The Virtual Observatory
&
How to access it with Python and PRISM

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V1.0

The Astronomical Virtual Observatory

What it is NOT:

- A website, or a set of websites (they disappear)
- A program (they become obsolete)

What it actually is:

- A **long-term effort**
- ~50 data centers (CDS, ESA, ESO, NASA...) hosting astronomical **archives** in ~20 countries,
- Data Publishers, Curators and Operators for running services and a central infrastructure: the **Registry**
- Editors and writers of **standard protocols** for discovering, accessing, transporting, and using data
- Developers of **client applications** (TOPCAT, Aladin, etc.) using those standards

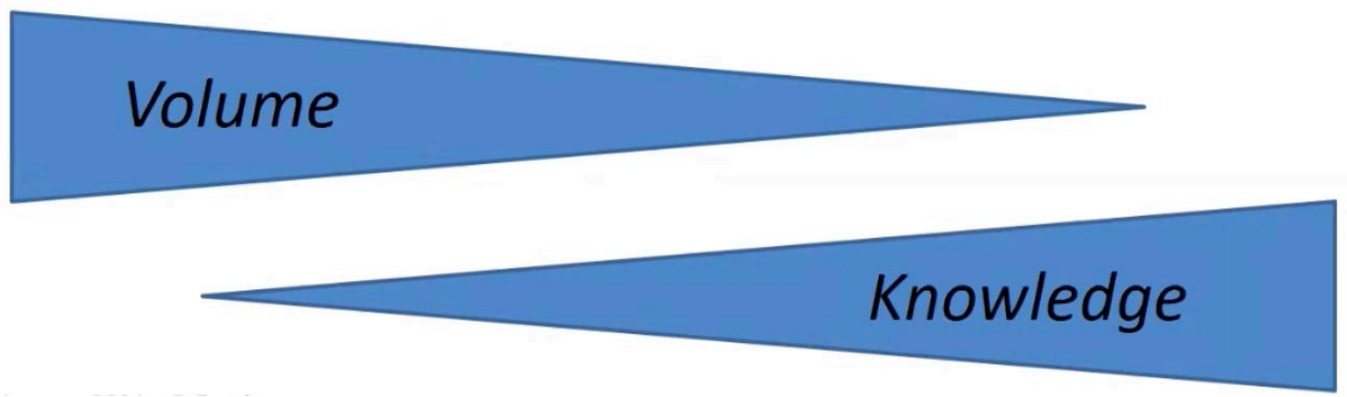
Wikipedia: A virtual observatory (VO) is a collection of interoperating data archives and software tools which utilize the internet to form a scientific research environment in which research programs can be conducted

In much the same way as a real observatory consists of a collection of unique instruments, the VO consists of a collection of data centres each with unique collections of observational data, software systems and processing capabilities.

The main goal is to allow transparent and distributed access to data available worldwide. This allows scientists to discover, access, analyze, and combine observational and laboratory data from heterogeneous data collections in a user-friendly manner.

