Second post-launch release (V2) of Gaia external Spectro-Photometric Standard Stars

prepared by: N. Sanna, E. Pancino, G. Altavilla, S. Marinoni, P. Marrese, F. De Angeli, M. Rainer
approved by: D. W. Evans
authorized by: M. G. Lattanzi

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Abstract

This document presents the SPSS V2 release, describes the release content and the SPSS V2 spectra validation results.

Document History

Issue	Revision	Date	Author	Comment
1	0	2019-11-08	NS	DWE comments implemented, doc approved
D	5	2019-10-30	NS	Comments implementation
D	4	2019-10-11	NS	Comments implementation
D	3	2019-08-09	NS	Validation description
D	2	2019-08-02	NS-EP	Literature extinction and V.2.2 release
D	1	2019-06-28	NS	Data preparation description
D	0	2019-04-30	EP	Document creation and release content section

Contents

1 Data preparation

The data preparation strategy is similar to the one used for the V0 and V1 releases, and described in EP-012, SR-005.

The data consist of absolute photometry, flux tables, and metadata for each of the SPSS. The absolute photometry is described in GA-007, while the spectroscopy is described in the following sections. The ingestion of the relevant data in the SSDC archive will be done as described in SMR-006 and SMR-007.

1.1 Observations and data reductions

The observation plan and strategy for the spectroscopic data are the same as for V0 and V1 releases and are described in EP-012 and SR-005. The data reduction is performed in subsequent steps, depending on the telescope used and spectral range covered (blue or red), as summarized in Table 1. Unlike in V0 and V1, the telluric correction in V2 has been performed before the relative flux calibration, and using molecfit[i] rather than the IRAF scripts described in GA-006 (the document will be soon updated) for all red spectra and spectra of SPSS observed in nights not included in V1, while for the blue spectra of the SPSS observed in nights included in V1 IRAF scripts have been used.

STEP	BLUE	RED	RED (G5)	REFERENCE
observations	all	all	NTT	EP-001, EP-006
2D pre-reductions	all	all	NTT	SMR-002, GCC-001
1D-wave calibration	all	all	NTT	GCC-001
fringing correction	none	NTT, TNG, Loiano	NTT	GA-006
slitloss correction	all	all	NTT	GA-006
second order correction	none	NTT, TNG	none	SR-007
telluric correction	all	all	NTT	GA-006

Table 1: Observations and data reduction scheme.

1.2 Calibration and flux tables preparation

After the telluric contamination correction, the spectra have been calibrated in flux. As already done in V1, this procedure requires two steps:

1. relative flux calibration. All the spectra observed in the same night with the same instruments have been calibrated, using the extinction and response curves (the same

[i] https://www.eso.org/sci/software/pipelines/skytools/molecfit

as in V1) for that night and telescope (document in preparation);

2. absolute flux calibration. All the wide spectra observed on photometric nights of the same SPSS have been used to build the median spectrum on which we scaled all the spectra obtained in step 1 for narrow spectra (see EP-006), spectra observed on different nights and with different instruments;

3. flux tables creation. All the spectra of the same SPSS calibrated in step 2 have been merged (after the rejection of the bad ones) to obtain the flux tables.

1.3 Extension with templates

All the flux tables were extended with template spectra to reach about 300 nm at the bluest wavelengths and about 1200 nm at the reddest ones (in most cases the spectra stop at 1100 nm). The detailed procedure is the same as for the V1 release, see SR-005 and SR-006. For stars already included in V1, we used the same templates adopted to extend the V1 flux tables, possibly reaching 1200 nm. For stars new in this release, we used CALSPEC templates (`http://www.stsci.edu/hst/instrumentation/reference-data-for-calibration-and-tools/astronomical-catalogs/calspec`, when available) and the public spectral libraries provided by Koester (2010), Levenhagen et al. (2017), Coelho (2014), Husser et al. (2013).

2 Release content

The release package contains the flux tables, one per star, of 113 SPSS. Some SPSS of V1 have been discoverd to be variable stars (SMR-004; (Marinoni et al., 2016)) and removed from V2, while new stars of various spectral types, including 2 M stars, have been added, covering all spectral types, as shown in Figure 1.

2.1 Differences from V1

All the spectra used in V2 have been reduced following the scheme in Section 1. The major differences with V1 are described below.

It was noted that some of the narrow-slit spectra, obtained mainly for wavelength calibration, appeared to have good quality, and thus they were corrected for differential slit-losses as described in detail in GA-006, by reporting them to the shape of the most reliable corresponding wide-slit spectrum. This way, the narrow-slit spectra do not carry any information about the flux calibration and spectral shape, but they improve the SNR and the small-scale imperfections when combined with the other spectra.

The V2 spectra were also treated to mitigate fringing effects, unlike the V1 ones. In GDR2 no

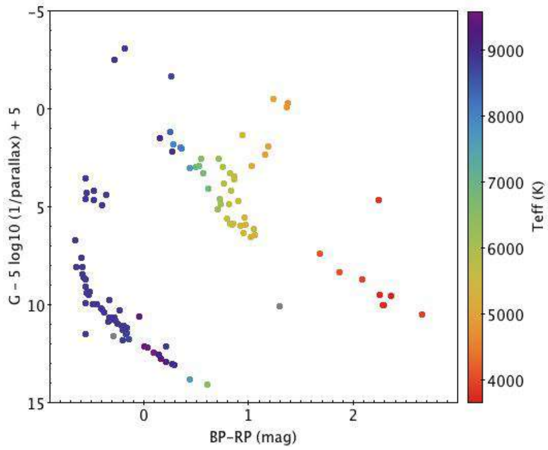

FIGURE 1: Distance-corrected CMD made with Gaia DR2 data of the 113 SPSS.

BP/RP spectra were released, and fringing oscillations have zero net effect on integrated magnitudes, thus V1 was adequate. However, in GDR3 there will be a selection of BP/RP spectra and the large fringing oscillations might spoil their quality during the calibration process, thus a fringing mitigation was necessary. Figure 2 shows examples of the fringing correction.

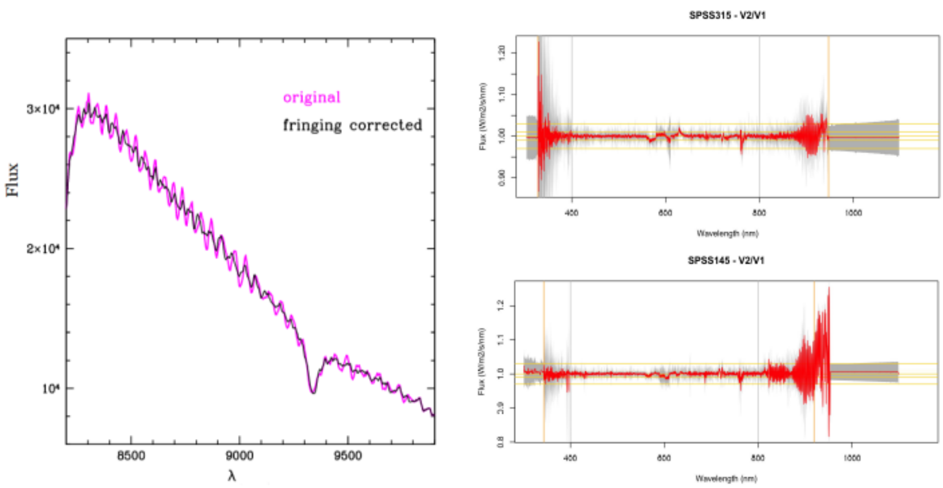

FIGURE 2: Examples of fringing correction effects. The left panel shows a spectrum before (magenta) and after (black) the fringing correction. The right panels show the ratio between the V2 and V1 for two stars. The oscillations caused by fringing are evident and, case by case, can be large or small.

