The S-PLUS Ultra-Short Survey: first data release

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Introduction

- The chemical and enrichment history of early Universe can be better understood by studying the oldest stars with lifetimes sufficiently long to still be found in the Milky Way today.
- In this context, metal-poor stars play a fundamental role in the study of (i) astrophysical sites for the formation of different elements , (ii) the metal-mixing processes that affect the formation of subsequent stellar generations , (iii) the earliest chemical evolution at high redshift ($z > 20$) , and (iv) the assembly history of the Milky Way.
- In the Galactic halo, a handful of accretion events have been revealed as well as various tidal streams.
- Moreover, the Galactic disk system also exhibits a very and extremely metal-poor component of unknown (but possibly primordial) origin.

The S-PLUS Ultra-Short Survey

- The dedicated telescope for the USS is called the T80-South (T80S), a 0.826m robotic telescope specifically designed for wide-field optical imaging.
- This camera is designed to capture wide-field images with dimensions of 1.4 by 1.4 degrees, using a CCD of 9232 × 9216 pixels (see Marin-Franch et al. 2012) and a plate scale of 0.55 arcsec/pixel.

Table 1. USS filter summary and exposure times.

Filter name	λ_{eff} [Å]	Feature	T_{exp} (s)	Filter name	λ_{eff} [Å]	Feature	T_{exp} (s)
u	3533		20	J0515	5133	Mgb Triplet	5
J0378	3773	[O II], CN	19	r	6251		3
J0395	3940	Ca H+K	10	J0660	6613	Hα	24
J0410	4095	Hδ	5	i	7670		4
J0430	4292	CH G-band	5	J0861	8607	Ca Triplet	7
g	4758		3	z	8936		5

The S-PLUS Ultra-Short Survey

The USS can be separated into two regions: the fields within the S-PLUS Galactic sub-survey area (represented by gold rings in Figure 1) and regions avoiding the Galactic plane (gray and purple symbols).

