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Reconstruction of Gaia BP/RP spectra in crowded fields

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Abstract. Gaia will produce a catalogue of 1 billion of Milky Way stars, along with huge number of extragalactic and solar system's objects, changing drastically our vision of the sky. The photometric cameras will supply low resolution spectra (from 3 to 29 nm/pixel) in two bands, BP (300-660 nm) and RP (650-1000 nm) for all targets with magnitude $G < 20$. This means that a large fraction of observed stars will be crowded. In this context, the development of an algorithm for the deblending of crowded images is a fundamental task and a real challenge.

Key words. Stars: abundances – Stars: Population II – Galaxy: globular clusters – Stars: Population I –Galaxy: abundances – Cosmology: observations

1. Introduction

Gaia's photometric camera will supply low resolution spectra provided through two different prisms for two channels: the "blue" one (300-660 nm) and the "red" one (650-1000 nm). The dispersion of the prisms ranges from 3 to 29 nm/pixel for the blue channel, BP, and from 7 to 15 nm/pixel for the red channel, RP. Data will be sent in windows 60 X 12 pixel wide (Along Scan X Across Scan) centered around the sources with a sampling different for bright and faint sources: bright sources ($6 < G < 13$) will be sent to ground in two dimensional windows, faint sources ($13 < G < 20$) in one dimensional window 60 pixel wide. With such sampling we expect most of the data will be sent to us in one dimensional windows.

These spectra will be used to derive astrophysical parameters (such as temperature, metallicity, gravity and interstellar absorption) for about 1 billion stars of the Milky Way, thus shaping a new, exciting vision of our Galaxy.

2. Task and approach

It is well known that the overall morphology of stellar spectra is a function of:

1) Temperature (Teff)
2) Metallicity ([M/H])
3) Gravity (logg)
4) Interstellar absorption (Av)

Send offprint requests to: G. Giuffrida (see Fig. 1) although they also depend on a number of additional parameters as optical distortion, charge transfer inefficiency (due to radiation damage), variation of the dispersion curve of the prisms, cosmic rays, gates and several others. With all these variable parameters the morphology of these spectra are indeed difficult to predict or to model: in particular the astrophysical parameters remain unknown for a large fraction of the stars. Even worse, considering the dispersion along-scan of the spectra, the superimposition of two field of views, and the large stellar density in many regions of the sky, overlap of stellar images will often occur. To obtain reliable values for the astrophysical parameters, an efficient algorithm capable to separate overlapped BP/RP fluxes is mandatory, otherwise we will not be able to acquire useful information for millions of stars.

Briefly, deblending BP/RP spectra in crowded fields is therefore a fundamental task and a real challenge.

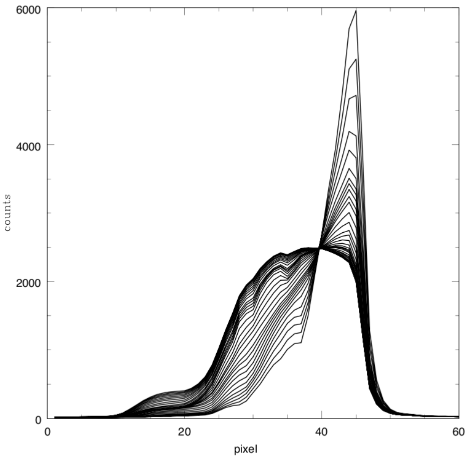

Fig. 1. Series of BP Gaia theoretical spectra with [M/H]=0.00 and $3500 < T_{eff} < 20000°K$;

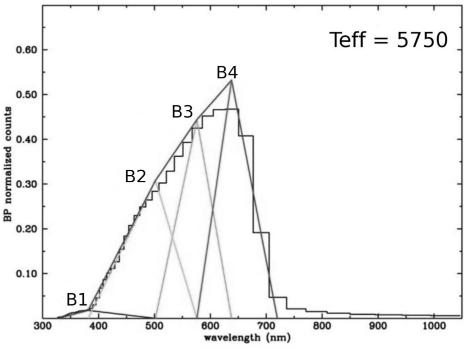

Fig. 2. Shape coefficients for BP spectra;

2.1. Deblending algorithm

We developed a software within the GAIA pipeline which, using a numerical best-fit of a grid of templates to the observed spectrum, performs the deblending at the same time for the BP and RP channels. Both templates and raw data are simulated using GIBIS (http://gibis.cnes.fr).

3. Our approach: the Shape Coefficients

Following the recent DPAC (Data Processing and Analysis Consortium) guidelines, the BP/RP spectra will be parametrized adopting the "Shape Coefficient".

In this frame, a given BP/RP spectrum E(λ) is approximated as

$$E(\lambda) \approx \sum_{i=1}^{4} S_i B_i(\lambda) \tag{1}$$

where the quantities S_i are the "spectrum shape coefficients". The normalization of these coefficients is such as that they sum to 1. The values of S_i are determined thought least square fits of the B-splines to the data E(λ). In this way each BP or RP spectra is identified by a set of only four parameters (see Fig. 2).

