
# Spectra in VO From Under Both Hats


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Astro-CC
European Data Provider Forum
IWH, Heidelberg, Germany
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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...)

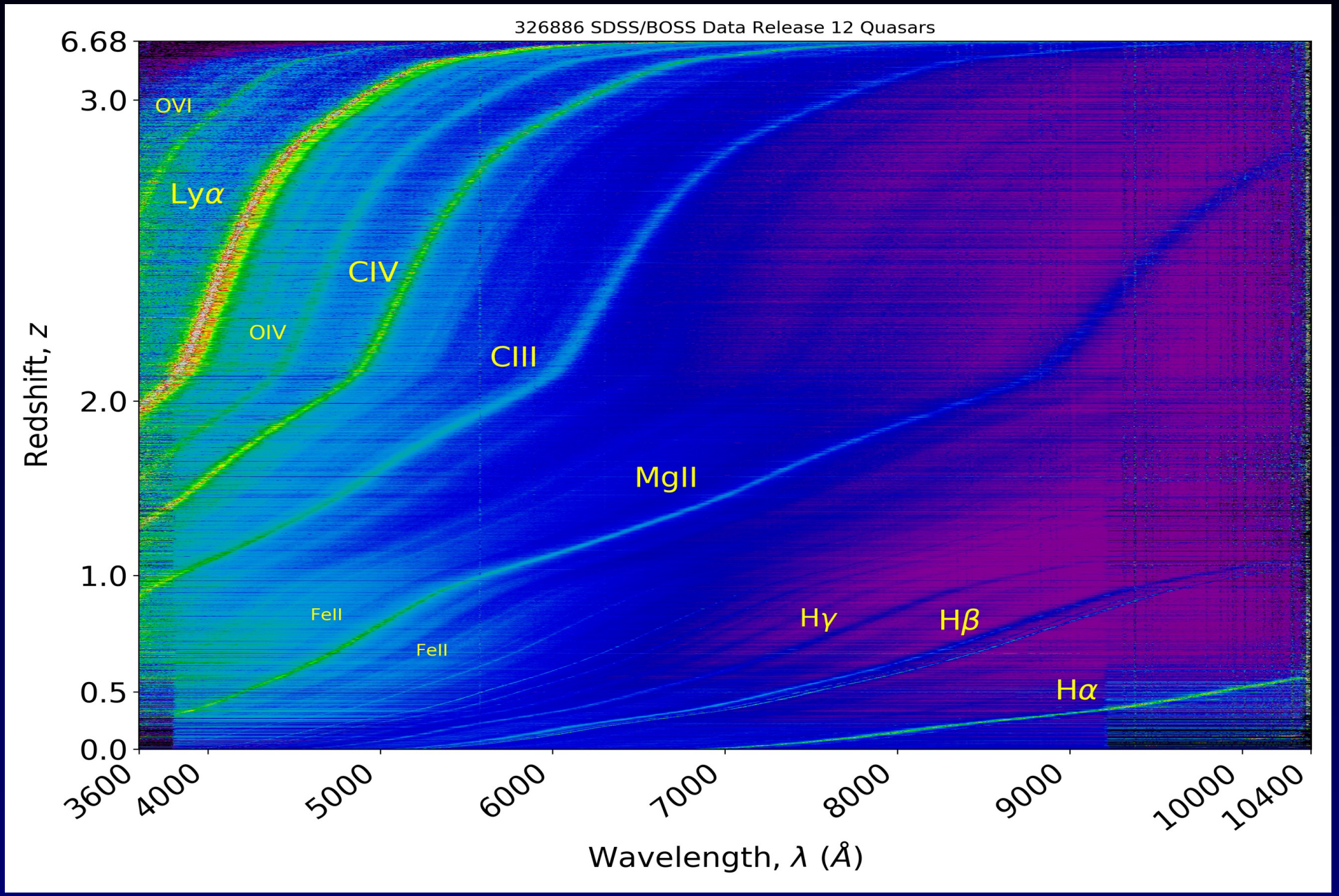
Shape

- Stellar parameters (Teff, log g, rotation)
- Stellar activity (Turbulence, granulation)
- core/wings – diferrent 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
6.68
3.0
2.0
1.0
0.5
0.0
Redshift, z
OVI
Lyα
CIV
OIV
CIII
MgII
FeII
FeII
Hγ
Hβ
Hα
3600
4000
5000
6000
7000
8000
9000
10000
10400
Wavelength, λ (Å)

# Eliminating false high-z QSO

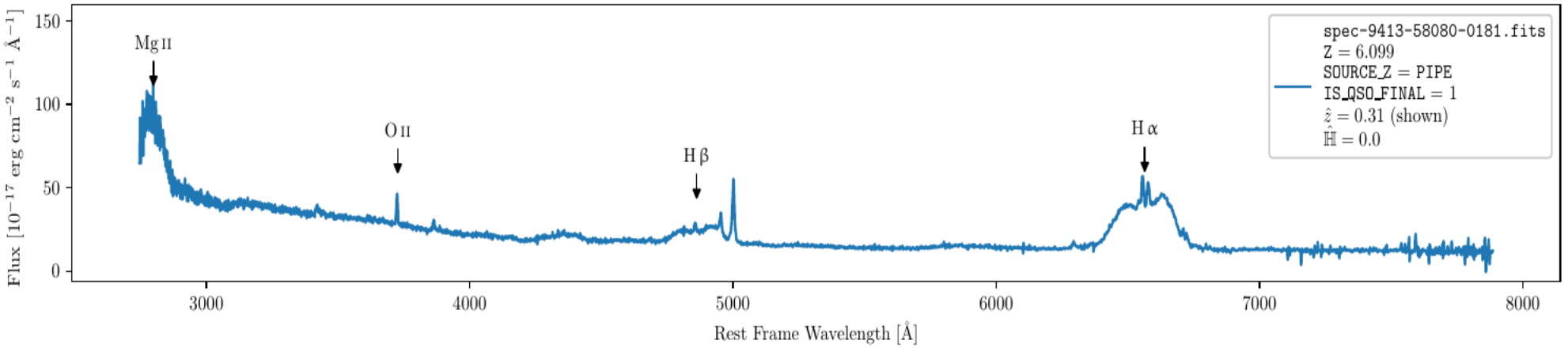



**Figure B6.** Spectrum with incorrectly high redshift prediction by the pipeline. The Bayesian CNN correctly predicted $\hat{z} = 0.31$ with $\hat{\mathbb{H}} = 0$.

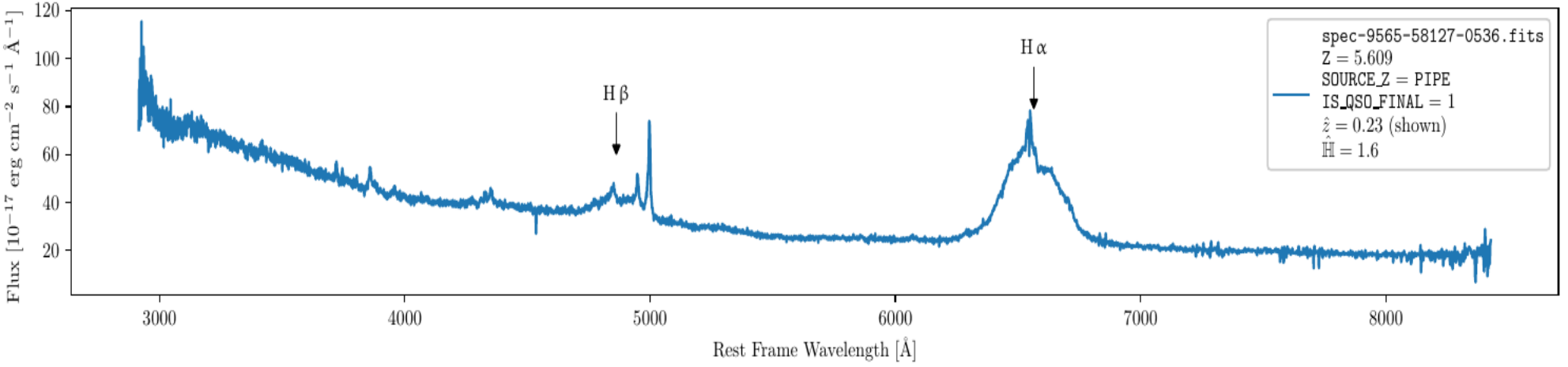
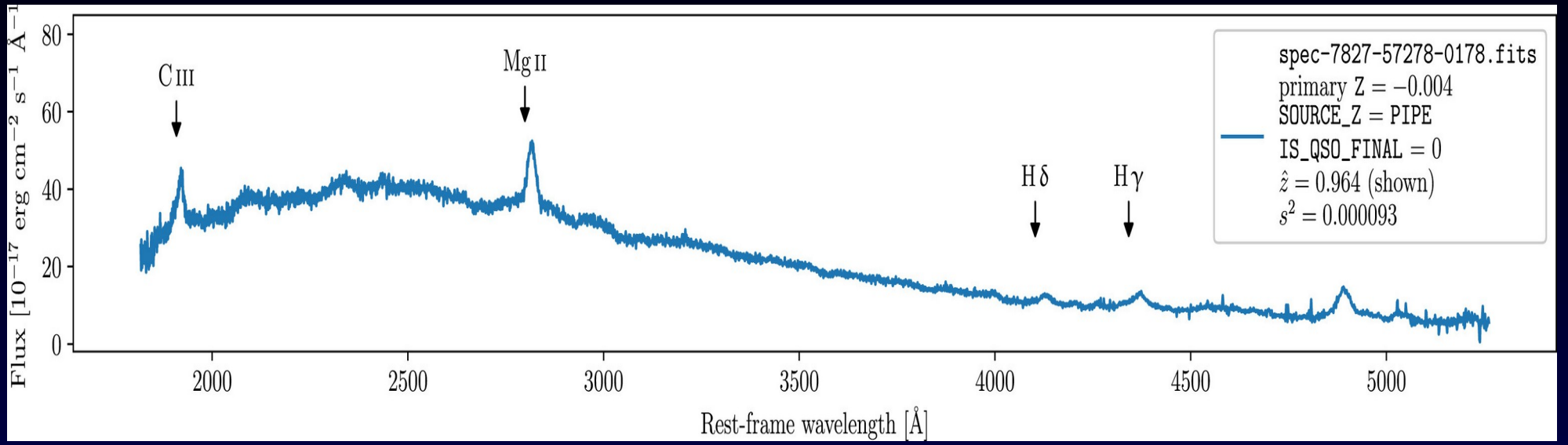
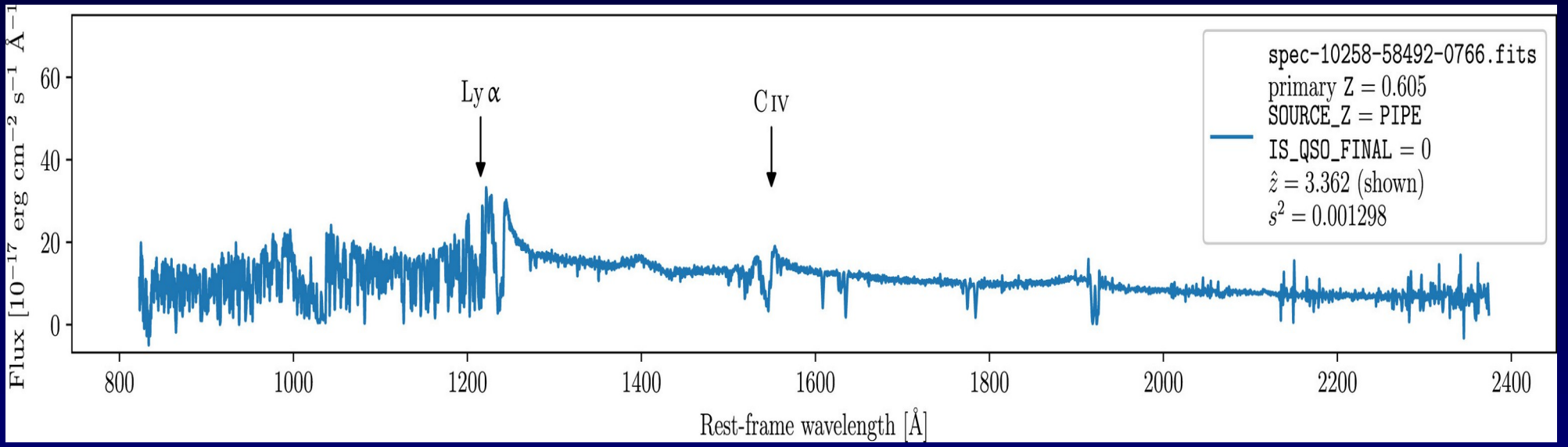