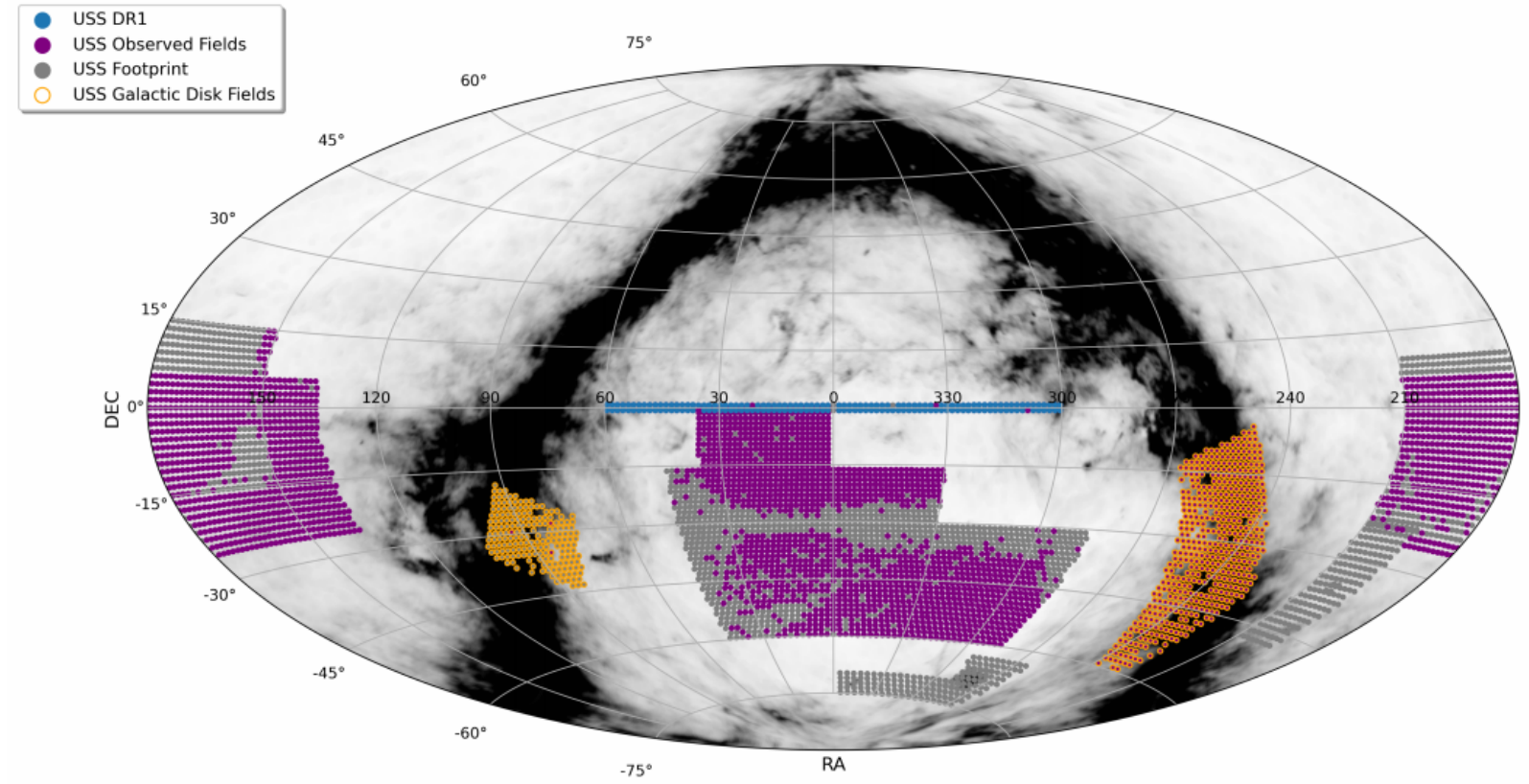


Fig. 1. USS footprint in equatorial coordinates using an Aitoff projection. The blue circles are the USS DR1 fields. The purple circles are the observed fields, and the gold ring indicates the fields in the region of the Galactic disk. The gray circles indicate the footprint area not observed yet. The background represents E$(B-V)$ values ranging from 0.0 (white) to 0.5 (black) according to the map by Schlegel et al. (1998).

The S-PLUS Ultra-Short Survey

Consequently, the saturation limit of the USS is ~10 mag for the r-band, or about four magnitudes brighter than for the S-PLUS Main Survey.
In the USS DR1 the median airmass of the observed fields is ~1.28, with a standard deviation of 0.14 (see Table 2).

Table 2. USS filters mean and standard deviations of the airmass and FWHM spatial coverage.

Filter	Airmass Mean	Airmass Std	FWHM (arcsec) Mean	FWHM (arcsec) Std
u	1.28	0.13	1.98	0.60
J0378	1.28	0.13	1.86	0.56
J0395	1.28	0.13	1.80	0.57
J0410	1.28	0.13	1.77	0.57
J0430	1.29	0.14	1.75	0.57
g	1.29	0.14	1.72	0.60
J0515	1.29	0.14	1.68	0.65
r	1.29	0.14	1.42	0.53
J0660	1.29	0.15	1.69	0.58
i	1.29	0.14	1.50	0.53
J0861	1.29	0.15	1.67	0.65
z	1.29	0.15	1.41	0.52