In Fig. 3 we plotted the behavior of the coefficient in respect to the effective temperature (K) for the BP spectra (RP spectra is not shown since it present a similar behavior). It can be immediately observed that the sensibility of such coefficient to a fixed variation in effective temperature is larger for the colder stars (lower effective temperatures) and it becomes detectably smaller for hotter stars. As a consequence, we cannot determine with high

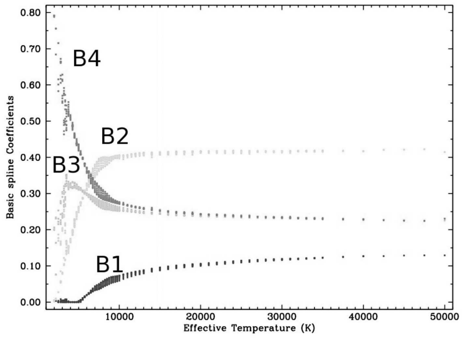

Fig. 3. The 4 shape parameters (BP spectra) versus T_e;

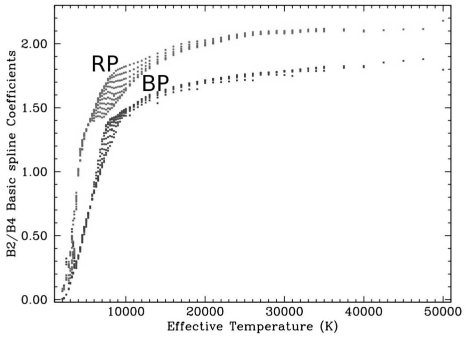

Fig. 4. B_2/B_4 versus T_e for both BP and RP colours;

precision the temperature of hot stars: this reflects the fact that the difference between spectra became smaller for higher temperature, and is also confirmed by our Fig. 4, where the behavior of the ratio of B2/B4 (the most sensitive to temperature variation) spline coefficient is shows, this time for both BP and RP colours: as a matter of fact, for temperature larger than about 30.000 K the ratio keeps almost constant.

During the firsts cycles the accumulated spectra will be parametrized with these coefficients, while astrophysical parameters will be calculated only in a second moment. We are now working on a algorithm of selection able to select template spectra using such ”shape coefficients“.

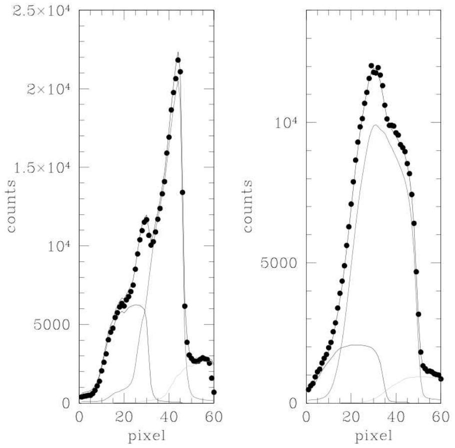

Fig. 5. BP (on the left) and RP (on the right) fit for three blended sources with Teff=6000-8000-10000 and [M/H]=-0.5, 0, 0.5. The 3 fitted spectra are plotted in gray together with the resultant fit.

4. First tests

Our software has been largely tested: we have applied it in a number of cases and verified that we are in condition to succesfully deblend up to three Gaia BP/RP sources localized on the same 60 X 12 window, discriminating effectively the contribution of each source to the overall flux (see Fig. 5).

5. Next steps

Having defined the core of a working deblending algorithm, we are now moving towards a more complete approach, our main goal being to face any kind of problematic expected from the peculiar nature of Gaia data acquisition.

5.1. More realistic tests

Deblending the 1D spectra is indeed a complex task. In order to gain a really satisfactory fit in the various cases that real Gaia data will present, we have identified a number of items to investigate in the next months. Among them, the most important is the need of more realistic tests for blended fields. In principle, the high spatial resolution of Gaia (58.933 mas AL and 176.798 AC) should allow us to disentangle several crowded fields like globular clusters core: anyway the along scan dispersion significantly increase the overlapping of the fluxes. Given that complexity, we still do not have a reliable estimate of Gaia photometric performance in such fields. We are thus working on realistic simulations of typical crowded fields, in order to quantify the degree of accuracy reachable from the analysis of data with our algorithms.

5.2. Windows shape

Apart from the problem of disentangling the spectra, we also have to handle not only simple 1D windows, but also take in account the occurrence of ”L shaped windows”, as well as the 2D windows that are related to bright sources. We can expect to receive L shaped windows in a number of situations, in dependence of the relative position and brightness of the blended stars: we know that when the windows of two sources overlap, only the window of the brighter source will be completely transmitted to ground, while the other will be sent without the overlapped region (typically acquiring a ”L” shape). Clearly, this occurrence will be most severe in the case of very crowded fields.

2D windows will be reduced using a specific algorithm currently under developement: we are now evaluating both analytics and numerical approaches in order to choose the one that most suits our needs.

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