

(Optical) Spectroscopy with the Virtual Observatory

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Ondřejov
Czech Republic

Lecture for Astronomical Computing centre (ARI),
University of Heidelberg 29th March 2012

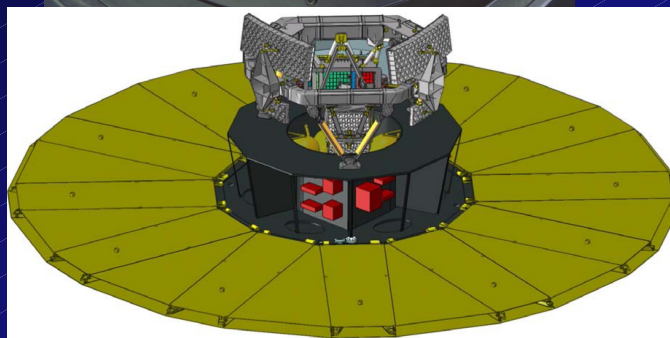
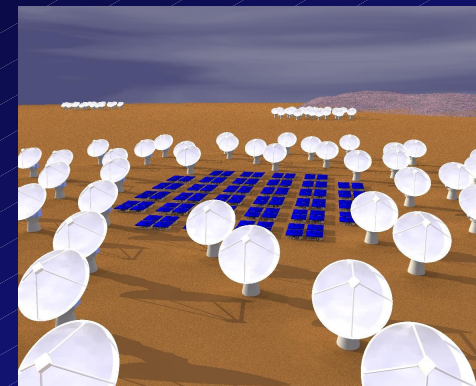
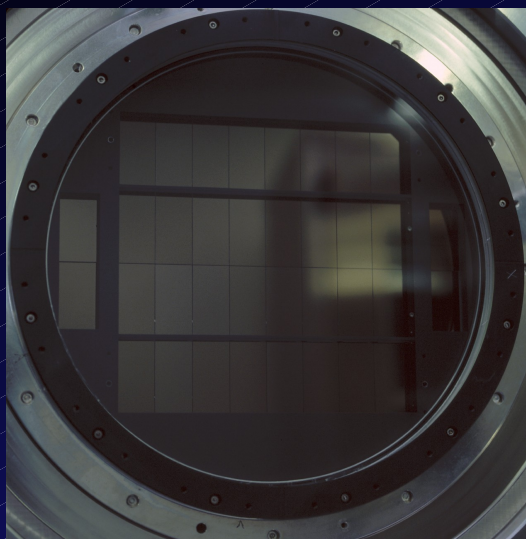
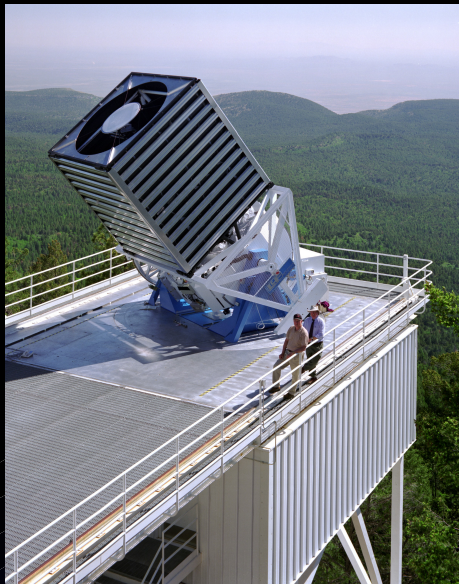
Credits

- 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, F. Le Petit, C. R. Blanco, M. Bresscia, R.D'Abrusco, G. Longo, T.Hey

Outline of the Talk

- Data Avalanche in astronomy
- History of VO
- Basic principles of technology
- Common tasks in stellar spectroscopy
- VO Tools for spectroscopy
- Theory in VO (model spectra, SEDs)
- Astroinformatics

Data Avalanche



Large Synoptic Survey Telescope



201 CCD 4kx4k,

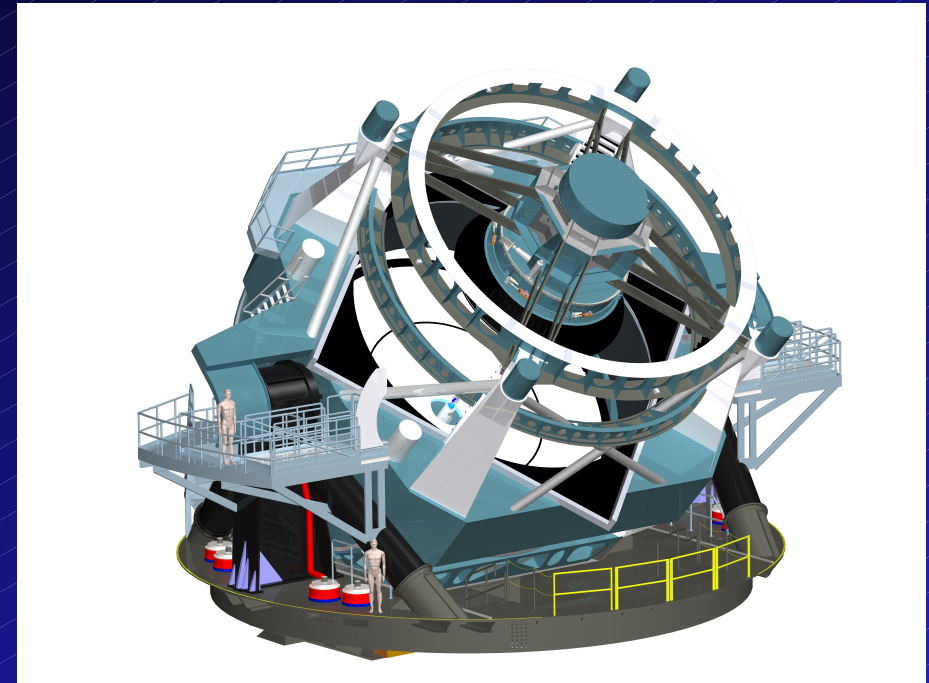
3.2 Gpix every 20 sec

3.5 deg FOV (64cm)

20 TB/day=6 PB/yr RAW

1.5 PB catalogue !!!

detection of changes 60s!



Atacama Large Milimeter Array ALMA

64 antennas 12m
Chajnator 5000m
Chile
2008-2013

it is spectrograph
as well as ...

0.5-2 PB/yr RAW



CD Sea

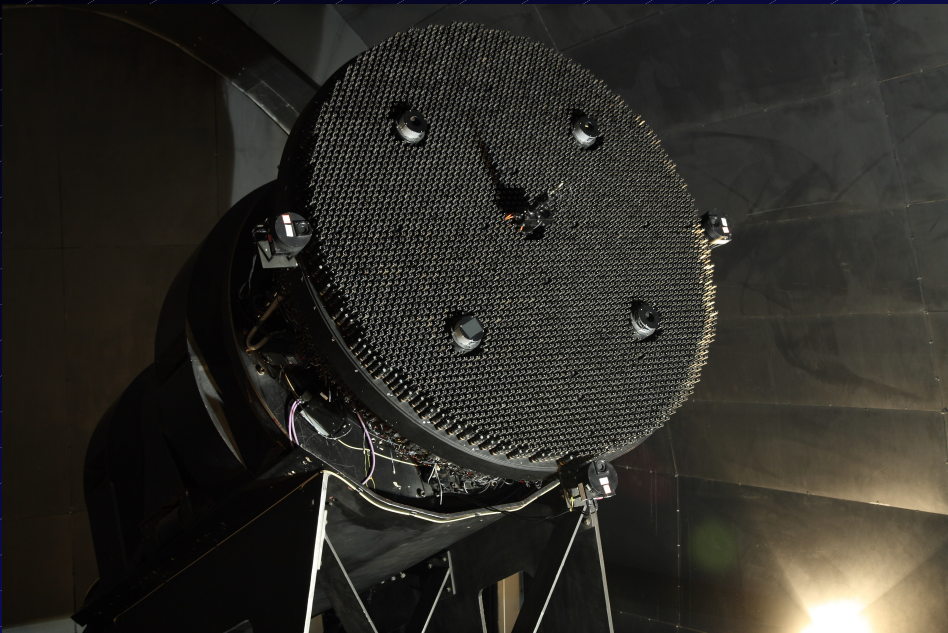
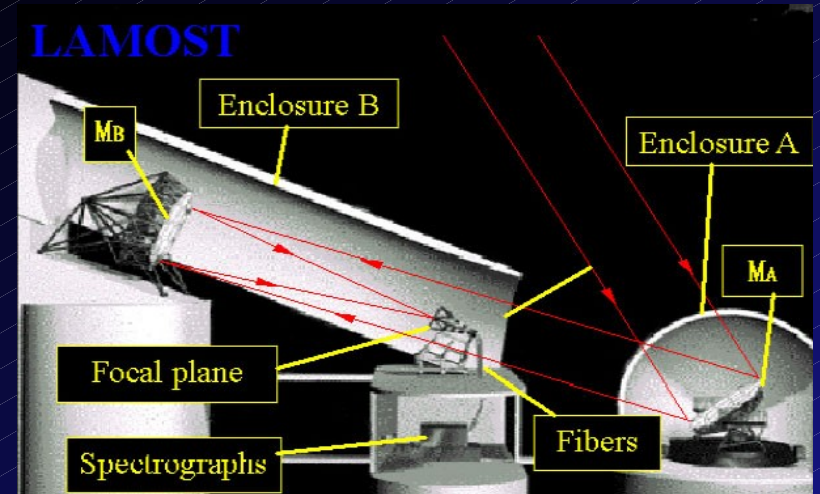


600 000 CD = 372 TB (CD 650MB)
600 000 DVD = 2.5 PB (DVD=4.5GB)

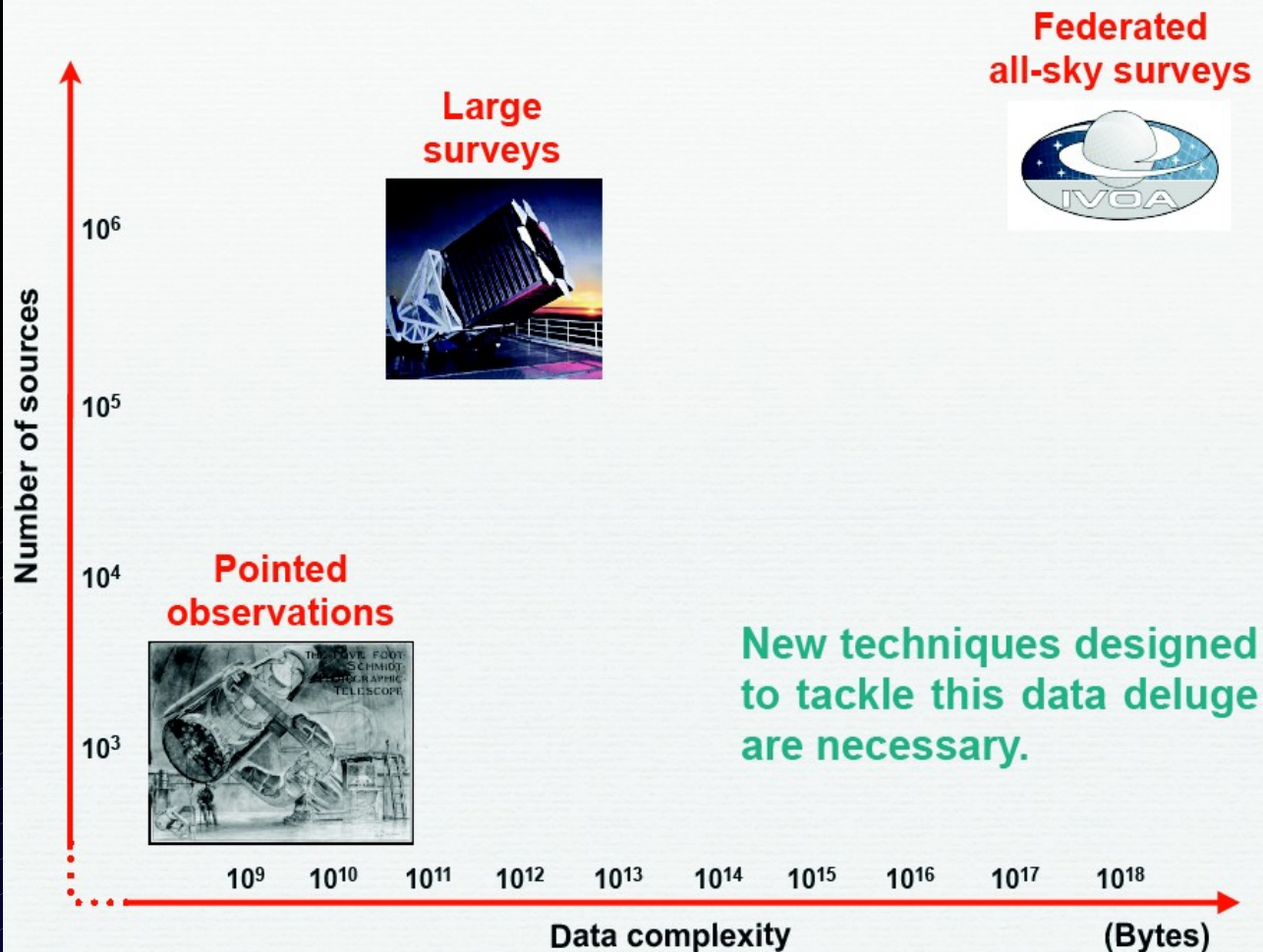
Bruce Monro
Kilmington UK

LAMOST (Guoshoujing)

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



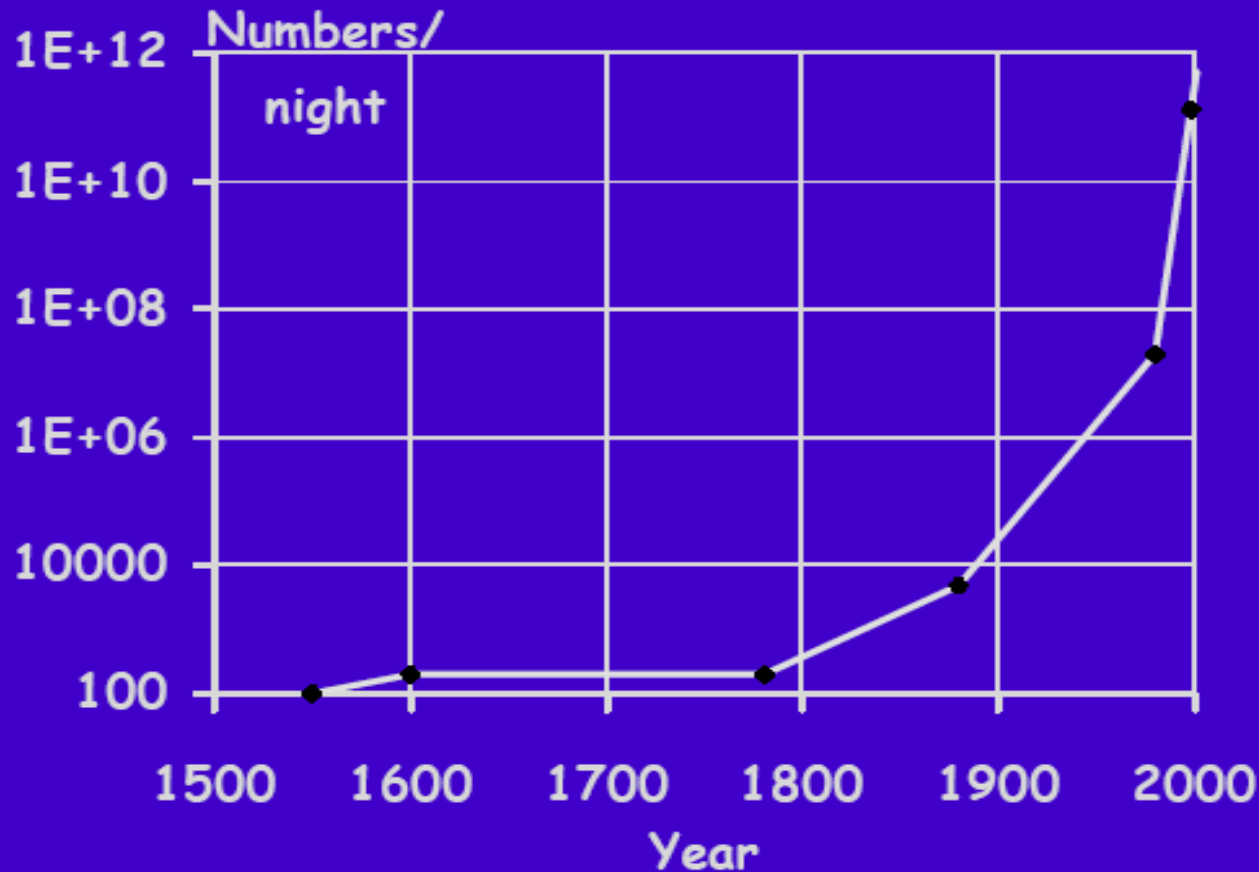
A paradigm shift



Data Avalanche

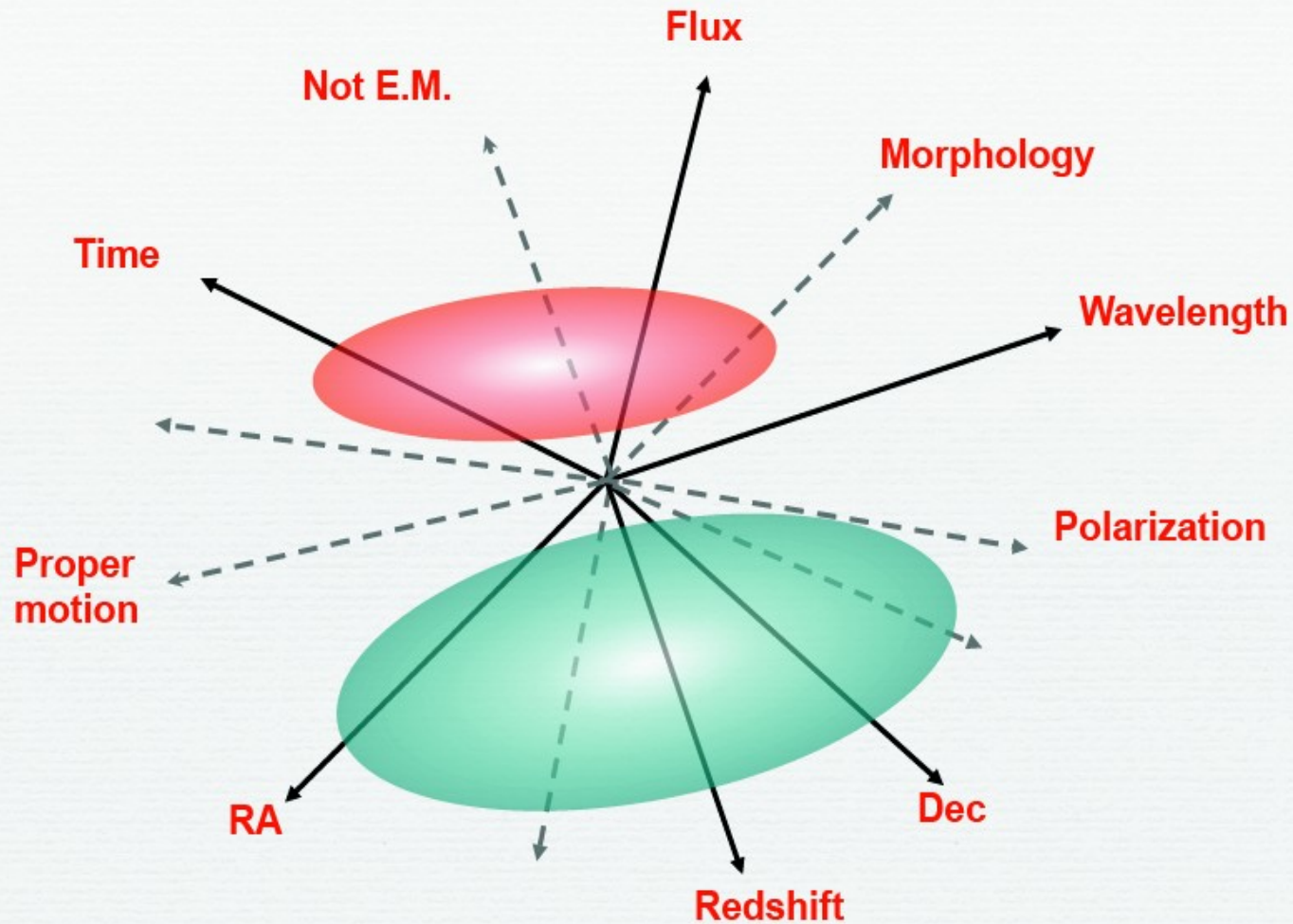
Moore law for chips –doubling 1.5 year

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



$T_2 < 18$ mths
1990-2000

A growing parameter space



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

History of VO

Success of IUE/HST archives

idea of the VO - end 2000

Federation of archives (MAST, NED)

Huge data – distributed processing

GRID - started in HEP (computing + storage)

Multispectral research : radio---gamma

Data for SDSS, SIMBAD, NED – key research

IVOA



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)

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)

Information from (multi) spectral lines

Position (wavelength):

- Chemical elements

- Excitation / Ionization state (Grid of models)

 - If unknown – SLAP, TSAP (molecules in IR)

- RV (binarity, orbital parameters...)

