Intro to the IVOA

Interop meeting 17-20 October 2022

Ada Nebot & the Committee on Science Priorities

CENTRE DE DONNÉES ASTRONOMIQUES DE STRASBOURG

ESCAPE
European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

Observatoire astronomique de Strasbourg | ObAS

Interoperability

- Few definitions:
  - Interoperability:
    - "The ability of computer systems or software to exchange and make use of information."
    - "The ability of different systems, devices, applications or products to connect and communicate in a coordinated way, without effort from the end user"

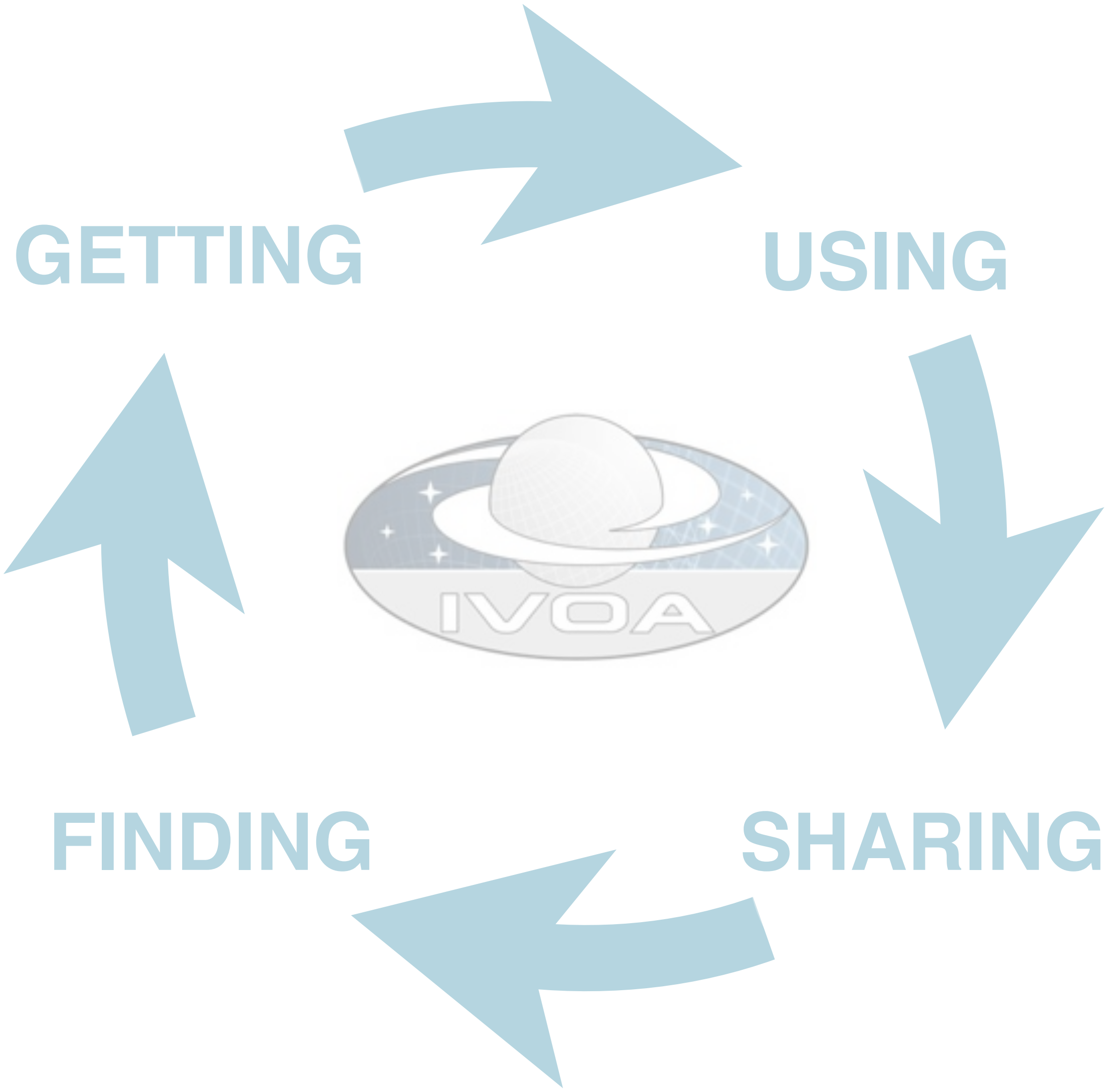
  - The Virtual Observatory: "Framework for astronomical datasets, tools, services to work together in a seamless way"

The VO and the IVOA: what?

“A multi-wavelength digital sky that can be searched, visualised and analysed in new and innovative ways” P. Fabianno

What is the International Virtual Observatory Alliance?

