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J-PLUS Data Release 1.

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Abstract

We present the first data release of the Javalambre Local Universe Photometric Survey (J-PLUS), an ongoing photometric survey with 12 optical bands observing thousands of square degrees of the sky from the JAST/T80 telescope at the Observatorio Astrofísico de Javalambre (OAJ). T80Cam is a 2 deg^2 field-of-view (FoV) camera mounted on JAST/T80, and is equipped with a unique system of filters spanning the entire optical range (3500 − 10000 Å), optimally designed to extract the rest-frame spectral features that are key to both characterize stellar types and to deliver a low-resolution photo-spectrum for each observed object. With a typical depth (5σ in 3 arcsec aperture) of AB $\sim$ 20.7 mag per band, we release the first 1022 deg^2 of J-PLUS data, containing about 4.3 million stars and 3.0 million galaxies at $r < 21$ mag.

1 Introduction

J-PLUS [5] is being conducted from the OAJ, using a unique set of 12 broad, medium and narrow-band filters (Fig. 1 and Table 1; [15]). This filter set has been particularly defined to be sensitive to key stellar spectral features in the rest frame, thus being optimal for Milky Way science and studies of galaxies in the local Universe. In addition, the survey strategy has been fine-tuned to optimize the scientific return in a wide range of applications in many other areas of Astrophysics.

The OAJ is an astronomical facility located at the Pico del Buitre (1957 m) of the Sierra de Javalambre, in Teruel, Spain. The site has excellent astronomical characteristics in

terms of median seeing (0.71 arcsec in V band), fraction of clear nights (53 % totally clear, 74% with at least a 30% of the night clear) and darkness, with a typical sky surface brightness of V $\sim$ 22 mag arcsec^{-1} at zenith during dark nights [18].

The OAJ was defined, designed and constructed to carry out large sky surveys with dedicated telescopes. The two main telescopes at the OAJ are the Javalambre Survey Telescope (JST/T250), a 2.55 m telescope with 3 deg diameter FoV, and the Javalambre Auxiliary Survey Telescope (JAST/T80), a 83 cm telescope with a FoV diameter of 2 deg. JAST/T80 is the telescope dedicated to the development of J-PLUS, whereas J-PAS (Javalambre Physics of the accelerating universe Astrophysical Survey, [2]) will be carried out at the JST/T250.

JAST/T80 is mounted with T80Cam, a sigle CCD 9.2k x 9.2k pixel camera with an effective FoV of 2 deg^2, and equipped with the twelve J-PLUS filters. Full technical details on T80Cam can be found in [14] and [16].

The management, reduction, validation, calibration, and public dissemination of the J-PLUS images have been done by the *Unidad de Procesado y Archivo de Datos* (UPAD) at CEFCA [6].

The J-PLUS, including extra technical details, survey strategy and science cases, is fully detailed on its presentation paper [5], so there is significant overlap between the present contribution and the content in that publication.

Table 1: The J-PLUS filter system and the goal limiting magnitudes of J-PLUS (5σ in 3 arcsec aperture), presented together with the averaged limiting magnitudes obtained for the DR1. The zero point calibrations and their uncertainties are also indicated. Comments: (a) In common with J-PAS; (b) SDSS.

Filter	Central Wavelength [Å]	FWHM [Å]	Comments	$m_{\rm lim}^{\rm J-PLUS}$	$m_{\rm lim}^{\rm DR1}$	$\langle$ZP$\rangle$	$\sigma_{\rm ZP}^{\rm DR1}$
u	3485	508	(a)	20.5	20.8	21.13	0.02
$J0378$	3785	168	[OII]	20.5	20.7	20.54	0.03
$J0395$	3950	100	Ca H+K	20.5	20.7	20.32	0.02
$J0410$	4100	200	H_δ	20.7	20.9	21.30	0.02
$J0430$	4300	200	G-band	20.7	20.9	21.37	0.02
g	4803	1409	(b)	21.5	21.7	23.58	0.02
$J0515$	5150	200	Mgb Triplet	20.7	20.9	21.52	0.01
r	6254	1388	(b)	21.5	21.6	23.52	0.01
$J0660$	6600	138	Hα; (a)	20.7	20.9	21.04	0.01
i	7668	1535	(b)	21.2	21.1	23.25	0.01
$J0861$	8610	400	Ca Triplet	20.0	20.2	21.54	0.02
z	9114	1409	(b)	20.2	20.3	22.63	0.02

