

The Virtual Observatory - *enabling interoperability in astronomy*

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What is the Virtual Observatory?

The VO is a paradigm for Supporting interdisciplinary and collaborative research in astronomy and exploiting the full power of growing and emerging data sets

The latest stage of good data practices in astronomy

FITS provided a first standardization, the Virtual Observatory is the natural progression towards interoperability of data, services and tools

The VO is a framework

- For data centers to provide co-operating data services,
- For software providers to offer a variety of compatible analysis and visualization tools and user interfaces



The VO **is not** a Killer Application



Dr. Strange

VO Infrastructure

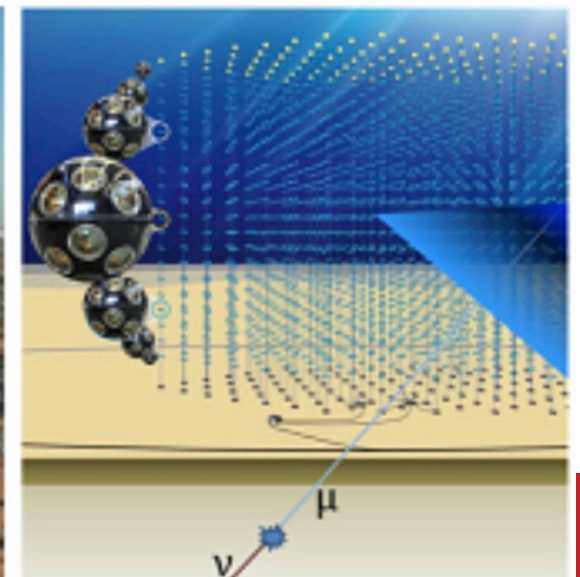
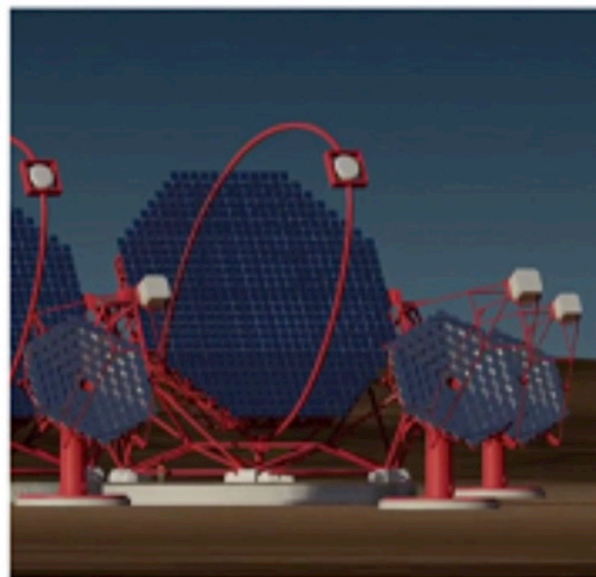
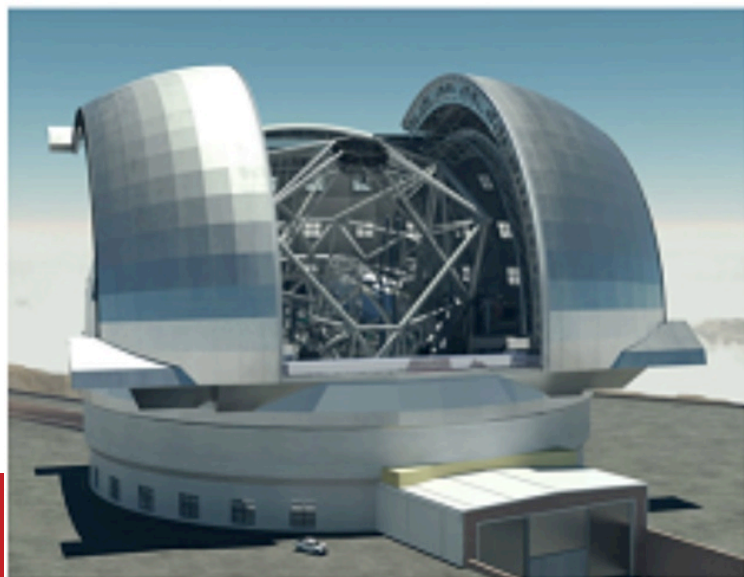
- VO = framework for interoperable access to astronomical data
-  IVOA is an alliance of worldwide VO projects who develop the required standards
- VO enabled tools and services offer new connected scientific capabilities
 - “VO-inside” — implemented in many services

Coordinated by the International Virtual Observatory Alliance - IVOA



ASTERICS

- Research Infrastructure “Cluster” funded by EC Horizon 2020 framework (2015-2019)
 - To help solve the **Big Data** challenges of European multi-messenger astronomy
 - Enabling ESFRI instruments in the VO framework (WP4)... follow on from **EURO** 



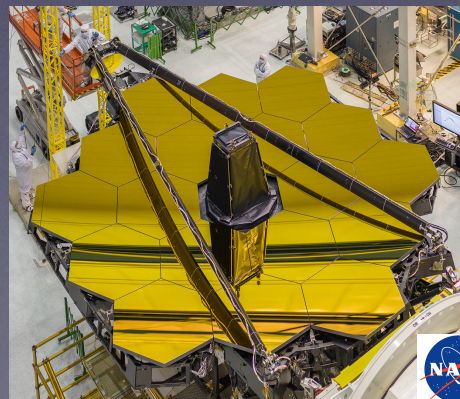
LST



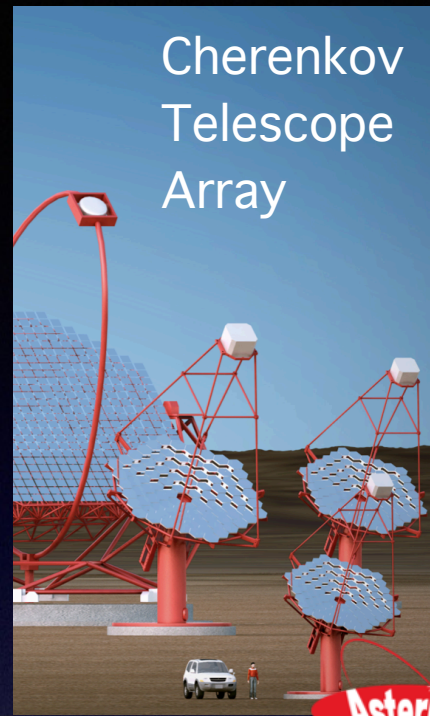
Large Synoptic Survey



Five-hundred-meter Aperture Spherical Telescope (FAST)



