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Dynamical and chemical evolution of the thin disc

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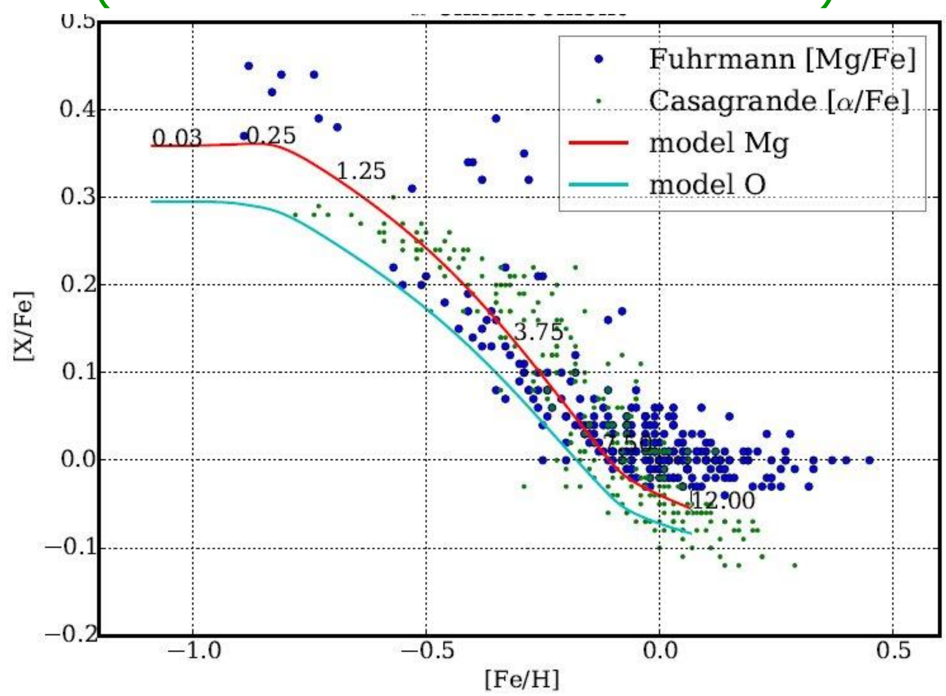
(Sarah Casura & Simon Sauer)



SFB 881

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  - Local disc model
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    - Age distributions
- Correlations
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- Disc evolution
  - Abundance gradients and inside-out growth

Introduction

- Ingredients for Milky Way disc models
  - Mass distribution (star counts)
    - SFR(R,t), IMF + stellar evolution
    - Gas infall/outflow
  - Dynamics
    - Dyn. Equilibrium + dynamical heating (AVR)
    - Vertical profiles, radial gradients
    - Radial mixing
  - Chemical evolution
    - SN2, AGB, SN1a yields
    - Metallicity and main sequence lifetimes
    - Element ratios, α-enhancement

Introduction

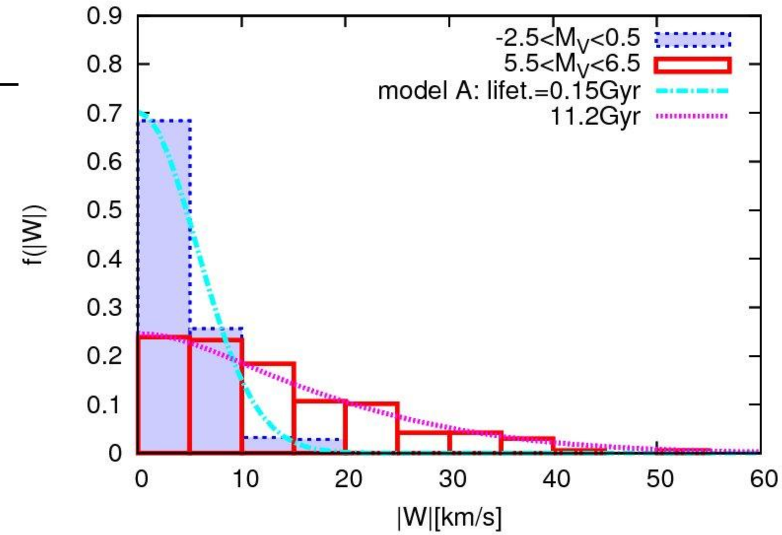
- Observations
  - Distribution functions
    - Star counts: PDMF, CMD
    - Kinematics: f(U,V,W)
    - Abundances: n([Fe/H]), n([Mg,H])
  - Correlations
    - AVR: age/lifetime + velocity dispersion
    - α-enhancement: [α/Fe]([Fe/H])
    - Radial scalelength – metallicity (Jeans-eq)

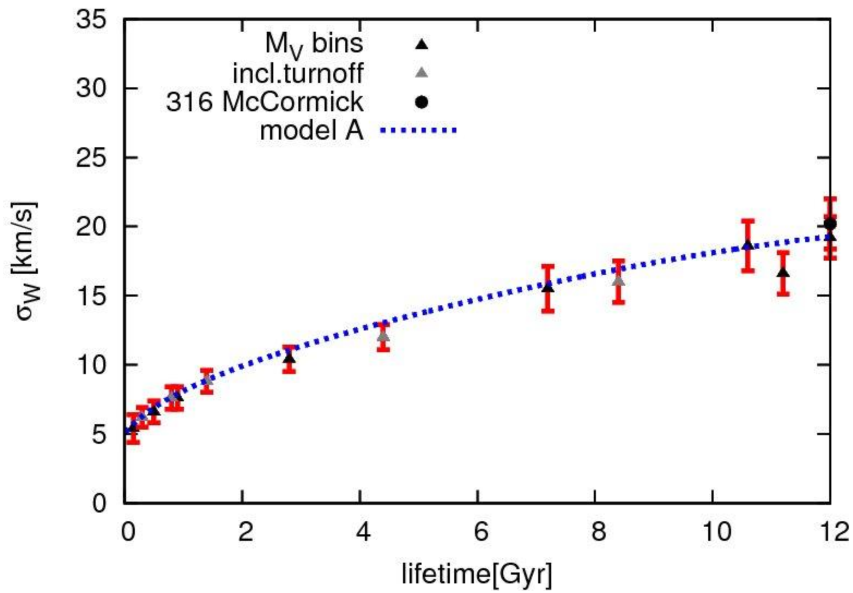
JJ-model: local disc model

- Just & Jahreiß, MNRAS 402, 461 (2010)
  - Modelling the solar cylinder of Galactic disc
  - Dynamical equilibrium model
  - Self-consistent vertical density profiles
- Input
  - **SFR(t)** + **σ_W(age)** + [Fe/H](t) + IMF
- Output
  - **vertical density profiles: ρ(z|age)**
  - **Age distributions** of all stellar types as function of height z above the plane

Main sequence kinematics

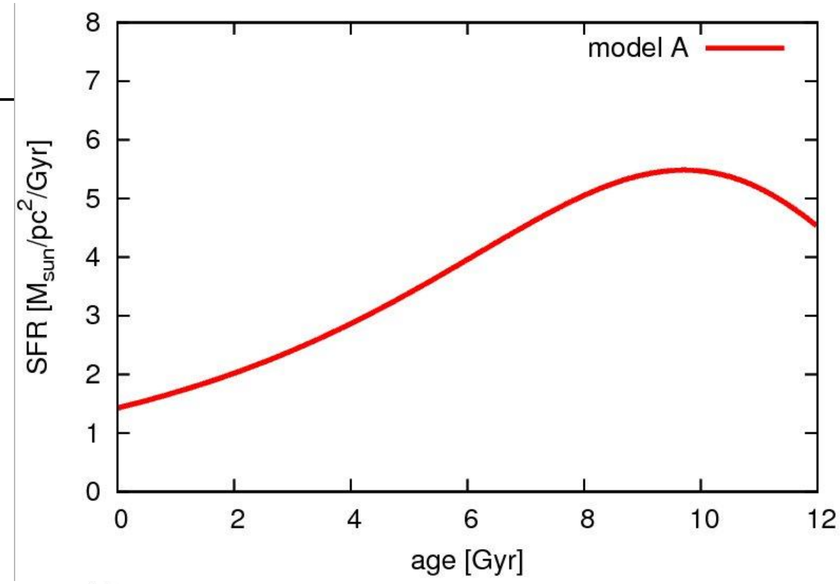
- **SFR + AVR**
- $f_{MS}(|W|)$
  - $M_V<0.5$
  - $M_V = 1,2,\ldots,6,8$
  - McCormick
- σ_{MS}(lifetime)
  - Dynamical heating (AVR) well constraint

