the IVOA ecosystem

share, find, access

Marco Molinaro

[INAF - OATs]

Astro-CC

European Data Provider Forum

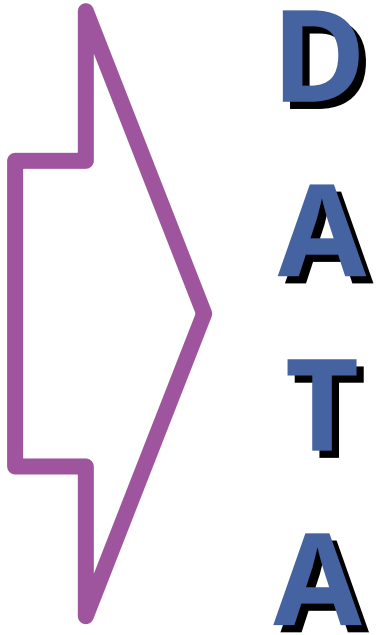
25-27 March 2026 – Heidelberg

The *observational* challenge

> "Any area of the sky not observed in a certain moment in time is missing data."

...and its consequences

- **Preservation**
  - *“forever”*
- Sharing
  - **Open/Public** accessibility
- **Interoperability**
  - Technical & Semantic



FITS: a first (technical?) solution

https://fits.gsfc.nasa.gov/fits_home.html

- Discussion started end of ‘70s
- First formal document in 1981
- Today it’s FITS v.4.0 (2018)
- Maintained by an IAU Working Group
  - Challenged by a growing number of other formats

IVOA: interoperable ecosystem

- **International Virtual Observatory Alliance**
- Formed in 2002
- Open standards organisation
- Interoperability as the core goal
- FAIR-enabler standards for astronomy

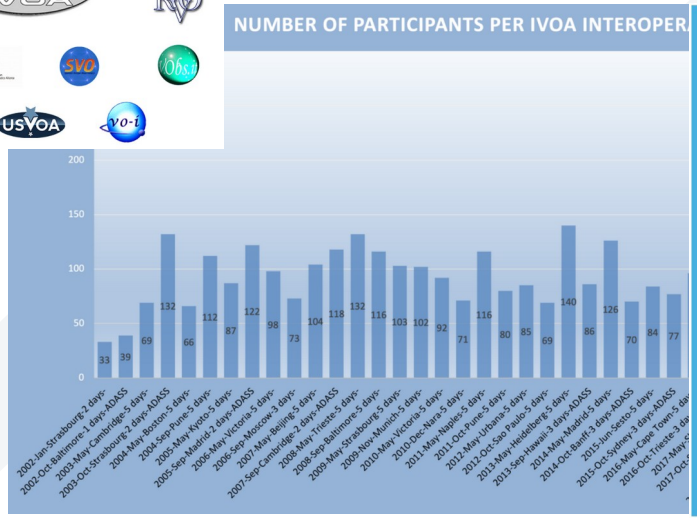
https://ivoa.net/

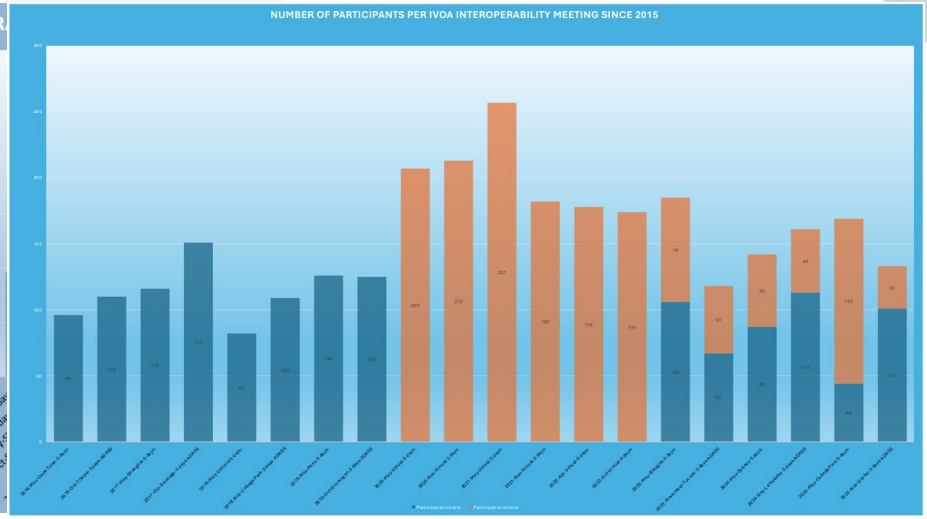
IVOA vision

> "The Virtual Observatory (VO) is the vision that astronomical datasets and other resources should work as a seamless whole. [...] The International Virtual Observatory Alliance (IVOA) is an organisation that debates and agrees the technical standards that are needed to make the VO possible."

IVOA “family picture”