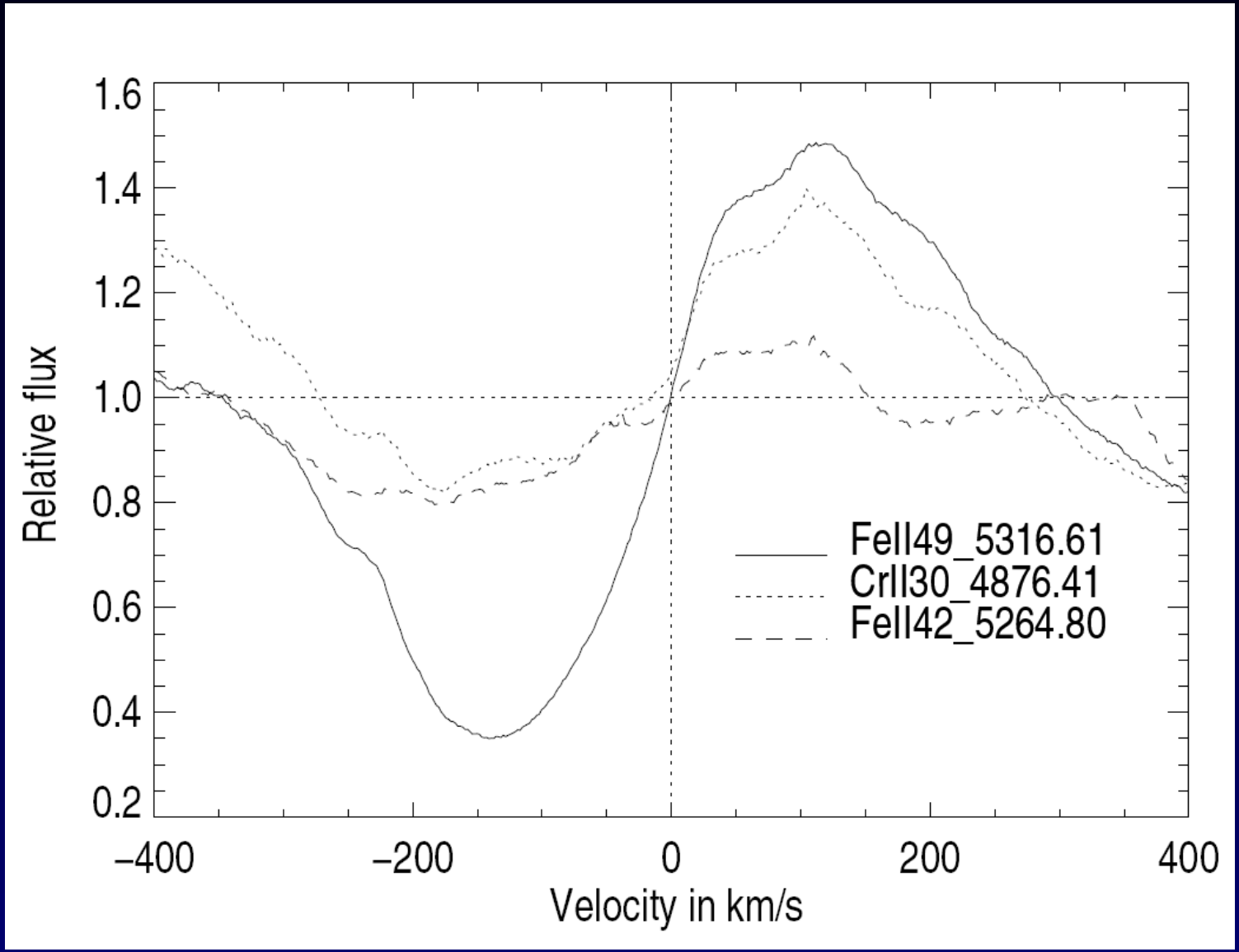

**Figure B7.** Spectrum with incorrectly high redshift prediction by the pipeline. The Bayesian CNN correctly predicted $\hat{z} = 0.23$ with $\hat{\mathbb{H}} = 1.6$.

