, on surface abundances, and the effect of initial metallicity,

Transport in the radiative zone:

chemical composition variations in the radiative zone due to particles transport processes

- Competition between g and g_{rad} approx. determines movement of elements

- Competing transport processes can hinder diffusion



G. Alecian, 2002

Burger's equations

Expression used in evolution calculations

$$\begin{cases} m_i N_i \left(g_i^{rad} - g \right) + N_i Z_i \left(eE \right) - \dfrac{\partial P_i}{\partial r} = -\sum_j K_{ij} \left[\left(w_j - w_i \right) + z_{ij} \dfrac{m_j r_i - m_i r_j}{m_i + m_j} \right] \\ \dfrac{5}{2} N_i k \dfrac{\partial T}{\partial r} = \sum_j K_{ij} \left[-\dfrac{5}{2} \dfrac{m_j z_{ij}}{m_i + m_j} \left(w_j - w_i \right) - a_{ij} r_i + b_{ij} r_j \right] \end{cases}$$

- 2 equations for each species (28 in the code)
- Solved for each mesh points (~1500)
- and at each time step (~1000)

Radiative accelerations

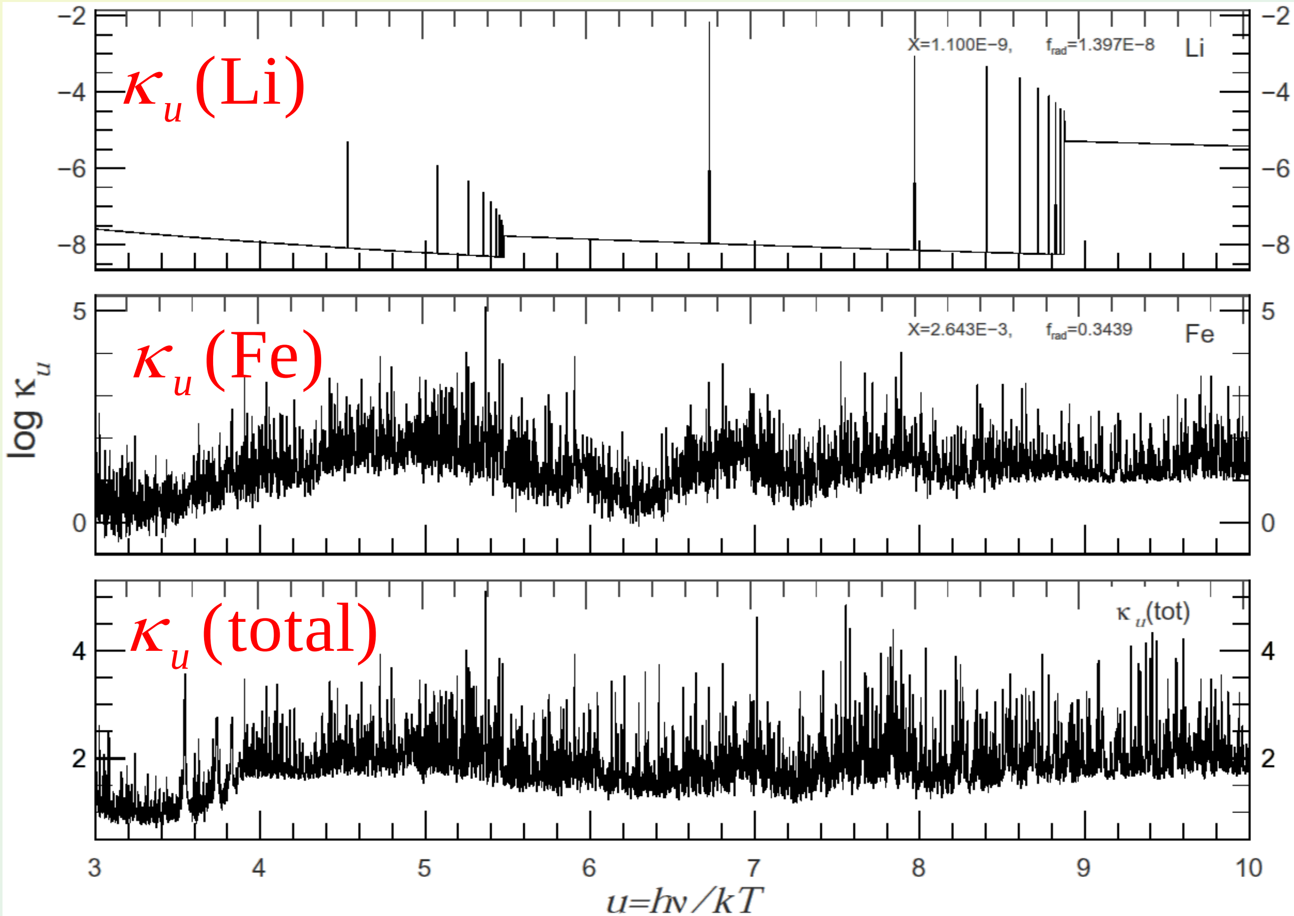
Expression used in evolution calculations

$$g_i^{rad} = \frac{1}{4\pi r^2}\frac{L_r^{rad}}{c}\frac{\kappa_R}{X_i}\int_0^\infty \frac{\kappa_u(i)}{\kappa_u(\text{total})}P(u)du$$

$$u = \frac{h\nu}{kT}$$ Dimensionless frequency

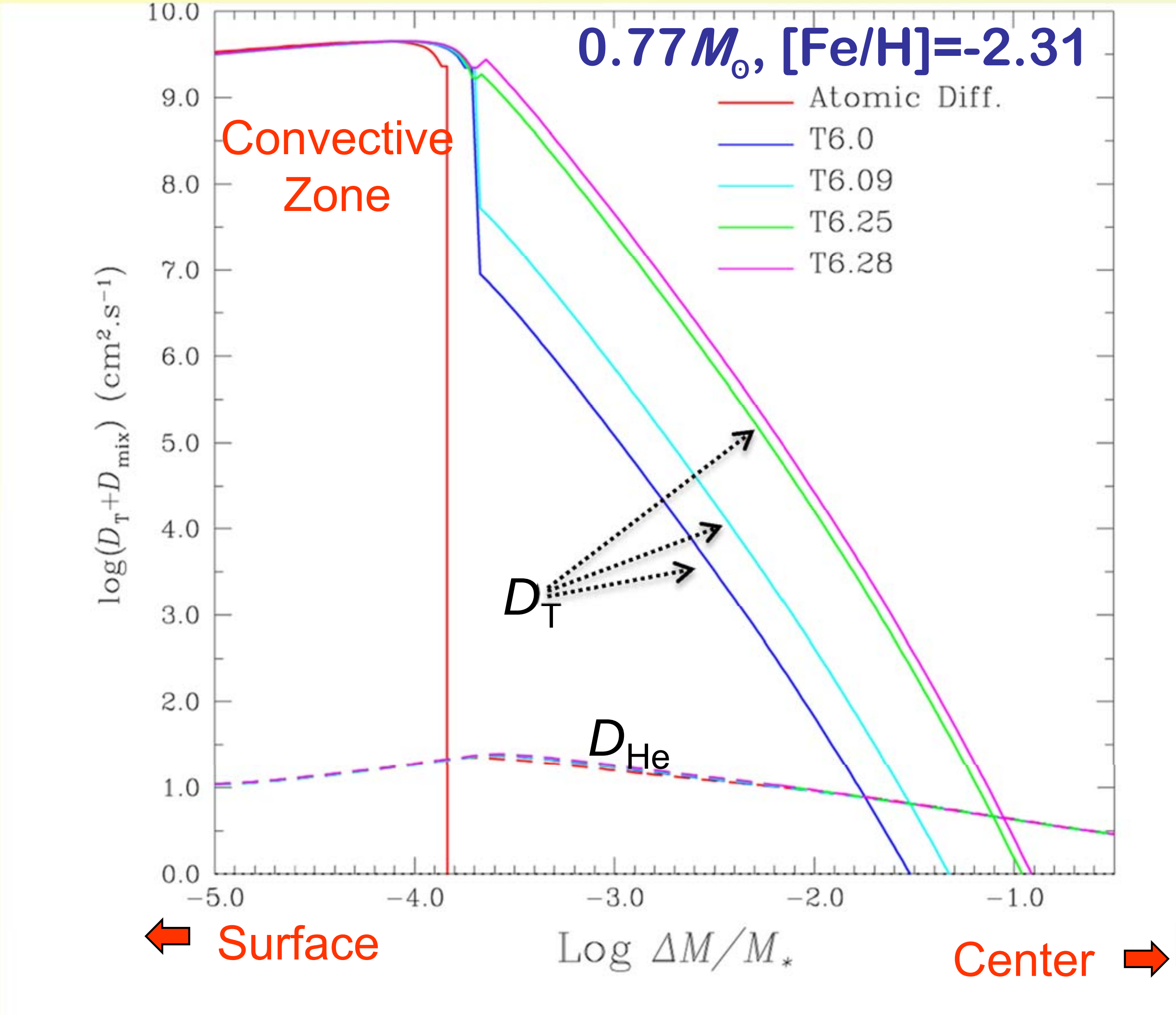
$$P(u) = \frac{15}{4\pi^4}\frac{u^4 e^u}{(e^u - 1)^2}$$ Normalised black body Flux distribution

- 1.5 GigaBytes of data $\kappa_u(i)$; OPAL (1996)
  - Integration over fraction of photons given to *i* at each frequency