IVOA community



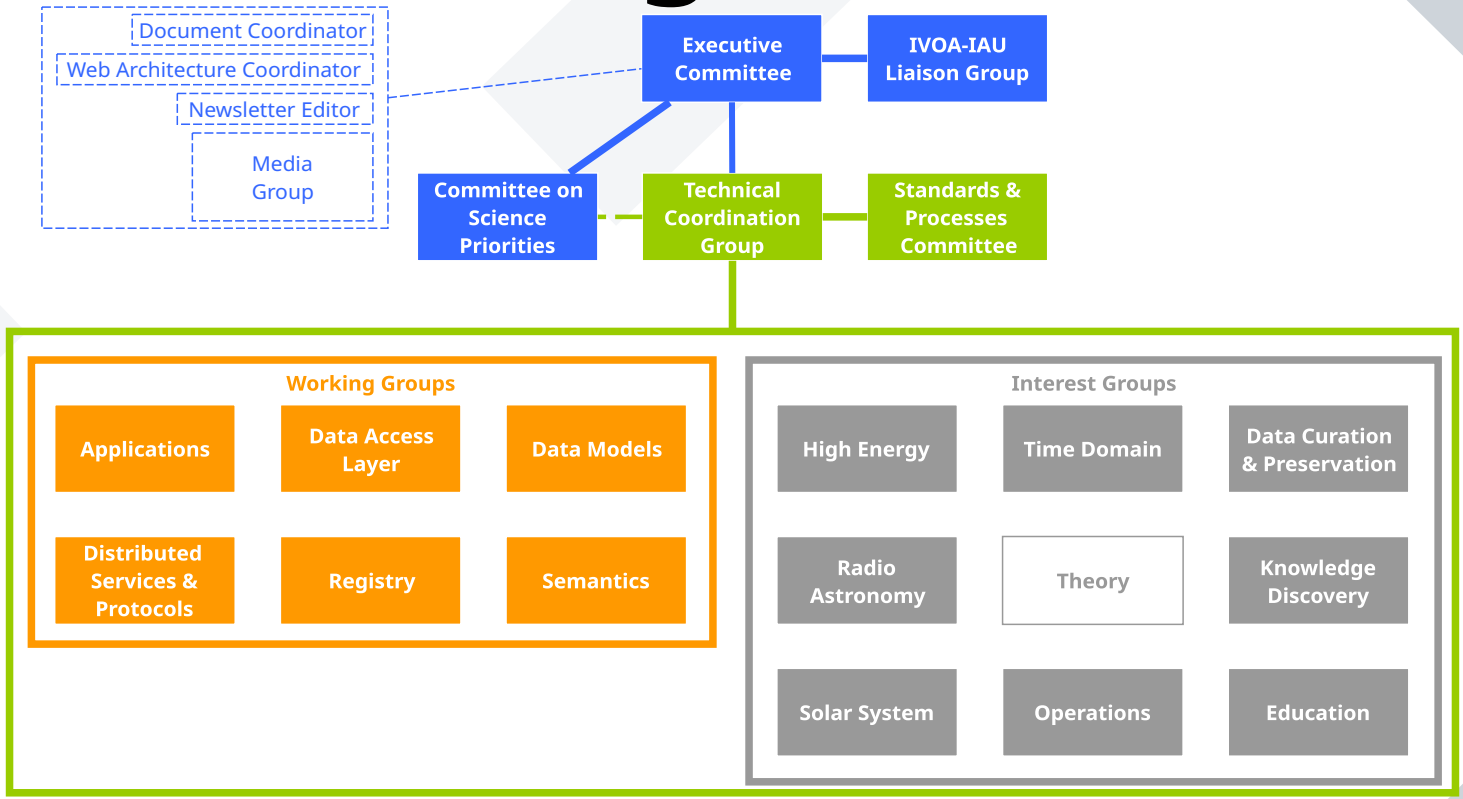


Semestral “Interoperability” Meetings with ~100 participants

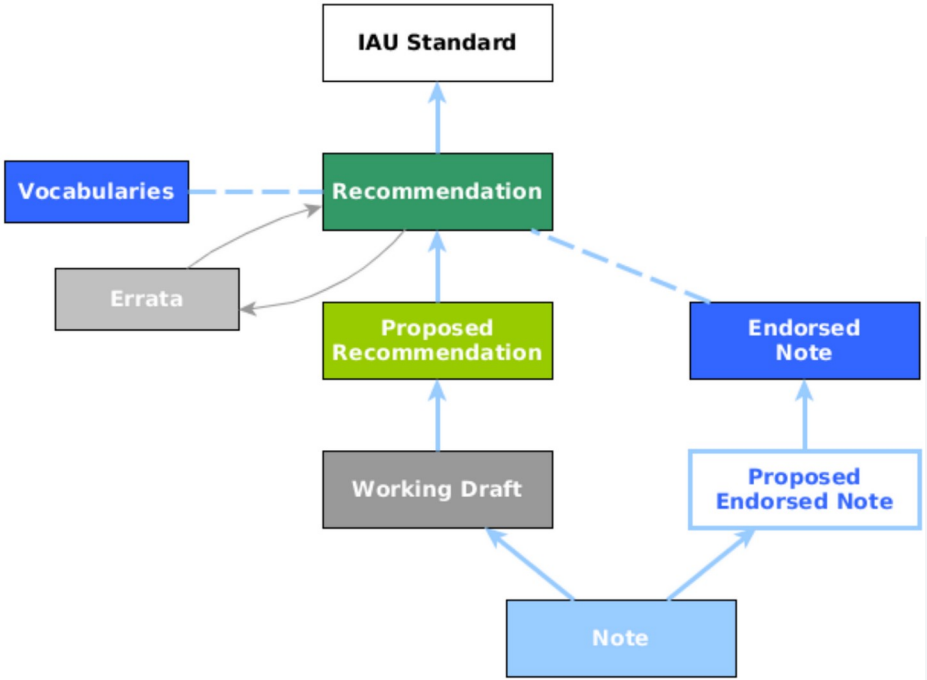
next ones

- 8-12 June 2026: Strasbourg - https://indico.ict.inaf.it/event/3454/
- 6-8 November 2026: Perth – back-to-back to 1-5 November ADASS XXXVI

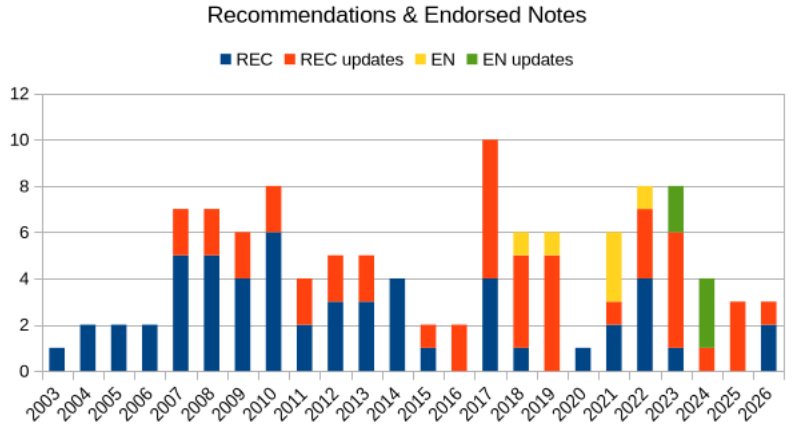
IVOA organisation



IVOA processes

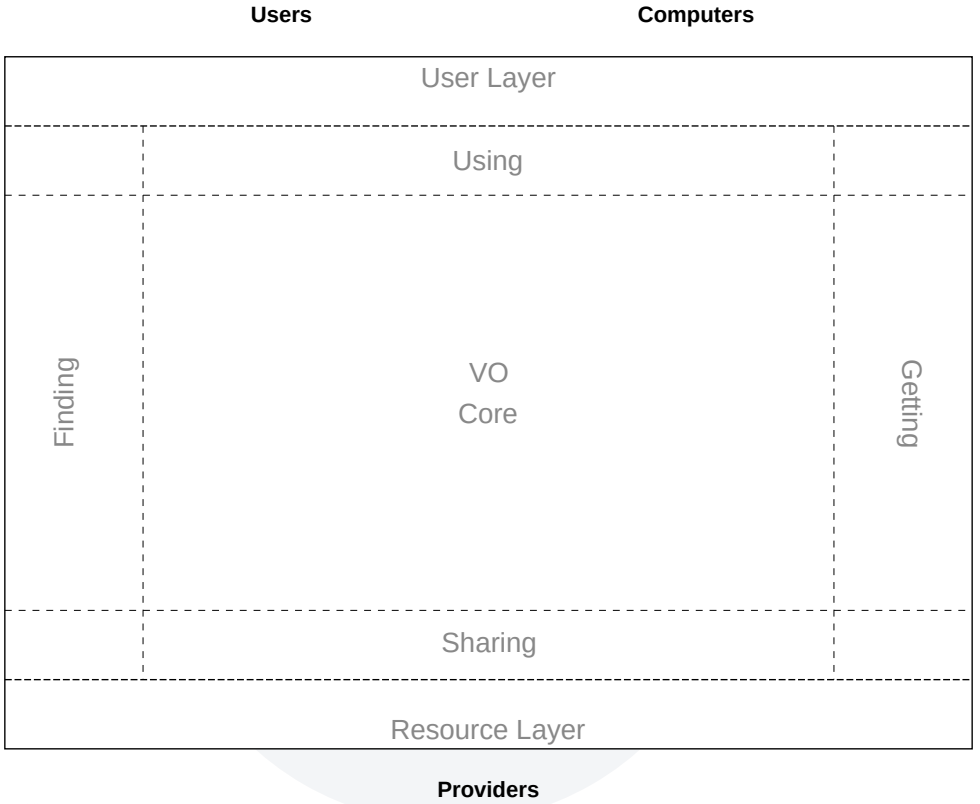


- **IVOA Document Standards 2.0**
  - 10.5479/ADS/bib/2017ivoa.spec.0517G
- **Vocabularies in the VO 2.1**
  - 10.5479/ADS/bib/2023ivoa.spec.0206D