Photometry Extraction

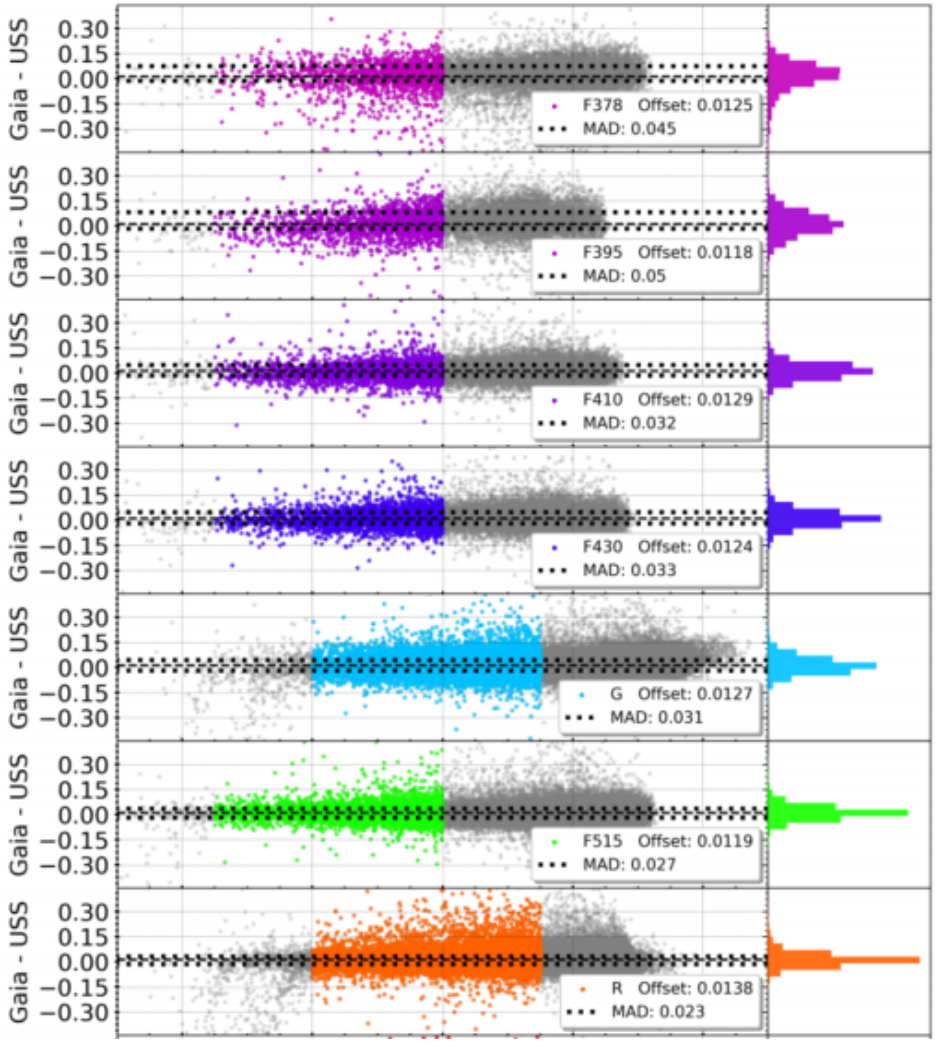
- Astrometry is calculated using the SCAMP code (Bertin 2006) and the point source catalog of the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006) as a reference.
- The USS DR1 provides circular aperture photometry obtained using SExtractor (Bertin & Arnouts 1996). The final catalogs contain magnitudes measured in 3- and 6-arcsec diameter apertures (labeled APER_3 and APER_6) and the aperture-corrected instrumental magnitudes (PStotal).

Photometric Calibration Method

- In this work, for the photometric calibration, we used the reference magnitudes from the ATLAS All-Sky Stellar Reference Catalog (ATLAS Refcat2; Tonry et al. 2018).
- This is done by fitting synthetic stellar spectral energy distributions (SEDs) to the reference magnitudes using chi-square minimization.
- The u, J0378, J0395, J0410, and J0430 filters are calibrated using a stellar locus-based technique, also presented in Almeida Fernandes et al. (2022).
- In this technique, the stellar locus of the observation in the $y - g \times g - i$ space, where y represents a blue filter (with g and i already previously calibrated), is compared to a reference stellar locus.

Photometric Quality Assurance

We obtained the S-PLUS photometry by synthesizing the flux in each S-PLUS filter from the Gaia XP photometry with the GaiaXPy python library.