Mixing parametrization

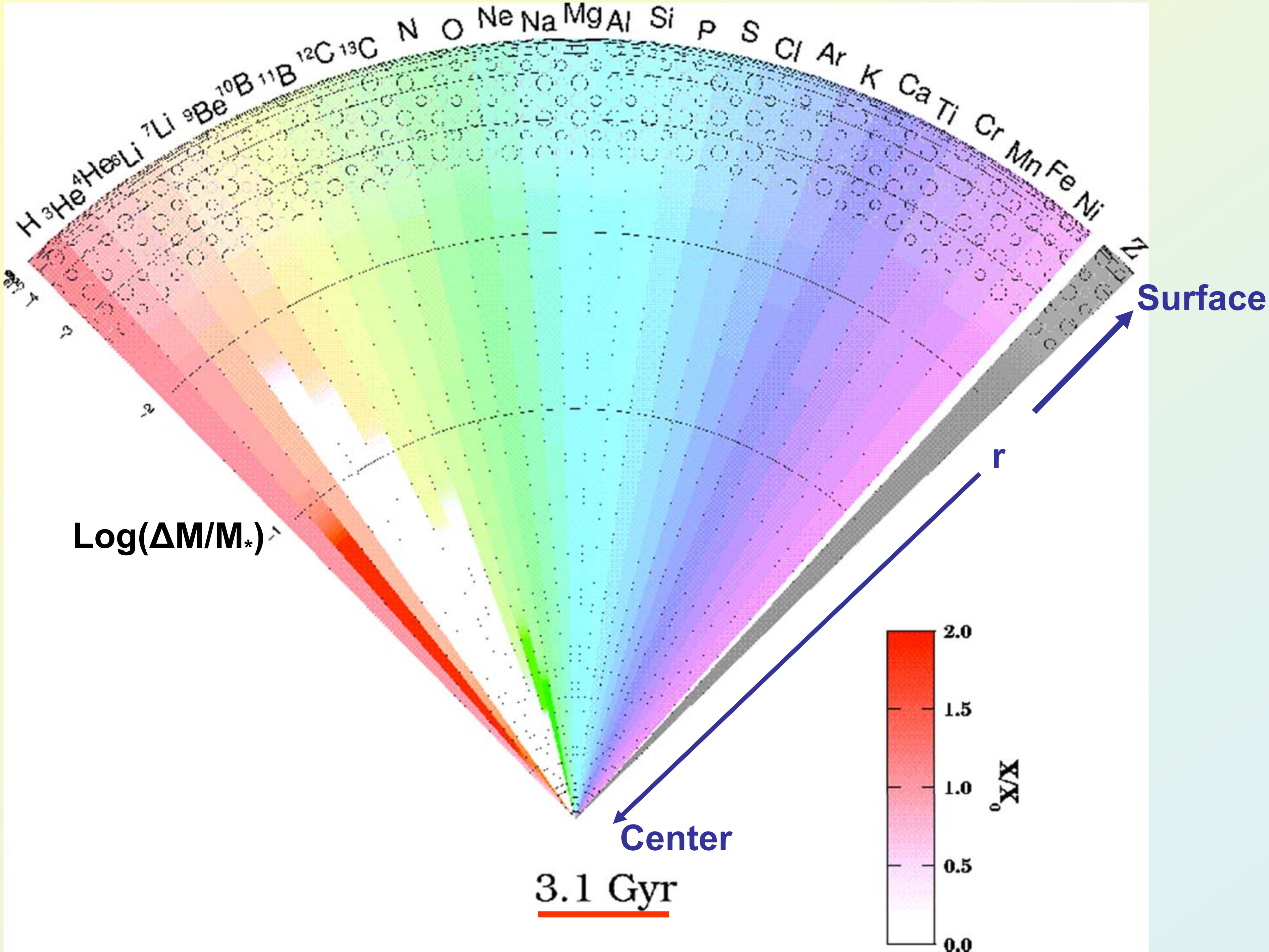
Expression used in evolution calculations



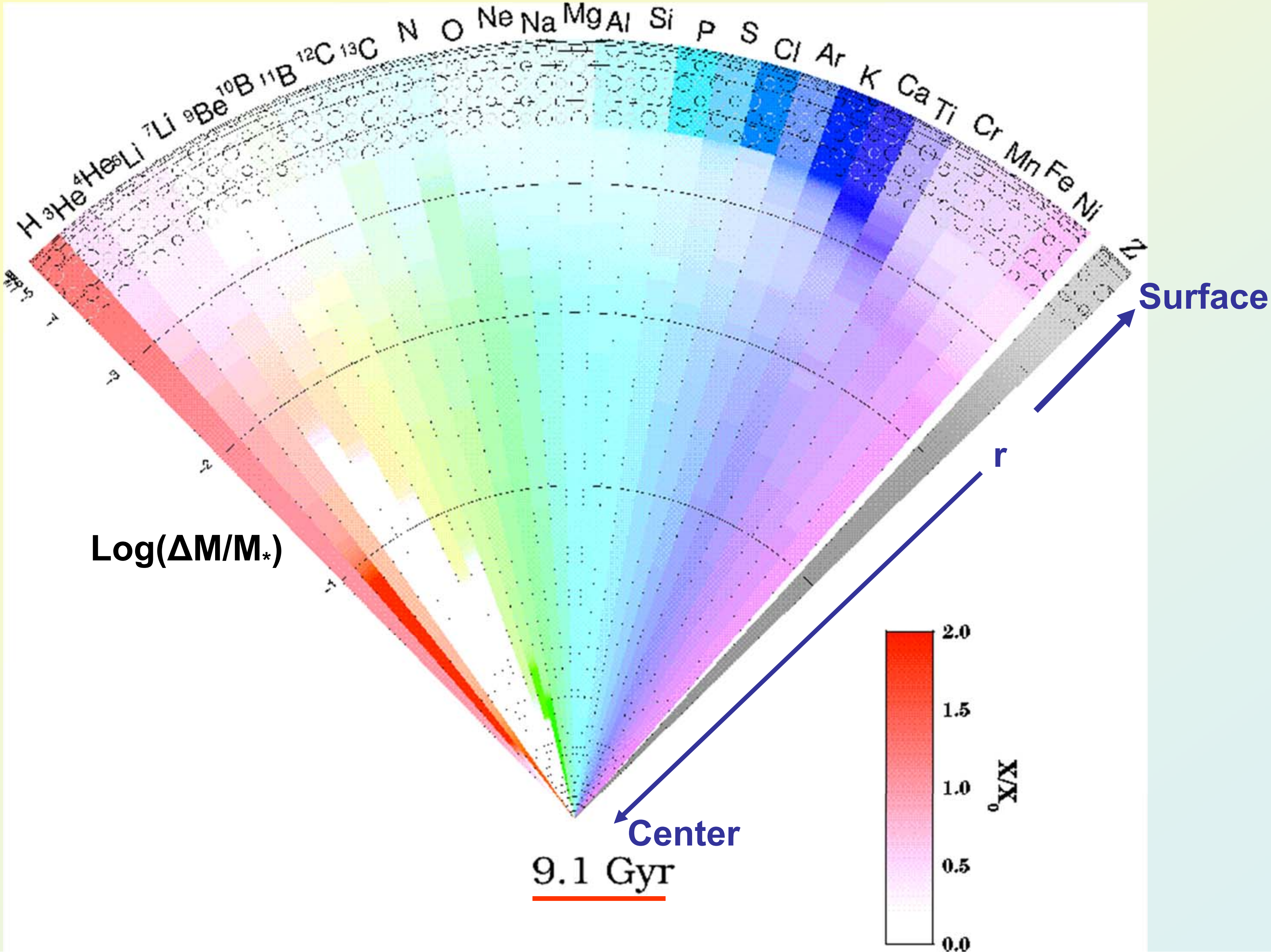
$$D_T = 400 D_{\mathrm{He}}(T_0)\left(\frac{\rho}{\rho(T_0)}\right)^{-3}$$

