Characterisation of the Gaia Red Clump

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Abstract

The Red Clump is a compact group of stars located in the giant branch which are burning helium in their core. They are known to have an absolute magnitude that fairly weakly depends on their age and metallicity, a peculiarity which makes them ***good distance indicators***.

Gaia will provide high precision astrometry, photometry and spectroscopy for a billion stars, allowing a very accurate characterisation of the properties of the Red Clump and a ***new calibration*** of this standard candle.

We are currently developping our method to calibrate the Red Clump on the Hipparcos catalogue, adding photometry from the Mermilliod and 2MASS catalogues, to cover wavelengths from the ultraviolet to the near-infrared. The calibration is being done by using the Padova isochrones and taking into account the extinction, the metallicity and the age factors. With the first release of the Gaia catalogue we will be able to give the ***Gaia G band calibration*** of the Red Clump.

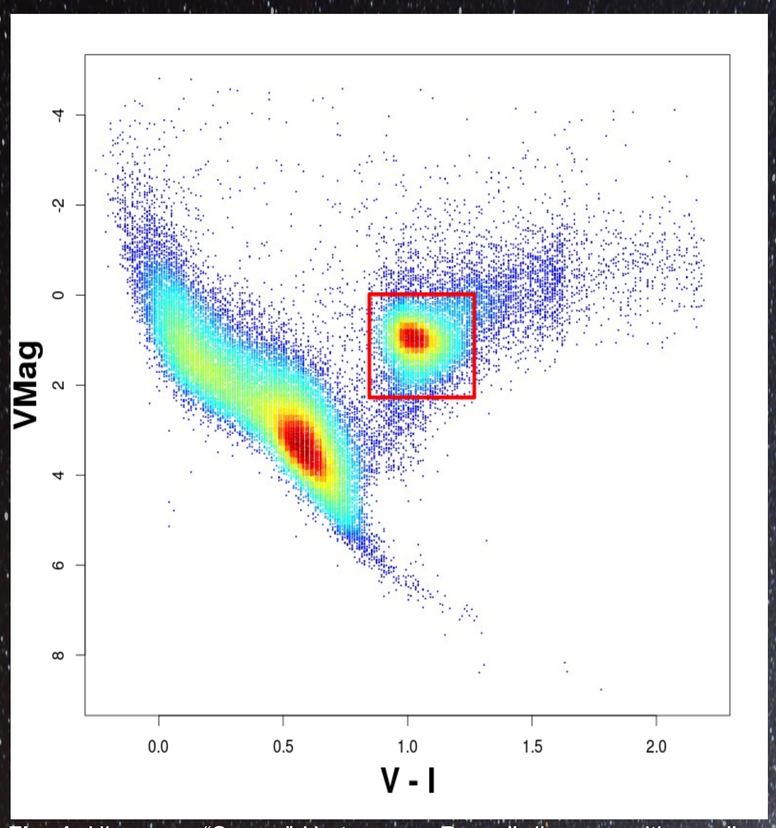


Fig. 1. Hipparcos "Survey" Hertzsprung-Russell diagram, with parallax precision <20%. Red Clump stars correspond to the overdensity region in the Giant Branch (red box in the top right side)

RC as standard candle

If we know how luminous a source is and how bright it appears we can know how far away it is. Such standard candles are used to study the spatial distribution of their home stellar populations.

Paczynski & Stanek (1998) found that the *I*-band absolute brightness *M*, of the Red Clump (RC) giants is almost insensitive to the intrinsic *V – I* colour, the age and the chemical composition of the stellar population, an important feature for an ***ideal standard candle for distance determination***. As remarked by Alves (2000) and Groenwegen (2008), an ***advantage of the RC*** as standard candle is its high number of stars within the solar neighbourhood: higher the number smaller the statistical error in distance calculations. However Girardi (1998, 2000) showed that for ***fine structures*** this dependence on V-I is not such negligible if we want the RC to be a useful distance indicator.

Several works already used RC stars to determine ***distances to large scale structures*** (Galactic Center and external galaxies, MW stellar population structure, Large Magellanic Couds,...).

The accuracy on these results strongly depends on the knowledge of the RC. A good understanding of their basic properties and a complete calibration is required.

Modelling of Hipparcos RC

To ***characterize the Hipparcos RC*** in terms of age and metallicity distribution, we use a synthetic stellar population code, similar to TRILEGAL (Girardi et al. 2005) but using the age-velocity dispersion relation as a constraint to the scale height of the populations as done in Just & Jahreiss (2010). The galactic disc is simulated as a sum of mono-age isothermal populations and the star positions are simulated by direct Monte-Carlo integration. The star physical parameters are taken from the Padova isochrones assuming by default a Chabrier 2001 log-normal Initial Mass Function (IMF), the Rocha-Pinto (2000) Age-Metallicity Relation (AMR) and a constant Star Formation Rate (SFR). The extinction model of Arenou (1992) is included. The Hipparcos astrometric and photometric errors are simulated.

