



# Spectra in VO From Under Both Hats



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# Information from (multi) spectral lines

Position (wavelength):

Chemical elements

Excitation / Ionization state (Grid of models) SLAP, LineTAP

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)

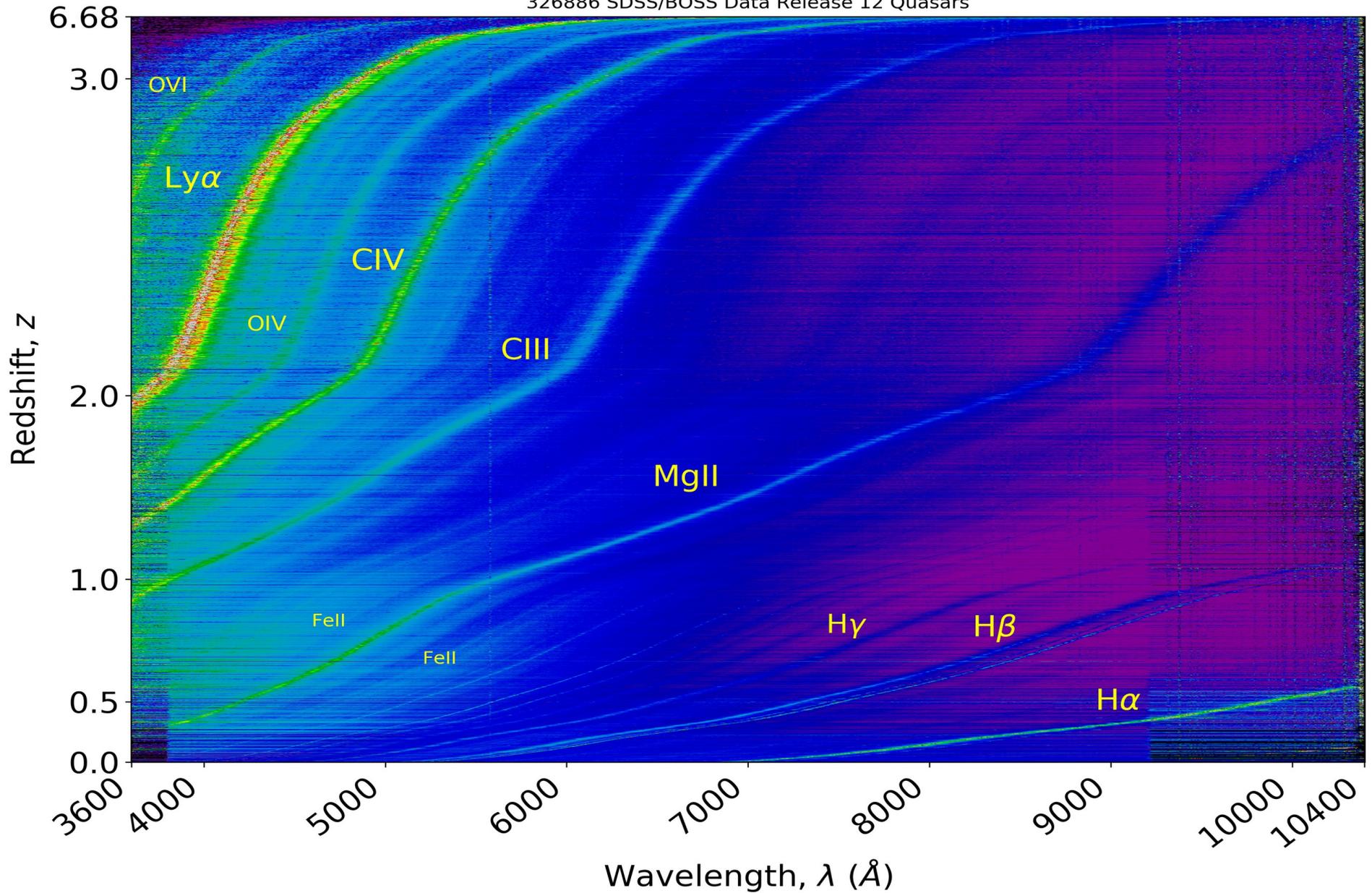
Non radial pulsations (NRP)

Multiple systems – disentangling of orbital parameters, individual spectra

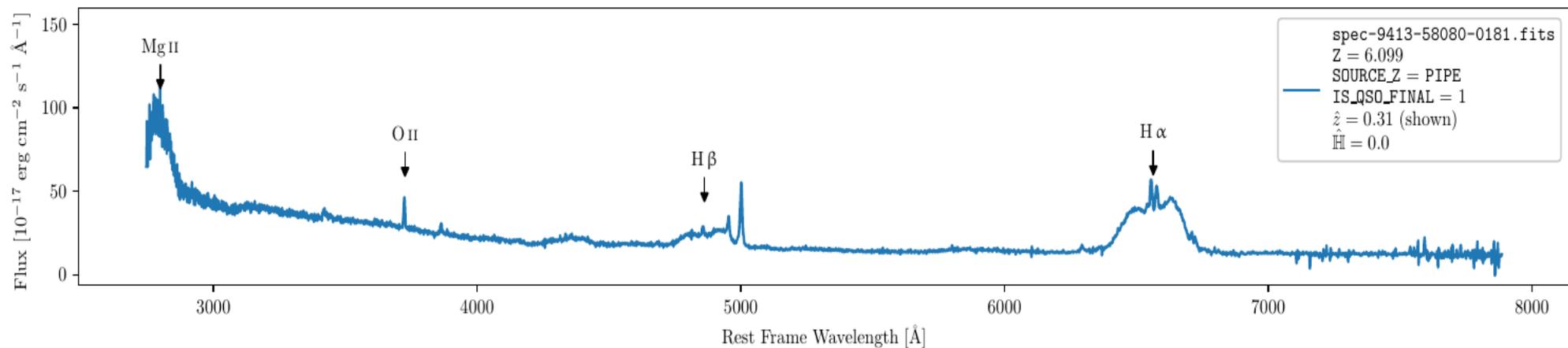
Detection of ES planets in spectra

# Redshift

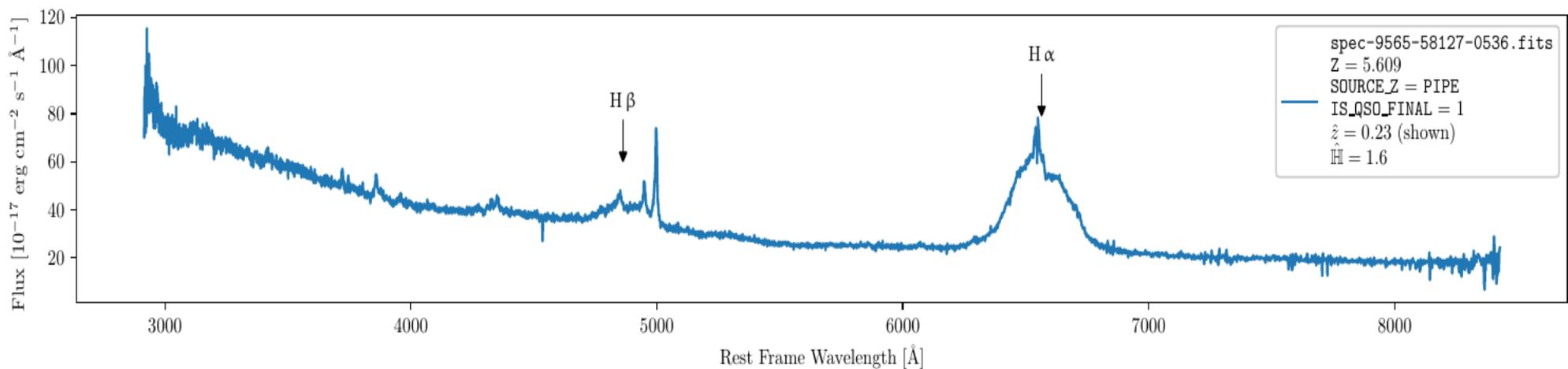
326886 SDSS/BOSS Data Release 12 Quasars



# Eliminating false high-z QSO

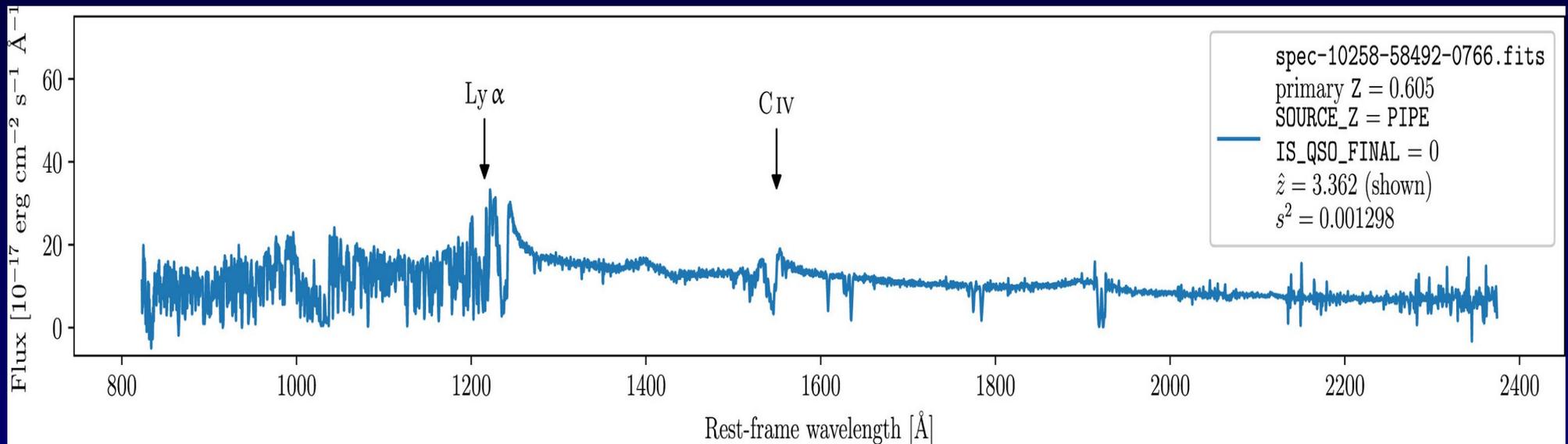
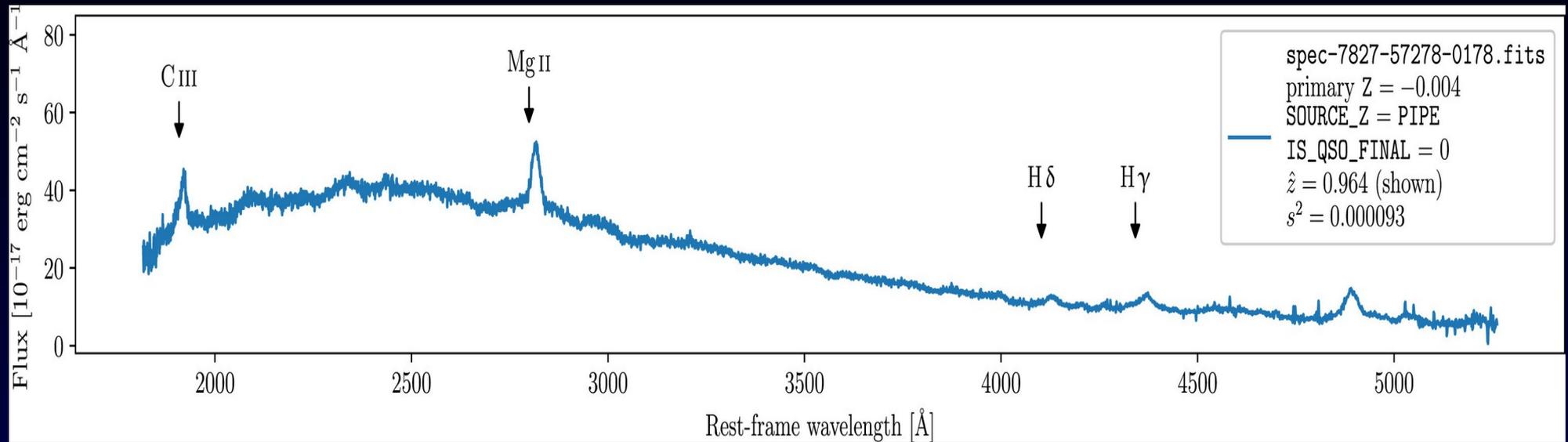


**Figure B6.** Spectrum with incorrectly high redshift prediction by the pipeline. The Bayesian CNN correctly predicted  $\hat{z} = 0.31$  with  $\hat{H} = 0$ .

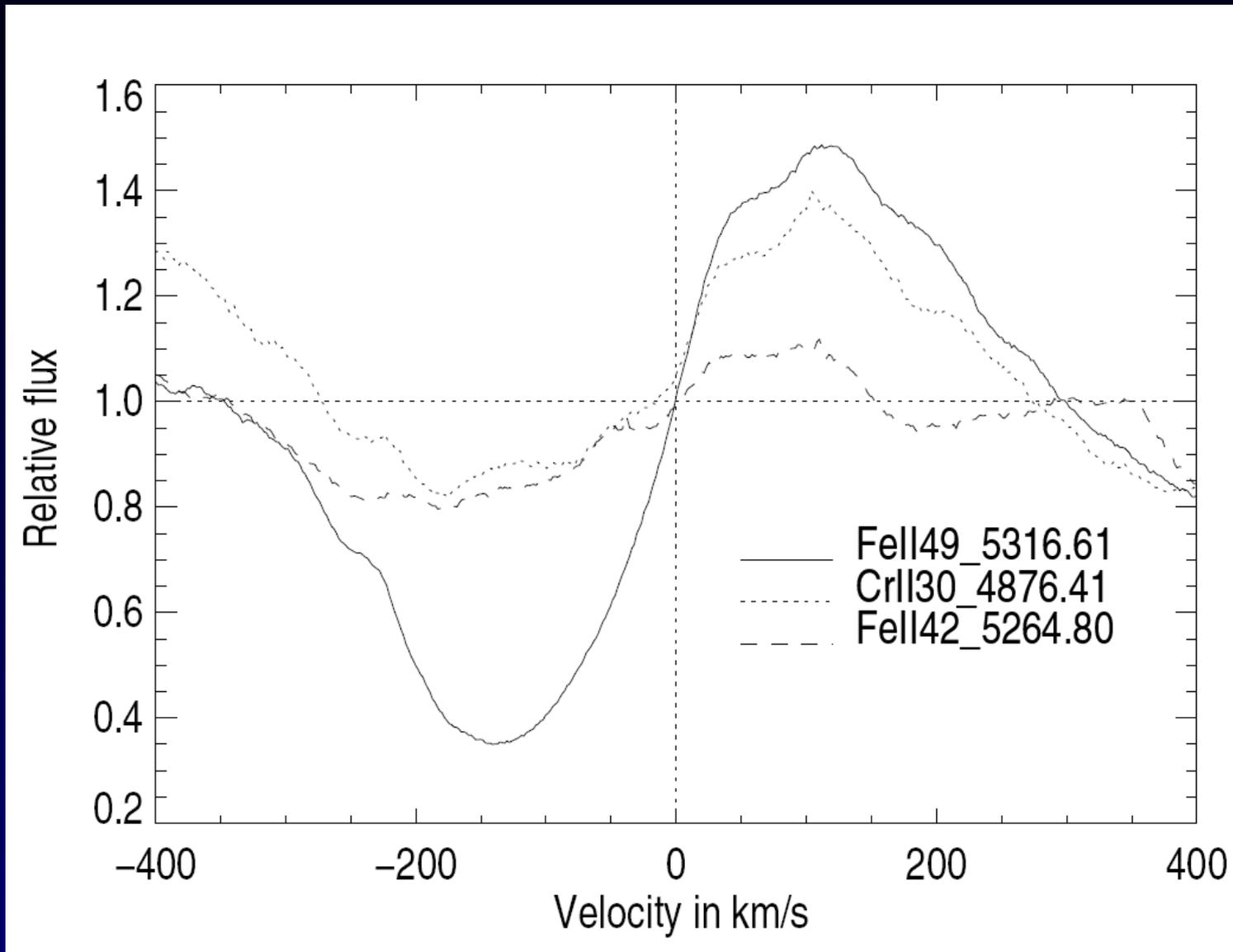


**Figure B7.** Spectrum with incorrectly high redshift prediction by the pipeline. The Bayesian CNN correctly predicted  $\hat{z} = 0.23$  with  $\hat{H} = 1.6$ .

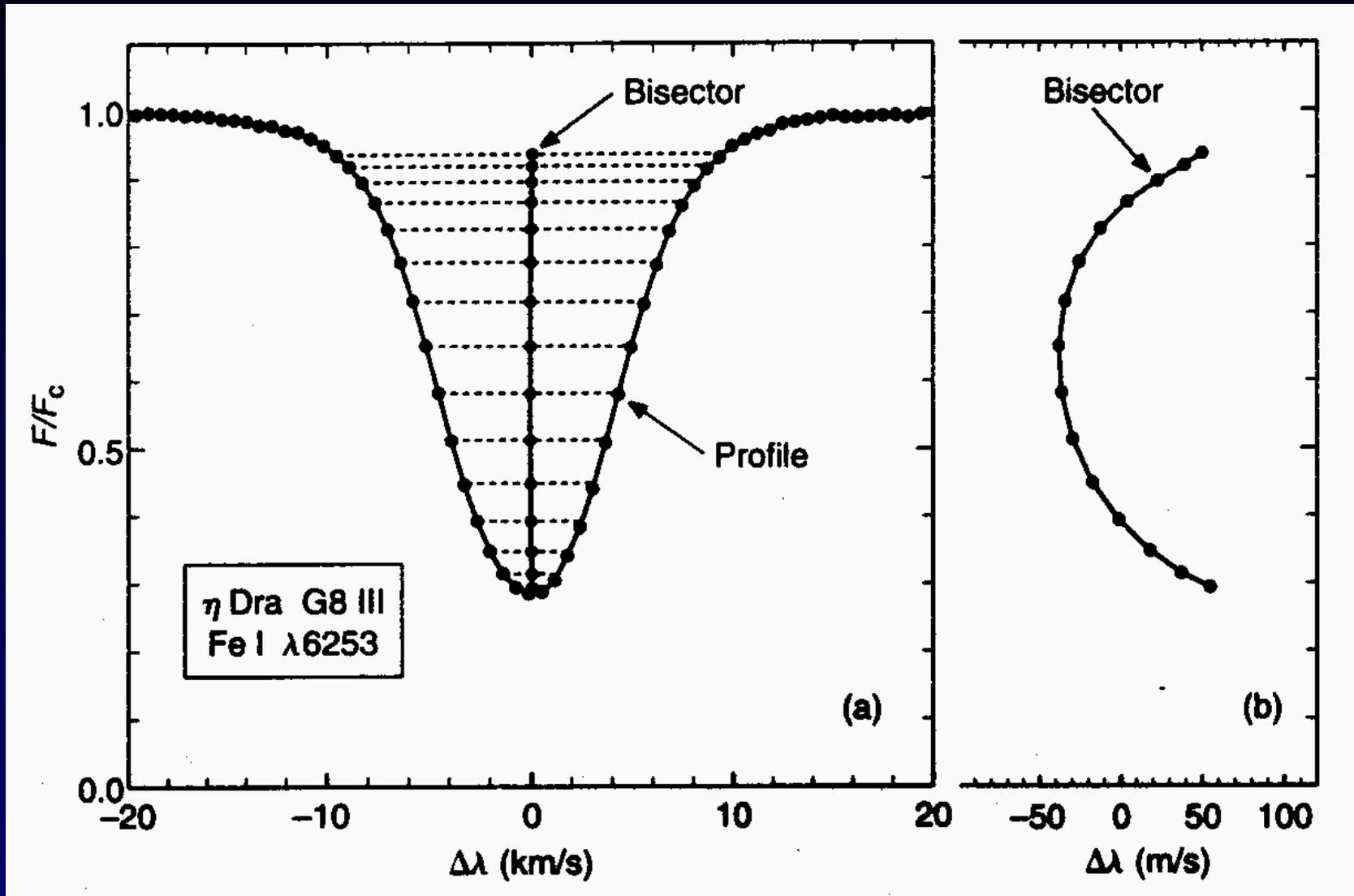
# QSOs missing due to SDSS pipeline error



# Different Lines overplotted in RV



# Bisector Method



# Line Profile- Bisectors

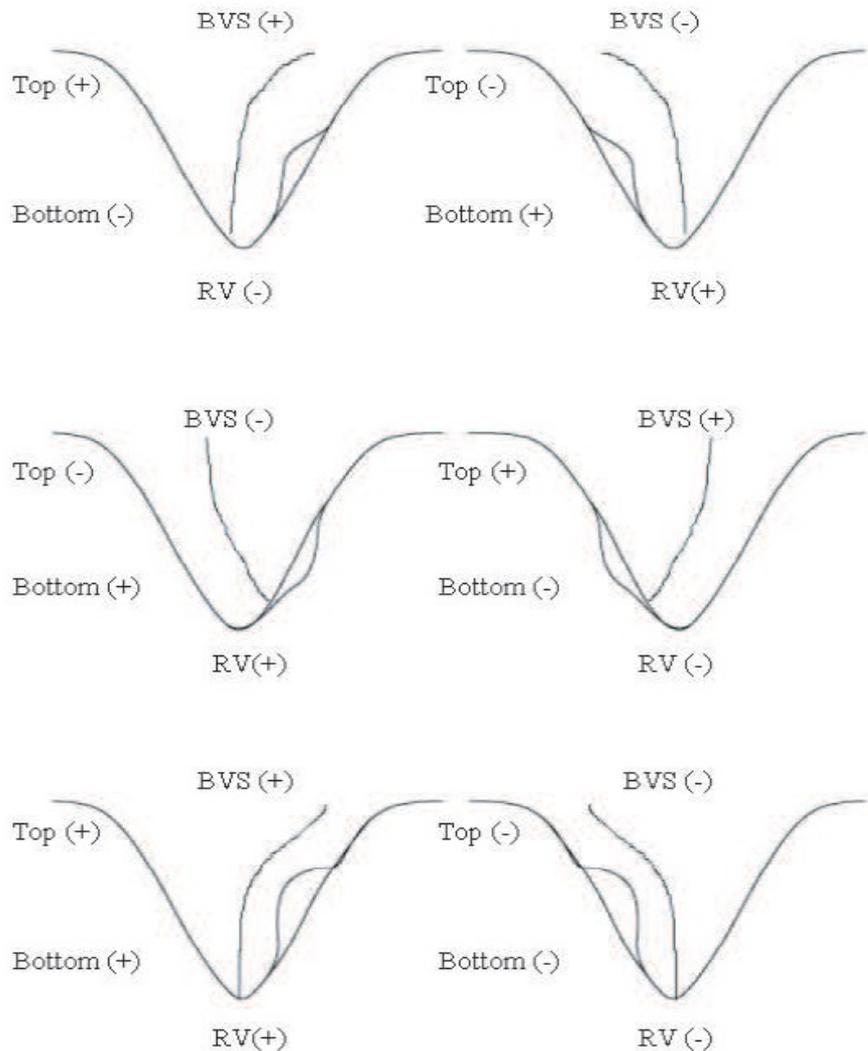
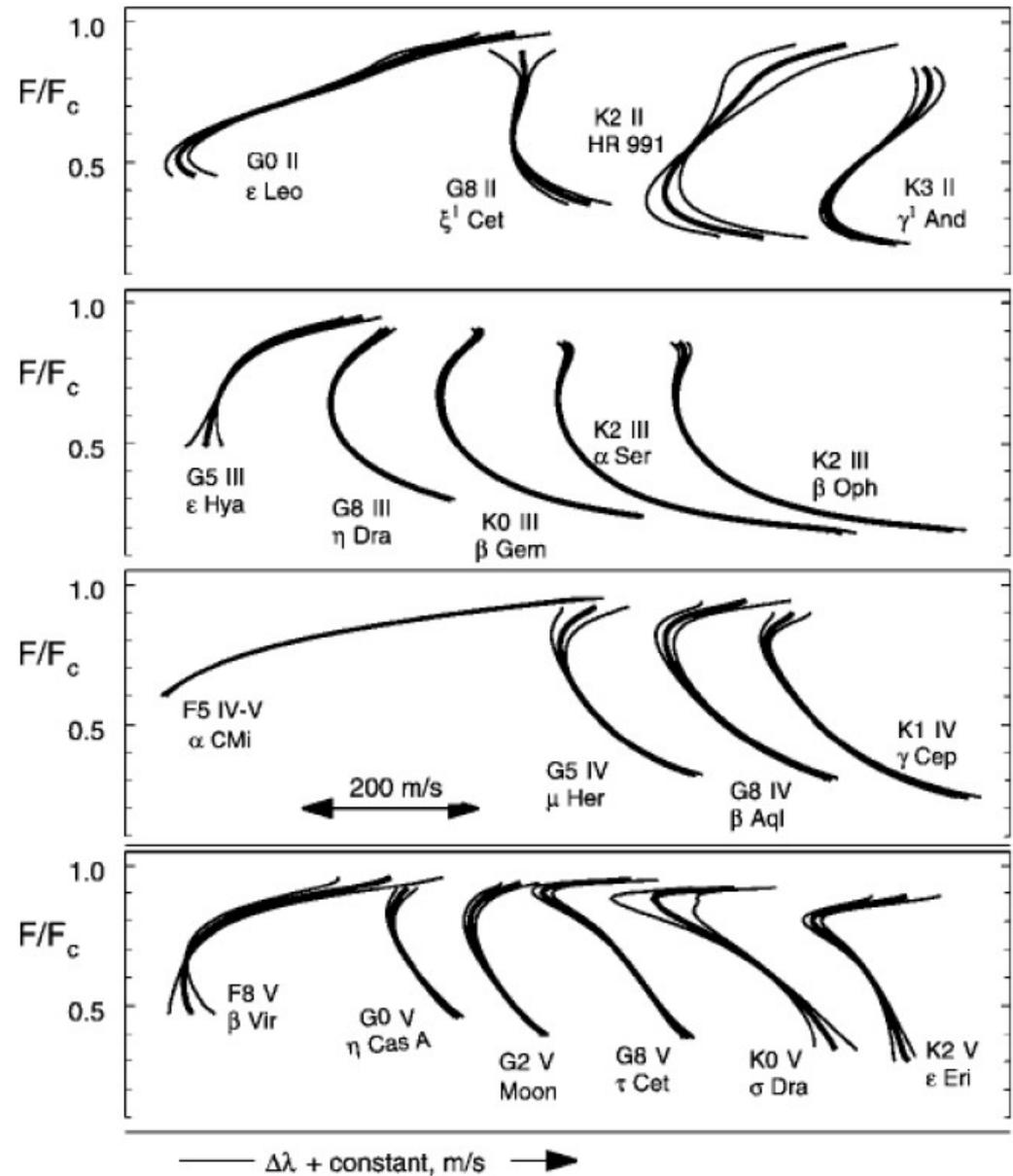


Figure 8.1: Schematic representation of different absorption profiles and their line bisectors, see text. Up: asymmetric absorptions due to spots (upward dip). Middle: asymmetric absorptions due to faculae (downward dip). Low: asymmetric absorptions due to light from a nearby object contaminating the spectrum of the star being observed (upward dip).



