New steps in population synthesis modelling

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Population Synthesis Modelling

- Population synthesis approach: many parameters but **more understanding**
- **Statistical treatment** : no individual distances and ages, but for groups of stars
- Link between **scenarios** and **observations**
- **Increasing** complexity (start simple…)
- Confront scenarios with **surveys** (combined, different wavelengths, methods)
- **Confronted to many observables** : magnitudes, colors (many bands), proper motions, radial velocities, Teff, logg, [Fe/H],[alpha/Fe], asterosismic paramaters in the future

Population synthesis

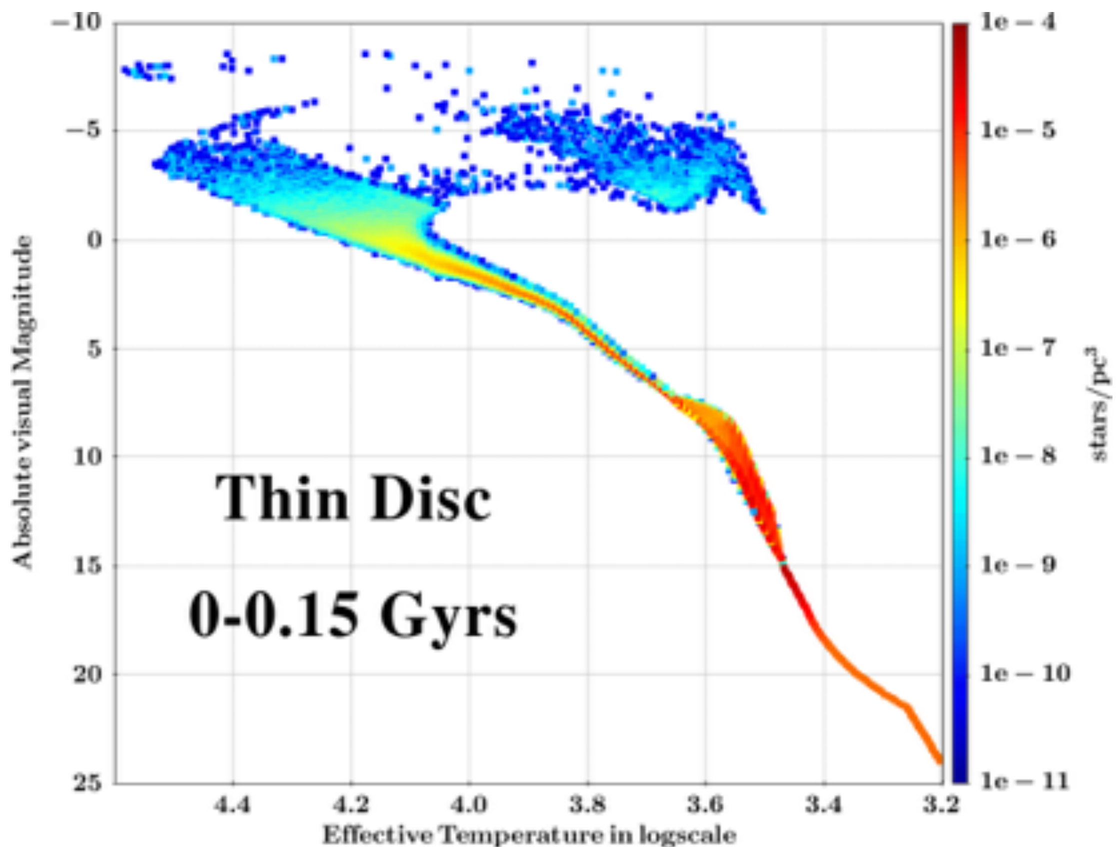
Simulations of surveys

$$N = \int_0^\infty \rho(r)\, \phi(M)\, \Omega\, r^2\, dr$$

or

$$N = \sum_{i=1}^{Npop} \int_0^\infty \rho_i(r)\, \phi_i(M)\, \Omega\, r^2\, dr$$

φ(Mv, Teff) for a thin disc decreasing SFR over 10 Gyr →



Mor et al, 2016

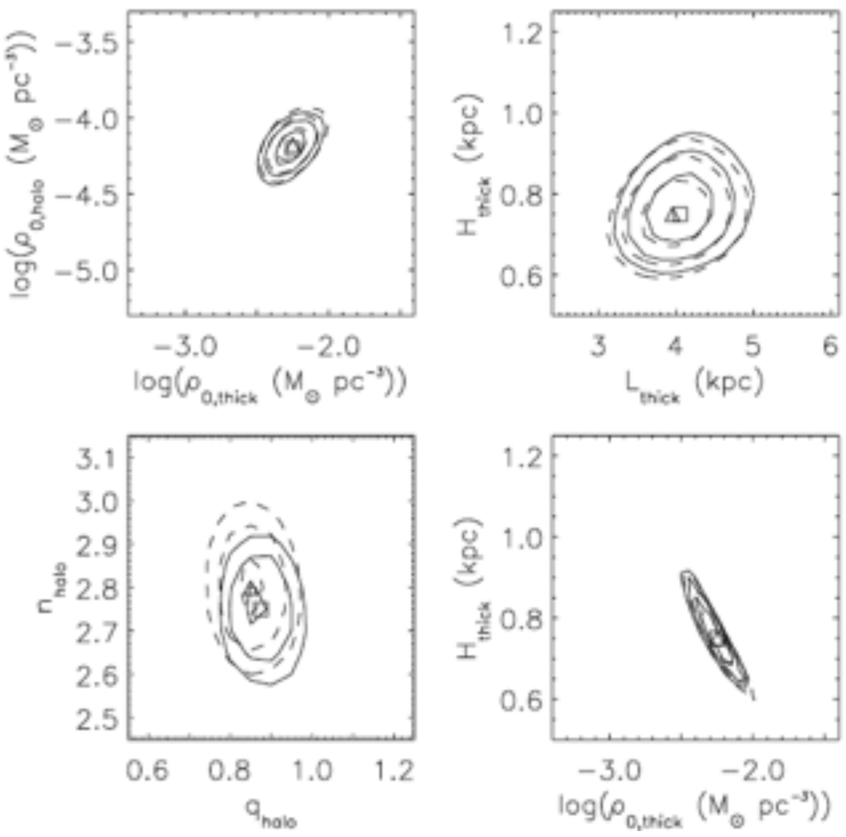
ρ(x,y,z) : density laws constrained by dynamics (Bienaymé et al, 1987)

3D extinction model

Simulate observational errors

Constraining parameters

- Statistical methods to constrain parameters (do not be satisfied with a solution !)
- Explore parameter space with efficient methods (MCMC, GA, …)