2.2 Flux tables files

The flux tables are in the form of ascii files with three columns as described below (see also Table 2), and with names like `V.2.X.SPSS193.ascii`, where `X` is the release sub-version (Section 2.4) and `193` is the actual DU13 SPSS number.

Column	Description	Type	Units
Wave	Wavelength	double	nm
Flux	Flux	double	$W/m^2/nm$
Error	Flux error	double	$W/m^2/nm$

Table 2: Flux tables description.

More in detail:

- Wavelength (**Wave**): is the wavelength of each sample in the flux tables; the samples start at 300 nm and end at 1200 nm with a step of 0.1 nm; not all flux tables could be extended until 1200 nm, some stop at 1100 nm, in that case the last samples are null in flux (not in wavelength)[ii]. There are 9001 samples per SPSS in this SPSS release.
- Flux (**Flux**): for each sample, the flux of the SPSS in Watt per square metre per nanometre; the extremes (roughly outside 350-950 nm, depending on the SPSS) where the ground-based spectrographs do not have enough signal are replaced with observed or theoretical templates. Can be null after 1100 nm for some SPSS.
- Error on flux (**Error**): for each sample, the error on the flux, computed using the spread of the fluxes of the absolutely calibrated SPSS spectra that formed the flux table; at the extremes, where the spectrum is observed with templates, the error is computed as a fixed value, corresponding to the median error of the last 100 samples of the observed spectrum summed in quadrature with the flux error of the template fitting procedure. Can be null after 1100 nm for some SPSS.

2.3 Metadata file

The release contains also one general CSV file with SPSS metadata named `V.2.X.SPSSmetadata.csv`, where `X` is the release version (Section 2.4), and described in Table 3.

Column	Description	Type	Units
spssId	Unique DU13 identifier	integer	
name	Name adopted by DU13	string	
sourceIdDR2	GDR2 source identifier	long	
sourceIdAGISnew	New AGIS source identifier	long	
alpha	Literature right ascension	string	hh mm ss
delta	Literature declination	string	dd mm ss

[ii]Null values in these ascii tables are marked with the string `NA`.

magB	DU13 Johnson B magnitude	double	mag
errB	B magnitude error	double	mag
magV	DU13 Johnson V magnitude	double	mag
errV	V magnitude error	double	mag
magR	DU13 Johnson R magnitude	double	mag
errR	R magnitude error	double	mag
litB	Literature Johnson B magnitude	double	mag
litV	Literature Johnson V magnitude	double	mag
spType	Spectral type	string	
extTeff	Effective temperature of model used for extension	double	K
extLogg	Surface gravity of model used for extension	double	log cgs
extFeH	Metallicity [Fe/H] of model used for extension	double	dex
extAv	Extinction of model used for extension	double	mag
litTeff	Literature effective temperature	double	K
litLogg	Literature surface gravity	double	log cgs
litFeH	Literature metallicity [Fe/H]	double	dex
litAv	Literature extinction Av	double	mag
wlErr	Error on wavelength	double	nm
inV1	Was this SPSS in V1 (yes or no)?	string	
notesSpectrum	Notes on flux table	string	
notesExt	Notes on flux table extension	string	
quality	Quality verdict	string	

Table 3: Metadata file description.

More in details:

- Unique identifier of the SPSS (**spssId**): Unique identifier for the SPSS established within DU13. It is a number ranging from 0 to 999. There can be no null value for this field.
- SPSS name adopted by DU13 (**name**): SPSS adopted name within DU13, among the various used in the literature.
- *Gaia* DR2 source identifier corresponding to the SPSS (**sourceIdDR2**): source identifier as cross-identified using the official *Gaia* cross-match software developed at SSDC. Cannot be null.
- *Gaia* new AGIS source identifier corresponding to the SPSS (**sourceIdAGISnew**): source identifier in AGIS 3.1 as cross-identified at DPCI in Cambridge. Cannot be null.

- Literature right ascension of the SPSS (**alpha**): approximate right ascension of the SPSS from various literature sources. It cannot be null.
- Literature declination of the SPSS (**delta**): approximate declination of the SPSS from various literature sources. It cannot be null.
- DU13 Johnson B, V, or R magnitude (**magB, magV, magR**): absolute magnitude of the SPSS determined by DU13 as described in GA-007. It can be null[iii].
- Error on DU13 Johnson B, V, or R magnitude (**errB, errV, errR**): absolute magnitude of the SPSS determined by DU13 as described in GA-007. It can be null.
- Literature B and V magnitude (**litB, litV**): litherature Johnson B and V magnitudes obtained from various literature sources. It can be null.
- Spectral type of the SPSS (**spType**): spectral type of the SPSS obtained from various literature sources. It is never null.
- Effective temperature used for the SPSS extension (**extTeff**): effective temperature of the model used for extending the SPSS observed flux table to cover the 300–1200 nm range. It can be null for those SPSS extended with observed or theoretical spectra from CALSPEC.
- Surface gravity used for the SPSS extension (**extLogg**): surface gravity of the model used for extending the SPSS observed flux table. It can be null for those SPSS extended with observed or theoretical spectra from CALSPEC or for SPSS extended using a blackbody spectrum.
- Metallicity used for the SPSS extension (**extFeH**): metallicity [Fe/H] of the model used for extending the SPSS observed flux table. It can be null for those SPSS extended with observed or theoretical spectra from CALSPEC or for SPSS extended using a blackbody or a WD spectrum.
- Literature effective temperature (**litTeff**): literature effective temperature of the SPSS, when known. Can be null.
- Literature surface gravity (**litLogg**): literature surface gravity of the SPSS, when known. Can be null.
- Literature metallicity (**litFeH**): literature metallicity [Fe/H] of the SPSS, when known. Can be null.
- Literature extinction (**litAv**): literature extinction of the SPSS in the Johnson V band from the literature, when known. Can be null.

[iii] Null values in this CSV file are represented by an empty field.

- Wavelength error of the SPSS flux table (**wlErr**): typical error on the wavelength scale of the SPSS flux table as obtained by combining in quadrature the formal error on the calibration and the offset between the SPSS flux table and the model used for the flux table extension. It is never null: for (almost) featureless stars or SPSS extended with blackbody spectra it is set equal to the MAD of the errors of other SPSS.
- Was this SPSS in V1 (**inV1**)? A string that can take the values `yes` if the SPSS was also part of the previous release or `no` if it is a new SPSS. Cannot be null.
- Notes on the SPSS flux table (**notesSpectrum**): notes on the quality of the SPSS flux table. When no notes are present there is the `'-'` string.
- Notes on the SPSS flux table extension (**notesExt**): notes on the quality of the SPSS flux table extension the the 300–1200 nm range with observed or theoretical templates. When no notes are present there is the `'-'` string.
- Final verdict of the SPSS flux table quality (**quality**): it can take the values `gold` for SPSS with no particular problems, `silver` for SPSS with minor problems, or `bronze` for SPSS of uncertian quality, that should be used with care.

