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TESTING STELLAR STRUCTURE AND EVOLUTION WITH GAIA *

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Abstract. It this note we briefly summarize a few relevant topics of stellar structure and evolution which will greatly benefit from *Gaia* observations.

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1. INTRODUCTION

The *Gaia* database will allow the derivation of accurate color-magnitude diagrams (CMD) for stars in the Galaxy. These diagrams, however, will not be restricted just to the immediate solar vicinity, as it was in the case of *Hipparcos* (see Bertelli et al. 1999).

2. STELLAR STRUCTURE AND EVOLUTION

The potential contribution of *Gaia* data to our understanding of stellar structure and evolution can be foreseen by means of a simple look at the results from *Hipparcos* (Perryman et al. 1995).

If we limit the *Hipparcos* data to an accuracy of $\sigma_\pi/\pi < 0.1$ (i.e., with accuracy in absolute magnitude of $\sigma(M_V) < 0.22$ mag), we have a M_V vs. $(B{-}V)_0$ diagram for about 19 100 stars. Reliable I-band photometry is also available for about 15 percent of them.

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This sample is complete only for $M_V \leq 3.5$ mag, i.e. for the about 9400 stars above the luminosity level of the oldest subgiant branch present in the CMD, which then defines the useful subsample for the study of evolved stars.

This database allowed the identification of a number of fine features in the CMD of nearby stars, which up to now were observable only in the closest Local Group galaxies (especially in the Magellanic Clouds) by means of HST WFPC2 observations. These features are e.g. a wide main sequence band with clearly defined red and blue edges; a well-defined band of subgiant and red giant branch (RGB) stars; a striking clump of red giants, located slightly to the blue of the RGB and containing substructures at its bluest extremity, like a faint secondary clump and a bright tail (Girardi et al. 1998, Beaulieu & Sackett 1998); and a faint concentration of RGB stars about 1 mag above the red clump, which would correspond to the clump of early-AGB stars. Some of these structures constitute already a nice confirmation of the predictions of stellar evolution theory (see Chiosi 1999 for a recent review and references).

The number ratios between the stars in these features provide constraints to both history of star formation in the solar vicinity, and the mixing processes in stellar interiors (see Chiosi 1999). For instance, the number ratio between stars in the red clump and in the main sequence (at suitably selected ranges of magnitudes) decreases with the amount of convective overshooting from stellar cores during the central H-burning phase, while the number ratio between stars in the red clump (core He-burning) and in the early-AGB is sensitive to the phenomena like convective overshooting, semi-convection and the *breathing pulses* of convection. The *Hipparcos* data provide significantly better number statistics than those obtained from star counts in CMDs of open clusters. However, they present a complicating factor since stars of different ages (initial masses) and metallicities are mixed together in the CMD. The requirement of having complete and accurate samples limit the analysis of number ratios to the stars in the immediate solar vicinity (less than 100 pc away).

Therefore, taking full advantage of *Hipparcos* data in order to constrain stellar models is not trivial. However, the situation will improve considerably in the *Gaia* database. First of all, the useful sample will extend up to much larger distances. For instance, for G8 subgiants in the absence of extinction a parallax accuracy of 10% will be reached at about 3.1 kpc, in comparison with < 100 pc for *Hipparcos*. Up to this distance, complete CMDs will be constructed down to $M_V \approx 4.5$ mag, therefore including all evolved subgiant and giant stars. Of course, the extinction along the disk will reduce this distance estimate significantly. However, it is clear that *Gaia* will provide complete and accurate CMDs extending out to kpc scales and containing millions of evolved stars (see Bertelli et al. 1999).

3. CMDs FOR THE DISK POPULATIONS

Gaia database will also allow the construction of CMDs for different regions of the disk, or for different kinematical groups of stars. In this way, even subtle effects such as the metallicity gradient in the disk, will probably be noticed in the CMDs by detecting changes in both the CMD morphology and in stellar number ratios from place to place. The accurate CMDs will include thousands of times more stars than now, allowing excellent number statistics. Stars in very fast phases of evolution (e.g. in the Hertzsprung gap of intermediate-mass stars, or during the He-flash of low-mass stars) will probably be identified by their peculiar position in the HR diagram, allowing for the first time an empirical estimate of their lifetimes, to be compared with those derived from theoretical models. Moreover, multicolor photometry will allow also the derivation of additional stellar parameters, like metallicity, which are completely absent in the *Hipparcos* database.

4. DISTANCES AND HELIUM CONTENT

Another important possibility of *Gaia* will be the measurement of distances accurate to 1 % for about 30 open clusters of different ages and metallicity. Although most of these objects have been extensively studied and compared with stellar evolution models, knowing their distances with this accuracy will allow the unprecedented possibility of testing helium content Y adopted in the models. In fact, Y is known to shift the zero-age main sequence vertically in the HR diagram, independently of the assumed metallicity, an effect which would be easily noticed in the cluster CMDs. So far, stellar models usually assume a fixed and linear shift in order to describe the metal-to-helium ratio. This assumption is based more on simple theoretical arguments than on direct observational evidence.

Of course, the disk CMDs may provide useful information only if the magnitudes and colors of individual stars are properly corrected for interstellar extinction. The multicolor photometric system of *Gaia* is expected to provide good estimates of this parameter. Another important aspect is the possibility of eliminating multiple stars from the CMDs, since most of them will be identified from the kinematical properties measured by *Gaia*.

5. STAR FORMATION HISTORY

Gaia multicolor photometry and low-resolution Ca II line spectroscopy will allow a preliminary separation of stars according to their metallicities. Therefore, color-magnitude-metallicity diagrams, giving new possibilities, may be constructed. For instance, once the stellar metallicity is known, the location in the CMD of low- and intermediate-mass stars depends essentially on their present masses and evolutionary stage. Especially for subgiants, RGB and clump stars, the mass (and hence age) can be directly derived from the CMD position. This will allow detailed studies of star formation history in different regions of the disk, for ages ranging from about 0.5 to 15 Gyr. For younger stars, the same information can in principle be obtained from the luminosity function of main-sequence stars.

Studies of star formation history, based on the Local Group galaxies and using the ground-based or HST data, have given reliable results in some cases. The huge amount of data provided by *Gaia*, however, will require the development of new automated codes capable of extracting the information about star formation rate and chemical enrichment history in automatic way, using objective statistical tests and unbiased models in order to find the best solutions. Suitable codes of this kind are now being developed for the analysis of the large photometric databases provided by the micro-lensing search experiments (*Macho, Eros* and *Ogle*). In the coming years, such codes will probably be tested and improved enough to be useful for the analysis of the *Gaia* database.

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