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 parameters in the future
Population synthesis

Simulations of surveys

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

or

\[ N = \sum_{i=1}^{N_{\text{pop}}} \int_0^\infty \rho_i(r) \phi_i(M) \Omega r^2 \, dr \]

\( \varphi(M_v, \text{Teff}) \) for a thin disc decreasing SFR over 10 Gyr

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

3D extinction model

Simulate observational errors

Mor et al, 2016
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, Reylé et al, 2014

- The 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
Analysis of the external Disk with 2MASS

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

Age (Gyr)

Amores, Robin, Reylé, subm
Warp: slope changing with age + asymmetry

Angle changing with age ~5°/Gyr

Node Angle vs. Age (Gyr)

Amplitude vs. Age (Gyr)

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 $\Rightarrow$ more accurate ages of stars, exploitation of detailed abundances ans asterosismology
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

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 profiles of C and N.
Effect of extra mixing process on $^{12}\text{C}/^{13}\text{C}$

**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)
Effect of extra mixing processes with age

**Std model**

**model with rotation and thermohaline mixing**

\[ \frac{^{12}\text{C}}{^{13}\text{C}} \text{ important witness of transport processes and for determining accurate ages} \]

*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 $f(R,z,\text{age})$. *Test on going with RAVE data + Gaia-TGAS*

- New dynamical modelling: Particle-test approach for inferring the dynamics of the bar (Fernandez-Trincado et al, 2016)

- Potential available as open source for easy computing of orbits (github: 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/

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

High-precision chemo-dynamics studies of the Milky Way
Fernández-Trincado et al. (2016c, in prep.)

Peculiar star from TGAS

Kinematics from Test particle simulations

t = 0
10^6 particles

t = 10 Gyr
10^4 particles
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