Astroinformatics – The New Paradigma of Astronomy in the Epoch of Petabyte-Scaled Archives

Petr Škoda

Astronomical Institute of the Academy of Sciences
Ondřejov
Czech Republic

Institute of Astronomy, Wroclaw Univerzity
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Credits

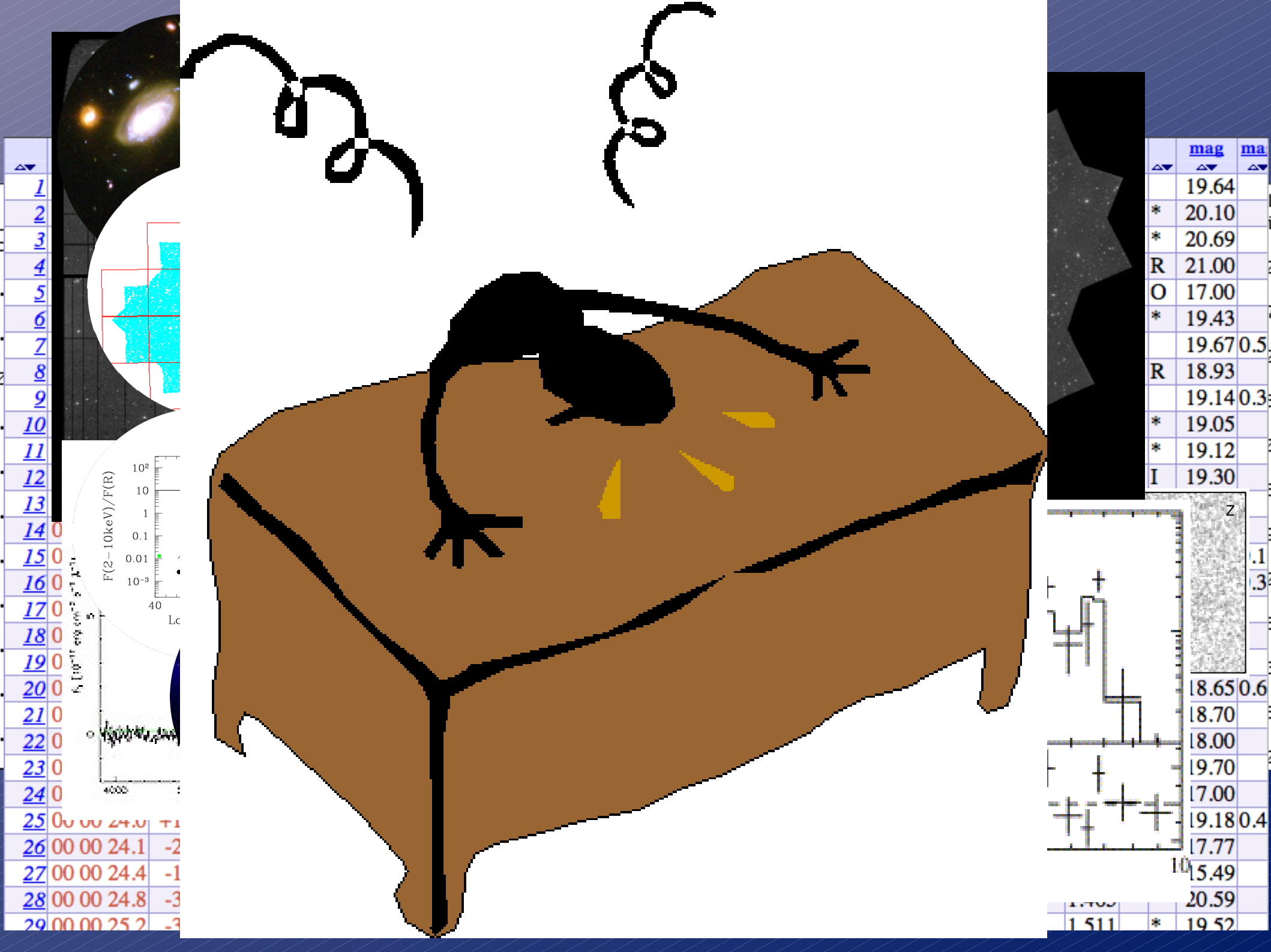
- The presentation is based on many different sources – mainly the on-line published slides from IVOA meetings, slides from Astroinformatics 2010 workshop or pictures found on internet.
- We acknowledge namely materials of E. Solano, D. De Young, F. LePetit, B.Hanish, G. Djorgovski, O. Laurino, L. Fortson, M. Graham, G. Longo, R. D'Abrusco, T.Hey and many others

Outline of the Talk

- VO – the hidden revolution in astronomy
- Data Avalanche in astronomy
- History of VO
- Basic principles of technology
- VO Tools
- Theory in VO
- VO Science
- VO and Society
- Astroinformatics (Citizen Science, 4th Paradigm)

VO – The Hidden Revolution

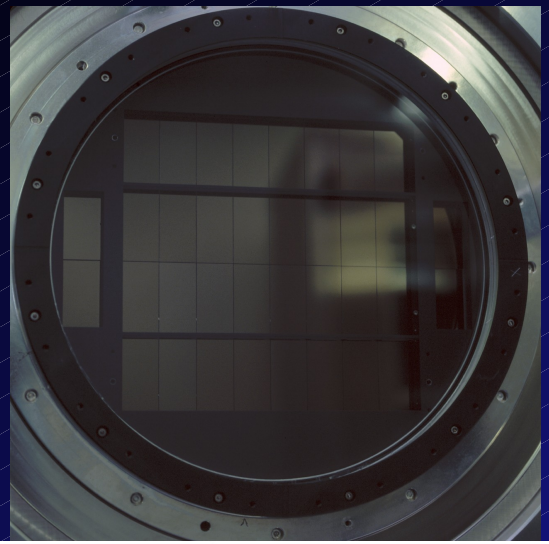
- VO is the radical change of the paradigma of the work of the scientists – effectiveness !!!
- Everyday question (what, where, format, units)
- Scientists are conservative (don't like change)
  - The fear of buzzword VO (multispec, large scale)
- Computer literacy – obligatory (part of job)
- Evanthia Hatsiminaoglou – cartoon !

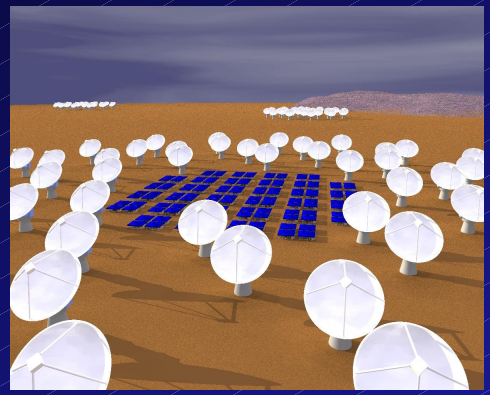


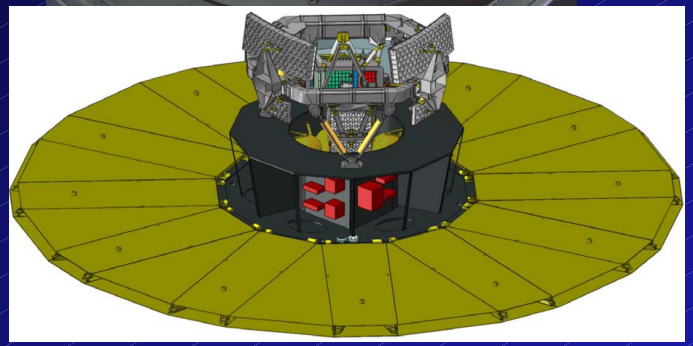
Analogy between VO and WWW

- Linking HYPERTEXT/DATA among servers
- Synergy effect of GLOBAL NET (Gopher,WAIS)
- Powerfull SEARCH (VERONICA – GOOGLE)
- DISTRIBUTED but CENTRAL Steering Organisation (W3C/IVOA)
- Recommendations = „Obligatory“ Standards
- Astronomers in forefront of development
- Scepticism (usefullness for my field ???)
- Steep Growth – average user can use it without knowledge of principles (effectivity, habits)

Data Avalanche







Large Scale Data

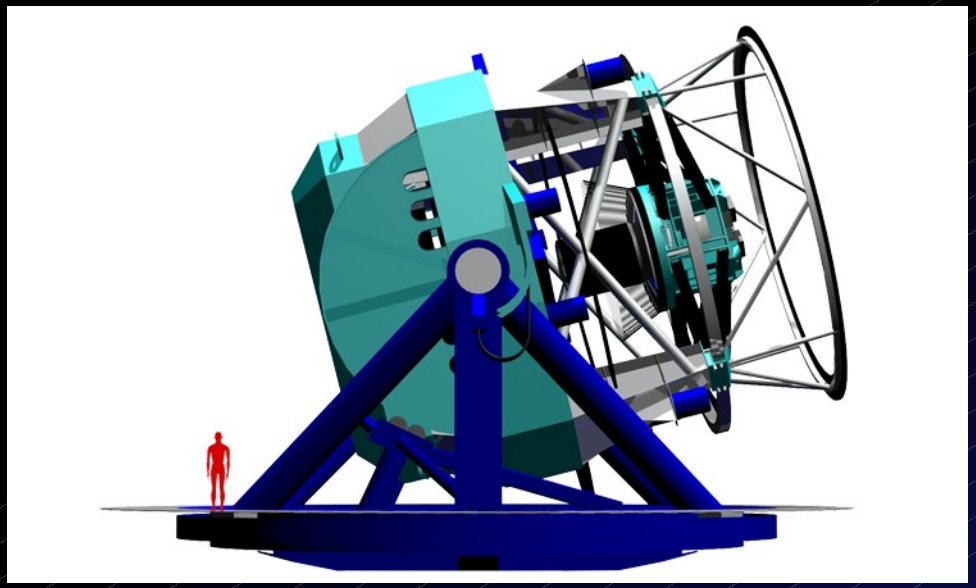
- *Huge surveys*:100 million sources at < 3000 sources per night ⇒> 100 years to identify them
- *Huge data collections*: download and data analysis on desktop problematic/impossible.
- Example: downloading Sloan Digital Sky Survey (SDSS) DR6 data:
  - images (10 Terabytes) ⇒~ 3 months at 10 Mbps
  - catalogues (2 Terabytes) ⇒~ 3 weeks
  - on DVDs ⇒~ 2,100 of them
- And *data analysis*?? (similar size for MACHO, 2MASS etc)

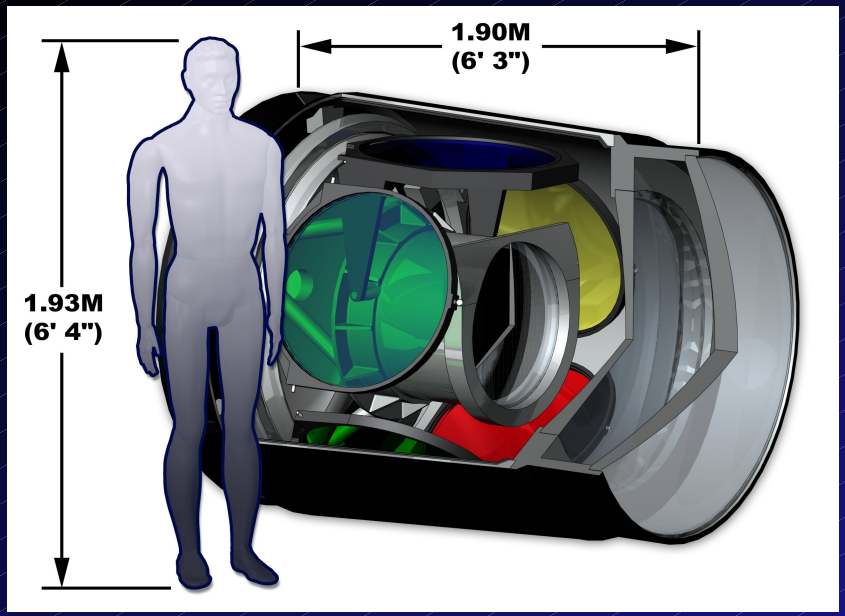
CD Sea

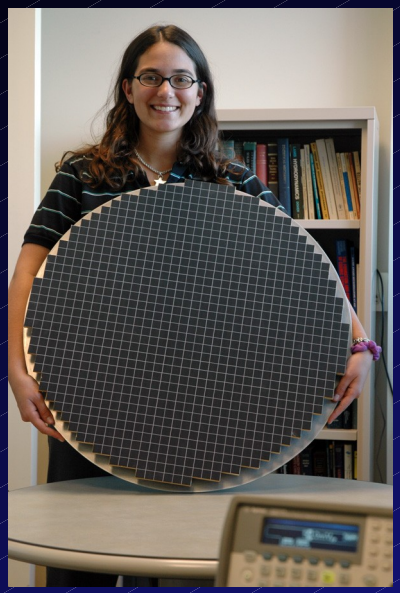
600 000 CD = 372 TB (CD 650MB)
600 000 DVD = 2.5 PB (DVD=4.5GB)

Bruce Monro
Kilmington UK

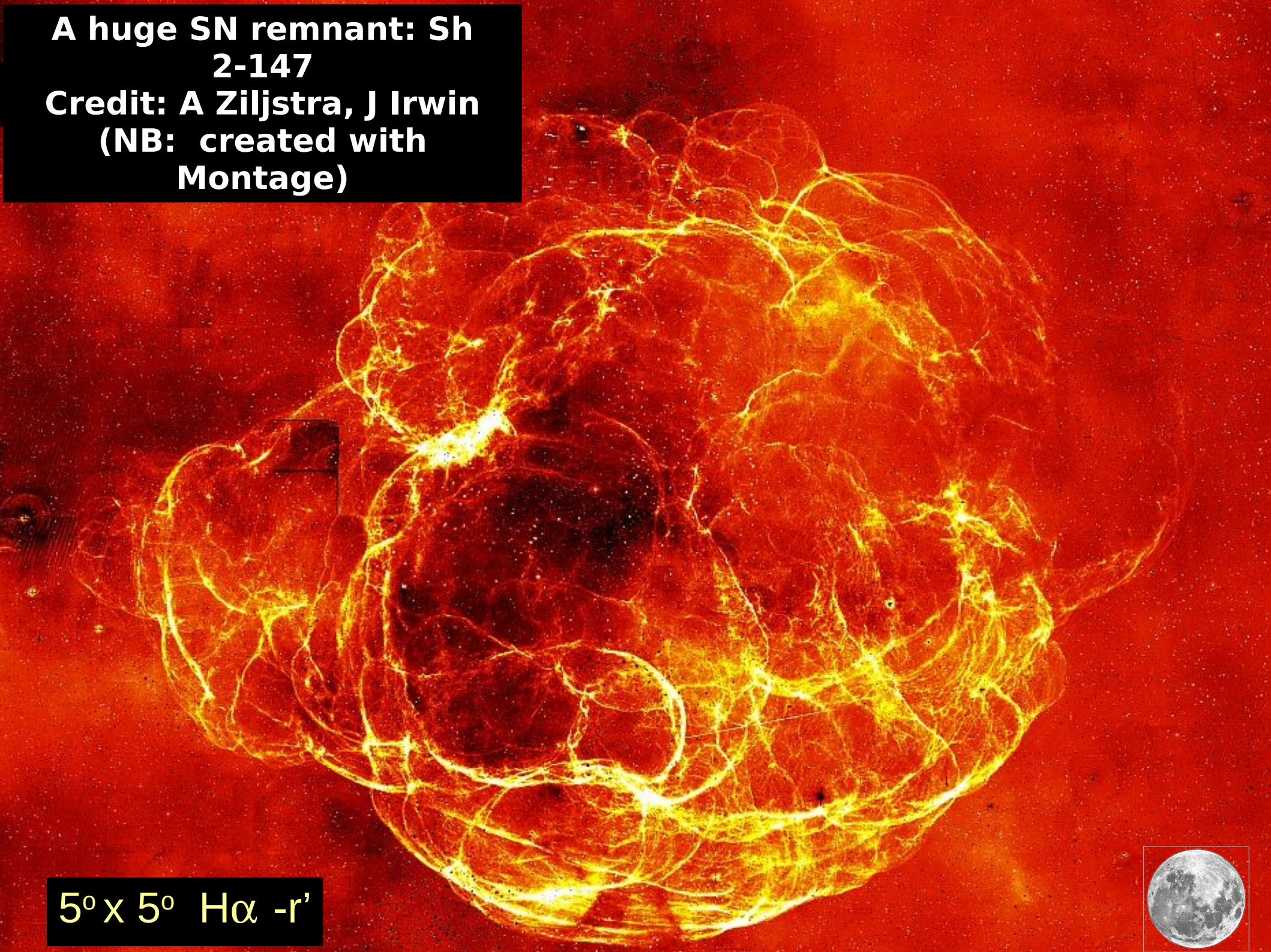
LSST (8.4m)

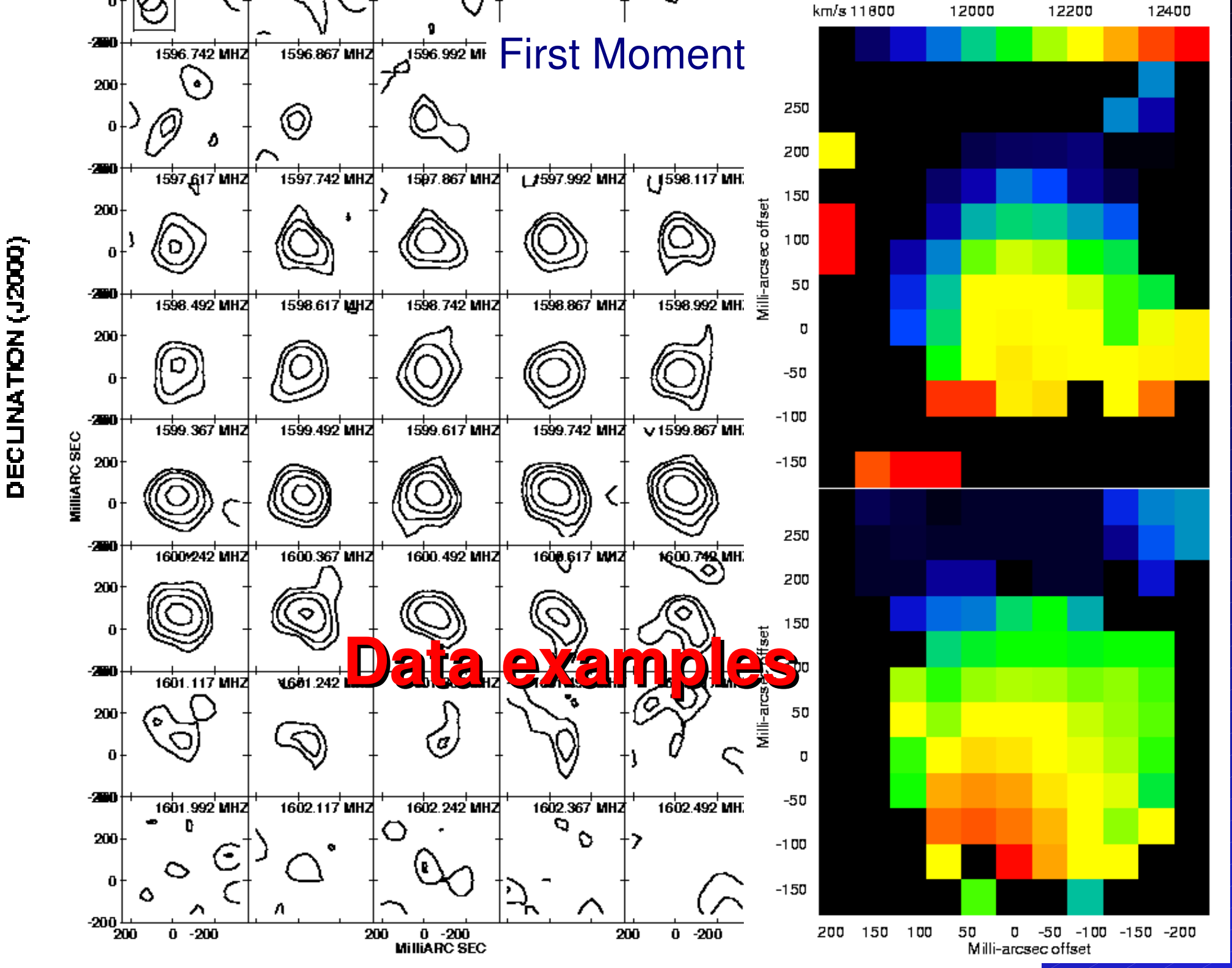






200 CCD 4kx4k,
32 channels (6400)
3.2 Gpix every 20 sec
64cm diameter
3.5 deg FOV
30 TB/night
2 TFLOPS
detection of changes
within 60sec

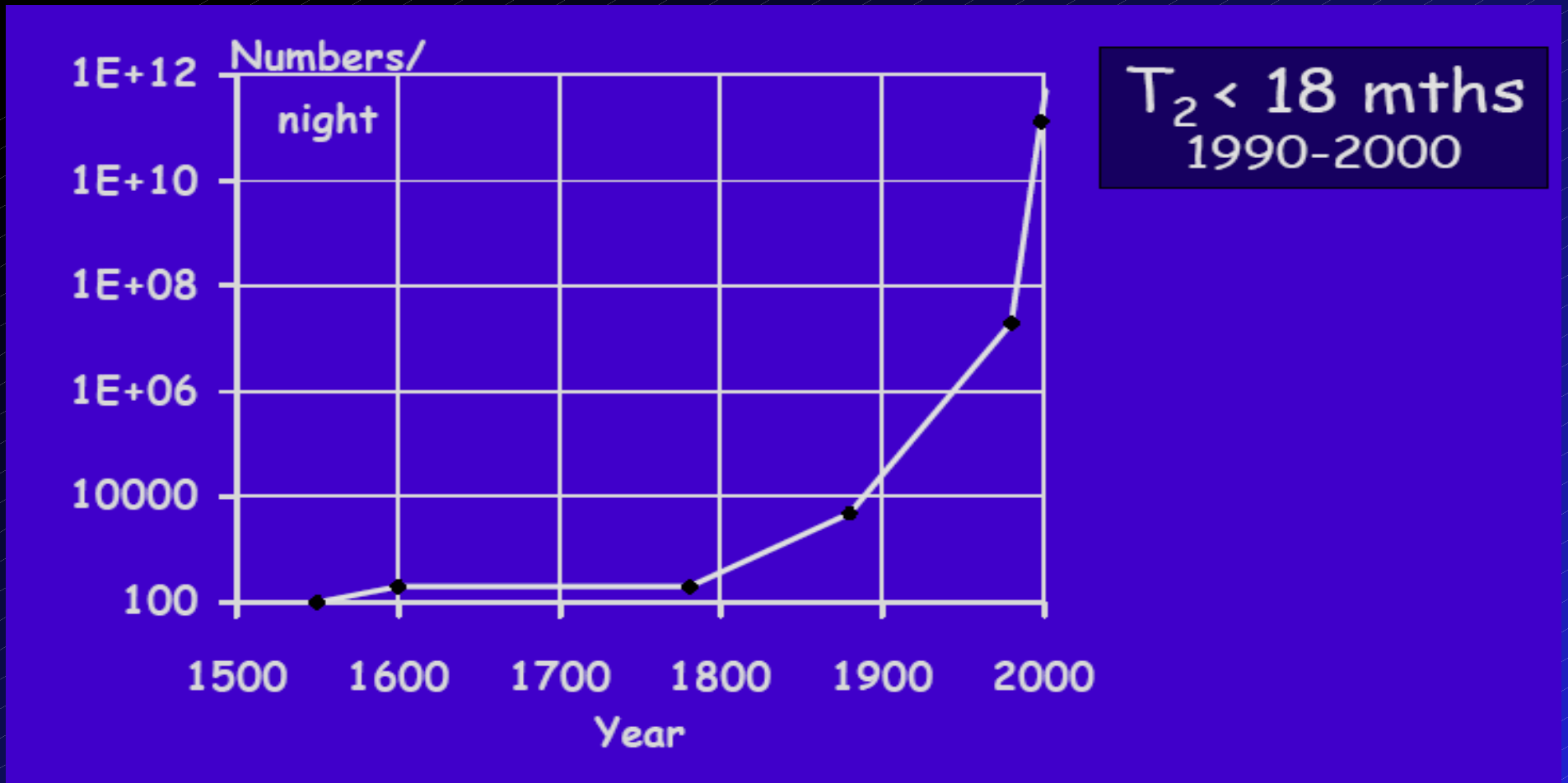

A huge SN remnant: Sh 2-147
Credit: A Ziljstra, J Irwin
(NB: created with Montage)
5° x 5° Hα -r'


First Moment
Data examples
DECLINATION (J2000)
MilliARC SEC
MilliARC SEC
Milli-arcsec offset
Milli-arcsec offset
km/s 11800
12000
12200
12400
1596.742 MHZ
1596.867 MHZ
1596.992 MH
1597.617 MHZ
1597.742 MHZ
1597.867 MHZ
1597.992 MHZ
1598.117 MH
1598.492 MHZ
1598.617 MHZ
1598.742 MHZ
1598.867 MHZ
1598.992 MH
1599.367 MHZ
1599.492 MHZ
1599.617 MHZ
1599.742 MHZ
1599.867 MH
1600.242 MHZ
1600.367 MHZ
1600.492 MHZ
1600.617 MHZ
1600.742 MH
1601.117 MHZ
1601.242 MH
1601.992 MHZ
1602.117 MHZ
1602.242 MHZ
1602.367 MHZ
1602.492 MH

Data Avalanche

Moore law for chips –doubling 1.5 year

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

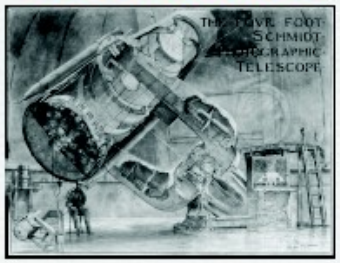


A paradigm shift

Federated all-sky surveys

Large surveys

Pointed observations



New techniques designed to tackle this data deluge are necessary.

Number of sources

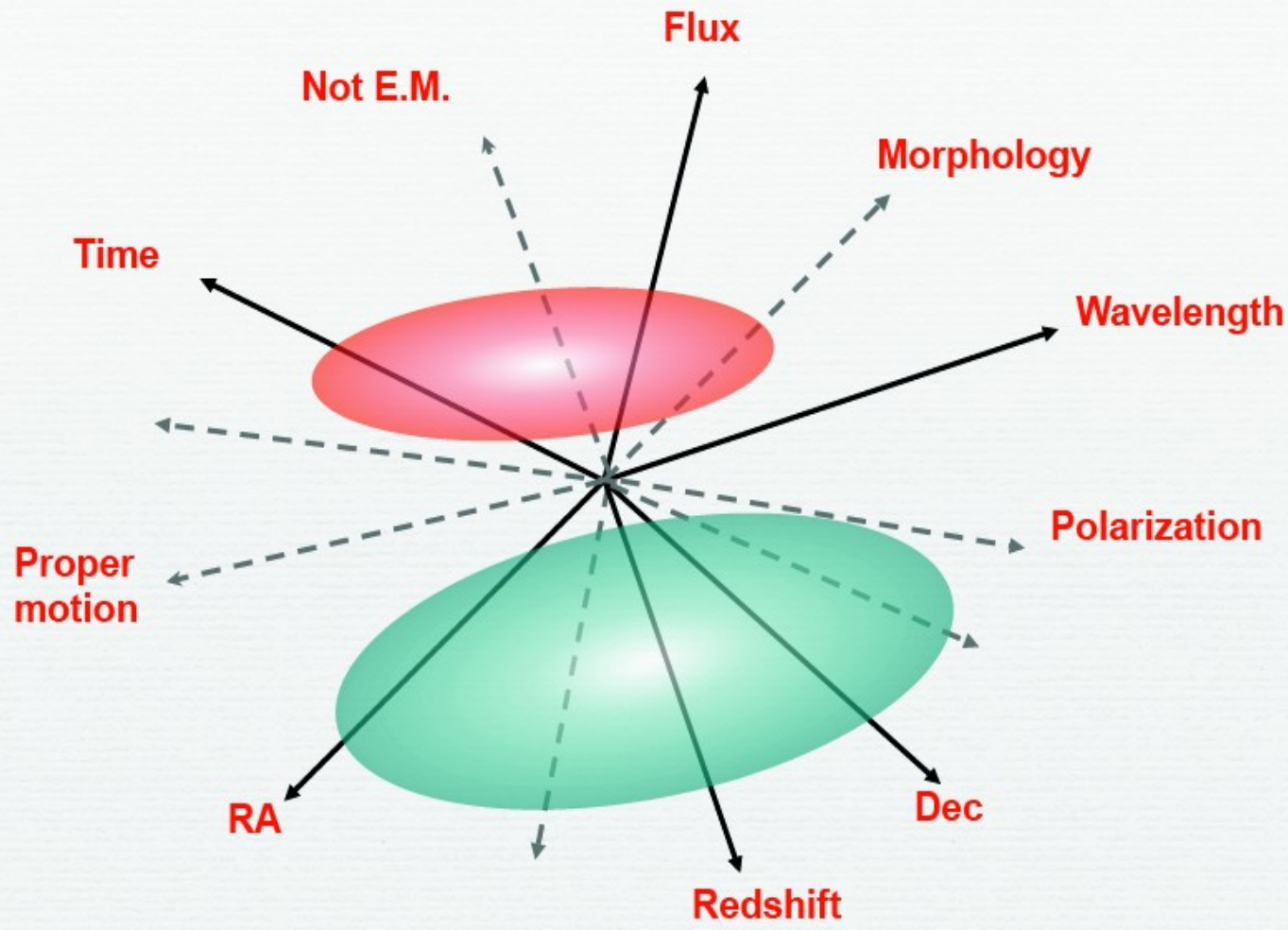
10^6 10^5 10^4 10^3

10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18}

Data complexity (Bytes)

D'Abrusco 2010

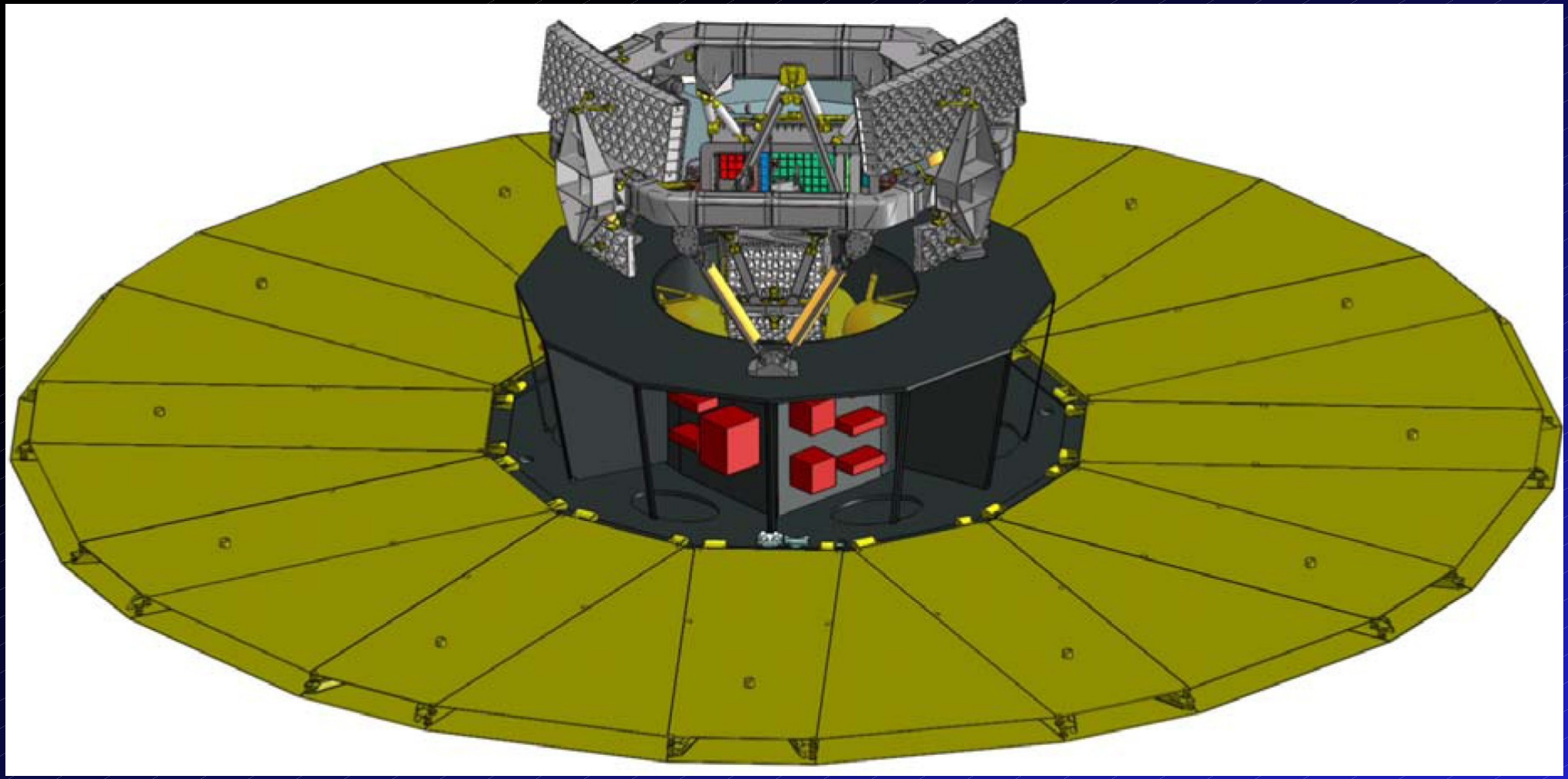
A growing parameter space



Most discoveries were made in small regions of subspaces or along some of these axes