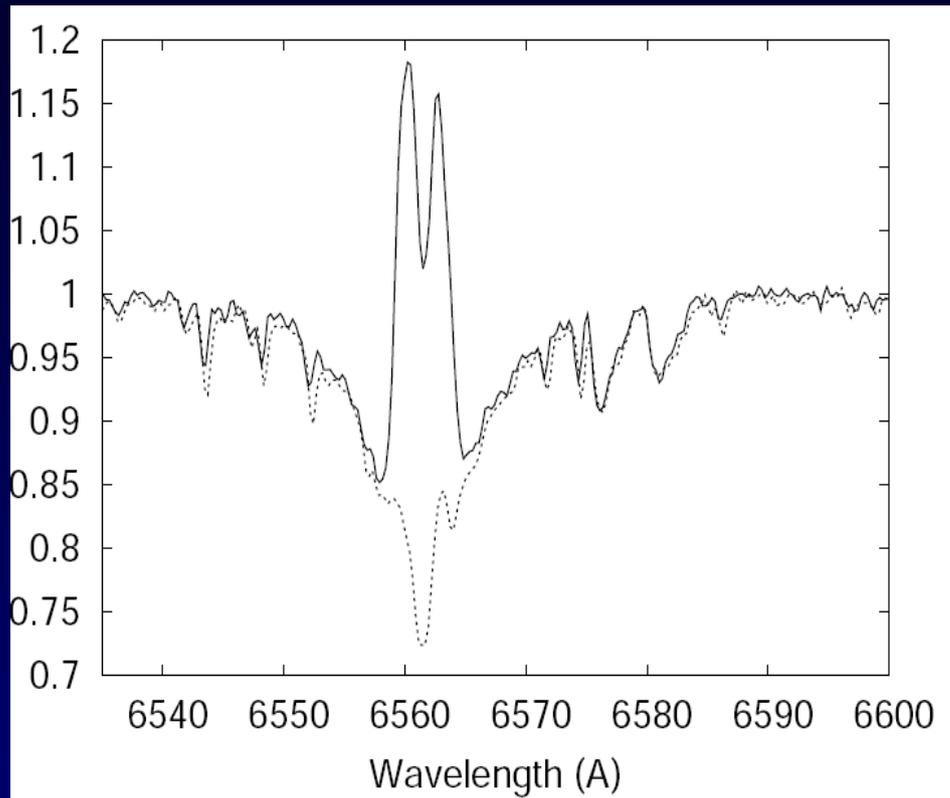
# Changes of Line Profiles in Time

Blind comparison of different exposures

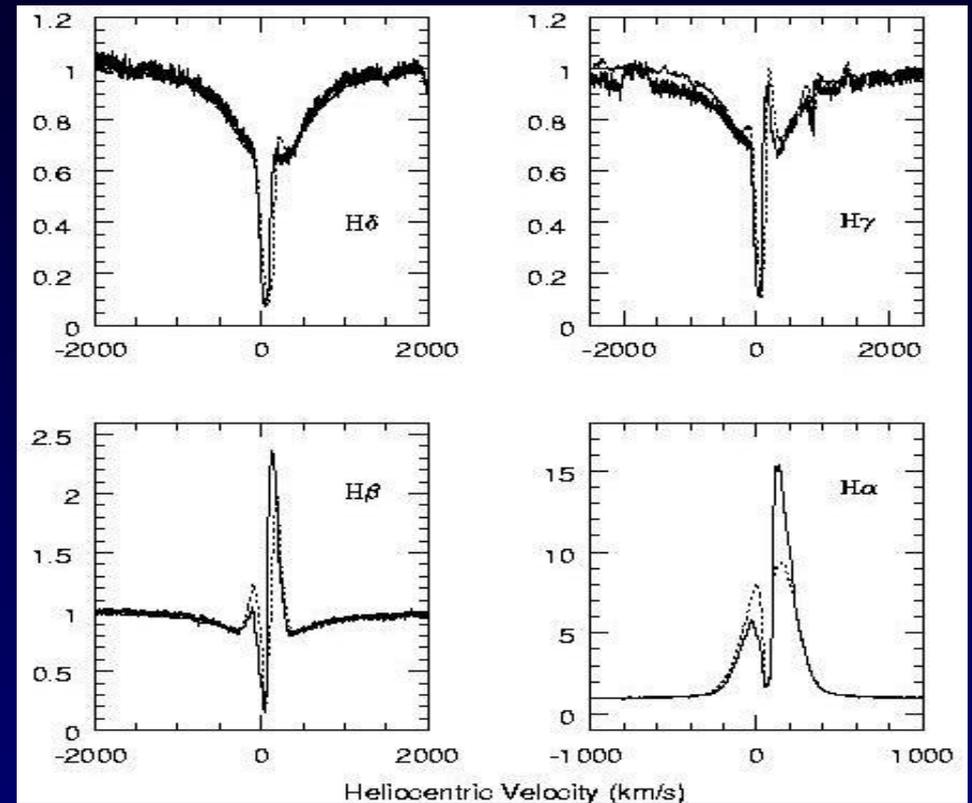
Emission/absorption, shell phases

Time evolution of object – mass transfer,

V/R variations



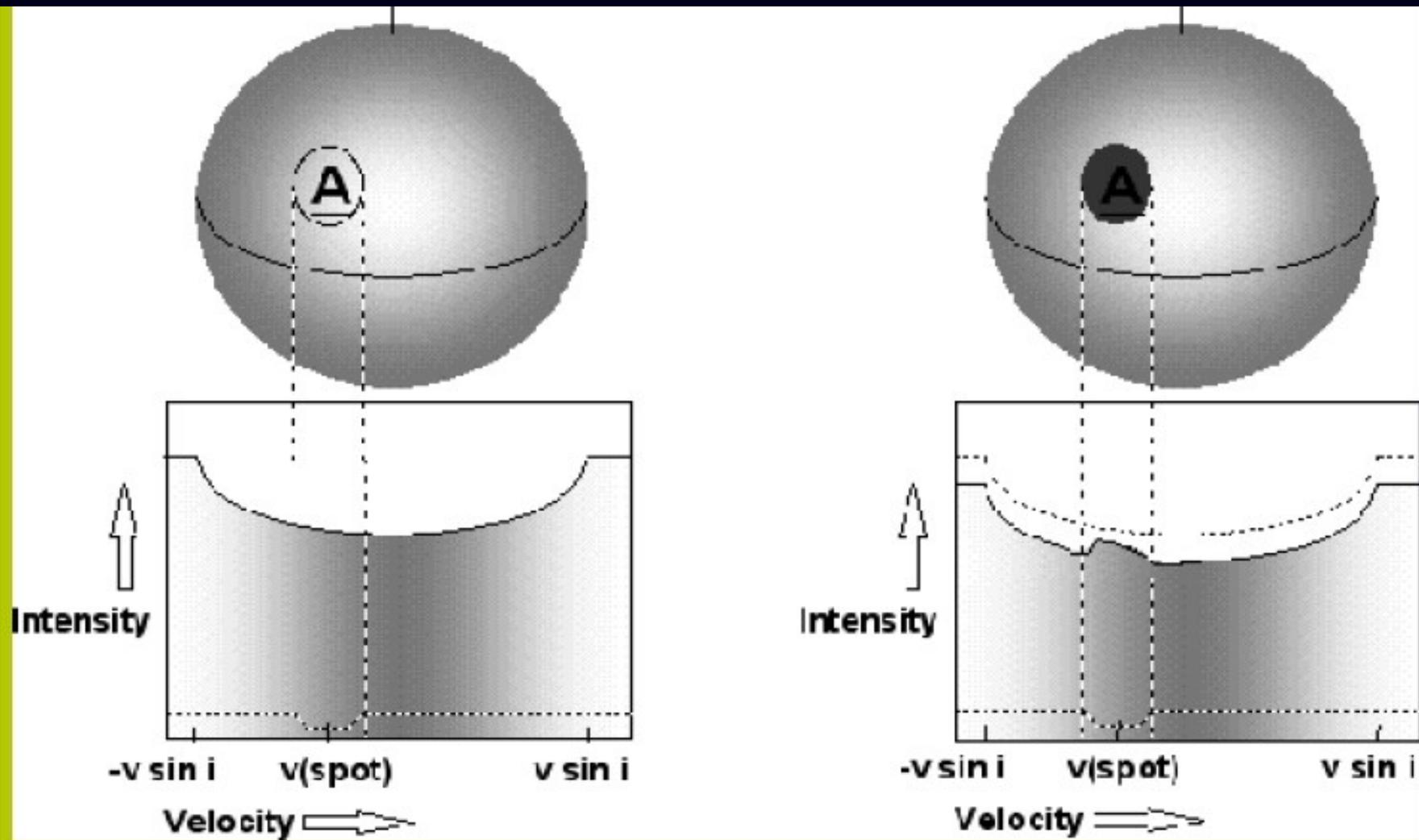
HD6226 : Slechta and Skoda 2004



Borges et al. 2008

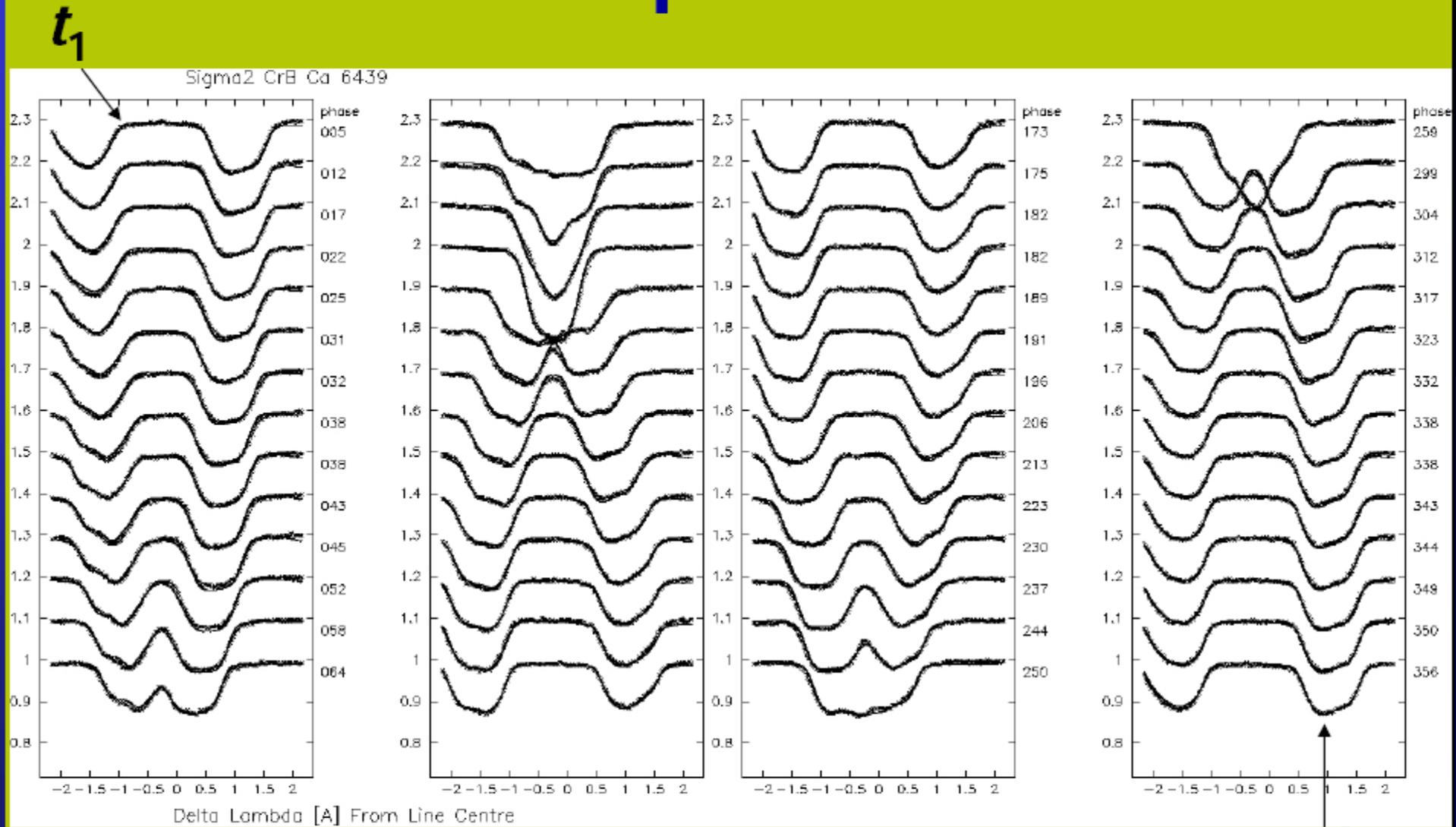
# Doppler Imaging

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





# Time series spectra of $\sigma^2$ CrB

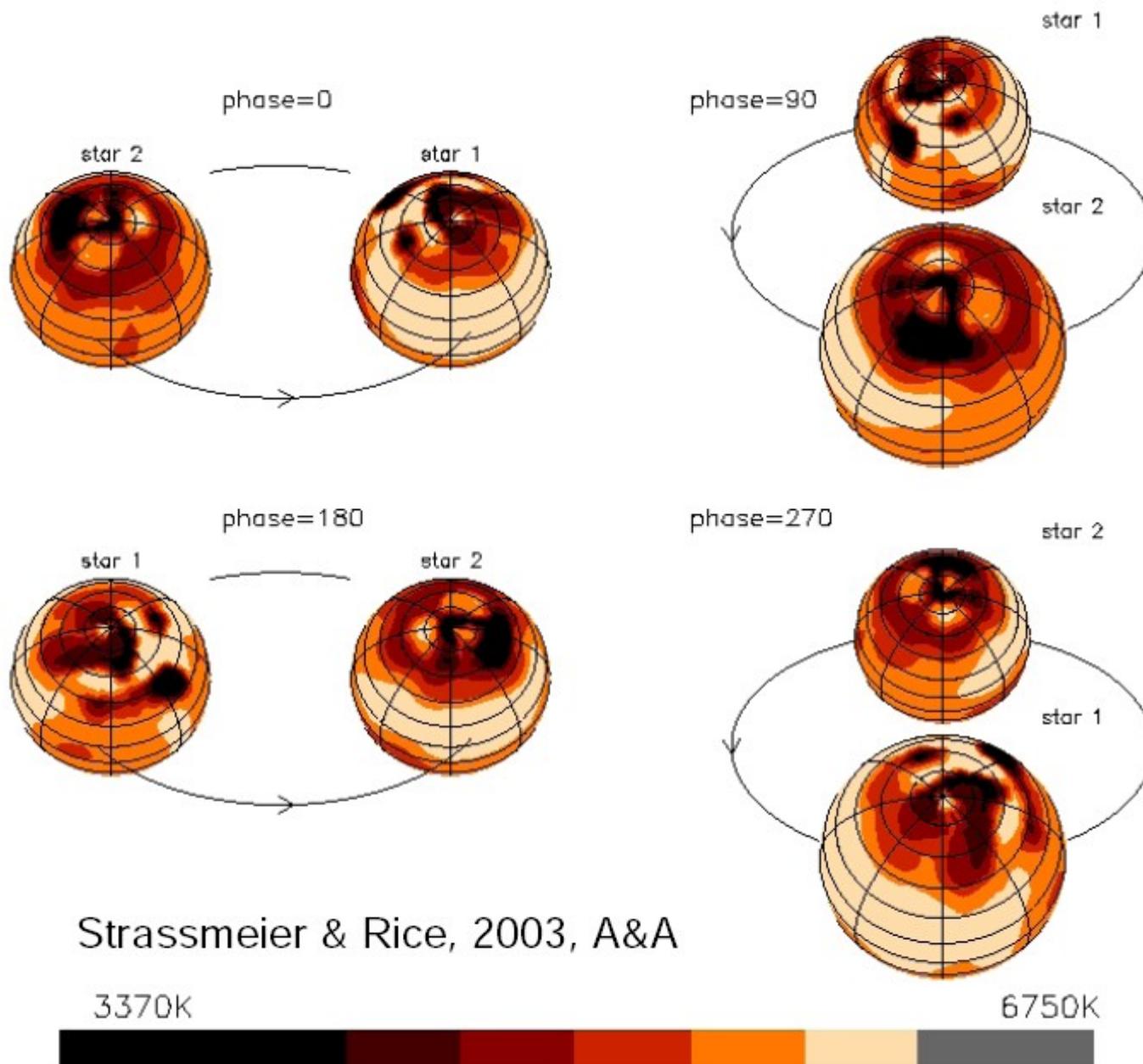


CFHT, Gecko:  $\lambda/\Delta\lambda=120,000$  (2.5 km/s);  $\Delta t=23min$ ;  $S/N=300:1$



