Implementing, with Python and PostgreSQL, Virtual Observatory services for publishing survey data from the OAJ

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CEFCA and the OAJ

The Observatorio Astrofısico de Javalambre (OAJ, Teruel, Spain)

CEFCA is an institution of the Government of Aragón for research in *Astrophysics and Cosmology*, whose activities focus on the technological development and operation of the Observatorio Astrofísico de Javalambre (OAJ, Teruel, Spain) and on its scientific exploitation.

Telescopes and instrumentation at OAJ

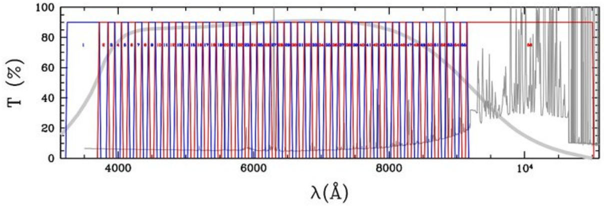
Two main telescopes with large fields of view (FoV) and image quality all over their entire FoVs:

- The 80cm Javalambre Auxiliary Survey Telescope, JAST/T80, with a FoV of **2 deg**.
- The 2.5m Javalambre Survey Telescope, JST/T250, a large-etendue telescope with a FoV of **3 deg** diameter.

The scientific instruments for the telescopes are:

- For the JAST/T80 a wide-field camera equipped with a **9.2k-by-9.2k** high efficiency CCD. The Filter Unit holds two removable filter wheels holding 12 filters.
- JPCam is a wide field **14 CCD-mosaic** camera that for the JST/T250. The Filter Unit admit five filter trays with 14 filters each.

J-PLUS and J-PAS Surveys

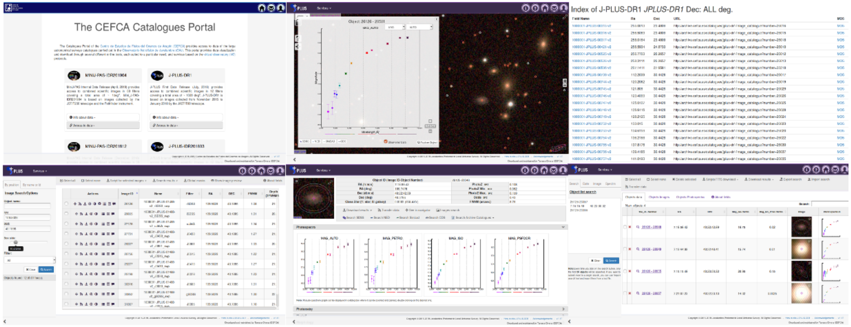


JPCam filter system

- The Javalambre-Photometric Local Universe Survey, J-PLUS, is a photometric sky survey of 8500 deg^2, using a set of **12** broad, intermediate and narrow band filters. Designed to carry out the photometric calibration of J-PAS.
- Javalambre Physics of the Accelerating Universe Astrophysical Survey, J-PAS, is an unprecedented photometric sky survey of 8500 deg^2 in **59 colors**, using 54 narrow plus 5 broad bands.

Data Publication

Web Portal: Sky Navigator, Image Search, Cone Search, Object Detail, Multiple Object Search, Image Catalogue Download.



archive.cefca.es - Poster 2.12 (Tamara Civera)

Enhancing Data Publication With VO

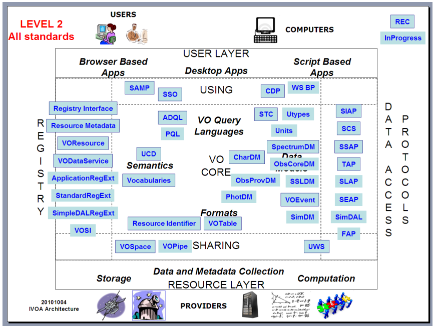
Portal OK but *not enough appropriate* for:

- Bulk data processing.
- Automation.
- Interoperability.

Virtual Observatory (VO) comes to scene:

- The IVOA (www.ivoa.net) Virtual Observatory promotes **standards** that allow seamless access to data.
- There is an increasing number of tools supporting them.
- Well suited to bulk access and automation scripts.

Choosing VO Services



- Simple Image Access: image search and download (full and *cutouts*).
- Simple Cone Search: catalogue object search.
- TAP: search images, catalogue objects, derived data (*photo-redshifts*, stellarity, ...). Describe data.
- SAMP: push data from our web portal.

Our own server side implementation

- There were available toolkits to publish data like DaCHS from GAVO, or SVOCat from Spanish VO. (`https://wiki.ivoa.net/twiki/bin/view/IVOA/PublishingInTheVO`)
- But they did not fulfil all our needs: integration with our portal, access control for certain catalogue versions, and support for a few custom extensions (*more later...*).
- IVOA services are mainly based on *web technology*, and in general they are simple.