JWST



Cherenkov Telescope Array



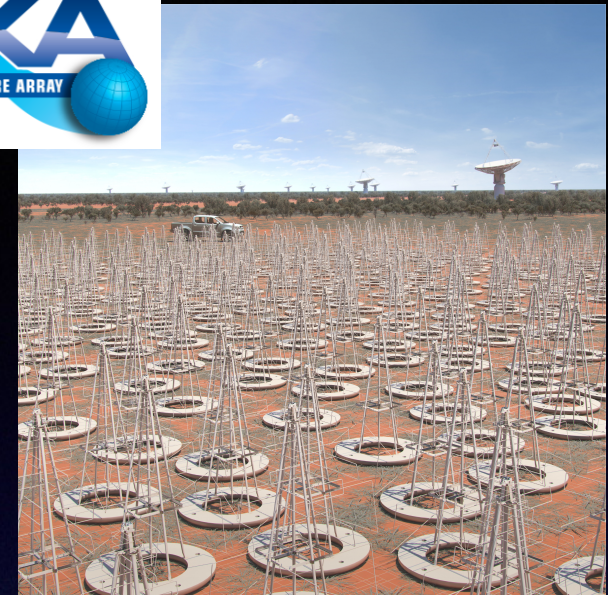
FOCUS SESSION participation 2016



Gaia & Euclid



Square Kilometre Array



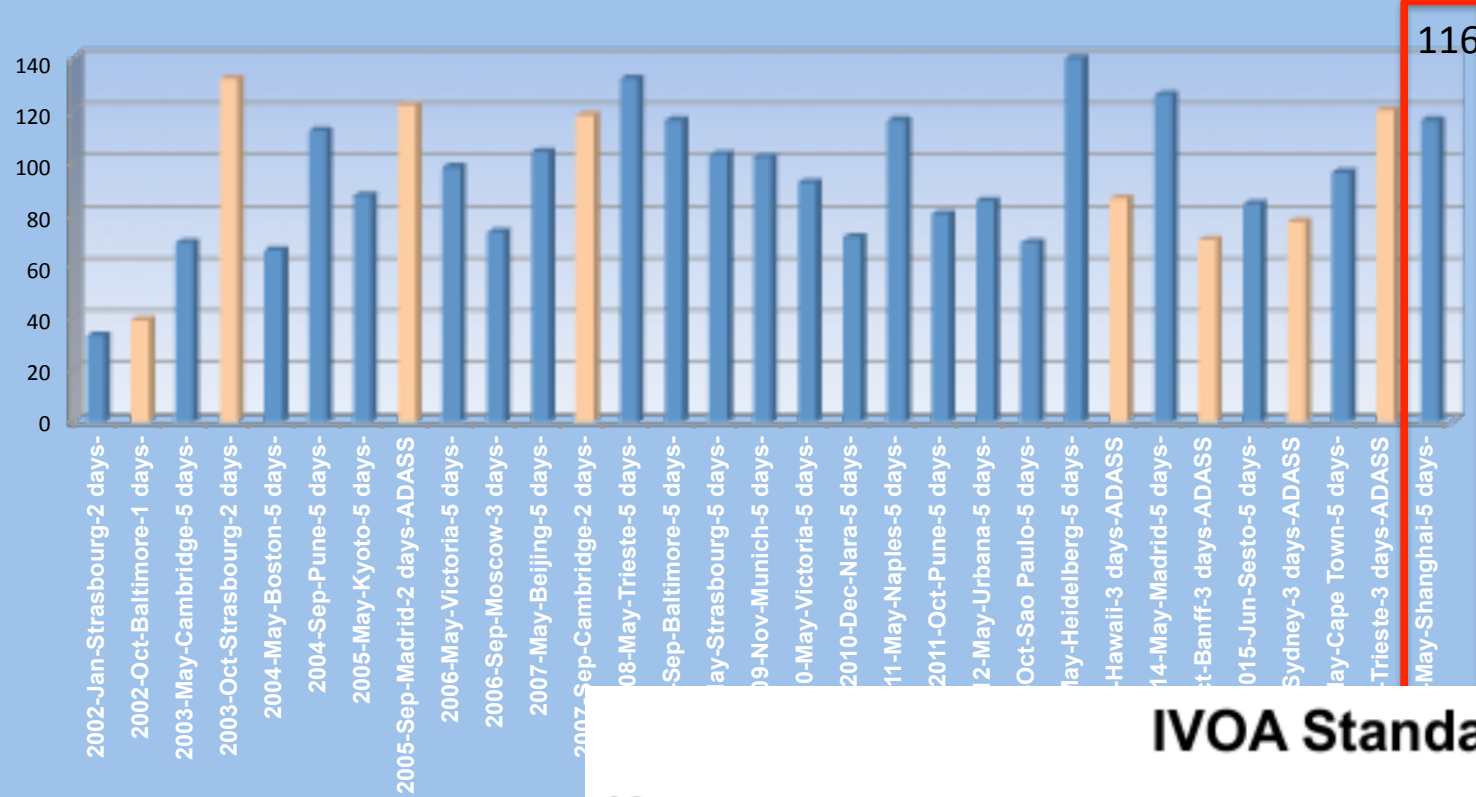
ASKAP



European Gravitational Observatory, EGO/VIRGO



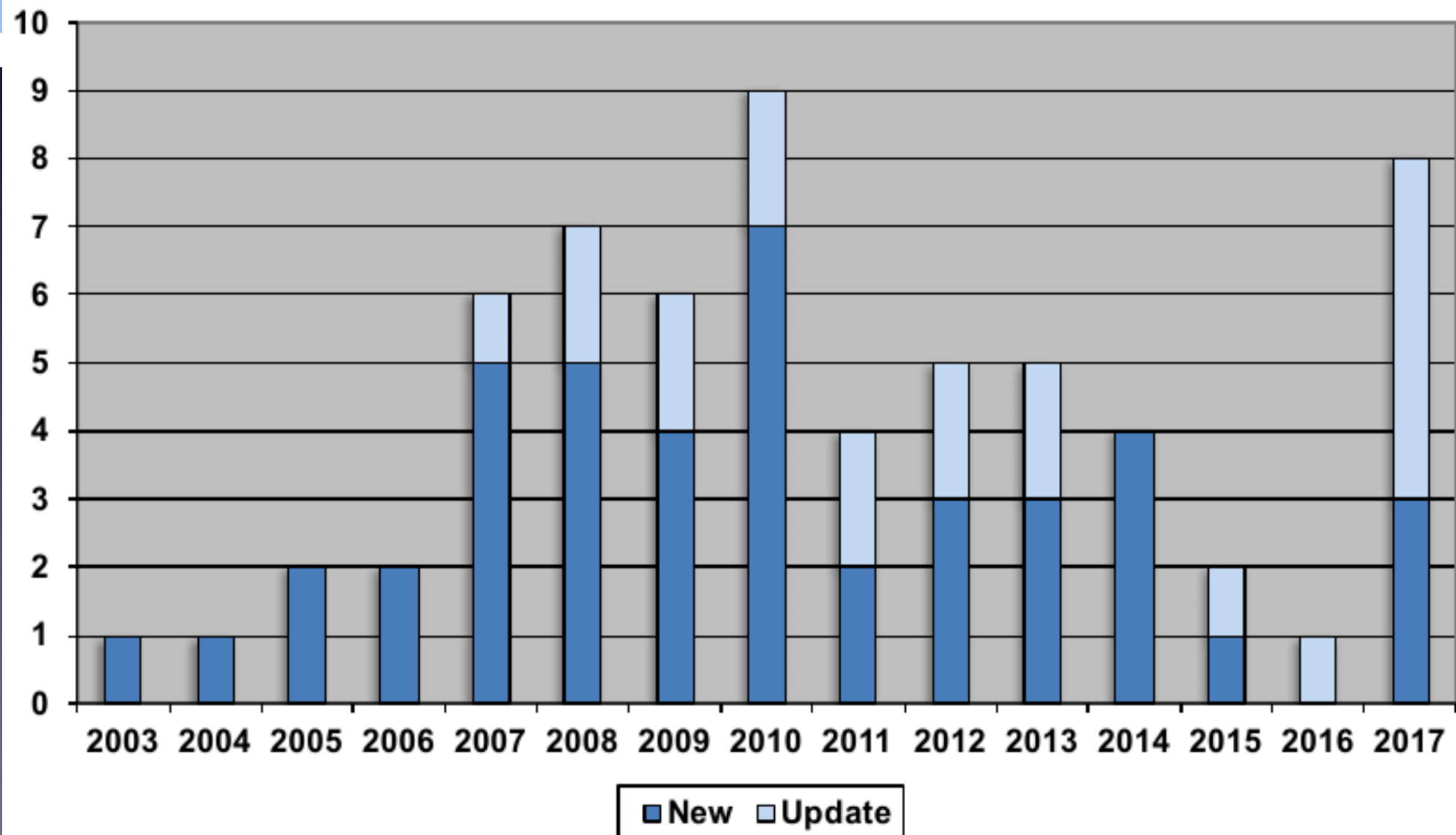
Number of Participants per IVOA Interoperability Meeting



Shanghai - 5/15/17

IVOA and Euro-VO
community working
for you!

