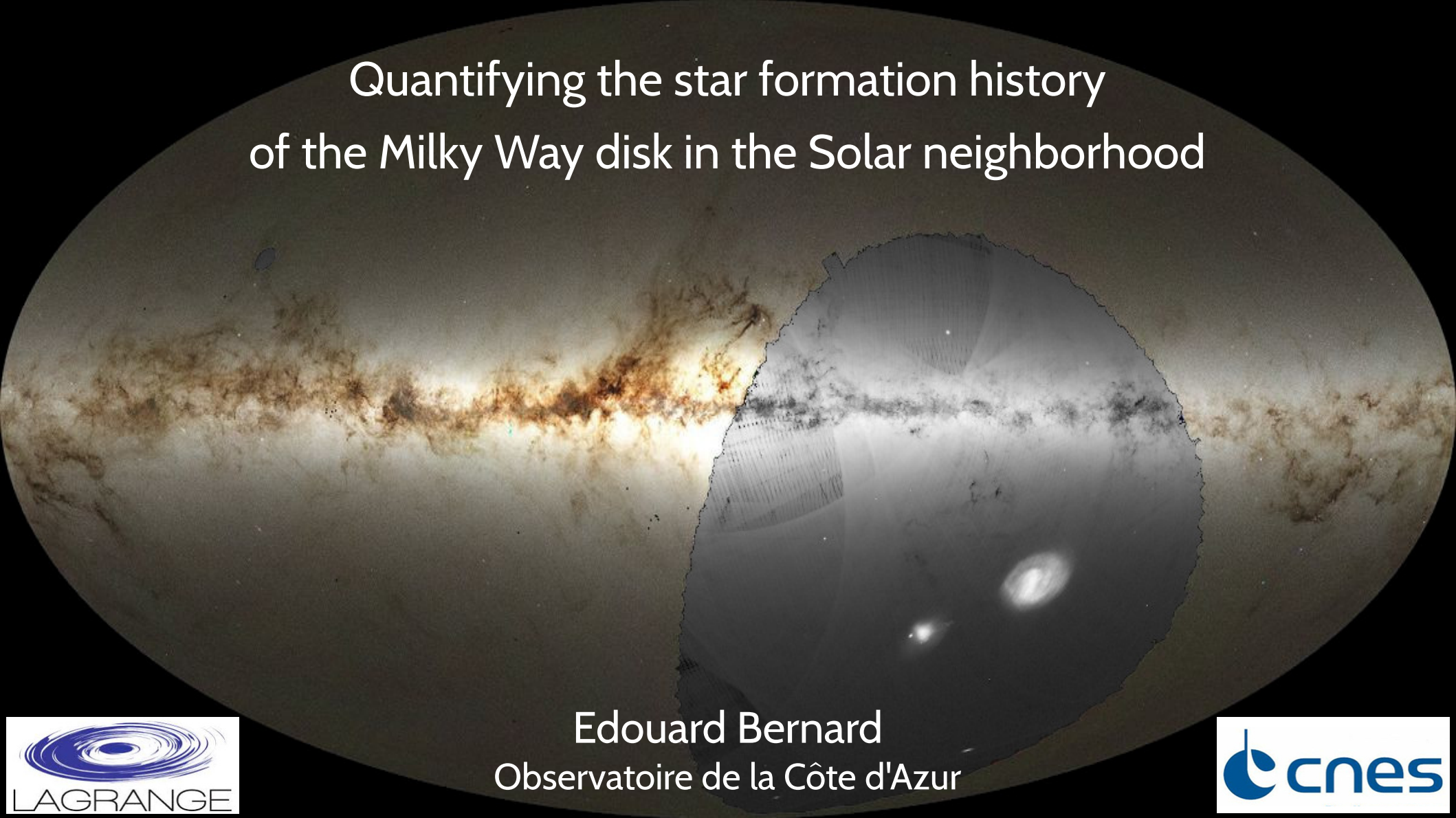
Quantifying the star formation history of the Milky Way disk in the Solar neighborhood

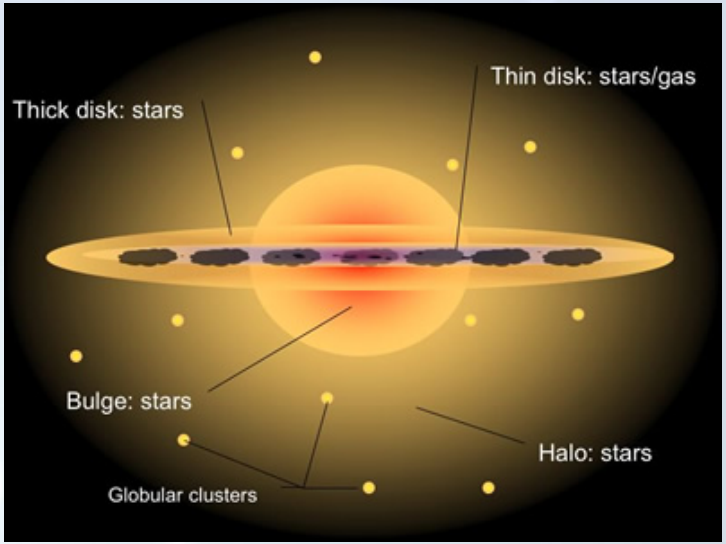


Edouard Bernard
Observatoire de la Côte d'Azur

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 *in-situ*?



Credit: Swinburn University of Technology

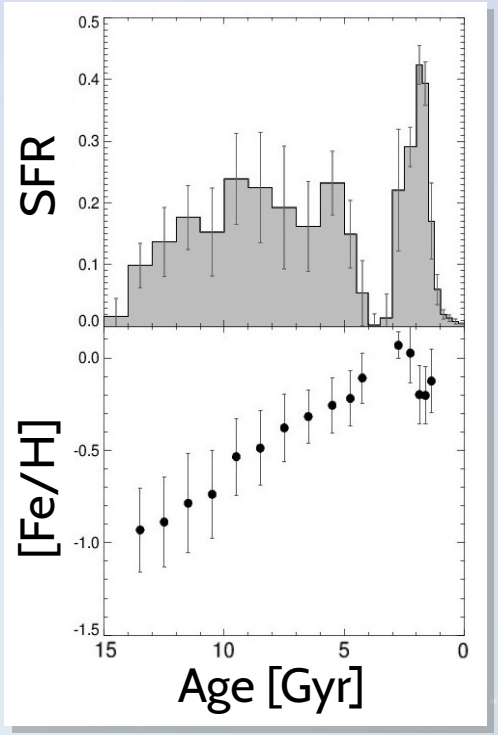
Context: the formation of disk galaxies

- 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 *in-situ*?