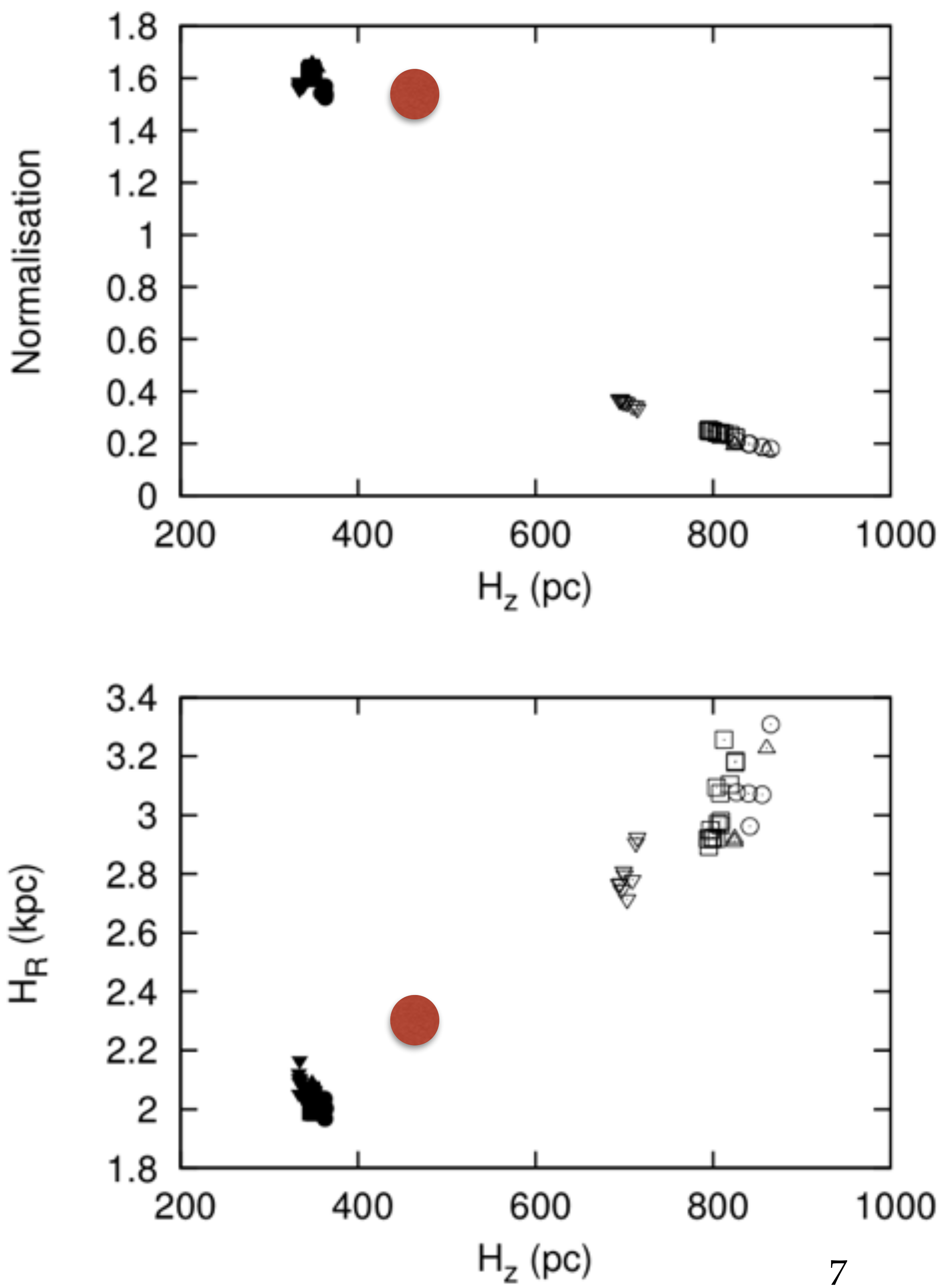
De Jong et al, 2010

Recent updates and constraints on the disc evolution

- Study of thick disc and halo from SDSS +2MASS *R., Reylé et al, 2014*
- *T*he outer disc from 2MASS *Amores, R., Reylé, 2015 subm*

How long the thick disc formed stars

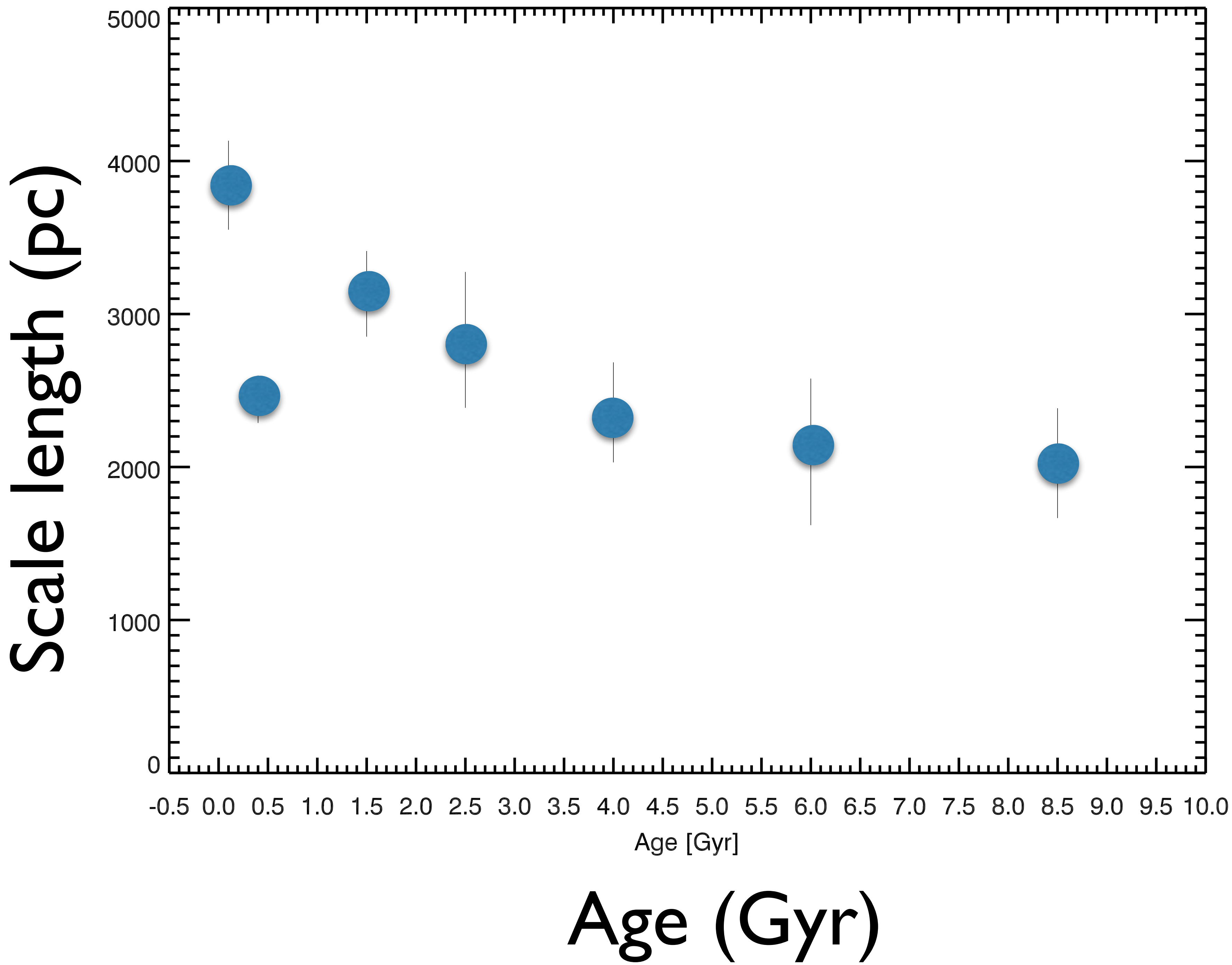
- Assuming 2 epochs of formation (or a continuity)
- Free parameters for each episode : scale height, length, normalisation, flare
- Try different ages



