Age-dating large samples of stars : the Gaia context

Céline Guédé, Yveline Lebreton, Carine Babusiaux, Misha Haywood
Gepi - Observatoire de Paris
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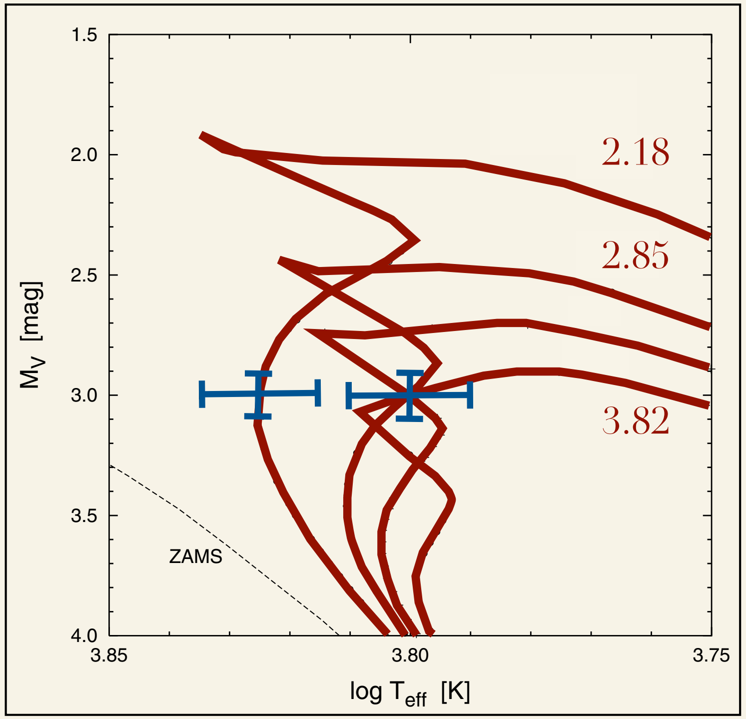
Introduction

- Importance of ages
  - Formation and evolution of Galaxy
  - Exoplanets : characterization, structure
- Methods based on stellar models
  - Adjustment with isochrones / evolutionary tracks
  - Asteroseismology
- Empirical methods

Age via stellar models

Observables : magnitude, effective temperature, metallicity

- Adjustment on isochrones/tracks : but degeneracy



Jorgensen & Lindegren (2005)

Bayesian estimation :

- $f(\tau, [Fe/H], m) \propto f_0(\tau, [Fe/H], m) \times L(\tau, [Fe/H], m)$
- PDF : f *a posteriori*, f_0 *a priori*
- Likelihood

$$L = \left(\prod_{i=1}^{n} \frac{1}{(2\pi)^{1/2} \sigma_i} \right) \exp\left(-\frac{\chi^2}{2} \right)$$

with $$\chi^2 = \sum_{i=1}^{n} \left(\frac{q_i^{obs} - q_i([Fe/H], m, \tau)}{\sigma_i} \right)^2$$

- Methods adapted and modified after Da Silva et al. (2006)

Choice of the a priori

- Models
  - Basti (Pietrinferni *et al.*, 2004), Padova (Girardi *et al.*, 2000)
  - tracks or isochrones
  - resolution of the grid
- Initial Mass Function (IMF)
  - Kroupa (2002)
- No metallicity distribution function (MDF)
- Stellar formation rate (SFR)
  - Flat between 0 to 14 Gyr, 0 elsewhere

Gaia simulated catalog

- Sample of 10 000 simulated stars, random selection of the :
  - metallicity (MDF), mass (Kroupa's IMF) and age (SFR) in the Basti grid

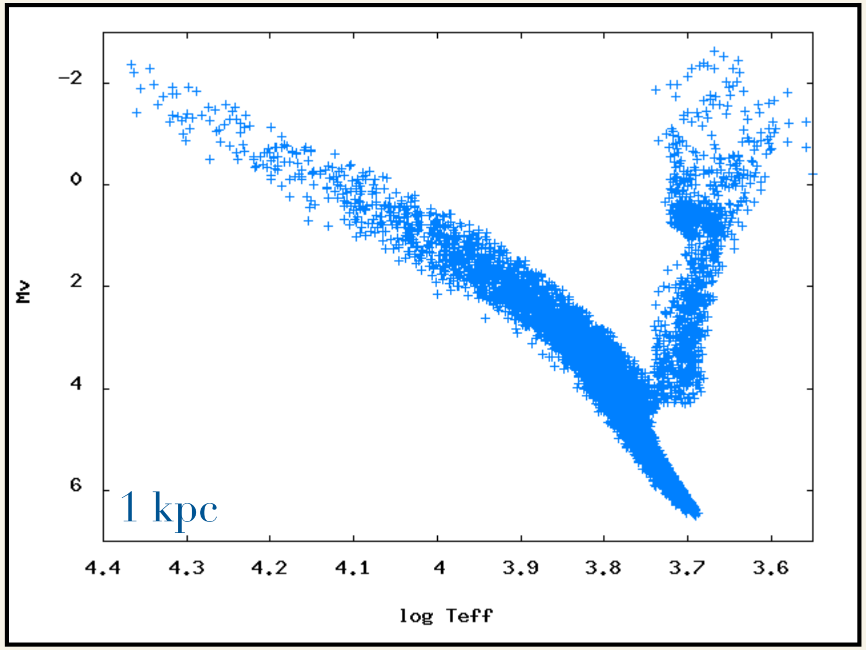
- Gaia "Star" specification
  - G>6
  - σ_π depends on G and (V-I)
  - $\sigma_G = \sigma_V = 10^{-3}$ mag
  - $\sigma_{T_{eff}} = 0.3\%$ at $G \leq 15$, rises linearly to $\sigma_{T_{eff}} = 4\%$ at G=20
  - $\sigma_{[Fe/H]} = 0.3$
  - $\sigma_{A_v} = 10\%$