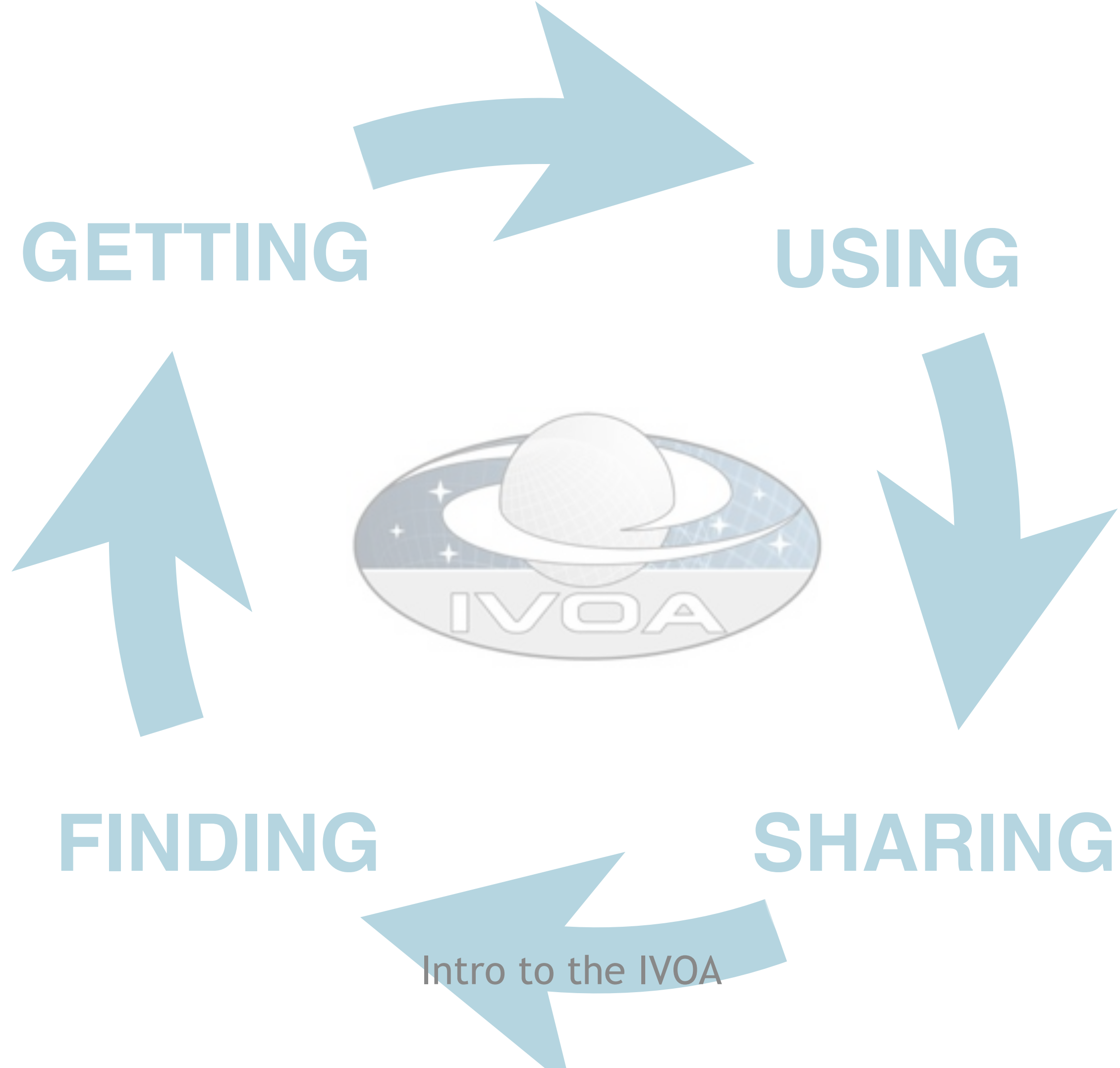
- A science driven organisation that builds the technical standards
- A place for discussing and sharing VO ideas and technology to enable science
- Promoting and publicising the VO



The VO and the IVOA: why?

Clear benefits

- Growth in the scientific return of data
- Capability to discover and fuse multiple data sets
- Application of the VO in planning new observations and observing strategies



The VO and the IVOA: who?

Who is the IVOA?

- **5 Committees:** Exec, Tech Coordination, Standards & processes, Media, Science priorities
- **6 Working Groups (WG):** Applications, data access, models, grid & web services, registry, semantics
- **8 Interest Groups (IG):** Time-domain, radio, solar system, theory, operations, data curation, knowledge & discovery, education

Want to get involved?

- Meetings: 2 interoperability meetings per year
- Don't know where to start? Email any chair/vice-chair of a IG/WG, CSP

http://ivoa.net/

The VO and the IVOA: where?

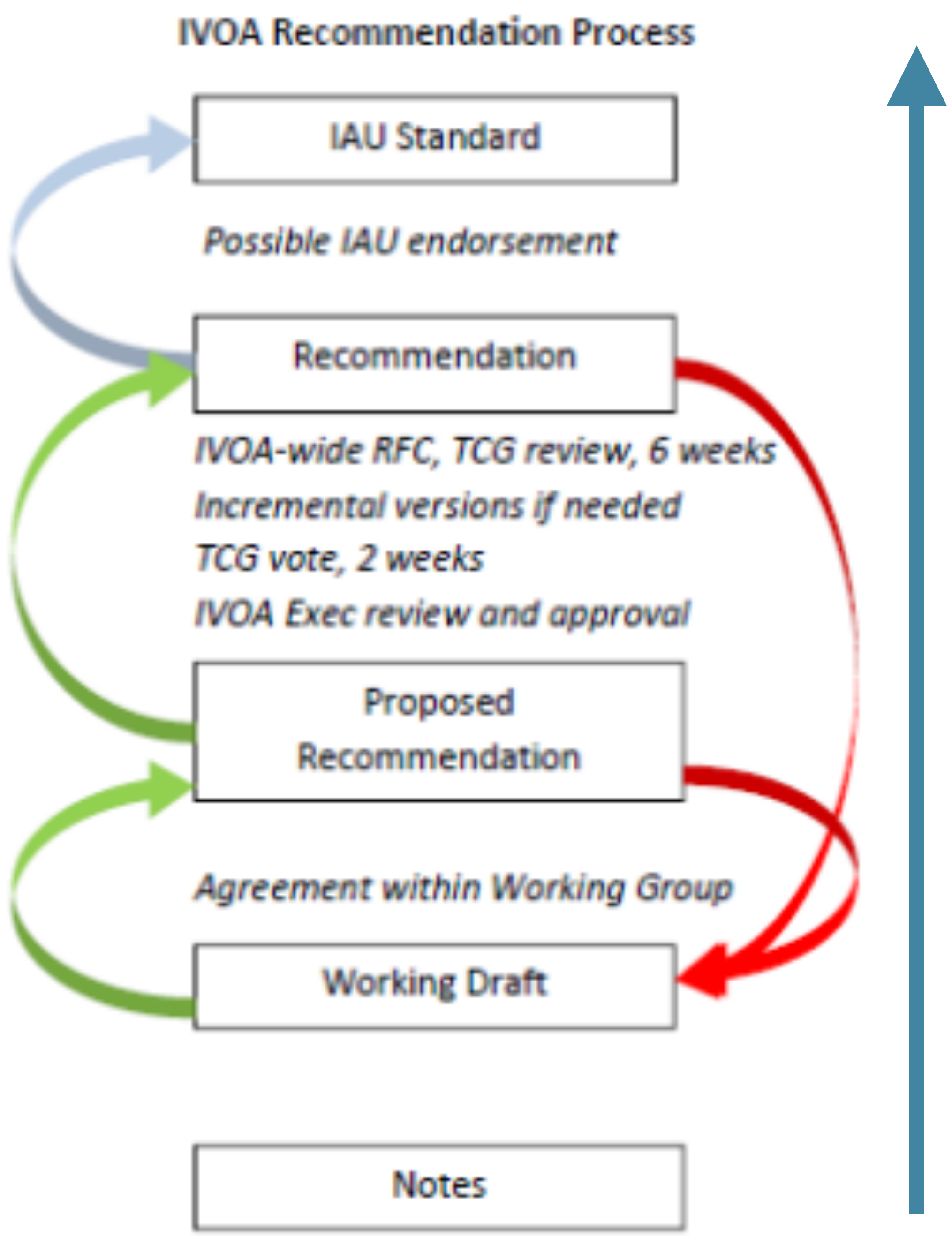
Existing global framework: populated by major data providers (space and ground based) that is heavily used by the community (e.g. Gaia data access is fully VO)

