Highlights on Spanish Astrophysics X, Proceedings of the XIII Scientific Meeting of the Spanish Astronomical Society held on July 16 – 20, 2018, in Salamanca, Spain. B. Montesinos, A. Asensio Ramos, F. Buitrago, R. Schödel, E. Villaver, S. Pérez-Hoyos, I. Ordóñez-Etxeberria (eds.), 2019

Status of the commissioning of the JPAS-Pathfinder camera at JST/T250 at the Observatorio Astrofísico de Javalambre.

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Abstract

The Javalambre Physics of the Accelerating Universe Astrophysical Survey (J-PAS) is an unprecedented photometric sky survey of $8,500\,\mathrm{deg}^2$ visible from the Observatorio Astrofísico de Javalambre (OAJ) in 59 colors, using a set of broad, intermediate and narrow band filters. J-PAS is going to provide the first complete 3D map of a large volume of the Universe and will contribute on many astrophysical science cases, from Solar System minor bodies to Cosmology. The survey will be conducted by the Javalambre Survey Telescope, JST/T250, with Javalambre Panoramic Camera (JPCam), which is currently in its engineering phase. Until then, the interim JPAS-Pathfinder camera, mounting a single CCD covering the center of the FoV, is installed at the telescope. Its filter wheel is ready to host the J-PAS filters already available for use on sky. This is permitting the commissioning of the equipment and is providing the first scientific data: the mini J-PAS. The up-to-date JPAS-Pathfinder commissioning and the results of the science operation is summarized here.

1 Introduction

The science case motivating the J-PAS survey is the study of the nature of the dark energy causing the accelerating expansion of the universe through the measurement of the Baryon Acoustic Oscillations (BAO). In order to tackle this topic, large volumes of the universe have to be probed, sampling regions much larger than the typical spatial scales associated to the

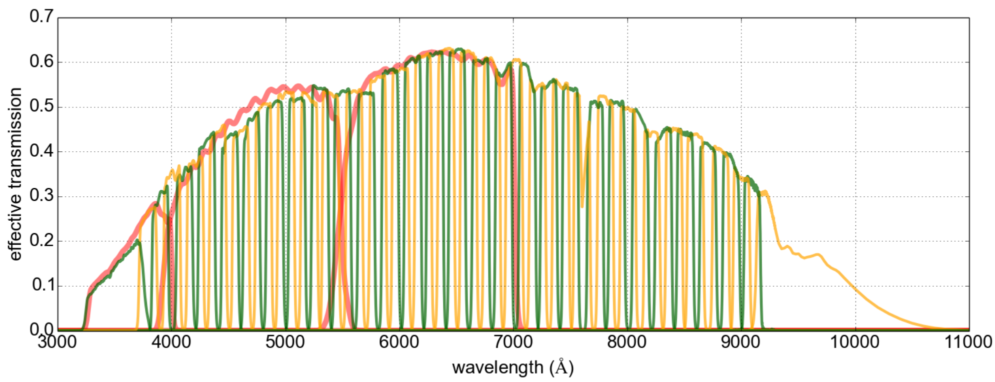

Figure 1: The J-PAS bandpass system. Overall expected efficiency for JPCam at JST/T250, filters system and assuming a particular atmosphere model.

BAO peak. Given the very weak nature of this signal, the positions and distances of millions of galaxies have to be measured with high enough accuracy, in particular, a precision in the redshift determinations of $\sigma_z/(1+z) < 0.003$ is required [1].

