

Global Scientific Data Sharing and Big Data Knowledge discovery

*** * * * ***

Czech Virtual Observatory and COST action Big Sky Earth

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Supported by grant COST LD-15113 of the
Czech Ministry of Education Youth and Sports
And COST Action TD1403 Big Sky Earth

RDA Meets Czech Researchers
Prague, Czech Republic, 27th October 2017

Credits

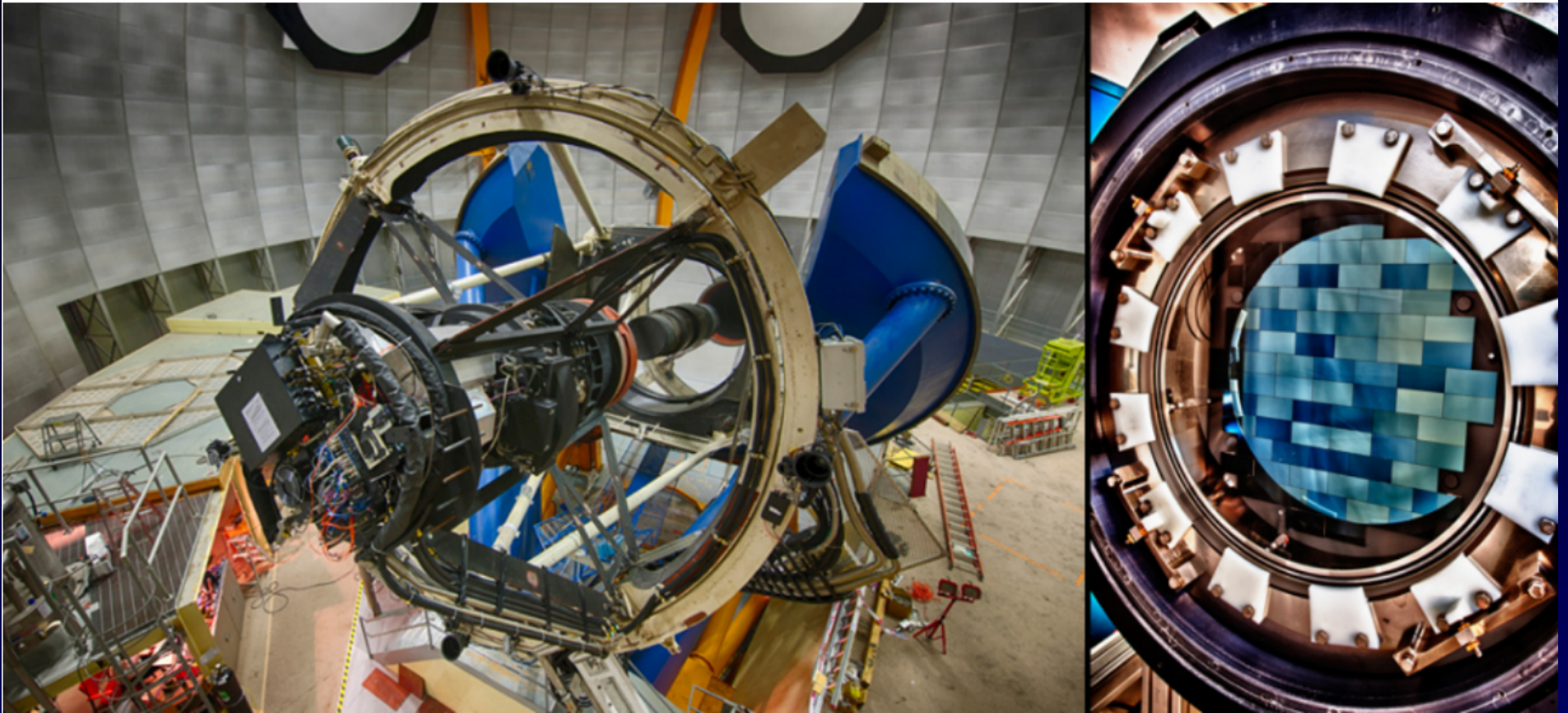
- The presentation is based on many different sources – mainly the on-line published slides from IVOA meetings, slides from Astrodynamics and COST meetings or pictures found on Internet.
- We acknowledge namely materials of B.Hanish, G. Djorgovski, G. Longo, T. Hey and M. Breddels, D Vinkovic, P. Baumann, A Nina and presentations from AI2016 in Sorrento

Outline of the Talk

- Data Avalanche in astronomy
- Virtual Observatory
- Astroinformatics
- Big Sky Earth
- Transfer of technology
- CZVO
 - Be stars discovery in LAMOST surveys
 - Ondrejov Southern Photometry Survey
- Future

Dark Energy Survey Camera

Dark Energy Camera (DECam)



~0.4 PB/yr

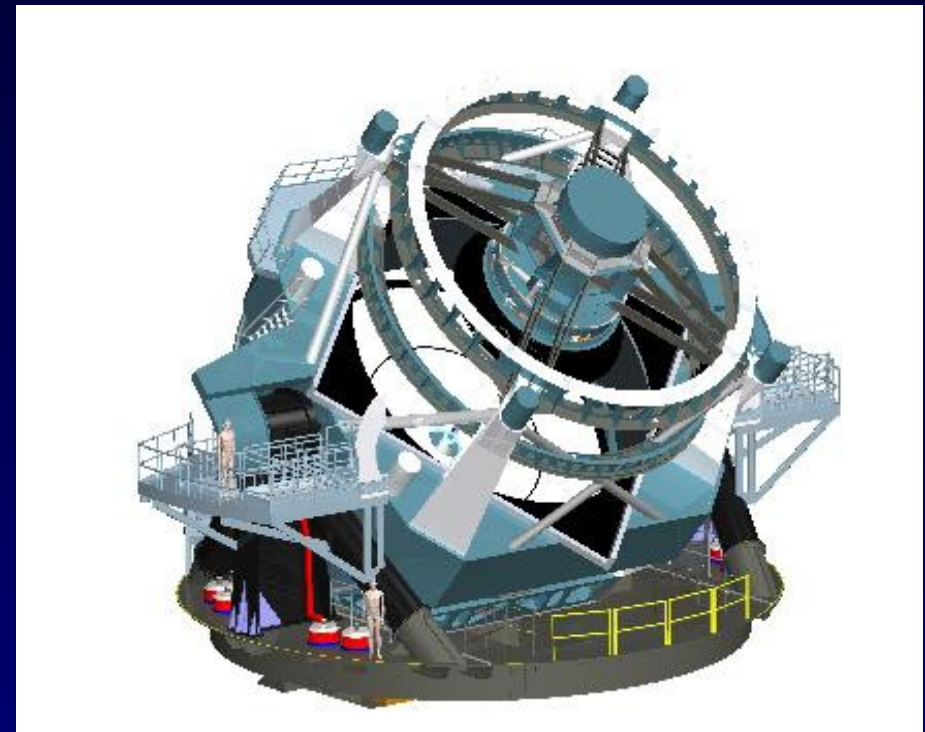
74 chips – 570 Mpixels - 4m Cerro Tololo

Large Synoptic Survey Telescope



201 CCD 4kx4k,
3.2 Gpix every 20 sec
3.5 deg FOV (64cm)
20 TB/day=6 PB/yr RAW
1.5 PB catalogue !!!
detection of changes 60s!

38 billion objects x 1000
32 tril. meas. -5 PB table

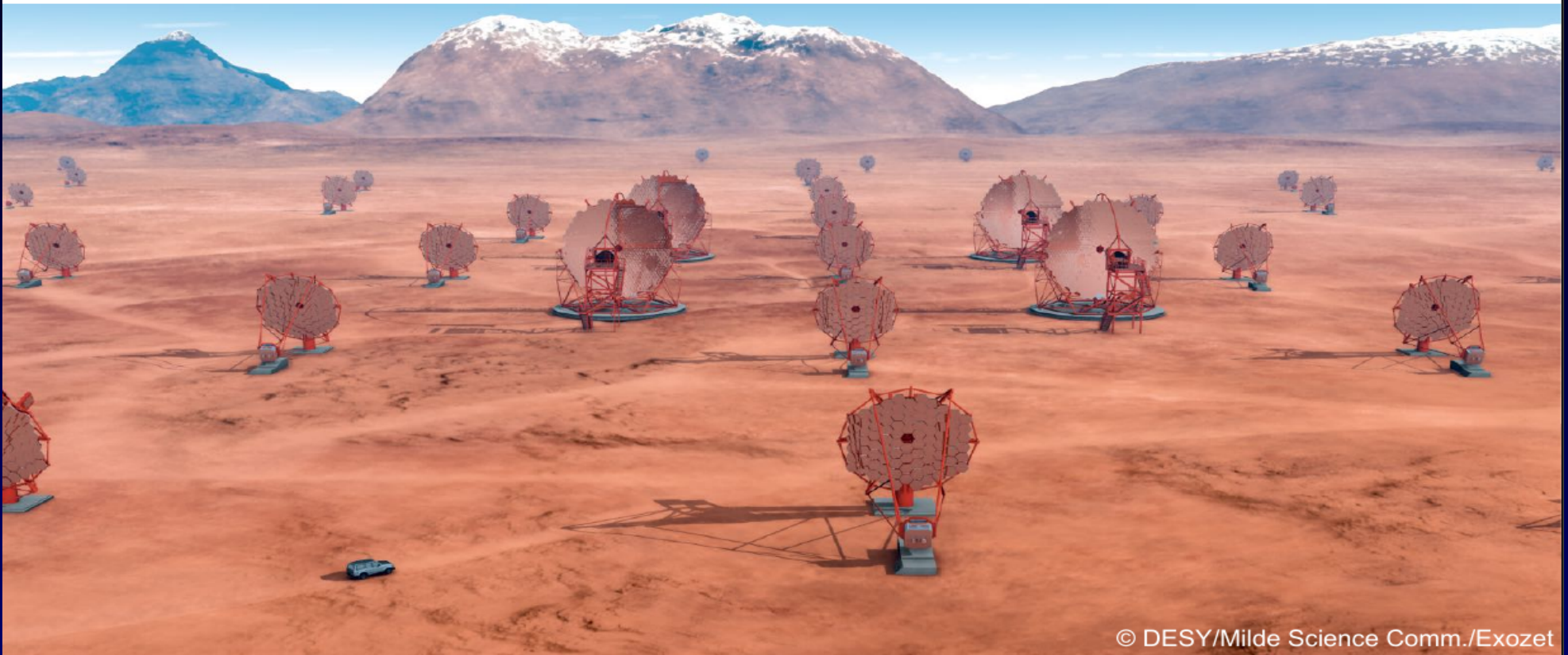


Cherenkov Telescope Array

Cherenkov Astronomy and CTA



- ◆ Two arrays of 100 (South) et 20 (North) telescopes
- ◆ July 2015: sites selection, Chile (ESO) and La Palma
- ◆ 2016: pre-production phase
- ◆ 2018-2013: production phase
- ◆ Observatory open to the community



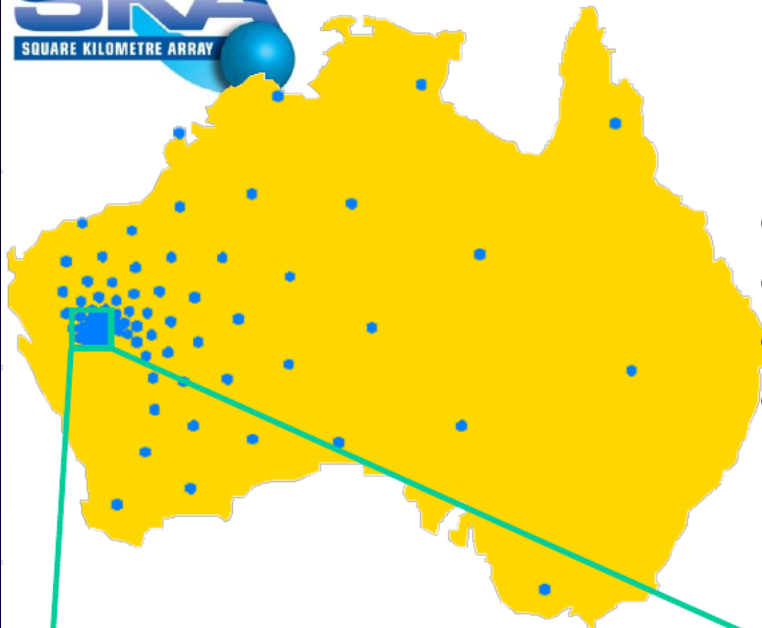
© DESY/Milde Science Comm./Exozet

SKA

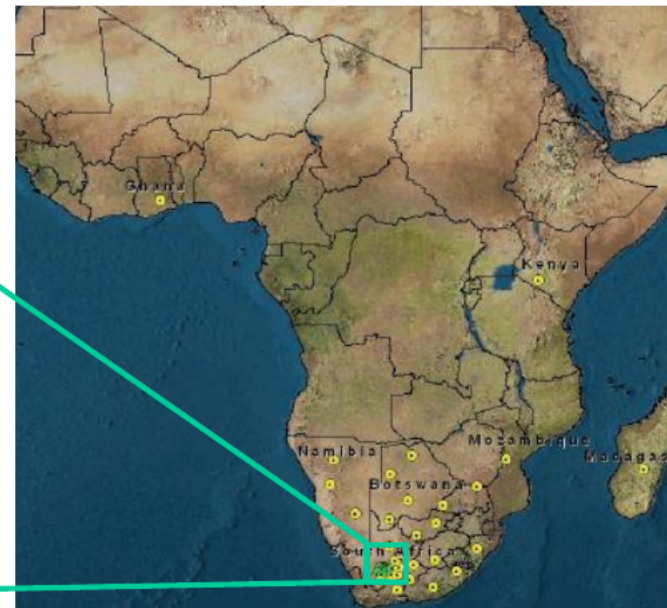
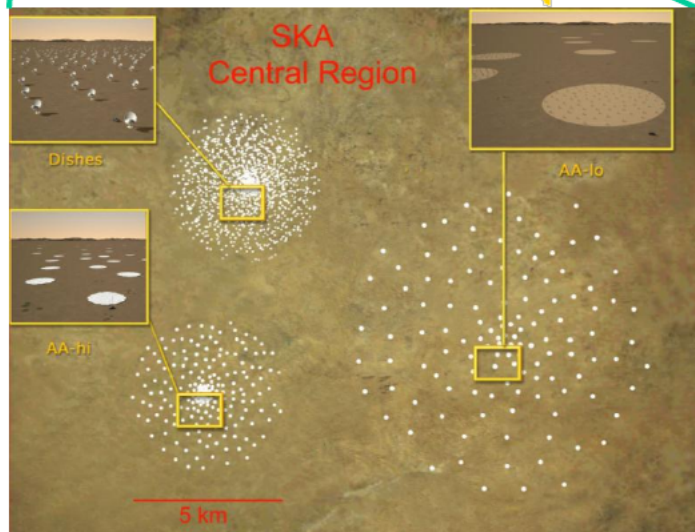


Dishes

SKA



- Need a radio-quiet site
- Very low population density
- Large amount of space
- Possible sites (decision 2012)
 - Western Australia
 - Karoo Desert RSA



LOFAR network



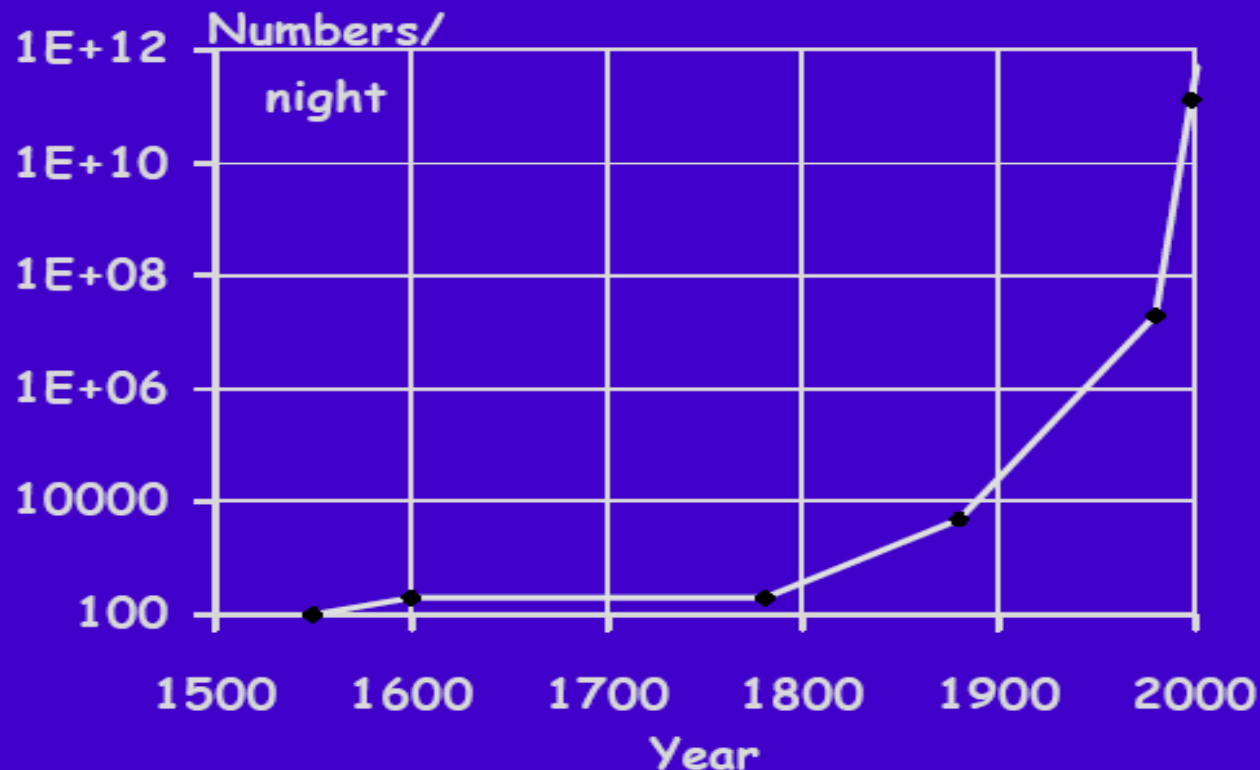
	LOFAR	SKA
Raw Telescope	112 PB/yr	60 EB/yr
Archive Rate	6 PB/yr	100 PB/yr

Data Avalanche

Moore law for chips –doubling 1.5 year

Data in astronomy – doubling < 1 yr ! (1000/10 yr)

====> Processing to data



$T_2 < 18$ mths
1990-2000

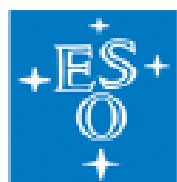
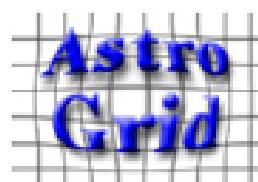
Virtual Observatory : Key Definitions

- “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.