The VO and the IVOA: how?

Through the **development and adoption** of common standards scientifically driven, as an international community effort where astronomers, software engineers and documentalists are involved

IVOA development process of standards

- Build IVOA standards to match users needs:
  - Find and report the community needs
  - Find and report gaps in the existing standards
  - Propose new ways to fill the gaps
  - Implement & validate
  - Standardise when consensus is reached



https://www.ivoa.net/documents/DocStd/index.html

OK, but where do I start?

- A good starting point to newcomers to the IVOA: **the architecture document**

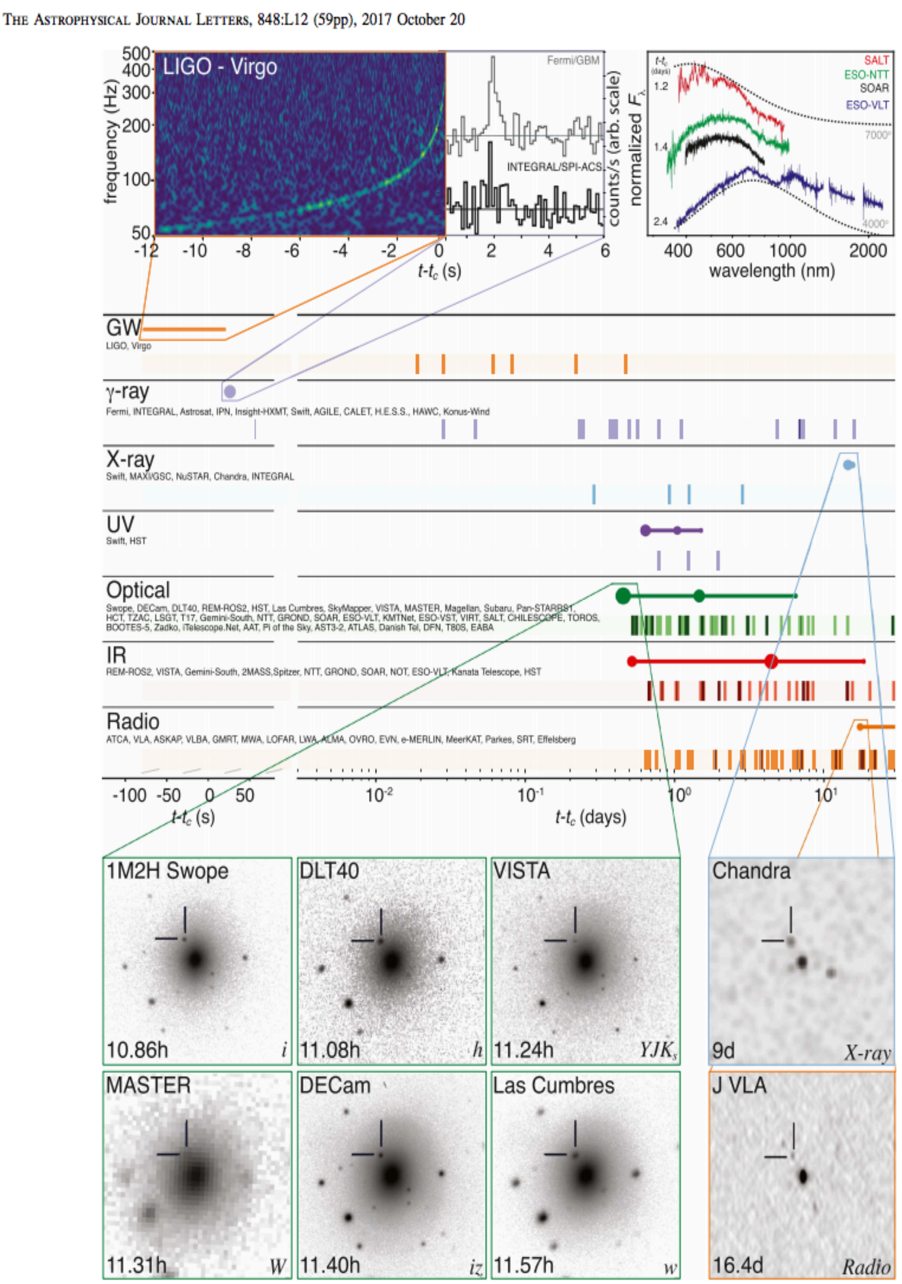
  https://www.ivoa.net/documents/IVOAArchitecture/20211101/index.html