Notation T6.0 => $\log(T_0)$=6.0

Abundance variations in metal poor stars: 0.8$M_{\odot}$, [Fe/H]=-2.31

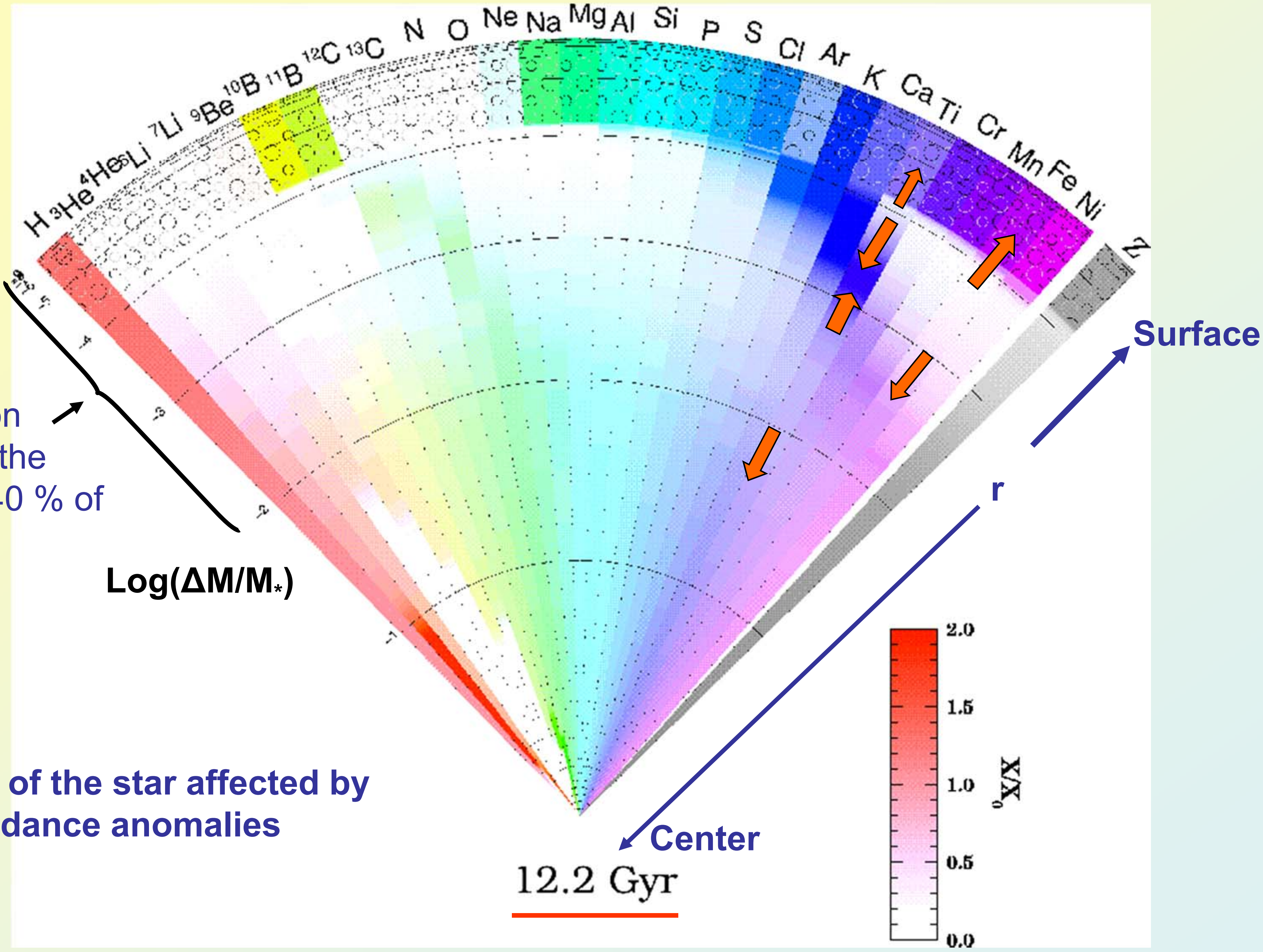


$0.8 M_\odot$, [Fe/H]=-2.31



Close to turn-off

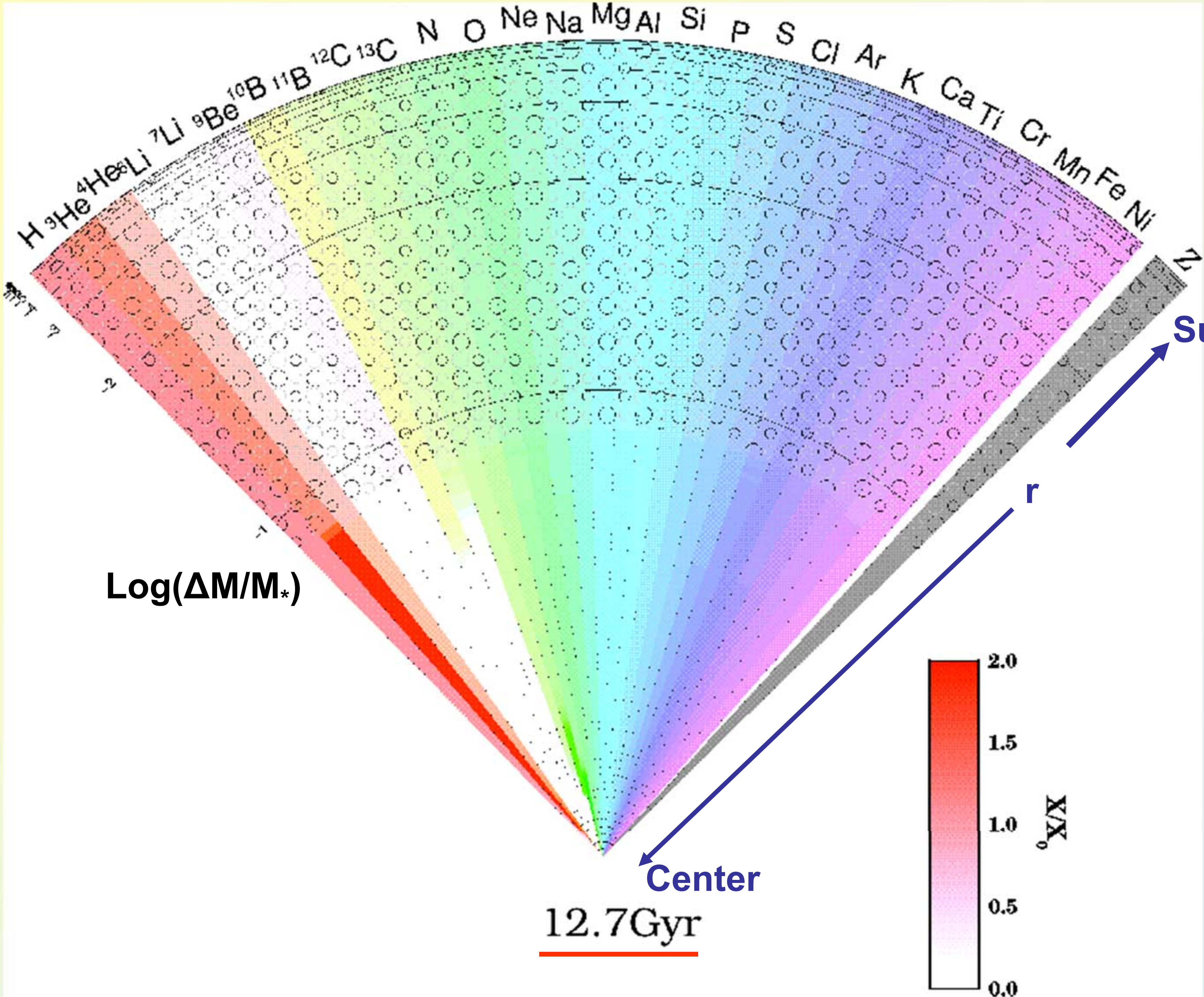
$0.8 M_{\odot}$, [Fe/H]=-2.31



Diffusion affects the upper 40 % of R_*

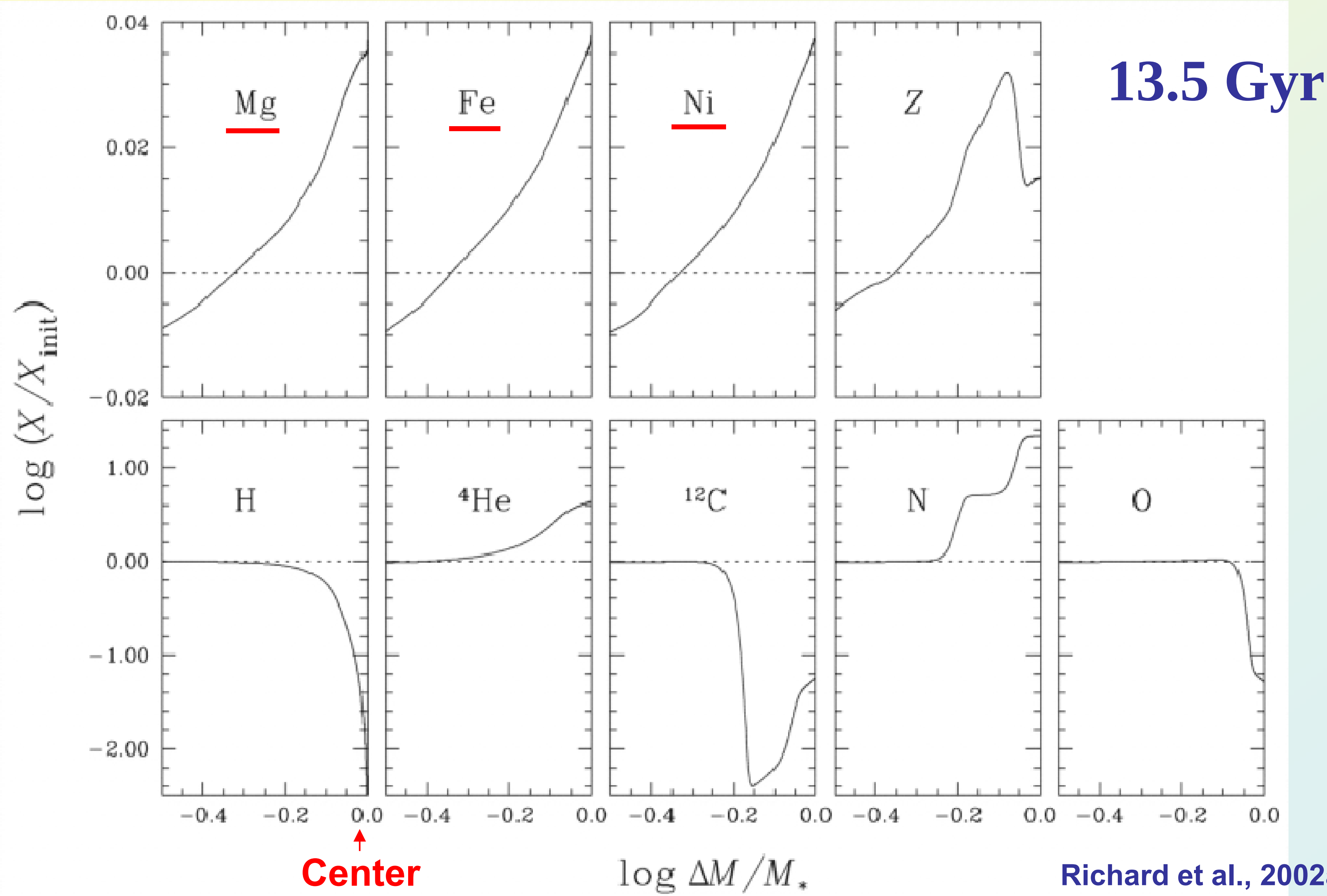
Most of the star affected by abundance anomalies