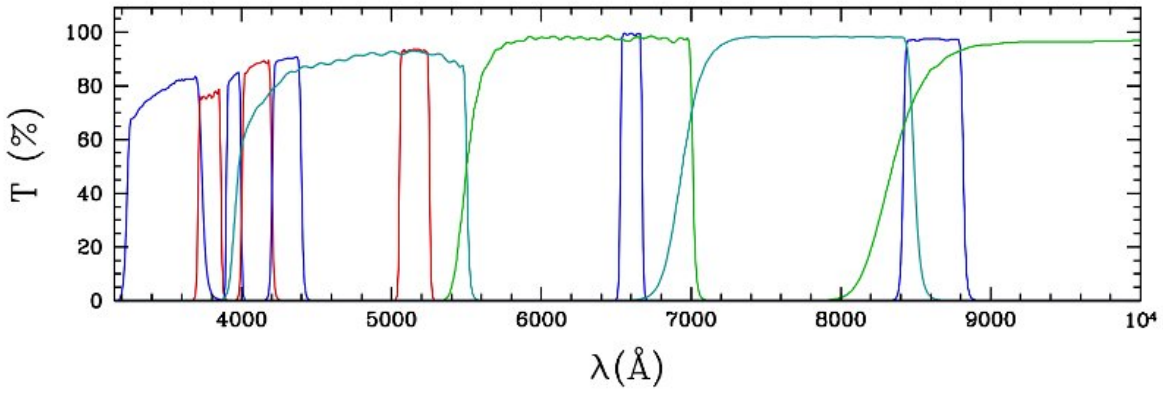

Figure 1: Transmission curves for the set of 12 J-PLUS filters.

2 J-PLUS DR1

J-PLUS DR1 comprises the J-PLUS tiles observed from the start of the survey up to the beginning of 2018, that is, 511 tiles amounting to 1022 deg^2 ($\sim$900 deg^2 after masking, Fig. 2), with more than 13 million objects in the catalogue and $\sim$8.3 million sources at $r < 21$. The DR1 is available at the J-PLUS web portal since this contribution, on July 2018.

The FWHM and ellipticity distributions of the J-PLUS DR1 $r-$band reference images are shown in Fig. 3. We note that DR1 includes all J-PLUS tiles irrespective of their final image qualities, explaining the tails with > 1.5 arcsec and < 0.98 in the FWHM and ellipticity distributions, respectively. These however have little impact on the average quality of the DR1 data.

The DR1 limiting magnitude (5σ in 3 arcsec aperture) distributions in the 12 J-PLUS bands are presented in Table 1 and in Fig. 4, where the expected J-PLUS limits are indicated by vertical dotted lines. The limiting magnitudes fulfil, on average, the targeted depths. The DR1 includes all tiles of the survey acquired so far, incorporating a few ones that were observed deeper in some bands at the beginning of the survey, when testing the system performance. They appear as a secondary, fainter peak in the depth distribution.The typical scatter in the survey depths is $\sim 0.2 - 0.3$ mag, depending on the band. This scatter reflects the variations in observing conditions from night to night, mainly in transparency and seeing.

The photometric calibration of J-PLUS faces two main challenges: the variety of observational conditions in which J-PLUS images are taken and the use of a unique set of filters. However, the difficulty of these tasks is alleviated by the large amount of reference external data from projects like SDSS [25], PanSTARRS [11], and *Gaia* [8]. We explored different calibration procedures, i.e. spectro-photometric standard stars, synthetic photometry of SDSS spectra, and direct comparison with SDSS and PanSTARRS photometry. Currently, the default calibration method is based on the *stellar locus* technique. This procedure profits from the way stars with different stellar parameters populate colour-colour diagrams, defining a well limited region (stellar locus). A specific stellar locus approach for the calibration of J-