AIP

# Doppler images $\sigma^2$ CrB

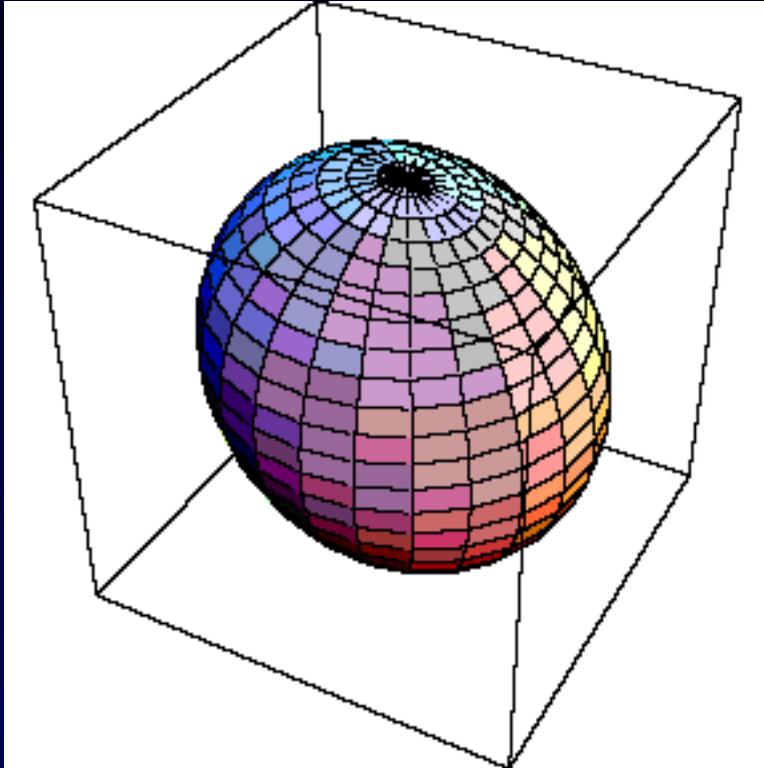


Strassmeier & Rice, 2003, A&A

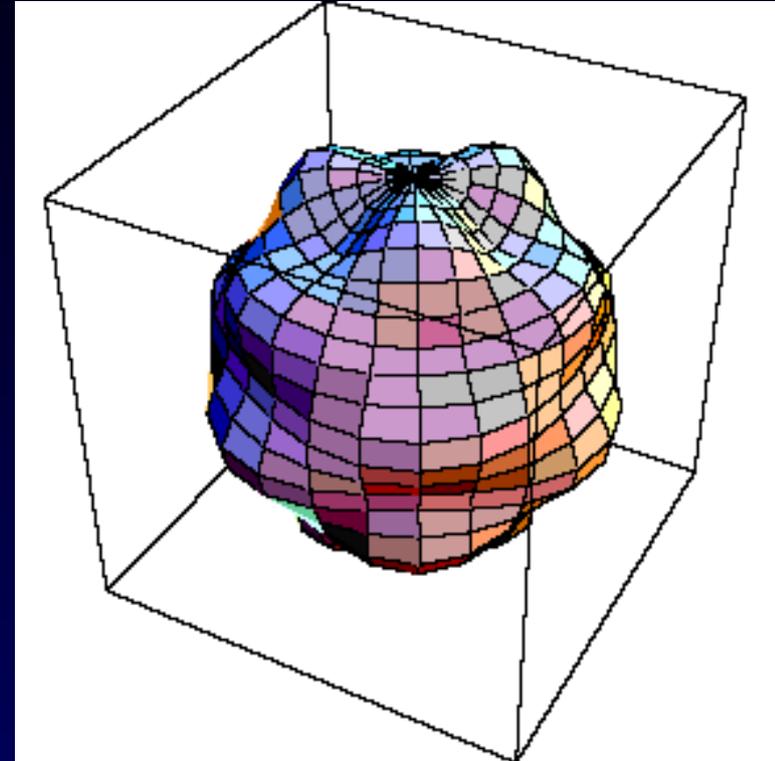
3370K

6750K

# Non Radial Pulsation



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

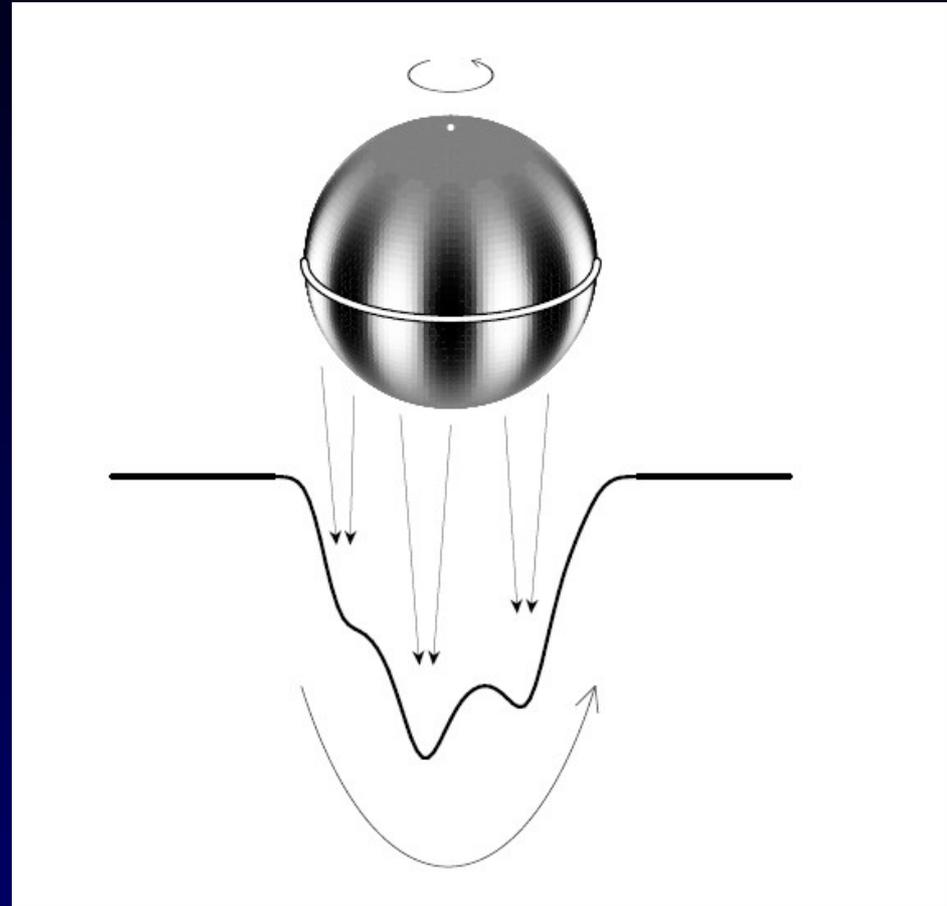


$$\ell = 8, m=3$$

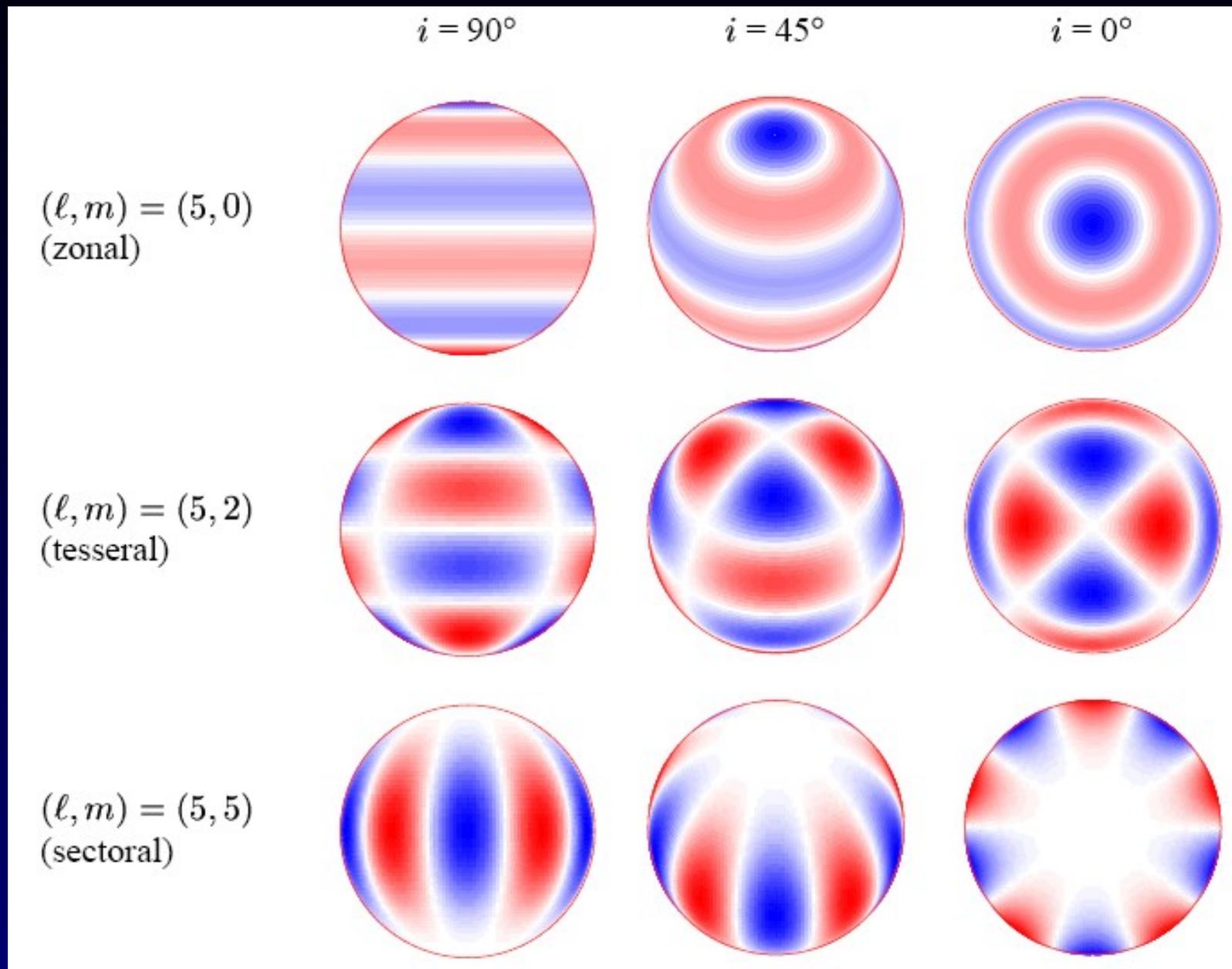
*Tim Bedding*

# Doppler Imaging - NRP

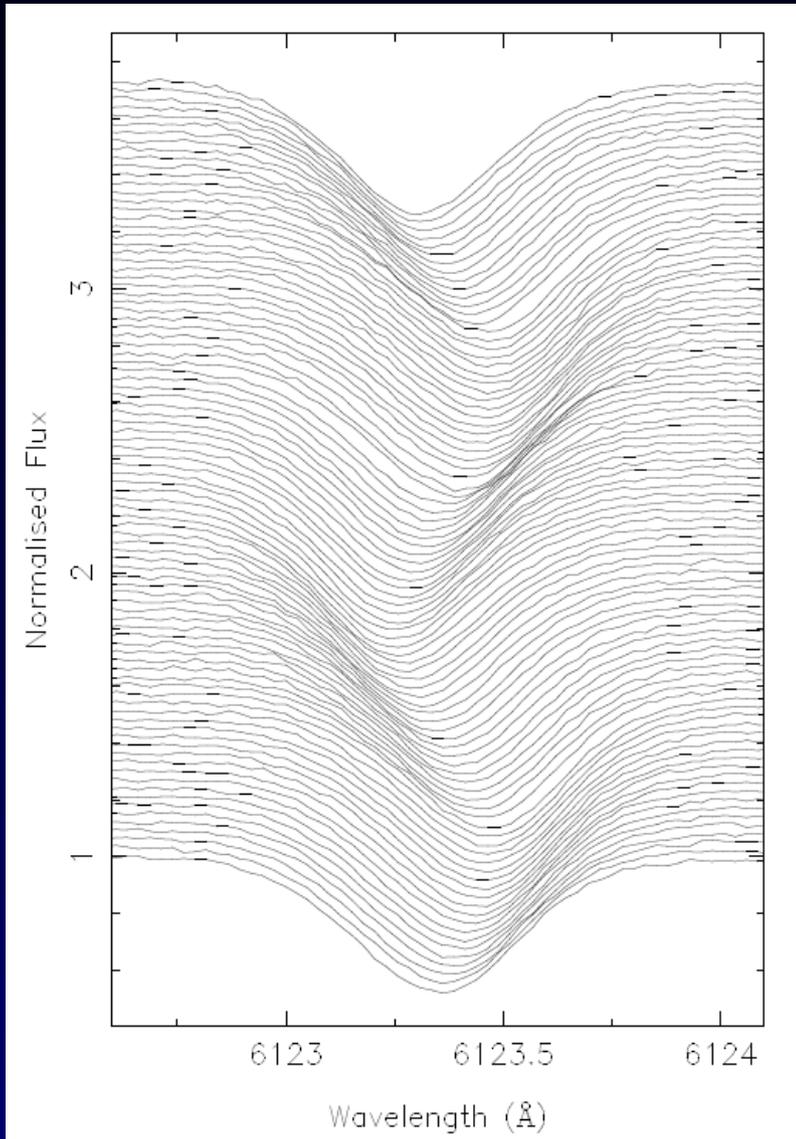
Vogt & Penrod -80s  
Zet Oph



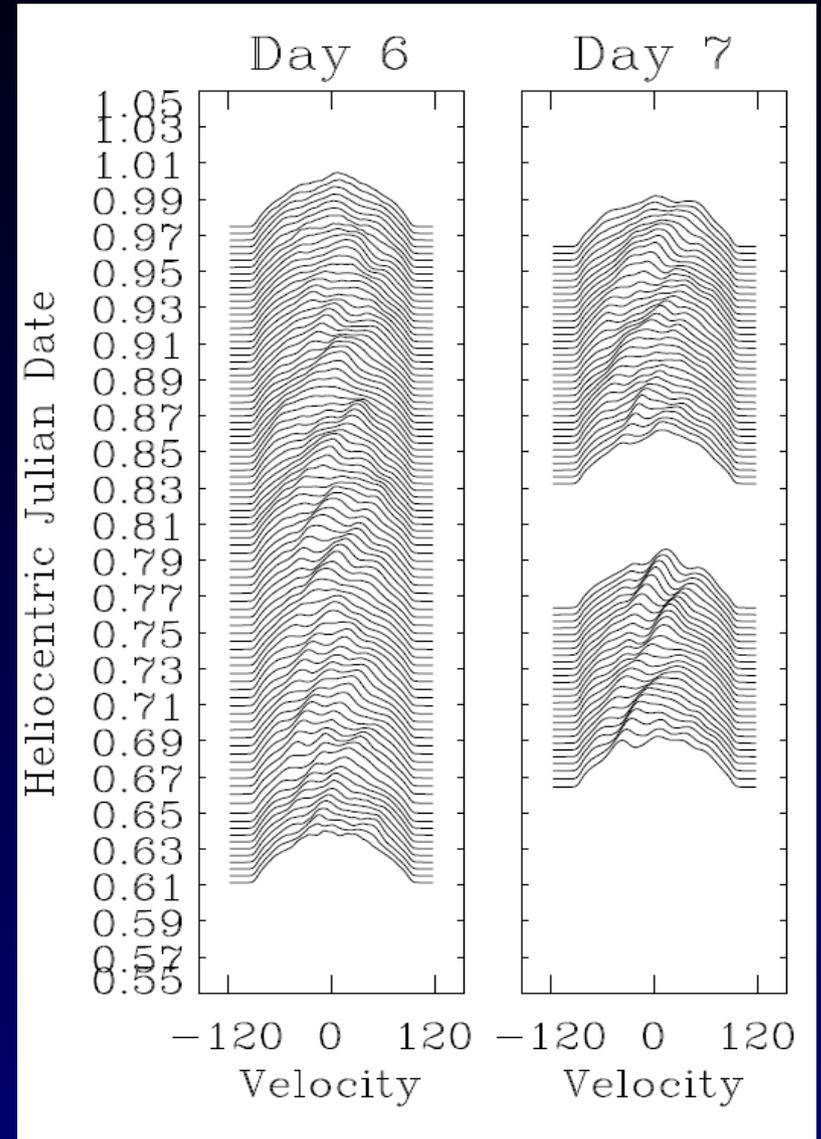
# Non Radial Pulsations Modes



# Measured Pulsations

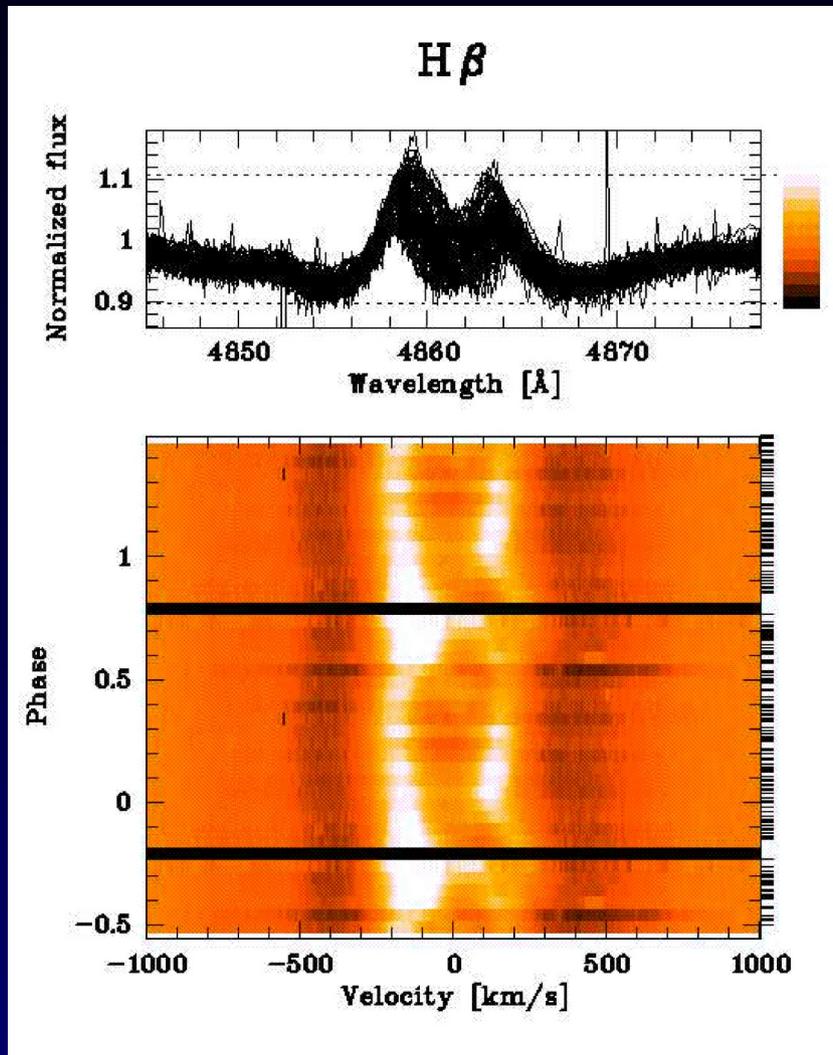


Rho Pup – del Sct type



Eps Cep - del Sct type

# Dynamic Spectra



Quotient, Difference template  
(average)

For study of LPV  
(asteroseismology, winds)

Requires

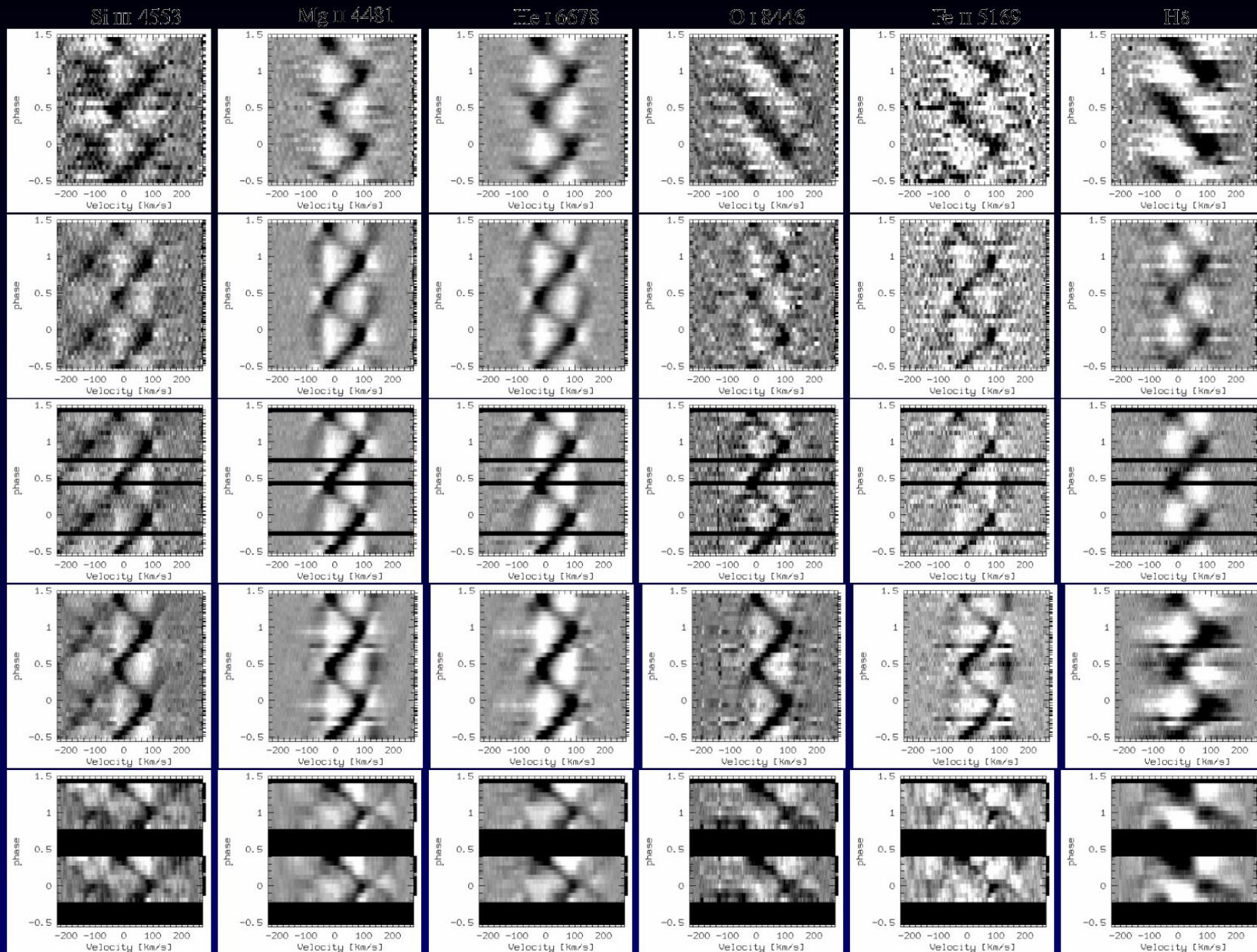
time (JD) - winds

period (see Period analysis) -  
phase (LPV)

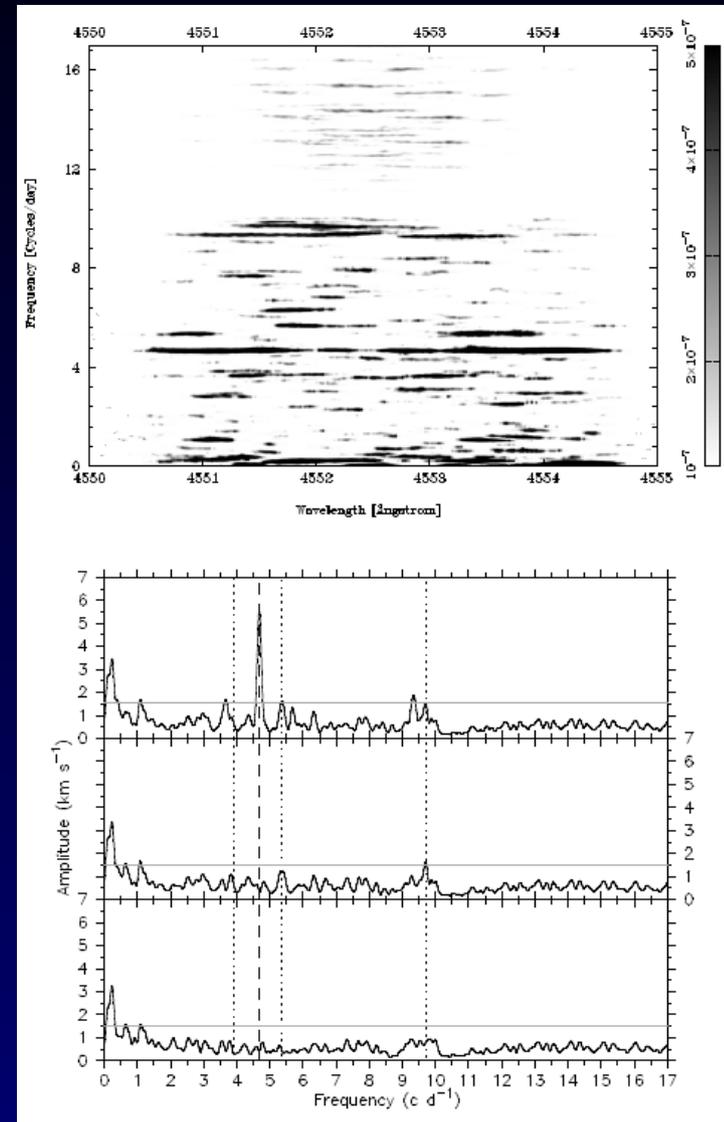
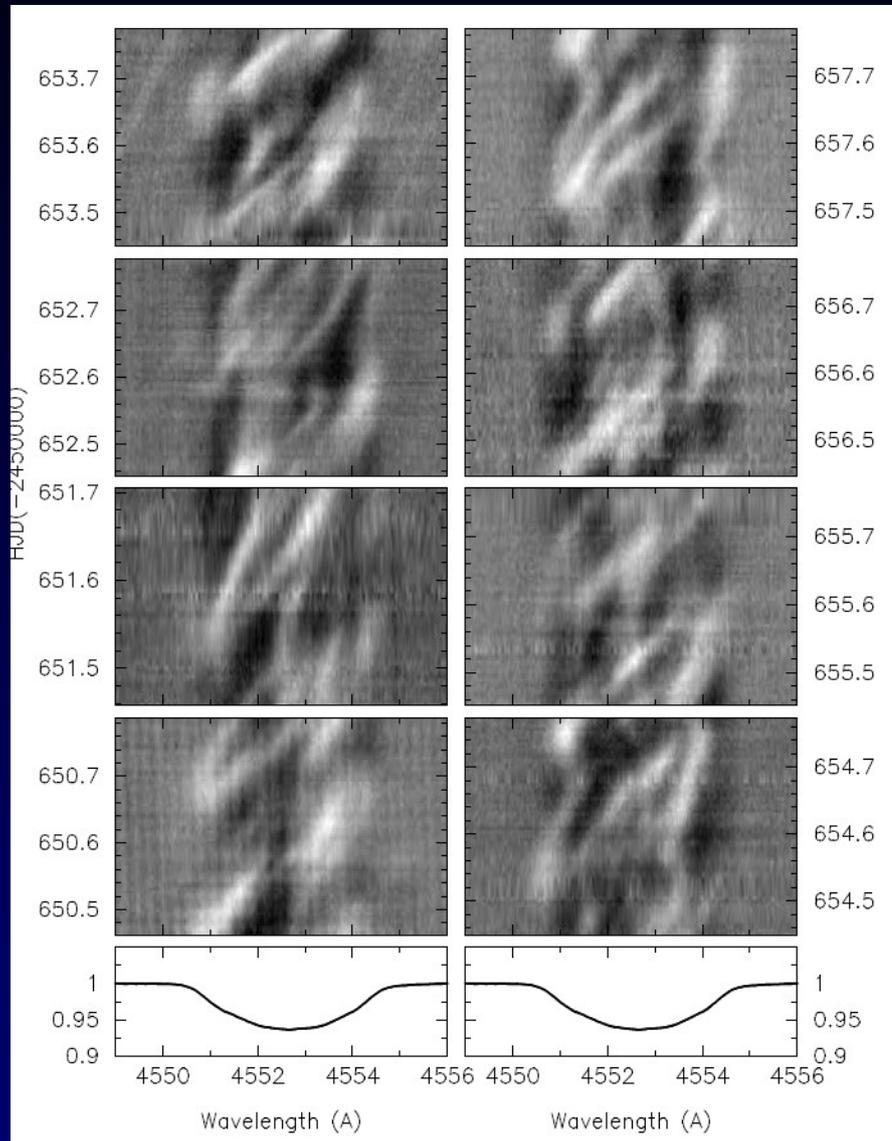
change of template (average,  
median)

removing bad data (interactive  
overplotting)

