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Stellar astrophysical parameters combining JPLUS and *Gaia* surveys.

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Abstract

The first JPLUS Data Release (July 2018) provided data in 12 filters, covering a total area of 1022 deg^2, collected from November 2015 to January 2018 by the JAST/T80 telescope. The JPLUS Consortium aims to include the astrophysical parameters of the sources in the JPLUS DR1 added value catalogue. As a first step temperatures are derived for a small set of stars (Gold sample) with the best photometric precision in all filters. This work derives temperatures from JPLUS colours of this Gold sample. The addition of *Gaia* mission second release (*Gaia*-DR2, April 2018) information, with magnitudes, parallaxes and colours for more than one billion sources is very useful to determine the astrophysical parameters of the stellar content in JPLUS data. In particular, the use of *Gaia* parallaxes are used to improve the characterisation of the observed sources.

1 Introduction

During the "XIII Reunión Científica de la Sociedad Española de Astronomía" (July 2018, this meeting), the first data release of JPLUS (Javalambre Photometric Local Universe Survey, [3]) project was made public. This first release consists on 511 fields observed in 12 optical bands covering a total sky surface of 1022 deg^2 observed from November 2015 to January 2018 by the JAST/T80 telescope. Besides this data some value added catalogues (VAC) are also published (photometric redshifts, star-galaxy separation, crossmatch with other surveys and stellar astrophysical parameters). This work belongs to the VAC working group in charge of the stellar parameters determination. In the first estimations included here, only temperature determination for a small set of well-behaved sources were explored, although in the future this temperature determination will be expanded to all other sources in JPLUS DR1.

Several approaches were explored in VAC working group to determine the astrophysical parameters: Spectral Energy Distribution (SED) fitting, machine learning [15] and colour based relationships. This work uses the third approach deriving stellar parameters from calibrated colour dependencies. For this purpose we try to avoid the use of external information

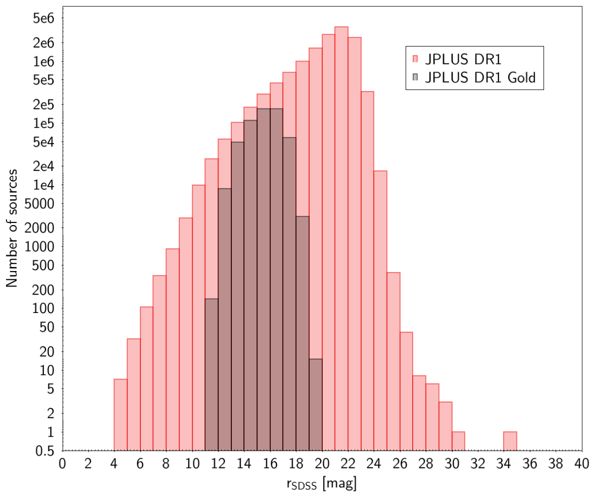

Figure 1: r JPLUS magnitude histogram of the total sample published in DR1 (red) and the gold sample used to derive their temperatures (black).

as much as possible, and only use JPLUS observables. Nevertheless, we also crossmatched JPLUS data with *Gaia* data release 2 (*Gaia*-DR2, April 2018, [6]) to refine our initial estimations by using *Gaia* parallaxes and photometry and also to derive photometric transformations between both surveys. In the first phase of stellar parameters determination by the VAC team, we have concentrated our efforts to determine effective temperatures for a set of stellar sources (morph_prob_star> 0.9) with photometric uncertainties better than 0.1 mag in all JPLUS passbands. This dataset (named as *Gold sample*) consists on 563 367 sources (see Fig. 1). All methods proposed in the VAC team have to provide effective temperatures and their uncertainties for this Gold sample.

2 Photometric transformations

This section crossmatch JPLUS DR1 dataset with *Gaia*-DR2 [6] and provide photometric transformations between them. From the initial amount of about 13.5 million sources published in JPLUS DR1, 5.5 million are also present in *Gaia*-DR2. Among them, 4.9 million have *Gaia* parallaxes available (1.4 million with parallax uncertainties better than 20%).

Among these common sources with *Gaia*-DR2 we filtered out those observations with $\sigma_{Gaia} < 0.003$ mag and $\sigma_{\rm JPLUS} < 0.03$ mag. The recommended *Gaia* excess flux factor filtering recommended by [5] was also applied $\left(\frac{F_{BP}+F_{RP}}{F_G} < 1.3 + 0.06(G_{\rm BP} - G_{\rm RP})^2\right)$. The fitted transformations are shown in Fig. 2 and Table 1.

