

Optical Spectroscopy with the Technology of Virtual Observatory

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8th Serbian Conference on Spectral Line Shapes in Astrophysics
Invited Lecture, 7-th June 2011, Divčibare, Serbia

Credits

- The presentation is based on many different sources – mainly the on-line published slides from IVOA meetings, slides or pictures found on internet.
- We acknowledge namely materials of E. Solano, D. De Young, F. Le Petit, B.Hanish, C.R. Blanco, E. Hatsiminaoglou, T.Hey

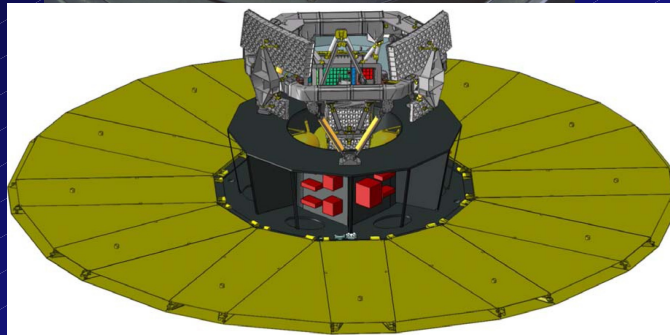
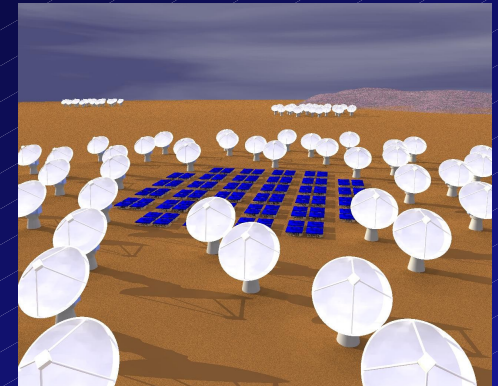
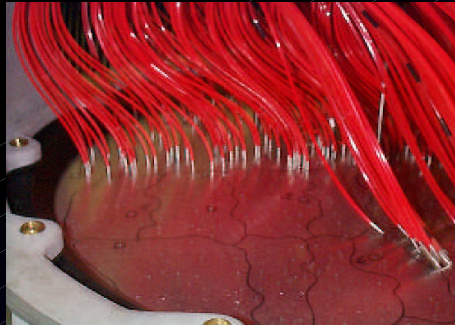
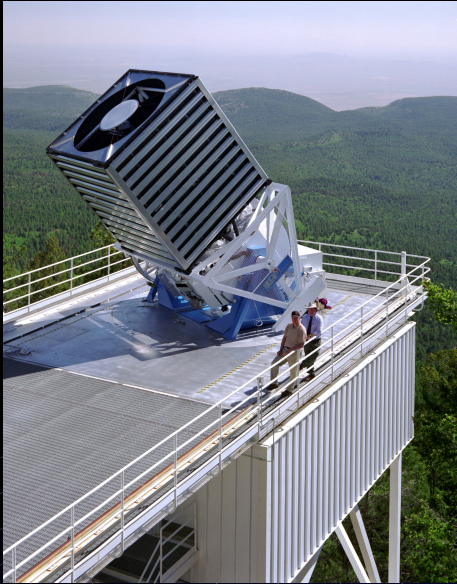
Outline of the Talk

- VO – the hidden revolution in astronomy
- Data Avalanche in astronomy
- History of VO
- Basic principles of technology
- VO Tools for spectroscopy
- Theory in VO (model spectra, SEDs)
- VO Science
- Astroinformatics

VO - The Hidden Revolution in Astronomy

- VO is the radical change of the paradigm of the work of the scientists – effectiveness !!!
- VO is there but hidden under the hood (Aladin, VizieR, Simbad, NED, MAST, ADS.....)
- Everyday question (what, where, format, units)
- Scientists are conservative (don't like change)
 - The fear of buzzword VO (multispec, large scale)
- IT literacy – obligatory in near future (scripts...)

Data Avalanche



Large Scale Data

- Huge surveys: 100 million sources at < 3000 sources per night \Rightarrow > 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) \Rightarrow ~ 3 months at 10 Mbps
 - catalogues (2 Terabytes) \Rightarrow ~ 3 weeks
 - on DVDs \Rightarrow ~ 2,100 of them
- And data analysis?? (similar size for MACHO, 2MASS etc)

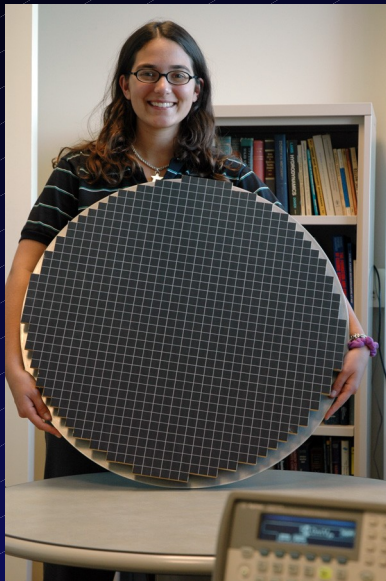
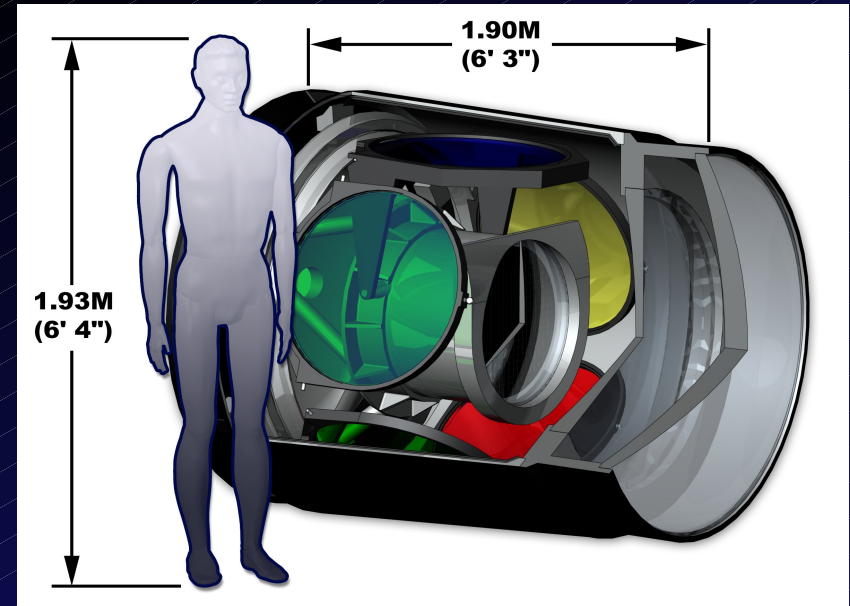
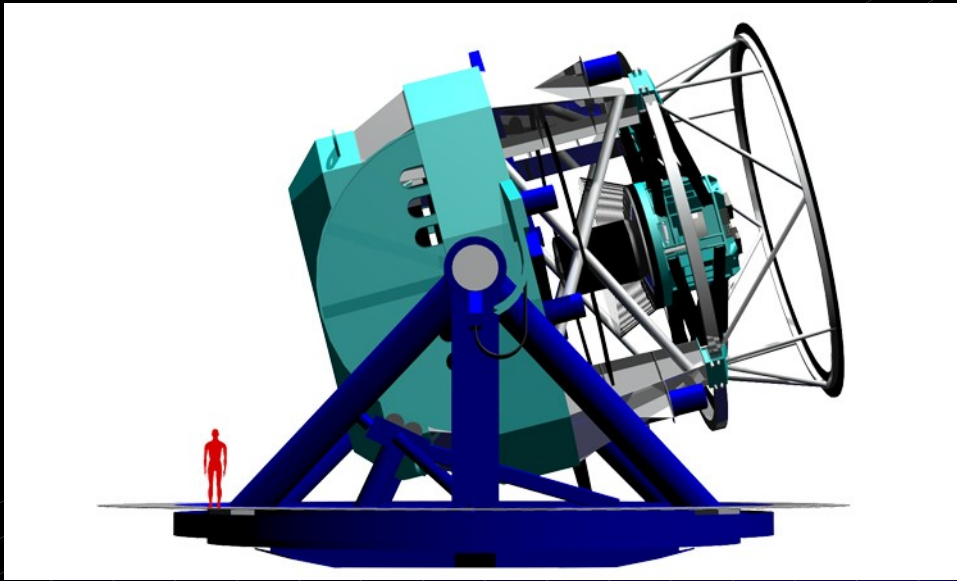
CD Sea



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

Bruce Monro
Kilmington UK

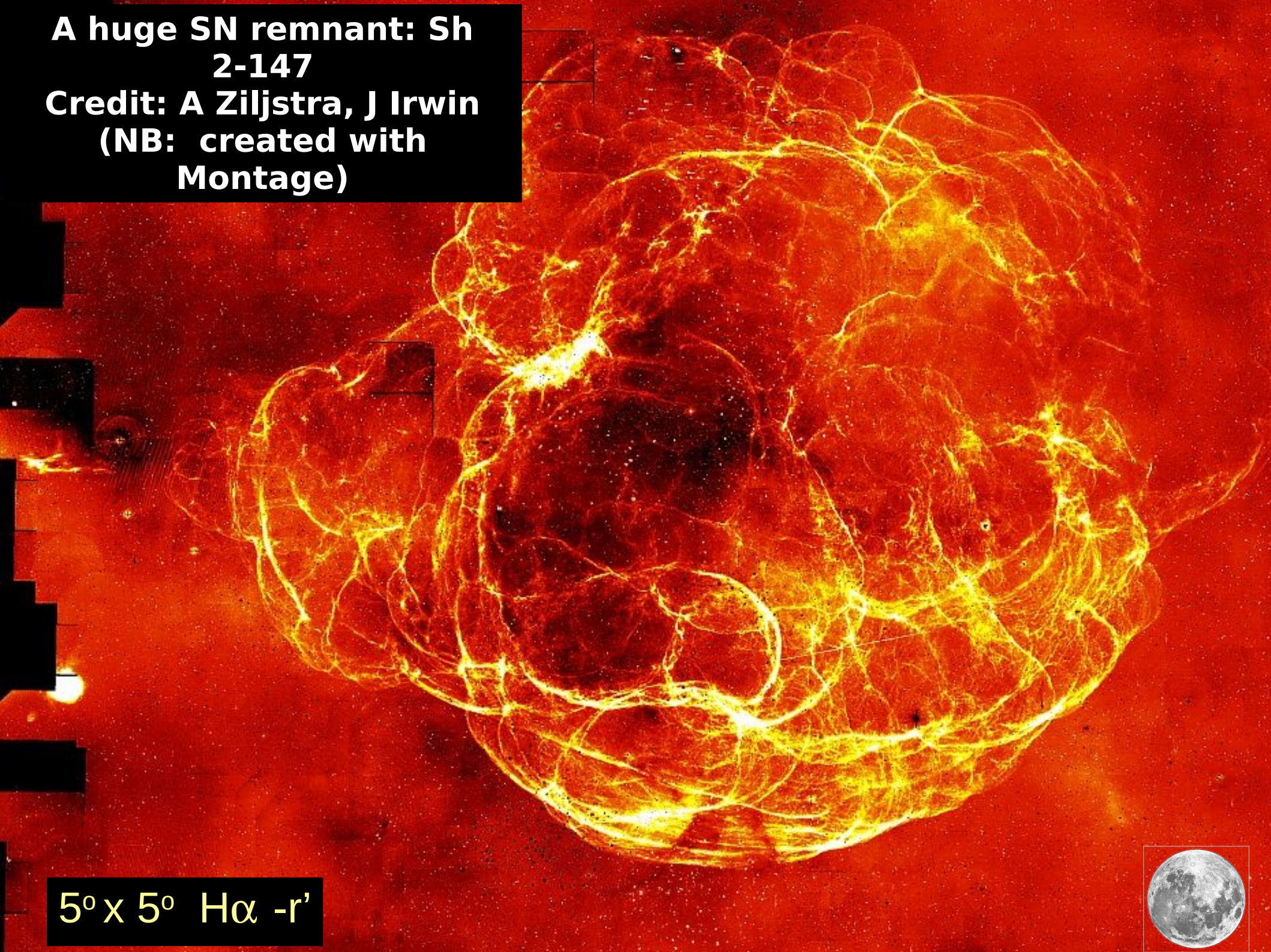
LSST (8.4m)



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 Zijlstra, J Irwin
(NB: created with
Montage)**



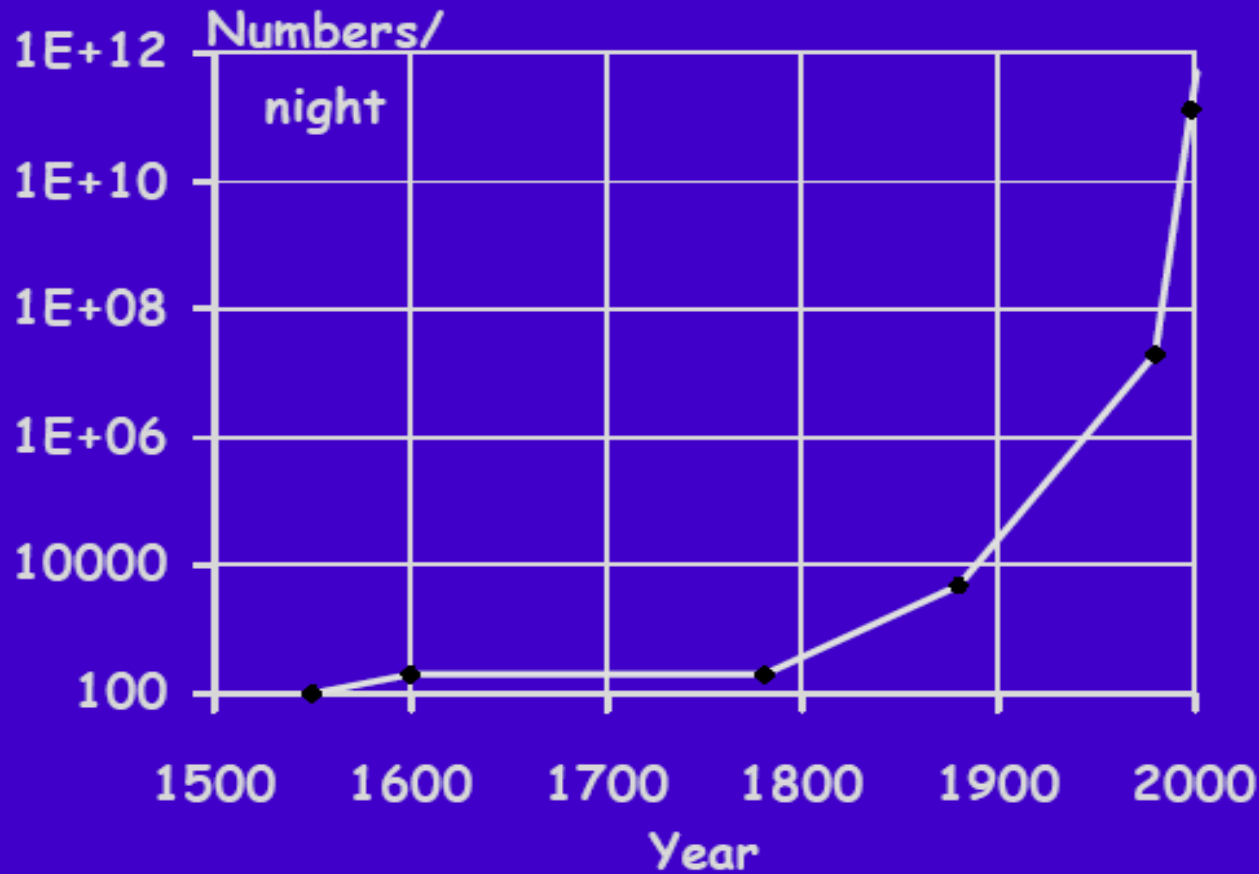
5° x 5° H α -r'



Data Avalanche

Moore law for chips –doubling 1.5 year

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



$T_2 < 18$ mths
1990-2000

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)

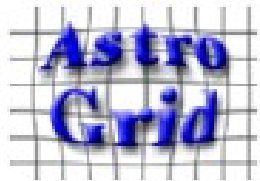
Data for SDSS, SIMBAD, NED – key research

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”

IVOA



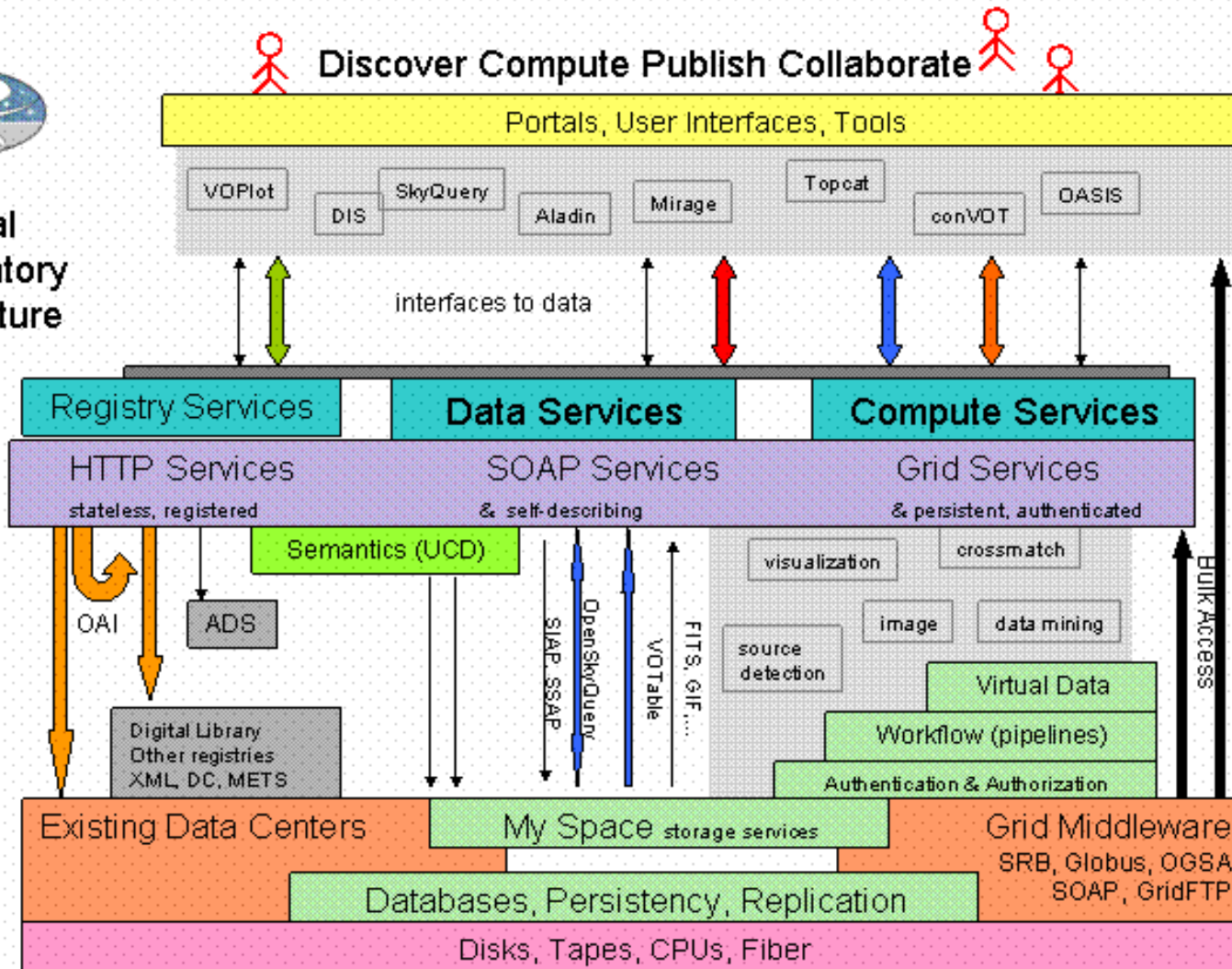
Analogy between VO and WWW

- 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 (usefulness for my field ???)
- Steep Growth – average user can use it without knowledge of principles (effectivity, habits)