Shape

- Stellar parameters (Teff, log g, rotation)

- Stellar activity (Turbulence, granulation)

- core/wings – different physics – optical depth, limb darkening

- Expansion, shells, winds (P Cyg, Novae)

Time variability (LPV)

- Change of physical state (Be, outburst)

- Spots (Mg field, overabundance – Ap)

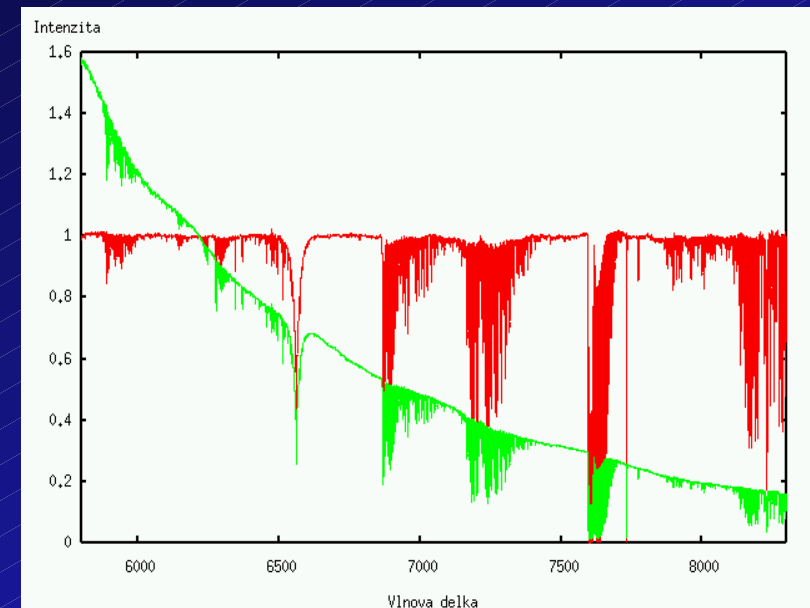
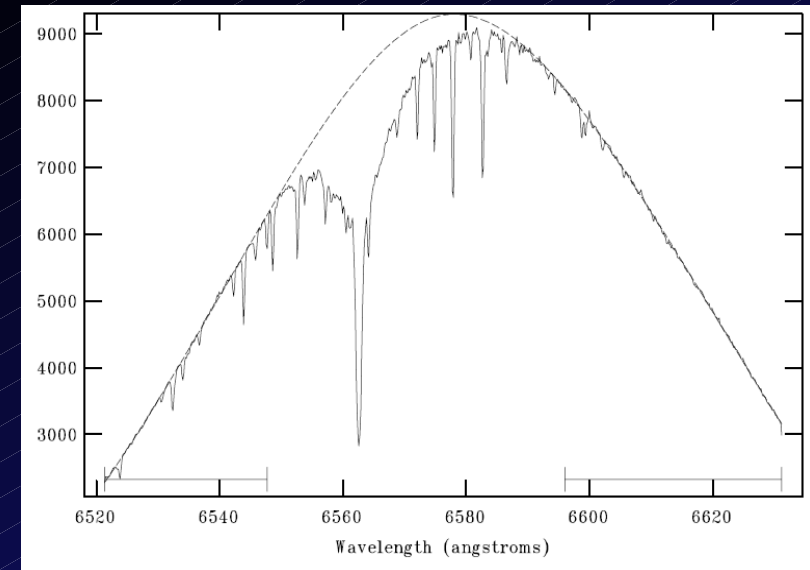
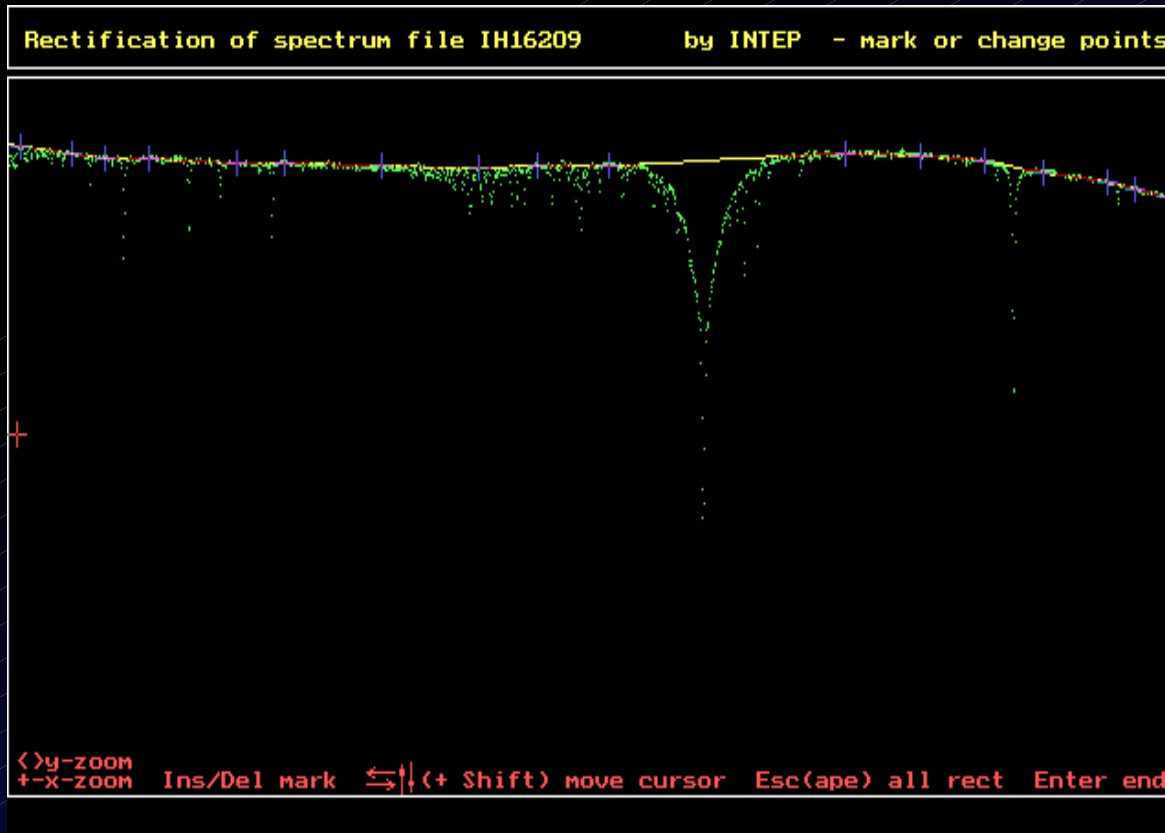
- Pulsations (Delta Ceph, RR Lyr, Miras)

- Non radial pulsations (NRP)

- Multiple systems – disentangling of orbital parameters, individual spectra

- Detection of ES planets in spectra (Bisector – small contributions enlarged)

Rectification (Normalization)



