The ESO Archive experience in adopting VO Technologies

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on behalf of the Archive Services Project group

Basic idea of this talk

- Show to other interested data providers the ESO experience in adopting VO standards
- by depicting how we went from high level requirements to implementation of selected standards, going through:
  - analysis of constraints
  - evolution of existing archive infrastructure
  - selection of databases,
  - DBMSes integration and maintenance in the operational environment,
  - using off-the-shelf components,
  - costs (FTEs),
  - obsolescence, and future steps

“Why should we consider the VO when building archive services?”

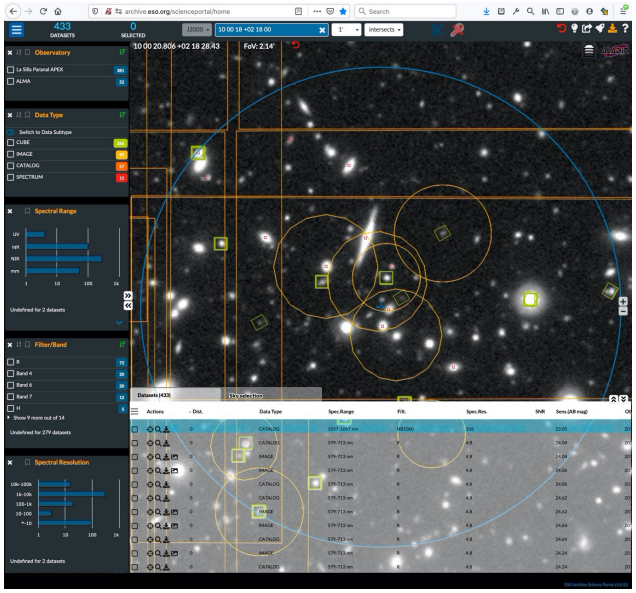
*Because we would save time in developing services, as all the **specifications are already written** and used by the community (guaranteeing a **high maturity** level); **no time wasted in thinking** what we need **and in design**, we just need to implement what already prescribed. On top of that, we will gain in **interoperability**, and we will allow easy interaction to the ESO science archive: **no need** for the users **to learn a ESO-specific/custom way** to browse and access the data; **ability to use community-provided VO-aware software and tools** to interact with the archive.*

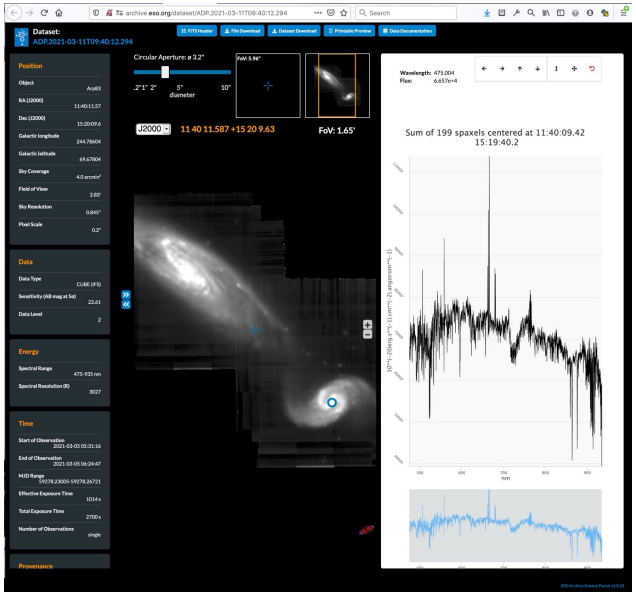
Archive Services Project (ASP)

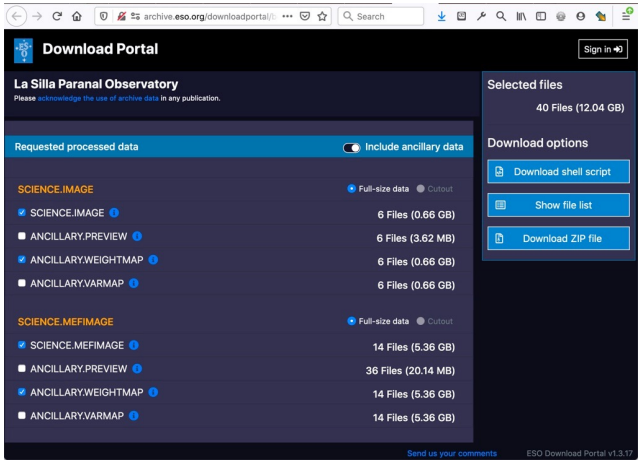
- We deployed new and modern archive services (ASP from now on) based on mature VO standard data models, protocols, and tools:
  - in 2018, ASP v1
  - in 2020, ASP v2 + Download Portal
  - In 2021, TAP Authentication and Authorisation: authorised searches

