Modelling the Galactic disc(s) with radial mixing

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What is your personal thick disc?
What is your personal thick disc?

Two-exponential fit of vertical density profile

Bimodal behaviour in $[\alpha/Fe]$

Asymmetric drift

Full chemo-kinematical representation
Model

Inflow ~ 25% of feed through disk

direct onflow ~ 75% of feed slightly pre-enriched

outflow/loss < 10% of processed gas

radial spacing 0.25 kpc

time spacing 30 Myrs
Basic ingredients

Gas disc:

- exponential disc, scalelength $l = 3.5$ kpc
- cold and warm gas

Star formation law:

Kennicut (1998) law:

$$\sum_g \propto e^{-R/l}$$

$$\frac{d}{dt} \sum_g = 1.2 \times 10^{-4} \begin{cases} \sum_g^{1.4} \text{ for } \sum_g \geq \sum_{crit} \\ C \sum_g^4 \text{ for } \sum_g < \sum_{crit} \end{cases}$$

Initial mass function:

Salpeter IMF:

$$\frac{dN}{dM} \propto M^{-2.35} \text{ for } 0.1 < M < 100$$

Adopted metallicity scale:

$$Z_{sun} \sim 0.019$$
Basic ingredients

Yields from SN Ia

Ascribe 7.5% of remnant mass of stars between 3.5 and 8 Msun to SN Ia progenitors.

Yields from Iwamoto et al. (2007), W70 model

\[
\frac{dM_{WD}}{dt} = \begin{cases} 
0 & \text{for } t < 150 \text{ Myr} \\ 
-M_{WD}/1.5\text{Gyr} & \text{for } t \geq 150 \text{ Myr}
\end{cases}
\]

(cp. Förster et al., (2006))
O/Fe ratios

Ramirez et al. (2007)
For an analytical approach of bimodality cf. Schönrich & Binney (2009a)
Model

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Churning
- mass exchange between neighbouring rings
- cold gas and stars
- no heating of the disc

Blurring
- stars on increasingly excentric orbits
  (heating of the disc)
  → broadening of the disc and increasing scale height
Blurring

radial distribution of stars born at 5 kpc, 7.5 kpc, 10 kpc

age 5 Gyrs

age 10 Gyrs
Churning

radial distribution of stars born at 5 kpc, 7.5 kpc, 10 kpc, age 10 Gyrs

probability vs R/kpc
GCS data (2007)

Best model

Model without churning

Model with neither churning nor blurring
GCS data (2007)

Best model

Model without churning

Model with neither churning nor blurring
local evolution

Simulated measurement in magnitude limited sample

Simulated measurement in

Bias corrected sample

\[ \sigma_Z \propto \tau^{0.53} \]

\[ \sigma_Z \propto \tau^{0.44} \]

\[ \sigma_Z = 25 \text{ km s}^{-1} \left( \frac{\tau}{10 \text{ Gyr}} \right)^{0.33} \]
Divide and conquer

How can we divide the disc?
Divide and conquer

How can we divide the disc?

- density
- ages
- abundance ratios
- metallicity
- kinematics
Thin and thick disc

$h_{\text{thin}} = 300$ pc  \quad $L_{\text{thin}} = 2.6$ kpc

$h_{\text{thick}} = 900$ pc  \quad $L_{\text{thick}} = 3.6$ kpc

$c_{\text{thick}} = 0.12$
\( h_{\text{thin}} = 317 \text{ pc} \)
\( h_{\text{thick}} = 838 \text{ pc} \)
\( c_{\text{thick}} = 0.13 \)
age
Velocity dispersion
Kinematical selection – thick disc
The kinematic thick disc
The kinematic thick disc

Bensby et al. 2004
Chemical dissection
Age distributions

The graph shows the age distributions for different populations:
- Thin disc: Green line
- Thick disc: Pink line
- Intermediate population: Blue dashed line

The x-axis represents age in Gyr (Giga-years), and the y-axis represents density.
Age distributions

Data from Haywood (2008)
The kinematical thick disc

Ratio of components:
thin:intermediate:thick

Haywood (2008): 1:0.085:0.029
GCS (2007): 1:0.095:0.029
model: 1:0.099:0.025
Thick disc properties

*Pluralitas non est ponenda sine necessitate* (Ockham, ~1300)

Two-exponential fit of vertical density profile  

Bimodal behaviour of in [alpha/Fe]  

Asymmetric drift  

Full chemo-kinematical representation  

Are we really allowed to treat it as a separate entity?
Summary I

Open problems

very crude galactic structure

no bulge

no ring/bar(s)

inside-out formation?

crude treatment of mixing

infall/inflow and outflows weakly constrained

exact observational gradients still an open question

SNIa delays weakly constrained
Summary

- Including radial mixing is compulsory from a theoretical point of view

- Classical models of chemical evolution might imply wrong Galactic histories

- The scatter in abundance ratios and in the age-metallicity relationship is fully explained by radial mixing processes

- Clean kinematic selection on a disc component is not possible

- The model can explain/replicates the chemo-dynamical structure of the solar neighbourhood and challenges the separate history of the thick disk