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Gaia & SSP libraries for Local Universe study

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Abstract. We present the contribution that Gaia will offer to un-resolved stellar population studies. We start presenting the set of synthetic stellar libraries, computed ad hoc for Gaia, that we implemented in a SSP code using different set of isochrones and IMF. We illustrate the possible use of the resulting large set of SSPs in the analysis of systems far beyond the purposes of Gaia.

Key words. Stars: abundances – Stars: atmospheres – Galaxies: abundances – Galaxies: star formation

1. Gaia: setting the framework

ESA's Gaia mission (Perryman et al. (2001), launch in Sept. 2013) in it's 5 year lifetime will obtain accurate magnitudes, positions, parallaxes and proper motions for 10^9 sources all over the sky, up to magnitude G=20 (V=20-22). The vast majority of these sources belong to our Galaxy, resulting in an incredibly accurate map of our home, which was long missing. For all stellar sources, their atmospheric parameters ($T_{\rm eff}$, $\log g$, [Fe/H]) will be part of the final catalog, together with the measure of the line-of-sight extinction. This will be achieved using the low resolution spectra measured by the BP/RP spectrograph, together with the higher resolution spectra provided by the Radial Velocity Spectrometer (RVS, $R_{\rm PS}\sim$ 11 500, for $G < 16.5$). Extragalactic sources will be observed too, with a foreseen harvest of 500 000 QSOs (Bailer-Jones et al. 2008) and approximately 10^6 unresolved galaxies (Kontizas et al. 2011).

A set of parameters will be derived, to properly characterize these extragalactic sources (for galaxies, the redshift and some parametrization of the Star Formation). For details on the mission and on the instrumentation, see Wilkinson et al. (2005) and Jordi et al. (2010).

Automated algorithms will deal with the complex task of the object-by-object characterization of this amount of sources. Whatever the source or the specific algorithm, they all require training data. Here we focus on stellar sources.

2. Spectral libraries for Gaia

A large effort was triggered in the european scientific community to provide state-of-the-art synthetic stellar libraries, including the most up-to-date knowledge of the dominant physical effects according to the stellar type: e.g. NLTE+rotation in early-type stars, atomic diffusion in late-B/A/early-F stars, molecular

Table 1. The set of libraries implemented in the present work: UCD: F. Allard (priv. comm.); PHOENIX (Brott & Hauschildt 2005), MARCS (Gustafsson et al. 2008), OB (Bouret et al. 2008), A (Kochukhov & Shulyak 2008), MUNARI (Munari et al. 2005). The range of $T_{\rm eff}$, $\log g$, [Fe/H] explored by the libraries is indicated.

	$T_{\rm eff}$	$\log g$	[Fe/H]
UCD	400−3000	−0.5−5.5	−4.0 − +0.5
PHOENIX	3000−10000	−0.5−5.5	−2.5 − +0.5
MARCS	4000−8000	0.0−5.0	−5.0 − +1.0
OB-Tlusty	15000−55000	2.0−4.75	+0.0
A-Kochuhov	6000−16000	2.5−4.5	−1.5 − +0.5
Munari	3500−50000	+0.0−5.0	−2.5 − +0.5

opacities in late type stars, etc. With this purpose, i.e. the best possible reproduction of our knowledge of stars, different grids of synthetic spectra are produced using different codes, optimized to specific regions of the HR diagram and extensively tested by providers themselves and/or by the whole community.
Different codes can be available for a given stellar type: overlap is encouraged, to avoid/map systematics due to the specific model of choice. The differences are due to computational input (e.g. atomic line lists, chemical composition...) and/or in the treatment of physical processes (mixing length, mass loss...).

This effort ends up with a very unique set of synthetic stellar libraries, covering the HR diagram with narrow spacing in the parameter space ($T_{\rm eff}$, $\log g$, [Fe/H]), in the same wavelength range. The libraries cover the BP/RP range (300−1100 nm) at 0.1 nm/pixand the RVS range (840−870 nm) at 0.001 nm/pix.
The complete set of libraries have been presented in a series of works, see for example Sordo et al. (2010) and reference therein. We here list only the subset of libraries used in this work, as listed in Tab. 1 with a brief description.

Together with this on-purpose computed library, the Munari et al. (2005) synthetic stellar library was and is used by the Gaia community in preparatory works for the mission (Zwitter, Castelli, & Munari 2004). This is a large, high resolution library computed from Kuruczs ATLAS9 NEWODF model atmospheres (Castelli & Kurucz 2004), covering the entire HR diagram for normal stars. Its implementation in PEGASE-HR (Le Borgne et al. 2004) is under development.

3. Single Stellar Population database

The comparison among the Gaia spectral libraries have been presented in several articles (see Sordo et al. (2011) and reference therein), the key point being that, despite the differences among the libraries they agree quite well except in the very low $T_{\rm eff}$ regime, with differences of course increasing in the blue, crowded part of the spectrum. For $T_{\rm eff}$ higher than ∼5000 K, the agreement is quite satisfactory. This makes possible to mix them, with some caution, into a Single Stellar Population (SSP) code.