Echelle - tricky

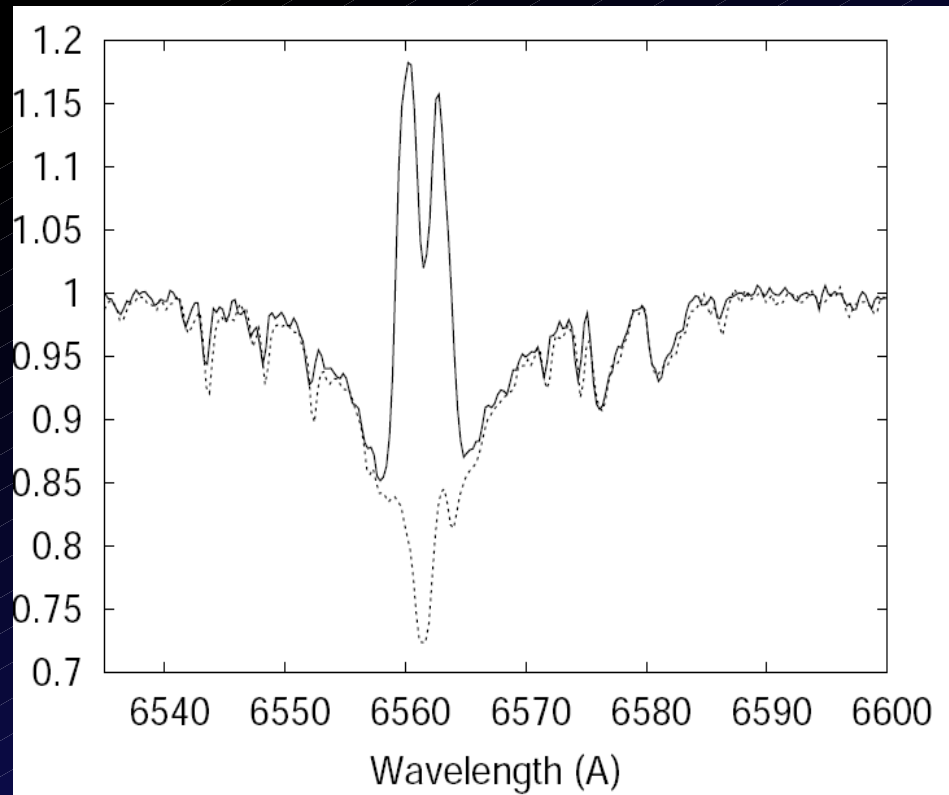
Changes of Line Profiles in Time

Blind comparison of different exposures

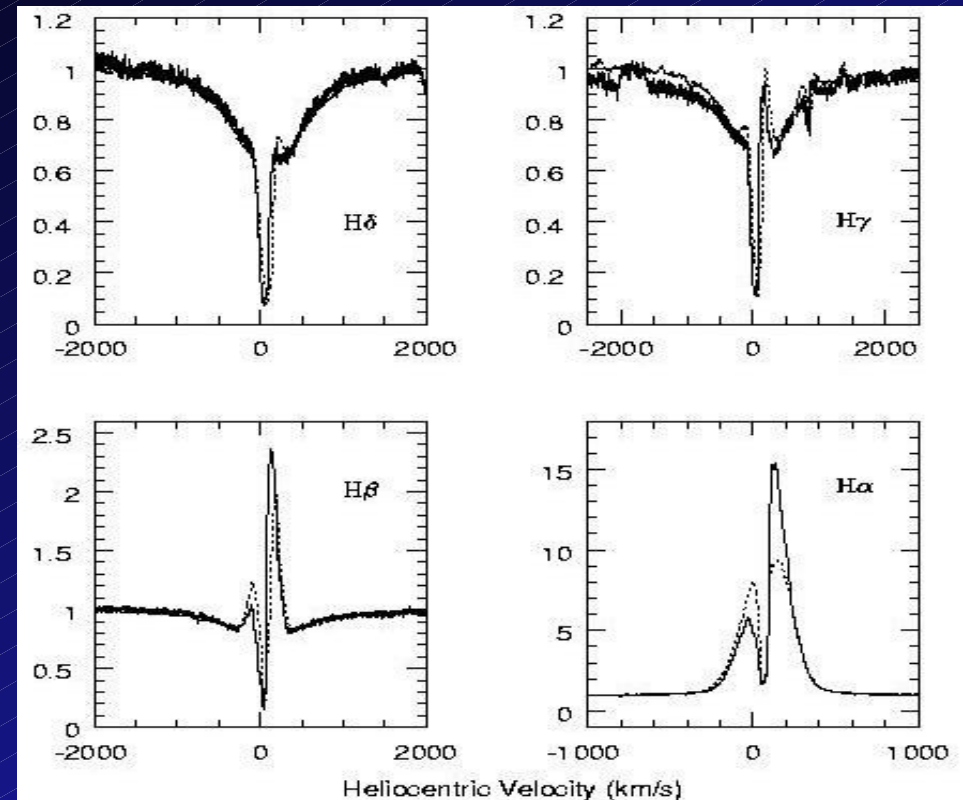
Emission/absorption, shell phases

Time evolution of object – mass transfer,

V/R variations

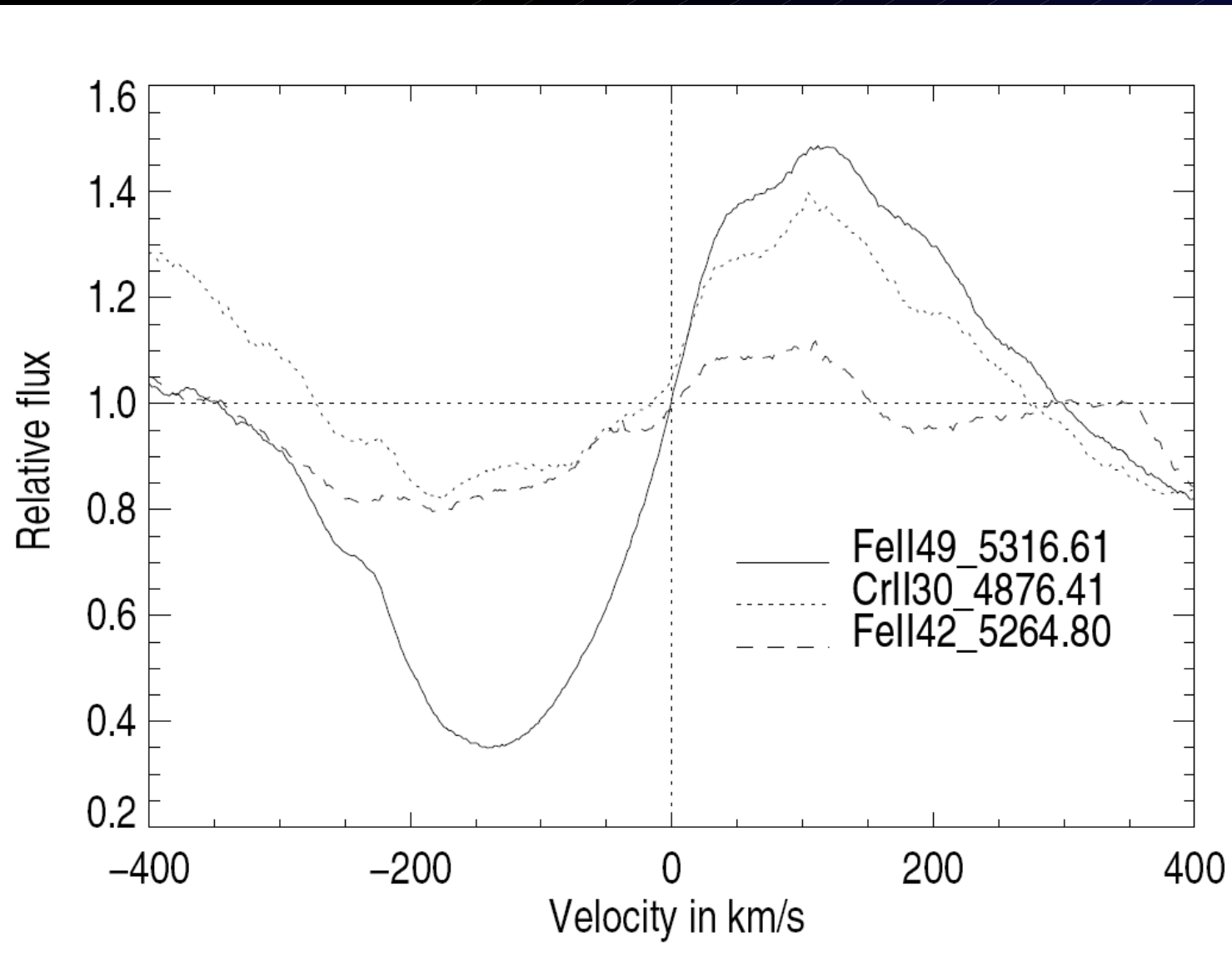


HD6226 : Slechta and Skoda 2004

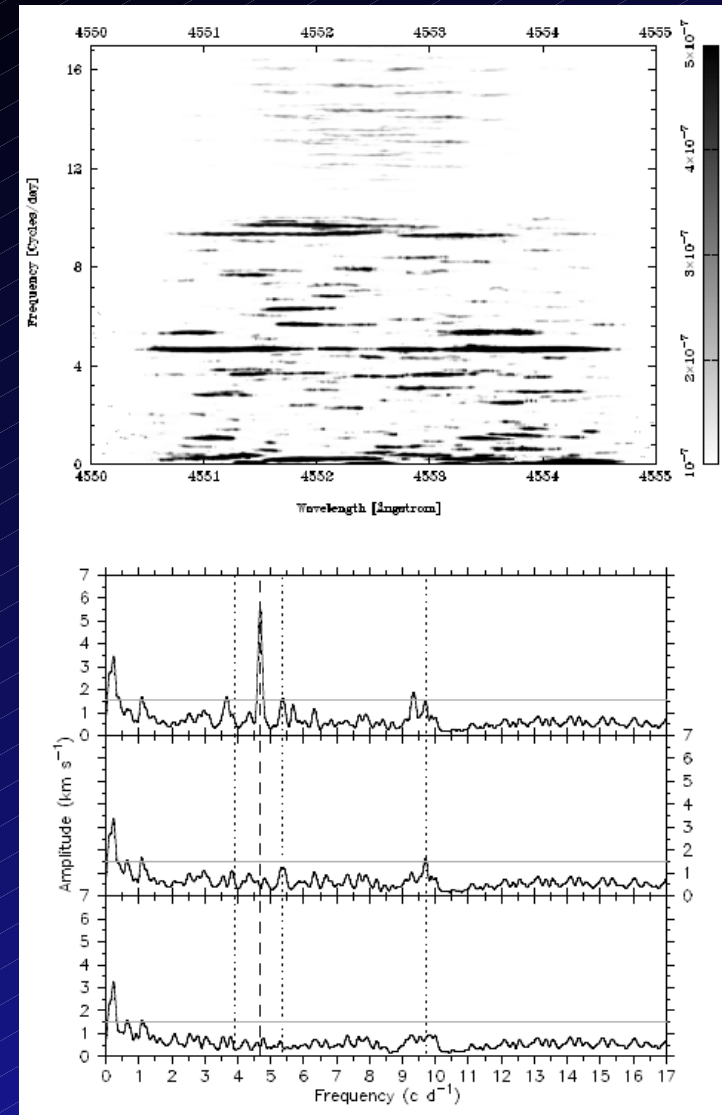
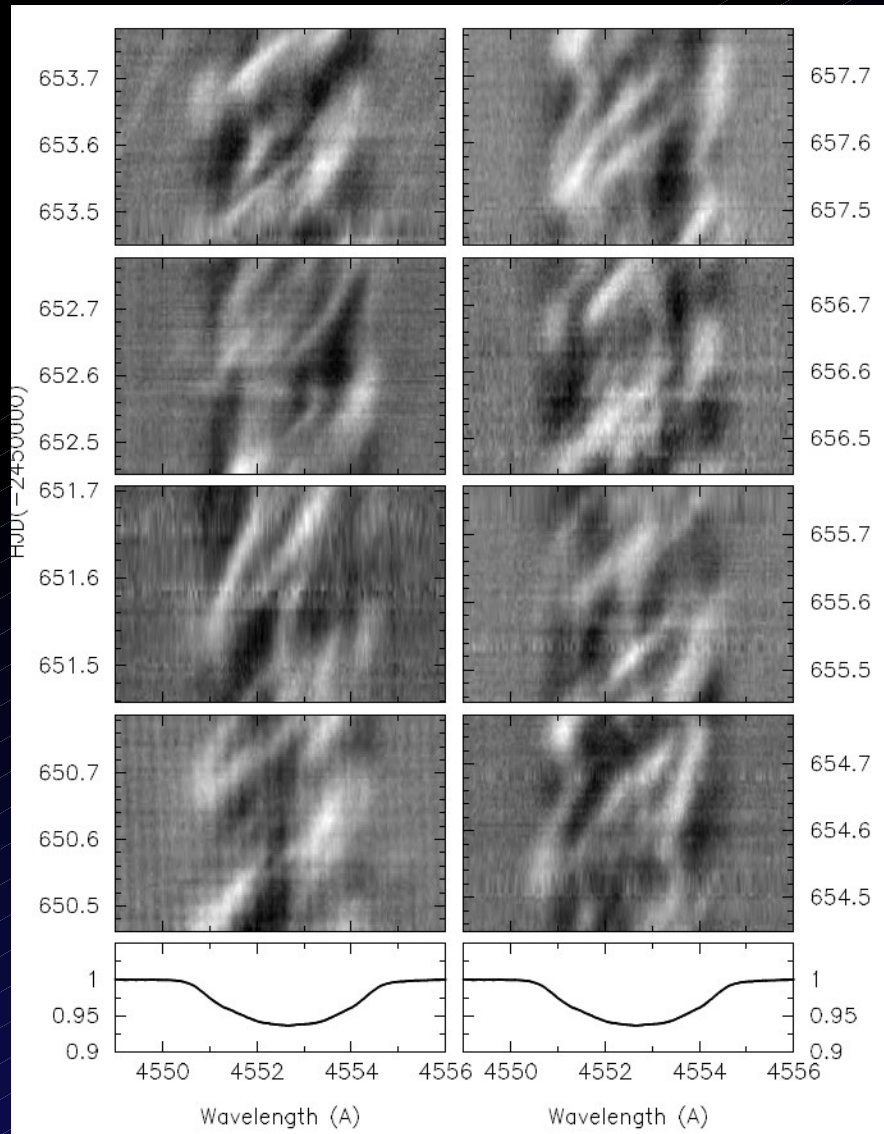


Borges et al. 2008

Different Lines overplotted in RV

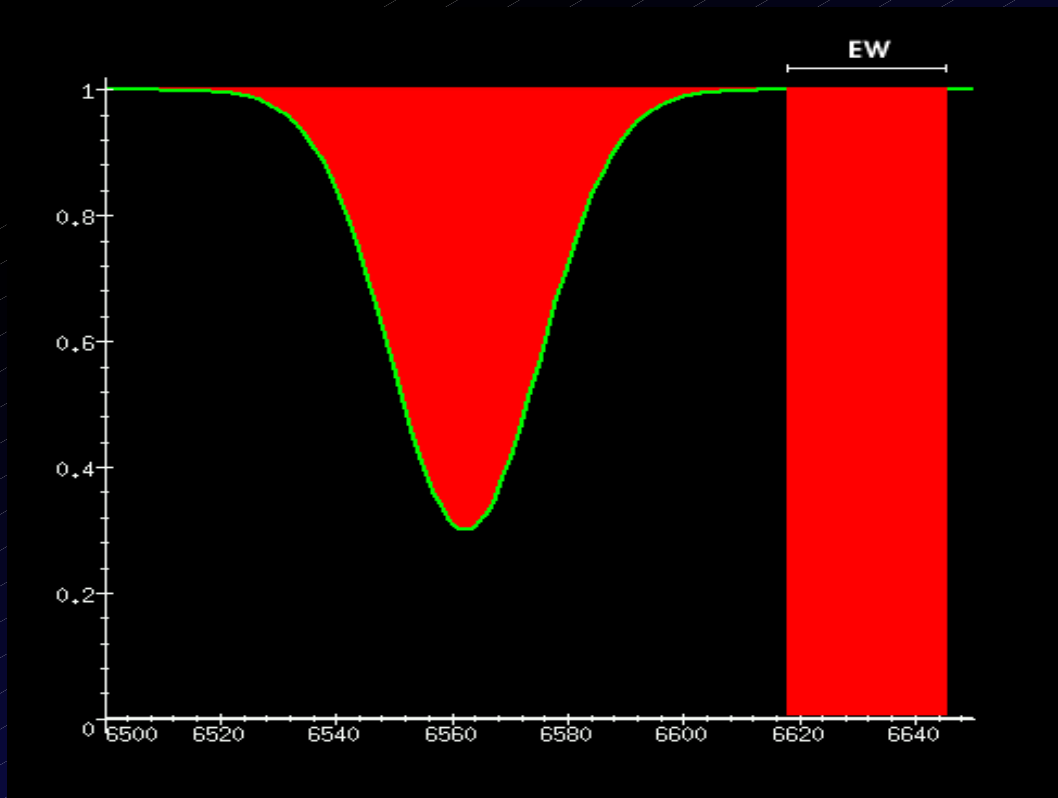


Periodogram of Line Profile NRP

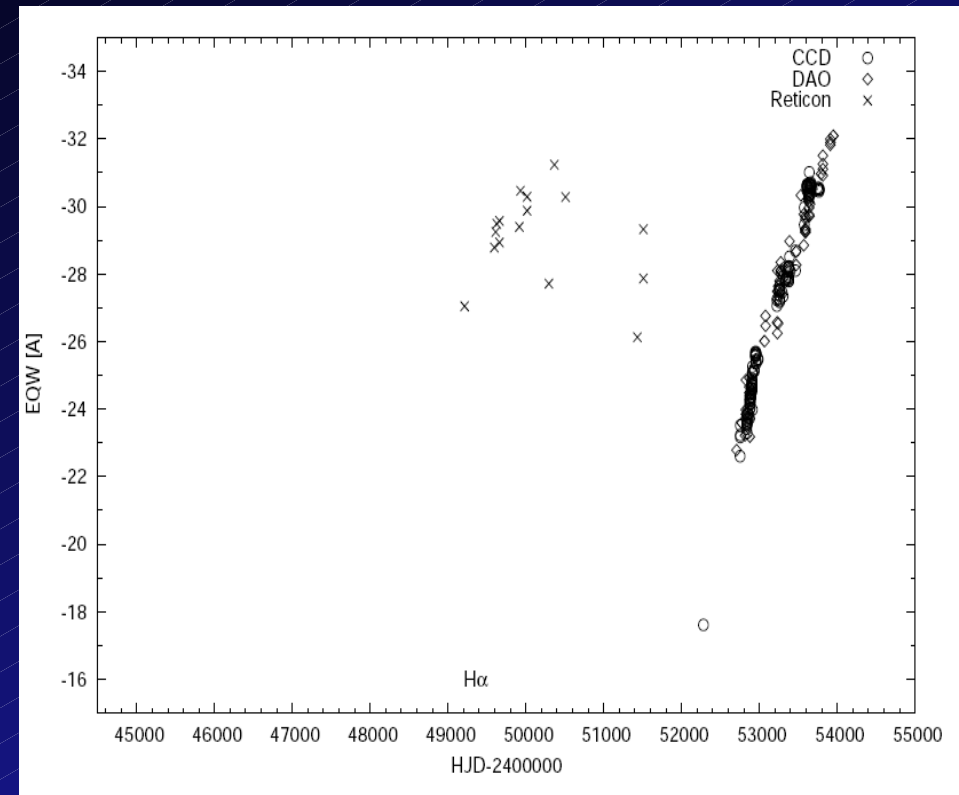


Equivalent Width (EW)

Definition by area under LP



EW changes – shell evolution

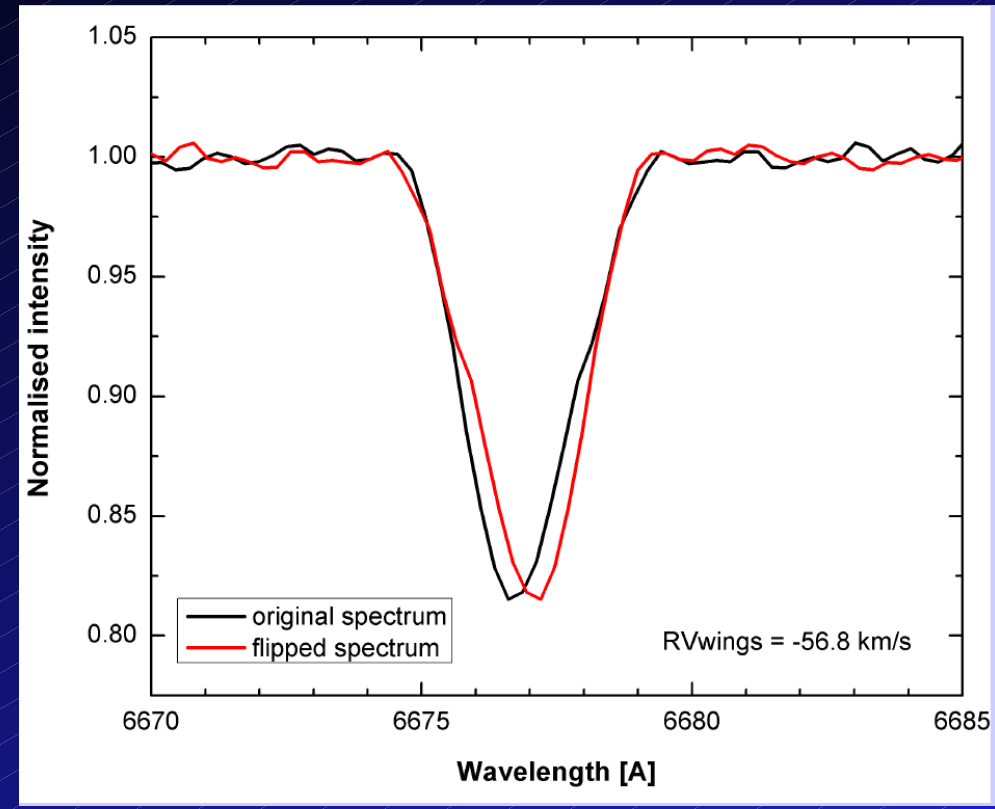
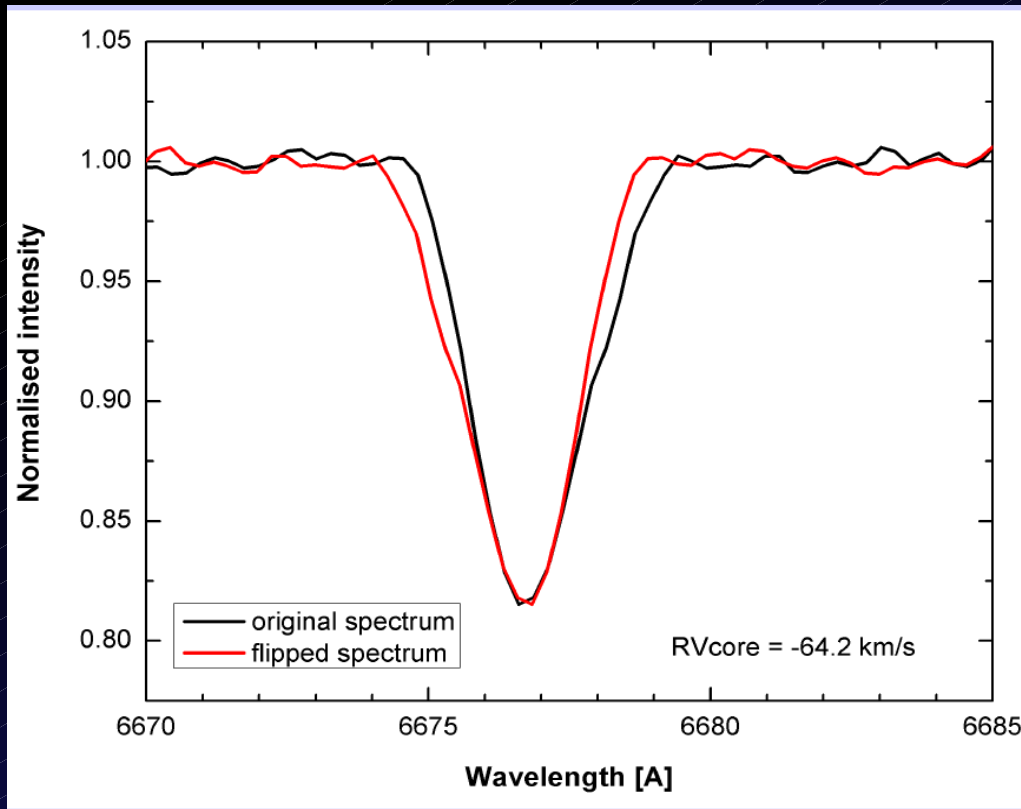


RV by Mirroring Method

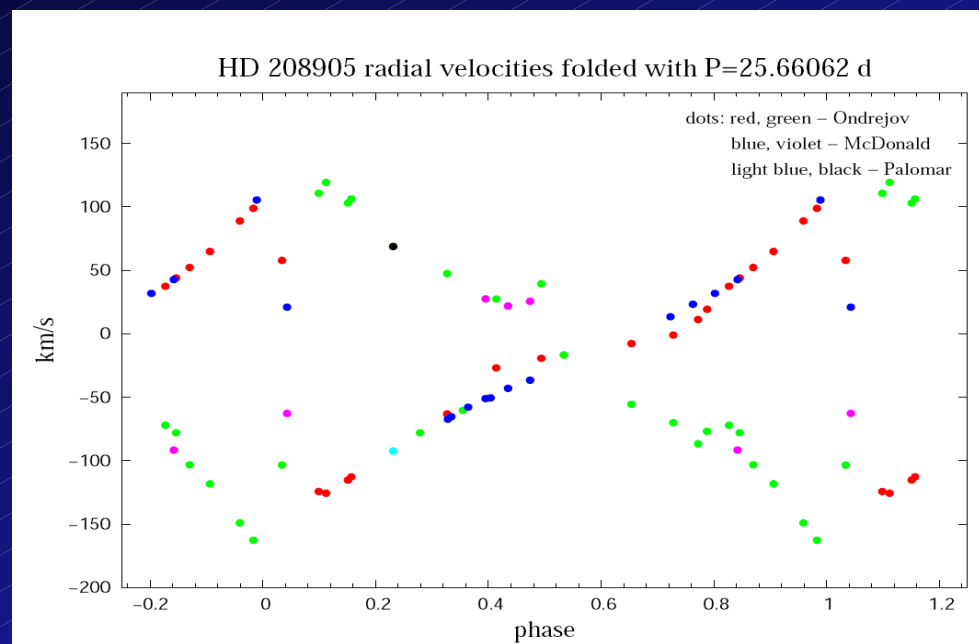
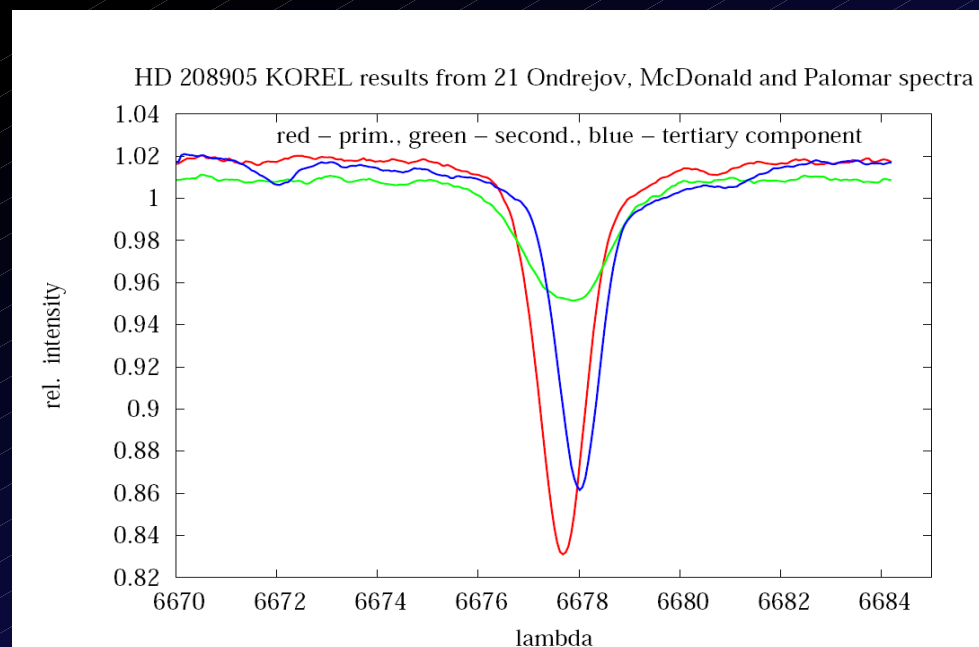
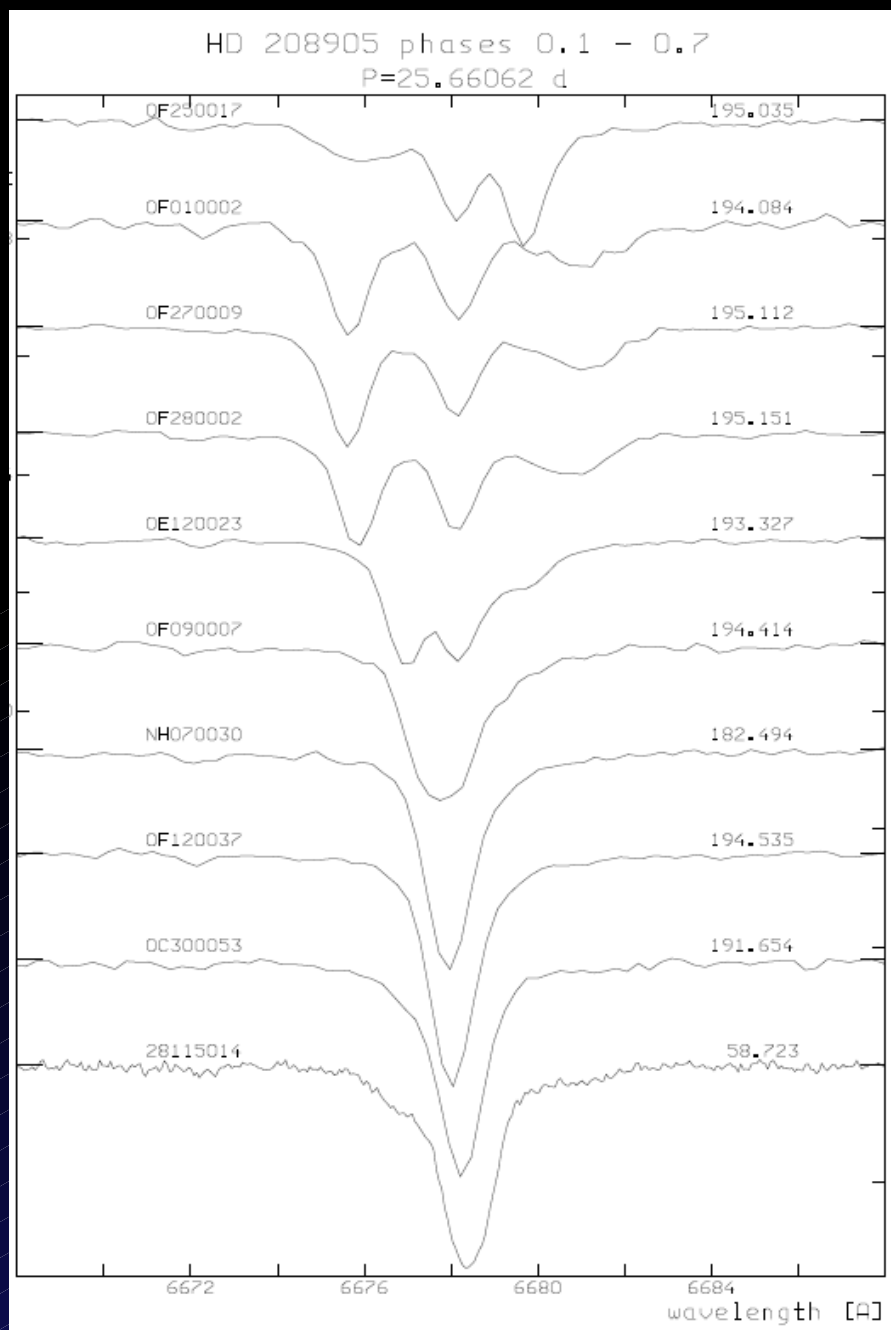
Separate match of core from match of wings – where in depth ?