Architecture of VO



Virtual
Observatory
Architecture



Technology of VO

Unified data format– VOTable, UCD (Vizier)

Transparent transport (unit conversion)

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

VOregistry (DNS like) Google for data+WS
protocols

ConeSearch (searching in circle on sky)

SIAP (Simple Image Access Protocol)

SSAP(Simple Spectral Access Protocol)

SLAP(Simple Line Access Protocol)

TAP (Table Access Protocol)

VOEVENT (transients, robotic telescopes, Sun)

VOTable

```
<TABLE name="SpectroLog">
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<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)

Technology of VO

ADQL (Astronomical Data Query Language)

XMATCH, REGION (2 catalogues - shifted)

Application interoperability – PLASTIC, SAMP

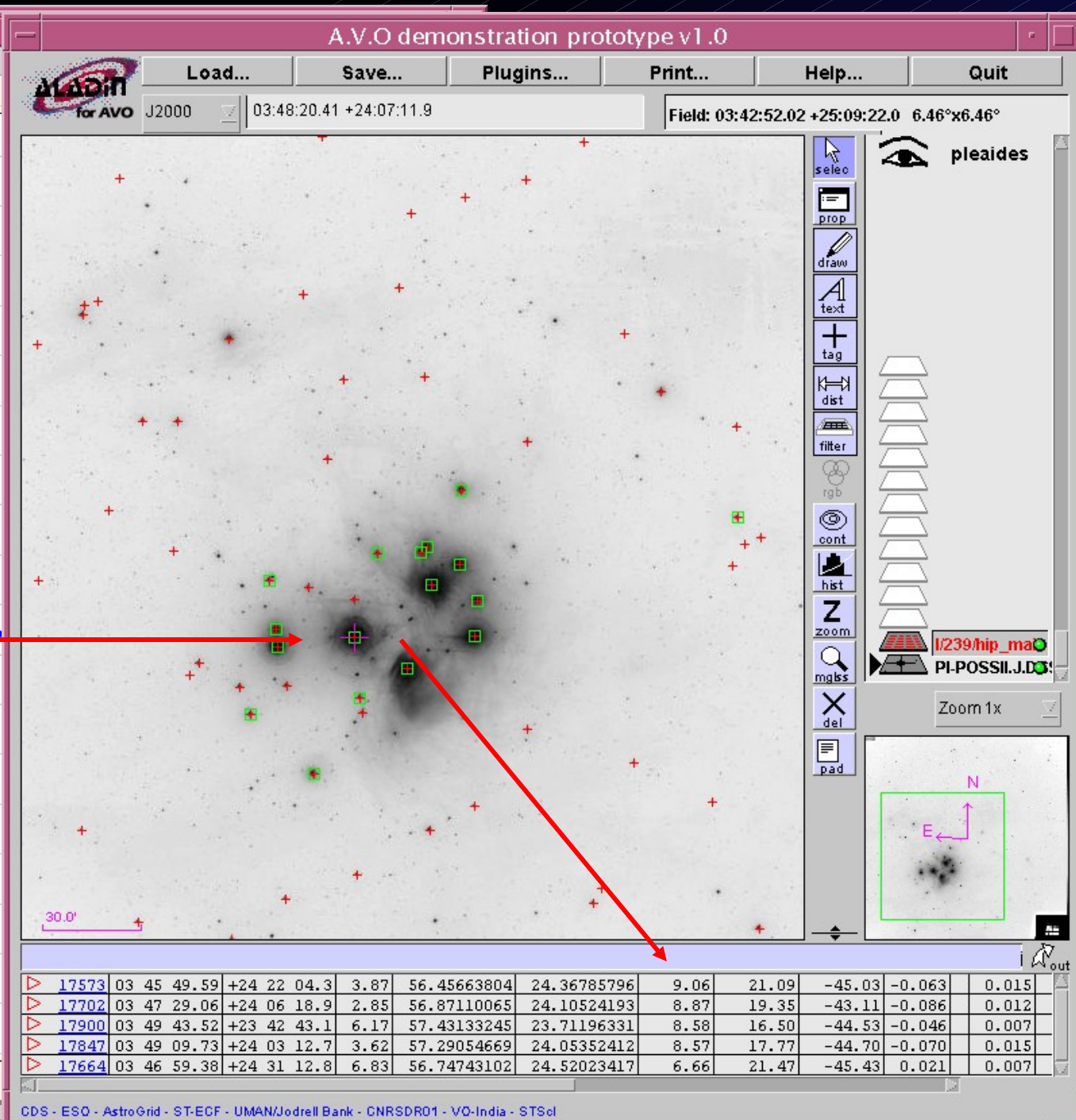
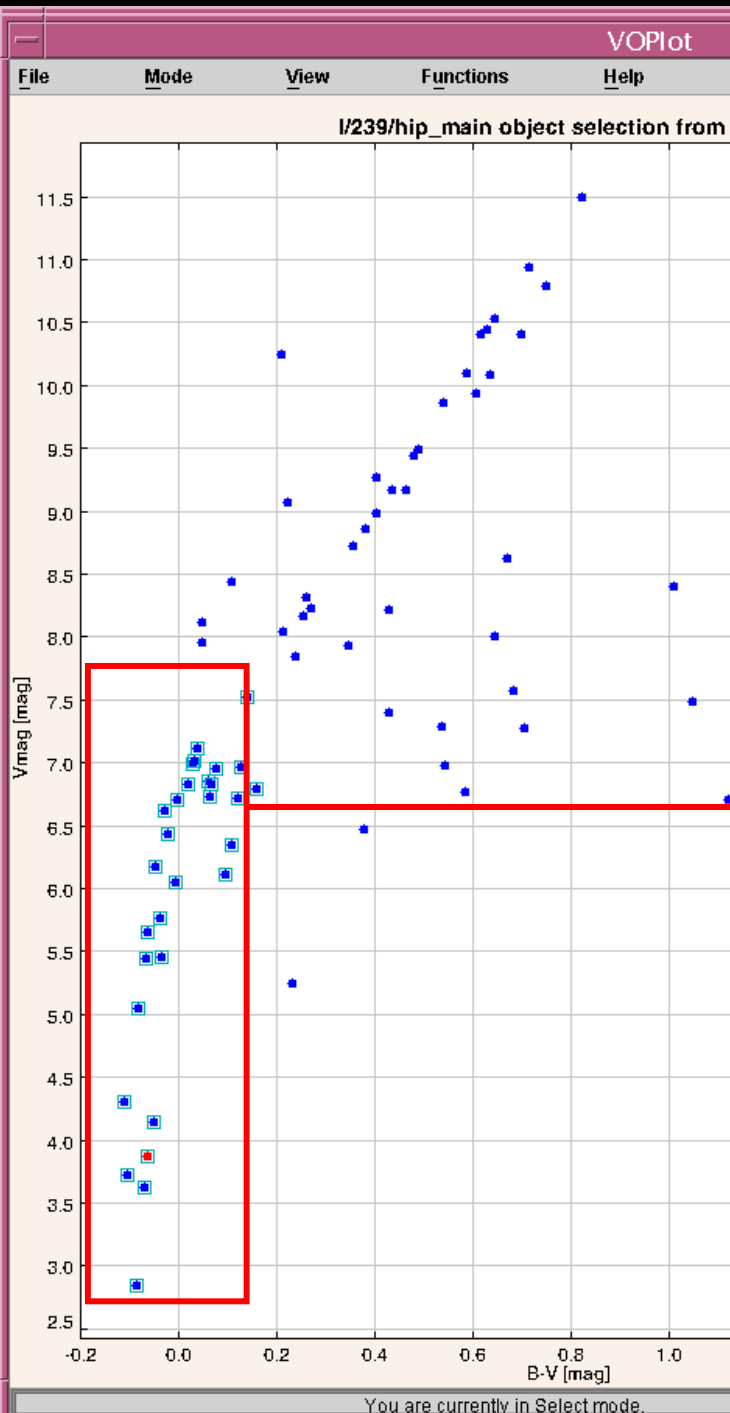
Allows develop applications as bricks

sending VOTABLES (catalogue-spectra-images)

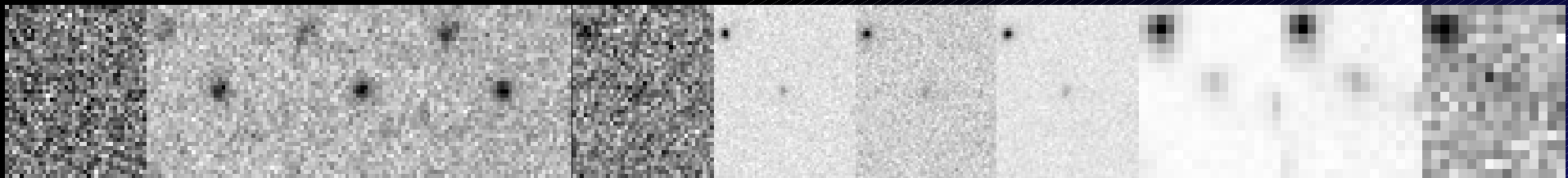
Commercial interest (GoogleSky, MS WWT)

Planetariums, Outreach (Stellarium)

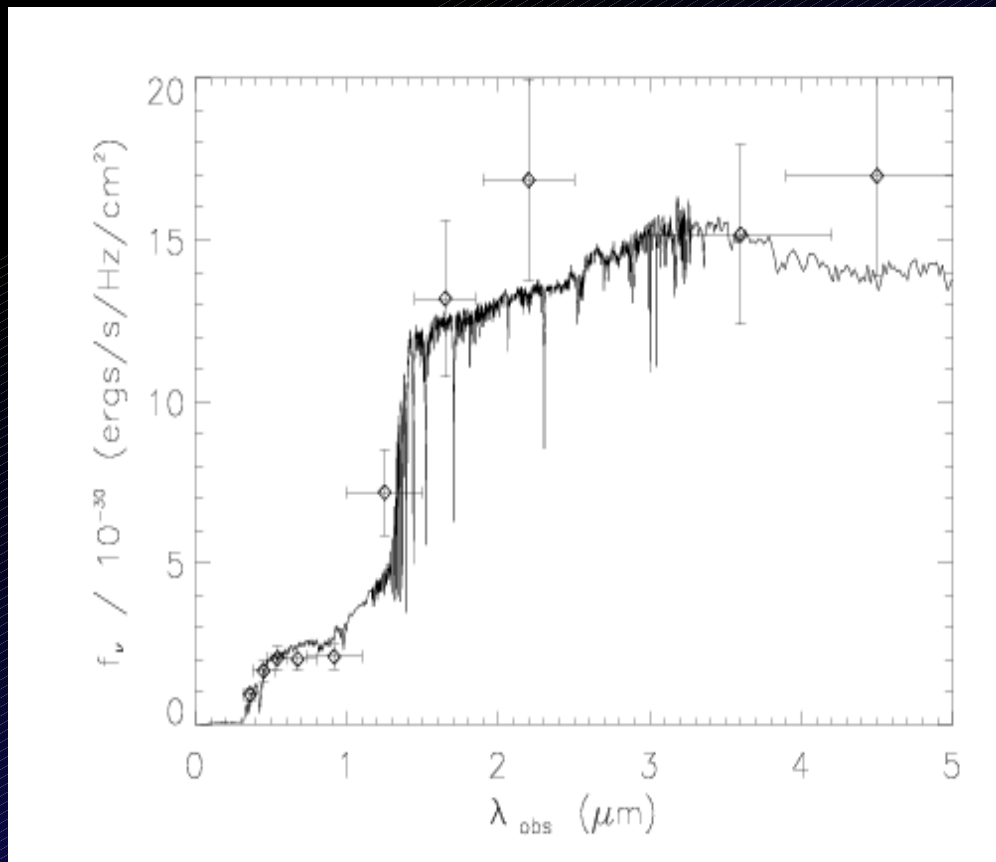
Colour-magnitude diagram



SED from photometry



U B V R I J H Ks 3.6 μ m 4.5 μ m 5.8 μ m



$z_{\text{phot}} = 2.52$

Age = 500 Myr

Stellar mass = $9.9 \times 10^9 M_{\text{sun}}$

Reduced chi-sq = 1.04

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

Where we need huge spectra collections ?

Many objects (automatic classification by fitting many models)

HR diagrams of stellar clusters

Many spectra of one object (time series)

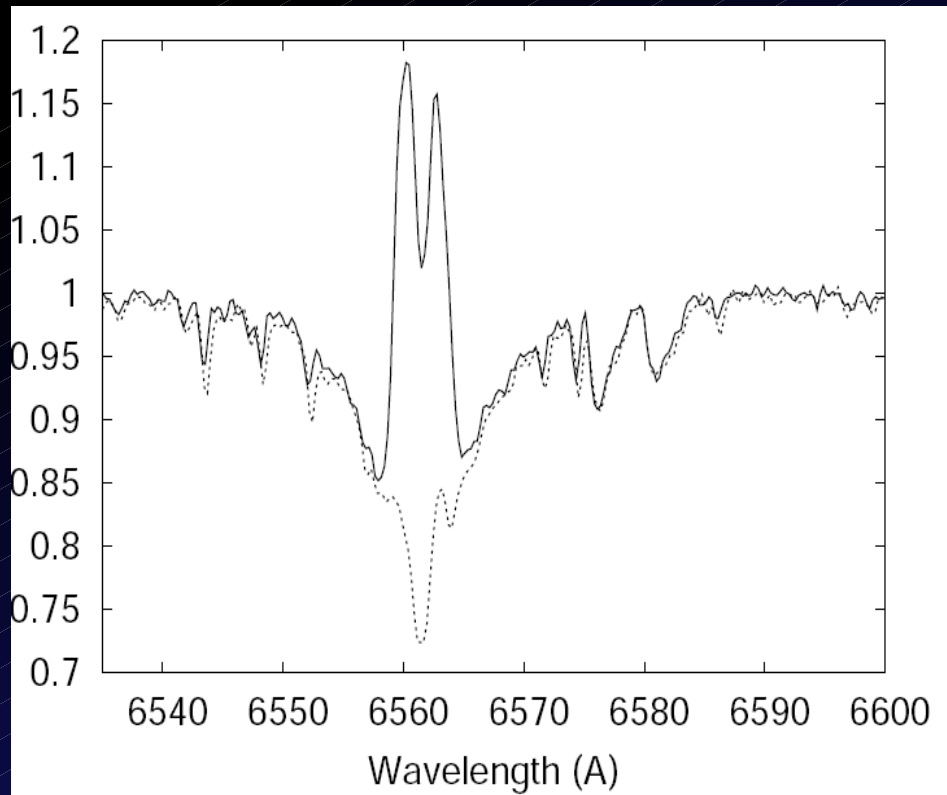
Changes of Line Profiles in Time

Blind comparison of different exposures

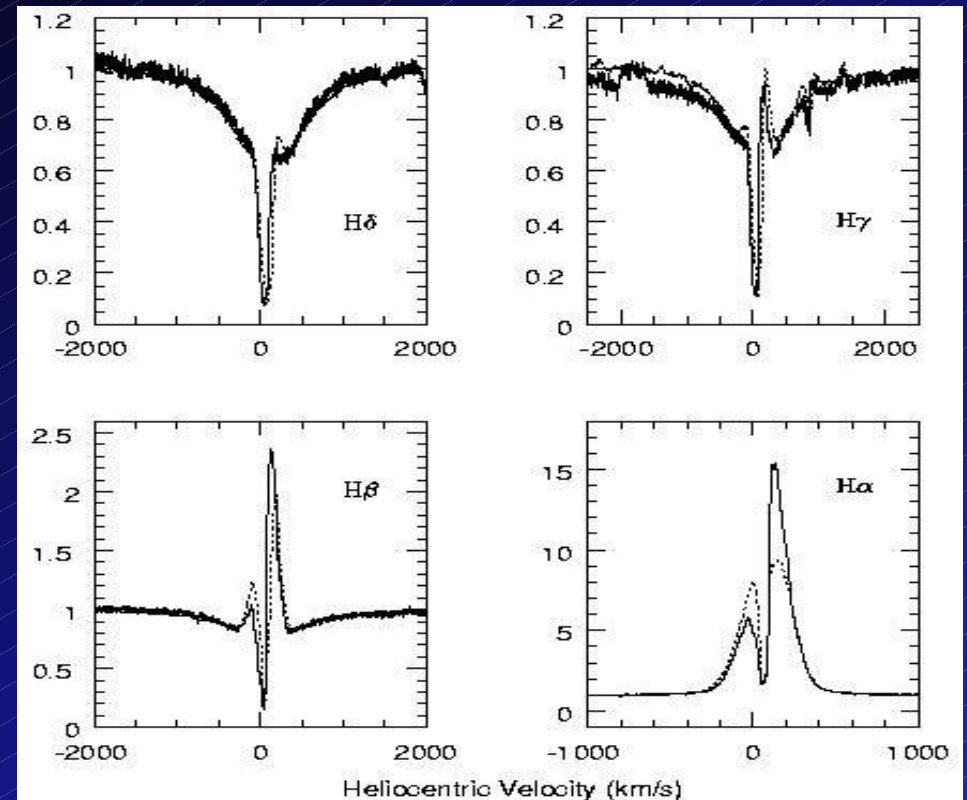
Emission/absorption, shell phases

Time evolution of object – mass transfer,

V/R variations

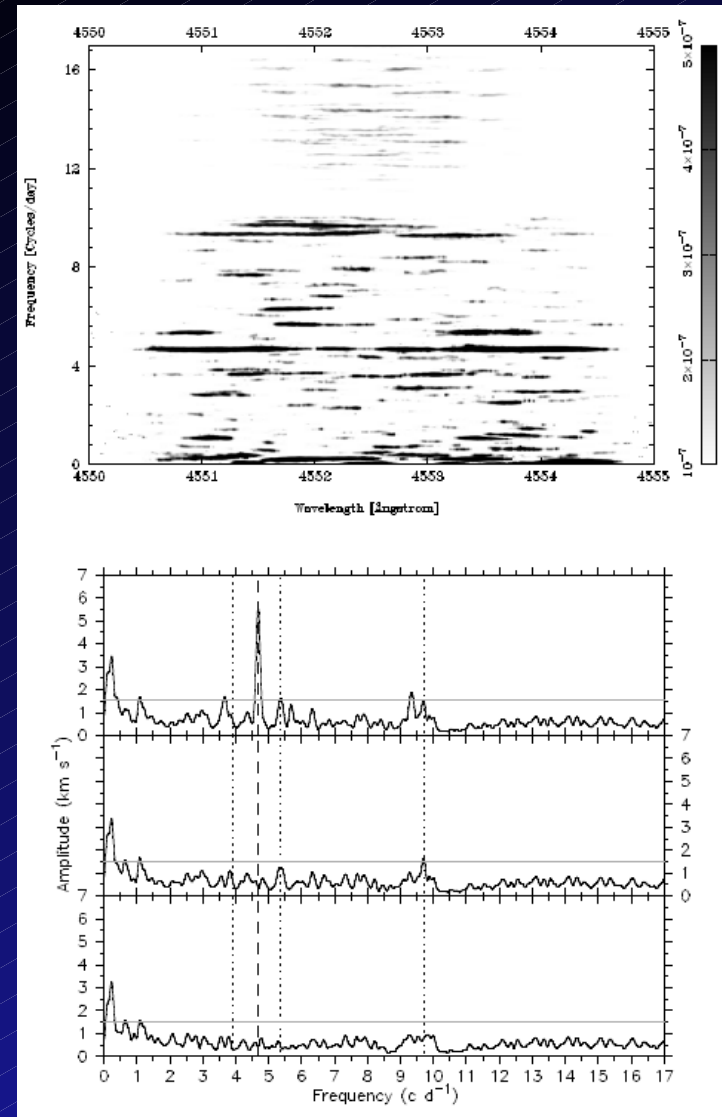
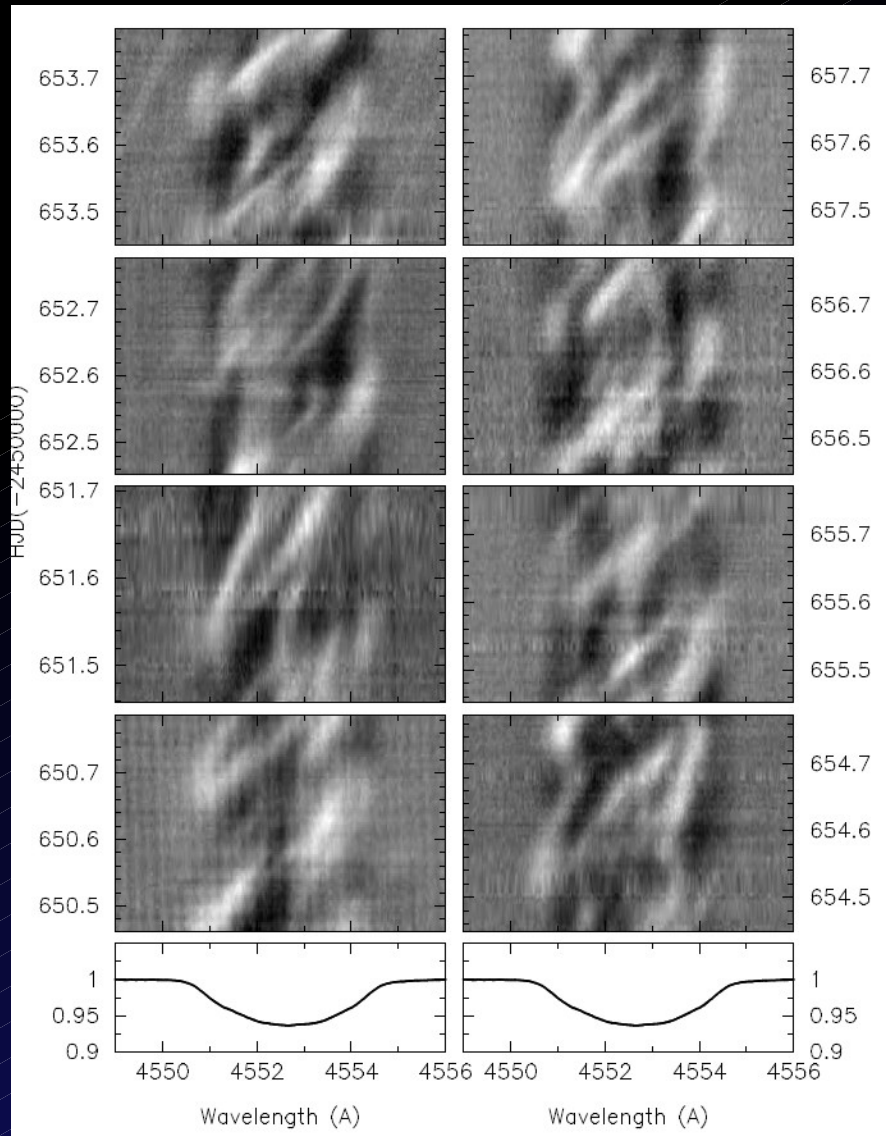


HD6226 : Slechta and Skoda 2004

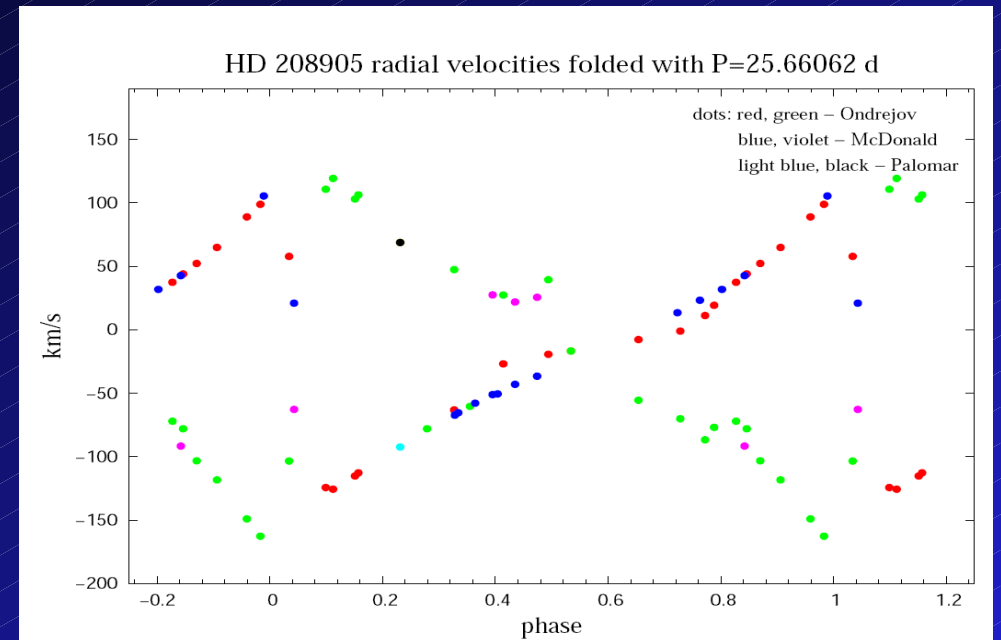
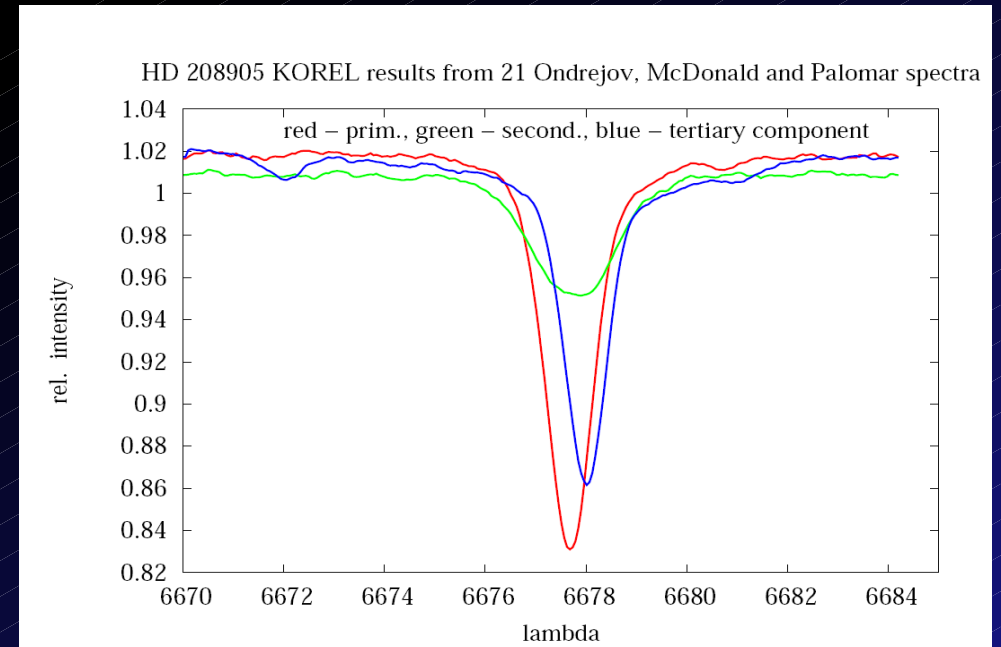
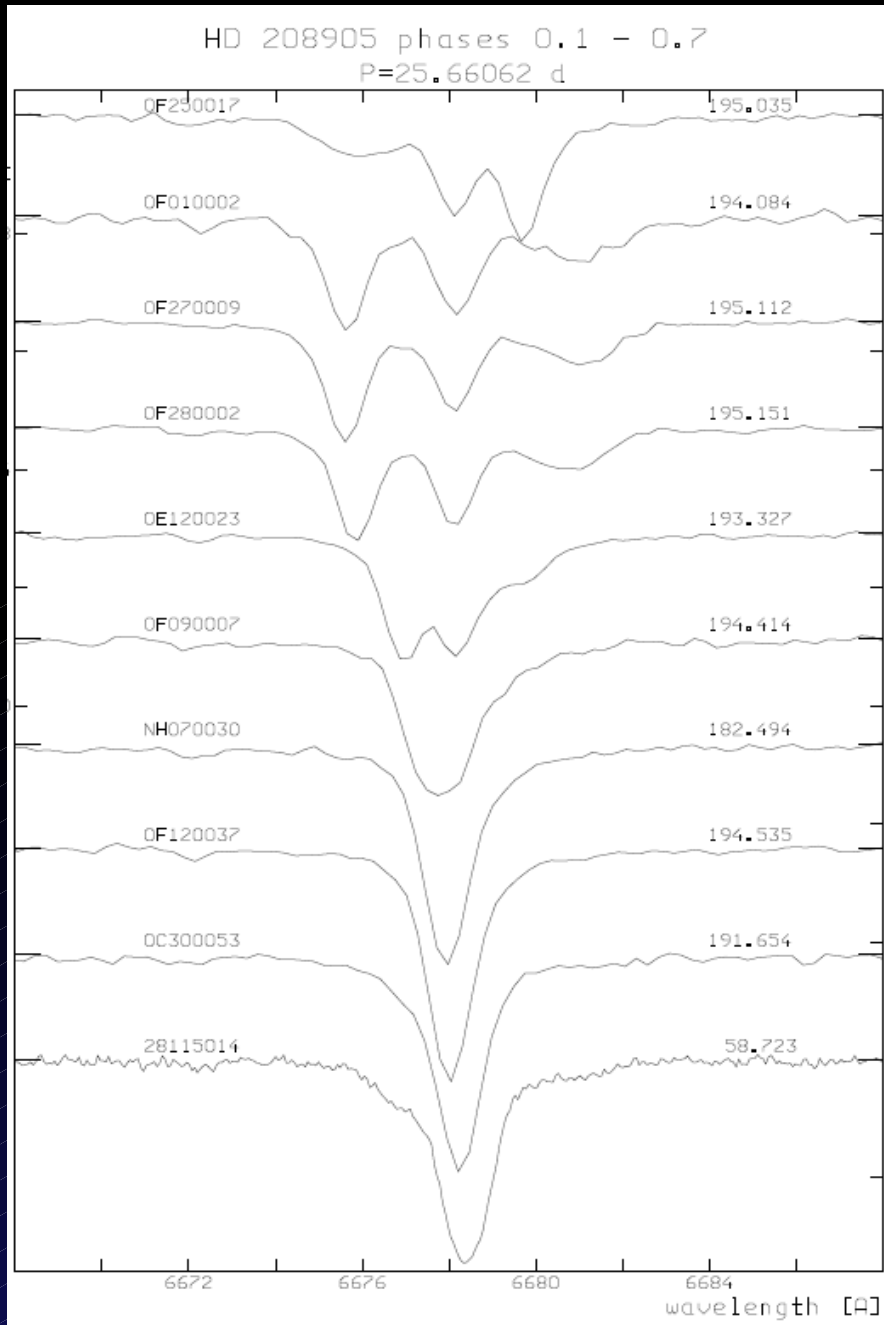


Borges et al. 2008

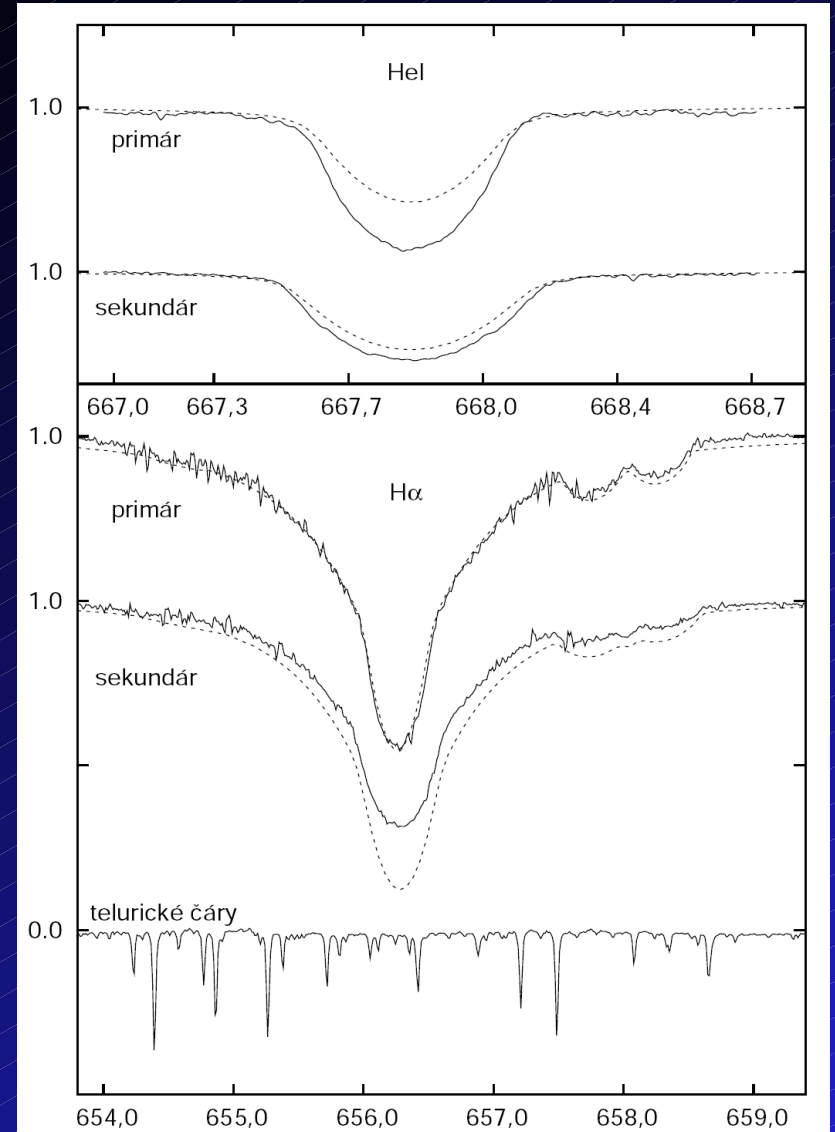
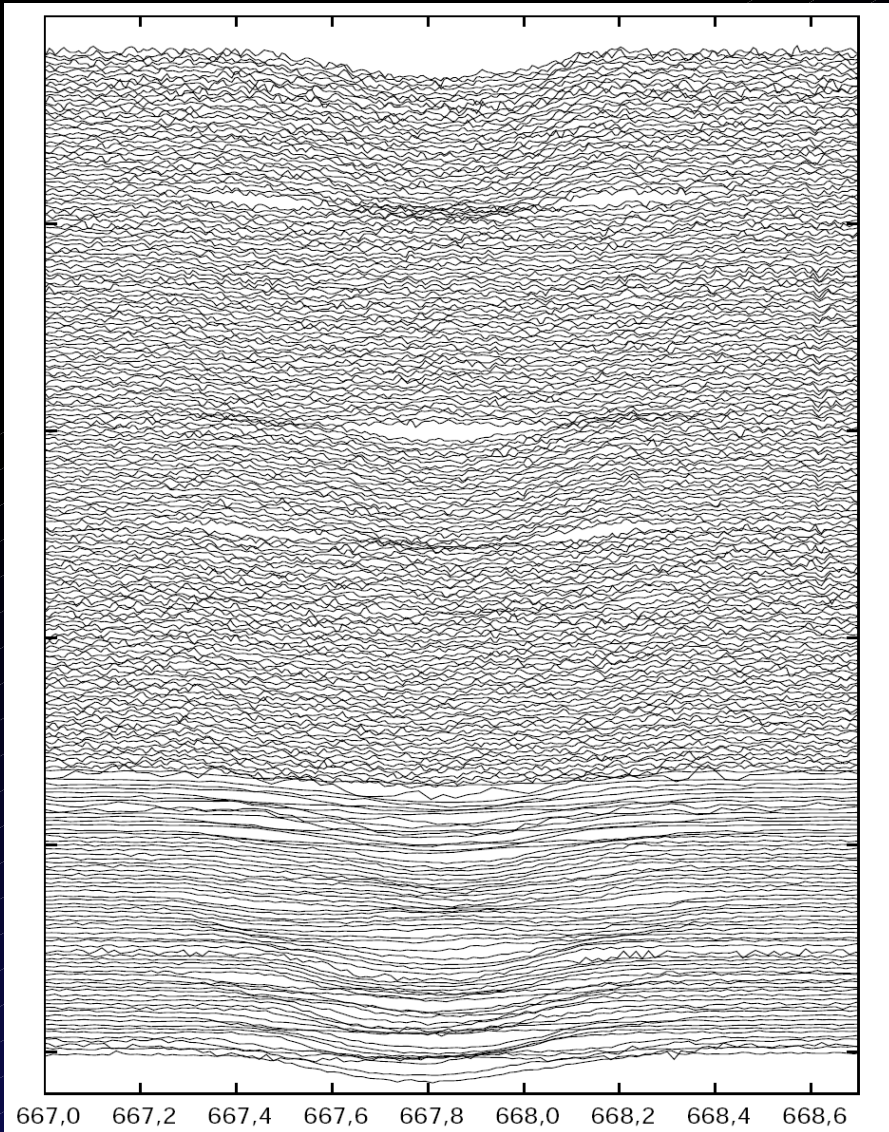
Periodogram of Line Profile NRP



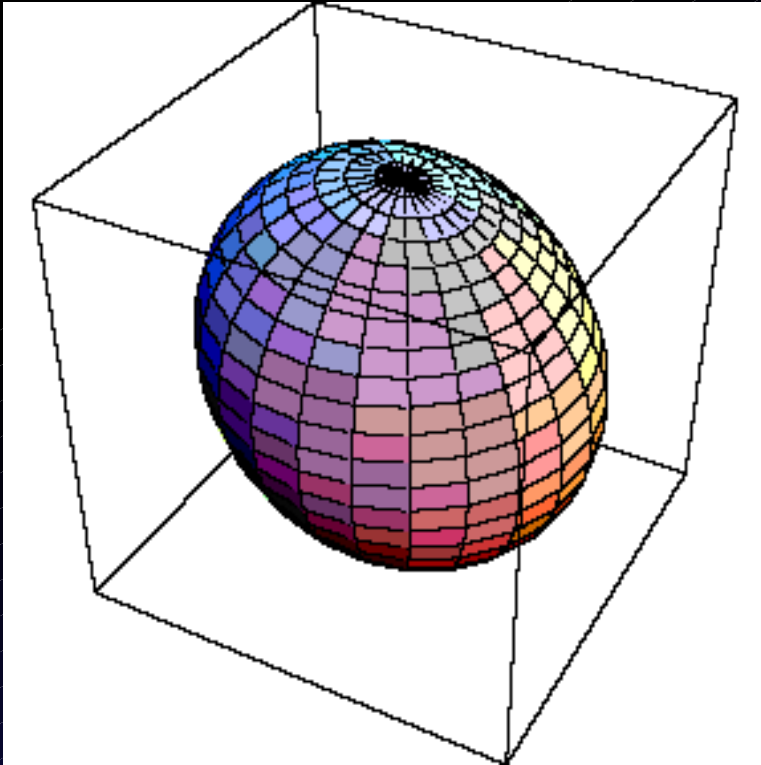
Spectra Disentangling in Fourier Space - KOREL



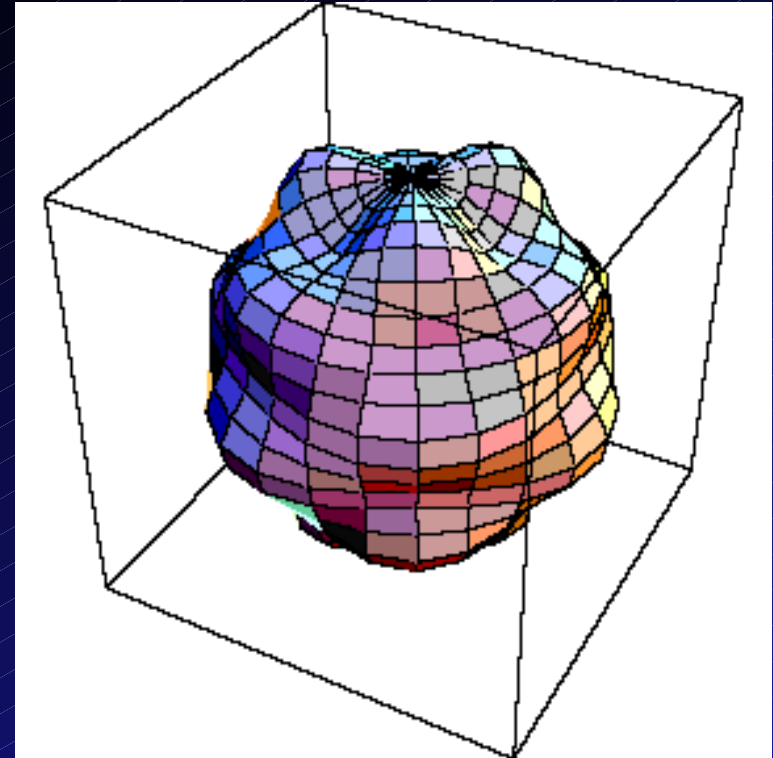
Many spectra overplotted to find cuts



Non Radial Pulsation