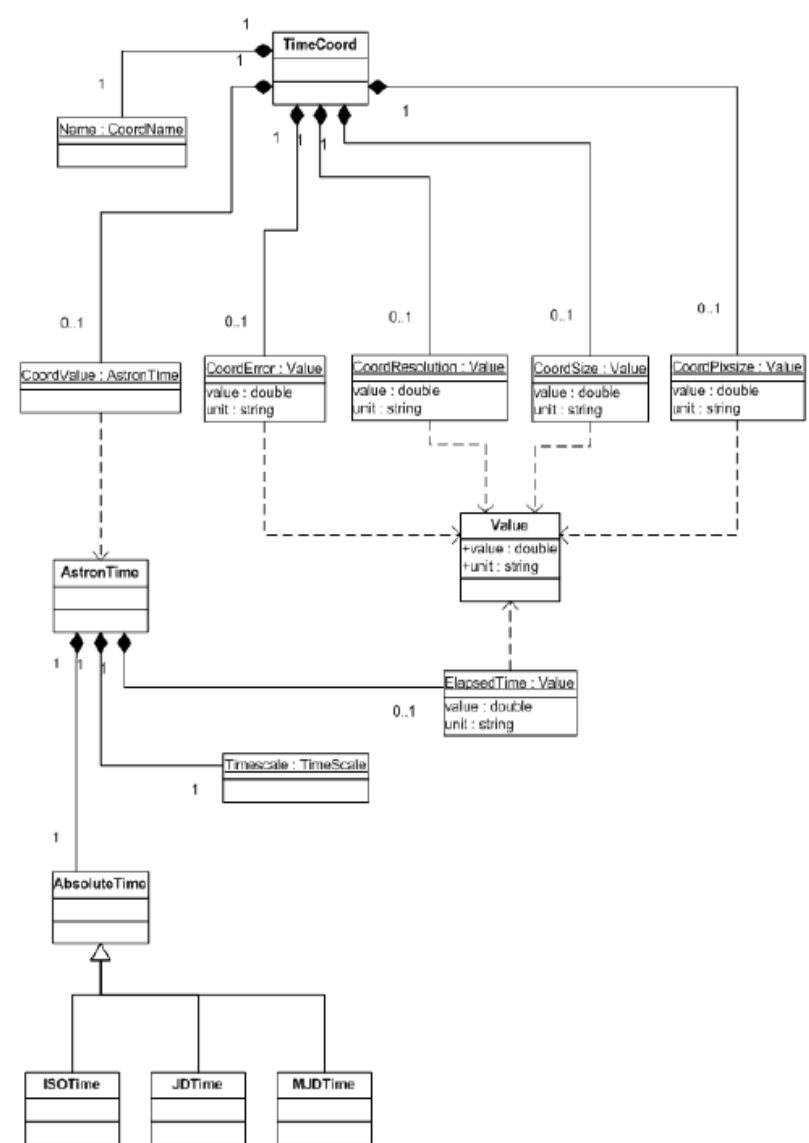
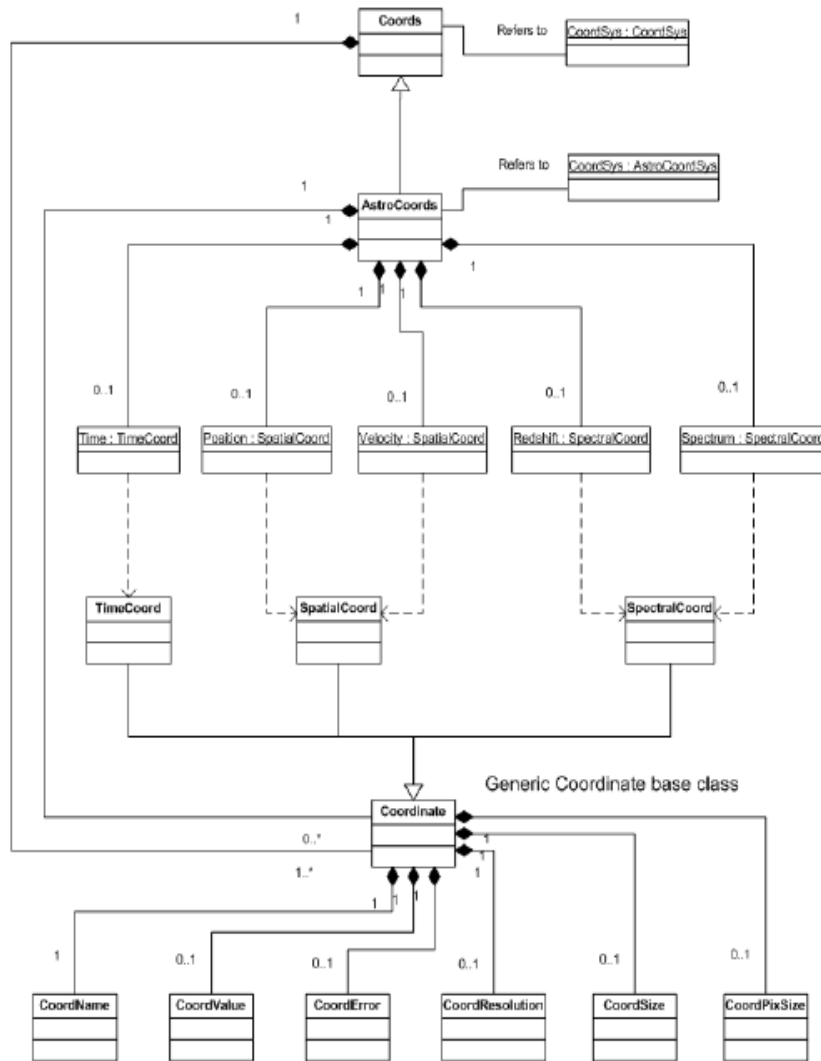
R.J.Hanisch, P.J.Quinn, in “IVOA – Guidelines for participation”

Start of VO – early 2000

IVOA



Space-Time-Coordinate Data Model



Technology of VO

Unified data format– VOTable, UCD (semantics)

Web services (WS)

VOregistry – 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)

datacubes, **DATALINK** on-the-fly data processing

Technology of VO

ADQL (Astronomical Data Query Language)

XMATCH, REGION (2 catalogues – shifted)

Application interoperability – SAMP

Allows develop applications as bricks

sending VOTABLES (catalogue-spectra-images)

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

Simple Spectra Access Protocol Spectral Data Model

Simple Spectral Access Protocol V1.04



*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>

Editors:

Jonathan McDowell, Doug Tody

Contributors:

Jonathan McDowell, Doug Tody, Tamas Budavari, Markus Dolensky, Inga Kamp, Kelly McCusker, Pavlos Protopapas, Arnold Rots, Randy Thompson, Frank Valdes, Petr Skoda, and the IVOA Data Access Layer and Data Model Working Groups.

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

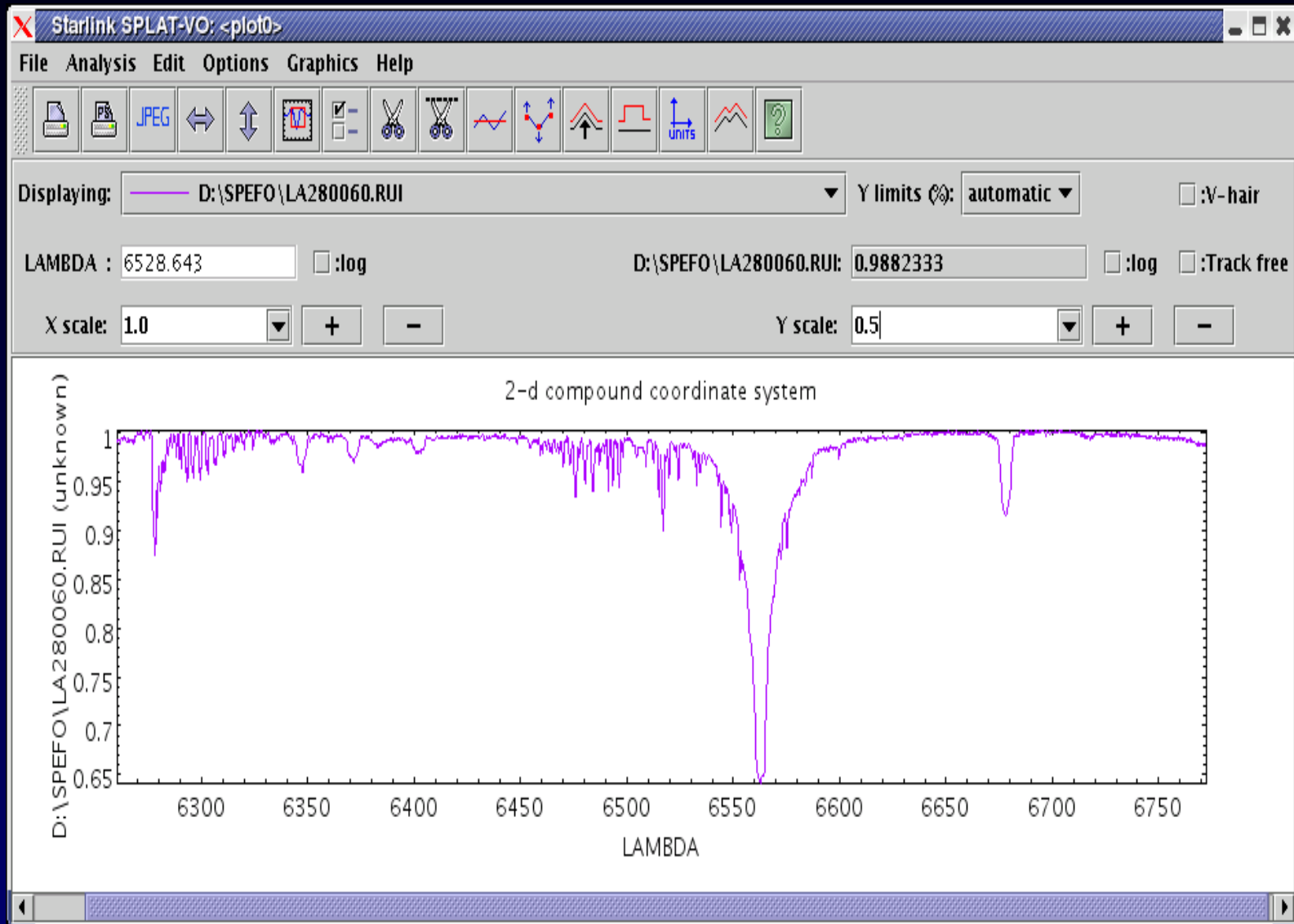
4.1.2 Recommended and Optional Query Parameters

Parameter	Sample value	Unit	Req	Datatype
APERTURE	0.00028 (=1")	degrees	OPT	double
SPECRP	2000	$\lambda/d\lambda$	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
CREATORID	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

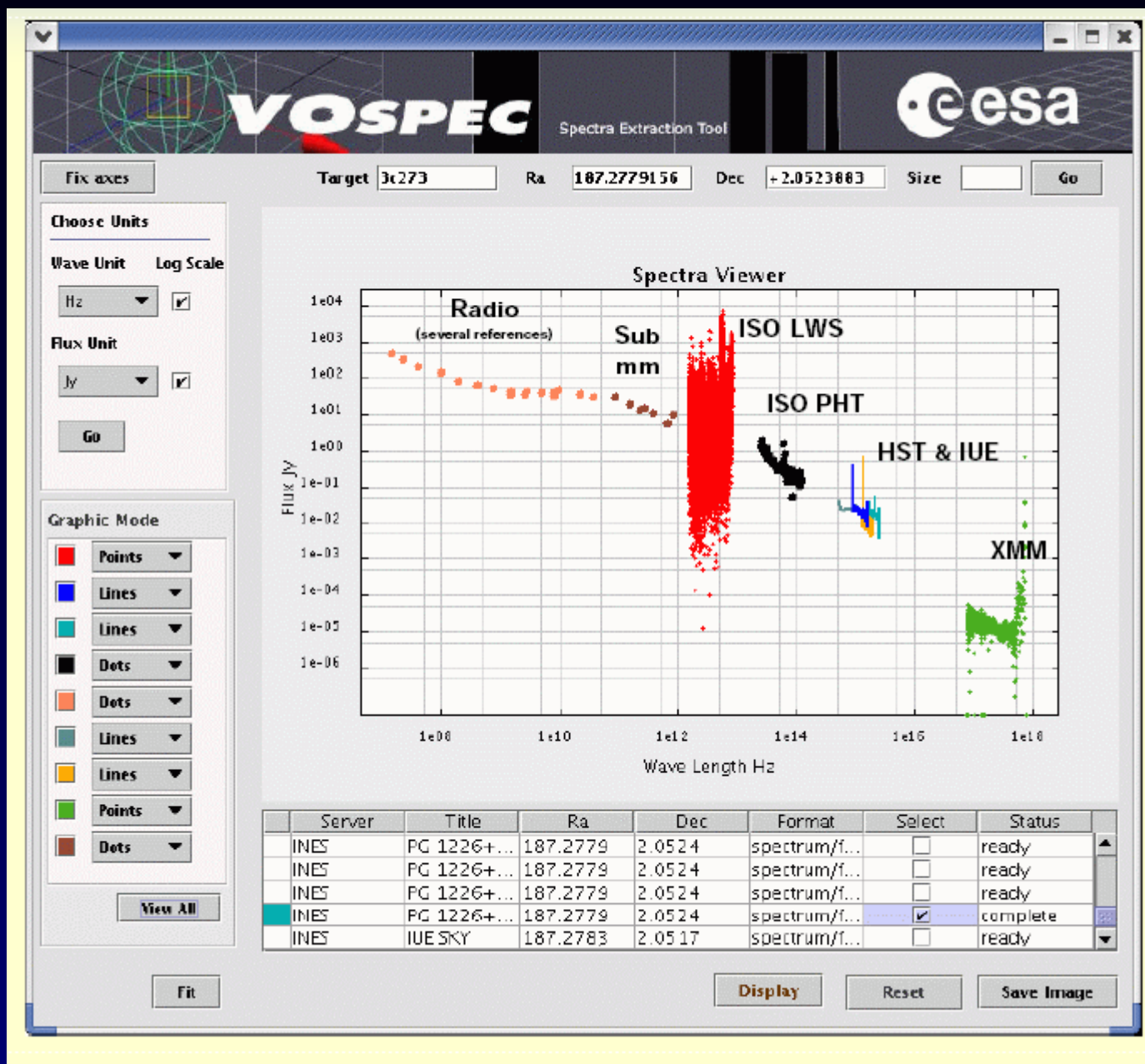
The spatial, spectral, and time resolution of the data may all be used as query parameters.

SPLAT-VO

(Starlink, Heidelberg, Ondrejov)



VOSpec (ESAC)

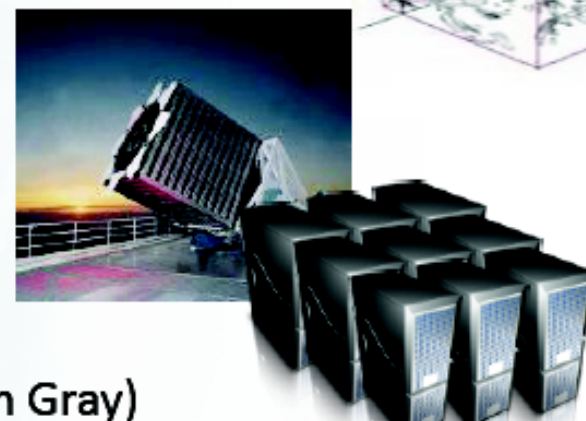
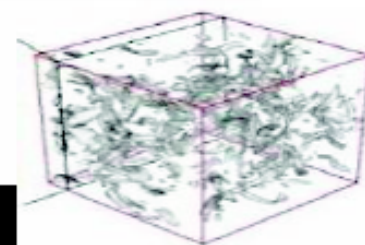


Emergence of a Fourth Research Paradigm

1. Thousand years ago – **Experimental Science**
 - Description of natural phenomena
 2. Last few hundred years – **Theoretical Science**
 - Newton's Laws, Maxwell's Equations...
 3. Last few decades – **Computational Science**
 - Simulation of complex phenomena
 4. Today – **Data-Intensive Science**
 - Scientists overwhelmed with data sets from many different sources
 - Data captured by instruments
 - Data generated by simulations
 - Data generated by sensor networks
- **eScience is the set of tools and technologies to support data federation and collaboration**
- For analysis and data mining
 - For data visualization and exploration
 - For scholarly communication and dissemination

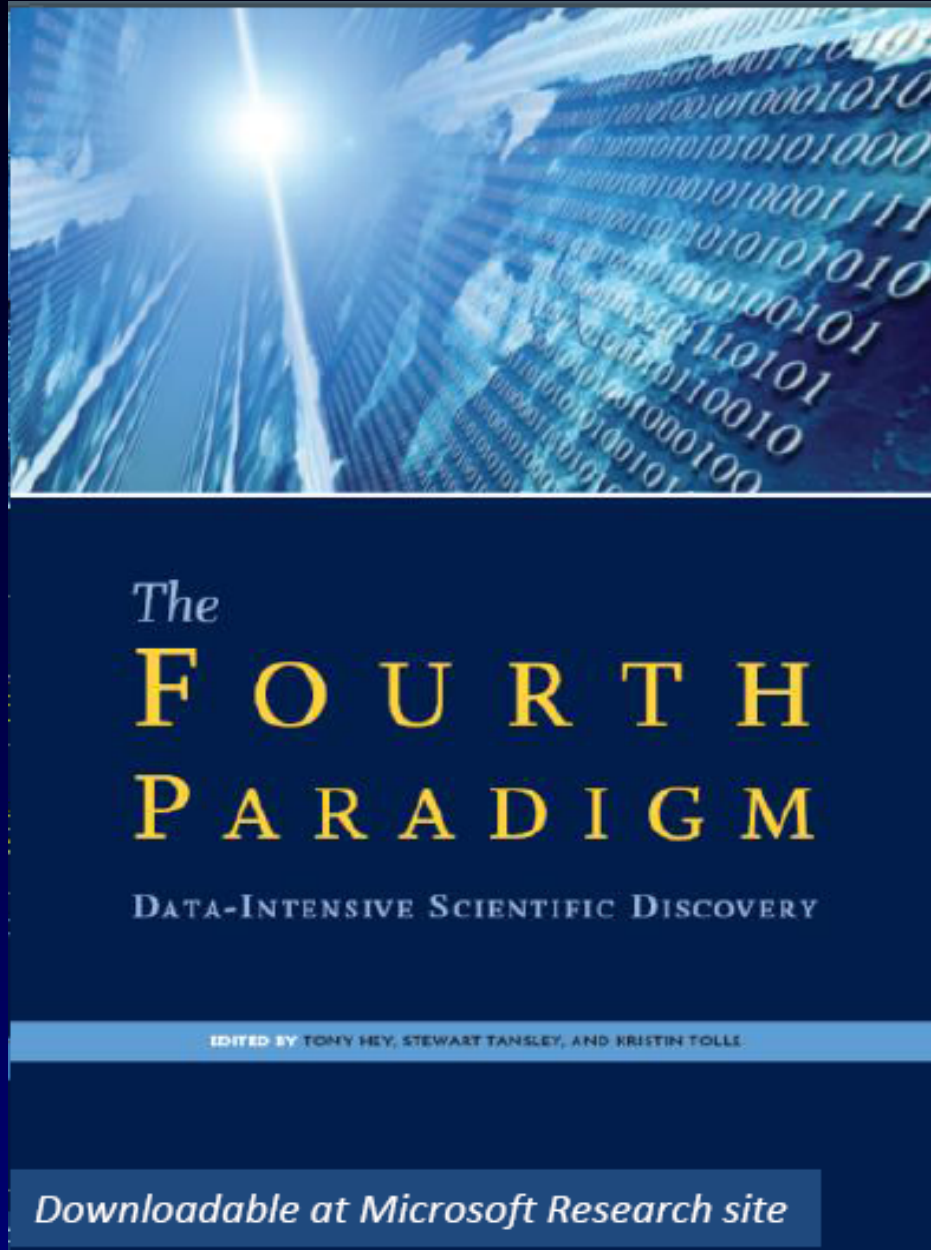


$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K \frac{c^2}{a^2}$$



(With thanks to Jim Gray)

X-informatics

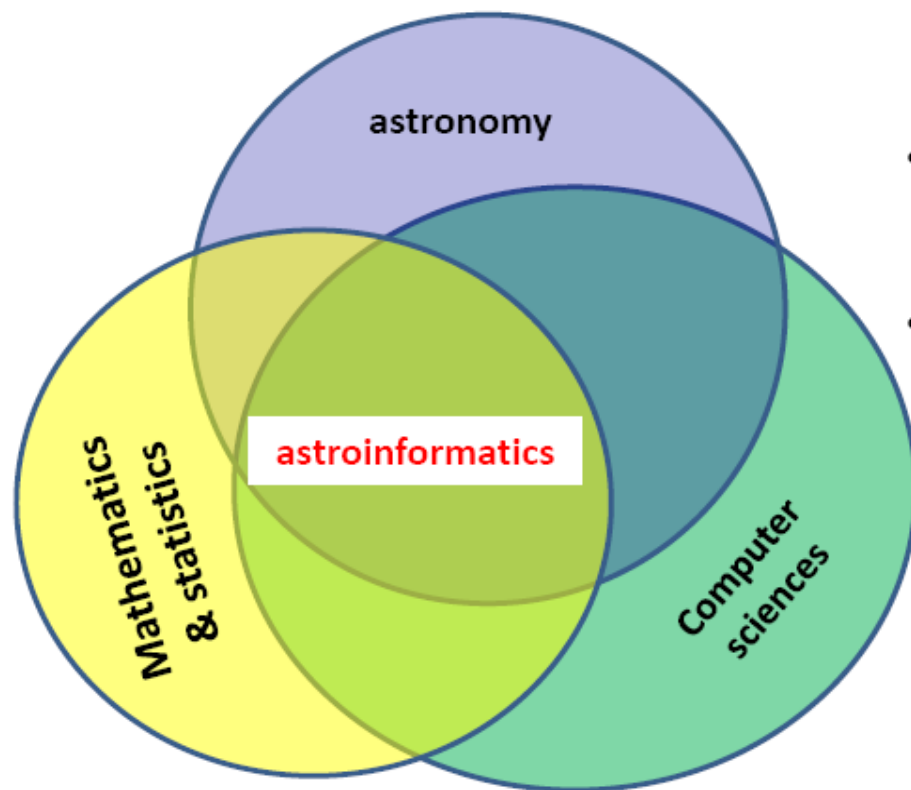


Changing methodology of
the Science

Synergy between different
worlds

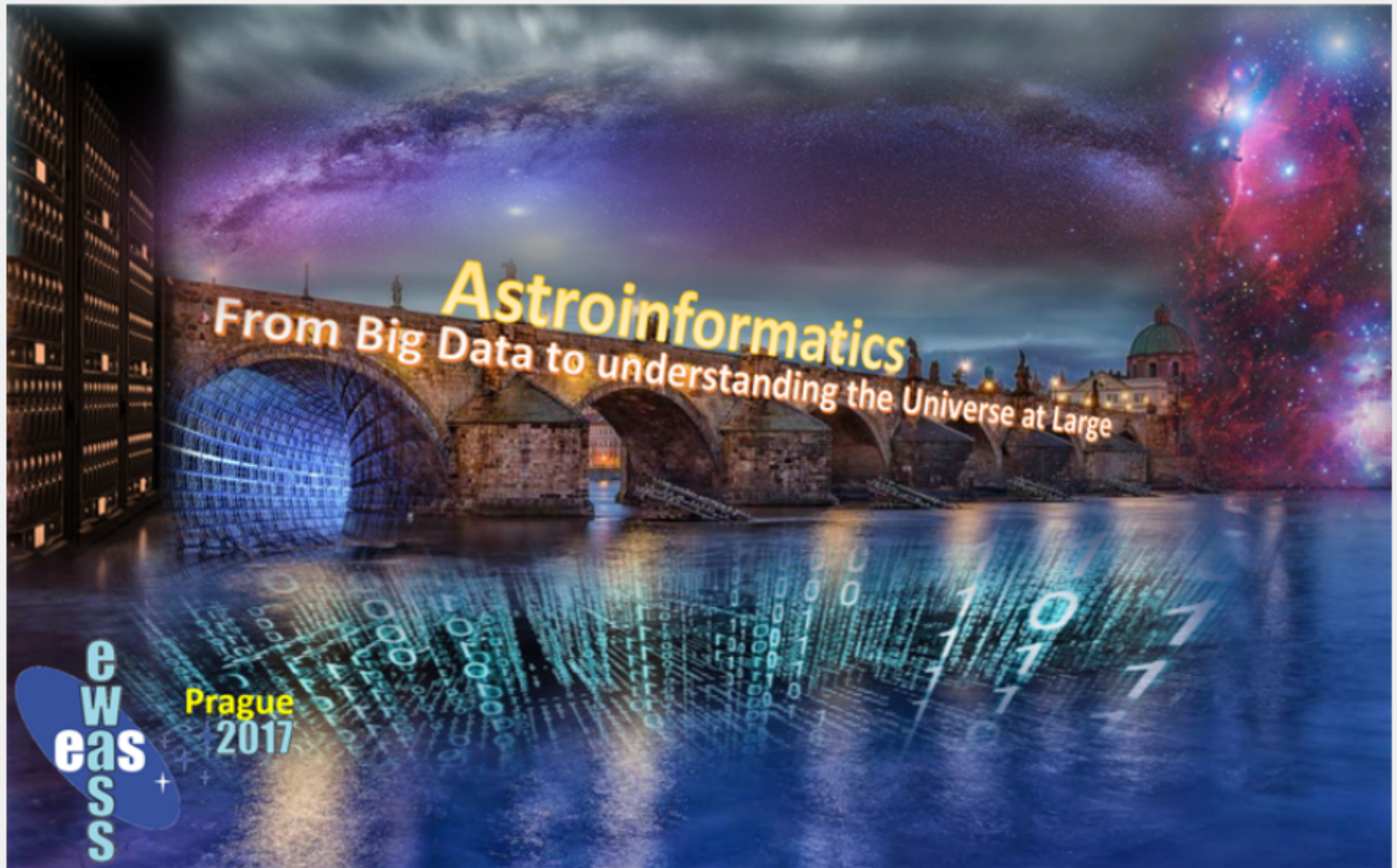
Sociological aspects
(net-based research
communities)

