Not Only
Stellar Spectroscopy with Virtual Observatory

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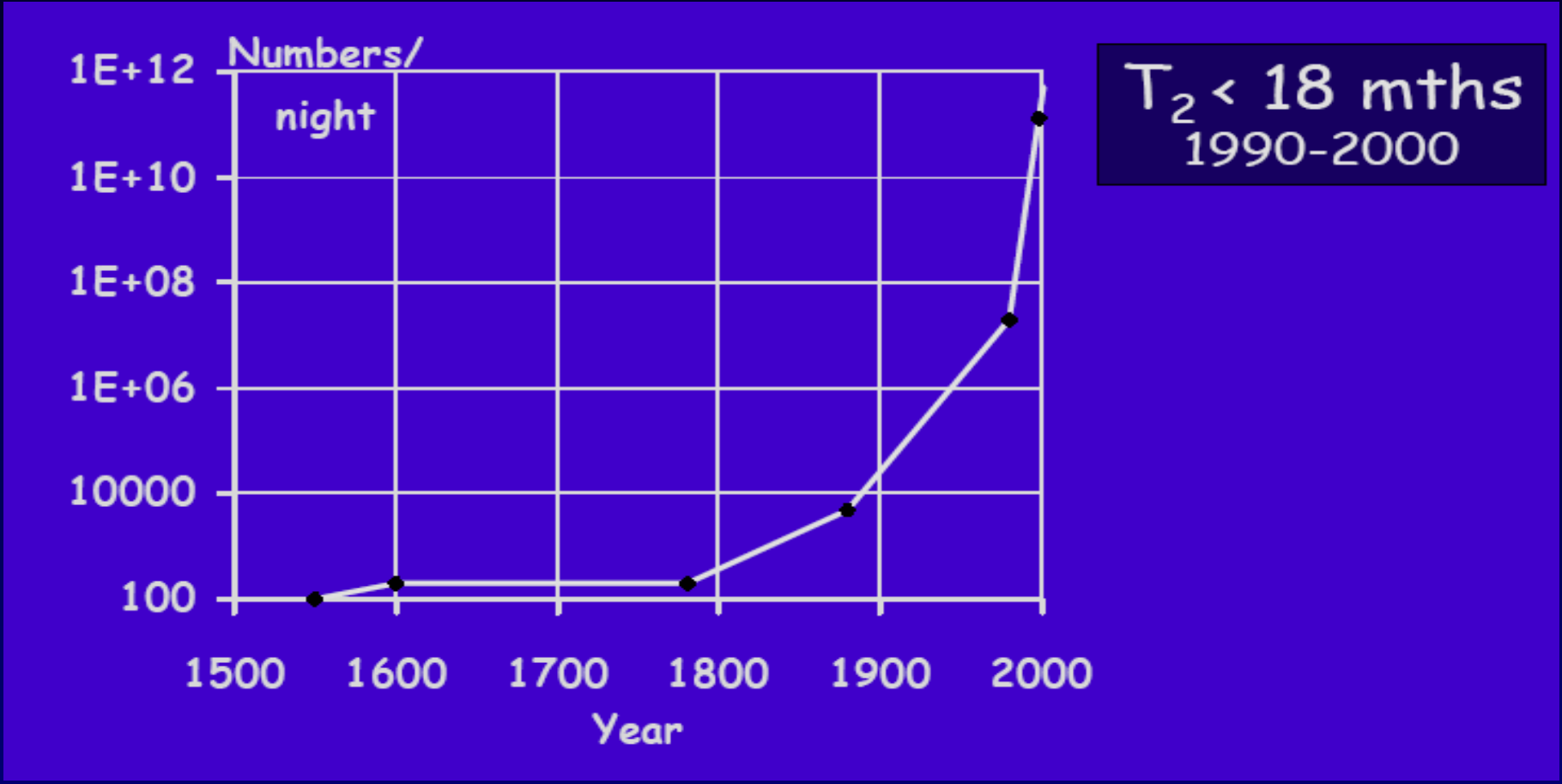
Lecture at workshop on observational techniques,
AI Ondrejov, 5th Sep 2024

Data Avalanche

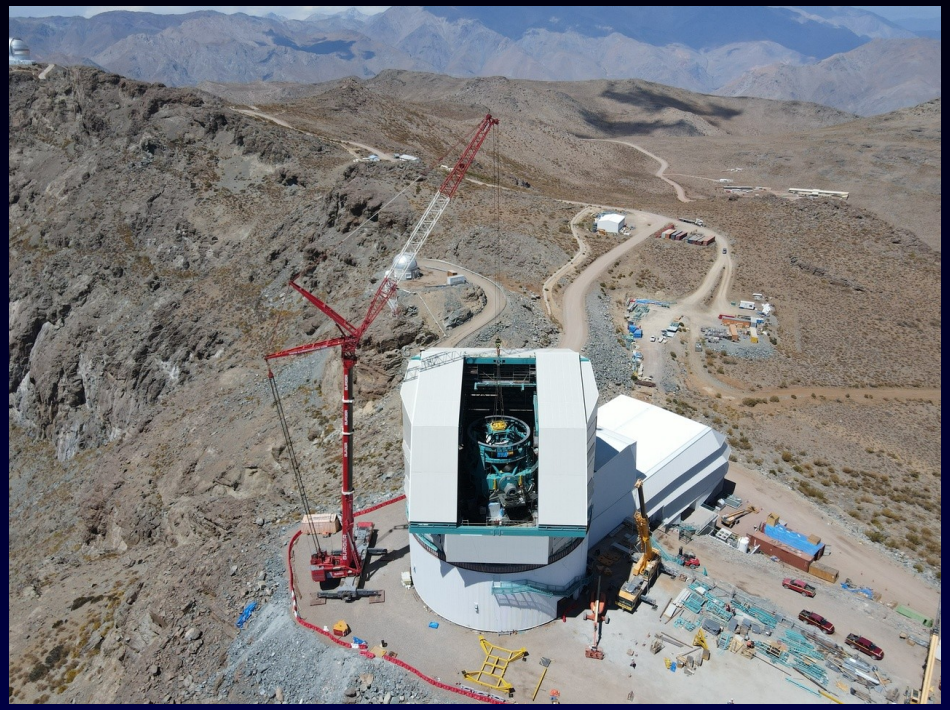
Moore law for chips –doubling 1.5 year

Data in astronomy – doubling < 1 yr ! (9 month current)

100 PB today, 100 TB/night

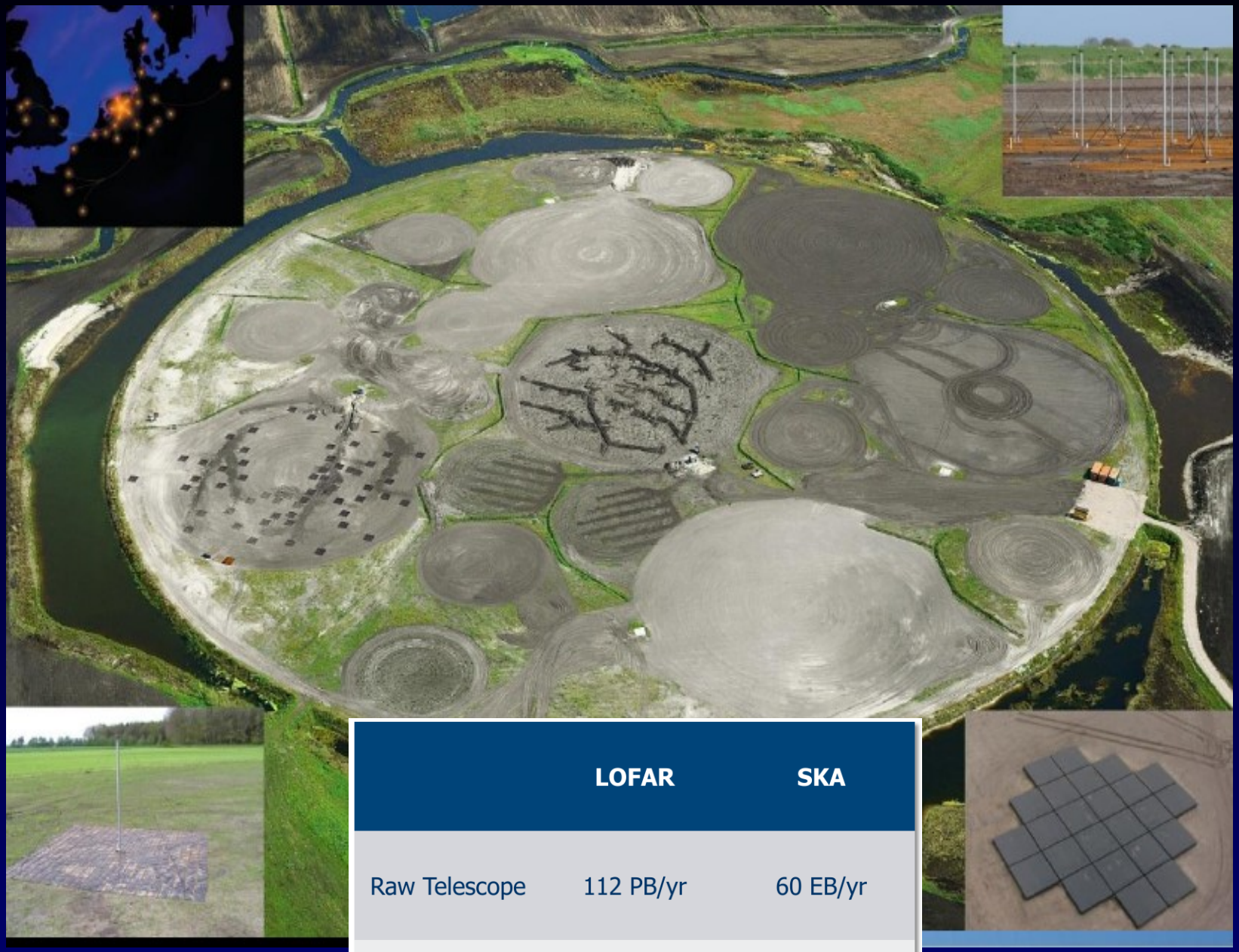


LSST – Vera C. Rubin Observatory



201 CCD 4kx4k,
3.2 Gpix every 15 sec
3.5 deg FOV (64cm)
20 TB/day=6 PB/yr RAW
1.5 PB catalogue !!!
detection of changes 60s!
10 million allerts/night !
38 billion objects x 1000
32 tril. meas. -5 PB table