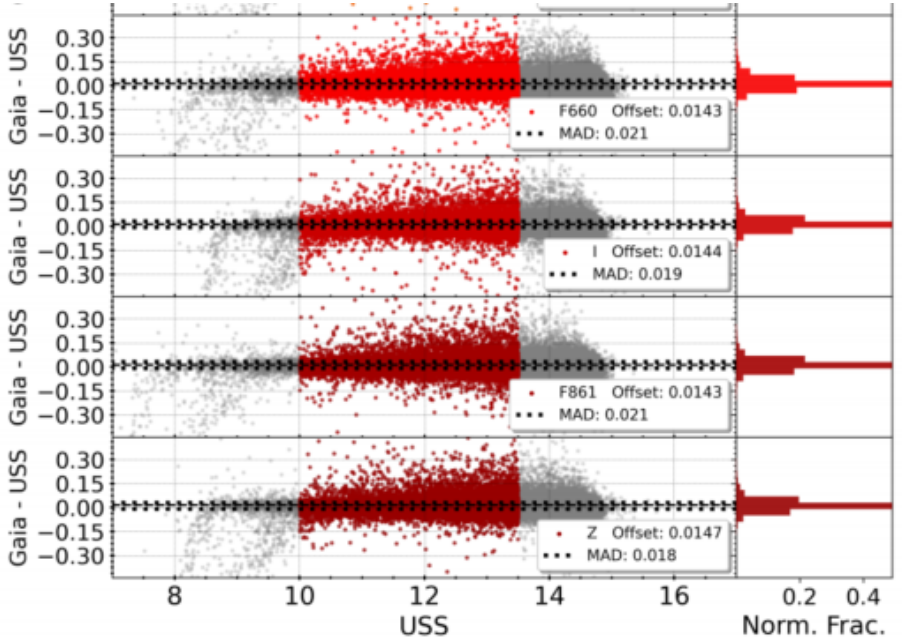
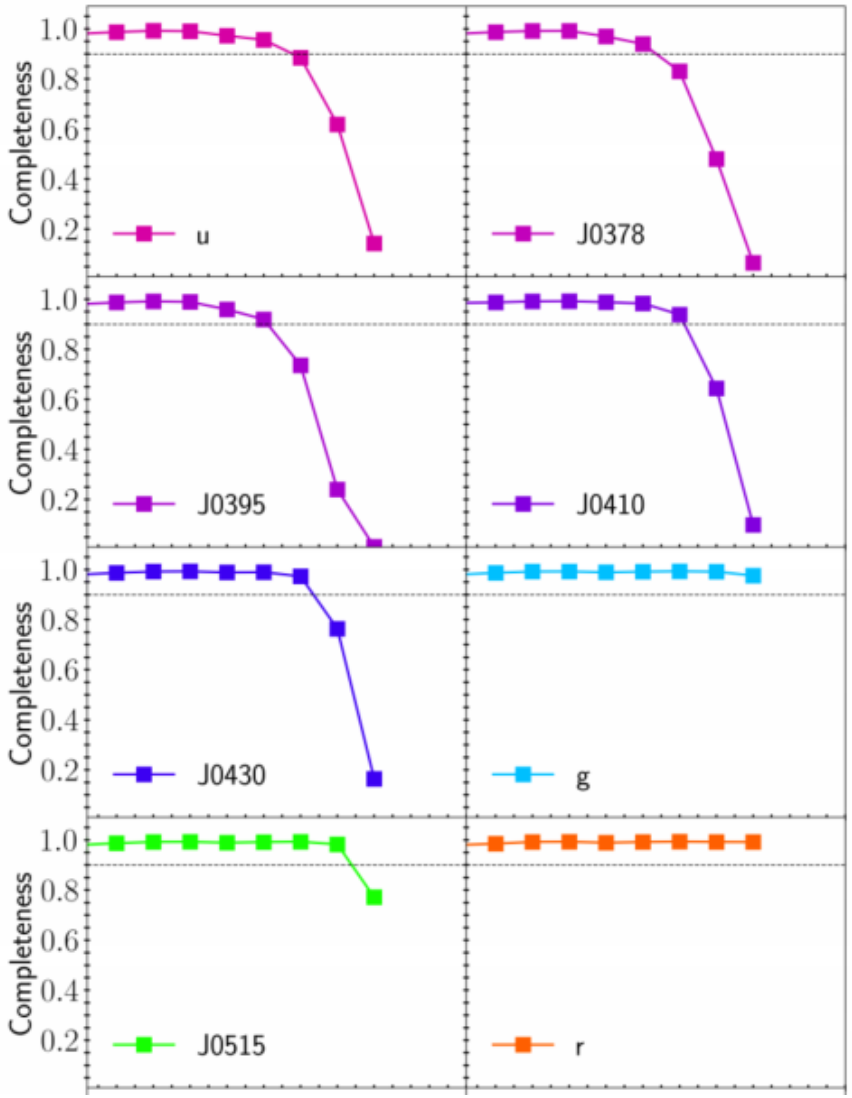


Fig. 2. Residual magnitude differences between S-PLUS magnitudes and the predicted S-PLUS XP spectra magnitudes are presented in each panel, as a function of the S-PLUS magnitudes. The corresponding offset for each filter is indicated in the upper right corner of the respective panel. The colored dots represent the region utilized for offset calculations. The gray dots are the sources with errors smaller than 0.04 mag. The black dotted lines indicate the Mean Absolute Deviation. In the right panels, the normalized fraction of the residual magnitude differences is shown.