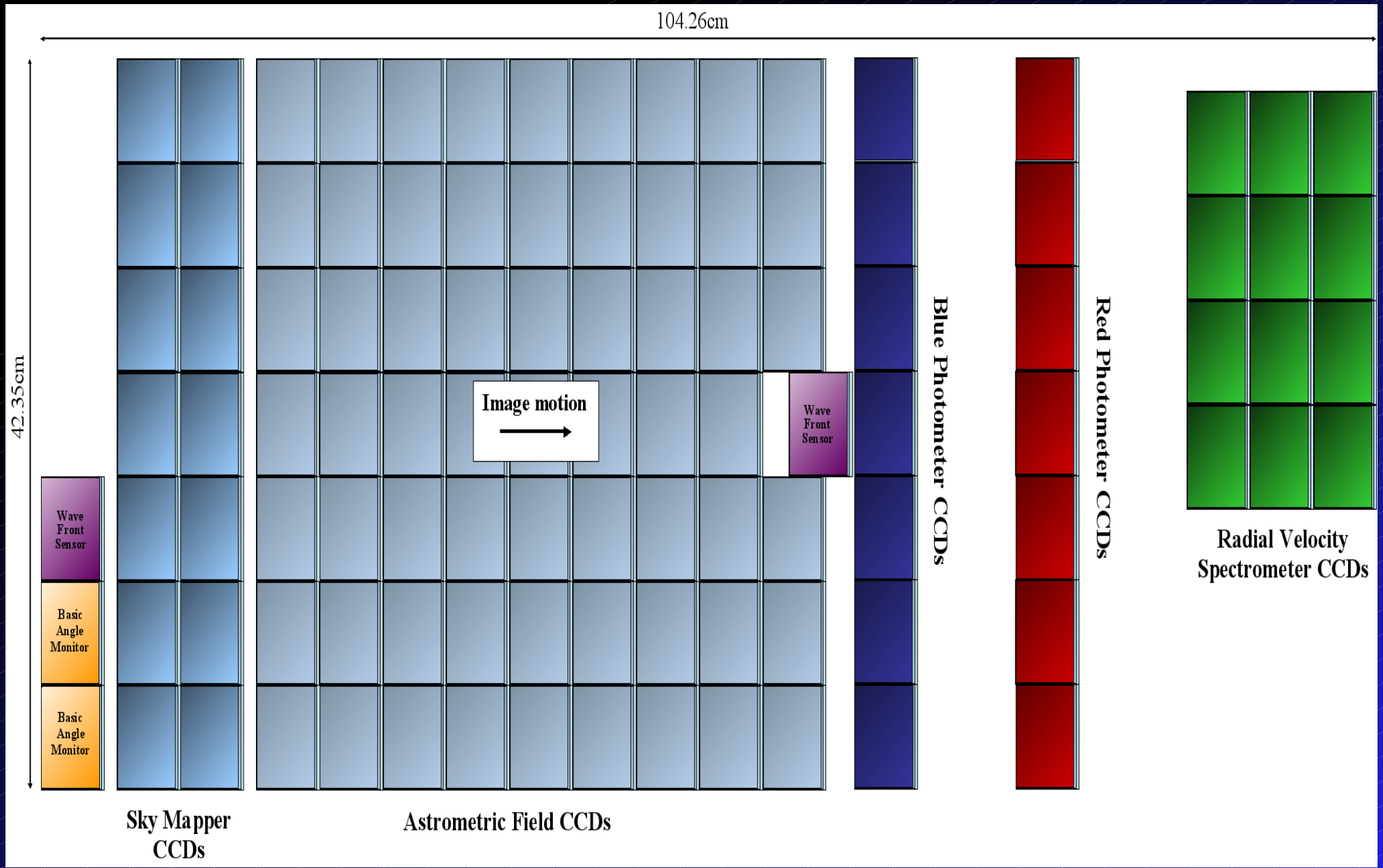
D'Abrusco 2010

GAIA (2012)



GAIA CCDs

106 CCDs
938 Mpix
2800cm²



History of VO

Success of IUE/HST archives

idea of the VO - end 2000

Federation of archives (MAST, NED)

- unified IF, data format for transport

Huge data – distributed processing

GRID - started in HEP (accelerator science)

Multispectral research : radio---gamma

- Virtual Universe (UK), AstroVirTel (ESO)

Data for SDSS, SIMBAD, NED – key research

Virtual Observatory : Key Definitions

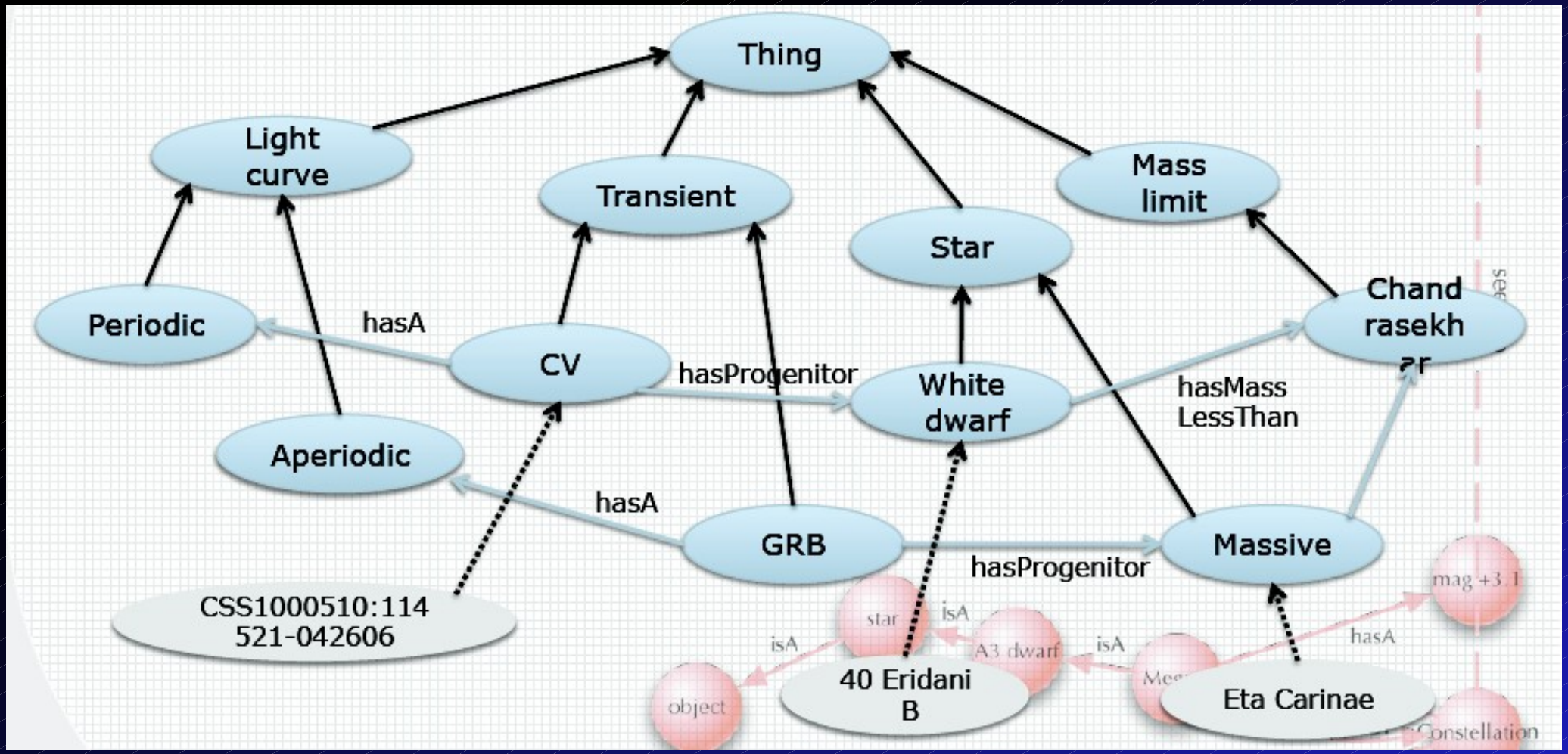
- "*The Virtual Observatory will be a system that allows astronomers to interrogate multiple data centers in a seamless and transparent way, which provides new powerful analysis and visualization tools within that system, and which gives data centers a standard framework for publishing and delivering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

VO Paradigma

- METADATA (name of column), ontologies (name)
- Unique format (VOTable – e.g Vizier)
- Transparent search, download, conversion
- Query for data – processing done on servers
- Federation of astronomical archives (protocols)
- Unified presentation – automatic units conversion (A,MeV,MHz->nm), Wm^-2s^-1 → Jy)
- Background computing on GRIDS
- Multiwavelength approach (SED)

Ontologies in Astronomy



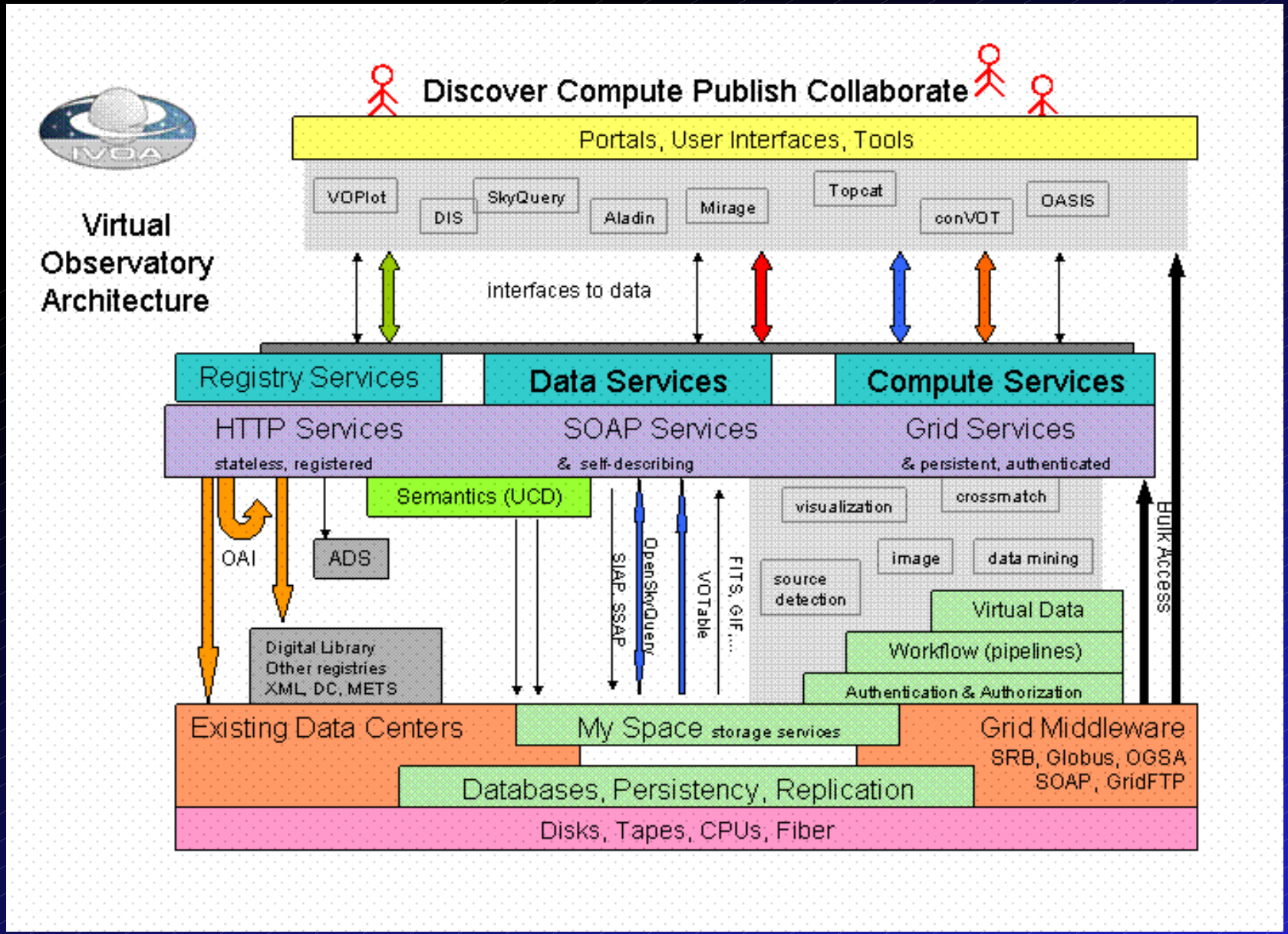
From Graham, M. AI2010

VOTable

```
<TABLE name="SpectroLog">
<FIELD name="Target" ucd="meta.id" datatype="char" arraysize="30*"/>
<FIELD name="Instr" ucd="instr.setup" datatype="char" arraysize="5*"/>
<FIELD name="Dur" ucd="time.expo" datatype="int" width="5" unit="s"/>
<FIELD name="Spectrum" ucd="meta.ref.url" datatype="float" arraysize="*"
      unit="mW/m2/nm" type="location">
<DESCRIPTION>Spectrum absolutely calibrated</DESCRIPTION>
<LINK type="location"
      href="http://ivoa.spectr/server?obsno="/>
</FIELD>
<DATA><TABLEDATA>
<TR><TD>NGC6543</TD><TD>SWS06</TD><TD>2028</TD><TD>01301903</
TD></TR>
<TR><TD>NGC6543</TD><TD>SWS07</TD><TD>2544</TD><TD>01302004</
TD></TR>
</TABLEDATA></DATA>
</TABLE>
```

Serialization (metadata first, end of data unknown, tree structure)

Architecture of VO



Technology of VO

Unified data format– VOTable, UCD (Vizier)

Transparent transport (SOAP , REST(youtube))

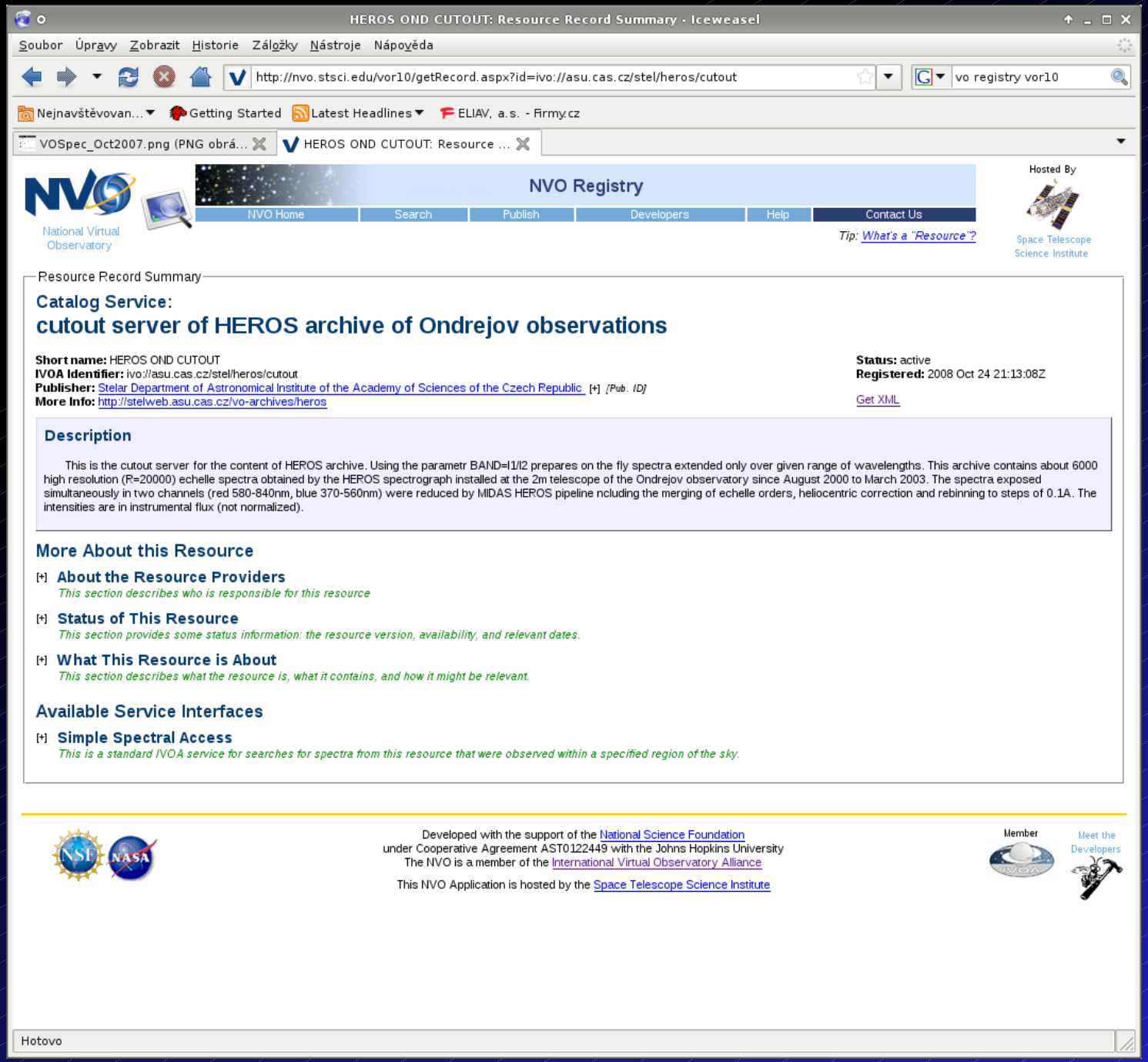
Web services (WS) e-commerce, B2B, J2EE, .Net

VOregistry (DNS like) Google for data+WS

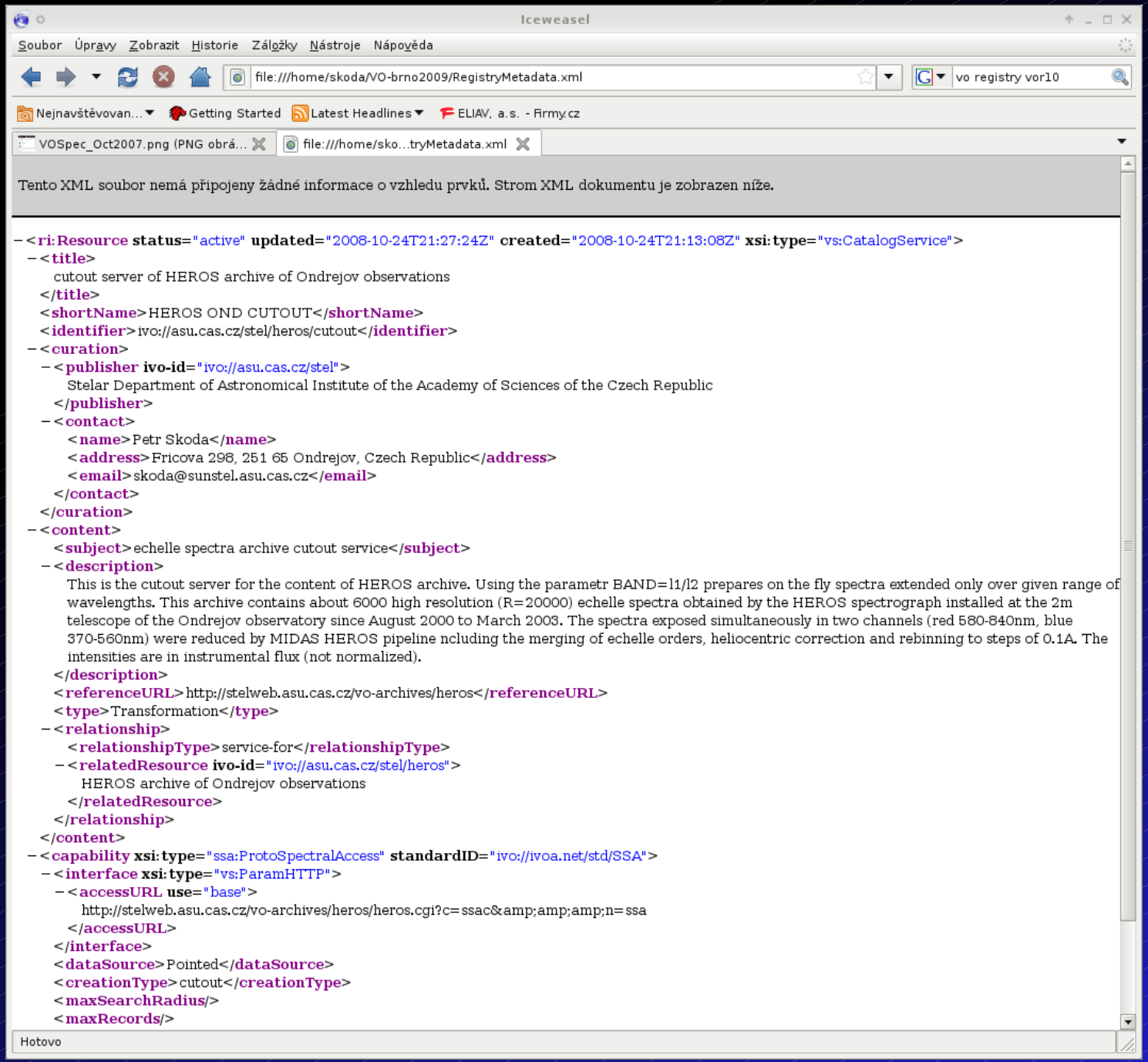
protocols (CGI)

- ConeSearch (searching in circle on sky)
- SIAP (Simple Image Access Protocol)
- SSAP(Simple Spectral Access Protocol)
- SLAP(Simple Line Access Protocol)
- TAP (Table Access Protocol)
- VOEVENT (transients, robotic telescopes,Sun)

VO Registry - web



VO Registry – XML




```
−<ri:Resource status="active" updated="2008-10-24T21:27:24Z" created="2008-10-24T21:13:08Z" xsi:type="vs:CatalogService">
  −<title>
     cutout server of HEROS archive of Ondrejov observations
   </title>
   <shortName>HEROS OND CUTOUT</shortName>
   <identifier>ivo://asu.cas.cz/stel/heros/cutout</identifier>
  −<curation>
    −<publisher ivo-id="ivo://asu.cas.cz/stel">
       Stelar Department of Astronomical Institute of the Academy of Sciences of the Czech Republic
     </publisher>
    −<contact>
       <name>Petr Skoda</name>
       <address>Fricova 298, 251 65 Ondrejov, Czech Republic</address>
       <email>skoda@sunstel.asu.cas.cz</email>
     </contact>
   </curation>
  −<content>
     <subject>echelle spectra archive cutout service</subject>
    −<description>
       This is the cutout server for the content of HEROS archive. Using the parametr BAND=l1/l2 prepares on the fly spectra extended only over given range of
       wavelengths. This archive contains about 6000 high resolution (R=20000) echelle spectra obtained by the HEROS spectrograph installed at the 2m
       telescope of the Ondrejov observatory since August 2000 to March 2003. The spectra exposed simultaneously in two channels (red 580-840nm, blue
       370-560nm) were reduced by MIDAS HEROS pipeline ncluding the merging of echelle orders, heliocentric correction and rebinning to steps of 0.1A. The
       intensities are in instrumental flux (not normalized).
     </description>
     <referenceURL>http://stelweb.asu.cas.cz/vo-archives/heros</referenceURL>
     <type>Transformation</type>
    −<relationship>
       <relationshipType>service-for</relationshipType>
      −<relatedResource ivo-id="ivo://asu.cas.cz/stel/heros">
         HEROS archive of Ondrejov observations
       </relatedResource>
     </relationship>
   </content>
  −<capability xsi:type="ssa:ProtoSpectralAccess" standardID="ivo://ivoa.net/std/SSA">
    −<interface xsi:type="vs:ParamHTTP">
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       </accessURL>
     </interface>
     <dataSource>Pointed</dataSource>
     <creationType>cutout</creationType>
     <maxSearchRadius/>
     <maxRecords/>
```

Technology of VO

ADQL (Astronomical Data Query Language)

XMATCH, REGION (2 catalogues - shifted)

Application interoperabilty – PLASTIC, SAMP

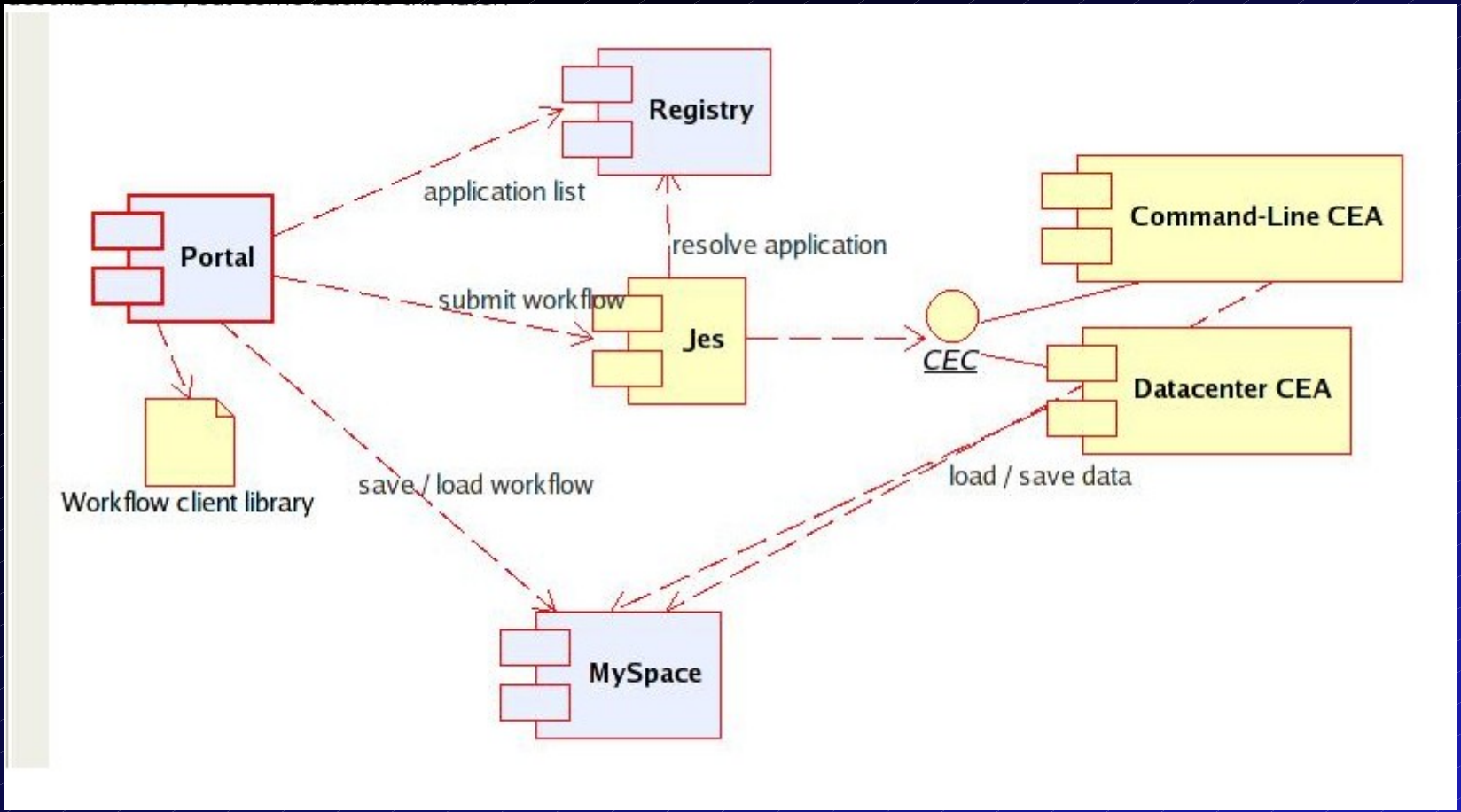
- Allows develop applications as bricks
- sending VOTABLES (catalogue-spectra-images)

Commercial interest (GoogleSky, MS WWT)

Planetariums, Outreach (Stellarium)

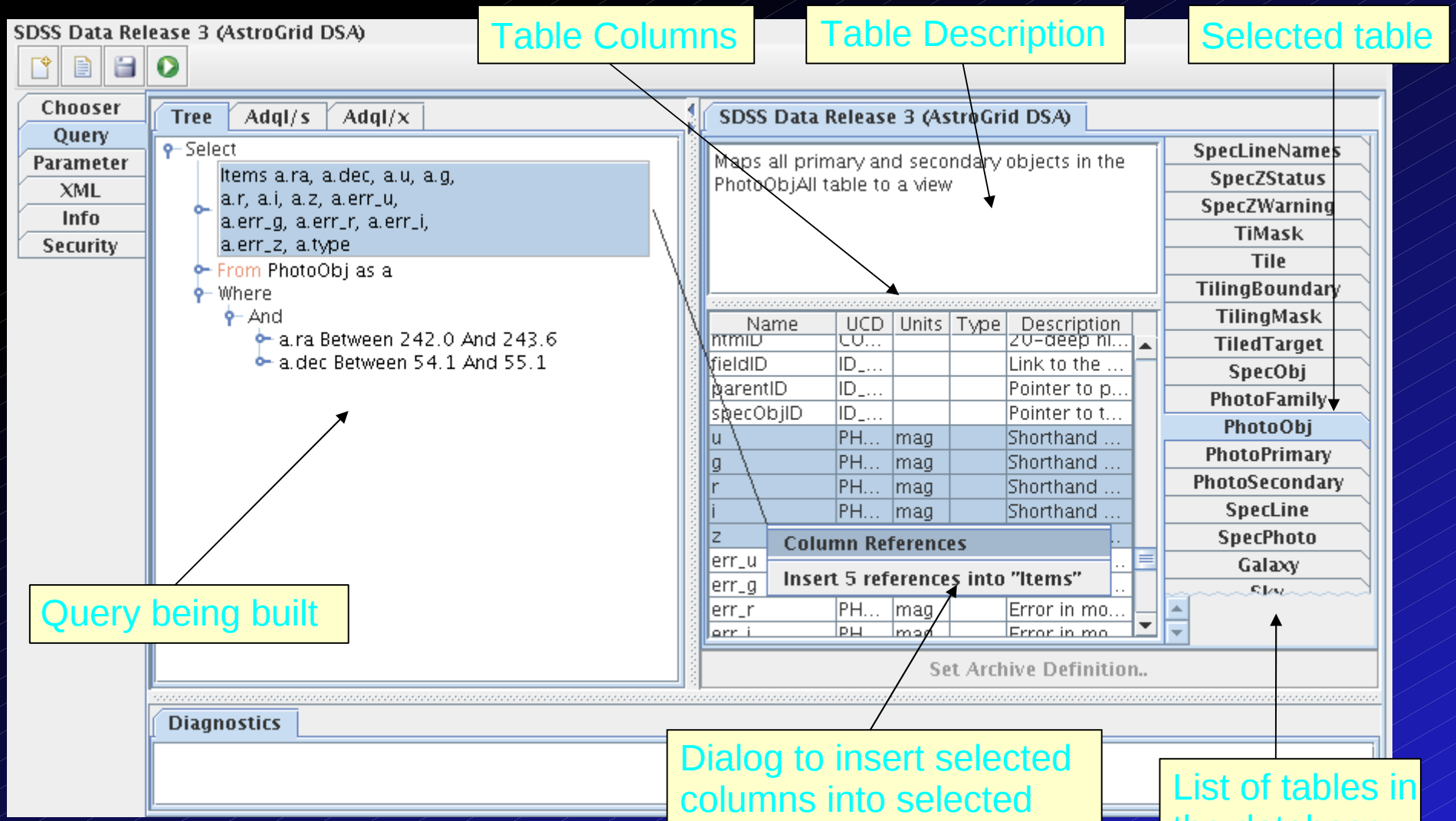
Workflows - Astrogrid

Running remote services – e.g. Sextractor, CASJobs, AstroNeural MLP....