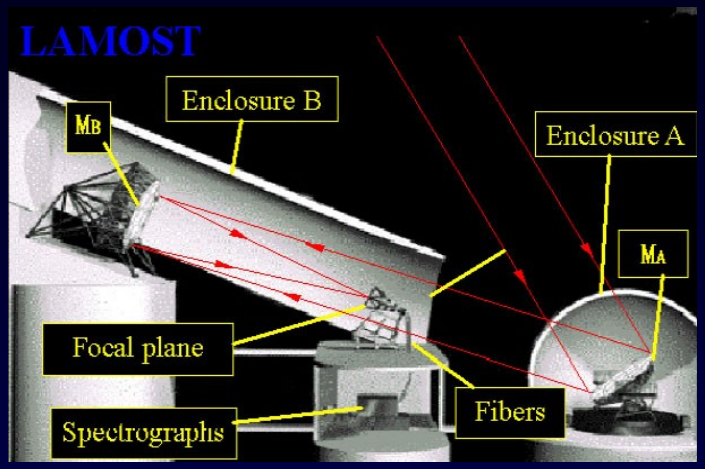
LOFAR network

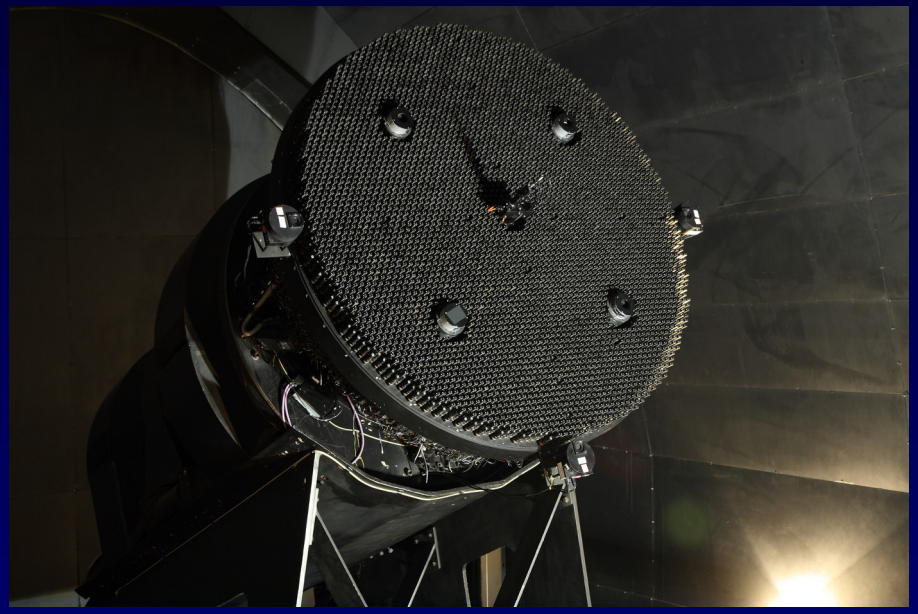


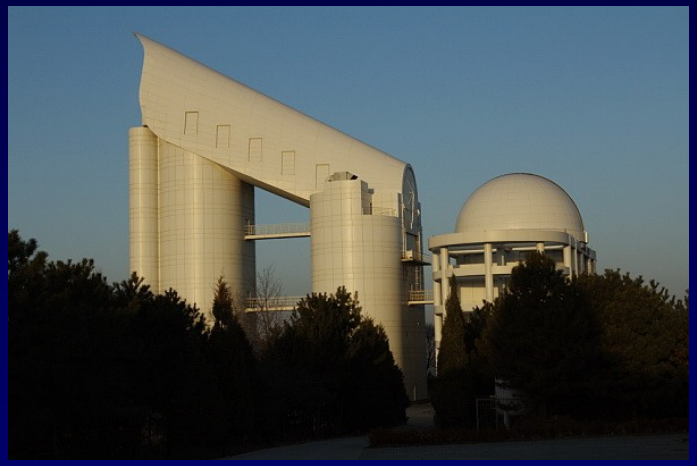
	LOFAR	SKA
Raw Telescope	112 PB/yr	60 EB/yr
Archive Rate	6 PB/yr	100 PB/yr

LAMOST (Guoshoujing)

- Xinglong, China
- 4 m mirror (30 deg meridian)
- 4000 fibres







LAMOST Spectral Surveys

DR1 (end 2013) **2 204 860** spectra
1 085 404 stars classified by pipeline

DR2 (beg 2015) **4 132 782** spectra
3 779 674 stars
307 000 unknown!

DR5 (half 2017) **9 017 844** spectra

...

DR8 (Feb 2022) 10 927 525 low res
+ 5 975 982 mid res

Each fibre – 2 motors
double arm 33mm circle

Fibre collects light from
3.3 arcsec circle on sky

Virtual Observatory : Key Definitions

- *"The Virtual Observatory will be a system that allows astronomers to interrogate multiple data centers in a seamless and transparent way, which provides new powerful analysis and visualization tools within that system, and which gives data centers a standard framework for publishing and delivering services using their data".*

- Standardization of data and metadata, and of data exchange methods.

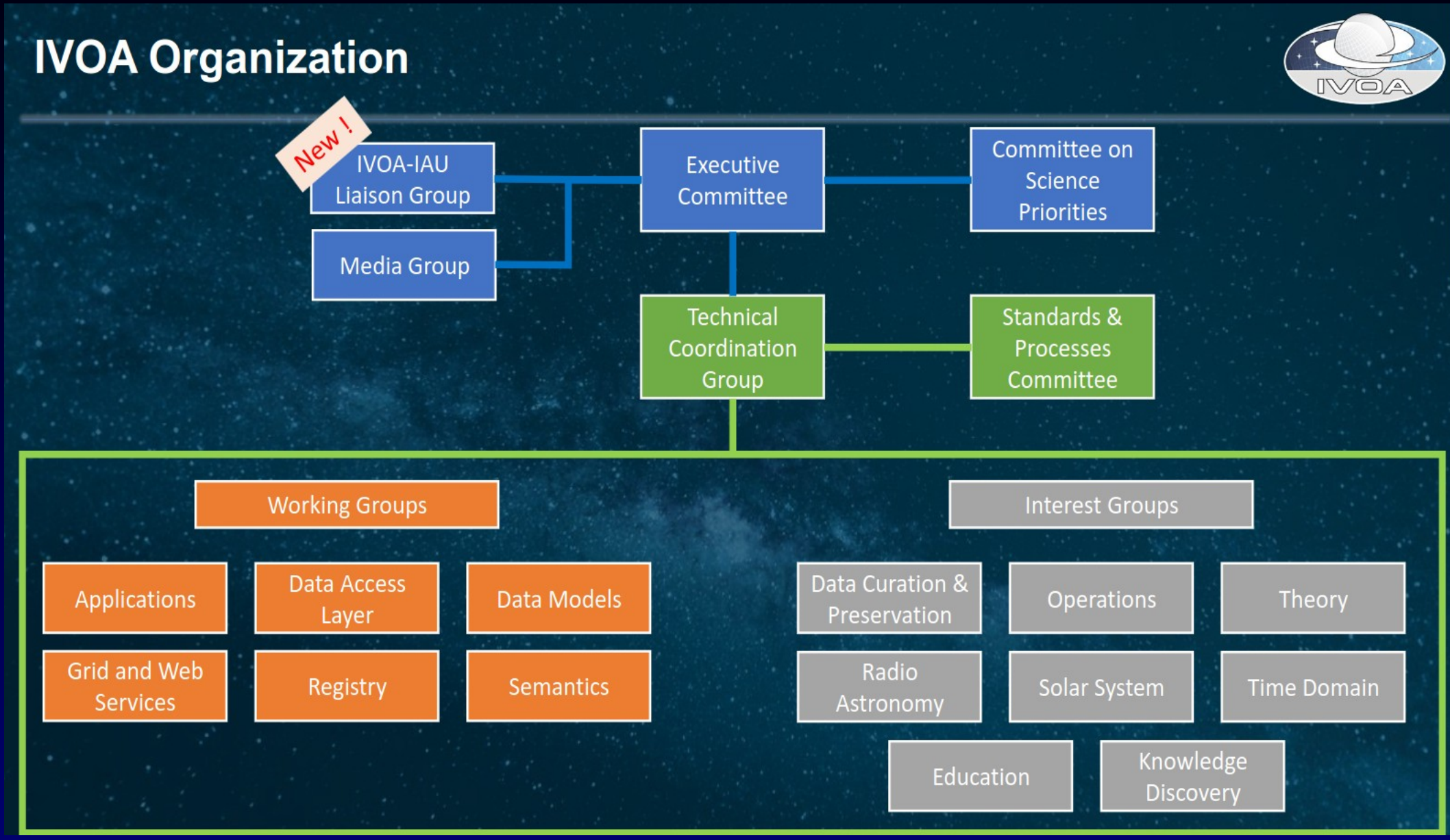
- Registry, listing available services and what can be done with them.

R.J.Hanisch, P.J.Quinn, in "IVOA – Guidelines for participation"

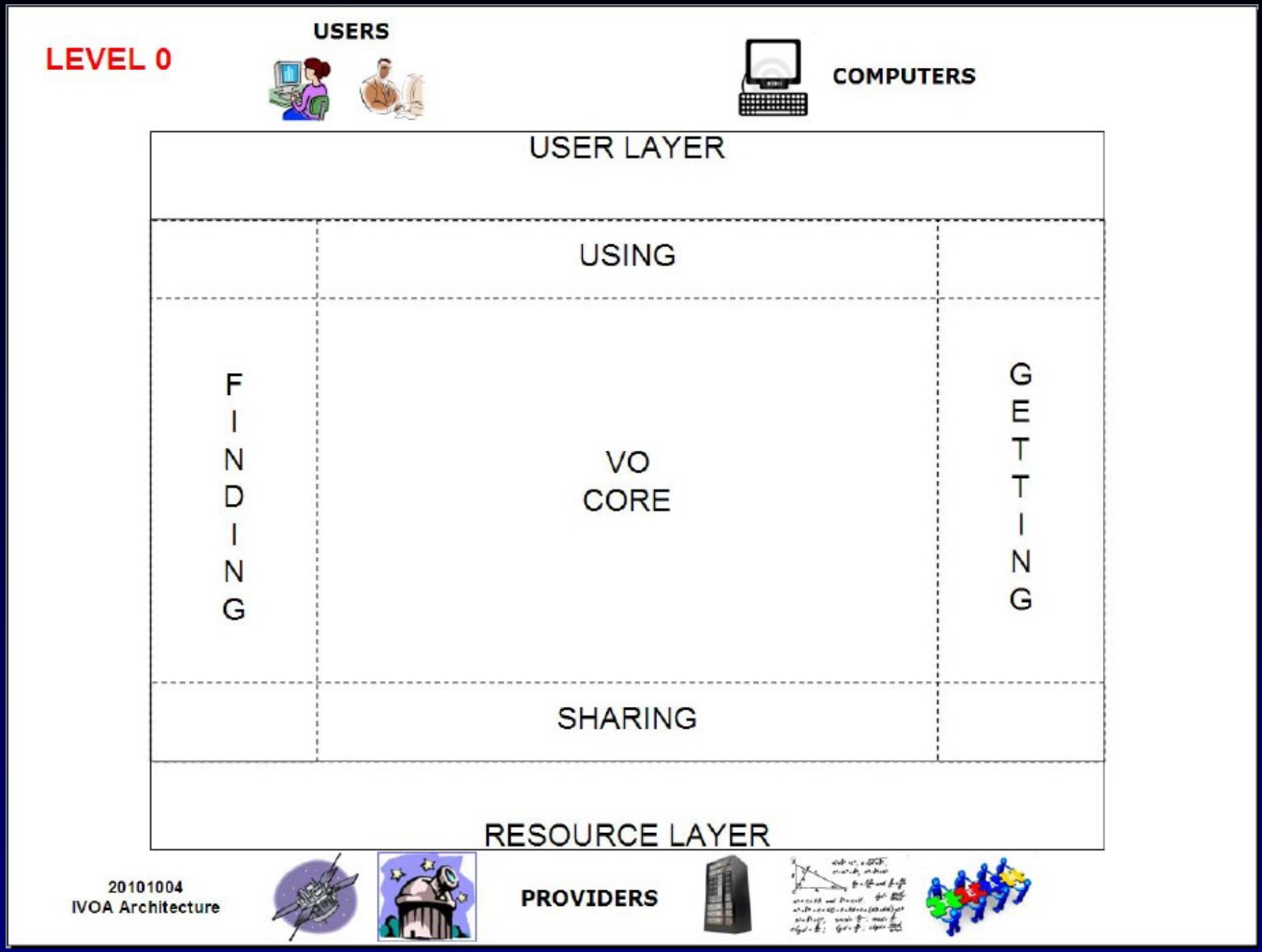
IVOA (established 2002)