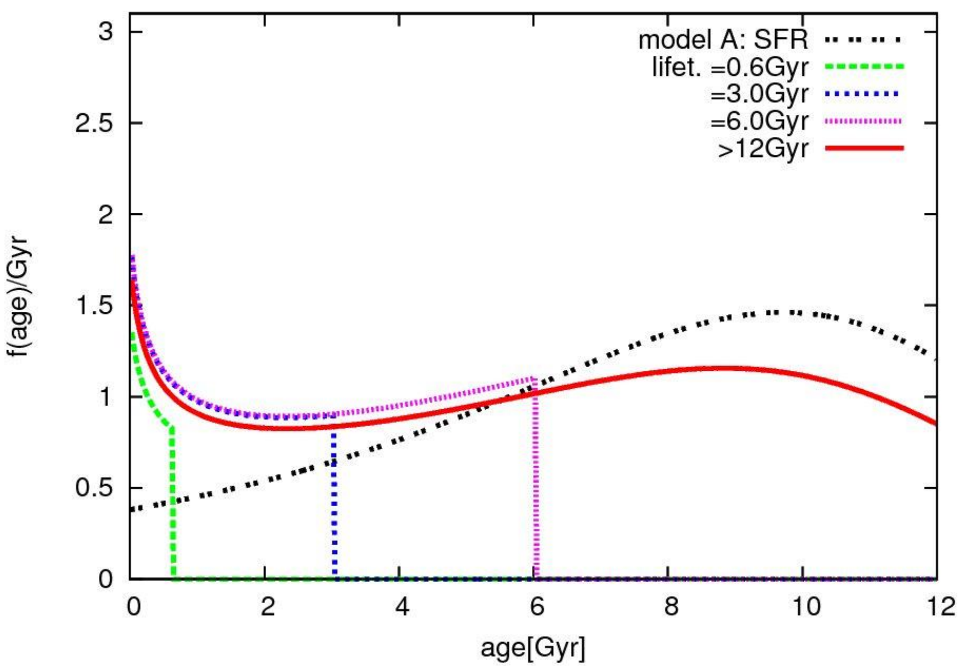


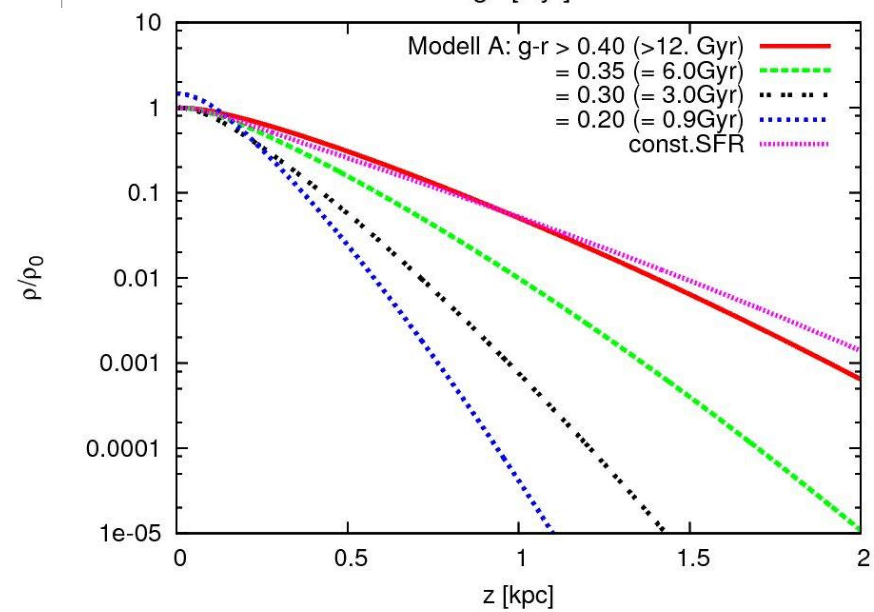


SFR + star counts

- SFR(t)
- Vertical density profiles
- age distributions z=0

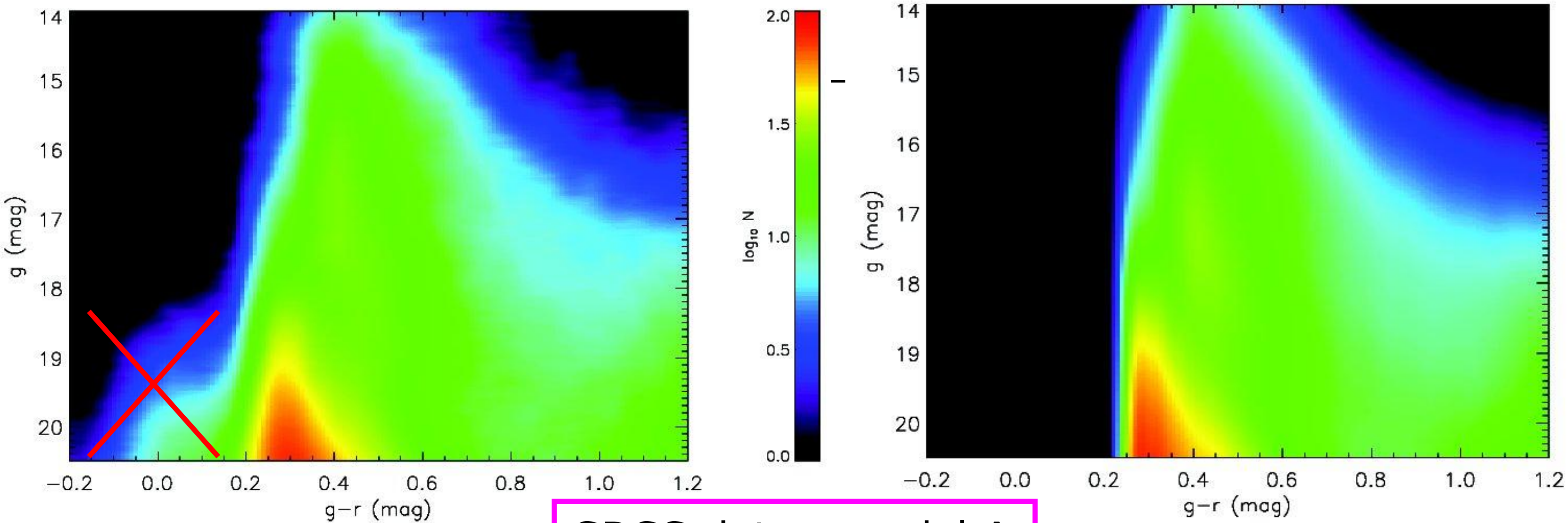






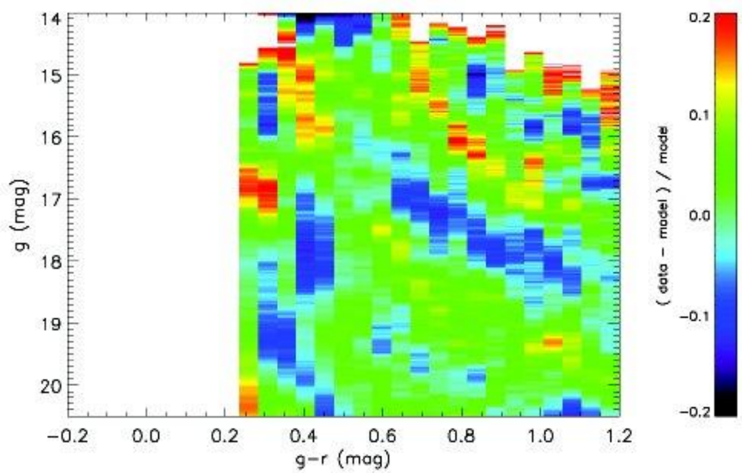
Just, Gao, Vidrih, MNRAS 411, 2568 (2011)

Fitting SDSS star counts

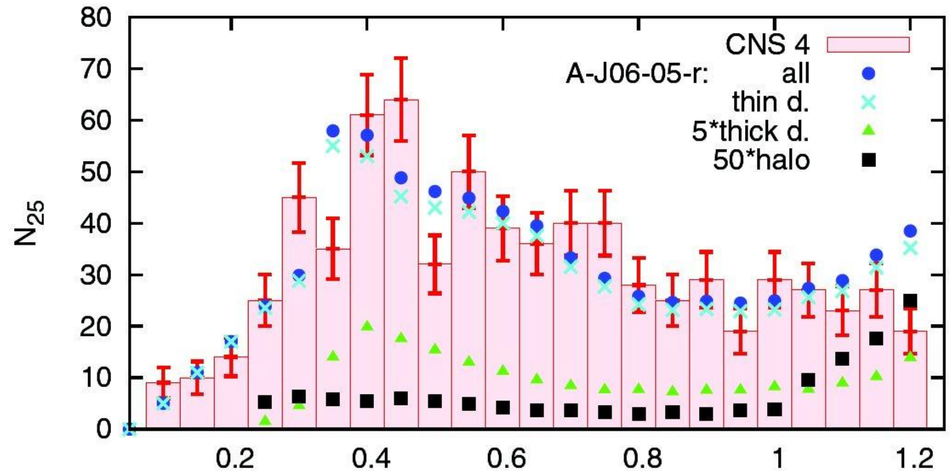


SDSS data - model A

Relative diff.=(data-model)/model:
<-20% (black) … **+20% (red)**
Median |relat.diff|=5.6%



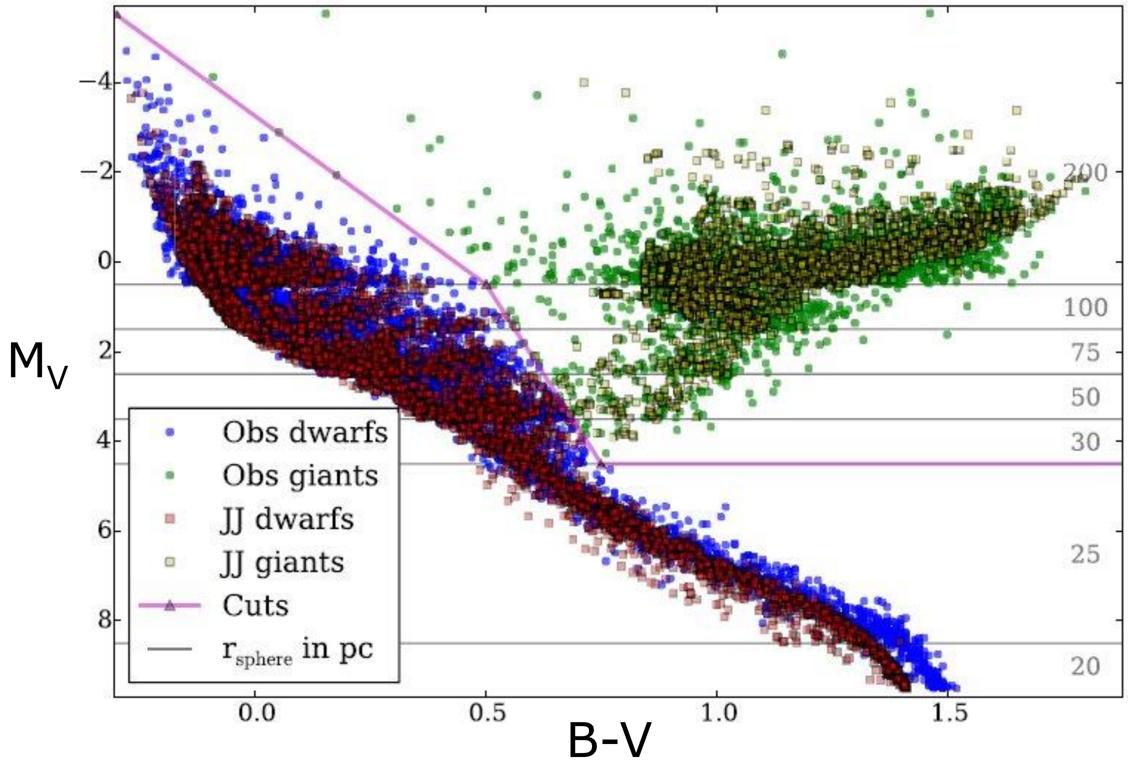
Local number densities (<25pc)