# QSOs missing due to SDSS pipeline error



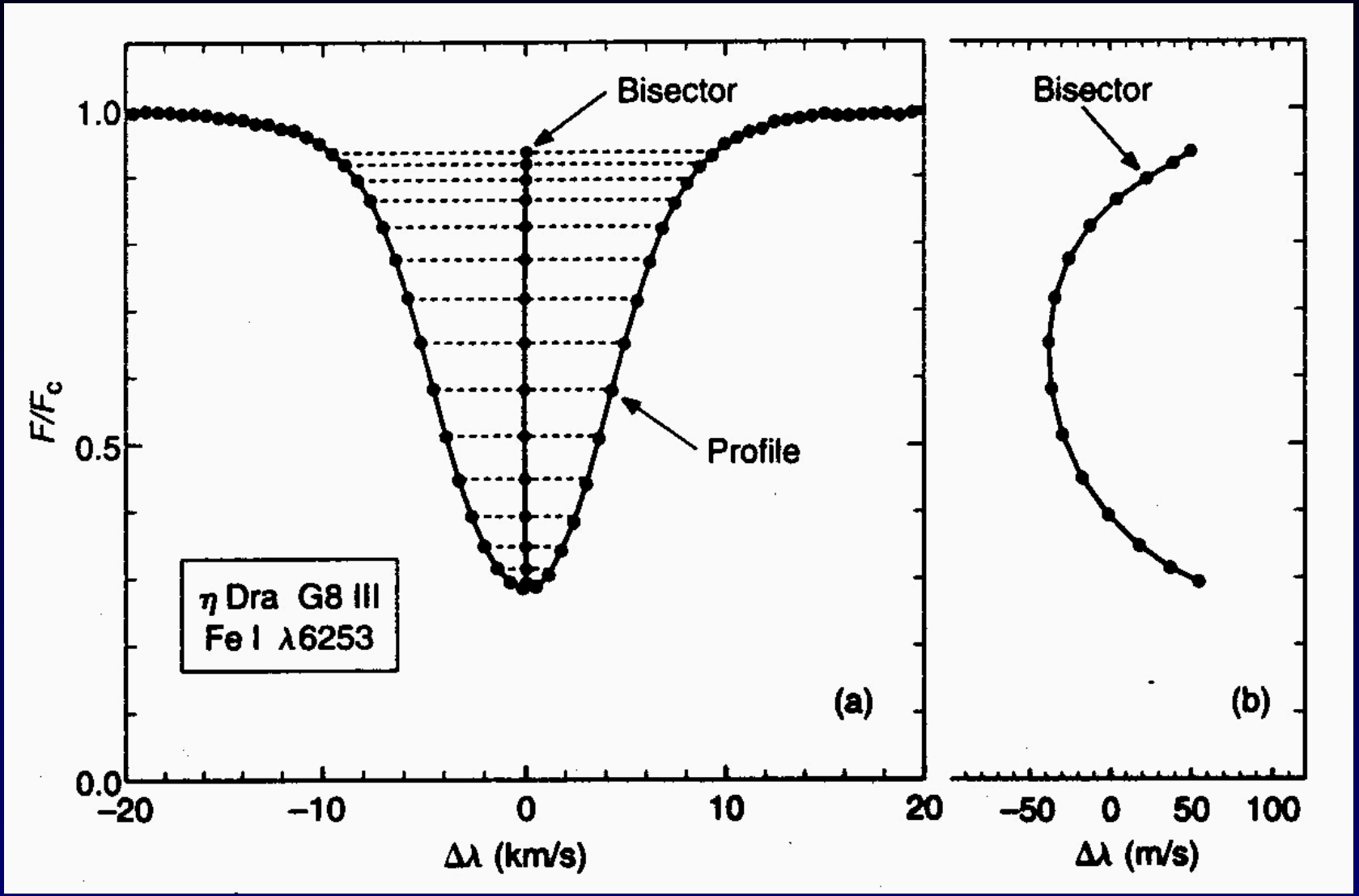



# Different Lines overploted in RV




V838 Mon: Kipper et al. 2004

# Bisector Method



# Line Profile- Bisectors

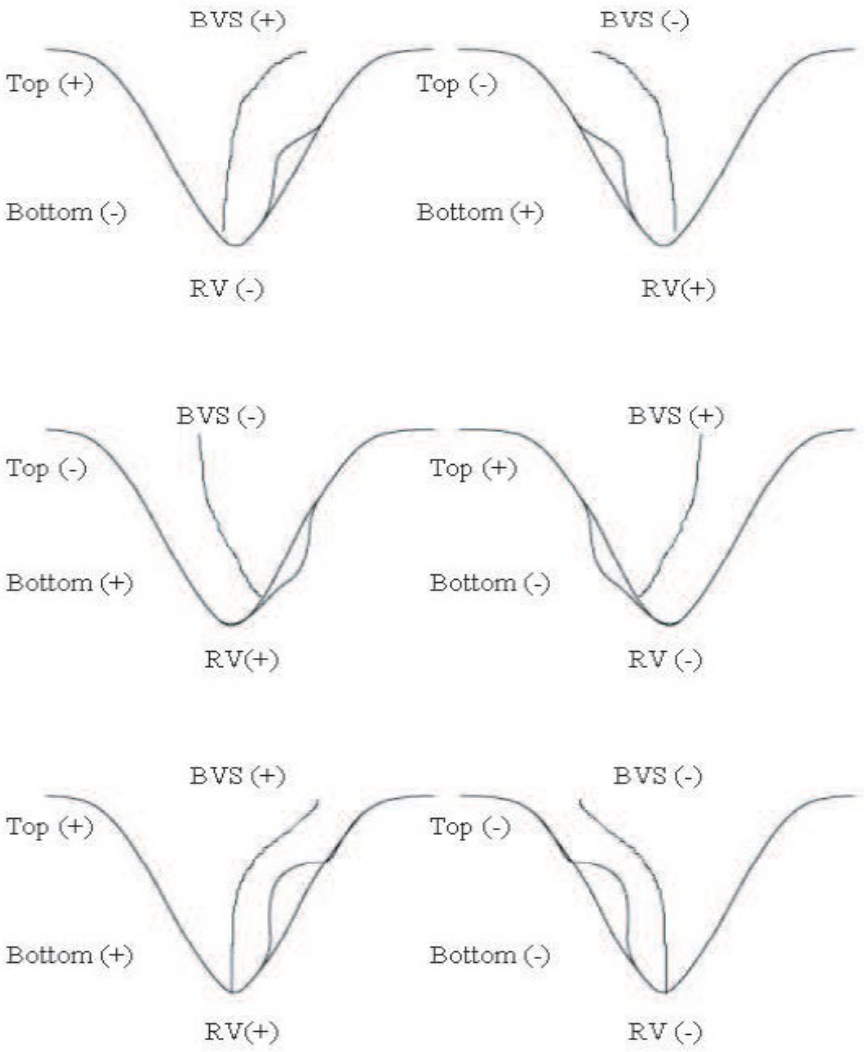
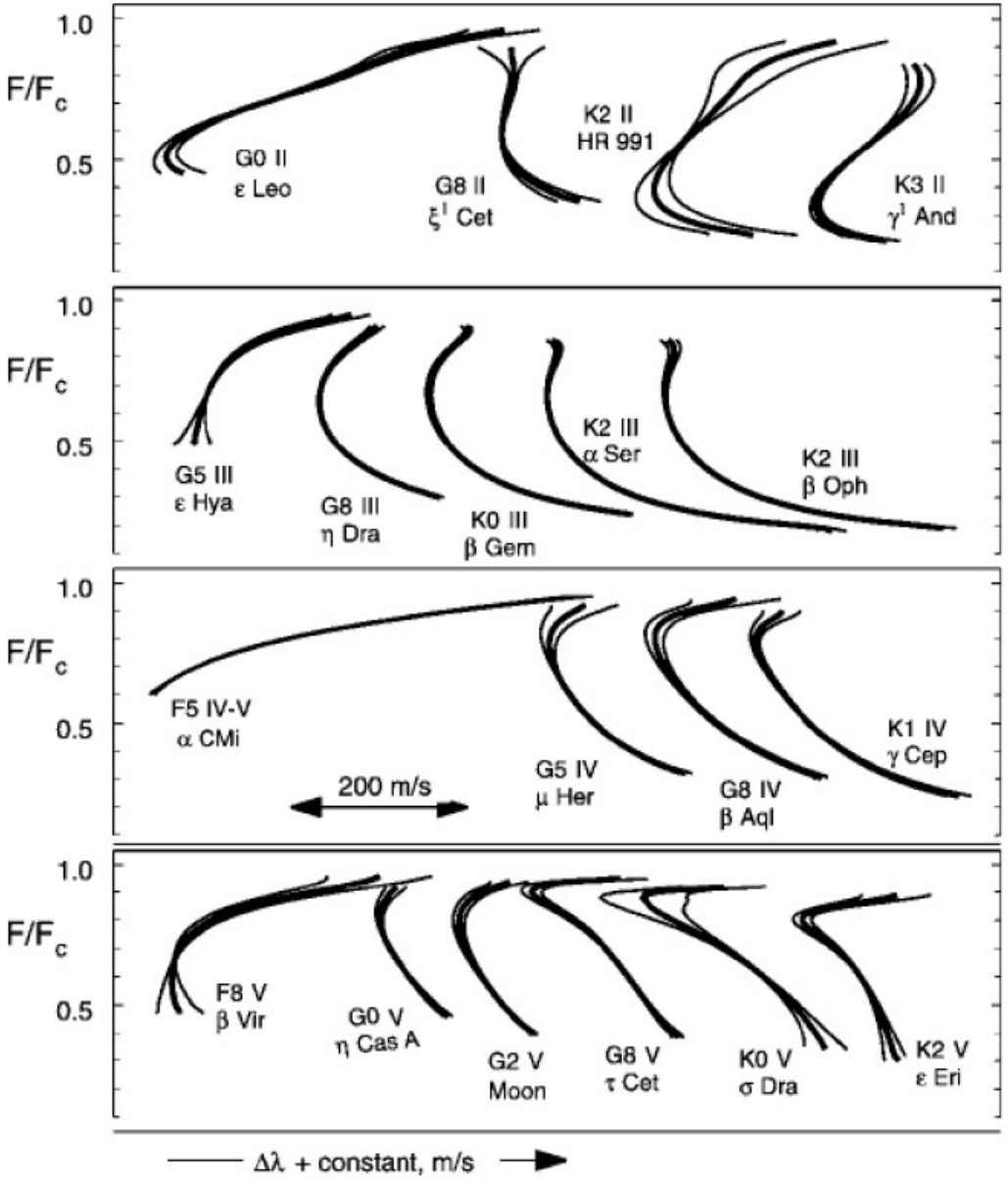



Figure 8.1: Schematic representation of different absorption profiles and their line bisectors, see text. Up: asymmetric absorptions due to spots (upward dip). Middle: asymmetric absorptions due to feculae (downward dip). Low: asymmetric absorptions due to light from a nearby object contaminating the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