IVOA Standards Recommended per Year



Status - *in operation*

- Core standards established
- Successes:
 - International collaboration and sharing of tools and infrastructure
 - Stable architecture
 - Important data sets available by VO
 - Integrated into infrastructure planning: Euclid, Gaia, CTA +
- Being used for science in many different ways - *see next talk by E. Solano*



Science Priority Areas

Multi-dimensional Data

Radio astronomy, Integral Field Spectroscopy, high energy, polarization, simulation, data mining datasets + ...

Recent milestone: Standards for access to data-cubes

Time Domain Astronomy

Time Series, light curves, transient event reports, +...

Realities

- Hard lessons learned about development and management of standards
- IVOA member projects have come and gone, some have persisted, some not...
- Seamless “VO-inside” can mean that VO is invisible

IVOA has survived because VO is a good idea

Working Groups:

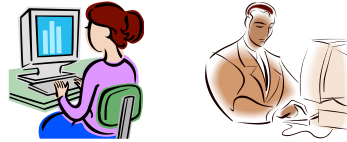
**Completely open
- please join**

- Applications (*VO software*)
- Data Access Layer (*distributed data access*)
- Data Modelling (*data characterization*)
- Grid and Web Services
- Resource Registry (*VO resources 'yellow pages'*)
- Semantics (*meanings*)

Interest Groups: Operations, Theory, Data Curation and Preservation, Data Mining, Education (EduIG), Time Domain, Solar System