2.4 Release versions

Table 4 summarized the versions of V2 that have been released

Version	**Description**	**Date**
V.2.0	Sent to FDA and PMN for testing	29 April 2019
V.2.1	Error computation corrected; re-sent to FDA and PMN	6 May 2019
V.2.2	Literature extinction and atmospheric parameters	2 August 2019
V.2.3	New AGIS cross-match revision	30 October 2019

Table 4: V2 versions releases.

3 Validation

In order to validate the current release, a series of tests have been done comparing V2 and V1 spectra as well as absolute and synthetic photometry and the stellar parameters of the templates used for the extension and the literature.

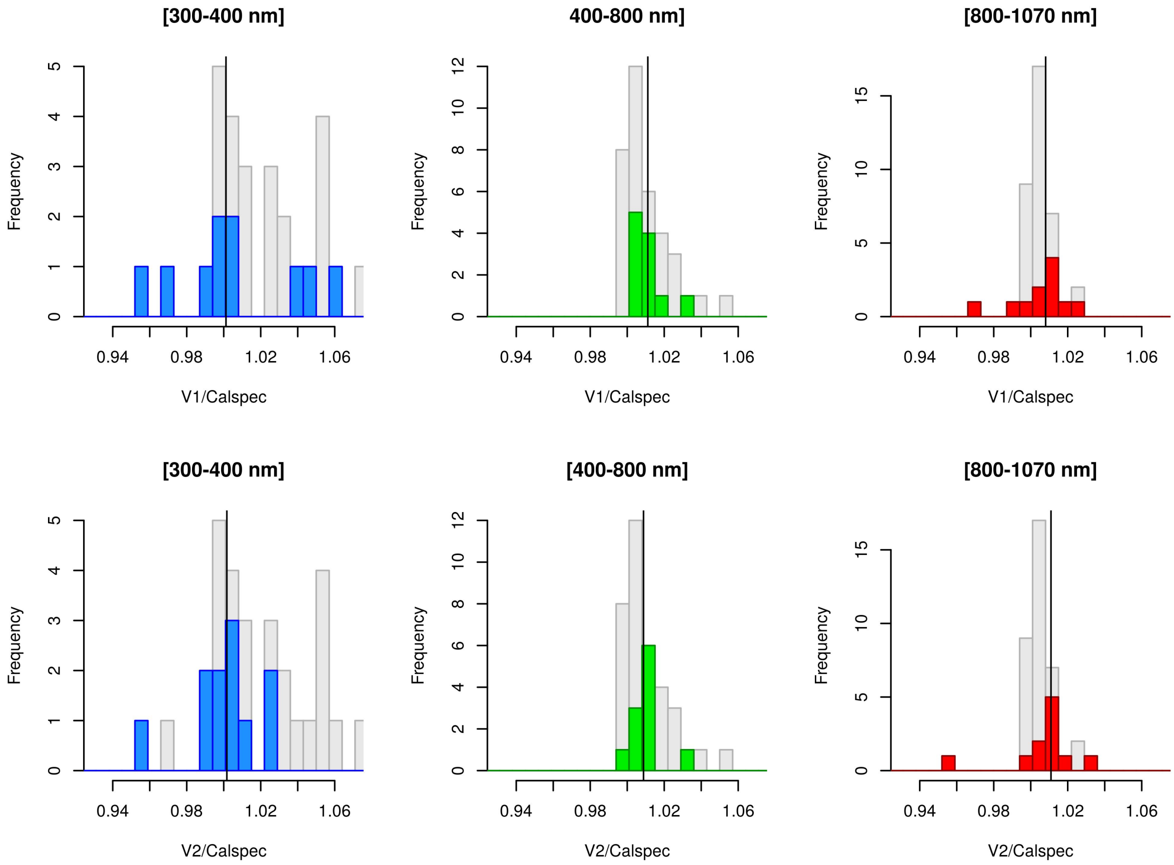

FIGURE 3: Comparison between SPSS and CALSPEC spectra in different regions (blue: 300 - 400 nm; green: 400 - 800 nm; red: 800 - 1070 nm) for the V1 (top) and V2 (bottom) releases. The internal CALSPEC spread is plotted in grey (see text).

3.1 Spectra comparisons

We compared the SPSS V2 spectra with the V1 ones. The overall agreement is extremely good as shown in Table 5. This essentially means that the two releases are on the same photometric system. There is a tendency of the V2 spectra to be slightly (a few %) brighter than V1 in the red in some stars and this reflects in the slightly larger ratio after 800 nm.

We also compared the SPSS V2 and V1 spectra with CALSPEC. We chose the latest CALSPEC version which contains observed and model spectra for 36 stars. The ratio between the model and the observed spectra is shown in Figure 3 in grey. We have computed the SPSS/CALSPEC ratio for the 11 common stars for both V1 and V2 and we have computed the median and the MAD in three different regions of the spectrum (300-400 nm, 400-800 nm, 800-1070 nm).

The results are shown in Figure 3 and in Table 5. In the central (middle panels) and the red part (right panels) of the spectra the two releases are consistent, while an improvement of the V2 spectra in the blue region (left) is evident. Both the SPSS releases are compatible with the CALSPEC internal spread (shown in grey) and are $\simeq 1\%$ brighter than CALSPEC. This is in part due to the CALSPEC revision of the flux scale downwards by about 0.6 % (Bohlin, 2014). Both SPSS releases are calibrated on the previous CALSPEC scale and are thus brighter.

Release	$300 - 400\ nm$	$400 - 800\ nm$	$800 - 1070\ nm$
V2/V1	1.001 ± 0.0025	1.0001 ± 0.0011	1.0018 ± 0.0034
V1/CALSPEC	1.0012 ± 0.0487	1.0111 ± 0.0058	1.0081 ± 0.0085
V2/CALSPEC	1.0017 ± 0.0118	1.0088 ± 0.0036	1.0109 ± 0.0060

Table 5: Median and MAD values of the spectra comparisons in three different ranges (see text).

3.2 Magnitudes comparisons

We compared the synthetic magnitudes derived using the SPSS spectra (see Appendix B and Table 7 for details) with the magnitudes obtained by the SPSS absolute photometry campaign (GA-007). Left panels of Figure 4 show the case of B (top), V (middle), R (bottom). The median values of $\Delta mags$ are in good agreement (see Table 6), suggesting that the SPSS spectra are in the same photometric system as the DU13 absolute photometry [iv]. A slight trend of ΔB as a function of B-V can be noticed for blue stars in the top left panel. We tried different passbands from the literature and the effect varies in strength but never disappears. The chosen set of passbands (see Appendix B) minimized the slope in all bands.