Building a query

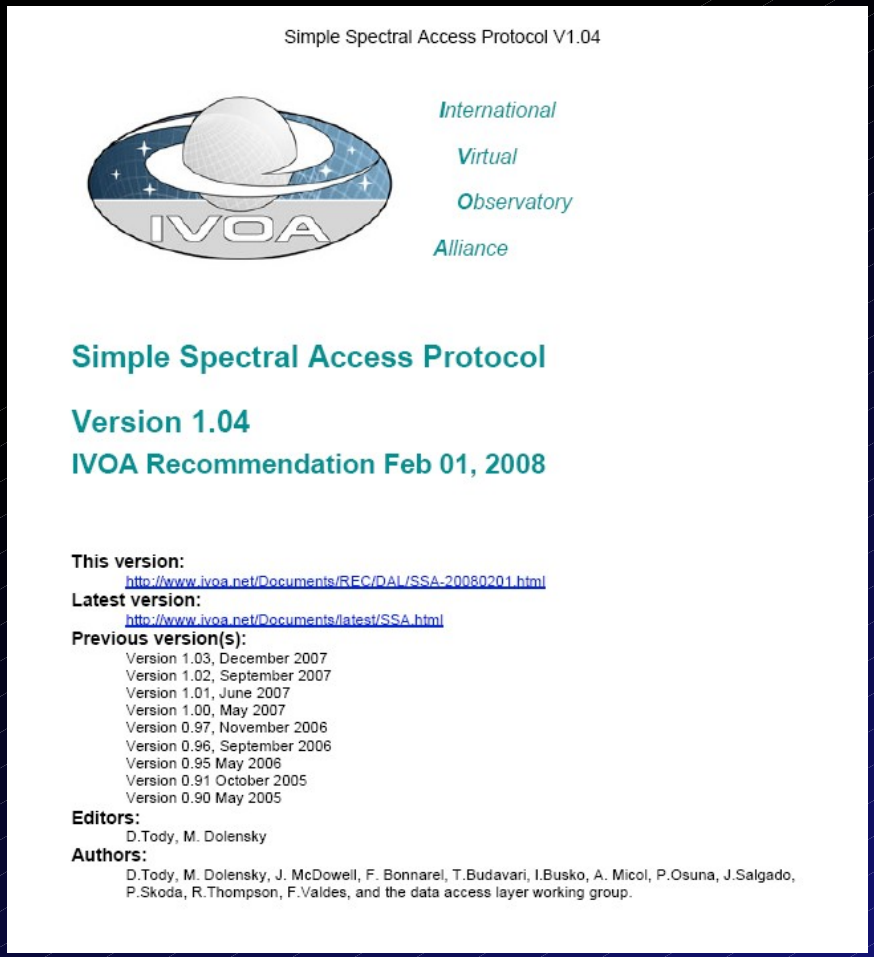
AstroGrid Query Builder



IVOA


Aus-VO
EURO VO
China-VO
VO-i
Astro Grid
CVO
RVO
SVO
NVO
IVOA
ArVO
JVO
HVO
GAVO
France

Simple Spectra Access Protocol
Spectral Data Model



Simple Spectral Access Protocol V1.04

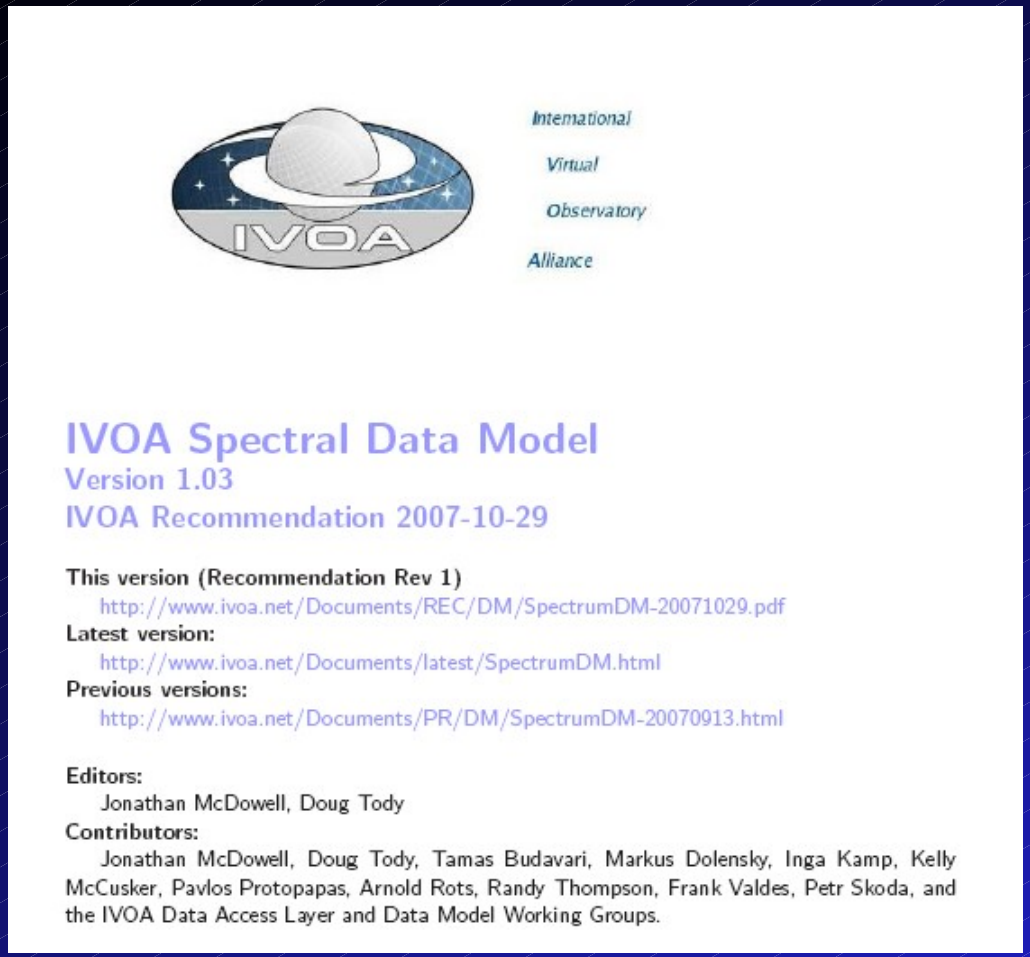
International Virtual Observatory Alliance

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	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

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

Universal Worker Service

RESTfull (PUT/GET/POST/DELETE)

URI	Description	Representation
/{jobs}	the Job List	the <jobs> element in the UWS schema
/{jobs}/(job-id)	a Job	the <job> element in the UWS schema
/{jobs}/(job-id)/phase	the Phase of job (job-id)	one of the fixed strings
/{jobs}/(job-id)/ executionduration	the maximum execution duration of (job-id)	Integer number of seconds
/{jobs}/(job-id)/destruction	the destruction instant for (job-id)	*[std:iso8601]*
/{jobs}/(job-id)/error	any error message associated with (job-id)	any representation appropriate to the implementing service
/{jobs}/(job-id)/quote	the Quote for (job-id)	Integer number of seconds
/{jobs}/(job-id)/results	any parameters for the job (job-id)	the <results> element in the UWS schema
/{jobs}/(job-id)/parameters	any parameters for the job (job-id)	the <parameters> element in the UWS schema
/{jobs}/(job-id)/owner	the owner of the job (job-id)	an appropriate identifier as discussed in 3.

VO-enabled tools

Aladin

VOPlot

TOPCAT

VOSpec

SpecView

SPLAT

ViSiVO (HPC simulations, cosmology)

VOSED

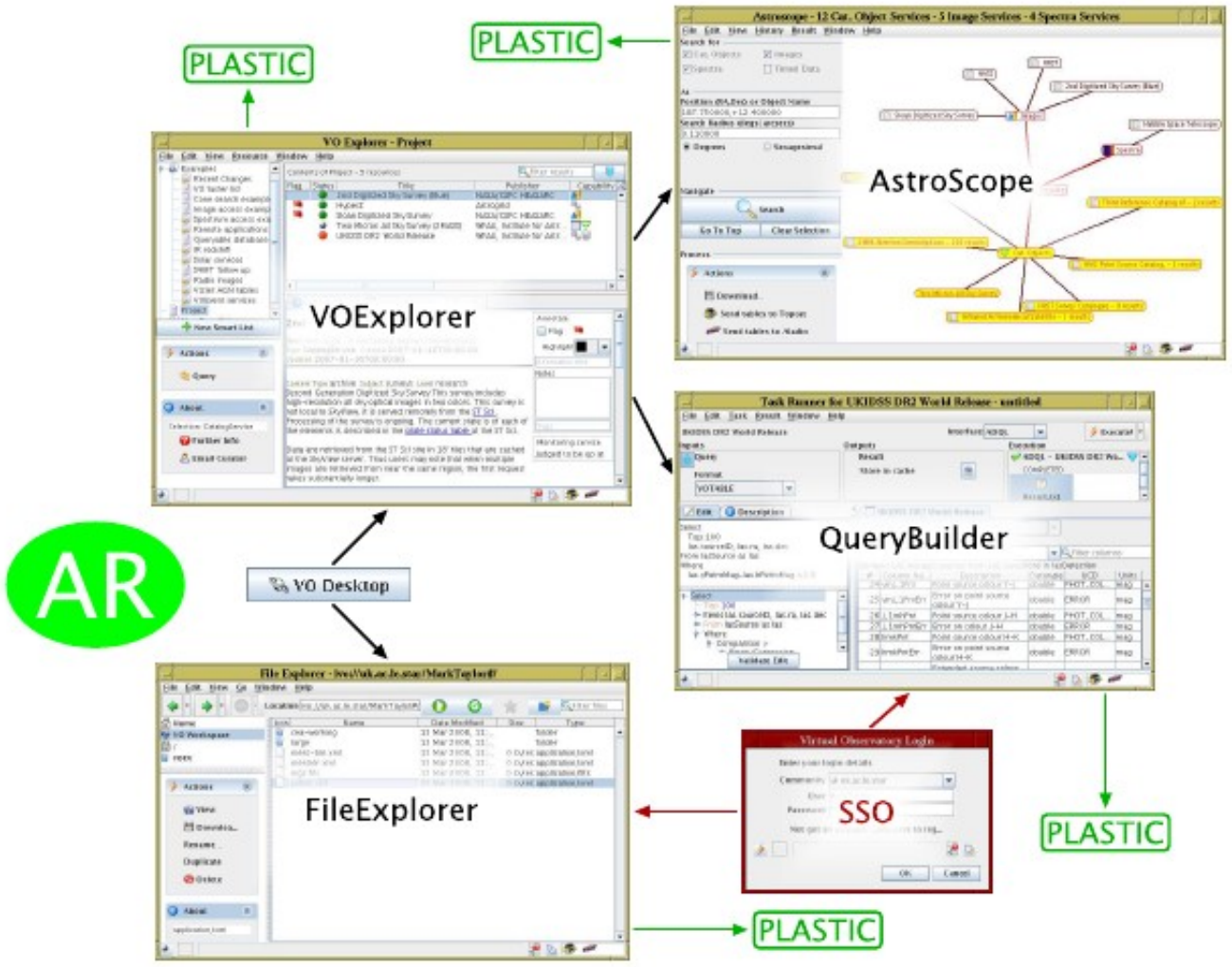
BASTI

SExtractor – WESIX (Web Enabled Source Identification with Cross Matching)

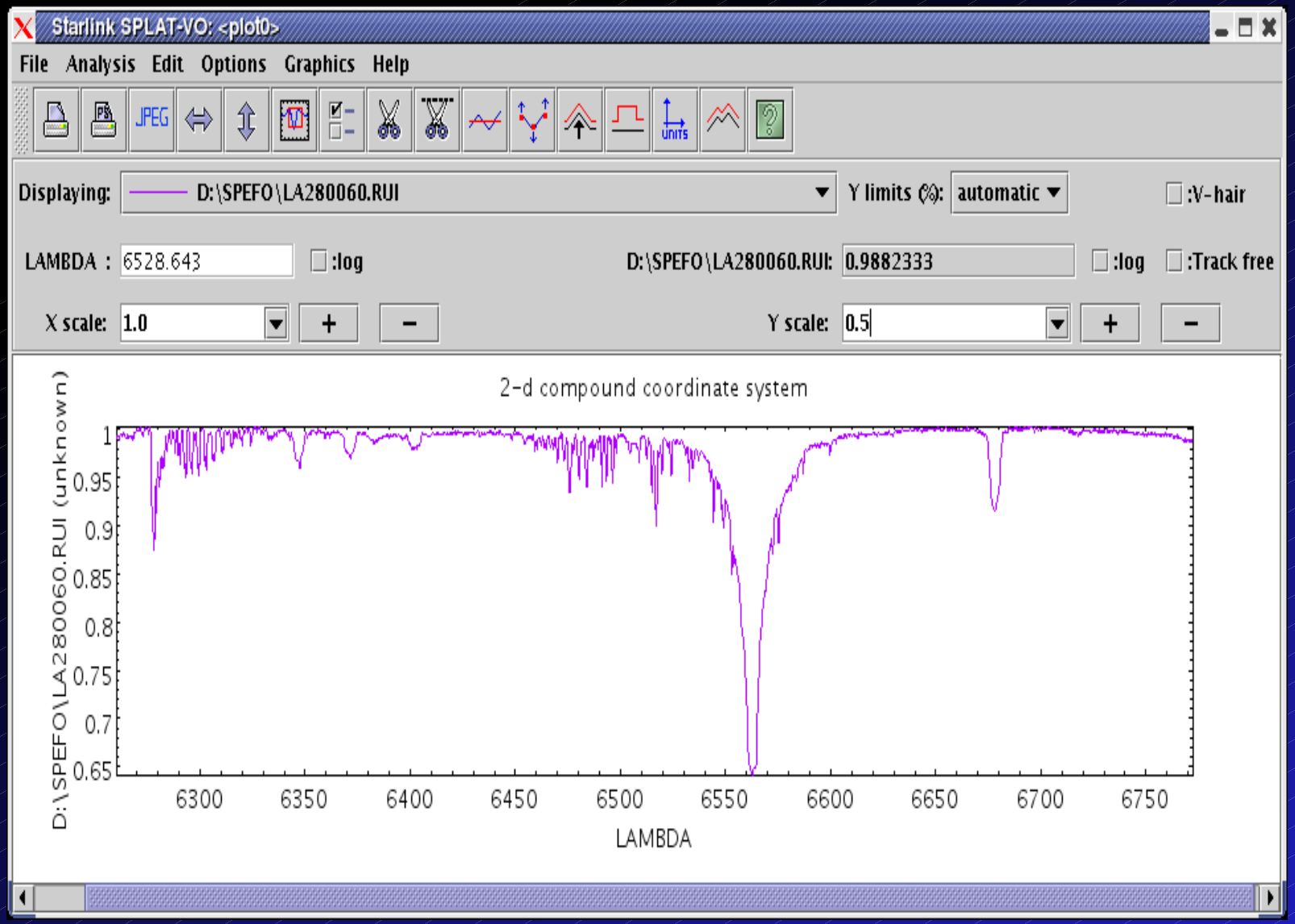
Period04 (since 18.9.08) - PLASTIC

AstroGRID VODesktop

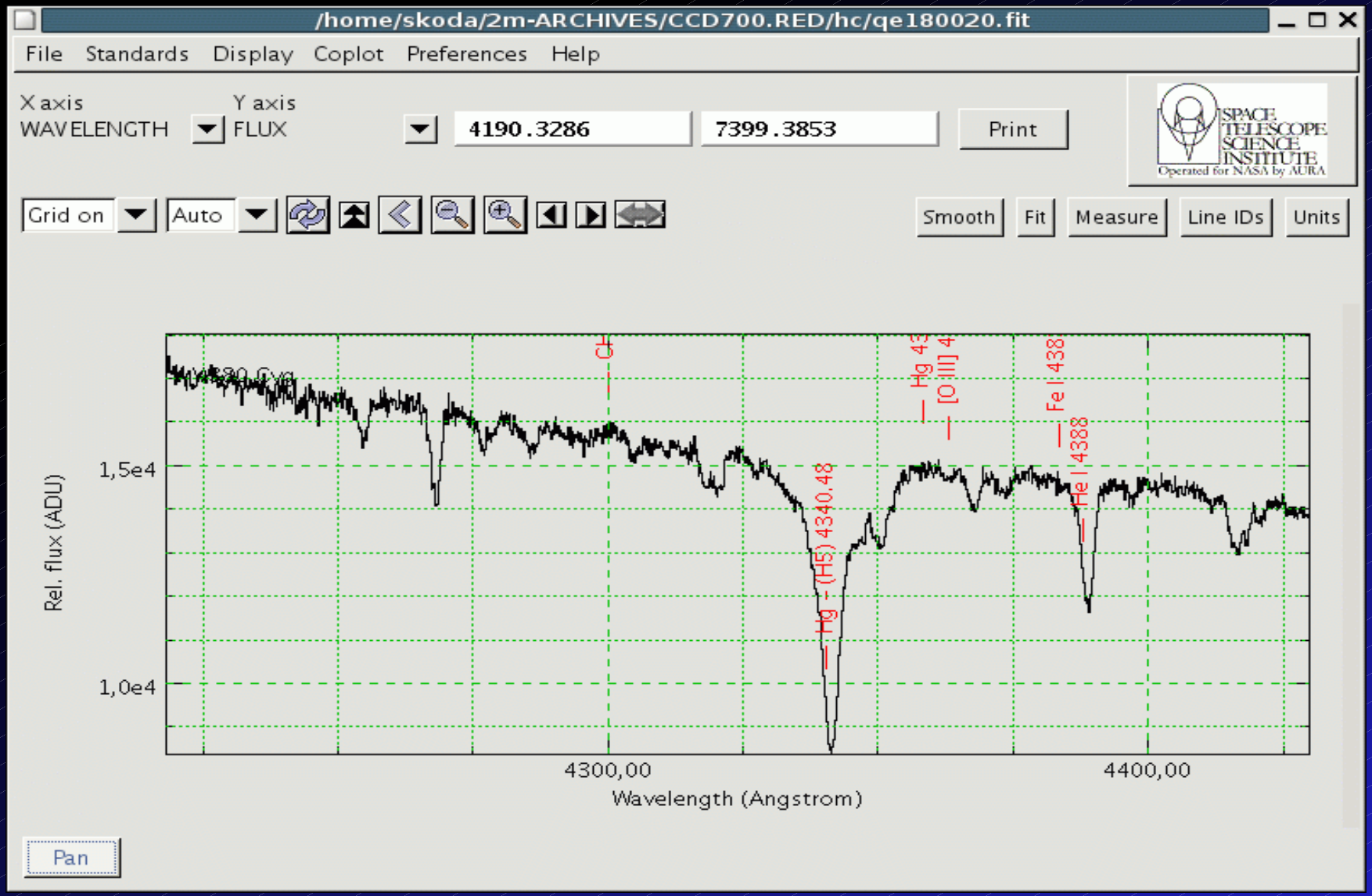
VODesktop Overview



SPLAT-VO (Starlink, JAC)



SpecView (STScI)



Spectrum Services for the VO - Microsoft Internet Explorer

Back Search Favorites File Edit View Favorites Tools

Address http://voservices.net/spectrum/search_list.aspx?search=cone&view=graph&page=o Go

NVO

National Virtual Observatory

Spectrum Services

home | docs | search | MySpectrum | collections | webservices | user

not logged in
login | register

Search Results

Found 12 objects. Displaying from 1 to 3

List mode Image mode

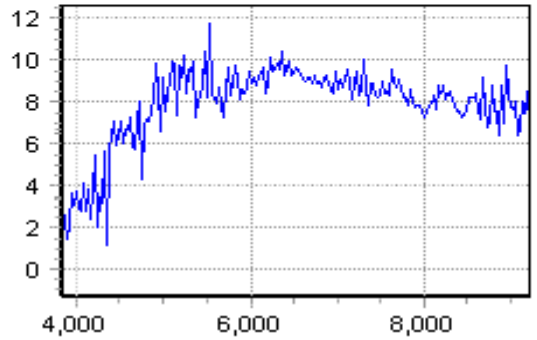
First Prev Next Last

1 . SDSS J115944.85+000000.00

ivo://jhu/sdss/dr4#80443408212033536 |
ivo://sdss/dr4/spec#80443408212033536 details

class: Galaxy , Z = 0.1009

ra = 179.936874 , dec = 0.941241

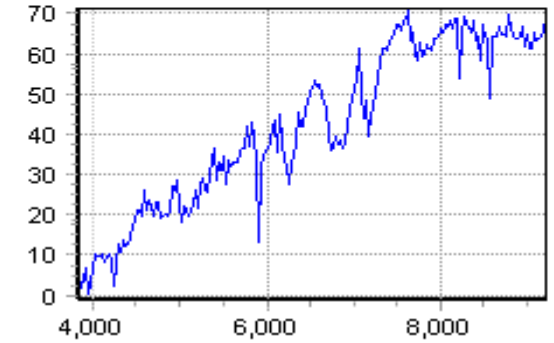


2 . SDSS J120008.29+016000.00

ivo://jhu/sdss/dr4#80443408262365184 |
ivo://sdss/dr4/spec#80443408262365184 details

class: Galaxy , Z = 0.0000

ra = 180.034561 , dec = 1.146855

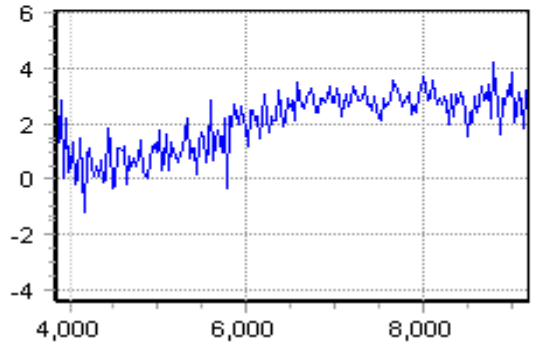


3 . SDSS J115923.80+000000.00

ivo://jhu/sdss/dr4#80443407863906304 |
ivo://sdss/dr4/spec#80443407863906304 details

class: Galaxy , Z = 0.4517

ra = 179.849167 , dec = 0.984768



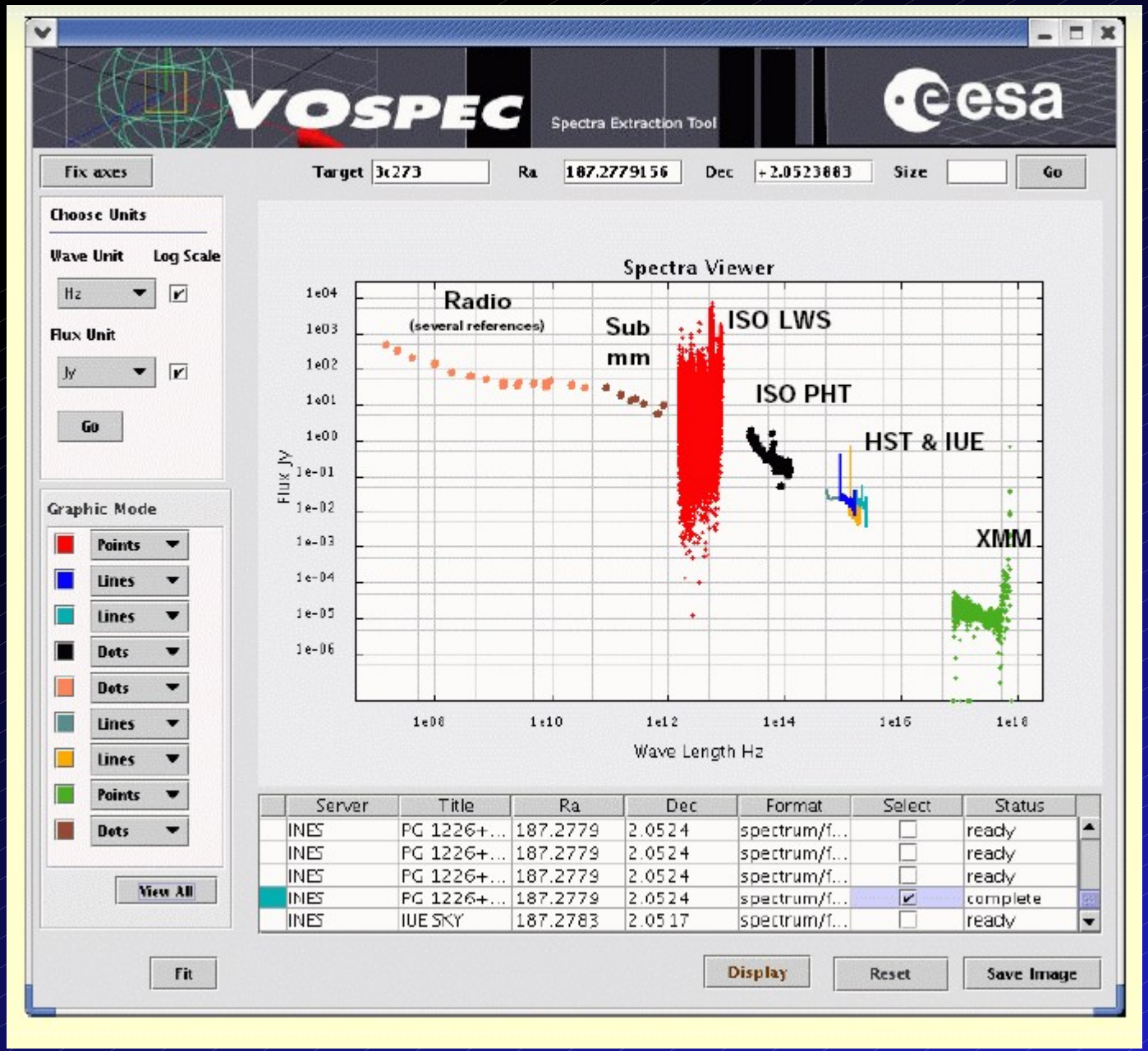
Select All Clear All What do you want to do with the results? Download data

Download data
Save to MySpectra
Plot on a graph
Calculate composite
Calculate synthetic magnitudes
Fit continuum & lines

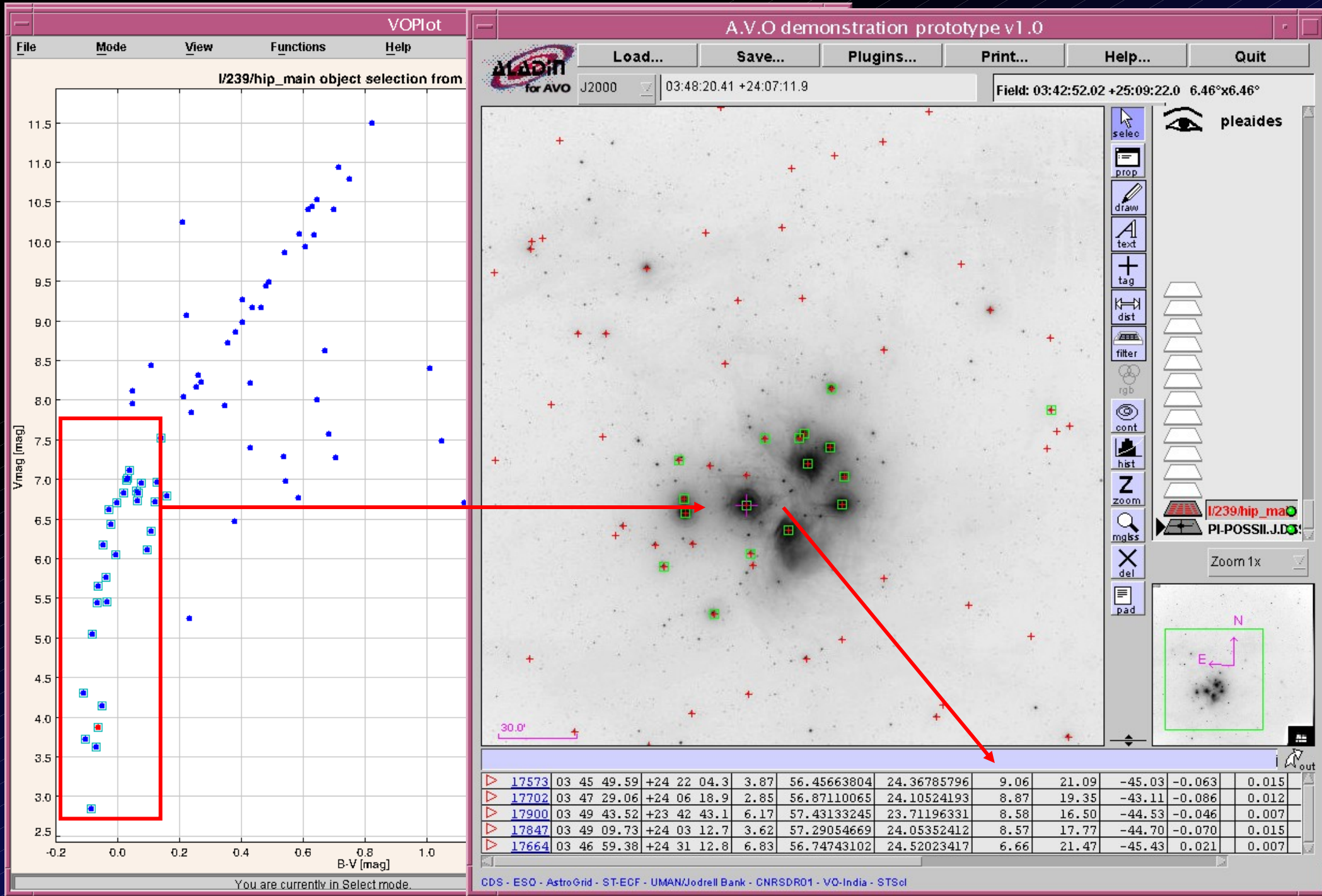
<< Results < Back Next > Finish >>

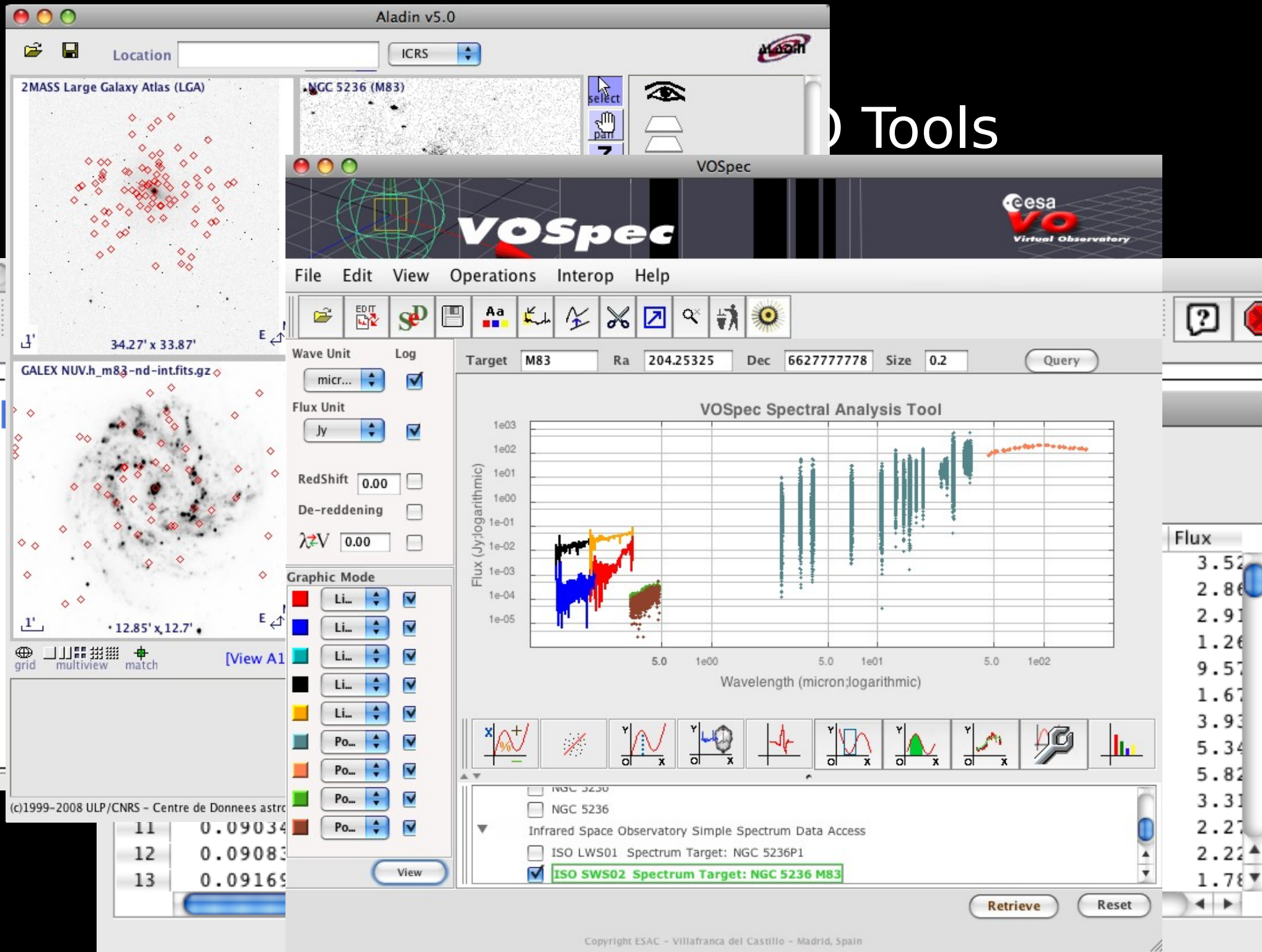
Internet

VOspec (ESAC)

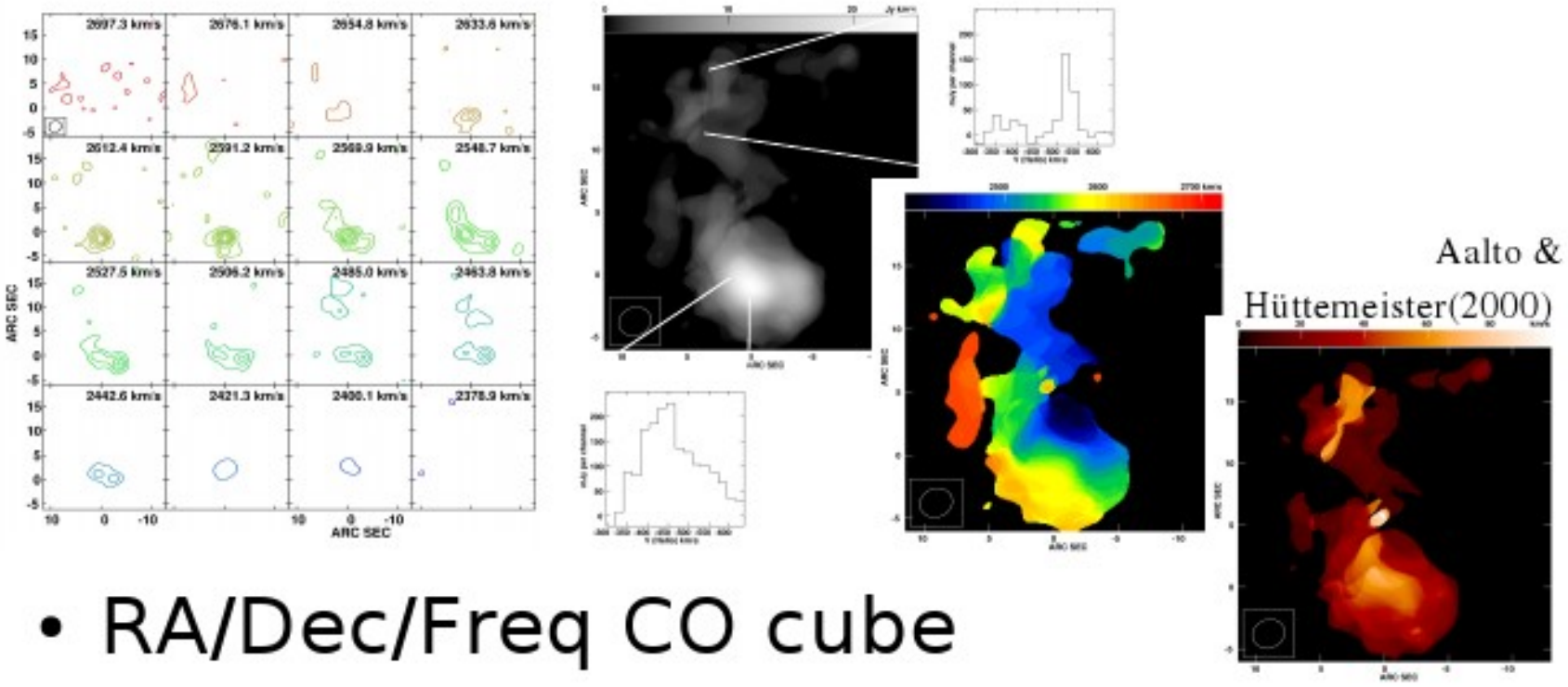

VOSPEC
Spectra Extraction Tool
esa
Fix axes
Target 3c273
Ra 187.2779156
Dec +2.0523883
Size
Go
Choose Units
Wave Unit
Log Scale
Hz
Flux Unit
Jy
Go
Graphic Mode
Points
Lines
Lines
Dots
Dots
Lines
Lines
Points
Dots
View All
Spectra Viewer
Radio
(several references)
Sub
mm
ISO LWS
ISO PHT
HST & IUE
XMM
Flux Jy
1e04
1e03
1e02
1e01
1e00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
1e08
1e10
1e12
1e14
1e16
1e18
Wave Length Hz
Server
Title
Ra
Dec
Format
Select
Status
INES
PG 1226+...
187.2779
2.0524
spectrum/f...
ready
INES
PG 1226+...
187.2779
2.0524
spectrum/f...
ready
INES
PG 1226+...
187.2779
2.0524
spectrum/f...
ready
INES
PG 1226+...
187.2779
2.0524
spectrum/f...
complete
INES
IUE SKY
187.2783
2.0517
spectrum/f...
ready
Fit
Display
Reset
Save Image