recommendations (standards) are **agreed on consensus**

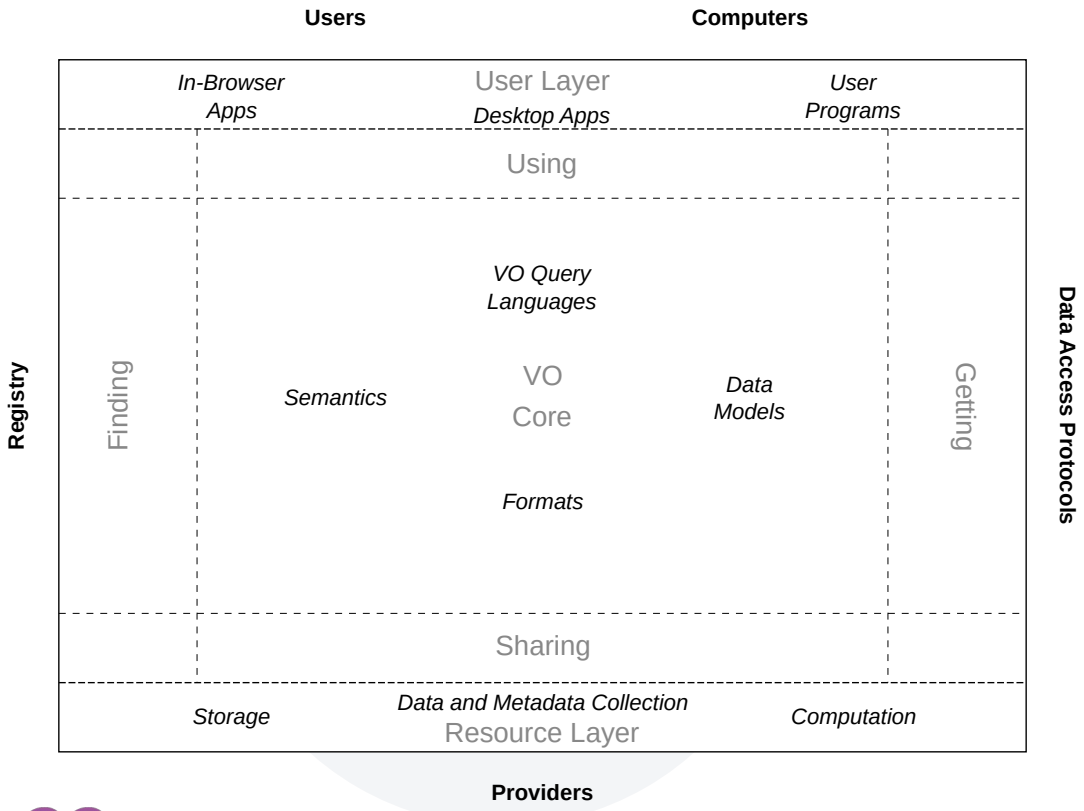
IVOA architecture



IVOA Architecture 2.1
https://ui.adsabs.harvard.edu/abs/2024ivoa.spec.1114E

level 0

IVOA architecture

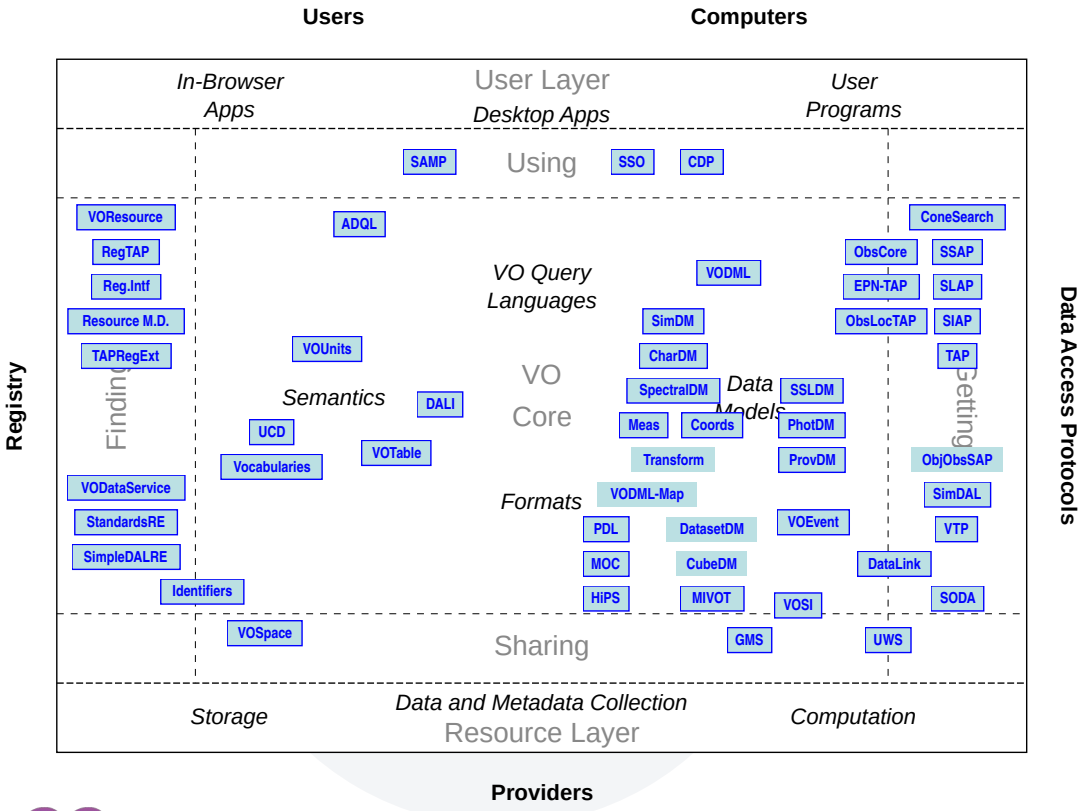


IVOA Architecture 2.1
https://ui.adsabs.harvard.edu/abs/2024ivoa.spec.1114E

level 1

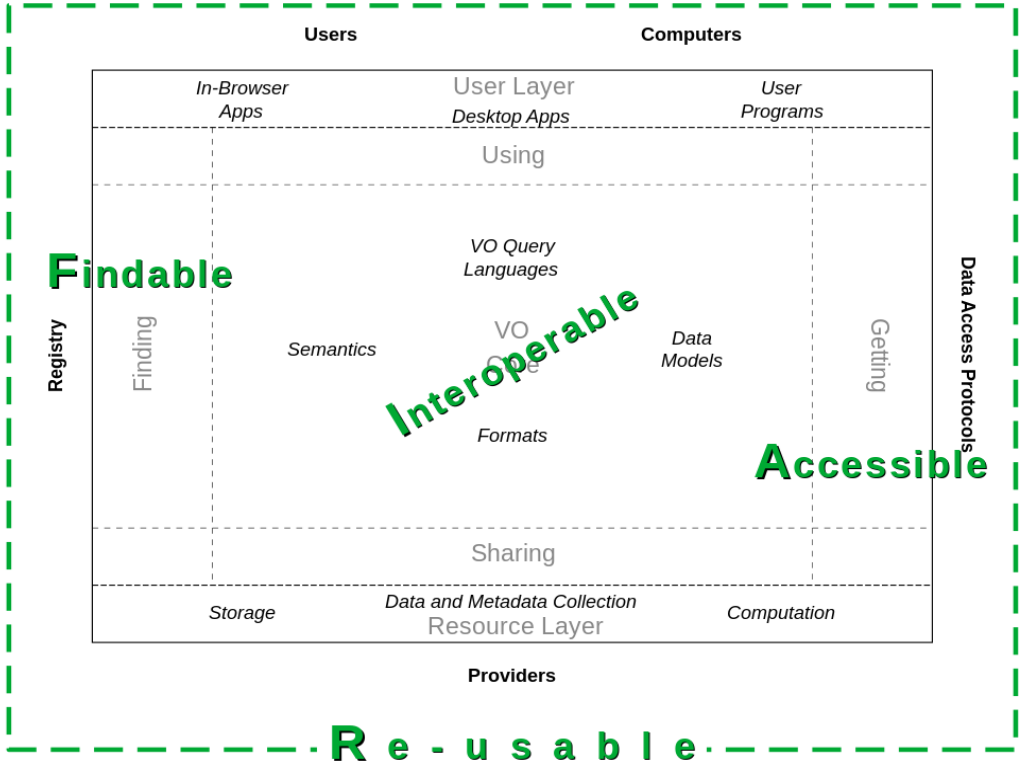
IVOA architecture

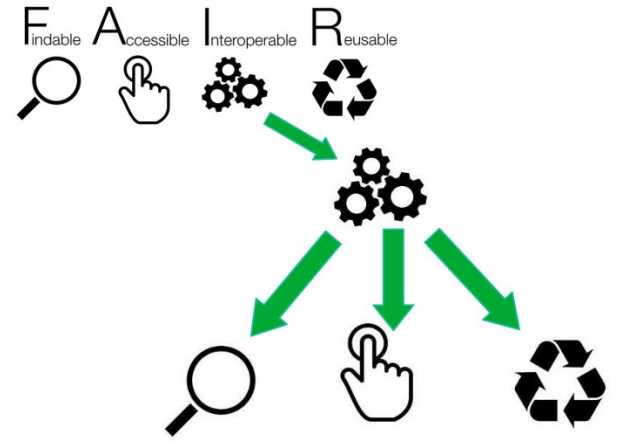
IVOA Architecture 2.1
https://ui.adsabs.harvard.edu/abs/2024ivoa.spec.1114E