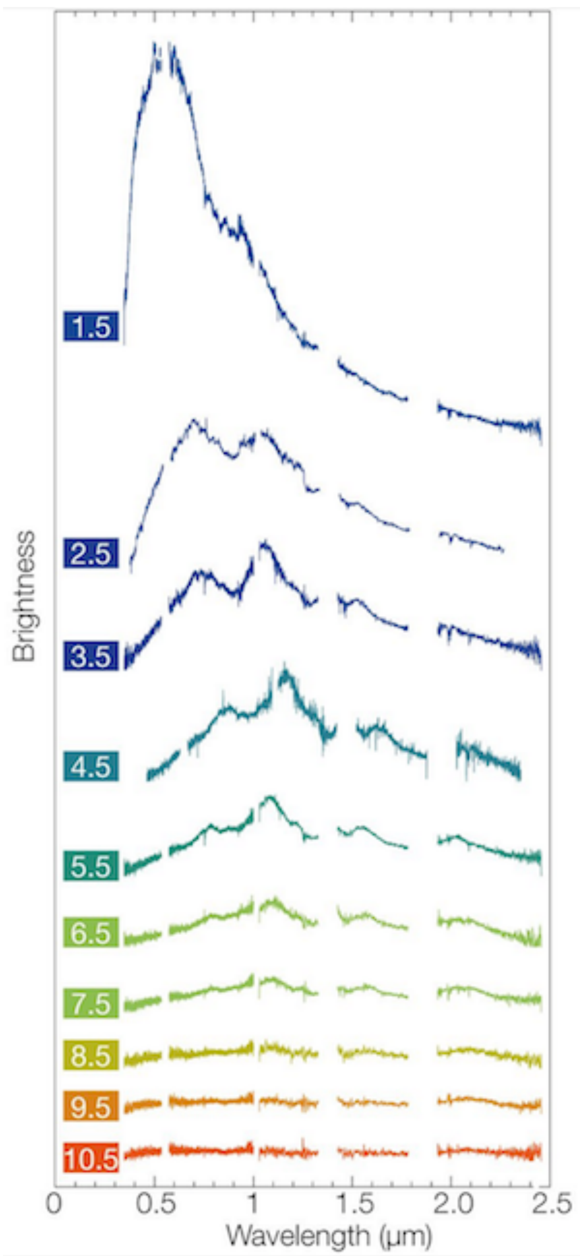
Things to keep in mind:

- The IVOA will not answer your scientific questions nor will it ask the questions for you
- The IVOA provides you with common formats and common ways of describing and accessing the data which when adopted will ease your work

Let's see it with an example

VO in the multi-messenger landscape





- Multi-wavelength / messenger approach is needed - different data types
- Follow-up observations and reaction time for that can be crucial - alerts
- Analysis, Visualisation & navigation through the data
- Coordination & transmission of information

The IVOA should match user's needs

Some selected standards

1. **VOTable** the format for tabular data for allowing interoperability (coosys, timesys, ucd, utype, VOunits, datalink).
2. **HiPS** more than a format for images - tailored for large data volumes
3. Search for data:
   - **Cone search** — spatial + temporal search
   - **MOC** — spatial and temporal indexing for large data volumes and more complex areas in the sky
   - **TAP + ADQL** — Table Access Protocol & astronomical data query language
   - **ObsCore & ObsTAP** — description of observations
4. Planning of observations:
   - **ObjVisSAP** — visibility of object to plan observations
   - **ObsLocTAP** — facilitate coordination of observations
   - Facilities / observatory list (under dev.)
5. Alerts: **VOEvents**
6. **… many more! SLAP, SIAP, SSA, Provenance, SAMP… each tailored to specific use cases**

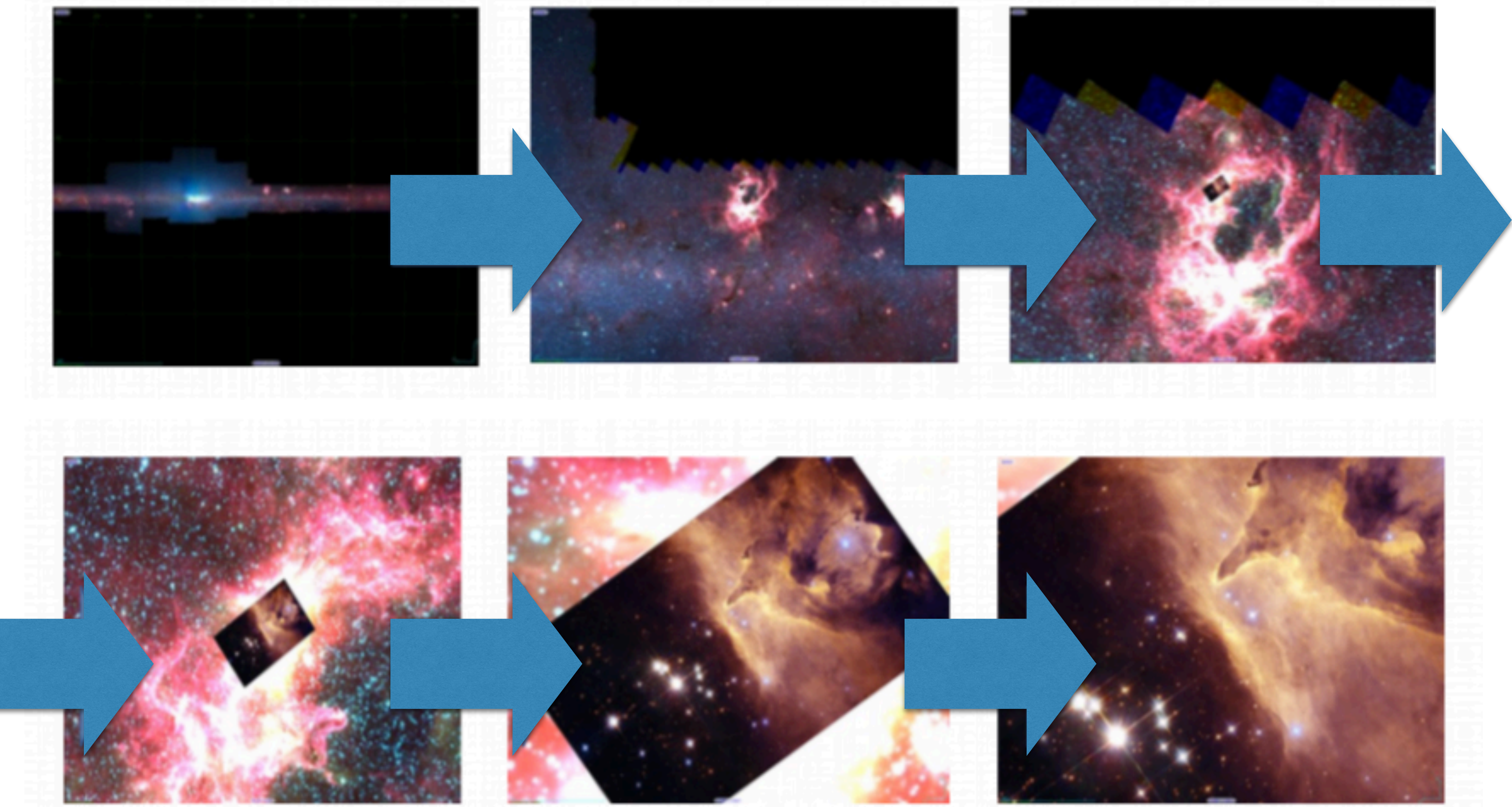
VOTable: format for tabular data

Standardisation of coordinate system annotation (time and space), UCD, utypes, VOUnits, datalink