Colour-magnitude diagram




Aladin v5.0
Location
ICRS
2MASS Large Galaxy Atlas (LGA)
NGC 5236 (M83)
select
pan
34.27' x 33.87'
GALEX NUV.h_m83-nd-int.fits.gz
12.85' x 12.7'
grid
multiview
match
[View A1
(c)1999-2008 ULP/CNRS - Centre de Donnees astro
11 0.09034
12 0.09083
13 0.09169
Tools
VOSpec
VOSpec
esa
Virtual Observatory
File Edit View Operations Interop Help
Wave Unit
micr...
Log
Flux Unit
Jy
RedShift 0.00
De-reddening
0.00
Graphic Mode
Li...
Po...
View
Target M83
Ra 204.25325
Dec 6627777778
Size 0.2
Query
VOSpec Spectral Analysis Tool
Flux (Jy;logarithmic)
1e03
1e02
1e01
1e00
1e-01
1e-02
1e-03
1e-04
1e-05
5.0
1e00
5.0
1e01
5.0
1e02
Wavelength (micron;logarithmic)
NGC 5236
Infrared Space Observatory Simple Spectrum Data Access
ISO LWS01 Spectrum Target: NGC 5236P1
ISO SWS02 Spectrum Target: NGC 5236 M83
Retrieve
Reset
Copyright ESAC - Villafranca del Castillo - Madrid, Spain
Flux
3.52
2.86
2.91
1.26
9.57
1.67
3.93
5.34
5.82
3.31
2.27
2.22
1.78

ALMA/IRAM use case



- RA/Dec/Freq CO cube
  - Convert to velocity (LSR, radio convention)
  - Cutouts, simple squashes - VO tools?
  - Smoothed spectra, moments with noise cut-off
    - Specialised server-side pipeline controlled via UWS

Other VOs

Virtual Solar Observatory

Virtual Solar-Terrestrial Observatory

Virtual Magnetospheric Observatory

Virtual Space Physics Observatory

Virtual Meteor Observatory – not proper - XML

SKYBOT – Minor planets ephemerides (1840-2019)

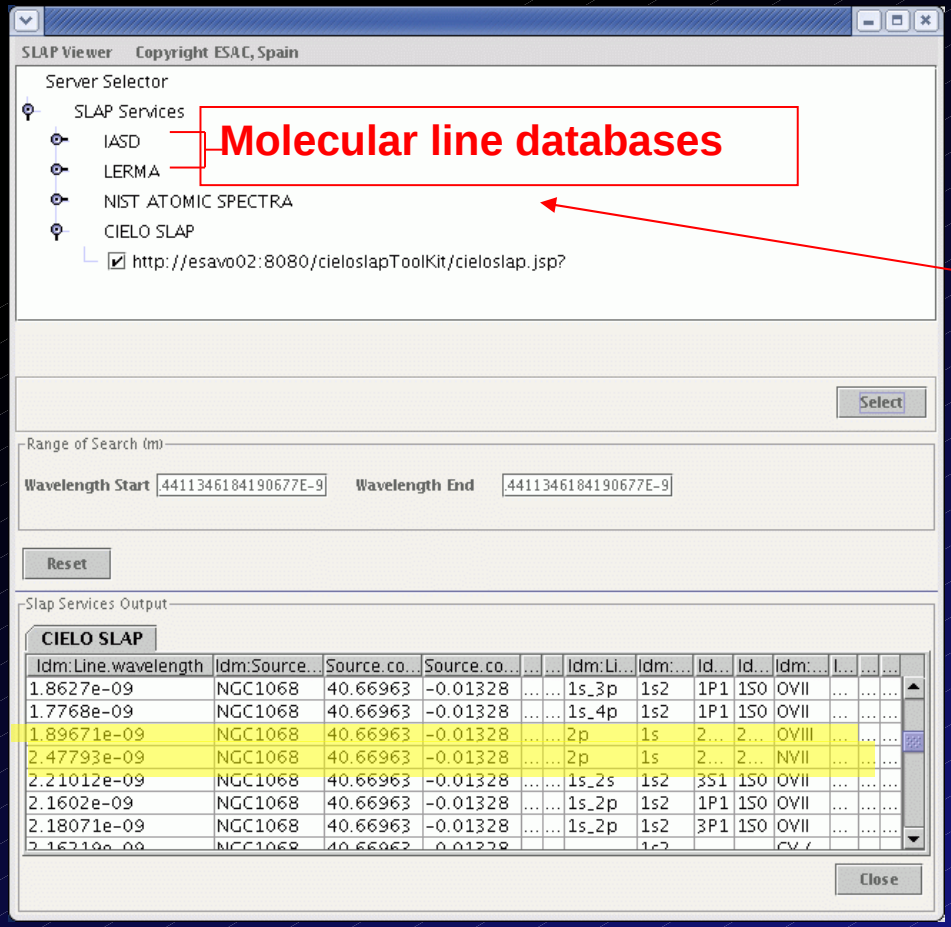
Interest of climatology, meteorology

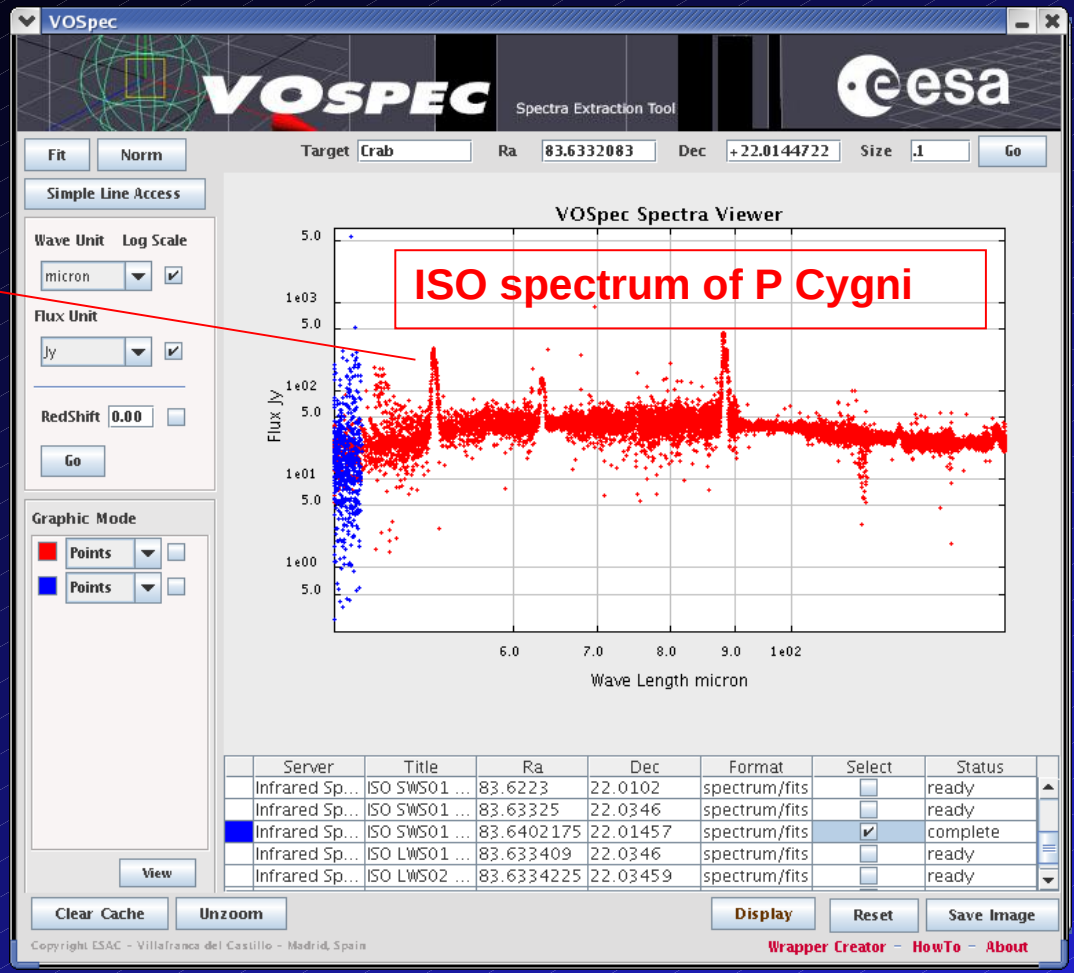
New branch of Science = e-Science

Theory VO (TVO)

- Methods of VO (parameters in DB, SQL...) for study of results of simulations , catalogues of simulated objects like SDSS...(PCA)
- Browsing of simulation space along different axes – parameters, regions...
- Evolutionary tracks, Photo Dissociation Regions
- Formation of artificial galaxies, clusters – N body models (Millenium Run 10 billions, 25TB)
- Theoretical Spectra (GAVO – Rauch, GRID)

CIELO VO – line catalogue SLAP





(IVOA Line Data Model: Dubernet, Osuna et al., in preparation)
(Simple Line Access Protocol: Salgado et al., in preparation)

VO for Atomic and Molecular Data

VAMDC (06/2009-12/2012 FP7)

13 organizations

Virtual Atomic and Molecular Data Centre

VO principles (web services, integration, registry, SAMP, VODesktop, TOPCAT, VOSpec)

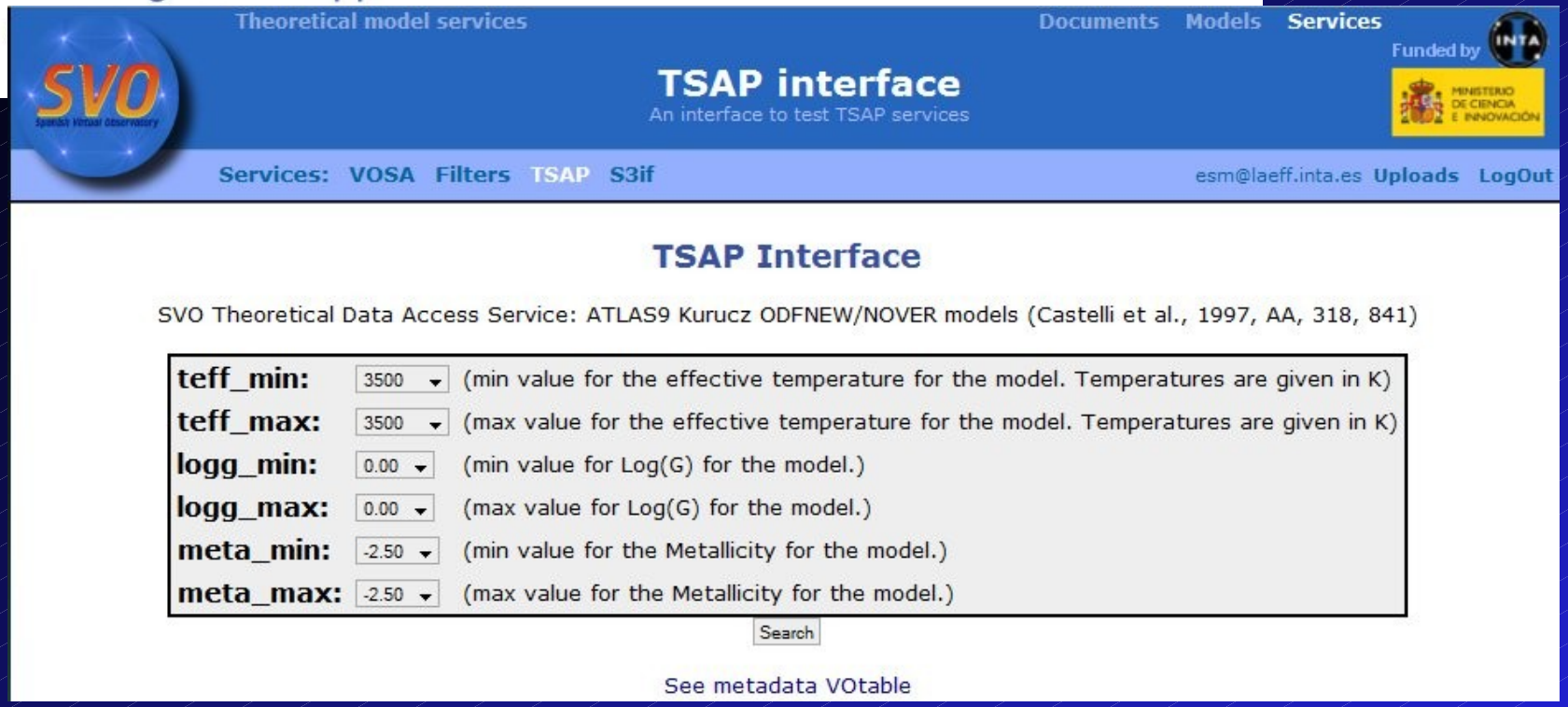
(includes VALD extractor, NIST)

extended citation system (all providers acknowledged)

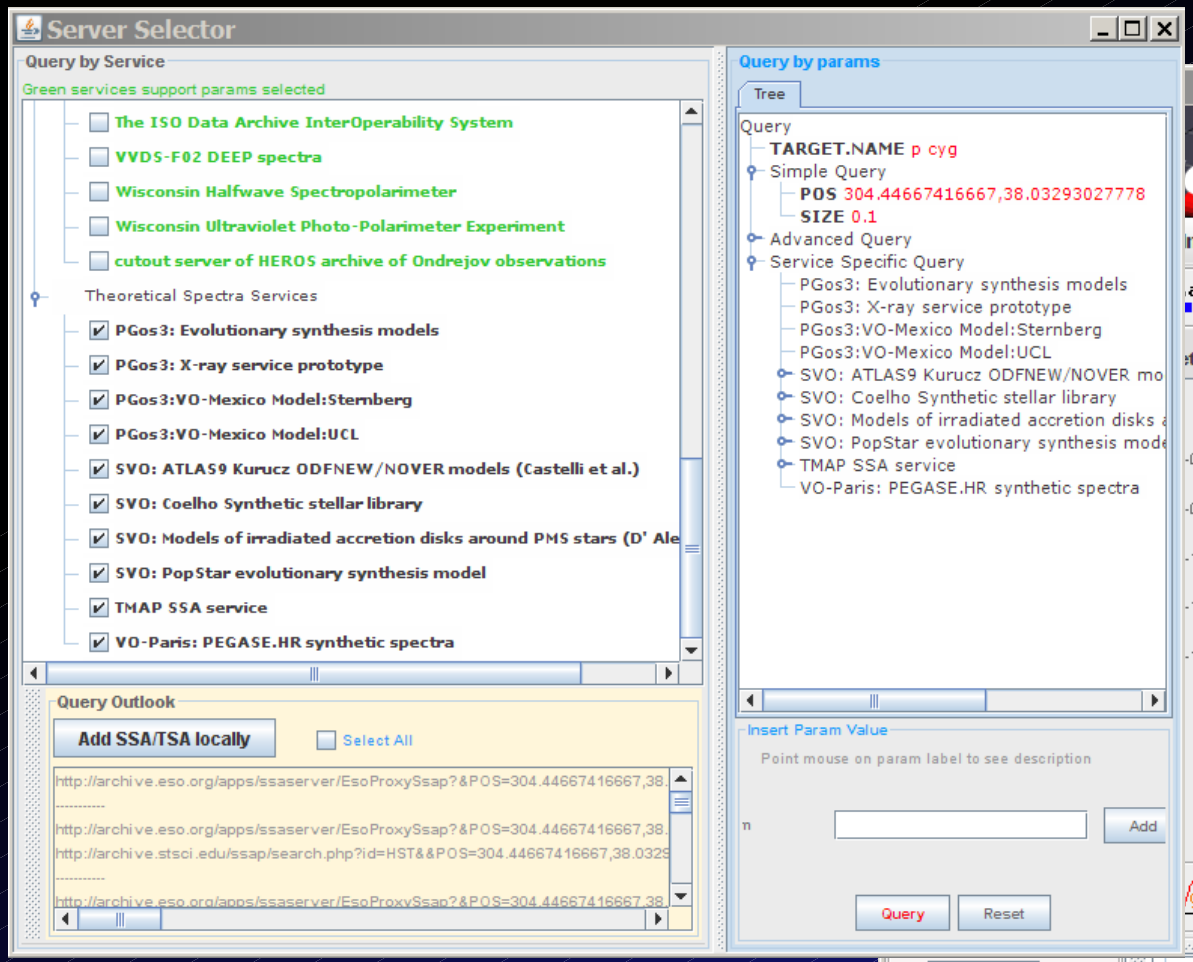
Access protocols in VO: TSAP

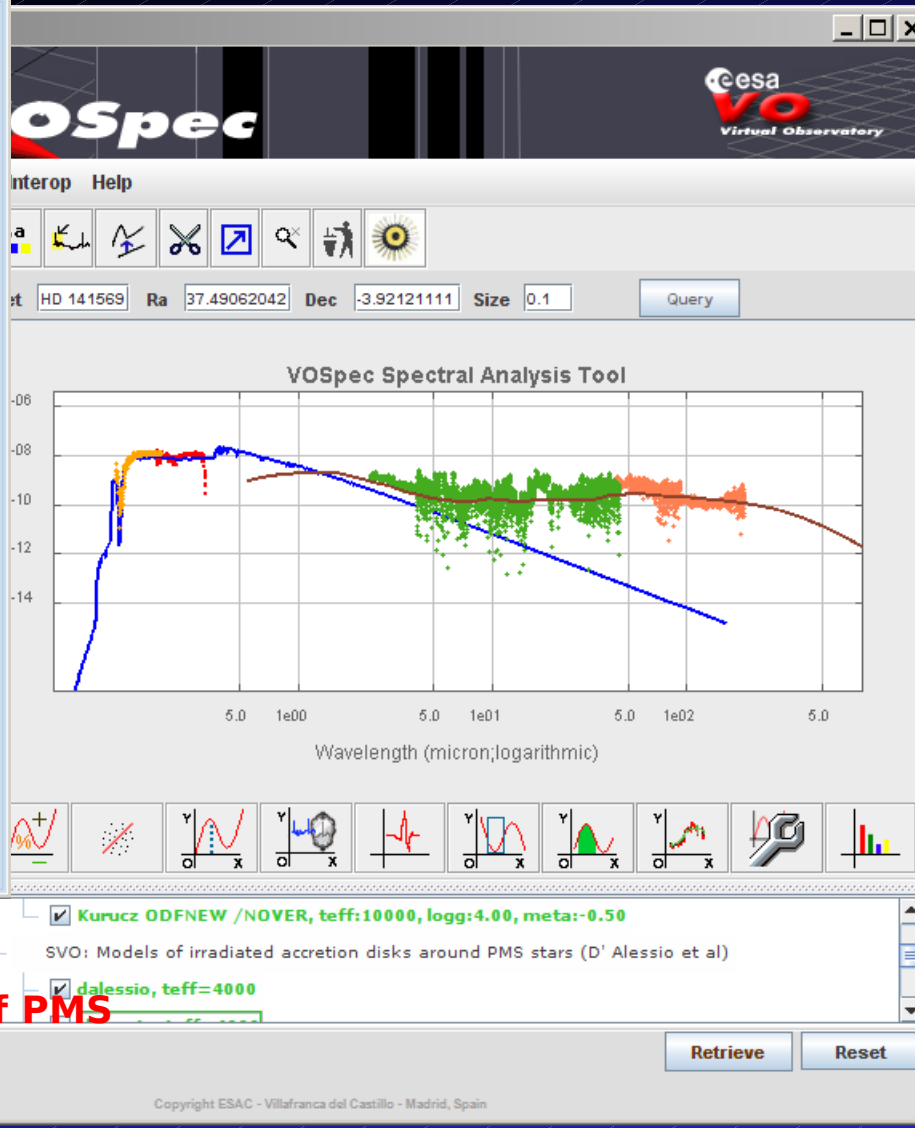
Theoretical models in the VO

- **Theoretical spectra: TSAP**
  - Included in the SSAP standard (use case for theoretical spectra)
  - A simple protocol.
  - Dialog server-application.



VOSpec – models by TSAP



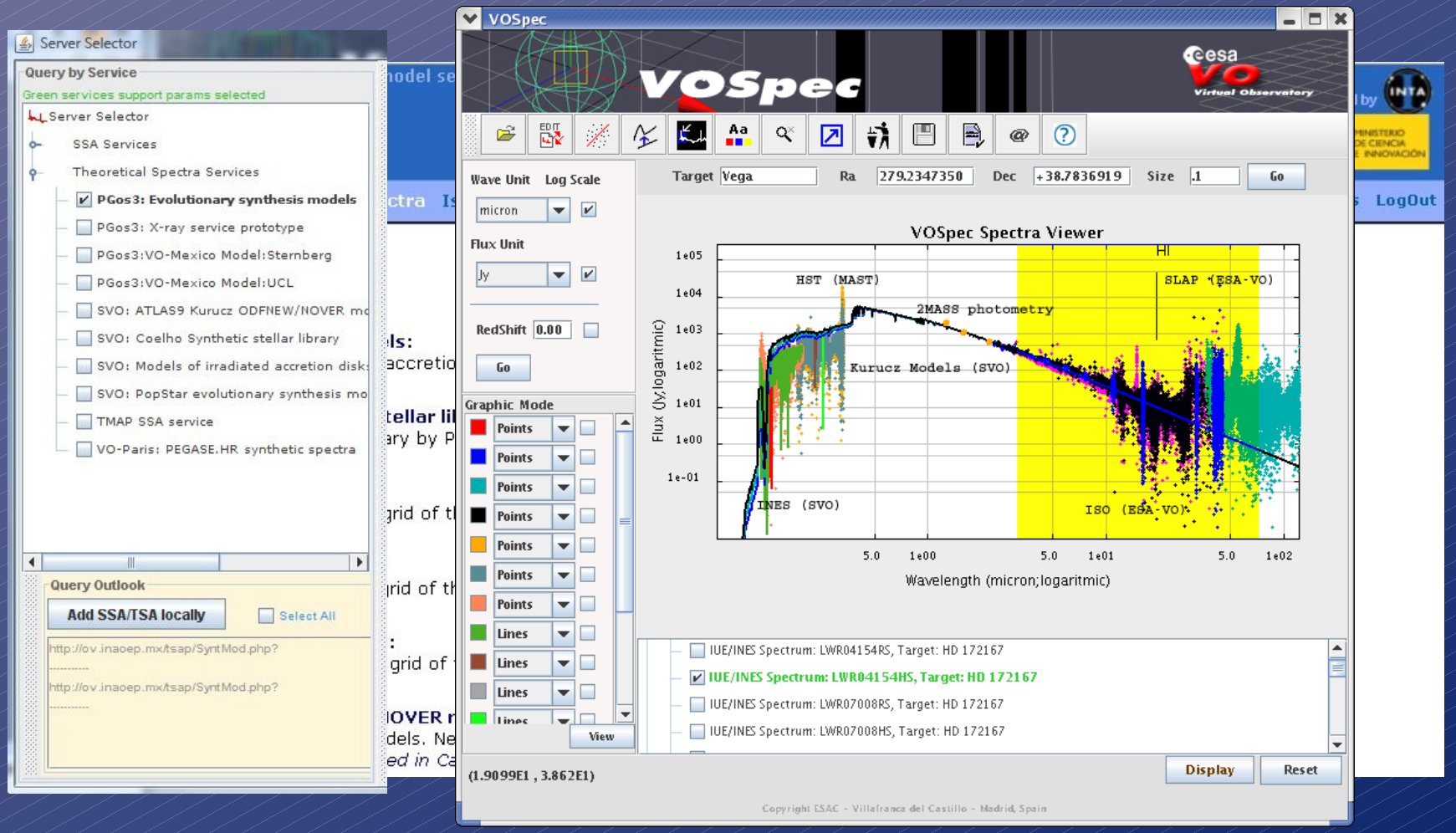


Kurucz stellar model and D'Alessio model of PMS discs fit to UV and IR spectra of HD 141569

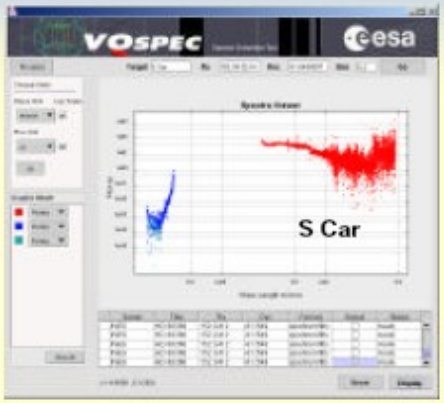
Archives, Theory, VO-Science, DataMining, E&O

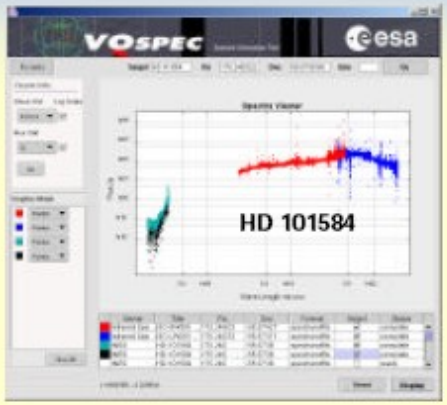
Simple Spectral Access Protocol V1.04

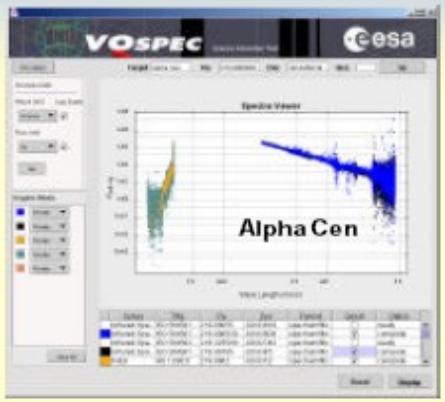
Appendix A: Theoretical Spectral Access Use Case