Fiorenzano PhD 2006

Gray 2005

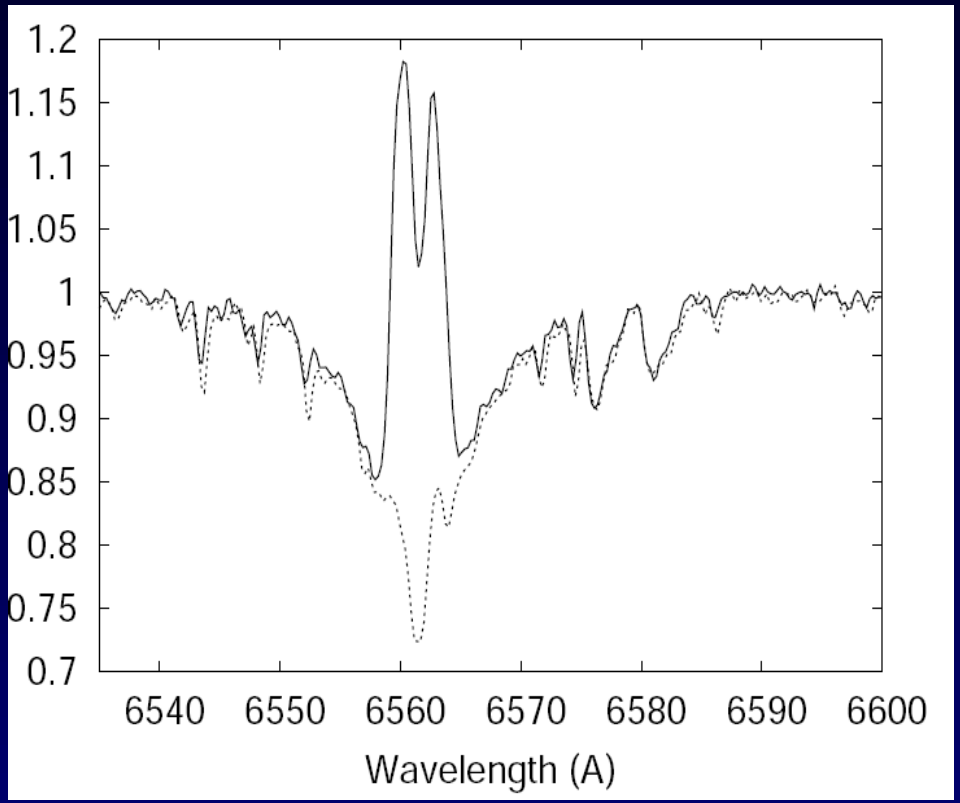
# Changes of Line Profiles in Time

Blind comparison of different exposures

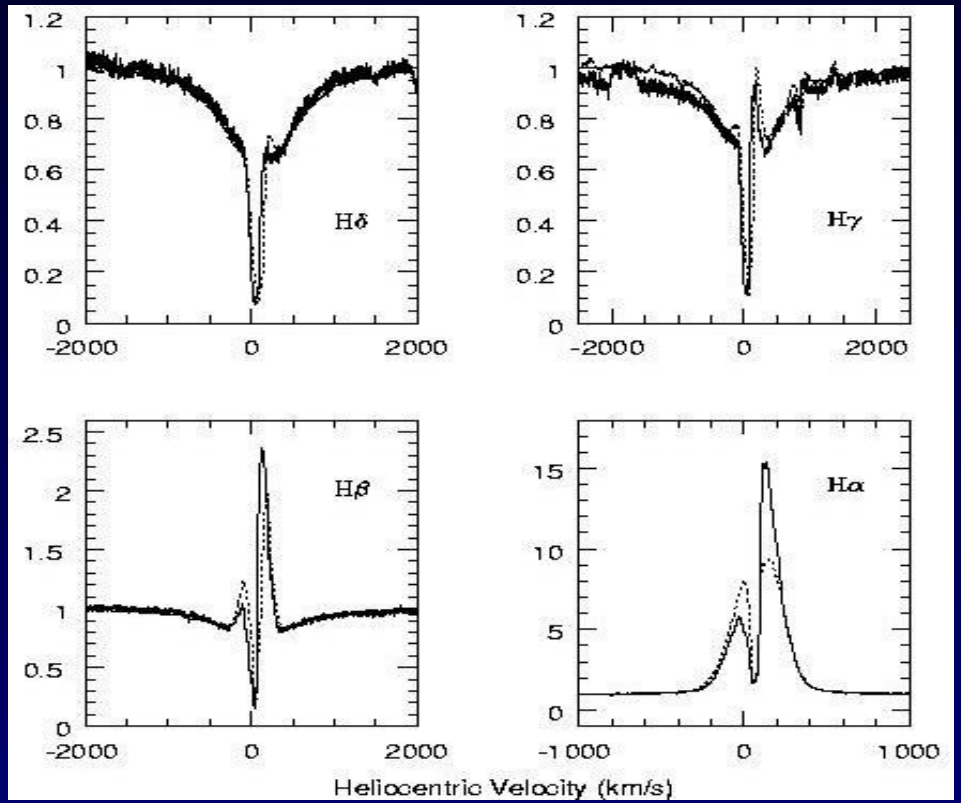
Emission/absorption, shell phases

Time evolution of object – mass transfer,

V/R variations



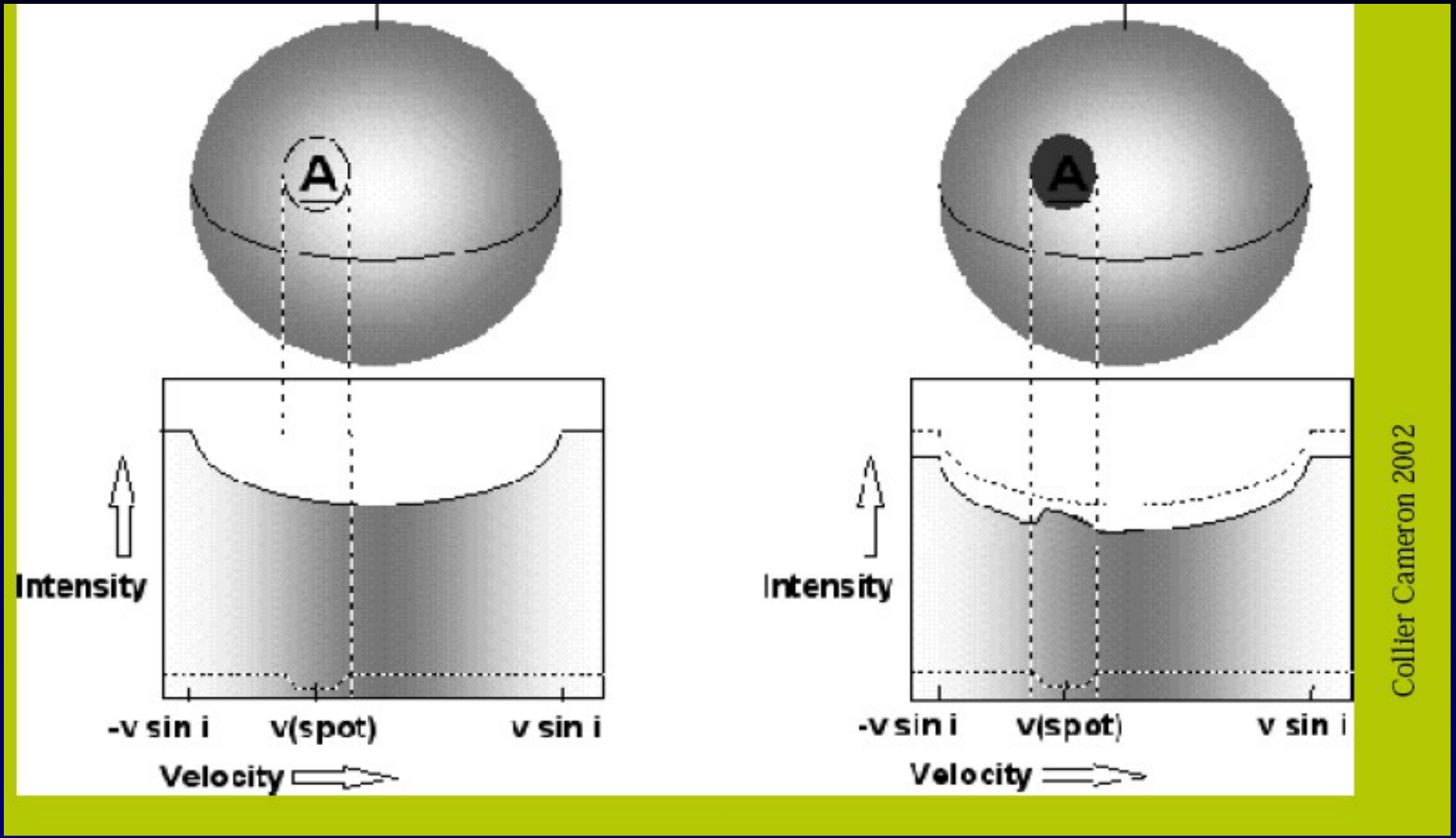

HD6226 : Slechta and Skoda 2004



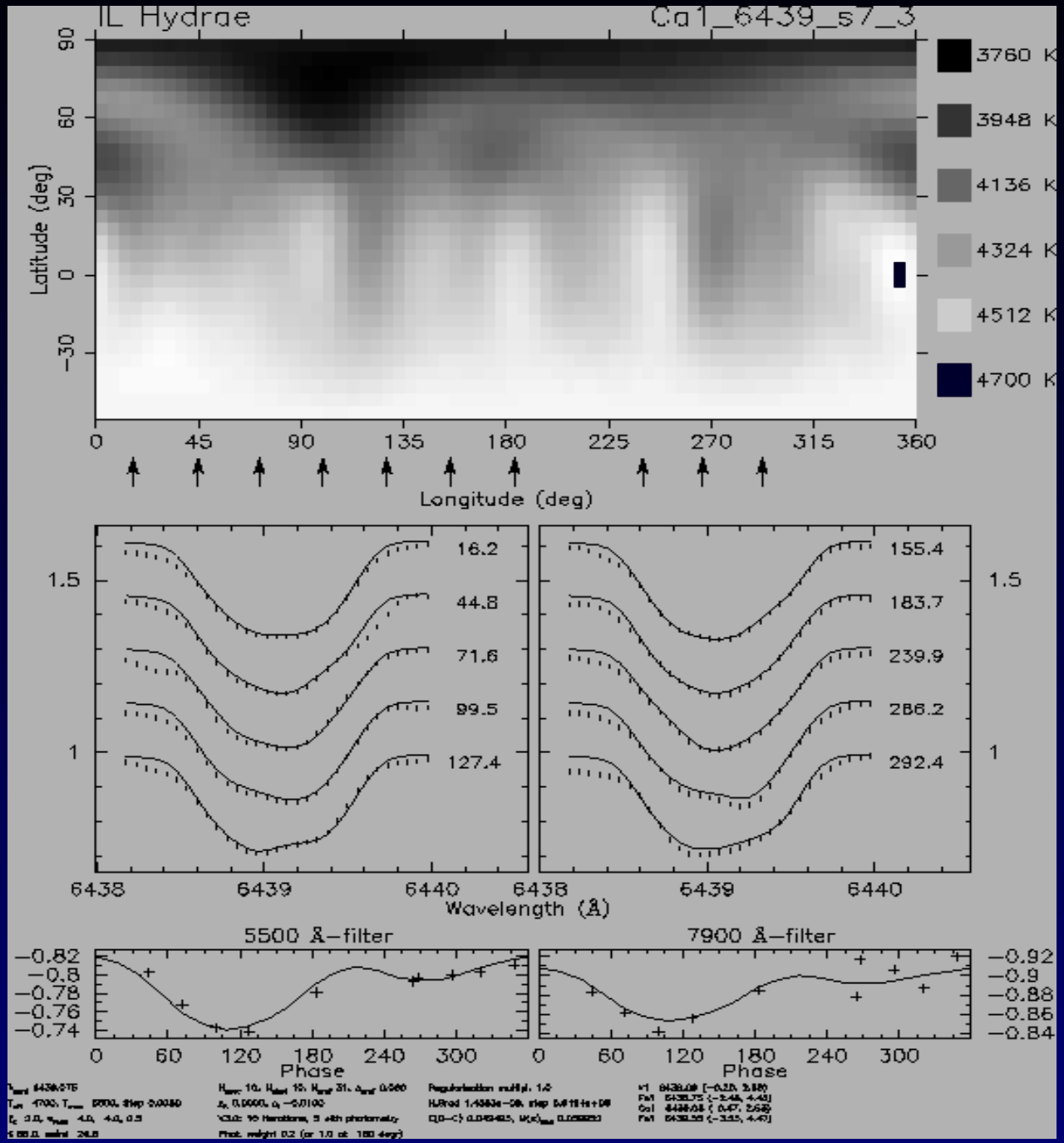

Borges et al. 2008