LEVEL 0

USERS



COMPUTERS

USER LAYER

USING

FINDING

VO
CORE

GETTING

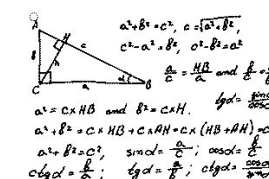
SHARING

RESOURCE LAYER

20101004
IVOA Architecture



PROVIDERS

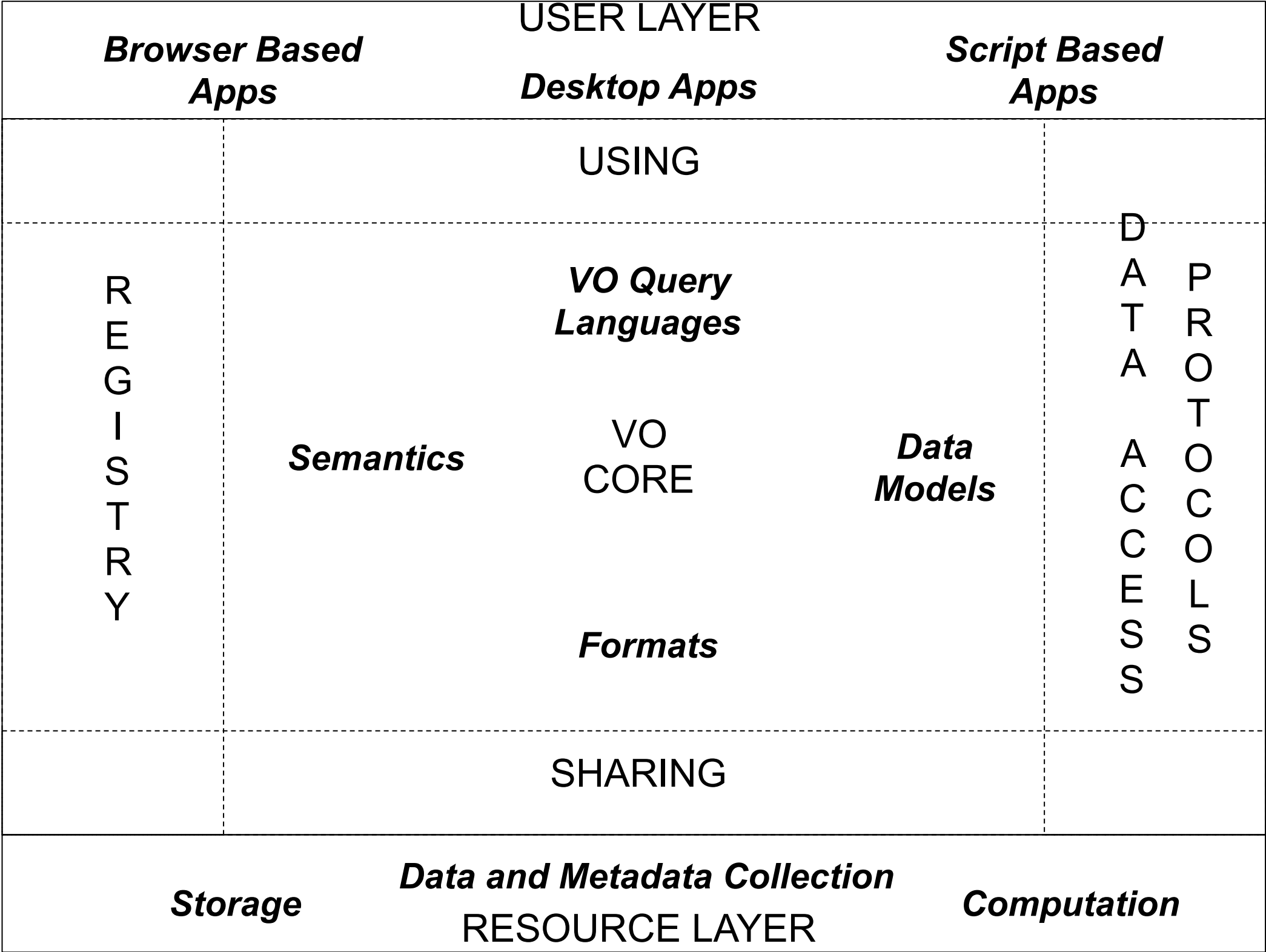


LEVEL 1

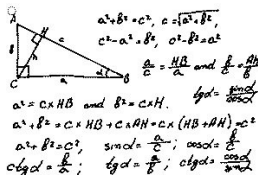
USERS



COMPUTERS



PROVIDERS



LEVEL 2
All standards



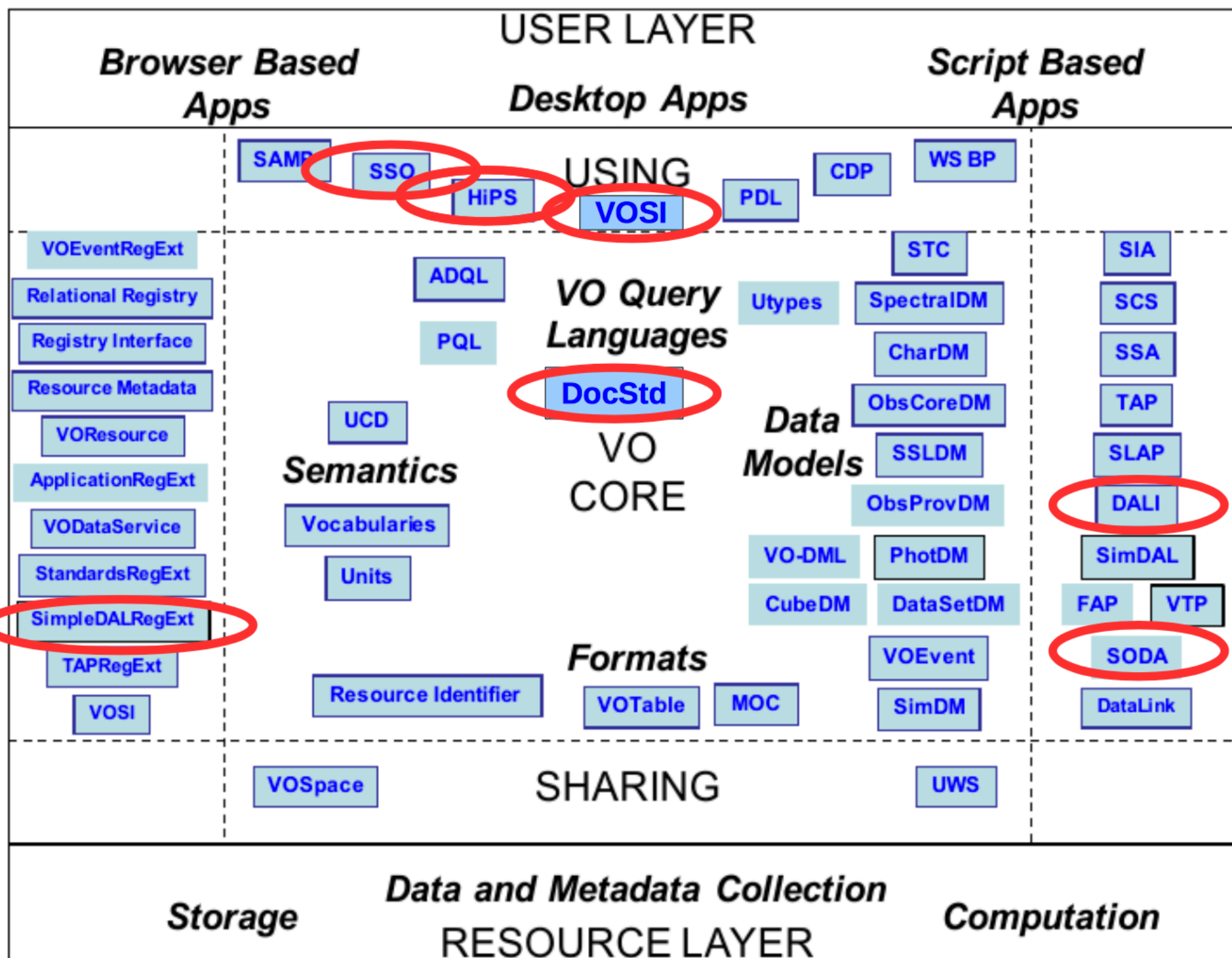
COMPUTERS

REC

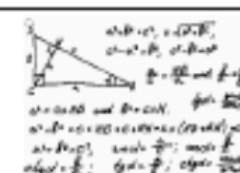
InProgress

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PROVIDERS



IVOA Document Standards Process



Specifications

	Title	Most stable	In progress	
	Application Messaging Protocol	1.3		1.3 1.3 1.3 1.3 1.3 1.2 1.2 1.2 1.11 1.11 1.11
	Access Layer Interface	1.0		1.0
	Cone Search	1.03		1.03 1.02 1.01 1.00
	Image Access	1.0		1.0 1.0 1.0 1.01 1.00
	Line Access	1.0		1.0 1.0 1.0 1.0 1.0
	Spectral Access	1.1		1.1 1.1 1.1 1.1 1.04 1.03 1.02 1.01 1.01 1.00
	Access Protocol	1.0		1.0 1.0 1.0 1.0 1.0 1.00
	agExt: a VOResource Schema Extension for Describing TAP Services	1.0	[RFC]	1.0 1.0 1.0 1.0 1.0 1.0
	Astronomical Data Query Language	2.00		2.00 2.00 2.00 1.01 1.00
	SkyNode Interface	1.01		1.01 1.00
	Photometry DM	1.0	[RFC]	1.0 1.0 1.0 1.0 1.0
	Simulation Data Model	1.0		1.0 1.0 1.0 1.0 1.0 1.0
	Space-Time Coordinate Metadata for the Virtual Observatory (STC)	1.33		1.33 1.31 1.30 1.21 1.20 1.10 1.00
	Data Model for Astronomical DataSet Characterisation	1.13		1.13 1.12 1.12 1.11 1.10 1.00
	Simple Spectral Lines Data Model	1.0		1.0 1.0 1.0 1.0 1.0
	IVOA Spectrum Data Model	1.1		1.1 1.1 1.1 1.03 1.02 1.01 1.01 1.01 1.00
	Observation Data Model Core Components and its Implementation in the Table Access Protocol	1.0		1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
	Parameter Description Language		[0.1]	[0.1]
	IVOA Single-Sign-On Profile: Authentication Mechanisms	1.01		1.01 1.01 1.00 1.00
	VOSpace service specification	1.15	[RFC]	2.0 2.0 2.0 2.0 2.0 2.0 1.15 2.0 1.15 1.15 1.14 1.13 1.12 1.12
	IVOA Credential Delegation Protocol	1.0		1.0 1.0 1.01 1.01 1.00
	Universal Worker Service	1.0		1.0 1.0 1.0 1.0 1.0 1.0
	IVOA Support Interfaces	1.0		1.0 1.0 1.0 1.0 1.0 1.0
	IVOA Web Service Basic Profile	1.0		1.0 1.0 1.0 1.0 1.0
	Describing Simple Data Access Services	1.0	1.0	1.0
	IVOA Identifiers	1.12		1.12 1.11 1.10 1.10 1.10 1.00
	IVOA Registry Interfaces	1.0		1.0 1.0 1.00 1.02 1.01 1.00
	Resource Metadata for the Virtual Observatory	1.12		1.12 1.12 1.10 1.10 1.01 1.01 1.00 1.00
	StandardsRegExt: a VOResource Schema Extension for Describing IVOA Standards	1.0		1.0 1.0 1.0 1.0 1.0 1.0
	SimpleDALRegExt: Describing Simple Data Access Services	1.0	[RFC]	1.0 1.0
	VOResource: an XML Encoding Schema for Resource Metadata	1.03		1.03 1.02 1.02 1.01 1.00
	VODataService: a VOResource Schema Extension for Describing Collections and Services	1.1		1.1 1.1 1.1 1.1 1.1 1.10
	Units in the VO	1.0	[RFC]	1.0 1.0 1.0
	An IVOA standard for Unified Content Descriptors	1.10		1.10 1.10 1.06 1.05 1.03
	UCD1+ Controlled Vocabulary	1.23		1.23 1.22 1.21 1.20 1.20 1.11 1.11 1.10 1.02 1.00
	Maintenance of the list of UCD words	1.20		1.20 1.20 1.10 1.00
	Vocabularies in the Virtual Observatory	1.19		1.19 1.18 1.16 1.15 1.13 1.00
	SDP	1.2		1.2 1.2 1.2 1.2 1.2 1.1 1.1 1.0 1.0
	VOE	2.0		2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 1.11 1.11 1.10 1.01
	VOT	1.2		1.2 1.2 1.2 1.20 1.20 1.10 1.00

Maturity level: ■ Recommendation ■ Proposed Recommendation ■ Working Draft

Most stable: New systems should be developed against this version with the highest maturity level.

In progress: Indicates (if any) a new version of the document under development (but with a lower maturity level than its predecessor) and a link to the relevant Request For Comments (RFC).

arXiv.org



CDS services



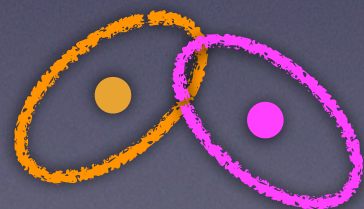
Astronomical Objects :



Catalogue Service :



Visualisation and integration :



X-Match :



Portal :



CDS services



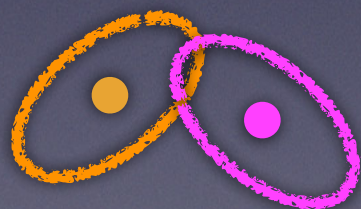
Astronomical Objects :



Catalogue Service :



Visualisation and integration



X-Match :



Portal :