CZVO
Czech Virtual Observatory

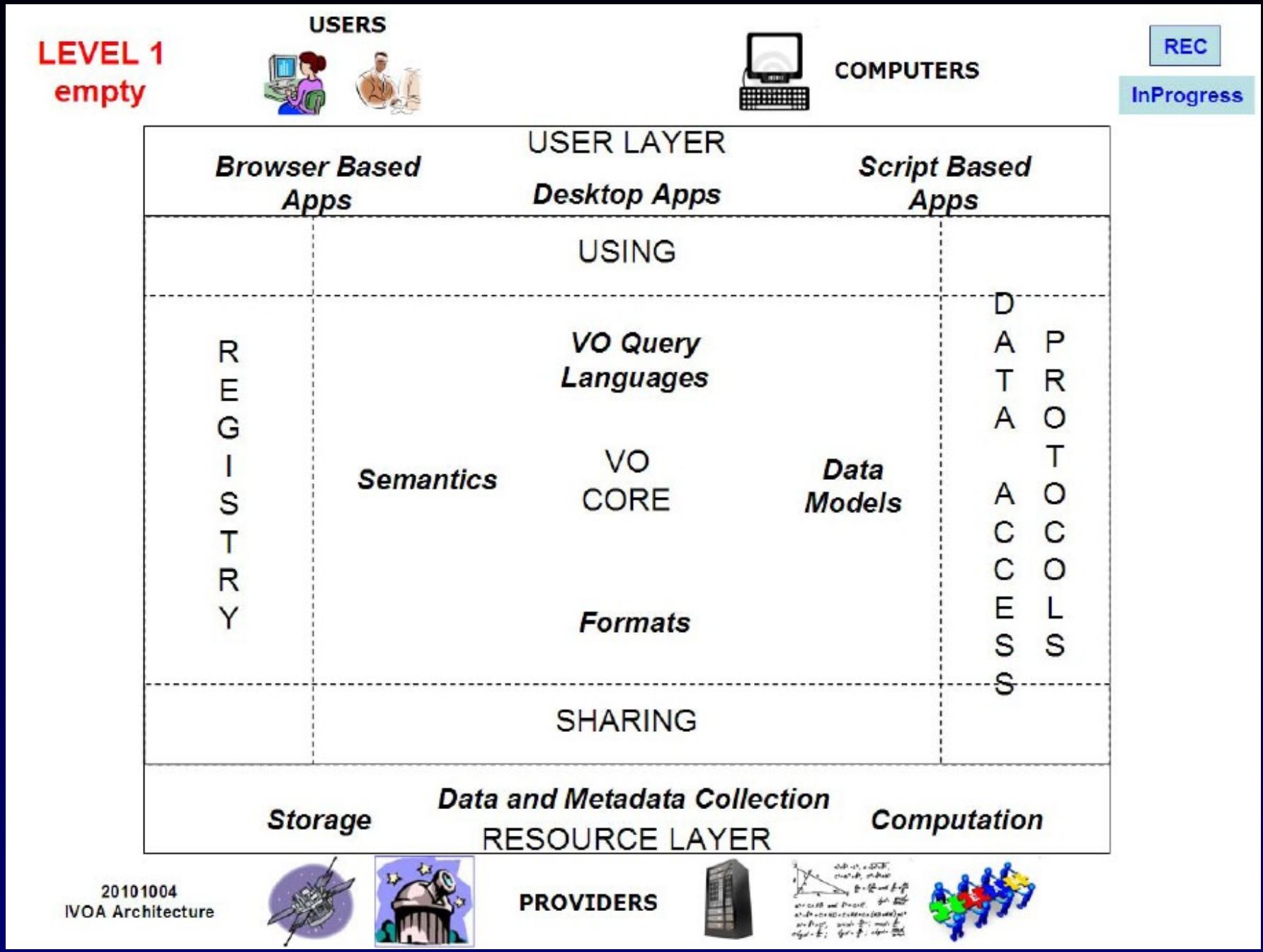
IVOA Structure



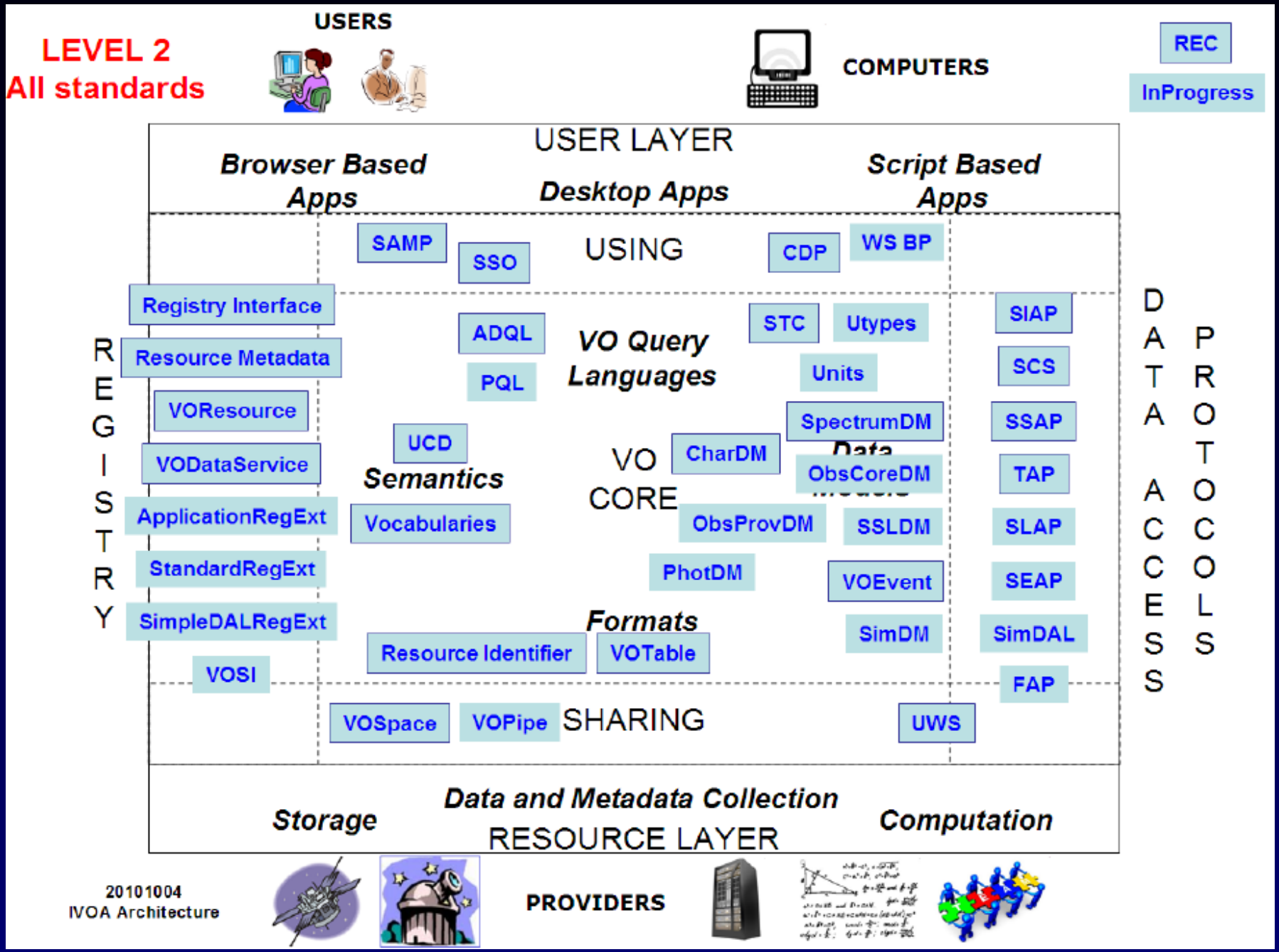
Ecosystem of VO – level 0



Ecosystem of VO – level 1



Ecosystem of VO – level 2

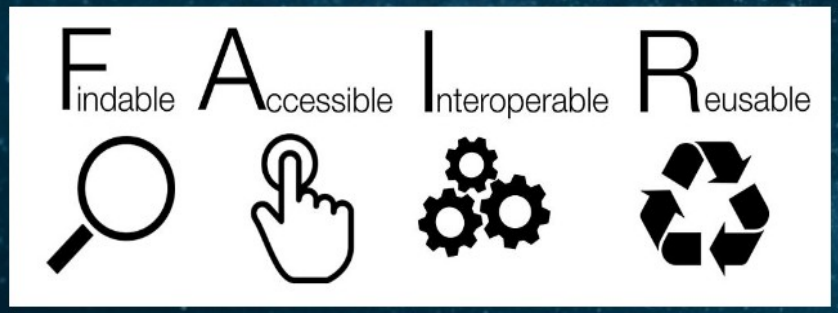


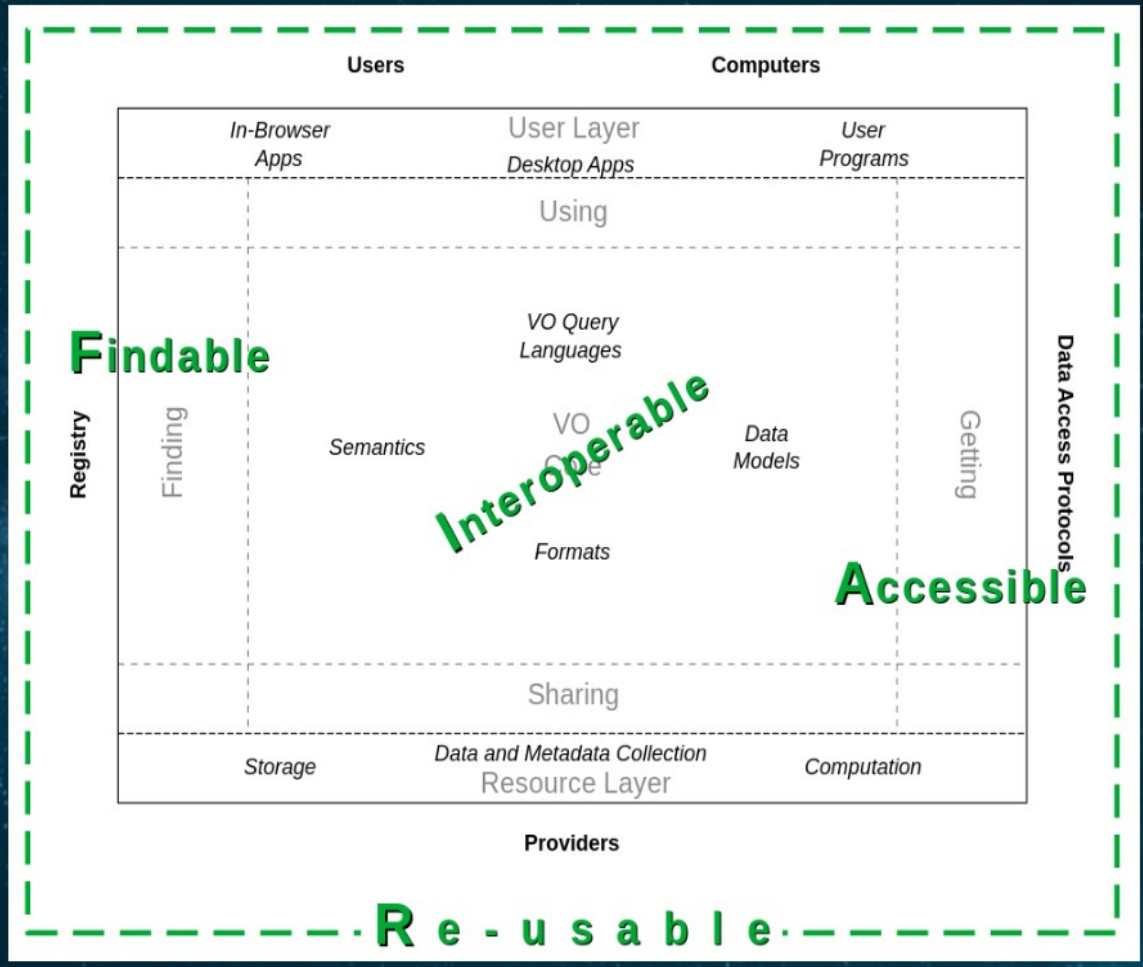
Open Science – EOSC

EURO-VO DCA, ICE, CoSADIE, ASTERICS, ESCAPE - Astroparticles

IVOA Architecture – FAIR data management

VO has been FAIR from the beginning!