$0.8 M_\odot$, [Fe/H]=-2.31



Effect of diffusion in the center of the star

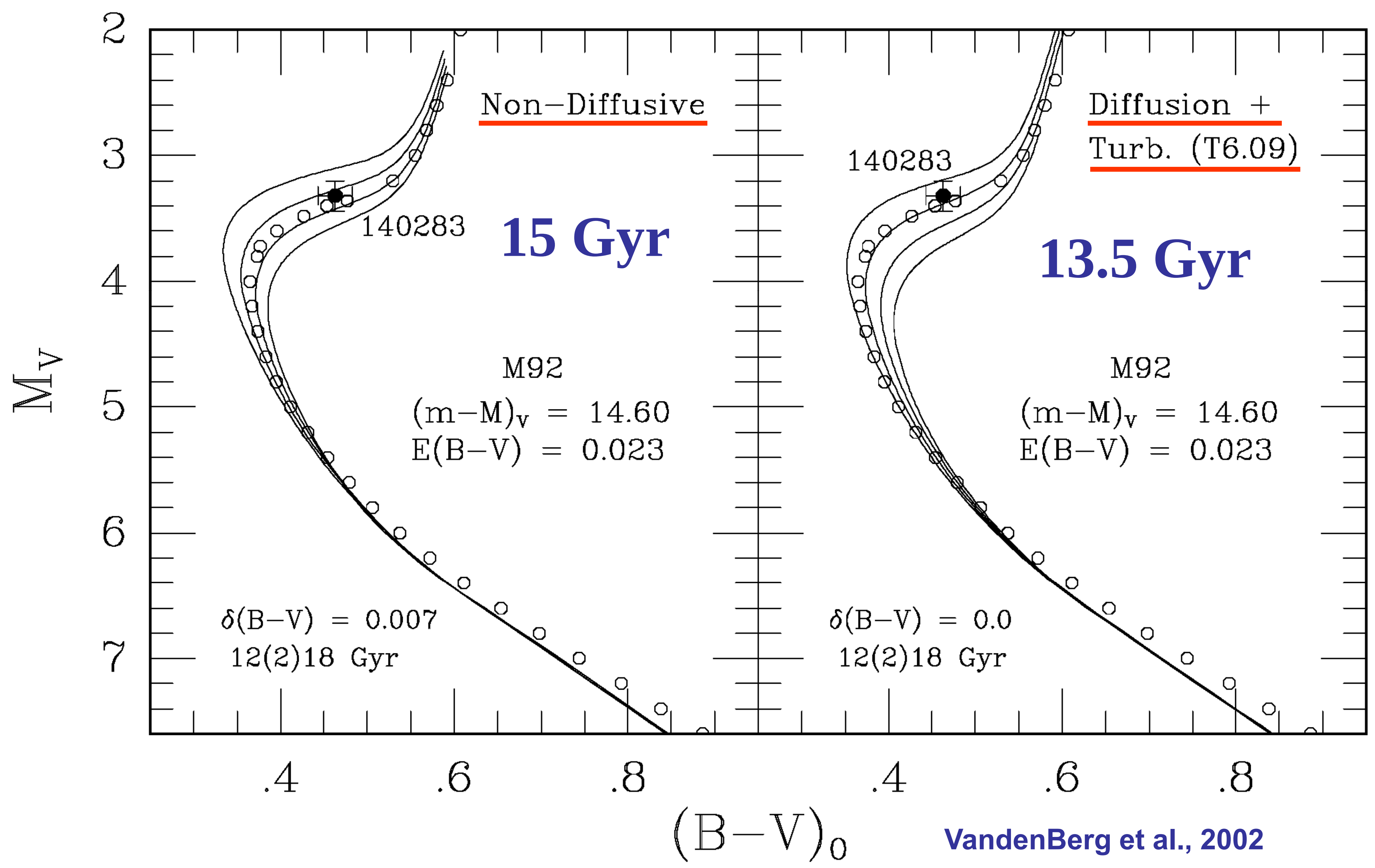
$0.8 M_{\odot}$, [Fe/H]=-2.31



Richard et al., 2002a

Globular cluster age: M92 case

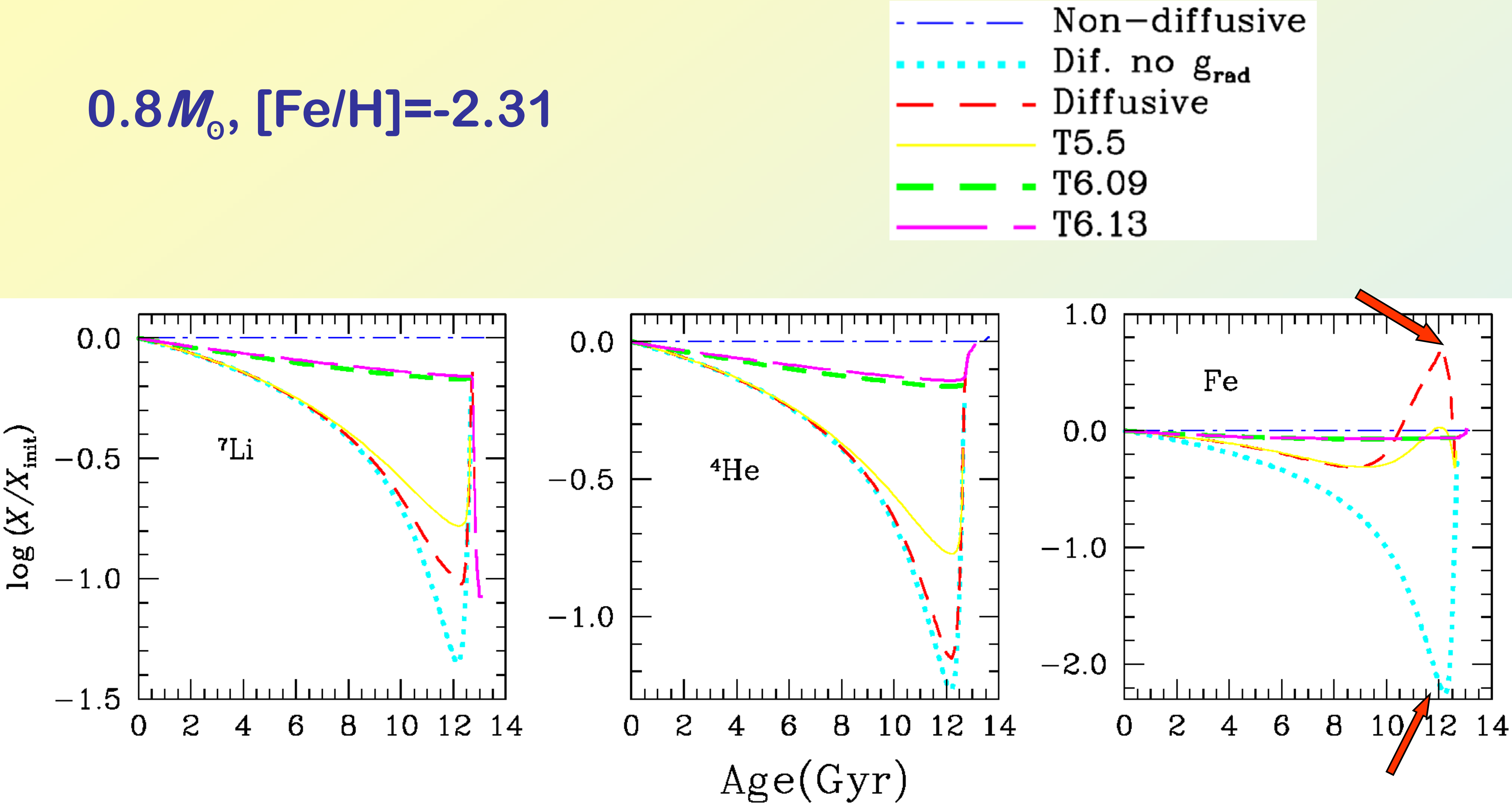
Age reduction: ~10%



VandenBerg et al., 2002

Predicted surface abundances

0.8 $M_{\odot}$, [Fe/H]=-2.31