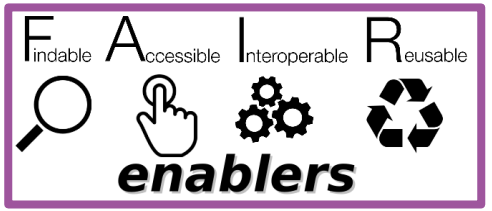


level 2

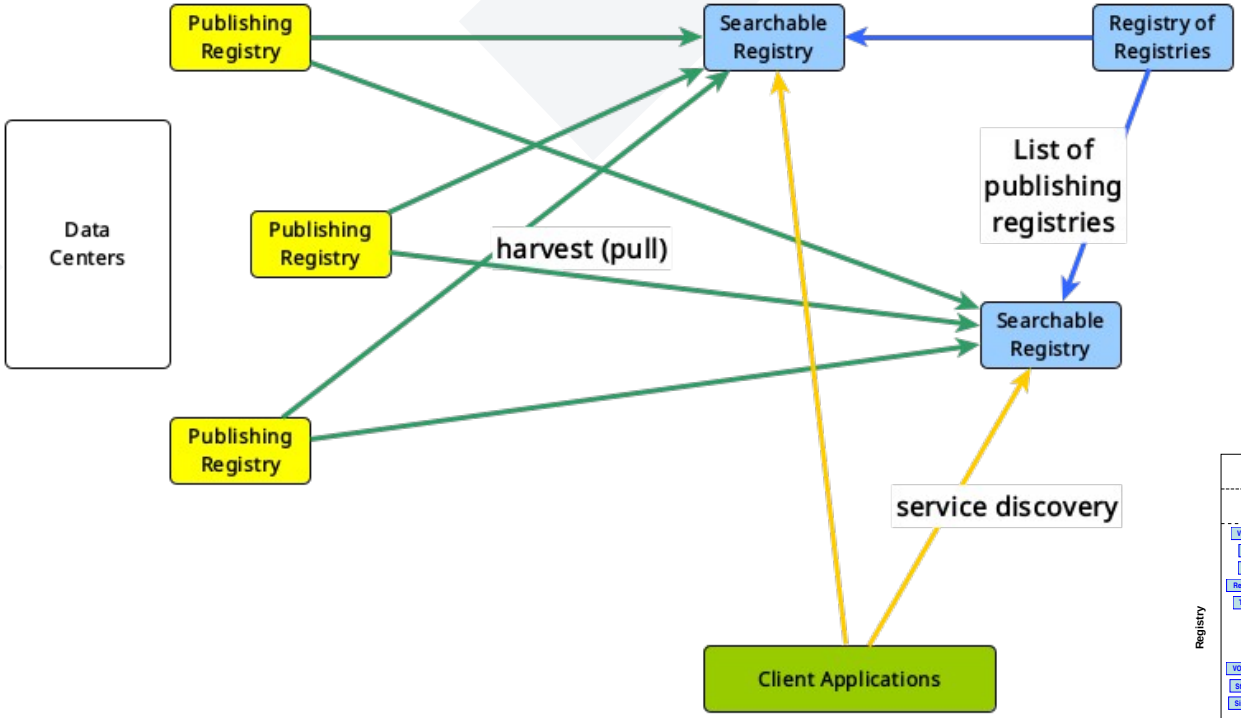
IVOA – FAIR mapping

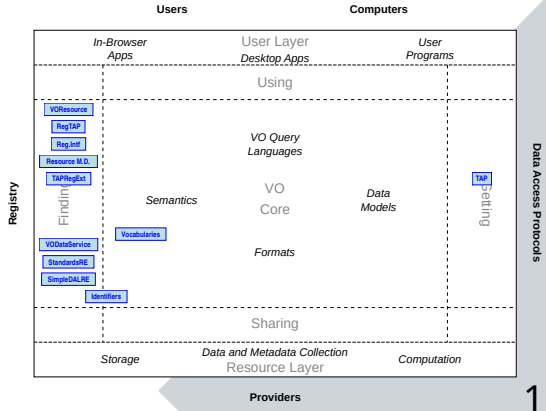






The IVOA Registry

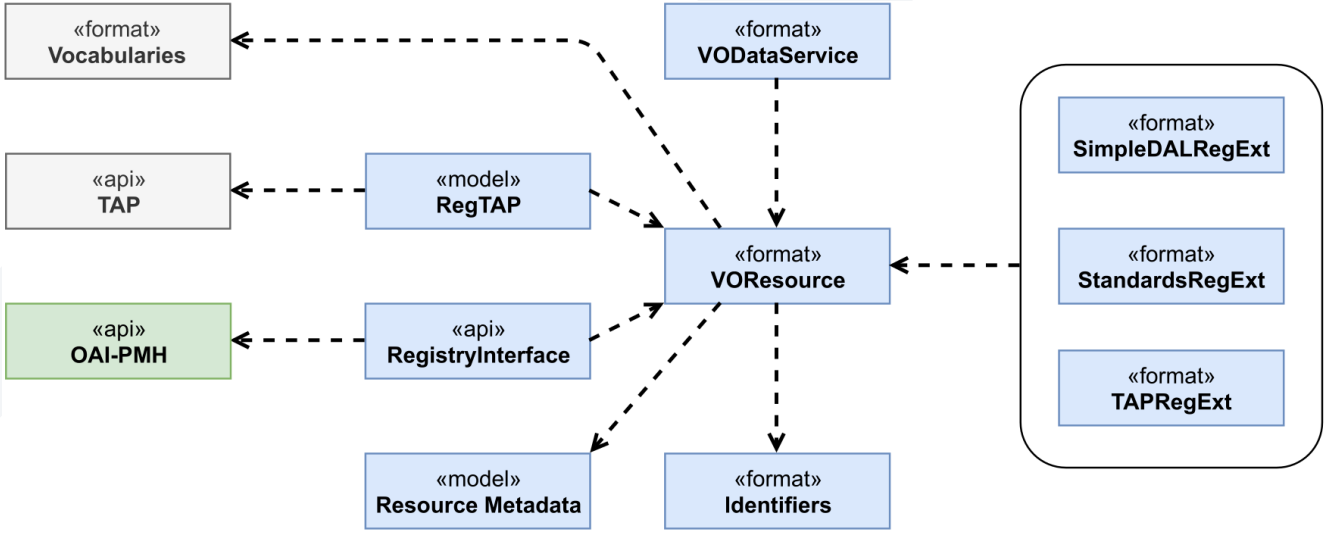


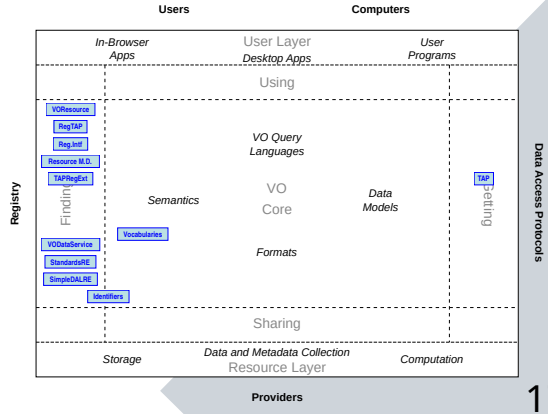


Registry: Resources

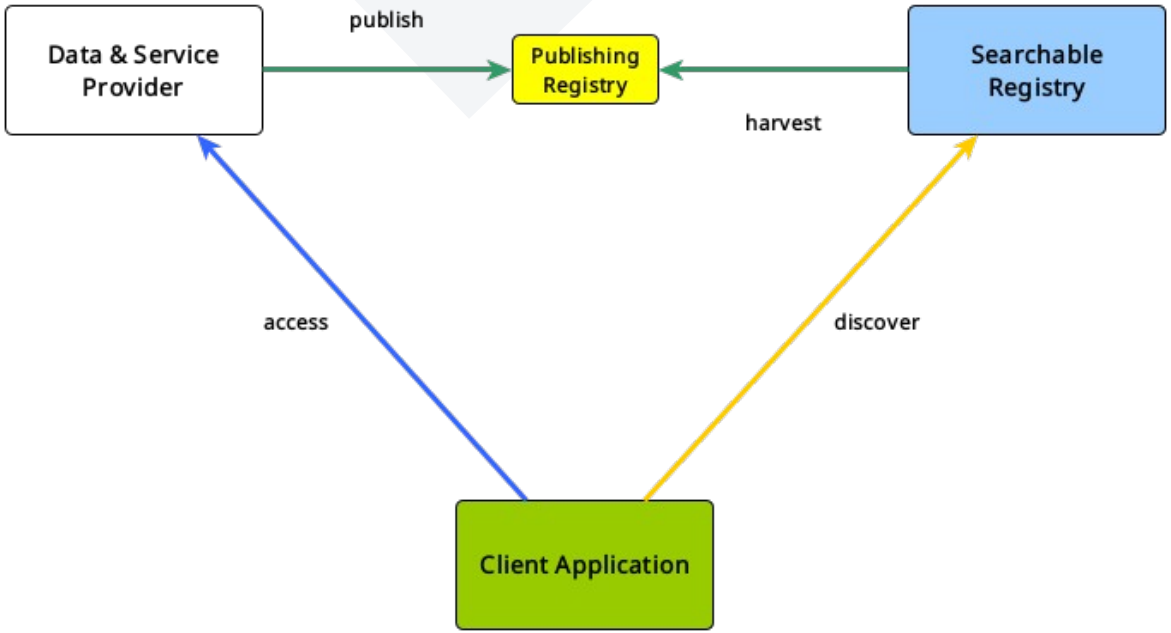
- Data Collections
- Source Catalogues
- Access Services (standardised)
  - Protocols
  - Registries (themselves)
- IVOA standards