Arviset 2023

Technology of VO

Unified data format– VOTable, UCD (Vizier)

Transparent transport (VOunits)

VOregistry (DNS like) Google for data+WS

Protocols

- ConeSearch (searching in circle on sky)
- SIAP (Simple Image Access Protocol)
- SSAP(Simple Spectral Access Protocol)
- SLAP(Simple Line Access Protocol) - VAMDC
- TAP (Table Access Protocol) – query e.g. whole SDSS
- VOEVENT (transients, robotic telescopes,Sun
- DATALINK (related data products, e.g. raw, mosaics..)
- SODA Server-side Operations for Data Acces

Technology of VO

ADQL (Astronomical Data Query Language)

- XMATCH, REGION (2 catalogues – shifted)

Application interoperabilty – SAMP

- Allows develop applications as bricks
- sending VOTABLES (catalogue-spectra-images)

Surveys visualization

- HIPS (Hiearchical Progressive Survey) - allsky zoom
- MOC (Multi order coverages) time, space, spectral (FoV)

Big Data handling

VO Space Moving big tables across (load only results)

SSO Authentication, authorization, groups and consortia

UWS Universal worker service (job synch, asynch)

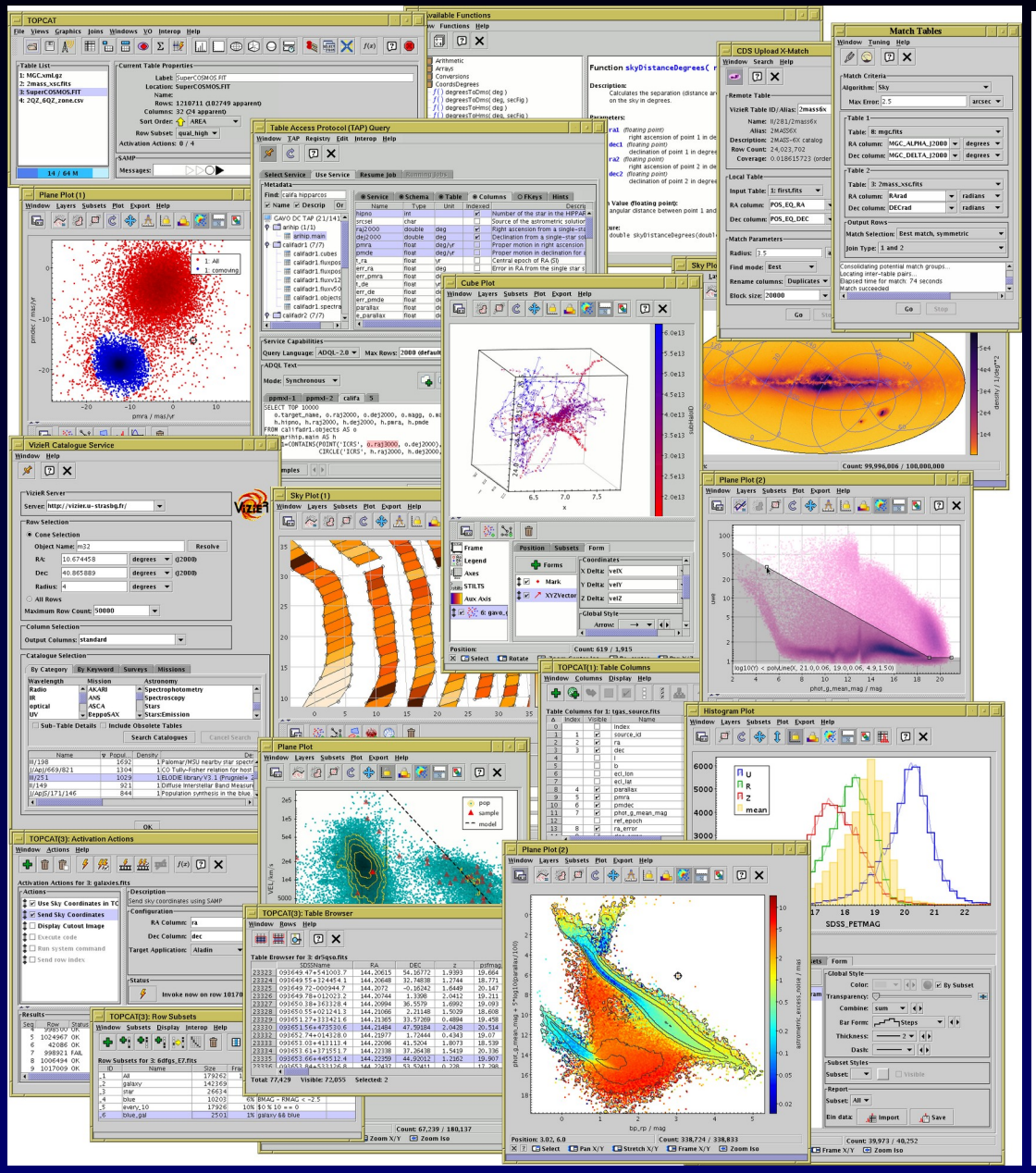
PDL Parameter Description Language

SIM-DB Simulations, theory data

Science platforms for BD analysis and ML

(*SciServer JHU, NOAO DataLab, CANFAR, Gaia, Jupyterhub, Docker, ASTROpy)*

TOPCAT



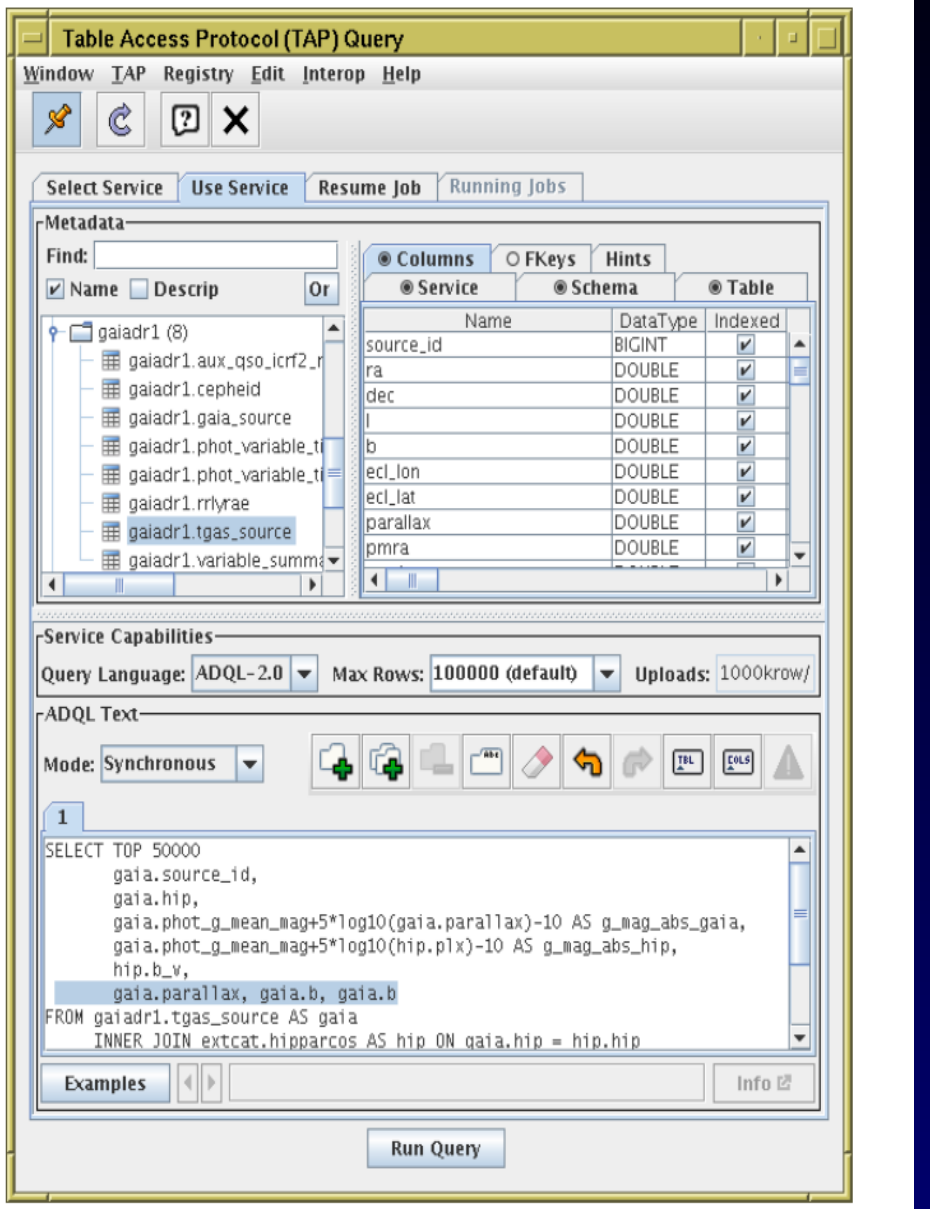
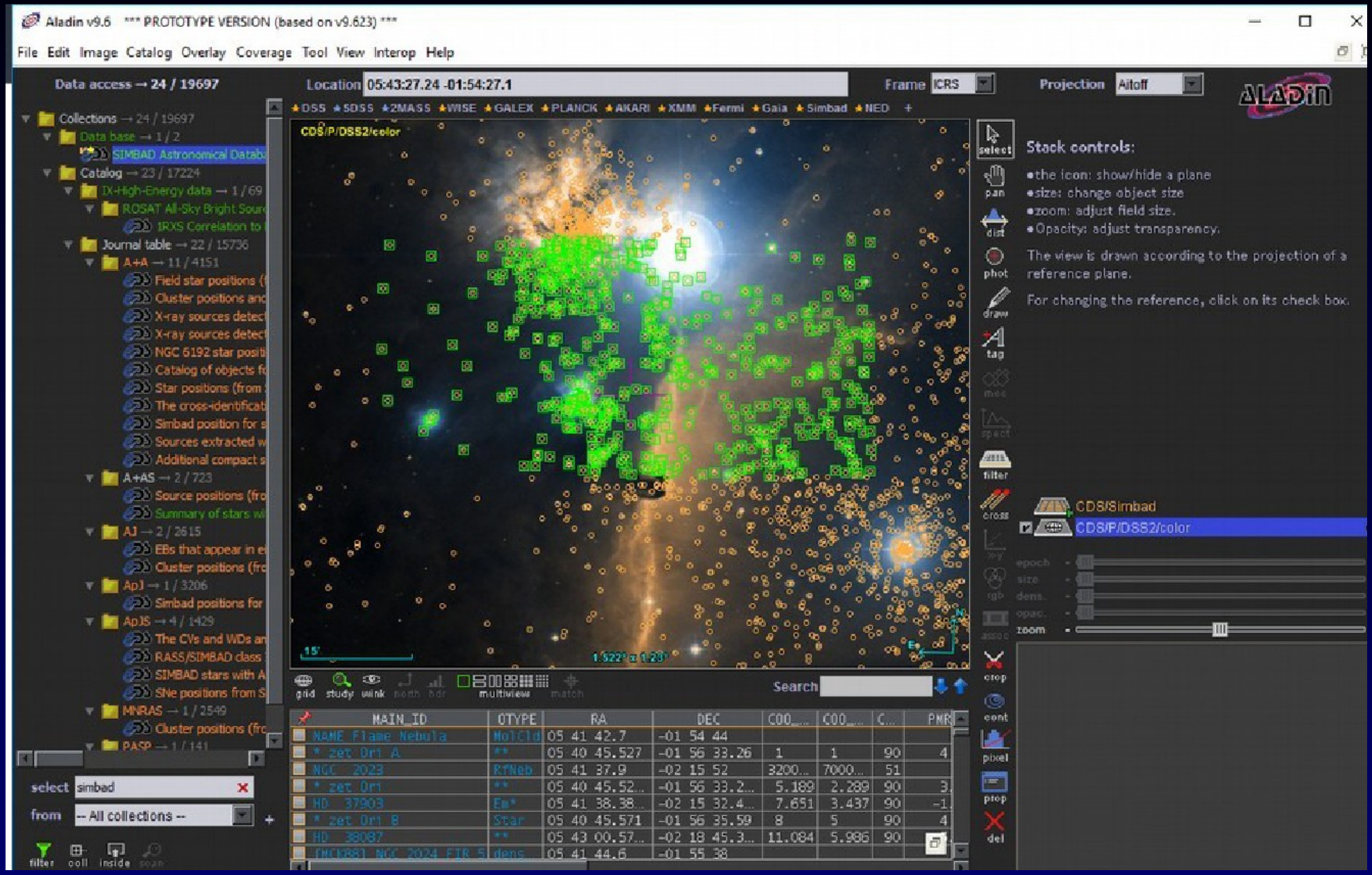