Registry Interface
Resource Identifier

TAP

VOTable

UCD

Resource Metadata

DataLink

SIAPv2

HiPS

SAMP

SCS

SODA

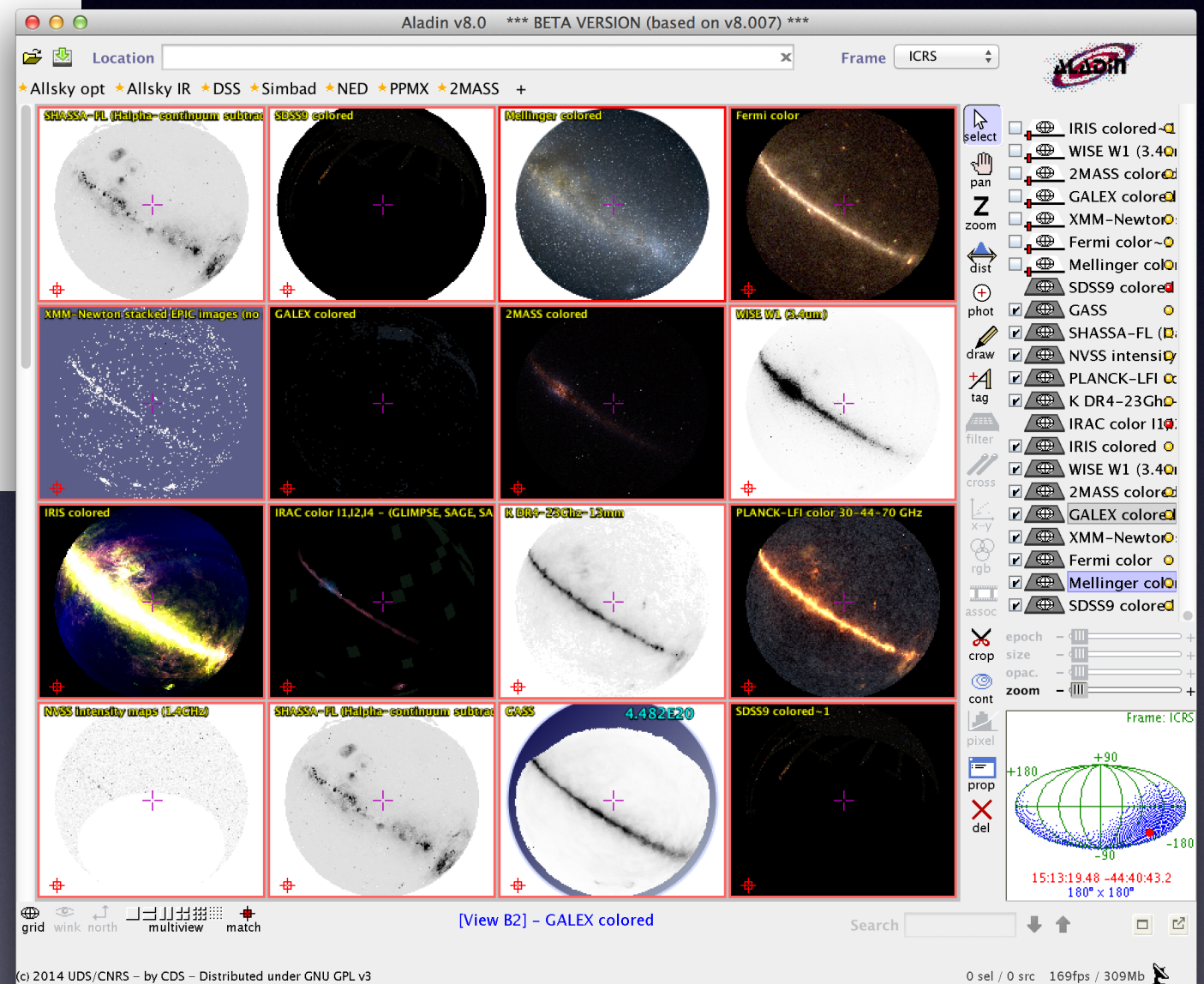
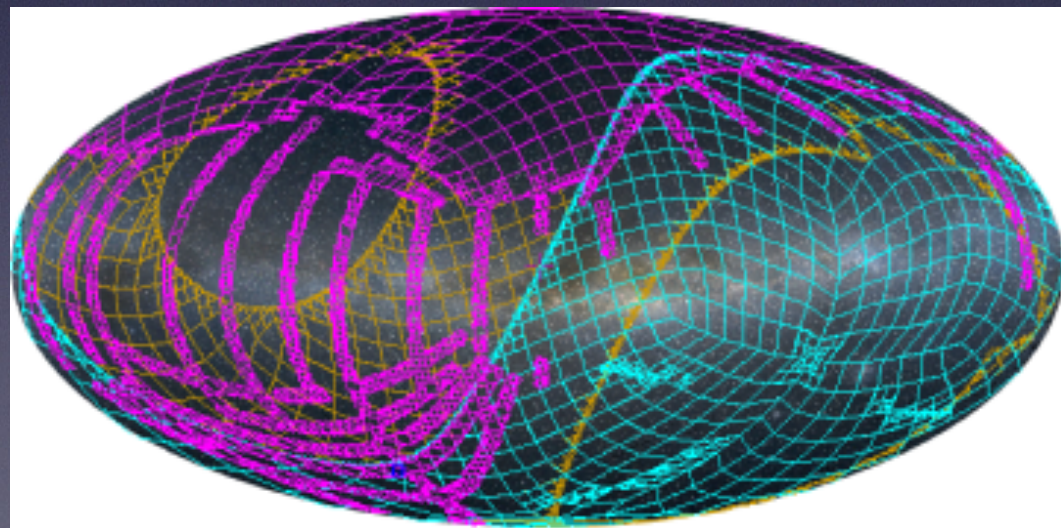
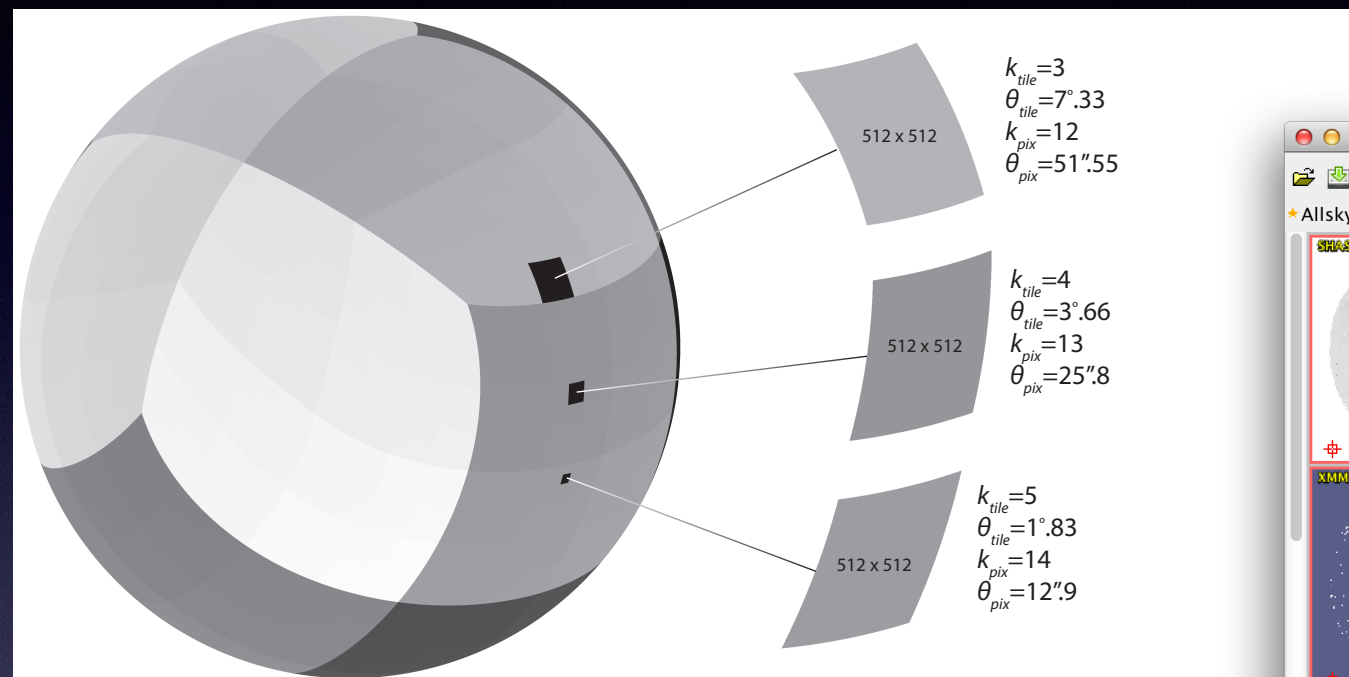
UWS