Different physics (shells, shears, winds)

Asymmetry – how to handle ?

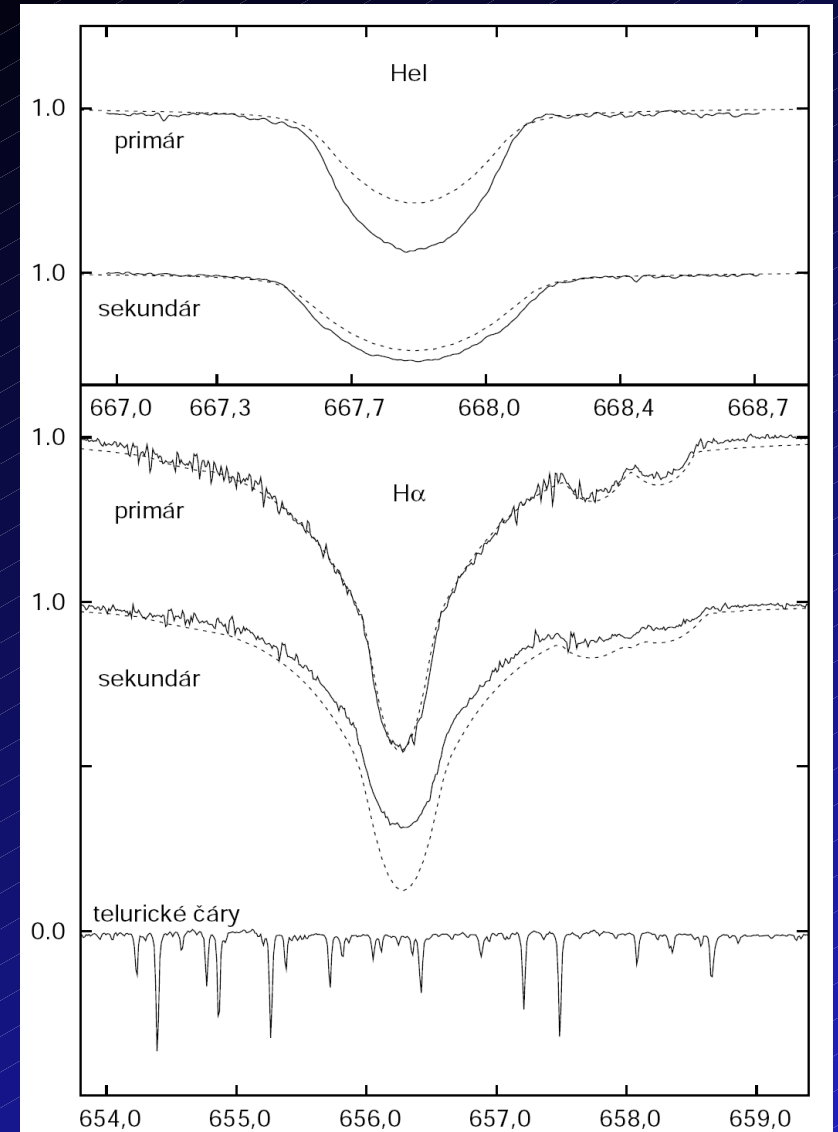
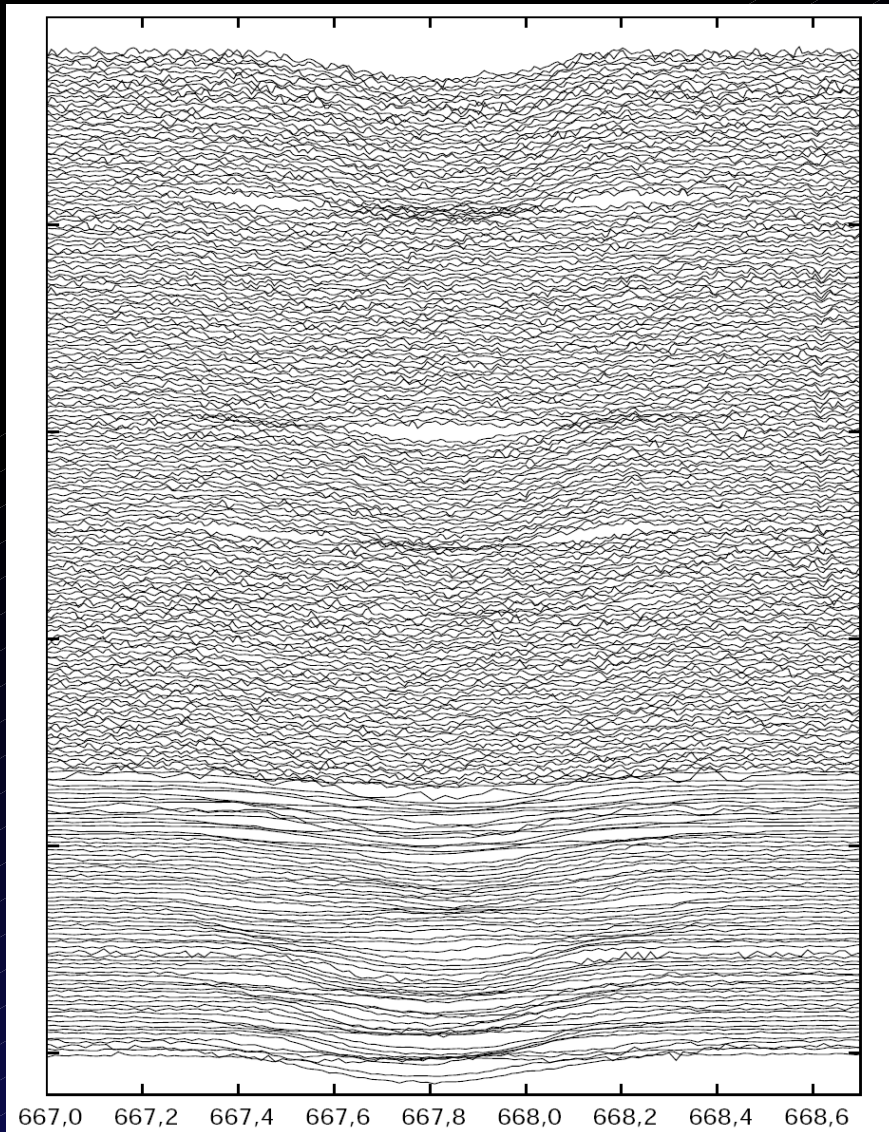