Local HRD and IMF (Jan Rybizki)

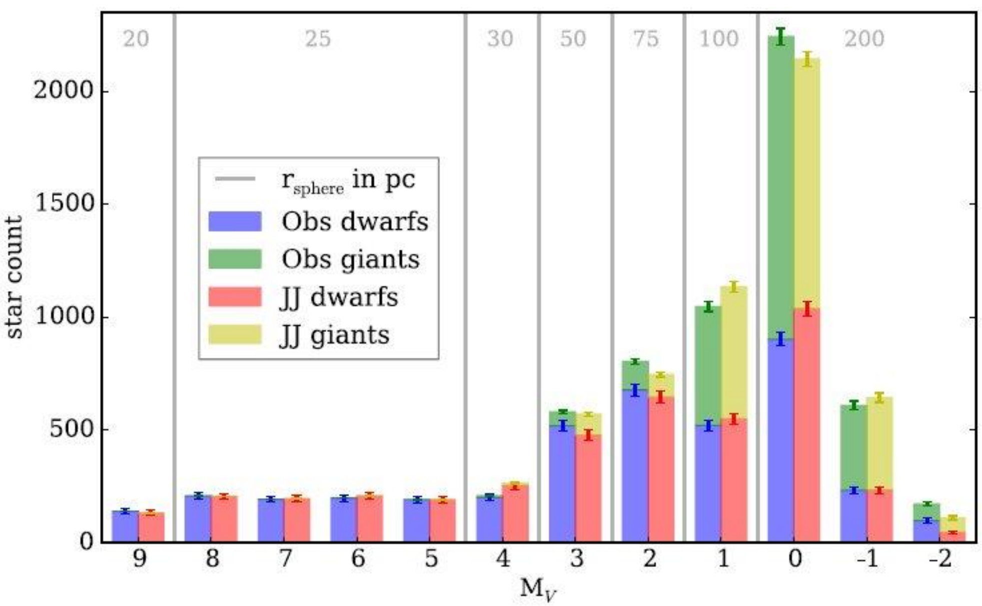
Rybizki, Just, MNRAS 447, 3880 (2015)

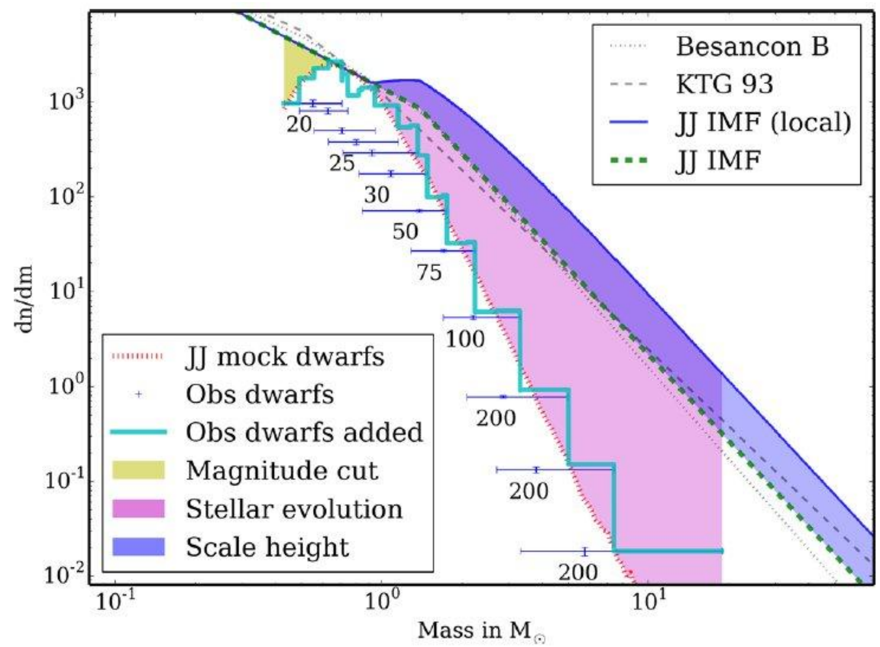
- $N(M_V)$ complete up to 20, …, 200pc
- Galaxia tool (new Padova): Mock samples
- Dwarfs and giants well reproduced



Luminosity function and IMF

- $dn/dm = n_0 \cdot m^{-\beta}$
  - β=1.5 for m<1.4 M_{sun}; β=3.0 else
  - high mass slope >8 M_{sun} undetermined



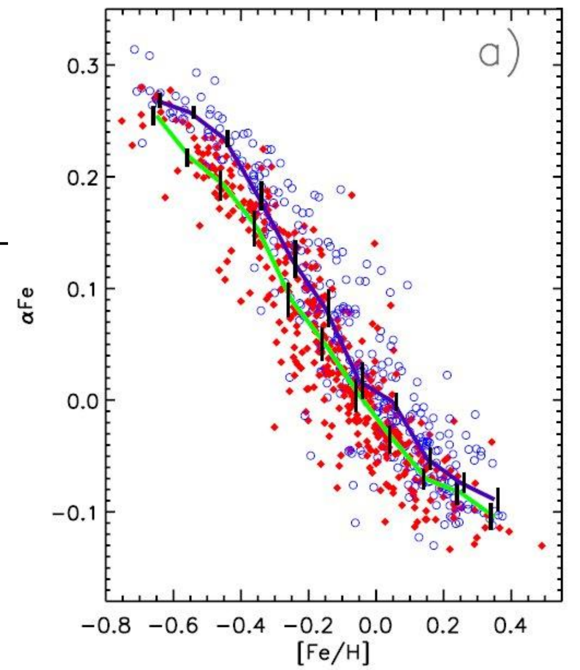


Chemical evolution

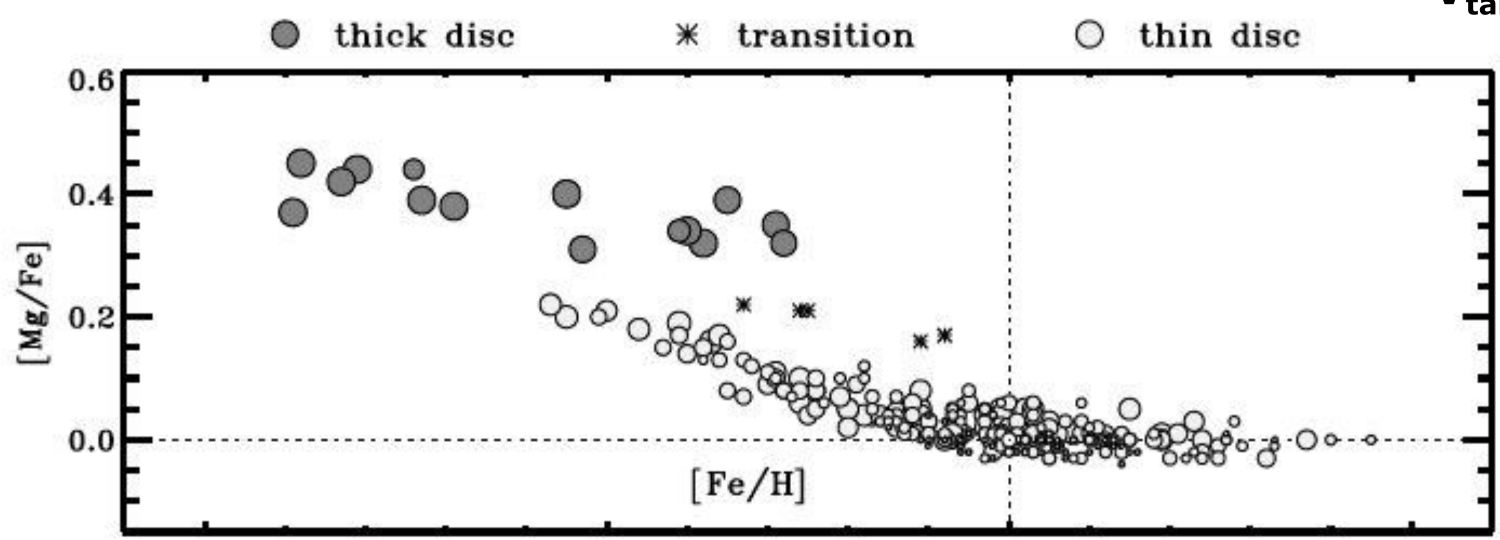
- Local 1-zone model
  - SFR, IMF from JJ-model
- Enrichment model
  - SN2: α, some Fe (instantaneous recycling)
    - n([α/H]) : determine gas infall rate
  - AGB: yields after main sequence lifetime
  - SN1a: delay time distribution for Fe, …
    - Returned mass M(Fe)=f(PN)*yield$_{Fe}$*DTD(t)
    - Fit [Fe/H] and [α/Fe]

Complete local samples

- GCS (Casagrande 2011, right panel)
  - Strömgren photometry
  - [Fe/H], [α/Fe]
- Hipparcos (Fuhrmann 2011, bottom)
  - Echelle spectra R=60 000
  - [Fe/H], [Mg/Fe], [Mg/H]