Reconstruct their star formation history (SFH)

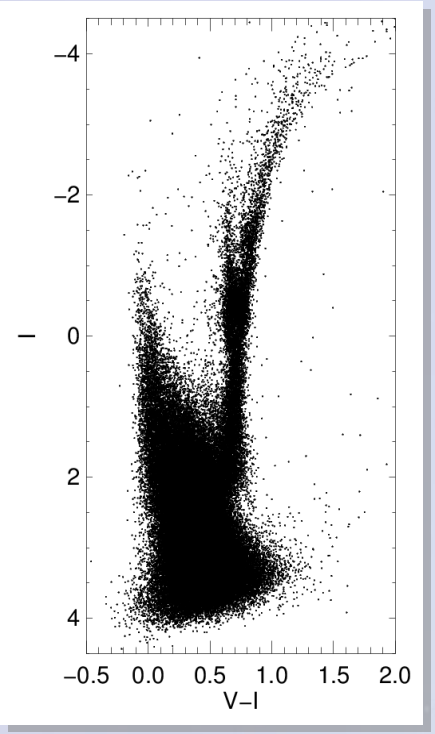
Star formation history



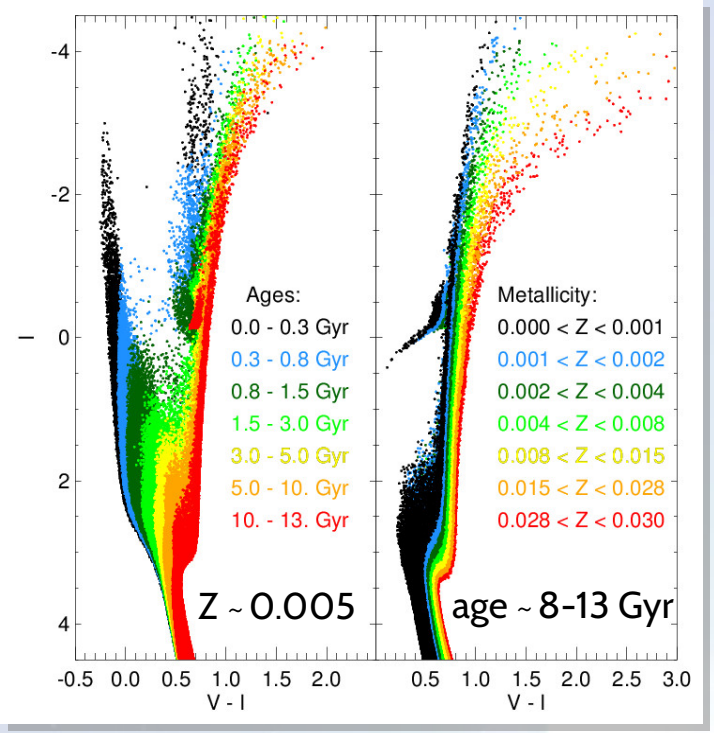
Bernard et al. 2012

Quantifying the star formation history: color-magnitude diagram fitting

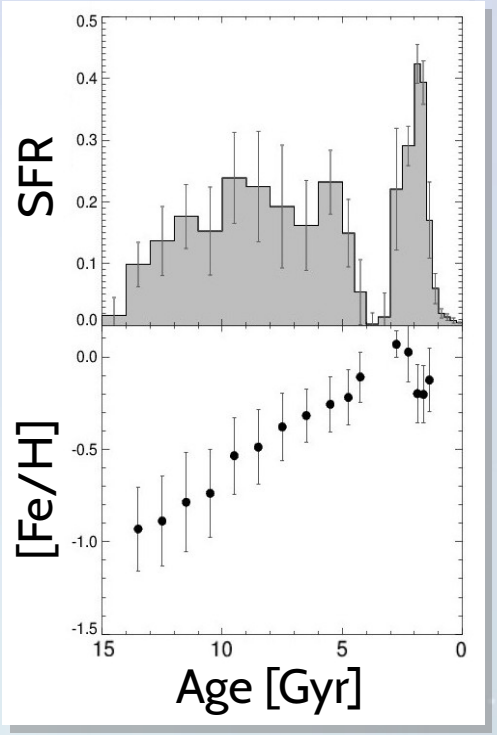
Observations



Stellar evolution models

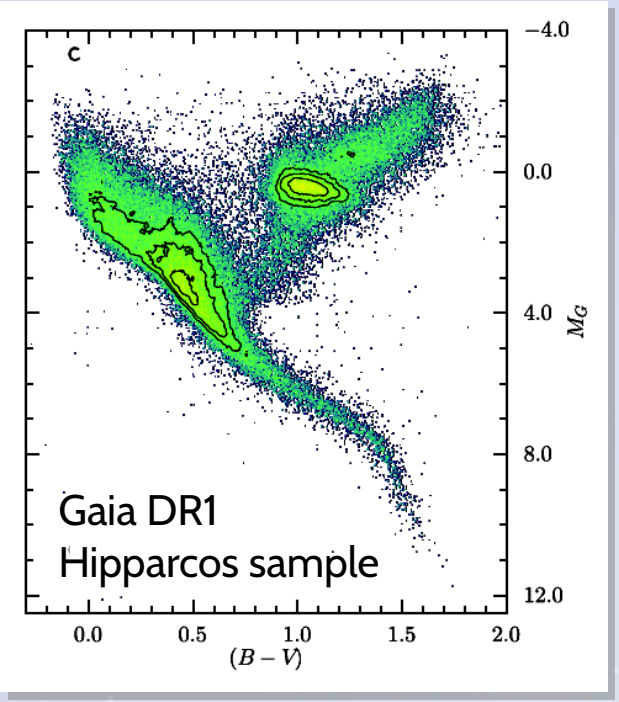


Star formation history



- Estimate the age and metallicity with a precision of 10-20%

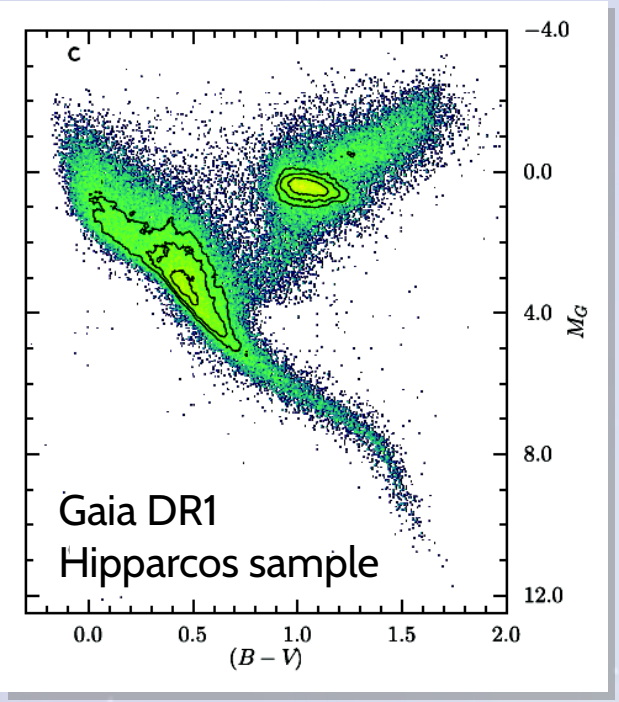
Gaia DR1 – TGAS



Brown et al. 2016

- 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 → intrinsic magnitudes!

Star Formation Histories from CMD-fitting



Brown et al. 2016

3 main requirements:

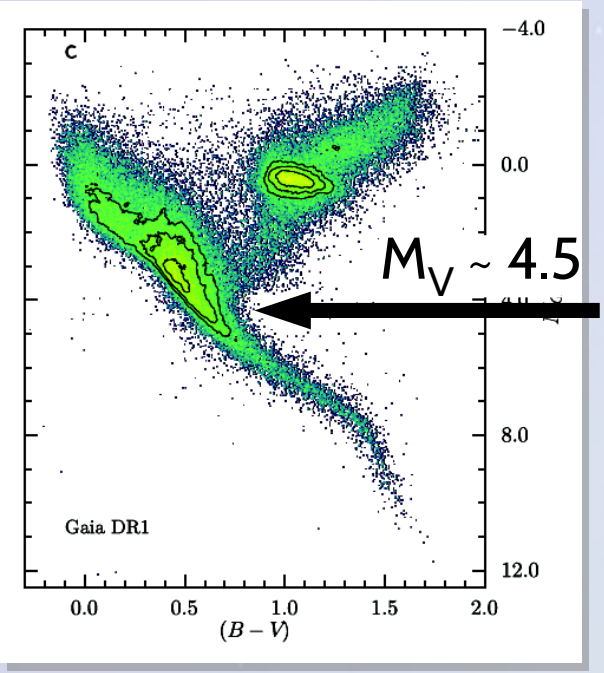
➔ depth – to reach the main-sequence turn-off (MSTO)

➔ well constrained completeness vs. color & magnitude

➔ accurate colors and magnitude

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



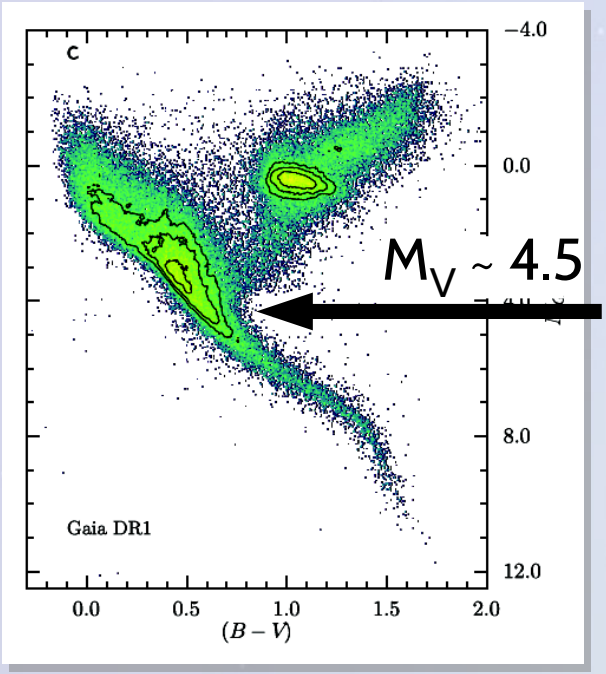
Brown et al. 2016

Depth limited by *Tycho*-2 completeness (Hog et al. 2000):

- > 90% at V < 11.5
- (m-M) = 7 → 250 pc

Requirement 1: Photometric depth

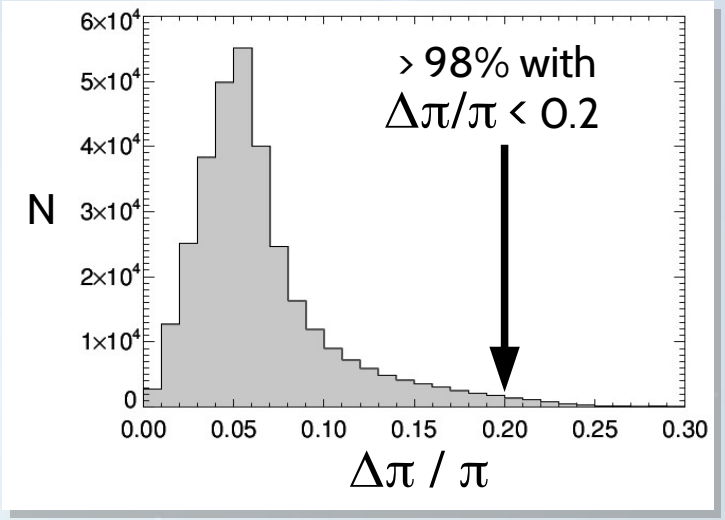
- Most accurate age estimate from the main-sequence turn-off (MSTO)
- Photometry should be deep and complete enough to sample the MSTO



Brown et al. 2016

Depth limited by *Tycho*-2 completeness (Hog et al. 2000):