Table Access Protocol (TAP) Query
Window TAP Registry Edit Interop Help
Select Service
Use Service
Resume Job
Running Jobs
Metadata
Find:
Name
Descrip
Or
Columns
FKeys
Hints
Service
Schema
Table
gaiadr1 (8)
gaiadr1.aux_qso_icrf2_r
gaiadr1.cepheid
gaiadr1.gaia_source
gaiadr1.phot_variable_t
gaiadr1.phot_variable_t
gaiadr1.rrlyrae
gaiadr1.tgas_source
gaiadr1.variable_summa
Name
DataType
Indexed
source_id
BIGINT
ra
DOUBLE
dec
DOUBLE
l
DOUBLE
b
DOUBLE
ecl_lon
DOUBLE
ecl_lat
DOUBLE
parallax
DOUBLE
pmra
DOUBLE
Service Capabilities
Query Language:
ADQL-2.0
Max Rows:
100000 (default)
Uploads:
1000krow/
ADQL Text
Mode:
Synchronous
1
SELECT TOP 50000
gaia.source_id,
gaia.hip,
gaia.phot_g_mean_mag+5*log10(gaia.parallax)-10 AS g_mag_abs_gaia,
gaia.phot_g_mean_mag+5*log10(hip.plx)-10 AS g_mag_abs_hip,
hip.b_v,
gaia.parallax, gaia.b, gaia.b
FROM gaiadr1.tgas_source AS gaia
INNER JOIN extcat.hipparcos AS hip ON gaia.hip = hip.hip
Examples
Info
Run Query

Aladin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Data access → 24 / 19697
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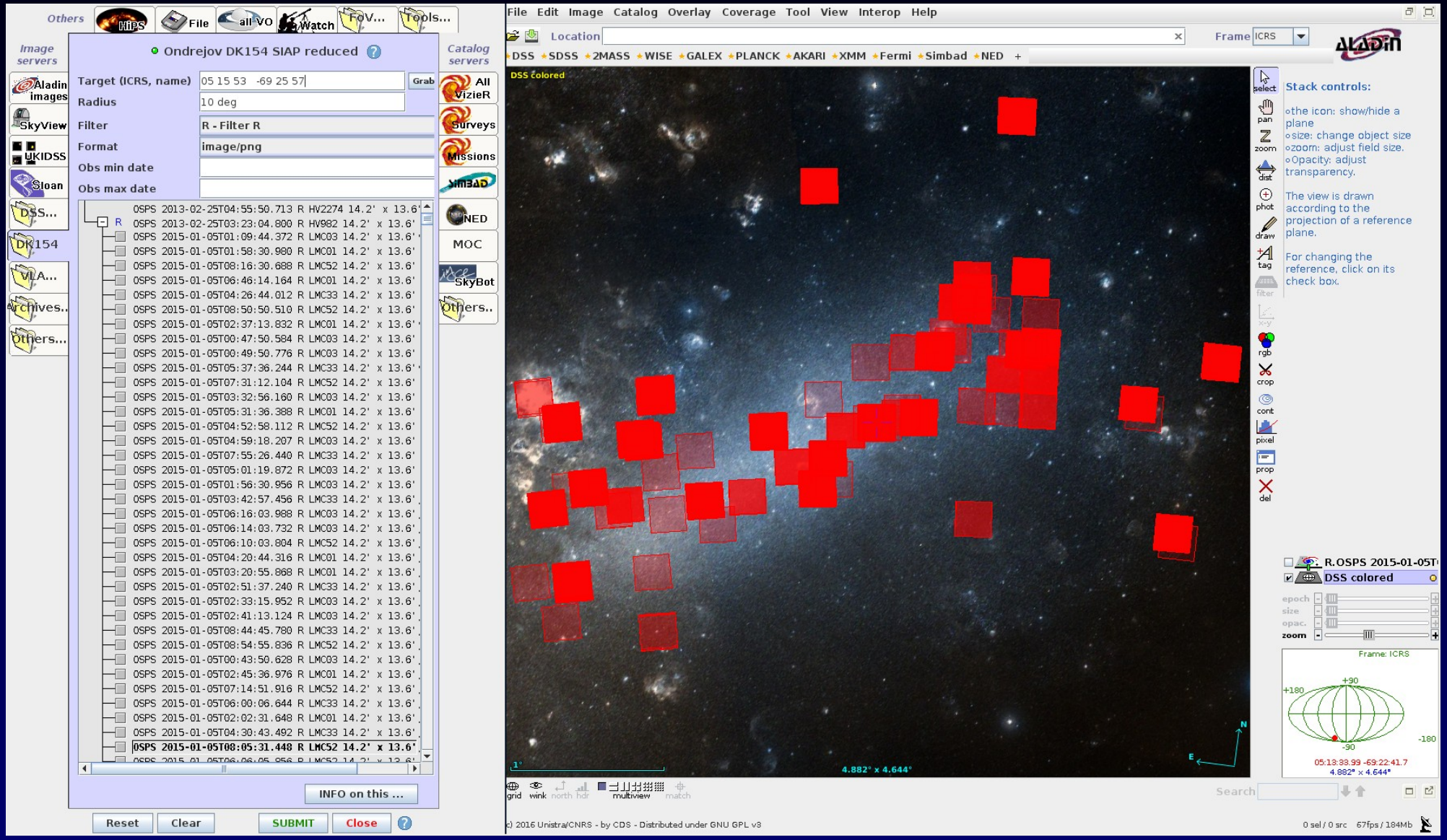
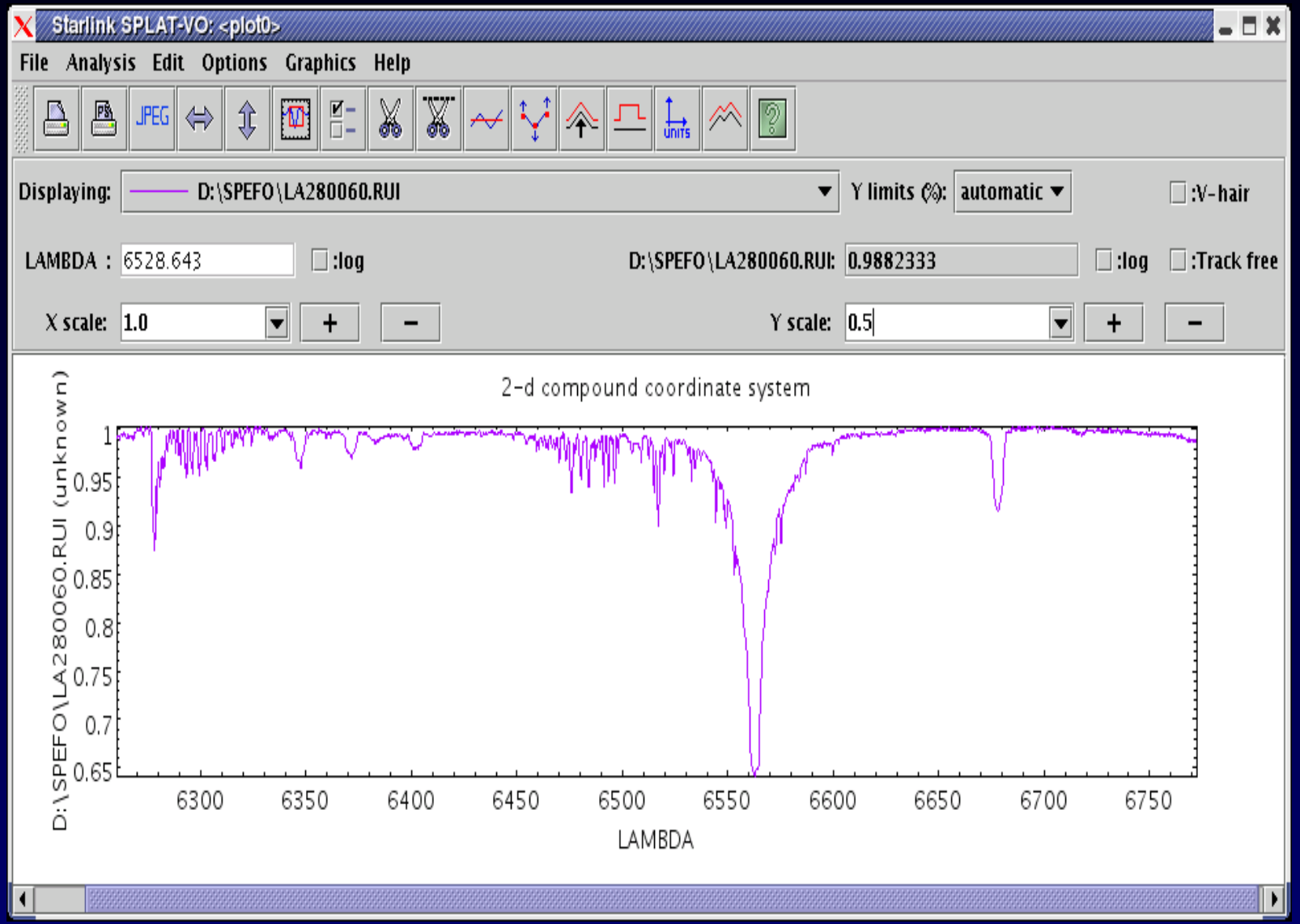
Frame ICRS
Projection Aitoff
ALADIN
★DSS ★SDSS ★2MASS ★WISE ★GALEX ★PLANCK ★AKARI ★XMM ★Fermi ★Gaia ★Simbad ★NED
CDS/P/DSS2/color
Stack controls:
•the icon: show/hide a plane
•size: change object size
•zoom: adjust field size.
•Opacity: adjust transparency.
The view is drawn according to the projection of a reference plane.
For changing the reference, click on its check box.
CDS/Simbad
CDS/P/DSS2/color
Search
MAIN_ID OTYPE RA DEC
NAME Flame Nebula MolCld 05 41 42.7 -01 54 44
* zet Ori A ** 05 40 45.527 -01 56 33.26 1 1 90 4
NGC 2023 RfNeb 05 41 37.9 -02 15 52 3200... 7000... 51
* zet Ori ** 05 40 45.52... -01 56 33.2... 5.189 2.289 90 3
HD 37903 Em* 05 41 38.38... -02 15 32.4... 7.651 3.437 90 -1
* zet Ori B Star 05 40 45.571 -01 56 35.59 8 5 90 4
HD 38087 ** 05 43 00.57... -02 18 45.3... 11.084 5.986 90
select simbad
from -- All collections --

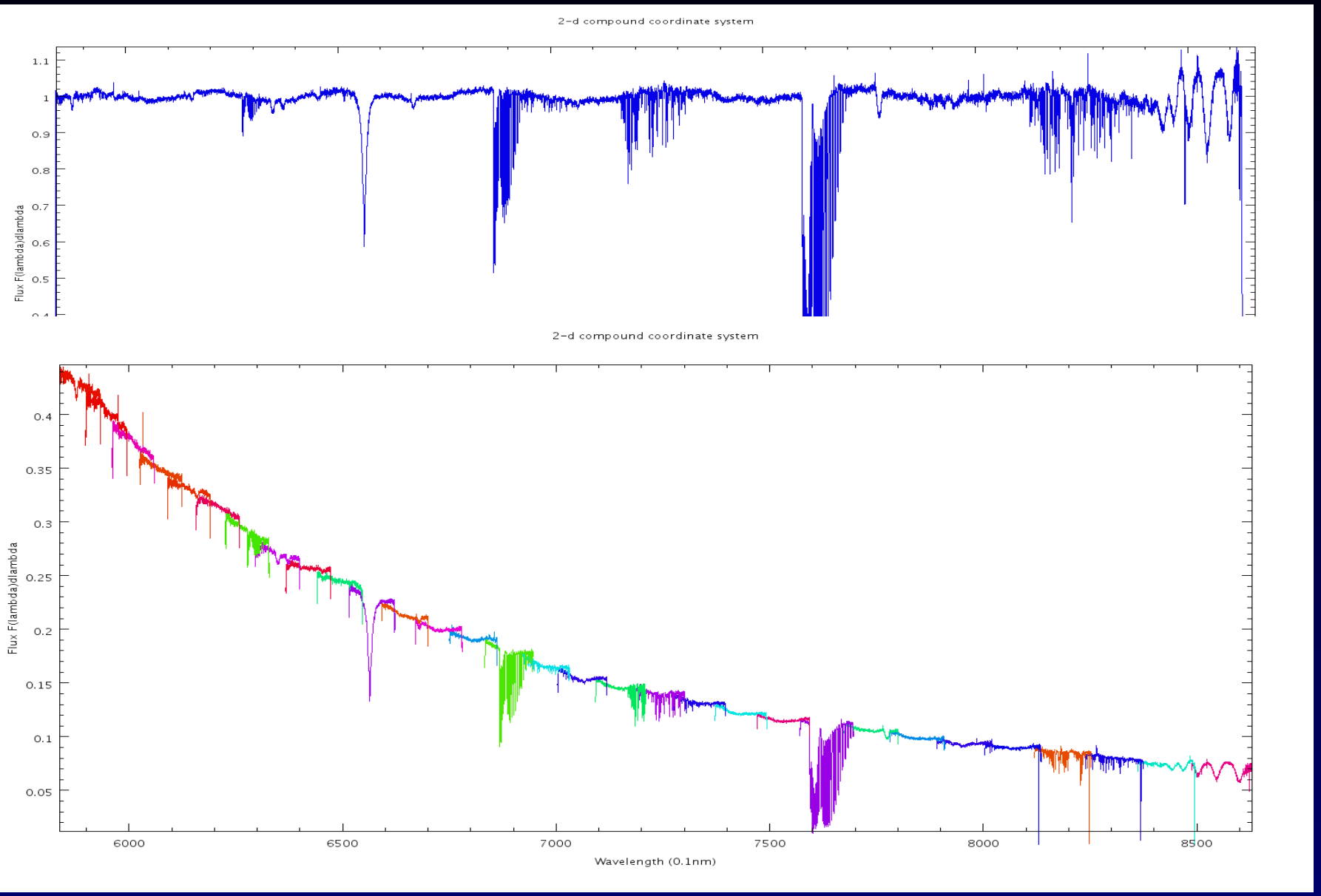
OSPS Image coverage (footprints)