Detection Completeness

The completeness is around a hundred percent for all bins for the filters g, r, J0515, J0660, i, J0861, and z.
For filters u, J0378, J0395, J0410, and J0430 the detection completeness reach about 100% until G < 11, and decreases significantly for fainter sources.



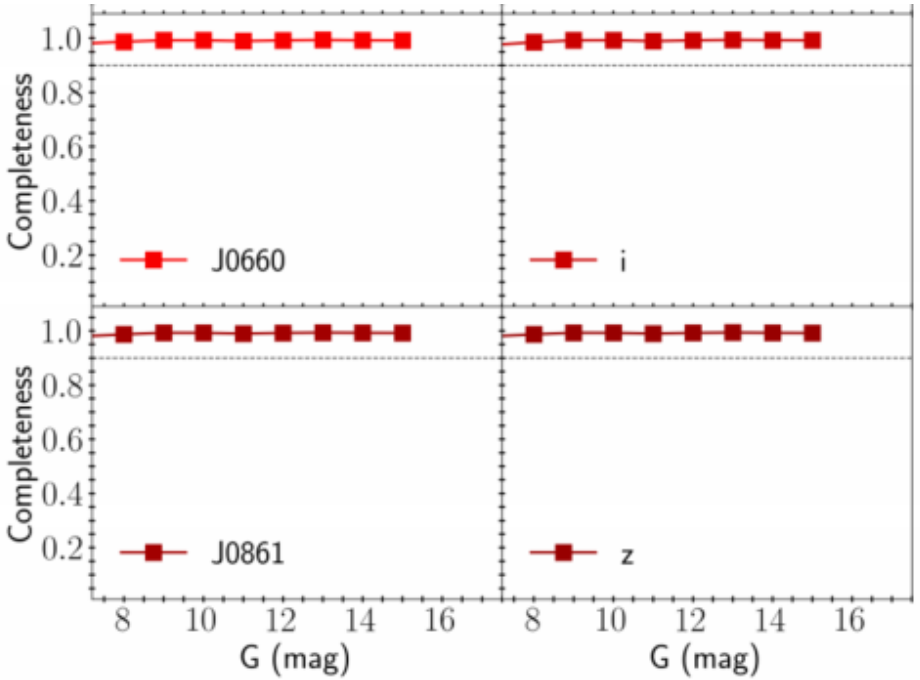


Fig. 4. Detection completeness in relation to the Gaia DR3 *G*-band for all filters from USS DR1. An internal legend indicates the filters that correspond to each panel. For visual reference, the gray dashed line indicates 90% of sources detected. We considered the detection of all the objects with S/N > 3 if the SExtractor attributed a magnitude value other than 99 for this filter.

Depth

For each filter and S/N value, the peak of the magnitude distribution was estimated using a kernel density estimator, applied individually to all fields.