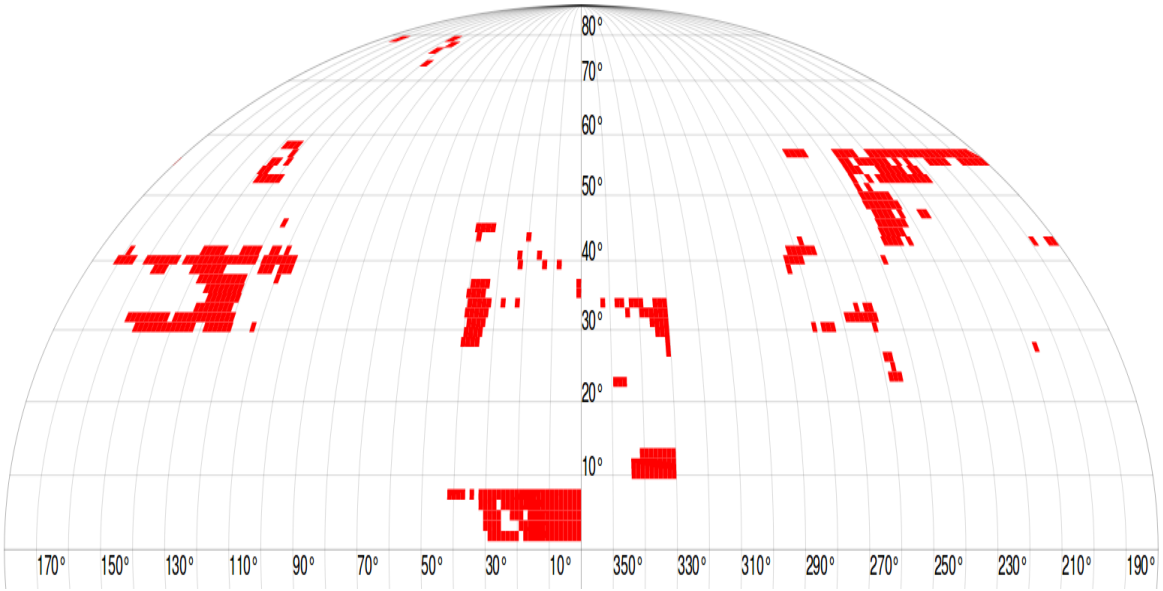

Figure 2: Footprint of the J-PLUS DR1. Red squares represent the 511 pointings of 2 deg^2 provided by T80Cam at JAST/T80. The DR1 amounts effectively to ~ 900 deg^2 after masking low exposure regions, the surroundings of bright stars, observational reflections or artefacts, and overlapping areas. Figure from [5].

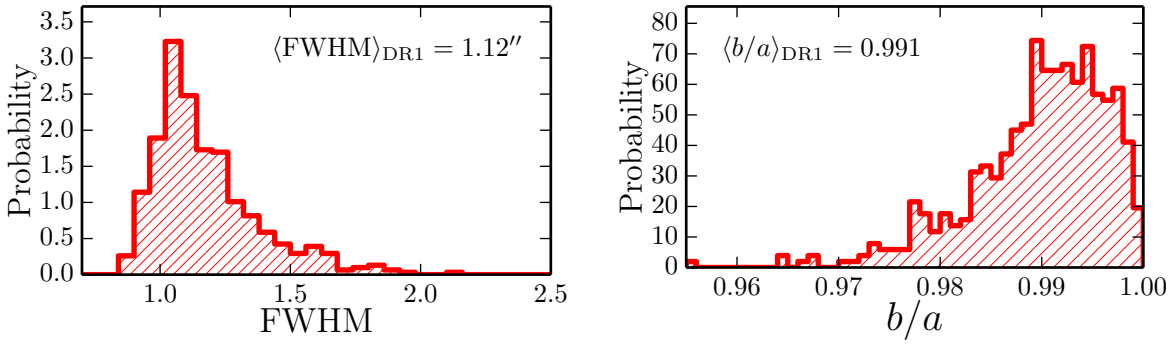

Figure 3: FWHM and ellipticity (b/a ratio) statistics of the J-PLUS DR1 (red hatched histograms) as measured in the reference r band on objects classified as point-like sources.