Experimental astronomy has become a three players game



- **astronomy:** problems, data, understanding of the data structure and biases
- **mathematics:** evaluation of the data, falsification/validation of theories/models, etc
- **computer science:** implementation of infrastructures, databases, middleware, scalable tools, etc

- **Astroinformatics:** AAS n. 215, Washington, December 2009, chairperson: K. Borne
- **Astroinformatics 2010:** Caltech (USA) June 16-19 2010; co-chairpersons: S.G. Djorgovski, G. Longo
- **Astroinformatics 2011:** UNINA – Sorrento, co-chairpersons: S.G. Djorgovski, G. Longo



Need for a new science: Astroinformatics

Knowledge Discovery in Databases

Data Gathering (e.g., from sensor networks, telescopes...)

→ Data Farming:

Storage/Archiving
Indexing, Searchability
Data Fusion, Interoperability, ontologies, etc.

→ Data Mining (or Knowledge Discovery in Databases):

Pattern or correlation search
Clustering analysis, automated classification
Outlier / anomaly searches
Hyperdimensional visualization

→ Data understanding

Computer aided understanding
KDD
Etc.

→ New Knowledge



Database technologies

Key mathematical issues

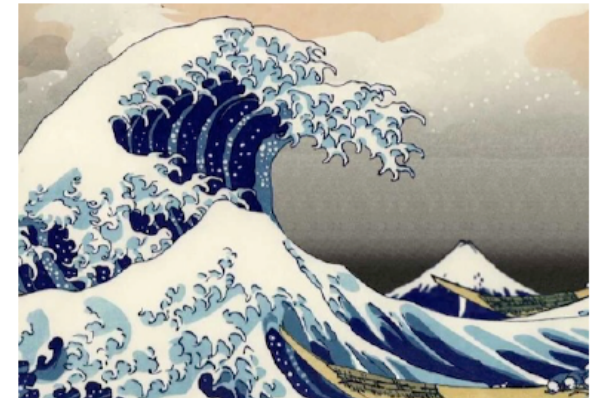
Ongoing research



Data Driven Science

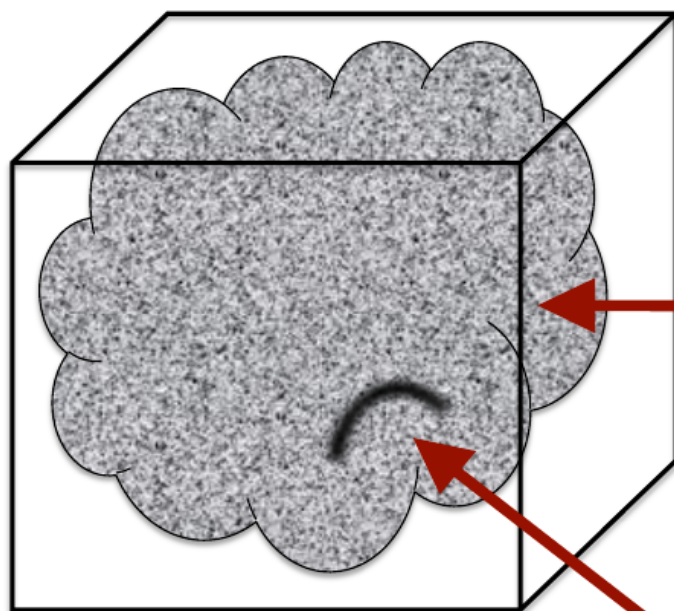
What is Fundamentally New Here?

- The *information volumes and rates* grow exponentially
→ *Most data will never be seen by humans*
- A great increase in the data *information content*
→ *Data driven vs. hypothesis driven science*
- A great increase in the *information complexity*
→ *There are patterns in the data that cannot be comprehended by humans directly*



Hidden Patterns in Data

Pattern or structure (Correlations, Clustering, Outliers, etc.) Discovery in High-Dimensional Parameter Spaces



$D \gg 3$ parameter
space hypercube

High-D data cloud:
mostly noise, of an
arbitrary distribution

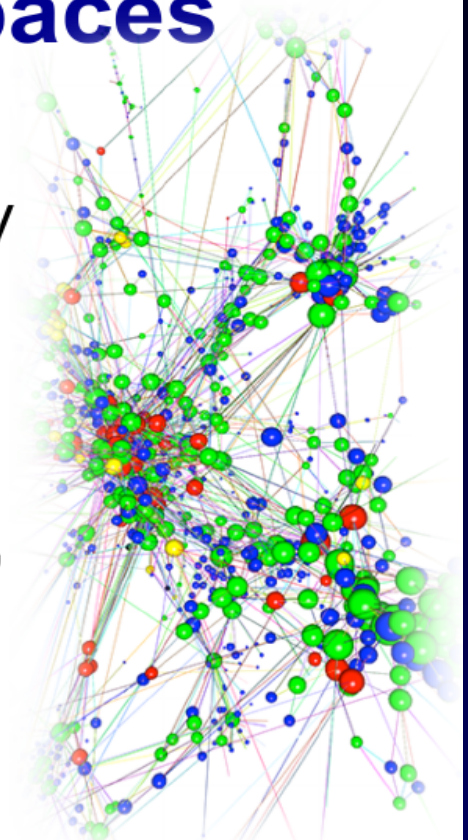
But in some corner of
some sub-D projection of
this data space, there is
something \neq noise

Visualization in Machine Learning

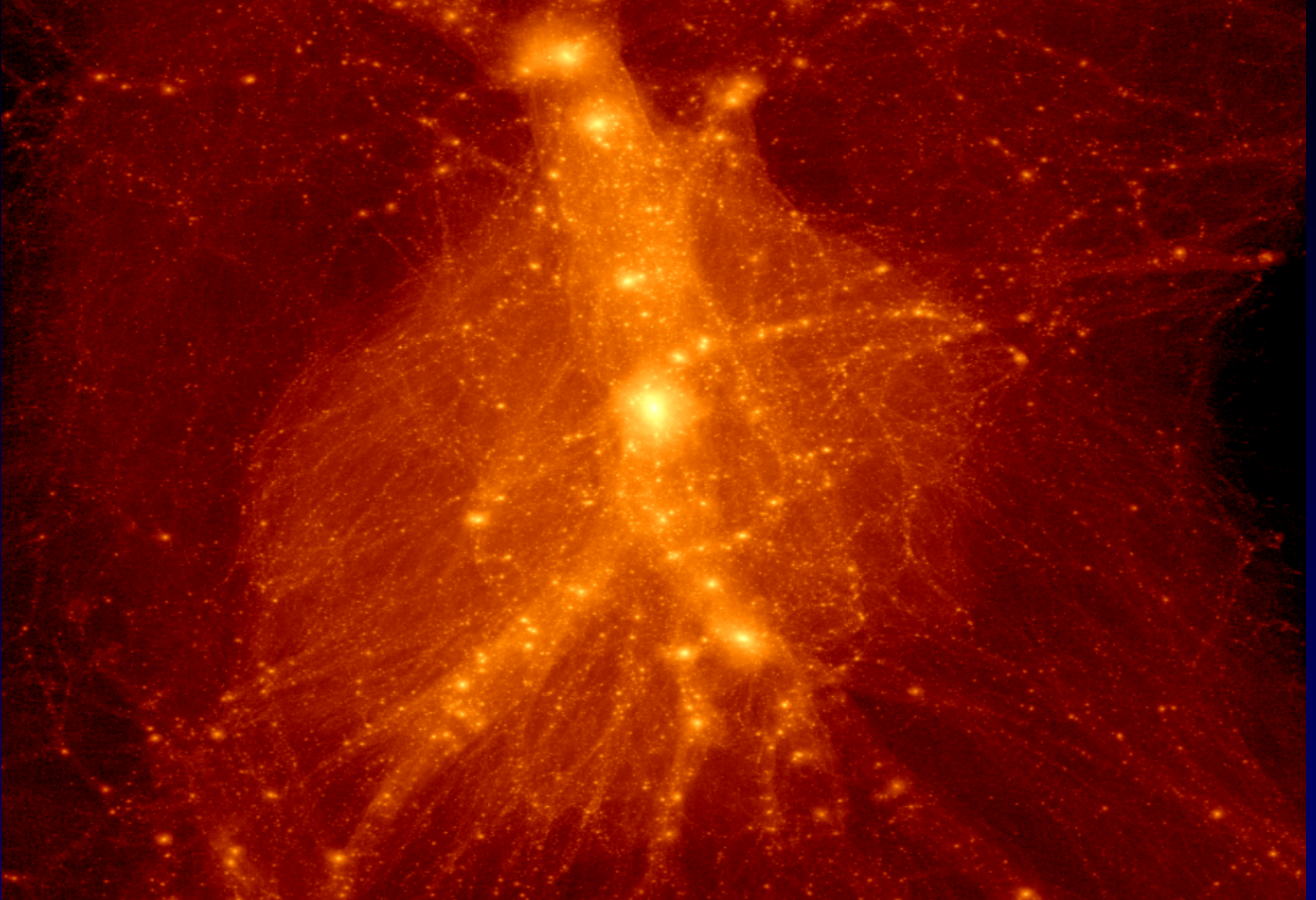
A Key Challenge: Visualising Multidimensional Data Spaces

- Hyperdimensional structures (clusters, correlations, etc.) may be present in many complex data sets, whose dimensionality may be $D \sim 10^2 - 10^4$, or higher
- It is a matter of ***data understanding***, choosing the right data mining algorithms, and interpreting the results
- We are biologically limited to perceiving up to $\sim 3 - 12(?)$ dimensions

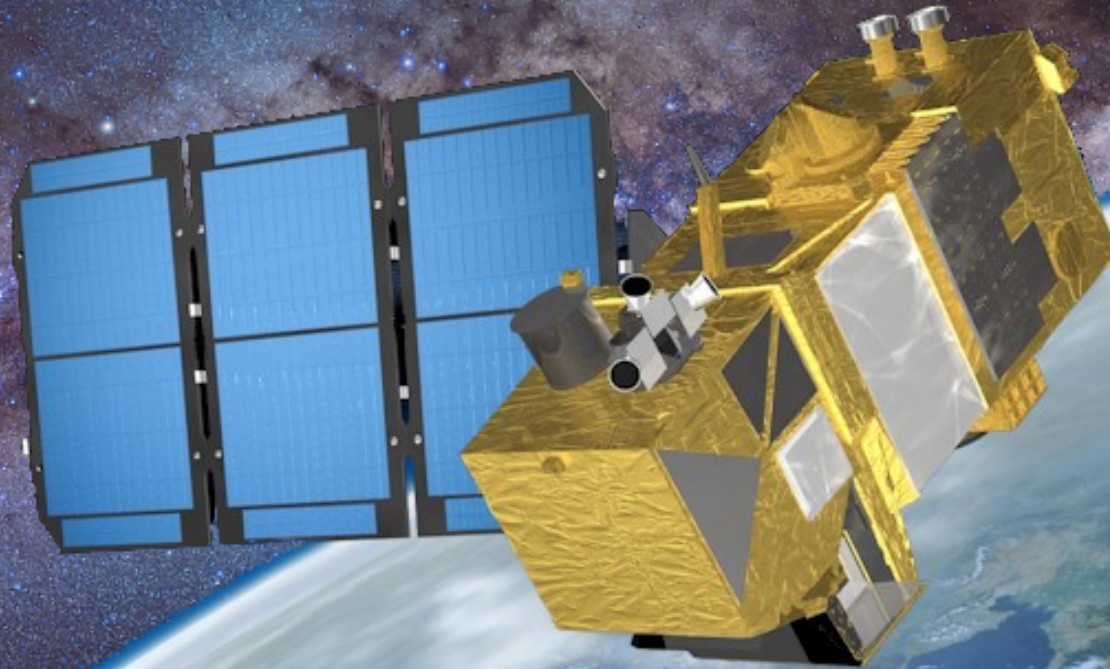
What good are the data if we cannot effectively extract knowledge from them?



Visualization of Big Data



Big Data Era in Sky and Earth Observation – TD 1403 COST action



P. Škoda
Czech Representative in MC



sentinel-1A

Launch date: 3. April 2014
 up to **2.4 TB/day** of imaging radar data for **7 years** (fully open and free data access policy)

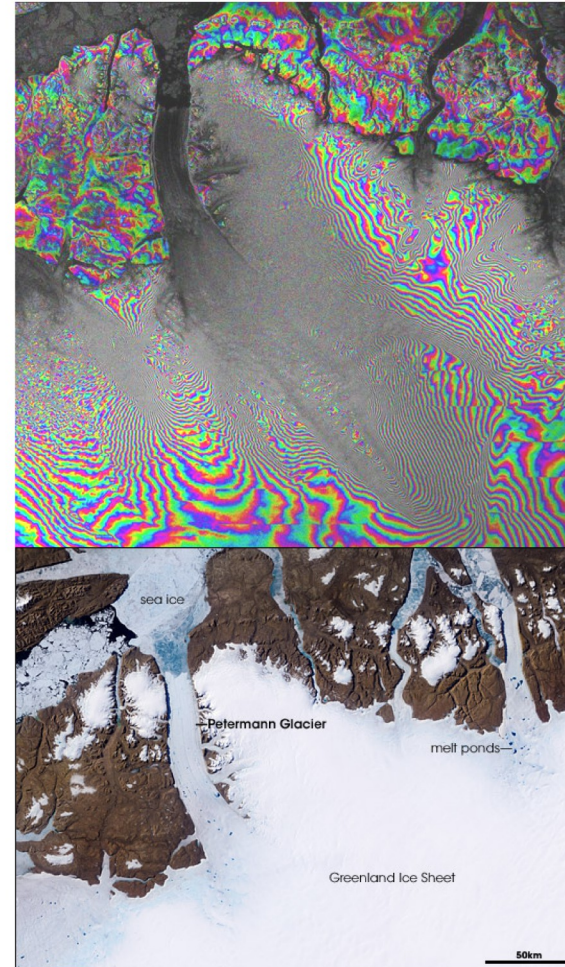
Applications: Oceans and ice, Changing lands, Emergency response

Part of the **European Earth Observation Programme Copernicus**: the most ambitious Earth observation programme to date: 30 satellites: **peta-bytes now: zetta-bytes in a decade**

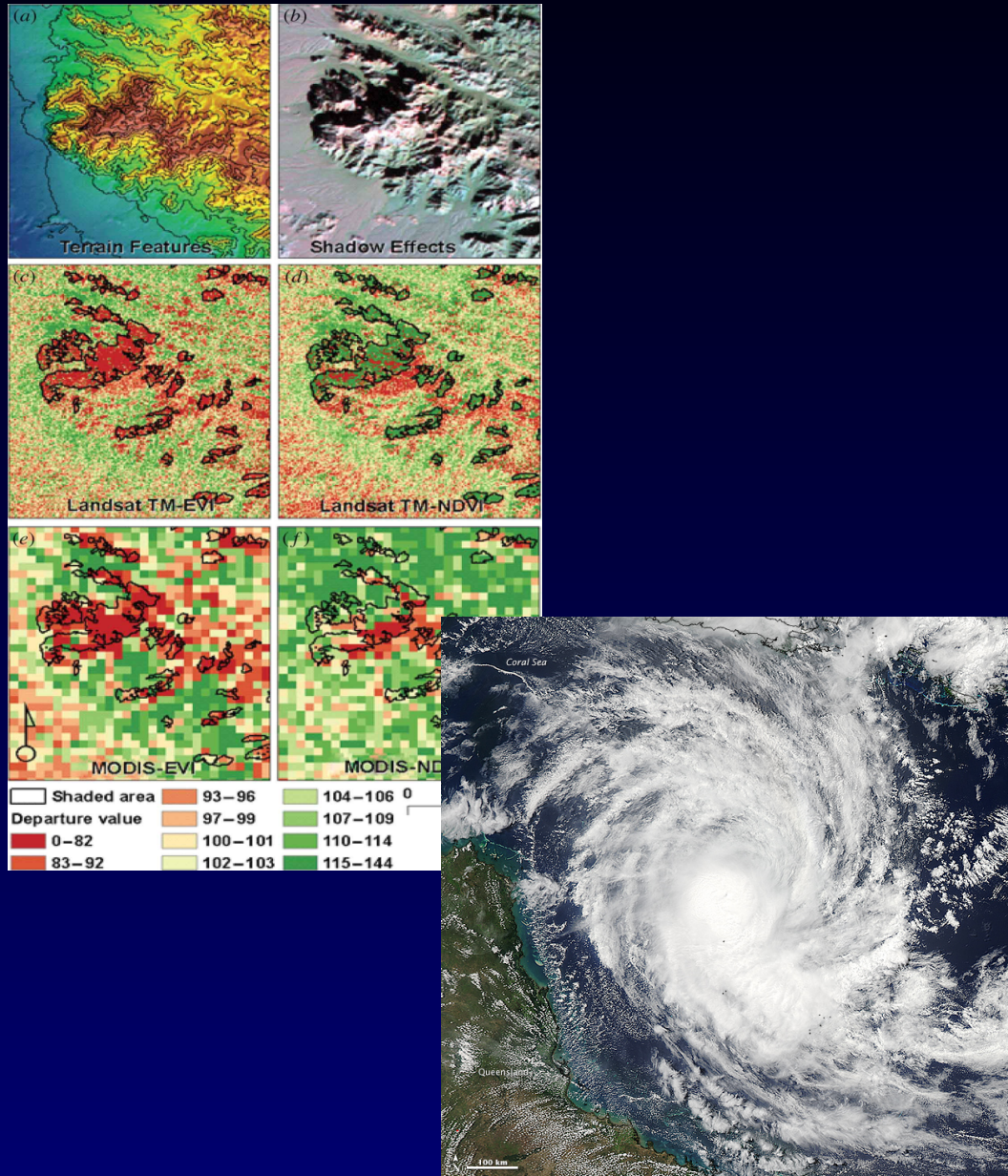


The era of Big Data has arrived!