SPLAT-VO
(Starlink, Heidelberg, Ondrejov)

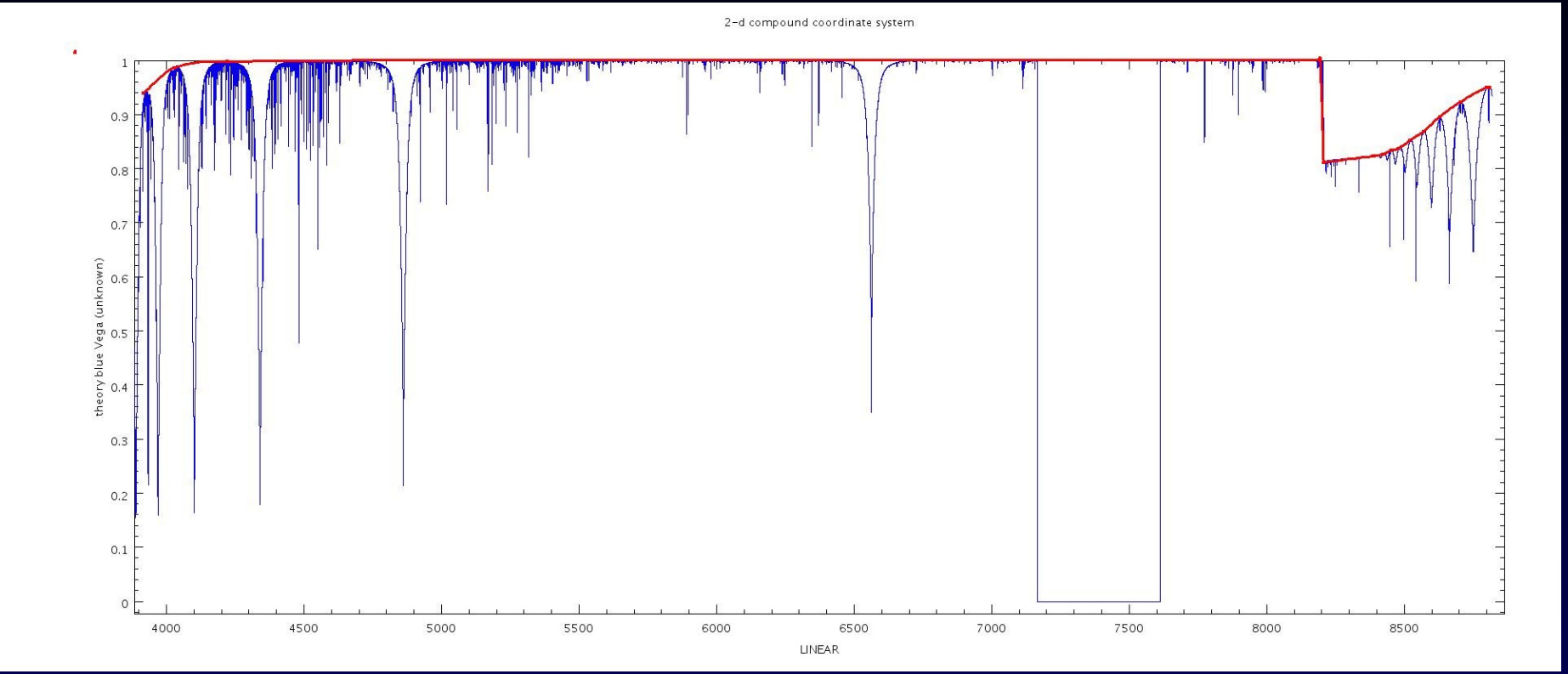


DaCHS Testbed Split-Order SSAP



nu Pup HEROS red

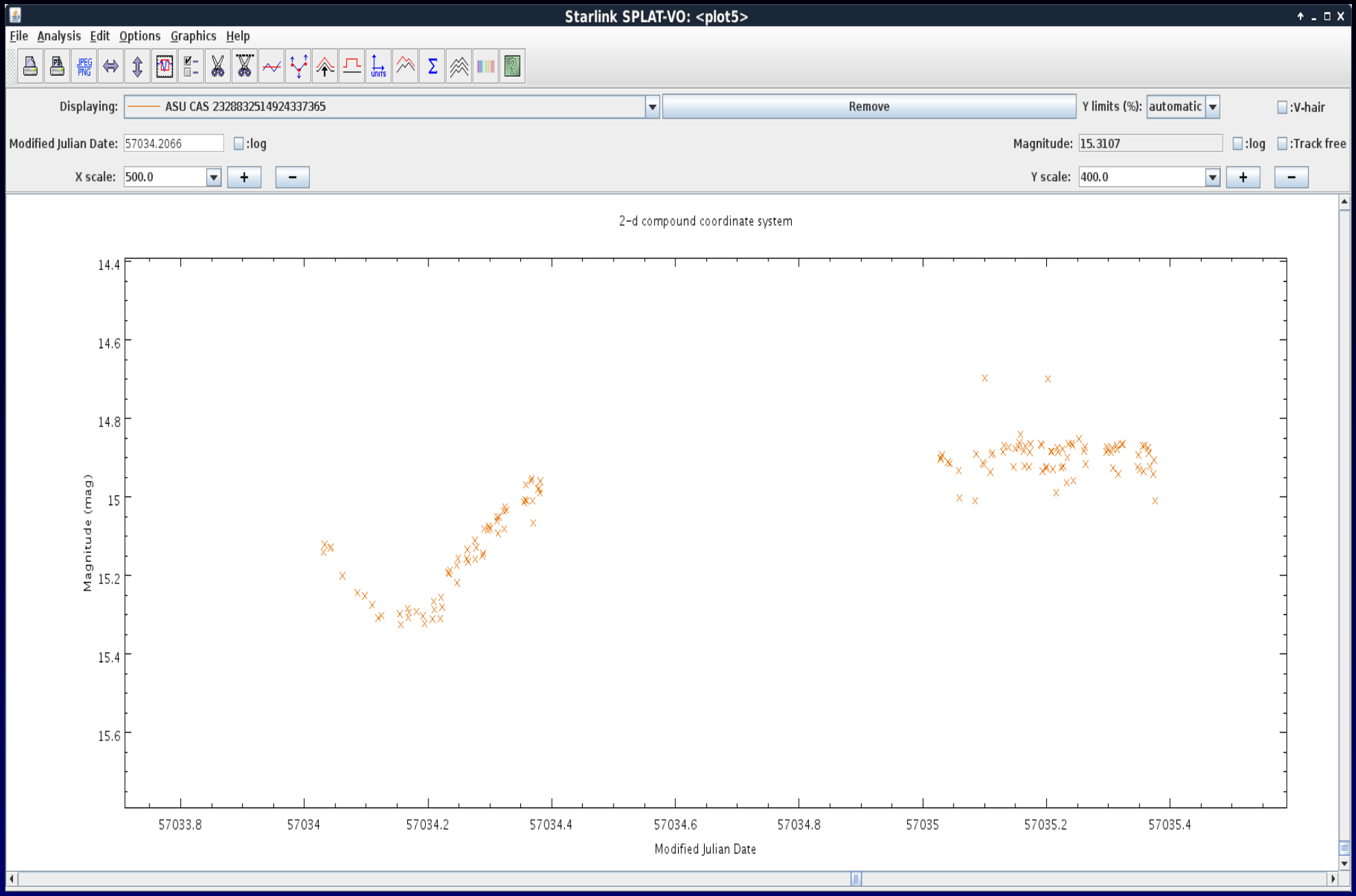
Continuum Normalisation



Theoretical spectrum of Vega

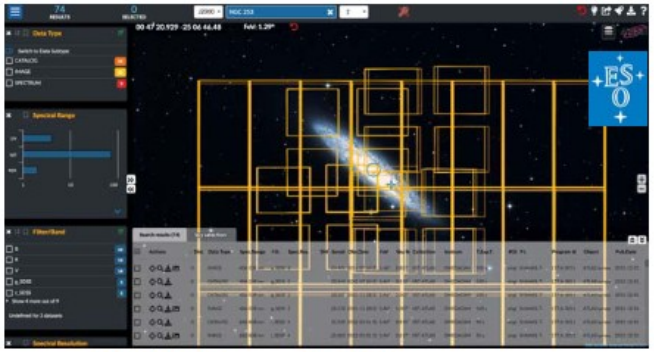
The continuum is NOT ALWAYS at 1.0 !

Light Curve in SPLAT-VO (zoom)

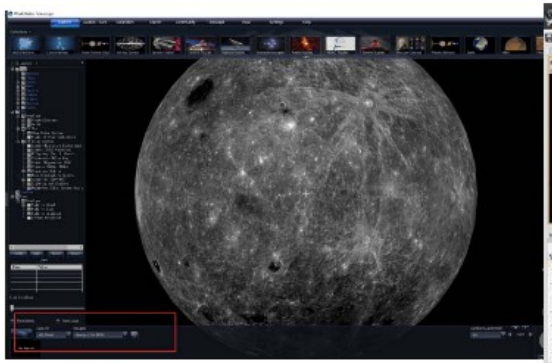


VO Science Portals

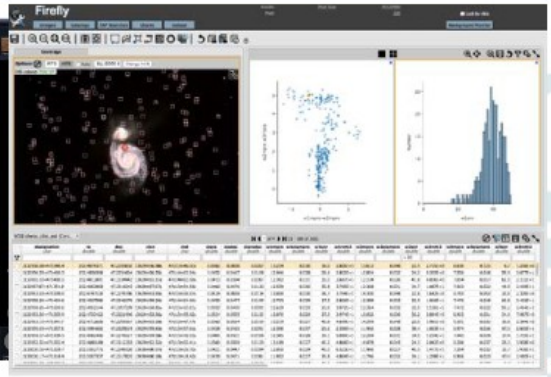
VO embedded in astronomy services



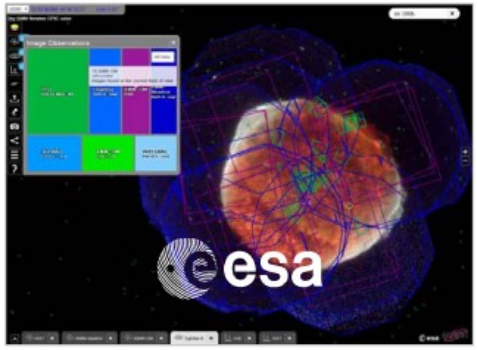
ESO Science Portal



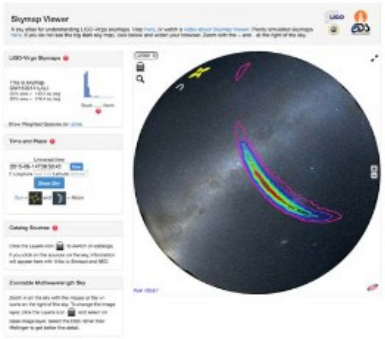
WWT



Firefly
Caltech-IPAC



ESA Sky



Grav. waves

CDS reference data service

SVO Filter Profile service

VO Science Portals

Stellarium + VirGo (ESO, unsupported)