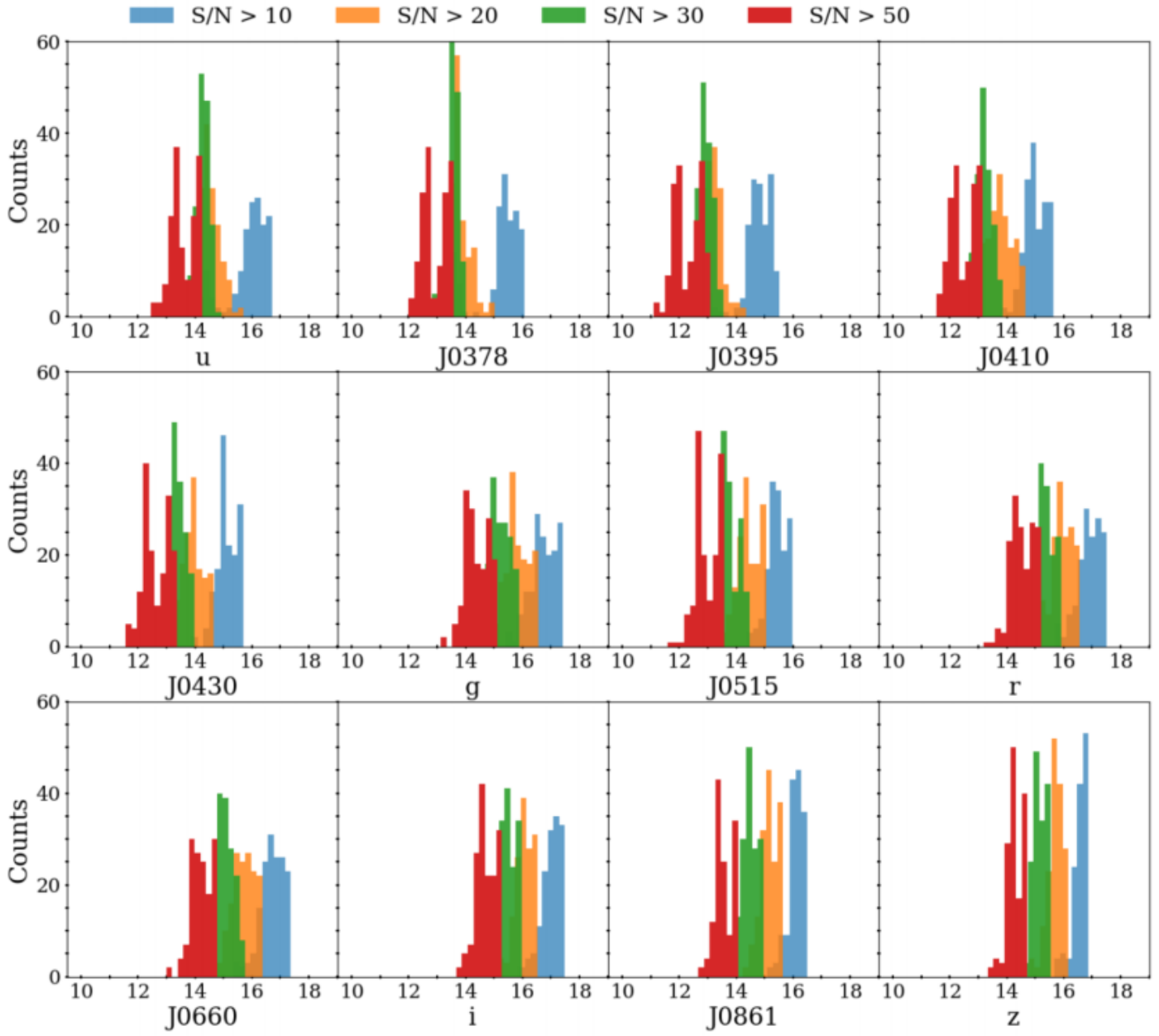


Fig. 5. Photometric depth in PStotal magnitudes for the 12 filters of the USS DR1 for the 163 fields. In the histograms, distinct colors represent different S/N threshold values of 10, 20, 30, and 50, represented in blue, orange, green, and red, respectively.

Contents of USS DR1

- The first data release of the USS includes observations of 163 fields, covering a total area of ~324 deg^2 , across the 12 bands. The catalog contains approximately 1 million detections, from which ~ 63,000 sources have r < 14.

Data Quality Control Cuts

- CLASS_STAR_R ≥ 0.90)
- not saturated (SEX_FLAGS_filter < 4, for all filters)
- e_filter_PStotal ≤ 0.2
- 0.2 ≤ g_PStotal-i_PStotal ≤ 1.4
- 0.3 ≤ J0410_PStotal-J0861_PStotal ≤ 3.5(to eliminate potential contamination from white dwarfs and A-type stars at the blue end, and objects cooler than Teff ~4000 K at the red end.)
- After applying these criteria, our final sample comprises 45,520 stars.

Methodology and Target Selection

Additionally, Placco et al. (2022) improved the color combination used by Starkenburg et al. (2017) and Da Costa et al. (2019) by employing (J0395-J0410)-(J0660-J0861), which increased the sensitivity to temperature variations. This refined color combination resulted in a success rate of approximately 83% the identification of stars with [Fe/H] < −2.0.