Spectra Disentangling in Fourier Space - KOREL

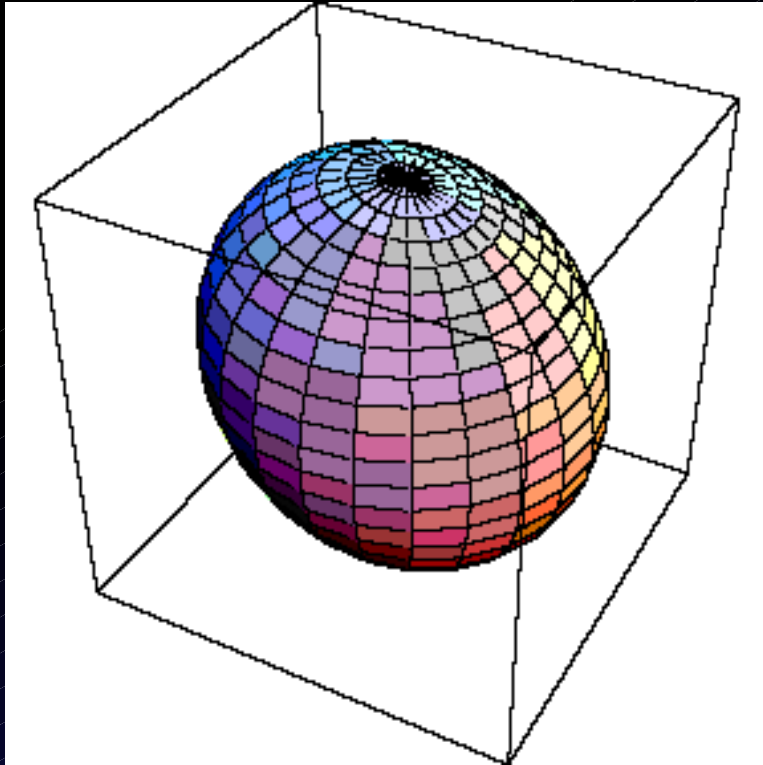


HD208905: Koubsky et al. 2006

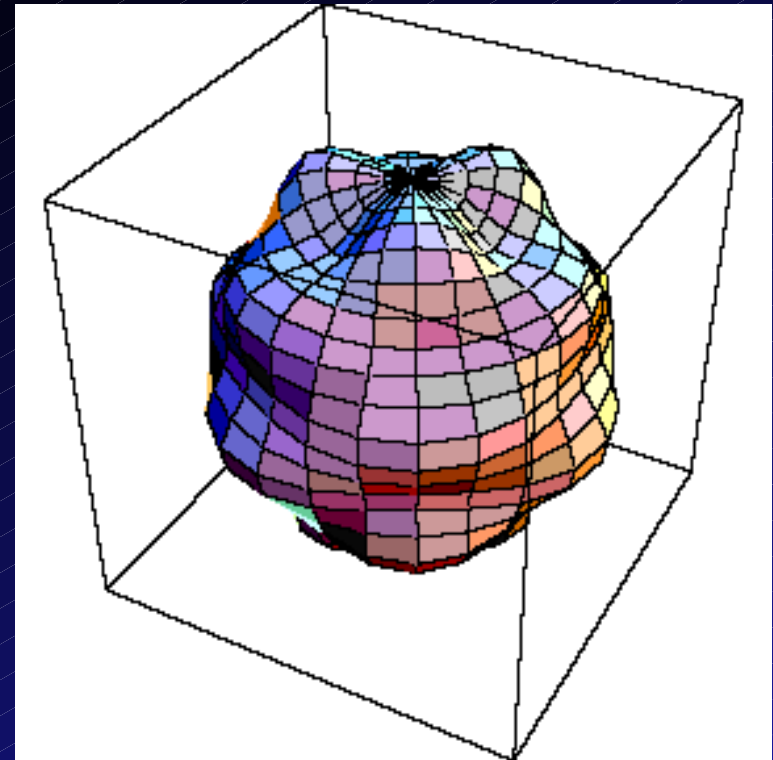
Many spectra overplotted to find cuts



Non Radial Pulsation



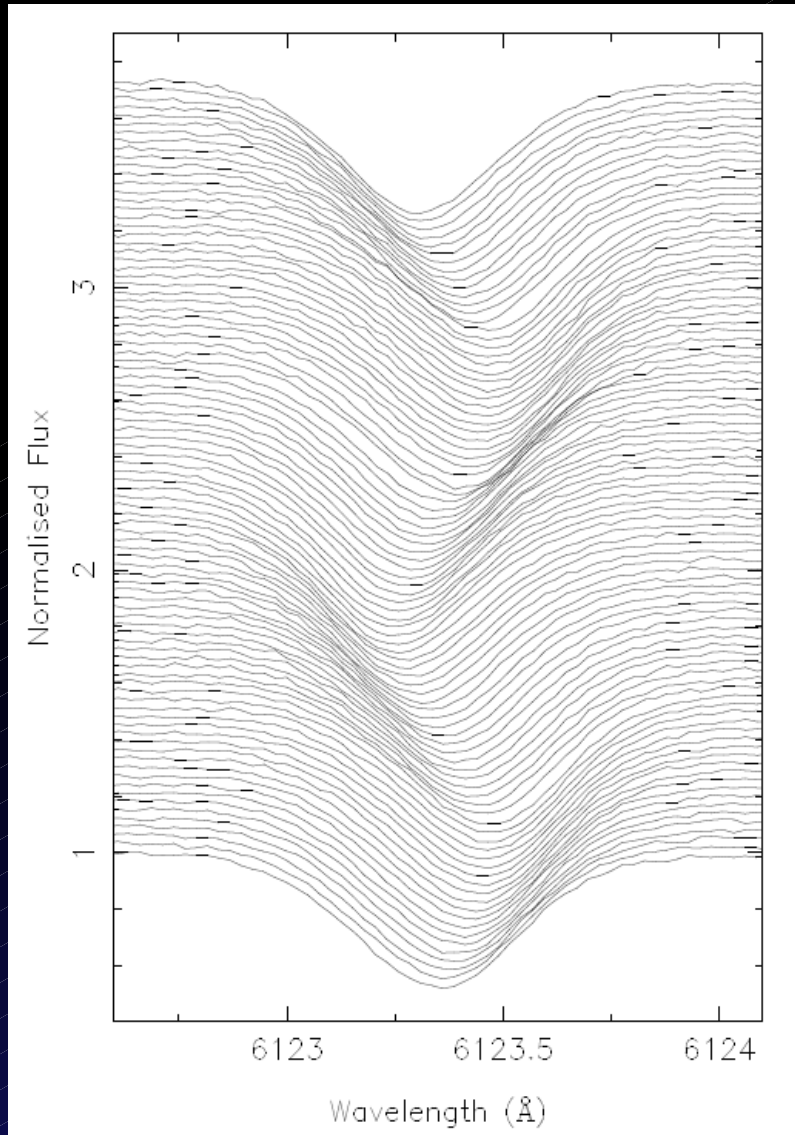
$$\ell = 2, m=1$$



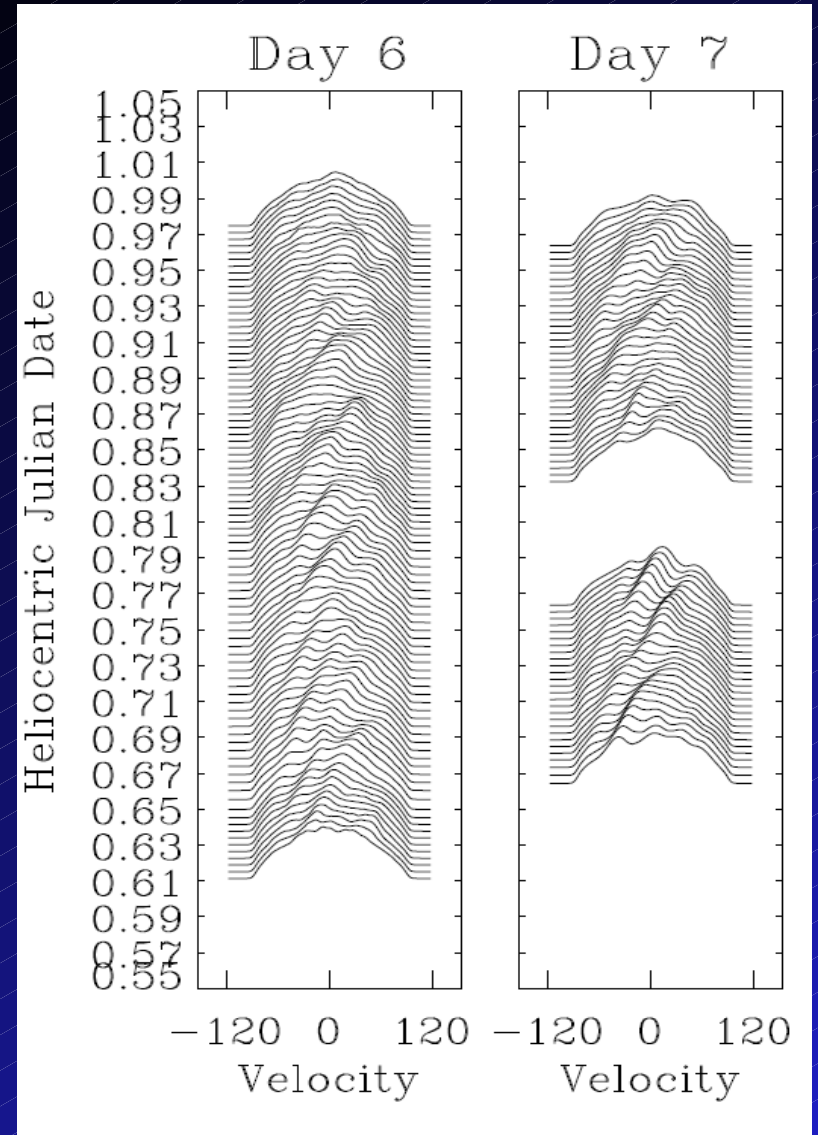
$$\ell = 8, m=3$$

Tim Bedding

Measured Pulsations



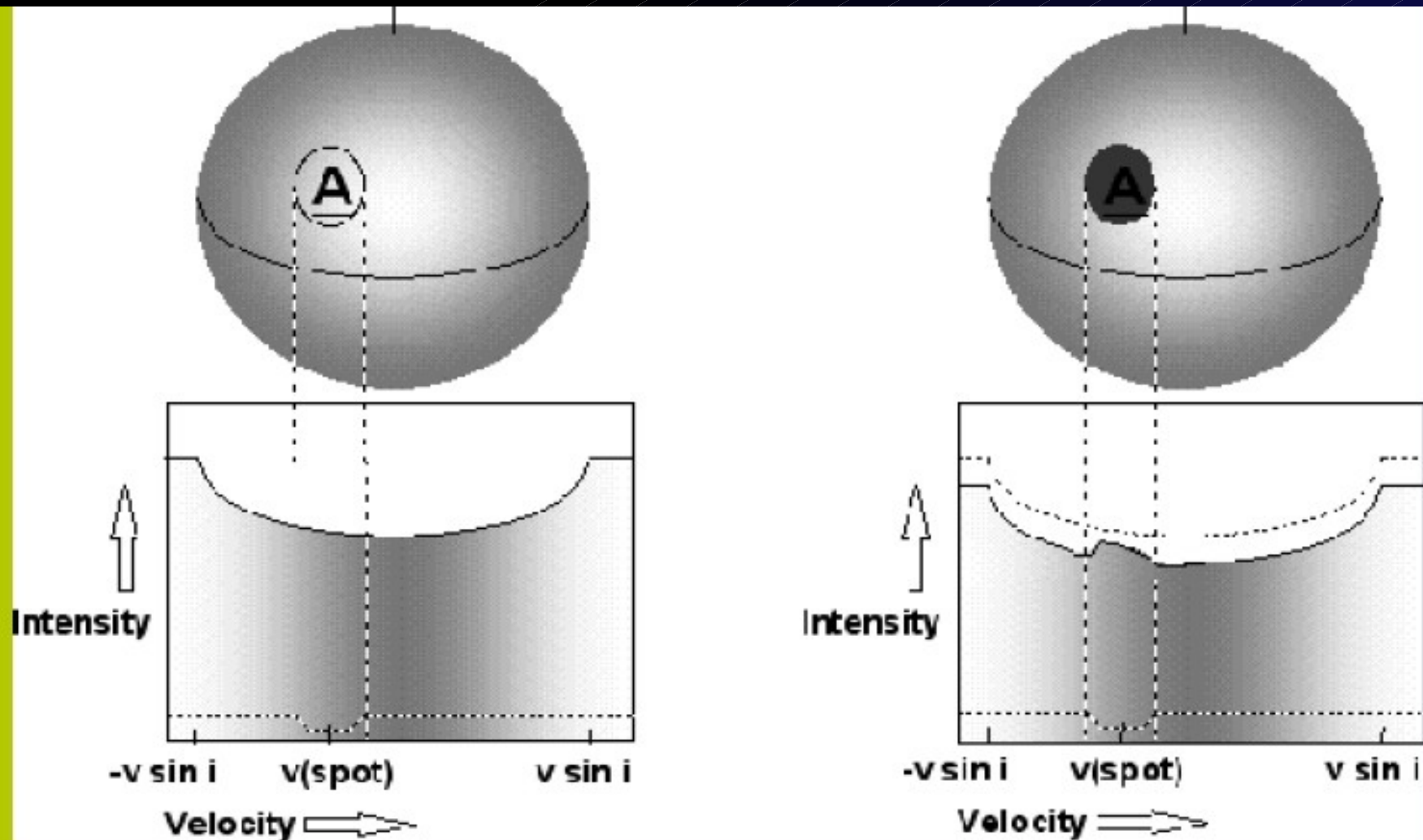
Rho Pup – del Sct type



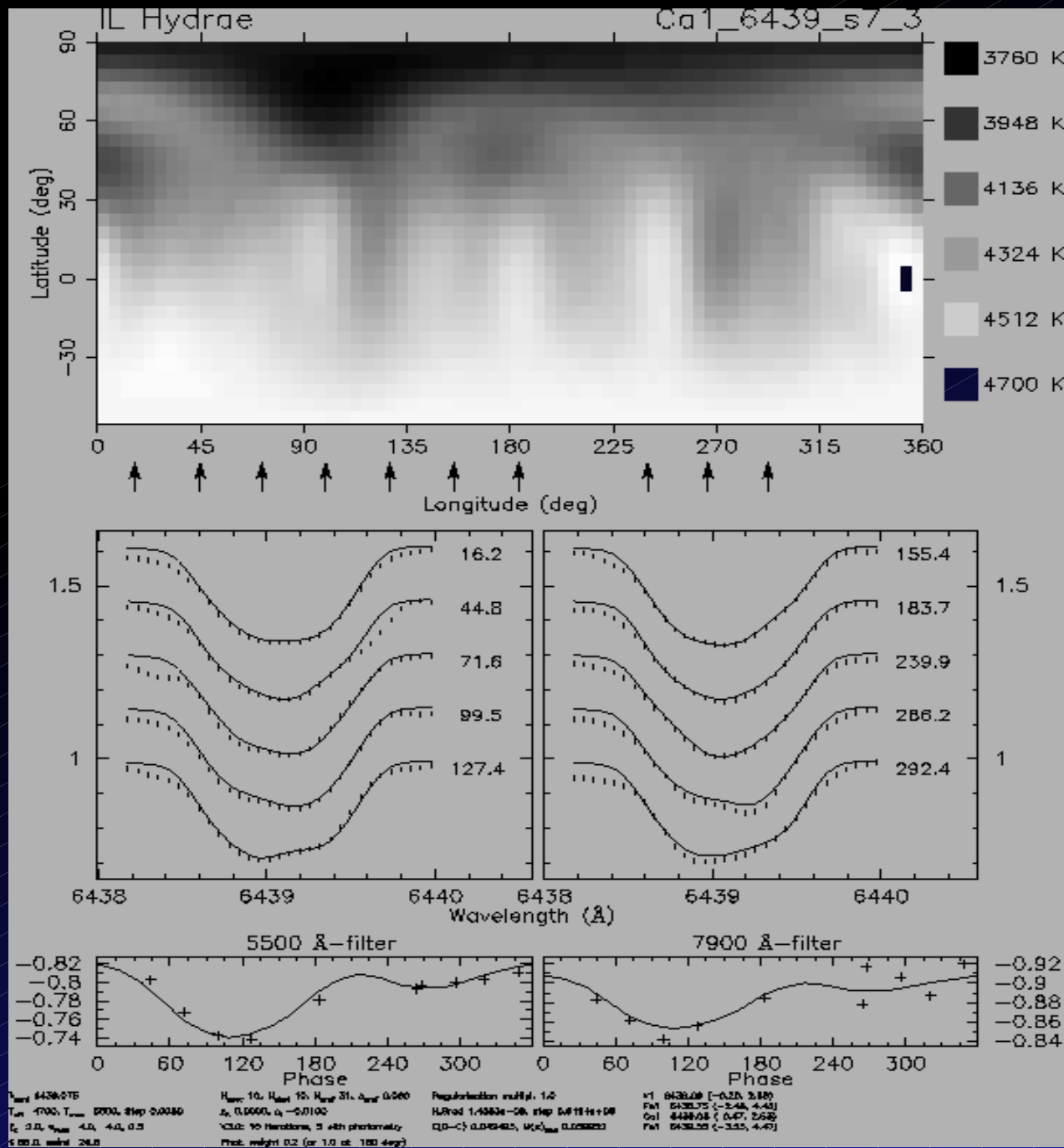
Eps Cep - del Sct type

Doppler Imaging

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



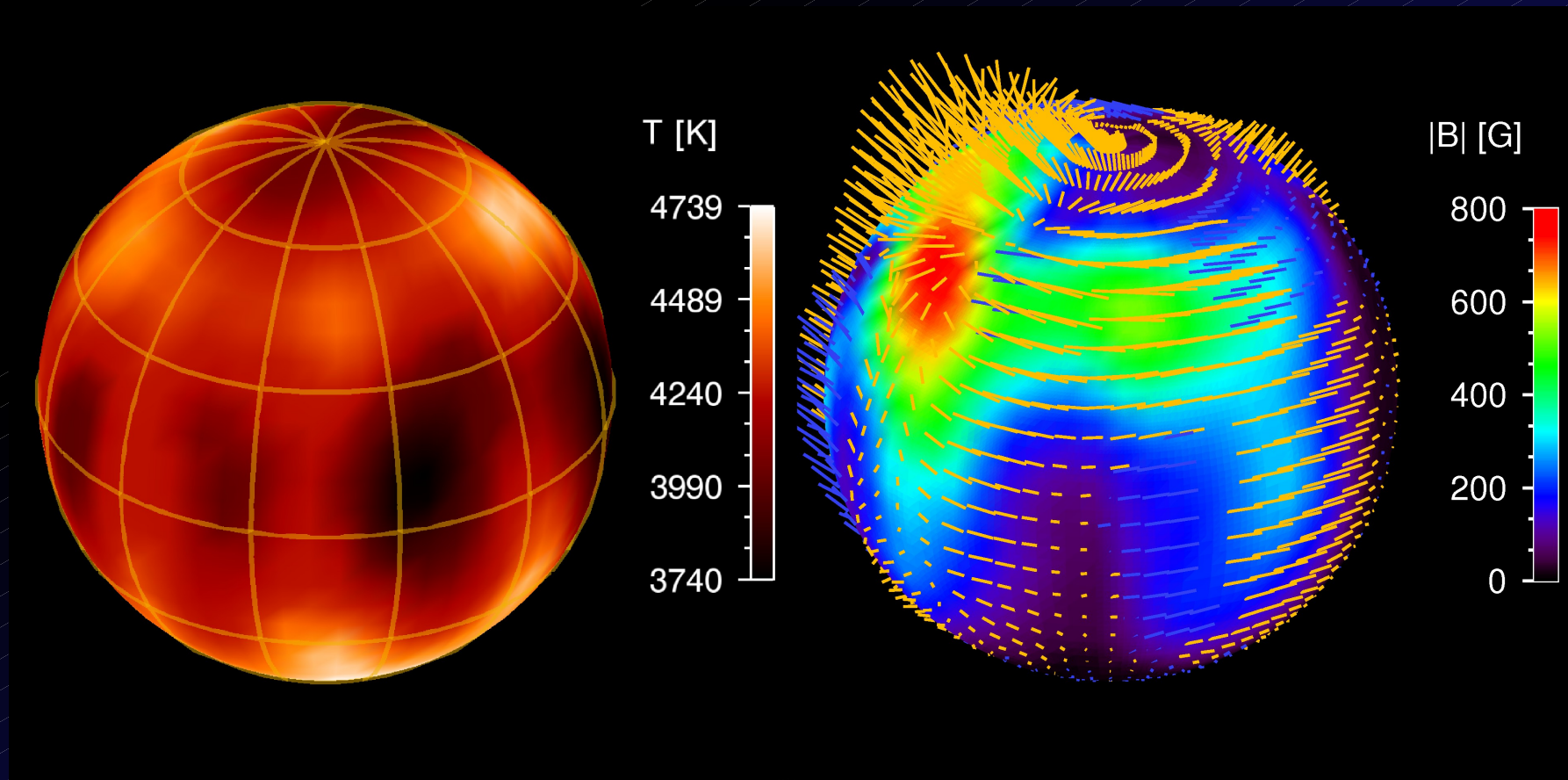
Doppler Imaging



Different elements

temperature
distribution

Zeeman Doppler Imaging



II Peg, Strassmeier 2007

Classification of hot subdwarfs

Winter 2006

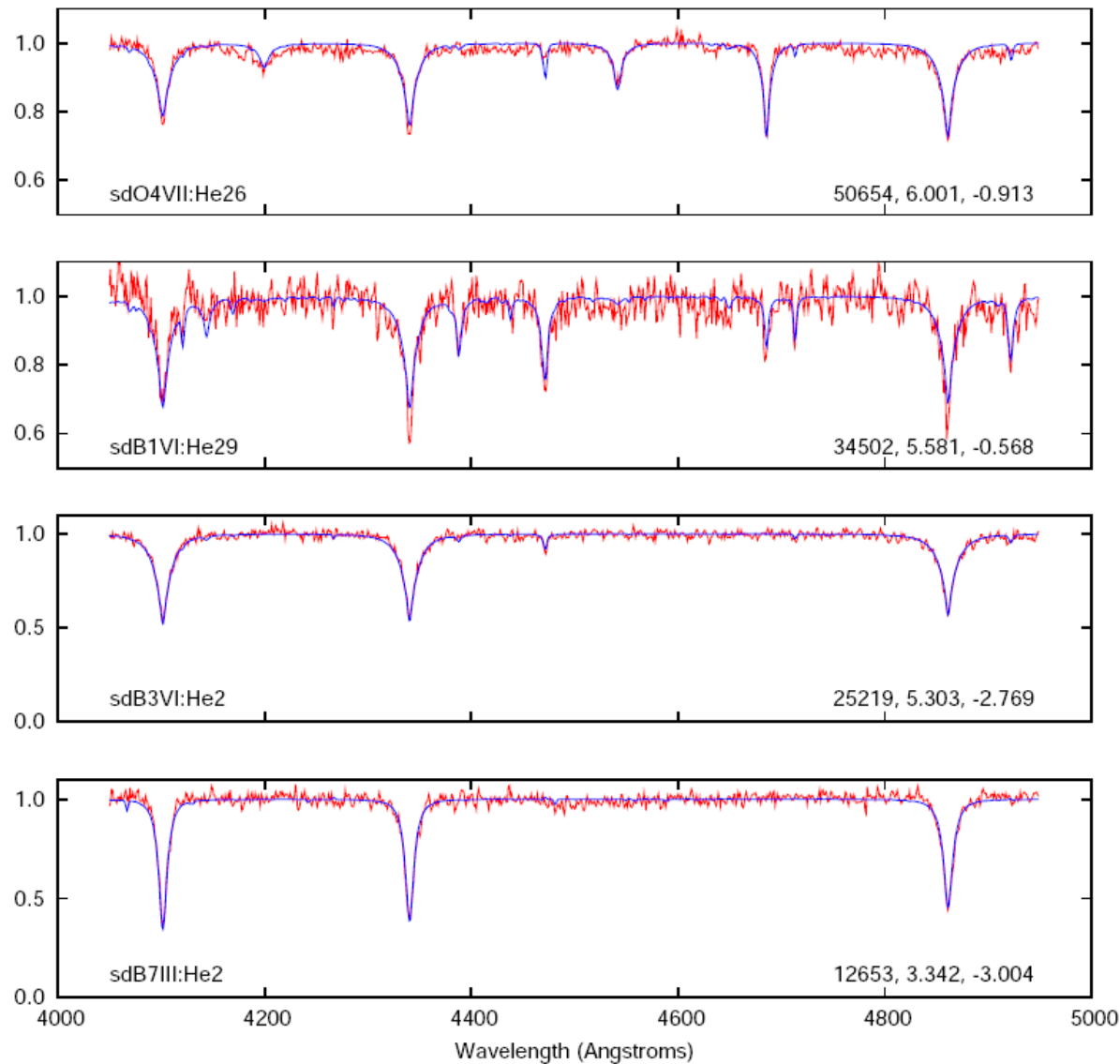


Figure 5.3: Four example fits from the 282 SDSS hot subdwarfs. The classification and physical parameters (T_{eff} (K), $\log g$, $\log(n_{\text{He}}/n_{\text{H}})$) obtained for each star are printed in the lower corners of each plot.

Simple Spectra Access Protocol Spectral Data Model

Simple Spectral Access Protocol V1.04



*International
Virtual
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Alliance*

Simple Spectral Access Protocol

Version 1.04

IVOA Recommendation Feb 01, 2008

This version:

<http://www.ivoa.net/Documents/REC/DAL/SSA-20080201.html>

Latest version:

<http://www.ivoa.net/Documents/latest/SSA.html>

Previous version(s):

Version 1.03, December 2007
Version 1.02, September 2007
Version 1.01, June 2007
Version 1.00, May 2007
Version 0.97, November 2006
Version 0.96, September 2006
Version 0.95 May 2006
Version 0.91 October 2005
Version 0.90 May 2005

Editors:

D.Tody, M. Dolensky

Authors:

D.Tody, M. Dolensky, J. McDowell, F. Bonnarel, T. Budavari, I. Busko, A. Micol, P. Osuna, J. Salgado, P. Skoda, R. Thompson, F. Valdes, and the data access layer working group.



*International
Virtual
Observatory
Alliance*

IVOA Spectral Data Model

Version 1.03

IVOA Recommendation 2007-10-29

This version (Recommendation Rev 1)

<http://www.ivoa.net/Documents/REC/DM/SpectrumDM-20071029.pdf>

Latest version:

<http://www.ivoa.net/Documents/latest/SpectrumDM.html>

Previous versions:

<http://www.ivoa.net/Documents/PR/DM/SpectrumDM-20070913.html>

Editors:

Jonathan McDowell, Doug Tody

Contributors:

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

SSAP Parameters

4.1.1 Mandatory Query Parameters

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

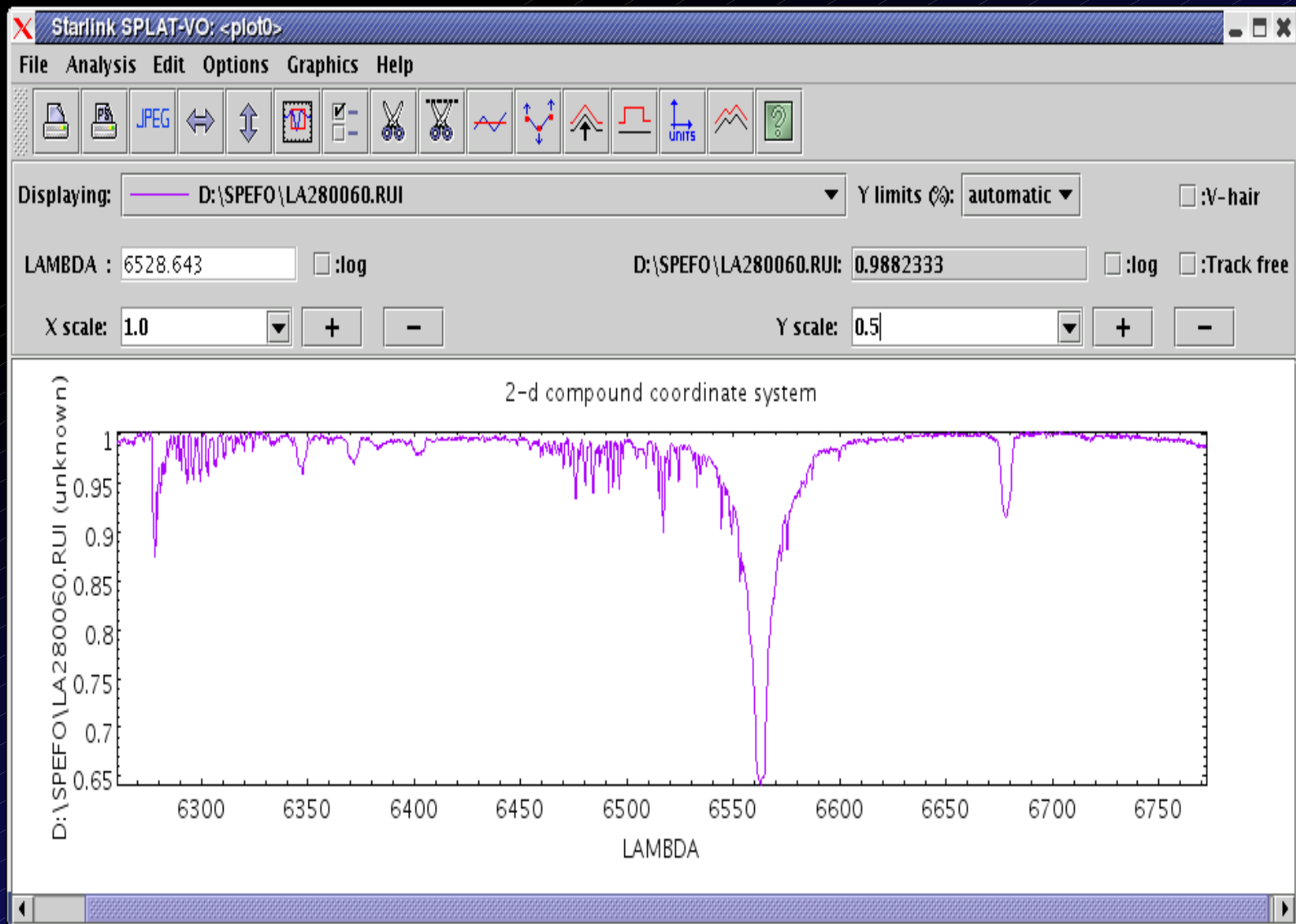
Parameter	Sample value	Physical unit	Datatype
POS	52, -27.8	degrees; defaults to ICRS	string
SIZE	0.05	degrees	double
BAND	2.7E-7/0.13	meters	string
TIME	1998-05-21/1999	ISO 8601 UTC	string
FORMAT	votable	-	string