In practice this implies carrying out a survey of large areas of the sky at an adequate depth, and for that, a telescope combining a large field of view (FoV) with a relatively large collecting area is needed; i.e. a telescope with a large étendue. This motivated the building of the OAJ, at the Sierra de Javalambre in Teruel, Spain, and the settling of a survey-oriented 2.55m-class telescope, the JST/T250, with a large FoV ($4.2\,\mathrm{deg}^2$ with JPCam, the camera that is going to be devoted to carry out the J-PAS survey). This configuration yields an étendue of $26.5\,\mathrm{m}^2\mathrm{deg}^2$. On the other hand, to obtain the 0.3% accuracy in the photometric redshifts, photo-z, a set of 54 narrow band filters, plus one mid-band one at the blue end and a high-pass one at the red end have been specifically designed for this purpose. Those are centred at the visible region of the spectrum (see Fig. 1). Their width, FWHM$\sim 145\,$Å, and separation of their central wavelengths $\Delta\lambda \sim 100\,$Å will allow the achievement of the degree of precision mentioned. The set is completed with three broad-band filters: u_{J-PAS} and two Sloan-like g_{J-PAS} and r_{J-PAS}. The goal of J-PAS is to observe $8,500\,\mathrm{deg}^2$ of the observable sky at the OAJ, avoiding the Galactic plane. J-PAS will provide a huge amount of pseudo-spectra with enormous potential not only for Cosmology and Galactic Evolution, but for many different science cases from high-z studies to Solar System minor bodies.

2 JPCam: the survey camera

The J-PAS survey will be carried out by JPCam, a mosaic of 14 CCDs covering an area on the sky of $4.2\,\mathrm{deg}^2$ once attached to the JST/T250. Details on the different subsystems of the camera and its main features can be found in [2]. JPCam is currently at the OAJ in the engineering phase. In the forthcoming months a dedicated team of scientists and engineers will work with the final goal of getting the camera ready for attaching it to the JST/T250, so allowing the starting of the commissioning of the main camera.

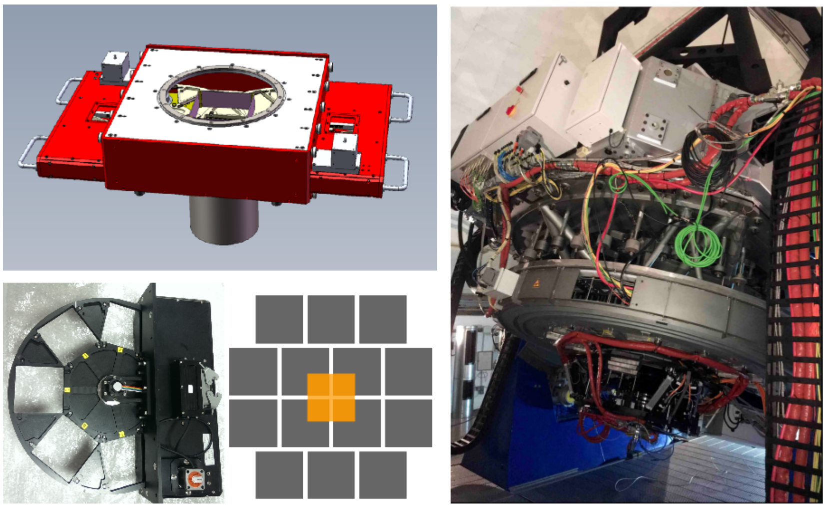

Figure 2: JPAS-Pathfinder. Sketch of JPAS-Pathfinder, a picture of the filter wheel and another of the camera attached to JST/T250, holded by the actuator system. The diagram illustrates the FoV of the camera (at the center in orange) compared to the whole JPCam FoV provided by the 14 CCDs.

3 JPAS-Pathfinder: the interim camera

Since February 2017 the interim JPAS-Pathfinder camera is attached to the JST/T250. In short, it is a replica of the T80Cam carrying out the Javalambre-Photometric Local Universe Survey (J-PLUS), also at the the OAJ with a 80cm-class telescope, whose first data release, DR1[1], has been presented during this meeting [3]. The JPAS-Pathfinder consists of a single CCD of 9.2k×9.2k pixels[2] and it mounts a filter wheel that can host up to 7 filters. From there it provides an unvignetted FoV of 0.34 deg^2 covering the central part of the FoV that JPCam will offer (see Fig. 2). The resulting spatial resolution is 0.227 arcsec/pixel. In the nominal read-out mode it offers a read-out noise below 3.4e$^-$, being the read-out time around 12 s. The goals with this camera are two-fold: i) carrying out a technical commissioning and ii) starting the scientific operation.