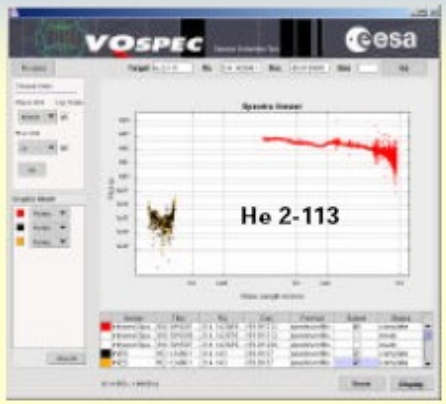


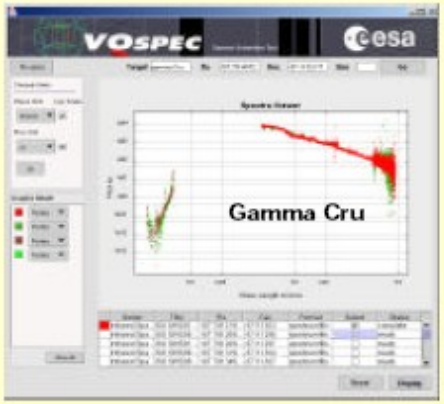
VOSpec working example: Sampling AGBs

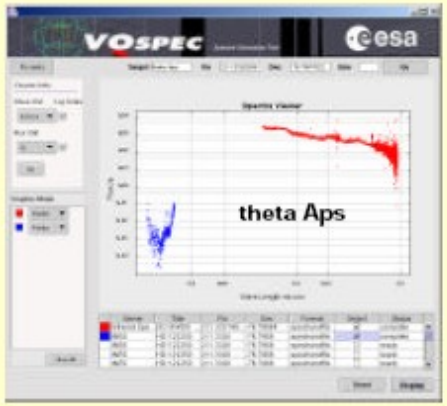


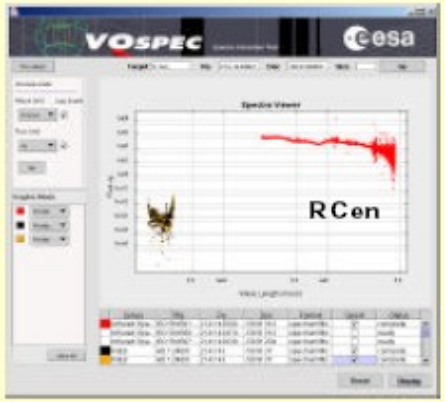


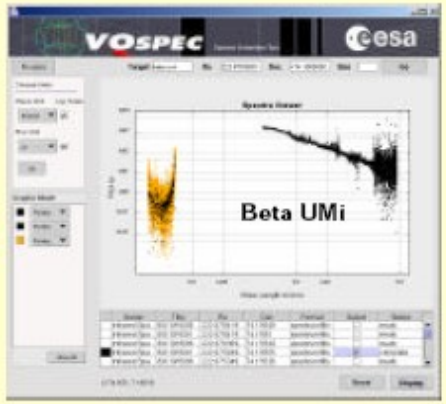


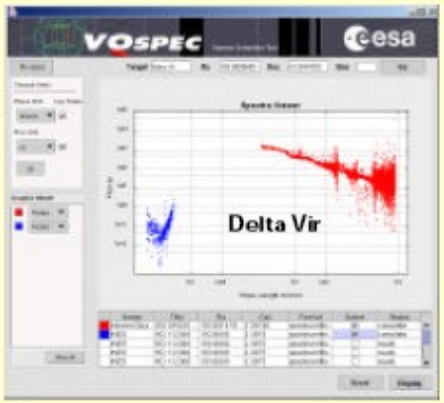


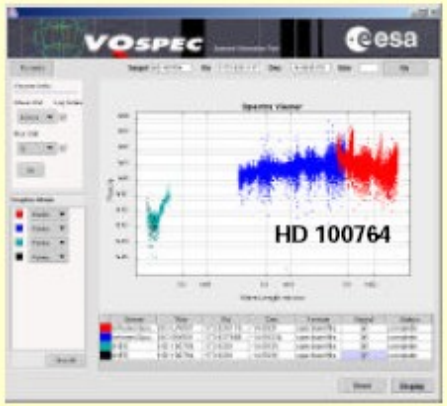


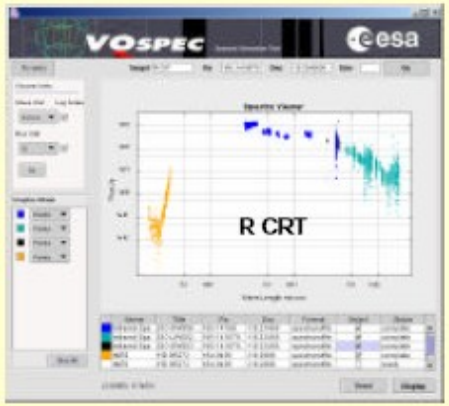


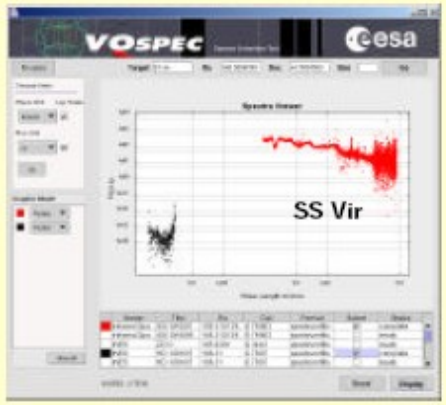




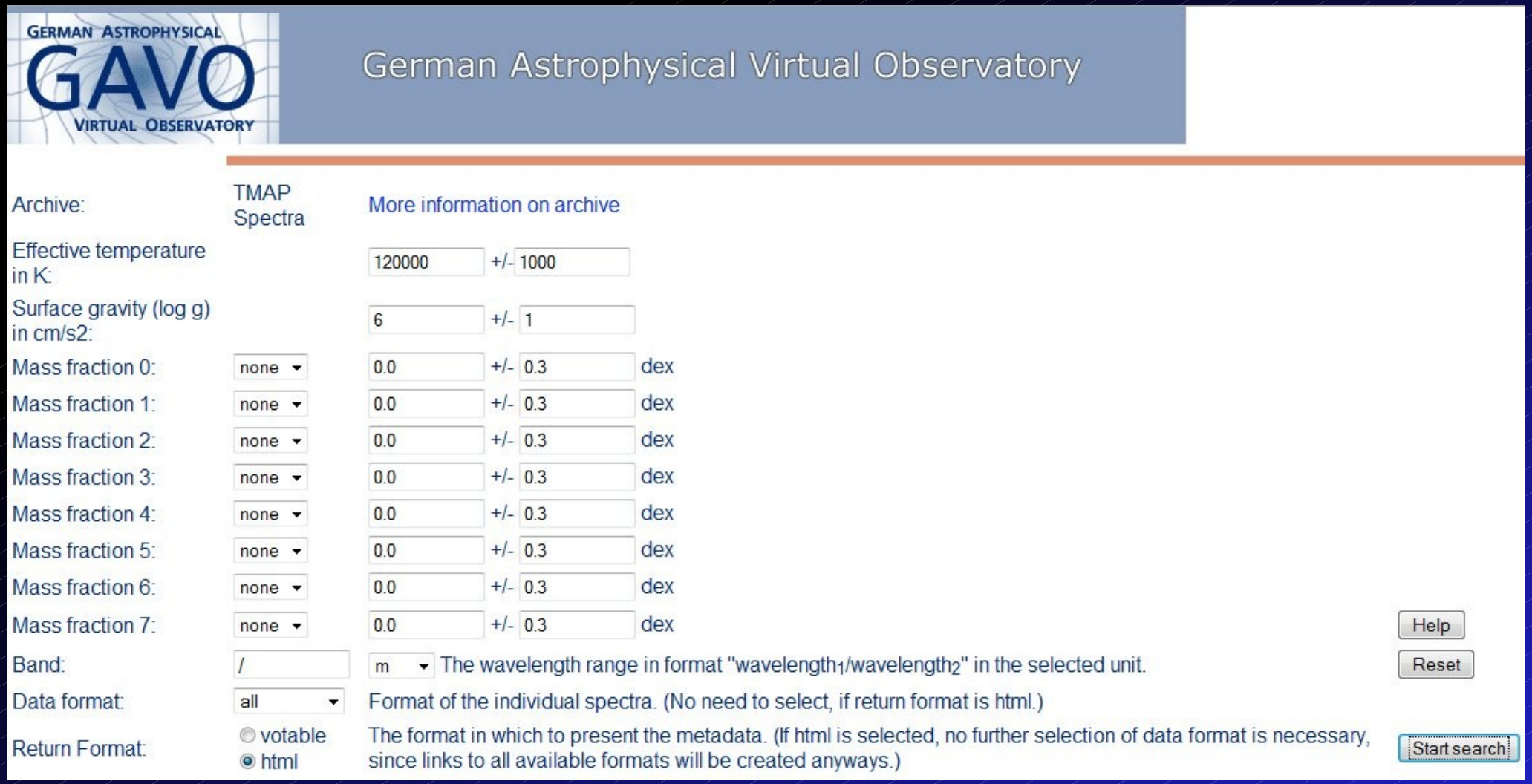






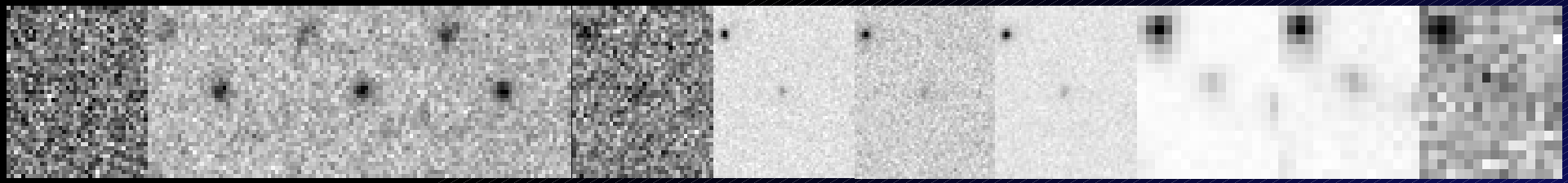


- Other VO Data Centres providing theoretical spectra using TSAP

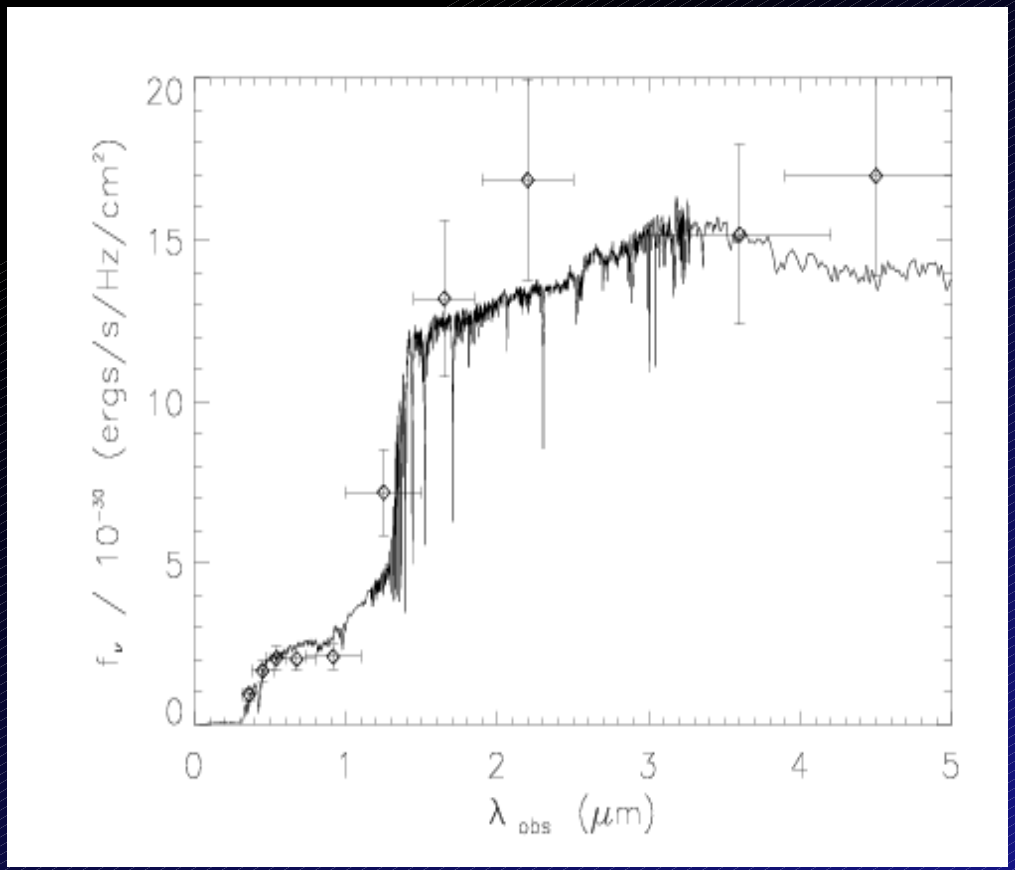


- PGos3 (Mexico), PEGASE (VO-Paris)

SED from photometry



U B V R I J H Ks 3.6μm 4.5 μm 5.8 μm



zphot = 2.52

Age = 500 Myr

Stellar mass = 9.9e10^9 M_{sun}

Reduced chi-sq = 1.04

SFR current = 0.79 M_{sun} yr^{-1}

BaSTI database

Micro-simulations inside the VO: the BaSTI case

P. Manzato[1], M. Molinaro[1], F. Gasparo[1], F. Pasian[1], A. Pietrinferni[2], S. Cassisi [2], C. Rodrigo[3], M. Cerviño[4], E. Solano [3]
INAF - SI / Trieste Astronomical Observatory; (2) INAF – Teramo Astronomical Observatory; (3) LAEFF-INTA / Spanish VO; (4) Instituto de Astrofisica de Andalucía – CSIC / Spanish VO

S3P (Simple Self-Described Service Protocol) implementations

In collaboration with SVO (the Spanish Virtual Observatory) we presented S3P in the last IVOA Interoperability Meeting. S3P (Simple, Self-described Service) is a protocol oriented to handle theoretical data in the VO framework. It is based in the ability of the data server to describe itself in a simple standardized way.

This is a step by step protocol:

1 step: the service described it self (input and output parameters);

http://myservice.com/s3.php?format=metadata

2 step: http query and response in VOTable format;

http://myservice.com/s3.php?param1=value1&param2=value2...

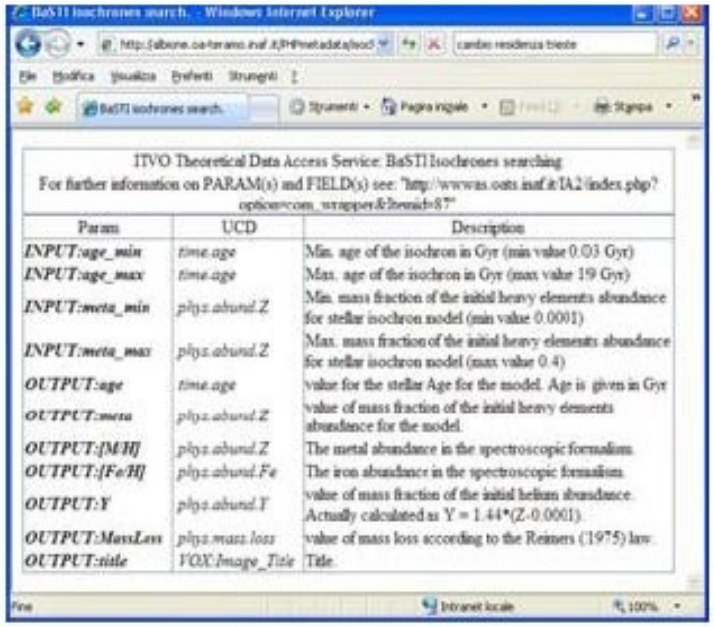
3 step: retrieve the simulated files of interest via http GET;

http://myservice.com/s3.php?id=12

We developed two prototype implementations of S3P for BaSTI: one for isochrones and one for tracks:

http://albione.oa-teramo.inaf.it/PHPmetadata/BaSTIisochron.php?format=metadata

http://albione.oa-teramo.inaf.it/PHPmetadata/BaSTItrack.php?format=metadata

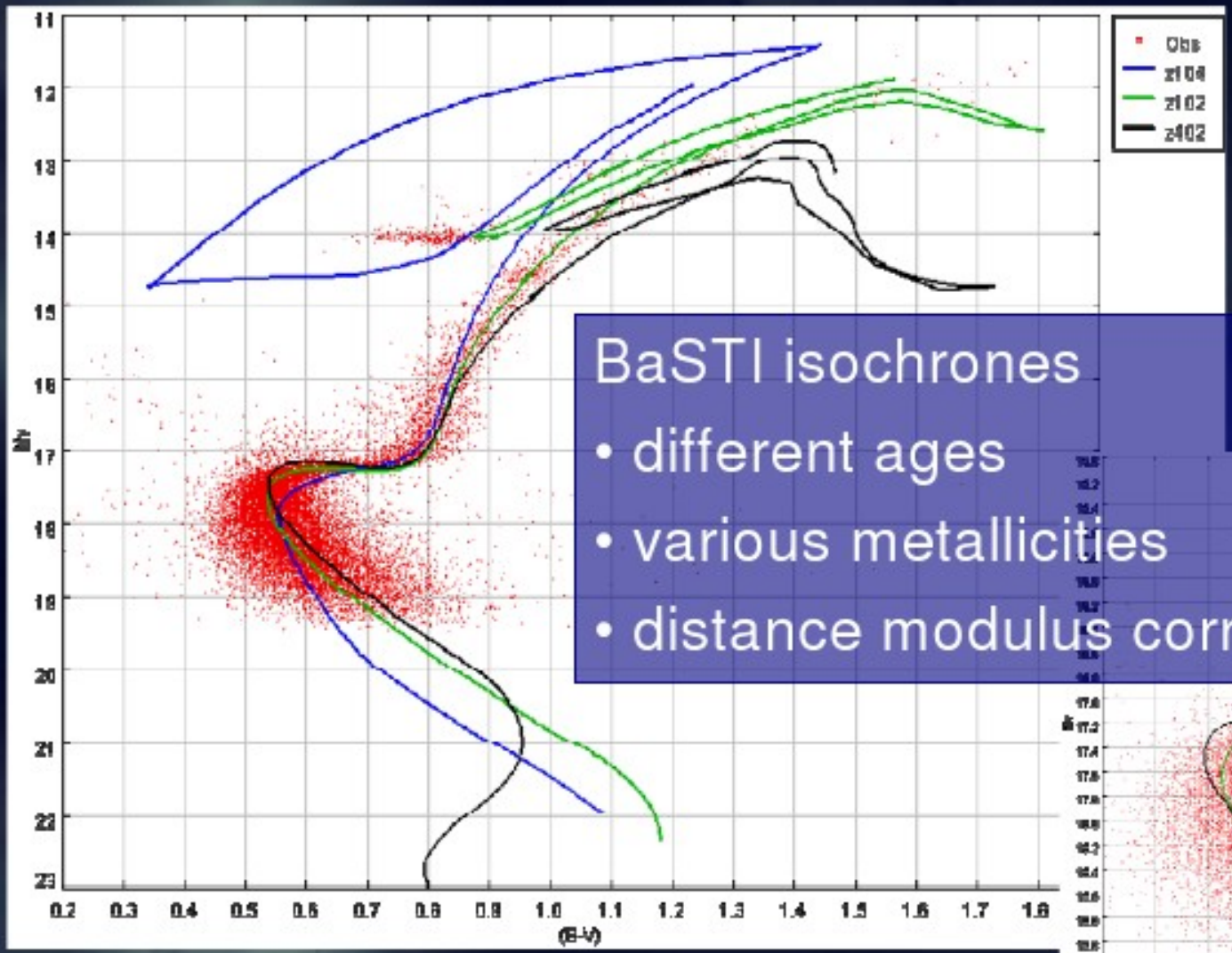


IVOA Theoretical Data Access Service: BaSTI Isochrones searching

For further information on PARAM(s) and FIELD(s) see: "http://www.oats.inaf.it/IA2/index.php?option=com_wrapper&Itemid=87"

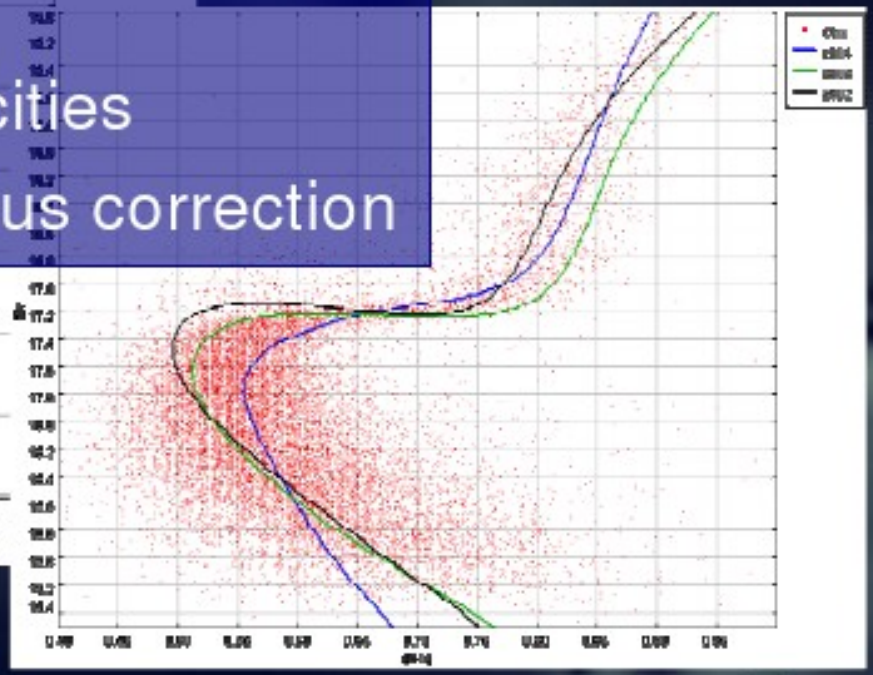
Param	UCD	Description
INPUT:age_min	*time.age*	Min. age of the isochron in Gyr (min value 0.03 Gyr)
INPUT:age_max	*time.age*	Max. age of the isochron in Gyr (max value 19 Gyr)
INPUT:meta_min	*phys.abund.Z*	Min. mass fraction of the initial heavy elements abundance for stellar isochron model (min value 0.0001)
INPUT:meta_max	*phys.abund.Z*	Max. mass fraction of the initial heavy elements abundance for stellar isochron model (max value 0.4)
OUTPUT:age	*time.age*	value for the stellar Age for the model. Age is given in Gyr
OUTPUT:meta	*phys.abund.Z*	value of mass fraction of the initial heavy elements abundance for the model.
OUTPUT:[M/H]	*phys.abund.Z*	The metal abundance in the spectroscopic formalism.
OUTPUT:[Fe/H]	*phys.abund.Fe*	The iron abundance in the spectroscopic formalism.
OUTPUT:Y	*phys.abund.Y*	value of mass fraction of the initial helium abundance. Actually calculated as Y = 1.44*(Z-0.0001).
OUTPUT:MassLoss	*phys.mass.loss*	value of mass loss according to the Reimers (1975) law.
OUTPUT:title	*VOX:Image_Title*	Title.

BaSTI Isochrones



step 1
metallicity

BaSTI isochrones
- different ages
- various metallicities
- distance modulus correction



z = 0.01 (α-enh) ; 0.008 (scaled solar)

Archives, Theory, VO-Science, DataMining, E&O

Theoretical model services

SVO

VOSA: VO Sed Analizer

VO SED Analyzer

Services: VOSA Filters TSAP S3if

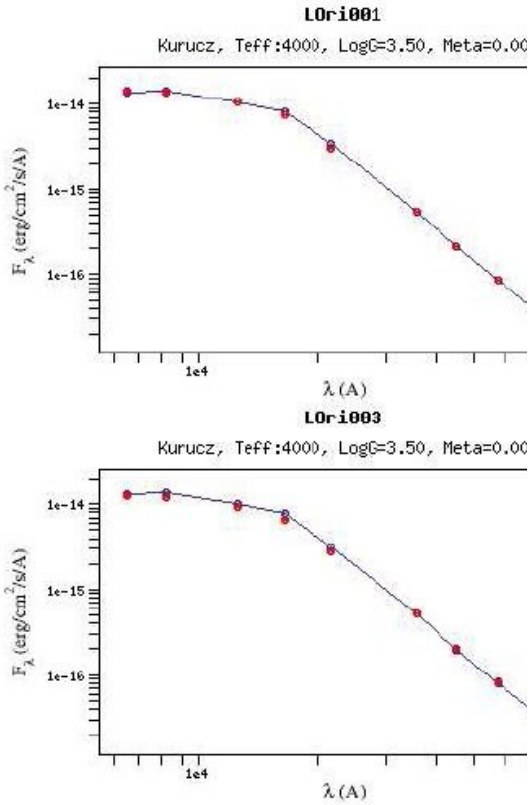
Astronomy & Astrophysics manuscript no. Synth˙VO˙PR1˙ref˙format
August 2, 2008

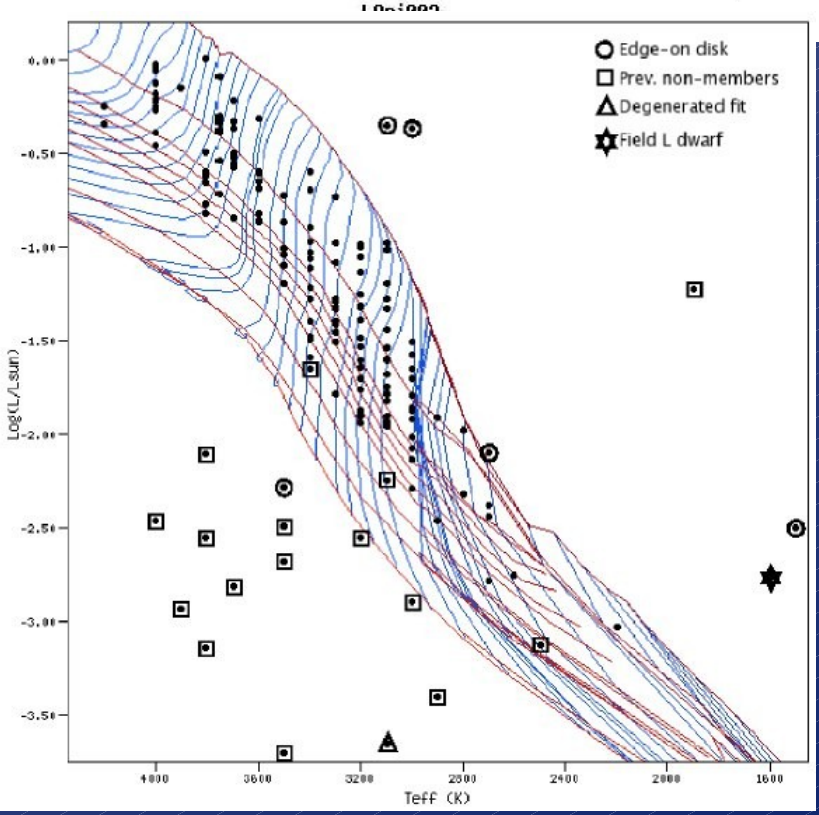
VOSA: Virtual Observatory SED Analyzer.

An application to the Collinder 69 open cluster

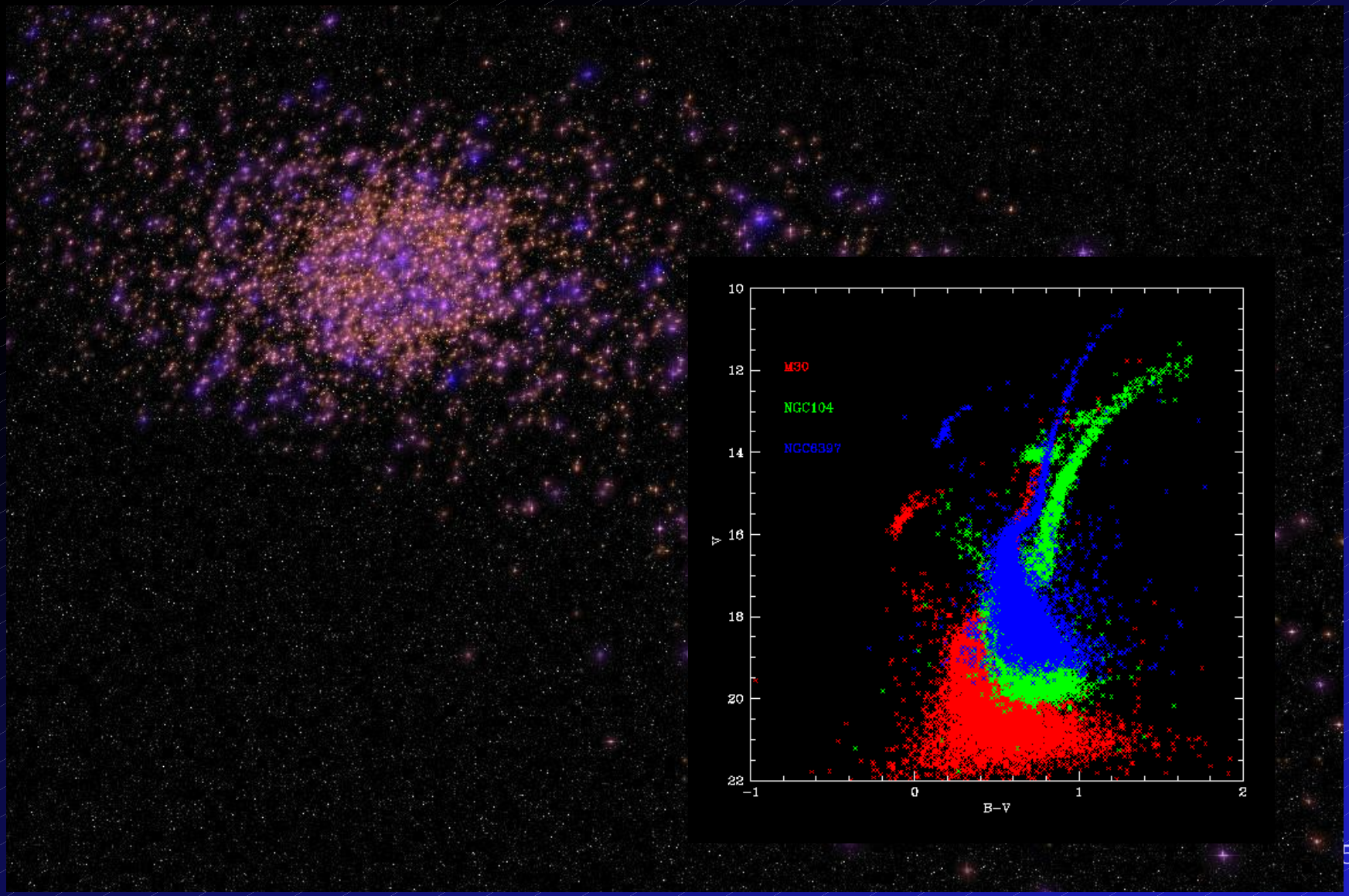
A. Bayo[1,2], C. Rodrigo[1,2], D. Barrado y Navascués[1,2], E. Solano[1,2], R. Gutiérrez[1,2], M.

Object	Model	T_{eff}	LogG	Metallicity	χ^2
LOri001	Kurucz	4000	3.50	0.00	1.71e
LOri002	NextGen	3800	4.5	0	1.44e
LOri003	Kurucz	4000	3.50	0.00	5.05e
LOri004	Kurucz	3750	4.00	0.00	2.82e
LOri005	NextGen	4000	4.0	0	9.20e
LOri006	Kurucz	4000	3.50	0.00	3.36e
LOri007	Kurucz	4000	4.50	0.00	2.49e
LOri008	Kurucz	4000	3.50	0.00	4.43e
LOri009	NextGen	4000	3.5	0	6.22e
LOri010	NextGen	4200	4.0	0	1.07e
LOri011	NextGen	3900	4.5	0	1.20e
LOri012	NextGen	4000	4.5	0	6.56e
LOri013	NextGen	3700	4.5	0	3.50e
LOri014	Kurucz	4000	4.50	0.00	4.70e
LOri015	Kurucz	4000	3.50	0.00	8.73e
LOri016	Kurucz	3750	4.50	0.00	5.63e
LOri017	NextGen	4200	4.0	0	7.56e
LOri018	Kurucz	3750	3.50	0.00	4.31e
LOri019	Kurucz	3750	3.50	0.00	1.90e
LOri020	NextGen	3800	4.5	0	2.98e
LOri021	Kurucz	4000	3.50	0.00	3.08e
LOri022	Kurucz	3750	4.00	0.00	1.78e
LOri023	NextGen	4000	4.5	0	2.35e
LOri024	Kurucz	3750	3.50	0.00	2.22e
LOri025	NextGen	3700	4.5	0	1.37e
LOri026	NextGen	3700	4.5	0	4.01e
LOri027	NextGen	4000	4.5	0	2.35e
LOri028	Kurucz	3750	4.00	0.00	1.26e
LOri029	NextGen	3100	4.5	0	7.28e
LOri030	NextGen	3700	4.5	0	2.15e
LOri031	NextGen	3800	4.5	0	2.77e
LOri032	NextGen	3700	4.5	0	1.70e
LOri033	NextGen	3700	4.5	0	7.12e
LOri034	NextGen	3000	4.0	0	1.77e
LOri035	NextGen	3700	4.5	0	1.61e

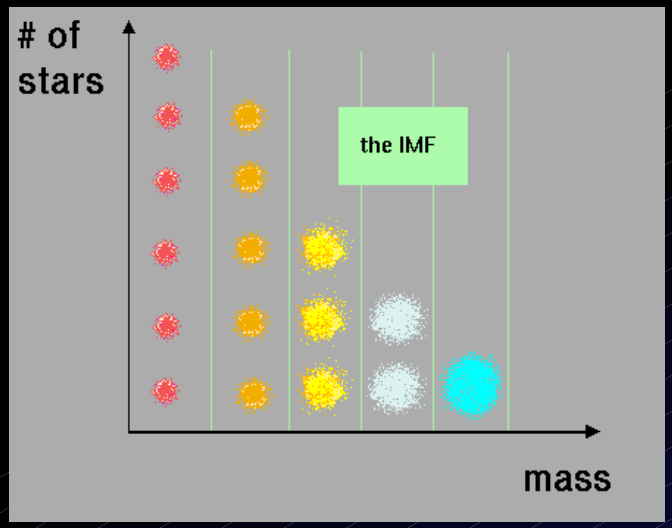


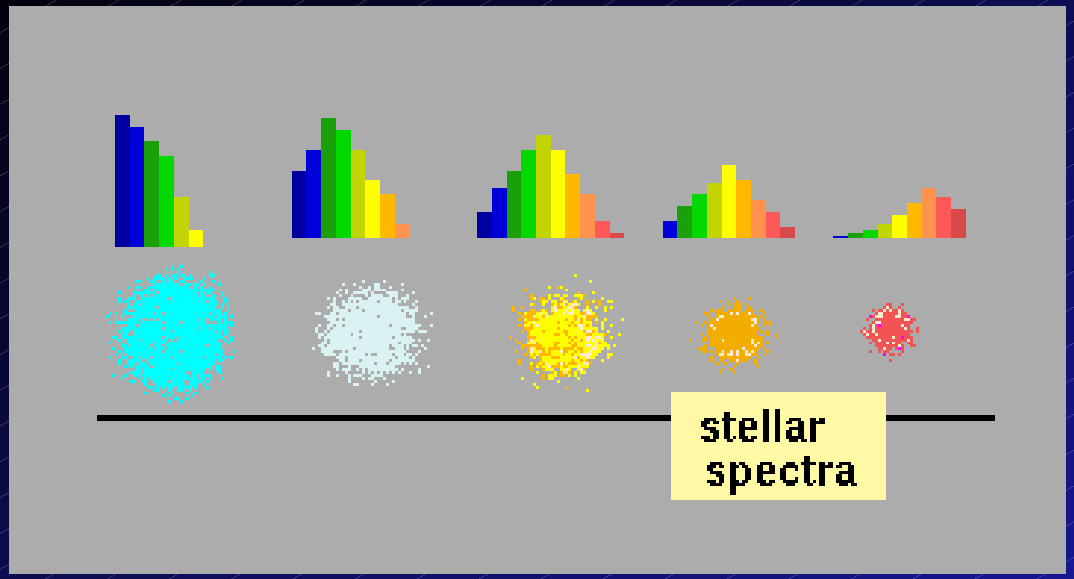


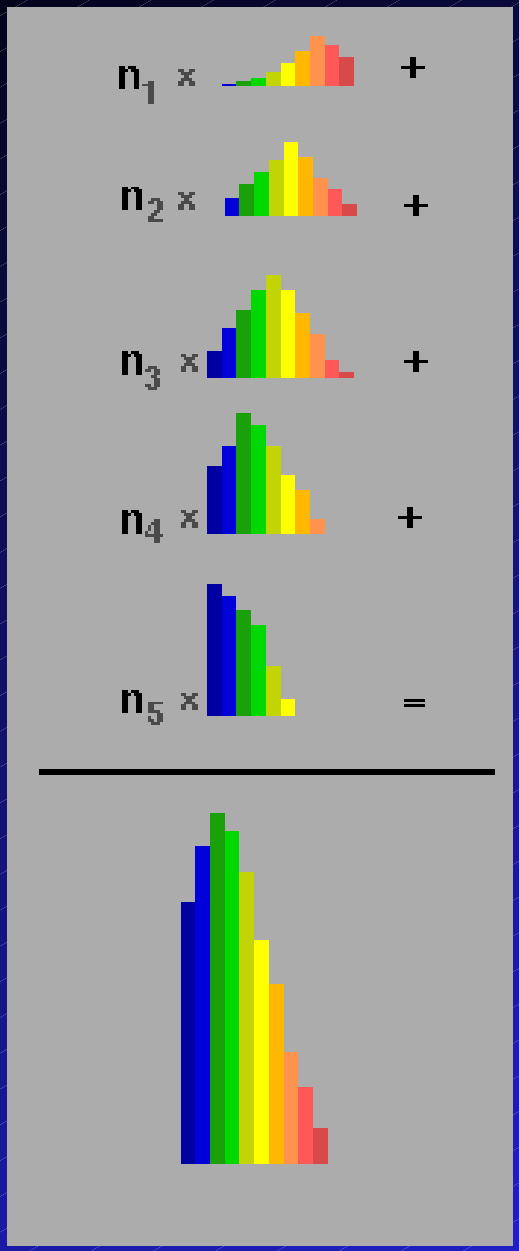
N Body Simulations of Globular Cluster Evolution



Stellar populations are modeled with synthesis models



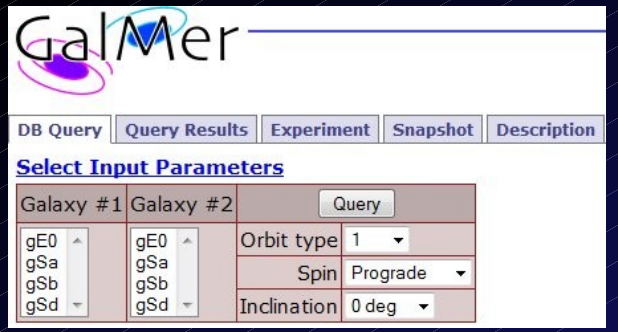


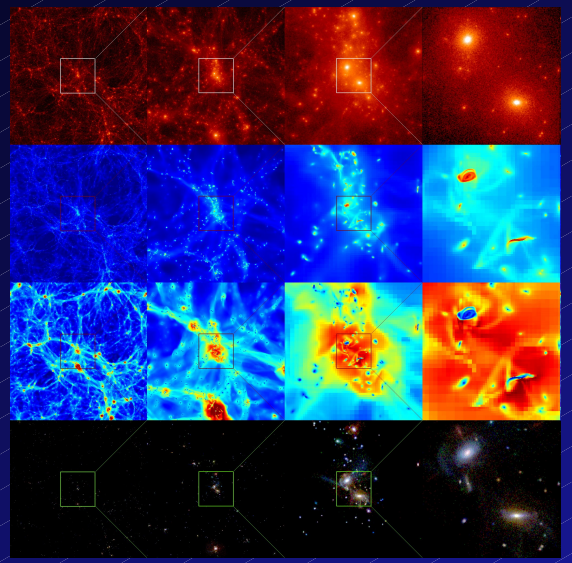


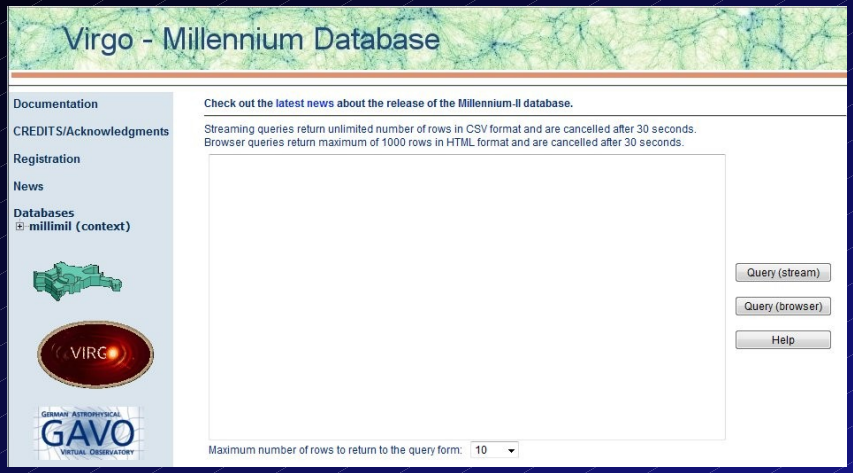
(Available as *Theoretical Simple Access Protocol* server :`http://ov.inaoep.mx`)