single burst
old thd
young thd

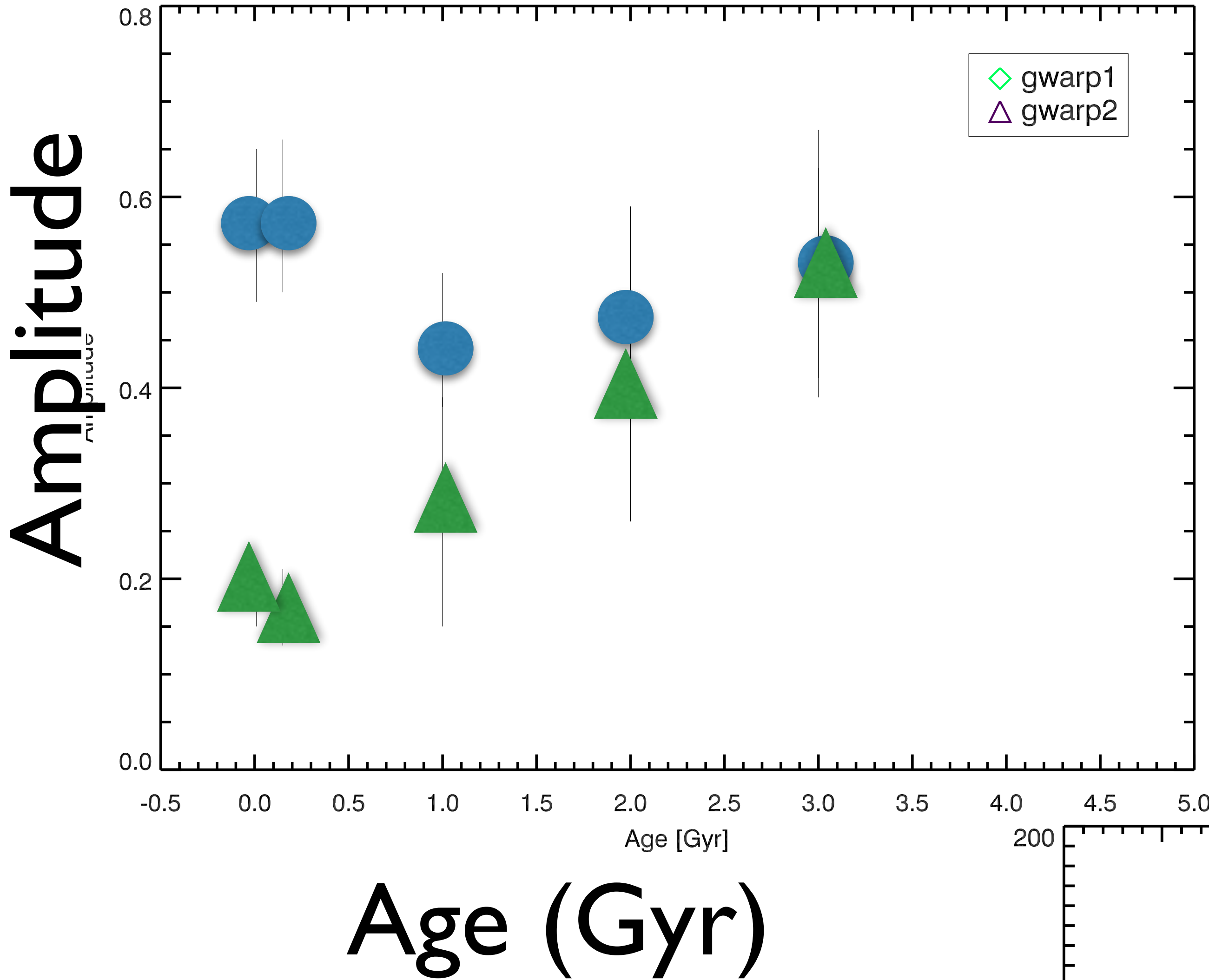
Robin, Reylé et al, 2014

Analysis of the external Disk with 2MASS



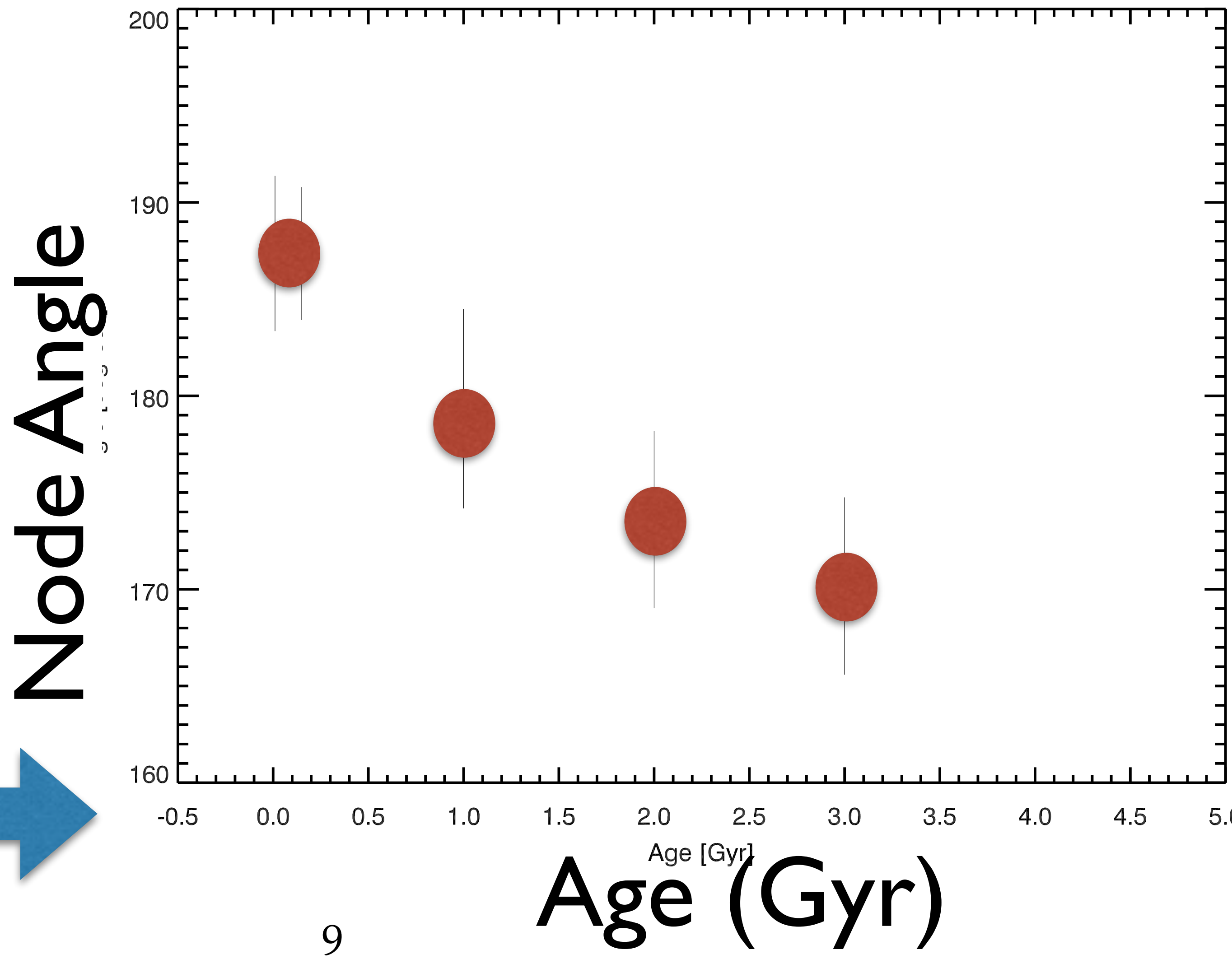
Thin disc scale length changing with age, from 4 kpc to ~2 kpc