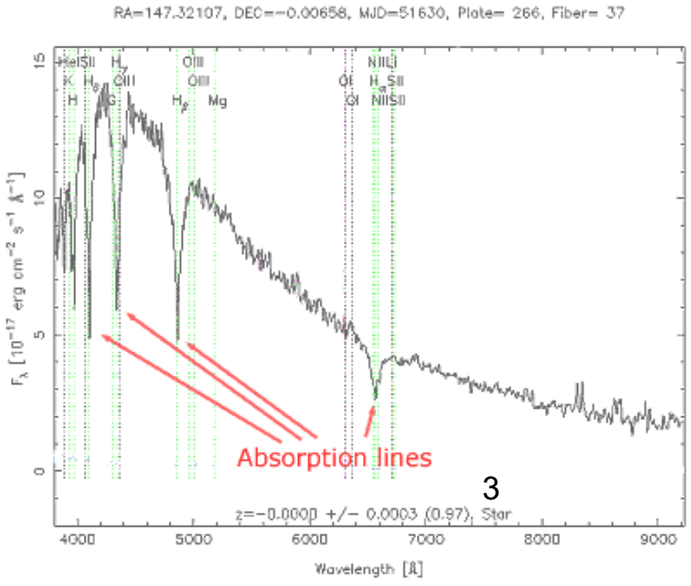
Data in the Virtual Observatory

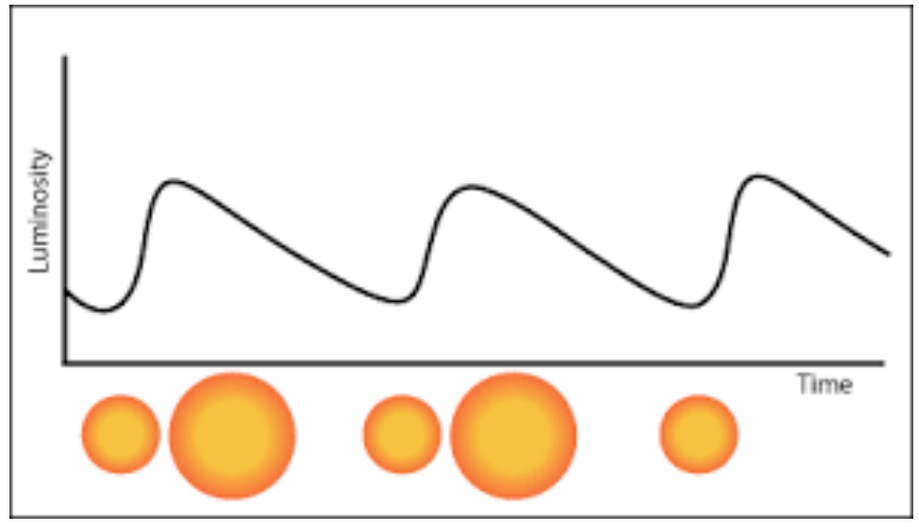
- Images
- Catalogs



Credit: Pierre Fernique, CDS

- Spectra
- Time Series
- Spectral Cubes
- …





The International Virtual Observatory Alliance (IVOA)

What is the IVOA?

- IVOA founded in 2002
- 23 member projects
- Two interoperability meetings per year:
  - “Northern Spring”
  - “Southern Spring” (typically after ADASS)

The Vision of the IVOA