ESASky

https://sky.esa.int/

ESO Archive Science Portal

https://archive.eso.org/scienceportal/home

IRSA IPAC archive (Firefly)

http://worldwidetelescope.org/webclient/

WWT (original MS, now AAS, web client)

http://worldwidetelescope.org/webclient

GoogleSky

https://www.google.com/sky/

Science Portals using VO standards

CDS (Vizier, Simbad), NASA (MAST)

SKAO (SKA)

DataCentral Science Platform (Australia)

CfA Nexus (Harvard)

Rubin Science Platform (LSST)

CTA

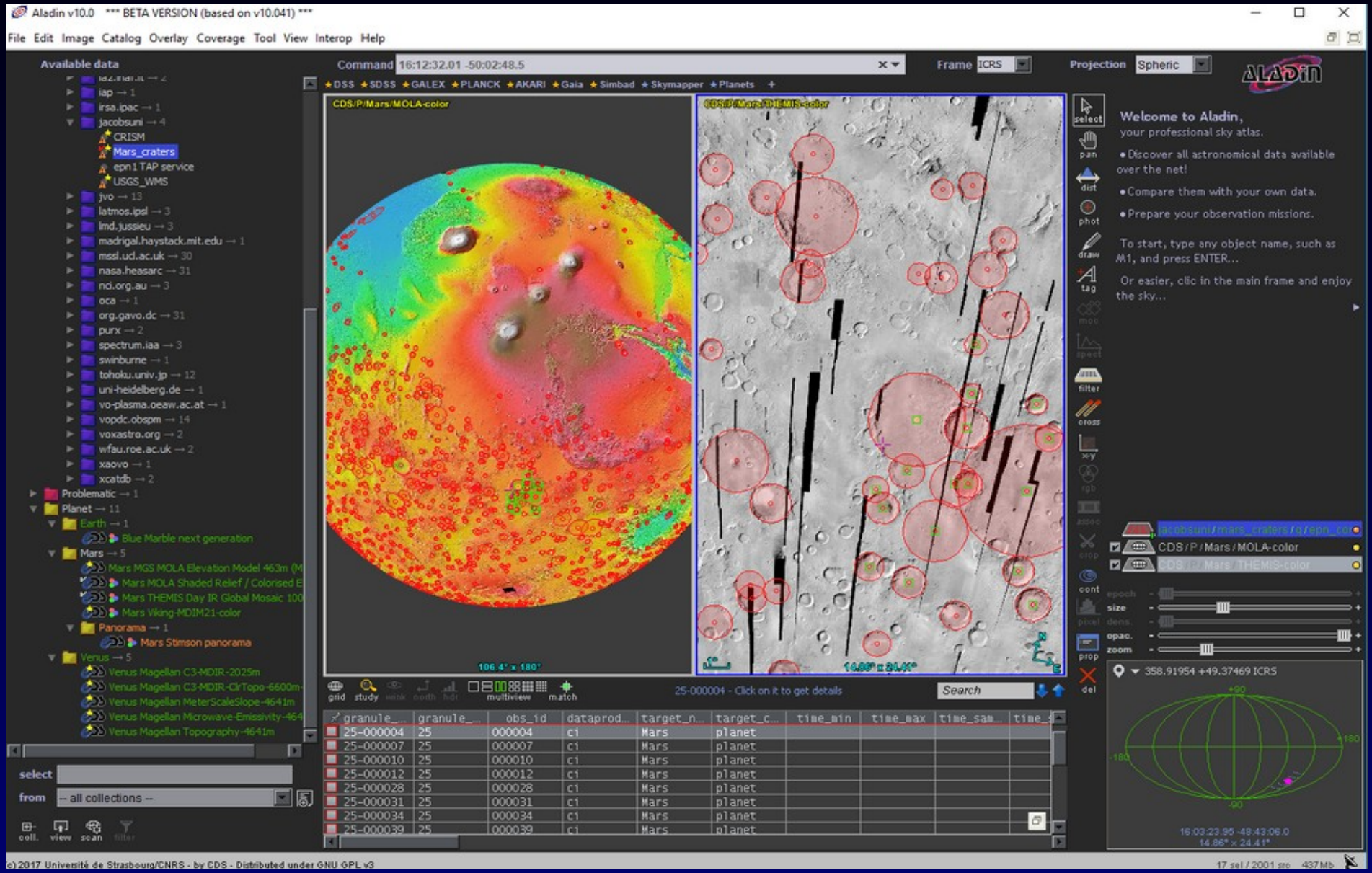
Astro-COLIBRI (real time alerts GW, Neutrinos, Gamma, Xray ……),
LIGO VIRGO..

CAESAR Space weather

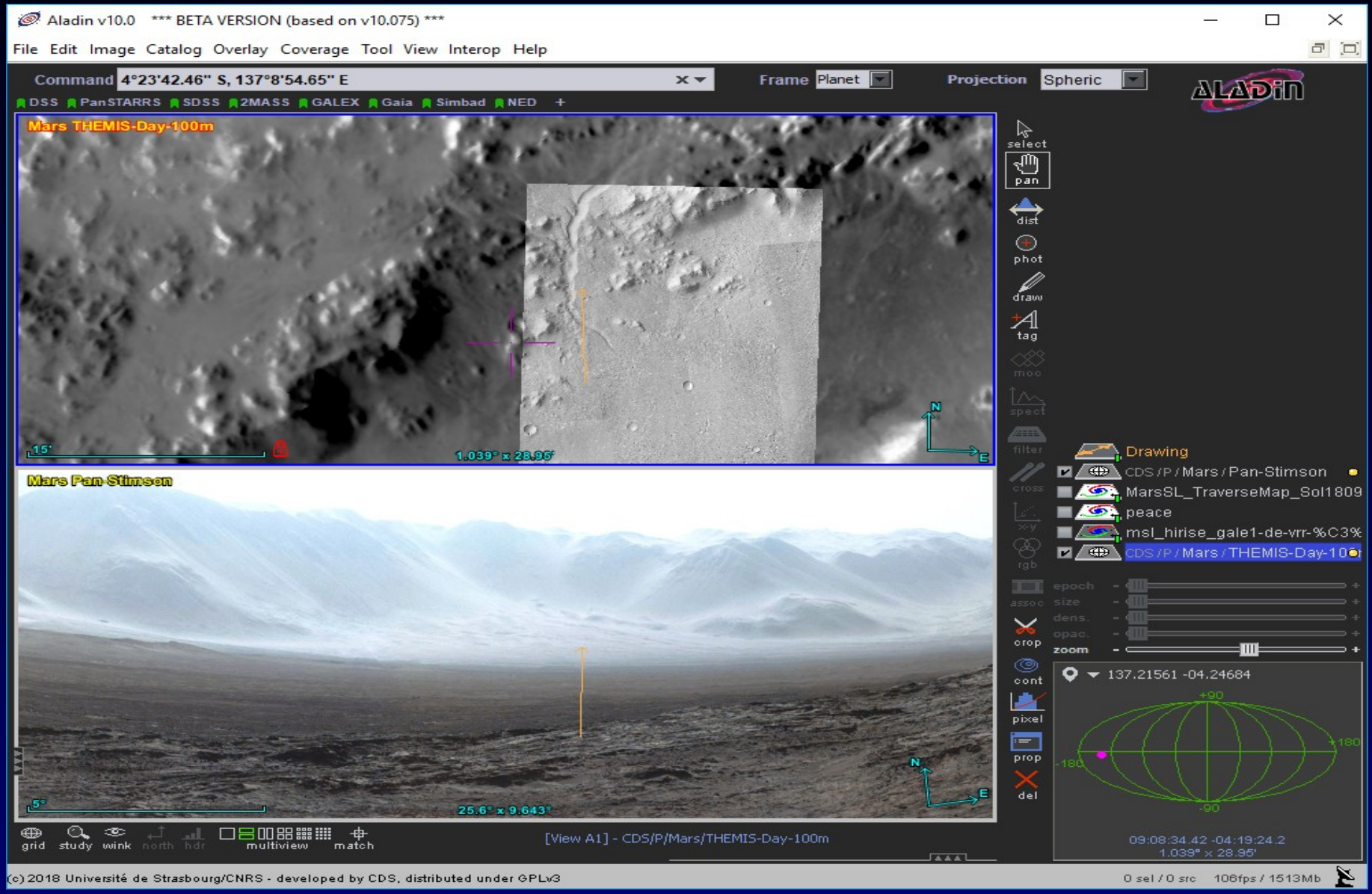
NEORocks

Theory:
- Simulations ILUSTRIS ...
- Spectra (Kurucz, TLUSTY…)
- SED builders ,fitters – IRIS, VOSA

EUROPLANET VESPA (EPN-TAP)



EUROPLANET VESPA (EPN-TAP)



VO in IAU

INTERNATIONAL ASTRONOMICAL UNION

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Home / Science / Scientific Bodies / Working Groups » Division B WG Virtual Observatory

Division B WG Virtual Observatory — **Functional**

Description

This functional Working Group is intended to provide the liaison between the International Virtual Observatory Alliance (IVOA) and the International Astronomical Union (IAU). The IVOA is an organization, composed of 22 international member initiatives, that develops and maintains the technical standards needed to find, access, interoperate and re-use astronomy data (according to the FAIR principles), thus realizing the Virtual Observatory (VO). IVOA also acts as a framework for discussing and sharing VO ideas and technology, for engaging astronomy projects, missions and researchers, and as a body for promoting and publicizing the VO. The IVOA processes for the development of interoperability standards includes the possibility for IAU endorsement. Since its beginnings in 2002 the VO is now a mature framework for the interoperability of astronomy data, with IVOA compliant services operated by astronomy data centers worldwide. This functional working group will provide a communication channel between the IVOA and the IAU on topics of FAIR-compliant standards, use of the VO for scientific research, and for promoting best practices for interoperability of data and services in Astronomy.

Links:

- WG Annual Report (2022) - Virtual Observatory

Search www.iau.org

Search Scientific Bodies

Search...

Search

Follow the IAU on social media

Tutorials of VO

https://hendhd.github.io/ivoa_newcomers/

https://www.canfar.net/storage/list/pdowler/ivoa/virtual2021a (video)

IVOA Interoperability meetings (May + November)
Newcomers Intro

Watch the link https://www.ivoa.net

Number of VO Schools:

EURO-VO DCA, AIDA, ICE
CoSADIE, ASTERICS, ESCAPE

FITS standard

>30 years, separation of metadata (human readable and data)

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 2048 / length of data axis 1
NAXIS2  =                 2048 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
BZERO   =                32768
BSCALE  =                    1 / REAL=TAPE*BSCALE+BZERO
ORIGIN  = 'PESO    '           / AsU AV CR Ondrejov
OBSERVAT= 'ONDREJOV'           / Name of observatory (IRAF style)
LATITUDE=             49.91056 / Telescope latitude  (degrees), +49:54:38.0
LONGITUD=             14.78361 / Telescope longitud  (degrees), +14:47:01.0
HEIGHT  =                  528 / Height above sea level [m].
TELESCOP= 'ZEISS-2m'           / 2m Ondrejov observatory telescope
GAIN    =                    2 / Electrons per ADU
READNOIS=                   10 / Readout noise in electrons per pix
TELSYST = 'COUDE   '           / Telescope setup - COUDE or CASSegrain
INSTRUME= 'OES     '           / Coude echelle spectrograph
CAMERA  = 'VERSARRAY 2048B'    / Camera head name
DETECTOR= 'EEV 2048x2048'      / Name of the detector
CHIPID  = 'EEV 42-40-1-368'    / Name of CCD chip
```

VOTable Example

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 xmlns:stc="http://www.ivoa.net/xml/STC/v1.30" >
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        <FIELDref utype="stc:AstroCoords.Position2D.Value2.C2" ref="col2"/>
      </GROUP>
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             datatype="float" width="6" precision="2" unit="deg"/>
      <FIELD name="Dec"  ID="col2" ucd="pos.eq.dec;meta.main"
             datatype="float" width="6" precision="2" unit="deg"/>
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      <FIELD name="e_RVel" ID="col5" ucd="stat.error;spect.dopplerVeloc"
             datatype="int" width="3" unit="km/s"/>
      <FIELD name="R" ID="col6" ucd="pos.distance;pos.heliocentric"
             datatype="float" width="4" precision="1" unit="Mpc">
        <DESCRIPTION>Distance of Galaxy, assuming H=75km/s/Mpc</DESCRIPTION>
      </FIELD>
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        <TABLEDATA>
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        </TR>
        <TR>
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        </TR>
        <TR>
          <TD>023.48</TD><TD>+30.66</TD><TD>N 598</TD><TD>-182</TD><TD>3</TD><TD>0.7</TD>
        </TR>
        </TABLEDATA>
      </DATA>
    </TABLE>
  </RESOURCE>
</VOTABLE>
```