We compare this simulation to the Hipparcos Survey H-R diagram in Fig. 2-4. Fig. 4. also shows the effect of changing the SFR on this simulation. It illustrates the work (in progress) which is still needed to properly understand the stellar population content of the Hipparcos RC.

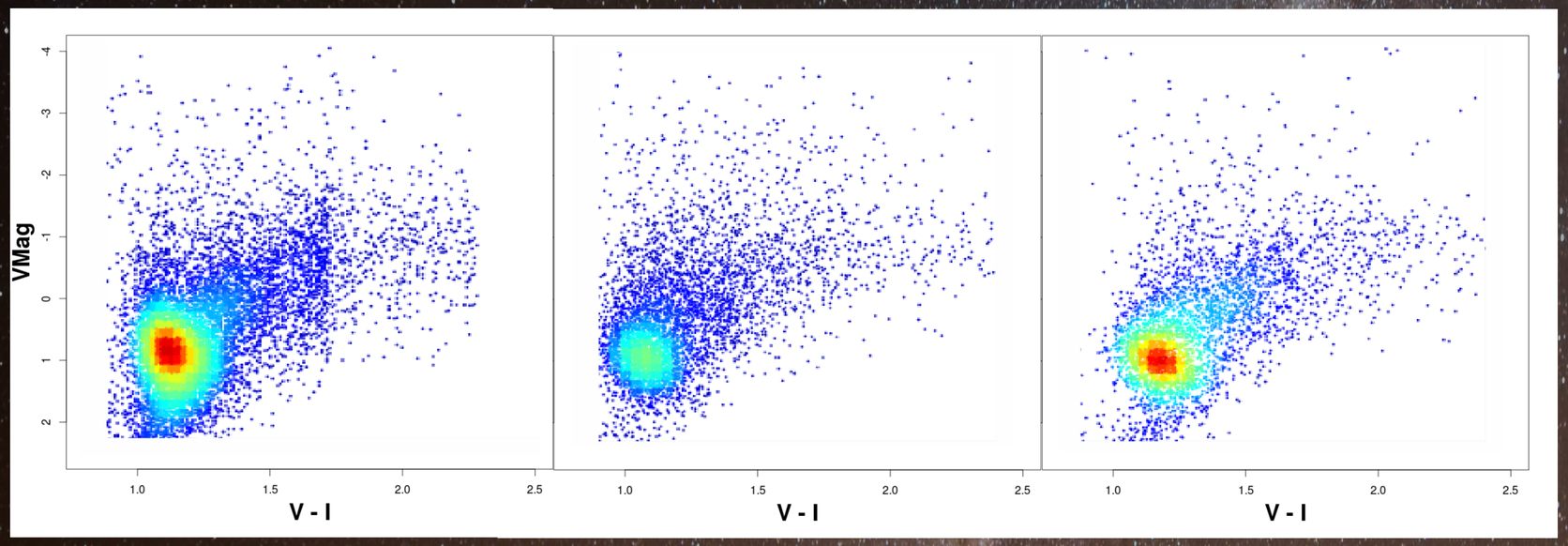
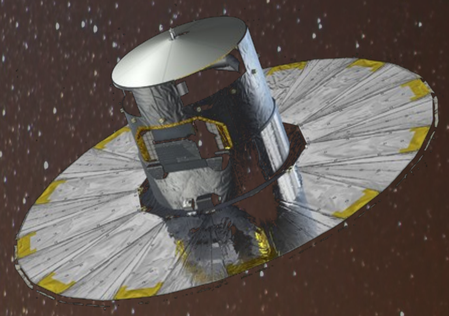


Fig. 2-4. Hertzsprung-Russell diagrams of RC stars.
From left to right:
(Fig. 2) Hipparcos "Survey"
(Fig. 3) Simulation default parameters (constant SFR)
(Fig. 4) Simulation with decreasing SFR



Calibration of Hipparcos RC colours

To ***calibrate the Hipparcos RC*** colours we use RC stars with parallax precision <20%, high photometric quality and single systems. We complete the Hipparcos photometric information with Mermilliod (UBV) and 2MASS (JHK) catalogues. A sample of 610 stars is obtained, with a subgroup of 54 with known metallicity.

Atmosphere models are one of the most important ingredients when simulating the colours of a population of stars. As illustrated in Fig. 5. with ATLAS models used in the Padova isochrones, this "ingredient", as we know today, do not allow us to get a good colour-colour relation. Other atmosphere models (MARCS, PHOENIX) as well as variations of age and metallicity have also been tested with the same result.

The method we are developing aims to derive an ***empirical calibration*** by taking into account the extinction, the age and the metallicity parameters. The calibration covers all bands from the ultraviolet to the near-infrared.