Develop a FAIR data management framework for astronomy

- Interoperability standards (VO framework) amongst astronomical (ground and space based) archives
- Publishing tools for data centres

Enable new science through the VO

- Multi wavelength science, combining datasets from multiple sources
- Data discovery and data access tools
- Data analysis and visualization tools

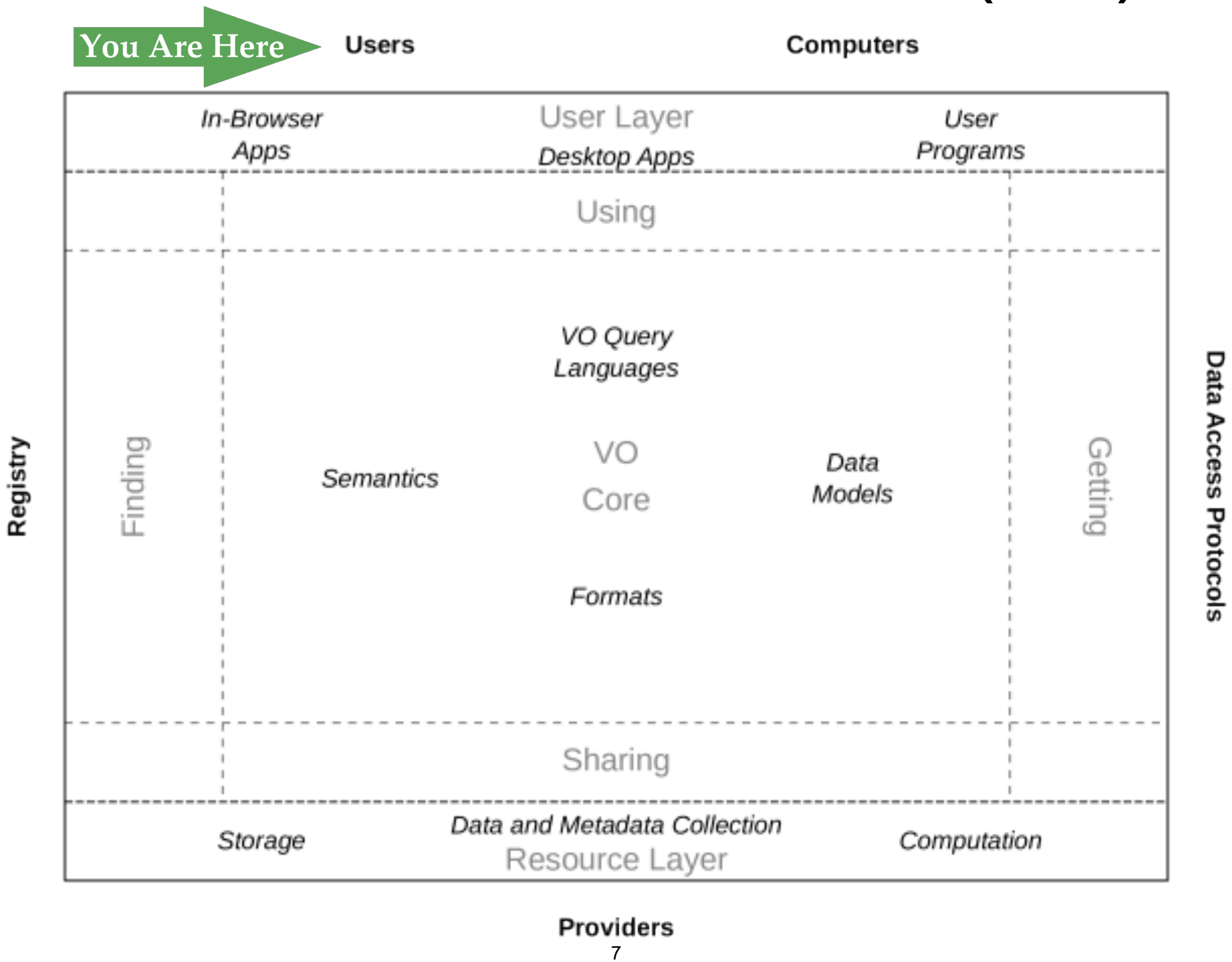
World wide collaboration amongst astronomical VO projects