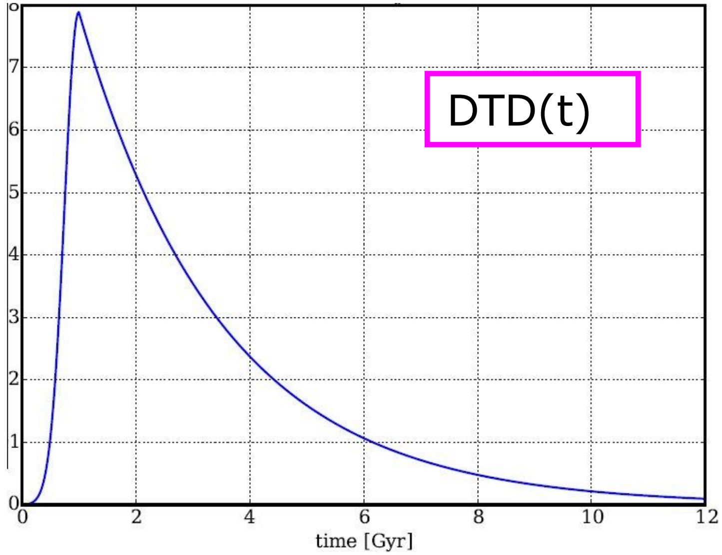


V_{tan}<-40km/s
V_{tan}>20km/s



α-enhancement and SN2/SN1a yields

- Default parameters
  - JJ-model
    - SFR, AVR, IMF
    - +high mass slope β=2.7
  - SN2 yields
    - Francois 2004
  - SN1a
    - Iwamoto 1999 yields
    - f(PN)=0.002
    - DTD(t)
      - Max at 1Gyr
      - Delay timescale 2.5Gyr

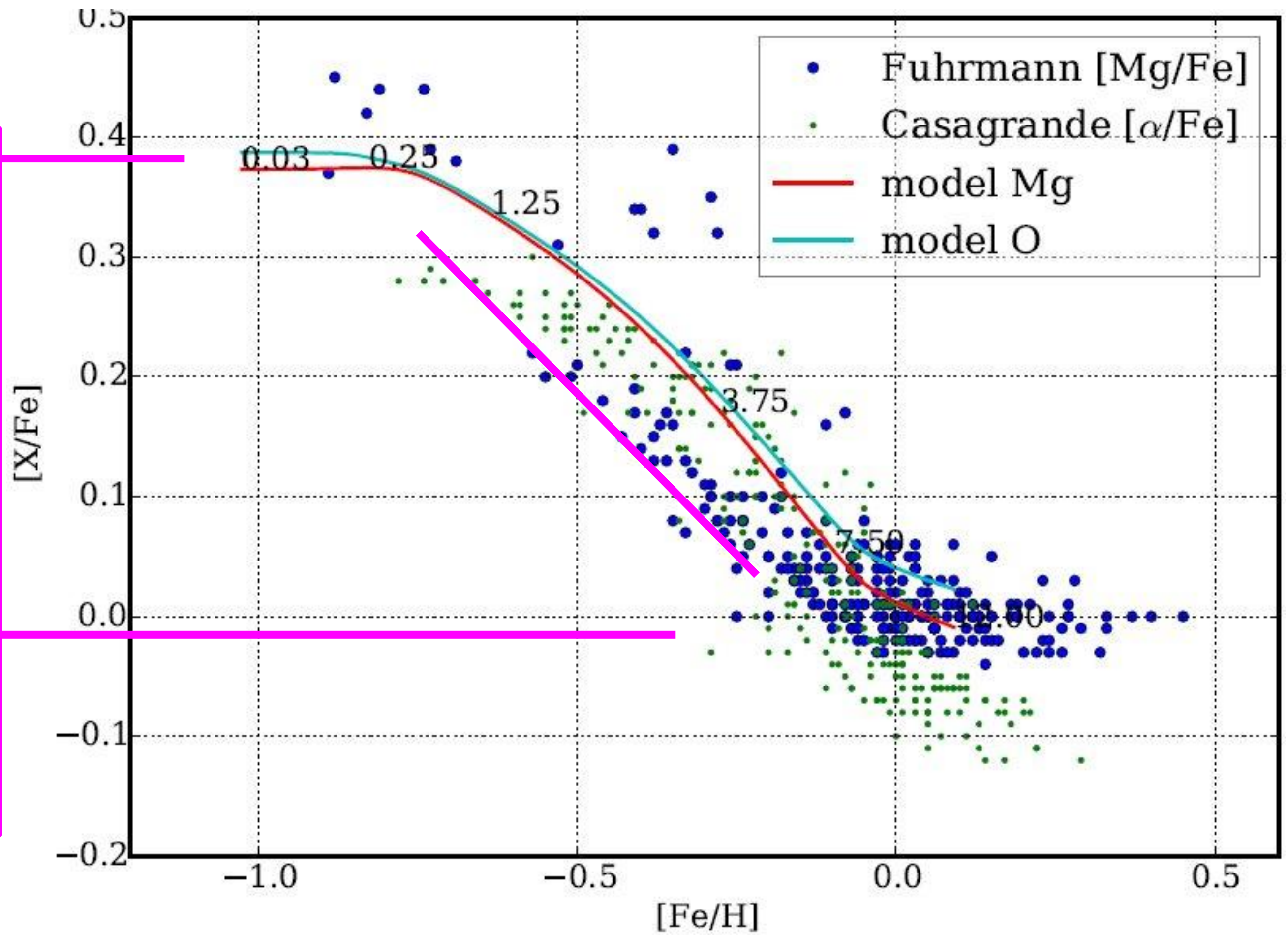


α-enhancement and SN2/SN1a yields

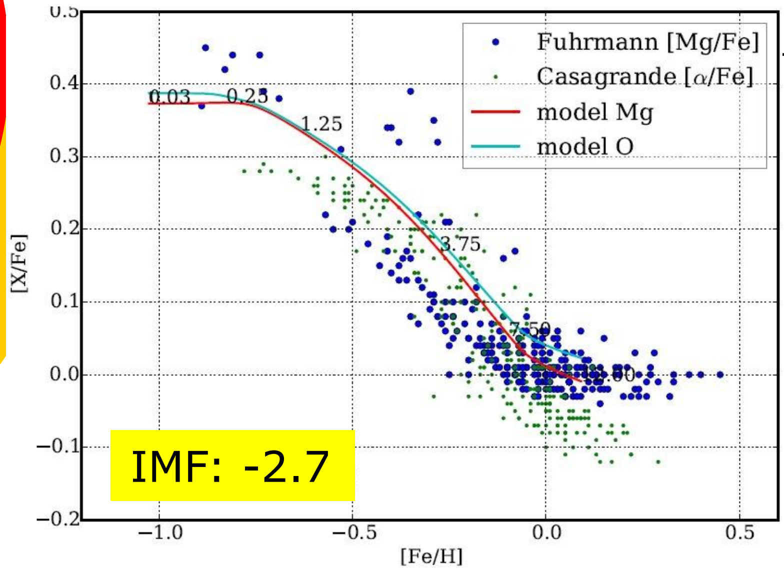
❖ Main features in [Fe/H]-[X/Fe] plane

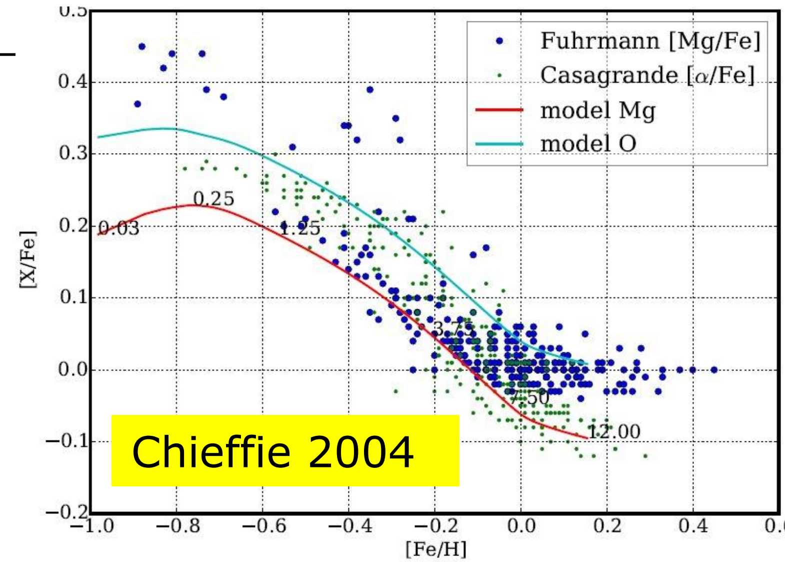
Enhancement level: SN2+IMF slope

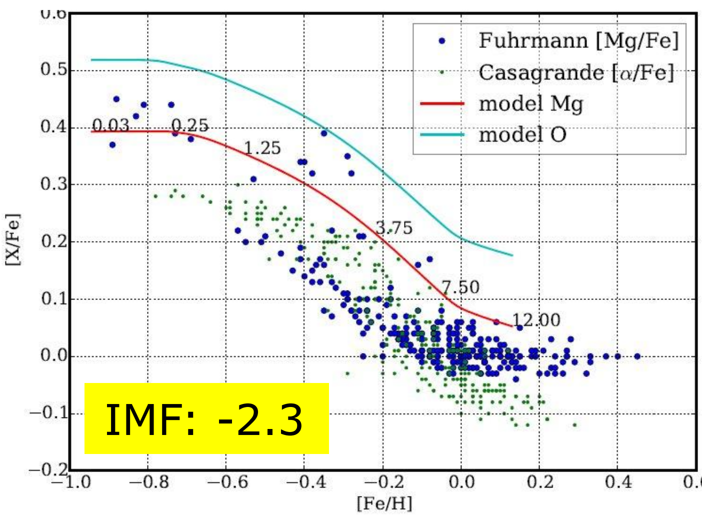
SN1a (+gas infall):
- Decline time, metallicity and slope: max of DTD
- Lower level: f(PN)
- Difference: SN2/SN1a rates