3.1 Technical commissioning

The goal of the commissioning is to advance in as many aspects as possible while JPCam is not ready to be installed to the telescope and, at the same time, to minimize the risks when that happens. This phase allows the identification of issues, needs and implementation of solutions at different levels: on the technical side, concerning the optics, the observation procedures and the image reduction and data processing.

JPAS-Pathfinder is mainly aimed to perform the commissioning of the actuators system (AS) that supports the camera and permits the its postitioning to compensate for mechanical

[1] `http://archive.cefca.es/catalogues/jplus-dr1`

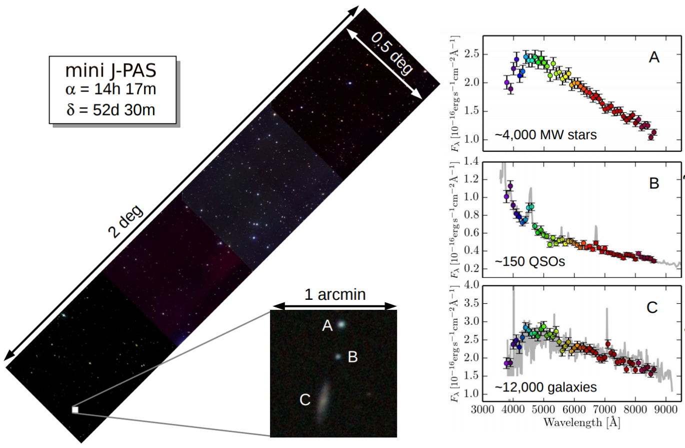

Figure 3: The area covered by the mini J-PAS. The zoom-in shows 3 objects, a star, a quasar and a galaxy, whose J-spectra are shown on the right together with a smoothed spectrum taken from SDSS-DR14 (when available). The number of each type of objects with J-spectra in the mini J-PAS is also shown. Classification and z also taken from SDSS-DR14.

flexures caused by gravity so the alignment of the optics, in conjunction with an hexapod at the level of the secondary mirror, M2, is optimized in every pointing of the telescope. The exact optimal positions of both the AS and M2 hexapod (amounting 10 degrees of freedom) depend on the pointing of the telescope, the angle of the de-rotator and the temperature. The analysis of a pair of intra- and extra-focal images taken on each new pointing allows the study of the main aberration components through the fitting of 3D Zernike polinomials, that yields a best solution for AS and M2 hexapod position to get the best image quality.

So far, the performance of the active optics system as a whole (hardware, control and analysis software) is satisfactory within the FoV of JPAS-Pathfinder. The statistics of the first few thousands images (both scientific and technical) has yielded a mode of the PSF of 0.7 arcsec with a mode in the homogeneity of the same parameter of 2.5% across the image. Further details on this and other commissioning tasks can be found here [4].

3.2 First scientific operation: mini J-PAS

In parallel to the commissioning, the first scientific operation with JPAS-Pathfinder has started. Given the complete set of J-PAS filters are already available for use, the J-PAS Collaboration decided to observe a patch on the sky with all of them to get the first J-PAS-like data. That field was carefully selected favouring those with lots of ancillary data to compare with ours. The choice was the All-wavelength Extended Groth strip International Survey[2] (AEGIS) with around 20 thousand spectroscopic redshift determinations up to $R_{\rm AB} = 24$ and also overlaping with other surveys, like Sloan Digital Sky Survey (SDSS)[5] and one of the Advance Large Homogeneous Area Medium-Band Redshift Astronomical (ALHAMBRA)[6]