- No formal funding, nationally funded projects
- Diversity makes IVOA's richness

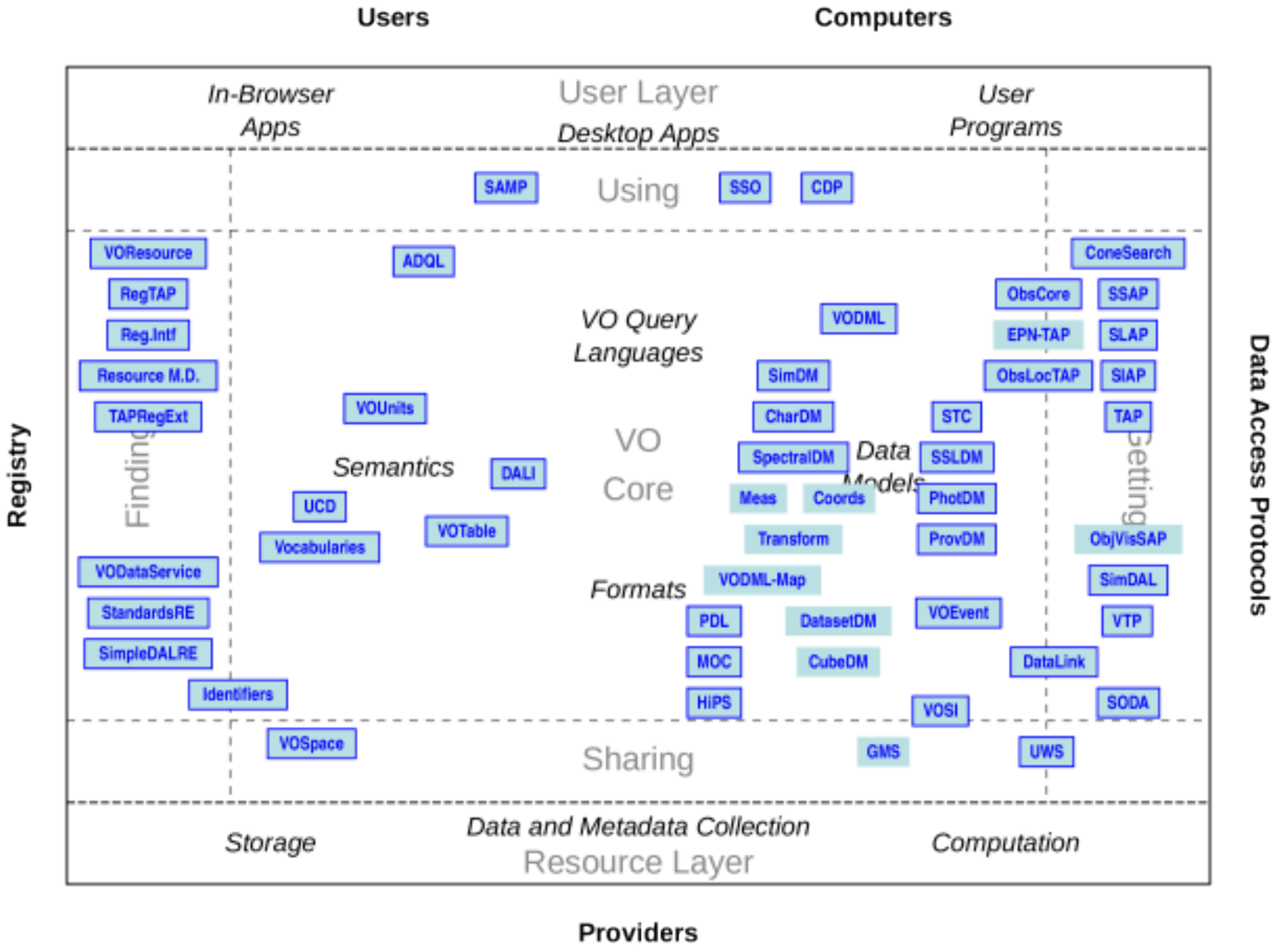
A few high level IVOA Standards

- Standards for designing **applications**
  - **VOTable** the format for exchanging tabular data including rich metadata (coosys, timesys, ucd, utype, VOunits, datalink…) - used by many other standards
  - **HiPS** (Hierarchical Progressive Survery) - tailored for large image data volumes
- Standards describing *web services* to **discover** and **transport** data*:*
  - **VOEvent** for alerts
  - **Simple Cone Search** - spatial and temporal search for catalogs
  - **Simple Image Access**
  - **Simple Spectral Access**
  - **MOC** Multi-Order Coverage map - spatial and temporal indexing for large data volumes
  - **TAP + ADQL** — Table Access Protocol & astronomical data query language
  - **ObsCore & ObsTAP** — description of observations, and upcoming extensions
- **Registry** Standards – to define how to register and discover resources
- Planning of observations: (under dev.)
  - **ObjVisSAP** — visibility of objects
  - **ObsLocTAP** — facilitate coordination of observations from different facilities

The IVOA Architecture (1/2)