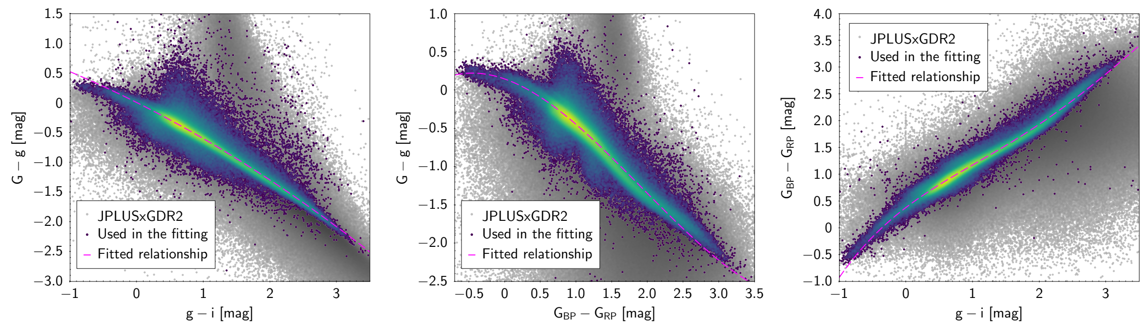

Figure 2: Photometric transformations between JPLUS and *Gaia*-DR2 surveys.

Table 1: Polynomial transformations between *Gaia*-DR2 and JPLUS colours. These transformations fit one colour (C_1) as a function of another colour (C_2) as a polynomial: $C_1 = a_0 + a_1 C_2 + a_2 C_2^2 + a_3 C_2^3 + a_4 C_2^4$.

C_1	a_0	a_1	a_2	a_3	a_4	σ	N
			$\mathbf{C_2 = G_{BP} - G_{BP}}^a$				
$G - g_{\rm SDSS}$	0.147	-0.327	-0.323	0.056	-	0.089	1513781
			$\mathbf{C_2 = g_{SDSS} - i_{SDSS}}^b$				
$G - g_{\rm SDSS}$	0.0075	-0.562	-0.045	-	-	0.078	1387830
$G_{\rm BP} - G_{\rm BP}$	0.386	0.947	-0.244	0.102	-0.011	0.054	1387830

[a] Applicability: $-0.7 < G_{\rm BP} - G_{\rm BP} < 3.5$
[b] Applicability: $-1.0 < g_{\rm SDSS} - i_{\rm SDSS} < 3.2$

3 Colour index and χ^2 method

Crossmatch between JPLUS DR1 sources and other catalogues in the literature including temperature values (see Table 2) was done. Among these literature catalogues, LAMOST DR2 [11] and Kepler Input Catalogue (KIC) [8] for the central range of temperatures were used. In order to expand this calibration also to high and low temperatures, white dwarfs (WDs, [9],[13]) and hot subdwarfs ([7]) and also late type stars ([12]) libraries were added.

Table 2: Range of JPLUS sources with effective temperatures works covered by the different literature used to calibrate our relationships in Fig. 3.

Reference	$T_{\rm eff}$ range [K]	$N_{\rm sources}$	Reference	$T_{\rm eff}$ range [K]	$N_{\rm sources}$
LAMOST DR2 [11]	3735–8454	90550	KIC [8]	2661–11076	3332
WDs [13]	6530–126360	237	WDs [9]	6127–87641	456
Hot subdwarfs [7]	23290-99999	208	Late type [12]	2490–3289	1206

After testing several JPLUS colours ($g_{\rm SDSS} - J861$, $g_{\rm SDSS} - z_{\rm SDSS}$, $J410 - J660$, $J410 - J861$, $J430 - z_{\rm SDSS}$, $J515 - i_{\rm SDSS}$, $J515 - J861$ and $J515 - z_{\rm SDSS}$) we concluded that $g_{\rm SDSS} -$