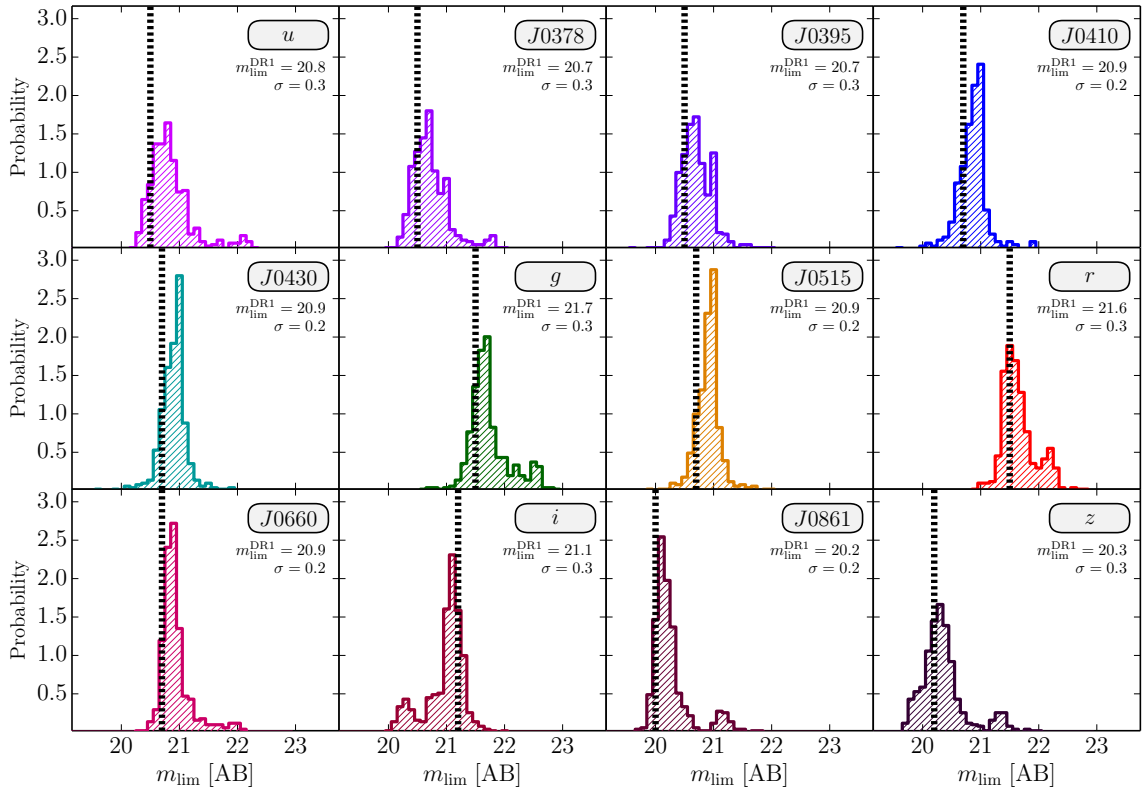

Figure 4: Normalised distribution of the limiting magnitudes (5σ, $3''$ aperture) of the J-PLUS DR1 (511 tiles). The black dashed vertical lines mark the targeted J-PLUS limiting magnitudes as reported in Table 1.

PLUS has been developed, obtaining consistent zero point calibrations over the full J-PLUS area and spectral range with $\sigma_{\rm ZP} \sim 0.02$ (Table 1).

In addition to several calibrated magnitudes for each source, the J-PLUS DR1 also comprises a set of value-added properties: a Bayesian star/galaxy classification, with a prior based on *Gaia* data for those sources having a parallax measured with SNR$>$ 3 classified as stars [13], effective temperatures estimates for Milky Way stars, and photometric redshift for galaxies.

The J-PLUS star and galaxy number counts are studied in [13], providing results in agreement with the literature up to $r = 21$. We report 4.3 million stars and 3 million galaxies in DR1. We present a representative example of a J-PLUS pointing in Fig. 5, with the J-PLUS SEDs of several astrophysical objects (stars, galaxies, and QSOs) in Figs. 6, 7, and 8, respectively.

Photometric redshifts for J-PLUS DR1 galaxies have been computed using BPZ2 [1, 19], *LePhare* [9], and TPZ [4] . These three estimations are providedin the DR1 catalogues. A quantitative comparison between J-PLUS DR1 photometric redshifts from BPZ2 and SDSS spectroscopic values is provided in Fig. 9. We find that the spectroscopic values are retrieved with no significant bias ($|\Delta z| \equiv |z_{\rm phot} - z_{\rm spec}| < 0.005$ for $r-$band magnitude < 20), and a typical error $\delta_z/(1+z)$ in the range $0.005 - 0.03$ for $r \in [16, 20]$. In particular, we find $\delta_z/(1+z) < 0.02$, 0.03 and 0.05 precision for z < 0.1, 0.3 and 0.5 galaxies, respectively.

The access to J-PLUS DR1 data can be done in several ways, from a sky navigator (Fig. 10) to an ADQL query service, including cone and list search. The data is also accessible with Virtual Observatory tools.

3 J-PLUS science

The J-PLUS data have already provided a set of scientific papers, some of them in press at Astronomy & Astrophysics, including among others:

- **Multiple stellar population in the M15 globular cluster** [3]. This cluster has been observed well beyond the tidal radius with uniform photometry thanks to the large Fov of T80Cam. We show that the colour-magnitude diagram (CMD) $J0378$ versus $(J0378 - J0861)$ yields the detection of a clear split into two distinct sequences, suggesting a link to light elements abundances, because the $J0378$ and $J0861$ filters are sensitive to N and Ca.

- **Study of the nearby galaxy clusters A2589 (z$=0.0414$) and A2593 (z$=0.044$)** [20]. The indiscriminate photo-z estimation for galaxies in these clusters opens the way to statistical study cluster membership, while providing valuable data for optimal target selection in spectroscopic follow-ups. In particular, photo-zs produced by J-PLUS are going to be used by the WEAVE cluster surveys in the process of target selection. It is expected that this will increase the spectroscopic success rate by a factor 2–3. Also the intracluster light of nearby surveys can be studied, providing clues about their origin [10].