- Main ASP components:
  - ESO Science Portal (web interface)
  - ESO Programmatic and Tool Access Layer

http://archive.eso.org/scienceportal







ESO Science Portal (web interface)

Facet-based whole-sky data discovery tool, based on a wealth of high-level metadata characterising the reduced data (e.g., wavelength coverage, resolving power, SNR, abmaglim, footprints)

Programmatic and Tool Access

Science Archive Programmatic and Tools Access Demo page

The purpose of this page is to help you to learn:

1. *how to compose URLs to interact with the different ESO science archive services, either programmatically or via tools;*
2. *how to construct queries to interrogate the various database tables of the ESO science archive, using ADQL and TAP;*
3. *how to put it all together and script your access to the ESO science archive, using the pyvo python module.*

If some terms in this page are not familiar to you, please read the overview page first.

In this page: [open] click here to read the page description...

Query a TAP Service | async Query Manager | Script your access | Configure tools | Learn dataset actions | VO standards & software | Change Log

TAP Service: tap_obs (http://archive.eso.org/tap_obs): raw, reduced and ambient data — its list of jobs: /async — ESO TAP Query Manager

/capabilities /availability /tables /examples

TAP_SCHEMA database diagram

Service type: /sync
REQUEST: doQuery
FORMAT: votable votable/td votable/b votable/b2 votable/fits fits text json
LANG: ADQL
MAXREC: 200
QUERY : ObsCore: Find spectra of sources observed in the H band by the VVV public survey

```
SELECT spectrum.* FROM
    (select * FROM ivoa.Obscore WHERE dataproduct_type='spectrum' and snr > 500) spectru

    (select * FROM ivoa.Obscore WHERE dataproduct_subtype ='tile'
    AND obs_collection = 'VVV'  AND em_min < 1.66E-6 AND em_max > 1.66E-6 ) VVV_H

WHERE CONTAINS( spectrum.s_region , VVV_H.s_region)=1
```

Submit the Query | Decode the ADQL string | Show the URL | Parse/Validate the ADQL | Create li

http://archive.eso.org/programmatic

4. Spatial joins

Are you interested in finding images in different bands of the same sky region, for photometrical studies?

The following example shows how you can compose a spatial join, so to find:

- HAWKI images,
- within 10 degrees from the galactic plane,
- taken in the J and H filters,
- where the J and H images overlap,
- and ensuring that they overlap for at least 80% of the J band image area.

In [12]:
```
query = """SELECT J.* FROM
      (select * FROM ivoa.Obscore WHERE dataproduct_subtype ='srctbl'
      AND obs_collection = 'HAWKI'
      AND gal_lat < 10 AND gal_lat > -10
      AND em_min < 1.265E-6 AND em_max > 1.265E-6 ) J,

      (select * FROM ivoa.Obscore WHERE dataproduct_subtype ='srctbl'
      AND obs_collection = 'HAWKI'
      AND gal_lat < 10 AND gal_lat > -10
      AND em_min < 1.66E-6 AND em_max > 1.66E-6 ) H

WHERE INTERSECTS( J.s_region , H.s_region)=1 and
ESO_INTERSECTION( J.s_region , H.s_region) > 0.8*AREA( J.s_region )"""
```

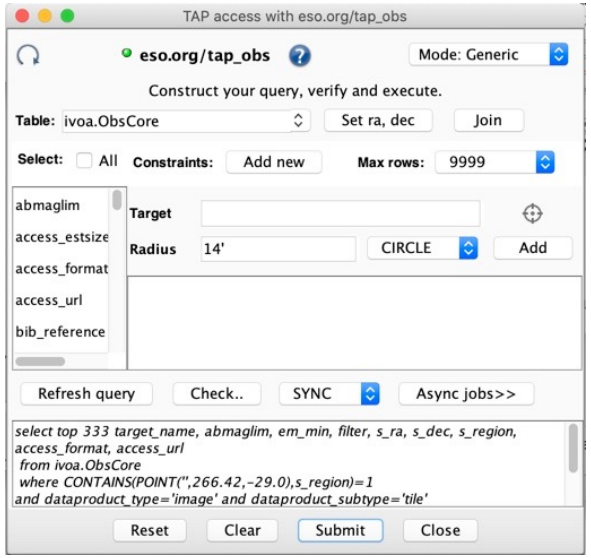
In this page: [open] click here to read the page description...