Example: images + time = surface movements



Remote sensing - Big Data Machine Learning



Precise farming

Forestry

Ore mining

Water resources monitoring

Automatic classification of terrain

Resistance of buildings (Aquila)

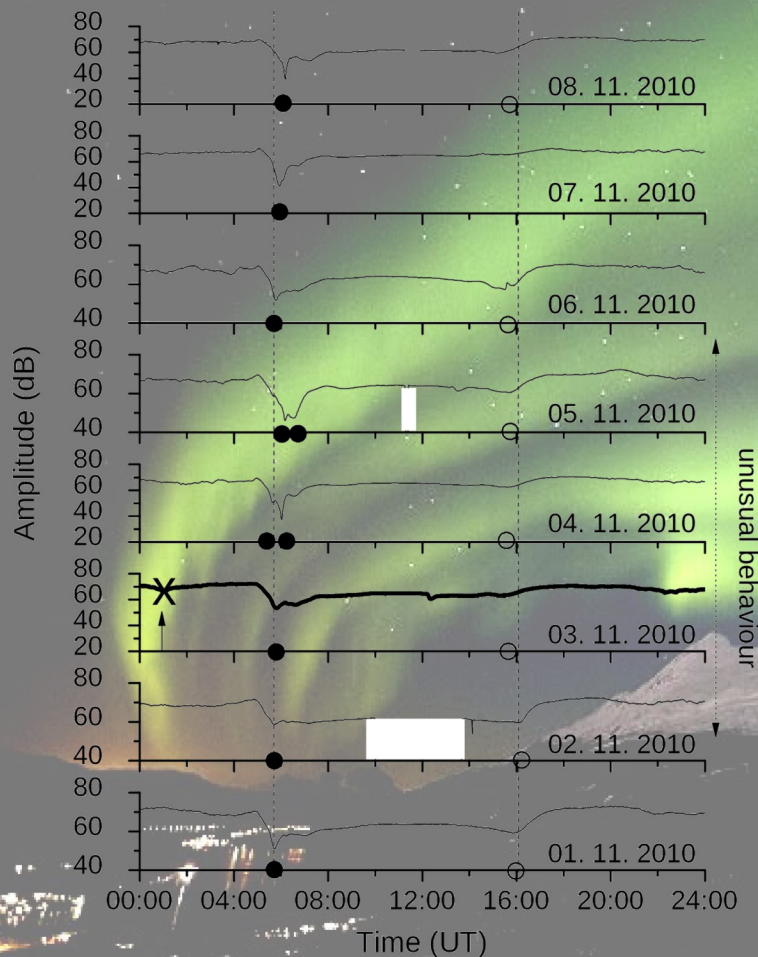
Mobile network structure – disasters

Customized product for every user

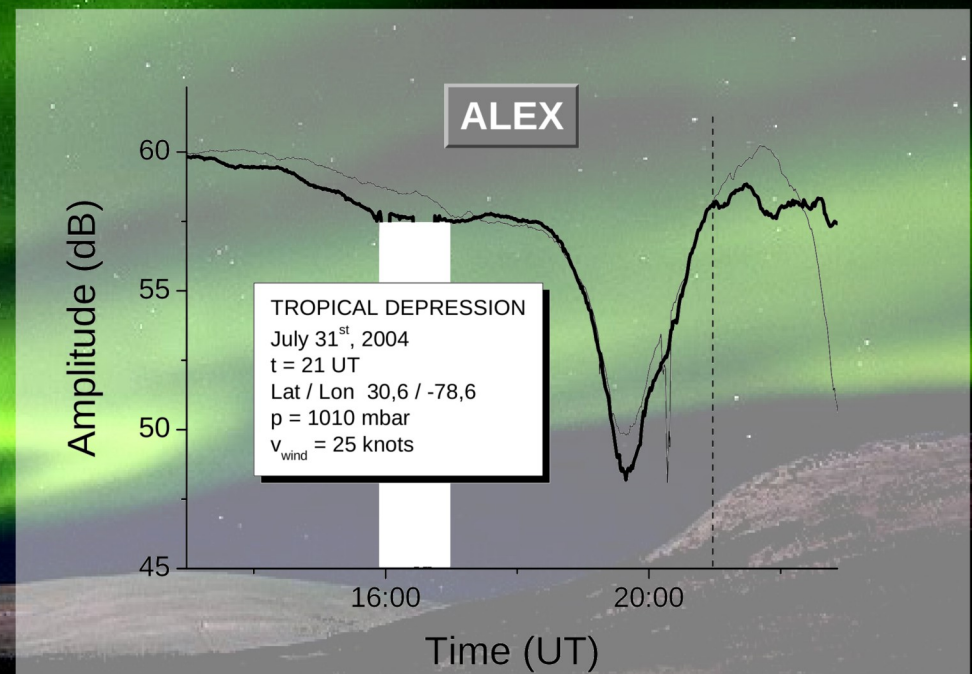
Ionospheric variations and natural disasters predictions

Earthquake

Kraljevo (43.74 N, 20.69 E), November 3, 2010

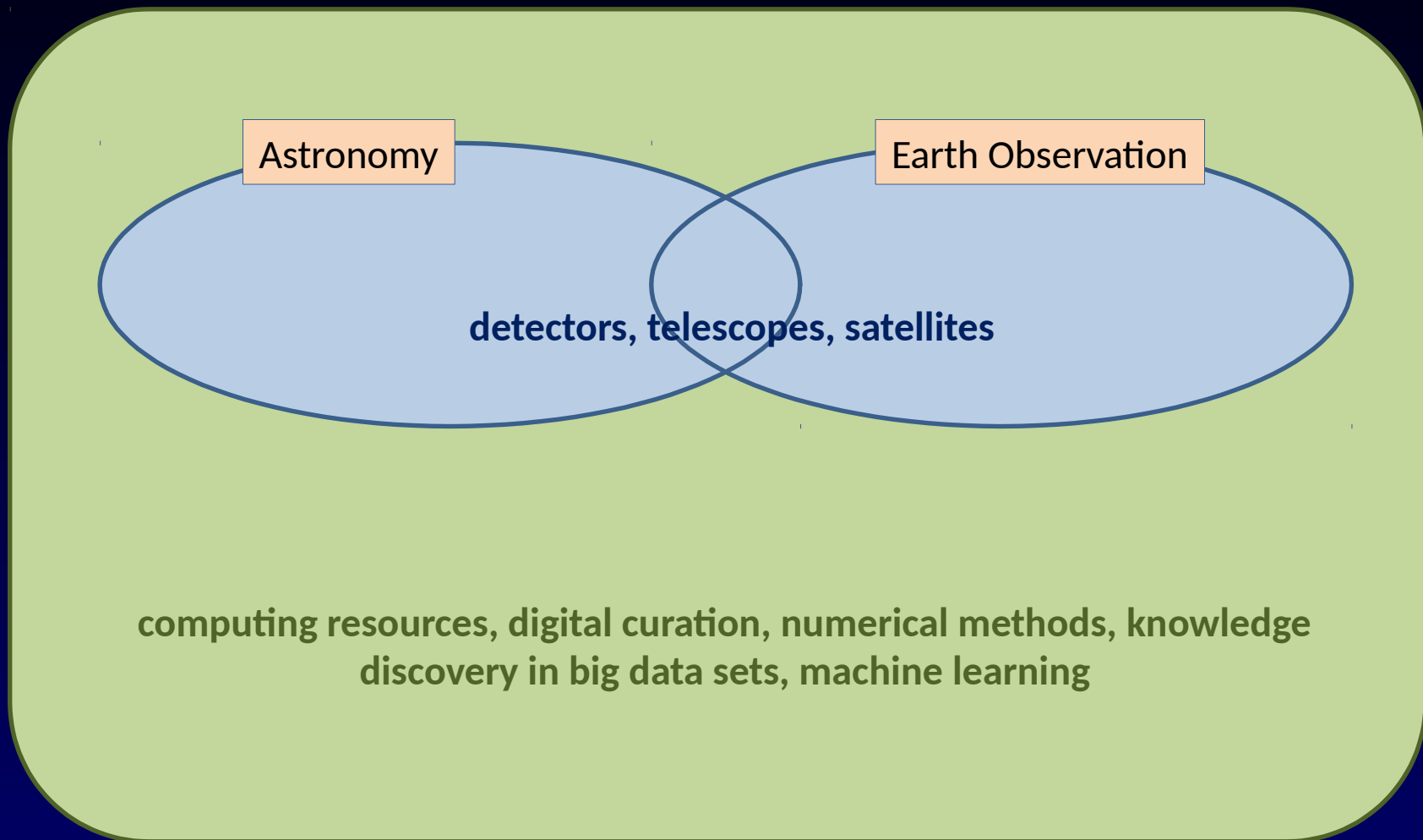


Cyclon



Nina 2016

Big Sky Earth Commons

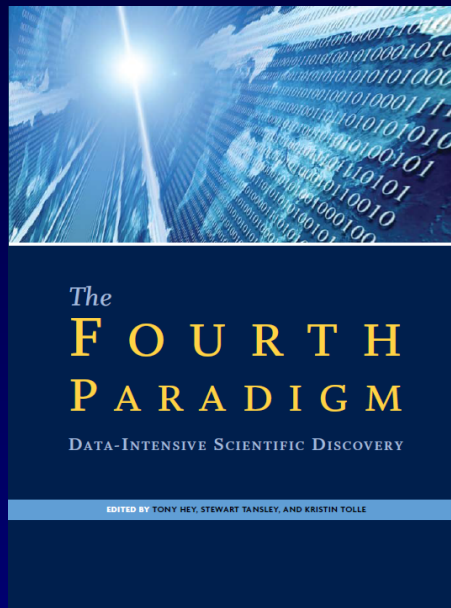


Impact

Big Data is not just bigger, it is different!

Success in research will depend on the ability
to mine knowledge from that data.

And some of the most interesting science
probably hasn't even been imagined!

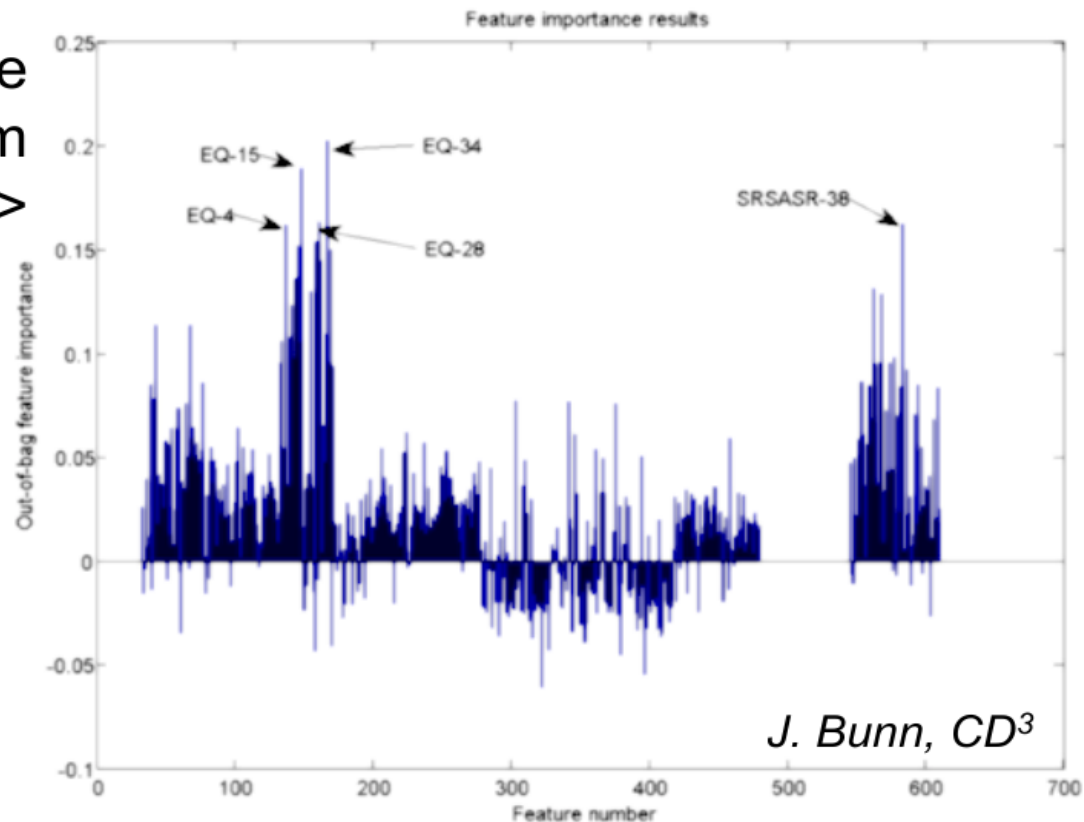


Astro-Neurology

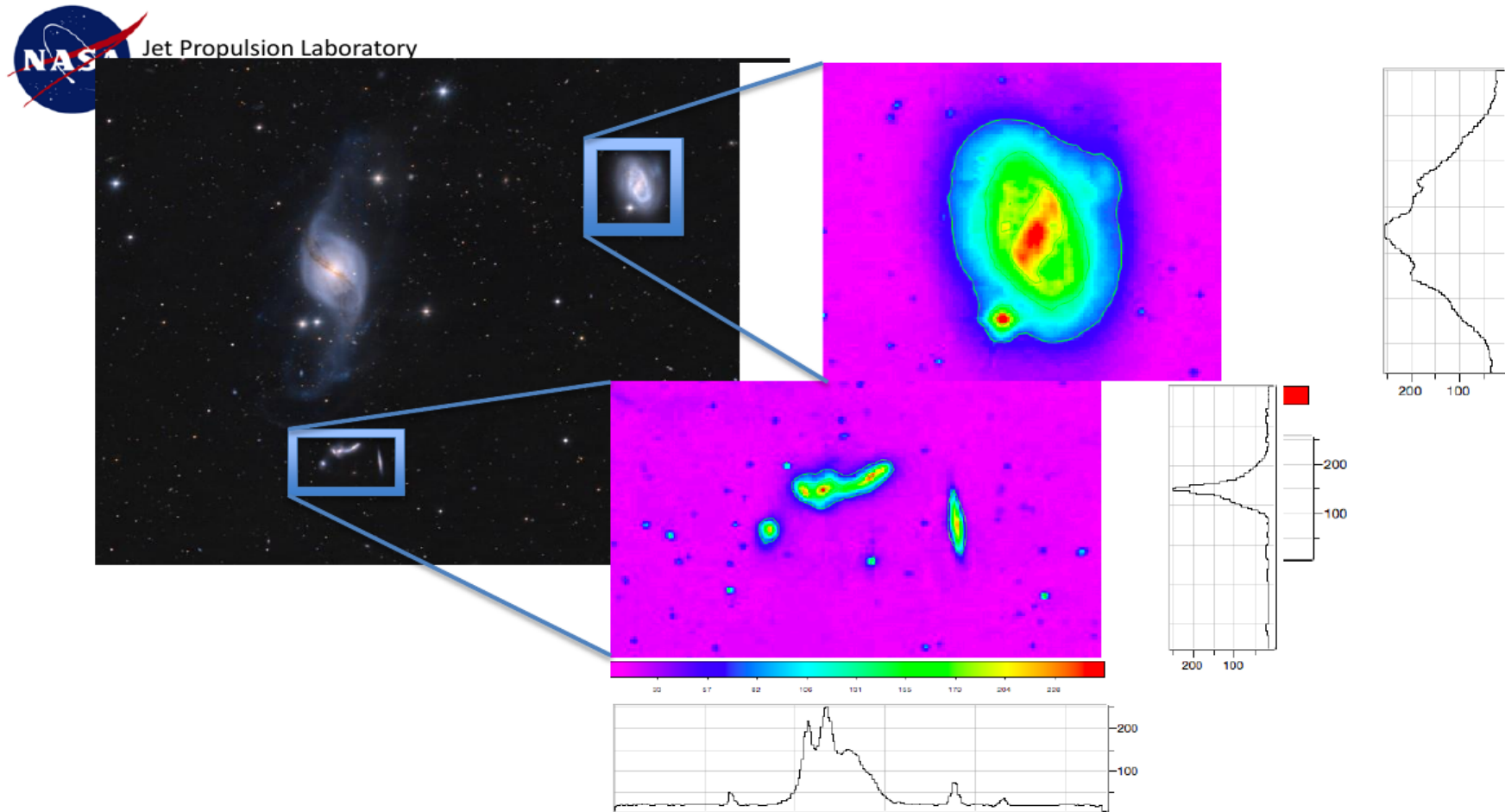
From Sky Surveys to Neurobiology

- Using the data analytics tools based on ML, developed for the analysis of sky surveys, to design a better diagnostics for autism
- Feature importance using random forests =>
 - Next: correlate with MRI scans

(with R. Adolphs et al.)



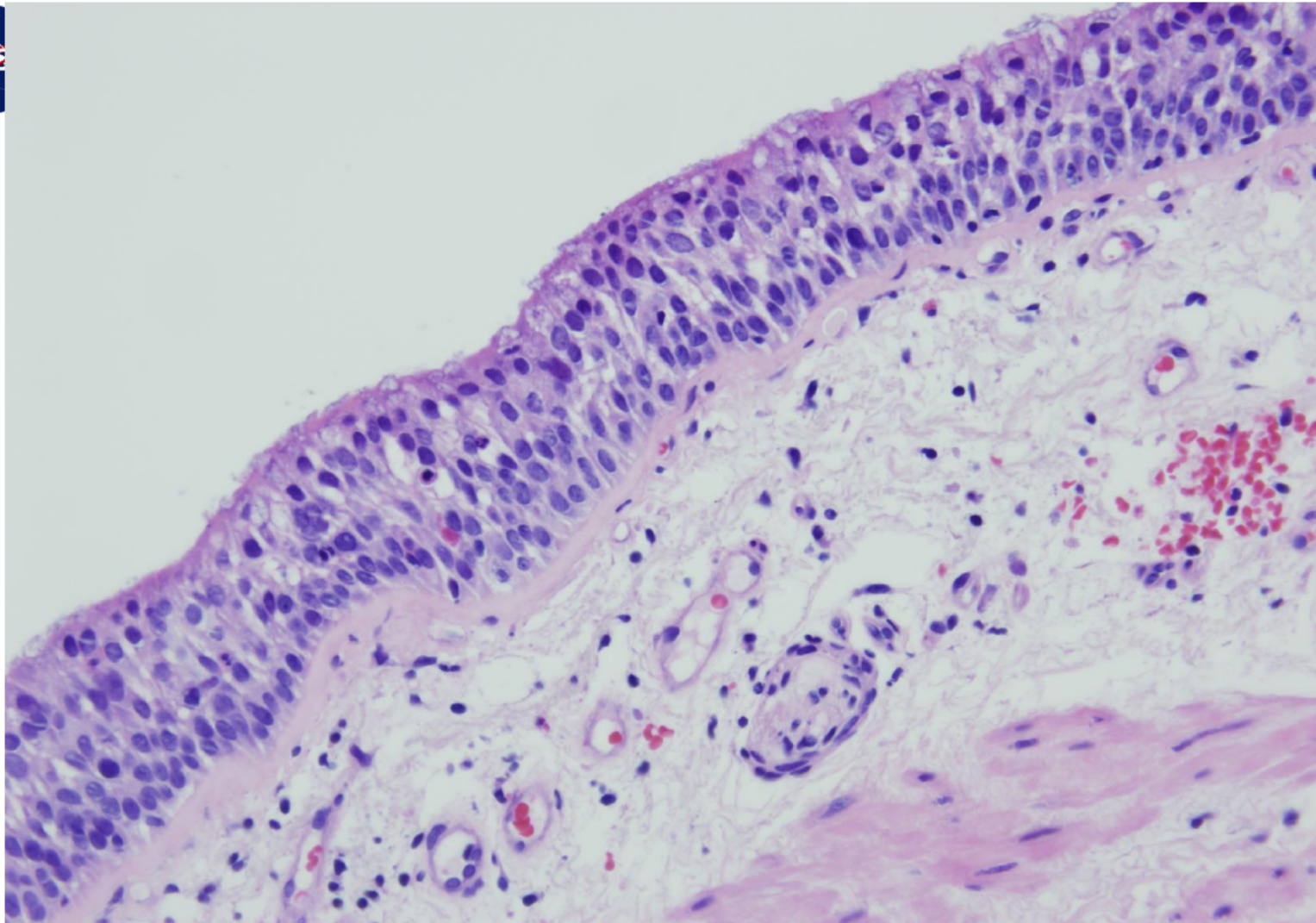
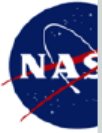
Finding Galaxies by Shape NASA



Description: Detecting objects from astronomical measurements by evaluating light measurements in pixels using intelligent software algorithms.

Image Credit: Catalina Sky Survey (CSS), of the Lunar and Planetary Laboratory, University of Arizona, and Catalina Realtime Transient Survey (CRTS), Center for Data-Driven Discovery, Caltech.