[2] `http://aegis.ucolick.org`

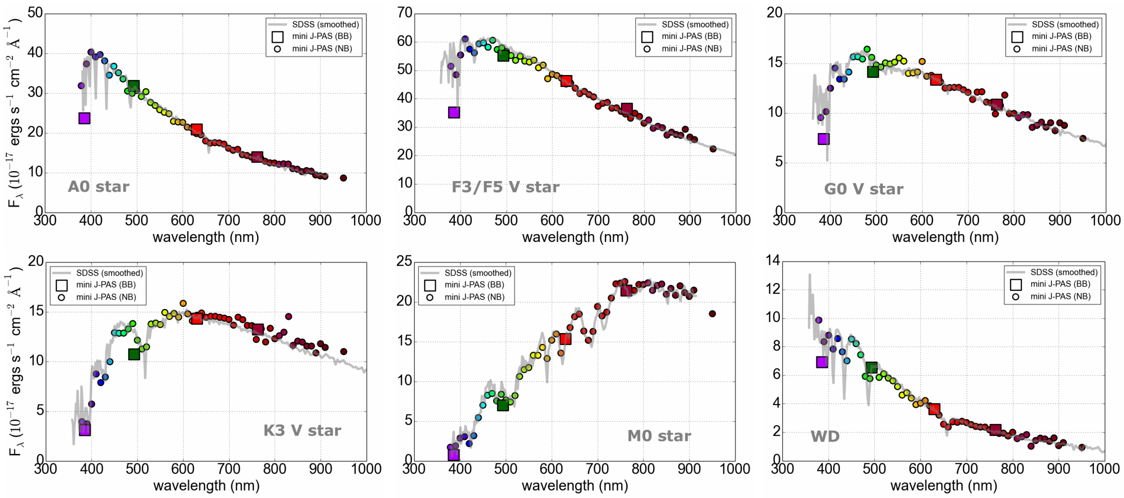

Figure 4: mini J-PAS: Galactic J-spectra samples. Classification taken from SDSS-DR14.

fields, among some others. The area eventually observed with the whole set of filters is a stripe of $\sim 1\,\mathrm{deg}^2$ ($1.9\,\mathrm{deg} \times 0.5\,\mathrm{deg}$) and it is shown in Fig. 3.

An initial reduction, source extraction and photometry was made by the Processing and Data Archival Unit (UPAD) at CEFCA using the same pipeline employed for J-PLUS, `jype`[7], with a few modifications required to fit the JPAS-Pathfinder setup. An initial photometric calibration has been performed as well using the synthetic photometry computed from the available SDSS-DR14[3] stellar spectra on each of the fields associated with J-PAS bandpasses. The pseudo-spectra, *J-spectra* presented here are preliminary since the image acquisition was very recent and there's still, in some cases, a few steps missing on the processing (like the fringing in the reddest filters and the illumination correction) or several of them could be improved, so the figures have to be considered a frozen result of a work in progress. At present, the catalogs are only available for internal use of the J-PAS Collaboration.

Some examples of normalized J-spectra of Galactic Fig. 4 and extra-Galactic sources Fig. 5 are shown together with the J-PLUS DR1 pseudo-spectra and the smoothed spectra of the same objects taken from SDSS-DR14. Despite the preliminary state of the whole data processing, these first results are really encouraging and show the enormous potential of the J-PAS data, tracing with detail many of the spectral features of the objects. It is worth highlighting the ability of the J-PAS data to trace broad features such as the molecular absorption bands of cool stars and the broad emission lines of the QSOs. As mentioned, those data must allow the determination of the photo-z with an accuracy of 0.3%; this is currently under assessment for confirmation.