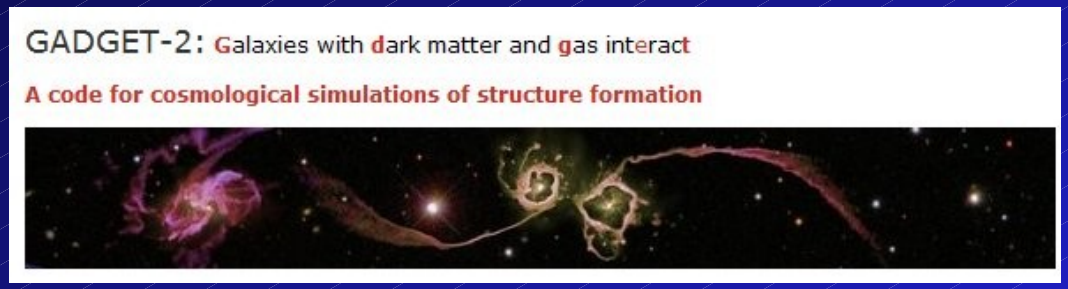
Using SimDB/SimDAP

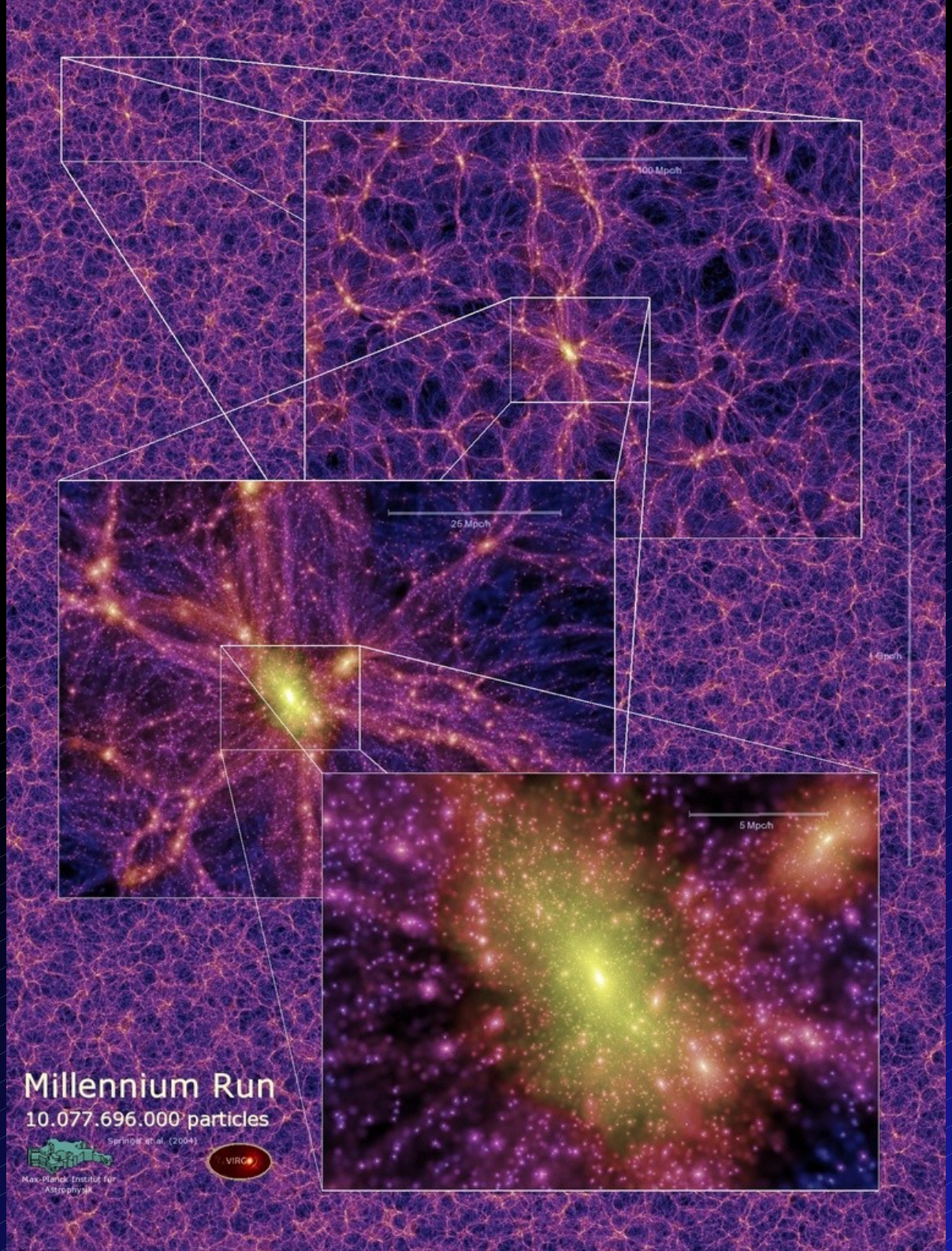
- Cosmological simulations
  - Prototypes for GalMER, Horizon
- PDR simulations
  - test implementation of Meudon PDR code
- Isochrones/evolutionary tracks
  - BaTSI
- Visualization tools
  - VisIVO











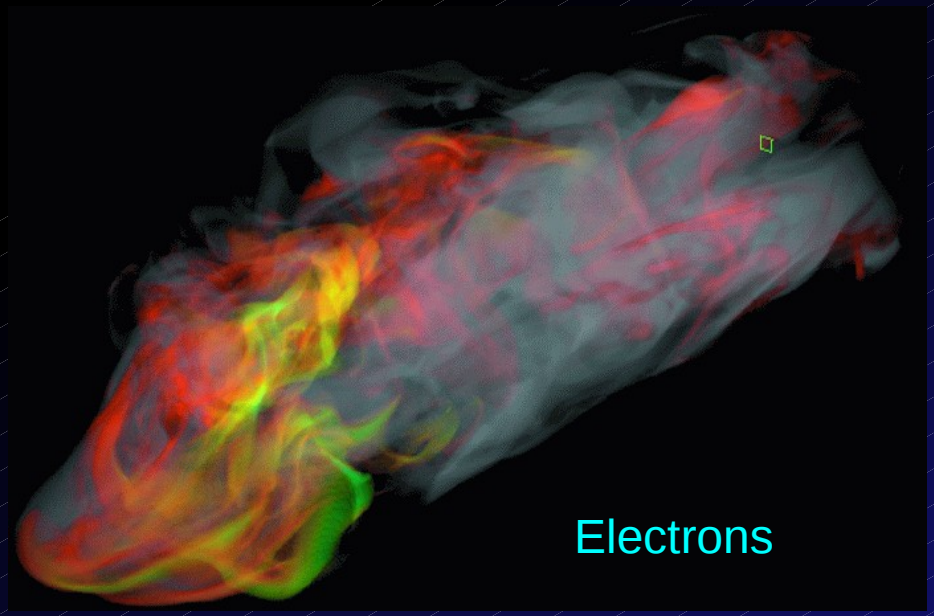
Millenium Run

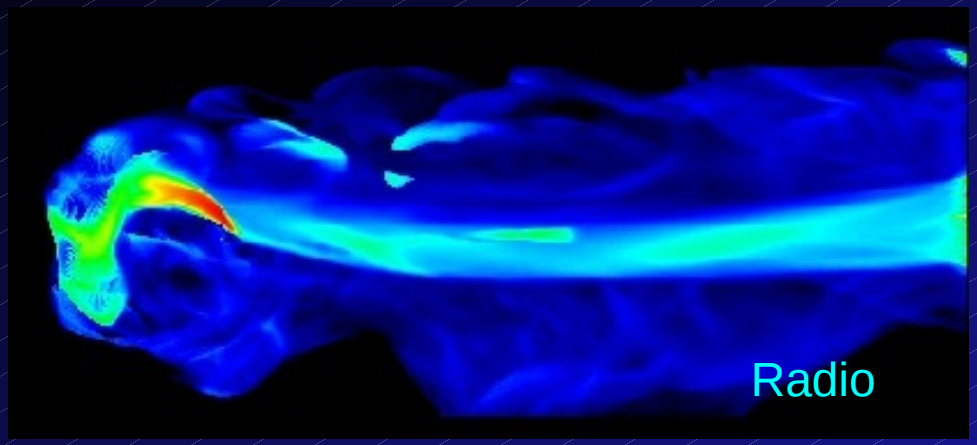
- 10^10 particles
- Several Gpc to
- 10 kpc
- Cube 2 billion ly
- One month MPSSC
- 25 TB
- Evolution of 20 mil galaxies
- Evolution merger tree

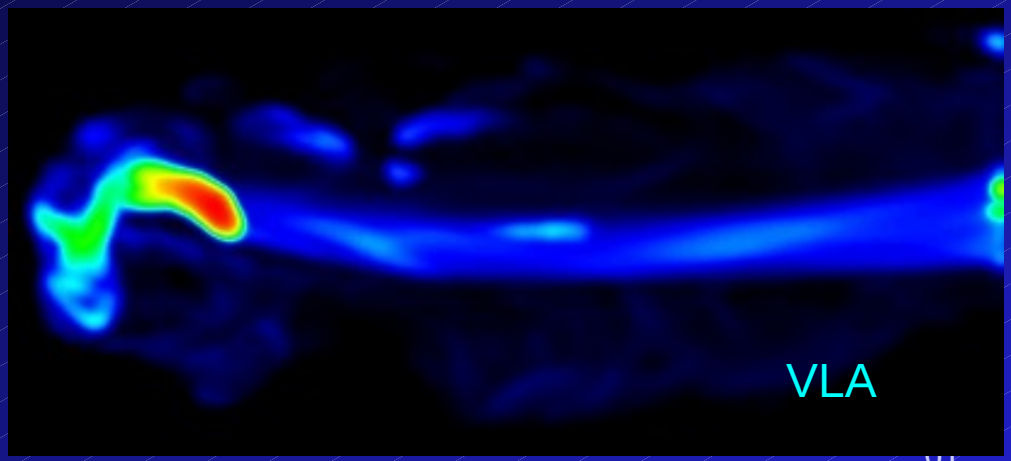
Collimated Outflows from AGN

- 3C 175

MHD Simulations of Collimated Outflows from AGN – Virtual Telescope Observations

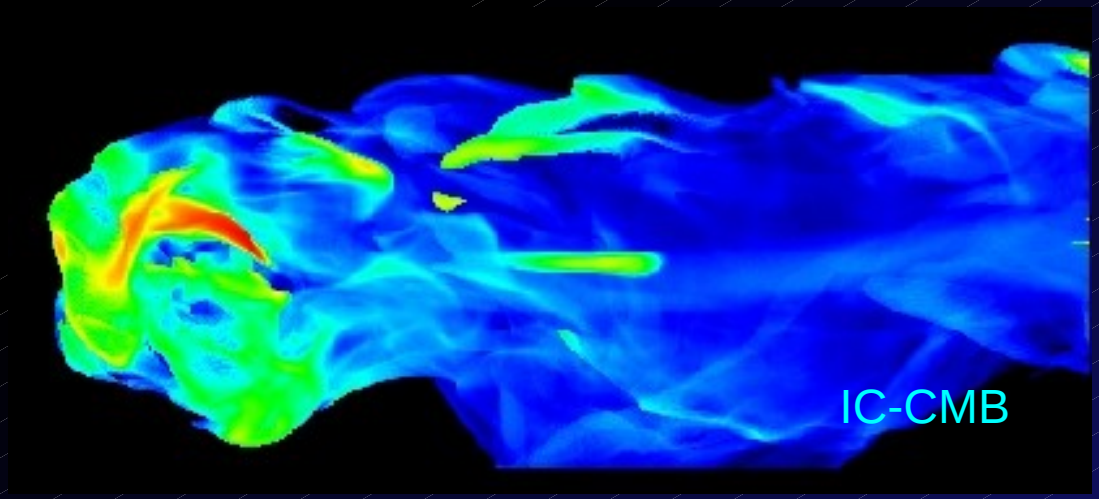


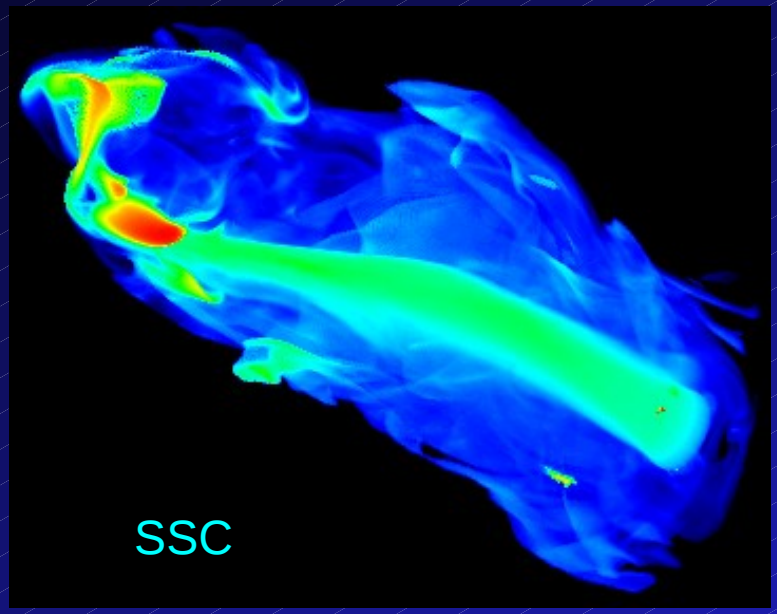


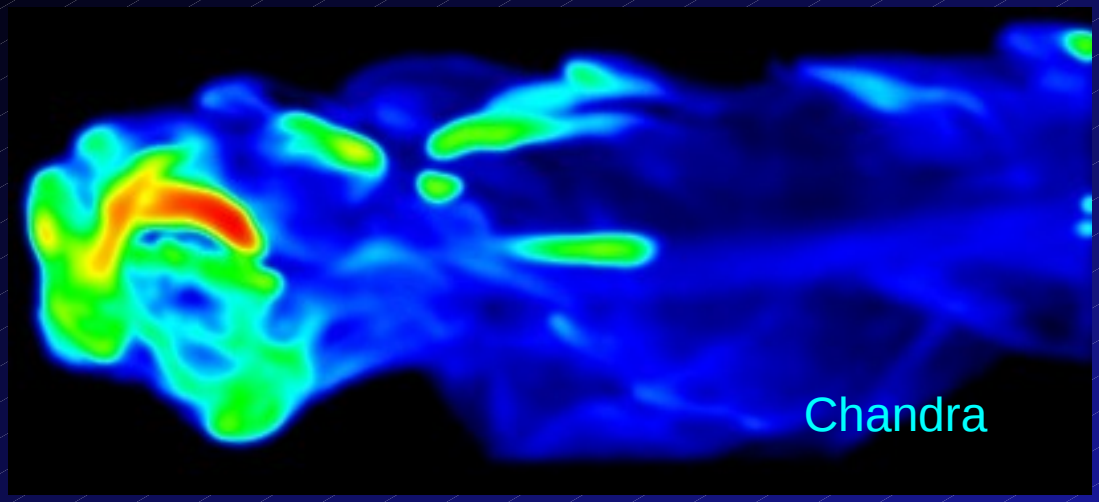


Compare with Radio Archives

MHD Simulations of Collimated Outflows from AGN – Virtual Telescope Observations



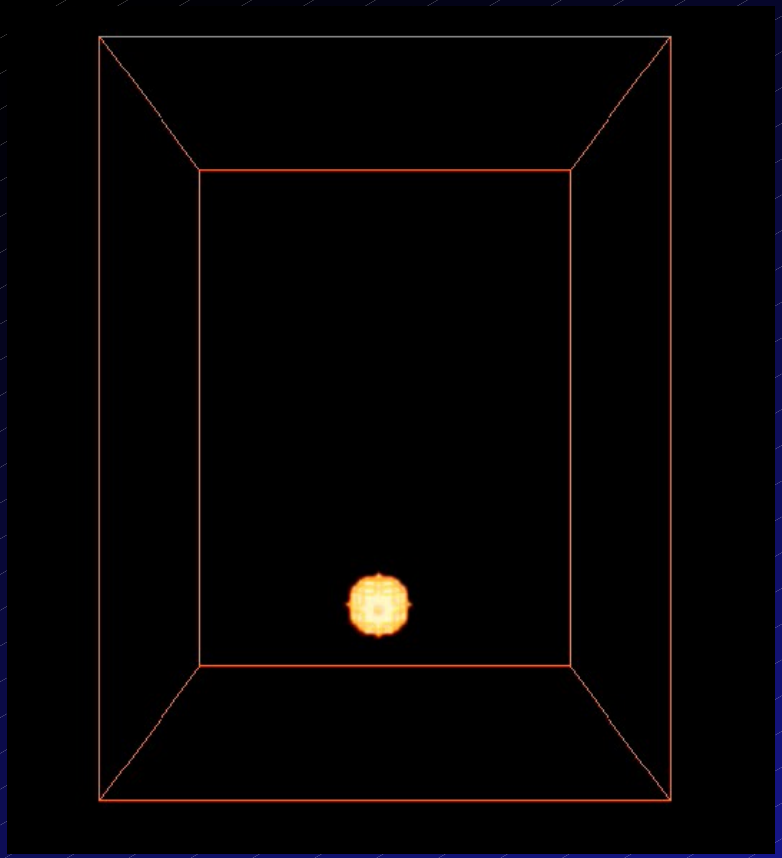


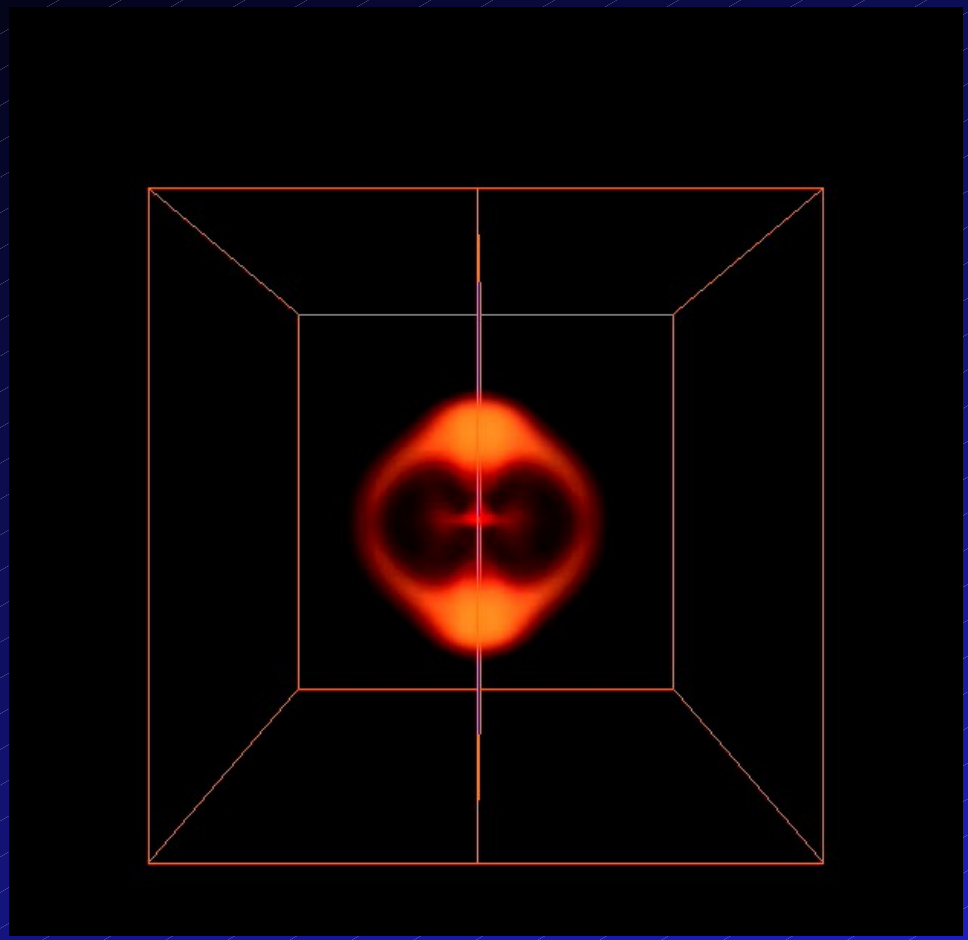


Compare with Chandra Archives

Three Dimensional MHD Calculations

- β = 3000

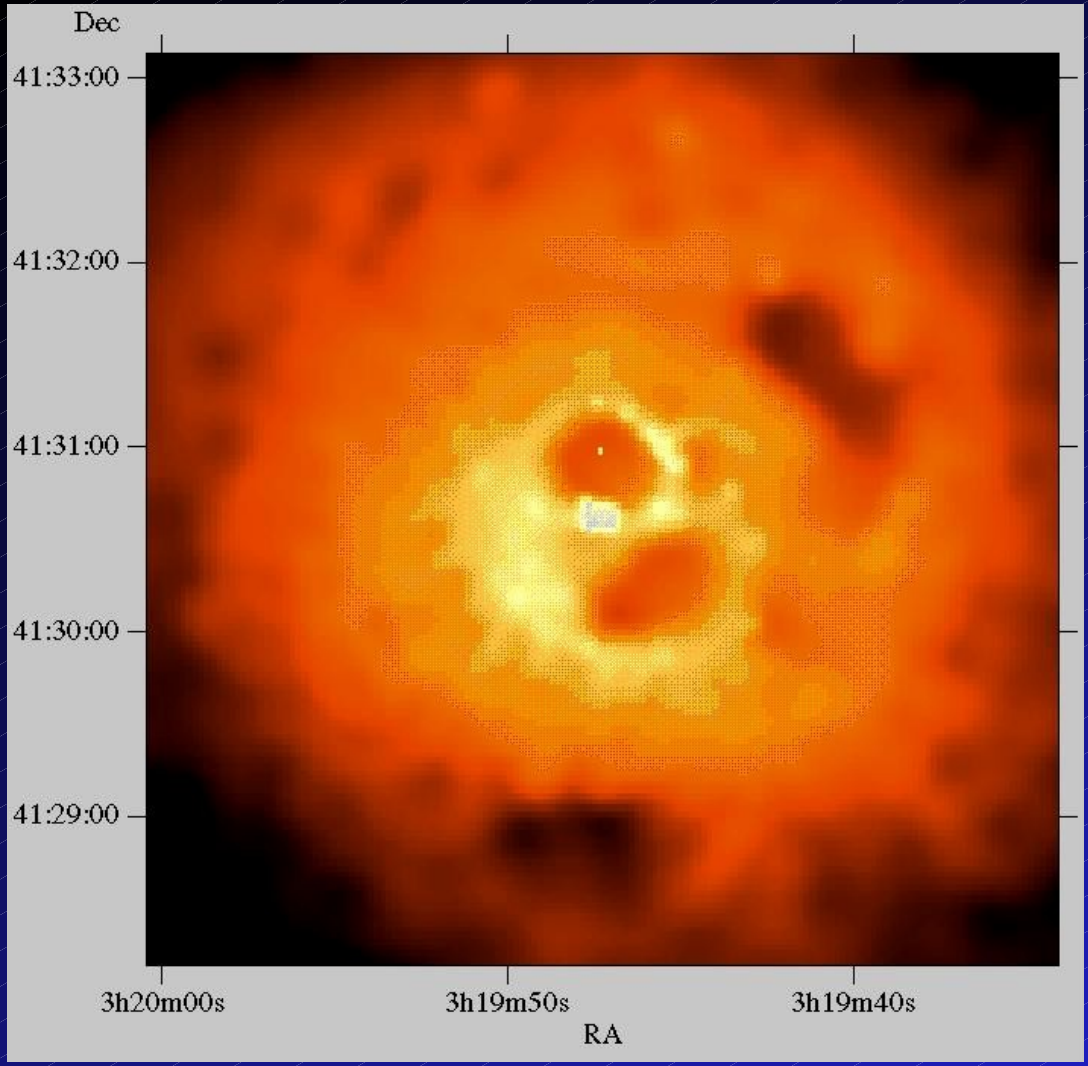




Relic Radio Bubbles in Galaxy Clusters

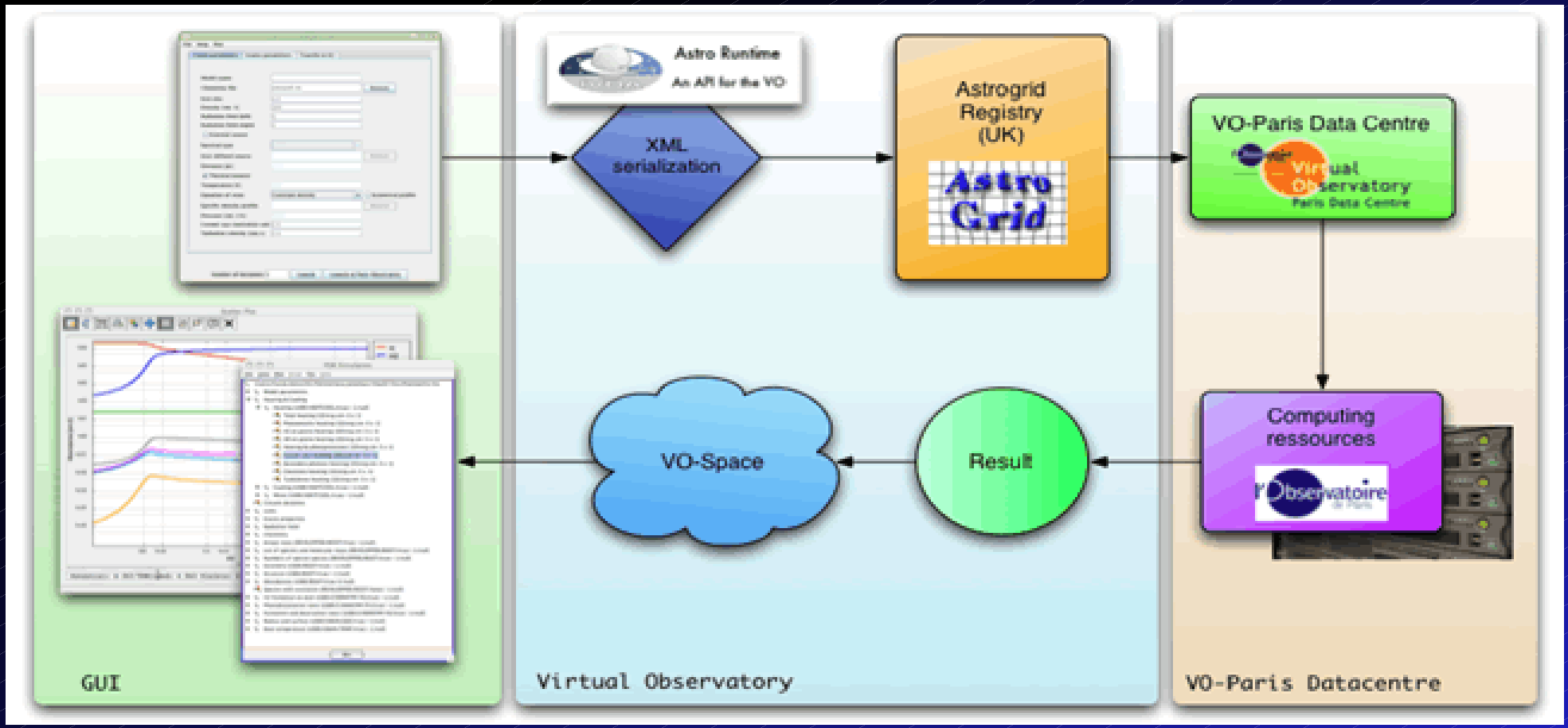
- N1275

Compare with Chandra Archives



Fabian et al. 2000

PDR VO-infrasctructure



PDR database and clients

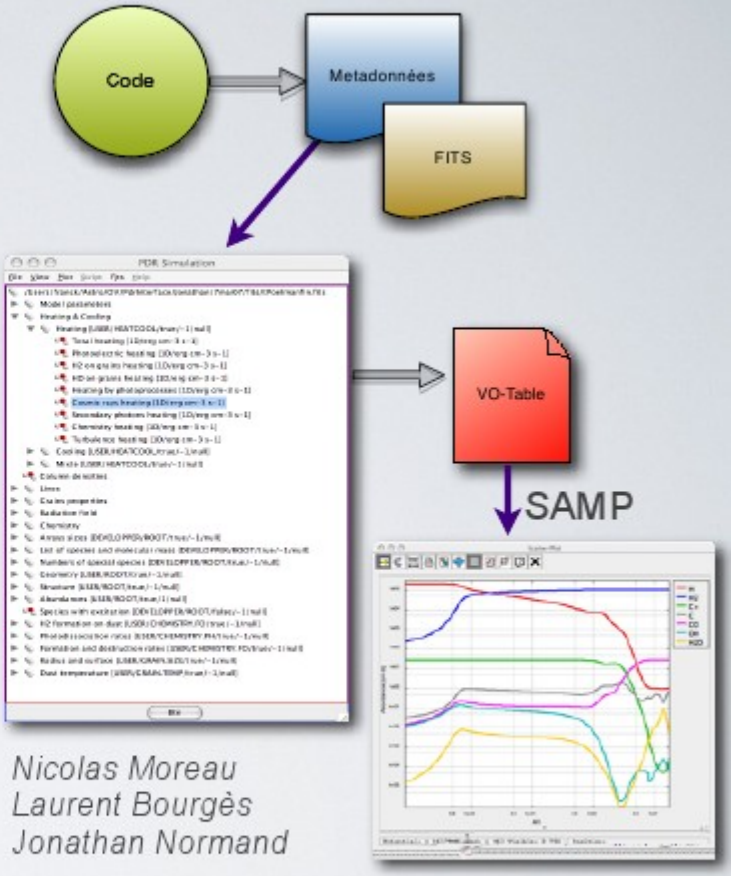
PDR Database

Output Files

Code produces
- raw data : FITS File
- XML / VO-TABLE : meta-data
  (name, description, units, UCD, ...)