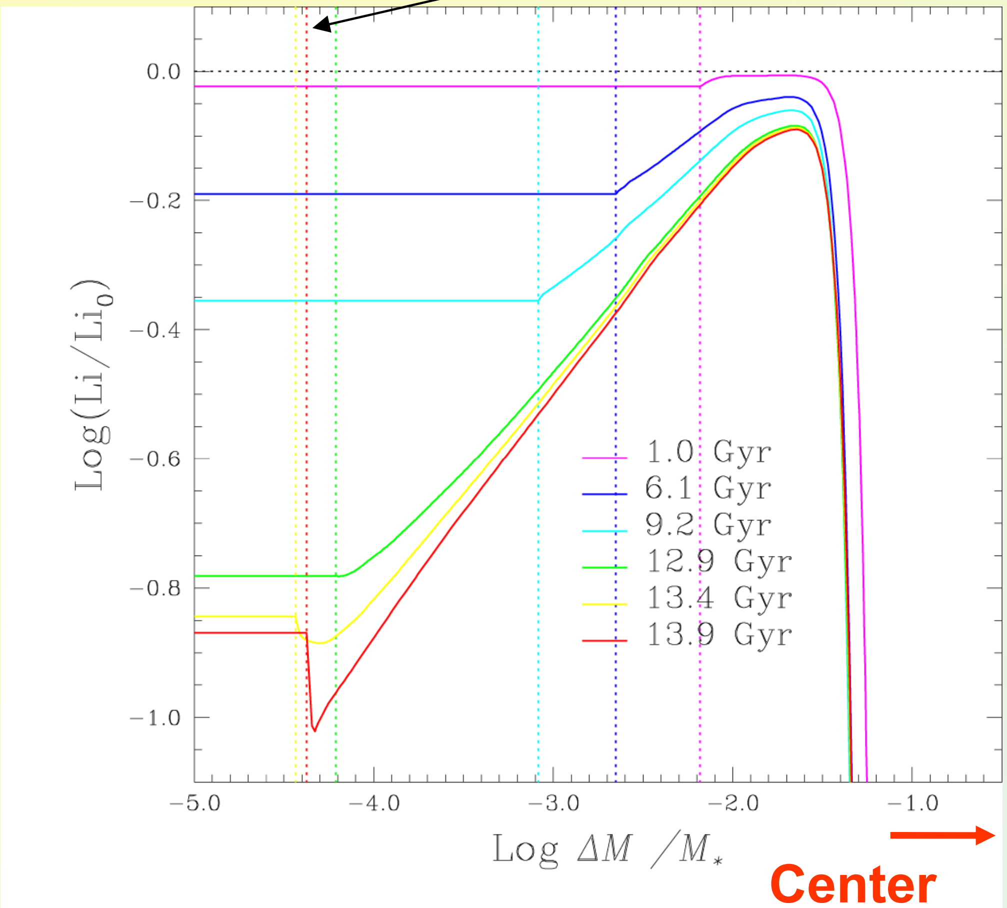


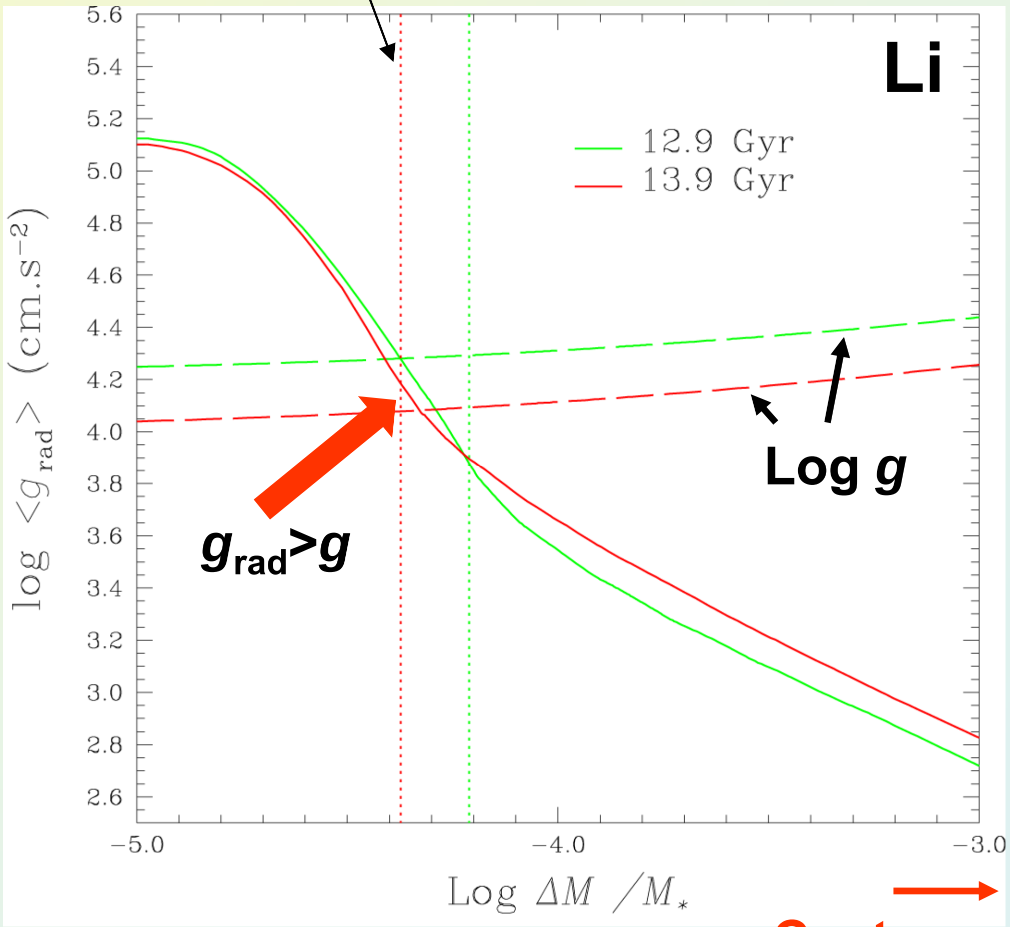
Richard et al., 2002a

Factor of ~1000 in the predicted surface Fe abundance

Lithium abundance and radiative acceleration in a 0.77 $M_\odot$, [Fe/H]=-3.31

Bottom of the surface CZ

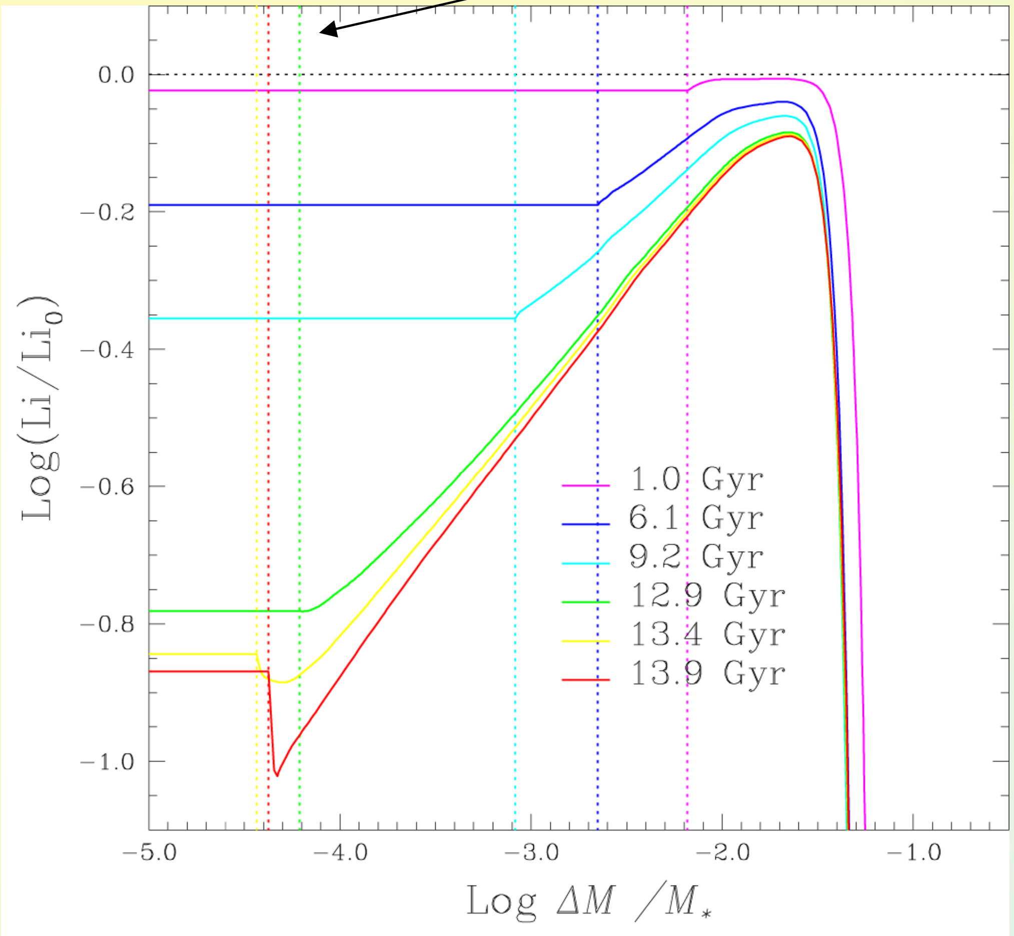


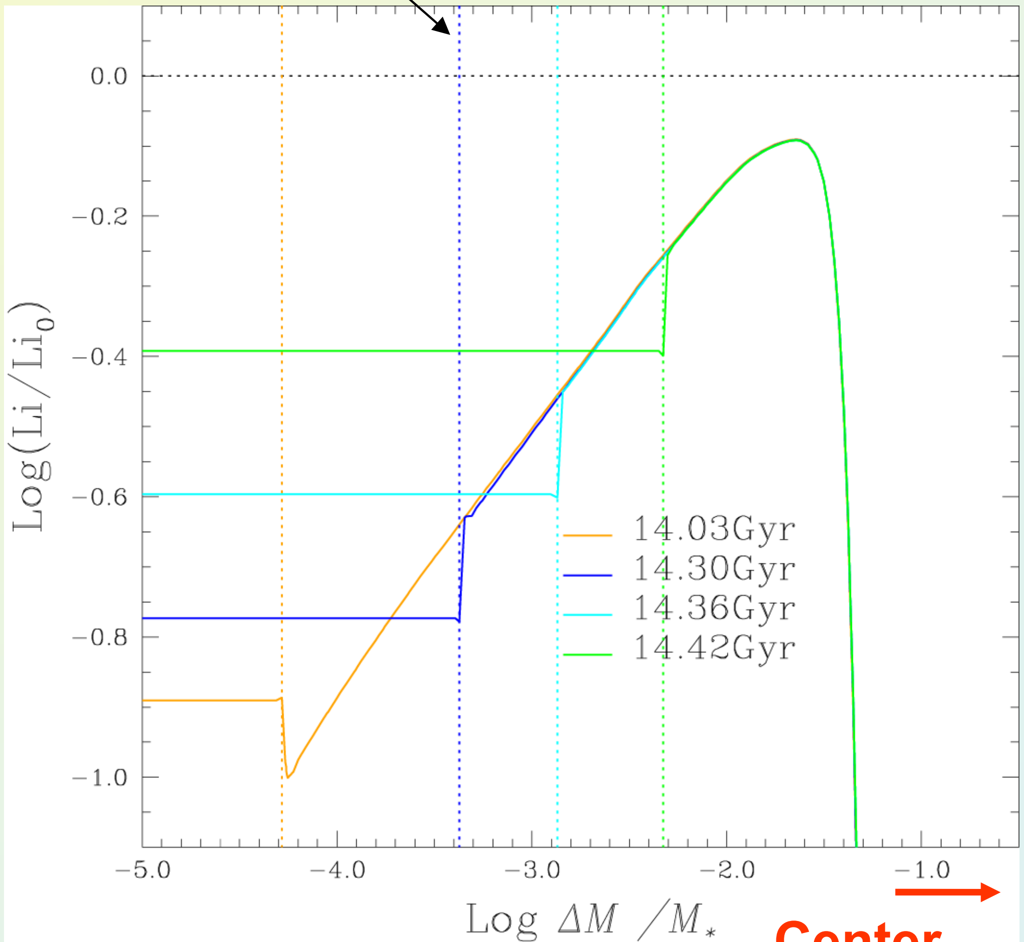