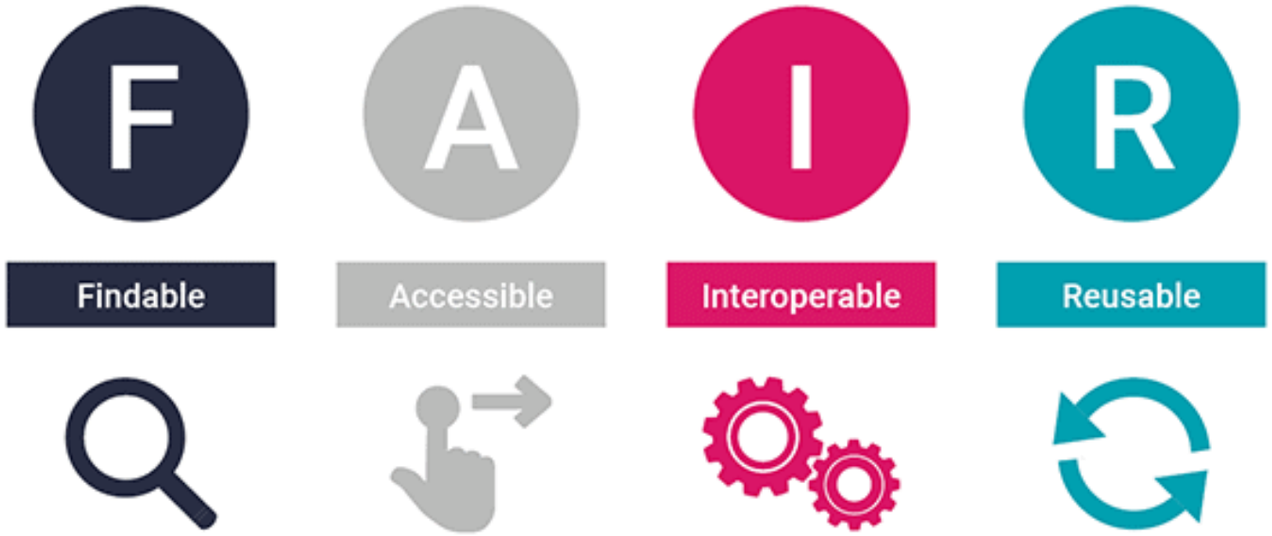


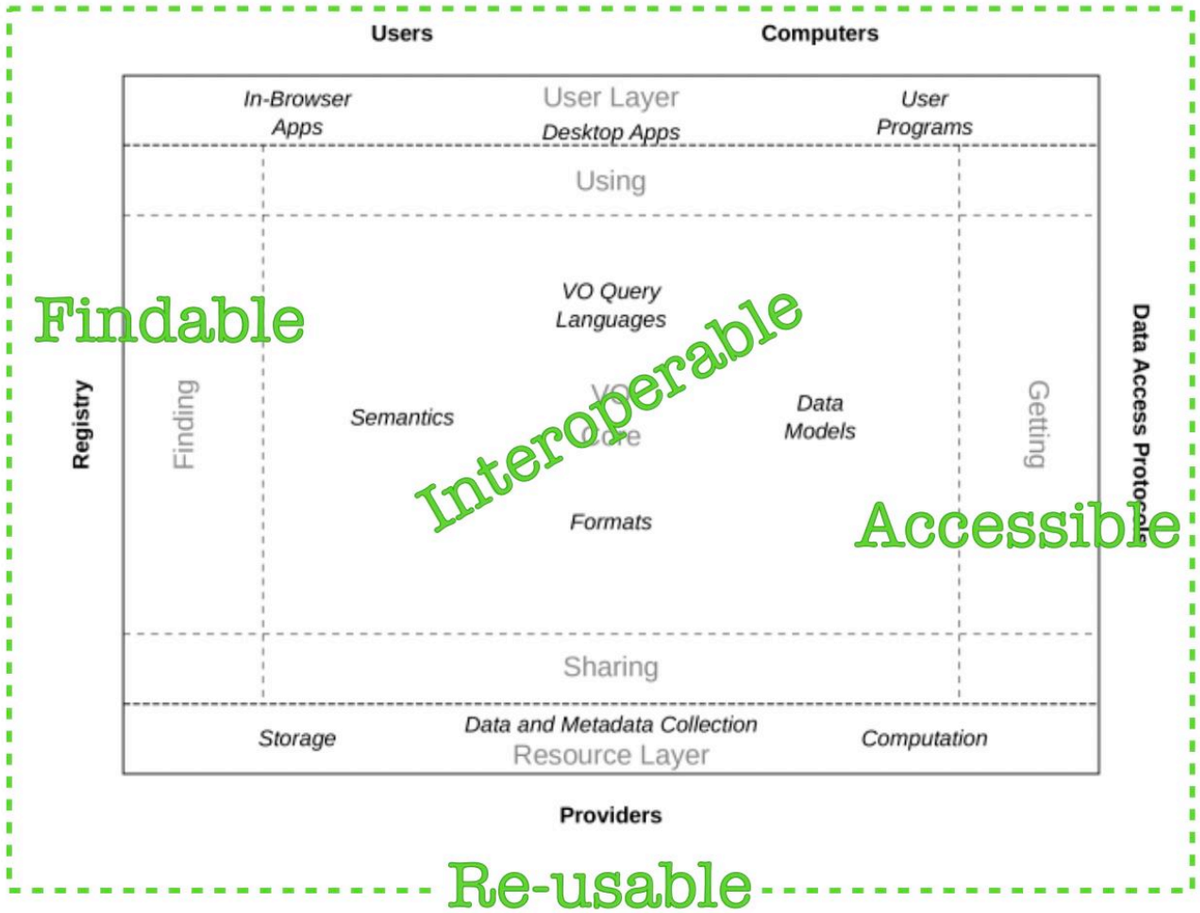
The IVOA Architecture (2/2)