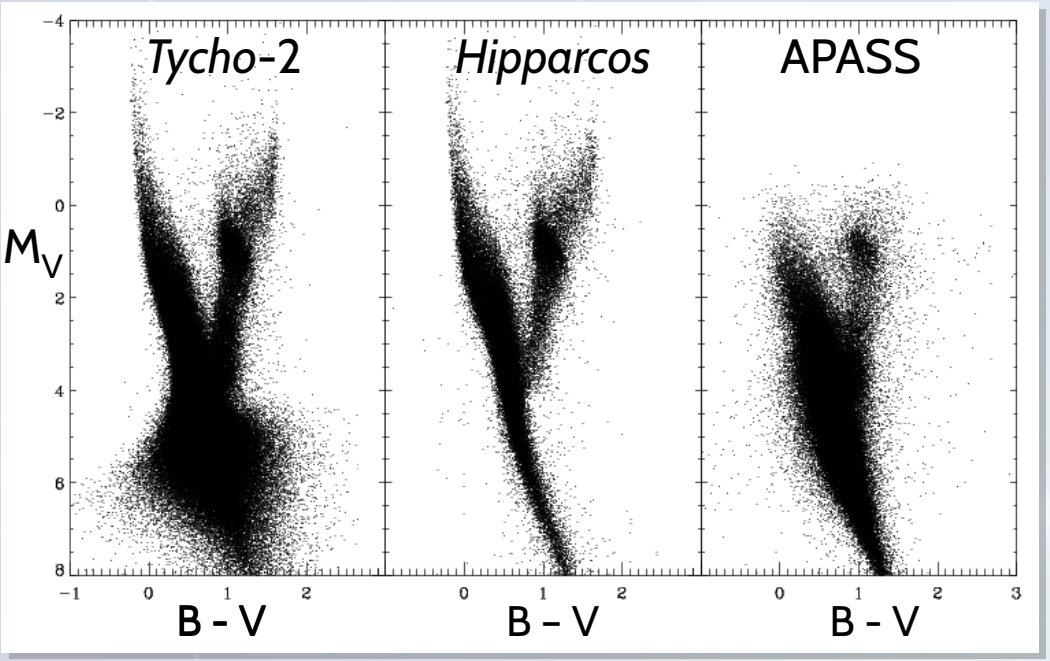
- > 90% at V < 11.5
- (m-M) = 7 → 250 pc



Fractional uncertainty on the parallax

Requirement 2: accurate colors and magnitudes

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



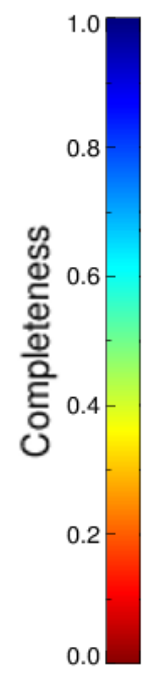
Out of ~327 000 stars within 250 pc:

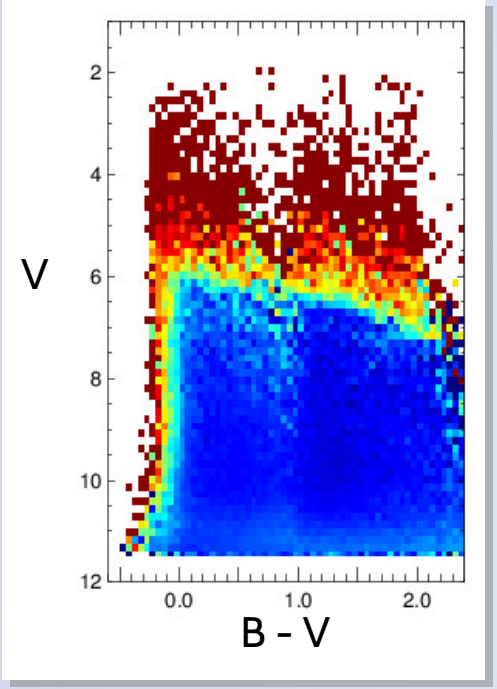
- 100 % have *Tycho*-2 colors
- 20 % have *Hipparcos* colors
- 77 % have APASS colors

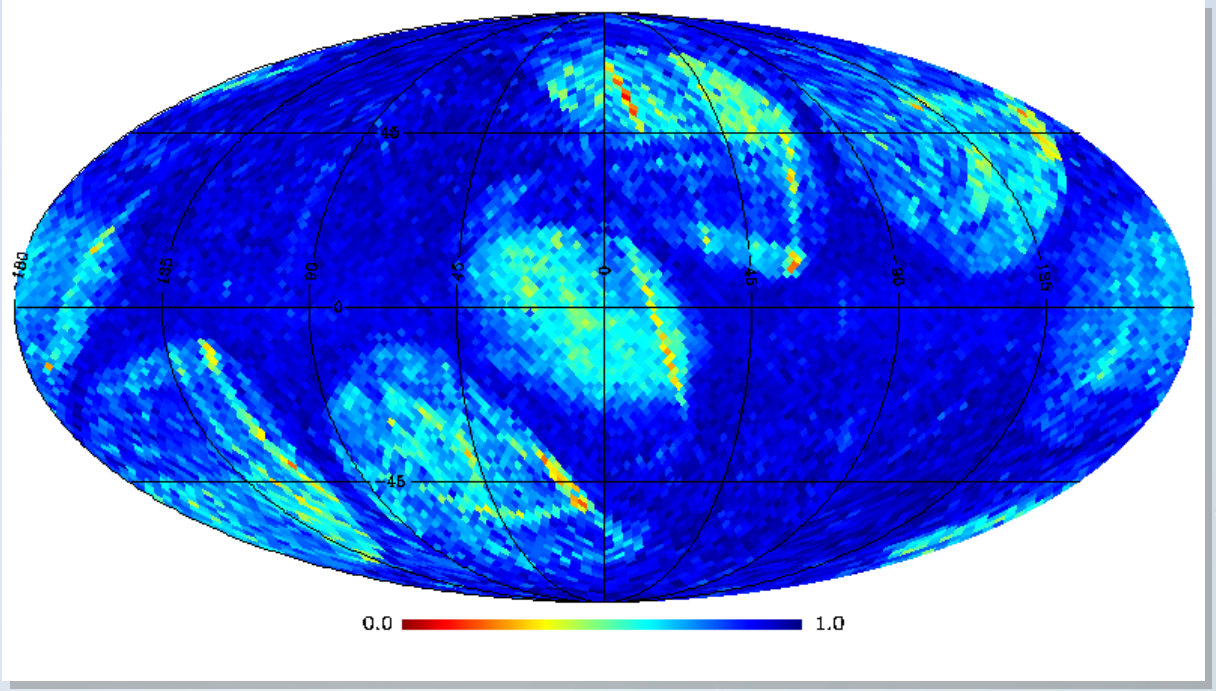
→ weighted average colors

Requirement 3: known completeness

- Within 250 pc, *Tycho*-2 is >90% complete down to MSTO
- But only ~80% have TGAS parallaxes!



