Mem. S.A.It. Vol. 86, 342

Memorie della

Stellar age-dating for different Gaia simulated catalogs

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Abstract. The determination of stellar ages is essential in many fields of astrophysics. For instance, it is used to understand the formation and evolution of the Galaxy. We focus on age-dating combining the observed position of stars in the HRD and stellar evolutionary models. Bayesian methods provide the most probable ages. We test the method on different simulated catalogs to test the precision of the method.

Key words. Stars: fundamental parameters - Methods: statistical - (Stars:) Hertzsprung-Russell and color-magnitude diagrams

1. Introduction

Stellar age determination is crucial for galactic evolution studies and many other fields of astrophysics. In particular, accurate ages are essential to establish the age metallicity relation and the stellar formation history. There are many methods to date the stars, we focus on the one based on stellar models which consists in adjusting the observed star on model isochrones or evolutionary tracks (Pont & Eyer 2004 and Jørgensen & Lindegren 2005).

2. Bayesian estimation

To date stars we use 3 observables: the effective temperature $T_{\rm eff}$, the absolute magnitude $M_{\rm v}$ and the metallicity [Fe/H]. The position of the star is adjusted in the HRD[1] by isochrones. The nearest isochrone corresponds to the age of star. The selection is difficult in some regions of the HRD[1] where the isochrones have a complex shape. We select the more probable age with a Bayesian estimation. The PDF[2] *a posteriori* is defined by

$$f(\tau, [\mathrm{Fe/H}], m) \propto f_0(\tau, [\mathrm{Fe/H}], m) \times L(\tau, [\mathrm{Fe/H}], m) \qquad (1)$$

with f_0 is the PDF[2] *a priori*. L is the likelihood, it determines the distance between the models and the star. We base our method on Da Silva et al. 2006's work to which we bring modifications. We have worked with evolutionary tracks (Basti, Pietrinferni et al. 2004) rather than isochrones, which reduces the number of interpolations and therefore the numerical errors. For the *a priori* we have userd a flat stellar formation rate (SFR, from 0 to 14 Gyr and 0 elsewhere), the initial mass function (IMF) of

[1] Hertzsprung-Russell diagram

[2] Probability distribution function

Kroupa (2002) and no metallicity distribution function (MDF).

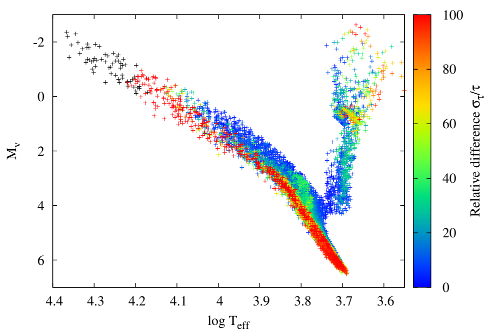

Fig. 1. HRD of the simulated catalog to 1kpc. The color indicates the percentage of the relative age difference. The stars in blue have a well-determined age and the stars in red have an ill-determined age.

3. Gaia simulated catalogs

We create a simulated catalog to test the determination of ages. We simulate a catalog of 10 000 stars representative of Gaia observations at a distance of 1 kpc. For this purpose we randomly take three parameters in the Basti grid: the metallicity in the MDF, the mass in the Kroupa's IMF and the age in the SFR. We only keep stars with apparent magnitudes greater than 6 which is the Gaia lower threshold. The observational errors are those expected from the Gaia mission: σ_π depends on G and (V-I), $\sigma_{T_{\rm eff}}$=0.3% at G≤15 mag and rises linearly to $\sigma_{T_{\rm eff}}$=4% at G=20 mag, $\sigma_G = \sigma_V = 10^{-3}$ mag, $\sigma_{\rm [Fe/H]}$=0.3 dex and $\sigma_{\rm A_V}$=10%. We have chosen to retain the stars with $\sigma_\pi/\pi < 10\%$. The catalog is represented in Fig. 1.

4. Age from HRD and [Fe/H]

We estimated the relative age difference (σ_τ/τ) between the estimated age and the real simulated one. It is less than 10% for 38% of the stars in the catalog. The stars are represented in Fig. 1 with their relative difference. The stars close to the ZAMS (Zero age main sequence), the massive stars in the upper MS (Main sequence) and the stars on the RGB (Red giant branch) have very ill-determined ages.

5. Complementary spectroscopy

With the complementary spectroscopic observations planned in the Gaia context, the observational error on [Fe/H] will decrease to 0.1 dex. We determine the ages of the simulated catalog considering error. We find 62% of stars with σ_τ/τ <10%. The age are improved for the stars close to the ZAMS and in the RGB.

Spectroscopic observations will yield the surface gravity. Adding this constraint to the dating, we find 66% of stars with σ_τ/τ<10%. The degeneracy is minimized in the RGB where the gravity varies a lot.

6. Different distances

We created several catalogs for different distances with $\sigma_{\rm [Fe/H]}$=0.1 dex. For d<100 pc, 55% of the stars have σ_τ/τ<10%. The constraint G>6 mag favours the stars in the bottom of the HRD, where the age degeneracy is high. For 100 pc<d<5 kpc, 60% have σ_τ/τ<10%. For d>5 kpc, 40% have σ_τ/τ<10%. The ages are poorly defined because of the large observational errors.

7. Conclusions

The Gaia mission will observe 1 billion of stars, the age-dating of these stars using three observables allows to correctly determine 38% of the ages. There is a degeneracy in 3 problematic regions: close to the ZAMS, in the upper MS and in the RGB. With better observational errors there are 62% of the stars with good ages. This improvement will be crucial to characterize the exoplanetary systems and to study the galactic structure and evolution.

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