In a SSP, all stars are coeval and share the same initial chemical composition. According to the stellar mass (through the Initial Mass Function, IMF) and to the metallicity, an isochrone regulates their behavior of the bulk of stars in the HR diagram, fixing the location and the relative proportion of objects. The $T_{\rm eff}$, $\log g$, [Fe/H] are thus fixed by evolutionary theory. The coupling with synthetic stellar spectra is the missing step to enable the direct comparison with the observed spectral properties of single or complex populations (through

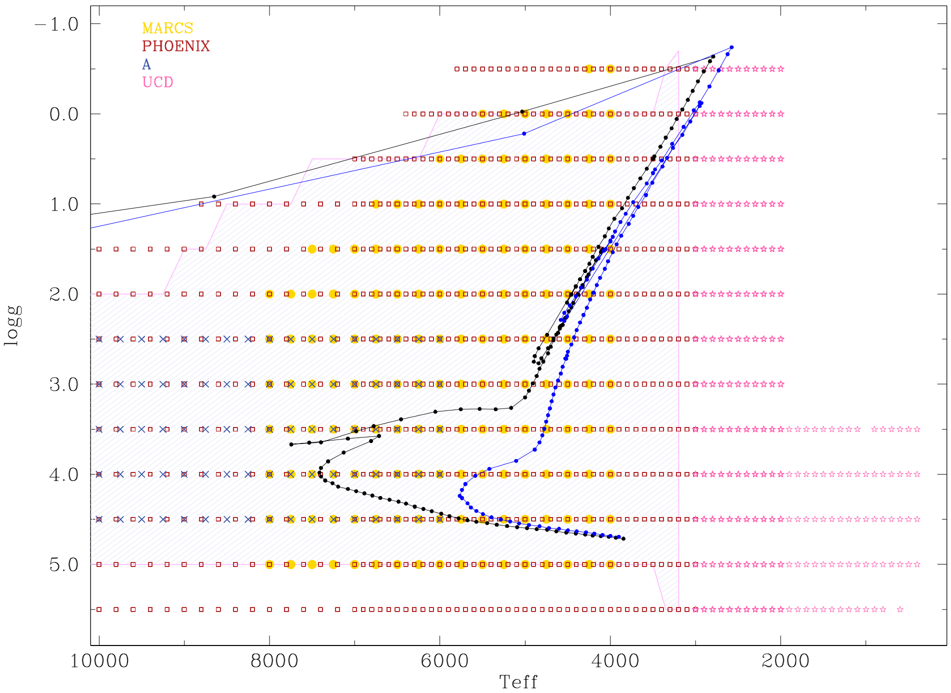

Fig. 1. Coverage of the set of libraries implemented in our SSP code, color coded. Shaded in light blue, the coverage of the Munari et al. (2005) library. The parameter space is here restricted to $T_{\rm eff} < 10\,000$ K. Two isochrones are superimposed, at 1 and 10 Gyr (Girardi et al. 2000)

an additional Star Formation History hypothesis). We quote among others Fioc & Rocca-Volmerange (1997); Vallenari & Sordo (2011); Tsalmantza et al. (2012).

We implemented in our SSP code Tantalo (2005) the stellar libraries presented in Table 1, their coverage in the HR diagram being sketched in Fig 1. The mixing of different libraries can introduce boundary effects, at lower temperature or at lower gravities. A careful analysis and detailed comparison was always taken into consideration (Sordo et al. 2009, 2011), avoiding unnecessary mixing but encouraging diversity: the availability of different sets of SSP, with different ingredients (isochrones, IMFs, stellar libraries) can help investigate the impact of the single ingredients on the results of the comparison with observations, allowing an error estimation.

As anticipated, we implemented different set of IMF recipes and different isochrone set, namely: Girardi et al. (2000), Marigo et al. (2008), Pietrinferni et al. (2006). The inclusion of the BASTI isochrones allows to consistently explore the α-enhancement effects on the integrated spectra, allowing a more suitable analysis of populations with different SFHs.

The database of SSPs can be used in full spectrum fitting softwares or in the comparison with broad band color observations or color indexes, or can be implemented in softwares for the analysis of complex populations like galaxies. All those possibilities, the validation of the SSPs and torough tests are fully described in

Tantalo et al. (2013). The database will be open to the community.

4. Conclusions

We presented the purposes of a new database of Single Stellar Population spectra, triggered by the availability of large, complete and up-to-date libraries of stellar spectra, computed for the Gaia mission.

Even though the impact of Gaia on the characterization of extragalactic sources is of somehow limited impact (no metallicity information, for example), the Gaia stellar libraries can and must be intensively used to extend our ability to derive information on the un-resolved stellar populations which can be observed at relatively high resolution nowadays, requiring high resolution SSP models for a meaningful analysis.

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