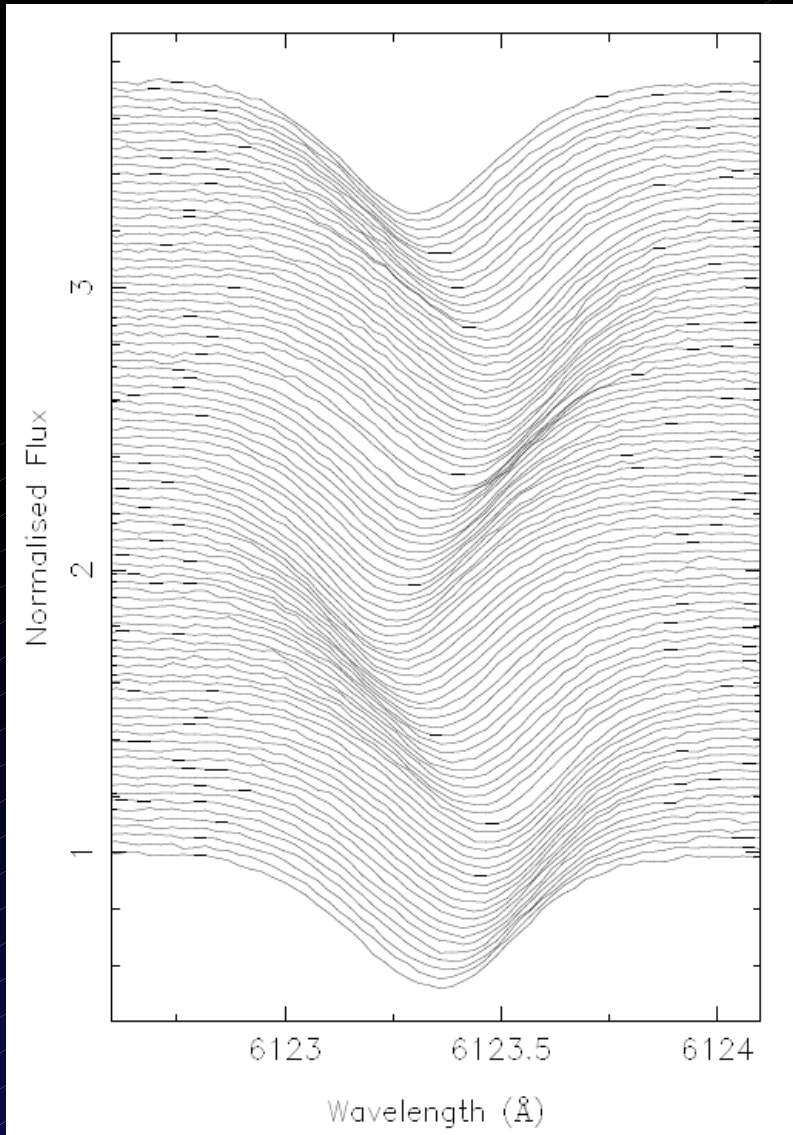
$$\ell = 2, m=1$$



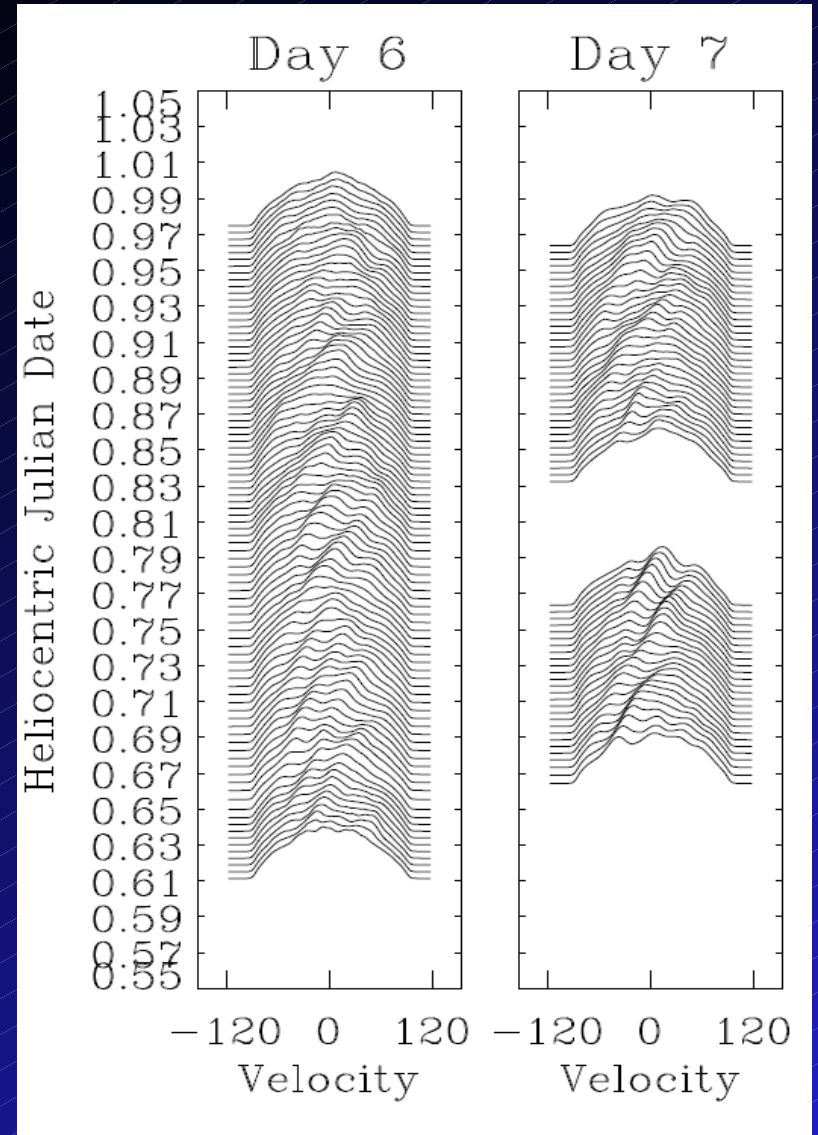
$$\ell = 8, \\ m=3$$

Tim Bedding

Measured Pulsations



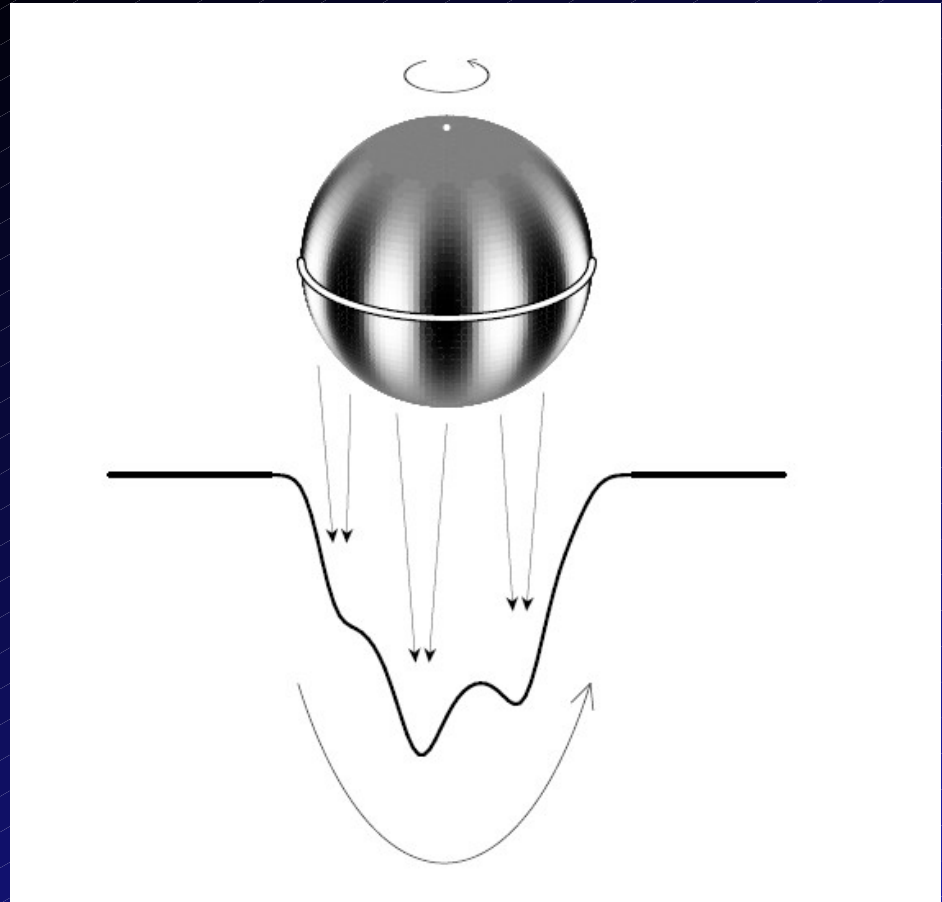
Rho Pup – del Sct type



Eps Cep - del Sct type

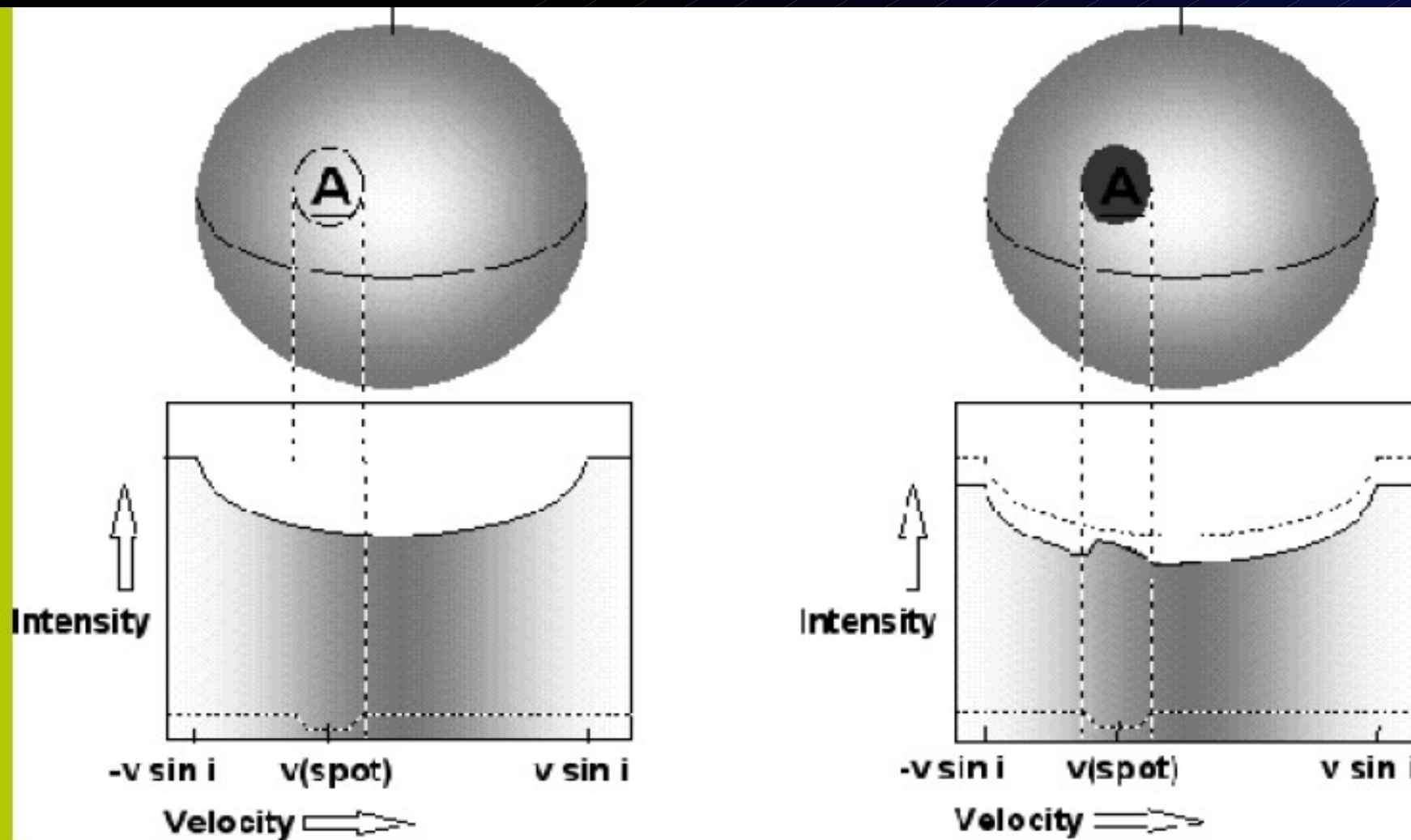
Doppler Imaging - NRP

Vogt & Penrod -80s
Zet Oph

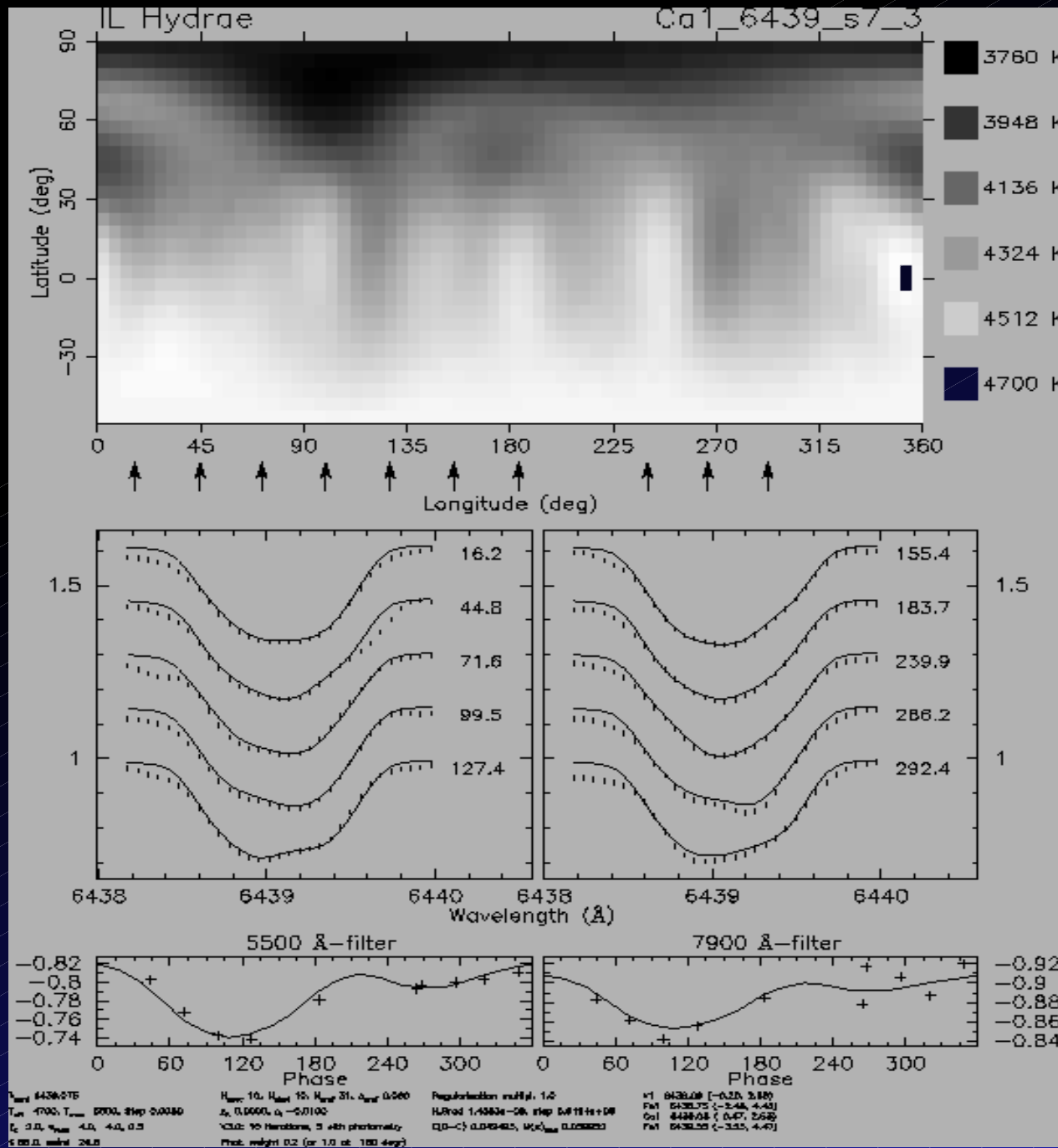


Doppler Imaging

From LPV due to rotation
stellar Spots - darker, brighter – chemical patch

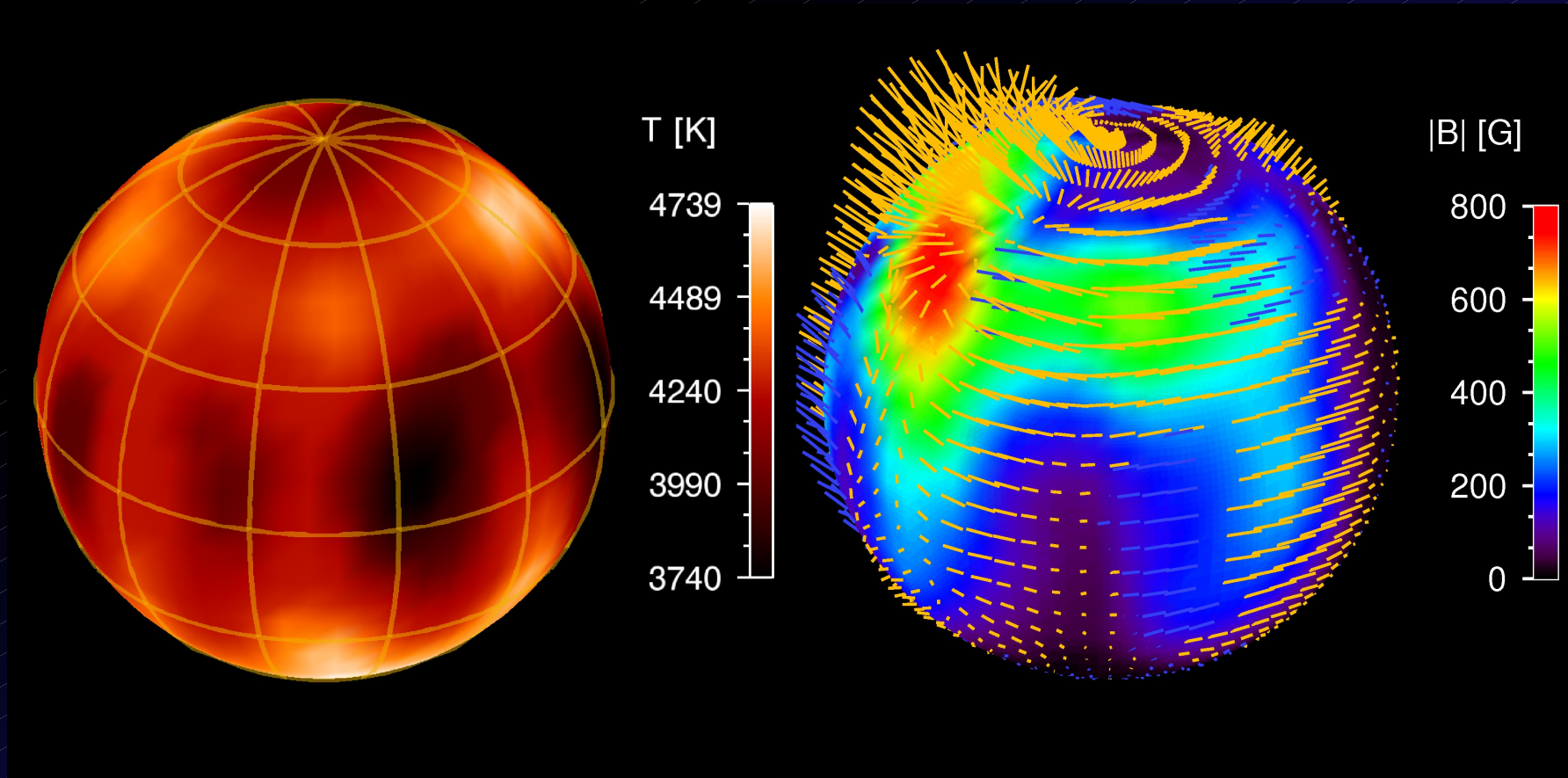


Doppler Imaging



Different elements
temperature
distribution

Zeeman Doppler Imaging



II Peg, Strassmeier 2007

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:

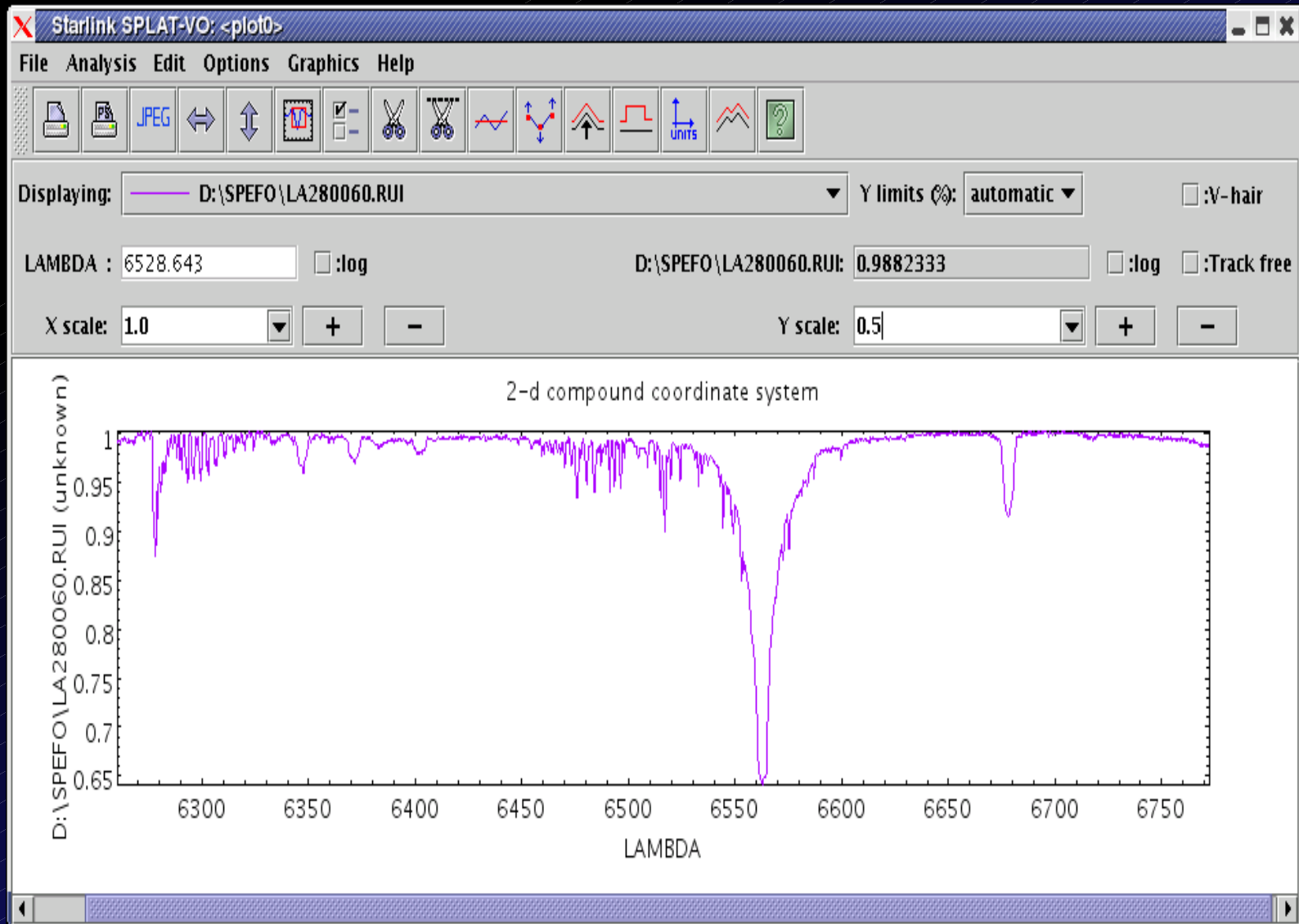
<i>Parameter</i>	<i>Sample value</i>	<i>Physical unit</i>	<i>Datatype</i>
POS	52, -27.8	degrees; defaults to ICRS	string
SIZE	0.05	degrees	double
BAND	2.7E-7/0.13	meters	string
TIME	1998-05-21/1999	ISO 8601 UTC	string
FORMAT	votable	-	string

4.1.2 Recommended and Optional Query Parameters

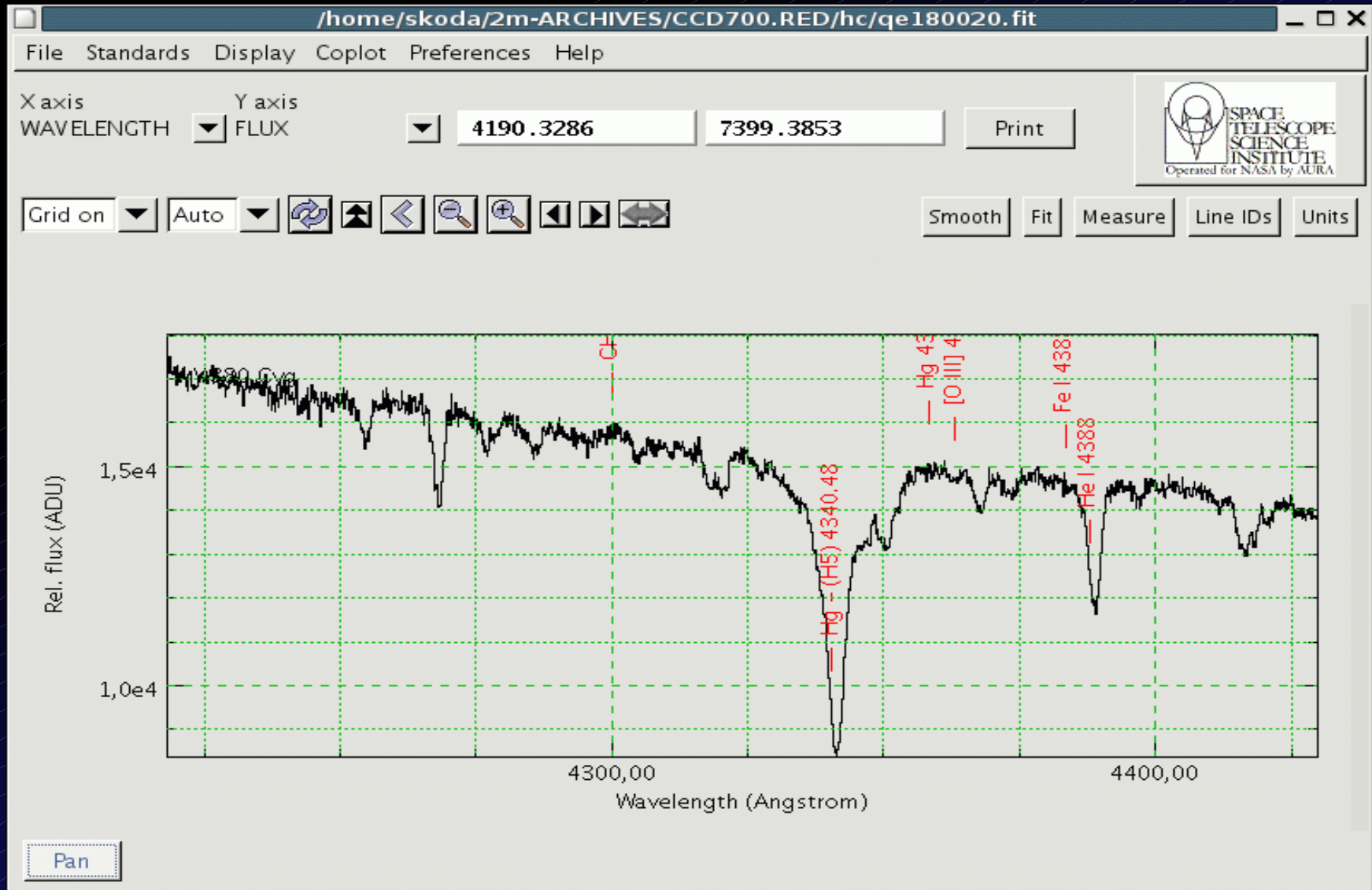
Parameter	Sample value	Unit	Req	Datatype
APERTURE	0.00028 (=1")	degrees	OPT	double
SPECRP	2000	$\lambda/d\lambda$	REC	double
SPATRES	0.05	degrees	REC	double
TIMERES	31536000 (=1yr)	seconds	OPT	double
SNR	5.0	dimensionless	OPT	double
REDSHIFT	1.3/3.0	dimensionless	OPT	string
VARAMPL	0.77	dimensionless	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 must all be used as query parameters.

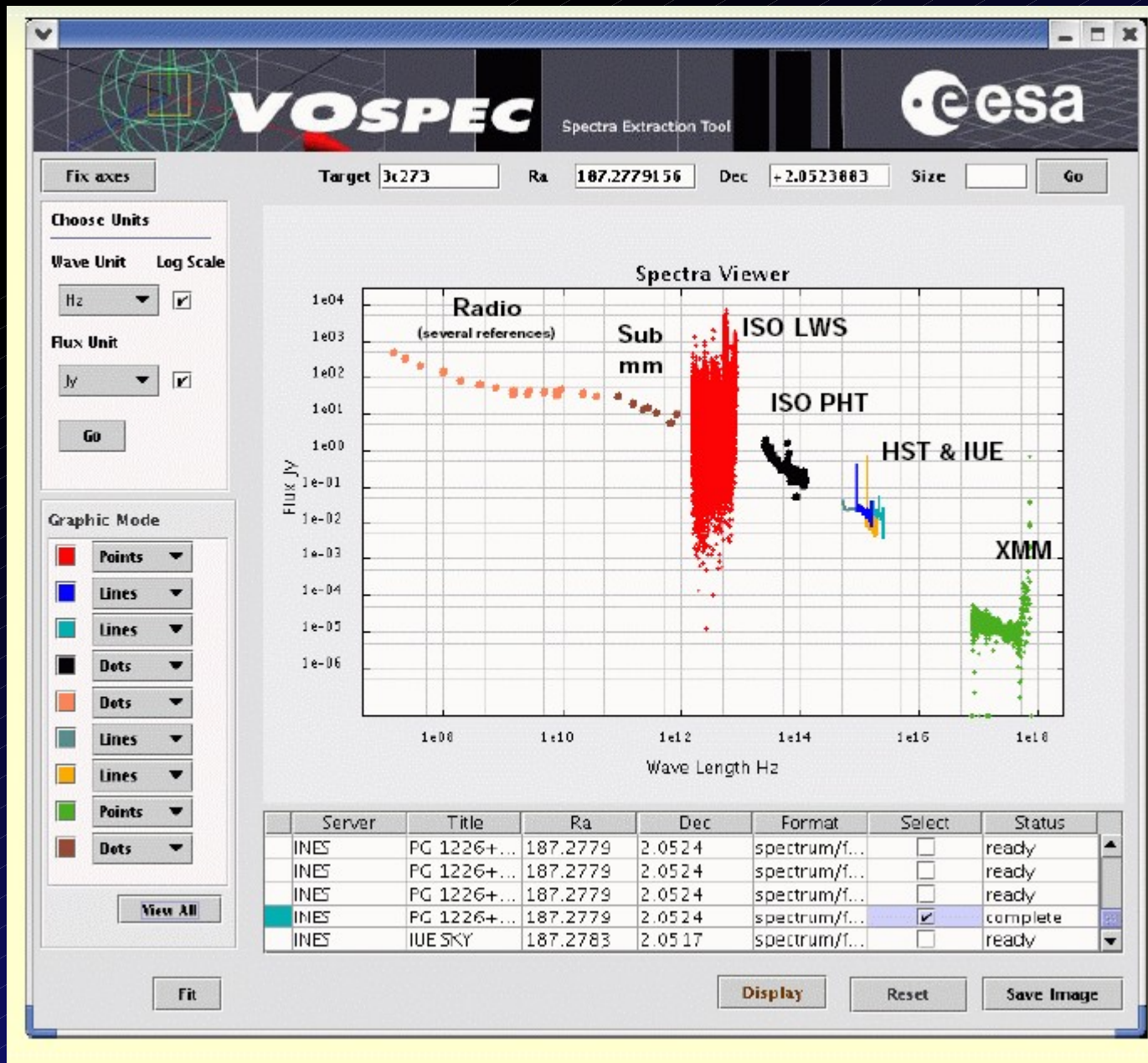
SPLAT-VO (Starlink, JAC)



SpecView (STScI)



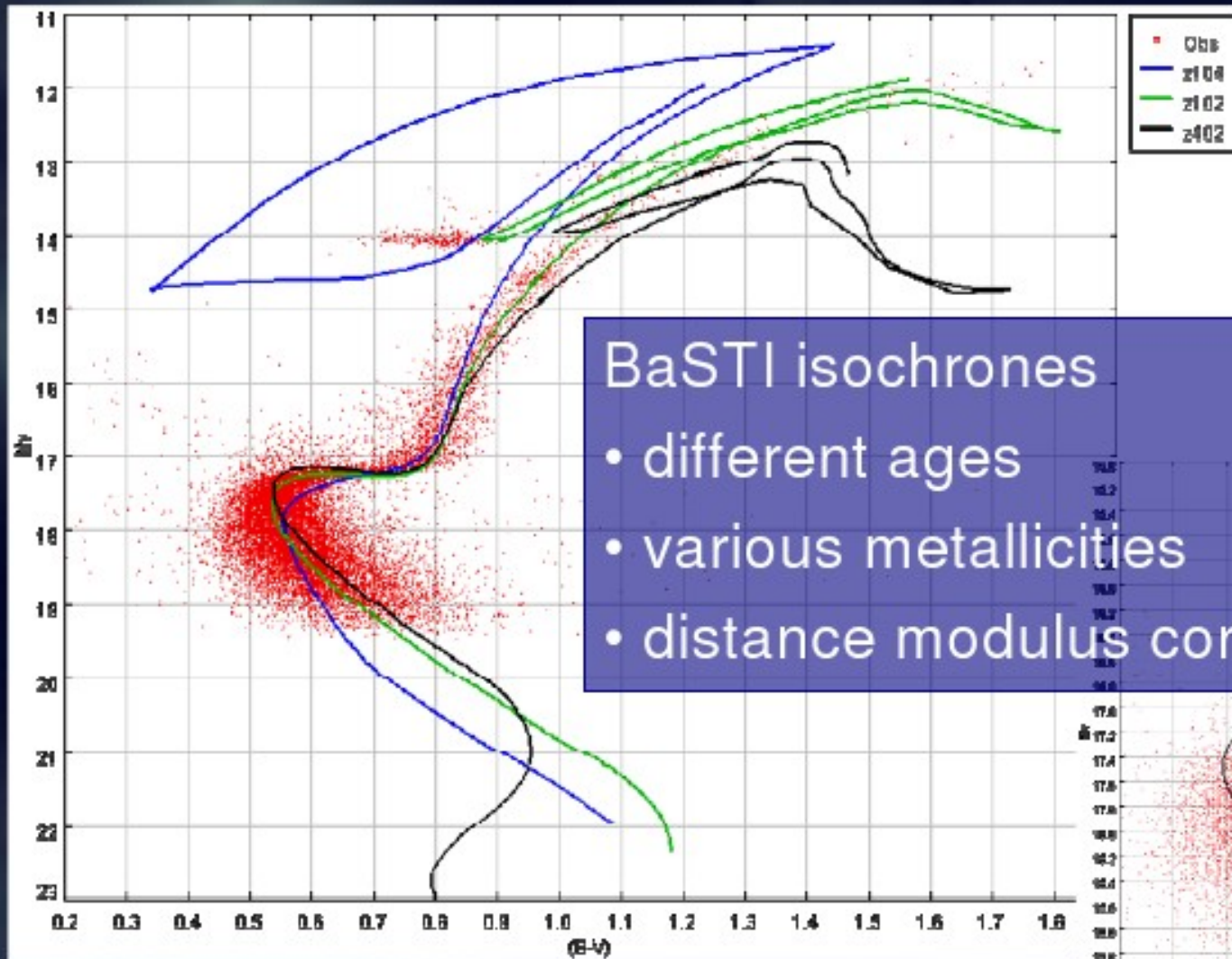
VOSpec (ESAC)



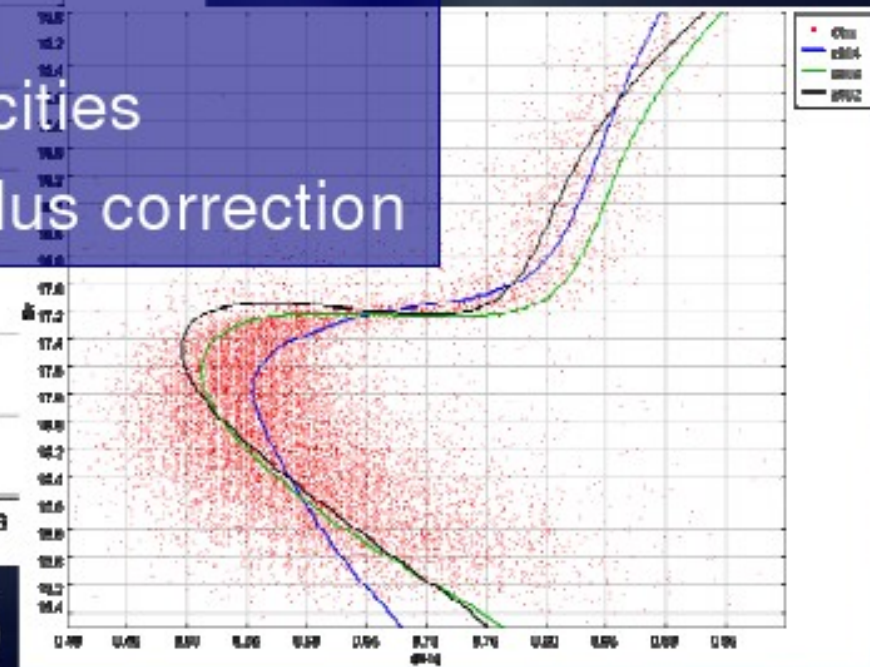
Theory VO (TVO)

- 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 – VAMDC
- Formation of artificial galaxies, clusters – N body models (Millenium Run 10 billions, 25TB)
- Theoretical Spectra (GAVO – Rauch, GRID)

BaSTI Isochrones



step 1
metallicity



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

Using SimDB/SimDAP

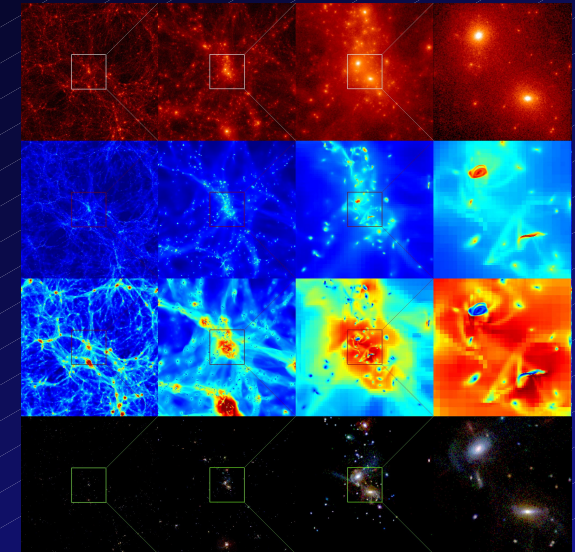
- Cosmological simulations
 - Prototypes for GalMER, Horizon
- PDR simulations
 - test implementation of Meudon PDR code
- Isochrones/evolutionary tracks
 - BaTSI
- Visualization tools
 - VisIVO

GalMER

DB Query | Query Results | Experiment | Snapshot | Description

Select Input Parameters

Galaxy #1	Galaxy #2	Query	
gE0 gSa gSb gSd	gE0 gSa gSb gSd	Orbit type	1