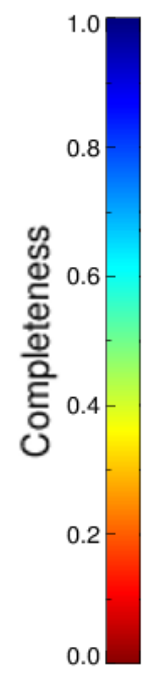


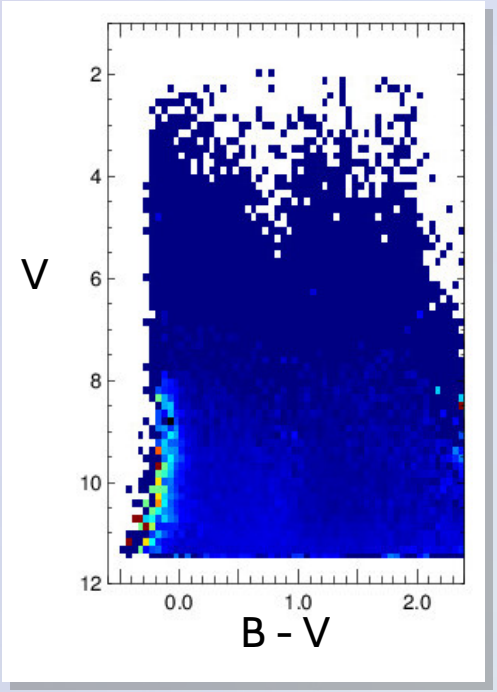


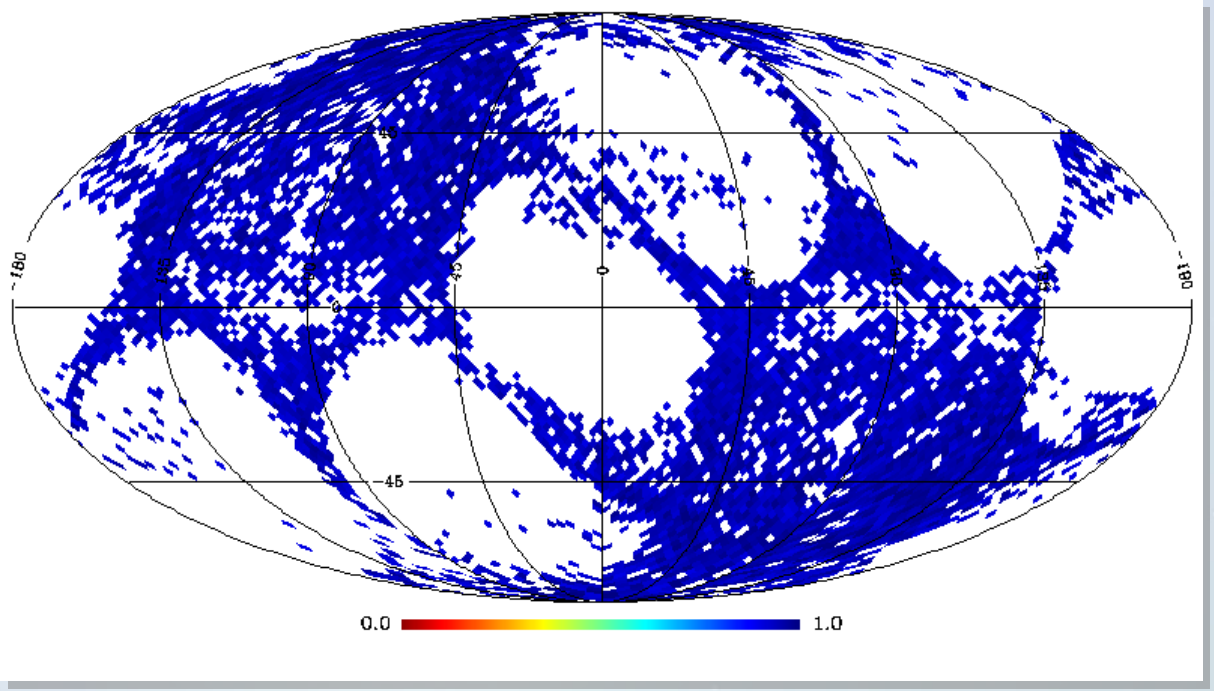
Requirement 3: known completeness

Solution:

- Complete with *Hipparcos* parallaxes
- Excise 57% of the sky area with completeness < 90%