The IVOA Registry

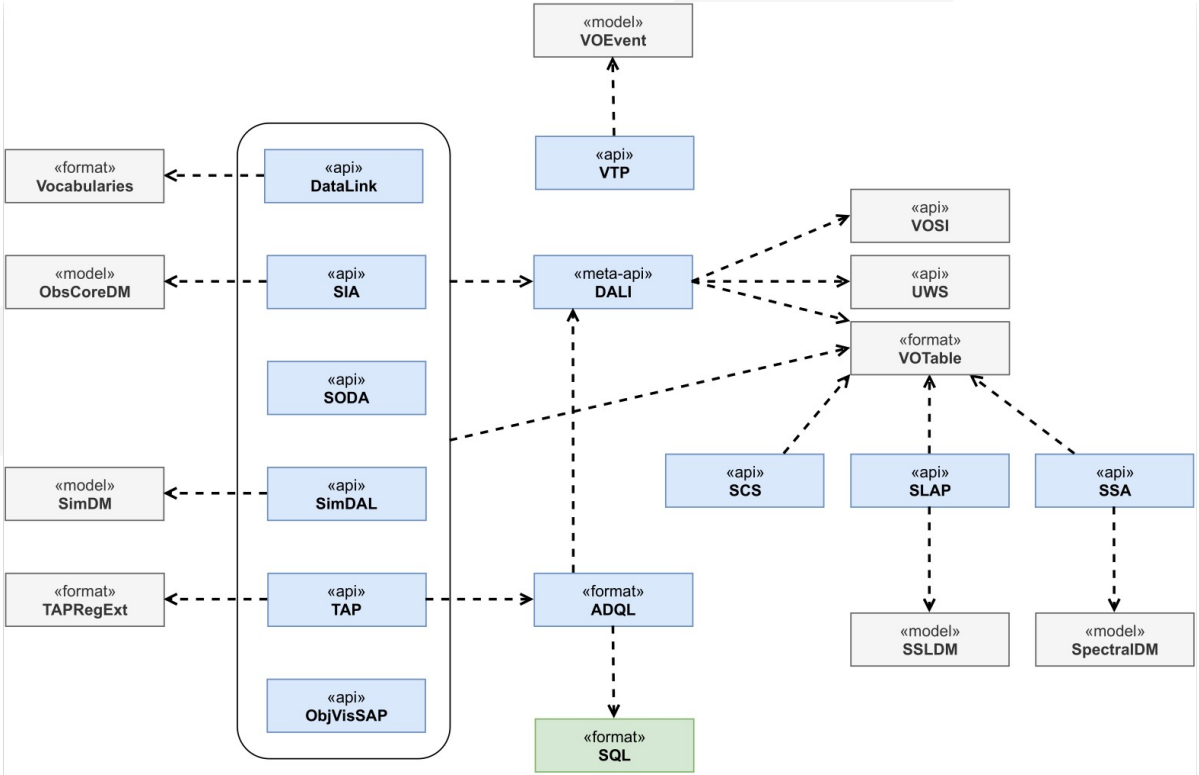




Data Access


Data & Service Provider
publish
Publishing Registry
Searchable Registry
harvest
access
discover
Client Application

Data Access


«model»
VOEvent
«api»
VTP
«format»
Vocabularies
«api»
DataLink
«model»
ObsCoreDM
«api»
SIA
«meta-api»
DALI
«api»
VOSI
«api»
UWS
«format»
VOTable
«api»
SODA
«model»
SimDM
«api»
SimDAL
«api»
SCS
«api»
SLAP
«api»
SSA
«format»
TAPRegExt
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TAP
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ADQL
«model»
SSLDM
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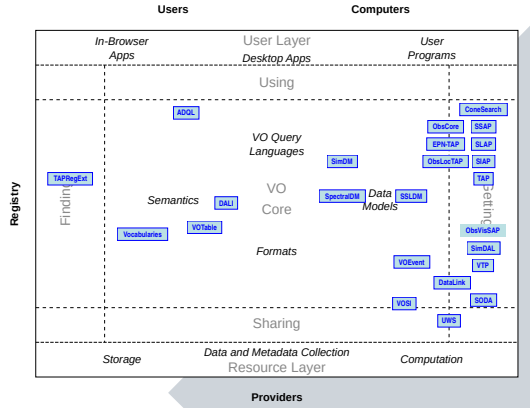
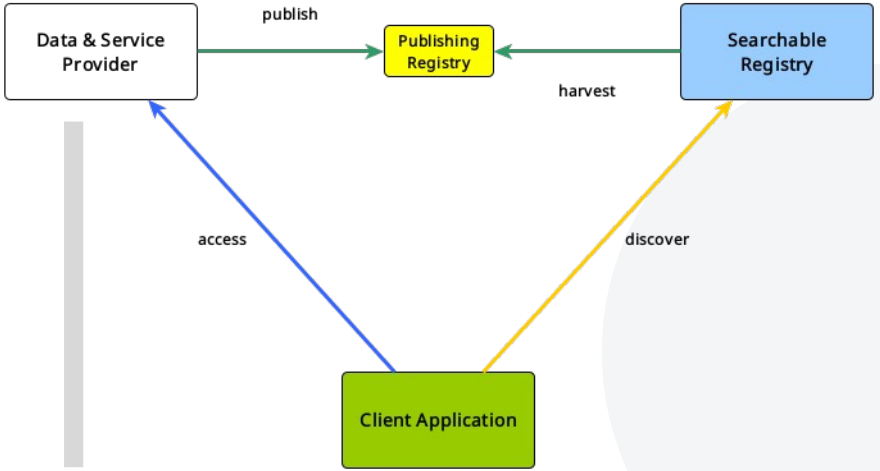
SpectralDM
«api»
ObjVisSAP
«format»
SQL


Users
Computers
In-Browser Apps
User Layer
Desktop Apps
User Programs
Using
VO Query Languages
VO Core
Semantics
Formats
Data Models
Registry
Finding
Getting
Data Access Protocols
Sharing
Storage
Data and Metadata Collection
Resource Layer
Computation
Providers

Access action-ability



- Client applications that are aware of
  - Registry
  - Access Layer (protocol)
  - Formats
- Can automatically move
  - from the resource description document
  - to consuming its endpoints
  - and use the meta/data contents

N x M → N + M

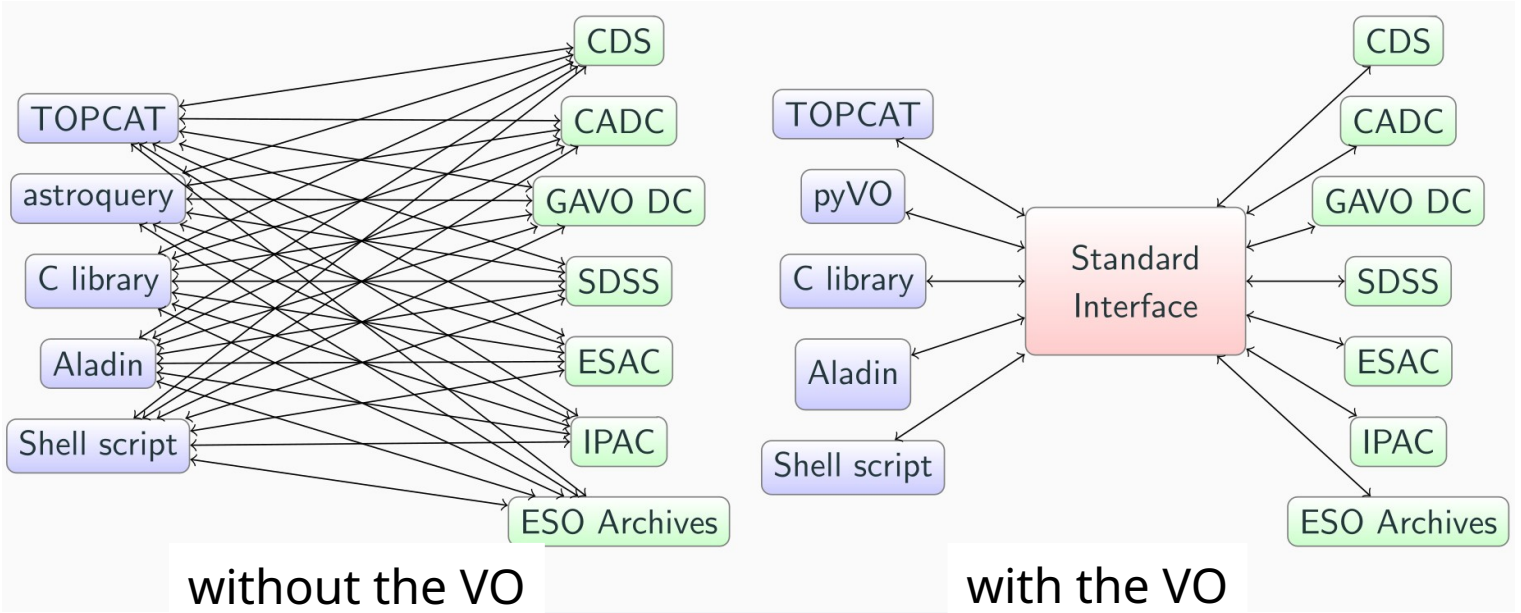
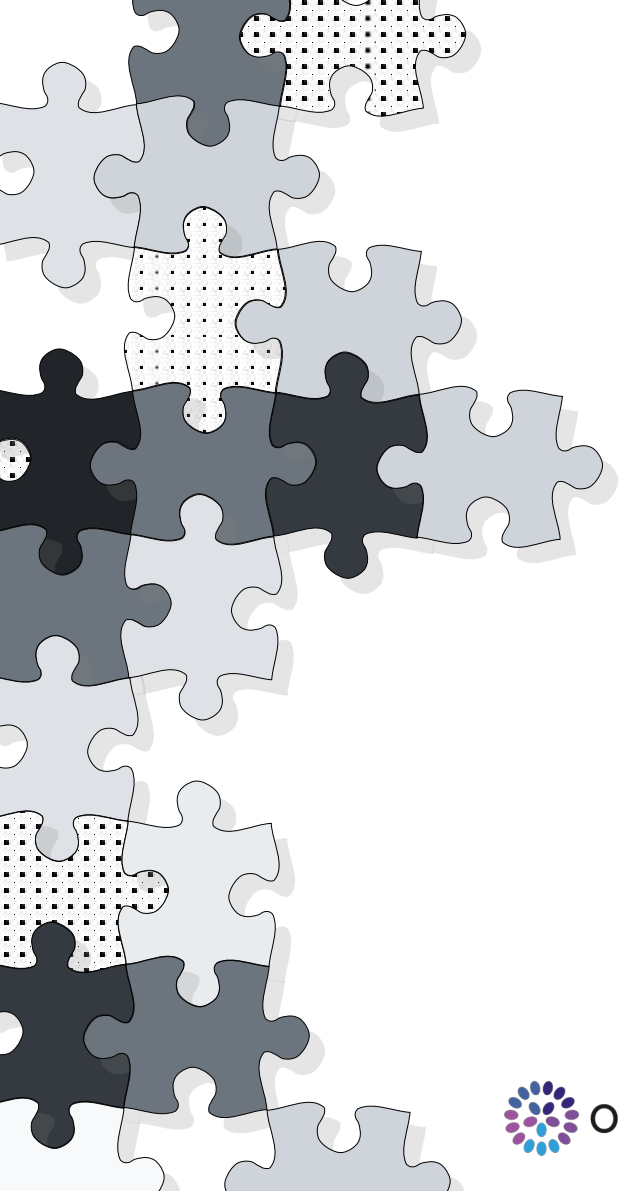