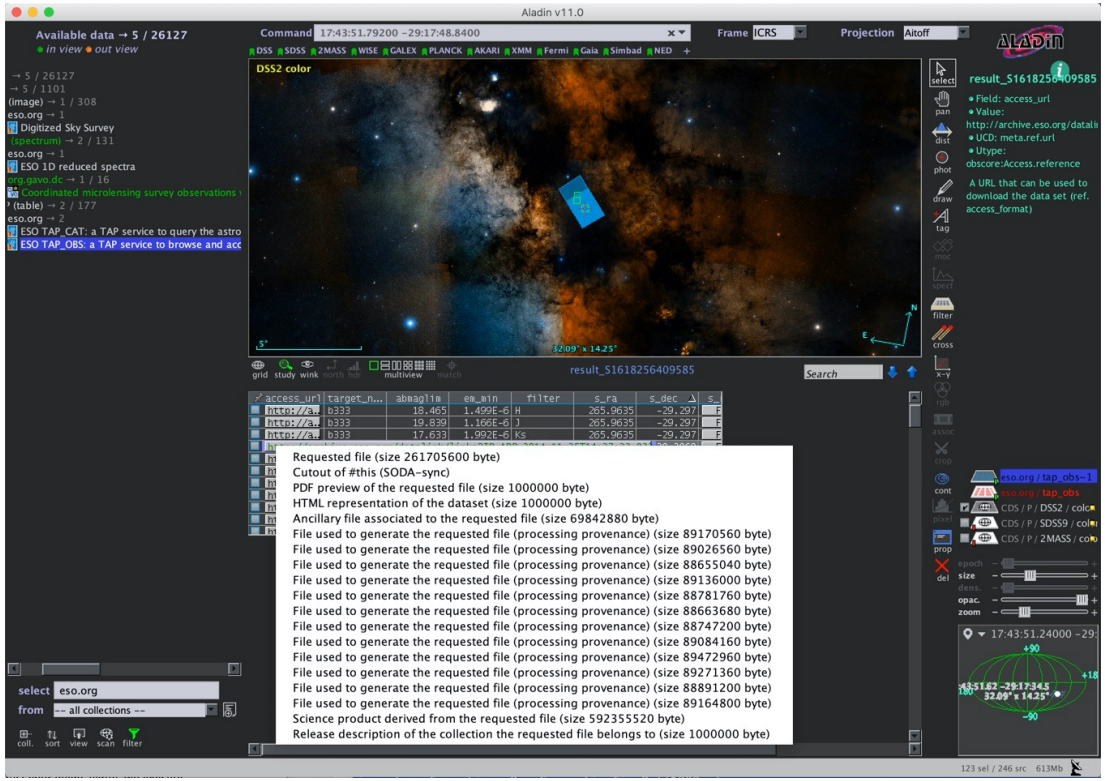
Query a TAP Service | async Query Manager | Script your access | Configure tools | Learn dataset actions | VO standards & software | Change Log

Implemented IVOA Standards:	ADQL 2.0	DataLink v1.0	ObsCore v1.1	SSAP v1.1	TAP v1.1	UWS v1.1	DALI v1.1 2017-05-17	SODA v1.0
Software:	github taplib implements: ADQL, TAP, and UWS; by Grégory Mantelet (ARI - Astronomisches Rechen Institut, Heidelberg)							
	github SSAPServer implements SSAP v1.1; by Vincenzo Forchì (ESO)							
	ESO code (not distributed) implements DataLink, SODA; by DFI/ESO							

Last modification date of *IVOA standards & ESO software*: 2021-11-22

Tool access:
Aladin showing ObsTAP, ADQL, STC-S, Datalink in action





Where did we start from?