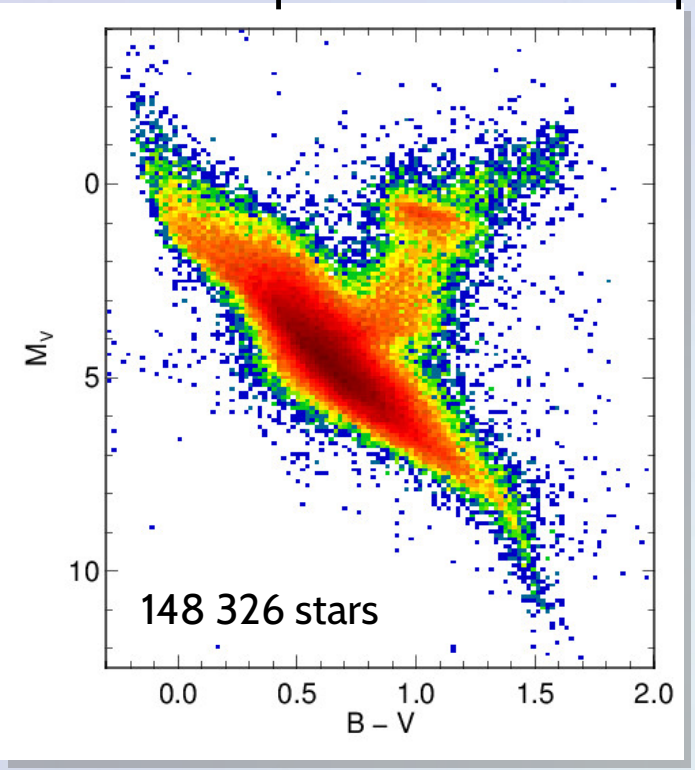




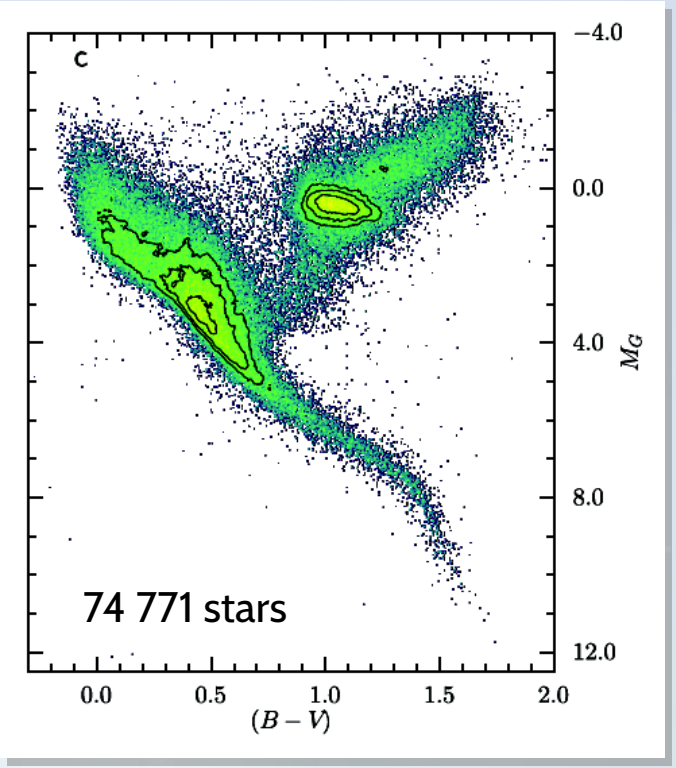


Resulting color-magnitude diagram

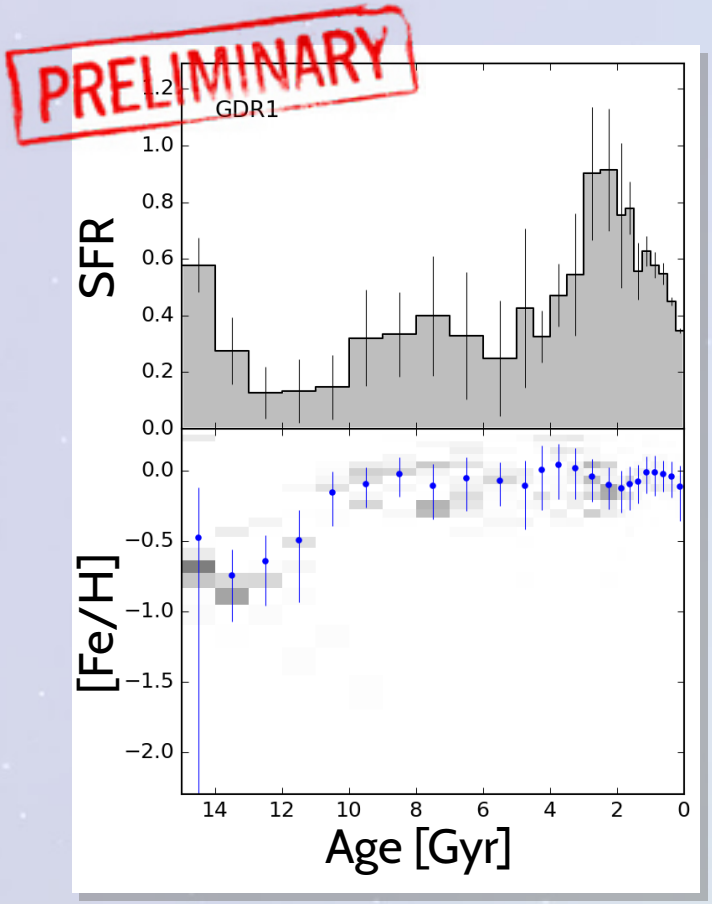
Gaia/*Hipparcos*/*Tycho*/APASS
"volume complete" within 250 pc