SAMP

VOTable

ObsCoreDM

All-sky approach - IVOA HiPS standard



HiPS network - ~250 surveys



version 10 prototype

Aladin v9.6 *** PROTOTYPE VERSION (based on v9.621) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Data access Location Frame Projection

☒ DSS
 ☒ SDSS
 ☒ 2MASS
 ☒ WISE
 ☒ GALEX
 ☒ PLANCK
 ☒ AKARI
 ☒ XMM
 ☒ Fermi
 ☒ Gaia
 ☒ Simbad
 ☒ NED
 +

CDS/P/DSS2/color

★ New HIPS

SIMBAD Astronomical Database [\(more...\)](#)

Provenance: CNRS/Unistra

Sky coverage: 19.06% Pub. year: 2000

☐ HIPS
 ☒ Cone search
 ☐ MOC search
 ☐ Xmatch
 ☐ TAP
 +
 ☐ Coverage

[CDS/Simbad \(more...\)](#)

data in view

Collections → 19589
 Image → 301
 Data base → 2
 SIMBAD Astronomical Database
 The NASA/IPAC Extragalactic Database
 Catalog → 17184
 I-Astrometric Data → 254
 Gaia DR1 (Gaia Collaboration)
 GaiaSource data
 TGAS: Subset of Gaia DR1
 Cepheid stars identification
 Auxiliary Quasar Solution
 RR Lyrae stars identification
 TGAS supplement with Hipparcos
 The USNO-B1.0 Catalogue
 UCAC4 Catalogue
 NOMAD Catalogue
 The PPMXL Catalogue
 The USNO-A2.0 Catalogue
 The Tycho-2 Catalogue (Høg et al.)
 The Guide Star Catalog, Version 2.2
 The Initial Gaia Source List
 The GSC 2.2 Catalogue
 XPM Catalog of positions and motions
 The Hipparcos and Tycho Catalogues
 The HST Guide Star Catalogue
 PPMX Catalog of positions and motions
 All-sky Compiled Catalogue of Stars
 UCAC2 Catalogue
 SAO Star Catalog J2000 (Stern et al.)
 Hipparcos, the New Reduction
 Tycho Input Catalogue, Revised
 The AC 2000.2 Catalogue
 The ACT Reference Catalogue
 The Tycho Reference Catalogue
 URAT1 Catalog (Zacharias et al.)

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Mouse controls:
 • Left: source selection.
 • Middle: quick panning.
 • Right: contrast adjustment.
 • Wheel: quick zoom on the reticle.
 • Simple-click: move the reticle.
 • Double-click: re-center.
 Let you mouse pointer on an object for discovering associated Simbad data.

Filter0
 CDS/IR337/gaia
☒ CDS/P/DSS2/color

J2000 - +
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 20:46:37.76 +30:34:07.6
 56.95' x 55.39'

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0 sel / 14135 src 111fps / 391Mb

Aladin Lite API example

AAS225 demonstration

[Aladin Lite](#) / [Documentation](#) / [API](#) / [Examples](#) / AAS225 demonstration

SDSS DR9 band r image of APG 240 pair of galaxies, with an overlaid HST image and a WFPC2 footprint.

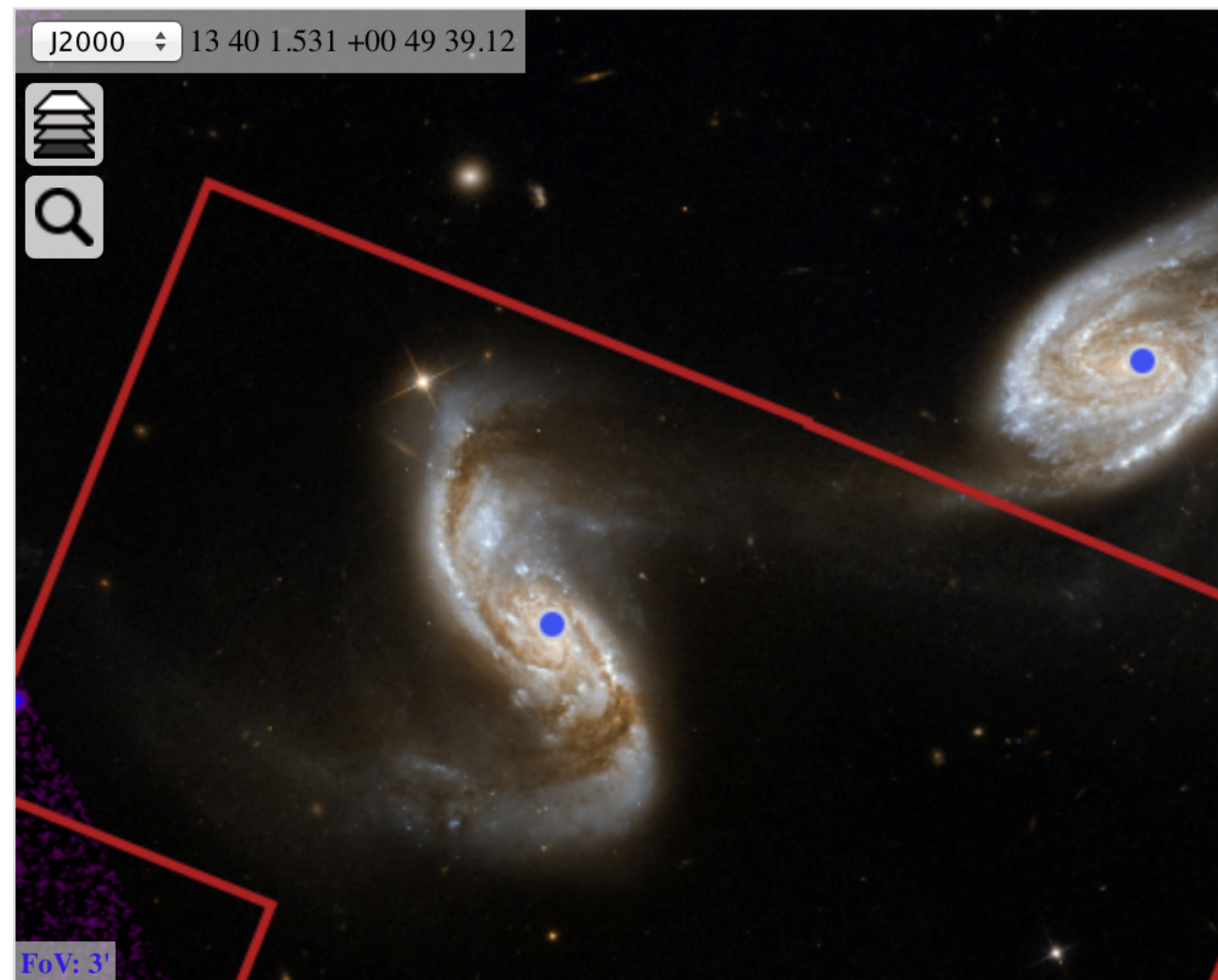
Javascript

```
var aladin = A.aladin('#aladin-lite-div', {fov:0.15, tar
aladin.setBaseImageLayer(aladin.createImageSurvey('SDSS-
aladin.getBaseImageLayer().getColorMap().update('rainbow
var simbad = A.catalog({name: 'Simbad', sourceSize: 16,
aladin.addCatalog(simbad);
simbad.addSources([A.marker(204.97010833333336, 0.840016

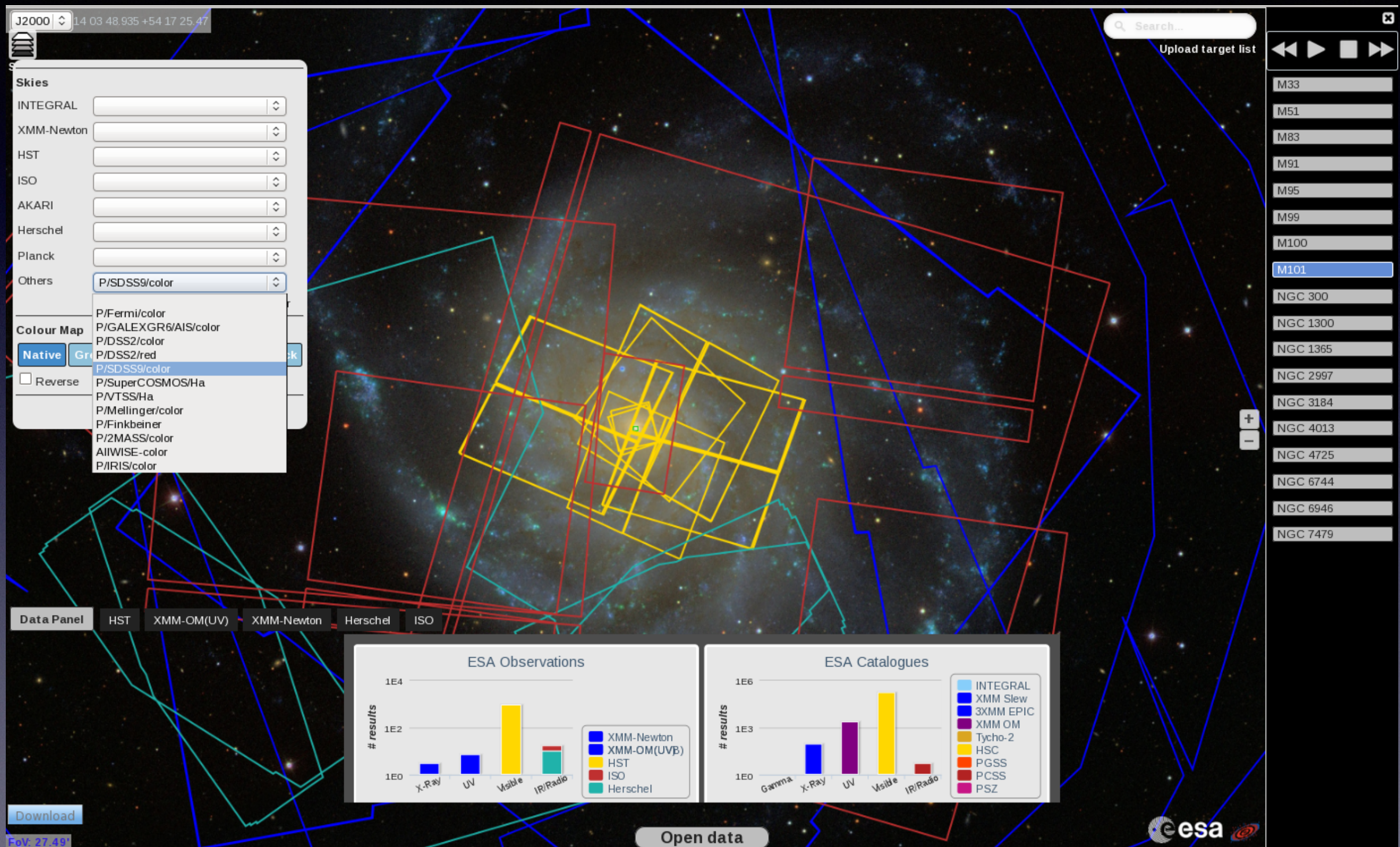
var overlay = A.graphicOverlay({color: '#aa2222', lineW
aladin.addOverlay(overlay);

overlay.addFootprints(A.polygon([[204.970214, 0.81206],
aladin.displayJPG('http://images.ipac.caltech.edu/stsci/
```