		Spin	Prograde
		Inclination	0 deg



Virgo - Millennium Database

Documentation

CREDITS/Acknowledgments

Registration

News

Databases
millimil (context)

Check out the latest news about the release of the Millennium-II database.

Streaming queries return unlimited number of rows in CSV format and are cancelled after 30 seconds.
Browser queries return maximum of 1000 rows in HTML format and are cancelled after 30 seconds.

Query (stream)

Query (browser)

Help

Maximum number of rows to return to the query form: 10

GADGET-2: Galaxies with dark matter and gas interact

A code for cosmological simulations of structure formation



Millennium Run

10^{10} particles

Several Gpc to

10 kpc

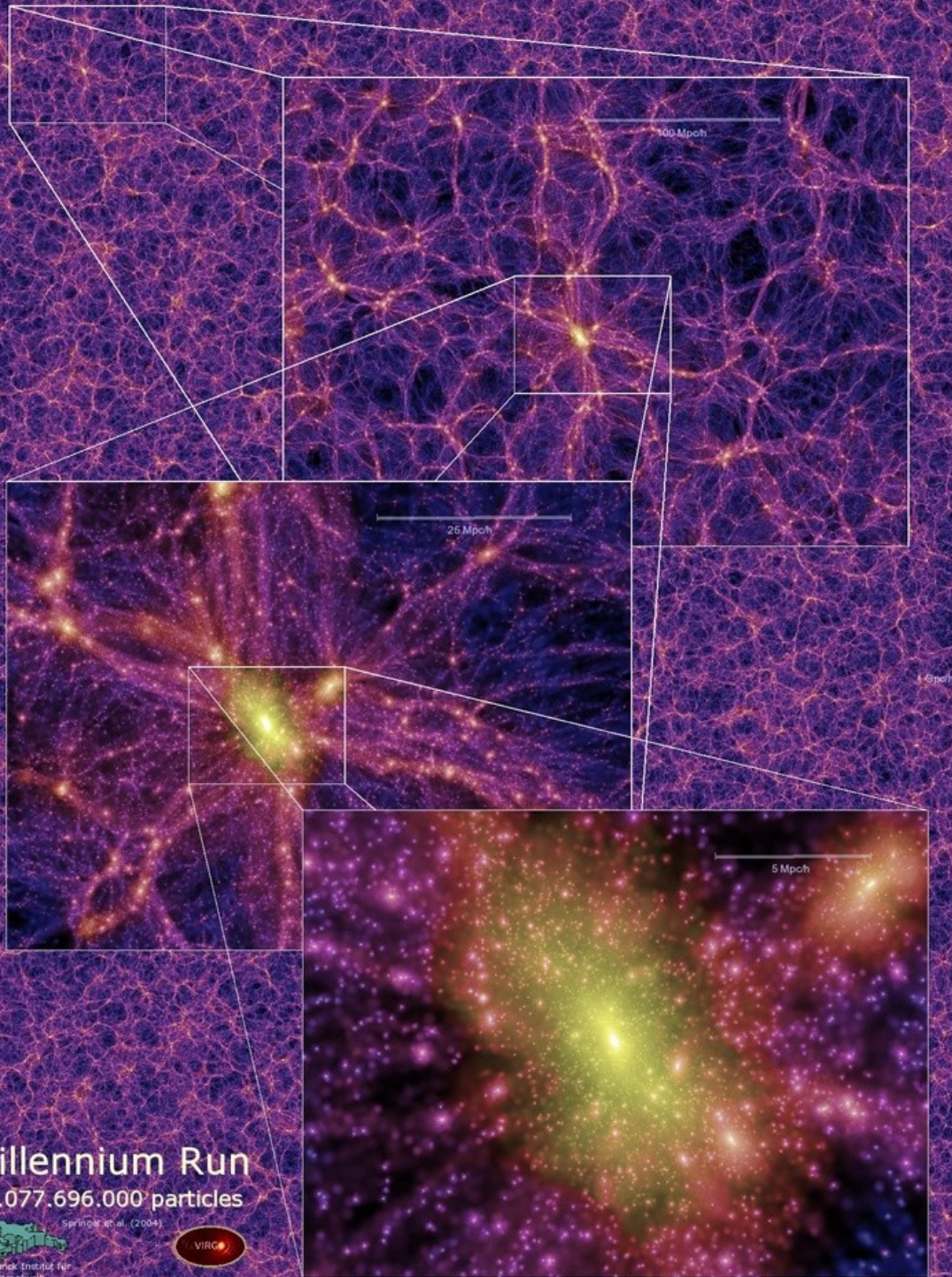
Cube 2 billion ly

One month MPSSC

25 TB

Evolution of 20 mil
galaxies

Evolution merger tree



CIELO VO - line catalogue SLAP

SLAP Viewer Copyright ESAC, Spain

Server Selector

- SLAP Services
 - IASD
 - LERMA
 - NIST ATOMIC SPECTRA
 - CIELO SLAP

Molecular line databases

Range of Search (m)

Wavelength Start Wavelength End

Reset

Slap Services Output

CIELO SLAP

Idm:Line_wavelength	Idm:Source...	Source.co...	Source.co...	Idm:Li...	Idm:...	Id...	Id...	Idm:...	I...
1.8627e-09	NGC1068	40.66963	-0.01328	1s_3p	1s2	1P1	150	OVII	...
1.7768e-09	NGC1068	40.66963	-0.01328	1s_4p	1s2	1P1	150	OVII	...
1.89671e-09	NGC1068	40.66963	-0.01328	2p	1s	2...	2...	OVIII	...
2.47793e-09	NGC1068	40.66963	-0.01328	2p	1s	2...	2...	NVII	...
2.21012e-09	NGC1068	40.66963	-0.01328	1s_2s	1s2	3S1	150	OVII	...
2.1602e-09	NGC1068	40.66963	-0.01328	1s_2p	1s2	1P1	150	OVII	...
2.18071e-09	NGC1068	40.66963	-0.01328	1s_2p	1s2	3P1	150	OVII	...

Close

VOSpec Spectra Extraction Tool

Target Ra Dec Size Go

Simple Line Access

Wave Unit Log Scale

Flux Unit

RedShift

Go

Graphic Mode

Points

Points

View

Clear Cache Unzoom Display Reset Save Image

Copyright ESAC - Villafranca del Castillo - Madrid, Spain

Wrapper Creator - HowTo - About

VOSpec Spectra Viewer

ISO spectrum of P Cygni

Server	Title	Ra	Dec	Format	Select	Status
Infrared Sp...	ISO SWS01 ...	83.6223	22.0102	spectrum/fits	<input type="checkbox"/>	ready
Infrared Sp...	ISO SWS01 ...	83.63325	22.0346	spectrum/fits	<input type="checkbox"/>	ready
Infrared Sp...	ISO SWS01 ...	83.6402175	22.01457	spectrum/fits	<input checked="" type="checkbox"/>	complete
Infrared Sp...	ISO LWS01 ...	83.633409	22.0346	spectrum/fits	<input type="checkbox"/>	ready