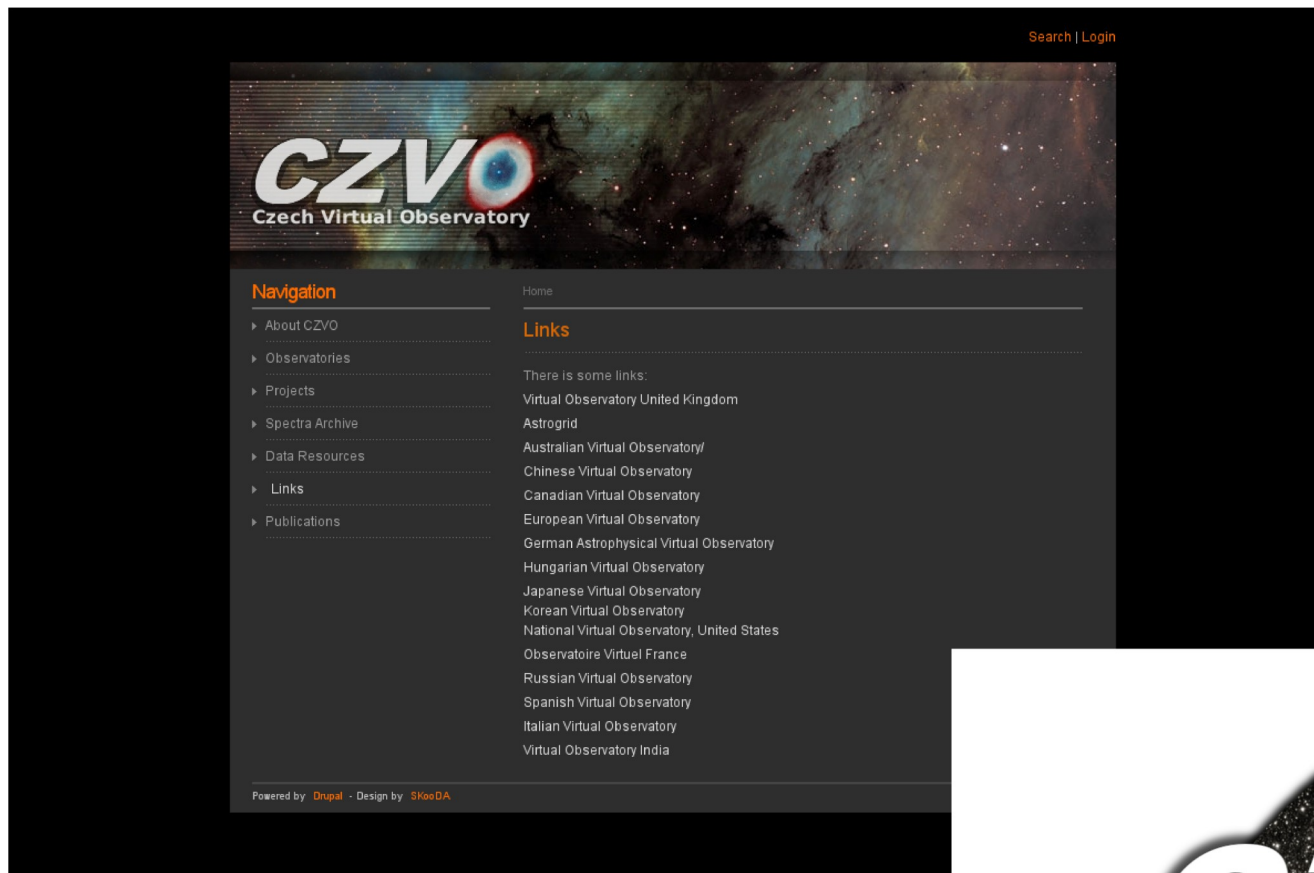
Finding Cancer Signatures NASA



Description: Detecting objects from oncology images using intelligent software algorithms transferred to and from space science.

Image Credit: EDRN Lung Specimen Pathology image example, University of Colorado

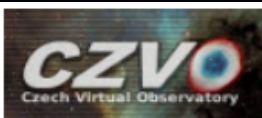
Czech VO - CZVO (not in IVOA)



BT and MT at Faculties of IT astroinformatics and VO

- FIT VUT Brno
 - 2011 1 BT (Random Forests in Astronomy)
 - 1 PhD – Wavelets Dimensionality Reduction (pending)
- VŠB-TU Ostrava
 - 2013+2015 1 BT + 1 MT - SPLAT-VO
- FIT ČVUT (8 BT+5 MT)
 - 2012 2 BT (VO-Korel+SSA proxy)
 - 2013 2 BT (OSPS Image + Catalogue Server)
 - 2014 2 BT (Random Forests + SOM)
 - 2015 1 BT (VO-Cloud)
 - 2 MT (Clustering OSPS + Deep Learning)
 - 2016 2 MT (Semisupervised learning + Outlier finding)
 - 2017 1 MT (VO Cloud) + 1 BT (deep learning)+ 1 PhD (VO light curve)

VO Services of CZVO



AIASCR VO Services

Welcome to ASU CAS Data Center.

In addition to the services listed below, on this site you probably can access [numerous tables](#) using [TAP](#) or [form-based ADQL](#).

Please check out our [site help](#).

The early stages of development of this archive in years 2013-2015 was supported by grant 13-08195S of Czech Science Foundation.

Its current extended version has been funded by grants COST LD-15113 (spectra and light curves) and INGO LG-15010 (images and photometry) of Czech Ministry of Education Youth and Sport.

Services Available

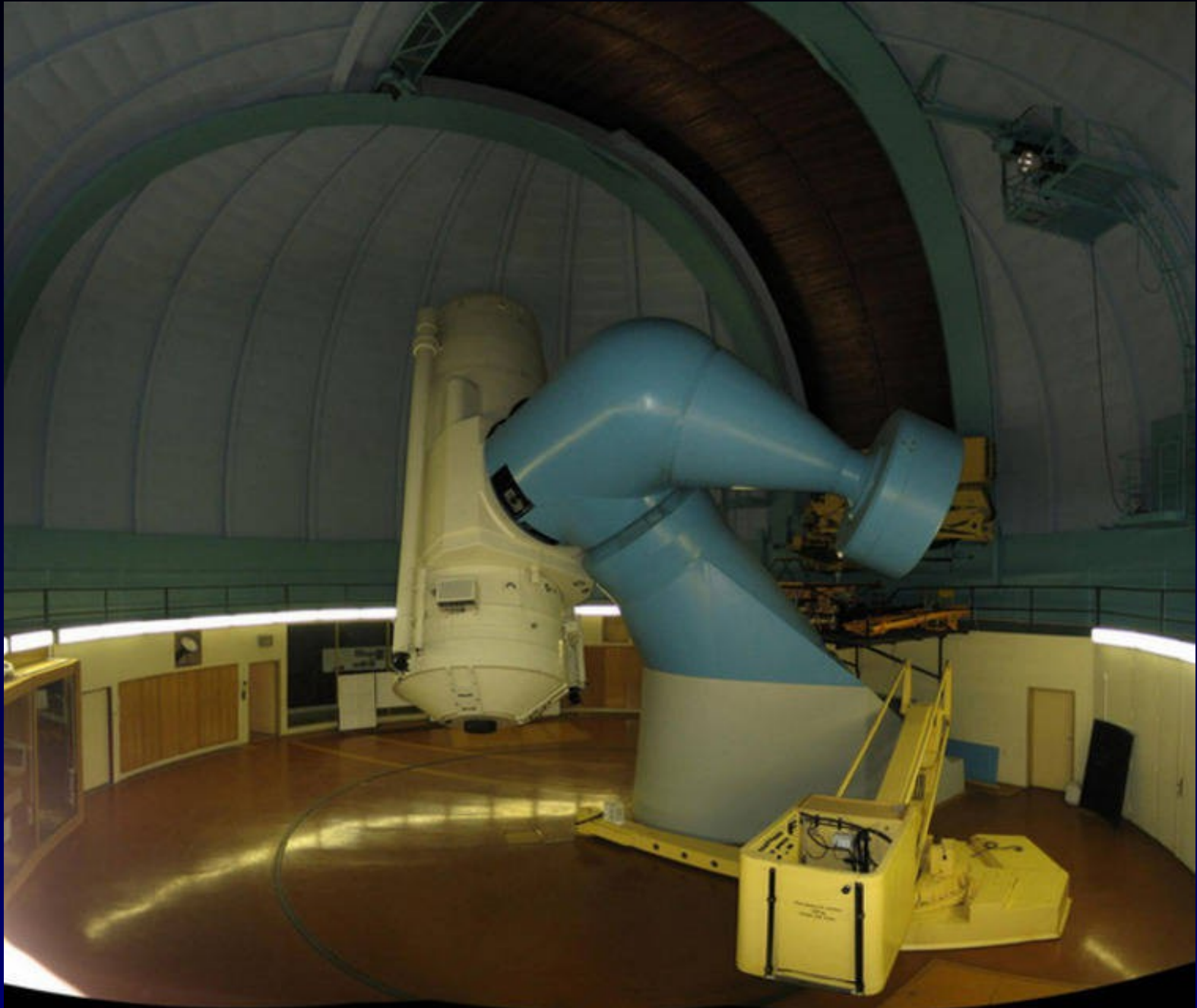
By Title

By Subject

By Author

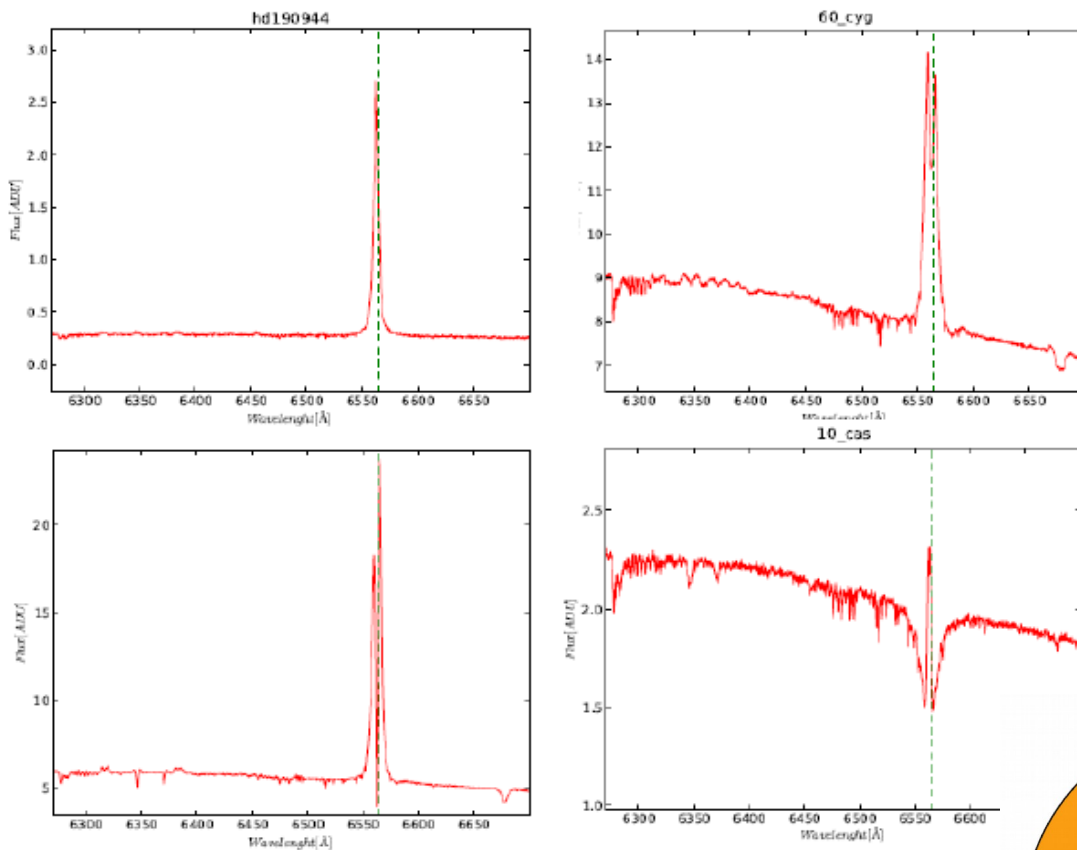
- ▶ [CCD700 Spectra Web Interface](#) [i](#) [Q](#)
- ▶ [DK154 Lightcurves Web Interface](#) [i](#) [Q](#)
- ▶ [DK154 Ondrejov RAW observations SIAP](#) [i](#) [Q](#)
- ▶ [DK154 Ondrejov REDUCED observations SIAP](#) [i](#) [Q](#)
- ▶ [DK154 SCS for observed objects](#) [i](#) [Q](#)
- ▶ [HEROS Public Spectra Web Interface](#) [i](#) [Q](#)
- ▶ [LAMOST DR1 Spectra Web Interface](#) [i](#) [Q](#)
- ▶ [LAMOST DR3 Spectra Web Interface](#) [i](#) [Q](#)
- ▶ [LAMOST PILOT Spectra Web Interface](#) [i](#) [Q](#)

2m Perek telescope (1967)



Machine Learning of Spectra

Use case: ML of spectra profile of H α line (Be stars)

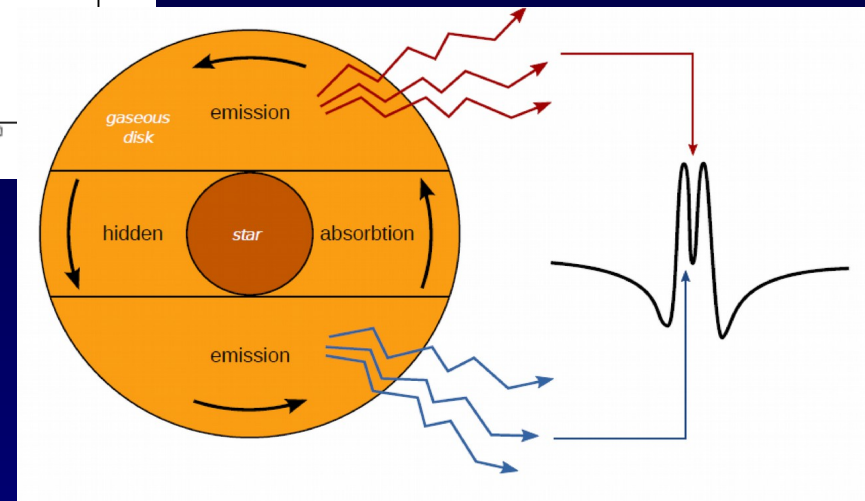


Be stars


Disk or envelope

Rotates, Hot

Origin ?????



Spectra - query output and previews



[Help](#)
[Service info](#)

Related
[CCD700 SSAP](#)

Metadata
Identifier
 ivo://asu.cas.cz/ccd700/q/

Description
 CCD700 public web interface

Keywords
 Optical spectroscopy

Creator
 [Logo]

Created
 2014-05-09T10:57:00

Data updated
 2016-06-14

Reference URL
[Service info](#)

Try [ADQL](#) to query our data.

Please report errors and problems to the [site operators](#). Thanks.
[Privacy](#) | [Disclaimer](#)
[Log in](#)

CCD700 Spectra Web Interface

[Parameters](#)

- Object standard name: [psiper]

Result

Matched: 44

[Send via SAMP](#)
[Quick Plot](#)

Product key	Object	Raj2000	Dej2000	Band start [Angstrom]	Band end [Angstrom]	Date Obs.	Observer	Exp. Time [s]	MHJD
tg180048.fit	psi Per	03:36:29.380	+48:11:33.40	6261.00	6773.40	2010-07-19T01:43:36Z		150.0	55396.0696765
 oc220022.fit	psi Per	3:37:01.1	48:12:17.1	6262.34	6774.66	2005-03-22T21:16:04Z	Kubat, Sarounova	899.564	53451.8889388
 ul070006.fit	Psi Per	03:36:29.380	+48:11:33.40	6252.67	6764.96	2011-12-07T20:21:43Z	Kraus, Kotkova	800.0	55902.8579726
va300019.fit	psi Per	03:36:29.380	+48:11:33.40	6252.09	6764.42	2012-01-30T17:13:10Z		130.0	55956.7202446
mi180074.fit	psi Per	3:37:03.2	48:10:44.2	6259.63	6772.03	2003-09-19T02:34:39Z		60.0	52901.1096669
ng290040.fit	Psi Per	3:36:46.8	48:11:39.4	6261.83	6774.26	2004-07-30T00:40:28Z	Kubat, Kalas	600.0	53216.0292701
 nh100015.fit	psi Per	3:36:42.4	48:13:02.0	6264.34	6776.77	2004-08-11T01:02:47Z	Steff + Rezna	218.373	53228.0435205
 nh310030.fit	Psi Per	3:36:46.3	48:13:02.4	6264.01	6776.40	2004-09-01T00:22:31Z	Libich, Sarounova	60.0	53249.016454

Spectra in SPLAT-VO - query

Starlink SPLAT-VO: Query VO for Spectra

File Options Resolver Interop Help

Service selection options
Data Source
☒ Observed data ☐ Theoretical data

Wave Band
☐ Radio ☐ Millimeter ☐ Infrared
☐ Optical ☐ UV ☐ EUV
☐ X-ray ☐ Gamma-ray ☒ ALL

Tags
+ -

SSAP Servers

short name	title
BeSS	Be Stars Spectra
califa ssa	CALIFA DR2
castor	Espadons/Narval leg...
castor+	Espadons/NARVAL le...
CCD700-voarchive	ccd700 OND
ccd700-vos2	
CDFS SSAP	Optical Spectroscop...
CENCOS-VVDS_DEEP	CENCOS-VVDS_DEEP...
CENCOS-VVDS_DEEP+	CENCOS-VVDS_DEEP...
Cfa Hectospec	Cfa Hectospec Spec...
dk154	
dk154-extr15	
dk154-extr15jan	dk154
dk154-extr16jan	dk154
DK154-SSA	DK154 SSA
ELODIE	ELODIE archive
ELODIEinterp	Spectrum interpolat...
ESO SAF SSA	ESO Science Archive...
EUVE	Extreme Ultraviolet ...
extract_jul16	DK154
F/H Orders SSAP	Flash/Heros Split-Or...
FEROS SSAP	FEROS Public Spectra
Flash/Heros SSAP	Flash/Heros SSAP
FUSE	Far Ultraviolet Spect...
GALEX	Galaxy Evolution Exp...
GIRAFFE	GIRAFFE archive of r...
H.E.S.S.	High Energy Stereos...
HEAVENS @ ISDC	Mining the HEAVENS...
HEROS OND	HEROS archive of On...
HEROS OND CUTOUT	cutout server of HE...

Select all Deselect all
Query registry Add New Server

Search parameters:
Simple Query

Object: psi per Lookup Clear

RA: 03:36:29.38 Dec: +48:11:33.48

Radius: 10.0 MAXREC:

Band: 6530e-10 / 6580e-10

Time:

Query Format: votable

Wavelength calibration: None

Flux calibration: None

Optional Parameters

Use	Name	Value	UCD
<input type="checkbox"/>	REDSHIFT		src.redshift
<input type="checkbox"/>	TARGETCLASS		src.class
<input type="checkbox"/>	MTIME		
<input type="checkbox"/>	SPECPRP		spect.resolution;em.wl
<input type="checkbox"/>	SPATRES		pos.angResolution
<input type="checkbox"/>	PUBDID		
<input type="checkbox"/>	CREATORID		meta.id

Select all Deselect all Update

Query: <SERVER>?REQUEST=queryData&POS=54.122416666666666,48.192633333333333&FORMAT=votable&SIZE=0.166666666666666&BAND=6530e-10/6580e-10

SEND QUERY

Query results:

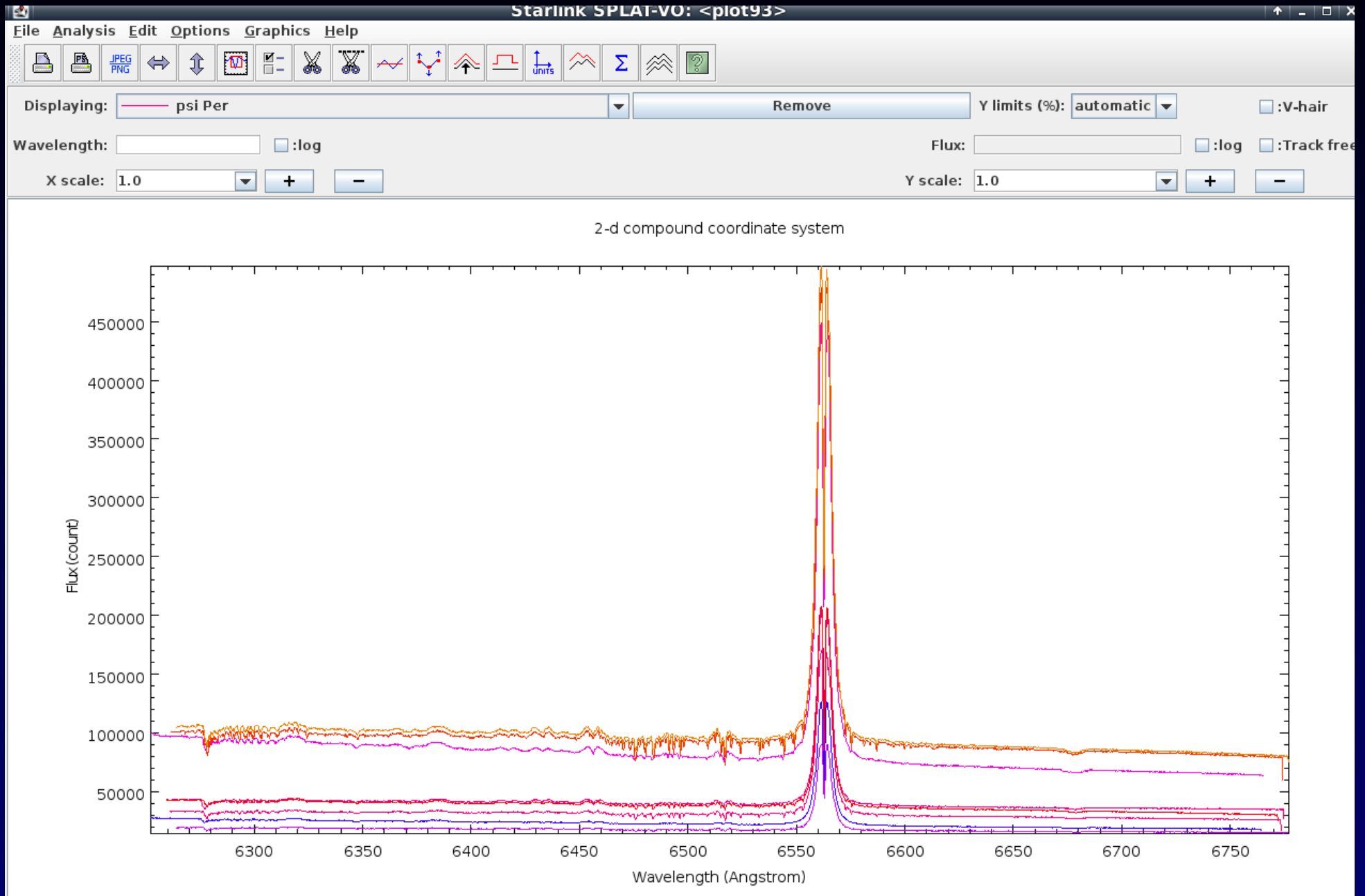
CCD700-voarchive

l...	ssa_specstart	ssa_specend	ssa_dstitle	ssa_targname	ssa_dateObs	ssa_timeExt	ssa_snr	ssa_length	accref	
12	6.26183E-7	6.77426E-7	ccd700/data/psiper/6255-676...	Psi Per	53216.0049	1800.		1997	http://voarchive.asu.cas.cz/ge...	appli
27	6.24978E-7	6.76217E-7	ccd700/data/psiper/6255-676...	psi Per	54701.97209	1333.19		1997	http://voarchive.asu.cas.cz/ge...	appli
13	6.25854E-7	6.77081E-7	ccd700/data/psiper/6255-676...	psi Per	52982.77964	1300.		1997	http://voarchive.asu.cas.cz/ge...	appli
31	6.26359E-7	6.73614E-7	ccd700/data/psiper/6260-673...	psi Per	56884.01015	1201.		2047	http://voarchive.asu.cas.cz/ge...	appli
30	6.26359E-7	6.73614E-7	ccd700/data/psiper/6260-673...	psi Per	56884.02565	901.		2047	http://voarchive.asu.cas.cz/ge...	appli
2	6.26234E-7	6.77466E-7	ccd700/data/psiper/6255-676...	psi Per	53451.88616	899.564		1997	http://voarchive.asu.cas.cz/ge...	appli
28	6.26587E-7	6.77822E-7	ccd700/data/psiper/6255-676...	psi Per	54209.80019	899.214		1997	http://voarchive.asu.cas.cz/ge...	appli
3	6.25267E-7	6.76496E-7	ccd700/data/psiper/6255-676...	Psi Per	55902.84843	800.		1997	http://voarchive.asu.cas.cz/ge...	appli
10	6.25163E-7	6.76402E-7	ccd700/data/psiper/6255-676...	psi Per	54757.88729	730.		1997	http://voarchive.asu.cas.cz/ge...	appli
6	6.26183E-7	6.77426E-7	ccd700/data/psiper/6255-676...	Psi Per	53216.02811	600.		1997	http://voarchive.asu.cas.cz/ge...	appli
14	6.24978E-7	6.76217E-7	ccd700/data/psiper/6255-676...	psi Per	54701.96266	600.		1997	http://voarchive.asu.cas.cz/ge...	appli
9	6.25809E-7	6.77051E-7	ccd700/data/psiper/6255-676...	psi Per	52897.07116	556.599		1997	http://voarchive.asu.cas.cz/ge...	appli
18	6.26587E-7	6.77822E-7	ccd700/data/psiper/6255-676...	psi Per	54209.81274	450.		1997	http://voarchive.asu.cas.cz/ge...	appli
20	6.25854E-7	6.77081E-7	ccd700/data/psiper/6255-676...	psi Per	52982.79788	350.		1997	http://voarchive.asu.cas.cz/ge...	appli
16	6.26235E-7	6.77492E-7	ccd700/data/psiper/6255-676...	psi Per	53475.85182	300.043		1997	http://voarchive.asu.cas.cz/ge...	appli
19	6.26401E-7	6.77640E-7	ccd700/data/psiper/6255-676...	Psi Per	53249.01697	300.		1997	http://voarchive.asu.cas.cz/ge...	appli
23	6.25161E-7	6.76378E-7	ccd700/data/psiper/6255-676...	psi Per	54519.80405	300.		1997	http://voarchive.asu.cas.cz/ge...	appli
24	6.25161E-7	6.76378E-7	ccd700/data/psiper/6255-676...	psi Per	54519.7984	300.		1997	http://voarchive.asu.cas.cz/ge...	appli
7	6.26434E-7	6.77677E-7	ccd700/data/psiper/6255-676...	Psi Per	53228.0436	218.373		1997	http://voarchive.asu.cas.cz/ge...	appli
11	6.25641E-7	6.76875E-7	ccd700/data/psiper/6255-676...	psi Per	55443.86444	200.		1997	http://voarchive.asu.cas.cz/ge...	appli
22	6.25161E-7	6.76378E-7	ccd700/data/psiper/6255-676...	psi Per	54519.81162	200.		1997	http://voarchive.asu.cas.cz/ge...	appli
25	6.25908E-7	6.77147E-7	ccd700/data/psiper/6255-676...	psi Per	52901.91749	194.574		1997	http://voarchive.asu.cas.cz/ge...	appli
15	6.25937E-7	6.77178E-7	ccd700/data/psiper/6255-676...	psi Per	52904.03609	180.		1997	http://voarchive.asu.cas.cz/ge...	appli
1	6.26100E-7	6.77340E-7	ccd700/data/psiper/6255-676...	psi Per	55396.07196	150.		1997	http://voarchive.asu.cas.cz/ge...	appli
6	6.26359E-7	6.73614E-7	ccd700/data/psiper/6260-673...	psi Per	56884.01015	1201.		2047	http://voarchive.asu.cas.cz/ge...	appli

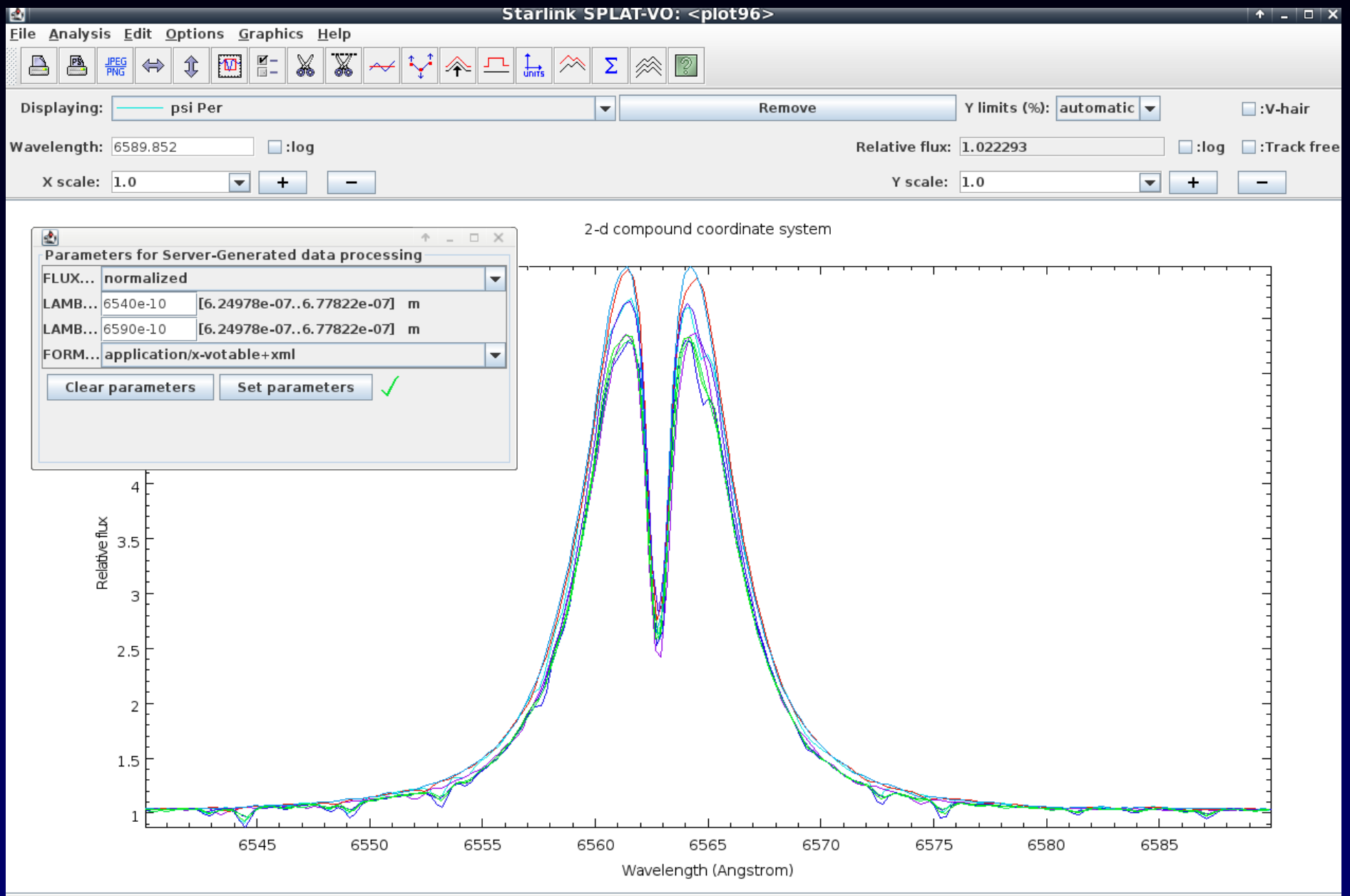
Display selected Display all Download selected Download all Deselect table Deselect all DataLink Services

Save query results Restore query results Close

Spectra in VO - direct access plot

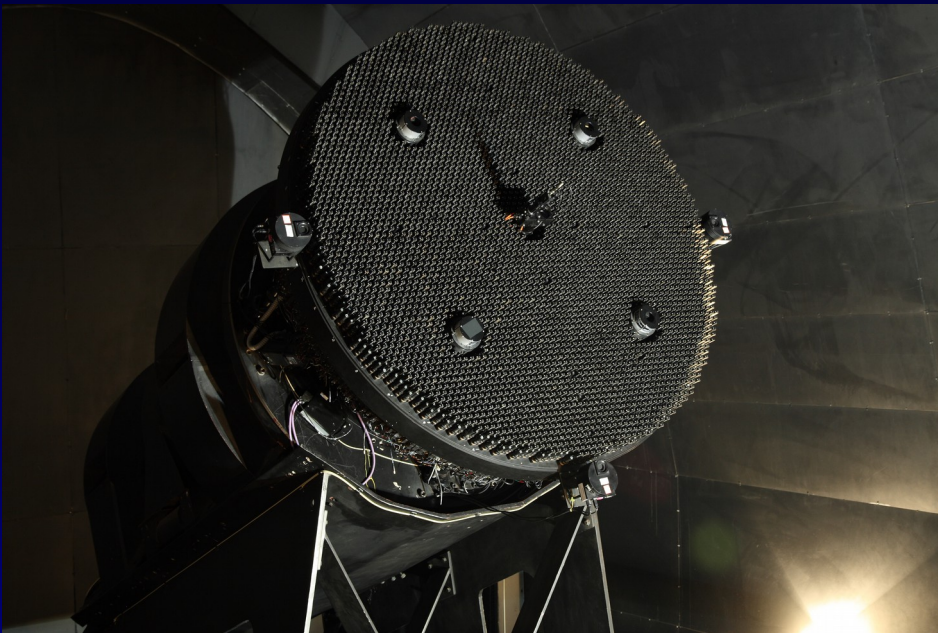
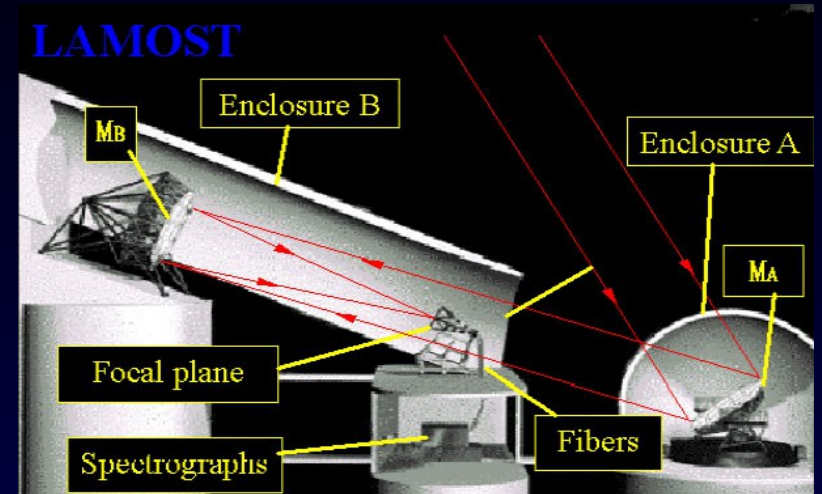


Spectra in SPLAT-VO - DataLink



LAMOST (Guoshoujing)

Xinglong- China
4m mirror (30 deg meridian)
4000 fibers
10 mil spectra / 5 yr
Automatic RV-z



LAMOST Spectral Surveys

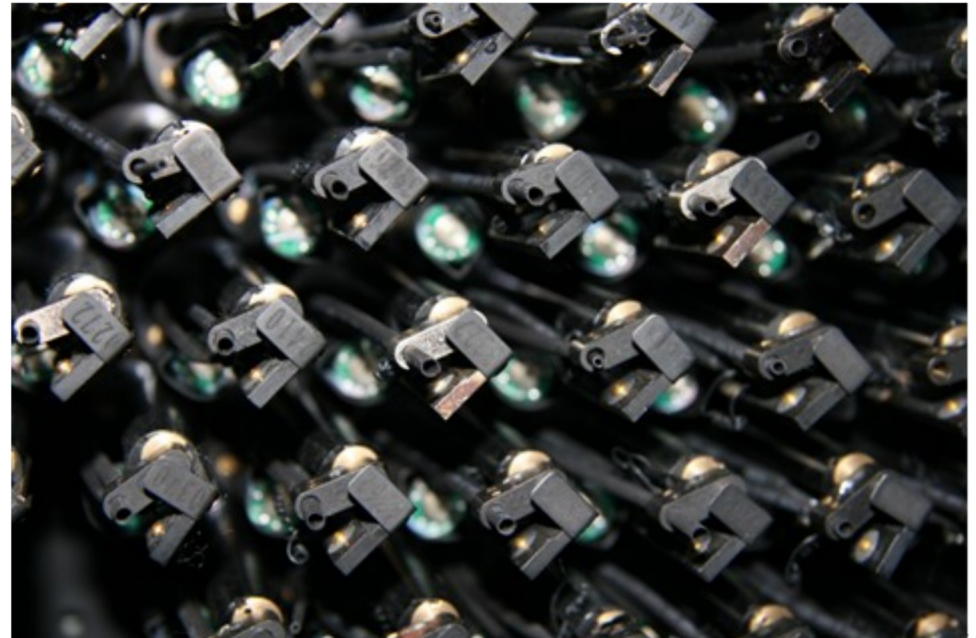
DR1 (end 2013) **2 204 860** spectra
 1 085 404 stars

DR3 (half 2015) **5 755 126** spectra

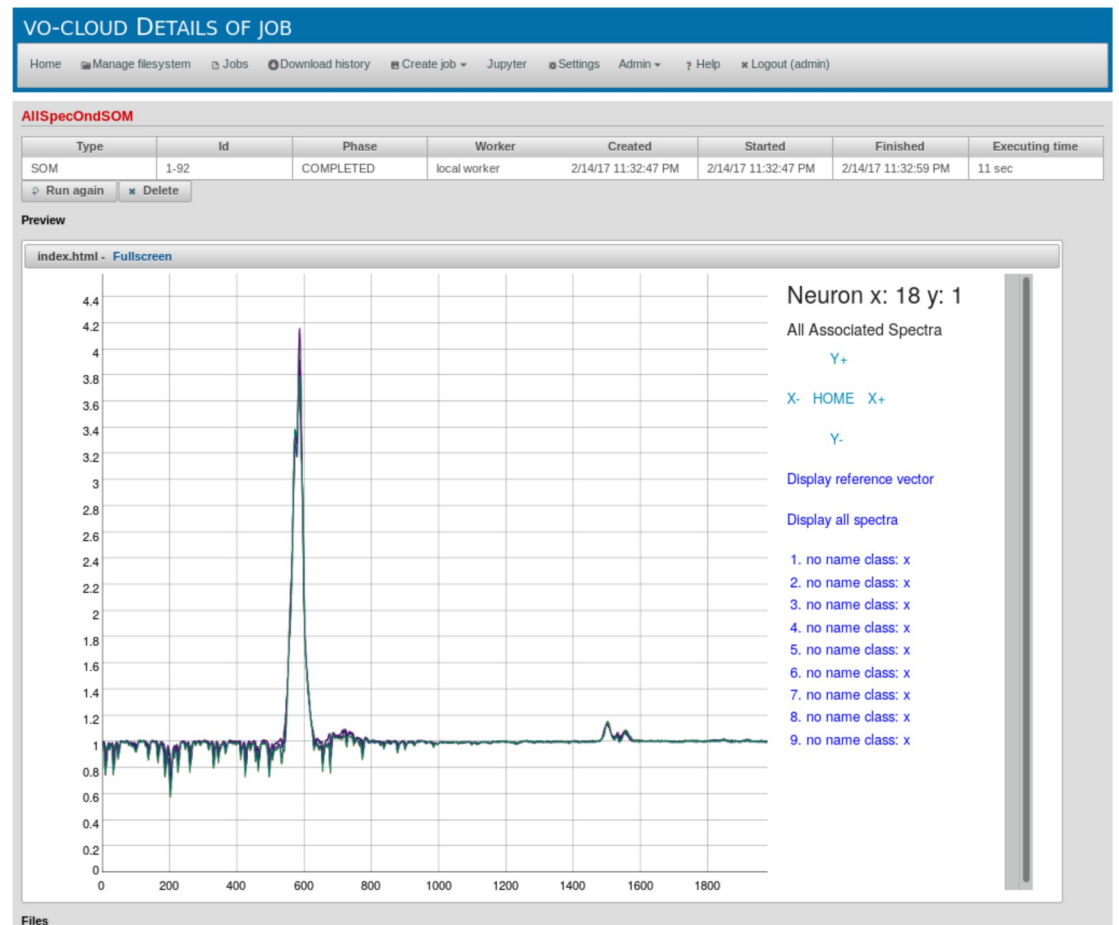
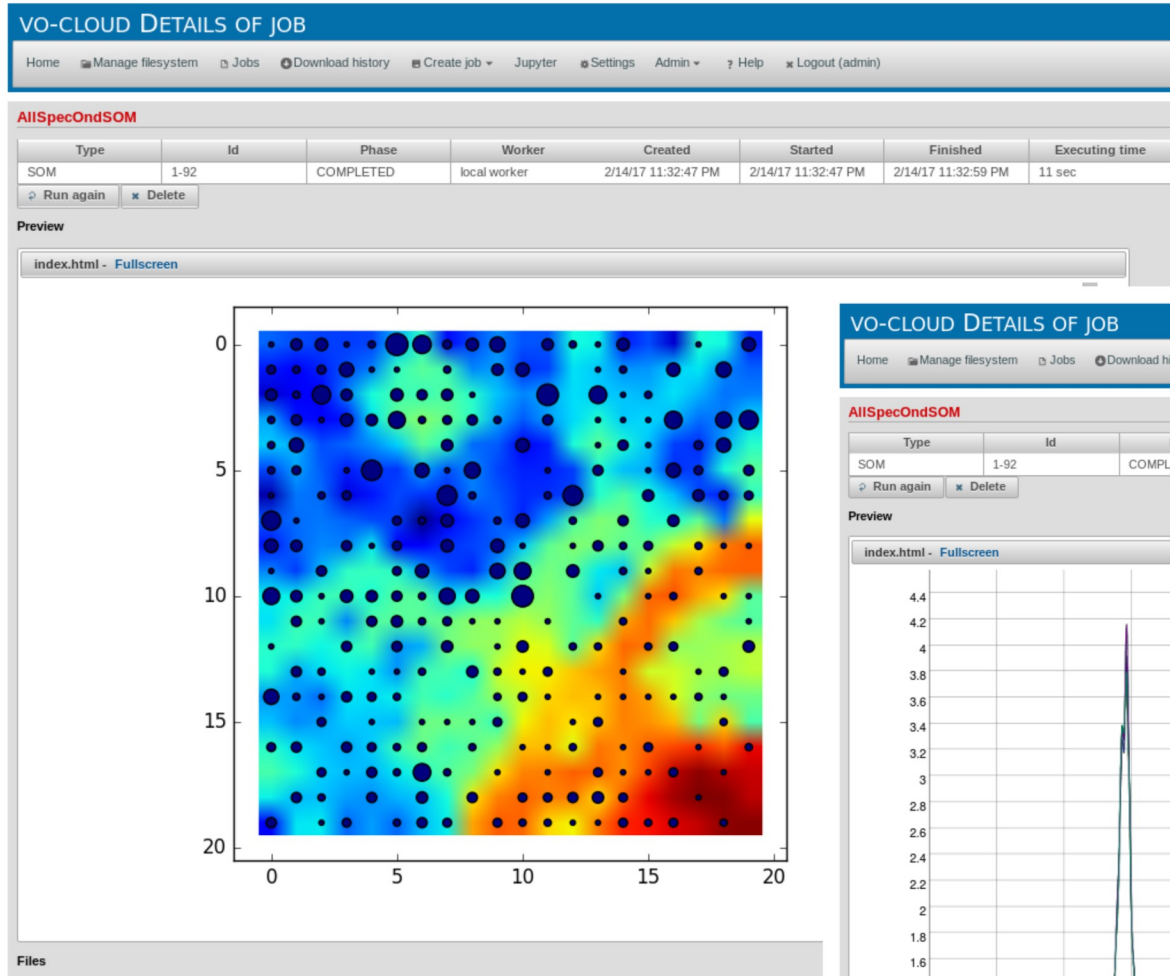
DR4 (Feb 2016) **+ 741 522**