- **COOSYS** ("ICRS", “eq_FK5”,…)
- **TIMESYS** (scale: TT, TAI, …, refposition: barycenter,… timeorigin: JD, MJD,…)
- **Unified Content Descriptor** (**UCD**): controlled vocabulary for describing astronomical data quantities - related to the nature of the values
- **UTypes:** relationship between the columns and the data model components
- **VOUnits:** units expressed as a simplified text label (e.g. m.s**-2 instead of m s^{-2})
- **Datalink**: links to other associated data

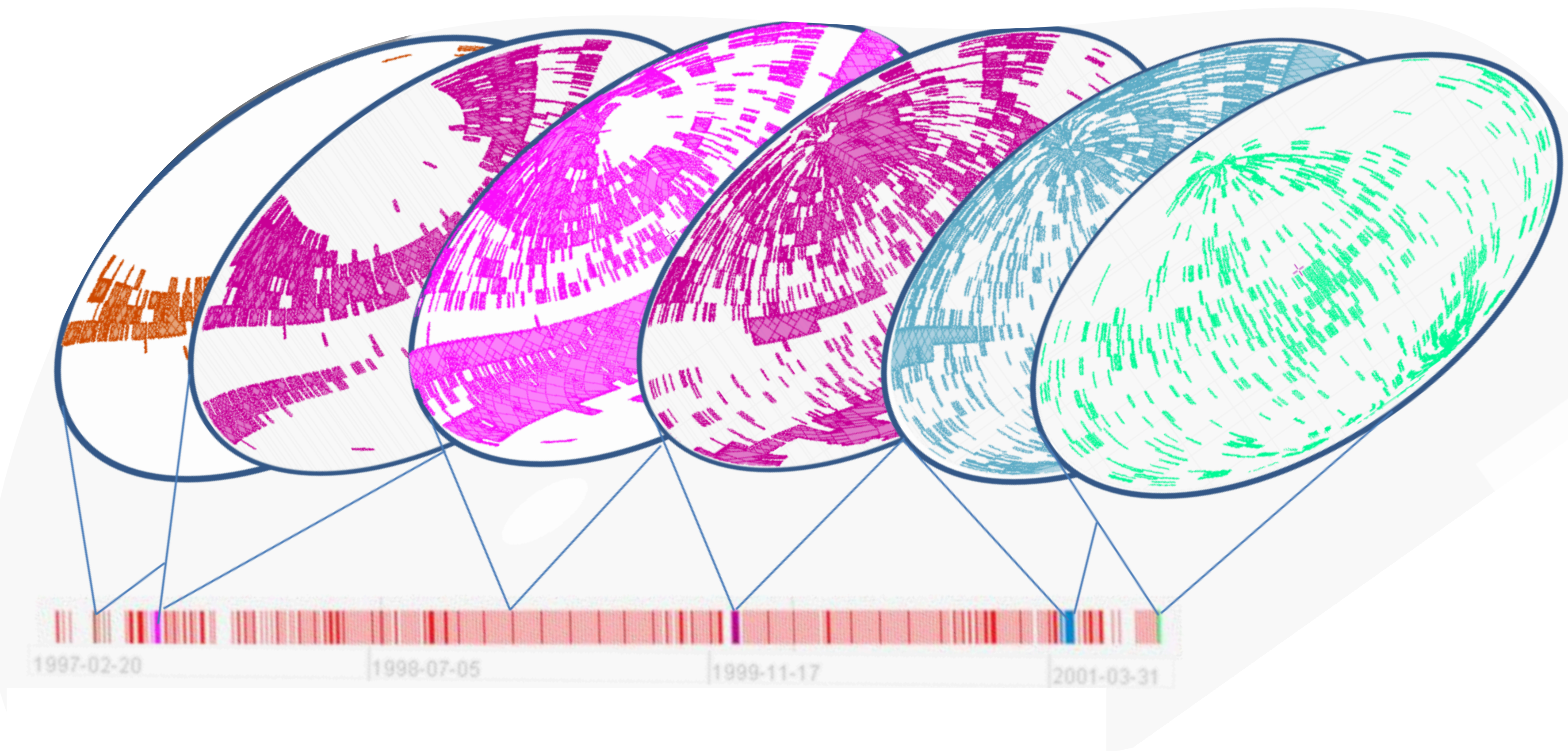
HiPS: Hierarchical image Progressive Survey

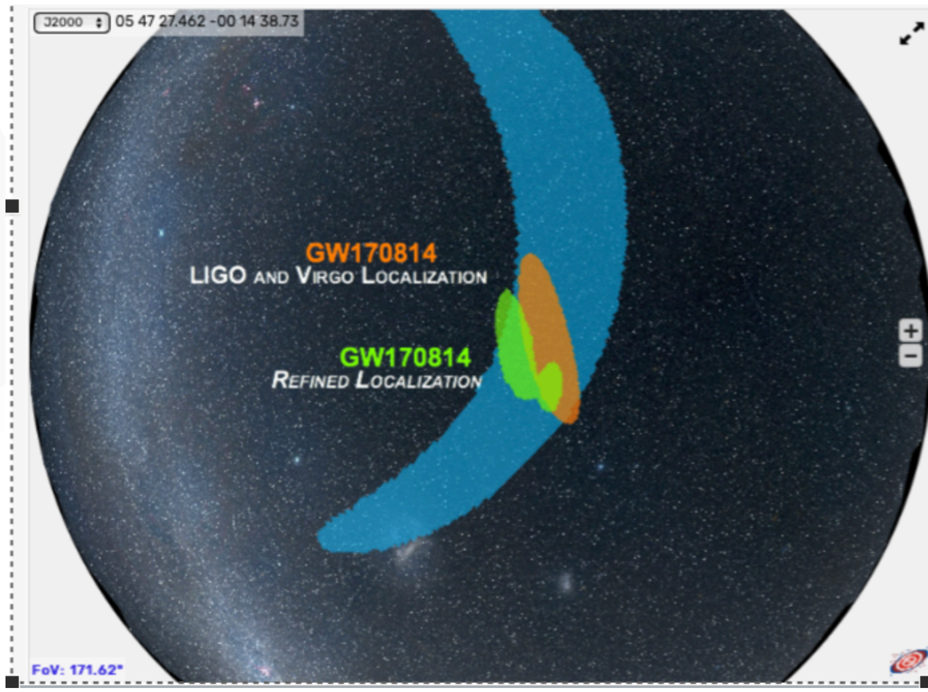
- A hierarchical scheme for the description, storage and access of sky survey data (the more you zoom-in the more the details)