Amores, Robin, Reylé, subm



Warp : slope changing with age
+ asymmetry

Angle changing with age
~5°/Gyr



20 microas/

Thin-thick disc relation

- Thick disc formation outside-in ! Lehnert+ 2009, Bournaud + 2009 : gas turbulent phase. Explain well the mixing seen in the thick disc abundances in APOGEE (Hayden+ 2014)…. Slow collapse new.

- Thin disc formation inside-out confirmed.

Martig, Minchev & Flynn, 2014

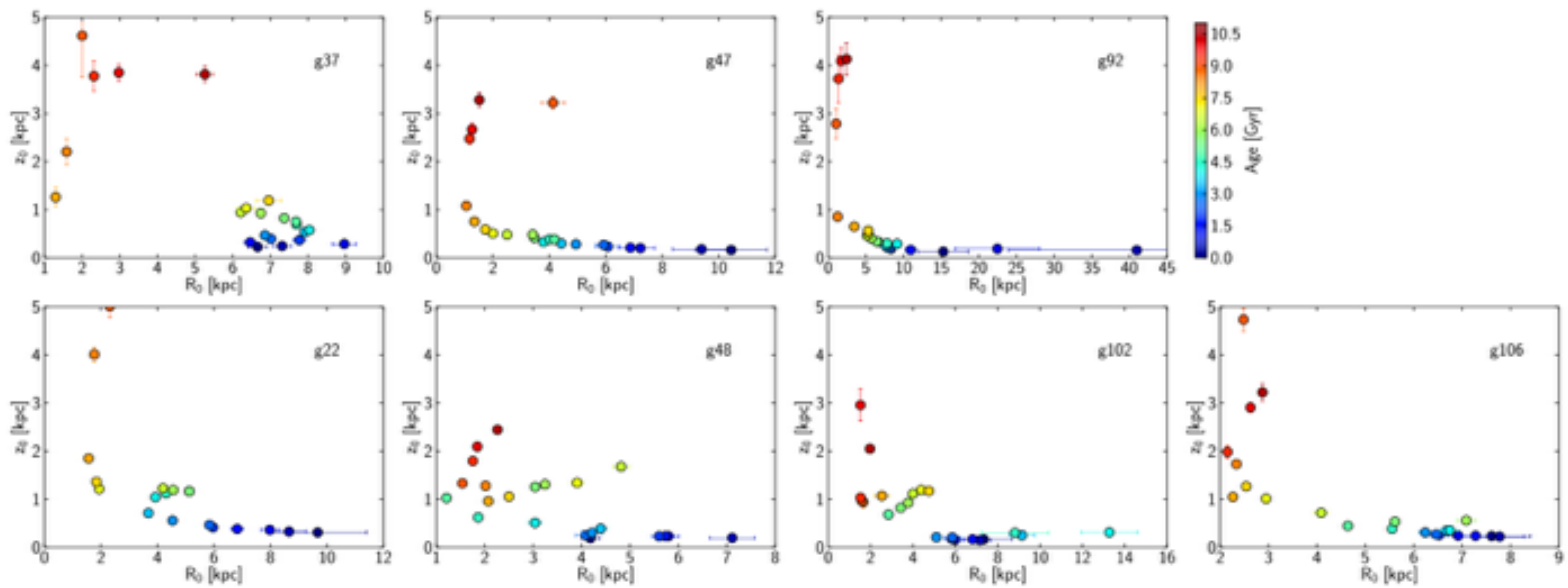


Figure 10. Scale-height as a function of scale-length for mono-age populations in the 7 simulated galaxies. The scale-heights are measured at a radius of $2R_d$. The colourcode and panel order are the same as in Figure 5. We find that the observed anti-correlation between scale-height and scale-length can be reproduced in the simulations, and does not necessarily imply an absence of mergers.

New steps

With the Gaia perspective and new surveys: Galactic archeology with distances, velocities and ages

- Dynamical consistency
- Improvement of stellar models => more accurate ages of stars, exploitation of detailed abundances ans asterosismology

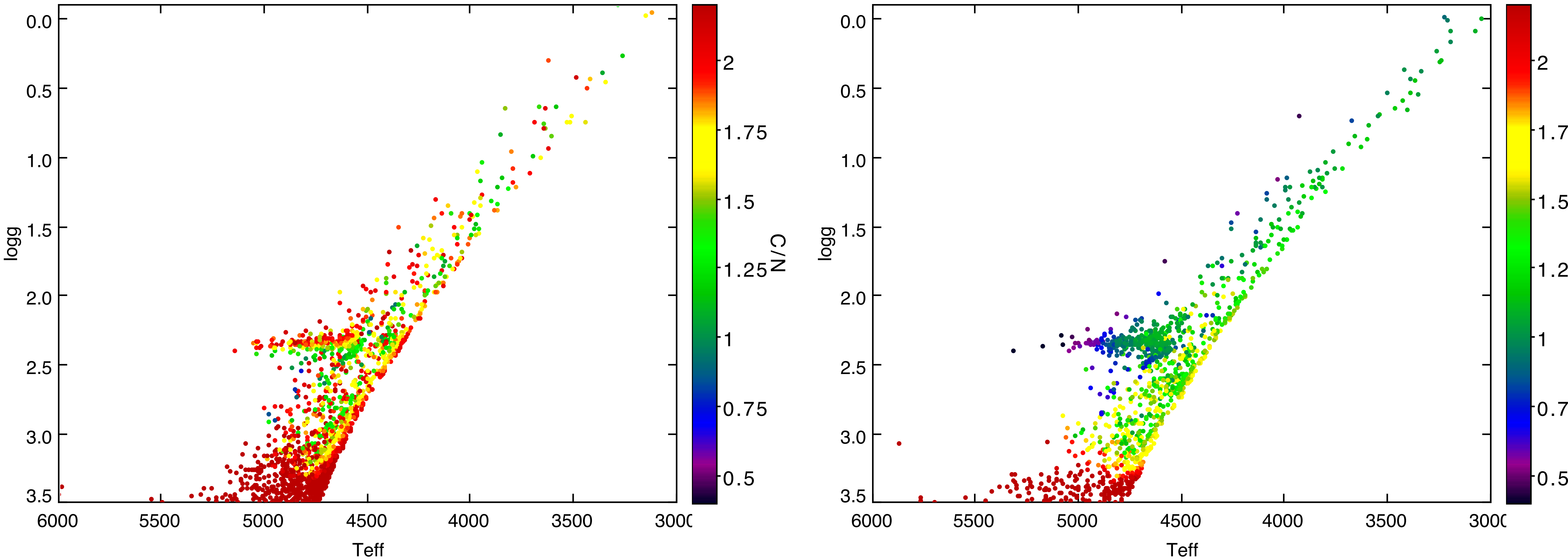
Stellar models

Importance of stellar models for distance and age determination

Role in chemical evolution => yields

- New stellar models **STAREVOL** (*Lagarde et al, 2012, 2016 in prep*) including mixing processes
- Includes computation of global **asterosismic** parameters (delta nu, numax, delta Pi), **surface abundances** along the stellar evolution
- Allows testing the **physics** of transport processes (rotation induced mixing, efficiency of thermohaline mixing during the RGB, etc.)
- Allows accurate computation of **ages**