There is one star (SPSS140, not shown in Figure) with a higher value of Δmag. This is due to the fact that during the acquisition of the spectra of SPSS140 the wrong star had been observed, so the synthetic photometry derived from SPSS V2 is not compatible with the DU13 absolute one. We are testing whether this star can be used as a spectro-photometric star.

Band	**Synthetic-Absolute**	**Synthetic-Landolt**
B	0.0053 ± 0.0145	0.0110 ± 0.0072
V	0.0045 ± 0.0096	0.0087 ± 0.0044
R	-0.0007 ± 0.0077	0.0016 ± 0.0067

Table 6: Median and MAD values of the photometries comparisons (see text).

[iv] We realized that the SPSS192 magnitudes were wrong up to the V.2.2 release. The correct magnitudes will be presented in GA-007.

We compared the synthetic magnitudes derived using the SPSS spectra with the literature values derived by Landolt, for the 37 stars in common. The results are shown in the right panels of Figure 4. The median values of $\Delta mags$ are in very good agreement (see Table 6) for the R band, but our SPSS synthetic magnitudes are slightly fainter ($\simeq 1\%$) than the Landolt ones in B and V.

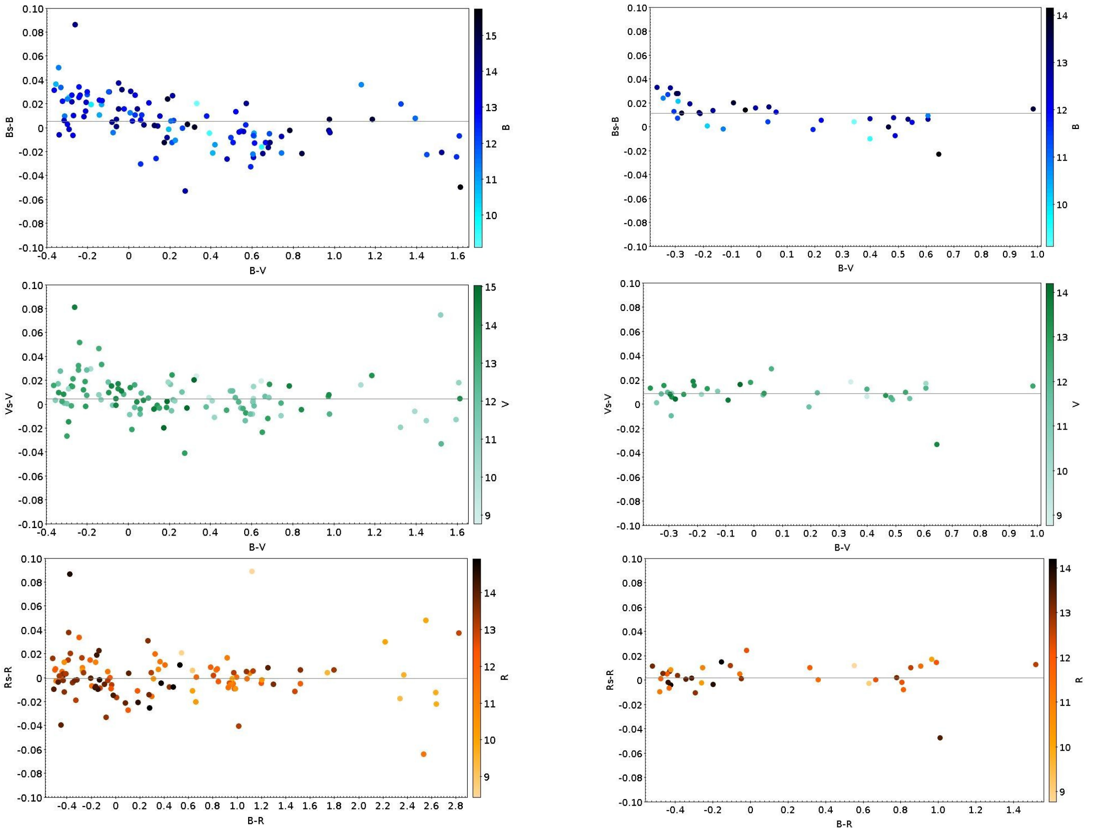

FIGURE 4: Left: Comparison between synthetic photometry obtained using the SPSS V2 spectra and the DU13 absolute photometry for B (top), V (middle), R (bottom). Right: Comparison between synthetic photometry obtained using the SPSS V2 spectra and photometry by Landolt for B (top), V (middle), R (bottom).

3.3 Parameters comparisons

In order to test the template choice of the SPSS spectra extension, we have also compared the stellar parameters of the models used for this scope with the values available for each SPSS in the literature. Figure 5 shows the comparison between temperature, gravity, and metallicity. The median differences (and MAD) are: $\Delta T_{eff} = -60$ (± 697) K, $\Delta \log g = -0.14$ (± 0.33) dex, $\Delta [Fe/H] = -0.17$ (± 0.56) dex . The temperatures and gravities are in good agreement, while this is less true for the metallicities. An explanation for this could be that the SPSS spectra are low resolution spectra (tipically $R \sim 500 - 1000$) and thus not very sensitive to $[Fe/H]$. Moreover, most of the spectra used to derive the metallicity in the literature are low resolution spectra too, so the literature $[Fe/H]$ values could not be accurate. Anyway, the overall agreement of the parameters is satisfactory for the purpose of the present work.

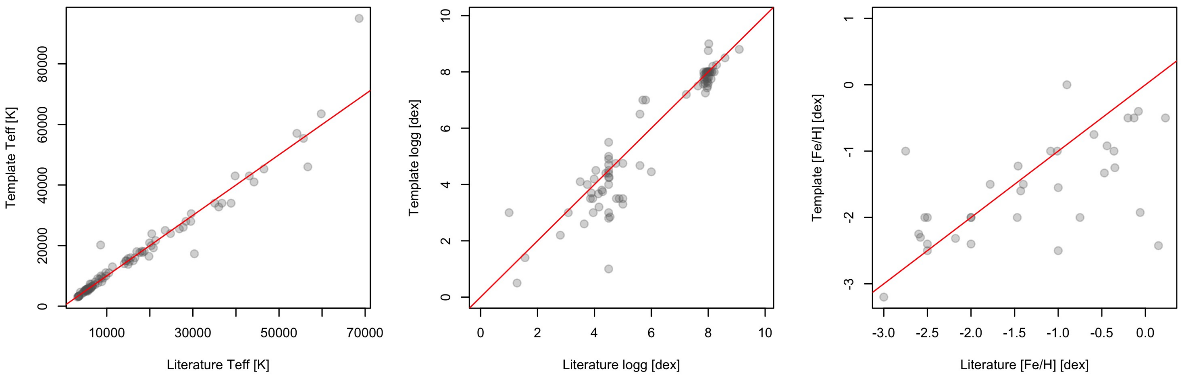

FIGURE 5: Stellar parameters comparison. Temperatures (left) and gravities (middle) of the models used to extend the SPSS spectra are in good agreement with the literature ones. This is less true for the metallicities (right).