Search: know where & when

- Cone search extension to add a time interval for search in catalogs
- MOC : Search by temporal+spatial coverage of surveys for the more complicated areas





TAP & ADQL

- **Table Access Protocol (TAP)** - defines a service protocol for accessing general table data, including astronomical catalogs as well as general database tables. Access is provided for both database and table metadata as well as for actual table data.

- **Astronomical Data Query Language (ADQL)** Based on Structured Query Language (SQL) with special restrictions and **extensions** in order to support generic and astronomy specific operations

```
SELECT DISTANCE(
  POINT('ICRS', 266.41683, -29.00781),
  POINT('ICRS', ra, dec)) AS dist, *
FROM gaiaedr3.gaia_source
WHERE 1=CONTAINS(
  POINT('ICRS', 266.41683, -29.00781),
  CIRCLE('ICRS',ra, dec, 0.08333333))
ORDER BY dist ASC
```

ObsCore & ObsTAP

- **Goal: "to give data providers a set of metadata attributes that they can easily map to their database system in order to support queries of the sort listed below."**

- Science cases:
  - Support multi-wavelength as well as positional and temporal searches.
  - Support any type of science data product (**image, cube, spectrum, time series, instrumental data, etc.**).
  - Directly support the sorts of file content typically found in archives (FITS, VOTable, compressed files, instrumental data, etc.).

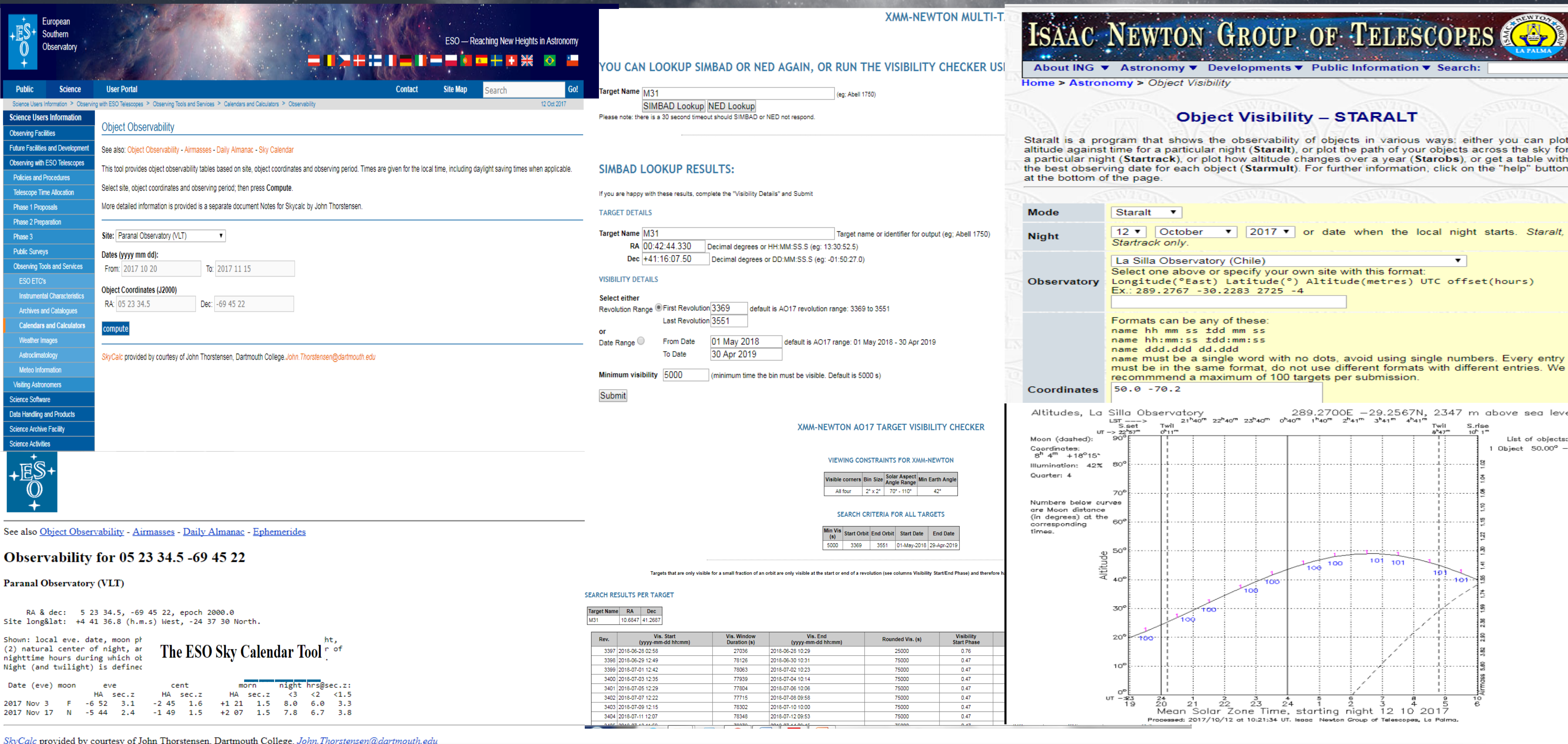
ObsCore & ObsTAP are Key IVOA standards for searching, finding and combining all sorts of data and allow for interoperability