Effect of extra mixing process on C/N



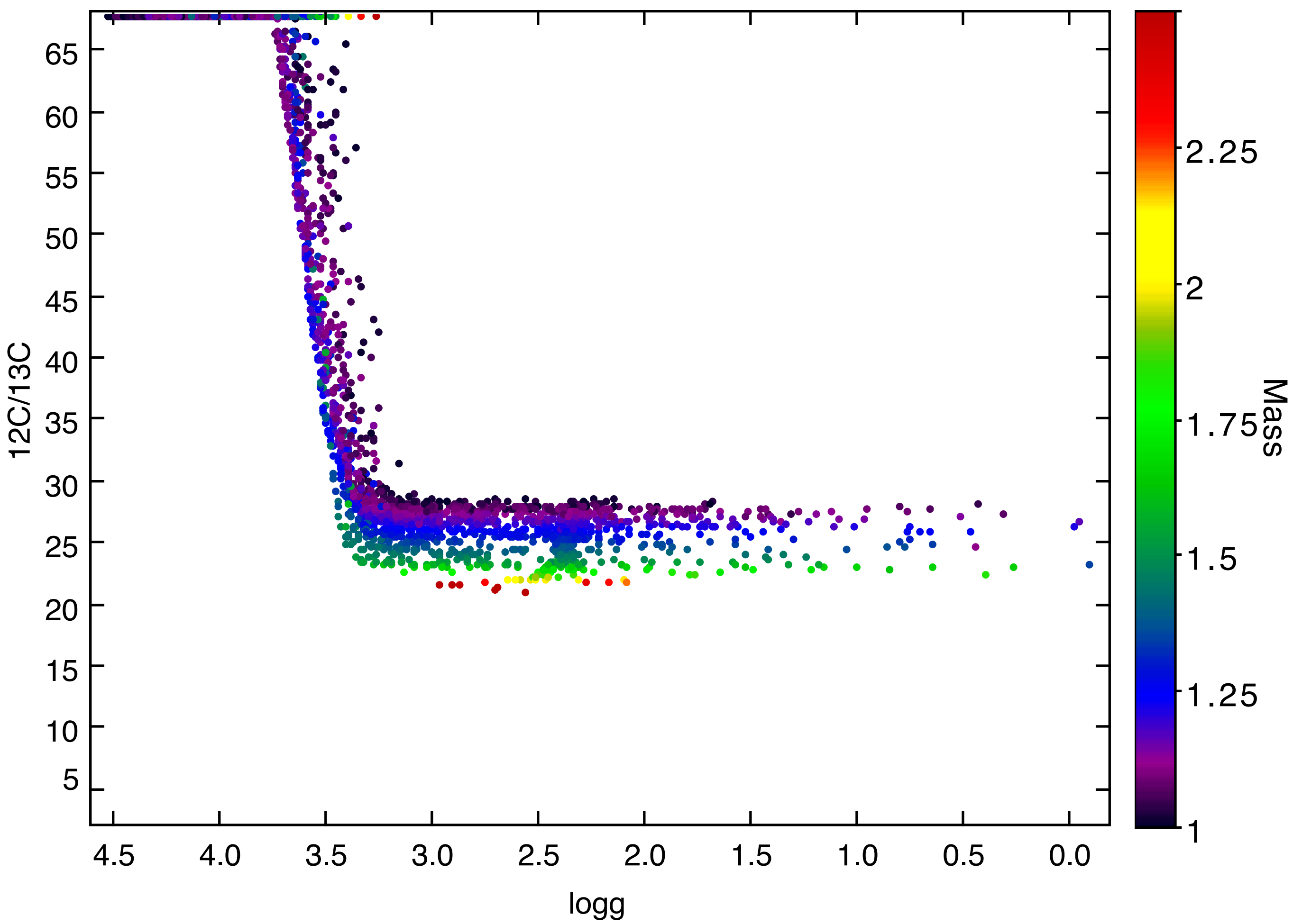
Std models

models with rotation and thermohaline mixing

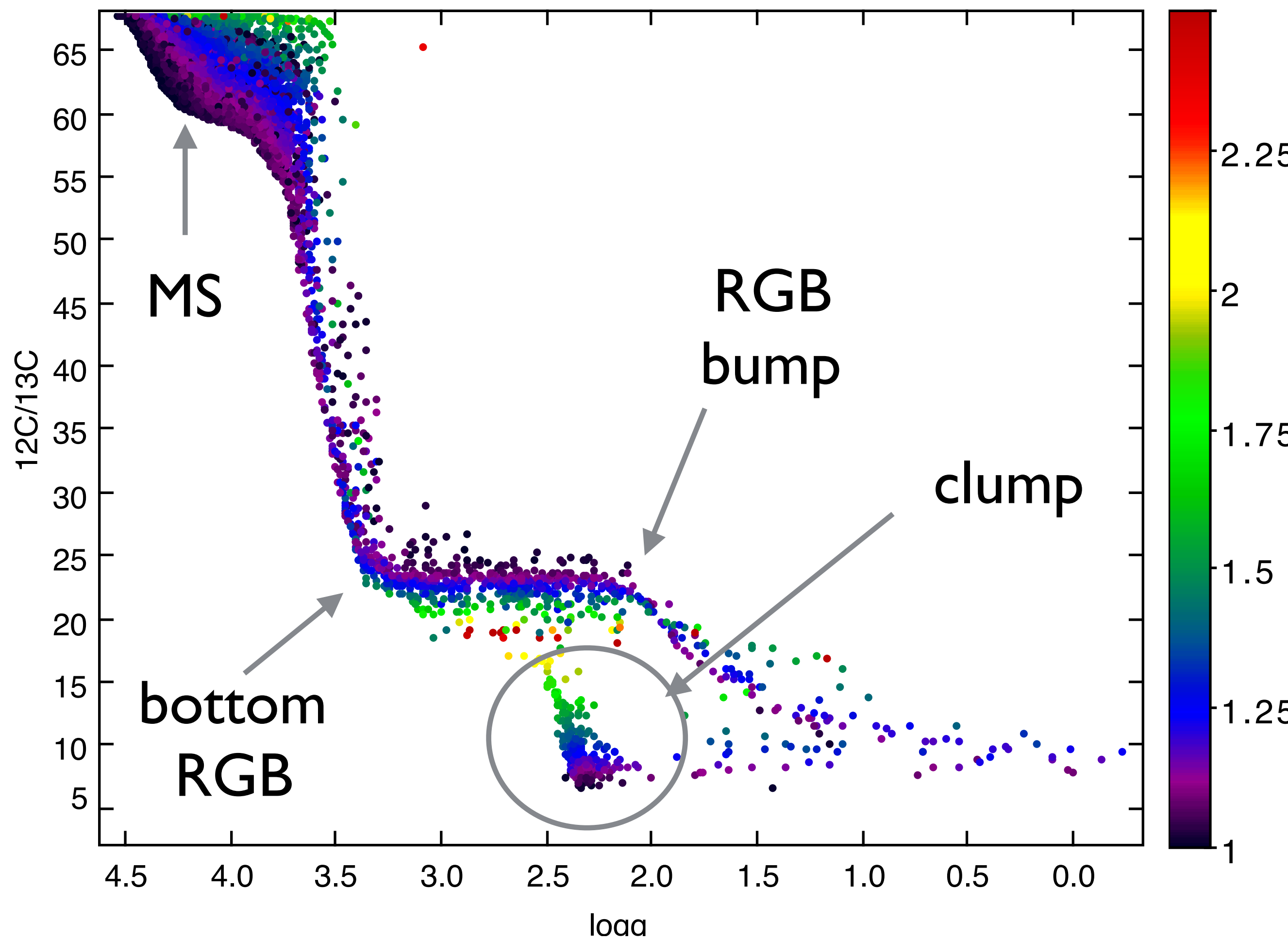
***Thermohaline mixing** : decreases C and increases N after the RGB bump. Stronger effect on small masses and at low metallicity*