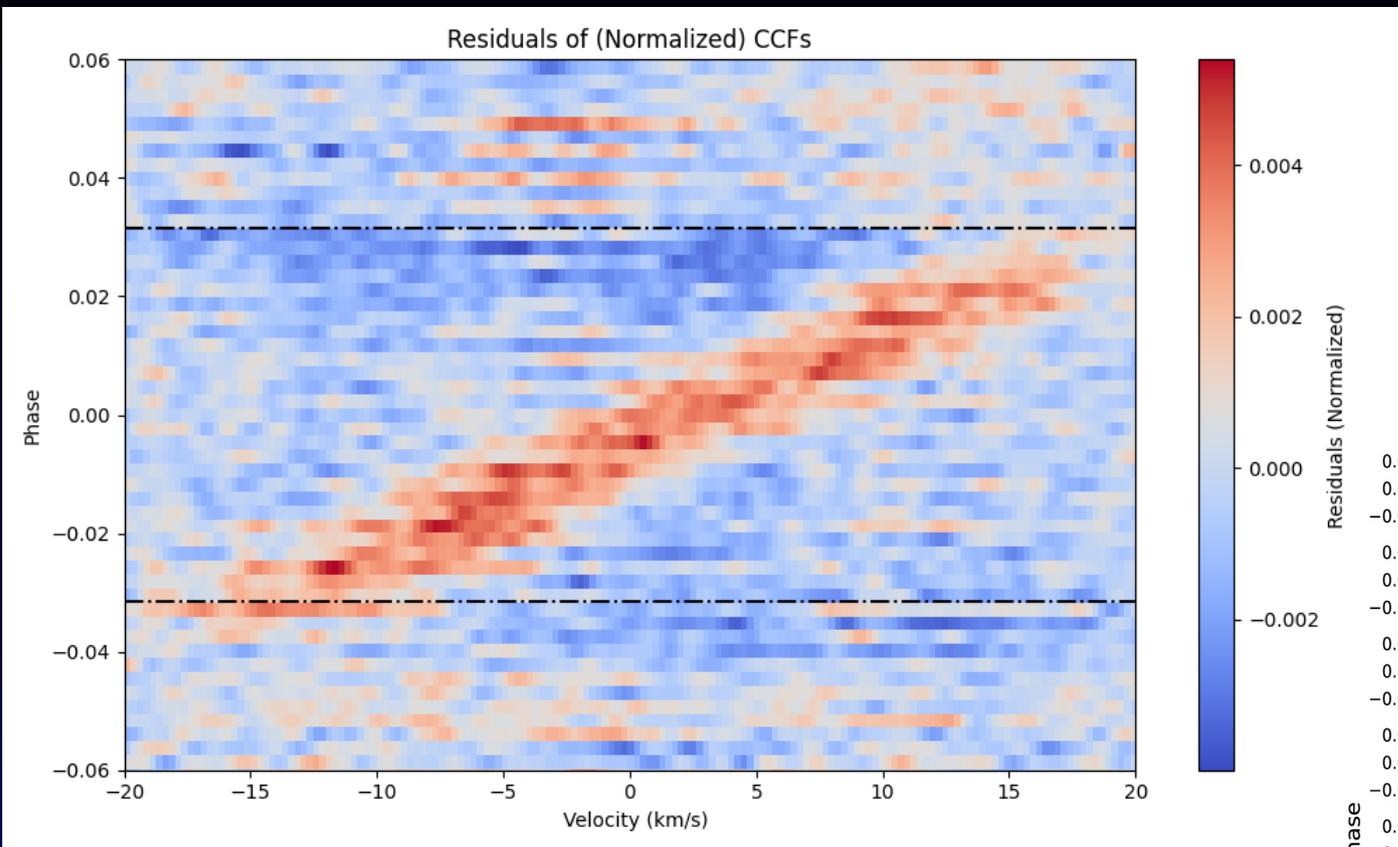
# Dynamic Spectra



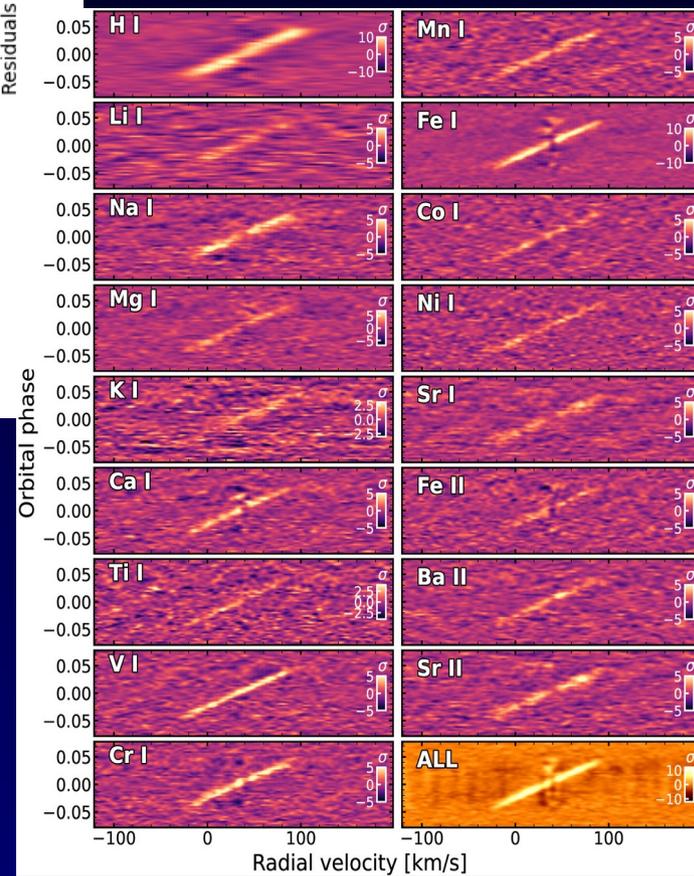
# Periodogram of Line Profile NRP



# Doppler Shadow



HARPS-N archival CCF of HAT-P-41A. Balková 2025



# Echelle Spectra

# ESO X-Shooter

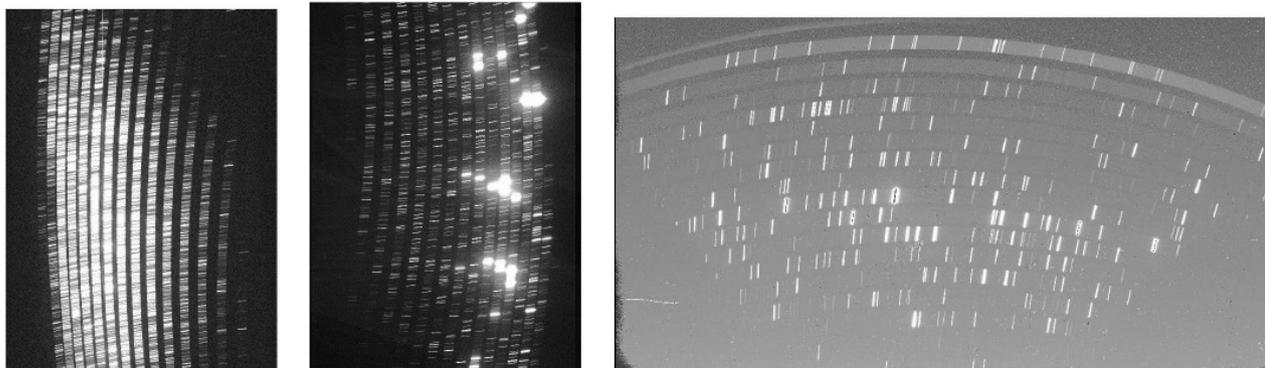
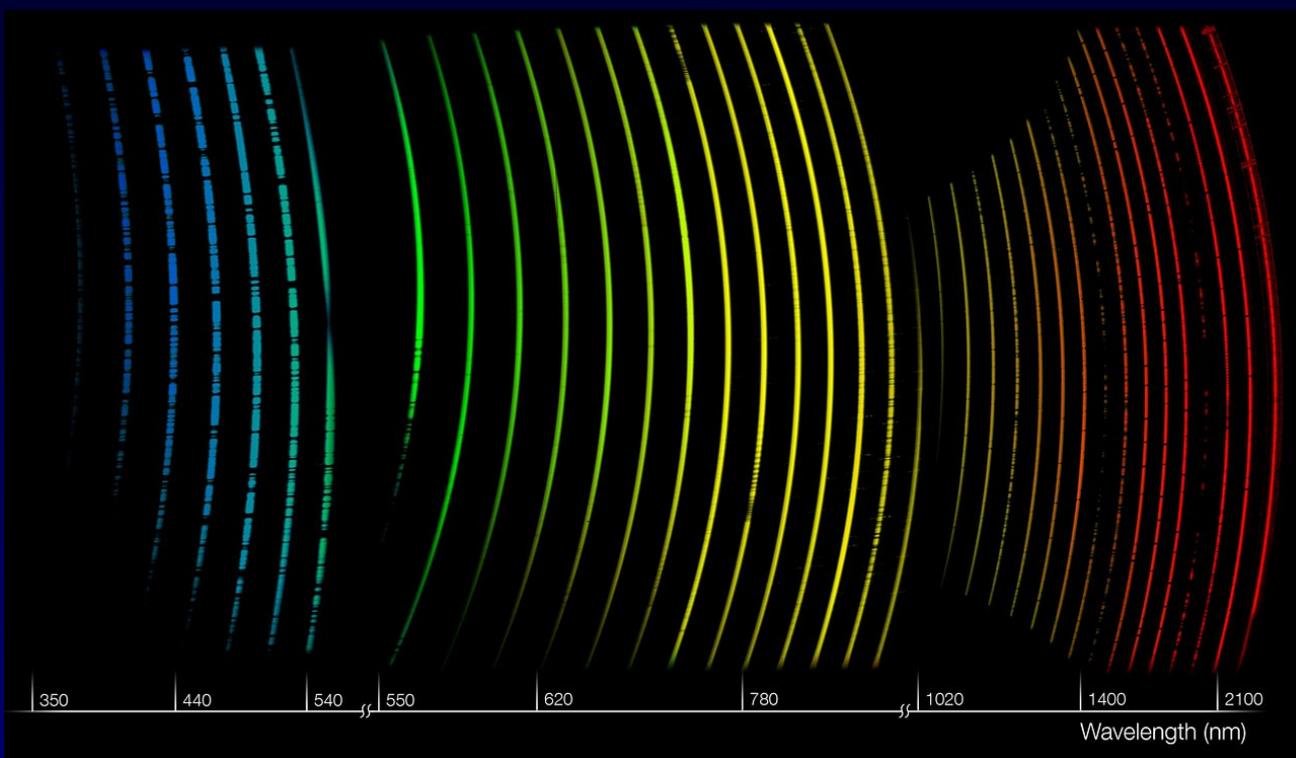
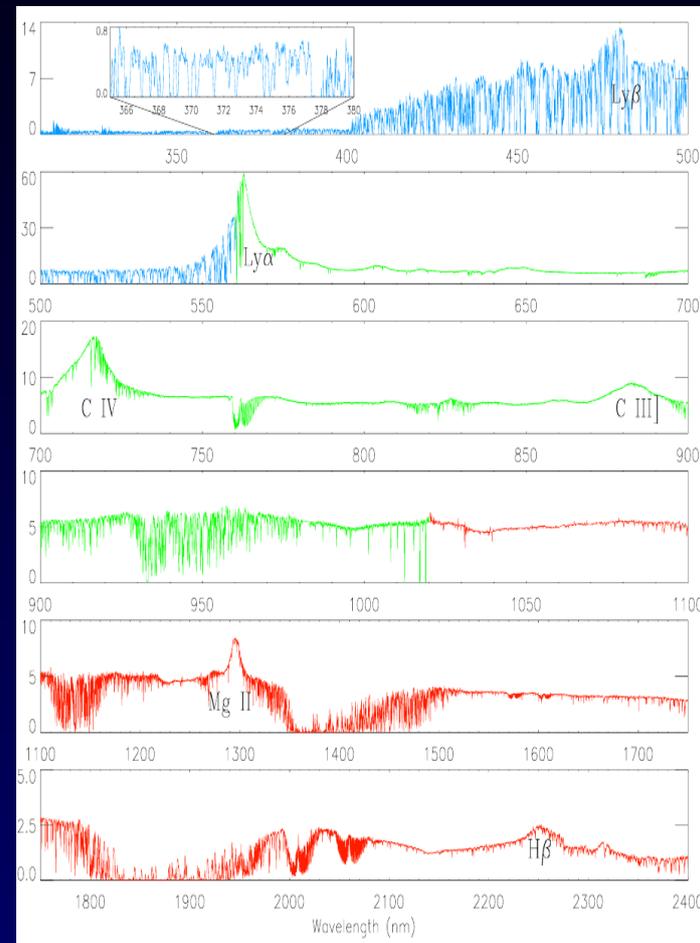


Figure 1. This image displays left to right the XSH UVB, VIS and NIR spectral formats with different image scales.



Modigliani et al. 2010

2936-24807 A,  
R ~9100,17400,11300  
0.5arcsec slit



High-z QSO  
Vernet et al. 2011

# HARPS-S



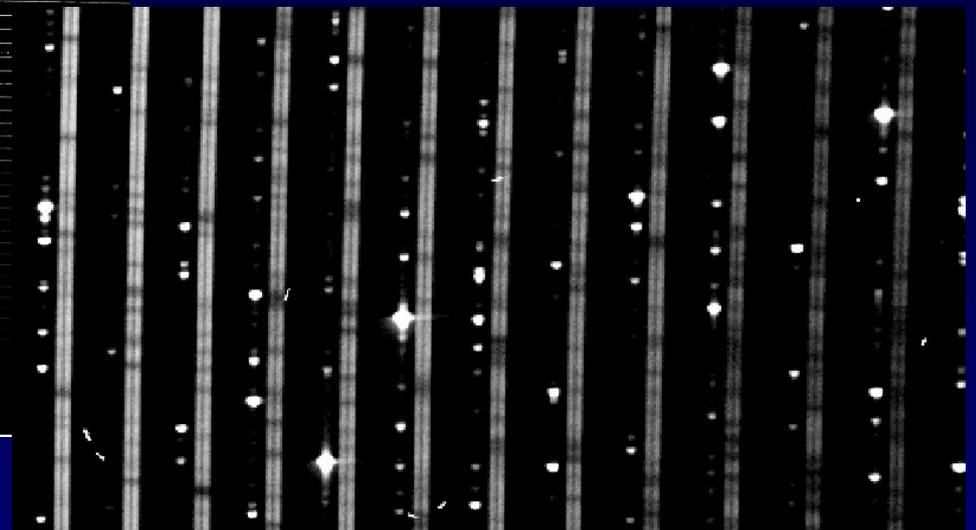
71 orders (89-161) – 115 not

3780-6910 Å

R~115000

dRV~3m/s

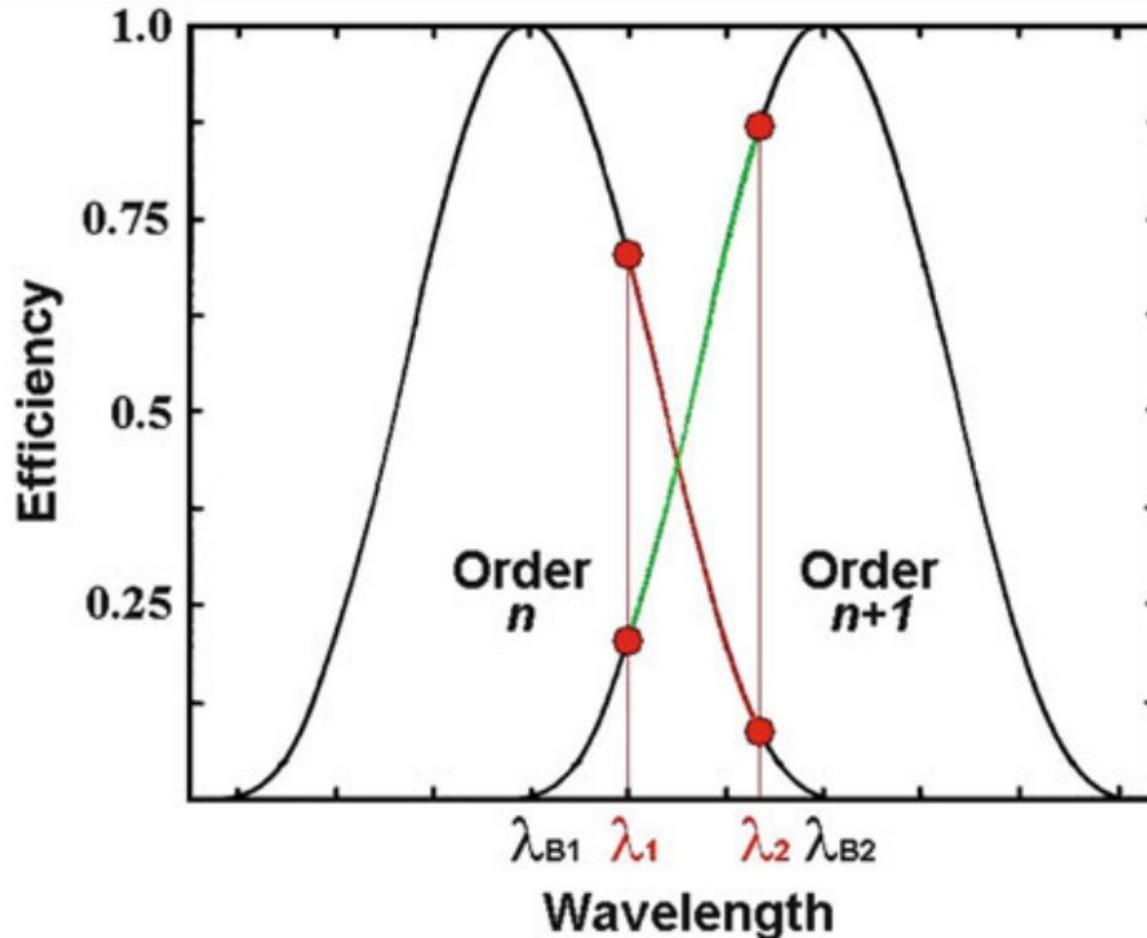
Simultaneous ThAr/Laser  
comb/Fabry Perot



<https://cdn.eso.org/images/large/eso0308c.jpg>

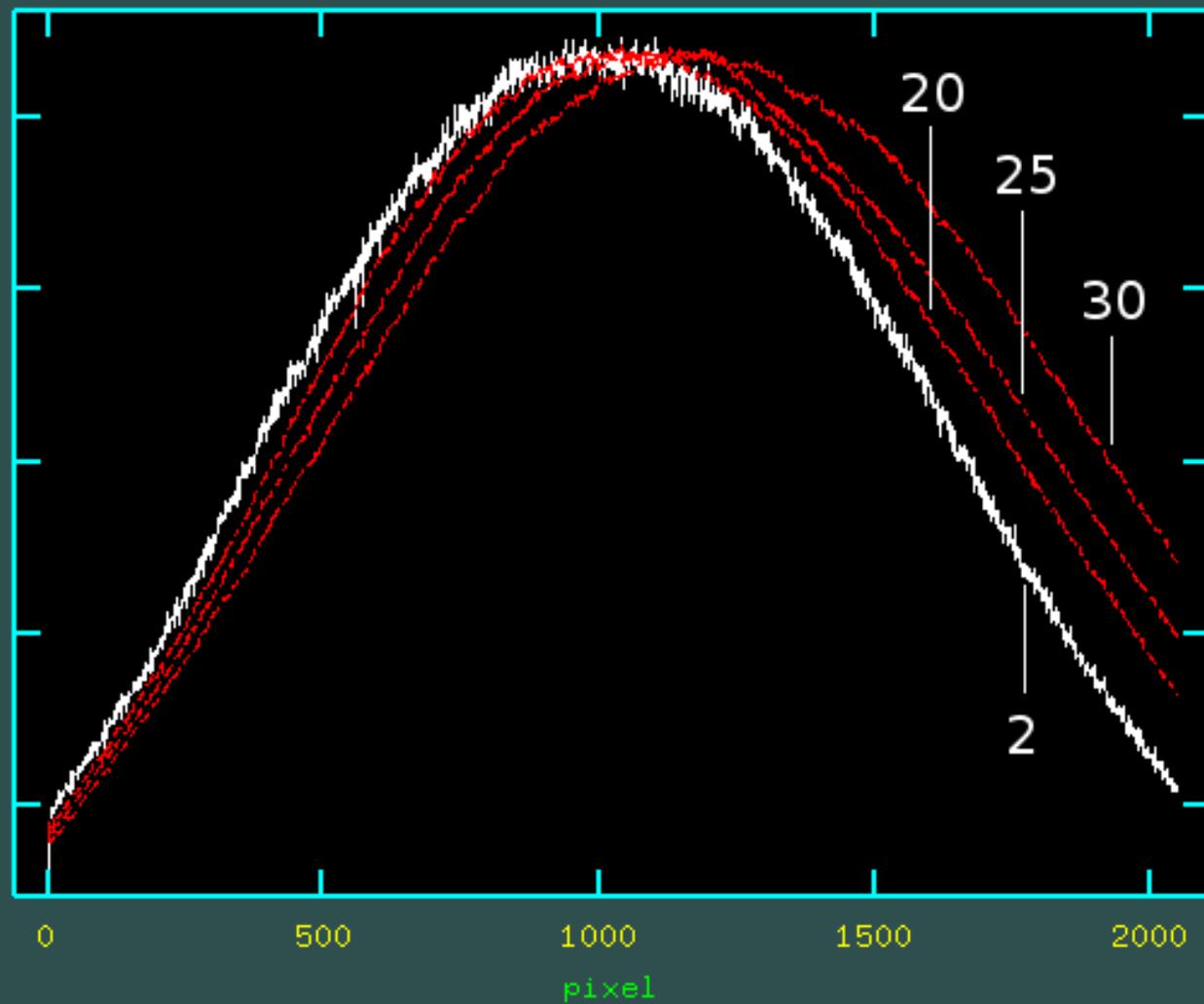
PlatoSpec simul ThAr

# Overlapping Orders

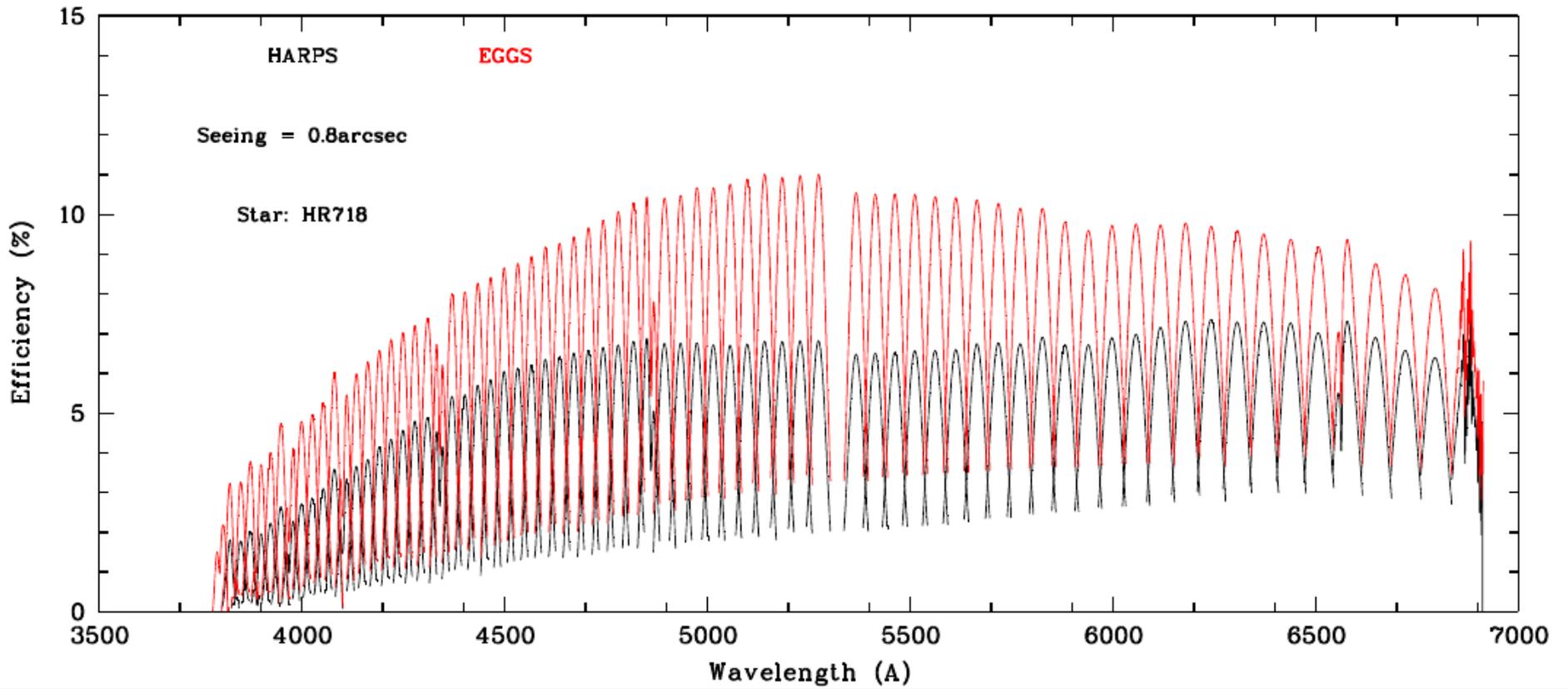


**Fig. 5.15** Sketch of the efficiencies in two adjacent orders. Identical wavelength intervals in the orders are indicated in *red* and *green*. Both wavelengths  $\lambda_1$  and  $\lambda_2$  are imaged in the two orders  $n$  and  $n + 1$ . The two blaze peaks of the orders are positioned at  $\lambda_{B1}$  and  $\lambda_{B2}$

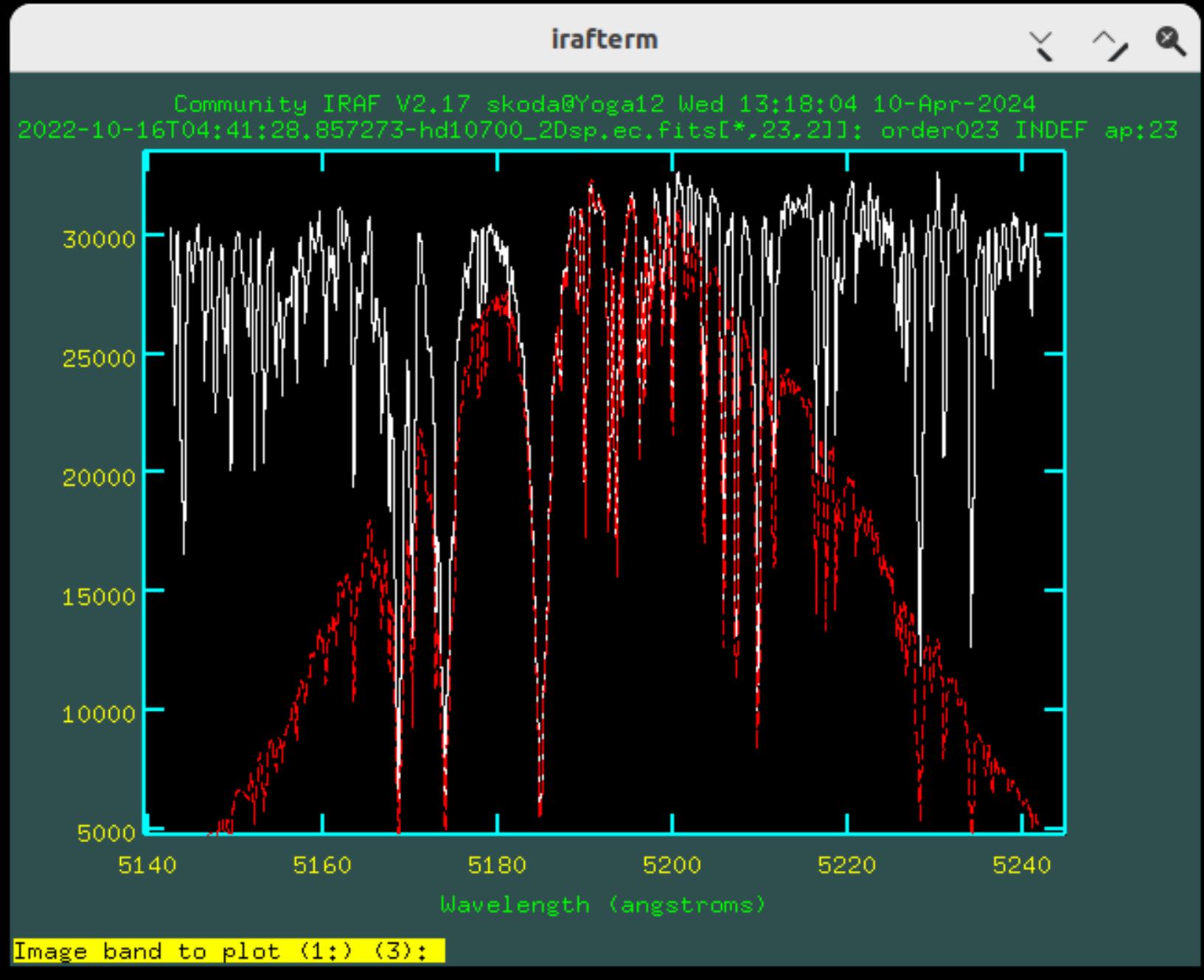
# OES Blaze shift



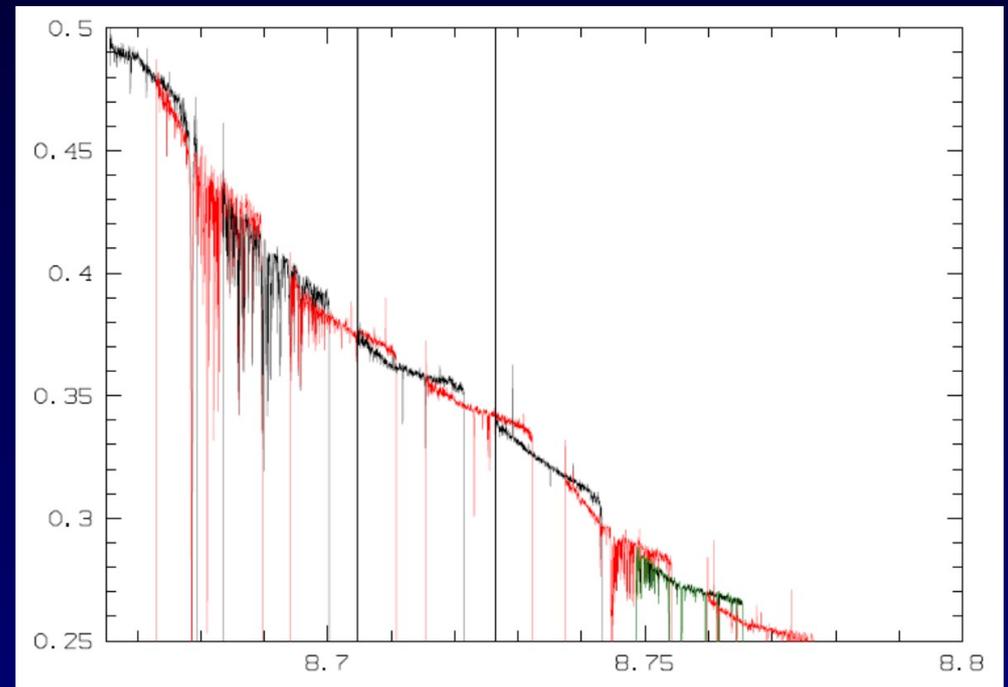
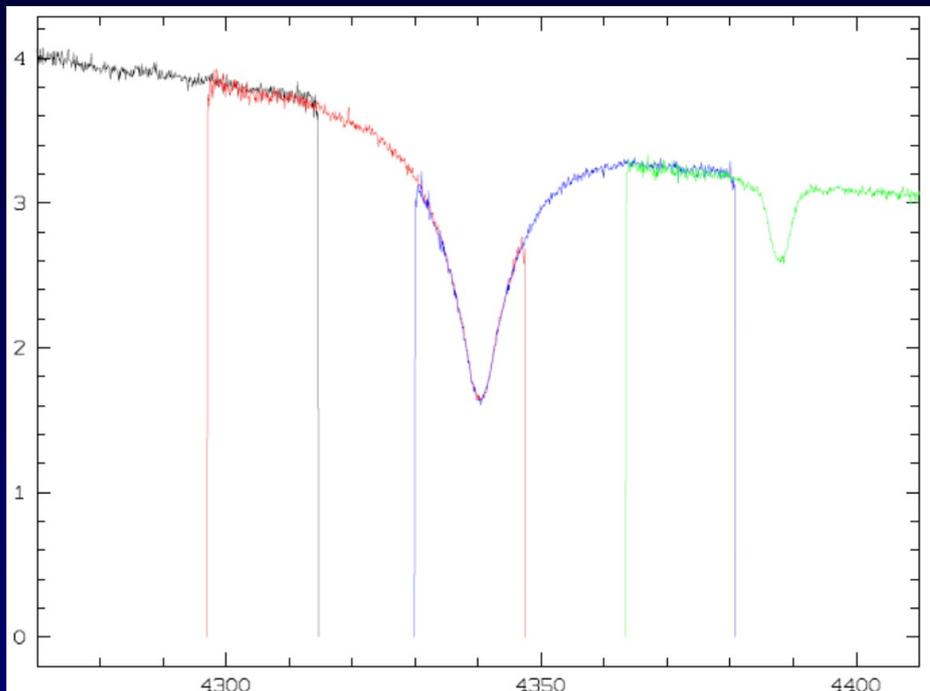
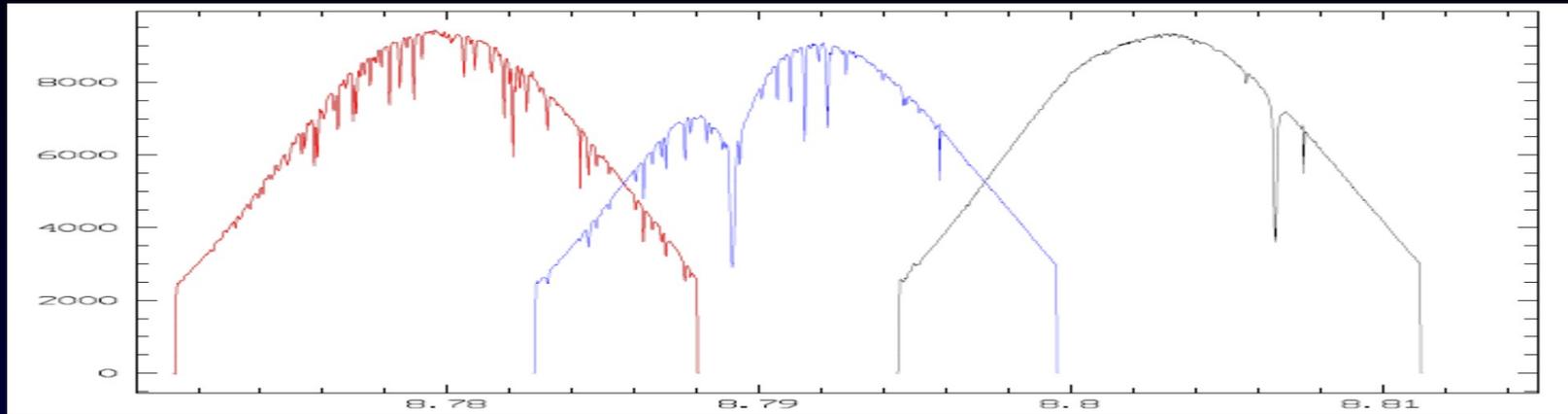
# HARPS-S