Each Fiber – 2 motors
double arm 33mm circle

Fibre collects light from
3.3 arcsec circle on sky



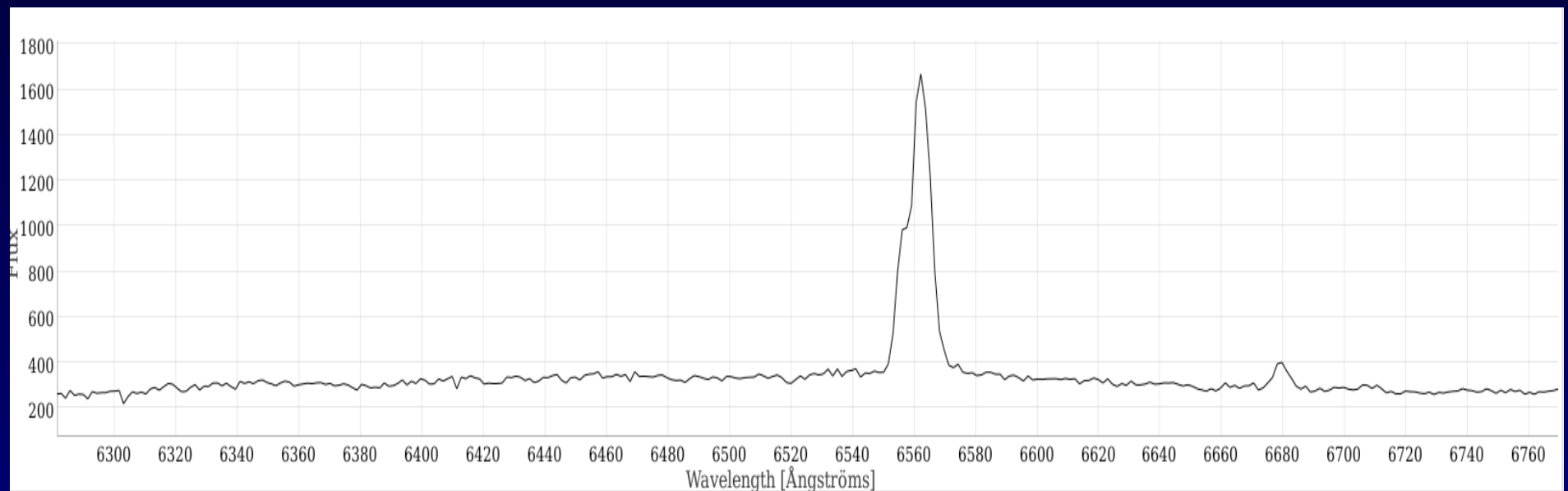
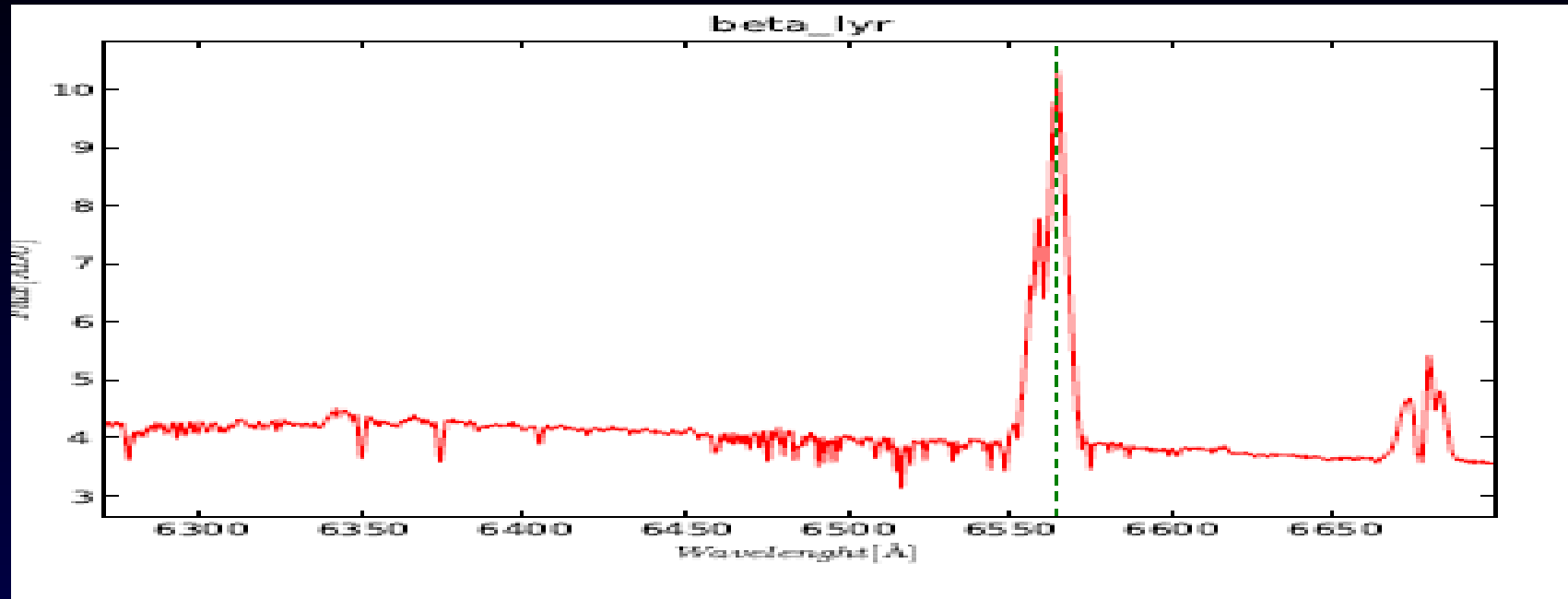
SOM Worker example



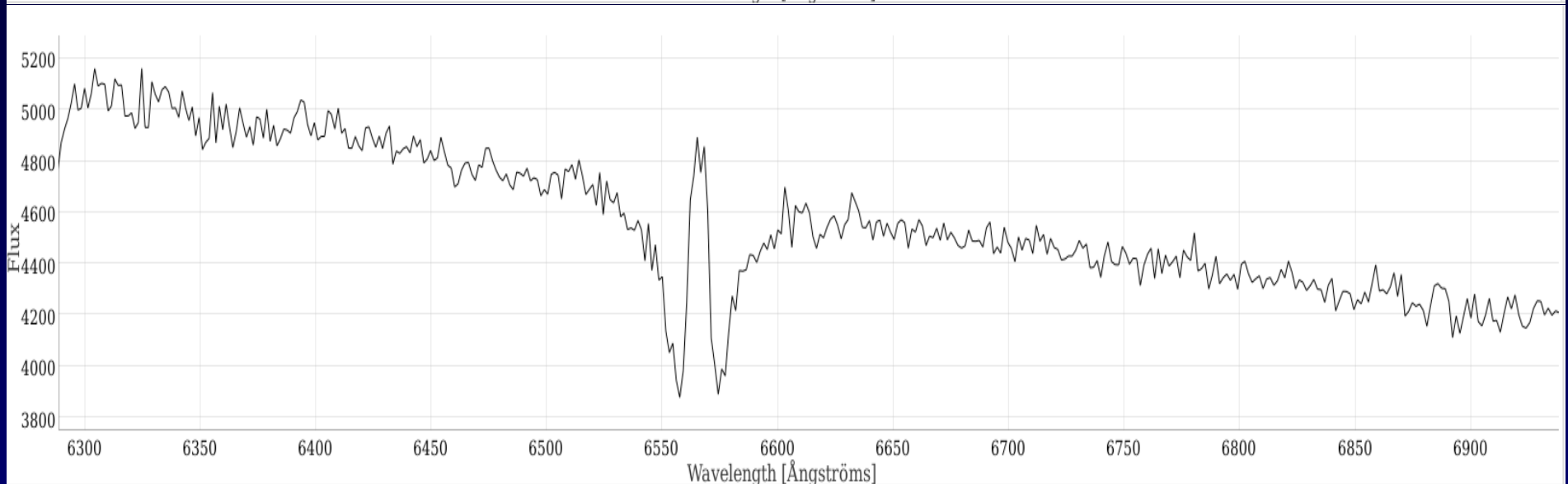
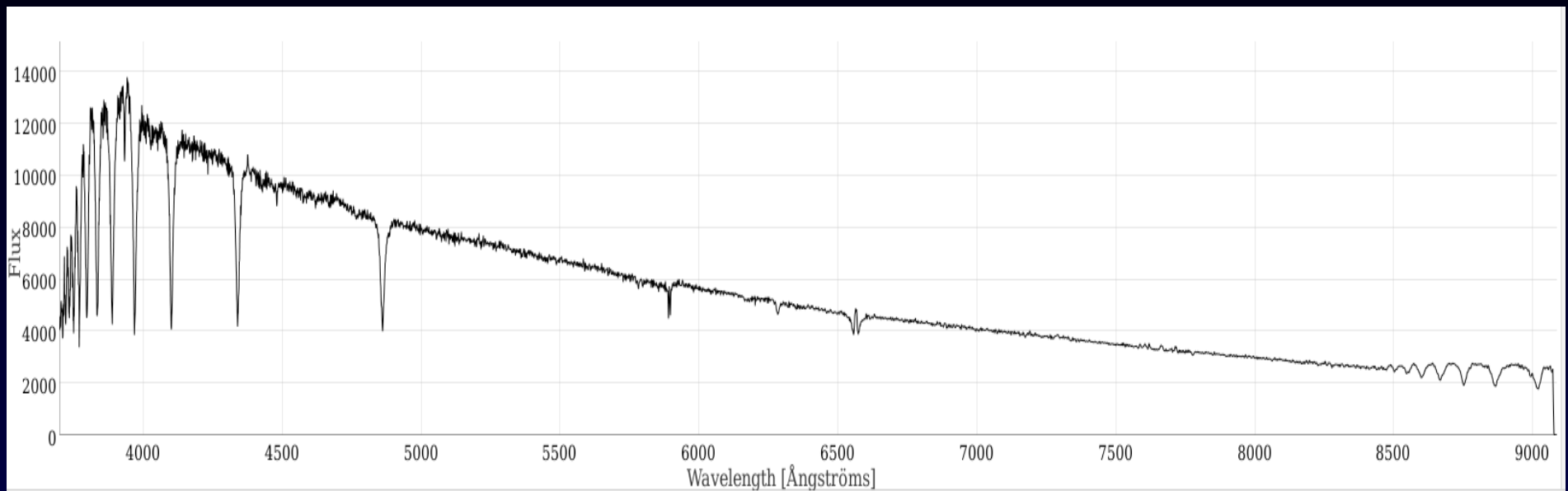
VO-CLOUD spectra visualisation



Be Candidates Found



Yet Unknown Be Star (UCAC ...)



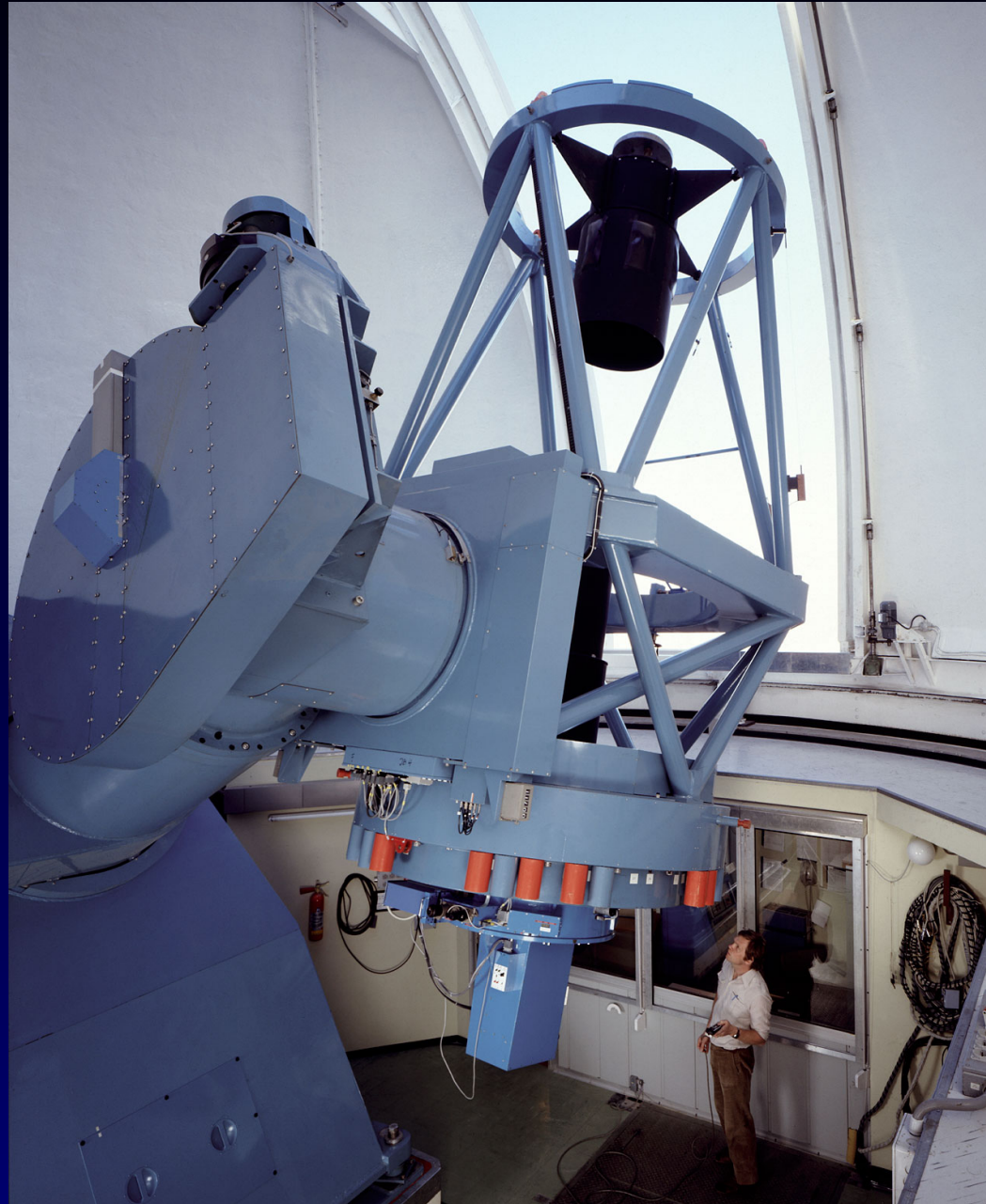
Virtual Observatory inside

- OND 2m archive on **SSAP** protocol (spectra access)
- LAMOST DR1 on **SSAP** (using DaCHS)
- Preprocessing (rectify, cutout) – **DataLink** on server
- **SAMP** (send spectra to **SPLAT-VO** - view details)
- Visualization on sky **ALADIN, X-MATCH CDS**
- VO-CLOUD – cloud engine based on **UWS** REST jobs
- Cross-matching (**ADQL, TAP, TOPCAT, TAPhandle, pyVO, Vizier**)
- Very similar methodology in e.g. Mass spectrography
- DNA analysis – search for patterns

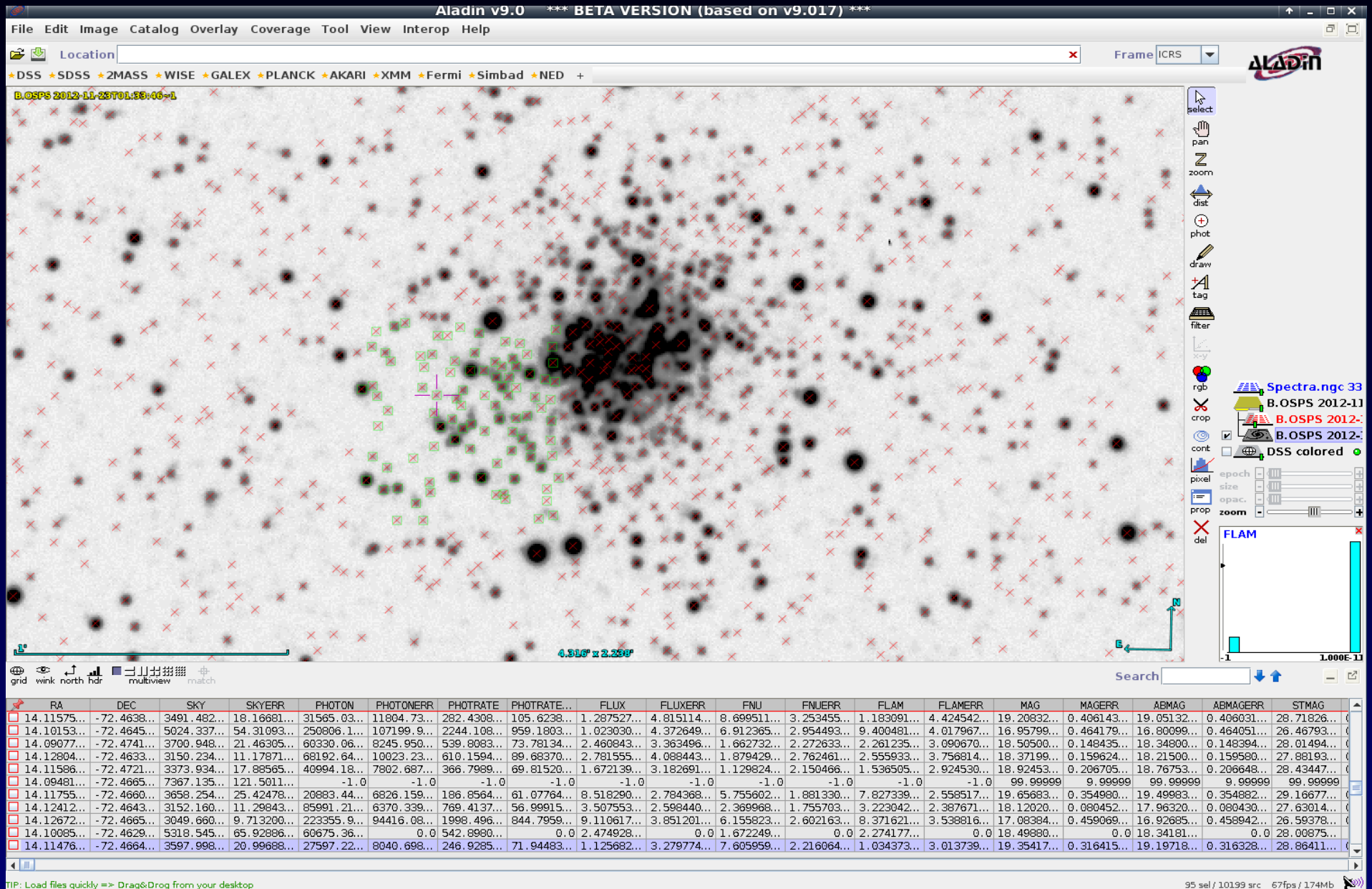
Danish 1.54m at La Silla robotized in Summer 2012



Danish 1.54m Telescope



Reduced OSPS image + bintable photometry in 2nd extension



SIAP - Raw images query



Czech Virtual Observatory

[Help](#)
[Service info](#)

Metadata
Identifier
ivo://asu.cas.cz/dk154_raw
Description
Observations captured by .
Keywords
DK154
Creator
[Logo]
Created
2012-04-27T00:00:00
Data updated
2016-03-12
Reference URL
[Service info](#)

[Try ADQL](#) to query our data.

Please report errors and problems to the [site operators](#). Thanks.
[Privacy](#) | [Disclaimer](#)
[Log in](#)

DK154 Ondrejov RAW observations SIAP

Observations captured by ASU CAS facility by DK154 telescope

Position [deg]
ICRS Position, RA,DEC, or Simbad object (e.g., 234.234,-32.45)

Field size [deg]
Size in decimal degrees (e.g., 0.2 or 1,0.1)

Intersection type
☒ Image overlaps Rol
☐ Image covers Rol
☐ Rol covers image
☐ The given position is shown on image
Relation of image and specified Region of Interest.

File format
☐ ANY
☐ image/png
☒ image/fits
Requested format of the image data

Img_type
Type of observation (SCIENCE, FLAT, or BIAS)

Band [m]
Wavelength (range) of interest (or symbolic bandpass names)

Minimum Date / / (day/month/year)
Minimum date (If empty, returns everything until Maximum date)

Maximum Date / / (day/month/year)
Minimum date (If empty, returns everything until Maximum date)

Table Sort by ASC
Limit to items.