Li abundance decrease due to atomic diffusion and nuclear burning

0.77 $M_\odot$, [Fe/H]=-3.31

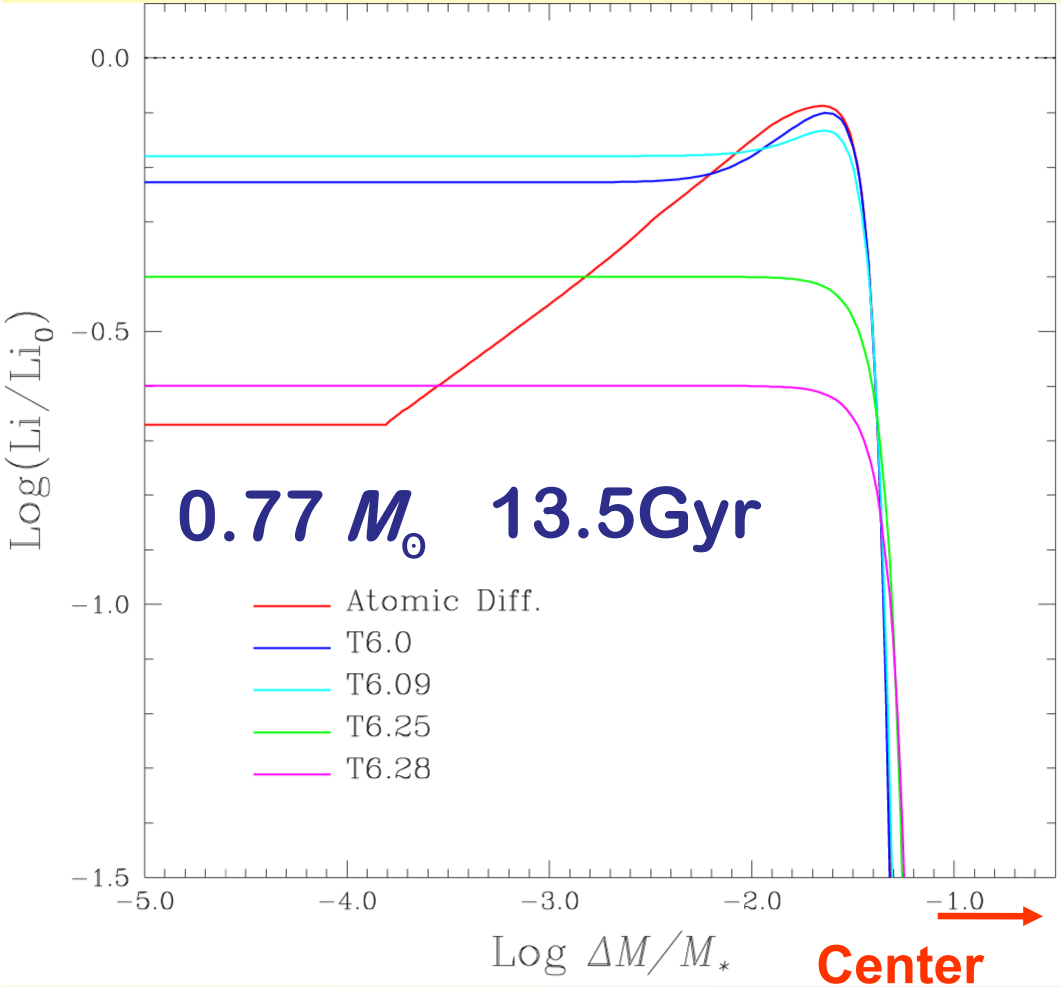
Bottom of the surface CZ

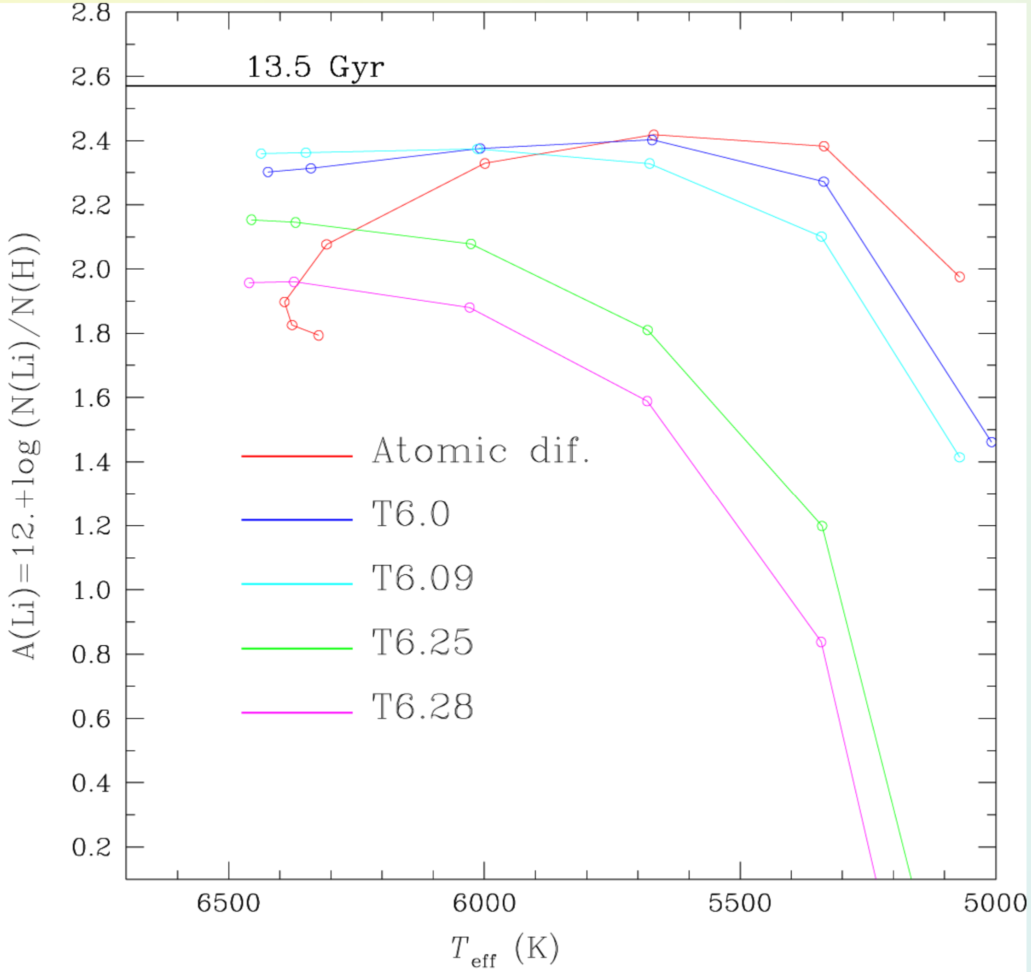




Lithium dredge-up after TO

Lithium in models for [Fe/H]=-2.31





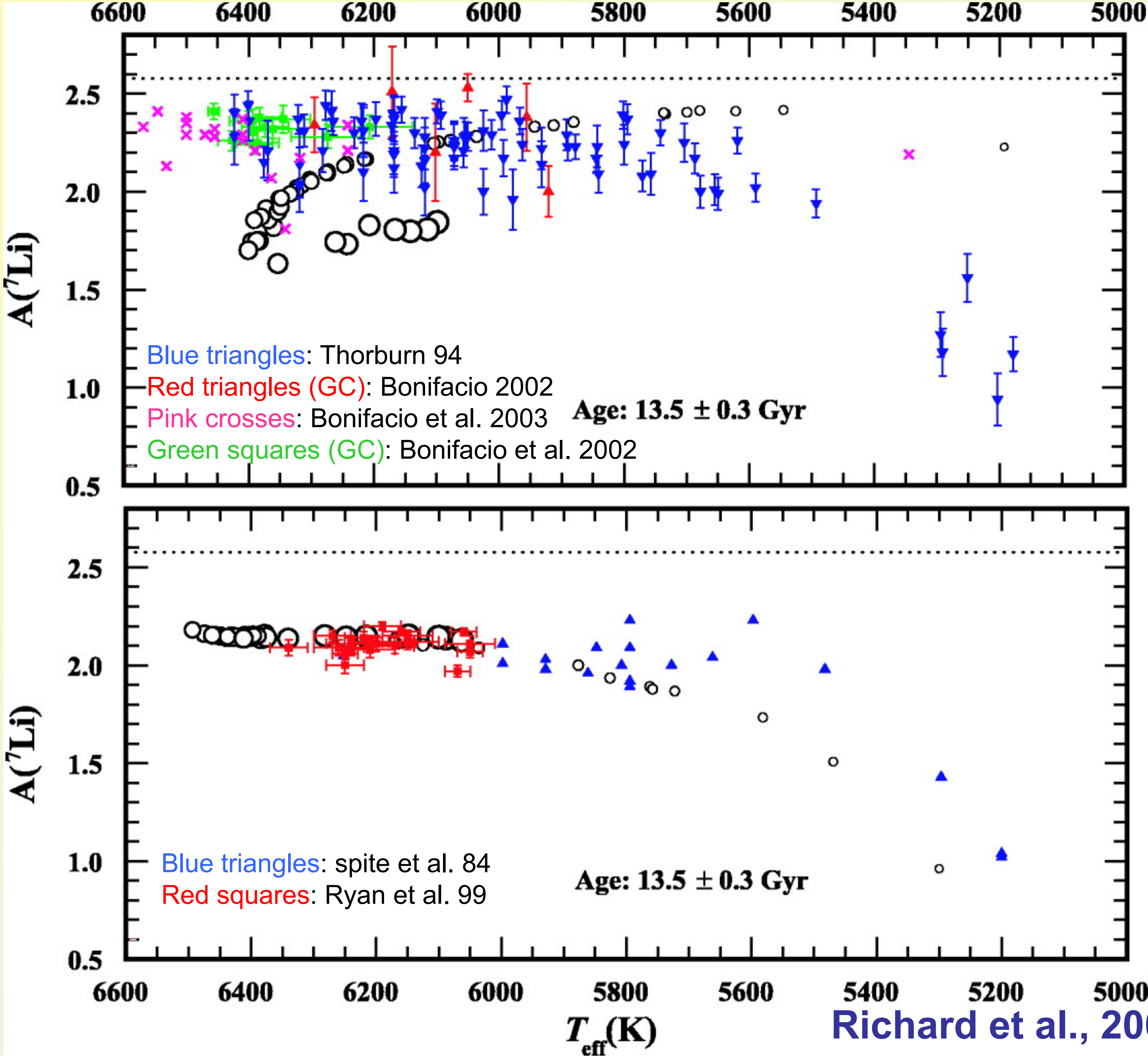
Richard et al., 2005

13.5Gyr isochrones for main-sequence models