ObsCore & ObsTAP

- Map the METADATA of your project data into ObsCore Keywords
- Set a TAP Service
- Register it! —> *“The yellow pages of the IVOA”*

➡ Search, find, and combine the data coming from multiple missions

Visibility of an object



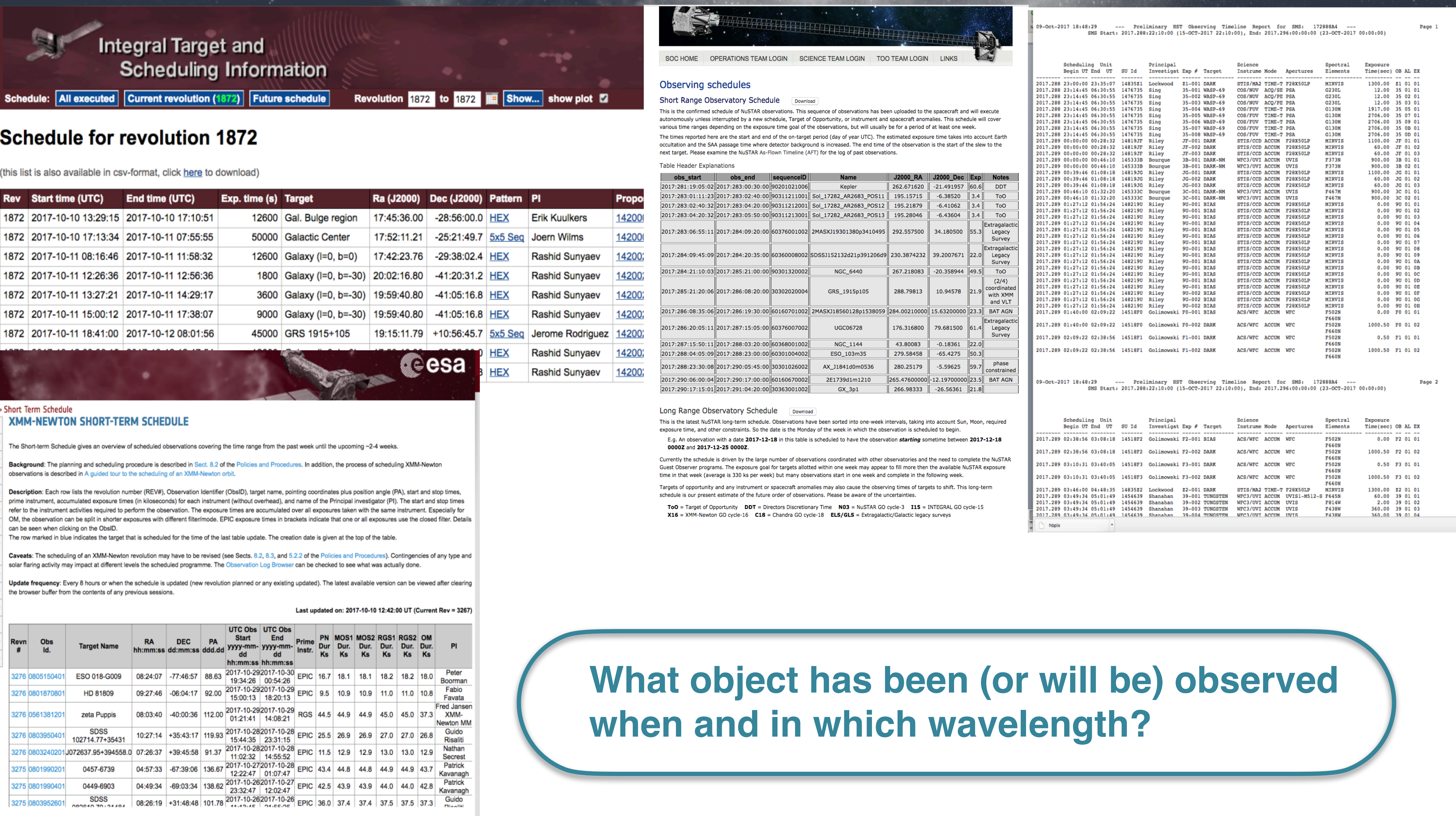
Different services have different inputs / outputs

Facilitate the work by having some level of standardised input / output

Object Visibility Simple Access Protocol, Aitor Ibarra, Richard Saxton, Jesús Salgado et al. 2020

http://www.ivoa.net/documents/ObjVisSAP/index.html

Coordination of observations



What object has been (or will be) observed when and in which wavelength?

Observation Locator Table Access Protocol, Aitor Ibarra, Jesús Salgado et al. 2021
http://www.ivoa.net/documents/ObsLocTAP/

VOEvent: Sky Event Reporting Metadata

- **"Defines the content and meaning of a standard information packet for representing, transmitting, publishing and archiving information about a transient celestial event, with the implication that timely follow-up is of interest"**
  - **Who**: Identification of scientifically responsible Author
  - **What**: Event Characterization modeled by the Author
  - **WhereWhen**: Space-Time Coordinates of the event
  - **How**: Instrument Configuration
  - **Why**: Initial Scientific Assessment
  - **Citations**: Follow-up Observations
  - **Description**: Human Oriented Content
  - **Reference**: External Content

Register your services

- Describe what data and computational facilities are available where, and once identified, how to use them.

- **The yellow pages**

Want to access data in the VO?

- Different ways to access the data in the VO: eg via Aladin, Topcat, python
- Lots of tutorials available

https://wiki.ivoa.net/twiki/bin/view/IVOA/EduResourcesTutorials#Graduate_level

TUTORIALS	DESCRIPTION	Link
Discovery of Brown Dwarfs mining the 2MASS and SDSS databases	This tutorial uses the advanced VO functionalities of Aladin (interactive sky atlas) to find brown dwarfs in the 2MASS and SDSS surveys. The user learns about the filtering, cross-matching and visualization functions, the implementation of scripts in Aladin and many more Aladin features to identify brown dwarfs in these surveys. This tutorial has been last updated for the first ESCAPE "Science with interoperable data school", previous versions of this tutorial repeated the same discovery steps with TOPCAT and STILTS. For this tutorial you will need a parameter and script file.	Jupyter Notebook

NASA-NAVO Workshops Notebooks

Search the docs ...