4.1.2 Recommended and Optional Query Parameters

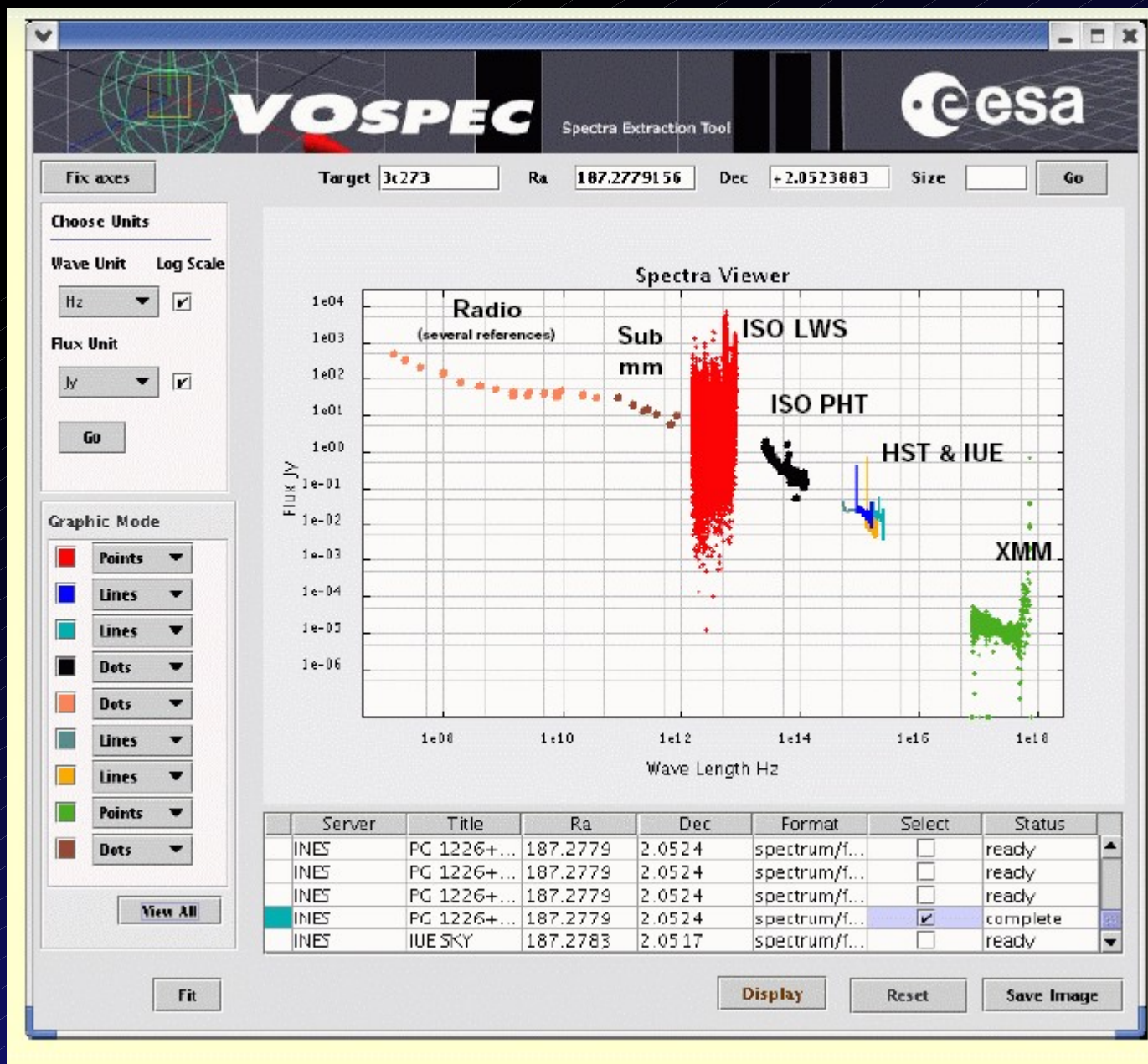
Parameter	Sample value	Unit	Req	Datatype
APERTURE	0.00028 (=1")	degrees	OPT	double
SPECRP	2000	$\lambda/d\lambda$	REC	double
SPATRES	0.05	degrees	REC	double
TIMERES	31536000 (=1yr)	seconds	OPT	double
SNR	5.0	dimensionless	OPT	double
REDSHIFT	1.3/3.0	dimensionless	OPT	string
VARAMPL	0.77	dimensionless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

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

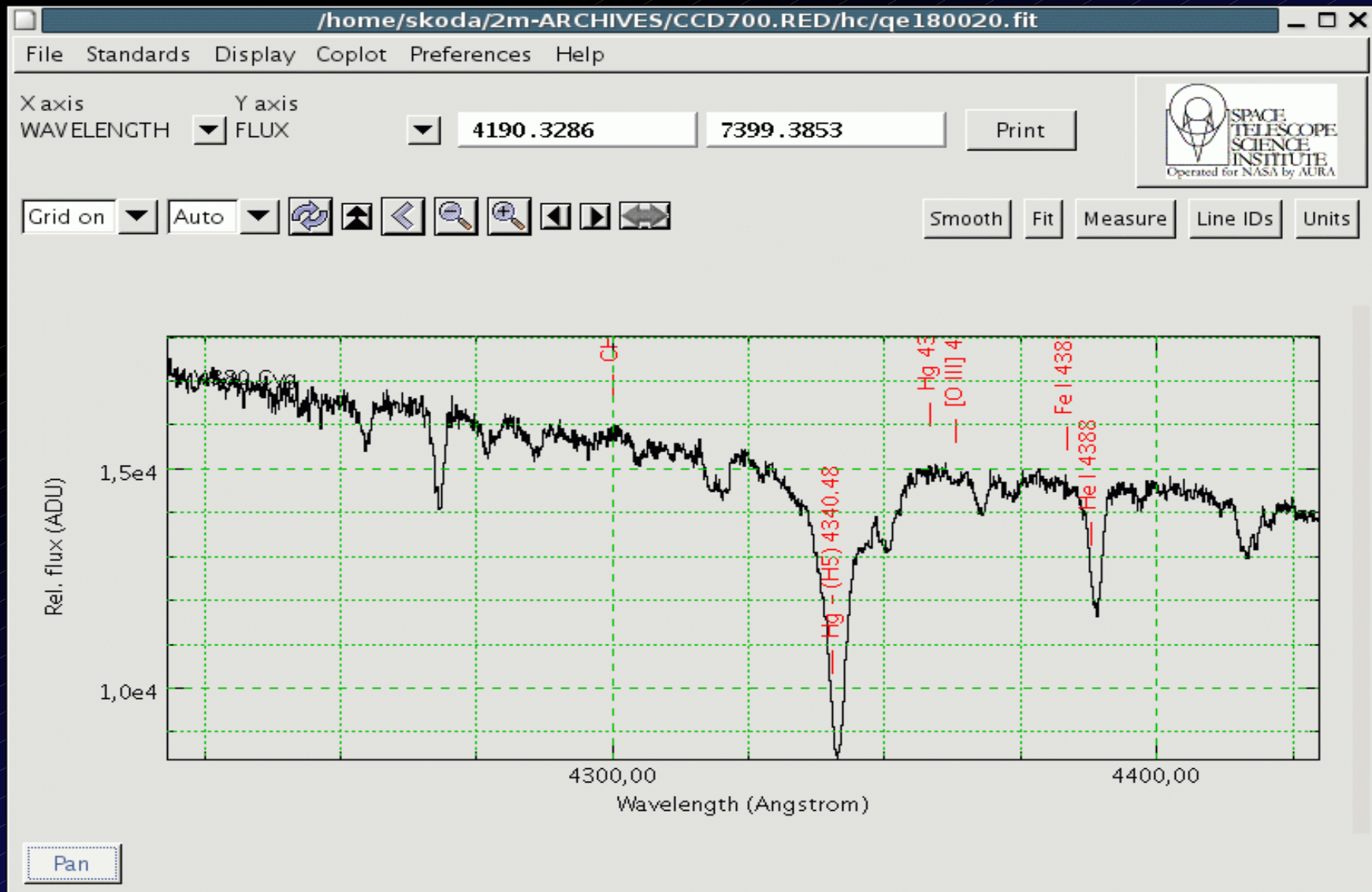
SPLAT-VO (Starlink, JAC)



VOspec (ESAC)



SpecView (STScI)



CIELO VO – line catalogue SLAP

SLAP Viewer Copyright ESAC, Spain

Server Selector

SLAP Services

- IASD
- LERMA
- NIST ATOMIC SPECTRA
- CIELO SLAP

Molecular line databases

<http://esavo02:8080/cieloslapToolKit/cieloslap.jsp?>

Select

Range of Search (m)

Wavelength Start Wavelength End

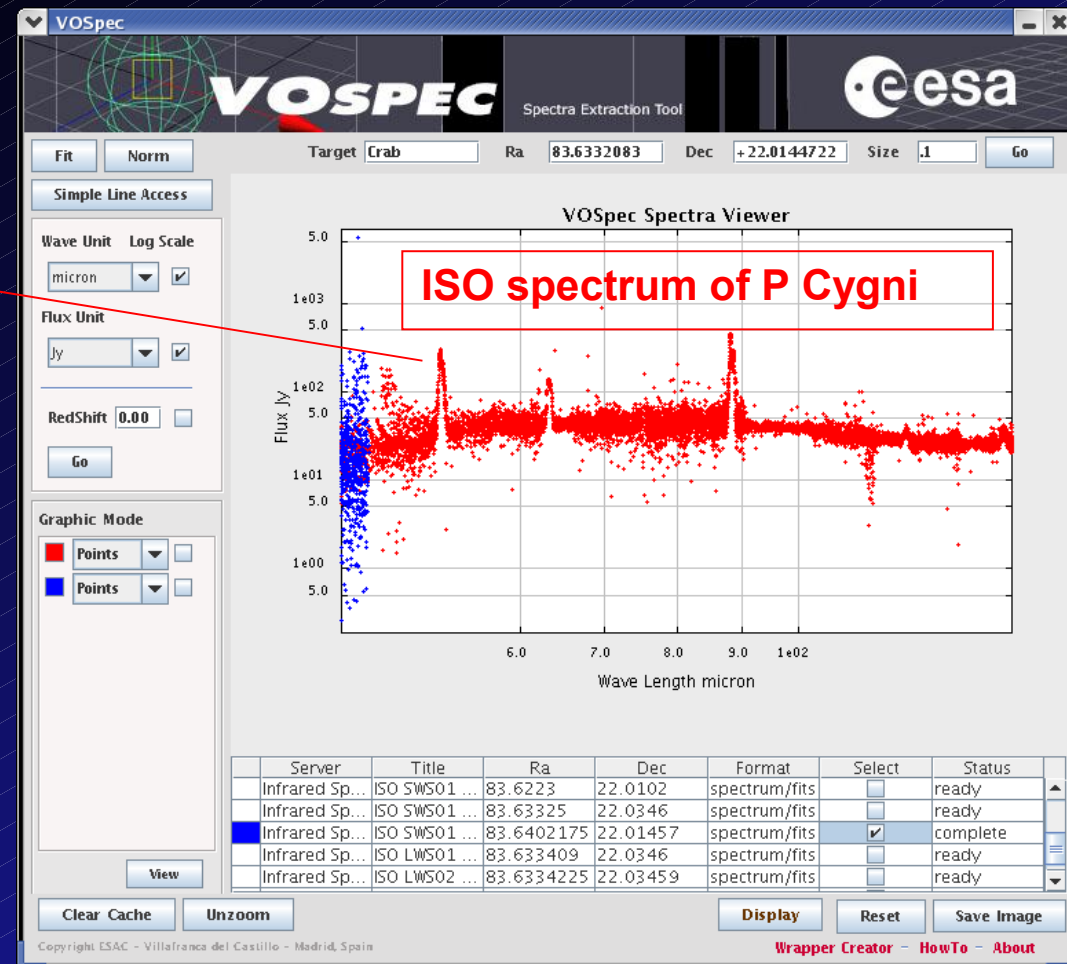
Reset

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	...
2.1621e-09	NGC1068	40.66963	-0.01328	1s_2p	1s2	3P1	150	OVII	...

Close



(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 ~20 databases

Virtual Atomic and Molecular Data Centre

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

(includes VALD extractor, NIST)

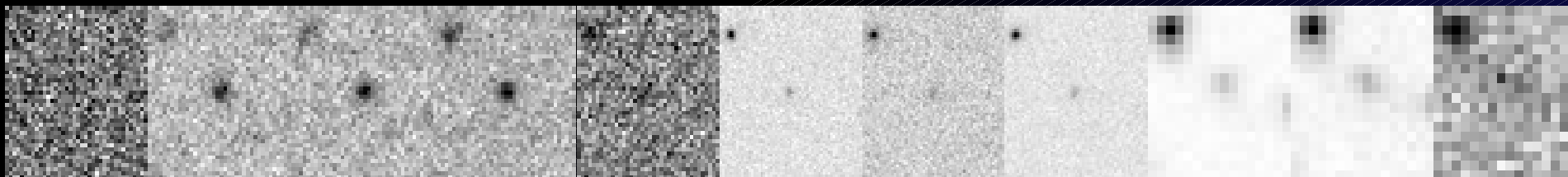
SLAP, XML

extended citation system (all providers acknowledged)

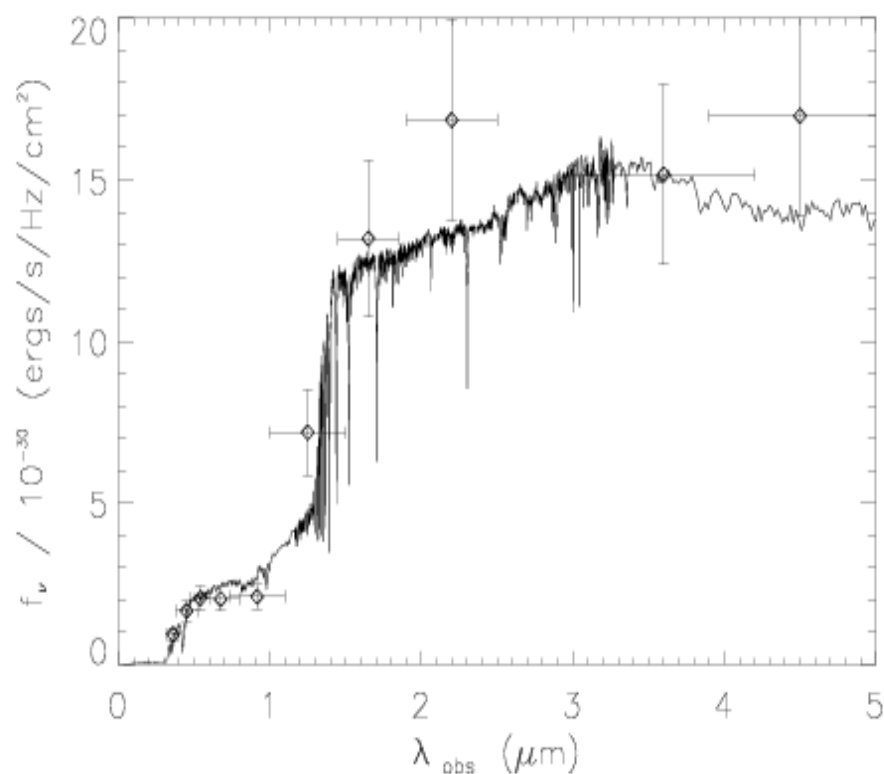
Theoretical spectra

- Methods of VO - accessing simulated spectra
- TSAP - difference (POS not mandatory)
- Other params ($\log g$, T_{eff} , metallicity ...)
- Theoretical Spectra converted to VO standards (SVO) or computed on the fly and stored (GAVO)
- Dialog client – server(capabilities, param range)

SED from photometry



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



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

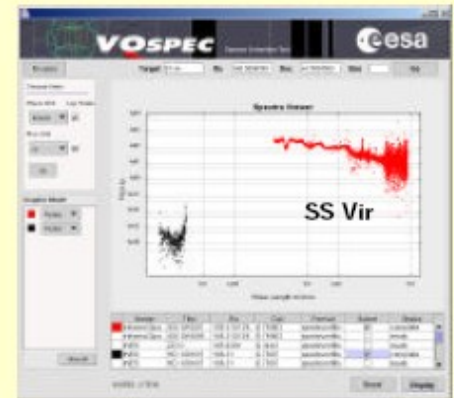
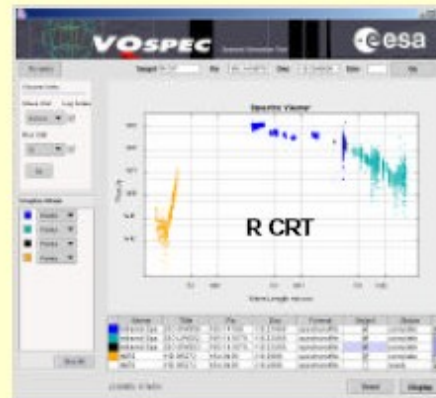
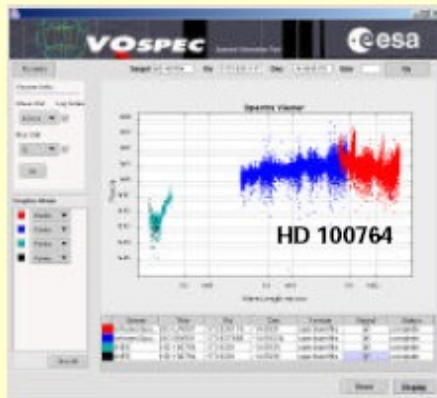
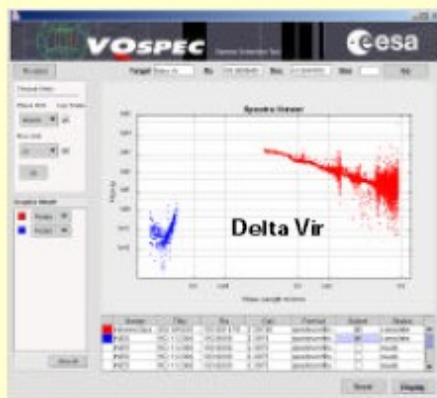
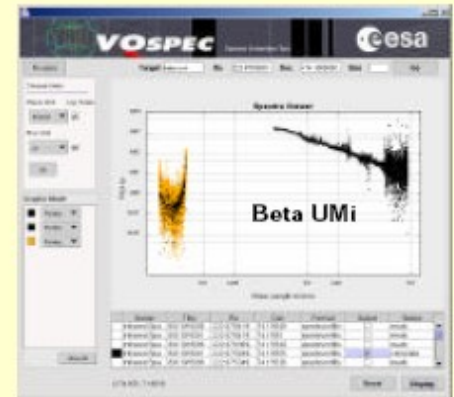
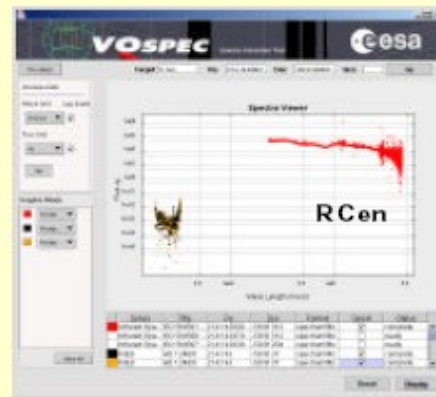
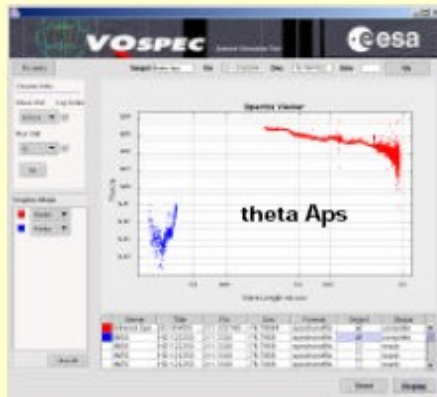
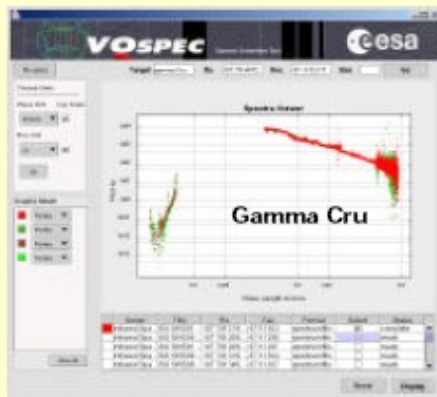
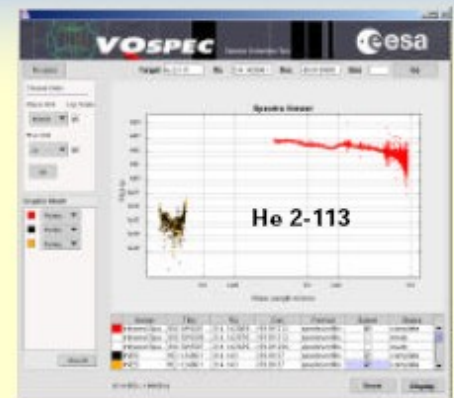
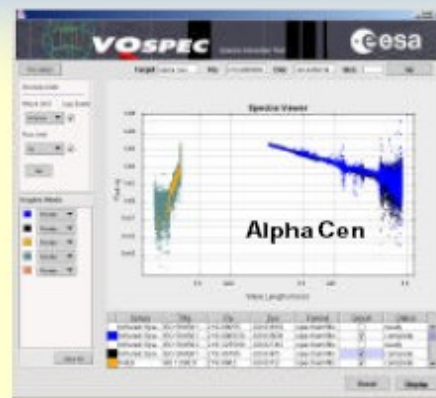
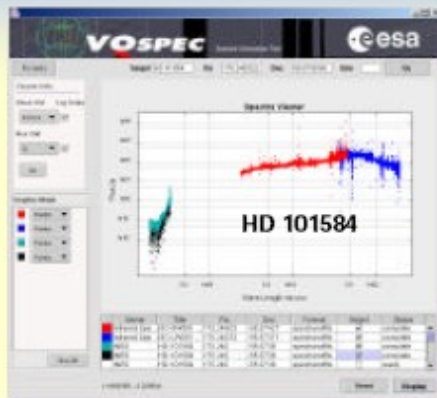
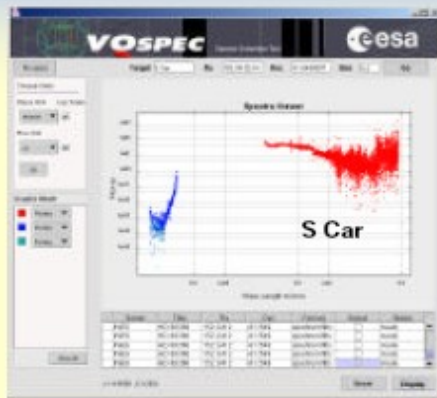
Age = 500 Myr