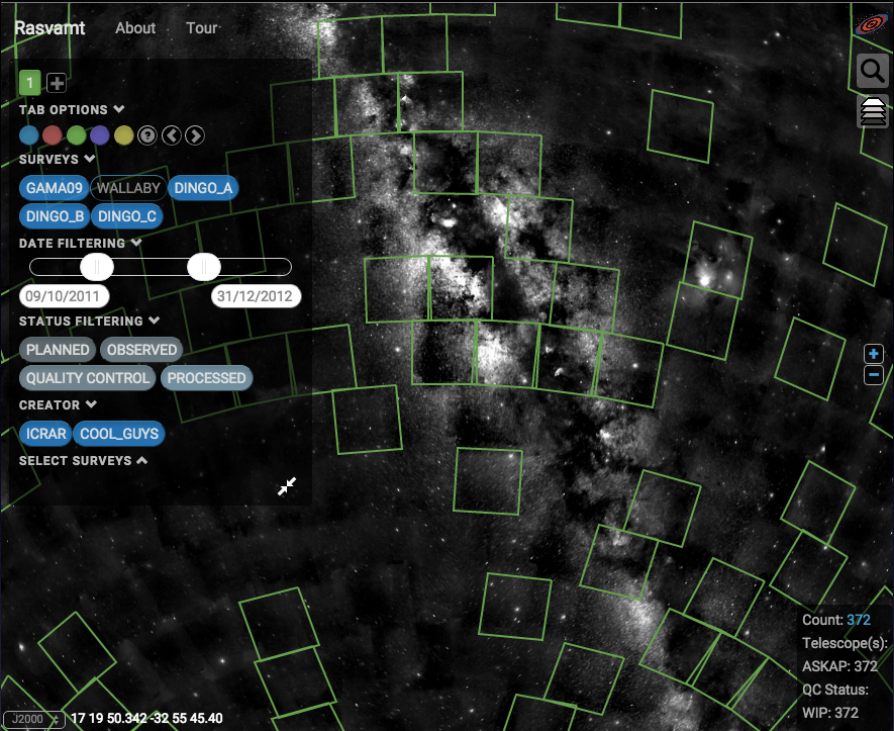
Result



ESASky archive interface - built on Aladin Lite



Radio Astronomy Survey Visualisation Monitoring Tool (ICRAR)