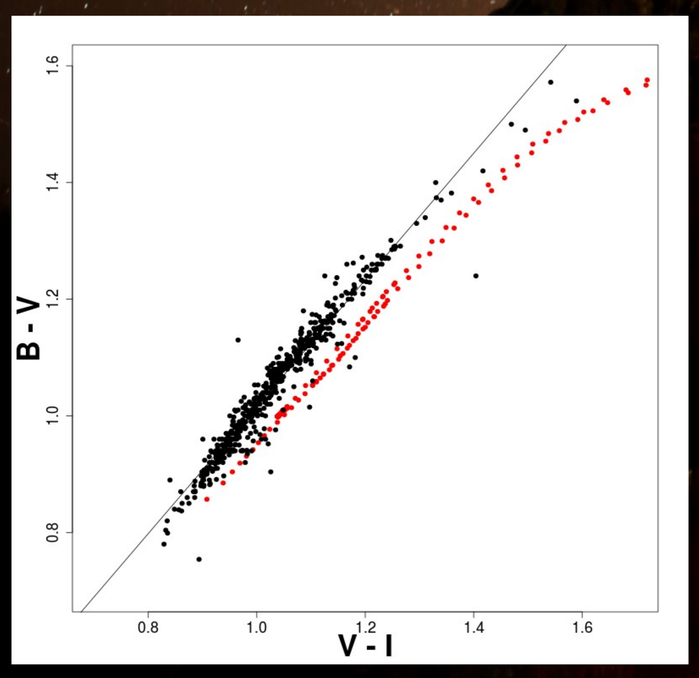


Fig. 5. B-V vs V-I colour-colour diagram of the 610 Red Clump sample. The Padova isochrone added (in red) correspond to an isochrone with a median age of 2Gyr and a median metallicity of 0.0 obtained by the simulation. Only the Red Giant Branch and the Early Assymptotic Giant Branch are shown

GAIA and the RC

Gaia will provide high precision information for Red Clump stars. From the ***First Data Release*** we will use our method to model the Red Clump within the G band. And at the end of the mission, with the ***Final Catalogue***, the improved parallaxes and photometry will allow us to re-model the Red Clump with higher accuracy and therefore get a better knowledge and understanding of this population of stars. Moreover the high number of stars will allow to subgroup the RC in terms of different parameters as metallicity, galactic positions,...: the ***RC Gaia will not be unique*** as in Hipparcos (Fig 7-8).

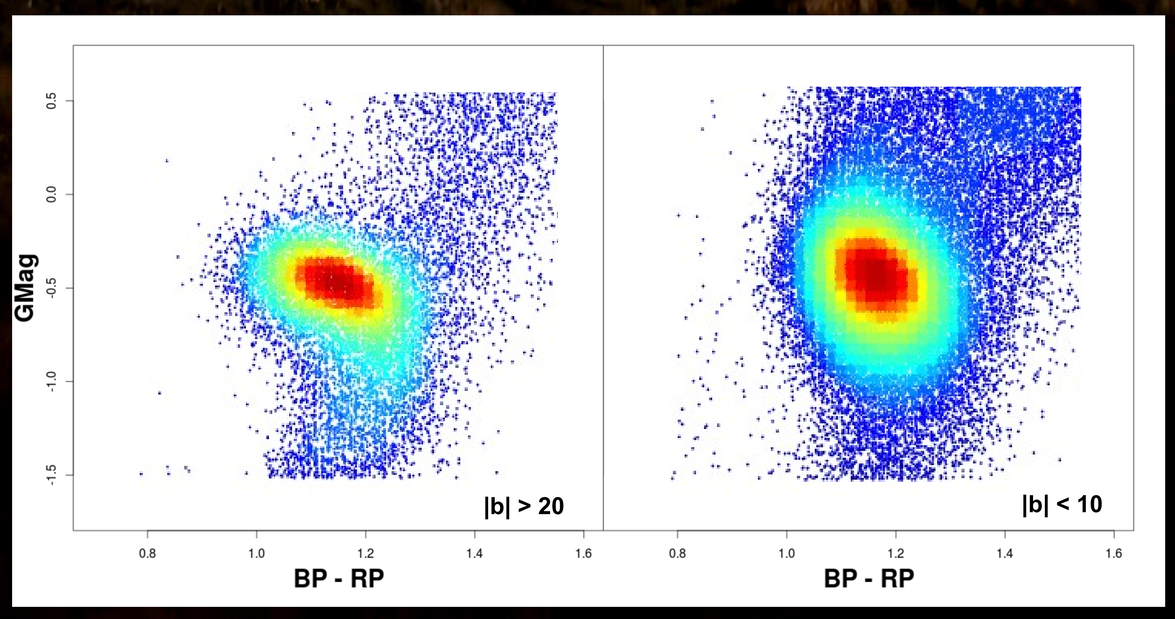


Fig. 6-7. Simulated Gaia Hertzsprung-Russell diagram of RC stars with parallax precision <10%.
This illustration shows the differences of shape as a function of the stellar population.
Left (Fig. 6): high latitudes, |b| > 20. Right (Fig. 7): low latitudes, |b| < 10

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