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

Reduced chi-sq = 1.04

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

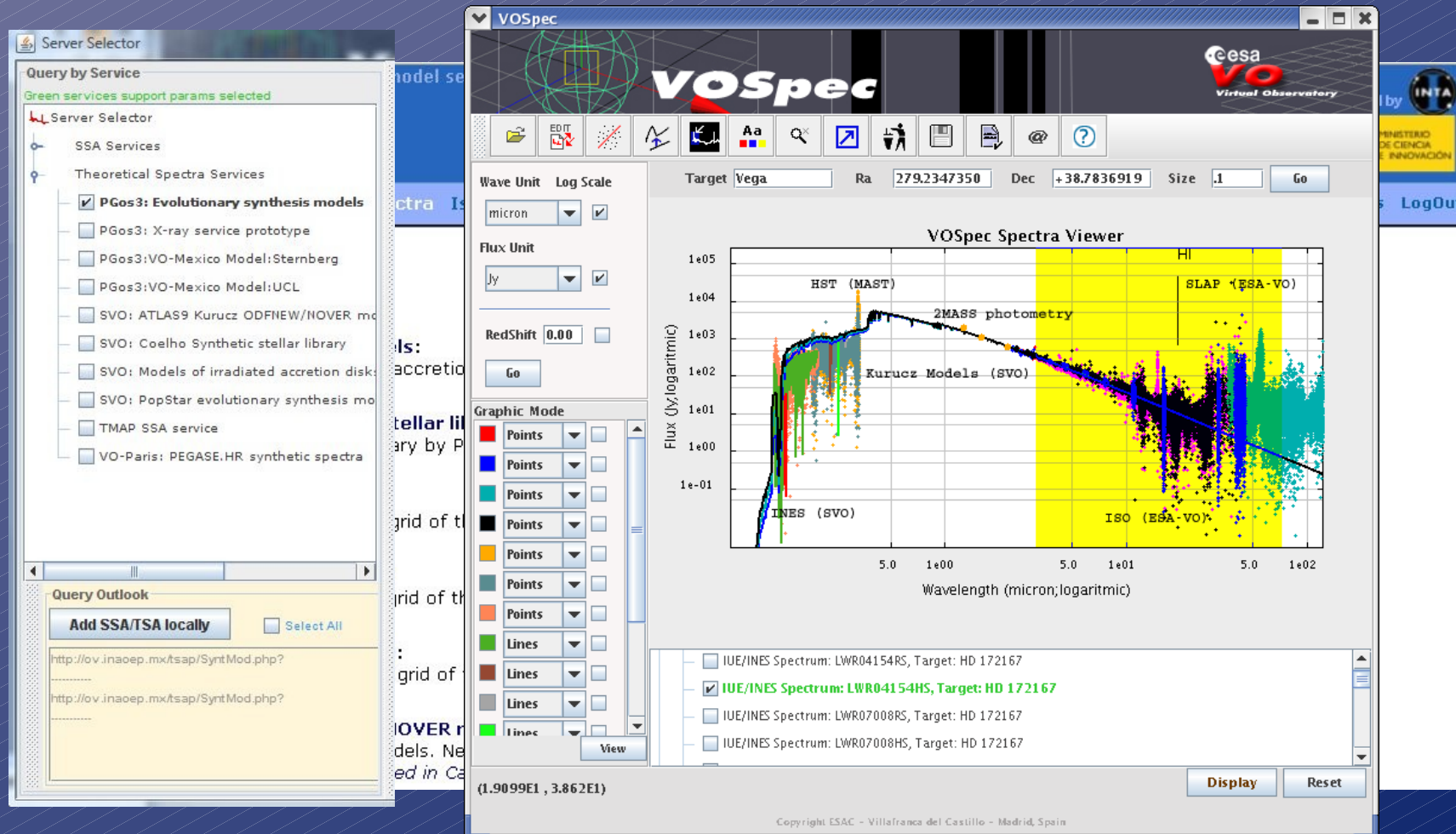
VOSpec working example: Sampling AGBs



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

Simple Spectral Access Protocol V1.04

Appendix A: Theoretical Spectral Access Use Case



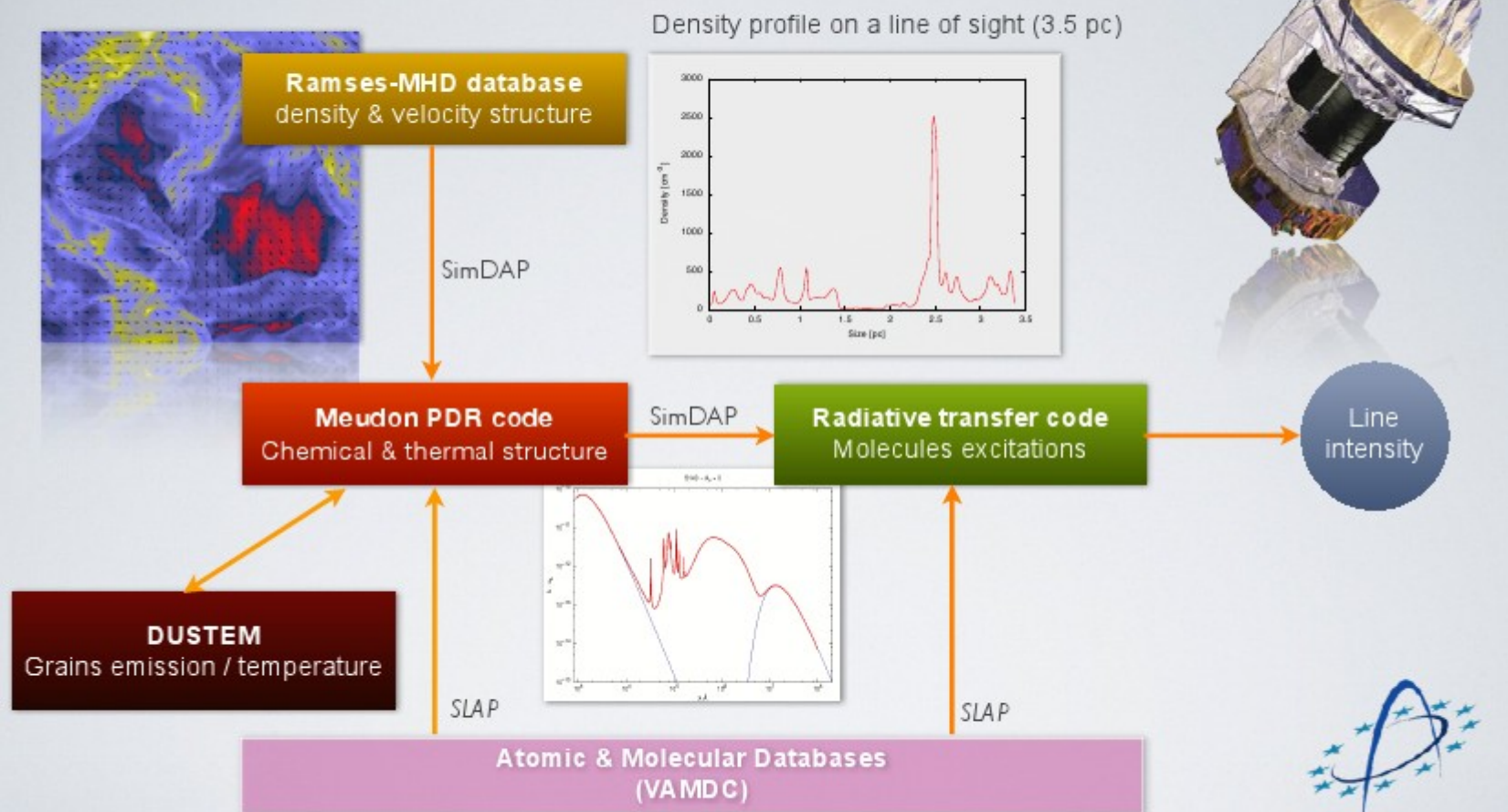
Theory VO (TVO)

- Methods of VO (parameters in DB, SQL...) for study of results of simulations , catalogues of simulated objects
- Browsing of simulation space along different axes – parameters, regions...
- Evolutionary tracks (BaSTI)
- Photo Dissociation Regions
- Formation of artificial galaxies, clusters
 - N body models
- Cosmology

Complex join of TVO bricks

□ Interstellar Medium Platform

STARFORMAT project (PI: P. Hennebelle)



Using SimDB/SimDAP

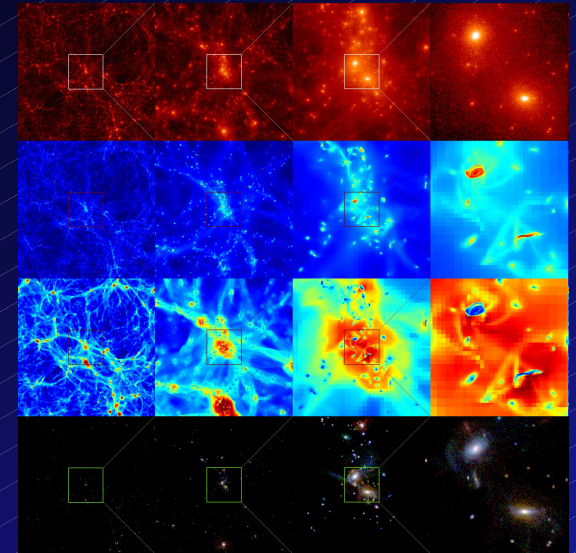
- Cosmological simulations
 - Prototypes for GalMER, Horizon
- PDR simulations
 - test implementation of Meudon PDR code
- Isochrones/evolutionary tracks
 - BaTSI
- Visualization tools
 - VisIVO

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

VIRGO

GA VO

GERMAN VIRTUAL OBSERVATORY

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

Millennium Run
10,077,696,000 particles

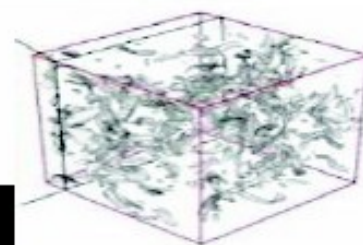


Emergence of a Fourth Research Paradigm

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

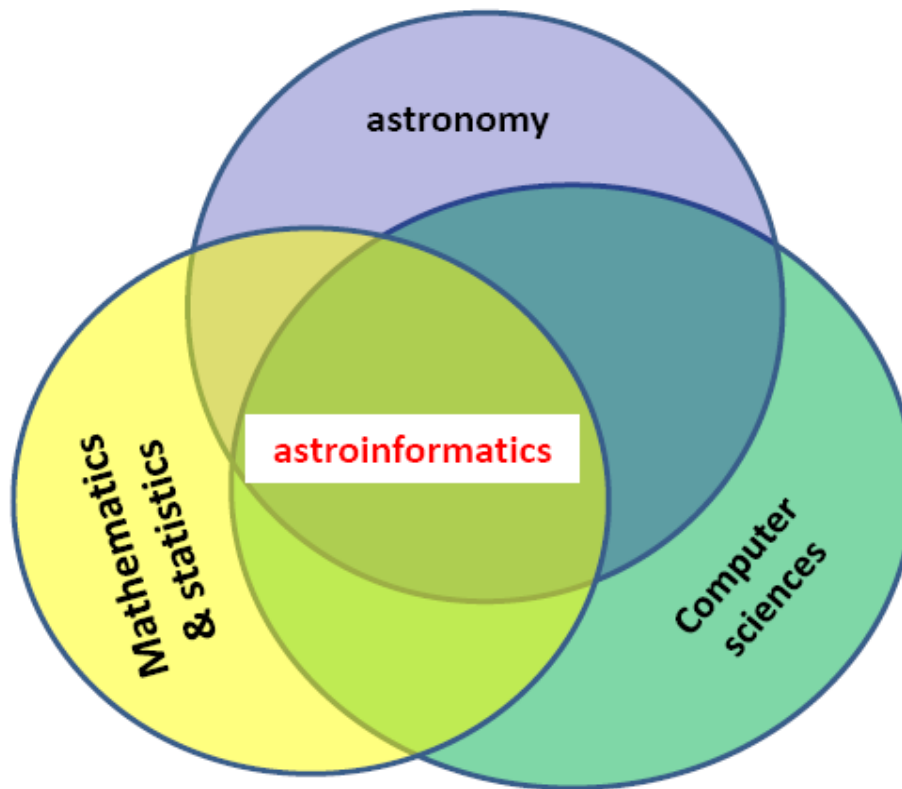


$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K \frac{c^2}{a^2}$$



(With thanks to Jim Gray)

Experimental astronomy has become a three players game



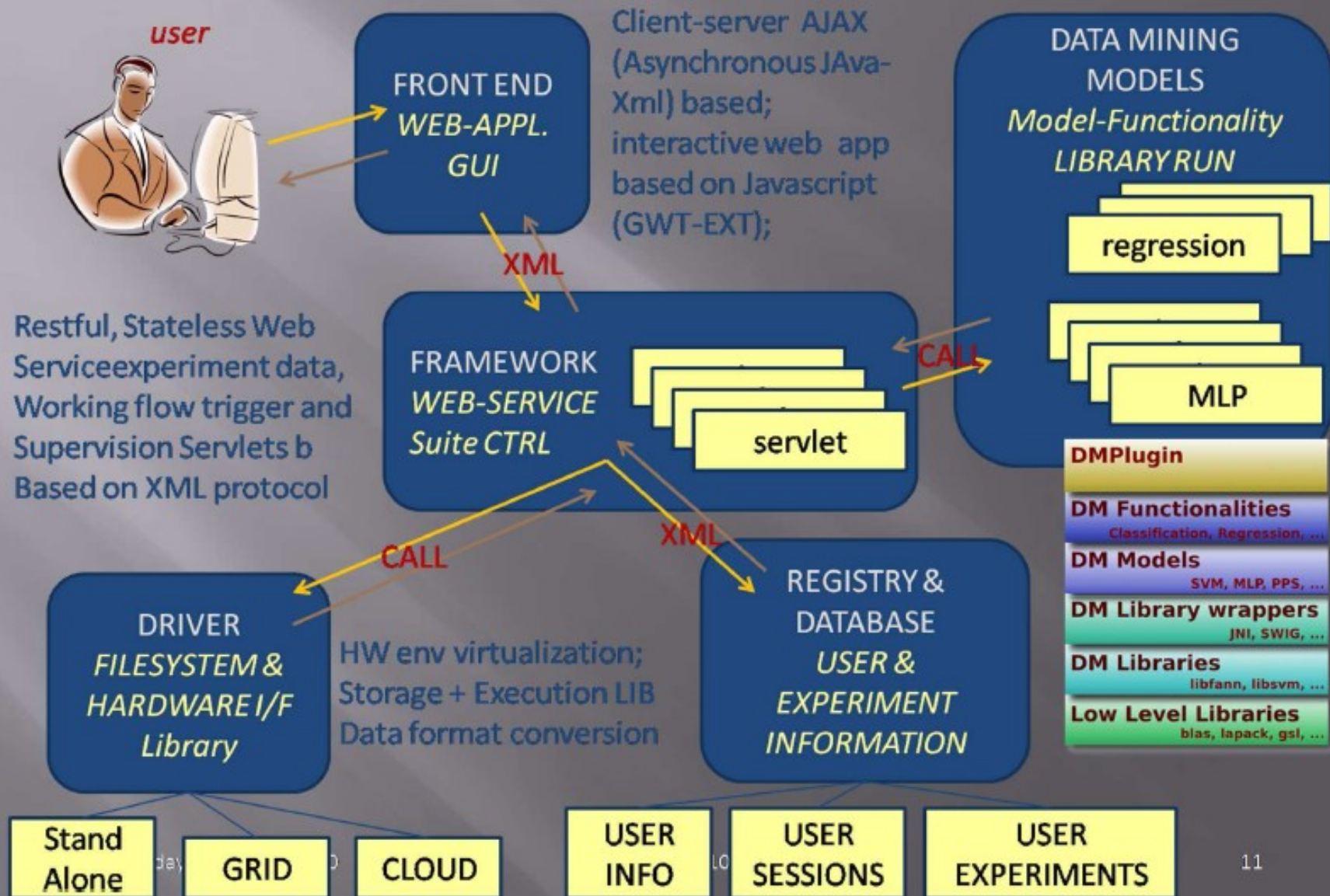
- **astronomy:** problems, data, understanding of the data structure and biases
- **mathematics:** evaluation of the data, falsification/validation of theories/models, etc
- **computer science:** implementation of infrastructures, databases, middleware, scalable tools, etc