# PUCHEROS+ in IRAF

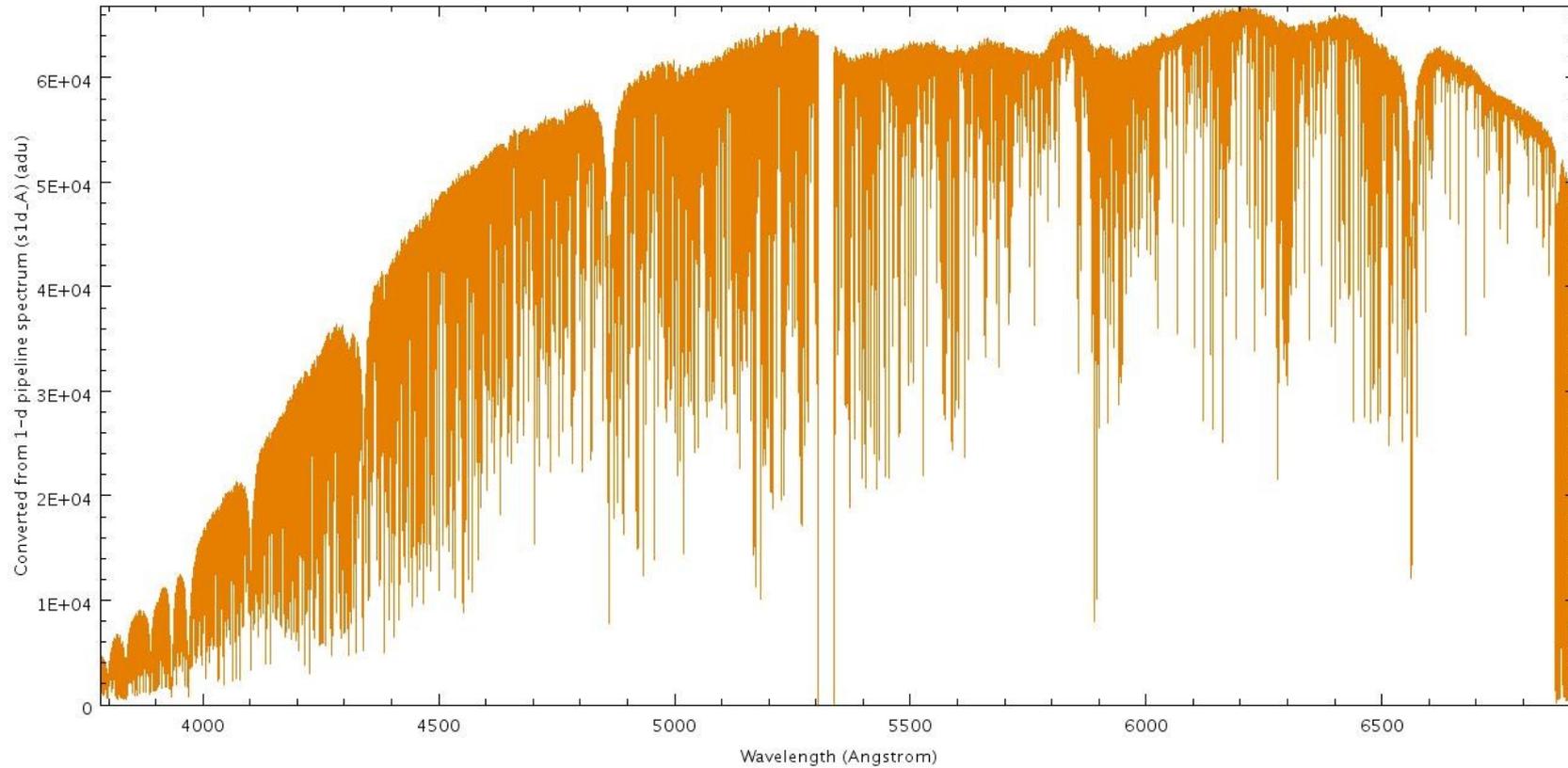


# Echelle Spectra Problems in Hot Stars



# HARPS-S in SPLAT

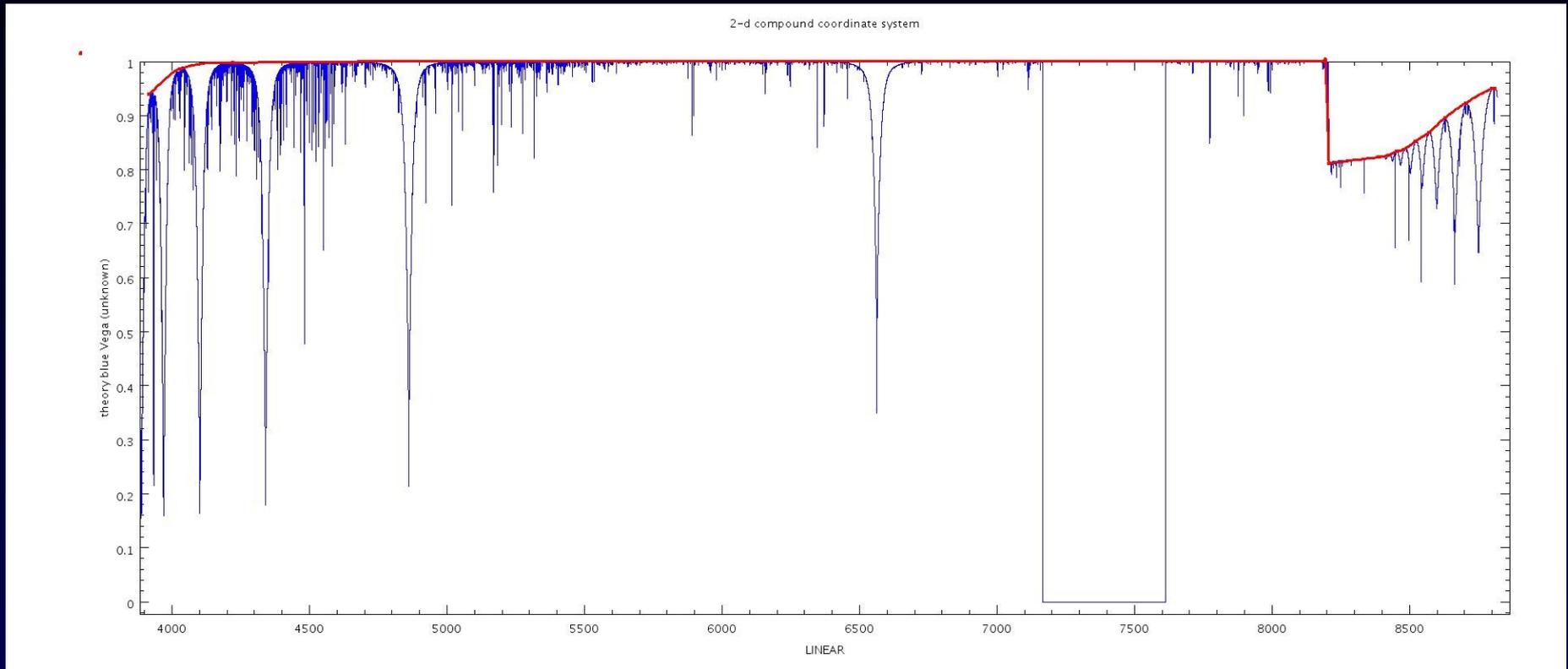
2-d compound coordinate system



313138 points

Procyon

# Continuum Normalisation



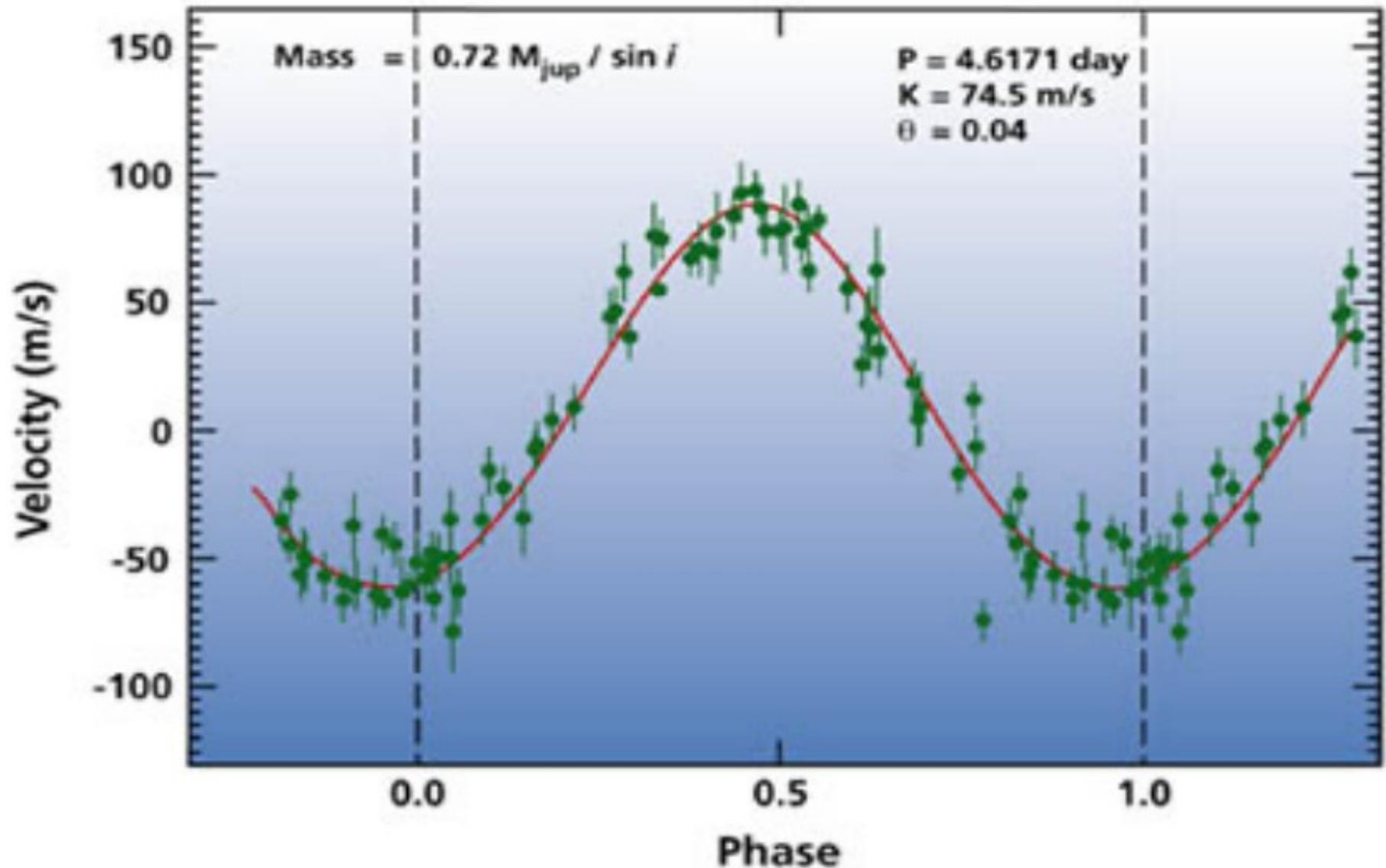
Theoretical spectrum of Vega

The continuum is NOT ALWAYS at 1.0 !

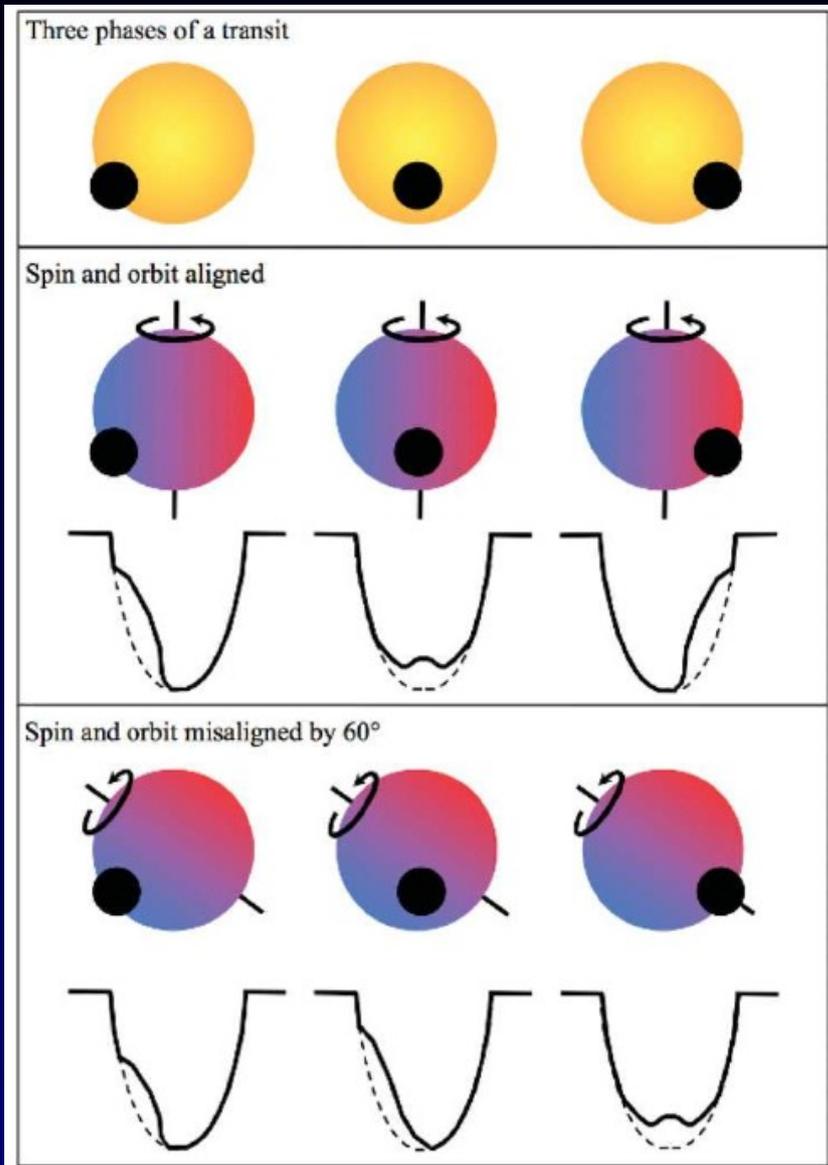
**Products derived from spectra**

# Radial Velocity Curve

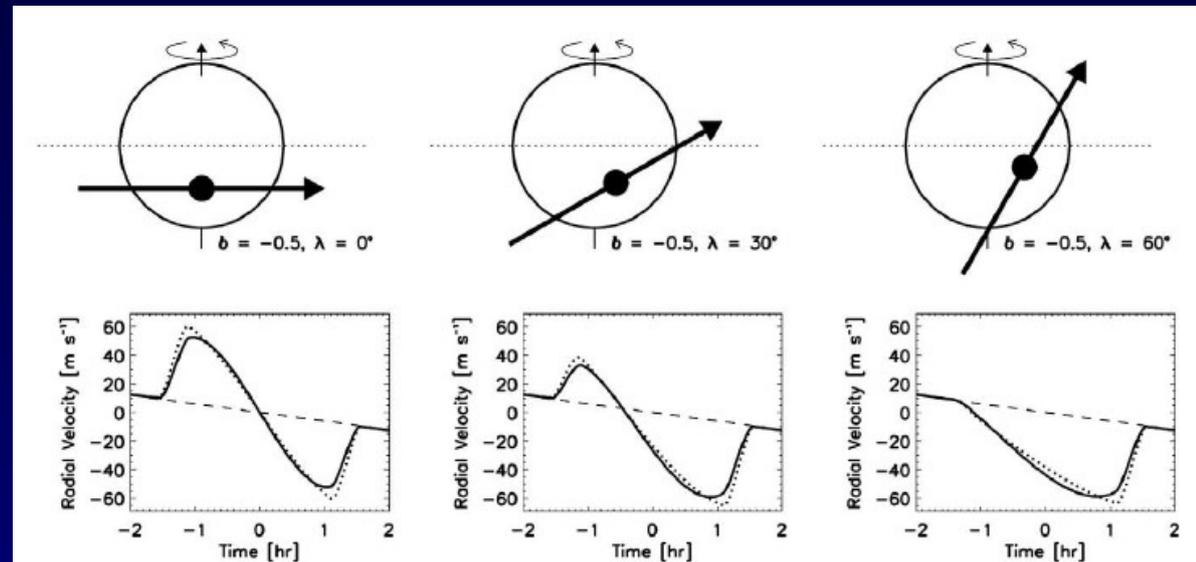
# Radial Velocity Curve



# Rossiter-McLaughlin effect

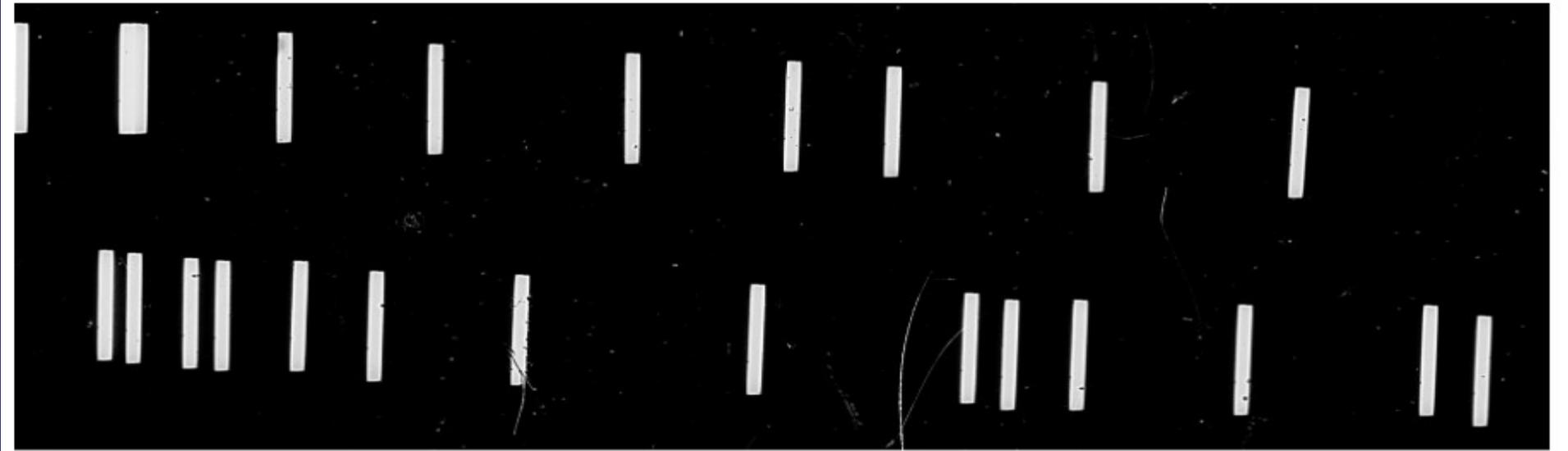
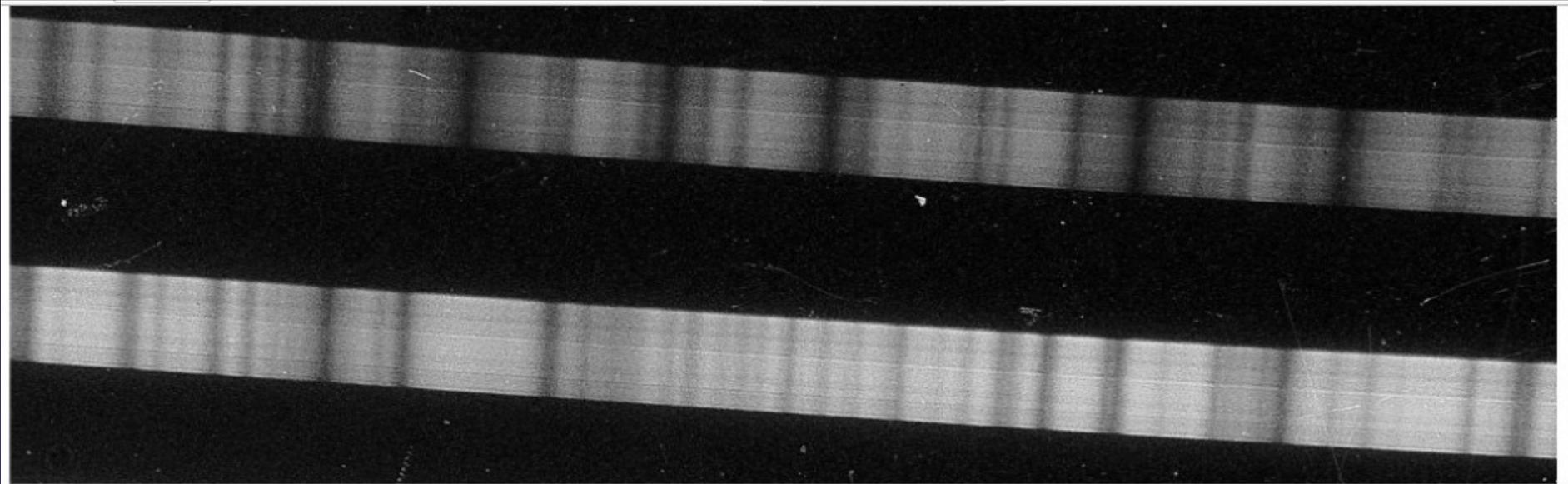