***Rotation** : effect on the MS and low RGB, changes the profils of C and N*

Effect of extra mixing process on 12C/13C



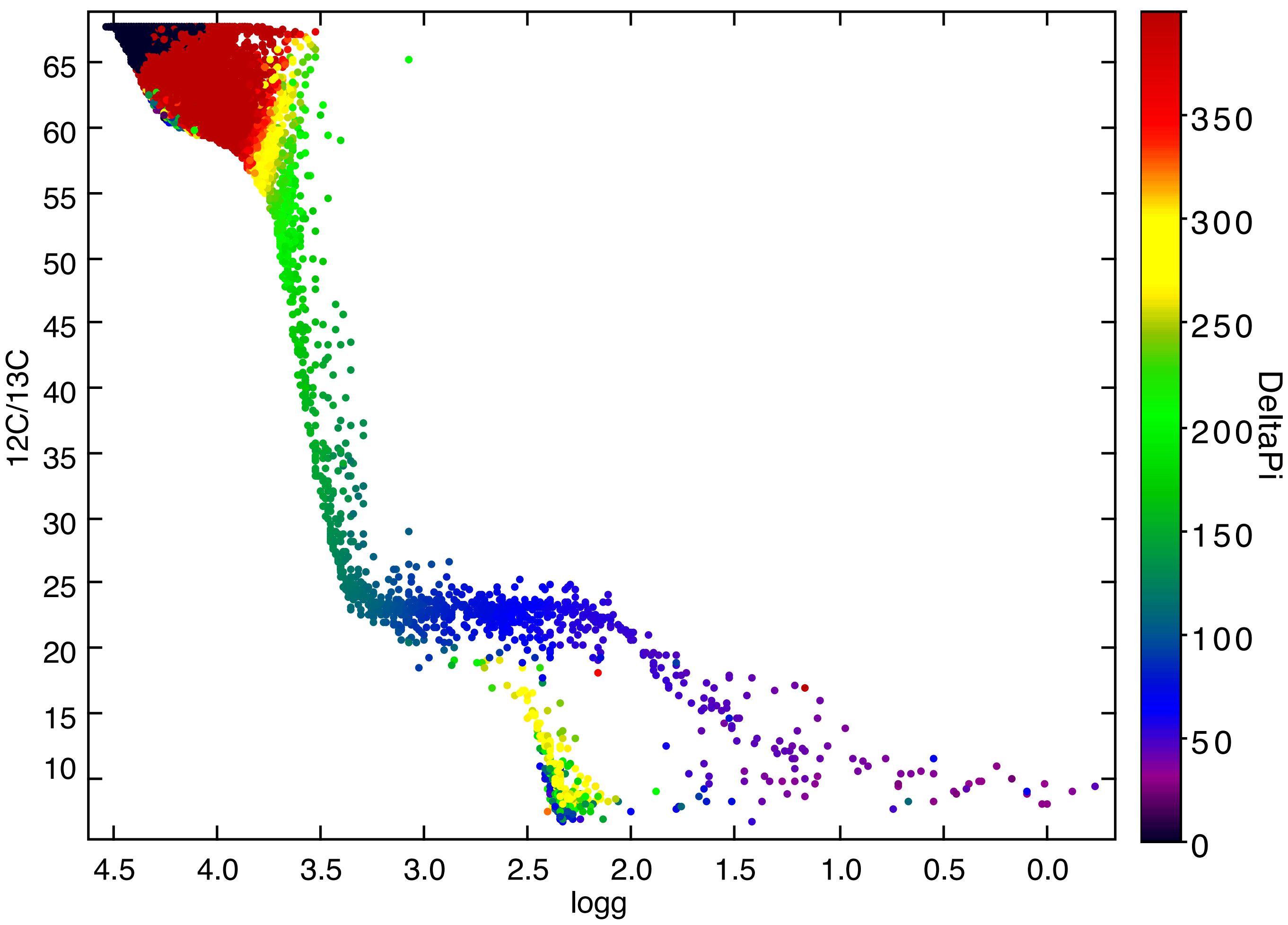
Std model



model with rotation and thermohaline mixing

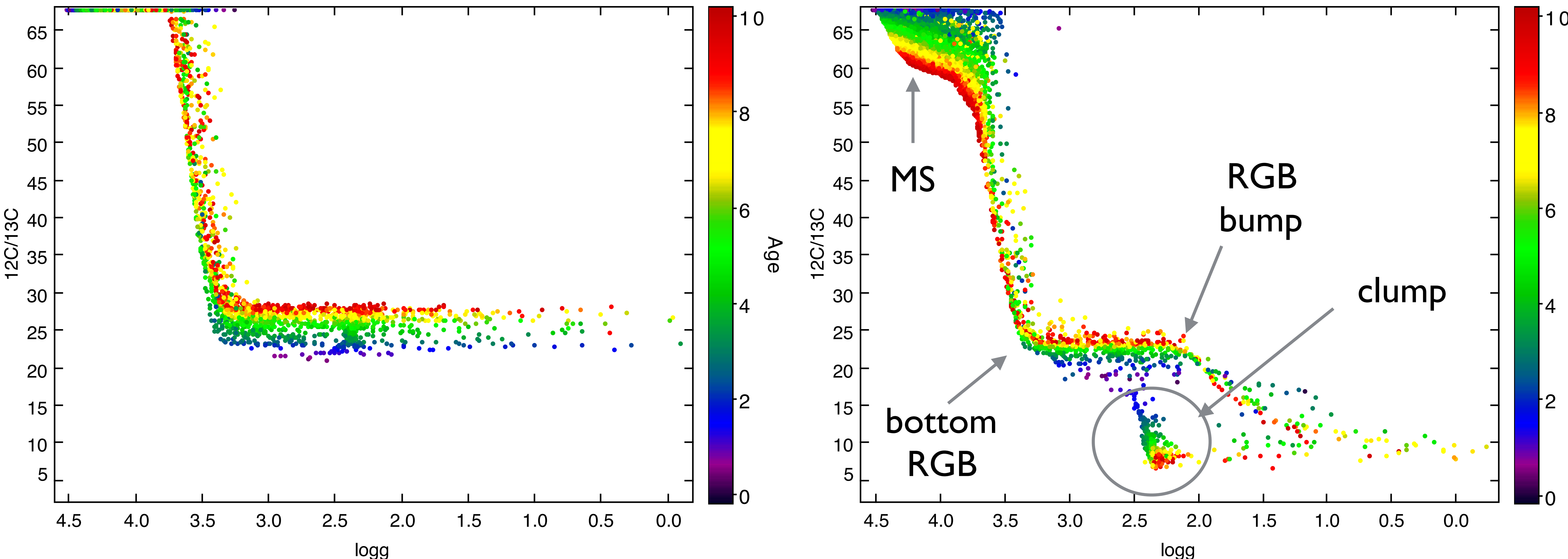
***Thermohaline mixing** : maximum effect after the RGB bump and top RGB . Small during the clump (Charbonnel & Lagarde, 2010).*

***Rotation** : effect on the MS and low RGB (Palacios et al, 2003)*



12C/13C
logg
DeltaPi
65
60
55
50
45
40
35
30
25
20
15
10
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
350
300
250
200
150
100
50
0

Effect of extra mixing processes with age



Std model

model with rotation and thermohaline mixing

12C/13C important witness of transport processes
and for determining accurate ages
Uncertainties on models => ages determination (Lebreton & Goupil, 2014)

Implications for Galactic archeology

- More accurate simulations in the population synthesis
- Determining the **star formation history** in different places in the Milky Way
- **Chemical evolution** model in prep.
- Full exploitation of spectroscopic + asterosismic data (+ astrometry from Gaia)