Archive Services Project Top Level Description

- **Interactive access** by the users, via web-based pages through which the user can browse and explore the assets through interactive, iterative queries, while being presented the results of their searches using various tabular and/or graphic ways allowing them to evaluate the usefulness of the data. Eventually, the user can select assets for retrieval.
- **Programmatic access,** whereby the users can formulate complex queries through their own programmes and scripts, and retrieve the corresponding assets.
- **Tool access**, whereby data are discovered, selected and accessed through standalone tools (developed by third parties) external to the web access channel.
- **Operational access**, whereby any keyword and any file shall be accessible for browsing and download for operation purposes to a selected subset of users.

From high level requirements to selected VO protocols

High Level Requirements

Data discoverability and access

IVOA Data Access Layer

Which protocols and standards to adopt?

Which data does the ESO archive serve and how?

Types of data	Users want to access	Searches based on (Metadata model)
Raw frames	FITS file	Custom observing-log DB table
⇒ Associated calibrations (e.g., flats, biases)	FITS file	No search, only association
Reduced data (our flagship!)	FITS file	ESO Science Data Product standard is based on VO DMs (SpectrumDM, ObsCore)
⇒ Associated ancillary files (e.g., weightmaps)	FITS file, PNG, readme	No search, only association
Ambient data	Individual record	Custom measurements DB tables
Scientific catalogues by ESO PIs	Individual record	Custom measurements DB tables

- TAP: natural choice to access custom database tables
- SSA and ObsTAP: should be used for reduced data
- DataLink: should be used for associating calibrations and ancillary files

What kind of reduced data?

	June 2018		April 2021	
	num of [%]	size [TB]	num of [%]	size [TB]
Spectra	**53.8%**	1.6 [2%]	64.0%	2.4 [2%]
Images	22.8%	**26** **[39%]**	18.6%	59 [44%]
Source tables & Catalogue tiles	22.5%	12 [18%]	13.5%	21 [16%]
Cubes	0.7%	**28** **[41%]**	3.7%	51 [38%]
Visibilities	0.2%	traces	0.1%	Some more traces
	100% (1.1M)	67 TB	100% (2.9M)	133 TB

June 2018: status at the time ASP v1 was deployed April 2021: current status

- Spectra are the most numerous products => SSAP high priority
- Cubes (<=65GB) and images (<=9GB) are the heaviest => Cutout => SIAv2, SODA
- Though big motivation came from cubes, cutout available also other data types

Confronting wishes with reality

As seen above:

- Wish list of VO protocols basically ready
- Even with some priorities attached
- Not too bad!

But the good data provider is confronted with:

- the existing archive infrastructure
- the existing resources
- the adopted data policy

Requirements (esp. Web I/F), Constraints, Priorities

Fundamental VO requirement

VO protocols require/Tools expect: an access URL that points to the dataset of interest.

~~If not possible => Plan B:~~
~~Build a VO-compliant (UWS) REST asynchronous service that will accept a request and serve back the requested dataset (only user's interaction is to provide his credentials); add the URL of this service to the list supported by the (future) ESO DataLink service.~~

Legend: **WI**-Web Interface, **PA**-Programmatic&Tool Access

WI-defined Requirements: Types of Queries

User's defined query	WI timeline	PA timeline	VO Standard	Comment
Range on parameters	R1	R1	ADQL	
Point in footprint	R1	R1	ADQL/spatial query	Footprints required
Cone interests footprint	R1	R1	ADQL/spatial query	"
Rectangular region intersects footprint	R2+	R2+		"
Polygon intersects footprint	R2+	R2+		"
Input target list (coords)	R1	R2+	DALI-UPLOAD	R2+ because User's script can loop through list.

VO Protocols

Protocol	PA timeline	Comment
TAP without UPLOAD	R1	Defines **REST** programmatic interface to both archive assets and catalogs. Satisfies **complex queries** requirement. Asynchronous queries (**UWS**) important for programmatic access. UPLOAD postponed to R2
DataLink	R1	Defines **REST** programmatic access to **previews and data** assets Data access to be implemented (policy?)
ObsTAP	R1	Defines TAP service based on standard metadata (names, formats, units, etc.) • Simple prototype already implemented (no data access) • Database mapping revised for upgraded phase 3 data model almost ready • Data access to be implemented
SSAP (sync)	R1	Phase 3 is dominated by spectra (80%). Community wants it. Database ready. Only little software effort required. **async** (optional) does not seem useful onto spectra, unless cutouts are requested on N>>1 spectra.
SIA V2	R2	Interesting for new cutout capability; but given that 'cutout' is for R2, no

Showing sections of documents related with the effort of defining priorities, also as answers to constraints

Constraints in 2017 (ESO-specific)

- Direct downloads (either anonymous, or authenticated) were not allowed
  - VO protocols require/VO Tools expect an access URL that points to the dataset of interest

  ➔ Change to the implementation of the data policy identified as critical for implementation of ASP v1.