Gaia DR1 – *Hipparcos* sample

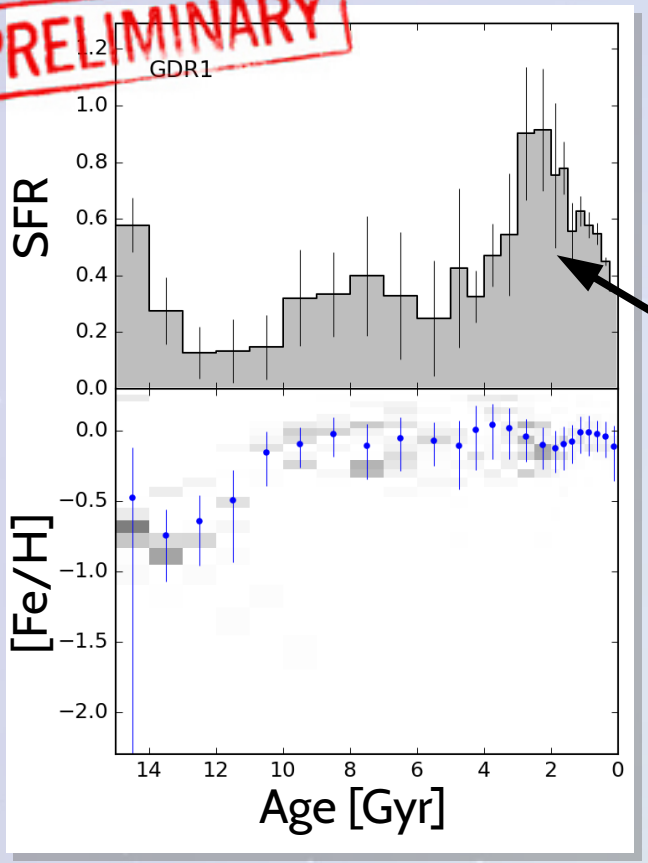


Star formation history of the disk in the solar neighborhood

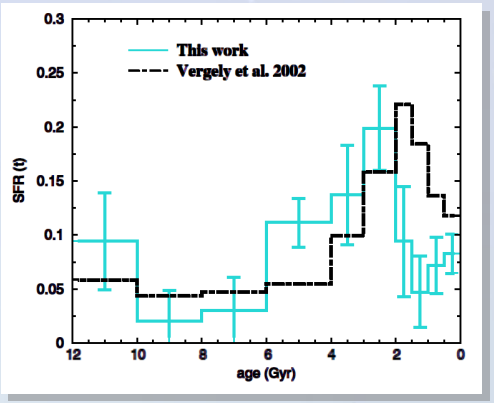


Star formation history of the disk in the solar neighborhood

PRELIMINARY

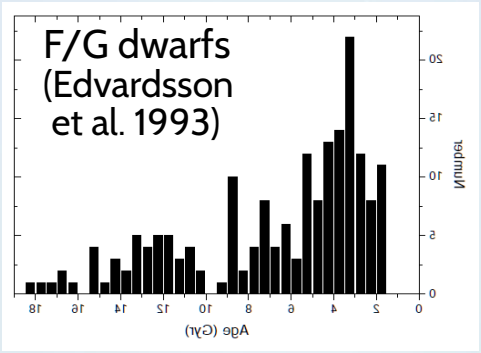


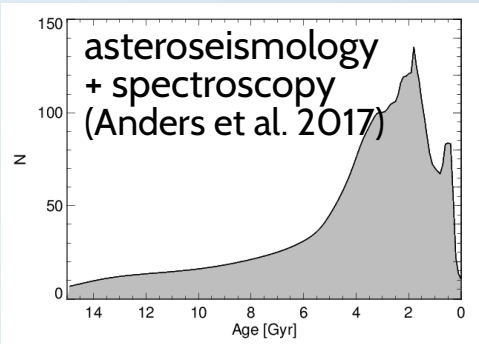
Fully consistent with SFH within 80pc from *Hipparcos*
(e.g. Vergely et al. 2002, Cignoni et al. 2006)