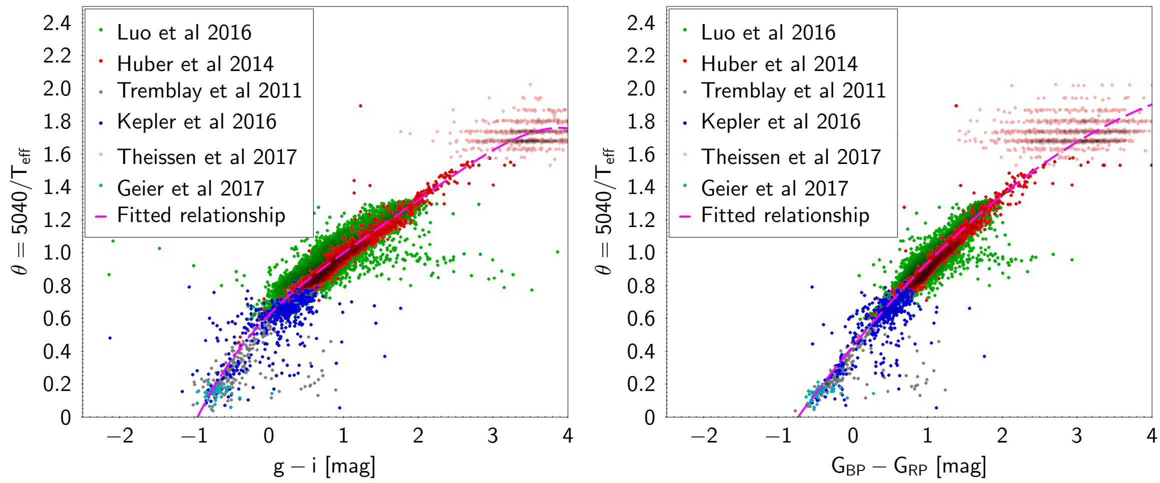

Figure 3: Effective temperature, represented in inverse using $\theta = \frac{5040}{T_{\rm eff}}$, calibrated from JPLUS $g_{\rm SDSS} - i_{\rm SDSS}$ colour (left) and from *Gaia*-DR2 $G_{\rm BP}-G_{\rm RP}$ colour using different temperature estimations from the bibliography.

$i_{\rm SDSS}$ provides the best correlation with effective temperature and we fitted a polynomial law (black line in left panel in Fig. 3). We also derived an analogous relationship using *Gaia*-DR2 colour (right panel in Fig. 3). The fitted relationships (Table 3) are applied to all other sources in JPLUS (red and orange points in Fig. 4).

Grey points in Fig. 4 show the temperature of the star with closest JPLUS photometry to our target source. The criterion to choose which photometry is closer to our source is a simple χ^2 weighted by the magnitude uncertainties (Eq. 1),

$$\chi^2 = \frac{\sum_{i=1}^{N_{\rm passb}} \omega_i \cdot (m_{\rm obs} - m_{\rm templ})^2}{N_{\rm passb} \cdot \sum_{i=1}^{N_{\rm passb}} \omega_i} \tag{1}$$

where $N_{\rm passb} = 12$ is the number of JPLUS passbands, $\omega_i = 1/\sigma_i$ is the weight of every observation, derived from its uncertainty σ_i. $m_{\rm obs}$ and $m_{\rm templ}$ are the JPLUS observed and template magnitudes, respectively. The template magnitudes used here are the ones observed by JPLUS for the sources included in the bibliography mentioned above. Then their magnitudes and temperatures associated to these sources are not coming from SED libraries but from preexisting determinations of real sources with photometry observed with JPLUS as our target star.

The application of the $T_{\rm eff}$-colour relationships derived results in reliable temperature estimations provided that the target sources have similar extinction that the literature sources from which the relationships have been determined. Being the stars in the halo, this is likely true.

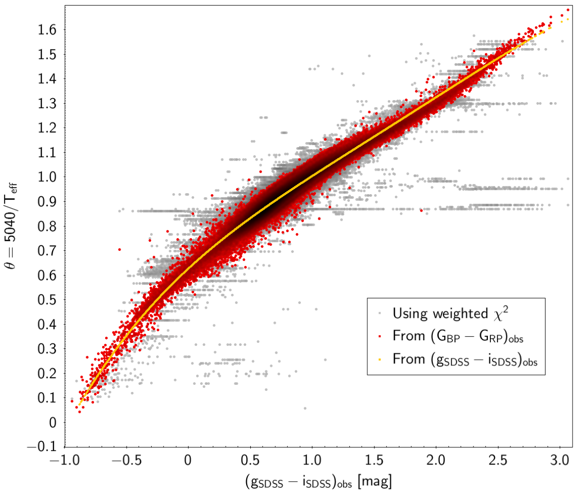

Figure 4: θ derived for all sources in the Gold sample using fitted polynomials represented in Fig. 3.

Table 3: Polynomial expressions $\theta = 5040/T_{\rm eff} = b_0 + b_1 C + b_2 C^2 + b_3 C^3 + b_4 C^4$ from JPLUS ($C = g_{\rm SDSS} - i_{\rm SDSS}$) or *Gaia*-DR2 ($C = G_{\rm BP} - G_{\rm BP}$) colours.

C	b_0	b_1	b_2	b_3	b_4	σ	N
$g_{\rm SDSS} - i_{\rm SDSS}$	0.625	0.465	-0.134	0.0539	-0.0079	0.036	94875
$G_{\rm BP} - G_{\rm BP}$	0.43547	0.553	-0.0464	-	-	0.037	95709

4 Conclusions and future work

This work shows the preliminary derivation of temperatures for JPLUS DR1. In the near future, these methods will be improved and also expanded to derive abundances and surface gravities (using colour-colour diagrams or improving the χ^2 method). Once the methods are finally settled, we aim to apply the astrophysical parameters estimations to all content in JPLUS DR1. The temperatures derived using our method will also be compared with other methods being tested in the JPLUS collaboration in order to determine the best temperature estimations for each star and their reliability.

Acknowledgments

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