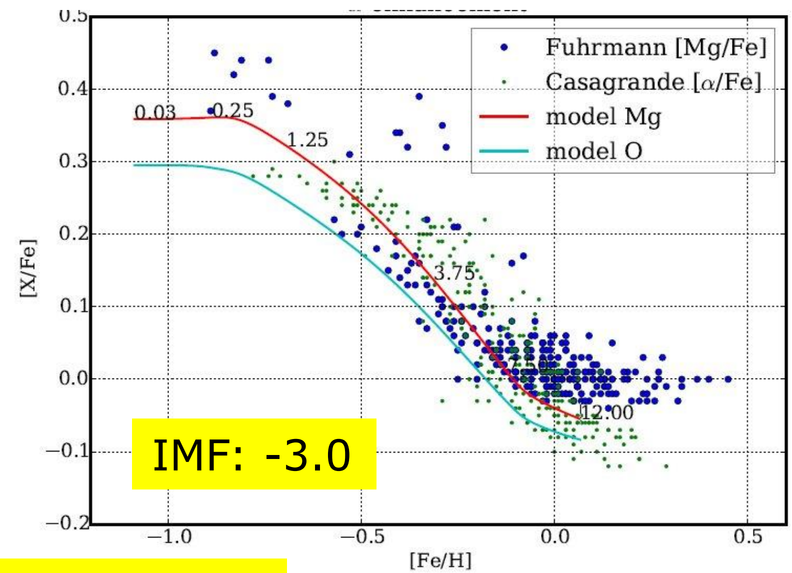


SN2 yields and IMF high mass slope





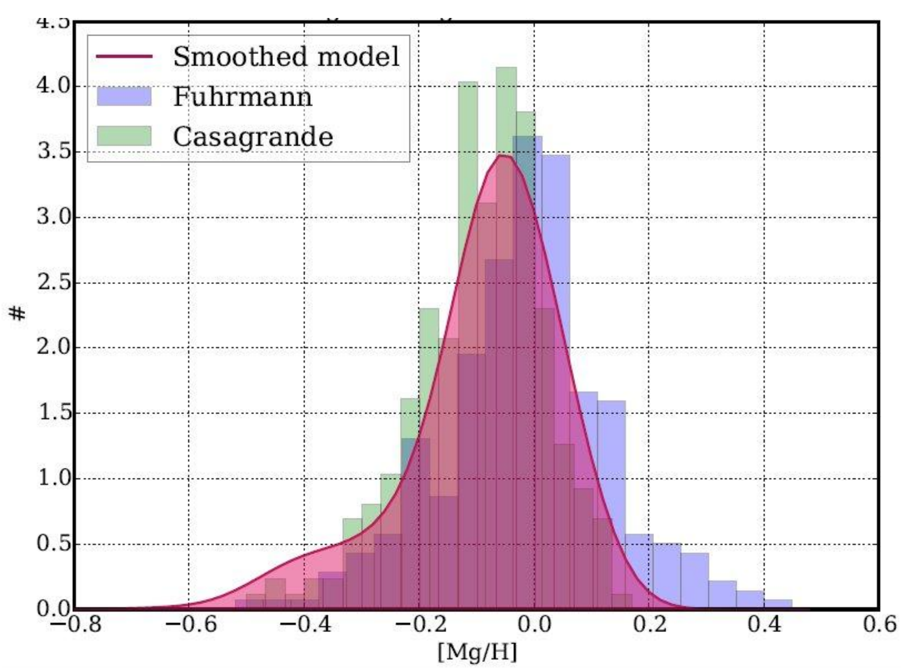


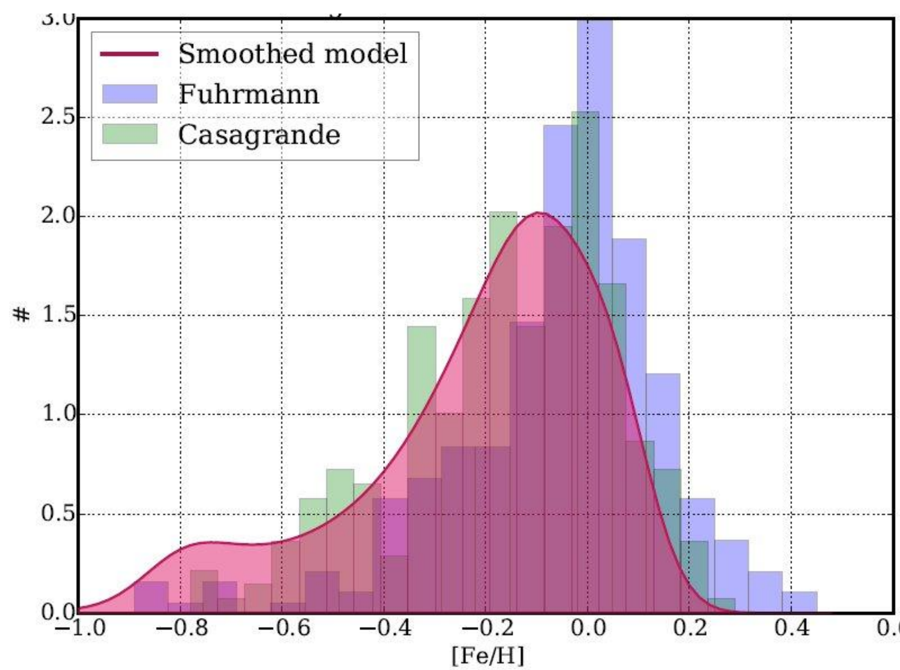


Please measure [O/Mg]

[Fe/H], [α/H] histograms

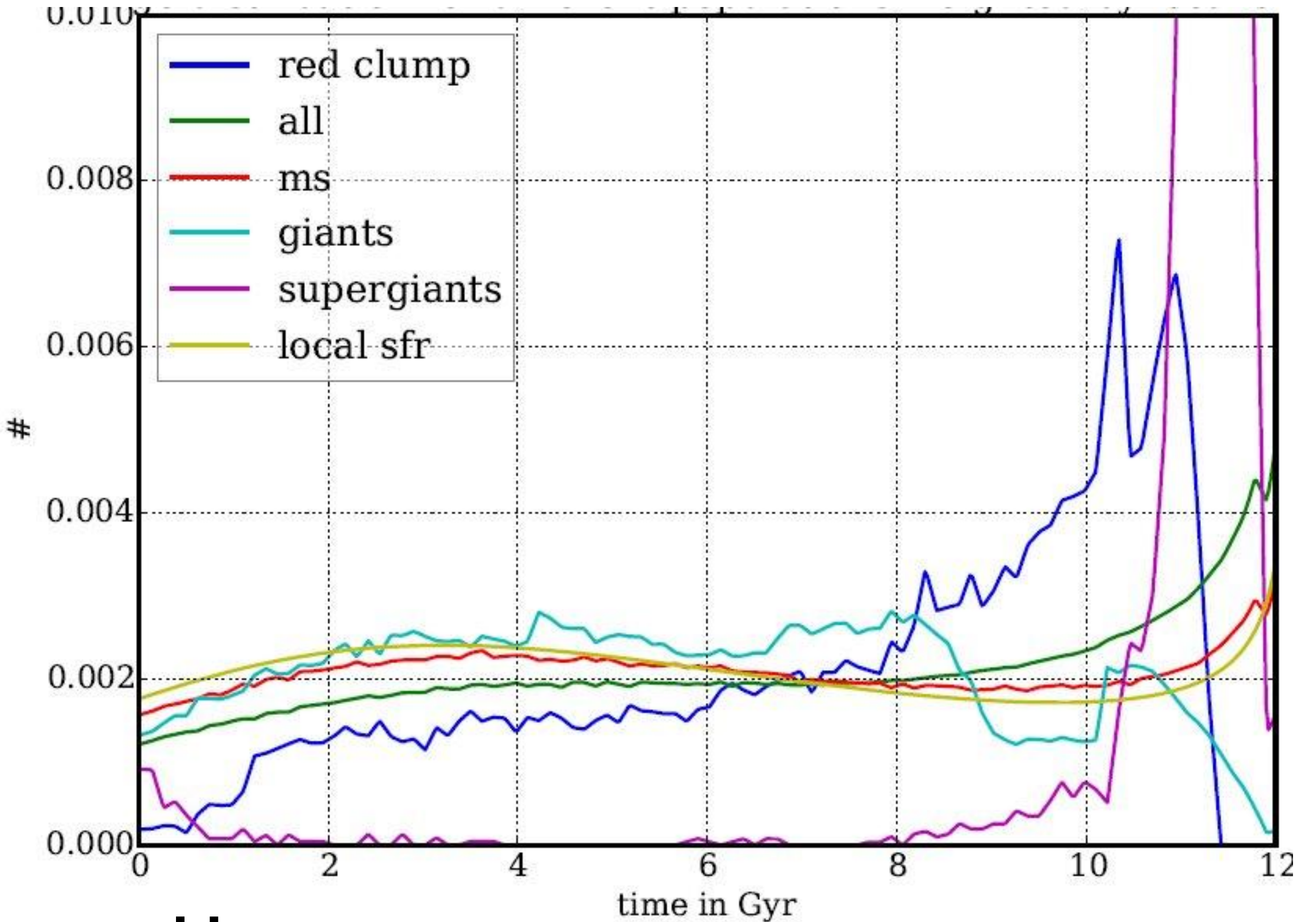
- [α/H]: fit of gas infall
- [Fe/H]: enrichment too small/slow
  - Play with SN1a yields
  - Gas infall: adapt SN1a and SN2 yields