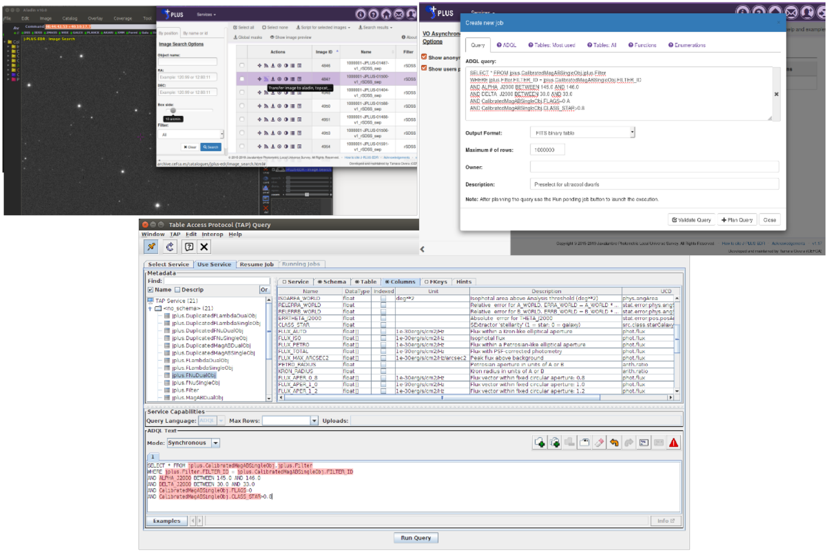
Implementation: The Data Layer

- We wanted a open source SQL database (*ADQL friendly*).
- J-PLUS and J-PAS Catalogue final data is expected to occupy several terabytes.
- With flux and error measures for about 16 apertures in 59 filters, just for photometry, we have 1888 columns of data in the object table.
- **PostgreSQL** has known support of big databases, support for custom functions, and *array types* (which simplify storing all filter flux data in one column).
- Spatial index in the database is very important, we opted to use **Healpix**.

Implementation: The Web Layer

- The **Python** programming language was in use in the house for the reduction pipelines, so we evaluated it for creating web applications.
- The Python WSGI specification, with a lot of implementations (Apache mod_wsgi, Unicorn, uWSGI, ...), supports web applications.
- A lot of frameworks (Pyramid, Flask, Django, ...) simplify development, easily map a Python function to a web URL, and access to web parameters.
- Large amount of libraries for astronomy, database access, and Healpix are available.

And some results ...



Create new job

ADQL query:

```
SELECT * FROM jplus.CalibratedMagABSingleObj,jplus.Filter
WHERE jplus.Filter.FILTER_ID = jplus.CalibratedMagABSingleObj.FILTER_ID
AND ALPHA_J2000 BETWEEN 145.0 AND 146.0
AND DELTA_J2000 BETWEEN 30.0 AND 33.0
AND CalibratedMagABSingleObj.FLAGS=0 A
AND CalibratedMagABSingleObj.CLASS_STAR>0.8
```

Output Format: FITS binary table

Maximum # of rows: 1000000

Owner:

Description: Preselect for ultracool dwarfs

Note: After planning the query use the Run pending job button to launch the execution.

Table Access Protocol (TAP) Query

Name	DataType	Indexed	Unit	Description	UCD
ISOAREA_WORLD	float		deg**2	Isophotal area above Analysis threshold (deg**2)	phys.angArea
RELERRA_WORLD	float			Relative error for A_WORLD. ERRA_WORLD = A_WORLD * ...	stat.error;phys.ang
RELERRB_WORLD	float			Relative error for B_WORLD. ERRB_WORLD = B_WORLD * ...	stat.error;phys.ang
ERRTHETA_J2000	float			Absolute error for THETA_J2000	stat.error;pos.posA
CLASS_STAR	float			SExtractor 'stellarity' (1 = star; 0 = galaxy)	src.class.starGalaxy
FLUX_AUTO	float[]		1e-30erg/s/cm2/Hz	Flux within a Kron-like elliptical aperture	phot.flux
FLUX_ISO	float[]		1e-30erg/s/cm2/Hz	Isophotal flux	phot.flux
FLUX_PETRO	float[]		1e-30erg/s/cm2/Hz	Flux within a Petrosian-like elliptical aperture	phot.flux
FLUX_TOTAL	float[]		1e-30erg/s/cm2/Hz	Flux with PSF-corrected photometry	phot.flux
FLUX_MAX_ARCSEC2	float[]		1e-30erg/s/cm2/Hz/arcsec2	Peak flux above background	phot.flux
PETRO_RADIUS	float			Petrosian aperture in units of A or B	arith.ratio
KRON_RADIUS	float			Kron radius in units of A or B	arith.ratio
FLUX_APER_0_8	float[]		1e-30erg/s/cm2/Hz	Flux vector within fixed circular aperture: 0.8	phot.flux
FLUX_APER_1_0	float[]		1e-30erg/s/cm2/Hz	Flux vector within fixed circular aperture: 1.0	phot.flux
FLUX_APER_1_2	float[]		1e-30erg/s/cm2/Hz	Flux vector within fixed circular aperture: 1.2	phot.flux

ADQL Text — Mode: Synchronous

```
SELECT * FROM jplus.CalibratedMagABSingleObj,jplus.Filter
WHERE jplus.Filter.FILTER_ID = jplus.CalibratedMagABSingleObj.FILTER_ID
AND ALPHA_J2000 BETWEEN 145.0 AND 146.0
AND DELTA_J2000 BETWEEN 30.0 AND 33.0
AND CalibratedMagABSingleObj.FLAGS=0
AND CalibratedMagABSingleObj.CLASS_STAR>0.8
```

SAMP with Aladin. TAP web interface. TAP Topcat.

A few lessons learned

- TAP more difficult that we thought. The idea to pass directly queries to the database was not feasible, needed a SQL dialect translation. But good for security, limiting result size or add our extensions (*enumerations* to assign names to filter positions *'jplus::rSDSS'*).
- Also in TAP we found that implementing the geometric functions is very complex due to the rich functionality defined, so at the moment only partial support for that functions exists.
- IVOA centres on public data so access control is not standardised. We finally achieved to support authentication for some tools like Topcat using *Basic HTTP* authentication.

A few lessons learned (II)

- Performance is always something that at some point you have to improve.
- We initially implemented in Python the needed database functions for ADQL but later we moved to a C implementation because it is *ten* times faster.
- TAP queries can take some minutes to execute, so executing concurrently them is mandatory. Python *threads* have some blocking issues, fortunately Python *multiprocessing* package has a similar API.

Thank you!

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