Infrared Sp...	ISO LWS02 ...	83.6334225	22.03459	spectrum/fits	<input type="checkbox"/>	ready

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

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.

The screenshot shows the TSAP interface web application. The header is blue with the SVO logo on the left, navigation links for 'Theoretical model services', 'Documents', 'Models', and 'Services' in the center, and 'Funded by INTA' and the Spanish Ministry of Science and Innovation logo on the right. Below the header, there are links for 'Services: VOSA Filters TSAP S3if' and 'esm@laeff.inta.es Uploads LogOut'. The main content area is titled 'TSAP Interface' and contains the text 'SVO Theoretical Data Access Service: ATLAS9 Kurucz ODFNEW/NOVER models (Castelli et al., 1997, AA, 318, 841)'. Below this text is a form with six rows of input fields, each with a dropdown menu and a description: 'teff_min: 3500 (min value for the effective temperature for the model. Temperatures are given in K)', 'teff_max: 3500 (max value for the effective temperature for the model. Temperatures are given in K)', 'logg_min: 0.00 (min value for Log(G) for the model.)', 'logg_max: 0.00 (max value for Log(G) for the model.)', 'meta_min: -2.50 (min value for the Metallicity for the model.)', and 'meta_max: -2.50 (max value for the Metallicity for the model.)'. A 'Search' button is located below the form, and a link 'See metadata VOTable' is at the bottom.

Theoretical model services Documents Models Services

SVO Spanish Virtual Observatory

TSAP interface
An interface to test TSAP services

Funded by **INTA**
MINISTERIO DE CIENCIA E INNOVACIÓN

Services: [VOSA](#) [Filters](#) [TSAP](#) [S3if](#) esm@laeff.inta.es [Uploads](#) [LogOut](#)

TSAP Interface

SVO Theoretical Data Access Service: ATLAS9 Kurucz ODFNEW/NOVER models (Castelli et al., 1997, AA, 318, 841)

teff_min:	<input type="text" value="3500"/>	(min value for the effective temperature for the model. Temperatures are given in K)
teff_max:	<input type="text" value="3500"/>	(max value for the effective temperature for the model. Temperatures are given in K)
logg_min:	<input type="text" value="0.00"/>	(min value for Log(G) for the model.)
logg_max:	<input type="text" value="0.00"/>	(max value for Log(G) for the model.)
meta_min:	<input type="text" value="-2.50"/>	(min value for the Metallicity for the model.)