Present day age distributions

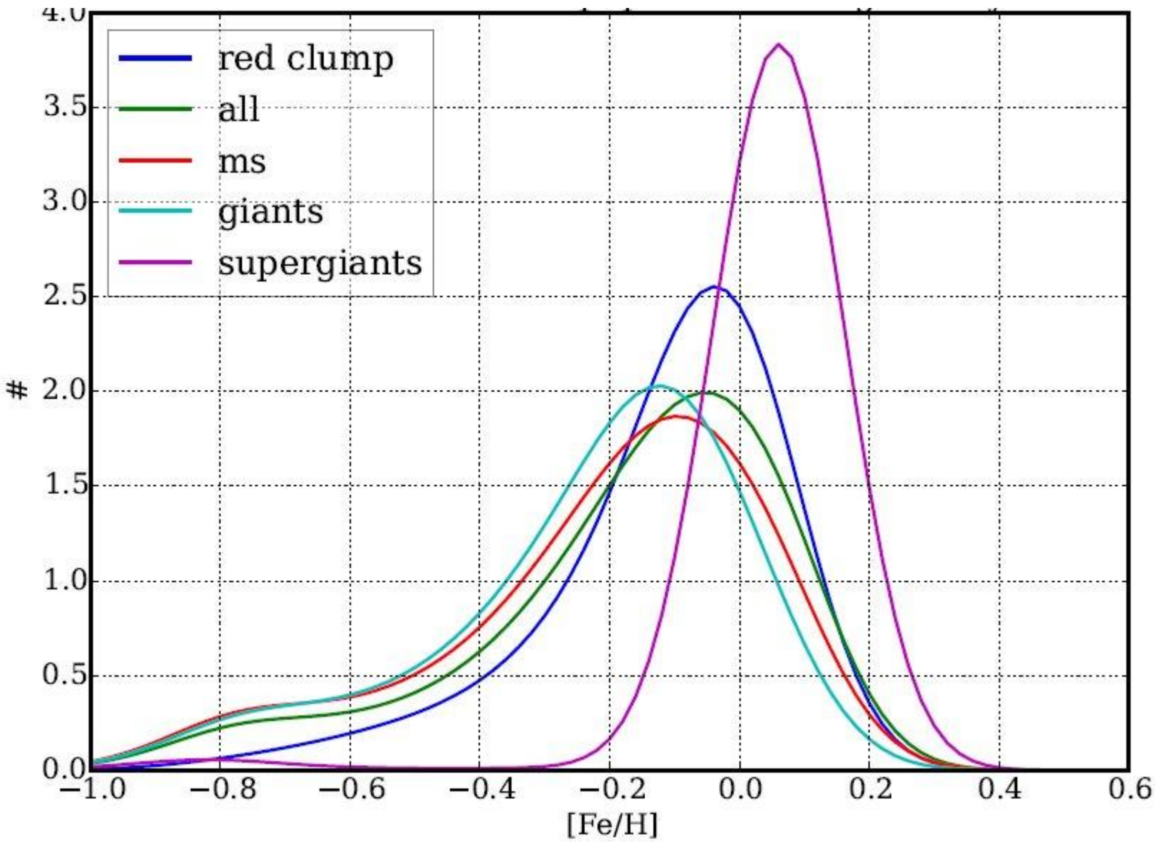
- Different stellar types (local z=0)



old **young**

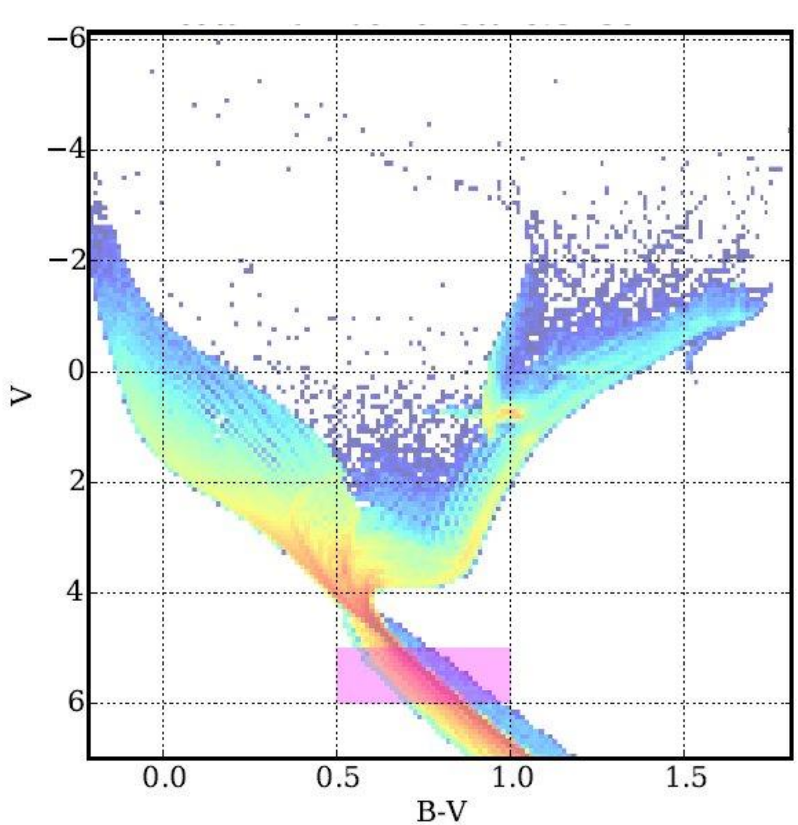
Local [Fe/H] distributions

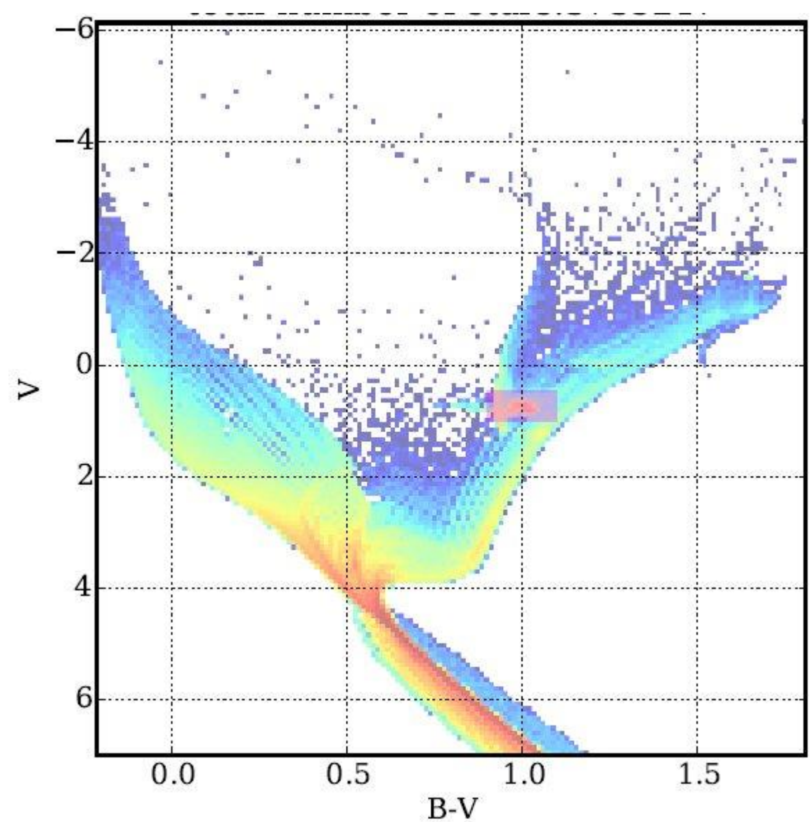
- Red clump and super giants younger
  - More metal rich



Different stellar types

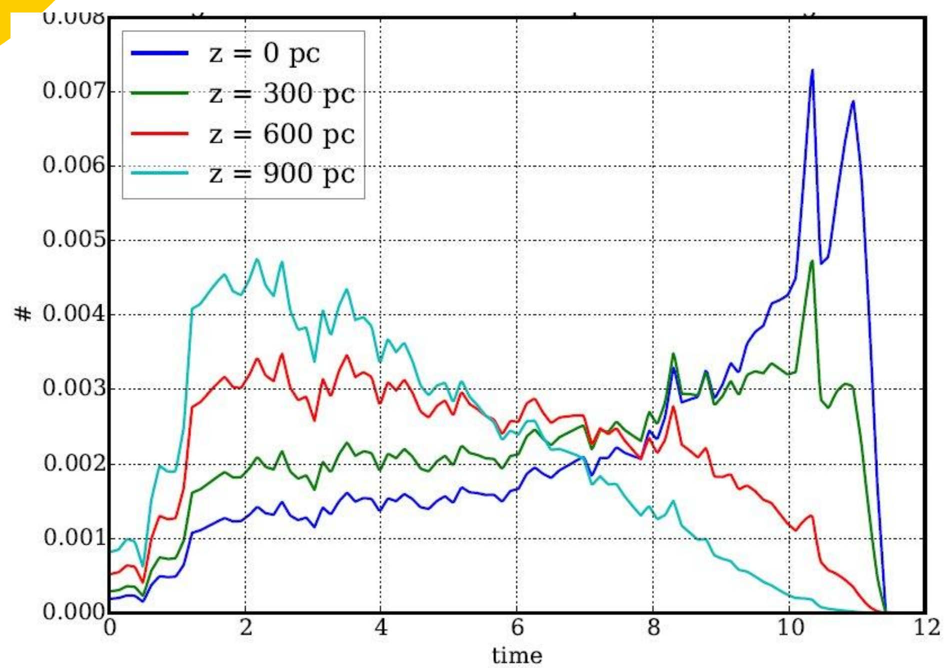
- Lower MS, red clump, …
  - Selection in CMD