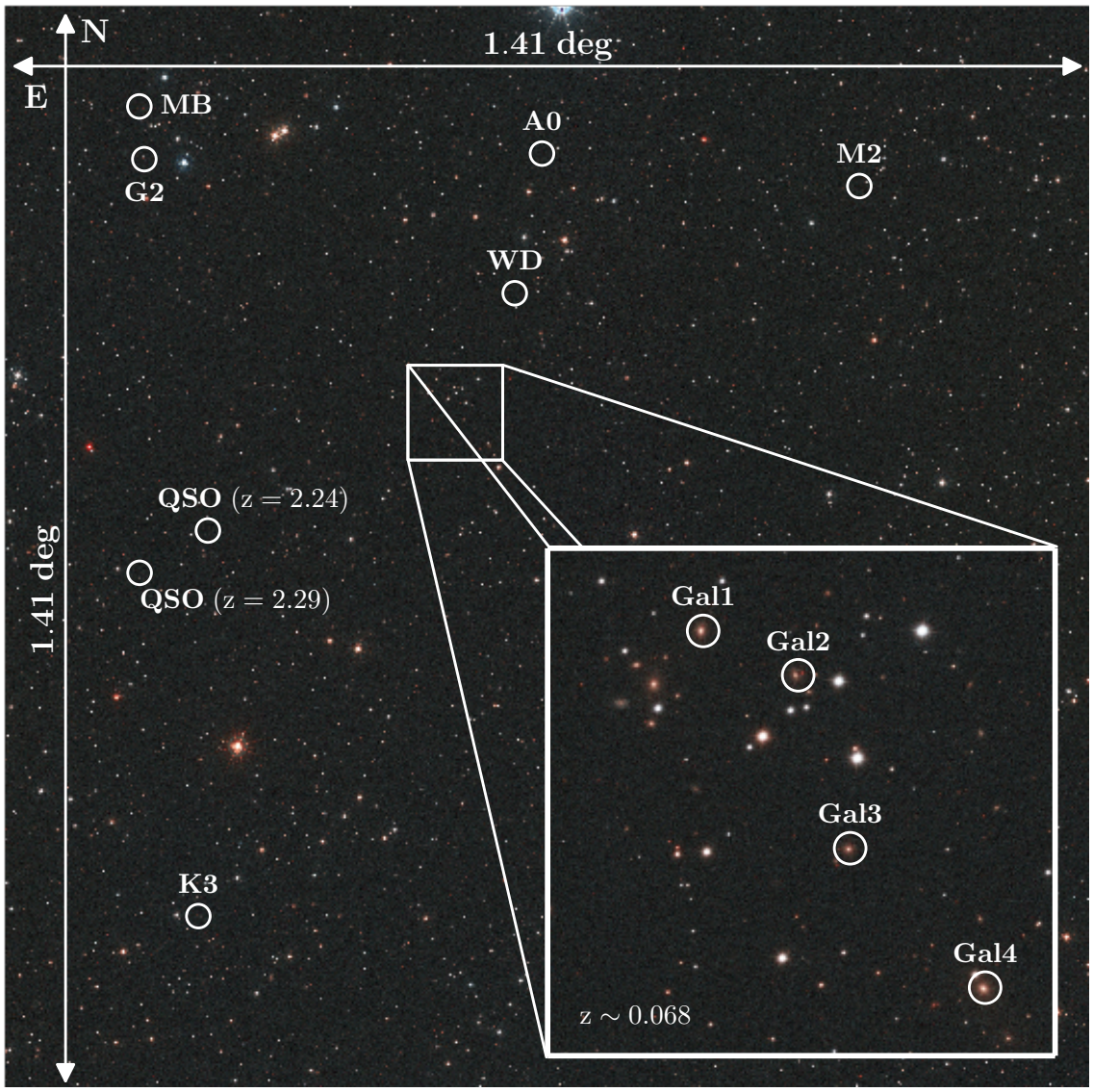

Figure 5: Colour composite of the J-PLUS pointing 1488. Several astrophysical objects are labelled in the figure: four MW stars of different spectral types (A0, G2, K3, M2, see Fig. 6); one white dwarf (WD), a minor body (MB) of the Solar System, four galaxies belonging to a $z = 0.068$ nearby cluster (Gal1, Gal2, Gal3, Gal4, see Fig. 7), and two high-z quasars (QSOs, see Fig. 8). Figure from [5].