- Header with metadata first
- Unknown end
- BIG DATA transfer
- Links to streams...
- Live pre-processing URLs
- On-the-fly creation of data

Universal Content Descriptors

S	em.IR	Infrared part of the spectrum
S	em.IR.J	Infrared between 1.0 and 1.5 micron
S	em.IR.H	Infrared between 1.5 and 2 micron
S	em.IR.K	Infrared between 2 and 3 micron
S	em.IR.3-4um	Infrared between 3 and 4 micron
S	em.IR.4-8um	Infrared between 4 and 8 micron
S	em.IR.8-15um	Infrared between 8 and 15 micron
S	em.IR.15-30um	Infrared between 15 and 30 micron
S	em.IR.30-60um	Infrared between 30 and 60 micron
S	em.IR.60-100um	Infrared between 60 and 100 micron

S	pos.eq	Equatorial coordinates
Q	pos.eq.dec	Declination in equatorial coordinates
Q	pos.eq.ha	Hour-angle
Q	pos.eq.ra	Right ascension in equatorial coordinates
Q	pos.eq.spd	South polar distance in equatorial coordinates
S	pos.errorEllipse	Positional error ellipse
Q	pos.frame	Reference frame used for positions (FK5, ICRS,..)
S	pos.galactic	Galactic coordinates
Q	pos.galactic.lat	Latitude in galactic coordinates
Q	pos.galactic.lon	Longitude in galactic coordinates

P	stat.stdev	Standard deviation
S	stat.uncalib	Qualifier of a generic incalibrated quantity
Q	stat.value	Miscellaneous statistical value
P	stat.variance	Variance
P	stat.weight	Statistical weight
Q	time	Time, generic quantity in units of time or date
Q	time.age	Age
Q	time.creation	Creation time/date (of dataset, file, catalogue,...)
Q	time.crossing	Crossing time
Q	time.duration	Interval of time describing the duration of a generic event or phenomenon
Q	time.end	End time/date of a generic event

VO Registry – XML

```
<validationLevel validatedBy="ivo://archive.stsci.edu/nvoregistry">2</validationLevel>
<title>Hubble Space Telescope Spectra</title>
<shortName>HST Spectra</shortName>
<identifier>ivo://mast.stsci/ssap/hst</identifier>
▼<curation>
  <publisher>MAST</publisher>
  ▼<creator>
    <name>MAST</name>
  </creator>
  <version>1.0</version>
  ▼<contact>
    <name>Archive Branch, STScI</name>
    <email>archive@stsci.edu</email>
  </contact>
</curation>
▼<content>
  <subject>UV</subject>
  <subject>Optical</subject>
  <subject>and Infrared Astronomy</subject>
  ▼<description>
    Spectra from the following HST instruments are available: GHRS (processed by CADC), FOS (processed by ECF), and STIS (1st
    order). Service is still under development. Links point to new (but incomplete) VO-compatible FITS files created by MAST staff.
  </description>
  <referenceURL>http://archive.stsci.edu/</referenceURL>
  <type>Archive</type>
  <contentLevel>Research</contentLevel>
</content>
▼<capability standardID="ivo://ivoa.net/std/SSA" xsi:type="ssa:SimpleSpectralAccess">
  ▼<interface role="std" version="0.5" xsi:type="vs:ParamHTTP">
    <accessURL use="base">http://archive.stsci.edu/ssap/search.php?id=HST&</accessURL>
    <queryType>GET</queryType>
  </interface>
  <complianceLevel>query</complianceLevel>
  <dataSource>pointed</dataSource>
  <creationType>archival</creationType>
  <maxSearchRadius>360.0</maxSearchRadius>
  <maxRecords>10000</maxRecords>
  <defaultMaxRecords>10000</defaultMaxRecords>
  <maxAperture>180.0</maxAperture>
  <maxFileSize>1000000000</maxFileSize>
</capability>
▼<coverage>
  ▼<STCResourceProfile xmlns="http://www.ivoa.net/xml/STC/stc-v1.30.xsd">
    <AstroCoordSystem id="mast.stsci_ssap_hstUTC-FK5-TOPO" xlink:href="ivo://STClib/CoordSys#UTC-FK5-TOPO" xlink:type="simple"/>
    ▼<AstroCoords coord_system_id="mast.stsci_ssap_hstUTC-FK5-TOPO">
      ▼<Position1D>
        <Size pos_unit="arcsec">0.0500000007450581</Size>
      </Position1D>
    </AstroCoords>
  </STCResourceProfile>
  <waveband>UV</waveband>
  <waveband>Optical</waveband>
</coverage>
</ri:Resource>
```

Simple Spectra Access Protocol
Spectral Data Model

International Virtual Observatory Alliance

Simple Spectral Access Protocol

Version 1.04

IVOA Recommendation Feb 01, 2008

This version:
http://www.ivoa.net/Documents/REC/DAL/SSA-20080201.html
Latest version:
http://www.ivoa.net/Documents/latest/SSA.html
Previous version(s):
Version 1.03, December 2007
Version 1.02, September 2007
Version 1.01, June 2007
Version 1.00, May 2007
Version 0.97, November 2006
Version 0.96, September 2006
Version 0.95 May 2006
Version 0.91 October 2005
Version 0.90 May 2005
Editors:
D.Tody, M. Dolensky
Authors:
D.Tody, M. Dolensky, J. McDowell, F. Bonnarel, T.Budavari, I.Busko, A. Micol, P.Osuna, J.Salgado, P.Skoda, R.Thompson, F.Valdes, and the data access layer working group.

International Virtual Observatory Alliance

IVOA Spectral Data Model

Version 1.03

IVOA Recommendation 2007-10-29

This version (Recommendation Rev 1)
http://www.ivoa.net/Documents/REC/DM/SpectrumDM-20071029.pdf
Latest version:
http://www.ivoa.net/Documents/latest/SpectrumDM.html
Previous versions:
http://www.ivoa.net/Documents/PR/DM/SpectrumDM-20070913.html

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SSAP Parameters

4.1.1 Mandatory Query Parameters

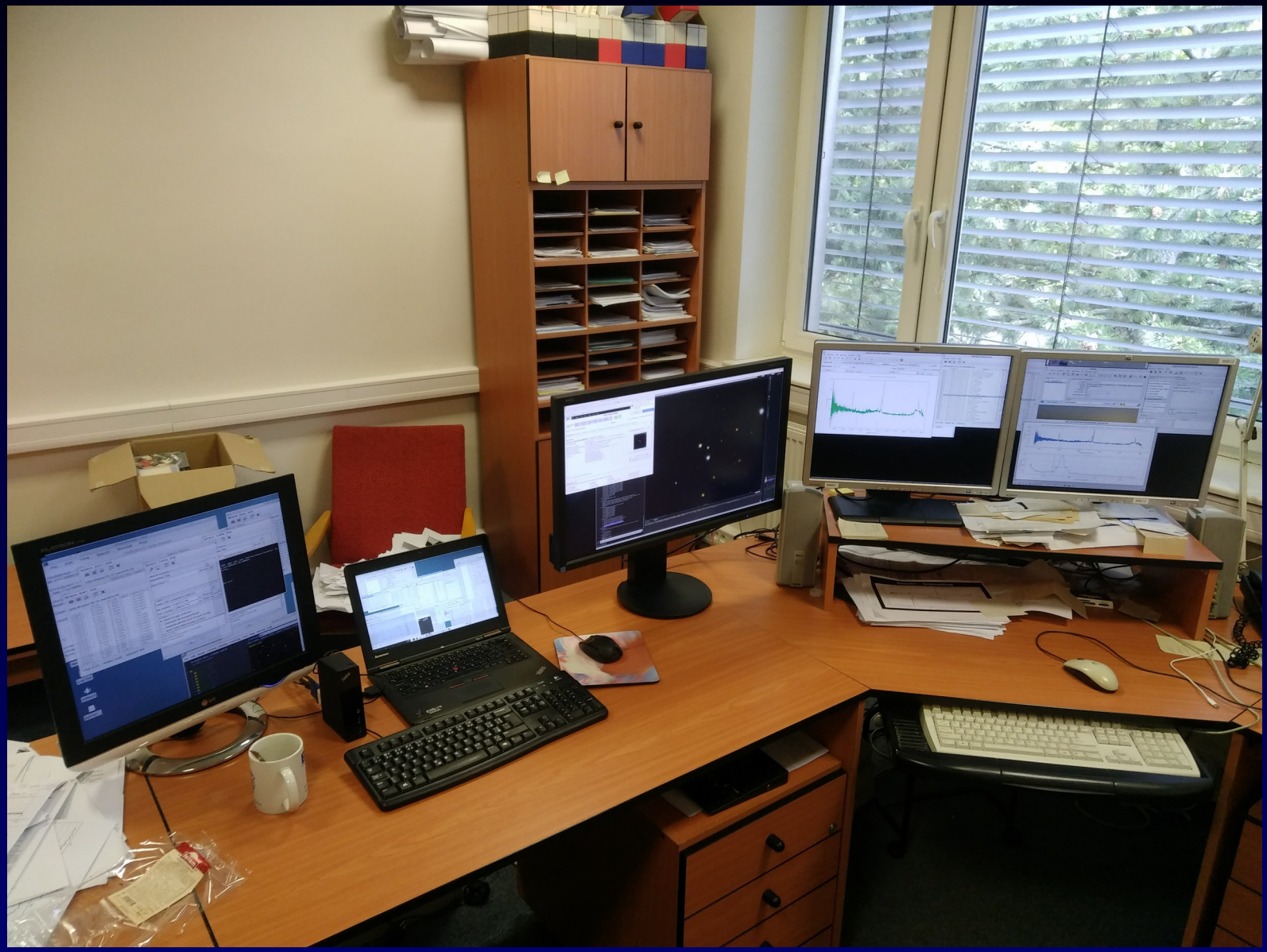
The following parameters **must** be implemented by a compliant service:

Parameter	*Sample value*	*Physical unit*	*Datatype*
POS	52,-27.8	degrees; defaults to ICRS	string
SIZE	0.05	degrees	double
BAND	2.7E-7/0.13	meters	string
TIME	1998-05-21/1999	ISO 8601 UTC	string
FORMAT	votable	-	string

4.1.2 Recommended and Optional Query Parameters

Parameter	Sample value	Unit	Req	Datatype
APERTURE	0.00028 (=1")	degrees	OPT	double
SPECRP	2000	λ/dλ	REC	double
SPATRES	0.05	degrees	REC	double
TIMERES	31536000 (=1yr)	seconds	OPT	double
SNR	5.0	dimensionless	OPT	double
REDSHIFT	1.3/3.0	dimensionless	OPT	string
VARAMPL	0.77	dimensionless	OPT	string
TARGETNAME	mars		OPT	string
TARGETCLASS	star		OPT	string
FLUXCALIB	relative		OPT	string
WAVECALIB	absolute		OPT	string
PUBDID	ADS/col#R5983		REC	string
CREATORDID	ivo://auth/col#R1234		REC	string
COLLECTION	SDSS-DR5		REC	string
TOP	20	dimensionless	REC	int
MAXREC	5000		REC	string
MTIME	2005-01-01/2006-01-01	ISO 8601	REC	string
COMPRESS	true		REC	boolean
RUNID			REC	string

Analysis



Live Demo...