# Doppler Imaging

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



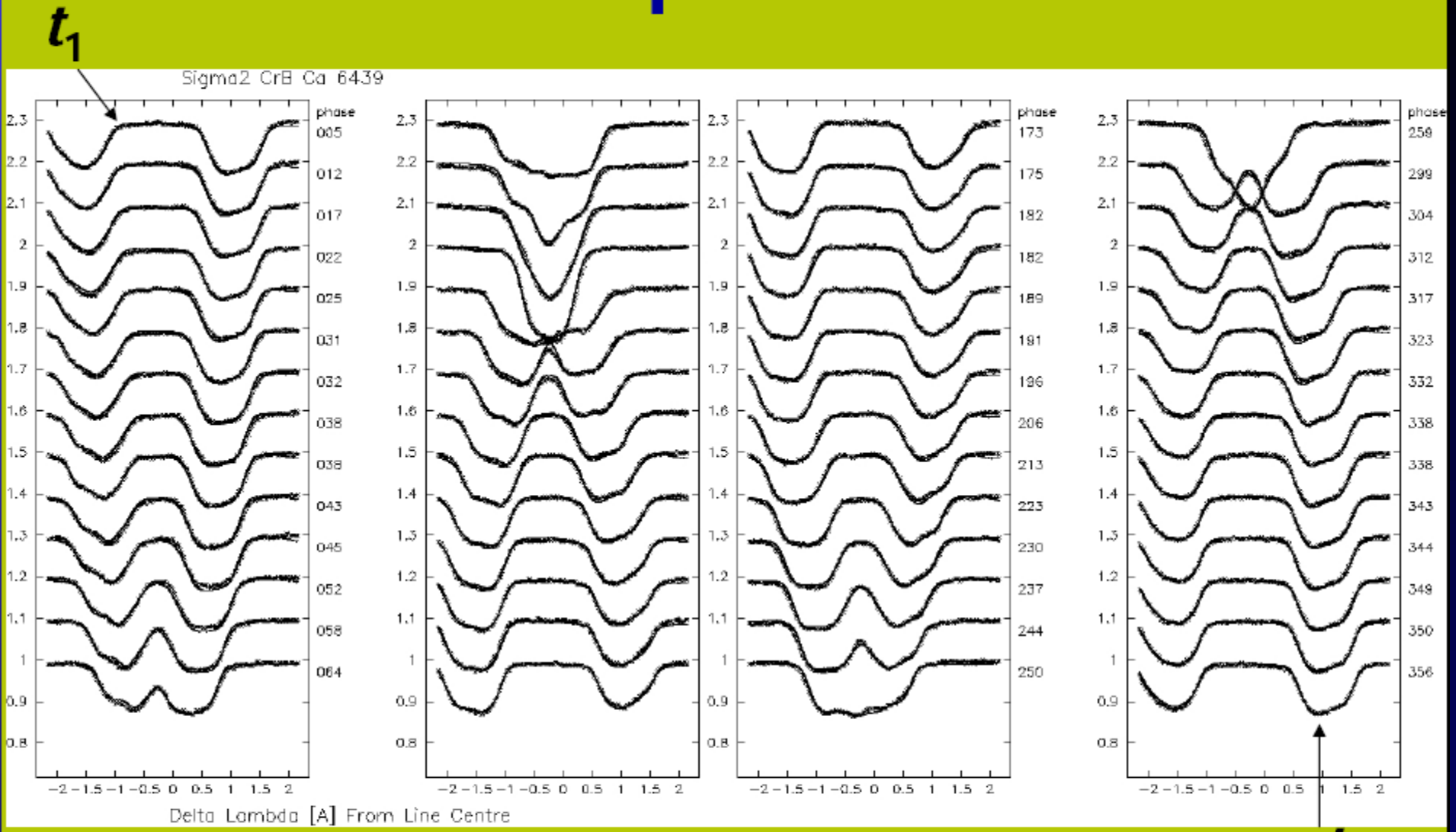
# Doppler Imaging




Different elements

temperature distribution

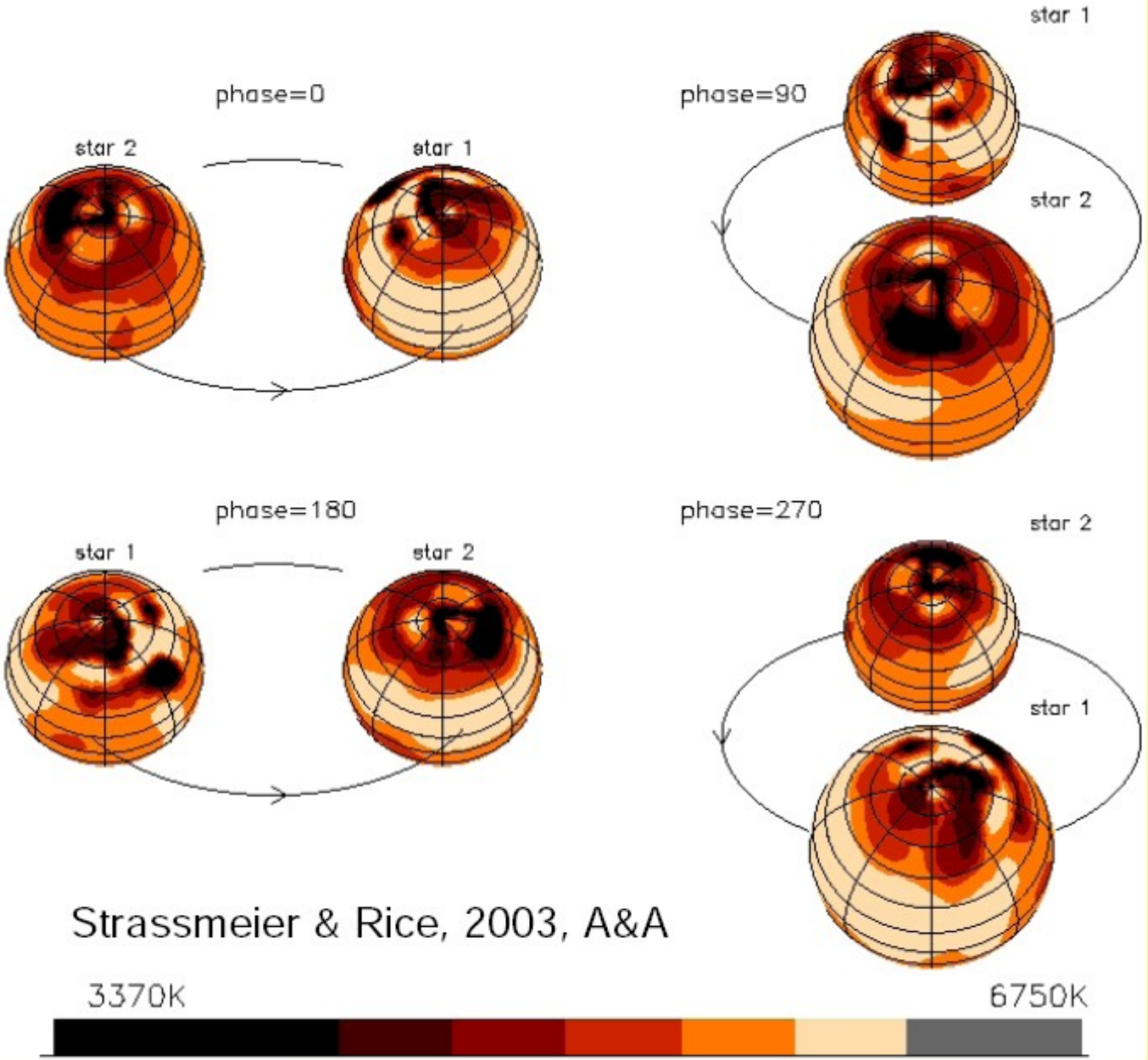
# Time series spectra of $\sigma^2$ CrB




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

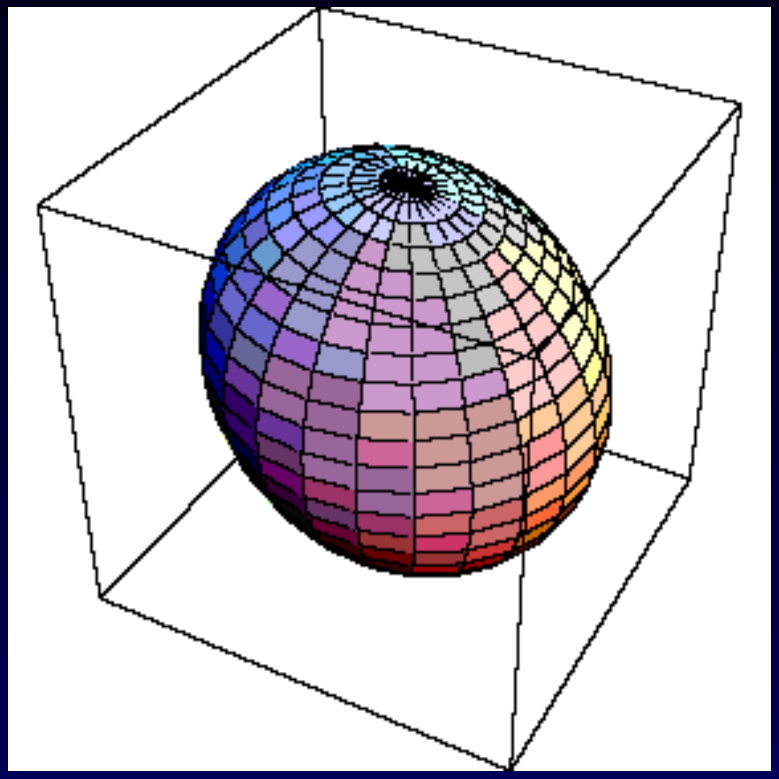
K. G. Strassmeier
Stellar Coronae, MPIfR, December 2006