  Anonymous access was a paradigm change: we would no longer be able to derive some useful statistics (example: how many users that never applied for ESO telescope time downloaded data from the archive?); no possibility to inform users of data issues discovered after download, etc.
- ESO archive infrastructure not ready to efficiently support cutouts
  - Evolution required (new hardware, new architecture)
  - Not difficult but required some time

  ➔ Cutout delayed to ASP v2

- Resources? it's a narrow bandpass:

  ➔ Example: TAP UPLOAD and SIAP v2 delayed to a later release

Constraints in 2017

- ESO DBMSes did not support complex spatial queries

  A DBMS study was conducted; recommendations were:
  - SQLServer (relational) for TAP
  - ELASTIC for Web application: Very efficient dynamic computation of facets
  - SYBASE IQ remained the only choice for large scientific catalogs (up to 110E9 records)

  ➔Consequences:

  ➔Two TAP Servers, one for the catalogues, one with full spatial queries support (see later)

  ➔Web application not based on TAP, though based on VO data model-prescribed metadata

Constraint in 2017

- ESO metadata characterising the reduced data were of good quality, but not yet fully ready to support all searches. Additional work on metadata was then required.

  ➔ Harmonisation of metadata across different types of data

Examples:

  - spectra and cubes had min and max wavelength, images didn’t;
  - images had footprint, derived source tables didn’t.
  - Some footprints had to be repaired (were not anti-clockwise onto the sky)