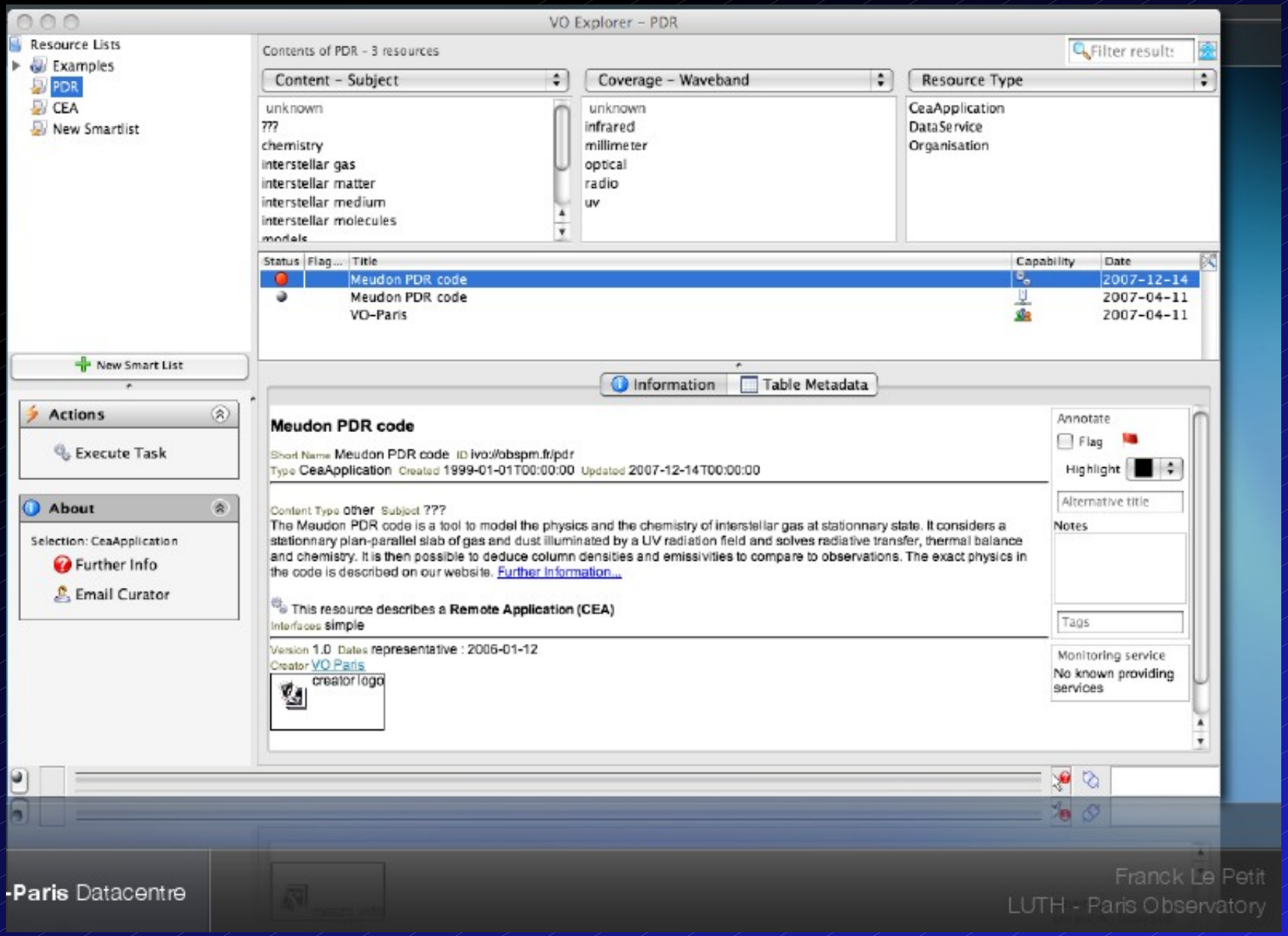
Provide all quantities computed by the code
- observables
- theoretical quantities

PDR Analyser
- browse the computed quantities
- extraction (ASCII, VO-Table)
- SAMP
- Download data from VO-Space
- Scriptable



Nicolas Moreau
Laurent Bourgès
Jonathan Normand

PDR code via VODesktop



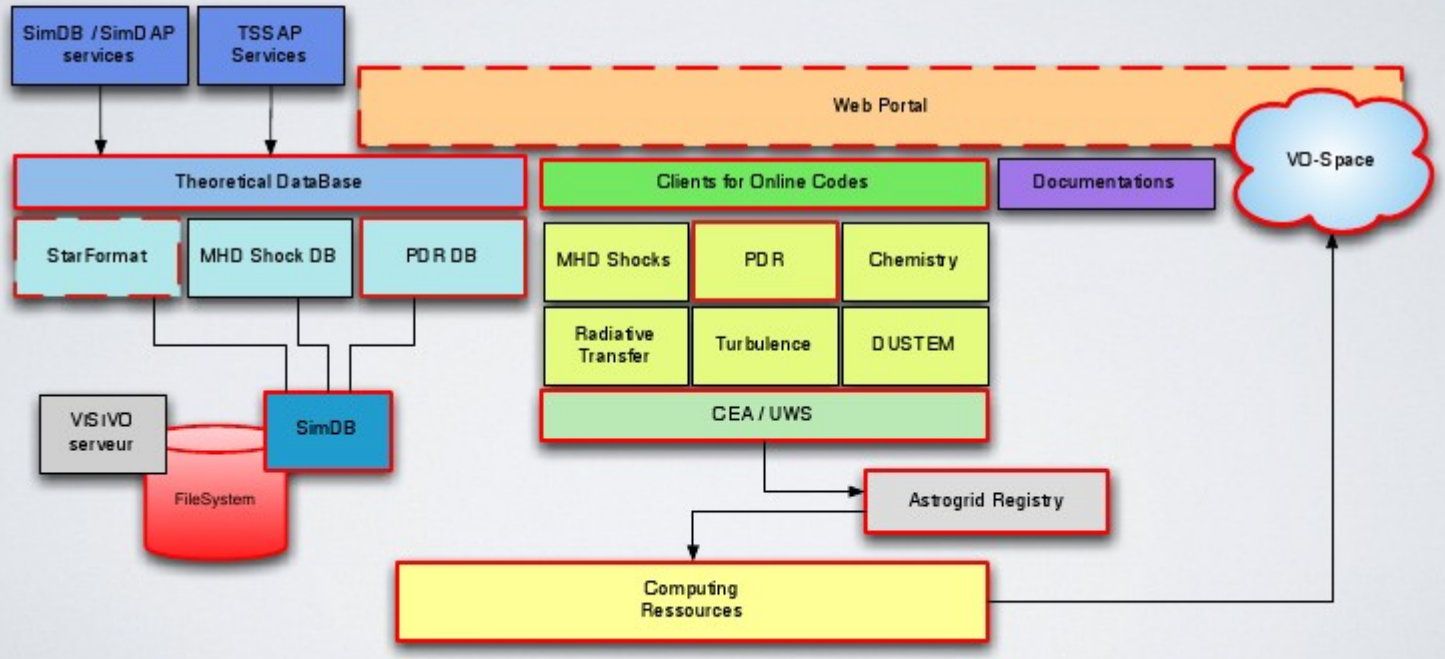
ISM platform

Interstellar Medium Platform

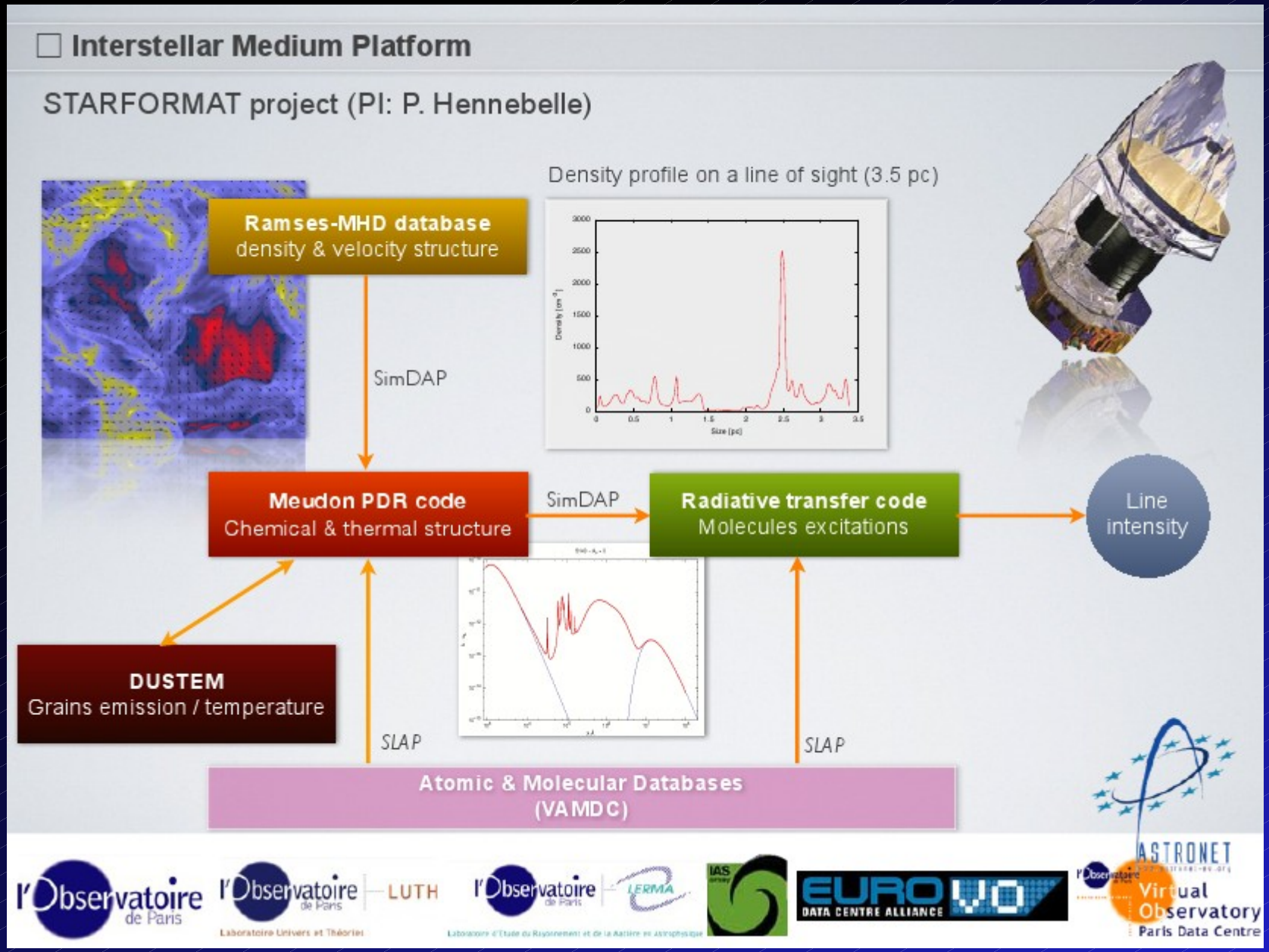
Bring together expertise in modeling / simulation of the ISM

Provide theoretical services about ISM

Codes - Databases - Tools & services



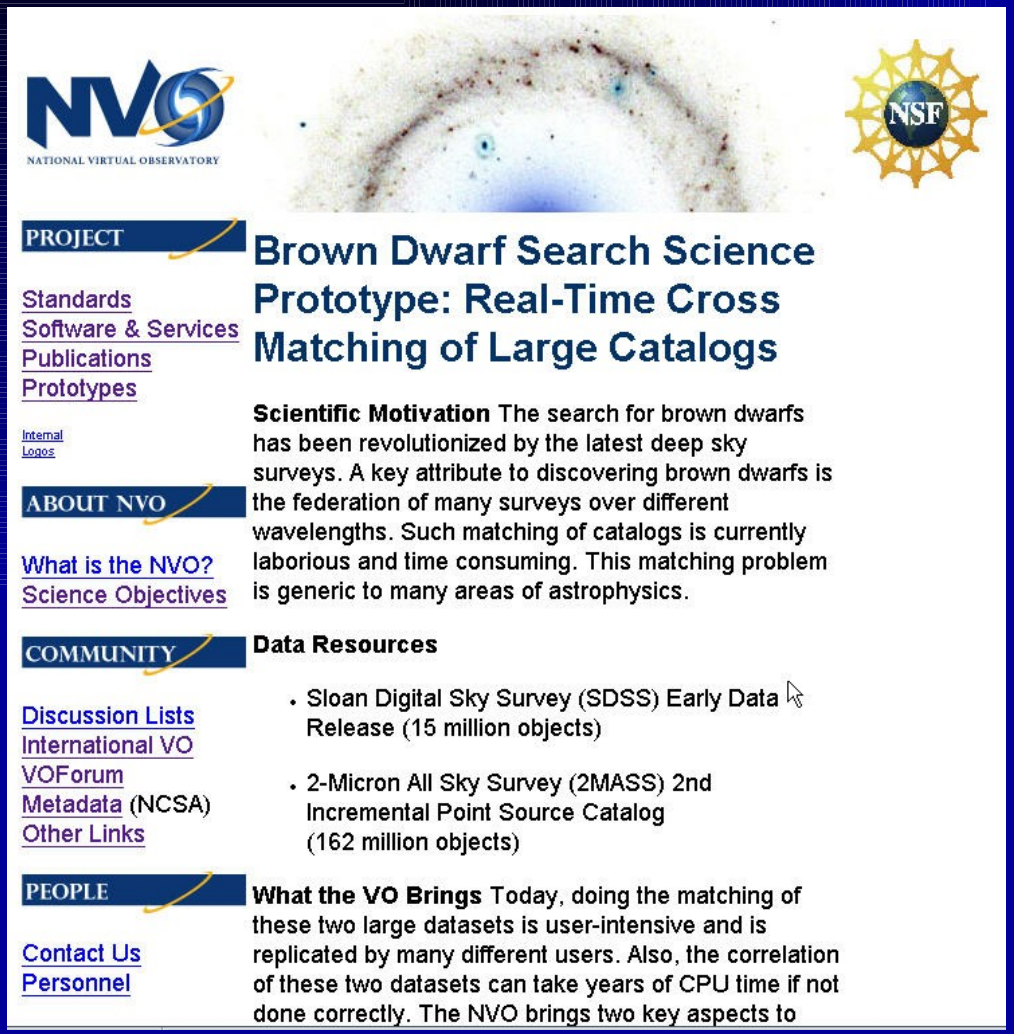
Complex join of TVO bricks



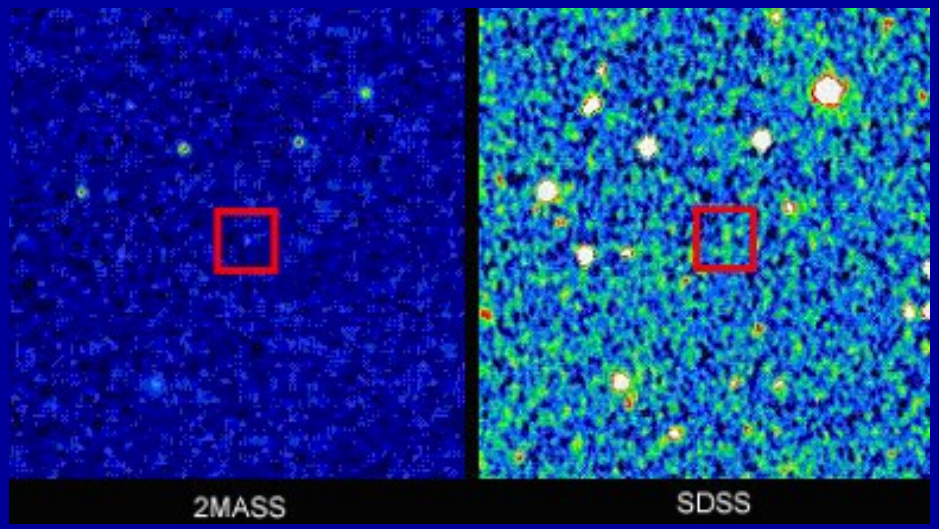
VO Science

- 31 (9) new obscured type 2 QSO (Padovani 2004)
- Brown dwarfs (about 20 candidates)
- Brightest (WD?) Albus-1 (Cabalero et al. 2008)
- Widest CPM binaries
- AGB to PNe - 100 new (200) with VO
- SED (Spectrum Energy Distribution)
- Bolometric magnitude
- VOEvent – robotic telescopes (GRB, transits,)
- Outreach , Education (MS WWT, GoogleSky)

BDs discovered using VO



- **Filtering criteria:** z & J-only detections with *z- J > 2.75*
- *SDSS: 15M obj.*
- *2MASS: 160M obj.*
- *300000 objects in common.*



✓ *However, systematic searches using a VO methodology have not been performed so far.*

Solano 2006

Democratization of Science

- Digital Divide
  technological barrier, data access free, access to journals
- International Council for Science CODATA
  Committee on Data for Science and Technology – UNO ICS
- CASPAR
  Cultural, Artistic and Scientific knowledge for Preservation, Access and Retrieval
  Digital curation centers
- ADS and VO
  links to ivo://, metadata, ontologies – semantic web
- Archive importance:
  5x IUE , 3x HST results from archives than PI articles
- Effectiveness
  50% of published data appears in Journals, links to data automatic ?

Objections to VO

Data quality – garbage in - garbage out

How and whom to give credit ? (button)

embedded ivo:// data in ApJ

VO for dissemination only

- technology for OPTICON, nextgen
- Virtual science – VO technology

VO only for public data ! Proprietary ?

(data jealousy)

- local archive - available data marked

The Astronomer's Data Manifesto

at 26 IAU GA Prague SPS3

(a) All significant tables, images, and spectra published in journals should appear inastronomical data centres.

(b) All data obtained with publicly-funded observatories should, after appropriate pro-prietary periods, be placed in the public domain.

(c) In any new major astronomical construction project, the data processing, storage,migration, and management requirements should be built in at an early stage of the project plan, and costed along with other parts of the project.

(d) Astronomers in all countries should have the same access to astronomical data and information.

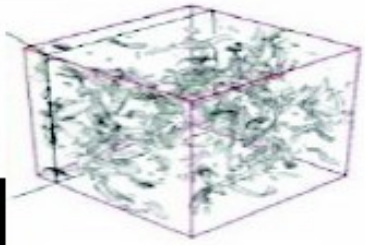
(e) Legacy astronomical data can be valuable, and high-priority legacy data should be preserved and stored in digital form in the data centres.

(f) The IAU should work with other international organisations to achieve our common goals and learn from our colleagues in other fields. ”

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

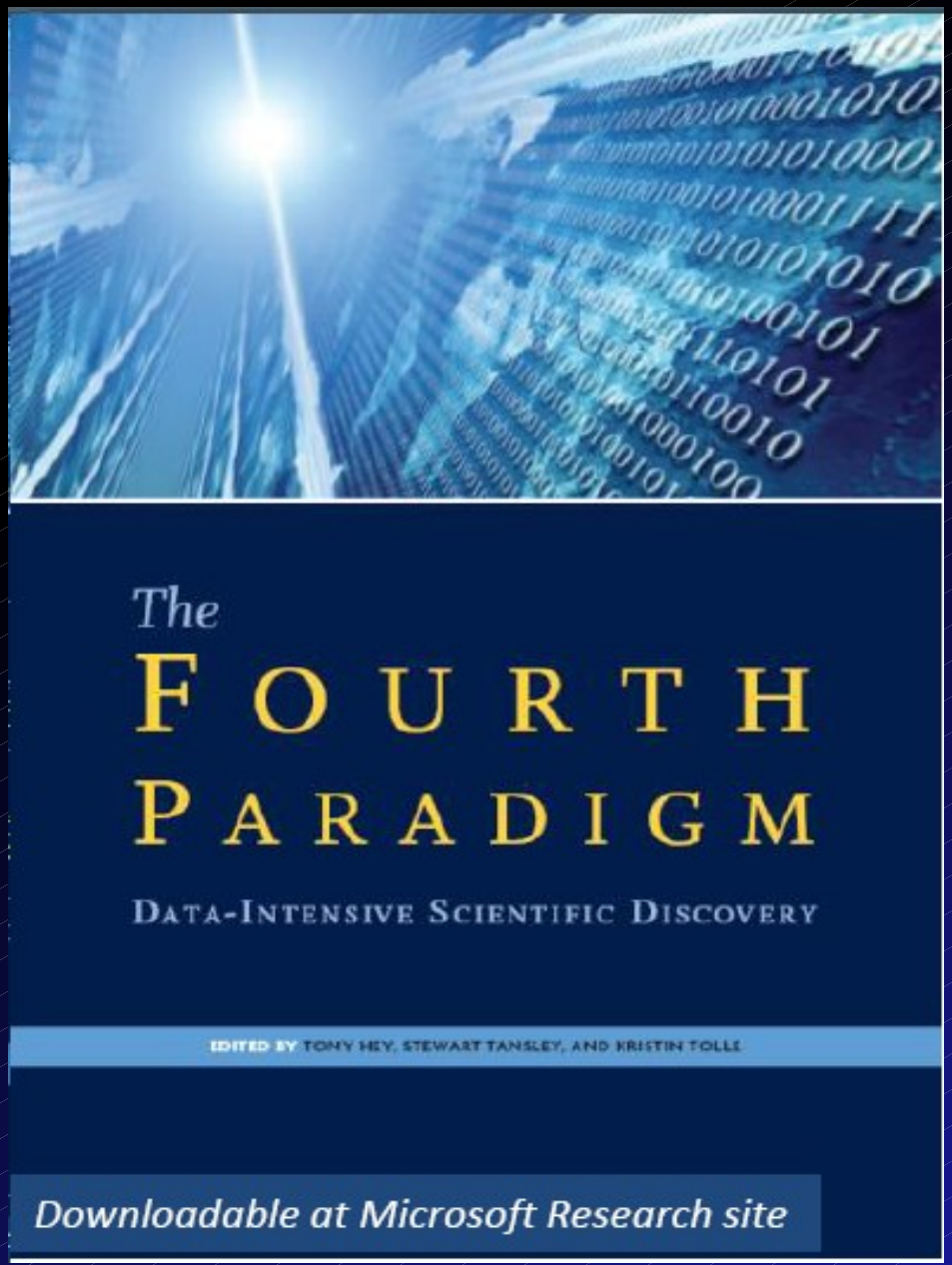
$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K\frac{c^2}{a^2}$$



(With thanks to Jim Gray)

From T. Hey, AI2010

X-informatics

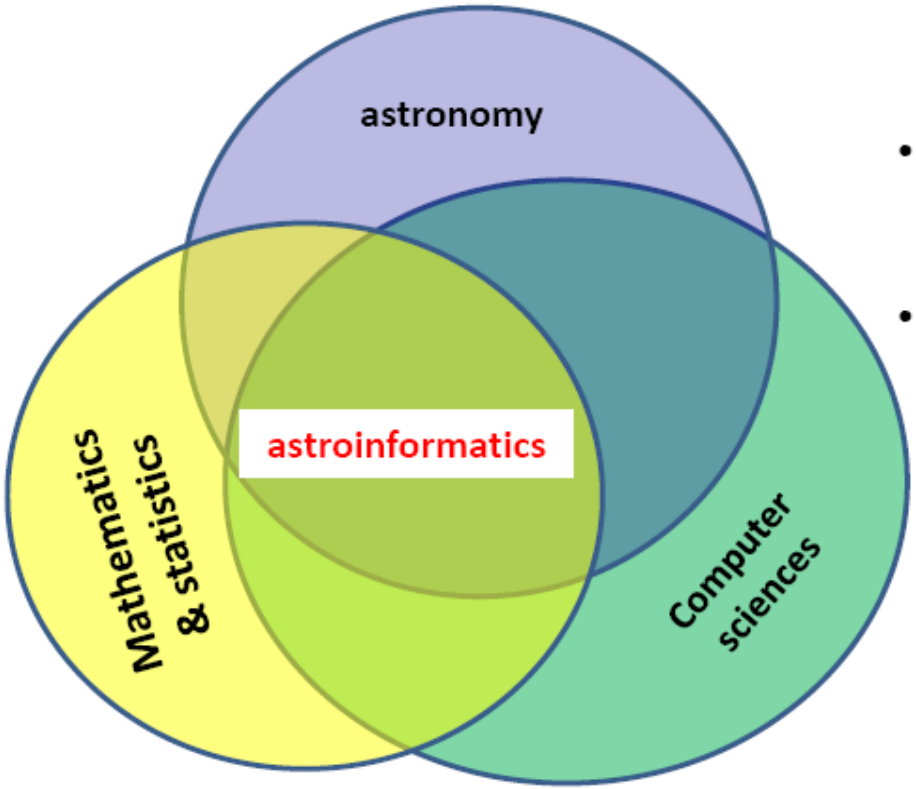


Changing methodology of the Science

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

Longo 2010

Astroinformatics

- Analogy – Bioinformatics (Genome analysis with GRIDS, ATB)
- e-Science in Astronomy - using informatics (computer science)
- 4-th Paradigma of science (observation,experiment, modeling, knowledge)
- Data mining, Knowledge discovery - VO-NEURAL, DAME
- Clustering
- Classification
- Supervised learning (Neural Networks, SVM)
- Examples
  - Photometric RedShift
  - Searching for QSO
  - Automatic Light curves classification (GAIA, LSST)
- Very NEW – emerging discipline

The answer is Data mining …. matching Donald Rumsfeld's epistemology

There are known knowns,
There are known unknowns, and
There are unknown unknowns

Classification
Morphological classification of galaxies
Star/galaxy separation, etc.

Regression
Photometric redshifts

Clustering
Search for peculiar and rare objects,
Etc.

"There are known knowns.
These are things we know that we know.
There are known unknowns.
That is to say, there are things that we know we don't know.
But there are also unknown unknowns.
There are things we don't know we don't know."

Longo 2010

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.

Database technologies

→ Data Mining (or Knowledge Discovery in Databases):

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

Key mathematical issues

→ Data understanding

Computer aided understanding
KDD
Etc.

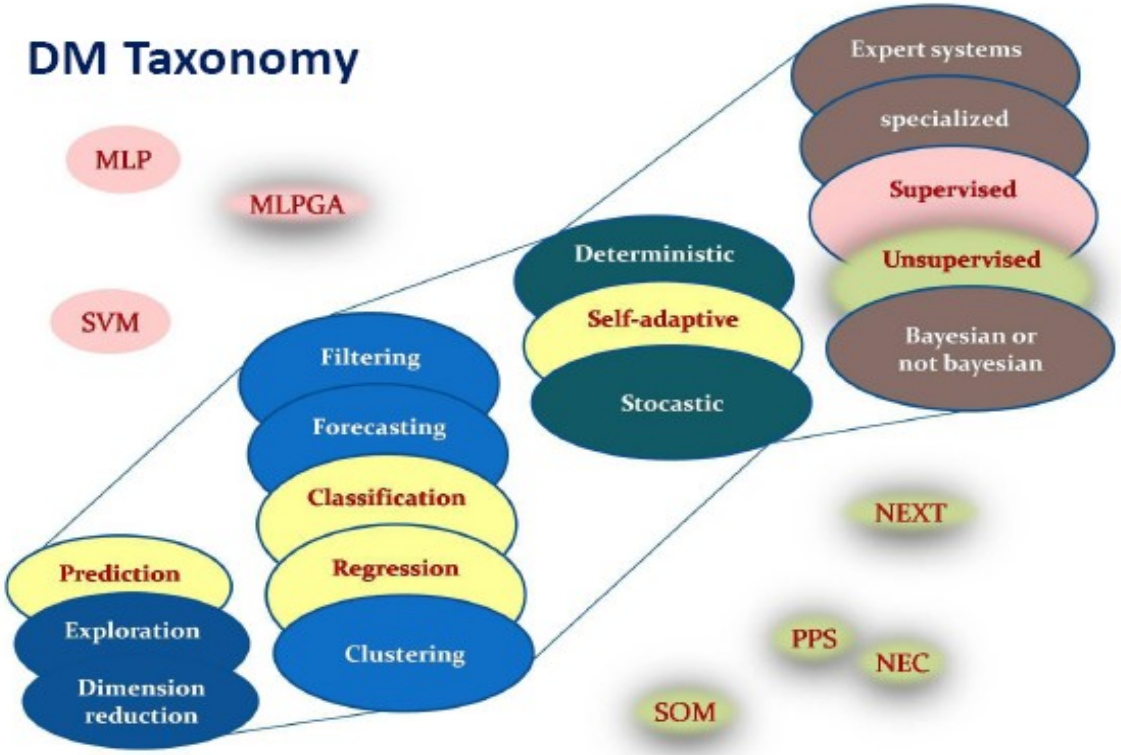
Ongoing research

→ New Knowledge

DA ME

Data Mining is the activity of extracting **USEFUL** information from **COMPLEX** data using Statistical Pattern Recognition and Machine Learning methods.

DM Taxonomy



1. To catalogue the known (classification)
2. Characterize the unknown (clustering)
3. Find functional dependencies (regression)
4. Find exceptions (outliers)

Supervised Methods

Patterns are learnt from extensive set of templates (Base of Knowledge = BoK)

Unsupervised Methods

Patterns are discovered using the data themselves

Scientific Communities

"The co-authorship network of scientists represents a prototype of complex evolving networks. In addition, it offers one of the most extensive database to date on social networks."[a]

[a]Barabàsi et al., "Evolution of the social network of scientific collaborations"

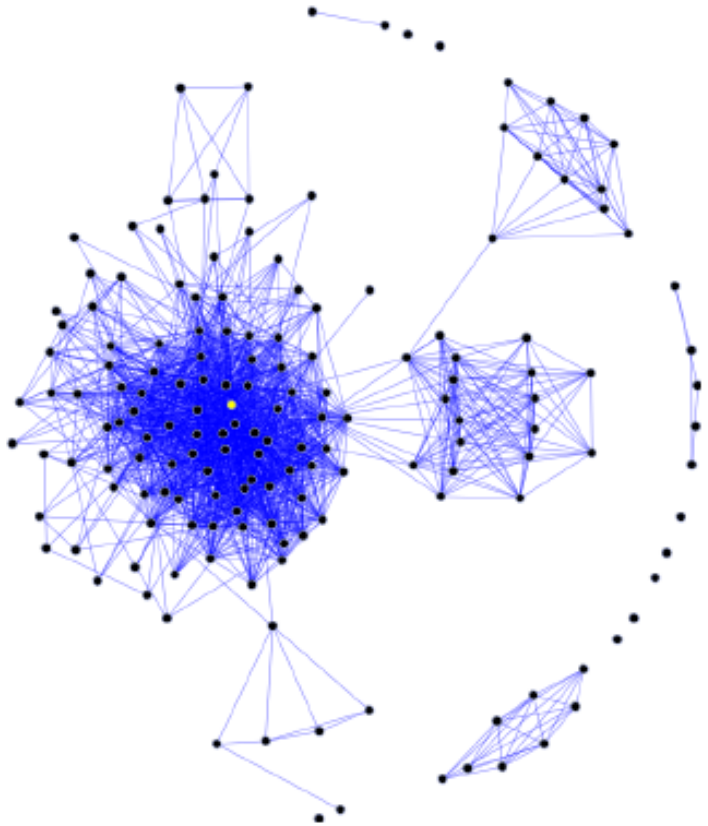
"Social scientists have long recognized the importance of boundary-spanning individuals in diffusing knowledge (Allen 1977; Tushman 1977), and recently, several papers have rigorously demonstrated that technological knowledge diffuses primarily through social relations, not through publications."[a]

[a]Sorenson, and Singh, "Science, Social Networks and Spillovers"

From O. Laurino - AI2010

Motivations of a social networking IT platform for science

- The importance of boundary-spanning individuals in social networks might be what X-informatics is all about;
- we break scientific *cliques* and create new, unexpected, effective links across the science community's network;
- an effective scientific social network platform may be an effective step towards *seamless astronomy*. Seamless not only in terms of data and applications access, but also in terms of social interactions between people in the scientific network.



From enterprise to research

Integrated Collaborative Environment

↓

Distributed Scientific Social Websites

- Each institution could develop its website (e.g. OpenSocial);
- institutions/developers could also provide interoperable web applications;
- researchers could customize their UI/preferred applications (custom portals!);
- researchers social data would be accessed from the web;
- social features (ranking, sharing, discussing, discovering);
- collaborative software (e.g. Google Wave).

If the social communication is effective, applications can spread and compete, new links can form in the network, and new collaborations can start!

http://mica-vw.org/

Search Go

Log in / create account

Navigation

- Main Page
- Charter
- Events
- Research
- Organization
- People
- How to Join
- MICA blog
- Publications
- Links

Meta Institute for Computational Astrophysics

The Meta Institute for Computational Astrophysics (MICA) is a professional scientific and educational, non-profit organization based in virtual worlds [VWs] (currently in Second Life [SL], but with an intent to expand its presence in other venues as the VWs evolve). The goals of MICA include:

- Exploration, development and promotion of VWs and virtual reality [VR] technologies for professional research in astronomy and related fields.
- Providing and developing novel social networking venues and mechanisms for scientific collaboration and communications, including professional meetings, effective telepresence, etc.
- Use of VWs and VR technologies for education and public outreach.
- Exchange of ideas and joint efforts with other scientific disciplines in promoting these goals for science and scholarship in general.

MICA is an experiment in the scholarly use of VWs technologies

- Currently ~ 50 professional members and > 100 affiliates
- Regular schedule of events: seminars, workshops, public lectures, etc.

Virtual Worlds (2nd Life for Science)

Now migrating to the *OpenSim*-based VWs, e.g., Intel's *ScienceSim*

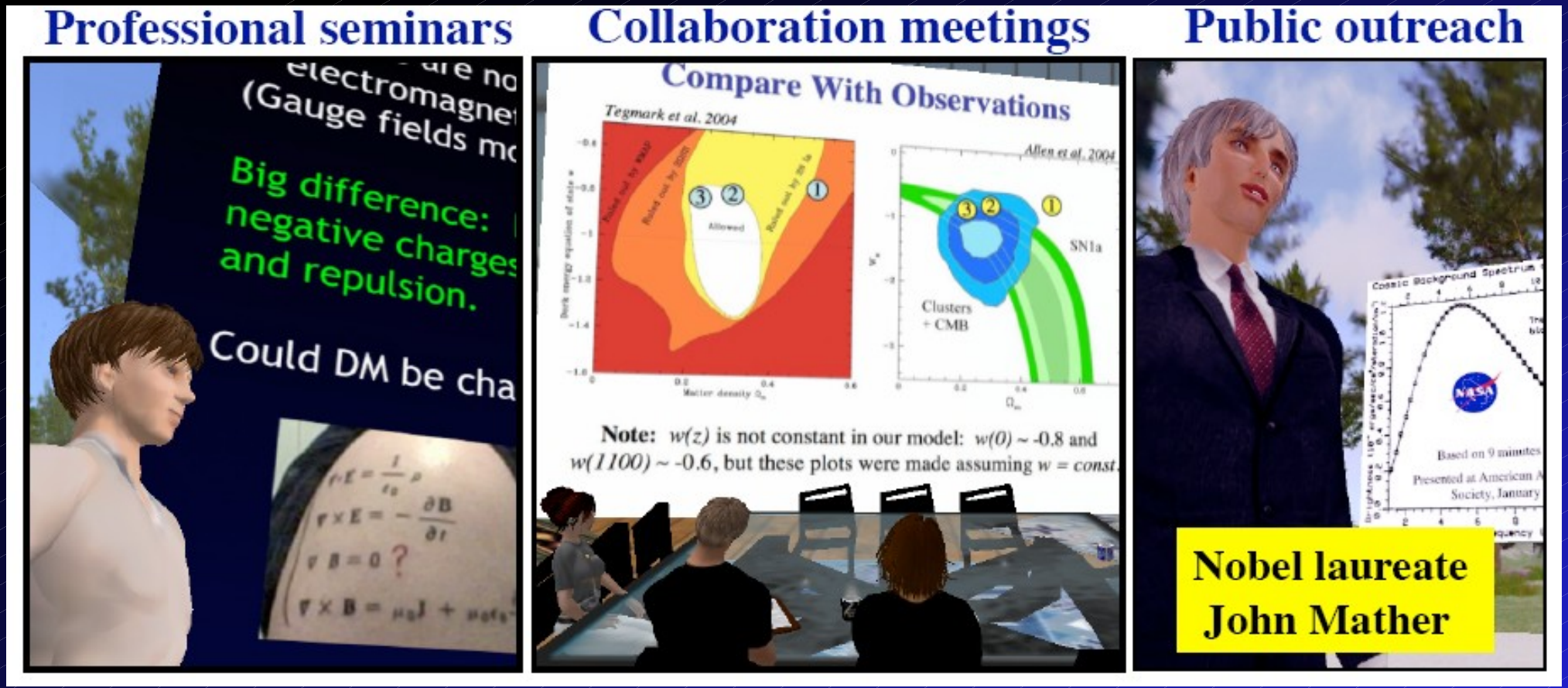
Djorgovski

Virtual Conferences

Virtual conferences at zero cost

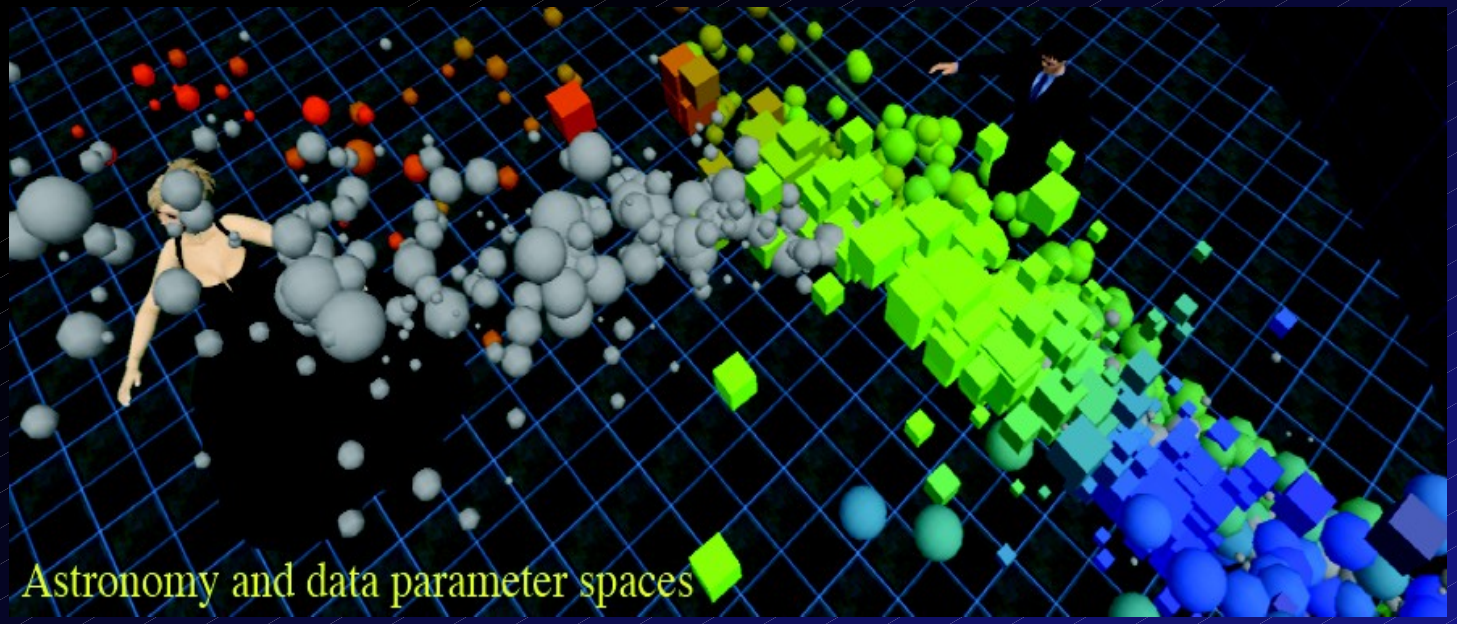
Problem with time zones

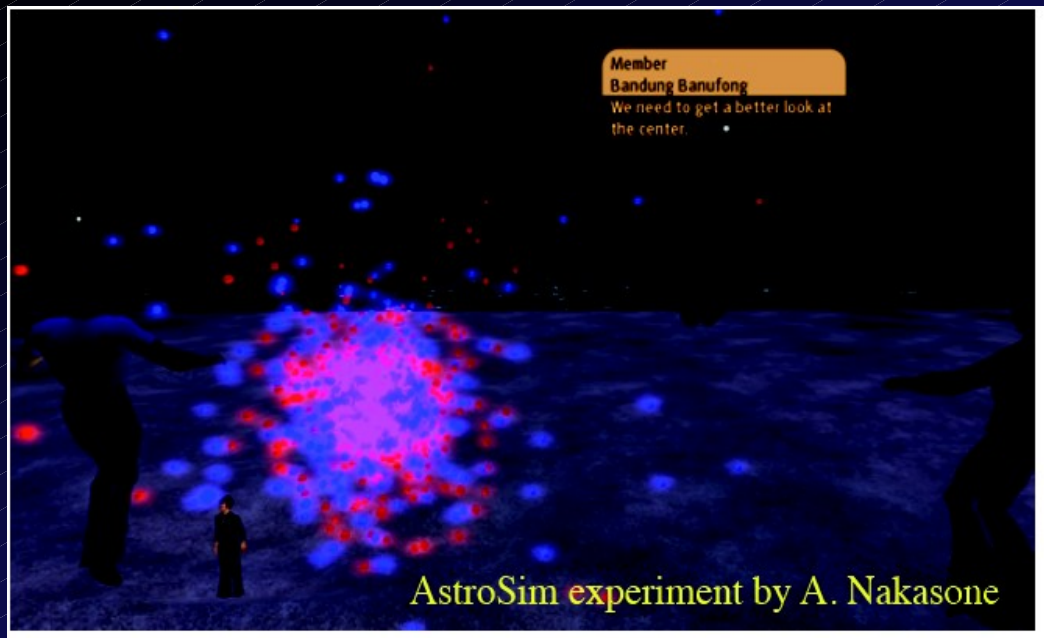
Outreach, education



From Djorgovski - AI2010

Immersive VR Experiments





Scientists immersed in, and interacting with, numerical simulations of star clusters