meta_max:	<input type="text" value="-2.50"/>	(max value for the Metallicity for the model.)

[See metadata VOTable](#)

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

Simple Spectral Access Protocol V1.04

Appendix A: Theoretical Spectral Access Use Case

The image displays the VOSpec interface, a tool for accessing and viewing theoretical spectra. It is divided into several main sections:

- Server Selector:** A panel on the left titled "Server Selector" with a "Query by Service" section. It lists various services under "Theoretical Spectra Services", including "PGos3: Evolutionary synthesis models" (checked), "SVO: ATLAS9 Kurucz ODFNEW/NOVER models", and "VO-Paris: PEGASE.HR synthetic spectra". A "Query Outlook" section at the bottom shows a list of URLs and a "Select All" button.
- VOSpec Main Window:** The central window features a header with the "VOSpec" logo and "Cesga Virtual Observatory" branding. Below the header is a toolbar with icons for editing, zooming, and other functions. A metadata bar shows the target "Vega" with coordinates "Ra 279.2347350" and "Dec +38.7836919", and a size of ".1".
- VOSpec Spectra Viewer:** The main plot area displays a spectral plot with "Flux (Jy; logarithmic)" on the y-axis (ranging from 1e-01 to 1e+05) and "Wavelength (micron; logarithmic)" on the x-axis (ranging from 0.5 to 100). The plot shows a spectrum with various features labeled, including "HST (MAST)", "2MASS photometry", "Kurucz Models (SVO)", "INES (SVO)", "SLAP (ESA-VO)", and "ISO (ESA-VO)". A blue line represents the model fit.
- Graphic Mode:** A panel on the left of the plot allows users to select the display mode for different data series, with options for "Points" and "Lines" in various colors.
- Spectra List:** A list at the bottom of the plot area shows several "IUE/INES Spectrum" entries. The entry "IUE/INES Spectrum: LWR04154HS, Target: HD 172167" is selected and highlighted in green.
- Footer:** The bottom of the window includes a "Display" and "Reset" button, a coordinate pair "(1.9099E1, 3.862E1)", and a copyright notice: "Copyright ESAC - Villafranca del Castillo - Madrid, Spain".

VO SED Analyzer (VOSA)

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

1

L0r1001
Position: (83.446583,9.9273611) Distance: 400. pc A.: 0.36209598
Data for this object:

Filter	Area	Flux	ΔF	User	Flux	ΔF	VO	Flux	ΔF