Kinematics and dynamics

- New dynamical self-consistency : Fit of Stäckel potentials for,axisymmetric Galaxy (*Bienaymé et al., 2015*) => distribution functions, asymmetric drift f(R,z,age). *Test on going with RAVE data + Gaia-TGAS*
- New dynamical modelling : Particule-test approach for inferring the dynamics of the bar (*Fernandez-Trincado et al, 2016*)
- Potential available as open source for easy computing of orbits (gitub: Galpot)

A new approach of the Besançon Model of Stellar Population Synthesis for orbit calculations and test particle simulations

J. G. Fernández-Trincado, A. C. Robin, E. Moreno, O. Bienaymé, et al. (2016a, 2016b, in prep.)

Galactic Model based on the classical scheme of self-consistency dynamic

GravPot16 documentation at **https://fernandez-trincado.github.io/GravPot16/**

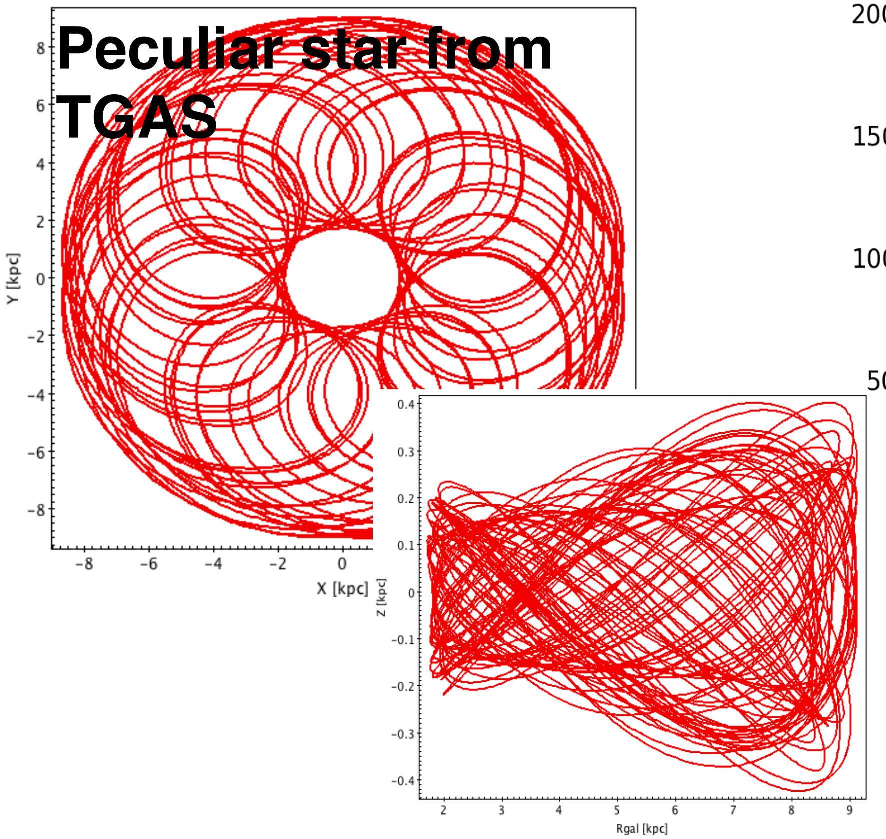
$$\Phi(\mathrm{R},\mathrm{z})_{\mathrm{Total}} + \Phi(\mathrm{R},\mathrm{z})_{\mathrm{axisymmetric}} + \Phi(\mathrm{R},\mathrm{z})_{\mathrm{Boxy-bar}}$$

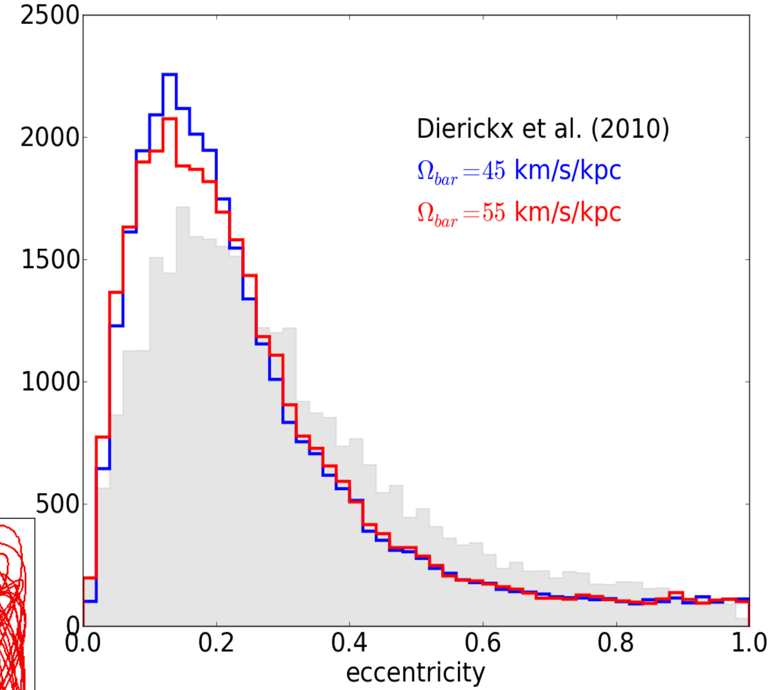
High-precision chemo-dynamics studies of the Milky Way