# Doppler images $\sigma^2$ CrB

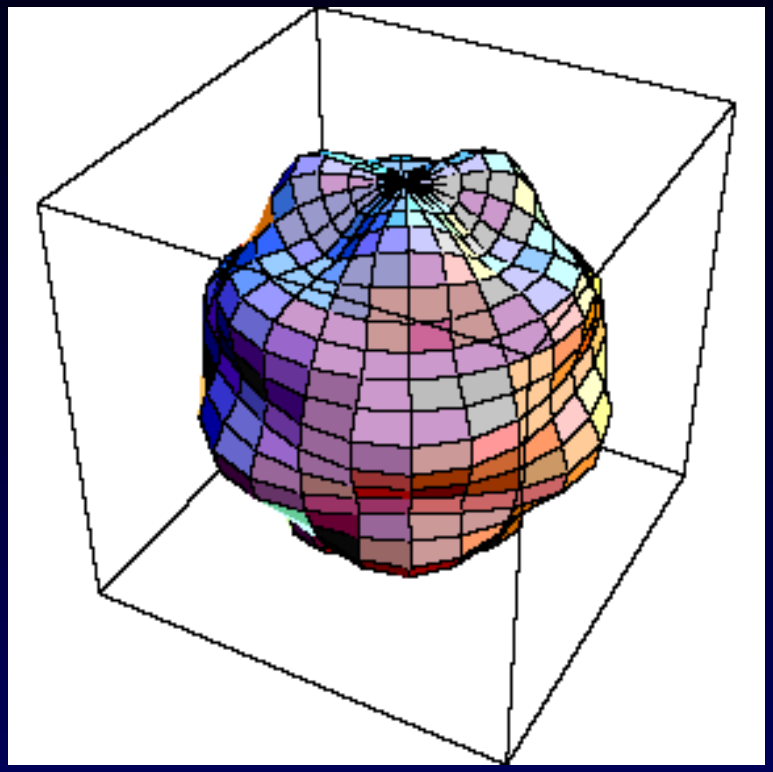



Strassmeier & Rice, 2003, A&A

# Non Radial Pulsation



$\ell = 2, m=1$

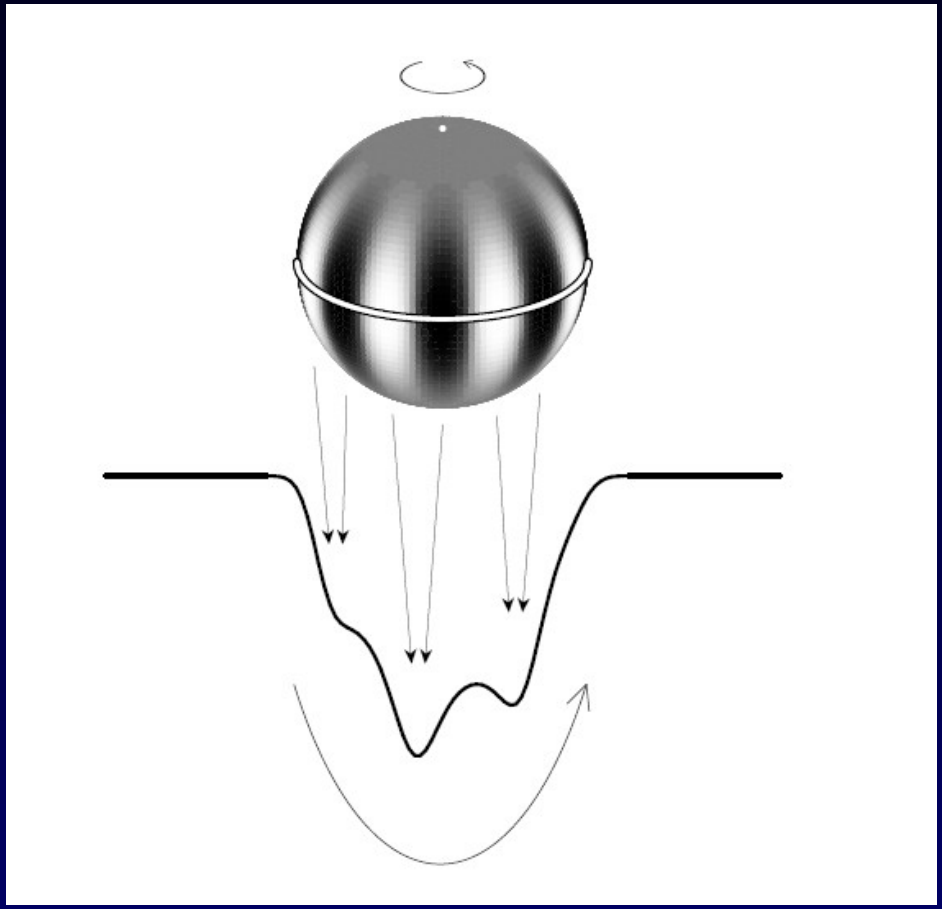


$\ell = 8, m=3$

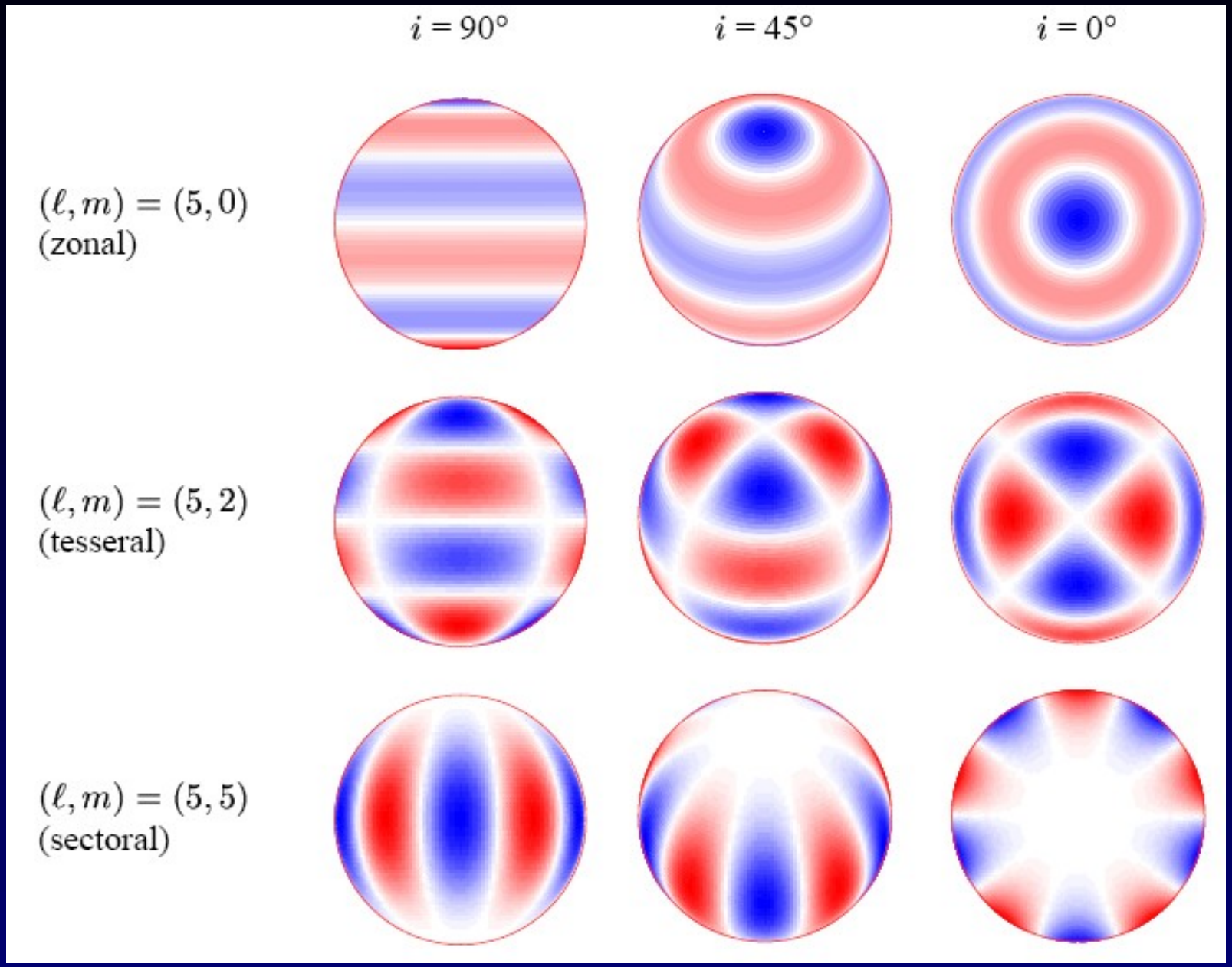
*Tim Bedding*

# Doppler Imaging - NRP

Vogt & Penrod -80s
Zet Oph

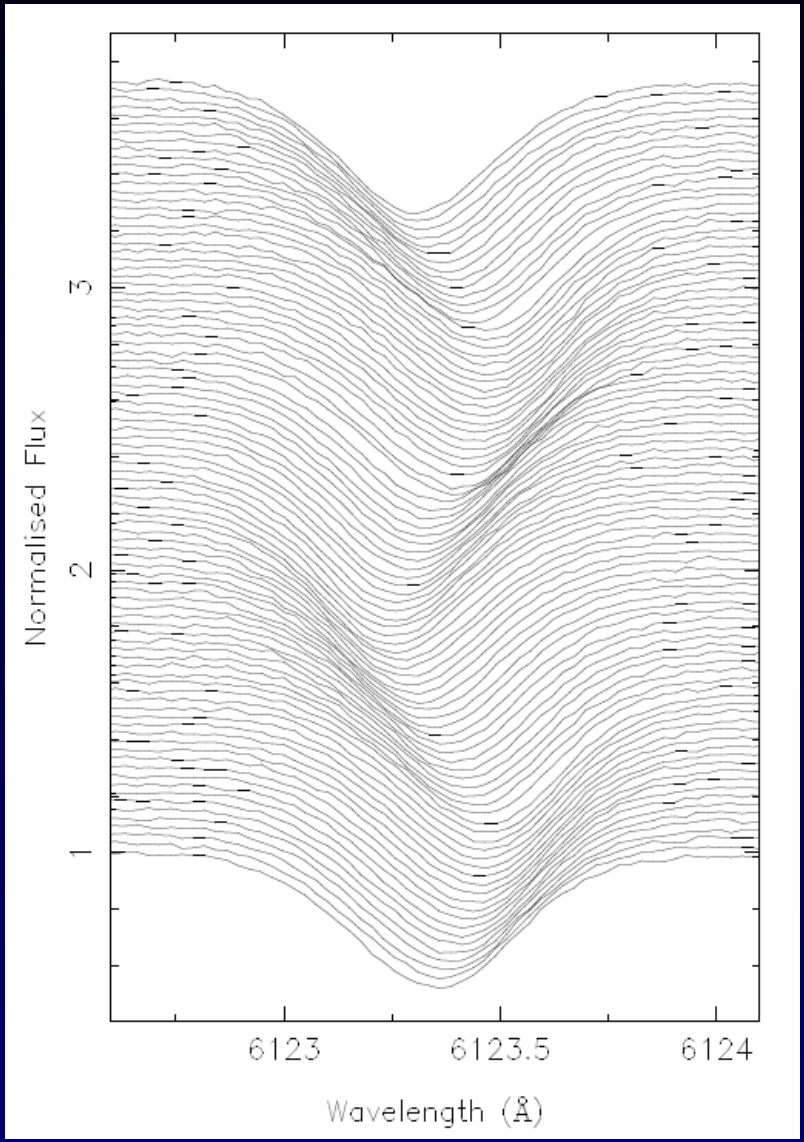


# Non Radial Pulsations Modes

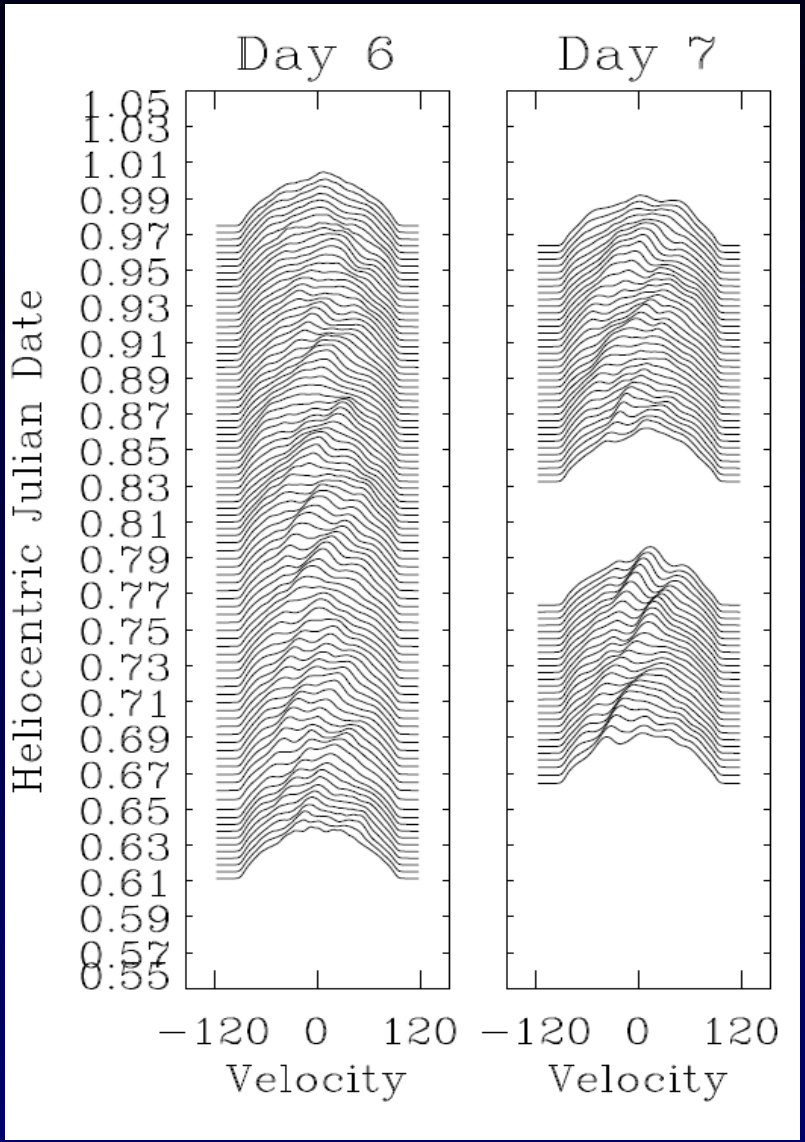



C. Schrijvers

# Measured Pulsations

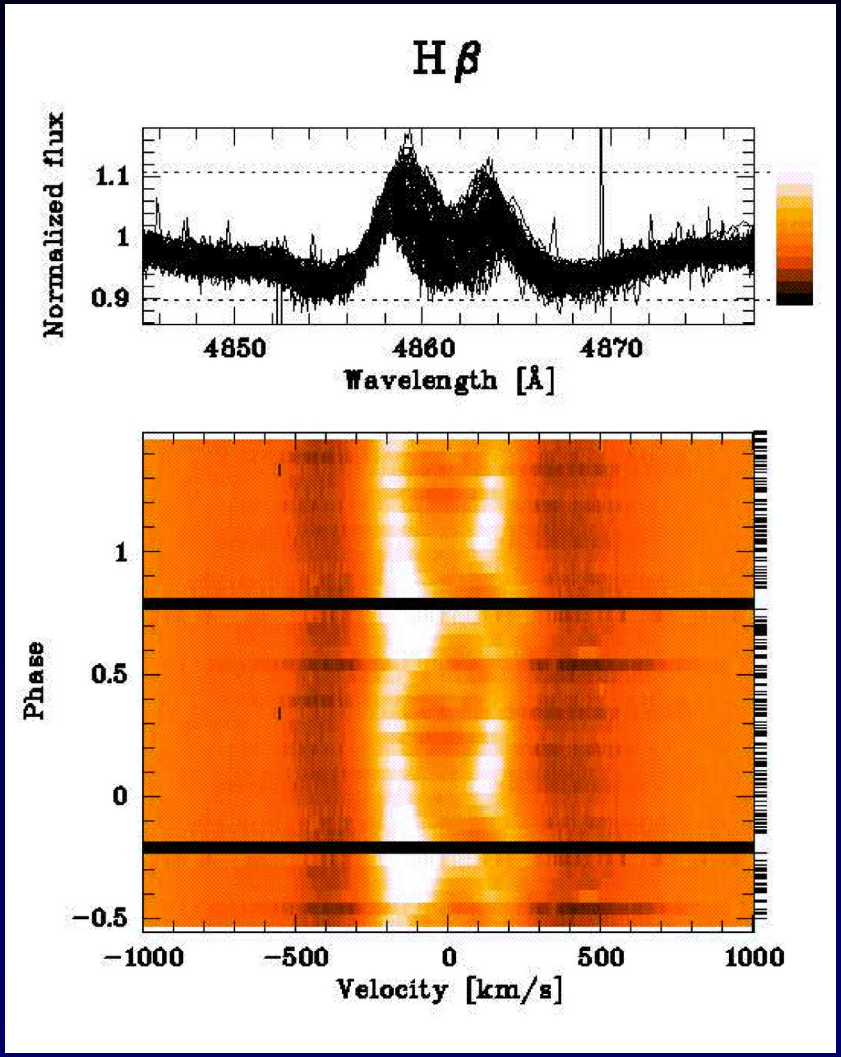



Rho Pup – del Sct type




Eps Cep - del Sct type

# Dynamic Spectra




Quotient, Difference template (average)

For study of LPV (asteroseismology, winds)