RV Curve – time series of RV  
Only for direct occultation



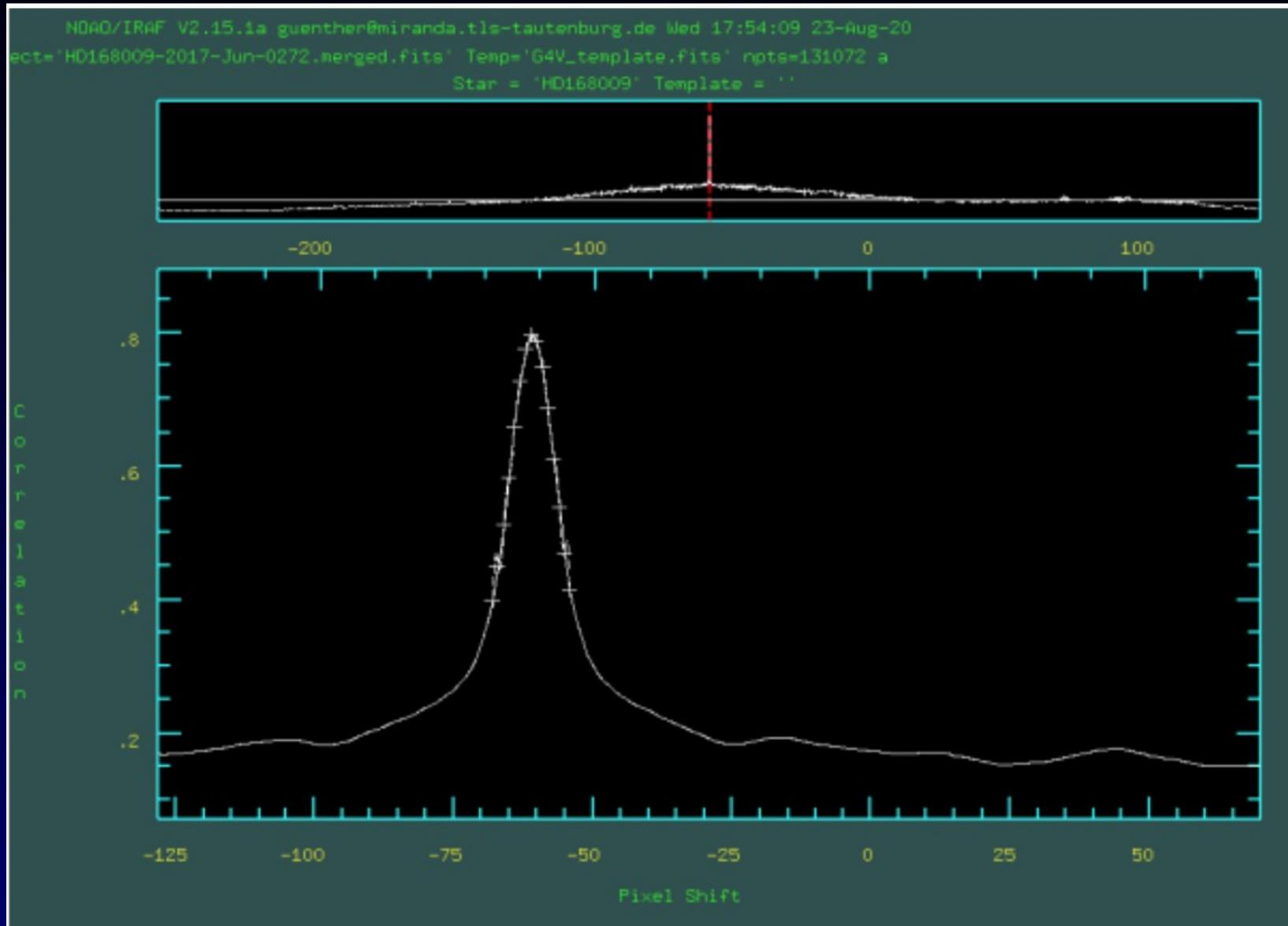
# Cross Correlation Function

# Analogue Technique



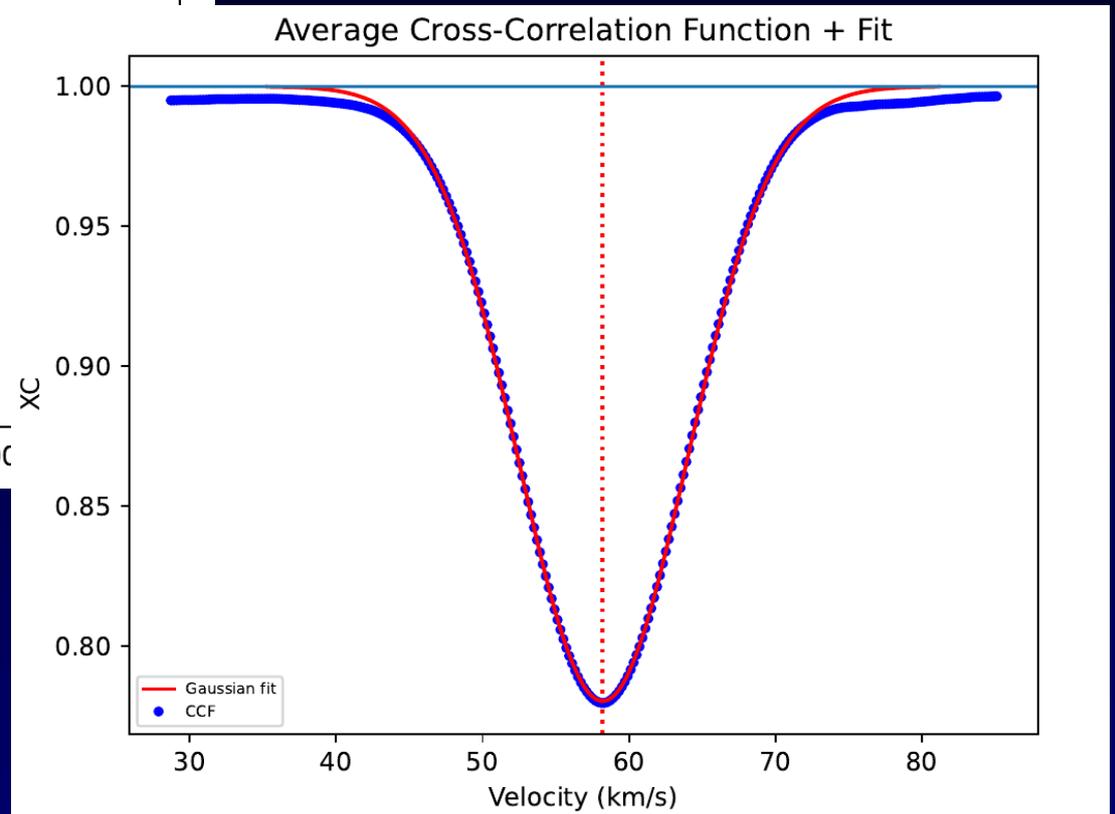
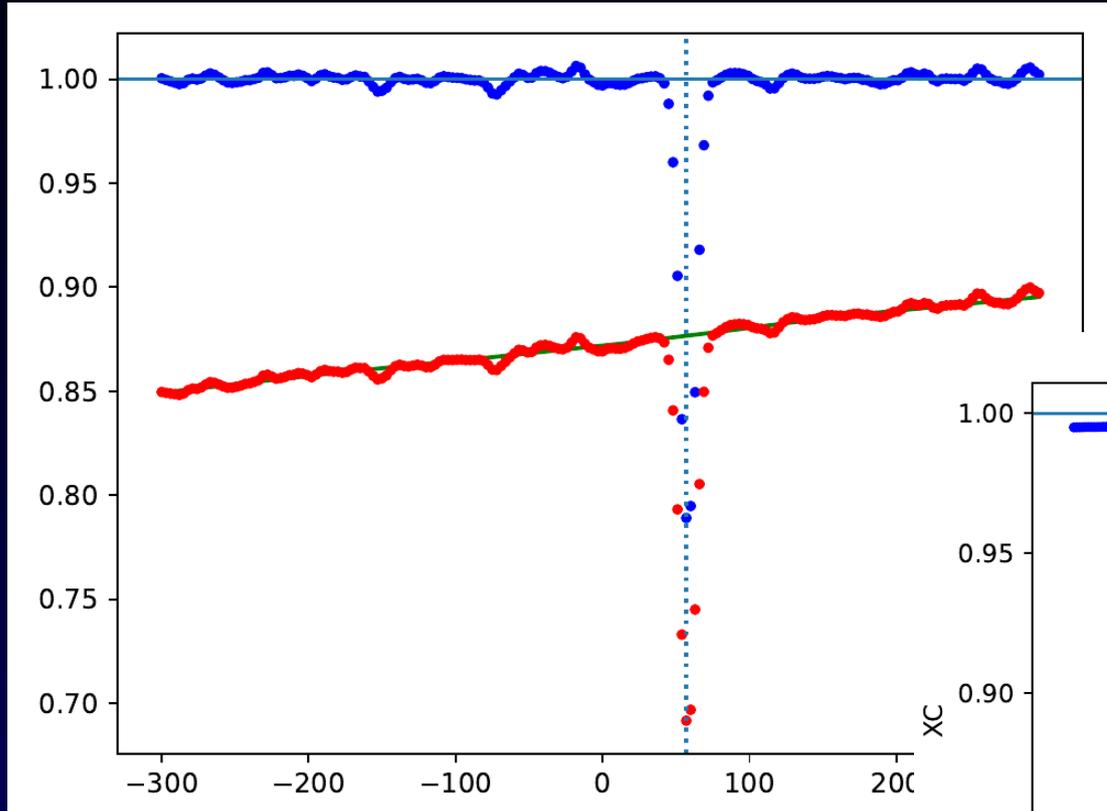
First principle Griffin 1967, DAO 122, CORAVEL ESO D154 1981

# Cross Correlation Function



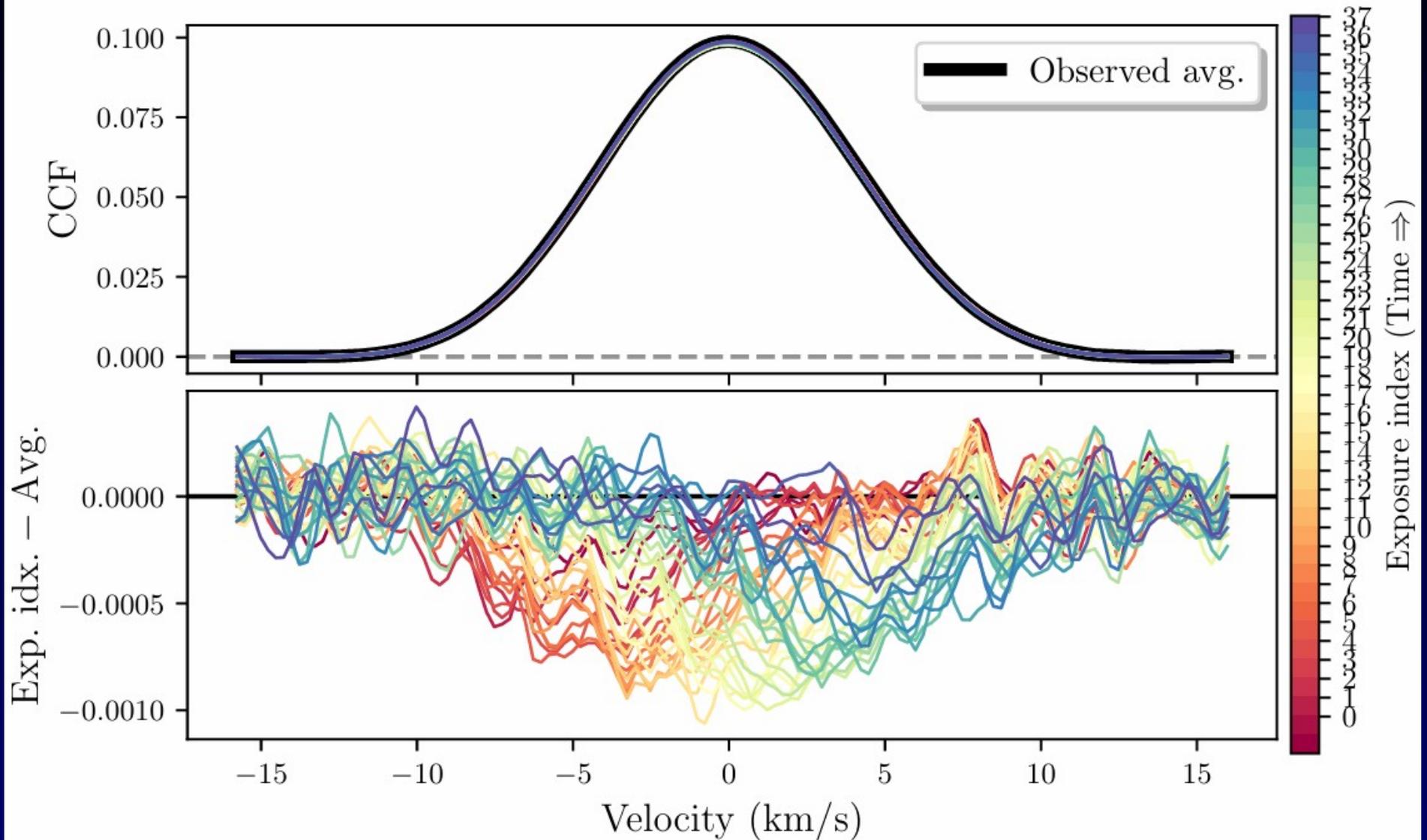
IRAF fxcor task

# Cross Correlation Function - CCF

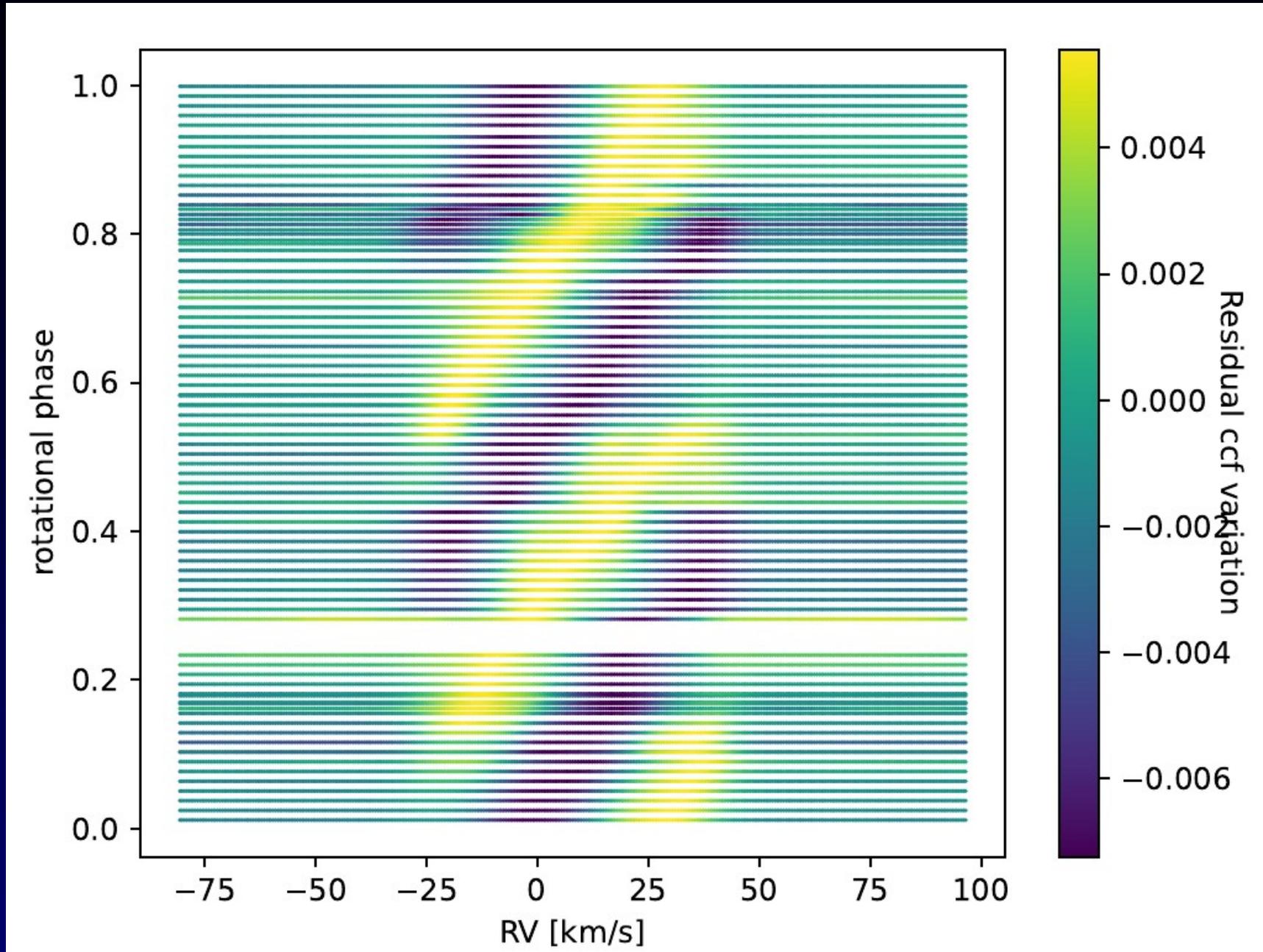


Example of PlatoSpec data reduced by CERES+

# Residual CCF



# Dynamic spectra – CCF



**(Simple) Spectra in VO**

# 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.



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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 resolution and time resolution of the data must be stated as query parameters.

# AST Library – SSAP “flux”

```
Nov 12, 2025 9:21:20 PM uk.ac.starlink.splat.ast.ASTJ makeSpectral
INFO: Data units unknown: km/s (AST: Error at line 420 in file AstObject.c.
astGetSystem(FluxFrame): The current units (km/s) cannot be used with any of the supported flux systems.
```

```
Nov 12, 2025 9:48:08 PM uk.ac.starlink.splat.ast.ASTJ makeSpectral
INFO: Data units unknown: s^-1 (AST: Error at line 420 in file AstObject.c.
astGetSystem(FluxFrame): The current units (s^-1) cannot be used with any of the supported flux systems.
```

## 4.2.5.4 General Dataset Metadata

General dataset metadata describes the overall dataset.

<i>UTYPE</i>	<i>Description</i>	<i>Req</i>	<i>Default</i>
<b>Dataset.DataModel</b>	Datamodel name and version	MAN	Spectrum-1.0
Dataset.Type	Type of dataset	OPT	Spectrum
<b>Dataset.Length</b>	Number of points in spectrum	MAN	
Dataset.Deleted	Set to deletion time, if dataset is deleted	OPT	
Dataset.TimeSI	SI factor and dimensions	OPT	
Dataset.SpectralSI	SI factor and dimensions	OPT	
Dataset.FluxSI	SI factor and dimensions	OPT	
Dataset.SpectralAxis	SpectralAxis column name (native data)	OPT	
Dataset.FluxAxis	FluxAxis column name (native data)	OPT	

SSAP

## 4.2.5.9 Dataset Characterization Axis Metadata

The Characterization axis metadata specifies the type of physical quantity on each physical measurement axis as well as the observable.

<i>UTYPE</i>	<i>Description</i>	<i>Req</i>	<i>Default</i>
Char.FluxAxis.Ucd	ucd for flux	REC	
Char.SpectralAxis.Ucd	ucd for spectral coord	REC	

# Spectra - query output and previews



## CCD700 Spectra Web Interface

Help

Service info

Related

CCD700 SSAP

Metadata

Identifier

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

Description

CCD700 public web interfa

Keywords

Optical spectroscopy

Creator

[Logo]

Created

2014-05-09T10:57:00

Data updated

2016-06-14

Reference URL

Service info

Try ADQL to query our data.

Please report errors and problems to the [site operators](#). Thanks.

[Privacy](#) | [Disclaimer](#)

[Log in](#)

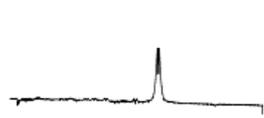
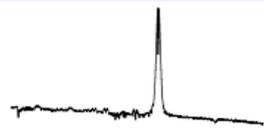
**Parameters**

- Object standard name: [psiper]

**Result**

Matched: 44

Send via SAMP
Quick Plot

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

# Spectra in VizieR (VO)

Importovat záložky... Getting Started Slack | astroinformat... Novinky.czNovinky.cz AstroInformatics 2021 fs\_linux [Phoenix Fire... Slack | Channel brow... Ostatní záložky

CDS PORTAL SIMBAD VizieR ALADiN XMATCH OTHERS HELP ?

VizieR Send to VO tools

Search Criteria  
Save in CDSportal  
Keywords Back  
V/149/dr2  
Tables Add  
V/149  
..dr2  
..stellar2  
..astars2  
..mstars2  
Enlarge Choose  
Constraints  
BT Cmi (arcmin 2)  
Modify Query  
Preferences  
max: 50  
HTML Table  
All columns  
Compute Submit  
Mirrors  
CDS, France

► Show the target form  
► Show constraint information

The 1 column in **color** are computed by VizieR, and are **not part of the original data**.

**V/149/dr2** LAMOST DR2 catalogs (Luo+, 2016) 2016yCat.5149....0L [ReadMe+ftp spectrum/fits](#)

[Post annotation](#) LAMOST DR2 catalog (30/06/2016 version) (4132782 rows)

[start AladinLite](#) [plot the output](#) [query using TAP/SQL](#)

Full	sp	ObsID	Target	PlanId	RAJ2000 deg	DEJ2000 deg	snru	snrg	snrt	snri	snrz	z	ma
1	<a href="#">plot</a>	109508056	J075703.80+025653.6	GAC118N03V1	119								
2	<a href="#">plot</a>	109608056	J075704.05+025652.5	GAC118N03V2	119								
3	<a href="#">plot</a>	109708056	J075704.21+025655.6	GAC118N03V3	119								
4	<a href="#">plot</a>	122514101	J075703.80+025653.6	GAC121N02V2	119								

Target retrieved from simbad (119.266643, 2.950844)  
[plot the output](#) [query using TAP/SQL](#)

VizieR → Cite/acknowl → Rules of usa

VizieR plot — Mozilla Firefox  
cdsarc.cds.unistra.fr/vizier/vizgraph.gml?s=V/149&i=.graph\_sql&ObsId=  
V/149 Lamost J075704.05+025652.5 (ObsID 109608056, file GAC118N03V2/spec-56316-GAC118N03V2\_sp08-056.fits)

Flux

λ [Angstroms]: 1231.62  
Flux: 4636.36

spectrum Equation  
Axes:  
X λ [Angstroms] Log Reverse  
Y Flux Log Reverse  
Opacity:  
Reset zoom  
Save plot as PNG  
Show limits  
Tooltips on plot

Download: VOTable, TSV

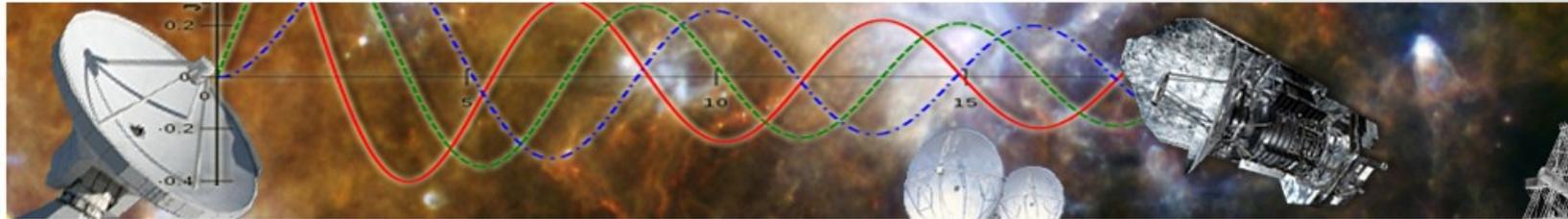
# VO Tools

- SPLAT-VO (GAVO – Ondrejov)
- CASSIS (OMP)
- IPAC Firefly (IRSAViewer)
  - All NASA data, LSST (Rubin)
  - Spectra in echelle – started
  - <https://github.com/Caltech-IPAC/firefly>
- Not Supported:
  - SpecView (HST)
  - VOSpec (ESA)

# CASSIS



**CASSIS**  
A free interactive spectrum analyser



## CASSIS

Presentation

Download & Installation

CASSIS Online

Documentation & Data

What's new?

FAQ

Caveats and tricks

Cassiss in Hipe

Bugs report

Publications and Talks

Credits

Authors

Catalogs

License

Links

Help Online

The current version of CASSIS is 6.3, released October 10, 2022

### • Project Scientists

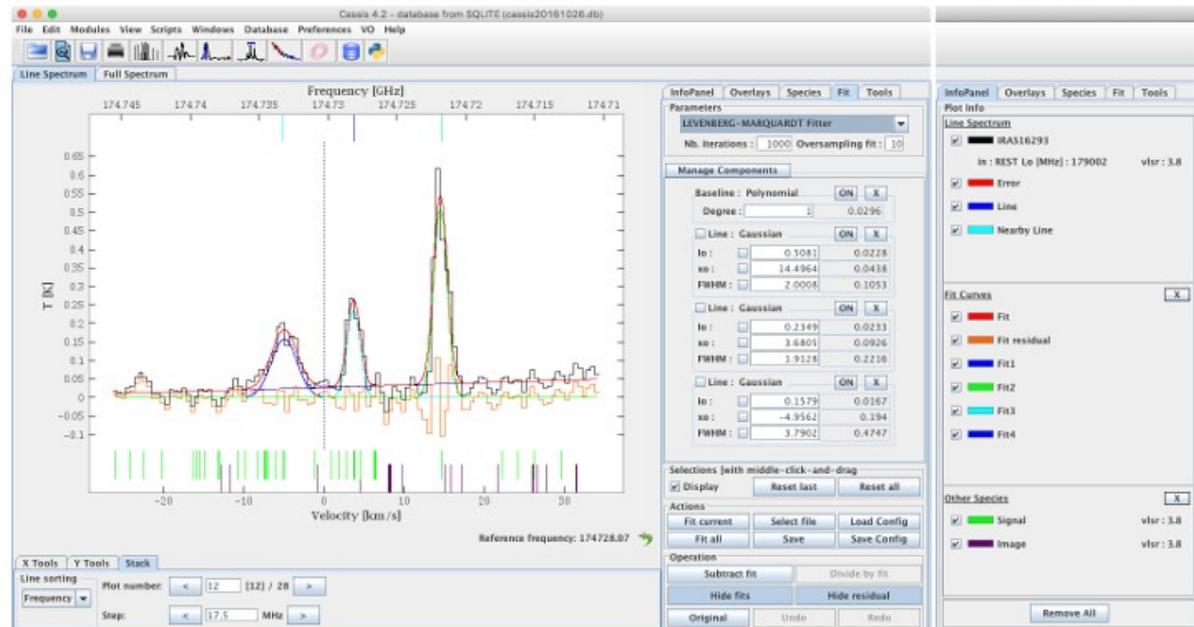
- o Sandrine Bottinelli: Sandrine.Bottinelli[at]irap.omp.eu
- o Emmanuel Caux (PI): Emmanuel.Caux[at]irap.omp.eu
- o Audrey Coutens: Audrey.Coutens[at]irap.omp.eu
- o Charlotte Vastel: Charlotte.Vastel[at]irap.omp.eu

### • Project Manager

- o Jean-Michel Glorian : Jean-Michel.Glorian[at]irap.omp.eu

### • Developer

- o Micka l Boiziot : Mickael.Boiziot[at]irap.omp.eu



# LAMOST Query Ha region

Starlink SPLAT-VO: Query VO for Spectra

File Options Resolver Interop Help

Service selection options  
Data Source  
 Observed data  Theoretical data

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

Tags

SSAP Servers

short name	title
HFA	HyperLeda FITS Archive...
INES ARCHIVE	INES: The IUE Newly Ext...
IUE	International Ultraviolet...
ISO SSAP	ISO ESA Archive SSAP
IUE highly processed s...	IUE highly processed s...
LAMOST.DR1.SSAP	LAMOST DR1 SPECTRUM...
M4AST	M4AST - Modeling for A...
Magic SSAP	Magic Public Spectra S...
MAGIC	MAGIC Spectrum Service
HEAVENS @ ISDC	Mining the HEAVENS wi...
NOVA Spectral Catalog	NOVA Spectral Catalog
OMC SSA	OMC: The INTEGRAL Opt...
CCD700 OND voarchive	Ondrejov CCD700 spect...
CCD700 OND vos2	Ondrejov CCD700 spect...
LAMOST DR1 OND voarc...	Ondrejov copy of LAMO...
LAMOST DR1 OND vos2	Ondrejov copy of LAMO...
LAMOST DR3 OND vos2	Ondrejov copy of LAMO...
HEROS OND voarchive	Ondrejov HEROS spectr...
HEROS OND vos2	Ondrejov HEROS spectr...
XIDResult SSA	Optical spectra of the X...
CDFS SSAP	Optical Spectroscopy in...
Polarbase SSAP	Polarbase SSAP service...
mlqso bidi ssa	Spectra of lensed QSO...
ELODIEinterp	Spectrum interpolator f...
GAUDIVO	SSAP for GAUDI
RCSED_SSAP	SSA service for RCSED ...
SubaruHDS	Subaru HDS Spectrum ...
SVO HERBIG AeBe	SVO EXPORT HERBIG Ae...
TBL Narval	TBL Narval legacy
COROT ARCHIVE	The COROT PUBLIC ARC...
The Mark-I solar spectr...	The Mark-I solar spectr...
NED/SED	The NASA/IPAC Extragal...
PCSLG SSAP	The Panchromatic High...
VIPERS Spectra	The VIMOS Public Extra...
TUES	Tubingen Echelle Spect...
Ultraviolet photometry...	Ultraviolet photometry...
VizieR SSA	VizieR SSA service
VUDS COSMOS DR1	VUDS-COSMOS (DR1) - ...