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A Acronyms

Acronym	**Description**
AGIS	Astrometric Global Iterative Solution
BP	Blue Photometer
CALSPEC	Calibration Spectra of the Hubble Space Telescope
CMD	Color-Magnitude Diagram
CSV	Comma Separated Values
DPCI	Data Processing Center at IoA
DU13	Development Unit 13
GDR2	Gaia Data Release 2
GDR3	Gaia Data Release 3
IoA	Institute of Astronomy, Cambridge
IRAF	Image Reduction and Analysis Facility
MAD	Median Absolute Deviation
NTT	New Technology Telescope
RP	Red Photometer
SNR	Signal-to-Noise Ratio
SPSS	Spectro-Photometric Standard Star

SSDC	Space Science Data Center
TNG	Telescopio Nazionale Galileo
WD	White Dwarf (star)

B Synthetic photometry

The synthetic photometry provided in this work is based on the following photonic passbands:

- **DR2:** the *Gaia* DR2 passbands [v] [vi];
- **REV:** the revised *Gaia* passbands [vii];
- **WEI:** the passbands by Weiler (2018) [viii]; this author provide two different passbands for *Gaia* BP, to be used with stars brighter or fainter than G=10.99 mag respectively;
- **MAW:** the passbands by Maíz Apellániz & Weiler (2018) [ix]; these authors provide two different passbands for *Gaia* BP, to be used with stars brighter or fainter than G=10.87 mag respectively;
- **UBVRI:** the passbands by Bessell & Murphy 2012 [x].

The synthetic magnitude m in the VEGAMAG system has been computed with

$$m = -2.5\, log \left(\frac{\int f_\lambda \, S_\lambda \, \lambda \, d\lambda}{\int f_\lambda^{Vega} \, S_\lambda \, \lambda \, d\lambda} \right) + m_{Vega} \tag{1}$$

where f_λ is the spectral energy distribution of a given star, f_λ^{Vega} is the spectral energy distribution of Vega, S_λ is the photonic passband, λ the wavelength, and m_{Vega} is the magnitude of Vega.

[v] https://www.cosmos.esa.int/web/gaia/iow_20180316
[vi] https://www.cosmos.esa.int/documents/29201/1645651/GaiaDR2_Passbands_ZeroPoints.zip/49cdce41-8eee-655d-7ed2-4e7a83598c1d
[vii] https://www.cosmos.esa.int/documents/29201/1645651/GaiaDR2_Revised_Passbands_ZeroPoints.zip/54db454f-69cb-ea0c-15be-f1b1f597f191
[viii] http://cdsarc.u-strasbg.fr/viz-bin/cat/J/A+A/617/A138#browse
[ix] http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/619/A180
[x] ftp://cdsarc.u-strasbg.fr/pub/cats/J/PASP/124/140/

We used the high-fidelity Vega model `A0VStar_Spectrum_Nu_002.fits` in the *Gaia* Parameter Database Version 21-0-0, converted into angstroms and c.g.s. units. Since Vega's magnitude is assumed to be $V_0 = 0.0$ mag and all its colours are by definition zero, $m_{Vega} = 0.0$ mag, even if the real value is known to be different (see Section 5.3.6 in the *Gaia* DR2 Documentation release 1.2).