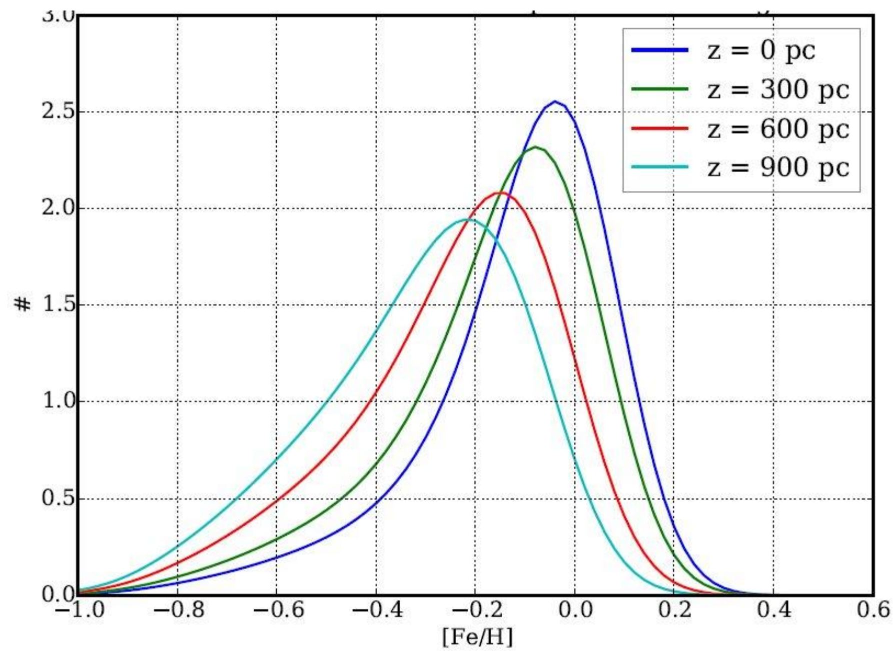




Red clump: vertical structure

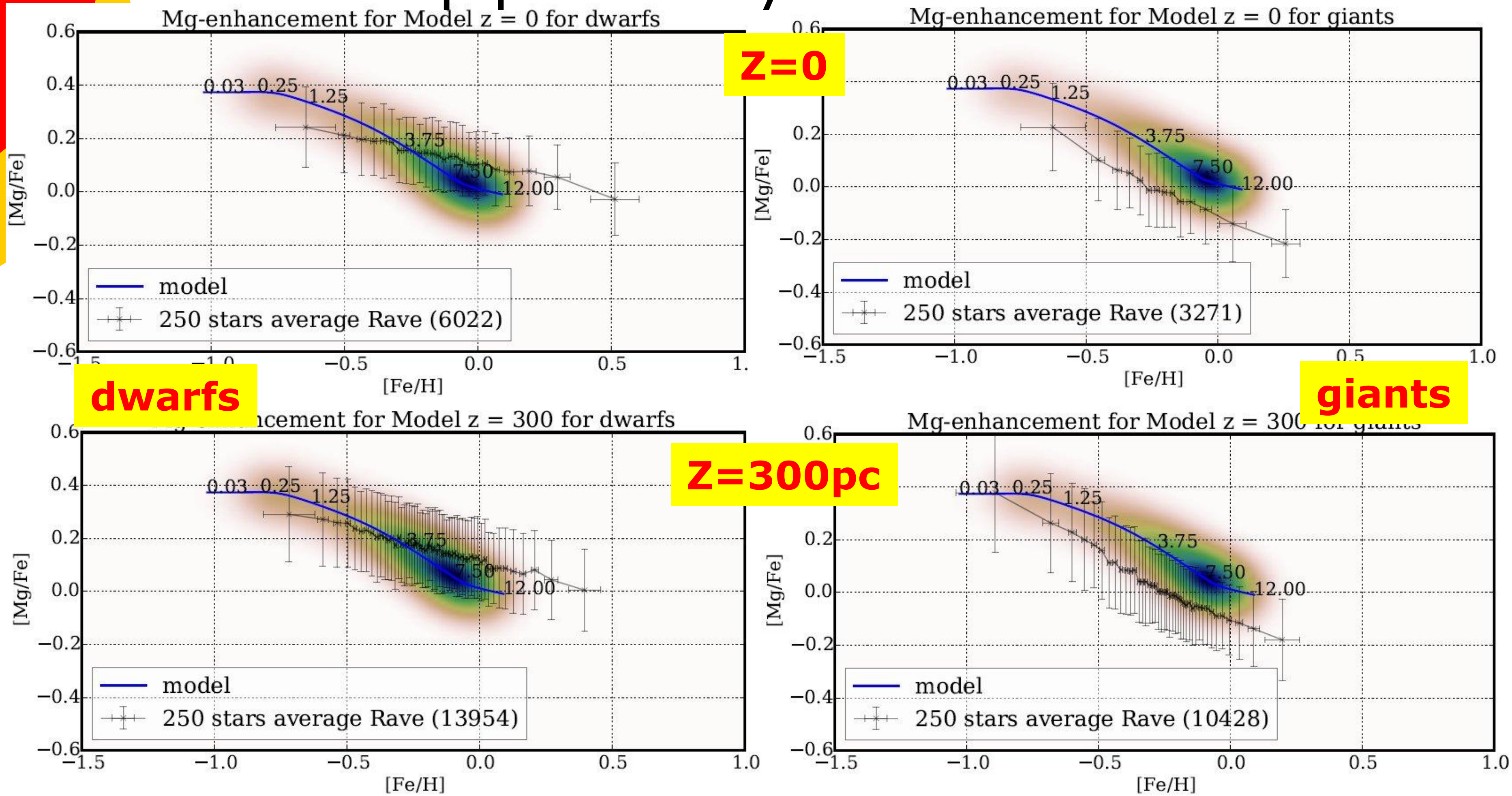
- Age and [Fe/H] distributions
  - Thin disc alone (no thick disc here)
  - Significant shift above plane





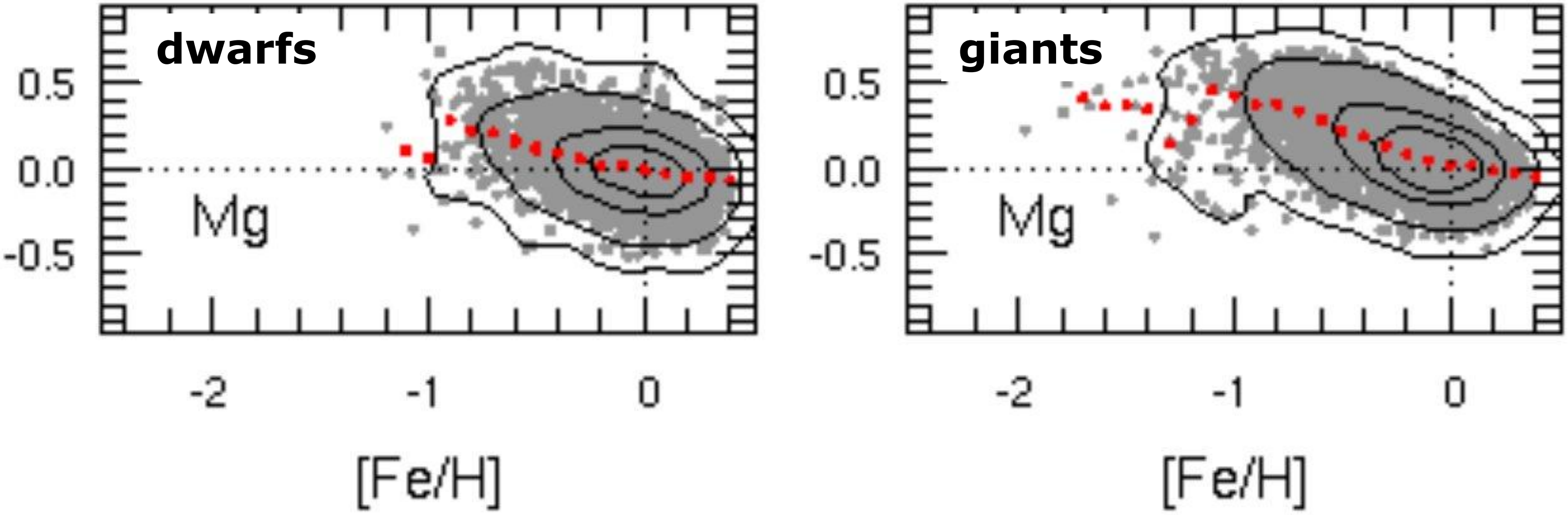
Local RAVE dwarfs/giants

❖ DR4 pipeline: systematic offset



RAVE with SPAce (Boeche 2015)

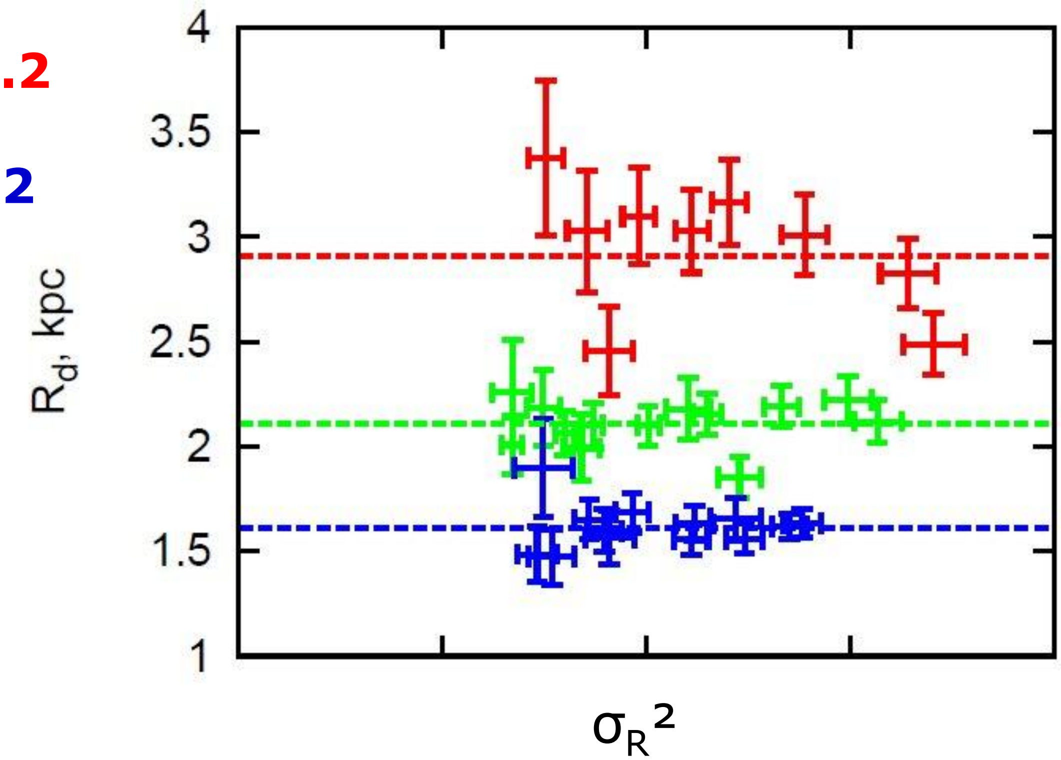
- New spectroscopic pipeline SPAce
  - Consistent results of dwarfs and giants