Anders et al. (2016, in prep.),

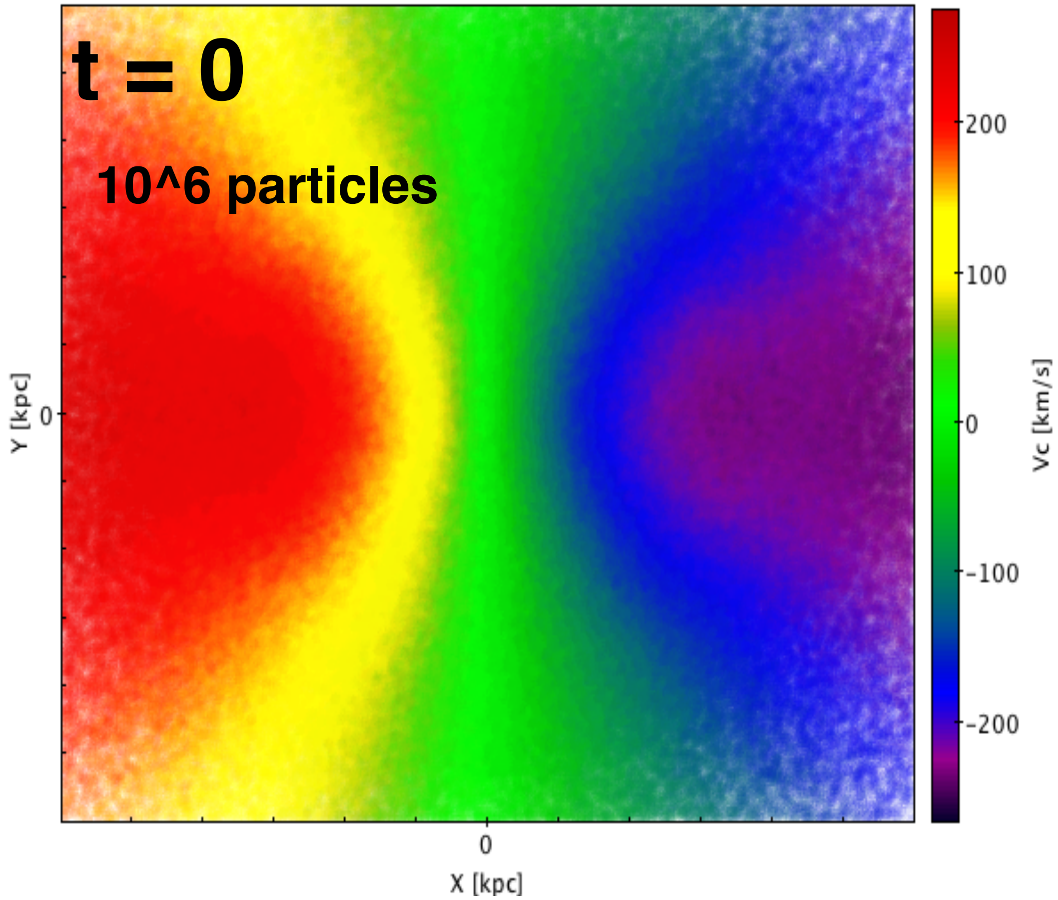
Fernández-Trincado et al. (2016arXiv160401279F)

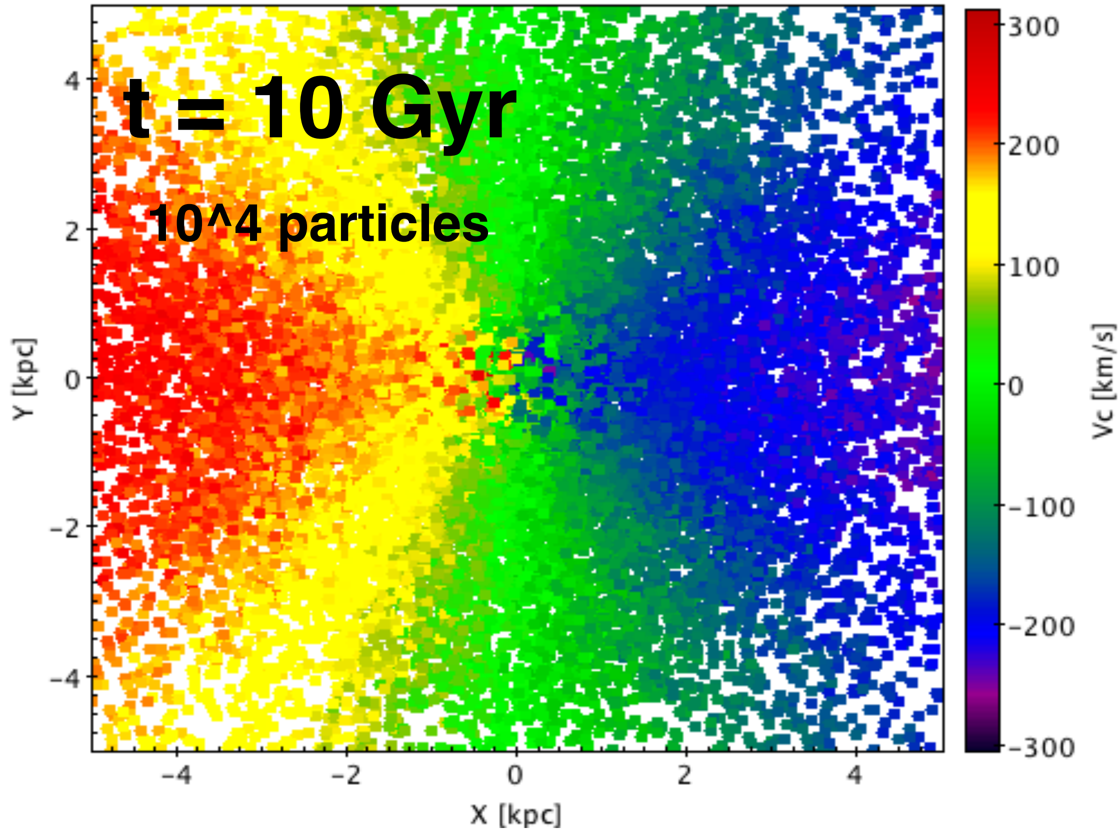
Fernández-Trincado et al. (2016c, in prep.)





Kinematics from Test particle simulations





Summary

- The thick disc formed during a long episode of formation, gas turbulence supported but slightly contracting
- The thin disc formed inside out, asymmetric warp and flare
- The new Thin disc/Thick disc model reproduces well the metallicity distributions seen in RAVE and APOGEE
- New perspectives with up-to-date stellar models, astero-sismology, chemical evolution & Gaia
- New dynamical self-consistency

- **Improved model available http://model2016.obs-besancon.fr and web service http://model2016.obs-besancon.fr/ws *(by 5th october)***