SPSS ID	U	B	V	R	I	G_{DR2}	BP_{DR2}	RP_{DR2}	G_{REV}	BP_{REV}	RP_{REV}	G_{WEI}	BP_{WEI}	RP_{WEI}	G_{DR2}	BP_{DR2}	RP_{DR2}
001	10.24672	11.48168	11.78929	11.93098	12.11202	11.73271	11.49007	12.07333	11.74457	11.48254	12.07388	11.74912	11.50510	12.07833	11.74221	11.50150	12.07536
002	11.66748	12.80411	13.04075	13.17464	13.33848	13.01130	12.80089	13.30935	13.02157	12.79408	13.30945	13.02495	12.81561	13.31338	13.01895	12.81224	13.31090
003	11.90792	13.08759	13.35462	13.49467	13.67118	13.31523	13.08975	13.63549	13.32610	13.08268	13.63519	13.33005	13.10448	13.63936	13.32369	13.10101	13.63661
005	10.68684	11.40308	11.37326	11.45868	11.52680	11.41400	11.32748	11.53759	11.42039	11.32256	11.53807	11.41981	11.34487	11.53946	11.41589	11.34198	11.53938
006	12.58295	13.79804	14.06681	14.20575	14.36871	14.02463	13.79652	14.34156	14.03626	13.78916	14.34196	14.04041	13.81186	14.34585	14.03360	13.80819	14.34346
007	12.92522	13.80695	13.88015	13.98030	14.08033	13.89413	13.76415	14.07190	13.90143	13.75871	14.07185	13.90237	13.77966	14.07380	13.89797	13.77674	14.07288
008	11.50745	12.07636	11.85522	11.76280	11.66509	11.84100	11.89438	11.70227	11.84748	11.89025	11.70516	11.84674	11.91246	11.70240	11.84208	11.90957	11.70550
009	12.37833	12.60658	12.21324	11.93199	11.62474	12.08890	12.32039	11.70218	12.09443	12.31778	11.70732	12.09399	12.33683	11.69934	12.08906	12.33464	11.70667
010	12.40809	13.36072	13.58157	13.66338	13.76746	13.54091	13.37778	13.75304	13.54820	13.37279	13.75428	13.55087	13.38685	13.75642	13.54678	13.38462	13.75551
011	9.63968	10.86172	11.18184	11.30923	11.45473	11.11339	10.87772	11.43080	11.12481	10.87060	11.43144	11.12946	10.89066	11.43457	11.12277	10.88721	11.43289
012	11.02192	11.68838	11.49423	11.32919	11.18154	11.42507	11.50178	11.22224	11.43221	11.49809	11.22807	11.43198	11.51665	11.22387	11.42676	11.51392	11.22828
013	9.11390	10.24119	10.51774	10.65027	10.81725	10.47393	10.25611	10.78327	10.48376	10.24959	10.78329	10.48757	10.29965	10.78716	10.48192	10.31817	10.78466
014	10.18400	11.38872	11.66307	11.80731	11.99762	11.62287	11.39000	11.95399	11.63410	11.38281	11.95350	11.63851	11.40471	11.95844	11.63190	11.40115	11.95494
016	9.91637	10.87869	11.01835	11.14472	11.25426	11.02030	10.85942	11.25029	11.02830	10.85365	11.25033	11.02995	10.87398	11.25210	11.02525	10.87096	11.25164
017	11.61497	12.28099	12.23472	12.31301	12.36944	12.27593	12.20073	12.38060	12.28198	12.19592	12.38104	12.28119	12.21830	12.38187	12.27745	12.21547	12.38209
019	11.95967	12.74747	12.76066	12.85041	12.92912	12.79000	12.68550	12.93493	12.79680	12.68033	12.93508	12.79674	12.70227	12.93626	12.79264	12.69939	12.93632
021	12.55010	12.67900	12.07802	11.69716	11.31976	11.90467	12.23949	11.40935	11.91171	12.23611	11.41575	11.91077	12.26363	11.40733	11.90456	12.26076	11.41498
023	10.35320	11.53943	11.84159	11.97469	12.12571	11.78415	11.55556	12.09848	11.79502	11.54855	12.09938	11.79929	11.56889	12.10296	11.79302	11.56561	12.10086
024	10.03349	10.62076	10.44522	10.30679	10.15581	10.38746	10.46160	10.19679	10.39336	10.45845	10.20060	10.39374	10.47487	10.19642	10.38930	10.48013	10.20053
026	10.37499	10.93827	11.05491	11.09270	11.15523	11.03701	10.95619	11.14194	11.03970	10.95456	11.14309	11.04119	10.95697	11.14435	11.03955	10.95594	11.14378
028	9.12058	9.10588	8.77812	8.56060	8.32465	8.69695	8.88099	8.38858	8.70134	8.87916	8.39359	8.69996	8.88098	8.38820	8.69618	8.87967	8.39342
030	9.15974	10.07139	10.26379	10.32725	10.42402	10.22561	10.08306	10.40105	10.23205	10.07892	10.40228	10.23491	10.11274	10.40485	10.23109	10.12557	10.40323
032	9.52725	9.42454	9.04190	8.80115	8.55664	8.95451	9.16382	8.61617	8.95888	9.16179	8.62038	8.95783	9.16275	8.61458	8.95384	9.16081	8.61981
033	12.05400	12.28022	11.80154	11.46374	11.11280	11.64631	11.93057	11.19777	11.65242	11.92773	11.20329	11.65206	11.94923	11.19434	11.64652	11.94683	11.20244
035	13.87467	13.78596	13.52223	13.38440	13.22377	13.48737	13.61677	13.26535	13.49016	13.61542	13.26828	13.48931	13.62827	13.26382	13.48664	13.62688	13.26787
036	12.51020	12.40961	12.29820	12.24346	12.17370	12.28909	12.34276	12.19277	12.29008	12.34211	12.19366	12.28951	12.34839	12.19195	12.28849	12.34788	12.19349
037	12.09694	11.94722	11.74185	11.64510	11.54346	11.72637	11.81841	11.56842	11.72833	11.81721	11.57050	11.72721	11.82864	11.56789	11.72529	11.82760	11.57024
039	11.87104	12.06455	11.51419	11.16400	10.82359	11.36178	11.66234	10.89978	11.36826	11.65906	10.90484	11.36810	11.68468	10.89746	11.36220	11.68188	10.90392
040	13.33665	13.61066	13.15178	12.83262	12.50226	13.00772	13.27273	12.57937	13.01387	13.26968	12.58455	13.01374	13.29187	12.57678	13.00822	13.28933	12.58372
041	12.46479	12.65845	12.17226	11.84100	11.50991	12.02446	12.30371	11.58369	12.03050	12.30068	11.58897	12.03029	12.32379	11.58124	12.02478	12.32131	11.58800
043	14.24821	14.11465	13.45855	13.08047	12.72065	13.29990	13.64133	12.80629	13.30645	13.63799	12.81151	13.30525	13.66793	12.80275	13.29927	13.66511	12.81061
045	14.88401	14.26143	13.29647	12.77623	12.29675	13.03892	13.54600	12.39826	13.04548	13.54243	12.40351	13.04596	13.57869	12.39169	13.03897	13.57549	12.40165
047	16.18811	15.14204	13.97189	13.34570	12.77520	13.62162	14.24929	12.89061	13.62791	14.24560	12.89568	13.62997	14.28442	12.88195	13.62246	14.28121	12.89323
049	10.81464	10.83523	10.23561	9.87681	9.51366	10.08208	10.40283	9.60704	10.08896	10.39957	9.61372	10.08719	10.40394	9.60466	10.08122	10.40178	9.61319
050	11.47884	12.33489	12.29701	12.23470	12.19214	12.25299	12.22326	12.20592	12.26086	12.21871	12.20990	12.26168	12.23688	12.20882	12.25640	12.23391	12.21053
101	12.83409	12.91639	12.38691	12.12870	11.88721	12.31288	12.53766	11.95204	12.32000	12.53378	11.95904	12.31672	12.56419	11.95355	12.31110	12.56119	11.95918
109	10.99965	11.87163	12.07459	12.17562	12.28516	12.04783	11.89282	12.26341	12.05402	11.88842	12.26464	12.05616	11.90095	12.26728	12.05271	11.89889	12.26575

TABLE 7: SPSS synthetic photometry using different passbands.