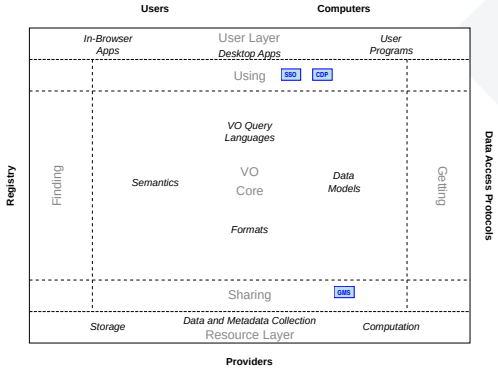
diagram courtesy of M. Demleitner, from
"Sustainability aspects of standards in data infrastructures: the example of the Virtual Observatory"
ErUM-Data Status Meeting: AI as a Driver of Science and Value Creation (2026.03.19, Berlin)

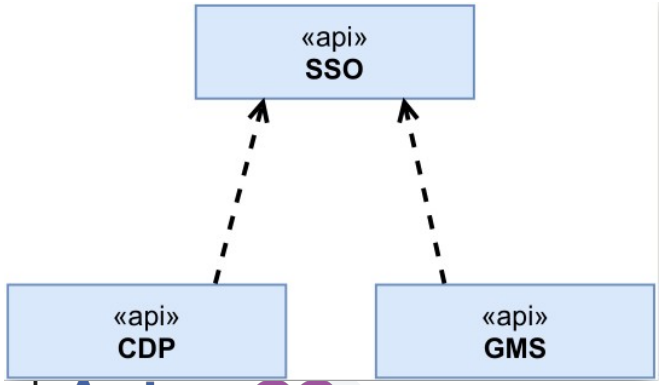


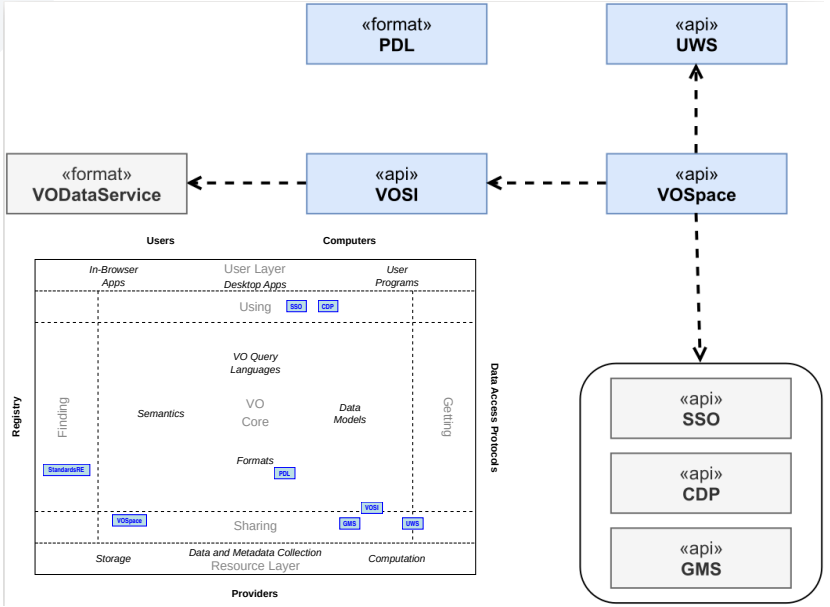
What to do?

> "As a data providers, manager, describe your resources, add them to the Registry, and let the applications connect."