Gaia simulated catalog

- Determination of σ_{M_V}

$$\sigma_{M_V} = \sqrt{\sigma^2_{m_V} + \sigma^2_{A_V} + \left(\frac{5}{\ln 10}\frac{\sigma_d}{d}\right)^2}$$

- Choice : keep star if $\frac{\sigma_\pi}{\pi} < 10\%$



Fixed distances or distances to particular objects :

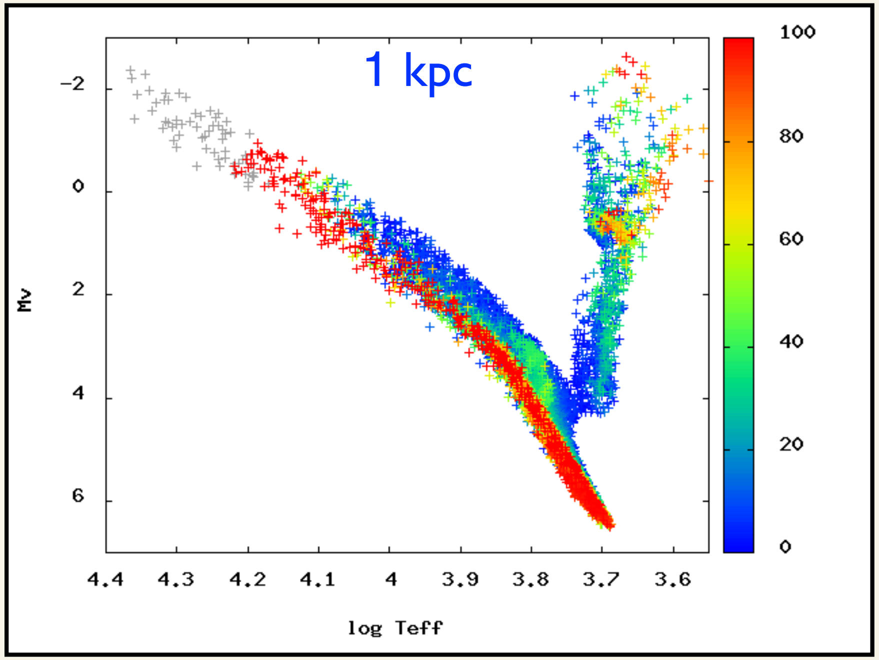
- 100 pc, 1 kpc and 10 kpc
- Hyades (46pc), Pleiades (135 pc) and NGC 6791 (4.1 kpc)

Comparison : "true" ages vs estimated

- Compare ages from inversion and "true" ages

From 1 kpc to 8 kpc

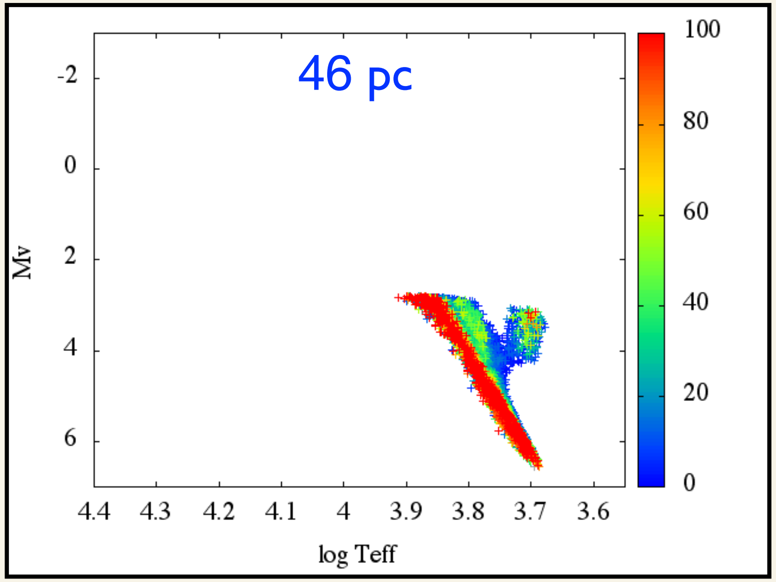
- 60 % of stars have $\frac{\sigma_\tau}{\tau} > 10\%$
- 3 problematic regions :
  - Close to the ZAMS
  - Massive stars in the upper MS
  - Red giant branch