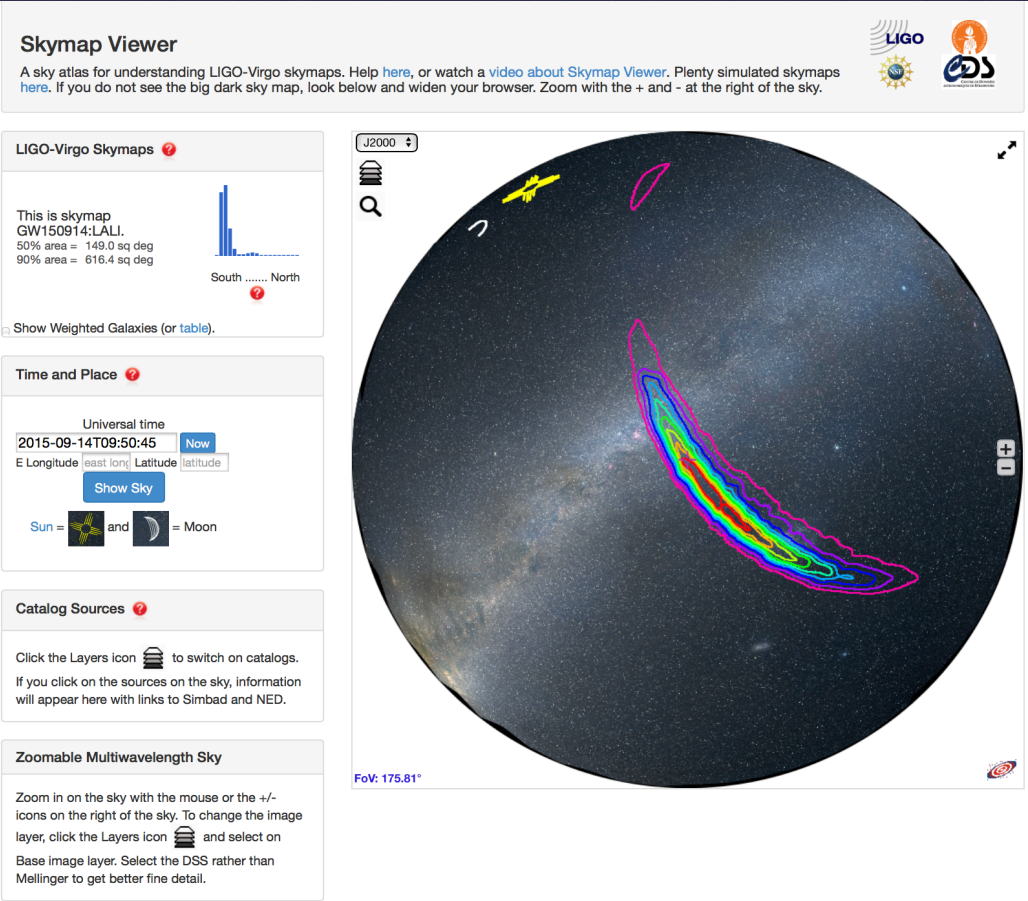
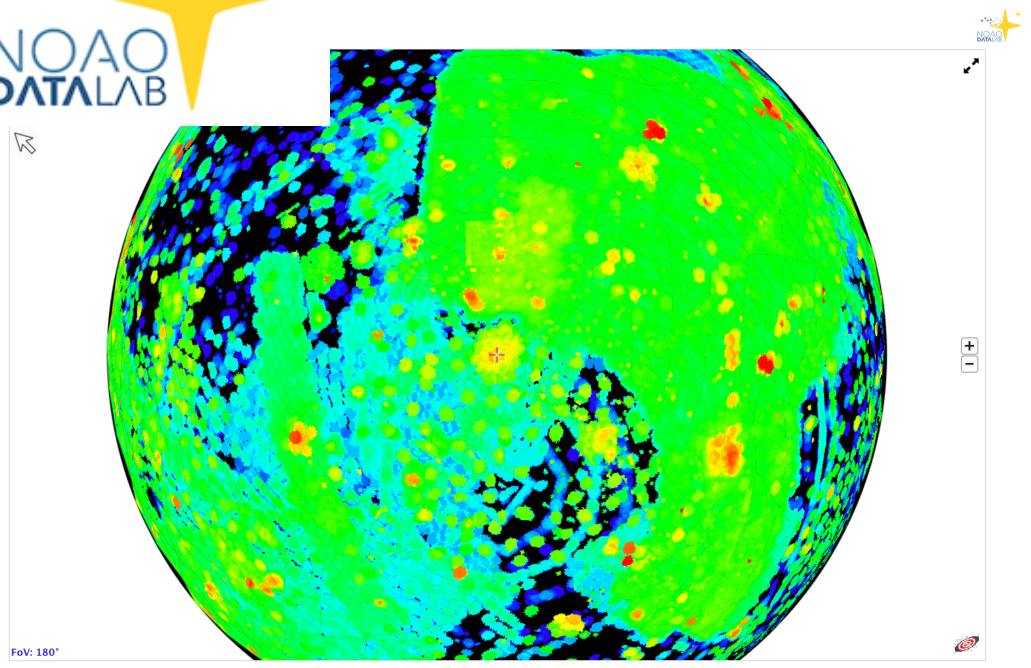
Spitzer GLIMPSE 360



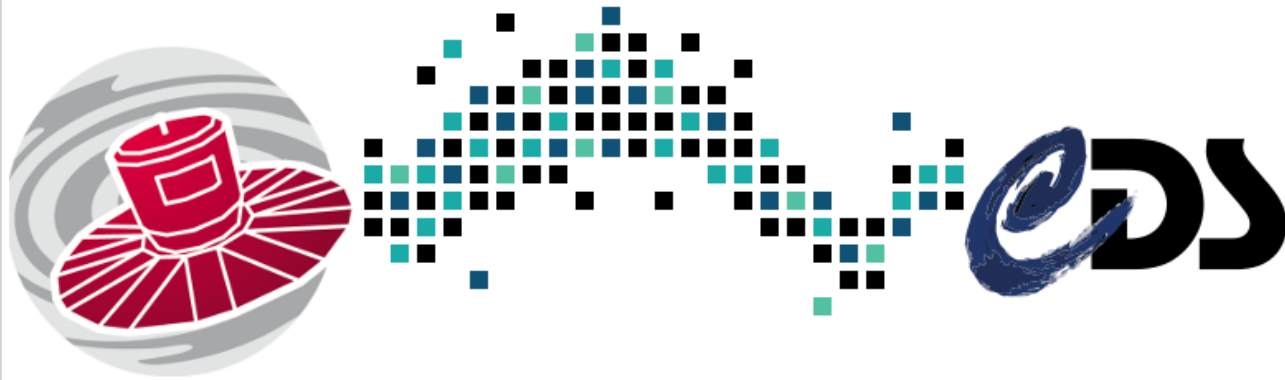
LIGO Skymap Viewer



NOAO Datalab (beta)



□ Gaia DR1 at CDS



<http://cds.unistra.fr/gaia>

- Gaia DR1 tables available in TAP VizieR
- Query and X-match Gaia tables with any available VizieR table
- Web interface:
<http://tapvizier.u-strasbg.fr/adql/>

Table Access Protocol (TAP) Query

Select Service Use Service Resume Job Running Jobs

Metadata

Find: gaia

☒ Name ☒ Descrip Or

TAPVizieR (21/31971)

- viz7 (11/10129)
- vizA (2/3392)
- vizIs (8/61)
 - "I/337/gaia"**
 - "VI/137/gum_gal"
 - "VI/137/gum_lmc"
 - "VI/137/gum_mw"
 - "VI/137/gum_qso"
 - "VI/137/gum_smc"
 - "VI/137/gum_sn"
 - "VI/145/attitude"

Name	DataType	Indexed	Unit	Desc
astrometric_n_obs_ac	SMALLINT	☐		Tota
phot_g_mean_flux	DOUBLE	☒	e-/s	G-bi
solution_id	BIGINT	☐		Solut
source_id	BIGINT	☒		Sour
ecl_lat	DOUBLE	☐	deg	Eclip
scan_direction_mean_k4	DOUBLE	☐	deg	Mea
dec_pmdec_corr	REAL	☐		? Coi
ra_error	REAL	☒	mas	Stani
phot_g_mean_mag	REAL	☒	mag	G-bi
astrometric_n_obs_al	SMALLINT	☐		Tota
pmra_error	REAL	☐	mas/yr	? Sta
scan_direction_mean_k3	DOUBLE	☐	deg	Mea
parallax_pmra_corr	REAL	☐		? Coi

Service Capabilities

Query Language: ADQL-2.0 Max Rows: 1000000000 (default) Uploads: 10krow/

ADQL Text

Mode: Synchronous

1

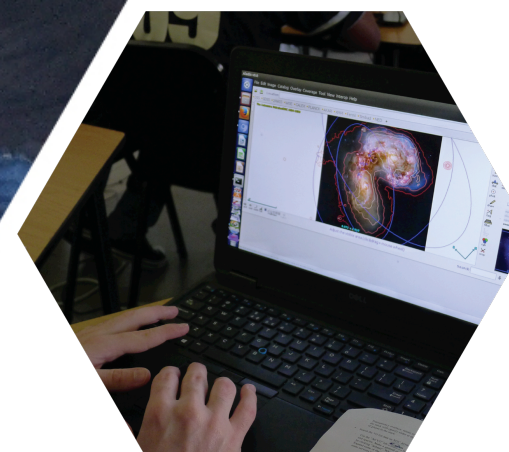
```
SELECT TOP 1000 * FROM "I/337/tgas"
```

Examples Info

Run Query

Hands-on Training

- Training and support
 - Science and Infrastructure
 - Next VO School: Nov 2017, Madrid



Next steps

- Build on work of Euro-VO and ASTERICS
- Prepare VO aspects of next Infrastructure Roadmap - sustainability
- Expand engagement with big astronomy projects
- Respond to needs of community (*e.g spectral services, time domain capabilities*)