SPSS ID	U	B	V	R	I	G_{DR2}	BP_{DR2}	RP_{DR2}	G_{REV}	BP_{REV}	RP_{REV}	G_{WEI}	BP_{WEI}	RP_{WEI}	G_{DR2}	BP_{DR2}	RP_{DR2}
110	10.55123	11.77430	12.09886	12.24482	12.42599	12.03828	11.79414	12.38326	12.04971	11.78681	12.38384	12.05452	11.80800	12.38783	12.04791	11.80459	12.38516
112	11.03466	11.97178	12.05667	12.16485	12.27984	12.07094	11.92784	12.27027	12.07895	11.92205	12.27011	12.08009	11.94412	12.27227	12.07527	11.94098	12.27134
115	12.30777	12.50761	11.92196	11.53082	11.13699	11.73502	12.07605	11.22776	11.74177	12.07277	11.23359	11.74151	12.09867	11.22444	11.73531	12.09587	11.23260
119	11.83767	12.86019	13.02466	13.12730	13.24134	13.00767	12.84101	13.22924	13.01643	12.83495	13.22900	13.01859	12.85543	13.23123	13.01343	12.85236	13.23031
121	12.41147	13.10927	13.06577	13.14181	13.21126	13.10635	13.02624	13.21646	13.11262	13.02127	13.21625	13.11197	13.04423	13.21707	13.10808	13.04139	13.21726
129	12.15666	11.25421	10.10227	9.47692	8.90358	9.74748	10.37630	9.01393	9.75344	10.37247	9.01764	9.75655	10.37173	9.00528	9.74915	10.36375	9.01492
130	13.55225	13.55593	12.82043	12.36034	11.90040	12.58656	13.01282	12.00135	12.59293	13.00942	12.00616	12.59348	13.03903	11.99485	12.58693	13.03609	12.00457
132	12.49653	12.67135	12.02425	11.60227	11.17903	11.81872	12.19292	11.27867	11.82554	12.18955	11.28455	11.82525	12.21684	11.27359	11.81880	12.21398	11.28340
133	13.09918	13.32029	12.74032	12.35791	11.96860	12.55874	12.89133	12.05775	12.56523	12.88792	12.06270	12.56528	12.91425	12.05302	12.55913	12.91142	12.06152
134	11.31670	11.38656	10.79538	10.40962	10.01645	10.61273	10.95716	10.10496	10.61874	10.95414	10.10997	10.61868	10.95831	10.09997	10.61280	10.95600	10.10871
135	12.10966	13.22589	13.44024	13.55846	13.67005	13.40762	13.21680	13.65791	13.41751	13.21021	13.65762	13.42057	13.23137	13.65931	13.41473	13.22807	13.65893
136	11.88299	11.98094	11.30717	10.88271	10.46017	11.10117	11.48435	10.55453	11.10767	11.48094	10.55943	11.10790	11.50947	10.54902	11.10150	11.50654	10.55803
139	9.44555	9.53640	8.92394	8.51592	8.10541	8.72579	9.09030	8.19735	8.73182	9.08745	8.20215	8.73222	9.09117	8.19242	8.72620	9.08866	8.20087
140	14.52246	14.27870	13.48309	13.00101	12.50434	13.23243	13.70500	12.61341	13.23824	13.70210	12.61833	13.23917	13.73016	12.60560	13.23279	13.72743	12.61649
141	11.70541	12.77401	12.95257	13.04981	13.01167	12.90073	12.75362	13.03389	12.90888	12.74719	13.03029	12.91309	12.76893	13.02729	12.90768	12.76564	13.02982
144	12.34979	13.04154	12.97281	13.05772	13.14368	13.02817	12.94812	13.14744	13.03446	12.94314	13.14625	13.03391	12.96666	13.14814	13.02996	12.96362	13.14736
145	11.51092	11.46400	10.73203	10.27939	9.83985	10.50902	10.92764	9.93327	10.51519	10.92443	9.93766	10.51599	10.92738	9.92750	10.50958	10.92371	9.93606
146	10.54972	11.44103	11.51959	11.62989	11.75840	11.54003	11.39975	11.74384	11.54749	11.39415	11.74272	11.54847	11.41578	11.74584	11.54405	11.41284	11.74394
147	11.00058	11.15255	10.56340	10.20933	9.84886	10.40885	10.72618	9.93020	10.41512	10.72303	9.93497	10.41509	10.72821	9.92592	10.40915	10.72685	9.93380
149	12.44683	13.09689	12.98354	13.05153	13.09514	13.03963	12.98345	13.11596	13.04591	12.97856	13.11524	13.04489	13.00301	13.11539	13.04085	12.99988	13.11638
156	12.34136	13.53452	13.80972	13.94168	14.10782	13.76156	13.53621	14.07095	13.77269	13.52900	14.07120	13.77682	13.55109	14.07505	13.77029	13.54759	14.07248
158	14.55808	14.47419	13.81458	13.41161	13.01217	13.62822	13.99257	13.10688	13.63483	13.98912	13.11245	13.63403	14.01931	13.10286	13.62787	14.01649	13.11136
159	11.95867	13.10586	13.36641	13.49839	13.60128	13.31819	13.11152	13.58775	13.32844	13.10472	13.58686	13.33233	13.12553	13.58929	13.32633	13.12219	13.58807
161	11.89991	12.90254	13.14950	13.26724	13.40001	13.11224	12.92536	13.37498	13.12011	12.91995	13.37522	13.12311	12.93549	13.37807	13.11870	12.93300	13.37653
168	12.45142	13.63751	13.95375	14.09841	14.25923	13.89494	13.66084	14.22481	13.90560	13.65398	14.22519	13.91014	13.67328	14.22875	13.90395	13.67000	14.22654
170	12.26902	13.54255	13.89698	14.04453	14.25022	13.82821	13.56798	14.20093	13.84038	13.56052	14.20065	13.84627	13.58057	14.20593	13.83919	13.57701	14.20216
173	12.42107	13.46596	13.64874	13.77724	13.92397	13.63602	13.45283	13.89575	13.64480	13.44671	13.89358	13.64766	13.46723	13.89735	13.64243	13.46401	13.89471
174	13.27988	13.54661	12.98551	12.60631	12.21019	12.80130	13.13088	12.30033	12.80773	13.12756	12.30536	12.80792	13.15273	12.29513	12.80180	13.14992	12.30407
175	13.16473	14.30697	14.56179	14.68367	14.82717	14.51932	14.31088	14.80375	14.52954	14.30424	14.80447	14.53309	14.32433	14.80734	14.52711	14.32107	14.80588
191	14.10334	14.20054	13.52465	13.08950	12.66660	13.31196	13.70047	12.76059	13.31857	13.69714	12.76559	13.31881	13.72549	12.75549	13.31237	13.72261	12.76426
192	13.92982	14.10805	13.50834	13.11653	12.72490	13.32258	13.66451	12.81418	13.32915	13.66114	12.81938	13.32901	13.68827	12.80942	13.32282	13.68542	12.81819
193	13.40101	13.95120	13.80731	13.84570	13.85812	13.85470	13.82718	13.88045	13.86038	13.82278	13.88099	13.85906	13.84586	13.88032	13.85529	13.84295	13.88179
194	13.25677	14.00614	13.82322	13.72187	13.63522	13.78815	13.81474	13.66357	13.79601	13.80953	13.66744	13.79506	13.83584	13.66504	13.78952	13.83252	13.66783
201	11.90467	13.08719	13.36528	13.50764	13.65714	13.32041	13.09614	13.63455	13.33136	13.08910	13.63530	13.33531	13.11031	13.63886	13.32896	13.10690	13.63683
204	12.56380	13.35008	13.30595	13.38941	13.44710	13.34711	13.25985	13.46248	13.35442	13.25436	13.46322	13.35391	13.27920	13.46377	13.34939	13.27594	13.46440
205	11.65489	12.80631	13.05502	13.18674	13.34269	13.01810	12.80474	13.31419	13.02856	12.79794	13.31465	13.03213	12.81909	13.31803	13.02598	12.81566	13.31604
206	13.24106	13.86347	13.64793	13.60035	13.51880	13.65855	13.68641	13.56399	13.66538	13.68178	13.56634	13.66437	13.70625	13.56315	13.65959	13.70304	13.56688
211	12.69514	13.40985	13.24543	13.10817	12.98321	13.18474	13.23694	13.01400	13.19201	13.23293	13.01870	13.19215	13.25209	13.01536	13.18690	13.24920	13.01891

TABLE 7: SPSS synthetic photometry using different passbands (continued).