Requires

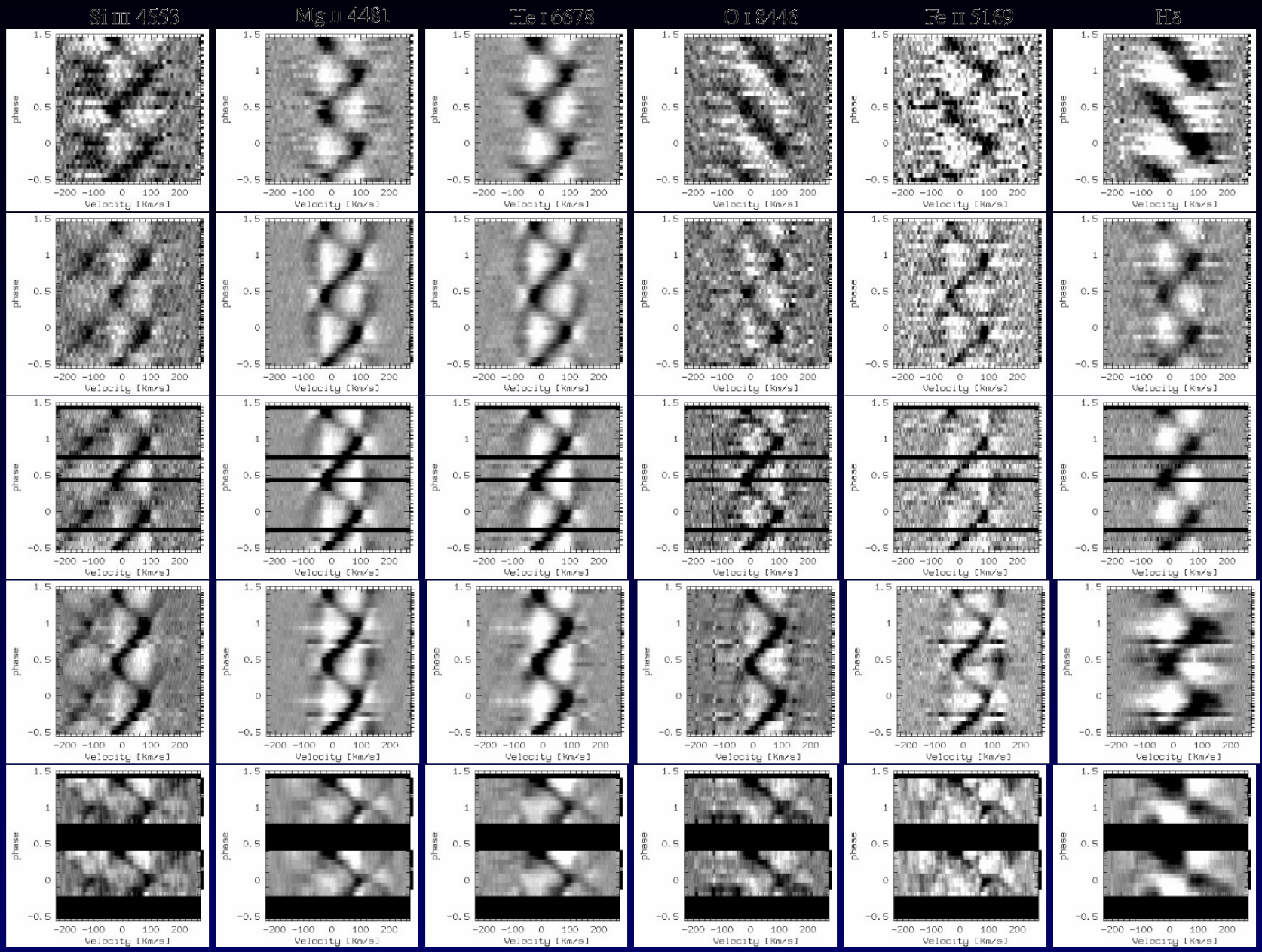
time (JD) - winds

period (see Period analysis) - phase (LPV)

change of template (average, median)

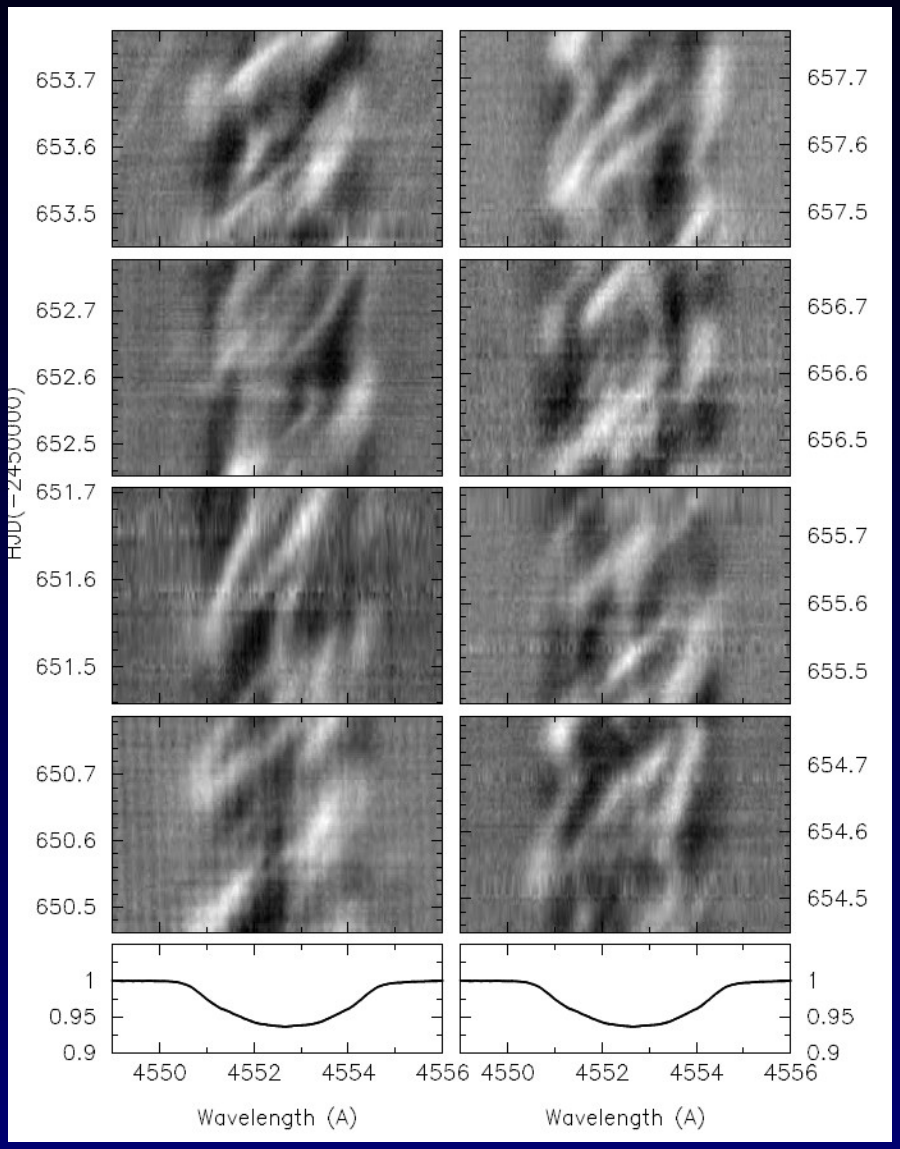
removing bad data (interactive overplotting)