Preliminary work: Metadata census & harmonisaton

		%IMAG	%MEFIMAGE	%SRCTBL	%SPECTRUM	COMPLETE	OBSCORE	WebForms	Notes
ID	dp_id	100.0%	100.0%	100.0%	100.0%	100.0%	obs_publisher_did	All	
PHASE 2	prog_id	100.0%	100.0%	100.0%	100.0%	100.0%		All	
PHASE 3	phase3_program	100.0%	100.0%	100.0%	6.4%	76.6%		All	IDPs
PHASE 3	phase3_collection	100.0%	100.0%	100.0%	100.0%	100.0%	obs_collection	All	
PHASE 3	phase3_pi_name	100.0%	100.0%	100.0%	6.4%	76.6%		Phase3 User	IDPs
	?							Pi Name?	To be
PHASE 3	p3orig	100.0%	100.0%	100.0%	100.0%	100.0%		All	
TARGET	object	100.0%	100.0%	100.0%	100.0%	100.0%	target_name	All	
SPATIAL	ra	100.0%	100.0%	100.0%	100.0%	100.0%	s_ra	All	
SPATIAL	dec	100.0%	100.0%	100.0%	100.0%	100.0%	s_dec	All	
SPATIAL	gal_lat	100.0%	100.0%	100.0%	100.0%	100.0%		All	
SPATIAL	gal_lon	100.0%	100.0%	100.0%	100.0%	100.0%		All	
SPATIAL	ecl_lat	100.0%	100.0%	100.0%	100.0%	100.0%		Not used	
SPATIAL	ecl_lon	100.0%	100.0%	100.0%	100.0%	100.0%		Not used	
OBS	tel_id	100.0%	100.0%	100.0%	100.0%	100.0%	facility obs_collection	All	
OBS	ins_id	100.0%	100.0%	100.0%	100.0%	100.0%	instrument	All	
OBS	obstech	100.0%	100.0%	100.0%	100.0%	100.0%		All	
OBS	dispelem	0.0%	0.0%	0.0%	100.0%	25.0%		S	
TEMPORAL	mjd_end	100.0%	100.0%	100.0%	100.0%	100.0%	t_max	All	
TEMPORAL	mjd_obs	100.0%	100.0%	100.0%	100.0%	100.0%	t_min	All	
TEMPORAL	exp_end	100.0%	100.0%	100.0%	100.0%	100.0%		All	
TEMPORAL	exp_start	100.0%	100.0%	100.0%	100.0%	100.0%		All	
TEMPORAL	m_epoch	100.0%	100.0%	100.0%	100.0%	100.0%		I,S,V (all but M)	
TEMPORAL	texptime	100.0%	100.0%	100.0%	72.4%	93.1%		I,V	VMC
TEMPORAL	exptime	100.0%	100.0%	100.0%	100.0%	100.0%	t_exptime	All	VMC
TIMESETTING	fill_factor	100.0%	100.0%	100.0%	72.4%	93.1%		Not used	
TIMESETTING	dit	99.7%	100.0%	96.7%	0.0%	74.1%		V	
TIMESETTING	ndit	97.3%	83.3%	86.3%	0.0%	66.7%		V	
TIMESETTING	njitter	99.0%	86.6%	89.4%	0.0%	68.8%		V	
TIMESETTING	noffset	0.0%	0.0%	0.0%	0.0%	0.0%		V	
TIMESETTING	nustep	99.1%	86.7%	89.4%	0.0%	68.8%		V	
PHASE 2	multi_ob	100.0%	100.0%	100.0%	100.0%	100.0%		All	GOOD
PHASE 2	ob_id	100.0%	100.0%	100.0%	100.0%	100.0%		V	
PHASE 2	obid1	100.0%	100.0%	100.0%	100.0%	100.0%			
PHASE 2	obid2	2.2%	3.4%	0.5%	1.9%	2.0%			
TYPE	prodcatg	100.0%	100.0%	100.0%	100.0%	100.0%	~dataproduct_type	All	
TYPE	product_type	99.0%	100.0%	100.0%	0.0%	74.7%	dataproduct_subtype	V	source
TYPE	imatype	99.0%	100.0%	100.0%	0.0%	74.7%	~dataproduct_subtype	V	TILE c
FILE	origfile	100.0%	100.0%	100.0%	100.0%	100.0%		All	
BIBLIO	referenc	100.0%	100.0%	100.0%	100.0%	100.0%	~bib_reference	All	
SPECTRAL	filter	100.0%	100.0%	100.0%	0.0%	75.0%		M,I,V	
SPECTRAL	wavelmax	0.0%	0.0%	0.0%	100.0%	25.0%	em_max	S	
SPECTRAL	wavelmin	0.0%	0.0%	0.0%	100.0%	25.0%	em_min	S	
SPATIAL	aperture	0.0%	0.0%	0.0%	100.0%	25.0%	~s_fov ~s_resolution	S	def :=

				WebForms	COMPLETENESS	OBSCORE
dp_id	ok			All	1	obs_publisher_did
prog_id	ok			All	1	
phase3_program	NULL for IDPs			All	76.6%	
phase3_collection	ok			All	1	obs_collection
phase3_pi_name	NULL for IDPs	Phase 3 User and not pi		Phase3 User	0.765916675	
? pi_name ?	absent		pi_name?	PI Name?		
p3orig	ok			All	100.0%	
object	ok			All	1	target_name
ra	ok			All	1	s_ra
dec	ok			All	1	s_dec
gal_lat	ok			All	1	
gal_lon	ok			All	1	
ecl_lat	ok			Not used	1	
ecl_lon	ok			Not used	1	
tel_id	ok			All	1	facility obs_collection
ins_id	ok			All	1	instrument
obstech	ok			All	1	
dispelem	SPECTRAL		optical element?	S	0.25	
mjd_end	ok			All	1	t_max
mjd_obs	ok			All	1	t_min
exp_end	ok			All	1	
exp_start	ok			All	1	
m_epoch	ok (add to main)			I,S,V (all but M)	1	
texptime	missing for old spectra			I,V	93.1%	
exptime	ok			All	100.0%	t_exptime
fill_factor	missing for old spectra			Not used	93.1%	
dit	sparse			V	74.1%	
ndit	sparse			V	66.7%	
njitter	sparse			V	68.8%	
noffset	sparse			V	0.0%	
nustep	sparse			V	68.8%	
multi_ob	missing in GOODS FORS2			All	99.99%	
ob_id	missing in GOODS FORS3			V	99.99%	
obid1	missing in GOODS FORS4				99.99%	
obid2					2.0%	
prodcatg	ok			All	1	~dataproduct_type
product_type	only set for VIRCAM/OMEGACAM			V	74.7%	dataproduct_subtype
imatype	only set for VIRCAM/OMEGACAM			V	74.7%	~dataproduct_subtype
origfile	ok			All	1	
referenc	ok			All	1	~bib_reference
filter	NON-SPECTRAL		optical element?	M,I,V	75.0%	
wavelmax	SPECTRAL		non-spectral = wavelmax	S	25.0%	em_max
wavelmin	SPECTRAL		non-spectral = wavelmin	S	25.0%	em_min
aperture	SPECTRAL			S	25.0%	~s_fov ~s_resolution
fov	IMAGING ONLY		See s_fov below	Not used	50.0%	s_fov