Preparing a proposal

The Story: Suppose that you are preparing to write a proposal on NGC1365, aiming to investigate the intriguing black hole spin this galaxy with Chandra grating observations (see: Monster Blackhole Spin Revealed)

Want to publish data in the VO?

https://wiki.ivoa.net/twiki/bin/view/IVOA/PublishingInTheVO

Several ways to publish you data into the VO (depending on needs):

- **Very little technical expertise** —> Contact your **national VO projects**
- **Find your VO services in applications** —> Publish in a **VO Registry**
- **Some technical expertise** —> existing **VO Publishing toolkits.**
- **Technical expertise** & prefer to **build VO interfaces** to your data:
    - There are useful **VO software tools and libraries.**
    - Determine what type of data you want to publish (images, catalogues, spectra, …)?
    - Have a look at the IVOA Architecture document to find out which IVOA standards that you might need to use

What else?

- Many more standards!
- Want to know more? Don’t know what an acronym means?
- Have a look at the architecture document!
- https://www.ivoa.net/documents/IVOAArchitecture/20211101/index.html

Summary of each standard

4.1 SSO

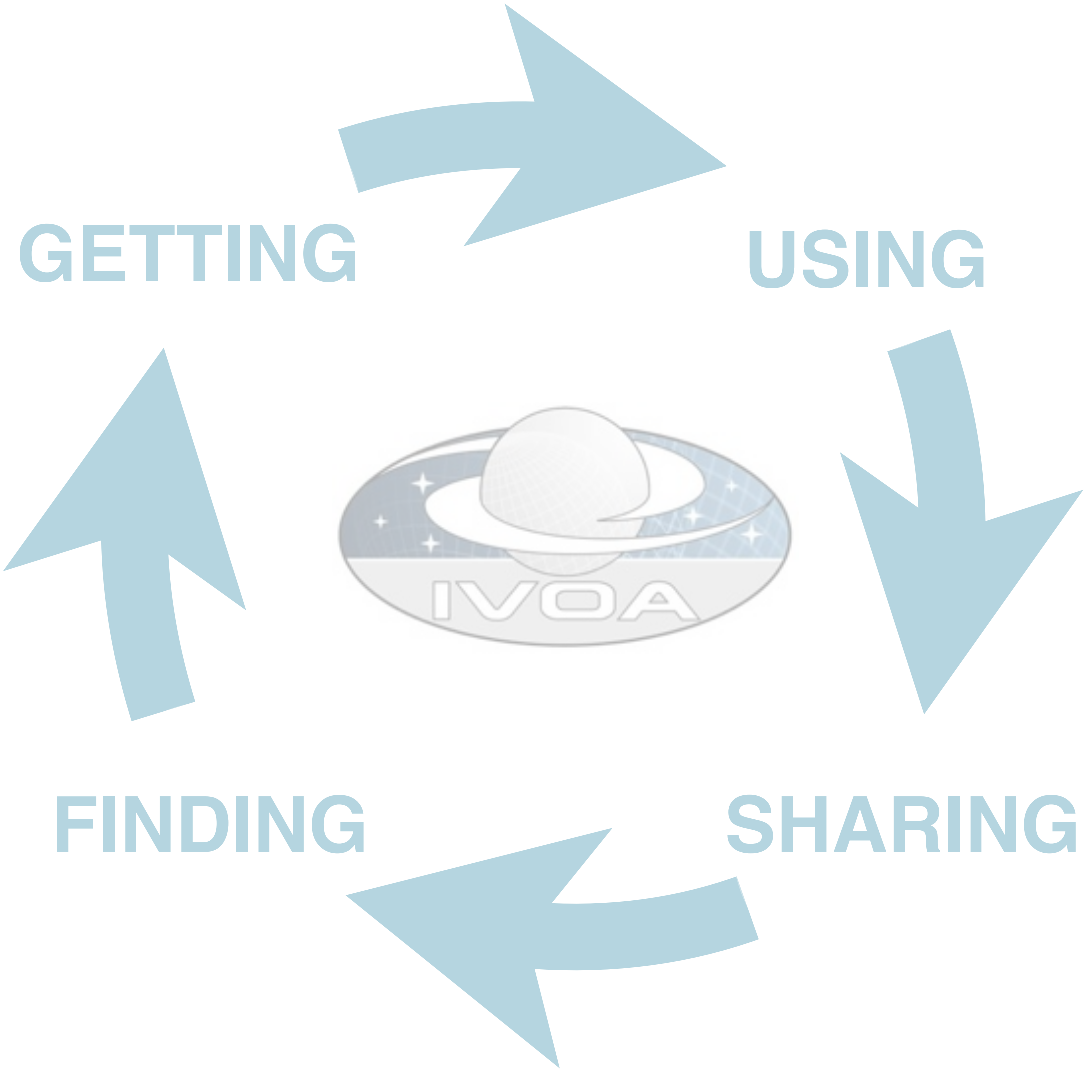
The Single-Sign-On (SSO) (Taffoni and Schaaf et al., 2017) profile describes authentication mechanisms. Approved client-server authentication mechanisms are described for the IVOA single-sign-on profile: No Authentication; HTTP Basic Authentication; TLS with passwords; TLS with client certificates; Cookies; Open Authentication; Security Assertion Markup Language; OpenID. Normative rules are given for the implementation of these mechanisms, mainly by reference to pre-existing standards.

A table with acronyms

Acronym	Expansion
ADQL	Astronomical Data Query Language - standard
API	Application programming Interface
CDP	Credential Delegation Protocol - standard
CharDM	Characterisation Data Model - standard
ConeSearch	Cone Search - simple positional search service standard

Summary

The IVOA standards are built to enable access, discovery and ultimately **interoperability**



Meeting **FAIR** principles by design

Findable

Accesible

Interoperable

Reusable

The IVOA needs the community to participate!

Some useful links

- https://www.ivoa.net
- Docs : https://www.ivoa.net/documents/
- GitHub : https://github.com/ivoa
- Mailing list : https://www.ivoa.net/members/index.html
- Architecture: https://www.ivoa.net/documents/IVOAArchitecture/20211101/index.html
- Slack: https://join.slack.com/t/ivoa/shared_invite/zt-1gsa589t2-cgadBVp7BWzuq7VFg8qlog