Comparison : “true” ages vs estimated

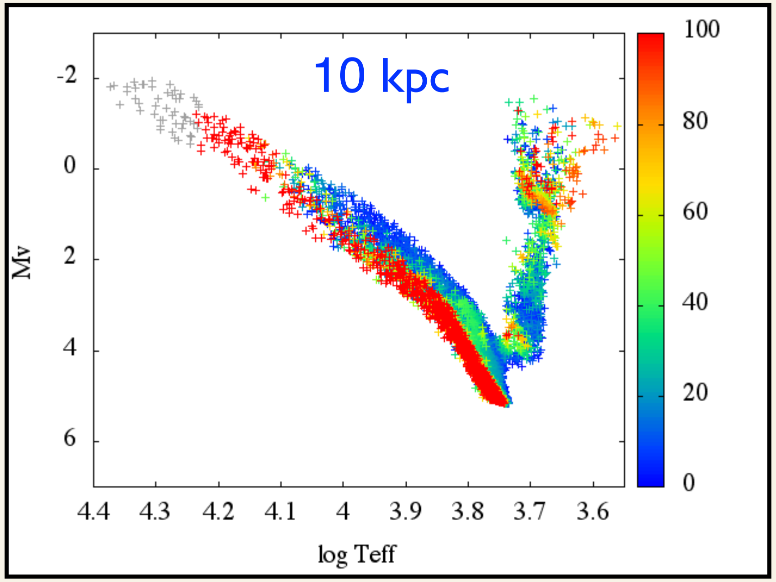
Less than 1 kpc

- 75 % of stars have $\frac{\sigma_\tau}{\tau} > 10\%$
- more stars in the bottom of the ms



Greater than 8 kpc

- 70 % of stars have $\frac{\sigma_\tau}{\tau} > 10\%$
- observational errors become large

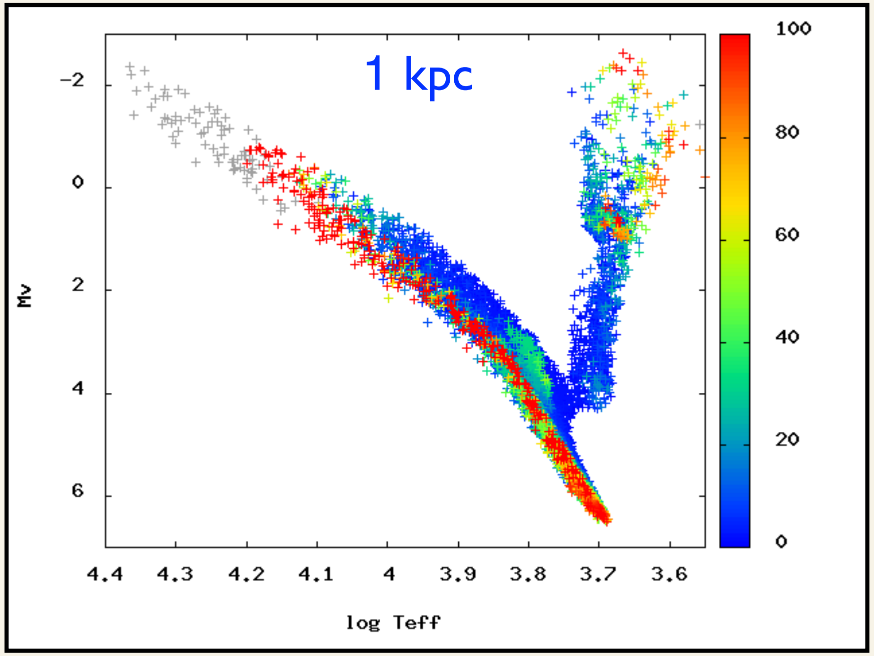


Comparison : "true" ages vs estimated

- With the complementary spectroscopic observation $\sigma_{[Fe/H]} = 0.1$

From 100 pc to 10 kpc

- 40 % of stars have $\frac{\sigma_\tau}{\tau} > 10\%$
- Great improvements close to the ZAMS and the RGB



Less than 100 pc

- 45 % of stars have $\frac{\sigma_\tau}{\tau} > 10\%$

Greater than 10 kpc

- 60 % of stars have $\frac{\sigma_\tau}{\tau} > 10\%$

Conclusion

- At less than 200 pc, Jupiter mass planets : Characterization of the exoplanets
- At less than 500 pc, open clusters
- Disk and the globular clusters :
  - Dating the Galaxy structure : Formation and evolution
  - Age-metallicity relation and stellar formation history
- Need a good accuracy on the metallicity

Comparison : “true” ages vs estimated

Distance	$\frac{\sigma_\tau}{\tau} > 10\%, \sigma_{[Fe/H]} = 0.1$	$\frac{\sigma_\tau}{\tau} > 10\%, \sigma_{[Fe/H]} = 0.3$
46 pc	44	75
100 pc	38	70
135 pc	37	69
750 pc	37	71
1 kpc	38	72
2.2 kpc	27	58
4.1 kpc	34	58
6kpc	43	63
8kpc	49	68
10 kpc	59	69