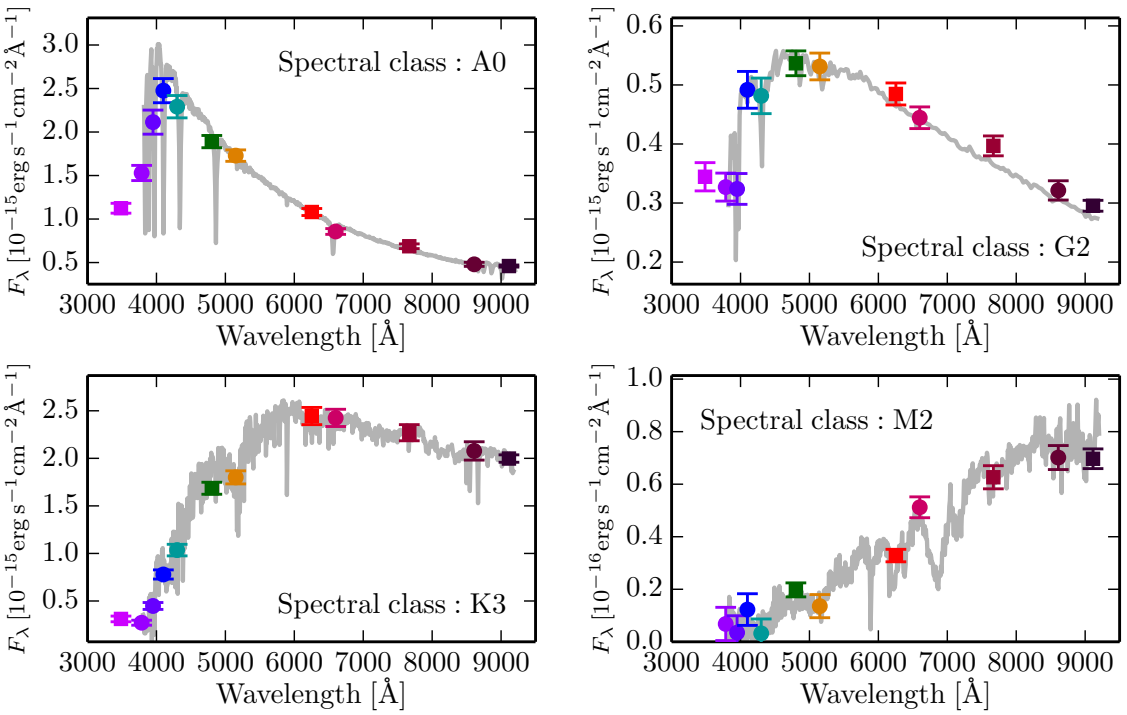

Figure 6: J-PLUS photo-spectra of the four Milky Way stars marked in Fig. 5. The grey lines show the SDSS spectra of these stars. Figure from [5].

- **Estimation of the Hα flux in nearby galaxies** [12]. We trace the Hα emission at $z < 0.017$ thanks to the $J0660$ filter and the continuum with the other eleven J-PLUS filters. The comparison with spectroscopically derived fluxes in common HII regions with SDSS and CALIFA [21] provides a ratio $R = 1.05 \pm 0.25$, confirming the expectations from [24]. The local star formation rate density derived from J-PLUS DR1 is presented in these proceedings by Vilella-Rojo et al.

- **2D Stellar Populations in the nearby galaxies NGC 5473 and NGC 5485** [23]. A technique for studying 2D stellar populations in multi-narrow band photometric surveys has been presented in [22], where resolved galaxies in the ALHAMBRA [17] survey are analysed via a Centroid Voronoi Tessellation and characterized by multi-color photometry SED fitting with MUFFIT [7]. This technique has been applied to the galaxies NGC 5473 and NGC 5485, observed by J-PLUS and CALIFA.

- **Lyα emitters ar z$\sim$** 2.2. The J-PLUS filter configuration allows to select samples of emission-line galaxies and QSOs at z$\sim$ 2.2, when the Lyα emission can be isolated and characterized with the $J0395$ filter (Fig. 8). We have more than 600 candidates selected in J-PLUS DR1, some of them already followed up with OSIRIS/GTC spectroscopy. That confirmed 85% of the candidates at high-z QSOs. More details are presented in these proceedings by Spinoso et al.