Radial gradients: RAVE dwarfs

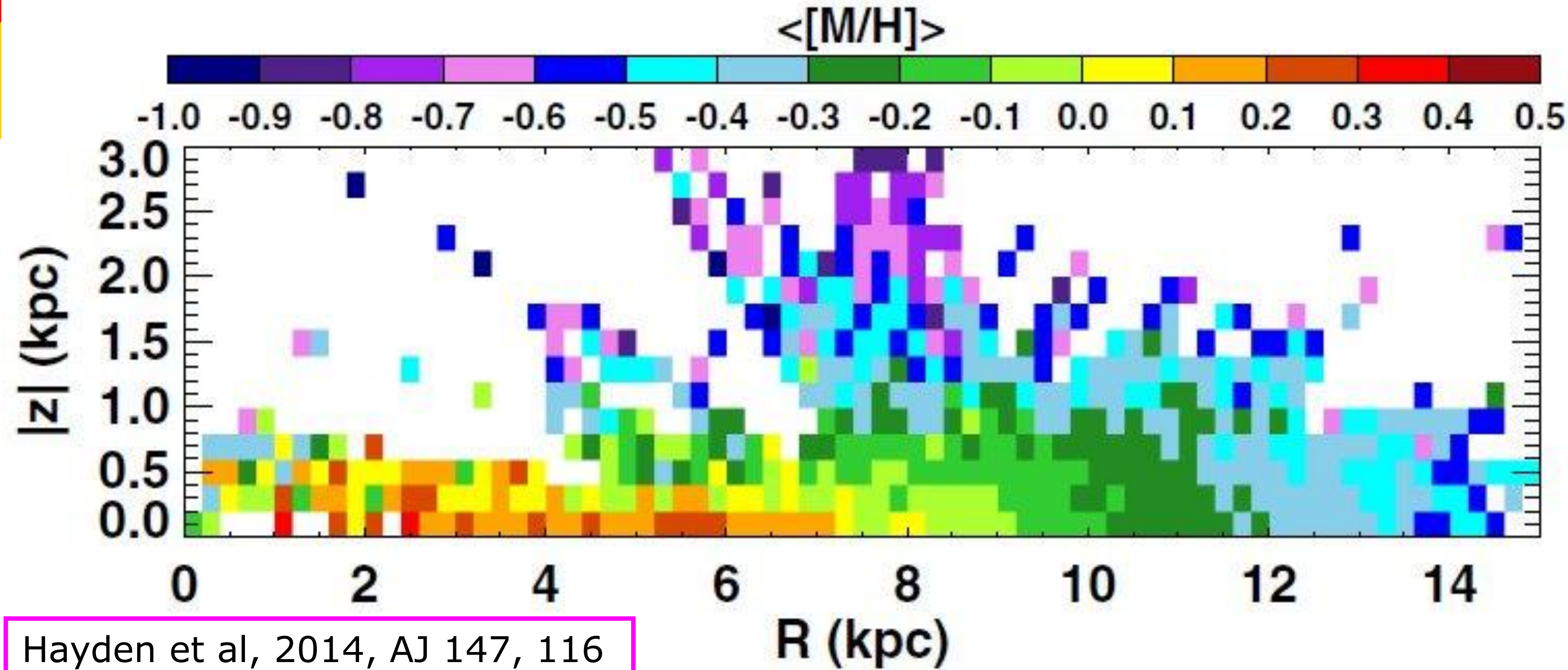
- Jeans analysis (Golubov et al. 2013)
  - Radial scalelength larger for lower metallicity

-0.5< [M/H] <-0.2
-0.2< [M/H] < 0
0< [M/H] < 0.2



Radial disc structure

❖ APOGEE data
- Radial and vertical metallicity gradients

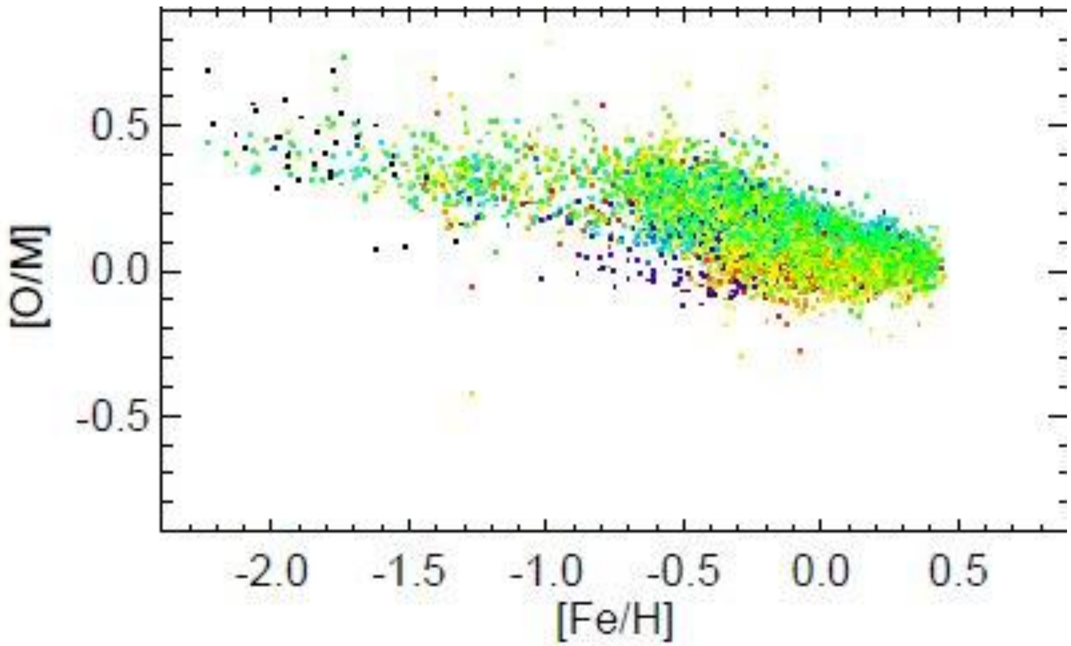


Hayden et al, 2014, AJ 147, 116

SEGUE/APOGEE survey

Holtzman et al, astroph 1505.04110

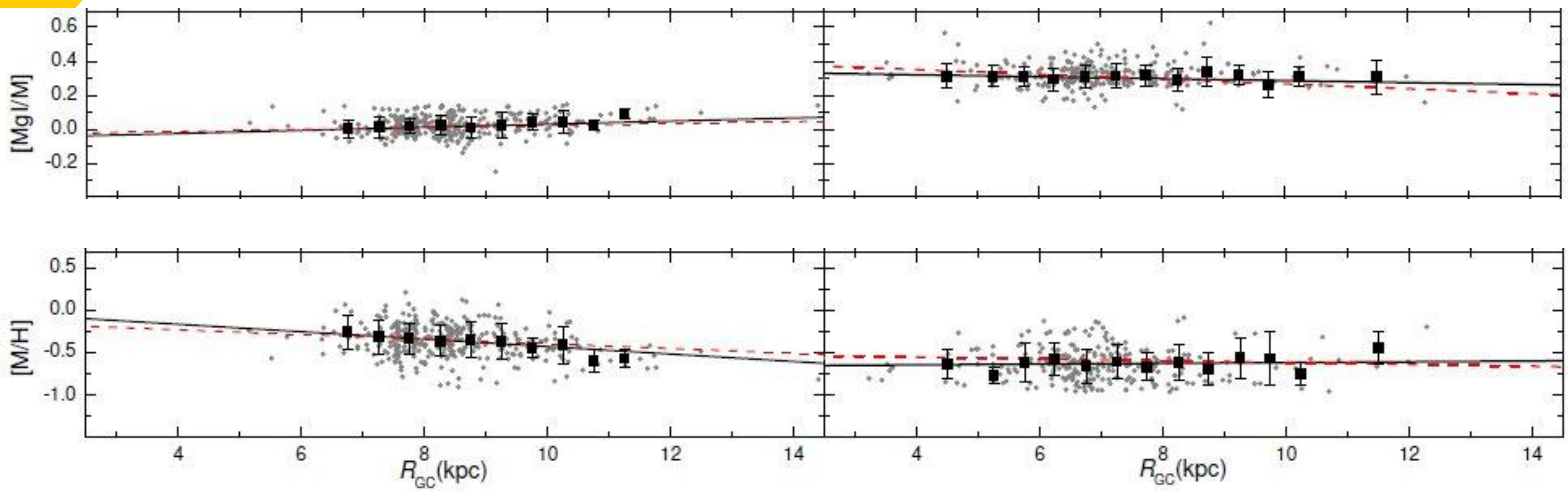
- R~22000 spectra in H band
  - C,N,O,Mg,Al,Si,S,K,Ca,Ti,V,Mn,Ni,Fe
  - [O/Mg] very important for IMF slope



Gaia-ESO survey

Smiljanic etal, 2014, A&A 570, A122

- UVES R~47000 spectra
  - Long list of elements
  - F,G,K dwarfs, red clump, open clusters



Mikolaitis et al, 2014, A&A 572, A33

Summary

- Consistent models required
  - Reproduce correlations
    - α-enhancement, …
- Local model
  - SFR,IMF,AVR determined
  - Gas infall from α-enhancement
- Radial gradients (inside-out growth?)
  - Abundance gradients needed
    - RAVE/APOGEE/Gaia-ESO surveys
  - Kinematics (asymmetric drift)
  - Direct star counts (Gaia parallaxes)