SDSS_R	6261	1.321349e-14	3.289015e-16	---	---	---	1.321349e-14	3.289015e-16	Delete
CFHT_R	8392	1.447153e-14	0.000000e+00	---	---	---	---	---	Delete
CFHT_I	8228	1.345174e-14	0.000000e+00	---	---	---	---	---	Delete
2MASS_J	12350	1.052144e-14	2.131032e-16	---	---	---	---	---	---
2MASS_M	16620	6.845070e-15	1.386989e-16	---	---	---	---	---	---
2MASS_Ks	21990	3.025102e-15	5.891066e-17	---	---	---	---	---	---
IRAC_J1	35634	5.502778e-16	1.520474e-16	---	---	---	---	---	---
IRAC_I2	43110	2.128429e-16	7.841524e-19	---	---	---	---	---	---
IRAC_I3	57563	8.049135e-17	7.169333e-18	---	---	---	---	---	---
IRAC_I4	79094	2.543987e-17	2.343098e-18	---	---	---	---	---	---

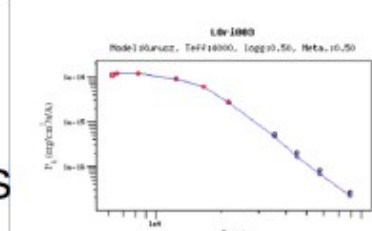
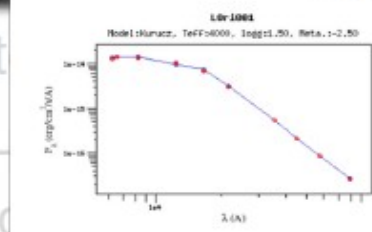
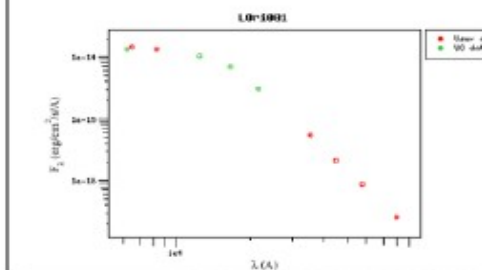
Model fit

Best fit results

Object	RA	DEC	Dist	Model	T _{eff}	logg	metal	alpha	xi	mu	F ₅₀₀	σ _{F500}	F ₆₀₀	σ _{F600}	F ₈₀₀	σ _{F800}
L0r1001	83.446583	9.927361	400.000	Murazz	4000	1.50	-2.50	---	---	1.19e+1	3.36e-1	1.86e-13	2.15e-12	0.53	---	---

No excess detected.
You can manually specify where excess starts.
Apply excess from

2



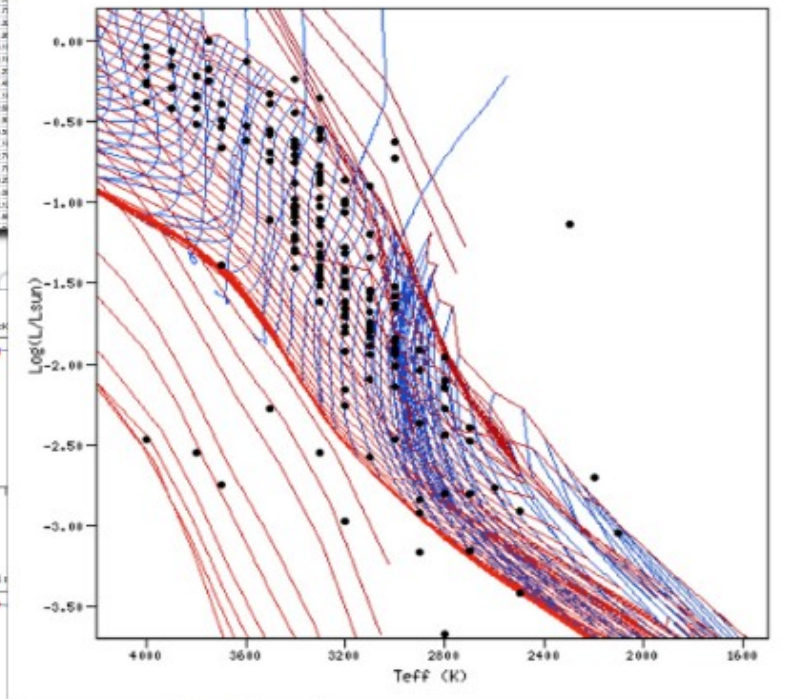
3

Save results as

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. Morales-Calderón¹, and F. Allard³



SED Science

A search for new hot subdwarf stars by means of Virtual Observatory tools

R. Oreiro¹, C. Rodríguez-López^{2,3}, E. Solano⁴, A. Ulla³, R. Østensen⁵, and M. García-Torres⁶

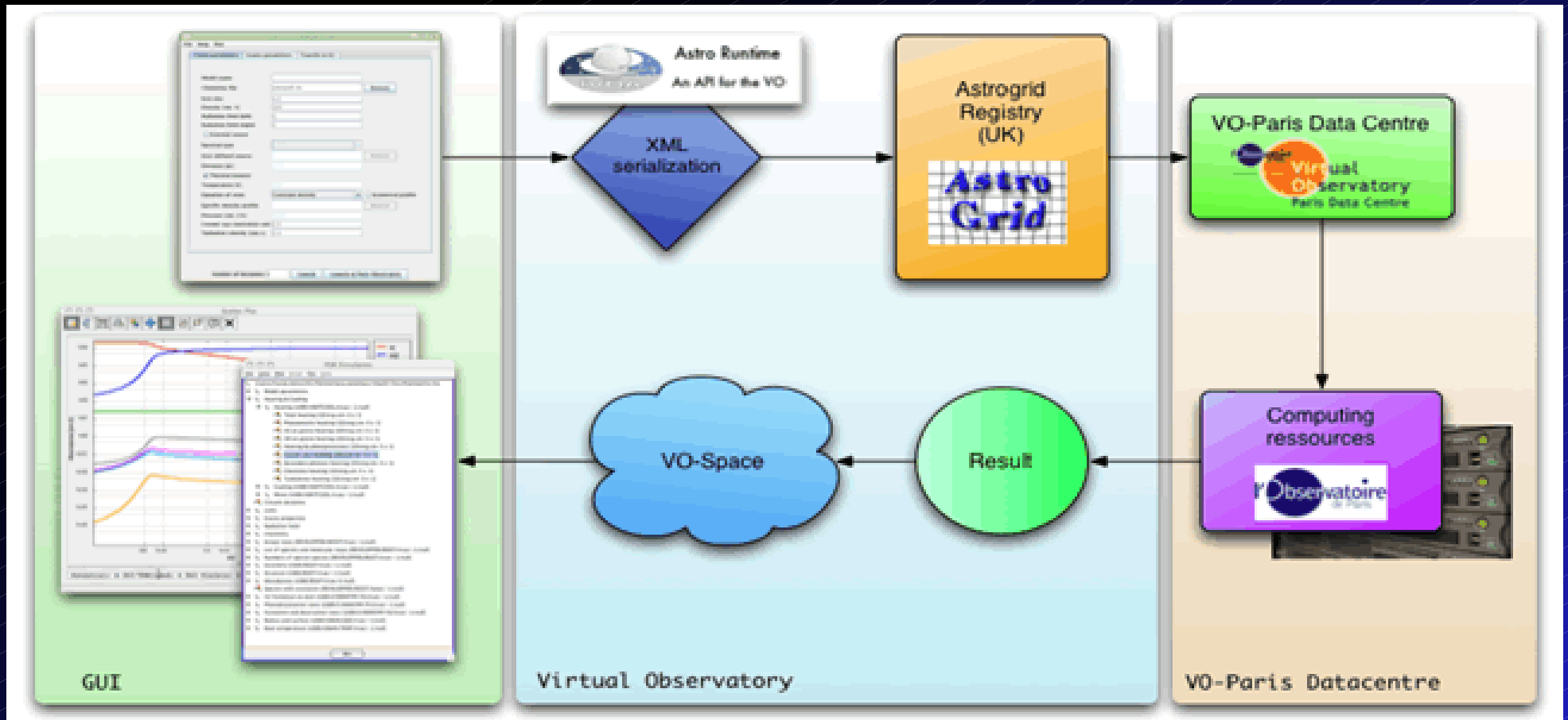
Identification of blue high proper motion objects in the Tycho-2 and 2MASS catalogues using Virtual Observatory tools

F. M. Jiménez-Esteban^{1,2,3}, J. A. Caballero⁴, and E. Solano^{1,2}

SEDs = priority science case for US VAO (NSF funded)

SED building in an automatic way (filter services, zero points)
VO Photometry Standard

PDR VO-infrasctructure



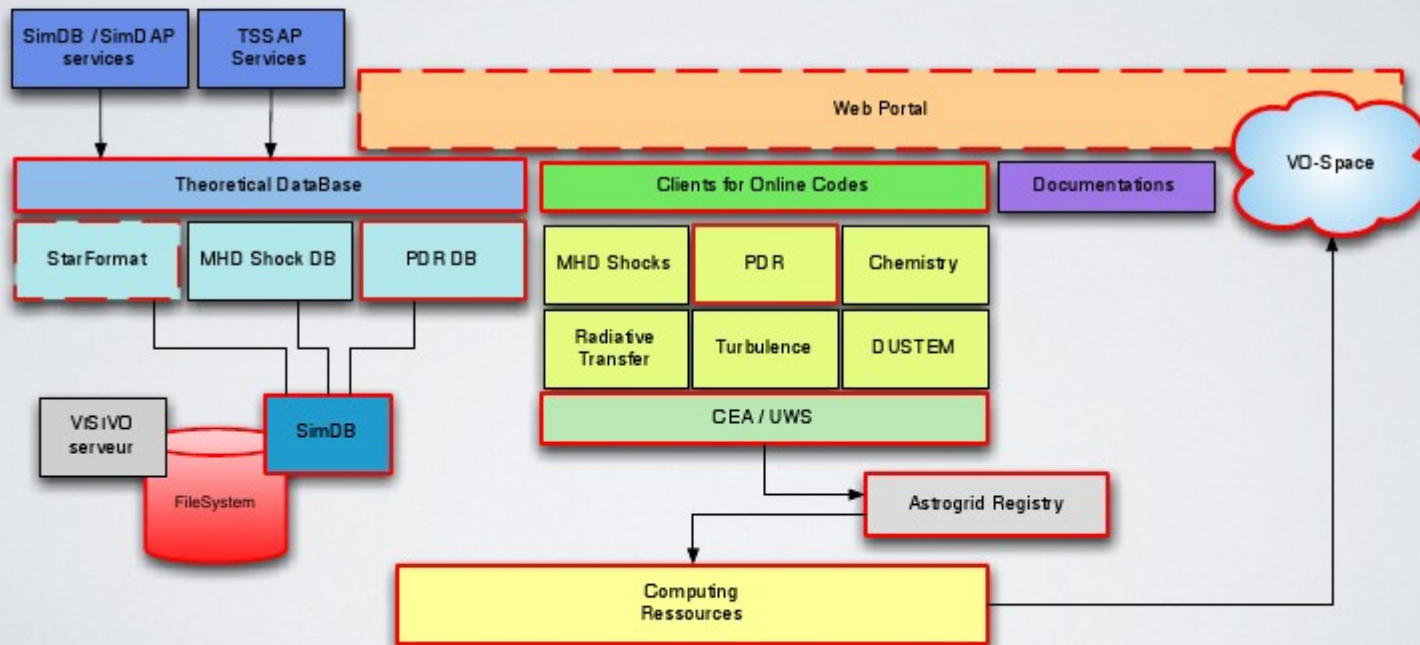
ISM platform

□ Interstellar Medium Platform

Bring together expertise in modeling / simulation of the ISM

Provide theoretical services about ISM

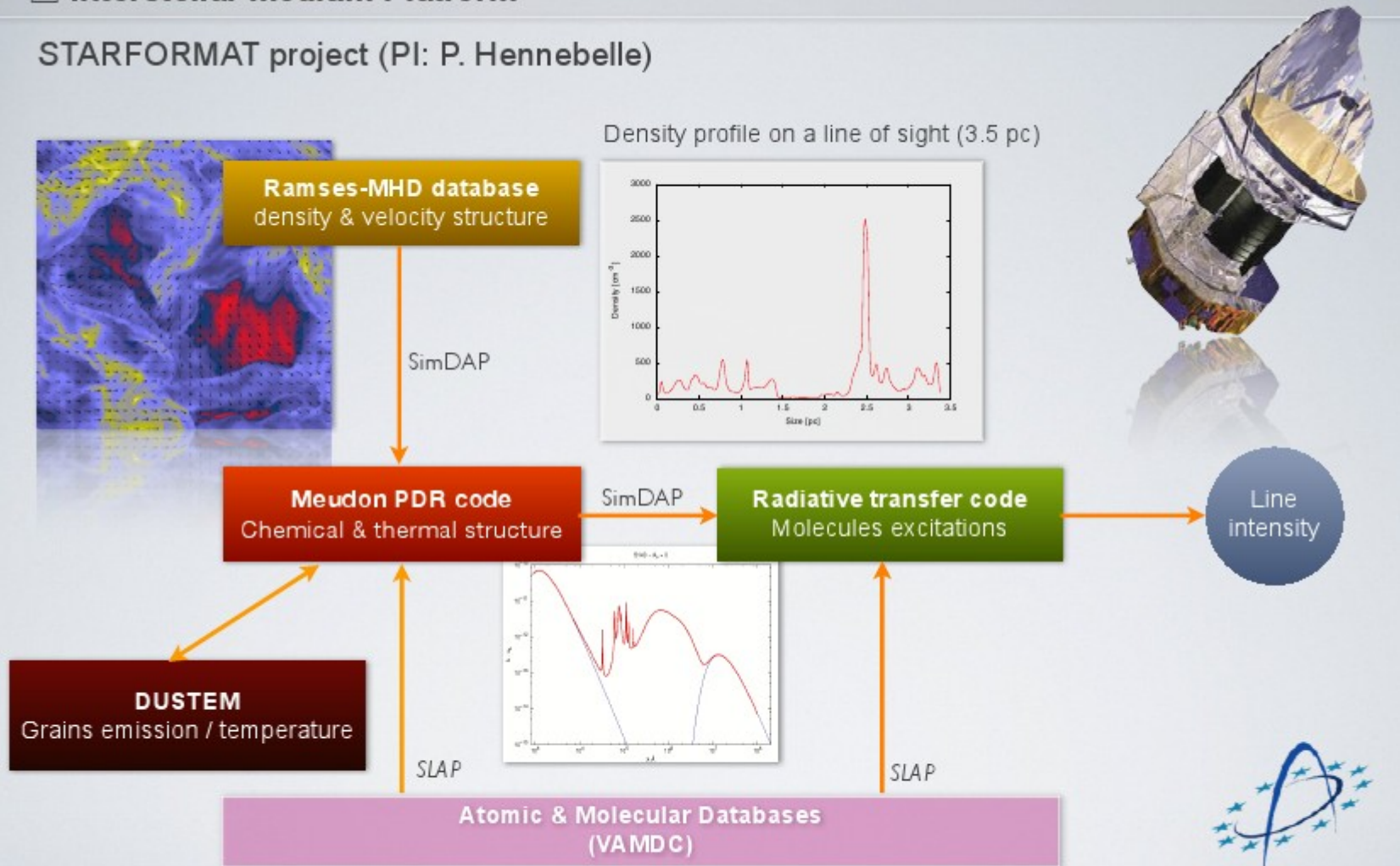
Codes - Databases - Tools & services



Complex join of TVO bricks

Interstellar Medium Platform

STARFORMAT project (PI: P. Hennebelle)



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)

Astroinformatics

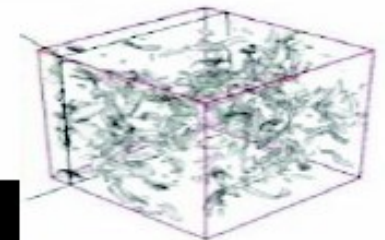
- Analogy – Bioinformatics (Genome analysis with GRIDS, ATB)