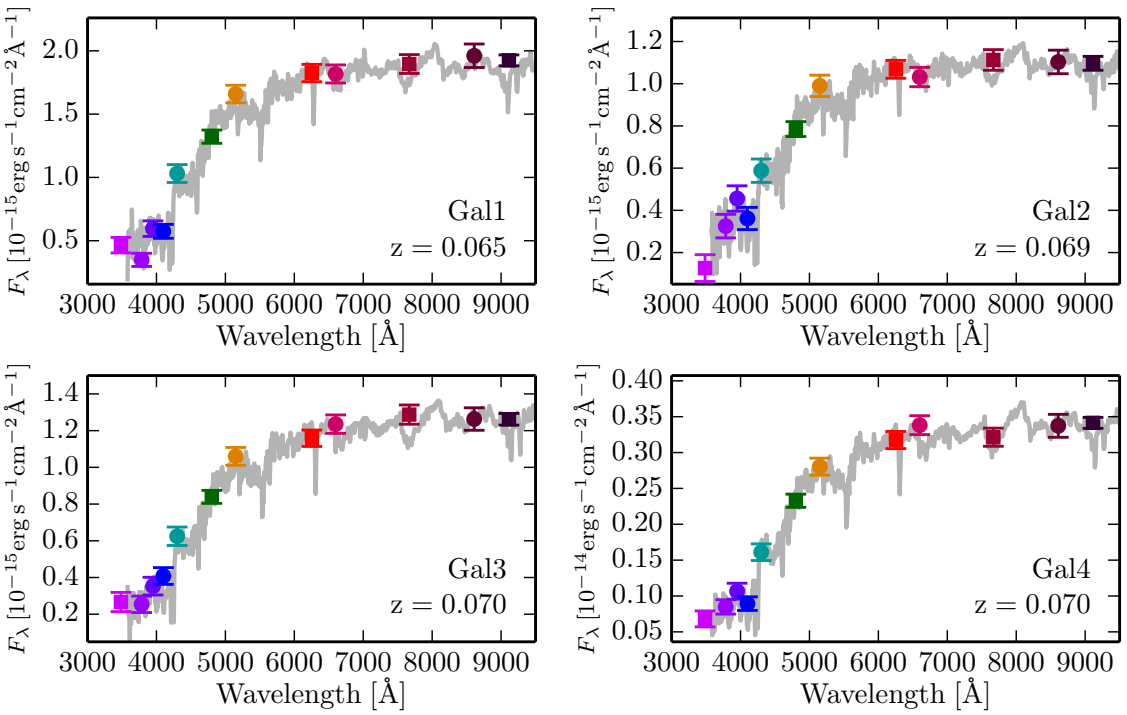

Figure 7: J-PLUS photo-spectra of the four galaxies marked in Fig. 5. The grey lines show the SDSS spectra of these galaxies and their spectroscopic redshift. Figure from [5].

4 Summary and Conclusions

This contribution aims to release the first 1022 deg^2 of J-PLUS data, amounting to 4.3 million stars and 3 million galaxies at $r < 21$ mag observed in 12 broad, intermediate and narrow optical bands. This dataset is used to illustrate some of the science cases that will be addressed by J-PLUS. At the time of writing this manuscript, J-PLUS has already mapped more than 1400 deg^2, providing unprecedented information of the SED for millions of stars and galaxies.

To conclude, J-PLUS may thus be opening an exciting and interesting new phase in optical, large scale, astrophysical surveys. Ultimately, J-PLUS will become a powerful multicolour view of the nearby Universe that will observe and characterize tens of millions of galaxies and stars of the Milky Way halo, with a wide range of astrophysical applications and a striking potential for bringing unexpected discoveries to our knowledge of the Universe. The J-PLUS data will be made public progressively in subsequent data releases, an expression of its commitment to become a major legacy project for the astronomy and astrophysics of the next decades.

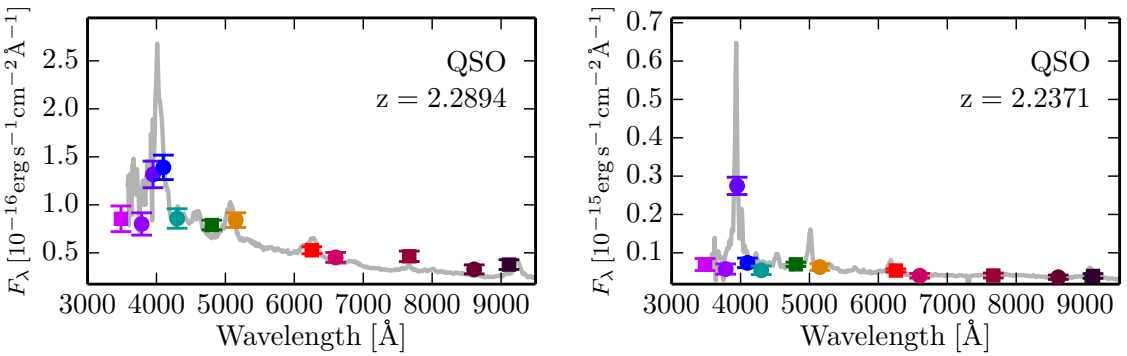

Figure 8: J-PLUS photo-spectrum of two QSOs with SDSS spectra (marked in Fig. 5). The Lyα broad-line emission is clear in both sources and is captured by the $J0395$ filter. Figure from [5].

