Chemo-dynamical modeling of thick/thin galactic disks

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Galactic disks

Most spirals have two disk components

Thicker disk:
- very common in other galaxies
- appears to be old (> 6-10 Gyr)
- moderately metal-poor

Thin disk:
- relatively younger
- moderately metal-rich
- dynamically colder

Thick disk recognizable as a relict of the early galaxy
ISM conditions at epoch of galaxy formation: density, chemical composition, turbulence
- Secular evolution affects galactic disk dynamics
- Dynamical information can be vanished through disk heating processes

The detailed abundance pattern reflects the chemical evolution of the gas from which the aggregate formed.

- Disks formation/evolution are still recognizable by their chemical signatures
Thick disk formation

- Gas rich mergers (e.g. Brook+ 2004, 2005). The thick disk stars are born in-situ

- Accretion of satellites (e.g. Abadi+ 2003). Thick disk stars come in from outside

- Perturbation by merging satellites (e.g. Di Matteo+ 2011). The orbital energy of the satellite goes into thickening the disk

- Formation in turbulent gas-rich thick gas disk (e.g. Bournaud+ 2009). Dissolution of giant gas agglomeration in clumpy galaxies (Kroupa 2002, Bournaud+ 2008).
Outline

Starting from turbulent gas rich disk...

- can we reproduce realistic thick / thin disks?
- what do we need to separate thin and thick disks formation phases?
- chemical evolution?
Model

- **Gasdynamics (grid based)**
  - static mesh refinement
  - TVD MUSCL, 2nd order in time, 3nd in space
  - Riemann solvers (HLLC)
  - passive scalars advection
    - (H, He, Si, Fe, Mg, O... 8 species in total)
  - radiative cooling/heating (metallicity dependent)
  - stellar feedback (only thermal):
    - SNI, SNII, AGB stars, metallicity dependent
  - star formation (T<100 K, $M_{\text{ini}}^*$,$>10^3 M_\odot$, div $V<0$)

- **Stellar component (N-body)**
  - stellar yields
  - mass loss
  - IMF (Kroupa 2001)

- **Dark matter (N-body)**

- **Gravity: TreeCode**
  ($\theta=0.5$, $\Delta t=10^4$ yr, AVX instructions)

- similar to Cole+2013, Aumer & White 2013, Marasco+ 2015

- live DM halo rotating gaseous halo
  $T_{\text{ini}} \sim 10^5$ - $10^6$ K

$\sim 10^{-5}$ - $10^{-6}$ K

Khoperskov & Berczik in prep
Star formation history

- Rapid decrease of star formation rate
Stellar disk formation

0.5 Gyr  1 Gyr  3 Gyr  4 Gyr  10 Gyr
Gas velocity dispersion in a gas-rich barred galaxy

Unbarred galaxy

Barred galaxy

Large scale turbulent flows, shear

SK, Haywood, Di Matteo + 2017
Star formation efficiency in a gas-rich barred galaxy

Unbarred galaxy

Barred galaxy

SK, Haywood, Di Matteo + 2017
Rapid decrees of SF can be explained by the formation of a bar in a gas-rich disk.

**Star formation history**

- **CEM by Snaith et al 2015**
- **MW star formation history**

![Graph showing star formation rate (SFR) over time](image)

- **Thick disk**

![Graph showing redshift and gas fraction over age](image)

**CEM by Snaith et al 2015**
Chemical evolution

Two distinct populations

alpha-rich
Me-poor

alpha-poor
Me-rich

solar neighbourhood stars
Adibekyan+ (2012) sample

Haywood+ 2013
Disks kinematics

([O/Fe]>0.1)
([O/Fe]<0.1)

Alpha-enriched disk rotates slower and it is kinematically hotter
Summary

• The thick disk formed in a well mixed turbulent gaseous disk which gave rise to a steep and monotonic chemical enrichment lasting a few Gyr.

• Thin disk is the result of slow (and long) star formation.

• Formation of the bar can separate these two phases decreasing global star formation rate. This provides evidence for the existence of two different epochs of star formation in the galaxy, which we have defined as the epochs of thick disk and thin disk formation.

• The transition between the two epochs is imprinted in [α/Fe] variation as a function of time/space/metallicity.