- e-Science in Astronomy - using informatics (computer science)
- Data mining, Knowledge discovery - VO-NEURAL, DAME
- Clustering
- Classification
- Supervised learning (Neural Networks, SVM)
- Examples
 - Photometric RedShift
 - Searching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

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

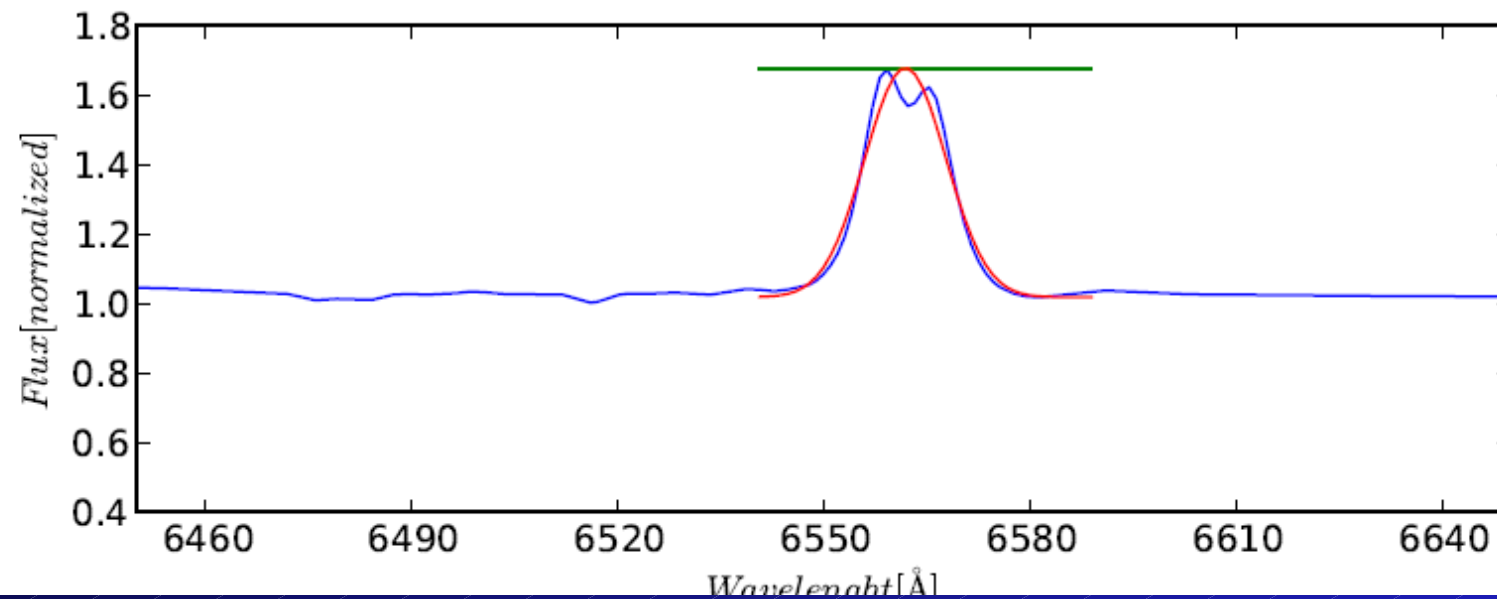
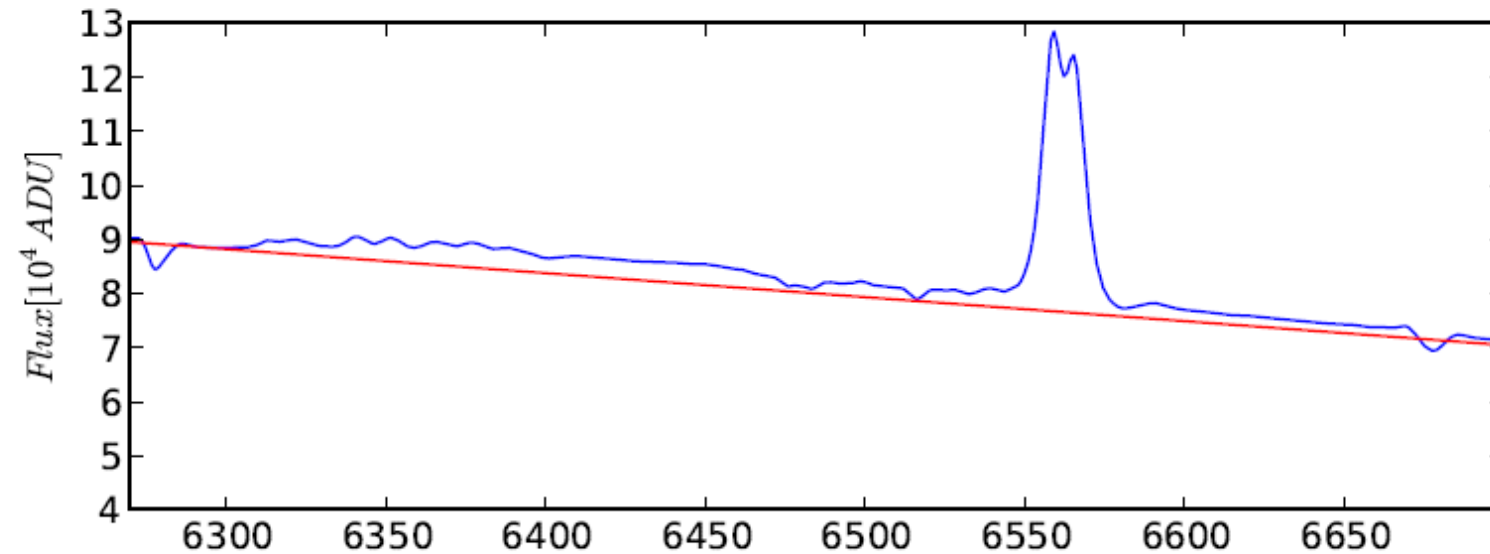


$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K \frac{c^2}{a^2}$$



(With thanks to Jim Gray)

Feature extraction (emission)



Be Star Candidate #1 in SEGUE

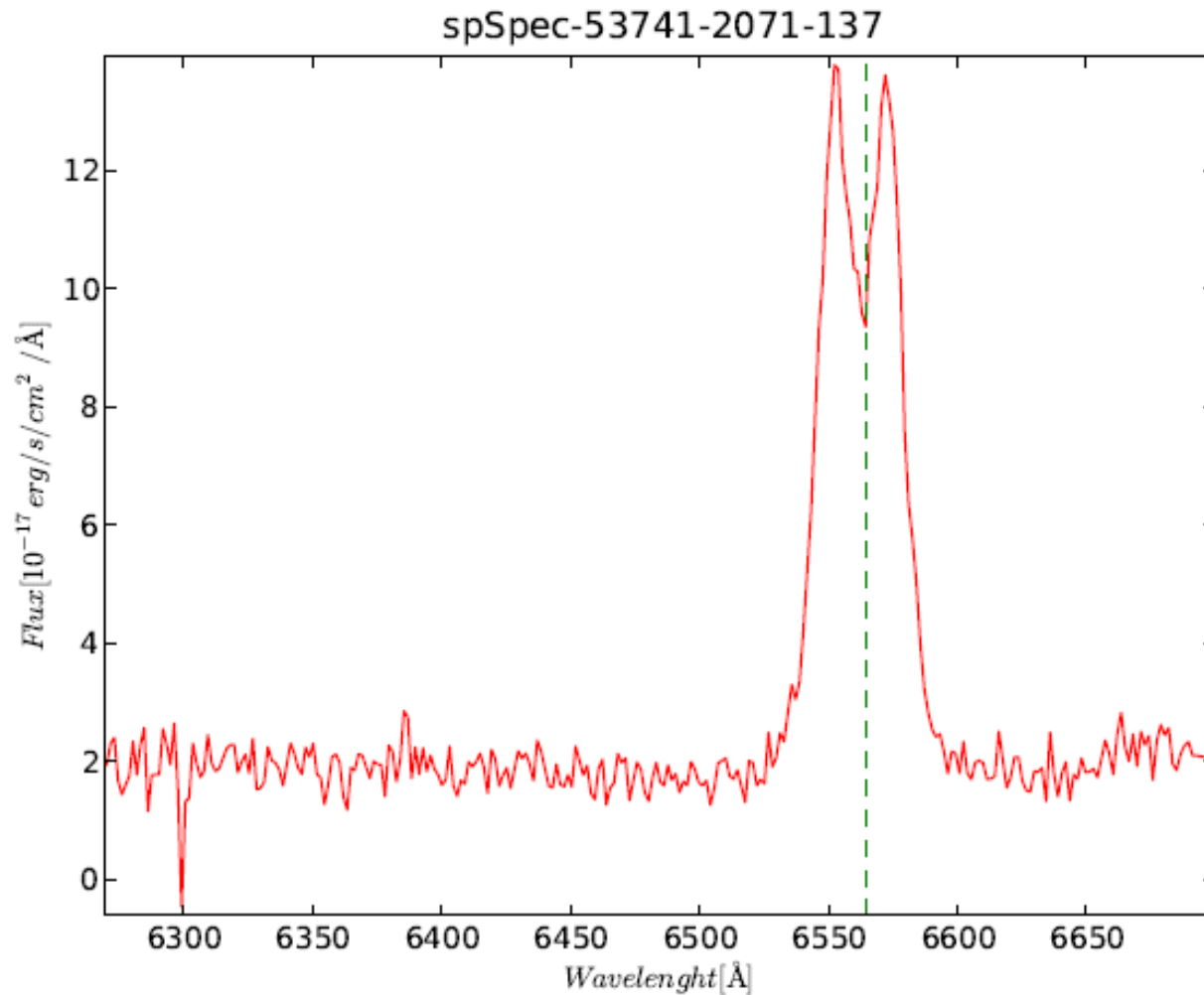
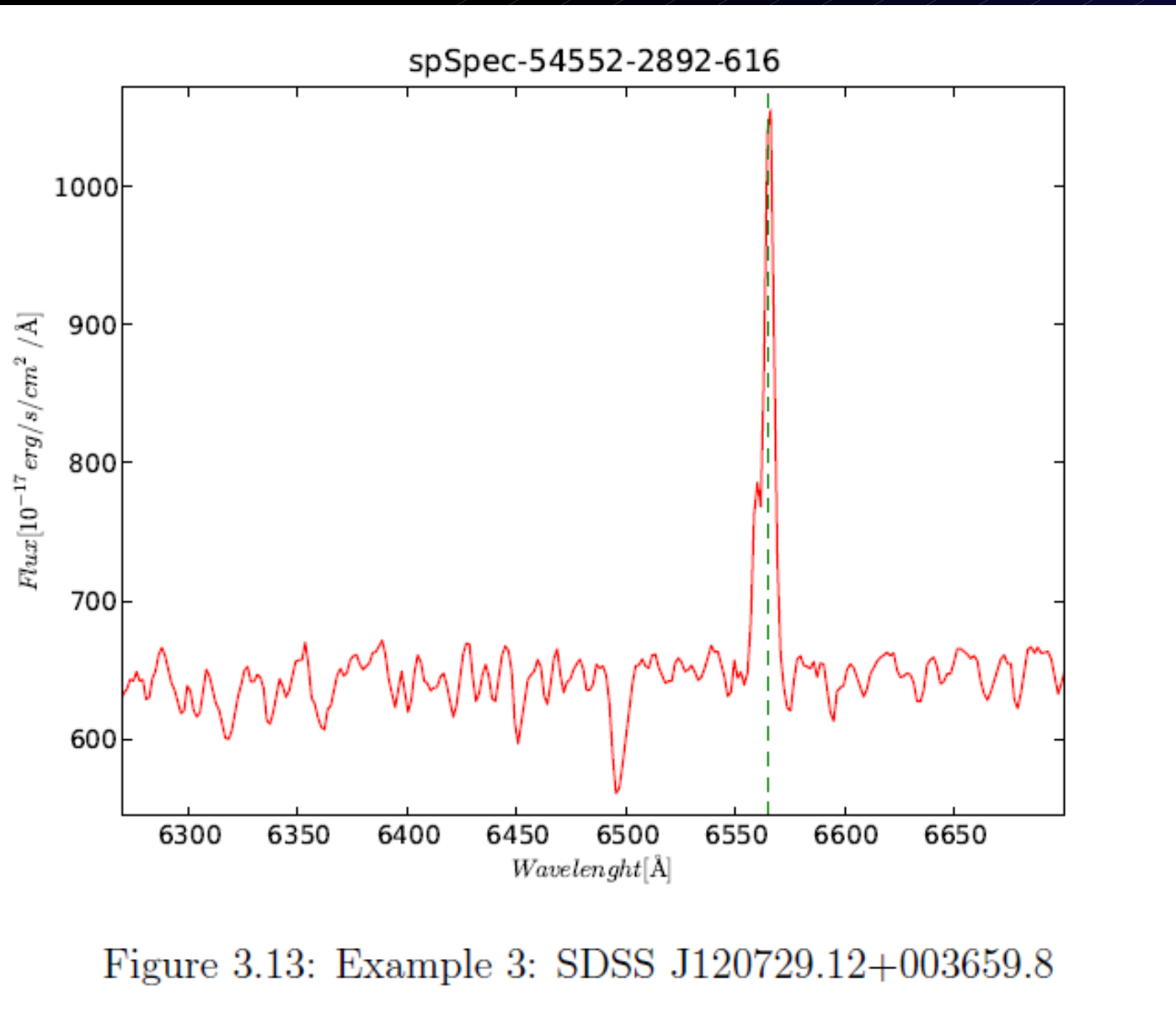
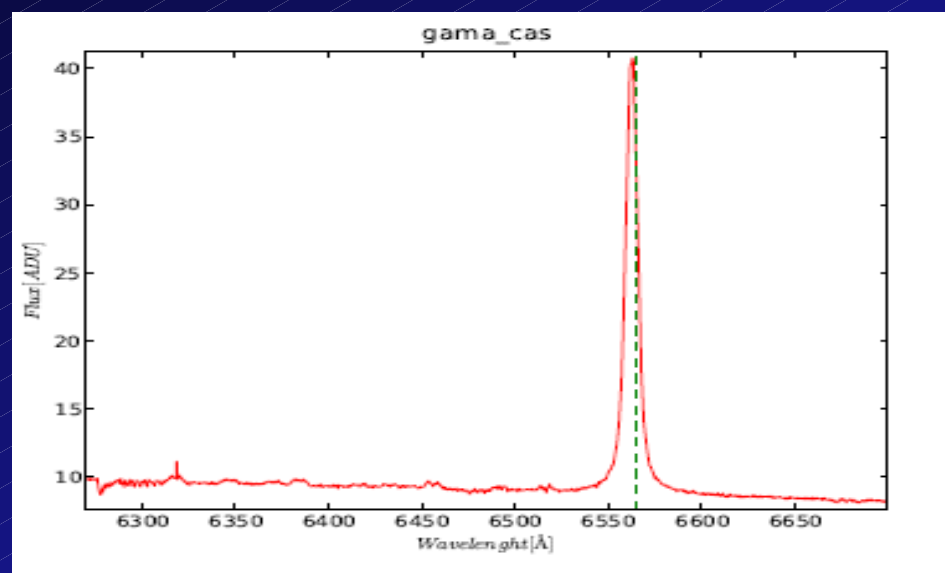
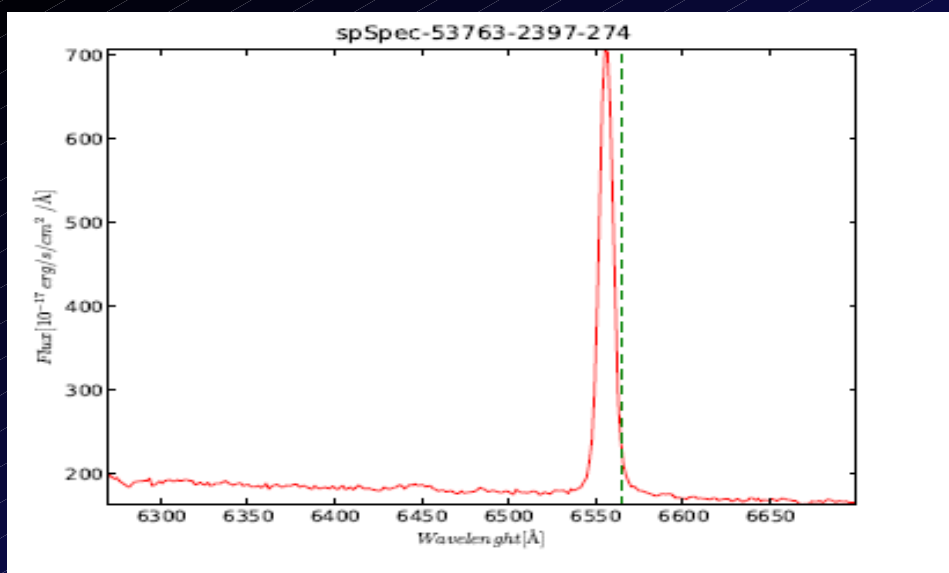
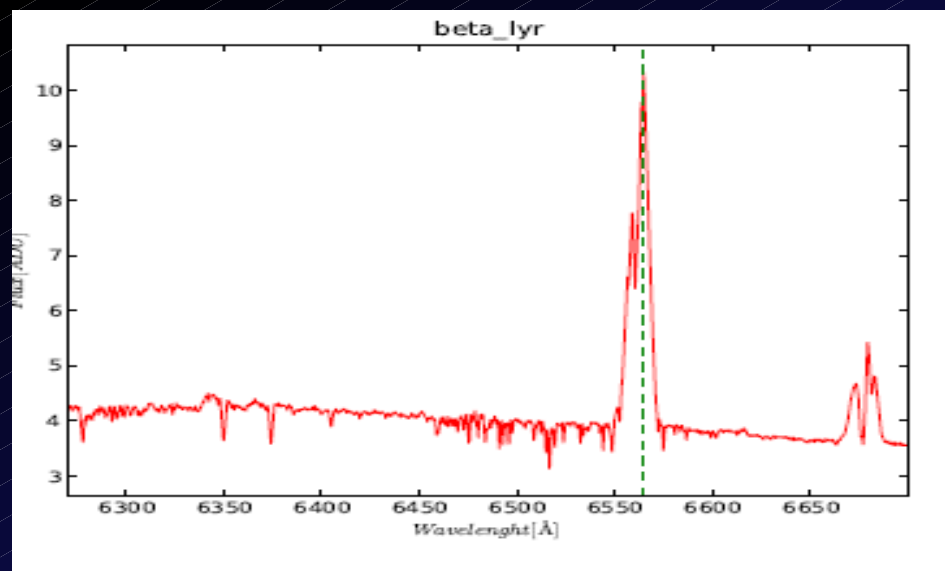
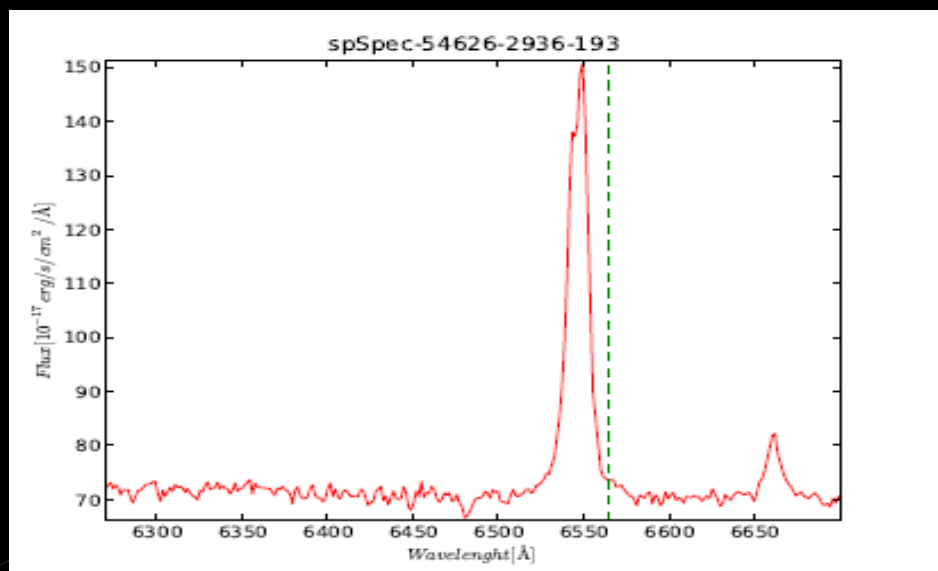


Figure 3.11: Example 1: SDSS J035747.16-063850.7

Be Star Candidate #3 in SEGUE



Candidates - Similarity !



Conclusions

VO is not „virtual“ – its a REAL instrument

Yields new discoveries (panspectral, rare obj.)

Doing spectroscopy in VO can speed up the spectra discovery and analysis

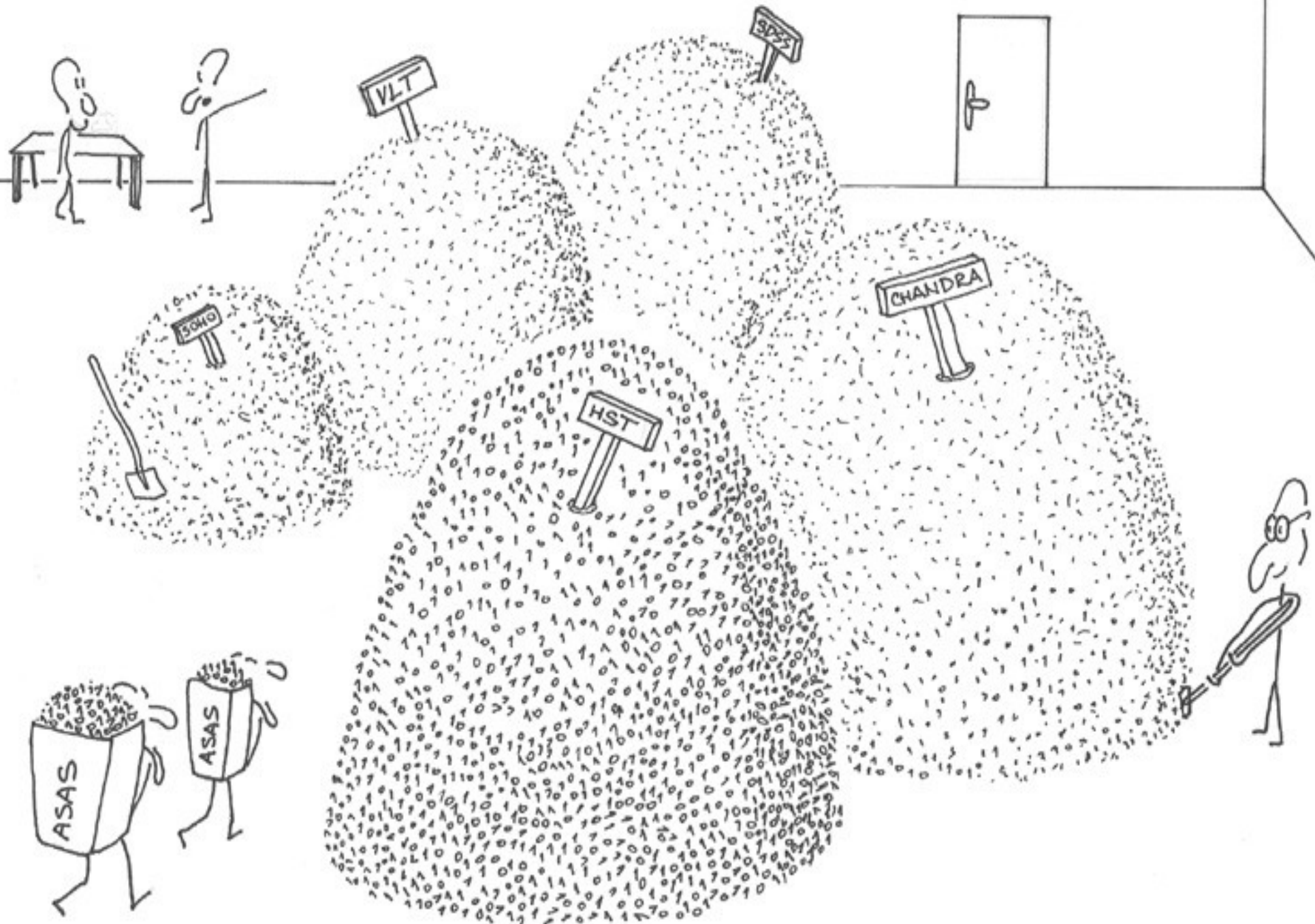
Tools are already here or will come soon

Power of joining bricks (spatial+spectral+time) inf.

Astroinformatics – extraction of knowledge

e-Science in astronomy, VO=harness of AI

VIRTUAL OBSERVATORY



VO Basics (tutorial by P. Skoda)

- VOTable (Metadata - UCD, data FITS, ASCII..)
- VO Registry – where, what, how - harvesting
- Protocols (not theory)
 - Conesearch (search in circle with given radius)
 - SIA (transfer of image given dimension, resampling)
 - SSA (spectrum of target, pos., spec. range, time...)
 - TAP (new – query of multiple tables and services)
 - SLAP (atom. and molecular transitions, oscil. str.,)
- ADQL (VOQL) – like SQL (query tables)
- CEA (jobs – VOSPACE) WS, GRID

Practical Examples and Tutorials

EURO-VO Scientific Tutorials

<http://www.euro-vo.org/pub/fc/workflows.html>

VO Schools EURO-VO - 2009,2010,2011

<http://cds.u-strasbg.fr/twikiAIDA/bin/view/EuroVOAIDA/VOSchool09/WebHome>

<http://cds.u-strasbg.fr/twikiAIDA/bin/view/EuroVOAIDA/VOSchool10/WebHome>

<http://www.eurovo-ice.eu/twiki/bin/view/EuroVOICE/ICESchool>

AIDA WP5 pages - VO in Education and Outreach

<http://cds.u-strasbg.fr/twikiAIDA/bin/view/EuroVOAIDA/WP5WorkProgrammeUseCases>