- **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

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
- Regression
- Supervised learning (Neural Networks, SVM)
- Examples
 - Photometric RedShift
 - Searching for QSO (light curves, spectra)
 - Automatic Light curves classification (GAIA, LSST)
- Very NEW – emerging discipline

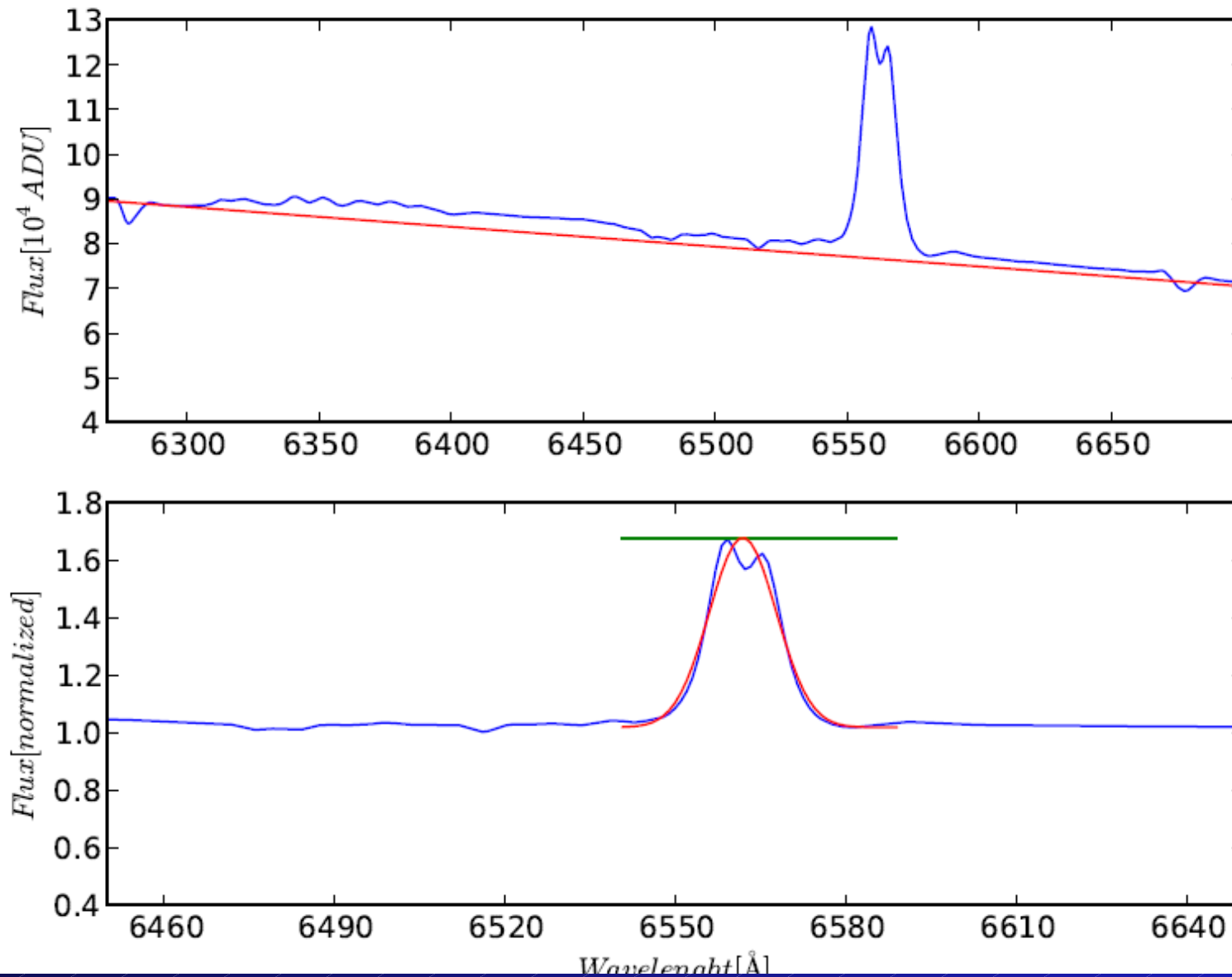
DAMEWARE SW Architecture



11

12

Feature extraction (emission)



Be Star Candidate #1 in SEGUE

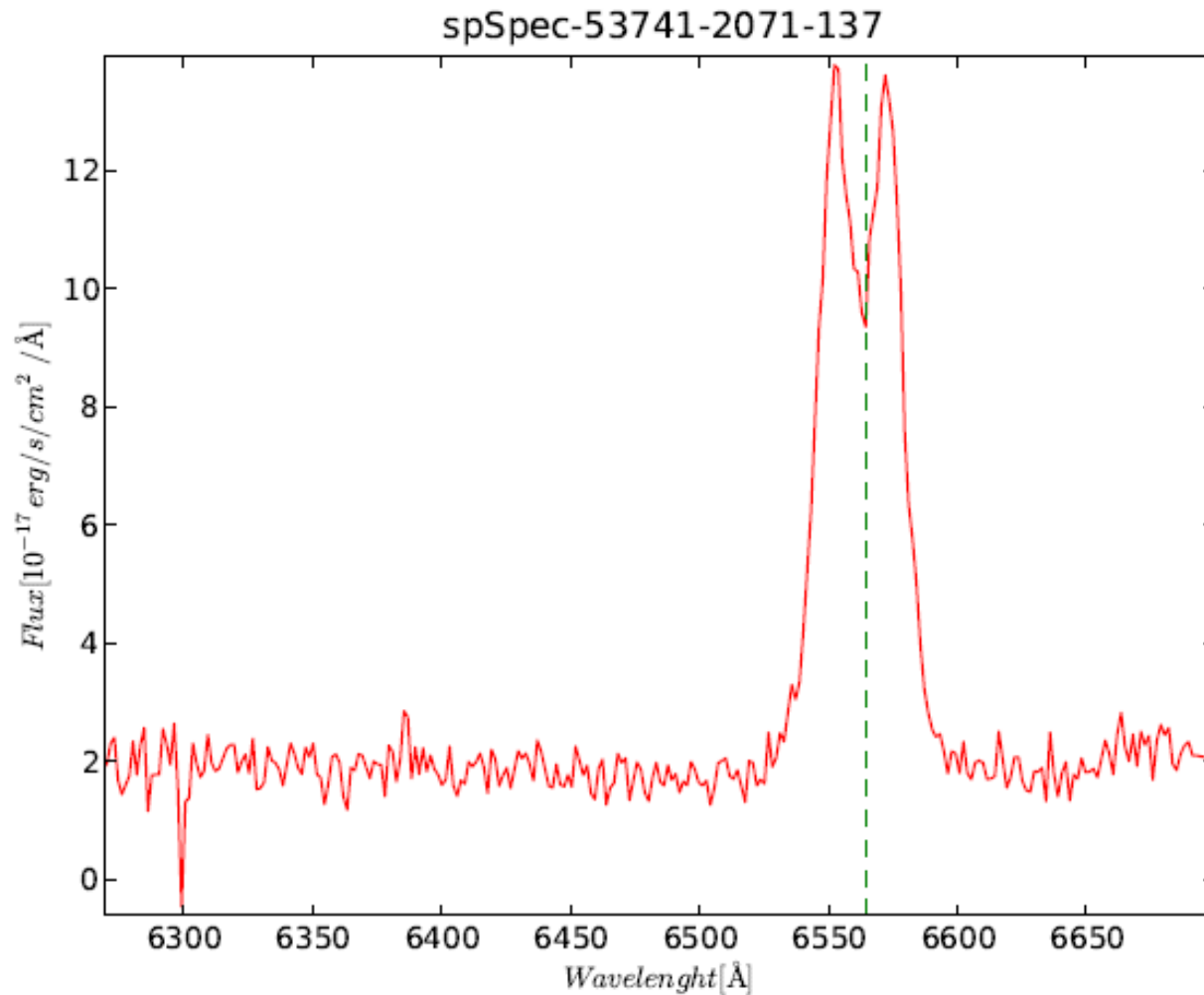
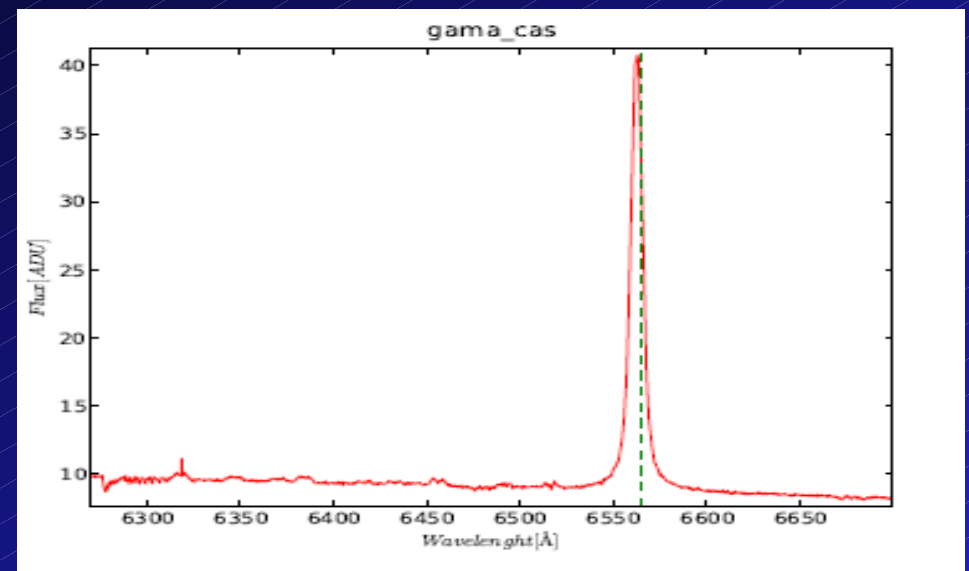
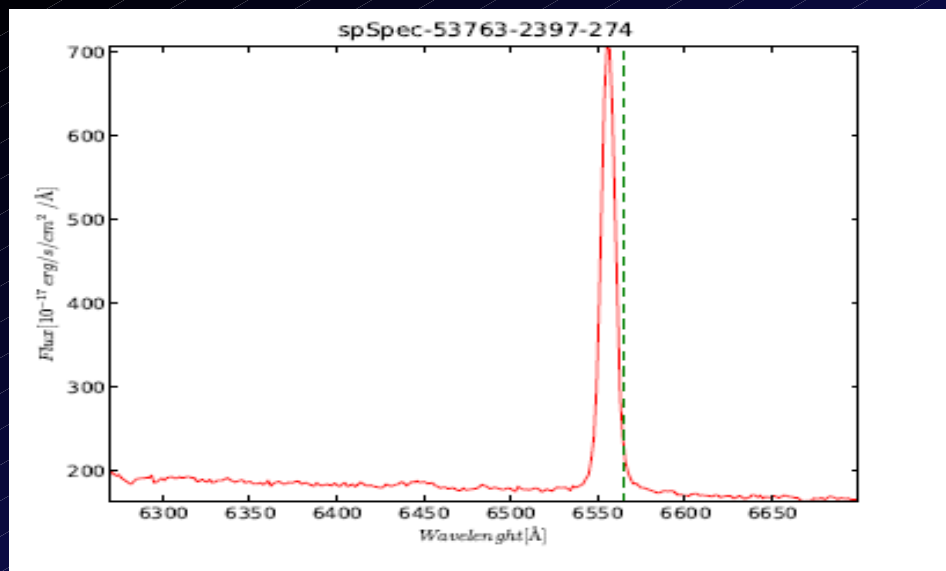
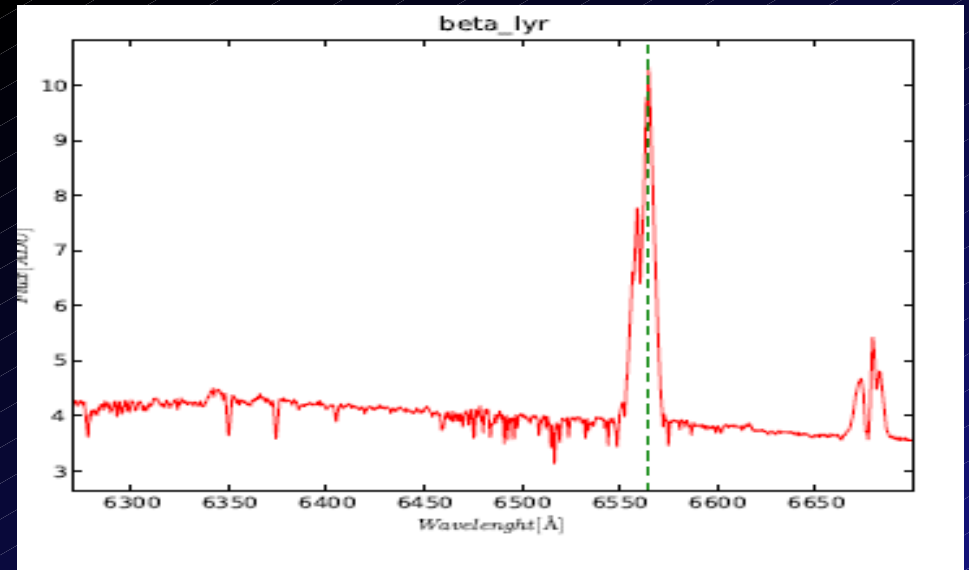
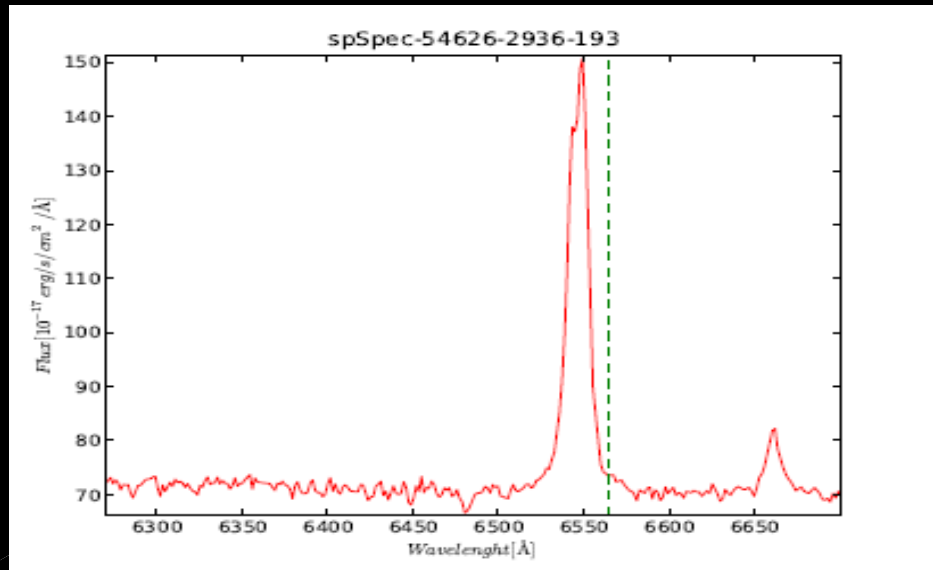


Figure 3.11: Example 1: SDSS J035747.16-063850.7

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

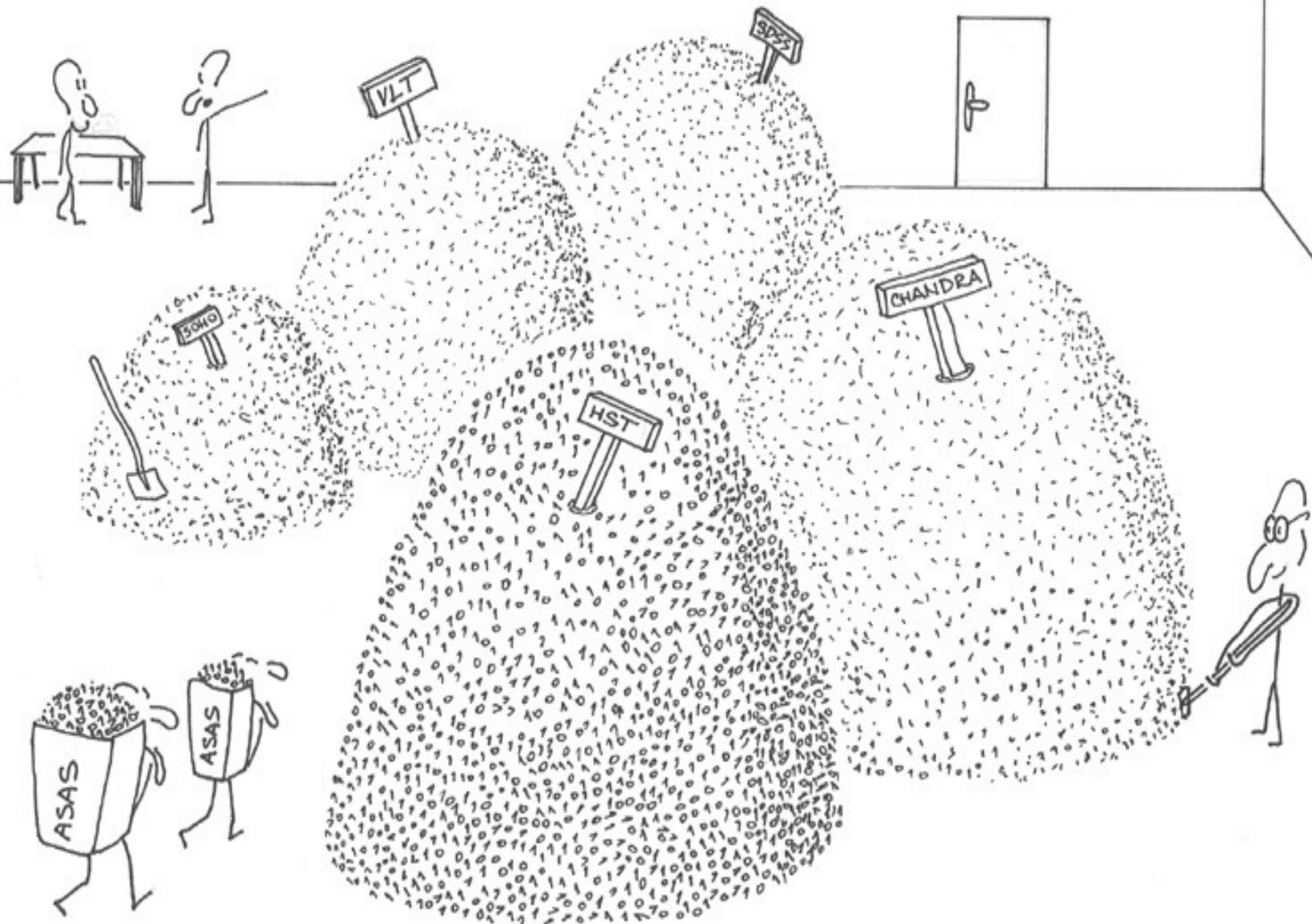
Tools are already here or will come soon

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

Astroinformatics – extraction of knowledge

e-Science in astronomy, VO=harness of AI

VIRTUAL OBSERVATORY



DEMO

SPLAT the BEST !!!!

SSA – HEROS CUTOUT SERVICE – blue and red channel

FLUXCALIB=normalized (NORM{b,r}xnnnnn.fit)

POS (name resolver) or TARGETNAME (no space!)

BAND=6550e-10/6570e-10 – cut Halpha line

Using SPLAT stacking – order offset 0.05 ...

DEMO

Zeta Tau in Halpha

Phi Per

V360 Lac - thick disk – messy profiles

Rho Aur – Binarity

96 Her - double absorption to single

del Sco – profile rising

Catch ! 28 Tau and 27 Tau in POS SIZE=10arcs

With TARGETNAME HR1847B