The IVOA Architecture is FAIR

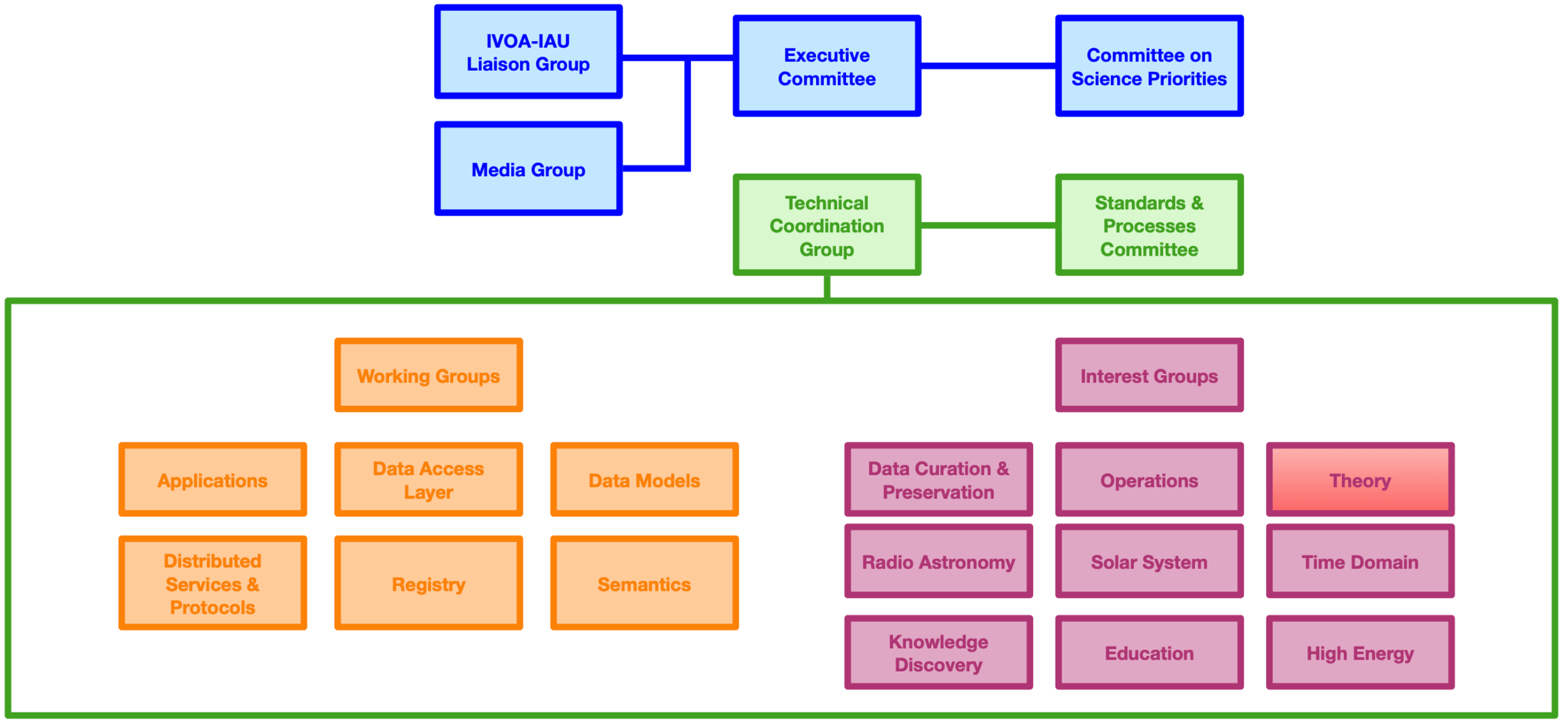
The Virtual Observatory has been FAIR from the beginning!





cf: FAIR standards for astronomical data by Simon O'Toole, James Tocknell 2024ASPC..535..265O

The Organization of the IVOA



Using Python to access the VO

- Use-case
  - Locate VO resources containing data collections related to GRBs using a UAT term
  - Use Simple Cone Search service for these resources to search for objects in an area of the sky
  - Save found objects in CSV and VOTable file for further use

- Demo with PRISM
  - Python console

- Python packages
  - **pyvo (v1.7): VO access**
  - astropy: core package for astronomy
  - astroquery: a set of tools for querying astronomical web services.