Fig. 3 shows the count of gathered J-spectra: 4,000 Milky Way stars, around 150 quasars and about 12,000 galaxies. Extrapolating this numbers to the expected total area it would yield obtaining $\sim$ 60 million stars, 1.3 million QSOs and $\sim$ 100 million galaxies at the completion of the survey. Each of these pseudo-spectra is similar to a low-resolution

[3] `https://skyserver.sdss.org/dr14`

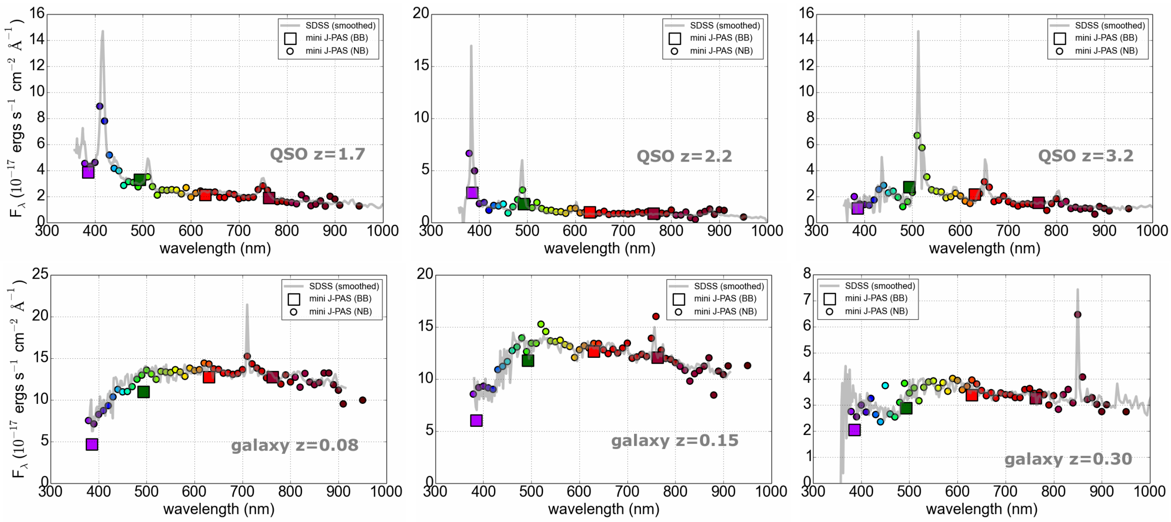

Figure 5: mini J-PAS: extra-Galactic J-spectra samples. Classification and z taken from SDSS-DR14.

one with $R \sim 50$, comparable to that of the low-resolution spectra Gaia will provide[8], but J-PAS is going to be ~ 2 magnitudes deeper. It is worth mentioning that in many cases, these currently represent the highest quality data for those objects. At the end of J-PAS, based on the mini J-PAS numbers, ~ 150 million J-spectra are going to be obtained.

Acknowledgments

The OAJ has been funded by the Governments of Spain and Aragón through the Fondo de Inversiones de Teruel, the Spanish Ministry of Economy and Competitiveness (MINECO; under grants AYA2015-66211-C2-1-P, AYA2015-66211-C2-2, AYA2012-30789, and ICTS-2009-14), and European FEDER funding (FCDD10-4E-867, FCDD13-4E-2685). The Brazilian agencies FAPESP and the National Observatory of Brazil have also contributed to the development of instrumentation for the OAJ.

References

[1] Benítez, N., Dupke, R., Moles, M., et al. 2014, `arXiv:1403.5237`

[2] Marín-Franch, A., Taylor, K., Santoro, F., et al. 2017, Highlights on Spanish Astrophysics IX, 670

[3] López-Sanjuan, C., et al. 2019, Highlights on Spanish Astrophysics XIII (these proceedings)

[4] Cenarro, A. J., Ederoclite, A., Íñiguez, C., et al. 2018, SPIE Conference Series, 10700, 107000D

[5] Abolfathi, B., Aguado, D. S., Aguilar, G., et al. 2018, ApJS, 235, 42

[6] Molino, A., Benítez, N., Moles, M., et al. 2014, MNRAS, 441, 2891

[7] Cristóbal-Hornillos, D., Varela, J., Ederoclite, A. & Vázquez Ramió, H. 2017, RIA J-PLUS EDR

[8] Carrasco, J. M., Evans, D. W., Montegriffo, P., et al. 2016, A&A, 595, A7