U-Science, Carbon Computing

e-Science emerged ~10 yrs ago using the web protocols that were common at that time:

– web services, XML-based information exchange, registries, distributed data access, distributed computing (Grid) = machine-to-machine communication

U-Science is now emerging from today's web protocols:

– social networking, ubiquitous devices, user-centric experiences, user-led activities, user-generated content, wikis, blogs, mashups, tagging, annotation, ontologies (semantic web), folksonomies, knowledge-sharing, user recommendations = user-to-user communication

- The emergence of Citizen Science:

– Anybody can participate in the science discovery process

- Anyone can annotate, tag, and label scientific results:

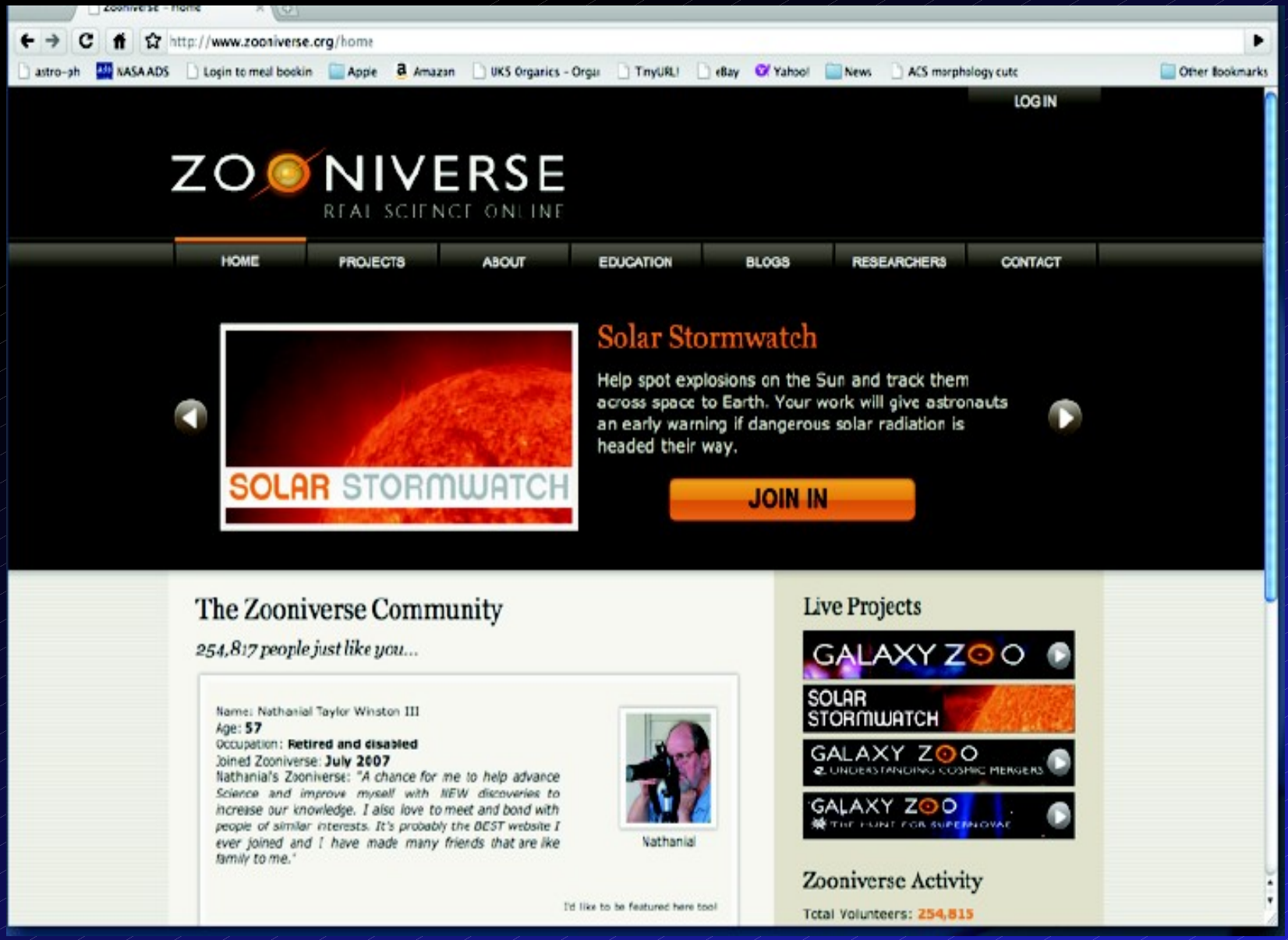
– scientists, students, and citizen scientists

From K. Borne AI2010

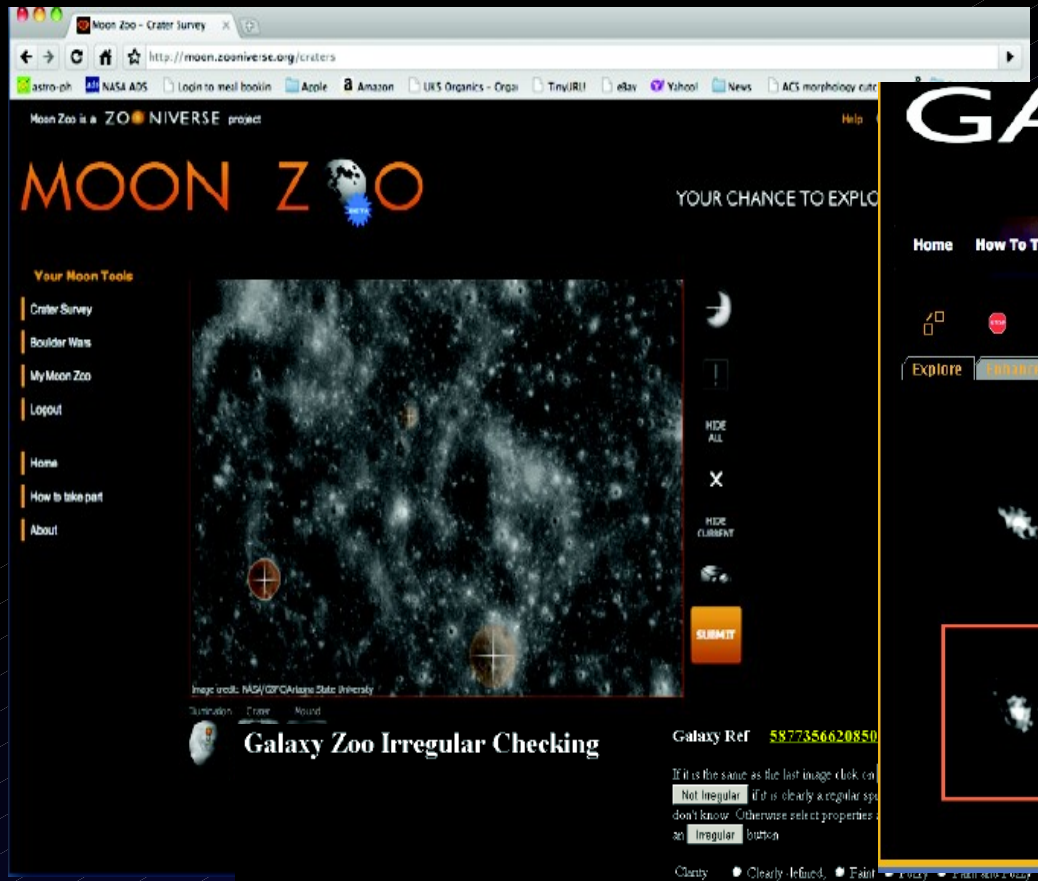
Galaxy ZOO

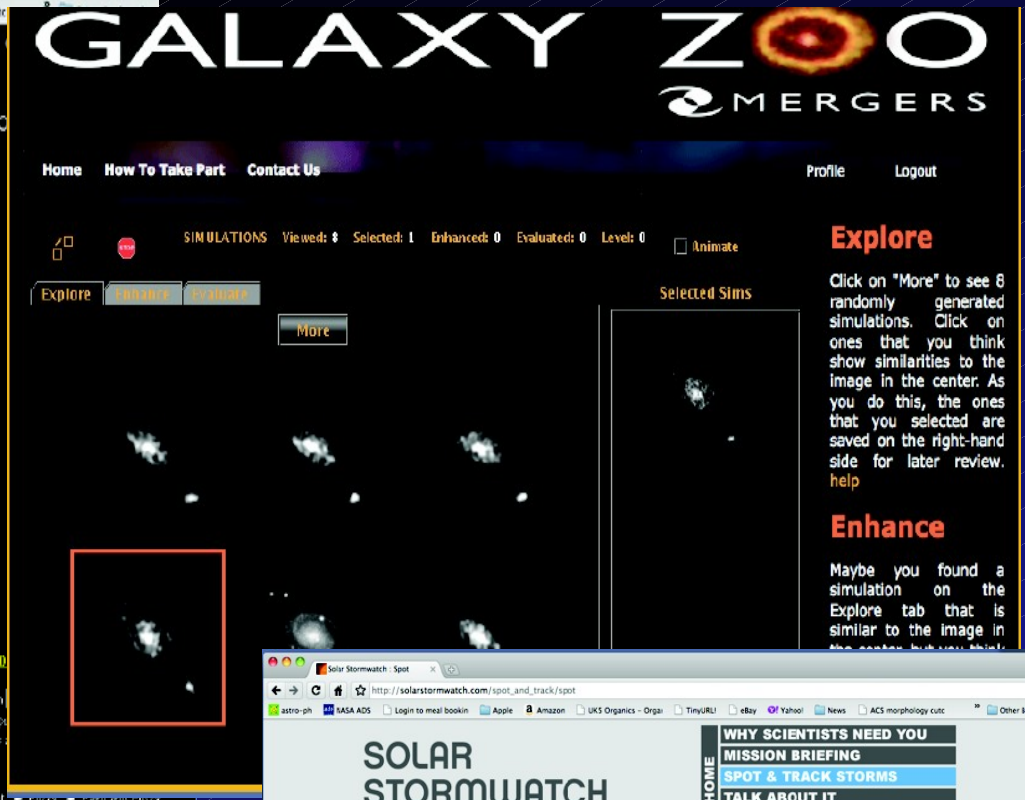
> 20 Science papers published so far

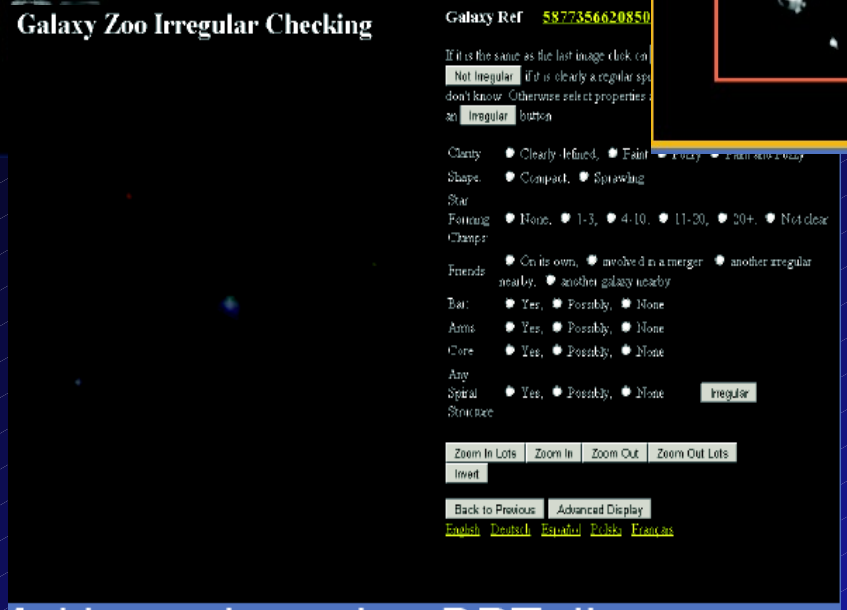
www.zooniverse.org

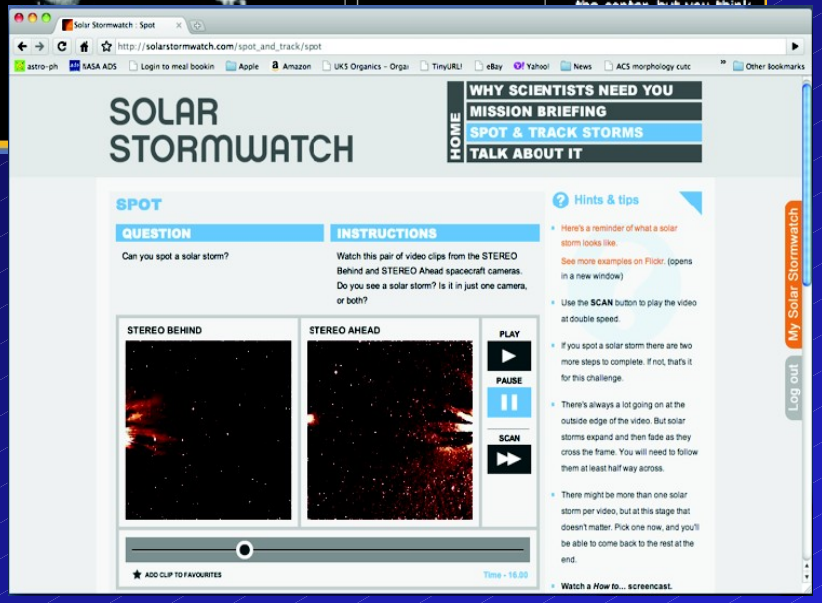


Examples ZOOniverse

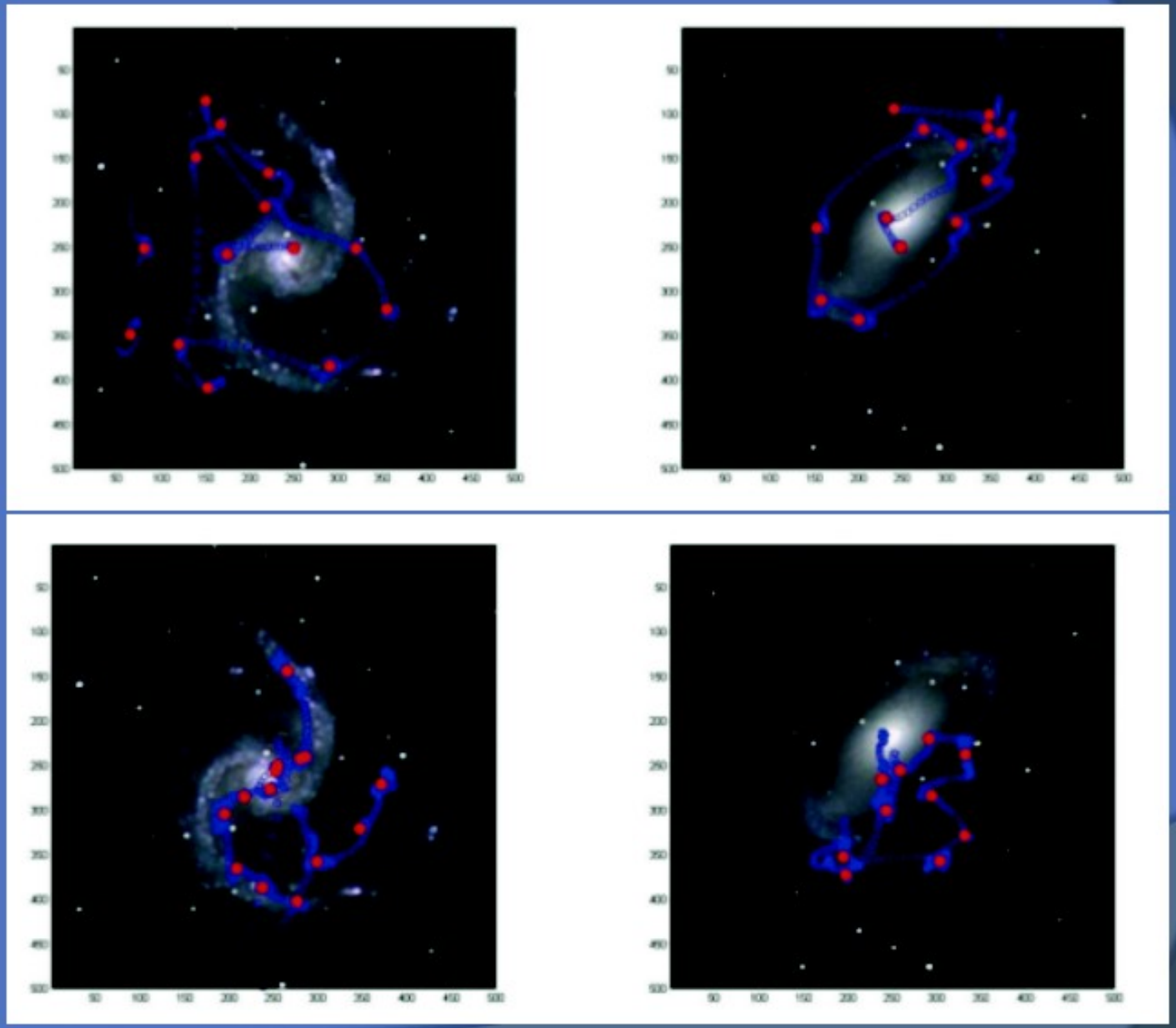




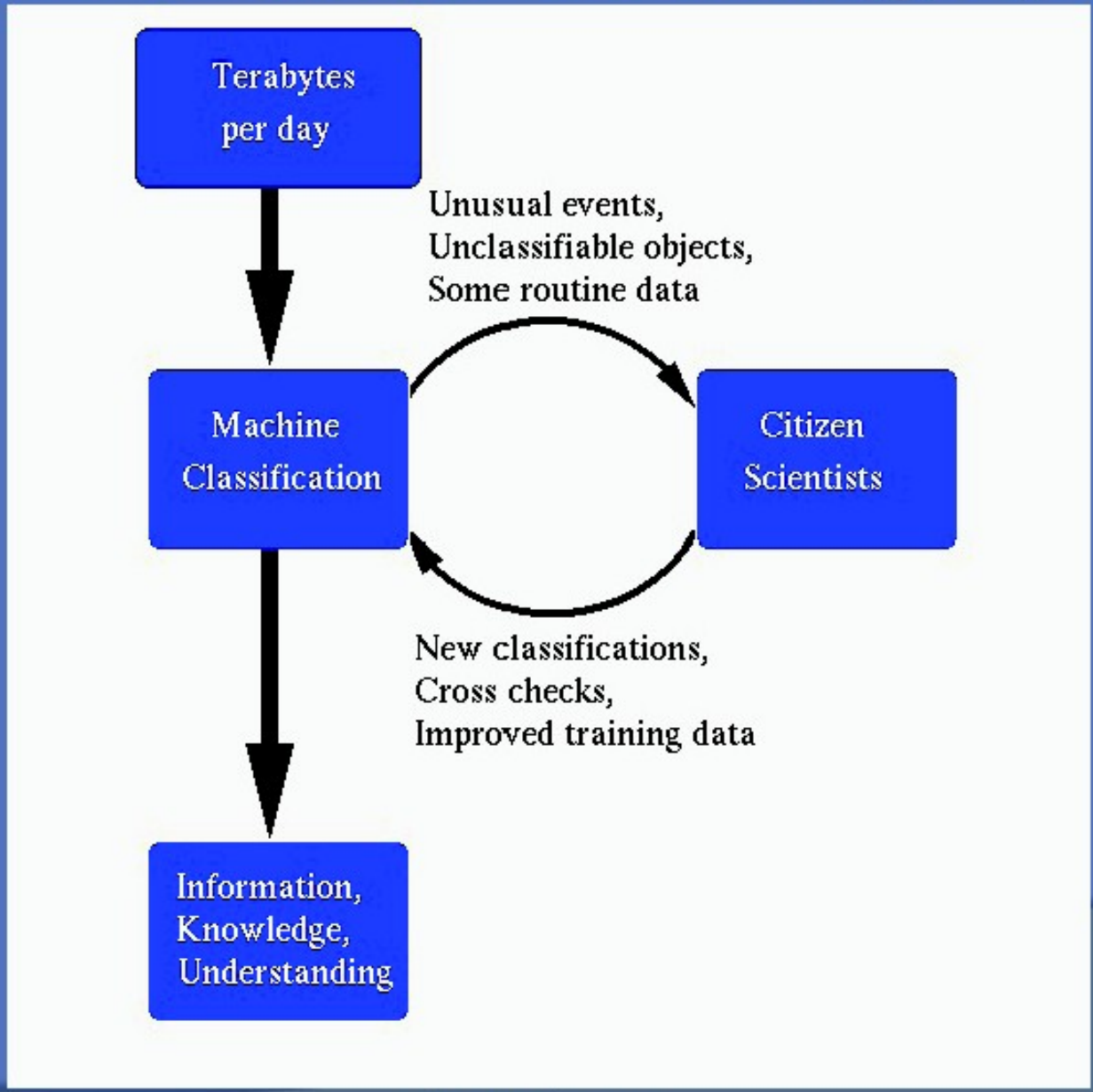




Expert vs Non-expert Classifier



Machine-Human Learning Cycle

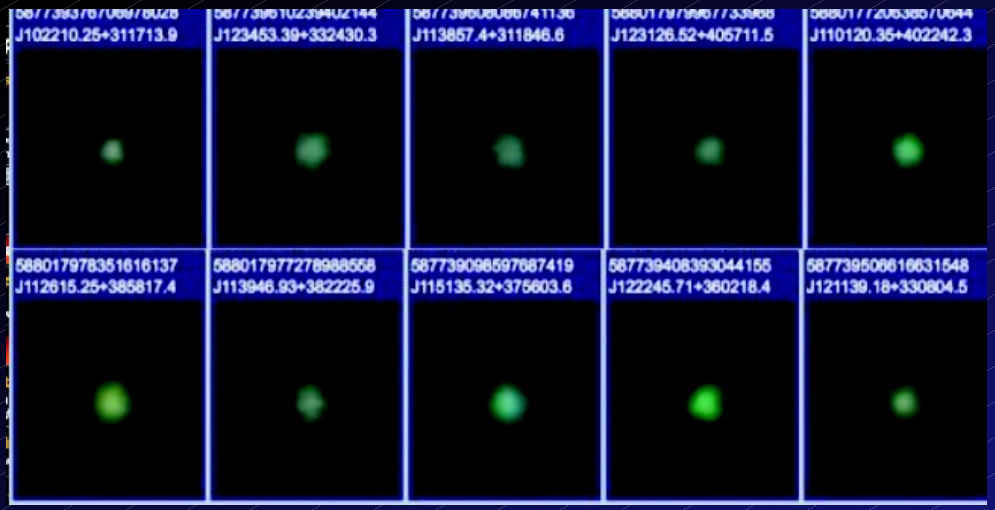


Citizen Science x Expert Science

Verified by human – training sets

Independent answers=estimate of error

Serendipitious discovery



Galactic Peas

Scale - complexity

Knowledge Discovery in U-Science

Hanny van Arkel - Voorwerp

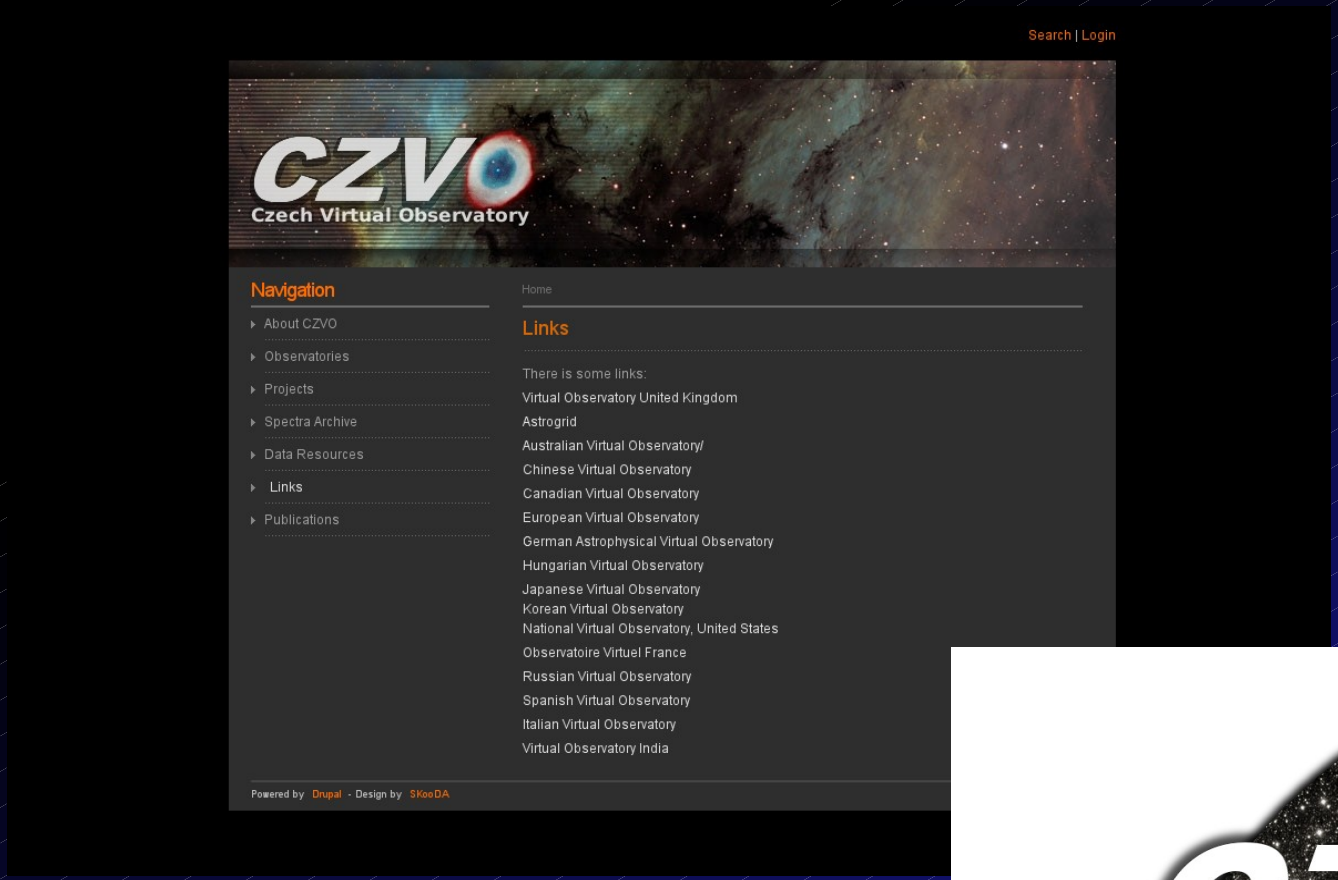
Light echo of quasar?

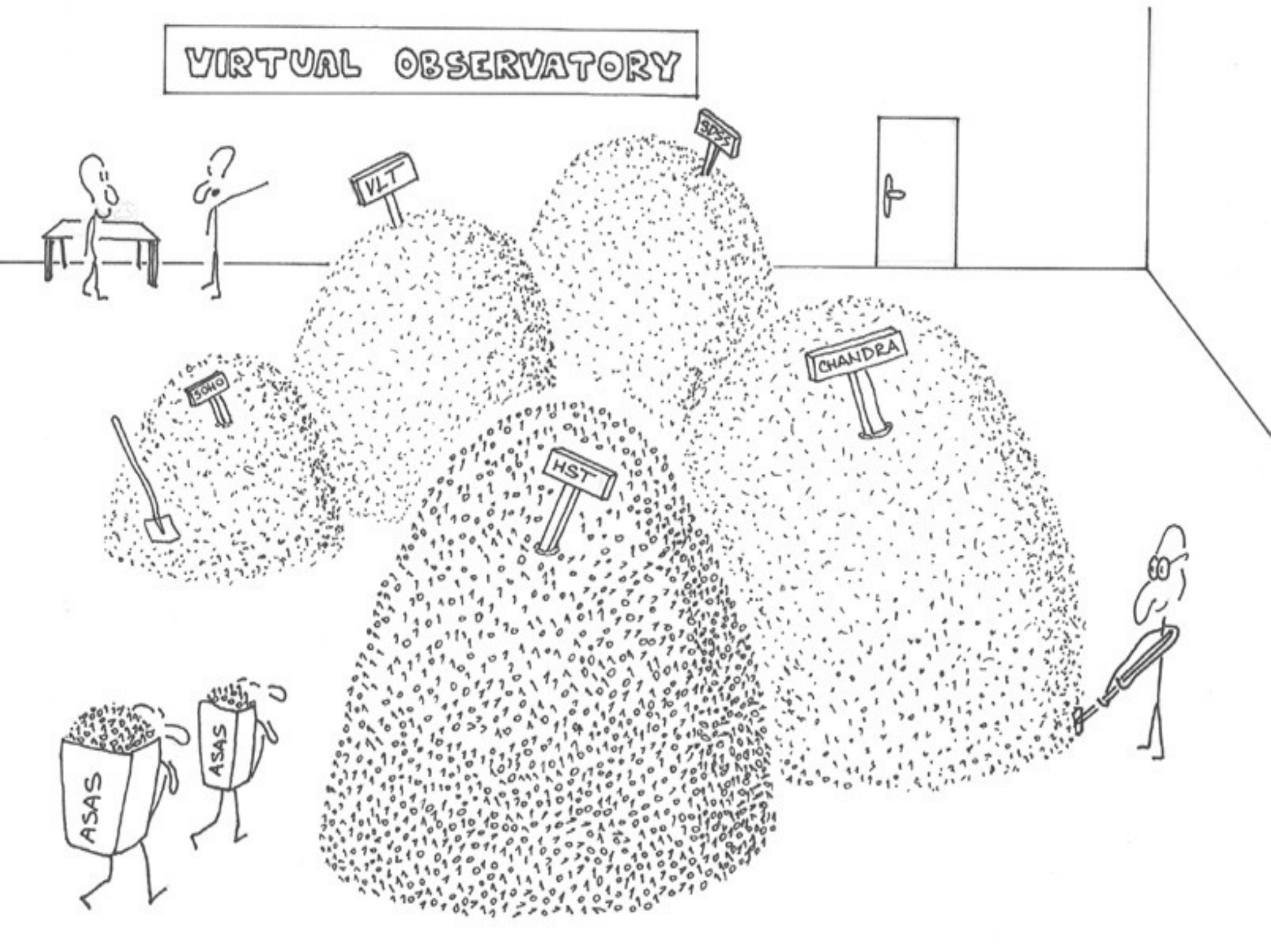
Known knowns :
Primary task. Data reduction by science team.

Known unknowns :
Related to primary task. Results funneled to specific researchers.

Unknown unknowns :
Serendipity. Currently rely on forum moderators to filter.

Czech VO - CZVO

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VLT
SDSS
SOHO
HST
CHANDRA
ASAS
ASAS

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