Acknowledgments

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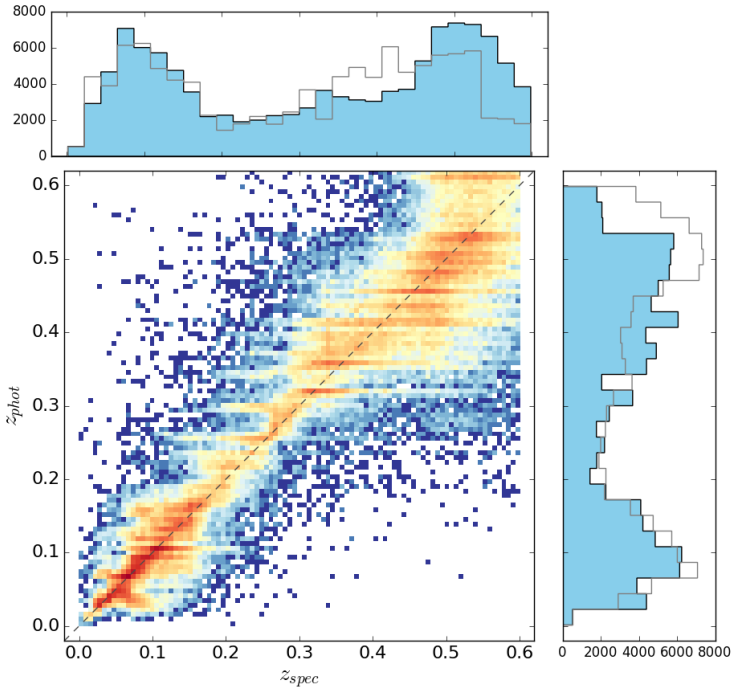

Figure 9: J-PLUS photometric redshifts from BPZ2 vs SDSS spectroscopic redshifts for the common sources in the DR1. The side panels show the projection in redshift space of the photometric (right) and spectroscopic (top) values. Figure from [5].

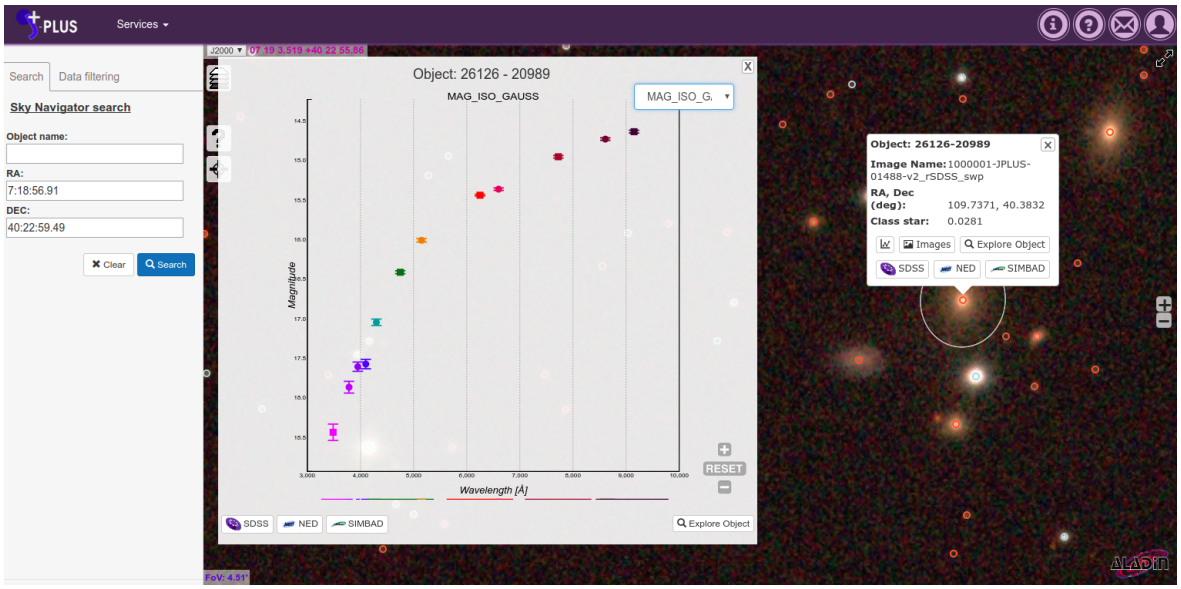

Figure 10: J-PLUS sky navigator.

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