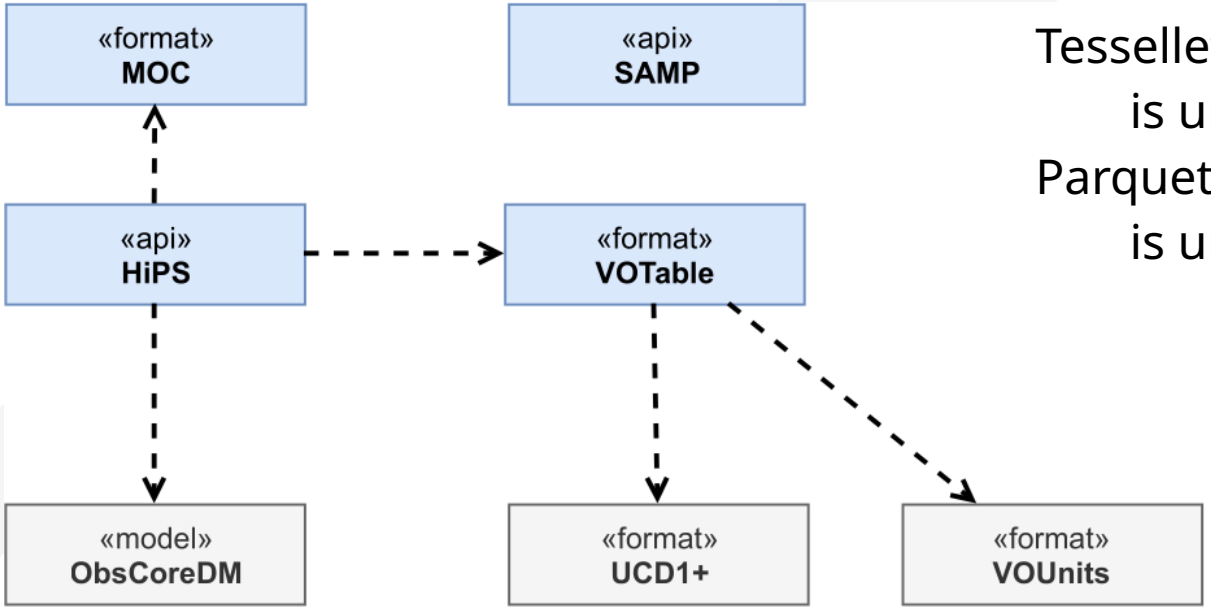
Infrastructure Services





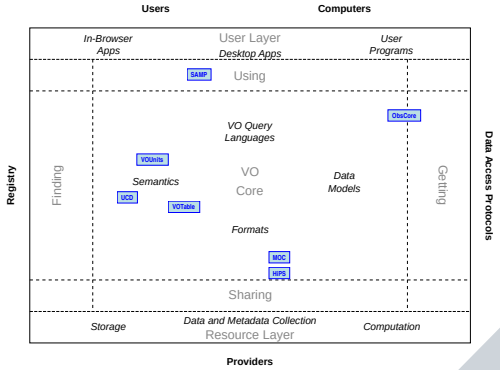


Formats

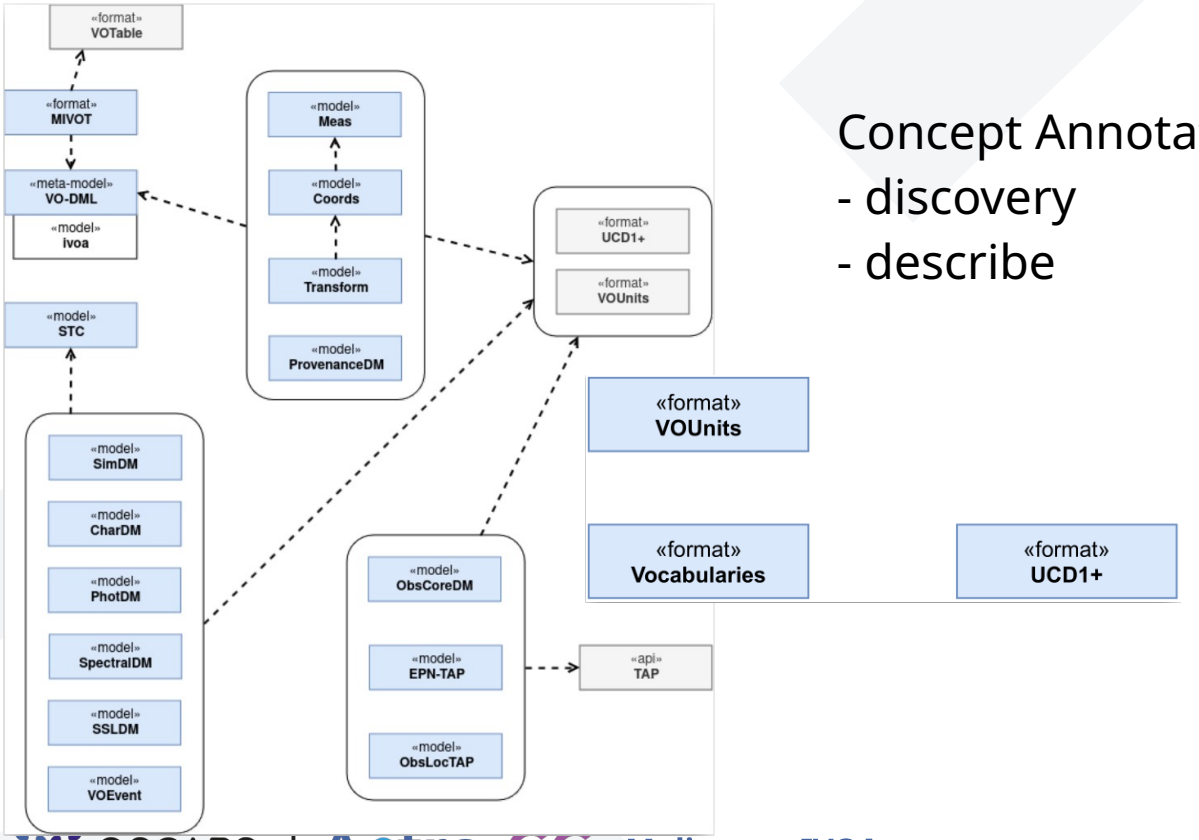


Tesselletion of Catalogues
is under study and usage

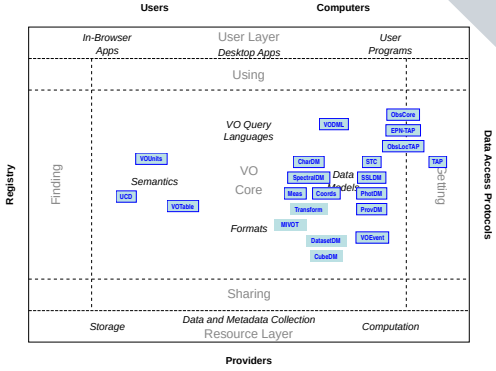
Parquet + VOTable
is undergoing endorsement

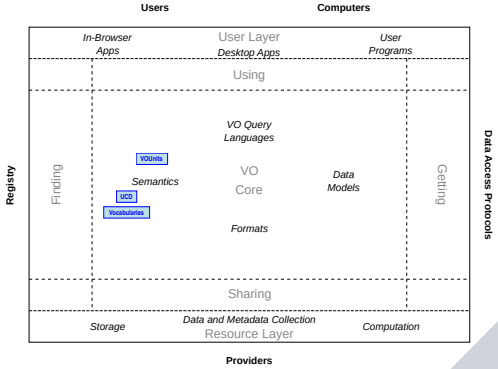


Metadata Schemata & Vocabularies



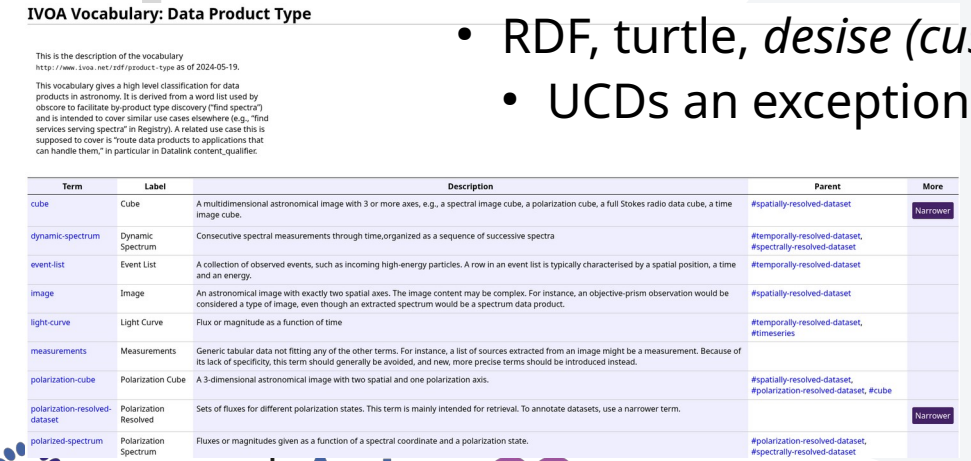
Concept Annotations
- discovery
- describe





Vocabularies

- 14 Vocabularies (ready)
  - Including IAU Thesaurus porting
- 2 more in draft phase
- Efforts to connect to general Semantics/Ontologies
- Available formats
  - RDF, turtle, *desise (custom JSON simplified)*
    - UCDs an exception (working on a solution)



IVOA Vocabulary: Data Product Type

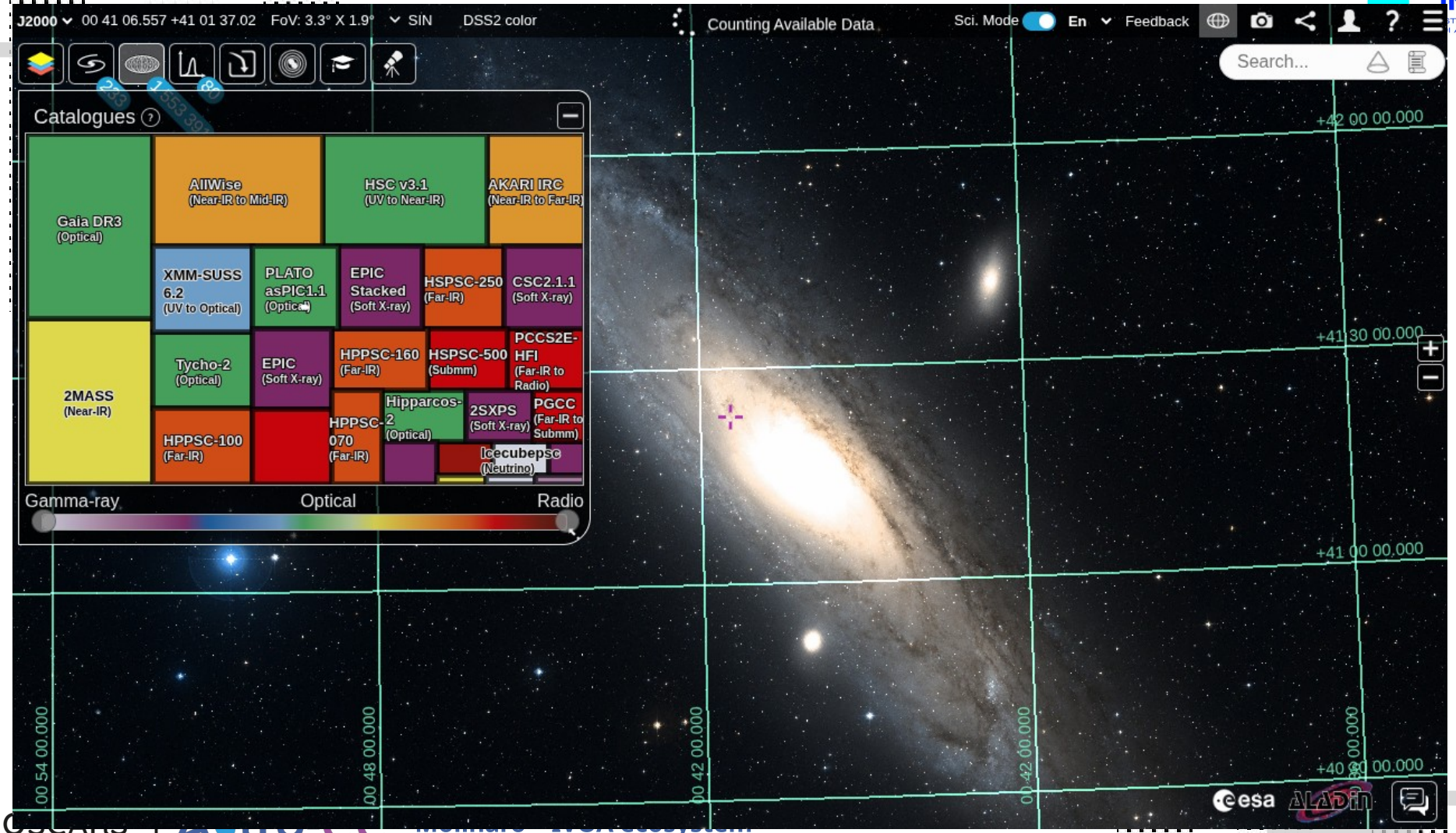
This is the description of the vocabulary `http://www.ivoa.net/rdf/product-type` as of 2024-05-19.

