Quantifying the star formation history of the Milky Way disk in the Solar neighborhood

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Context: the formation of disk galaxies

- Disk galaxies made of thin and thick disks, bulge, halo
- Each composed of different stellar populations
  - when did these structures form?
  - how do they relate to each other?
  - what mass fraction formed \textit{in-situ}?
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Reconstruct their star formation history (SFH)

Star formation history

Bernard et al. 2012
Quantifying the star formation history: color-magnitude diagram fitting

Observations

Stellar evolution models

Age [Gyr]

Z ~ 0.005

Age ~ 8-13 Gyr

Star formation history

Estimate the age and metallicity with a precision of 10-20%
Gaia DR1 – TGAS

- Combination of *Hipparcos*, *Tycho-2*, Gaia
- 2 057 050 stars, 90% within 1.5 kpc of the Sun
- Positions
- G-band magnitudes
- proper motions
- stellar parallaxes $\rightarrow$ intrinsic magnitudes!
Star Formation Histories from CMD-fitting

3 main requirements:

➔ depth – to reach the main-sequence turn-off (MSTO)
➔ well constrained completeness vs. color & magnitude
➔ accurate colors and magnitude

Gaia DR1
Hipparcos sample

Brown et al. 2016
Requirement 1: Photometric depth

- Most accurate age estimate from the main-sequence turn-off (MSTO)
- Photometry should be deep and complete enough to sample the MSTO

Depth limited by *Tycho-2* completeness (Hog et al. 2000):
- $> 90\%$ at $V < 11.5$
- $(m-M) = 7 \rightarrow 250 \text{ pc}$
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Fractional uncertainty on the parallax

$\Delta \pi / \pi < 0.2$

$M_V \sim 4.5$

Brown et al. 2016
Requirement 2: accurate colors and magnitudes

- Gaia DR1 only provides G-band magnitudes
- No color information → need to cross-match with other catalogs

Out of ~327,000 stars within 250 pc:

- 100% have Tycho-2 colors
- 20% have Hipparcos colors
- 77% have APASS colors

→ weighted average colors
Requirement 3: known completeness

- Within 250 pc, Tycho-2 is >90% complete down to MSTO
- But only ~80% have TGAS parallaxes!
Requirement 3: known completeness

Solution:
- Complete with *Hipparcos* parallaxes
- Excise 57% of the sky area with completeness $< 90\%$
Resulting color-magnitude diagram

Gaia/Hipparcos/Tycho/APASS
“volume complete” within 250 pc

Gaia DR1 – Hipparcos sample

148 326 stars

74 771 stars
Star formation history of the disk in the solar neighborhood
Star formation history of the disk in the solar neighborhood

Fully consistent with SFH within 80pc from *Hipparcos* (e.g. Vergely et al. 2002, Cignoni et al. 2006)

Excess of stars younger than ~4 Gyr

F/G dwarfs (Edvardsson et al. 1993)

Asteroseismology + spectroscopy (Anders et al. 2017)
Star formation history of the disk in the solar neighborhood

Flat age-metallicity relation in the past ~10 Gyr → consistent with e.g. Geneva-Copenhagen Survey

Haywood et al. 2013
Beyond the solar neighborhood: Future Gaia Data Releases

Star formation history of the Milky Way components out to ~4-5 kpc

Expected performances from In-Orbit Commissioning Review

- ~5 kpc
- Deep, complete Gaia CMDs

Hipparcos distances accurate to 10%

Gaia distances accurate to 10%

\[ d = 3 \text{ kpc} \]

\[ \Delta \pi / \pi < 0.15 \]
Star formation history of the Milky Way bulge from *HST* data

Proper-motion cleaned CMD of Baade's window

12 873 stars

Clarkson et al. 2008
Summary

- Gaia parallaxes allow the reconstruction of the SFH of the Milky Way
- SFH of the solar neighborhood fully consistent with that from Hipparcos
- DR2+ much deeper, more complete, with accurate colors
  → SFH of each Milky Way components