Search parameters:  
Simple Query  
Object: bt cmi    
RA: 07:57:03.994 Dec: +02:57:03.04  
Radius: 0.5 MAXREC:  
Band:  
Time:  
Query Format: ALL  
Wavelength calibration: None  
Flux calibration: None

Optional Parameters

Use	Name	Value	UCD
<input type="checkbox"/>	SPECRP		spect.resolution;em.wl
<input type="checkbox"/>	SPATRES		pos.angResolution
<input type="checkbox"/>	PUBDID		
<input type="checkbox"/>	CREATORID		meta.id
<input type="checkbox"/>	WILDTARGET		
<input type="checkbox"/>	WILDTARGETCASE		
<input type="checkbox"/>	TOP		

Query: <SERVER>?REQUEST=queryData&POS=119,2666416666667,2.9508444444444444&FORMAT=ALL&SIZE=0.008333333333333333

Query results:

CCD700 OND vos2 LAMOST DR1 OND vos2

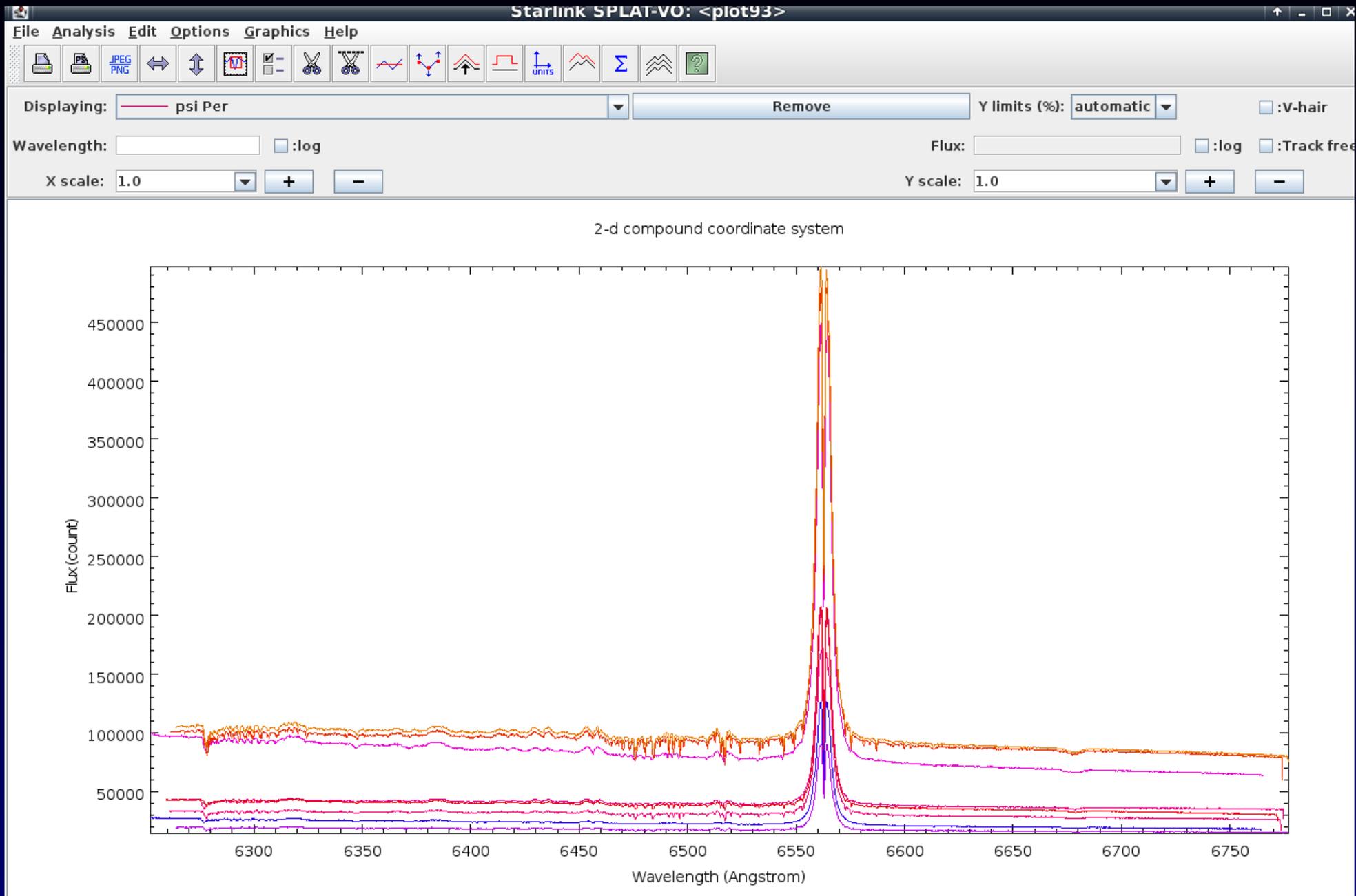
l...	ssa_specstart	ssa_specend	ssa_dstitle	ssa_targname	ssa_dateObs	ssa_timeExt	ssa_snr	ssa_length	accref
1	3.69999E-7	9.07403E-7	lamost_dr1/data/fits/GAC118N...	LAMOST J075704.05+025652.5	56315.65115	1200.		3897	http://vos2.asu.cas.cz/getpro...
2	3.69999E-7	9.07403E-7	lamost_dr1/data/fits/GAC118N...	LAMOST J075704.05+025652.5	56315.65115	1200.		3897	http://vos2.asu.cas.cz/getpro...
3	3.69999E-7	9.07403E-7	lamost_dr1/data/fits/GAC118N...	LAMOST J075704.21+025655.6	56315.67766	1200.		3897	http://vos2.asu.cas.cz/getpro...
4	3.69999E-7	9.07403E-7	lamost_dr1/data/fits/GAC118N...	LAMOST J075704.21+025655.6	56315.67766	1200.		3897	http://vos2.asu.cas.cz/getpro...
5	3.69999E-7	9.07821E-7	lamost_dr1/data/fits/GAC121N...	LAMOST J075703.80+025653.6	56341.66307	1200.		3899	http://vos2.asu.cas.cz/getpro...
6	3.69999E-7	9.07821E-7	lamost_dr1/data/fits/GAC121N...	LAMOST J075703.80+025653.6	56341.66307	1200.		3899	http://vos2.asu.cas.cz/getpro...

Parameters for Server-Generated data processing

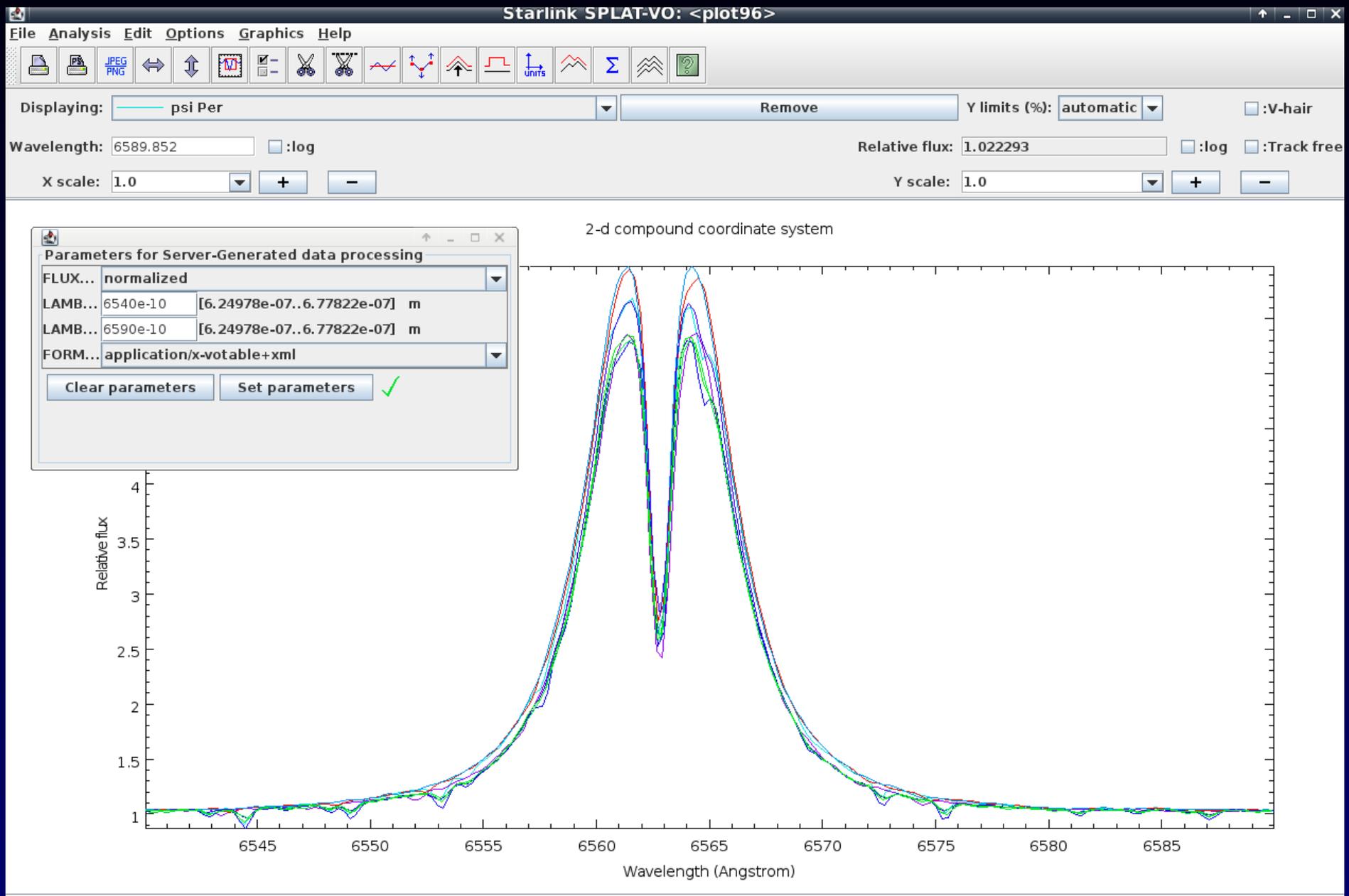
FLUXCALIB : normalized  
REDSHIFT :  
BAND : 6255e-10 / 6800e-10 [3.69999e-07..9.07821e-07] m  
FORMAT : application/x-votable+xml

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

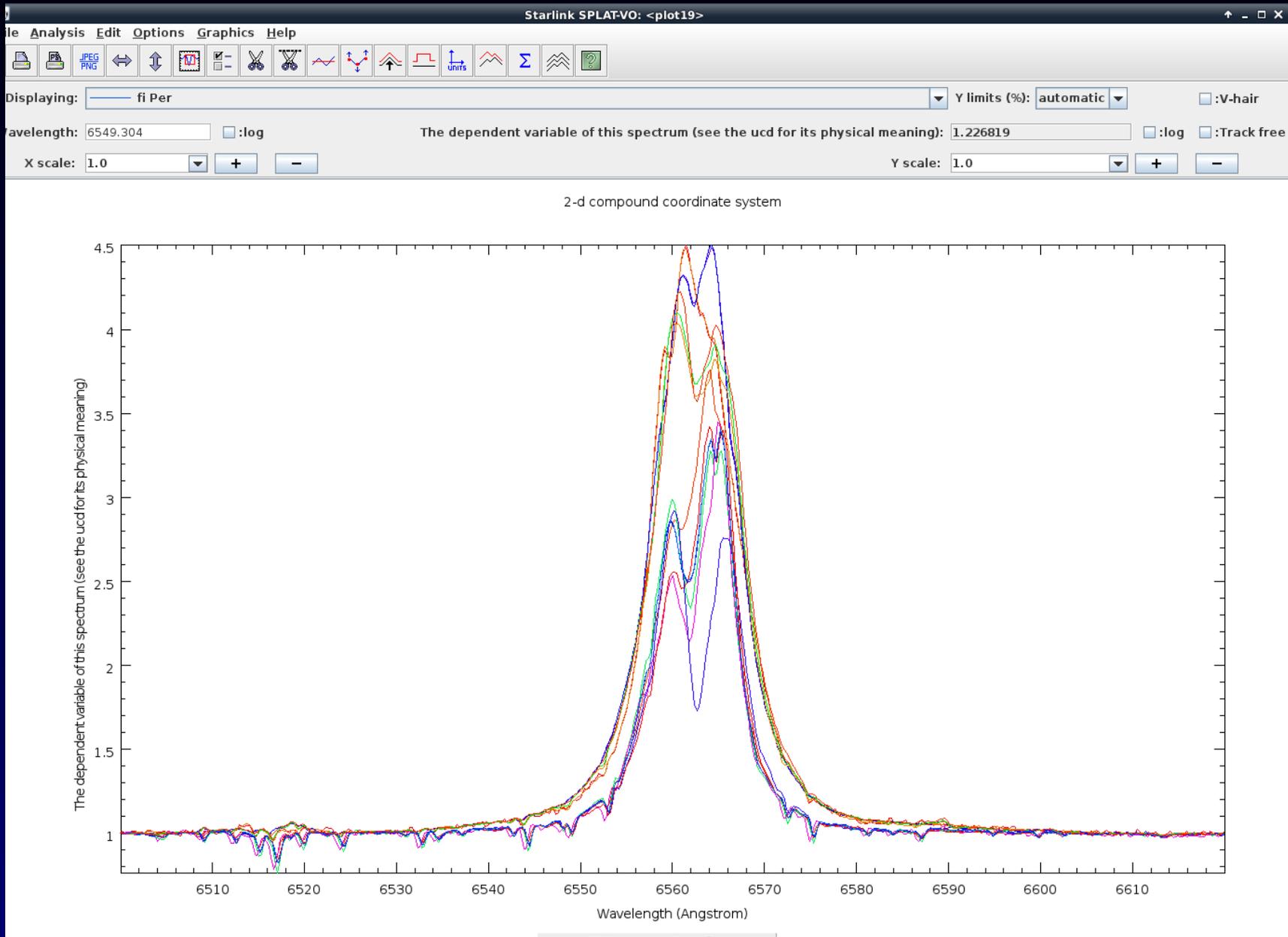
# Spectra in SPLAT-VO direct access



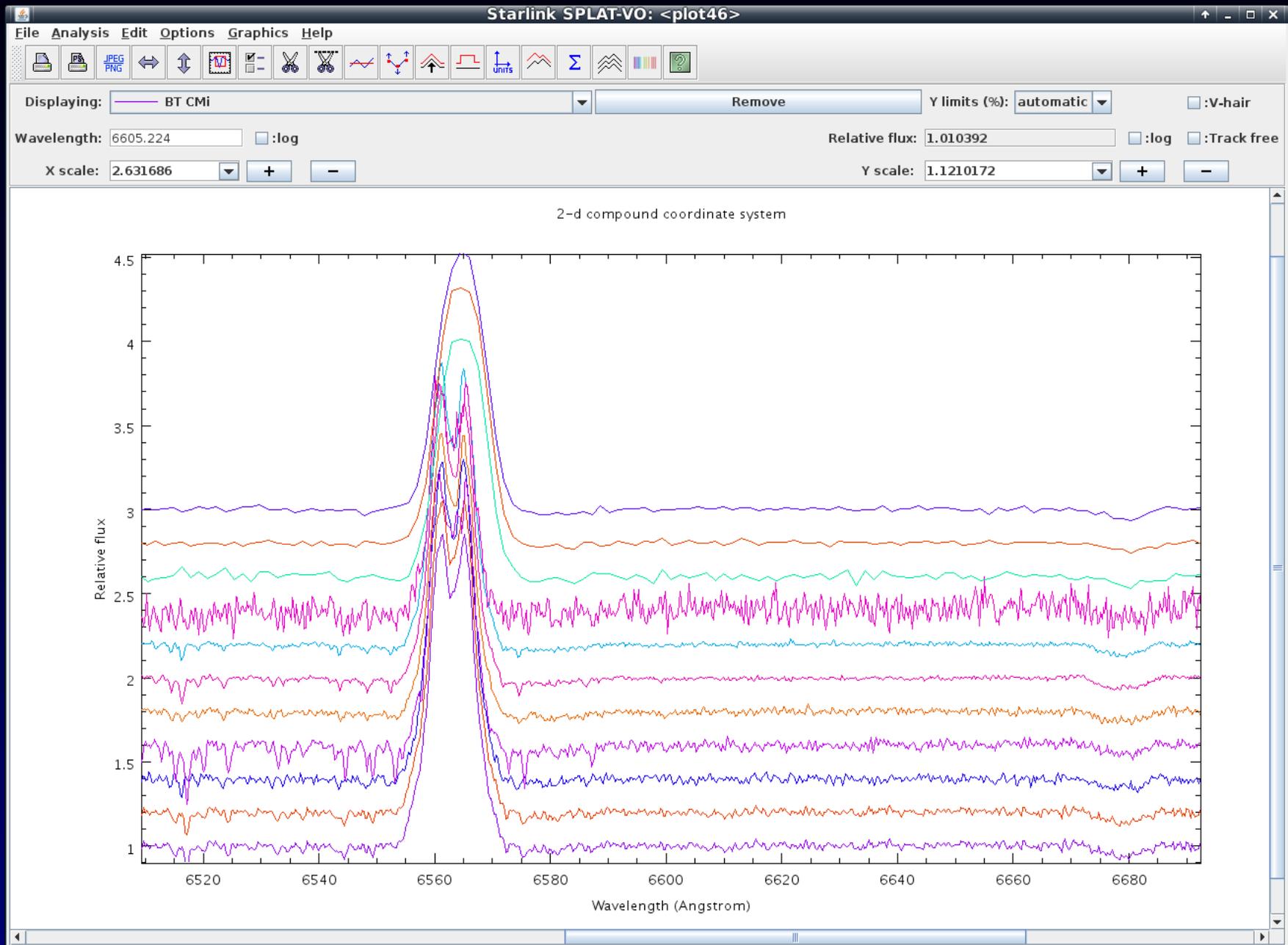
# Spectra in SPLAT-VO - DataLink



# Variability of Line Profile on Be star



# LAMOST emission candidate



# Series of Spectra – LPV

Starlink SPLAT-VO: <plot3>

File Analysis Edit Options Graphics Help



Displaying: 4 Her

Remove

Y limits (%): automatic

:V-hair

Wavelength: 6551.436  :log

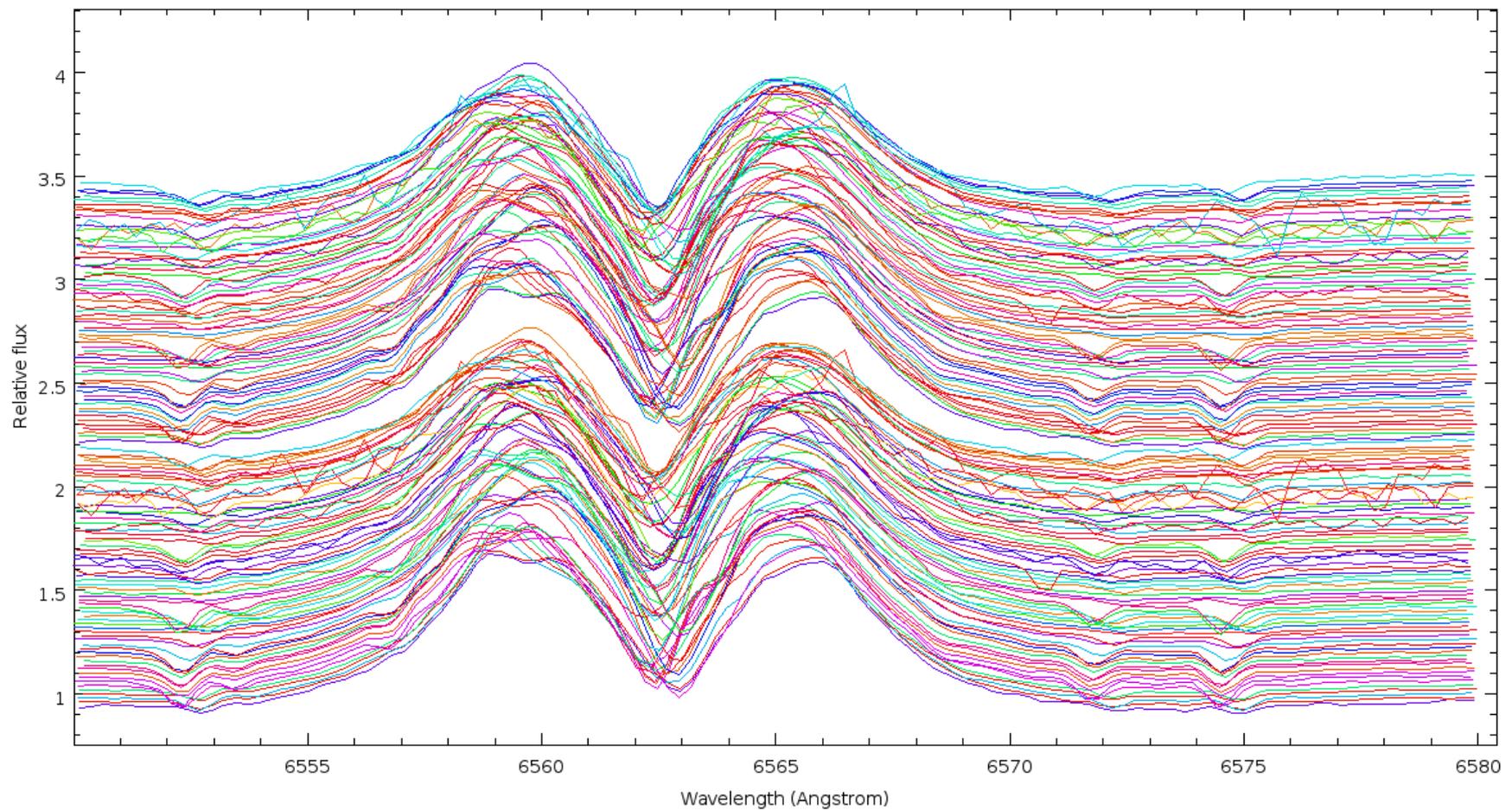
Relative flux: 0.9117984

:log  :Track free

X scale: 1.0

Y scale: 1.0

2-d compound coordinate system



# Echelle Spectra Formats

- MANY
- Each order is one spectrum (BeSS) - not seen easily
- Each order SEPARATED – different WCS + overlaps
- Tables CSV (Opera), FITS Binary tables
- 6-10 FITS extensions (CERES package)

# IRAF \*.ec files

**Figure 4: Echelle Spectrum with Legendre Polynomial Function**

```
WAT0_001= 'system=multispec'  
WAT1_001= 'wtype=multispec label=Wavelength units=Angstroms'  
WAT2_001= 'wtype=multispec spec1 = "1 113 2 4955.442888635351 0.05...  
WAT2_002= '83 256 0. 23.22 31.27 1. 0. 2 4 1. 256. 4963.0163112090...  
WAT2_003= '976664 -0.3191636898579552 -0.8169352858733255" spec2 =...  
WAT2_004= '9.081188912082 0.06387049476832223 256 0. 46.09 58.44 1...  
WAT2_005= '56. 5007.401409453303 8.555959076467951 -0.176732458267...  
WAT2_006= '09935064388" spec3 = "3 111 2 5043.505764869474 0.07097...  
WAT2_007= '256 0. 69.28 77.89 1. 0. 2 4 1. 256. 5052.586239197408 ...  
WAT2_008= '271 -0.03173489817897474 -7.190562320405975E-4"  
WCSDIM = 2  
CTYPE1 = 'MULTISPE'  
LTM1_1 = 1.  
CD1_1 = 1.  
CTYPE2 = 'MULTISPE'  
LTM2_2 = 1.  
CD2_2 = 1.
```

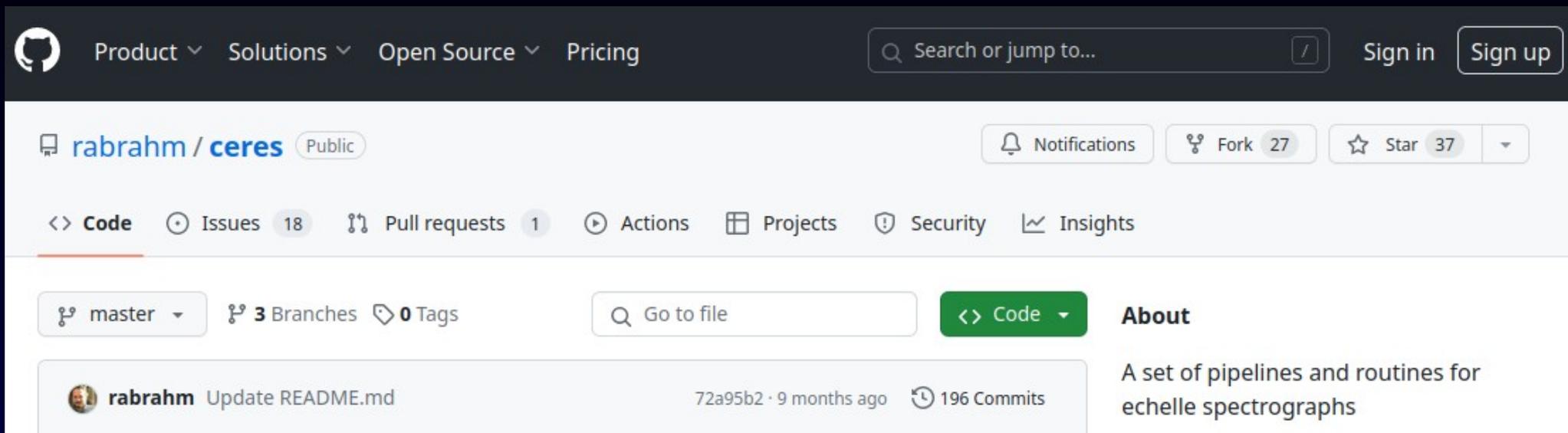
## 5.6 Pixel Array Dispersion Function

The parameters for the pixel array dispersion function consists of just the number of coordinates ncoords. Following this are the wavelengths at integer physical pixel coordinates starting with 1.