Output format

Raw images results

DK154 Ondrejov RAW observations SIAP

Parameters

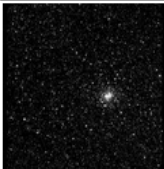
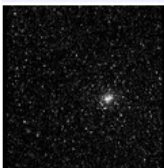
- Band: ALL
- Field size: 0.05
- File format: image/png
- Img_type: ALL
- Position: ngc 330

Result

Matched: 100

[Send via SFTP](#) [Quick Plot](#)

The query limit was reached. Increase it to retrieve more matches. Note that unsorted truncated queries are not reproducible (i.e., might return a different result set at a later time).

Accref	Owner	Embargo ends	Type	File size [byte]	Ctr. RA [deg]	Ctr. Dec [deg]	Title	Instrument	Obs. date	#axes	Axes Lengths [pix]	Scales [deg/pix]	Ref. Frame	Equinox [yr]	Proj.	Ref. pixel [pix]	Ref. values [deg]	CD matrix [deg/pix]	Bandpass	Bandpass unit	Band Ref. [m]	Band upper [m]	Band lower [m]	P. Flags	Coverage [deg]	Exp. time [s]	Telescope	Img_type
	beusers	2010-12-31 00:00:00	image/png	247.6kiB	14.19	-72.45	OSPS 2012-10-08T03:32:47.212 V ngc330field1	DFOSC_FASU	2012-10-08T03:32:46Z	2	[2148, 2048]	[0.000109996, 0.000109996]	ICRS	2000.0	TAN	[1074.0, 1024.0]	[14.193875, -72.45333333333333]	[[-0.000109996, -9.82956e-07, -9.82956e-07, 0.000109996]	V	m	5.4e-07	6.7e-07	4.85e-07	N/A	Polygon ICRS 14.5844654144 -72.5665328579 14.5862737491 -72.3413642854 13.807794488 -72.3392662543 13.7962514963 -72.564408589	120.0	DK-1.54	LIGHT
ngc330field1_000003.png																												
ngc330field1_000002.png	beusers	2010-12-31 00:00:00	image/png	234.7kiB	14.19	-72.45	OSPS 2012-10-08T03:29:15.728 B ngc330field1	DFOSC_FASU	2012-10-08T03:29:15Z	2	[2148, 2048]	[0.000109996, 0.000109996]	ICRS	2000.0	TAN	[1074.0, 1024.0]	[14.193875, -72.45333333333333]	[[-0.000109996, -9.82956e-07, -9.82956e-07, 0.000109996]	B	m	4.4e-07	5.6e-07	3.6e-07	N/A	Polygon ICRS 14.5844654144 -72.5665328579 14.5862737491 -72.3413642854 13.807794488 -72.3392662543 13.7962514963 -72.564408589	180.0	DK-1.54	LIGHT
ngc330field1_000005.png	beusers	2010-12-31 00:00:00	image/png	266.2kiB	14.19	-72.45	OSPS 2012-10-08T03:37:43.924 R ngc330field1	DFOSC_FASU	2012-10-08T03:37:42Z	2	[2148, 2048]	[0.000109996, 0.000109996]	ICRS	2000.0	TAN	[1074.0, 1024.0]	[14.193875, -72.45333333333333]	[[-0.000109996, -9.82956e-07, -9.82956e-07, 0.000109996]	R	m	6.2e-07	8.5e-07	5.8e-07	N/A	Polygon ICRS 14.5844654144 -72.5665328579 14.5862737491 -72.3413642854 13.807794488 -72.3392662543 13.7962514963 -72.564408589	120.0	DK-1.54	LIGHT
ngc330field1_000004.png	beusers	2010-12-31 00:00:00	image/png	246.5kiB	14.19	-72.45	OSPS 2012-10-08T03:35:12.456 V ngc330field1	DFOSC_FASU	2012-10-08T03:35:12Z	2	[2148, 2048]	[0.000109996, 0.000109996]	ICRS	2000.0	TAN	[1074.0, 1024.0]	[14.193875, -72.45333333333333]	[[-0.000109996, -9.82956e-07, -9.82956e-07, 0.000109996]	V	m	5.4e-07	6.7e-07	4.85e-07	N/A	Polygon ICRS 14.5844654144 -72.5665328579 14.5862737491 -72.3413642854 13.807794488 -72.3392662543 13.7962514963 -72.564408589	120.0	DK-1.54	LIGHT
	beusers	2010-12-31 00:00:00	image/png	260.8kiB	14.19	-72.45	OSPS 2012-10-08T03:40:09.216 R ngc330field1	DFOSC_FASU	2012-10-08T03:40:09Z	2	[2148, 2048]	[0.000109996, 0.000109996]	ICRS	2000.0	TAN	[1074.0, 1024.0]	[14.193875, -72.45333333333333]	[[-0.000109996, -9.82956e-07, -9.82956e-07, 0.000109996]	R	m	6.2e-07	8.5e-07	5.8e-07	N/A	Polygon ICRS 14.5844654144 -72.5665328579 14.5862737491 -72.3413642854 13.807794488 -72.3392662543 13.7962514963 -72.564408589	120.0	DK-1.54	LIGHT
ngc330field1_000006.png																												
ngc330field1_000001.png	beusers	2010-12-31 00:00:00	image/png	235.3kiB	14.19	-72.45	OSPS 2012-10-08T03:25:50.480 B ngc330field1	DFOSC_FASU	2012-10-08T03:25:50Z	2	[2148, 2048]	[0.000109996, 0.000109996]	ICRS	2000.0	TAN	[1074.0, 1024.0]	[14.193875, -72.45333333333333]	[[-0.000109996, -9.82956e-07, -9.82956e-07, 0.000109996]	B	m	4.4e-07	5.6e-07	3.6e-07	N/A	Polygon ICRS 14.5844654144 -72.5665328579 14.5862737491 -72.3413642854 13.807794488 -72.3392662543 13.7962514963 -72.564408589	180.0	DK-1.54	LIGHT

OSPS SIAP in Aladin (DSS in back)

The screenshot displays the Aladin v9.0 software interface, which is a tool for astronomical image processing and visualization. The interface is divided into several panels:

- Server selector:** A panel on the left side of the main window. It contains a list of image servers (Aladin images, SkyView, UKIDSS, Sloan, DSS..., DR154, VLA..., Archives..., Others...) and a list of catalog servers (All, VizieR, Surveys, Missions, SIMBAD, NED, MOC, SkyBot, Others...). The 'Ondrejov DK154 SIAP reduced' target is selected. The target details are: Target (ICRS, name) ngc 330, Radius 14', Filter B - Filter B, Format image/fits, Obs min date, and Obs max date. A list of observations is shown, including dates, times, and coordinates. The 'INFO on this ...' button is at the bottom.
- Main image view:** The central area showing a large astronomical image of the Orion Nebula (NGC 330). A smaller, zoomed-in view of a specific region is shown in the center, with a pink crosshair indicating the selected area. The image is labeled 'ALEX * PLANCK * AKARI * XMM * Fermi * Simbad * NED +'. The image is in the 'Frame ICRS' mode.
- Right panel:** Contains a list of image servers (Aladin images, SkyView, UKIDSS, Sloan, DSS..., DR154, VLA..., Archives..., Others...) and a list of catalog servers (All, VizieR, Surveys, Missions, SIMBAD, NED, MOC, SkyBot, Others...). It also includes a 'Spectra.ngc 33' link and a 'B. OSPS 2012-11' link. The 'DSS colored' checkbox is checked. The 'epoch' and 'size' sliders are visible.
- Bottom panel:** Contains a search bar, a 'Search' button, and a status bar showing '0 sel / 10199 src 26fps / 403Mb'.

OSPS Image coverage (footprints)

The screenshot displays the ALADIN software interface, which is used for visualizing astronomical data. The main window shows a deep-field image of the Orion region, with numerous red rectangular footprints overlaid, representing the locations and sizes of individual observations. The interface is divided into several panels:

- Left Panel (Image servers):** Contains a list of image servers including Aladin images, SkyView, UKIDSS, Sloan, DSS, DK154, VLA, Archives, and Others. Below this is a table of observation data for the target "Ondrejov DK154 SIAP reduced".
- Top Panel (Form):** Allows users to specify the target (ICRS name), radius, filter, format, and observation date range.
- Right Panel (Stack controls):** Provides controls for the image stack, including options to show/hide a plane, change object size, adjust field size, and adjust transparency. It also includes a small map of the sky showing the current field of view.
- Bottom Panel (Tools):** Contains various tools for interacting with the image, such as select, pan, zoom, dist, phot, draw, tag, filter, crop, cont, pixel, prop, and del.

The main image area shows the "DSS colored" view of the Orion region. The footprints are red rectangles of varying sizes, indicating the field of view for each observation. The interface also includes a search bar at the bottom right and a status bar at the bottom left.

OSPS	2013-02-25T04:55:50.713	R	HV2274	14.2"	x 13.6"
OSPS	2013-02-25T03:23:04.800	R <th>HV982</th> <th>14.2"</th> <th>x 13.6"</th>	HV982	14.2"	x 13.6"
OSPS	2015-01-05T01:09:44.372	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T01:58:30.980	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T08:16:30.688	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T06:46:14.164	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T04:26:44.012	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T08:50:50.510	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T02:37:13.832	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T00:47:50.584	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T00:49:50.776	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T05:37:36.244	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T07:31:12.104	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T03:32:56.160	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T05:31:36.388	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T04:52:58.112	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T04:59:18.207	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T07:55:26.440	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T05:01:19.872	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T01:56:30.956	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T03:42:57.456	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T06:16:03.988	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T06:14:03.732	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T06:10:03.804	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T04:20:44.316	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T03:20:55.868	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T02:51:37.240	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T02:33:15.952	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T02:41:13.124	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T08:44:45.780	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T08:54:55.836	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T00:43:50.628	R <th>LMC03</th> <th>14.2"</th> <th>x 13.6"</th>	LMC03	14.2"	x 13.6"
OSPS	2015-01-05T02:45:36.976	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T07:14:51.916	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T06:00:06.644	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T02:02:31.648	R <th>LMC01</th> <th>14.2"</th> <th>x 13.6"</th>	LMC01	14.2"	x 13.6"
OSPS	2015-01-05T04:30:43.492	R <th>LMC33</th> <th>14.2"</th> <th>x 13.6"</th>	LMC33	14.2"	x 13.6"
OSPS	2015-01-05T08:05:31.448	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"
OSPS	2015-01-05T06:06:05.956	R <th>LMC52</th> <th>14.2"</th> <th>x 13.6"</th>	LMC52	14.2"	x 13.6"

Data Cubes = Scientific Data Structure



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IVOA N-Dimensional Cube Model

Version 1.0

IVOA Working Draft 20150320

This version:

[WD-CubeDM-1.0-20140930](http://www.ivoa.net/documents/WD-CubeDM-1.0-20140930/)

Previous version(s):

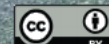
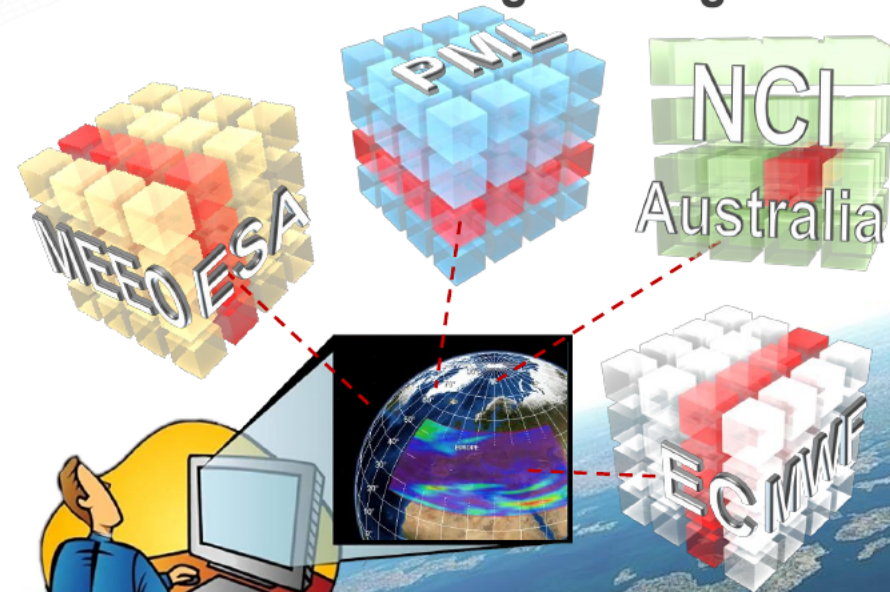
Editor(s):

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Authors:

Doug Tody, Francois Bonnarel, Omar Laurino, Mireille Louys, Arnold Rots, Jose Enrique Ruiz, Jesus Salgado, and the IVOA Data Model Working Group.

Datacubes as New Paradigm for Agile Analytics



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www.earthserver.eu

OSPS Light curves - plot (customized)



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Time Series Cube Data Model Version 1.1

IVOA Note 2017-02-05

Working group

Time domain interest group

This version

<http://www.ivoa.net/documents/cubeDM/20170205>

Latest version

<http://www.ivoa.net/documents/cubeDM>

Previous versions

Author(s)

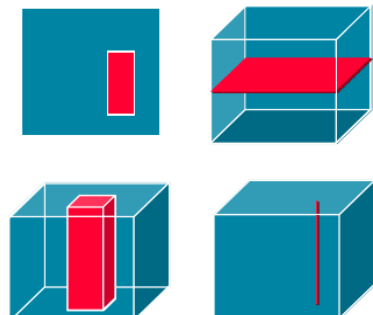
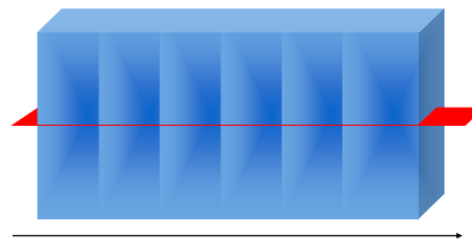
Jiří Nádvorník, Petr Škoda, Dave Morris, Pavel Tvrdlík

Editor(s)

Jiří Nádvorník

Datacube Services

rasdaman
raster data management



OSPS Light curves in SPLAT-VO using Sparse Cube DM

Starlink SPLAT-VO: Query VO for Spectra

File Options Resolver Interop Help

Service selection options

Data Source

☒ Observed data ☐ Theoretical data

Wave Band

☐ Radio ☐ Millimeter ☐ Infrared

☐ Optical ☐ UV ☐ EUV

☐ X-ray ☐ Gamma-ray ☒ ALL

Tags

SSAP Servers

short name	title
6dF Spectra	6dF DR3 Simple Spe...
BEFS	Berkeley Extreme an...
BeSS	Be Stars Spectra
califa ssa	CALIFA DR2
castor	Espadons/Narval leg...
castor+	Espadons/NARVAL le...
CCD700-voarchive	ccd700 OND
ccd700-vos2	
CDFS SSAP	Optical Spectroscop...
CENCOS-VVDS_DEEP	CENCOS-VVDS_DEEP...
CENCOS-VVDS_DEEP+	CENCOS-VVDS_DEEP...
CfA Hectospec	CfA Hectospec Spec...
dk154	
dk154-extr15	
dk154-extr15jan	dk154
dk154-extr16jan	dk154
DK154-SSA	DK154 SSA
ELODIE	ELODIE archive
ELODIEinterp	Spectrum interpolat...
ESO SAF SSA	ESO Science Archive...
EUVE	Extreme Ultraviolet ...
extropt-uv16	DK154

Search parameters:

Simple Query

Object: ogle lmc-dpv-056

RA: 05:15:53.21 Dec: -69:25:57.9

Radius: 0.05 MAXREC:

Band:

Time:

Query Format:

Wavelength calibration:

Flux calibration:

Optional Parameters

Use	Name	Value	UCD
<input type="checkbox"/>	REDSHIFT		src.redshift
<input type="checkbox"/>	TARGETCLASS		src.class
<input type="checkbox"/>	MTIME		
<input type="checkbox"/>	SPECRP		spect.resolution;em.wl
<input type="checkbox"/>	SPATRES		pos.angResolution
<input type="checkbox"/>	PUBDID		
<input type="checkbox"/>	CREATORID		meta.id

Query: <SERVER>?REQUEST=queryData&POS=78.97170833333332,-69.43275&FORMAT=votable&SIZE=8.333333333333334E-4

Query results:

dk154-extr16jan

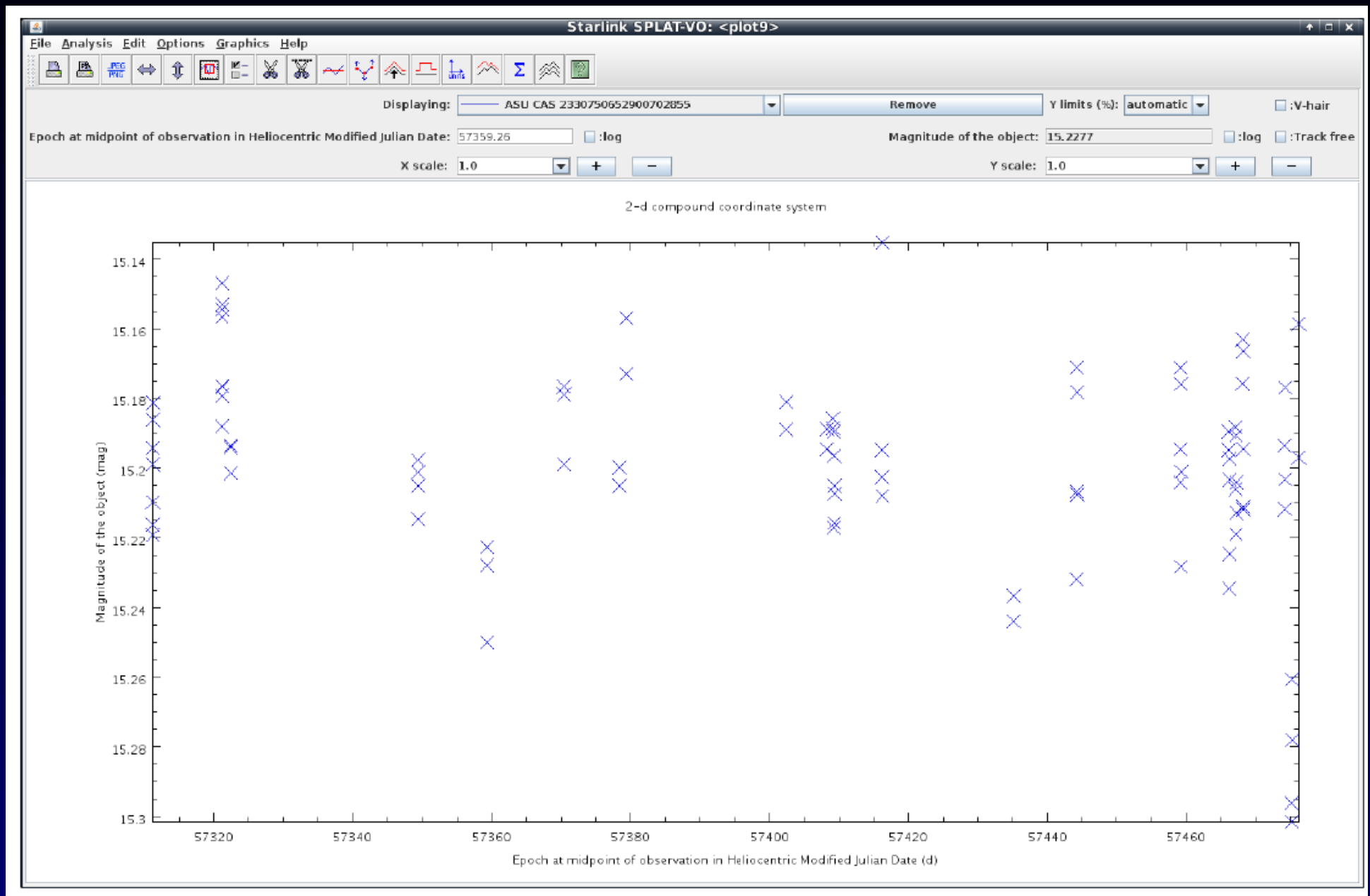
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4	ASU CAS 2329093547214535910	56953.99348	http://vos2.asu.cas.cz/getpro...	U	8	timeseries	application/x-votable+xml	(78.971725, -69.43276
5	ASU CAS 2329093547214535910	56953.98521	http://vos2.asu.cas.cz/getpro...	R	9	timeseries	application/x-votable+xml	(78.971725, -69.43276

Display selected Display all Download selected Download all Deselect table Deselect all DataLink Services

Query registry Add New Server

Save query results Restore query results Close

OSPS Light curves - plot (customized)



Conclusions

- Machine learning on Big Data archives may identify new interesting objects yet unknown
- Global Data Federation from Multiple fields
- Crucial is interactive visualization
- Future science will be multidisciplinary
- Wide collaboration of experts and informaticians
- Education of new expert – Data Scientist
- Transfer of technology – commercial interest
- X-Informatics ← Philosophia (love of wisdom)
- VO-like technology helps in every step