Primordial Lithium and the spite plateau

Diffusive models

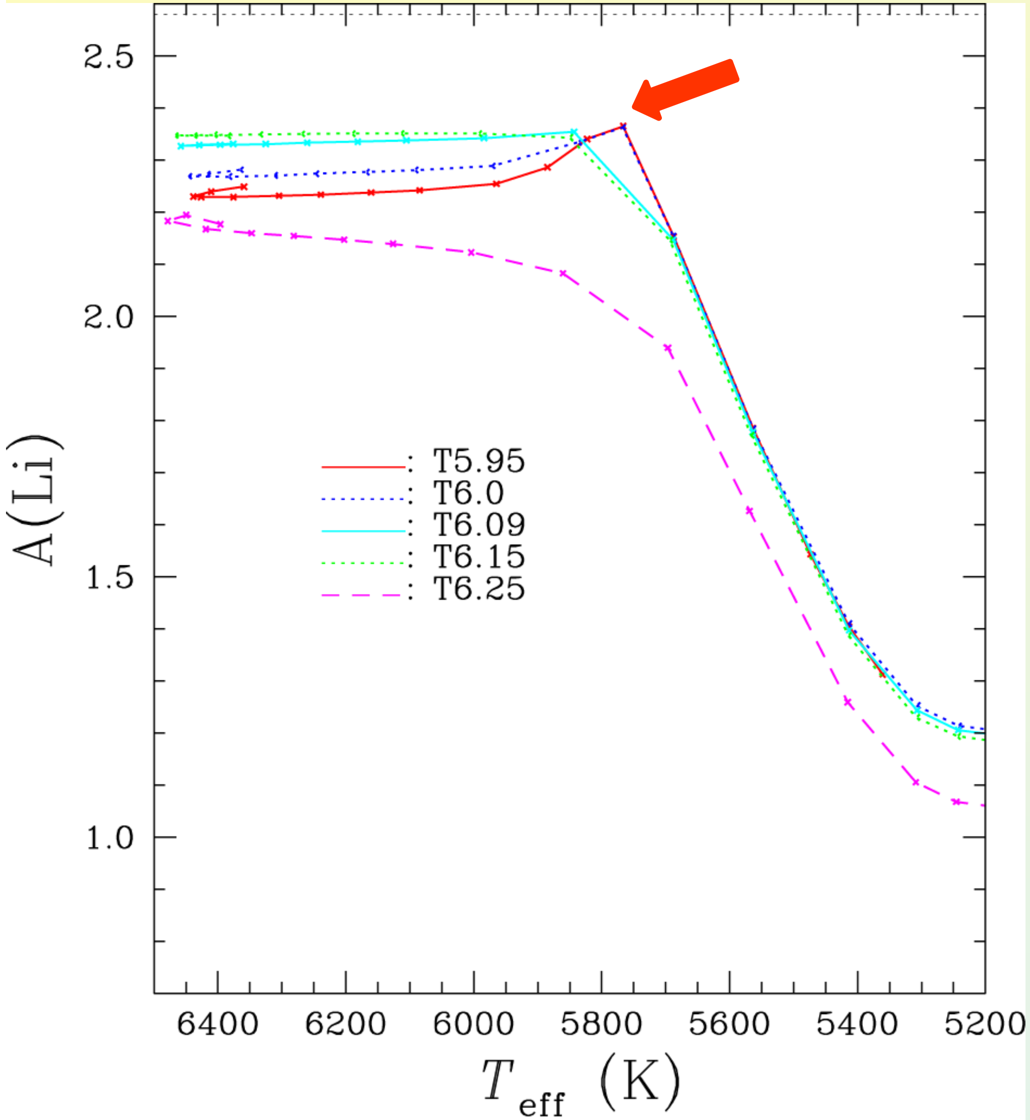
Diffusive models with additional mixing

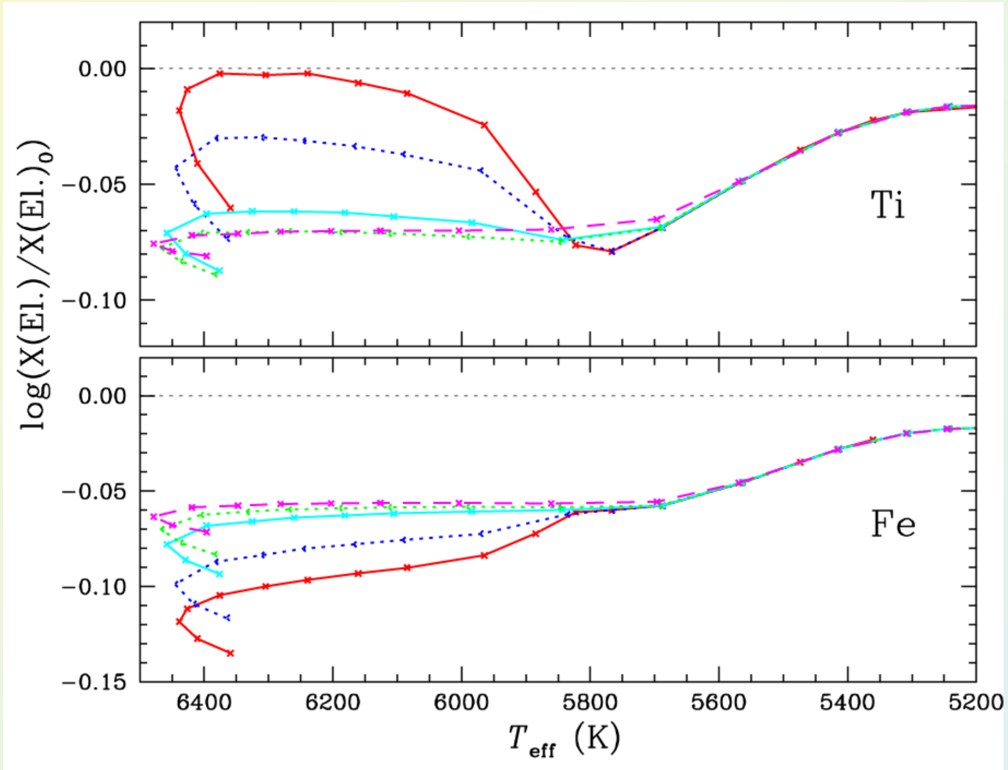


Richard et al., 2005

Abundance variation with Teff for [Fe/H]=-2.11

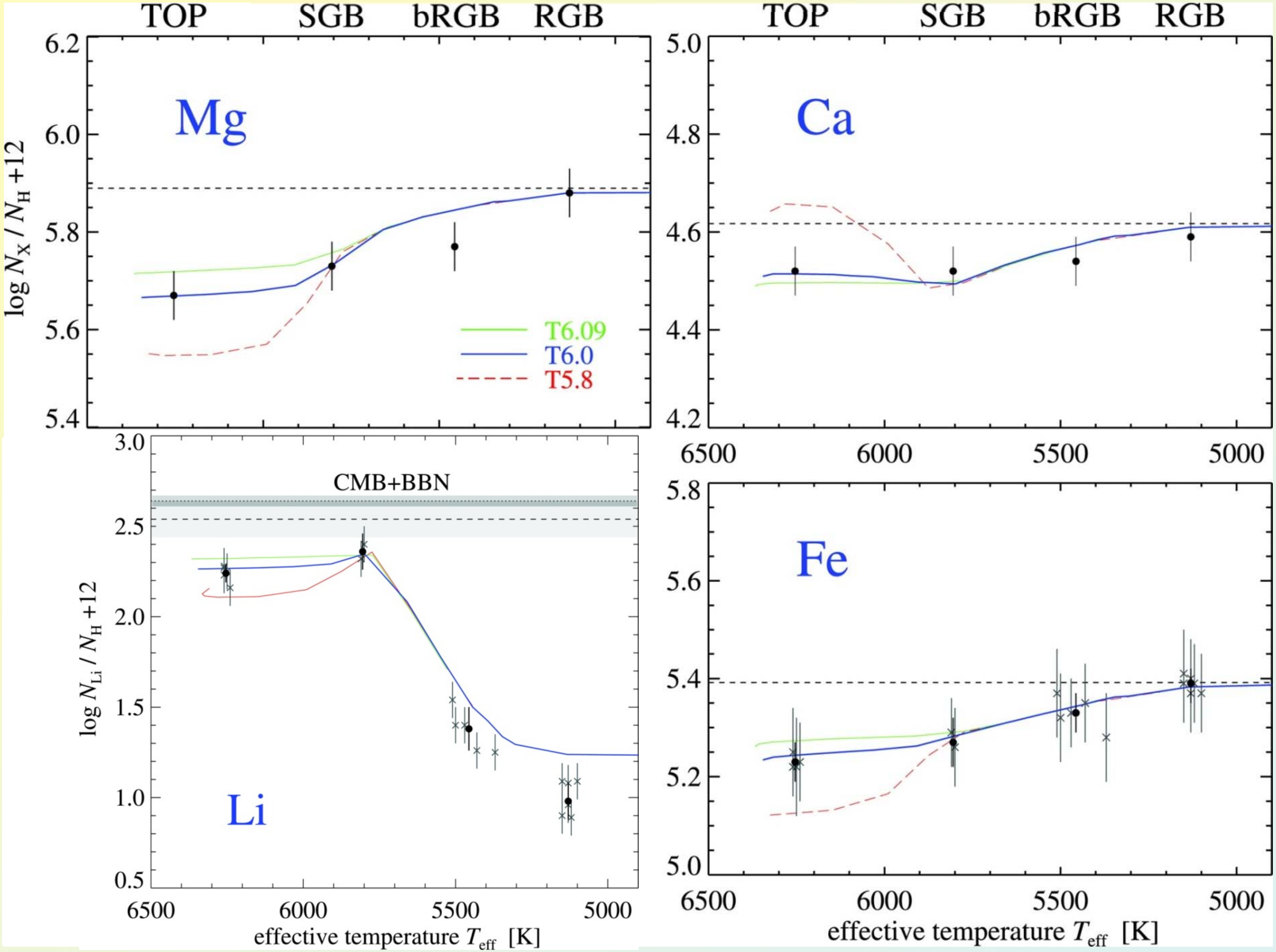
12.5Gyr isochrones for TO and past TO models