This vocabulary gives a high level classification for data products in astronomy. It is derived from a word list used by obscore to facilitate by-product type discovery ("find spectra") and is intended to cover similar use cases elsewhere (e.g., "find services serving spectra" in Registry). A related use case this is supposed to cover is "route data products to applications that can handle them," in particular in Datalink content_qualifier.

Term	Label	Description	Parent	More
cube	Cube	A multidimensional astronomical image with 3 or more axes, e.g., a spectral image cube, a polarization cube, a full Stokes radio data cube, a time image cube.	#spatially-resolved-dataset	Narrower
dynamic-spectrum	Dynamic Spectrum	Consecutive spectral measurements through time,organized as a sequence of successive spectra	#temporally-resolved-dataset, #spectrally-resolved-dataset	
event-list	Event List	A collection of observed events, such as incoming high-energy particles. A row in an event list is typically characterised by a spatial position, a time and an energy.	#temporally-resolved-dataset	
image	Image	An astronomical image with exactly two spatial axes. The image content may be complex. For instance, an objective-prism observation would be considered a type of image, even though an extracted spectrum would be a spectrum data product.	#spatially-resolved-dataset	
light-curve	Light Curve	Flux or magnitude as a function of time	#temporally-resolved-dataset, #timeseries	
measurements	Measurements	Generic tabular data not fitting any of the other terms. For instance, a list of sources extracted from an image might be a measurement. Because of its lack of specificity, this term should generally be avoided, and new, more precise terms should be introduced instead.		
polarization-cube	Polarization Cube	A 3-dimensional astronomical image with two spatial and one polarization axis.	#spatially-resolved-dataset, #polarization-resolved-dataset, #cube	
polarization-resolved-dataset	Polarization Resolved	Sets of fluxes for different polarization states. This term is mainly intended for retrieval. To annotate datasets, use a narrower term.		Narrower
polarized-spectrum	Polarization Spectrum	Fluxes or magnitudes given as a function of a spectral coordinate and a polarization state.	#polarization-resolved-dataset, #spectrally-resolved-dataset	

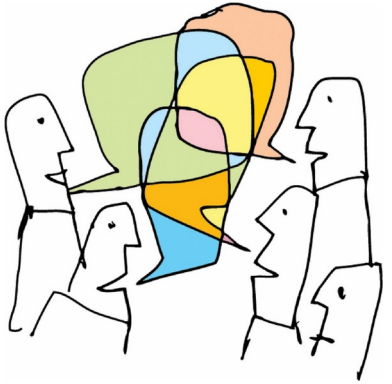
https://www.ivoa.net/rdf/

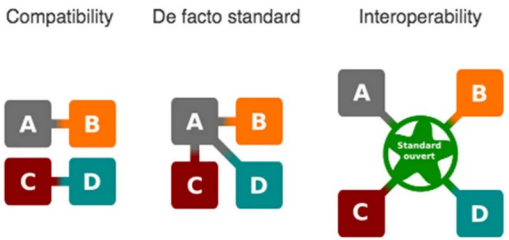

PORTAL
SIMBAD
VIZIER
ALADIN
XMATCH
OTHERS
HELP ?
VizieR
Search Criteria
Preferences
max: 50
HTML Table
All columns
Compute
Mirrors
CDS, France
VizieR home . Photometry viewer . Query VizieR using TAP . X-match tables . Query images/spectra
The VizieR service is now hosted by CDS domain (cds.unistra.fr). Please, modify your configuration for the new domain.
Find catalogs among 26799 available
Clear
Find...
Expand search
Catalog, author's name,
word(s) from title, description, etc.
e.g.: AGN, Veron, I/239, or bibcodes...
Search for catalogs by column descriptions (UCD)
Search for catalogs containing additional data
Wavelength
Radio
Millimeter
IR
optical
UV
EUV
X-ray
Mission
AKARI
ANS
ASCA
BeppoSAX
Cassini-Huygens
CGRO
Chandra
Astronomy
Abundances
Ages
AGN
Associations
Asteroseismology
Atomic_Data
Binaries:cataclysmic
Search by Position across 30413 tables
Target Name (resolved by Sesame) or Position:
Target dimension:
Clear
J2000
2
arcmin
Go!
NB: The epoch used for the query is the original epoch of the table(s)
Radius
Box size
More about VizieR
sort by : popularity
date
Find Catalogs
Tools related to VizieR
Catalogue collection : Search VizieR catalogues available via various services (FTP, VizieR, TAP, ...)
CDS Portal : Access CDS data including VizieR, Simbad and Aladin using the CDS portal
Spectra, images in VizieR : Search Spectra, images in VizieR
Photometry viewer : Plot photometry (sed) including all VizieR
TAP VizieR : query VizieR using ADQL (a SQL extension dedicated for astronomy)
CDS cross-match service : fast cross-identification between any 2 tables, including VizieR catalogues, SIMBAD
→ Cite/acknowledge VizieR catalogue
→ Rules of usage of VizieR data
Contact - Legals


J2000 00 41 06.557 +41 01 37.02 FoV: 3.3° X 1.9° SIN DSS2 color
Counting Available Data
Sci. Mode
En
Feedback
Search...
Catalogues
Gaia DR3 (Optical)
AllWise (Near-IR to Mid-IR)
HSC v3.1 (UV to Near-IR)
AKARI IRC (Near-IR to Far-IR)
XMM-SUSS 6.2 (UV to Optical)
PLATO asPIC1.1 (Optical)
EPIC Stacked (Soft X-ray)
HSPSC-250 (Far-IR)
CSC2.1.1 (Soft X-ray)
2MASS (Near-IR)
Tycho-2 (Optical)
EPIC (Soft X-ray)
HPPSC-160 (Far-IR)
HSPSC-500 (Submm)
PCCS2E-HFI (Far-IR to Radio)
HPPSC-100 (Far-IR)
HPPSC-070 (Far-IR)
Hipparcos-2 (Optical)
2SXPS (Soft X-ray)
PGCC (Far-IR to Submm)
Icecubepsc (Neutrino)
Gamma-ray
Optical
Radio
+42 00 00.000
+41 30 00.000
+41 00 00.000
+40 30 00.000
00 54 00.000
00 48 00.000
00 42 00.000
00 36 00.000

Driven by “open community”

- Open Science <> opposite of bad science
- Digital resources -> leverage FAIR principles
- Principle ≠ Rule/Convention/Norm
- Research domain -> Intrinsic characteristics
- Characteristics -> turn principles into conventions
- Conventions -> Standards
- Research domain :: Community





community shared conventions :: open standards

engage the community

establish agreement on conventions

Domain Granularity

- **Astronomy**
  - IVOA
- **Planetary Sciences**
  - IPDA, IVOA, IHDEA
- **Heliospheric physics**
  - IHDEA
- **Space Weather**
  - E-SWAN, COSPAR

OSCARS | Astro-CC

Astro-CC
European Data Provider Forum
25-27 March 2026 – Heidelberg

If you want to go fast, go alone.
If you want to go far, go together.

the IVOA ecosystem

share, find, access

Thank you for your attention!

Marco Molinaro
[INAF - OATs]
INAF
ISTITUTO NAZIONALE
DI ASTROFISICA