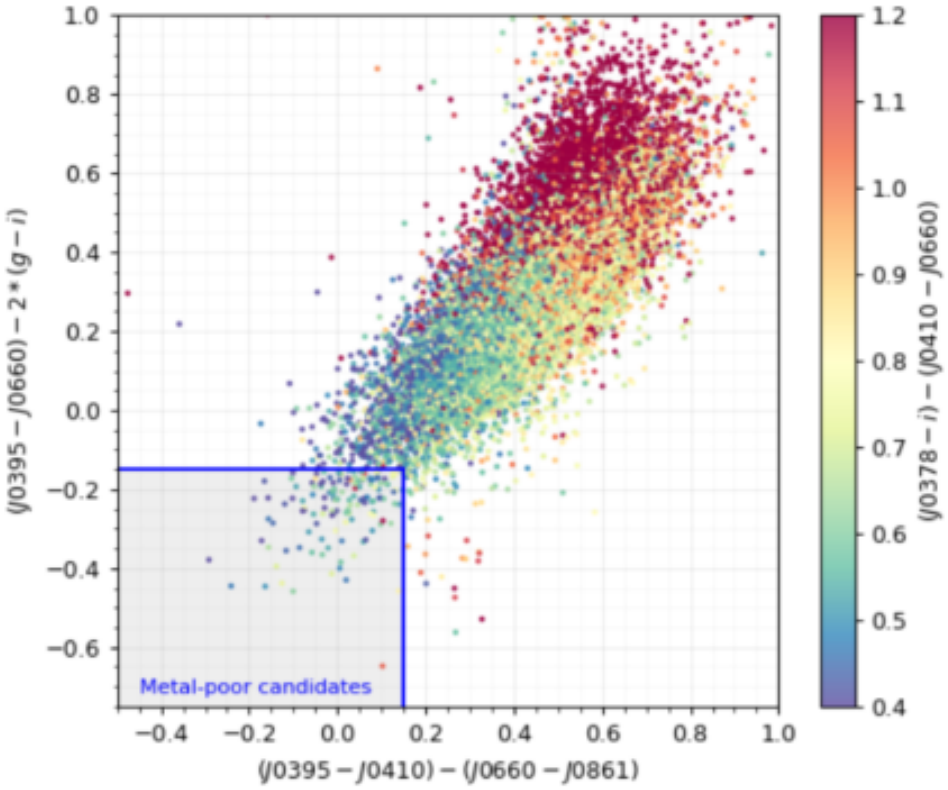


Fig. 6. Selection of low-metallicity stellar candidates in USS DR1, following the criteria proposed by Placco et al. (2022): (J0395-J0410)-(J0660-J0861) ≤ 0.15 and (J0395-J0660)-2x(g-i) ≤ −0.15. The points are color-coded according to the (J0378-i)-(J0410-J0660) color; only stars with measurements below 0.8 in this color are included in our final selection.

Methodology and Target Selection

- In this region, we identified a total of 152 stars, from which 91, 25, 7, and 2 targets have r-band magnitudes brighter than 14, 13, 12, and 11, respectively.
- Additionally, Placco et al. (2022) observed that a substantial fraction of stars with [Fe/H] > −1.0 exhibit higher temperatures (i.e., Teff > 5900 K). Taking this into account, we restricted our target selection to retain only objects that have (J0378-i)-(J0410-J0660) < 0.80.

Conclusion

- This paper presents the first data release of the S-PLUS Short Survey (USS), which will cover approximately 9300 deg^2 of the Southern Hemisphere sky.
- This data release contains the data from 163 observed fields, totaling ~324 deg^2 and detecting a total of ~1 million sources.
- The photometric quality is ensured by a small average offset of 15 mmag between the USS observed magnitudes and those predicted by GaiaXPy.
- To identify relatively bright EMP and UMP stars within the USS DR1 data, we apply the color magnitude combinations ((J0395-J0660)-2x(g-i) and (J0395-J0410)-(J0660-J0861)) validated by Placco et al. (2022).

Conclusion

- A refined selection, incorporating (J0378-i)-(J0410-J0660), reduces these numbers to 140 stars, with 84, 23, 6, and 1 brighter than r = 14, 13, 12, and 11, respectively.