Examples of spreadsheets built while studying the completeness and quality of the metadata

Consolidated list of VO standards for ASP v1

- TAP 1.0 => included in ASP v1 (2018)
  - without UPLOAD: programmatically cycle through your input list instead
  - UPLOAD => delayed to (at least) v2
  - ADQL 2.0 + STC-S(*): complex footprints (point, circle, polygon, array of polygons)
  - UWS
  - DALI
  - VOSI
- SSAP 1.1 => included in ASP v1 (2018)
- DataLink 1.0 => included in ASP v1 (2018)
- SODA 1.0 => delayed to ASP v2 (2020)
- SIAP 2.0 => delayed to (at least) v2

(*) STC-S, though widely used, is not a standard

TAP: two distinct servers

- Two TAP servers were deployed in 2018:
  - **tap_cat** for the scientific catalogues (http://archive.eso.org/tap_cat)
    - SYBASE IQ
    - Ability to support large catalogues (biggest: 110E9 records)
    - No support for spatial queries (cone search only)
  - **tap_obs** for the raw, reduced and ambient (http://archive.eso.org/tap_obs)
    - SQLServer
    - Ability to support the ESO footprints: points, polygons, arrays of polygons, and also circles for ALMA
    - Ability to support complex spatial queries

Reusing off-the-shelf software libraries (programmatic)

- TAP 1.0
  - **TAPLIB** was chosen (thank you Gregory Mantelet!) for its extensive documentation
    - TAPLIB covers: **TAP, UWS, VOSI, DALI**, and **ADQL parser**
  - ADQL translator to local SQL (SQLServer) was implemented at ESO
  - **STIL** (M. Taylor) to format query responses
  - **Taplint** (M. Taylor) to test the implementation

- SSAP 1.1
  - Sufficiently simple protocol: implemented at ESO (s/w made available on github)
  - The query and its response are actually handled by TAP, via a view built onto the ivoa.ObsCore table
- DataLink 1.0
  - Implemented at ESO
- SODA 1.0
  - Implemented at ESO (and offered via DataLink “service descriptors”)
- Pyvo
  - Used in scripts and jupyter notebooks to programmatically interface to the above protocols, for a very easy and powerful user experience (R. Plante, Stefan Becker, M. Demleitner, and the astropy developers)

Reusing off-the-shelf software libraries (web interface)

The Web interface, called Science Portal, uses:

- **Aladin Lite** (CDS) for sky view, to plot HiPSes and footprints (STC-S)
- **SAMP Javascript** (M.Taylor) to pass an ObsCore table of results from the science portal to desktop applications

The Preview Generation System uses:

- **HipsGen Aladin** java library to create HiPS previews of all images and cubes' white images

Amount of work required: ASP v1

- ASP v1 Programmatic Access **~ 1 FTE** development + 0.3 FTE project scientist
  - 0.5 FTE including development and testing of:
    - SSAP
    - TAP 1.0 adaptation
    - ADQL translator
    - DataLink
  - 0.55 FTE, though shared with Science Portal, including:
    - selection of suitable database
    - data model implementation, implementation of footprints
    - data replication design and implementation (to both ELASTIC and SQLServer)
  - 0.3 FTE of project scientist work (specifications, following development, acceptance, VO registration of services)

Amount of work required: ASP v2

- ASP v2 Programmatic Access **~ 1 FTE**
  - 0.2 FTE for Cutouts (including infrastrutural changes)
  - 0.6 FTE including:
    - SODA 1.0,
    - upgrading TAPLIB to most recent Mantelet's version (bug fixes)
    - implementation of new ADQL User Defined Functions
      - ADQL lacks many useful utility functions (substring, getdate, trim, round, etc)
    - datalink for associated calibrations
    - authenticated datalink and soda to support proprietary datasets
    - including developed but not yet accepted: SIAP v2, TAP UPLOAD.
  - 0.35 FTE of project scientist work, including integration of ALMA in ObsCore

Obsolescence?