Li bump at SGB stage

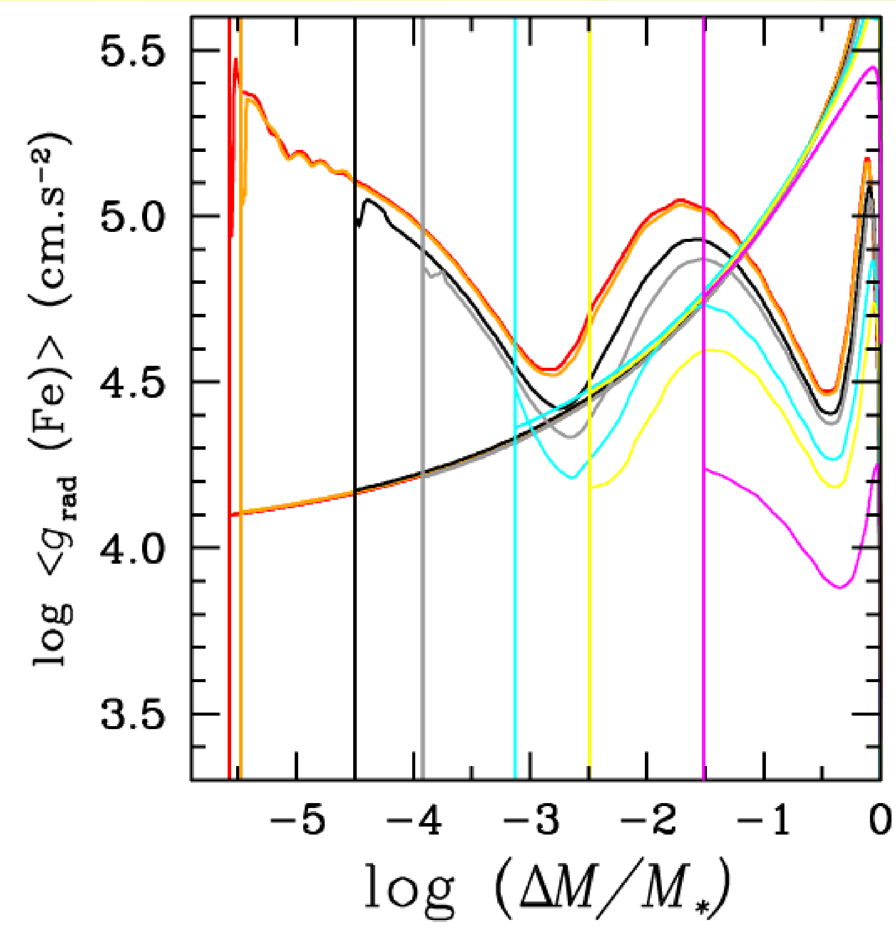
Globular cluster NGC6397



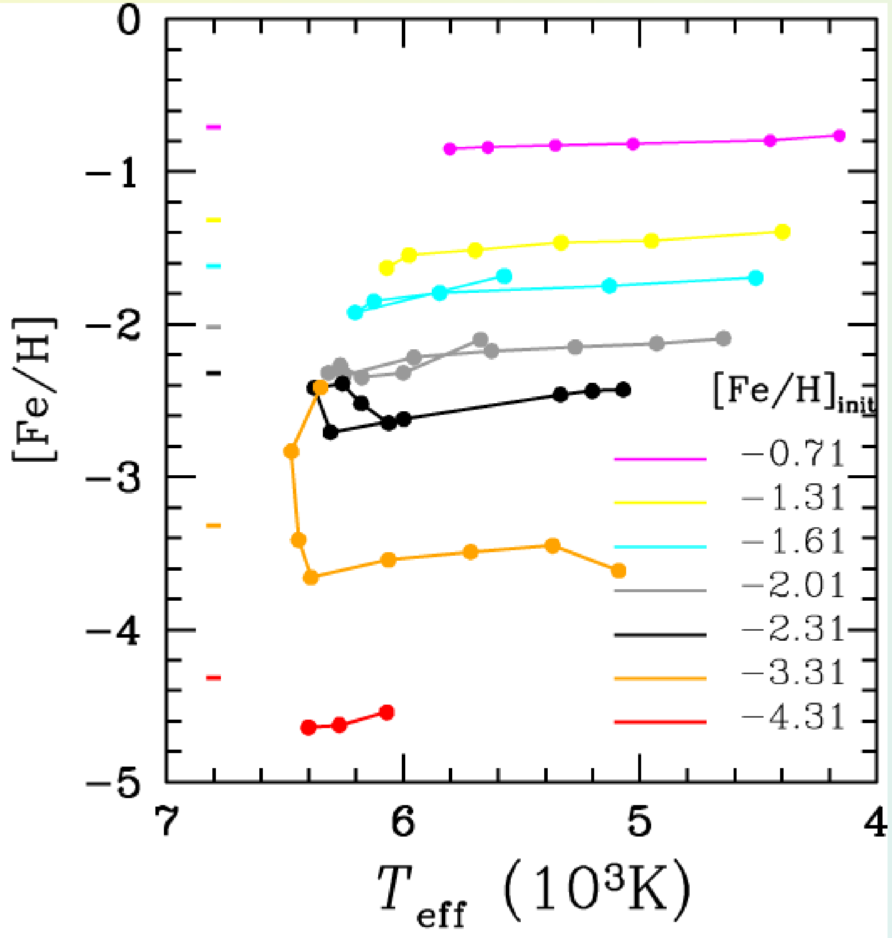
Korn et al., 2006, Korn et al., 2007

Effect of metallicity on Fe surface abundance

0.8 $M_\odot$ at 12Gyr



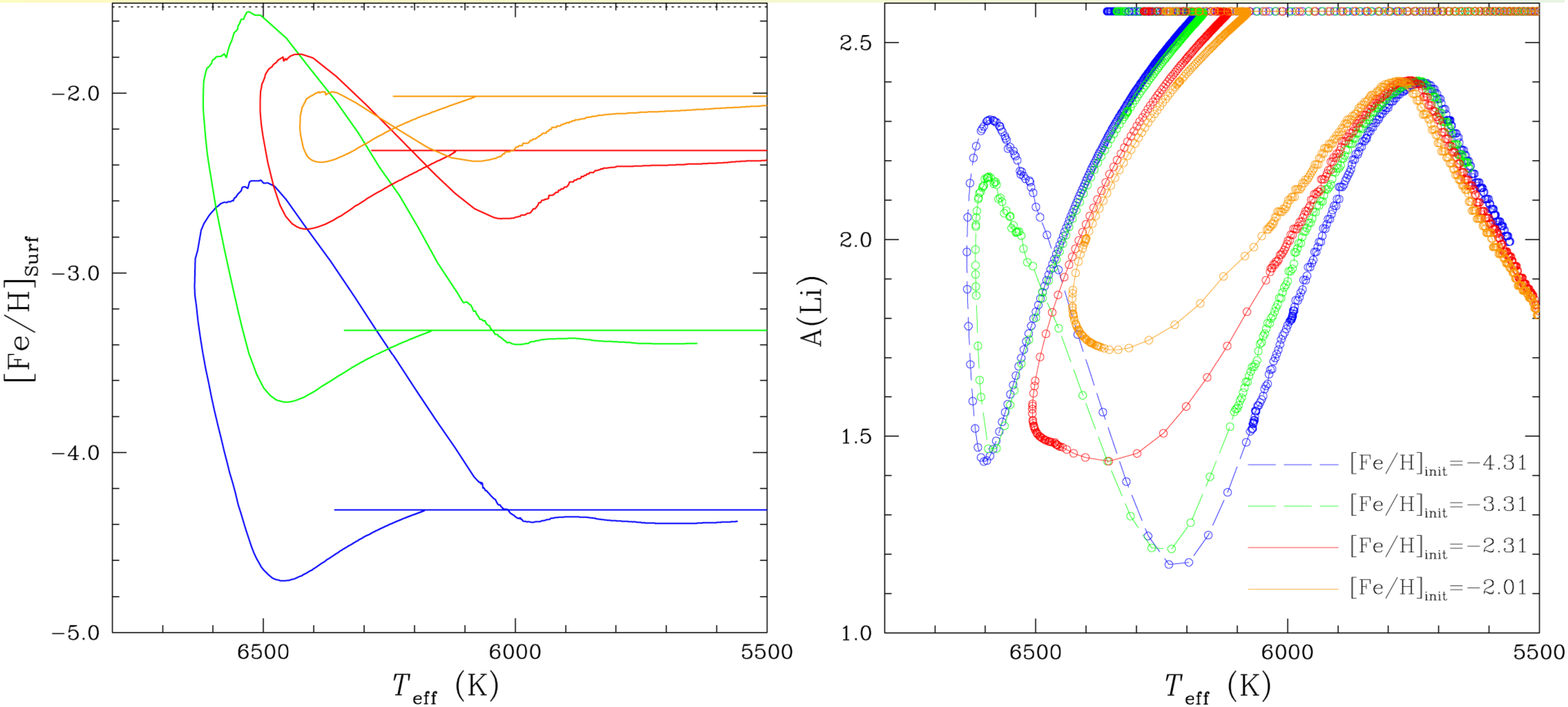
13.5Gyr isochrones



g_{rad}>g for models with $[Fe/H]_{init}$< -1.31

Li and Fe surface abundances evolution at different metallicity

0.8 $M_{\odot}$



Strong effect of radiative acceleration on Fe for very metal poor stars

=> thermohaline convection ?

Conclusion

Atomic diffusion have also to be taken into account in population II stars. It's lead to better agreement between cosmology and stellar physics (Lithium problem, globular cluster age)

Lithium abundances at subgiant branch stage gives constraints on competing processes

Atomic diffusion is need in models to better understand the physics of these competing processes

Radiative acceleration could have strong effects on very metal poor stars

Even if atomic diffusion is reduced by competing processes in the superficial zones effects remain in the center