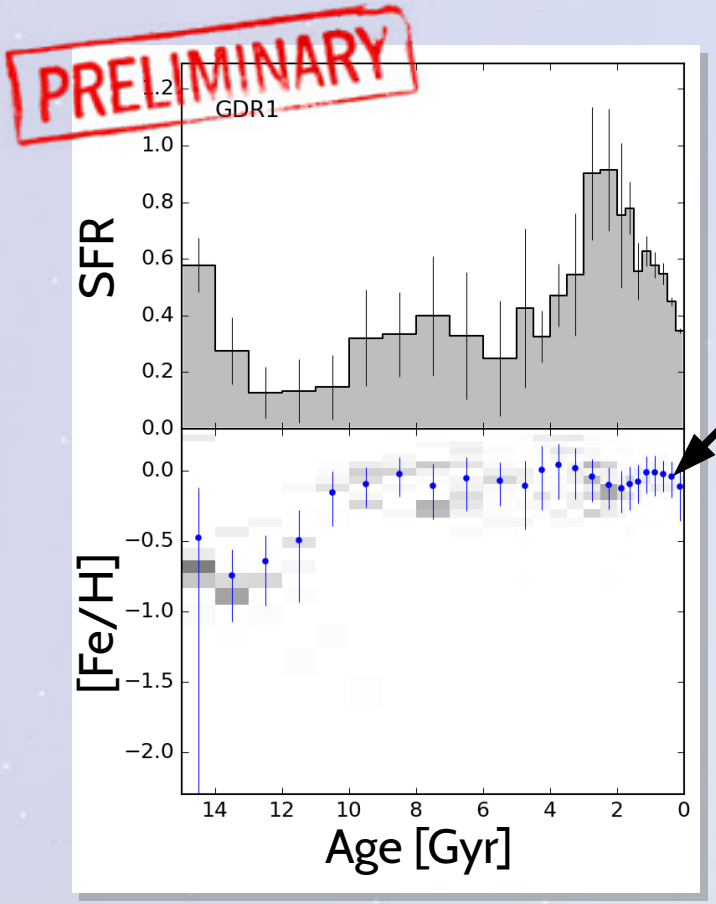
Cignoni et al. 2006

Excess of stars younger than ~4 Gyr

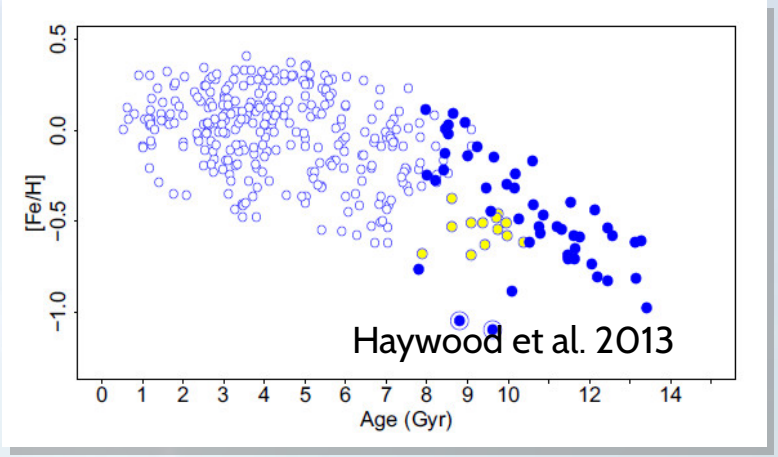




Star formation history of the disk in the solar neighborhood

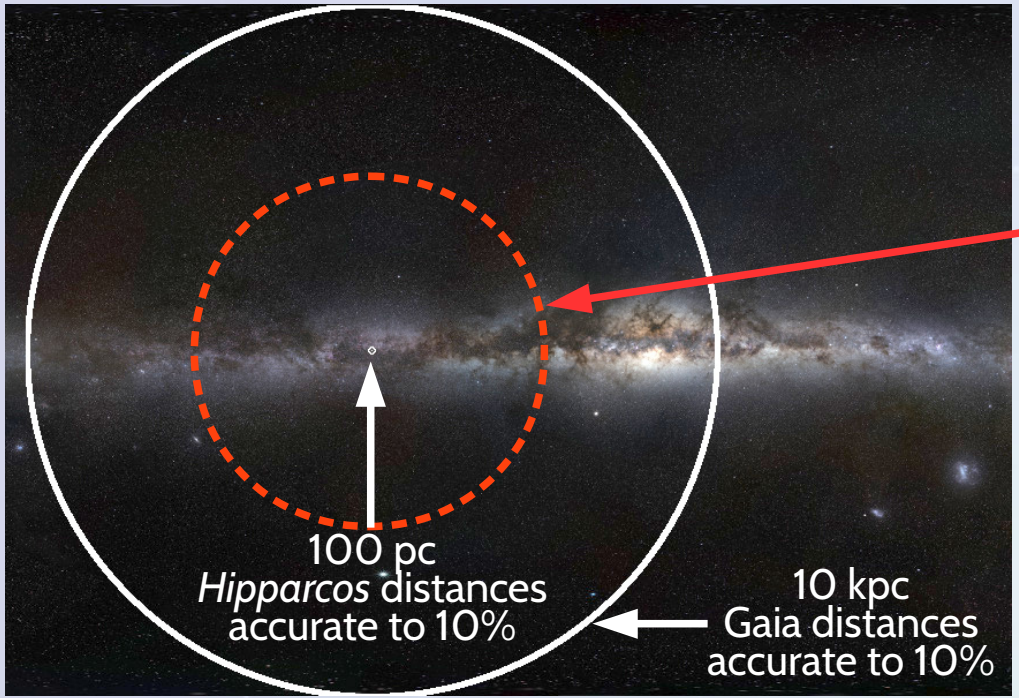


Flat age-metallicity relation in the past ~10 Gyr
→ consistent with e.g. Geneva-Copenhagen Survey



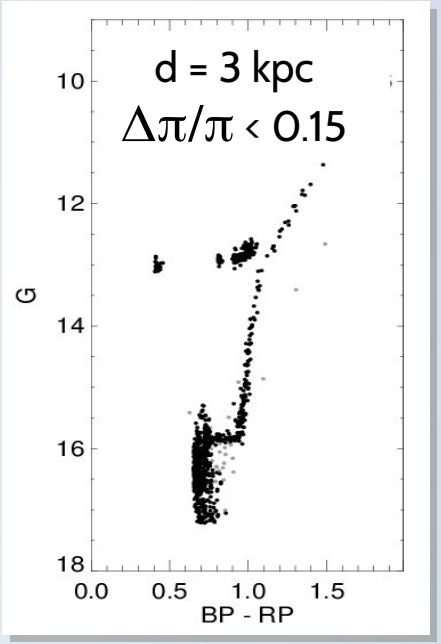
Beyond the solar neighborhood: Future Gaia Data Releases

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



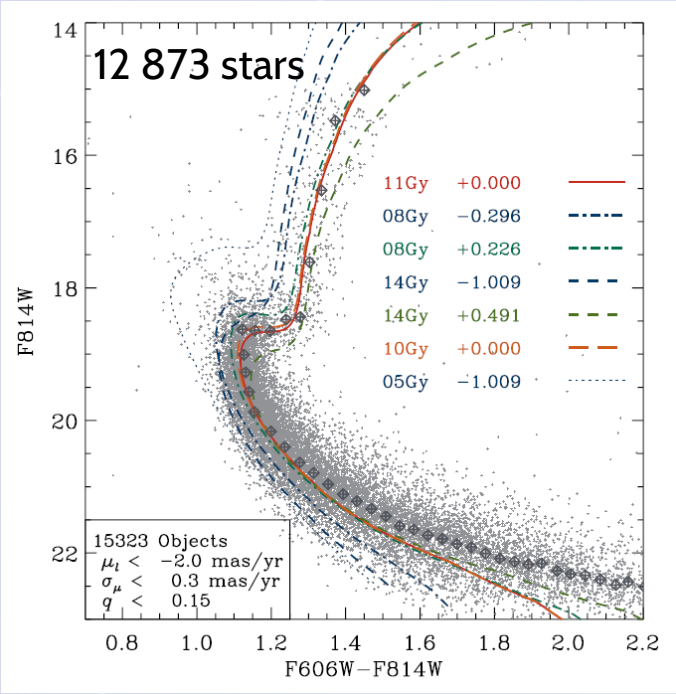
~5 kpc
Deep, complete
Gaia CMDs

Expected performances from
In-Orbit Commissioning Review



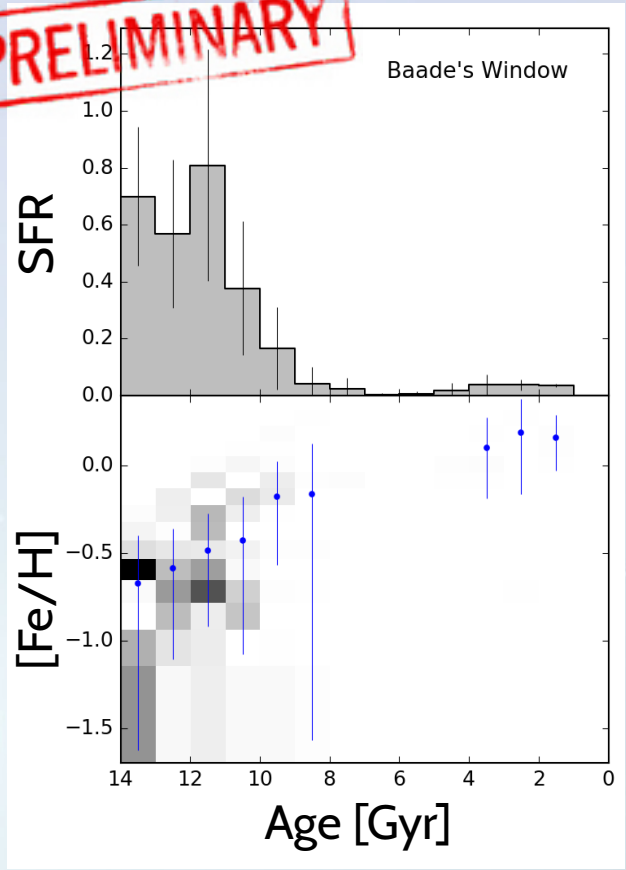
Star formation history of the Milky Way bulge from *HST* data

Proper-motion cleaned CMD of Baade's window



Clarkson et al. 2008

PRELIMINARY



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