- ADQL 2.1 needed (and pushed for) for improvements and bug fixes

  Examples:
  - ORDER BY does not accept table_name.column_name (fixed in 2.1)
  - A query like: SELECT TOP 10 * FROM ivoa.ObsCore where distance(centroid(s_region), point('',83.86675,-69.269741666)) < 0.5/3600 fails, while it works without centroid()

Obsolescence?

- TAP v1.0 standard dated: 27-Mar-2010
  - ASP v1 deployed June 2018
- TAP v1.1 standard dated: 27-Sep-2019
  - Shall we upgrade?
  - ASP v2 deployed April 2020 without upgrading
  - We did upgrade tap_obs (July 2021) in the scope of a new project which required support for authorised ADQL queries
    - Catalogues are still served via TAP 1.0: tap_cat still to be upgraded (on the todo list)

TAP support for authorised searches (Jul 2021)

- A new TAP (based on IVOA TAP 1.1) was released in July 2021.
- Background: **not all ESO observations have their metadata publicly visible**: to discover the existence and **to browse through the metadata of those, the user must be granted specific permissions**
  - e.g. science verification programmes, or datasets of particularly sensitive programmes.
- **The new tap_obs supports authentication, and it allows users to browse through all the raw observations they have been granted metadata access to.** To obtain this, the user's composed query is automatically and transparently modified to include the necessary SQL snippets that support the metadata access permissions of the specific user.
  - Info: http://archive.eso.org/cms/eso-data/programmatic-access/authentication-and-authorisation.html
  - Jupyter notebook: http://archive.eso.org/programmatic/HOWTO/jupyter/authentication_and_authorisation/programmatic_authentication_and_authorisation.html
- A rewrite of the web layer that implements the TAP protocol was necessary, keeping unchanged the ADQL and UWS library.
- Still to be done: we will have to add authentication and authorization to the preview server, to the ivoa.ObsCore hosting the reduced data, and to SSA/SIA. tap_cat to be upgraded to TAP 1.1.

How bumpy was the road?

- Change was required to the implementation of the ESO data policy (highly sensitive matter)
- Integration of new database technologies in the existing infrastructure
  => There have been significant delays for procuring the license for SAP Data Connect, for the synchronisation of the SQLServer (TAP) with the operational data flow database (SYBASE ASE) => Lot of issues in keeping up-to-date SQLServer
- Dependencies on third-party SW components (Aladin Lite, TAP library etc)
  => The development team had to invest a significant effort to fix issues and in, some cases, implement new features in Aladin Lite and TAP Library
- Previews: some of the more advanced features (e.g., sky coverage maps and robust scaling of images for previews) required a significant amount of R&D which was difficult to estimate.
- IVOA Standards:
  - not always crystal clear: interpretation/consultation with experts often required, especially for those things that rely on a combination of 4 or 5 underlying standards.
  - Errata: adoption of IVOA errata by existing applications, and especially validators, is not as fast as it should be.
  - Some software built based on a IVOA standard does not work in real world because existing VO tools cannot cope with the difficulty the standard bears, example:
    - non-schema aware parsers (e.g. the ones used by pyvo, see github issue 257) assume certain prefixes:

      checkout the list of canonical XML namespaces and prefixes at: https://ivoa.net/documents/RegTAP/20191011/REC-RegTAP-1.1.html#tth_sEc5
  - Standards evolve! Obsolescence must be coped with.
  - At times they evolve in unexpected ways: example: REGION defined in ADQL2.0 about to disappear in ADQL2.1, luckily someone noticed it in time. Personal comment: A standard should not change without asking consensus to the data providers, and not just to data providers attending the Interops.
  - Developers would prefer using light json instead of complex VOTable
- Taplint? Our best friend! The TAP validator (M.Taylor) is part of the software tests: it runs every time the application starts, ensuring stability; wishing more of those!
- Data provider, beware! No existing software package/library is faultless, but within the VO, my experience is quite positive: report your findings to the respective developers and things will get fixed, usually quickly!

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Thanks!