SPSS ID	U	B	V	R	I	G_{DR2}	BP_{DR2}	RP_{DR2}	G_{REV}	BP_{REV}	RP_{REV}	G_{WEI}	BP_{WEI}	RP_{WEI}	G_{DR2}	BP_{DR2}	RP_{DR2}
214	13.17244	13.88757	13.86113	13.93911	14.01279	13.89846	13.81114	14.02086	13.90475	13.80620	14.01979	13.90430	13.82844	14.02079	13.90042	13.82561	14.02100
215	11.94335	13.14472	13.43764	13.57652	13.71813	13.38186	13.15462	13.68802	13.39294	13.14741	13.68718	13.39753	13.16900	13.69088	13.39104	13.16552	13.68837
217	13.25892	14.10411	14.04811	13.98008	13.91868	14.00263	13.98310	13.93650	14.01036	13.97846	13.93985	14.01120	13.99774	13.93786	14.00594	13.99475	13.94032
218	13.38948	14.17092	14.22194	14.32445	14.41199	14.24562	14.12995	14.41294	14.25197	14.12504	14.41297	14.25225	14.14471	14.41474	14.24848	14.14204	14.41418
220	14.82491	15.36373	15.06339	14.84252	14.63901	14.97557	15.11878	14.68855	14.98272	15.11530	14.69490	14.98191	15.13563	14.69070	14.97646	15.13289	14.69501
221	15.22230	15.26032	14.49453	14.01602	13.54275	14.24944	14.69320	13.64844	14.25598	14.68975	13.65350	14.25669	14.71977	13.64177	14.24997	14.71683	13.65188
248	13.13602	13.95375	13.97672	14.07195	14.16450	14.00588	13.89332	14.16376	14.01291	13.88806	14.16419	14.01302	13.90985	14.16557	14.00875	13.90686	14.16535
250	13.48773	14.17207	14.09677	14.17209	14.23338	14.14606	14.07552	14.24257	14.15238	14.07058	14.24252	14.15165	14.09412	14.24303	14.14766	14.09111	14.24355
259	14.93706	14.90679	14.07981	13.62381	13.17298	13.86135	14.30119	13.26917	13.86805	14.29758	13.27398	13.86869	14.33021	13.26279	13.86190	14.32683	13.27226
262	13.50043	14.32633	14.38436	14.48180	14.56071	14.40142	14.28267	14.56576	14.40845	14.27739	14.56688	14.40864	14.29847	14.56848	14.40450	14.29566	14.56816
266	13.29872	14.28665	14.37798	14.41494	14.43661	14.34540	14.23118	14.43916	14.35395	14.22554	14.44015	14.35583	14.24616	14.44072	14.35051	14.24315	14.44116
271	13.66504	14.45566	14.46596	14.55157	14.63545	14.49370	14.39042	14.63311	14.50051	14.38519	14.63275	14.50063	14.40741	14.63421	14.49648	14.40450	14.63379
276	13.86781	14.66741	14.53683	14.45822	14.38748	14.49952	14.50055	14.40766	14.50747	14.49527	14.41122	14.50686	14.52061	14.40982	14.50134	14.51730	14.41188
279	13.25680	14.07621	14.13264	14.22439	14.27650	14.14424	14.03221	14.29061	14.15122	14.02701	14.29159	14.15130	14.04780	14.29182	14.14716	14.04503	14.29276
281	14.50954	15.16773	14.95753	14.76440	14.60202	14.87384	14.96650	14.64649	14.88115	14.96288	14.65156	14.88072	14.98177	14.64722	14.87533	14.97906	14.65184
300	11.75386	12.40985	12.34486	12.42381	12.49572	12.39478	12.32157	12.50085	12.40070	12.31687	12.50043	12.39994	12.33926	12.50146	12.39623	12.33641	12.50147
305	11.57238	12.80427	13.10504	13.24306	13.41663	13.04906	12.80999	13.38040	13.06093	12.80245	13.38116	13.06533	12.82531	13.38518	13.05841	12.82170	13.38261
307	12.05208	13.05001	13.19045	13.29259	13.41493	13.18339	13.02313	13.40157	13.19196	13.01708	13.40166	13.19368	13.03844	13.40404	13.18863	13.03542	13.40297
308	11.63233	12.89589	13.24111	13.39409	13.59071	13.17494	12.91578	13.54612	13.18716	12.90813	13.54581	13.19255	12.92972	13.55047	13.18542	12.92608	13.54727
309	12.19986	12.06707	11.81617	11.67100	11.52961	11.77730	11.90389	11.56040	11.77997	11.90261	11.56267	11.77914	11.91512	11.55921	11.77659	11.91389	11.56219
311	10.92035	10.97376	10.55756	10.30444	10.05570	10.46587	10.68040	10.11355	10.47103	10.67784	10.11791	10.47002	10.68167	10.11172	10.46545	10.68063	10.11730
313	15.62111	15.08935	14.11226	13.56581	13.02507	13.81668	14.36427	13.14026	13.82286	14.36077	13.14512	13.82410	14.39537	13.13204	13.81709	14.39224	13.14306
314	14.35782	13.62959	12.64464	12.10841	11.61592	12.37287	12.89568	11.71938	12.37932	12.89209	11.72437	12.37999	12.92883	11.71221	12.37298	12.92569	11.72240
315	13.13746	13.11315	12.58140	12.26377	11.96084	12.45774	12.73518	12.03164	12.46359	12.73235	12.03673	12.46242	12.75694	12.02898	12.45713	12.75446	12.03594
320	15.20001	15.31868	15.02629	14.82955	14.62414	14.95453	15.11185	14.67565	14.95876	15.10987	14.67900	14.95802	15.12511	14.67371	14.95432	15.12340	14.67863
324	15.24673	15.19802	15.01796	14.90165	14.77778	14.98349	15.07984	14.80882	14.98563	15.07886	14.81059	14.98502	15.08794	14.80730	14.98298	15.08703	14.81035
327	13.40703	12.59469	11.01145	9.95305	8.70628	10.02135	11.29075	8.96051	10.02030	11.28843	8.96082	10.03301	11.28838	8.93133	10.02604	11.27325	8.95604
328	13.35856	12.17522	10.81046	9.96745	9.22465	10.23597	11.06091	9.37568	10.24133	11.05767	9.37901	10.24653	11.05736	9.36218	10.23861	11.04569	9.37606
334	15.20459	13.97108	12.43581	11.39131	10.22212	11.49512	12.69504	10.45759	11.49493	12.69246	10.45702	11.50702	12.72665	10.43004	11.50000	12.72509	10.45239
336	12.77895	11.62422	10.21660	9.25773	8.19431	9.40154	10.47227	8.41385	9.40309	10.46948	8.41457	9.41246	10.47054	8.38934	9.40524	10.45645	8.41022
339	13.59318	12.34987	10.76554	9.71059	8.52288	9.80077	11.03009	8.75108	9.79936	11.02767	8.74845	9.81405	11.02798	8.72219	9.80734	11.01228	8.74327
340	13.58857	12.34866	10.76525	9.70683	8.50917	9.79209	11.03034	8.73941	9.79062	11.02792	8.73677	9.80540	11.02816	8.71043	9.79870	11.01245	8.73161
345	10.74466	10.77273	10.38737	10.14788	9.92034	10.30375	10.50365	9.97286	10.30856	10.50133	9.97734	10.30760	10.50447	9.97193	10.30333	10.50341	9.97678
346	12.15218	12.05666	11.45694	11.11128	10.79158	11.32108	11.62907	10.86390	11.32732	11.62594	10.86939	11.32619	11.65352	10.86192	11.32054	11.65084	10.86853
347	11.17519	11.07244	10.85767	10.73584	10.62685	10.83054	10.93415	10.65111	10.83300	10.93288	10.65363	10.83210	10.93313	10.65138	10.82989	10.93200	10.65337
348	12.54672	12.49748	11.92818	11.59472	11.31066	11.80657	12.09309	11.37594	11.81302	12.09017	11.38229	11.81147	12.11591	11.37640	11.80591	12.11334	11.38178
350	13.15014	11.97522	10.53275	9.62807	8.78465	9.88011	10.78984	8.97931	9.88761	10.78667	8.98670	9.88893	10.78644	8.96622	9.88046	10.77383	8.98453
352	16.86363	15.69599	14.13678	12.95921	11.52732	12.92572	14.40037	11.80071	12.92114	14.39810	11.79756	12.93838	14.42969	11.76498	12.93226	14.42849	11.79200

TABLE 7: SPSS synthetic photometry (continued).