To evaluate a wavelength at some physical coordinate, not necessarily an integer, a linear interpolation is used between the nearest integer physical coordinates and the desired physical coordinate

Valdes 1988 , part of IRAF help, docs, specwcs.ps.Z  
summary in ADASS 1993

# CERES output



The screenshot shows the GitHub repository page for `rabrahm / ceres`. The repository is public and has 27 forks and 37 stars. The main navigation bar includes links for Product, Solutions, Open Source, and Pricing, along with a search bar and Sign in / Sign up buttons. The repository navigation bar shows Code, Issues (18), Pull requests (1), Actions, Projects, Security, and Insights. The repository description is "A set of pipelines and routines for echelle spectrographs". A recent commit by `rabrahm` is shown: "Update README.md" (72a95b2, 9 months ago, 196 Commits).

direction. The ten entries in the first dimension correspond to:

- 0- Wavelength
- 1- Extracted Flux
- 2- Measurement of the error in the extracted flux [ $1./\sqrt{\text{Var}}$ ]
- 3- Blaze corrected Flux
- 4- Measurement of the error in the blaze corrected flux
- 5- Continuum normalized flux
- 6- Measurement of the error in the continuum normalized flux
- 7- Estimated continuum
- 8- Signal-to-noise ratio
- 9- Continuum normalized flux multiplied by the derivative of the wavelength
- 10- Corresponding error of the 9th entrance

Not in CERES+

# CERES+ 2D Format

```
hdu.info()
```

```
Filename: 2024-03-05T03:05:48.137129-zet_Pup_2Dsp.fits
```

No.	Name	Ver	Type	Cards	Dimensions	Format
0	PRIMARY	1	PrimaryHDU	125	(1024, 45)	float64
1	FLUX	1	ImageHDU	8	(1024, 45)	float64
2	FLUX_E	1	ImageHDU	8	(1024, 45)	float64
3	DFLUX	1	ImageHDU	8	(1024, 45)	float64
4	DFLUX_E	1	ImageHDU	8	(1024, 45)	float64
5	NFLUX	1	ImageHDU	8	(1024, 45)	float64
6	NFLUX_E	1	ImageHDU	8	(1024, 45)	float64

## Those extensions contain

0. *wavelength* in PRIMARY

1. *raw extracted flux* in FLUX

2. *Error of the flux* in FLUX\_E =  $\frac{1}{\sqrt{\text{variance}(FLUX)}}$

3. *Deblazed flux (extracted stellar flux divided by extracted flat)* in DFLUX

4. *Error of the deblazed flux* in DFLUX\_E

5. *Normalized flux (deblazed flux fitted by small order polynomial to get continuum normalization)* in NFLUX

6. *Error of the normalized flux* in NFLUX\_E

# EPRV Standard

- About 15 spectrographs ( ~ 5 passively following)  
e.g. CARMENES)
- Translators from native format
- Started 2024
- NASA JPL (EPRV project - WG )
- Bruce Berriman at IVOA 2025 June (after my advice to contact IVOA )

<https://github.com/EPRV-RCN/RVData>

<https://eprv-data-standard.readthedocs.io/en/latest>

# EPRV L2 – Order by Order Unblazed

HDU	Name	Data Type	MinBetDepth	Multiplicity	Required	Description
0	PRIMARY	PrimaryHDU		False	True	EPRV Standard FITS HEADER (no data)
1	INSTRUMENT_HEADER	ImageHDU		False	True	Inherited instrument header (no data)
2	RECEIPT	BinTableHDU		False	True	Table of operations that have been performed on this file
3	DRP_CONFIG	BinTableHDU		False	True	Pipeline details (settings etc) to go from native data to L2
4	EXT_DESCRIPTOR	BinTableHDU		False	True	Table describing contents of each extension
5	ORDER_TABLE	BinTableHDU		TRUE	TRUE	Table capturing the wavelength extent of each order
6	TRACE1_FLUX	ImageHDU		True	True	Flux in trace 1
7	TRACE1_WAVE	ImageHDU	64	True	True	wavelength solution for trace 1
8	TRACE1_VAR	ImageHDU		True	True	variance for trace 1
9	TRACE1_BLAZE	ImageHDU		True	True	blaze for trace 1
10	BARYCORR_KMS	ImageHDU		False	True	barycentric correction in km/s
11	BARYCORR_Z	ImageHDU		False	True	barycentric correction in redshift
12	BJD_TDB	ImageHDU	64	False	True	Photon weighted midpoint
13	DRIFT	ImageHDU		False	False	Drift measurement map in delta lambda
14	TRACE1_QUALITY	ImageHDU	UINT8	True	False	Quality of each pixel in trace 1
15	EXPMETER	BinTableHDU		False	False	Table of exposure meter counts timeseries over the exposure
16	TELEMETRY	BinTableHDU		False	False	Table of telemetry collected during the exposure
17	TRACE1_TELLURIC	ImageHDU		True	False	Telluric model for trace 1
18	TRACE1_SKYMODEL	ImageHDU		True	False	Sky model for trace 1
19	ANCILLARY_SPECTRUM	ImageHDU		True	False	Extension(s) that store ancillary spectra
20	IMAGE	ImageHDU		True	False	Extension(s) that store useful support images
21	CUSTOM1_TRACE1_FLUX	ImageHDU		True	False	Additionally corrected flux in trace 1
22	CUSTOM1_TRACE1_WAVE	ImageHDU		True	False	Additionally corrected wavelength solution for trace 1
23	CUSTOM1_TRACE1_VAR	ImageHDU		True	False	Additionally corrected variance for the flux in trace 1

# EPRV L3 – Merged orders normalized

This is what we already know – SSAP, “distorted data low precision”

HDU	Name	DataType	Multiplicity	Required	Description
0	PRIMARY	PrimaryHDU	False	True	EPRV Standard FITS HEADER (no data)
1	INSTRUMENT_HEADER	ImageHDU	False	True	Inherited instrument header (no data)
2	RECEIPT	BinTableHDU	False	True	Table of operations that have been performed on this file
3	DRP_CONFIG	BinTableHDU	False	True	Pipeline details (settings etc) to go from native data to L2
4	ORDER_TABLE	BinTableHDU	TRUE	TRUE	Table capturing the wavelength extent of each order
5	STITCHED_CORR_TRACE1_FLUX	ImageHDU	True	True	Order stitched blaze-corrected flux in trace 1
6	STITCHED_CORR_TRACE1_WAVE	ImageHDU	True	True	Order stitched BC- and drift-corrected wavelength solution for trace 1
7	STITCHED_CORR_TRACE1_VAR	ImageHDU	True	True	Order stitched variance for the flux in STITCHED_CORR_TRACE1_FLUX
8	COMBINED_STITCHED_CORR_FLUX	ImageHDU	True	True	Order stitched and blaze-corrected flux co-added across all traces
9	COMBINED_STITCHED_CORR_WAVE	ImageHDU	True	True	Order stitched BC- and drift-corrected wavelength solution
10	COMBINED_STITCHED_CORR_VAR	ImageHDU	True	True	Order stitched variance for the combined flux in COMBINED_STITCHED_CORR_FLUX
11	STITCHED_CUSTOMCORR1_TRACE1_FLUX	ImageHDU	True	False	Additional corrections made to STITCHED_CORR_TRACE1_FLUX
12	STITCHED_CUSTOMCORR1_TRACE1_WAVE	ImageHDU	True	False	Wavelength solution corresponding to STITCHED_CUSTOMCORR1_TRACE1_FLUX
13	STITCHED_CUSTOMCORR1_TRACE1_VAR	ImageHDU	True	False	Variance corresponding to STITCHED_CUSTOMCORR1_TRACE1_FLUX
14	COMBINED_STITCHED_CUSTOMCORR1_FLUX	ImageHDU	True	False	Additional corrections made to COMBINED_STITCHED_CORR_FLUX
15	COMBINED_STITCHED_CUSTOMCORR1_WAVE	ImageHDU	True	False	Wavelength solution corresponding to COMBINED_STITCHED_CORR_WAVE
16	COMBINED_STITCHED_CUSTOMCORR1_VAR	ImageHDU	True	False	Variance corresponding to COMBINED_STITCHED_CORR_VAR

# EPRV L4 – Derived core exo science

Radial Velocity and Cross Correlation Function (various masks ....)

It is the most important output of pipeline

But exoscientists need Time Series (RV curves , Doppler shadows)

VO can do it on the fly (select all observation, apply SODA extract , create time series)

HDU	Name	Data Type	Multiplicity	Required	Description
0	PRIMARY	PrimaryHDU	FALSE	TRUE	EPRV Standard FITS HEADER (no data)
1	INSTRUMENT_HEADER	ImageHDU	FALSE	TRUE	Inherited instrument header (no data)
2	RECEIPT	BinTableHDU	FALSE	TRUE	Table of operations that have been performed on this file
3	DRP_CONFIG	BinTableHDU	FALSE	TRUE	Pipeline details (settings etc) to go from native data to L2
4	RV1...N	BinTableHDU	TRUE	TRUE	Derived Radial Velocity Measurement
5	CCF1...N	ImageHDU	TRUE	FALSE	Array with same dimensionality of RV1...N, that contains the CCF that produced each RV1...N
6	DIAGNOSTICS1...J	BinTableHDU	TRUE	FALSE	Activity indicators, CCF metrics, etc
7	CUSTOM_CCF1...N	ImageHDU	TRUE	FALSE	Additional CCFs from (e.g.) different masks
8	CUSTOM_RV1...N	BinTableHDU	TRUE	FALSE	Derived Radial Velocity Measurement from CUSTOM_CCF1...N

# EPRV L4 – ESPRESSO Tau Cet

Fv: Summary of ESPRE.2021-10-03T06:24:23.449\_L4.fits in /home/skoda/EPRV/ESSPRESO/data\_standard/

Index	Extension	Type	Dimension	View		
0	Primary	Image	0	Header	Image	Table
1	INSTRUMENT_HFADFR	Image	n	Header	Image	Table
2	RECEIPT	Binary	0 cols X 0 rows	Header	Hist	Plot
3	DRP_CONFIG	Binary	0 cols X 0 rows	Header	Hist	Plot
4	RV1	Binary	6 cols X 1 rows	Header	Hist	Plot
5	EXT_DESCRIPTOR	Binary	6 cols X 6 rows	Header	Hist	Plot
6	CCF1	Image	81 X 171	Header	Image	Table
7	DIAGNOSTICS1	Binary	4 cols X 3 rows	Header	Hist	Plot
8	RV_TEL_CORR	Binary	6 cols X 1 rows	Header	Hist	Plot
9	CCF_TEL_CORR	Image	81 X 171	Header	Image	Table

Fv: Image of ESPRE.2021-10-03T06:24:23.449\_L4.fits[6] in /home/skoda/EPRV/ESSPRESO/data\_standard/

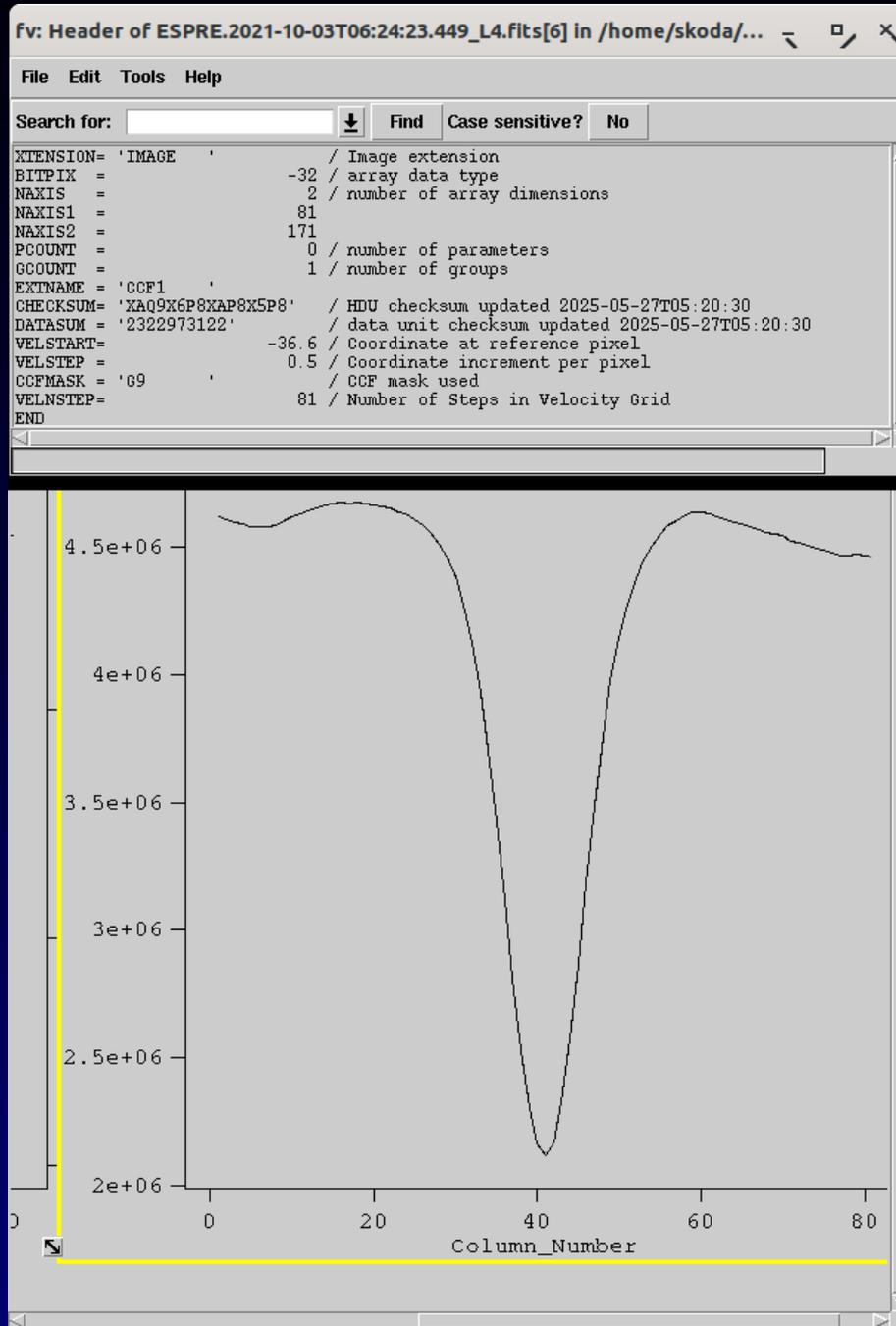
Select  All  Invert

	1	2	3	4	5	6
98	5.26381e+06	5.26814e+06	5.26253e+06	5.26152e+06	5.25577e+06	5.25909e+06
97	4.93282e+06	4.9213e+06	4.92542e+06	4.92336e+06	4.92463e+06	4.92166e+06
96	5.64695e+06	5.63776e+06	5.63015e+06	5.61536e+06	5.58759e+06	5.55647e+06
95	5.27117e+06	5.259e+06	5.24219e+06	5.2263e+06	5.2046e+06	5.1804e+06
94	5.50534e+06	5.47118e+06	5.43957e+06	5.39959e+06	5.35634e+06	5.30384e+06
93	5.02342e+06	4.99754e+06	4.9695e+06	4.93366e+06	4.89204e+06	4.84796e+06
92	2.18587e+06	2.19189e+06	2.18693e+06	2.18391e+06	2.18239e+06	2.18064e+06
91	1.86196e+06	1.86149e+06	1.8596e+06	1.85738e+06	1.85636e+06	1.85244e+06
90	4.54433e+06	4.53008e+06	4.52264e+06	4.51101e+06	4.50543e+06	4.50644e+06
89	4.61856e+06	4.61068e+06	4.59623e+06	4.58902e+06	4.58102e+06	4.57993e+06
88	5.21423e+06	5.23318e+06	5.24848e+06	5.26762e+06	5.27702e+06	5.29468e+06
87	4.90491e+06	4.91717e+06	4.93551e+06	4.95675e+06	4.97213e+06	4.98265e+06
86	6.9235e+06	6.91467e+06	6.9163e+06	6.90327e+06	6.87164e+06	6.83962e+06
85	6.53055e+06	6.53232e+06	6.52367e+06	6.50842e+06	6.48675e+06	6.45614e+06
84	3.60443e+06	3.60589e+06	3.60856e+06	3.60729e+06	3.60377e+06	3.59144e+06
83	3.36668e+06	3.3637e+06	3.36409e+06	3.36489e+06	3.36121e+06	3.35394e+06
82	125850	127562	130461	129012	129511	130110
81	119783	121979	123595	124569	124390	123490
80	4.75847e+06	4.7726e+06	4.78419e+06	4.78505e+06	4.79347e+06	4.79598e+06
79	4.52354e+06	4.53738e+06	4.54066e+06	4.54695e+06	4.55432e+06	4.56287e+06

Go to:  Edit cell:   Lock to Parent

Thanks:  
E.Fontanet  
2025 priv.com.

# EPRV L4 CCF in fv



VLSTART=-36.6 km/s  
VELSTEP=0.5 km/s

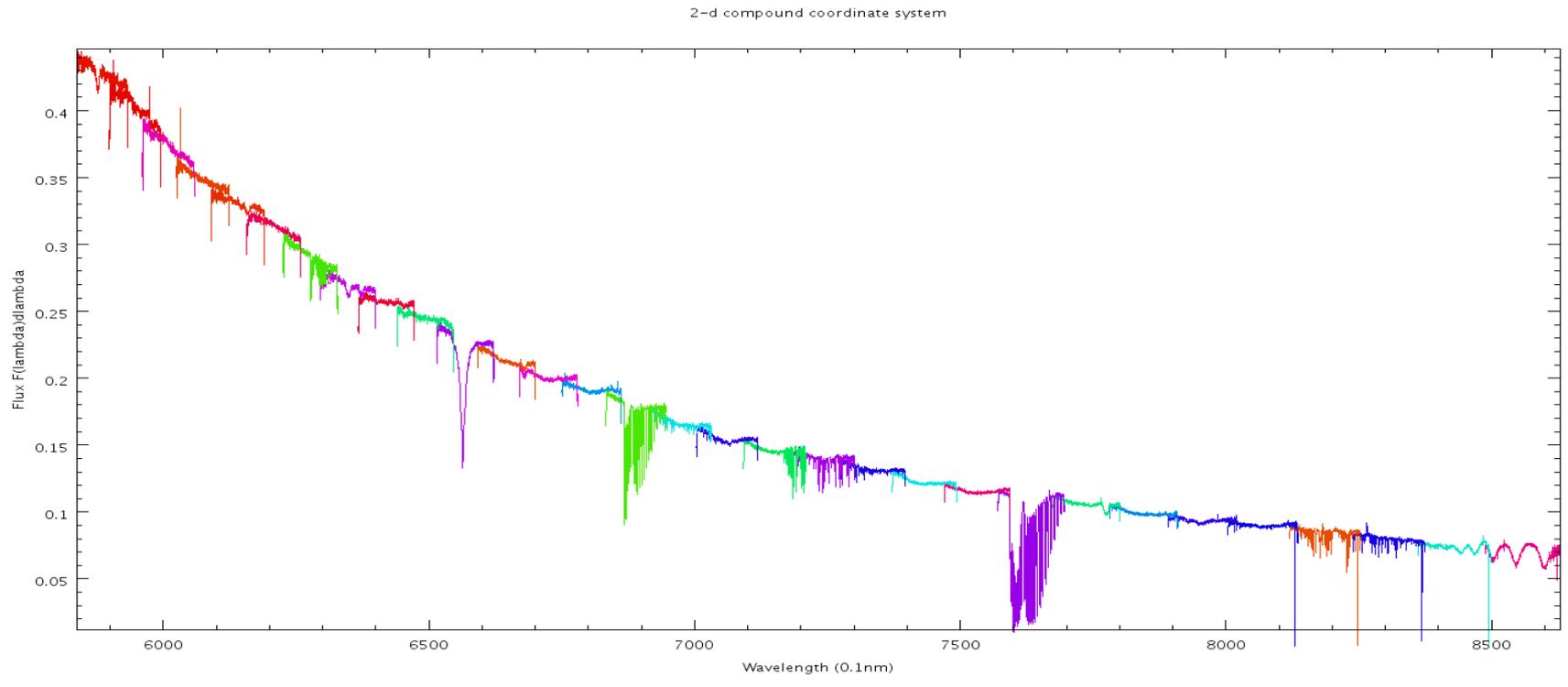
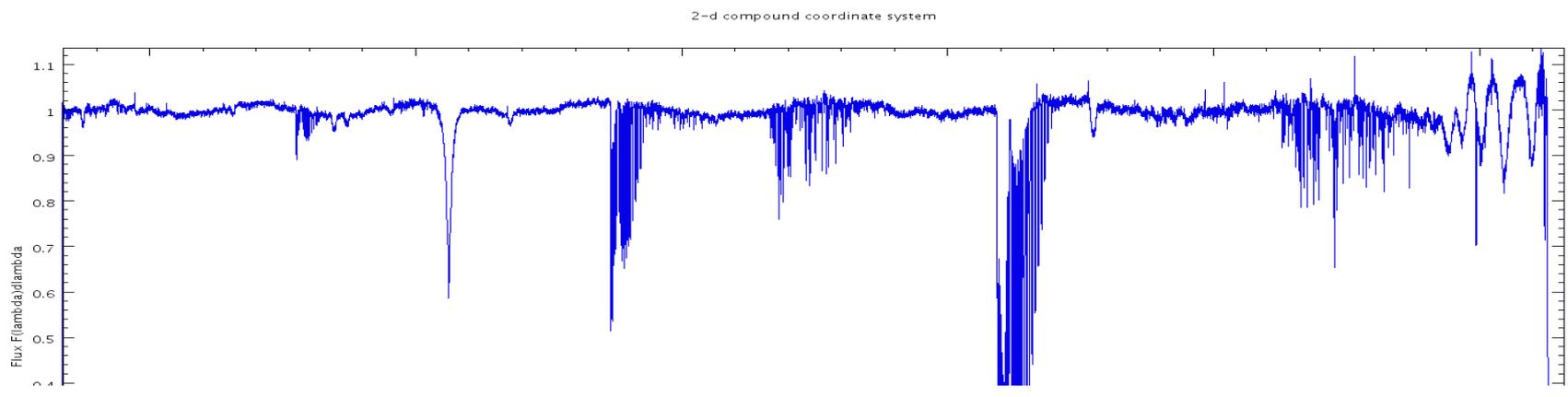
Center~41

$$-36.6 + 40 * 0.5 = -16.6$$

Astrometry	
Radial velocity ( $R_v$ )	$-16.68 \pm 0.05^{[5]}$ km/s
Proper motion ( $\mu$ )	RA: $-1721.728$ mas/yr <sup>[1]</sup> Dec.: $+854.963$ mas/yr <sup>[1]</sup>
Parallax ( $\pi$ )	$273.8097 \pm 0.1701$ mas <sup>[1]</sup>

Thanks:  
E.Fontanet  
2025 priv.com.

# DaCHS Testbed Split-Order SSAP



nu Pup HEROS red

# Trappist-1 RV Curve – Carmenes

Starlink SPLAT-VO: Query VO for Spectra

File Options Resolver Interop Help

**Service selection options**

Data Source  
 Observed data  Theoretical data

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

Data type  
 Spectrum  Time series

Tags  
[ ] [ + ] [ - ]

**SSAP Servers**

short name ^	title
SMUSES	5 mJy Unbiased Spitzer ...
6dF Spectra	6dF DR3 Simple Spectr...
AGN Arch. SSAP	Archive of AGN spectral...
AKARI_IRC_SPEC_DSP	AKARI/IRC NIR Low-resol...
AKARI_IRC_SPEC_GALPN	AKARI/IRC NIR Spectral ...
AKARI_IRC_SPEC_V1	AKARI/IRC MIR-5 slit-less...
ARCHES SED	ARCHES fully calibrated...
BEFS	Berkeley Extreme and ...
BeSS	Be Stars Spectra
BGDS TS SSAP	Bochum Galactic Disk S...
califa ssa	CALIFA DR3
CARMENES_Reiners	CARMENES_Reiners2018
carmenes SSAP	CARMENES DR1: Spectra
carmenes TS SSAP	Carmenes DR1 Radial V...
CaT library	CaT library. Empirical C...
CCD700N	CCD700 ver new
CCD700 SSAP	CCD700 Ondrejov Spec...
CDFS SSAP	Optical Spectroscopy I...
CfA Hectochelle	CfA Hectochelle Spectra
CfA Hectospec	CfA Hectospec Spectra
Chandra	Chandra Observations
Chiu2006	L and T dwarf (Chiu et ...
COROT ARCHIVE	The COROT PUBLIC ARC...
CSIRO ASKAP SSA	CSIRO ASKAP Science D...
DCSSA	Data Central SSA
DFBS SSAP	Digitized First Byurakan...
DIGIT	Herschel Dust, Ice, and...
Disks_SH_Spectra	Spitzer Disks Short-Hig...
DK-154 LC	DK-154 objects
DK-154 LCs	DK-154 objects
ELODIE	ELODIE archive
ELODIEinterp	Spectrum interpolator f...
ESO SSAP	ESO 1D reduced spectra
EUVE	Extreme Ultraviolet Exp...
F/H Orders SSAP	Flash/Heros Split-Order...

**Search parameters:**

Simple Query  
Object: trappist-1 [Lookup] [Clear]  
RA: 23:06:29.368 Dec: -05:02:29.04  
Radius: 5 MAXREC: [ ]  
Band: [ ]  
Time: [ ]

Query Format: [None] [v]  
Wavelength calibration: [None] [v]  
Flux calibration: [None] [v]

Optional Parameters  
Use Name Value UCD  
[ ] [ ] [ ] [ ]  
[Select all] [Deselect all] [Update]

Query: <SERVER>?REQUEST=queryData&POS=346.62236666666666,-5.0414&SIZE=0.08333333333333333 [SEND QUERY]

**Query results:**

carmenes TS SSAP

...	accref	ssa_dstitle	ssa_targname	ssa_dstype	ssa_timeExt	ssa_length	ssa_snr	ssa_dateObs
1	http://dc.g-vo.org/getproduct/...	CARMENES DR1 J23064-050 RVs	CARMENES J23064-050	timeseries	1.48386E7	163		

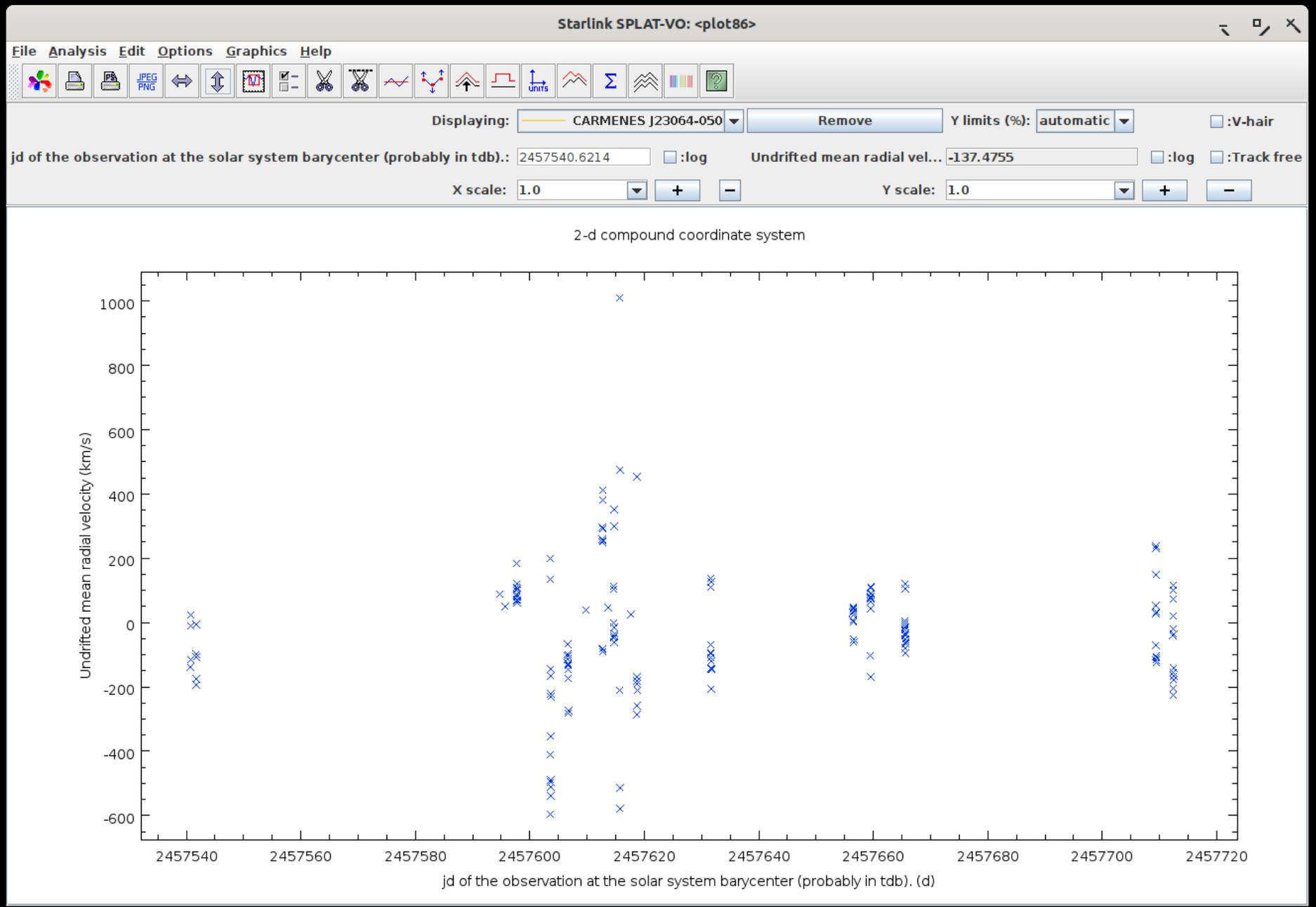
**SSAP Service Information**

**short name:** carmenes TS SSAP  
**title:** Carmenes DR1 Radial Velocity Time Series  
**description:**  
**identifier:** ivo://org.gavo.dc/carmenes/t/ssa  
**publisher:** The GAVO DC team  
**contact:** GAVO Data Centre Team  
(gavo@ari.uni-heidelberg.de)  
(gavo@ari.uni-heidelberg.de)  
**access URL:** http://dc.g-vo.org/carmenes/t/ssa/ssap.xml?  
**reference URL:** http://dc.g-vo.org/carmenes/t/ssa/info  
**waveband:** infrared, optical  
**content type:** archive  
**data source:** pointed  
**creation type:** archival

[OK]

[Select all] [Deselect all] [Query registry] [Add New Server] [Display selected] [Display all] [Download selected] [Download all] [Deselect table] [Deselect all] [DataLink Services] [Save query results] [Restore query results] [Close]

# Trappist-1 RV Curve – Carmenes



Thank you