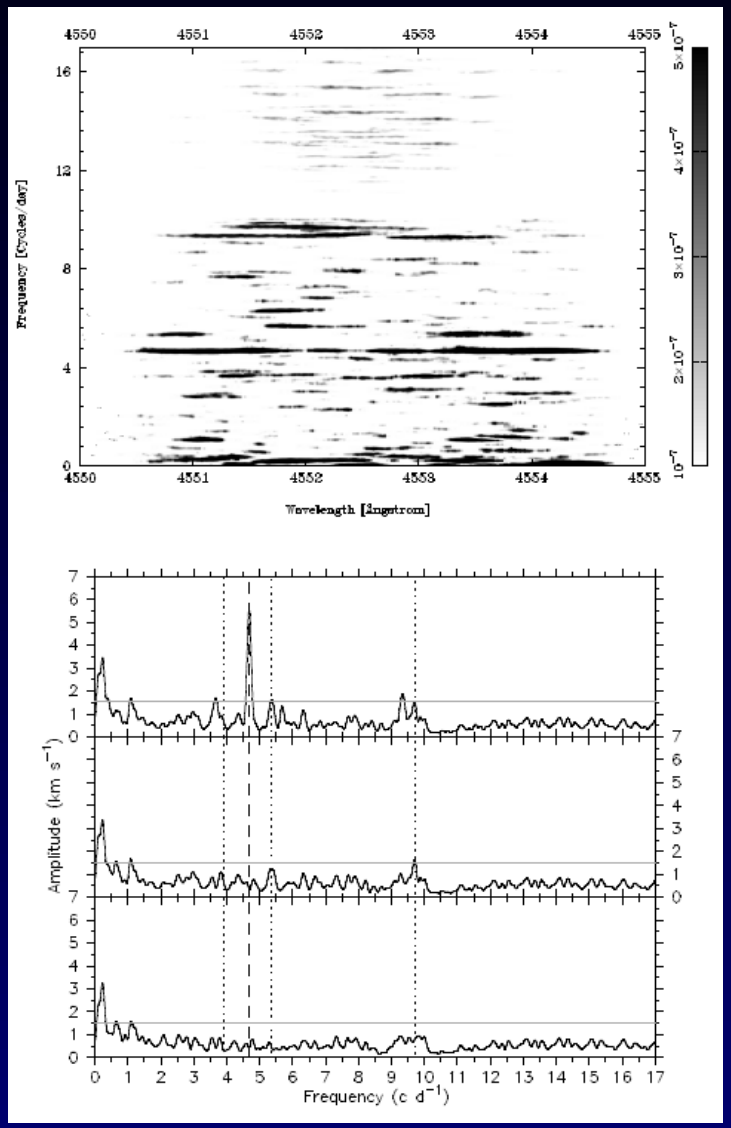
# Dynamic Spectra




28 CMa, Stefl et al. 2003

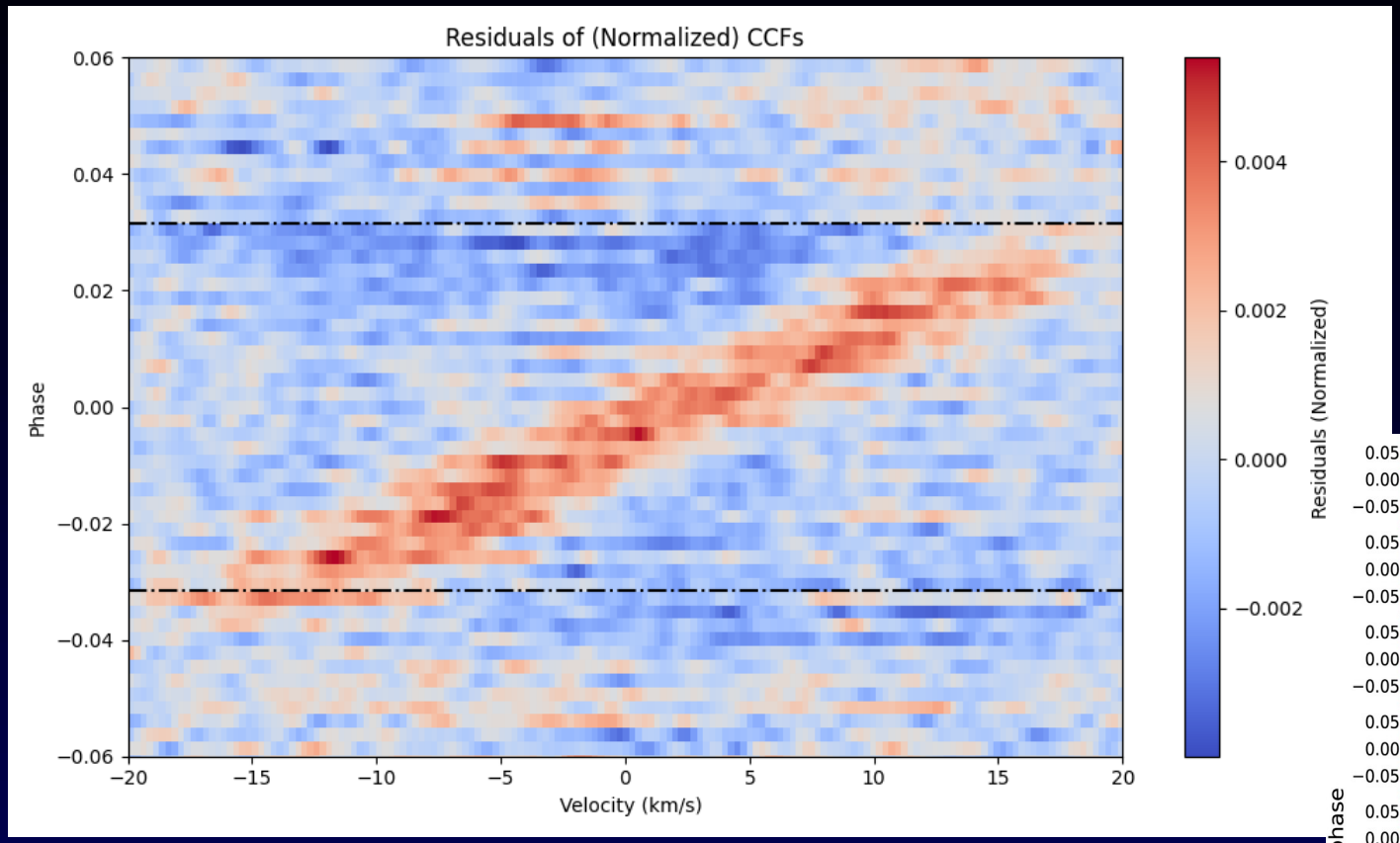
# Periodogram of Line Profile NRP

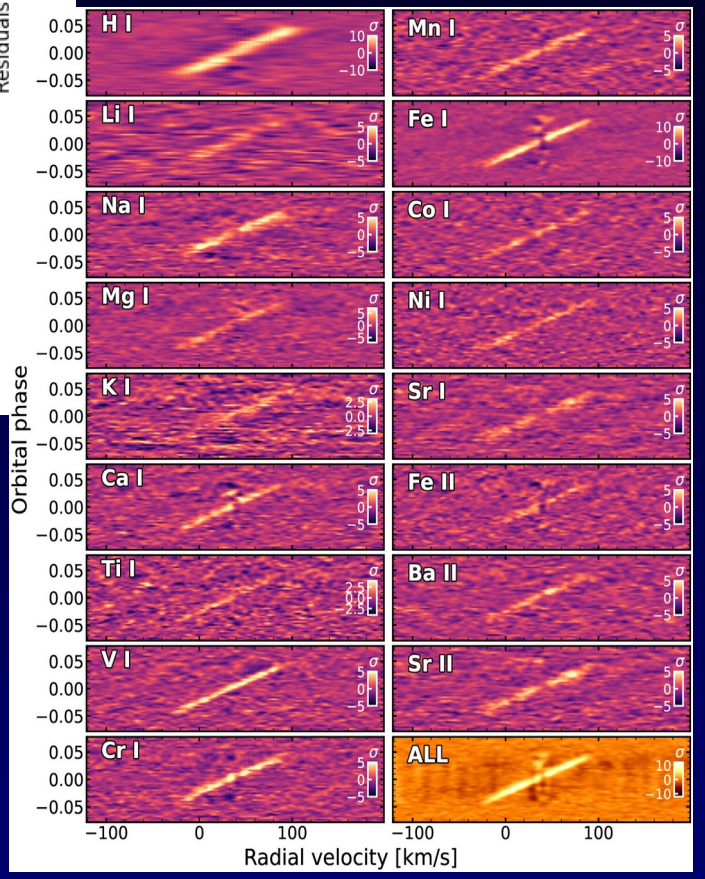



Lambda Sco: Uytterhoeven 2004

# Doppler Shadow




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

# Echelle Spectra

# ESO X-Shooter

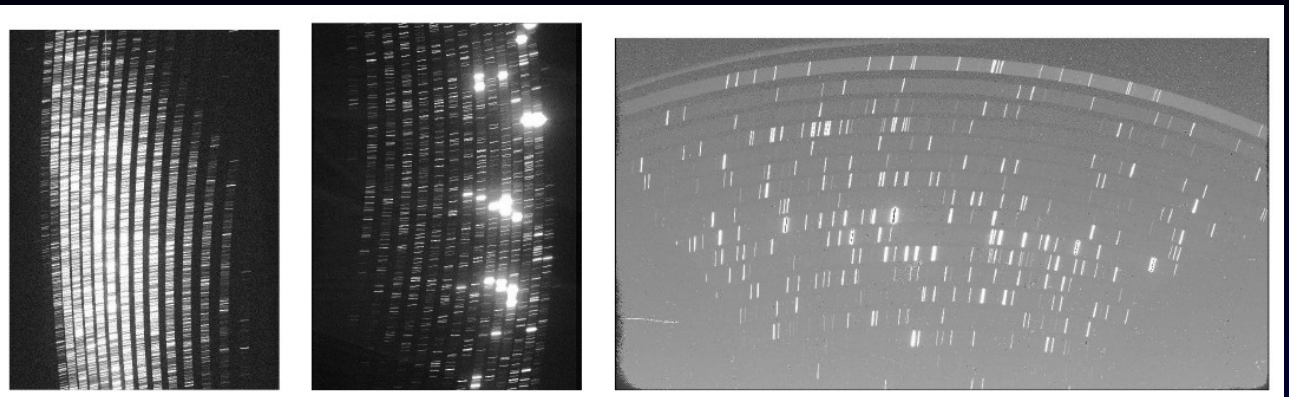
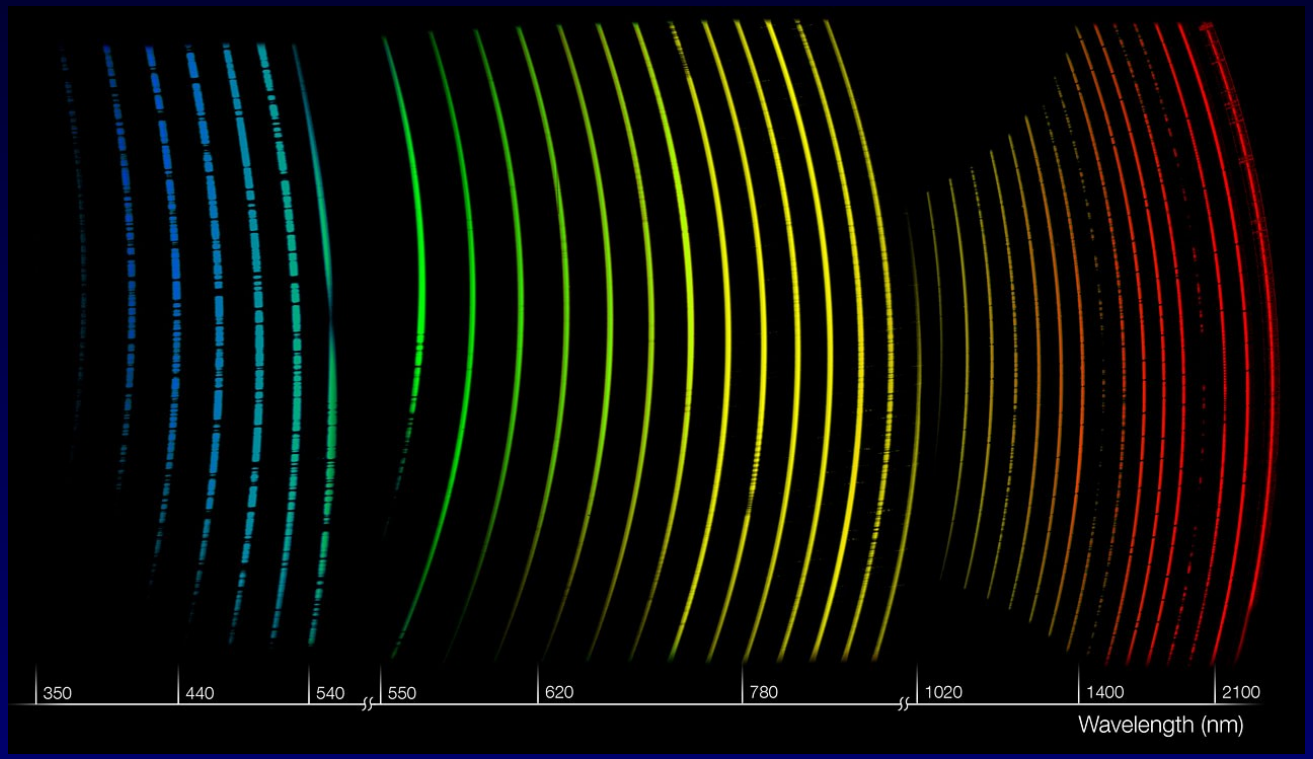
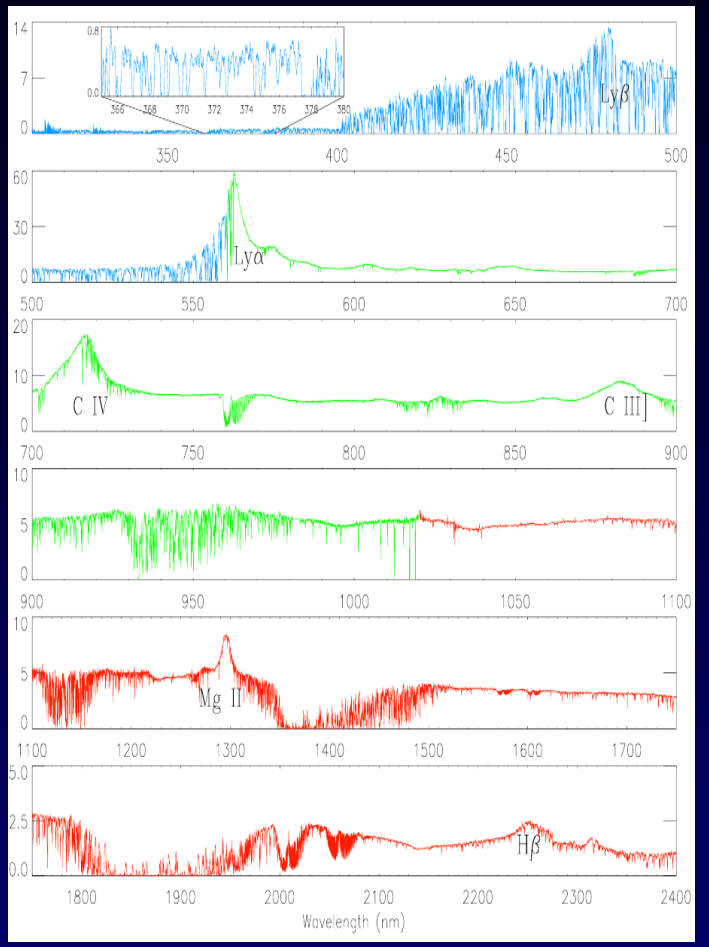


Figure 1. This image displays left to right the XSH UVB, VIS and NIR spectral formats with different image scales.



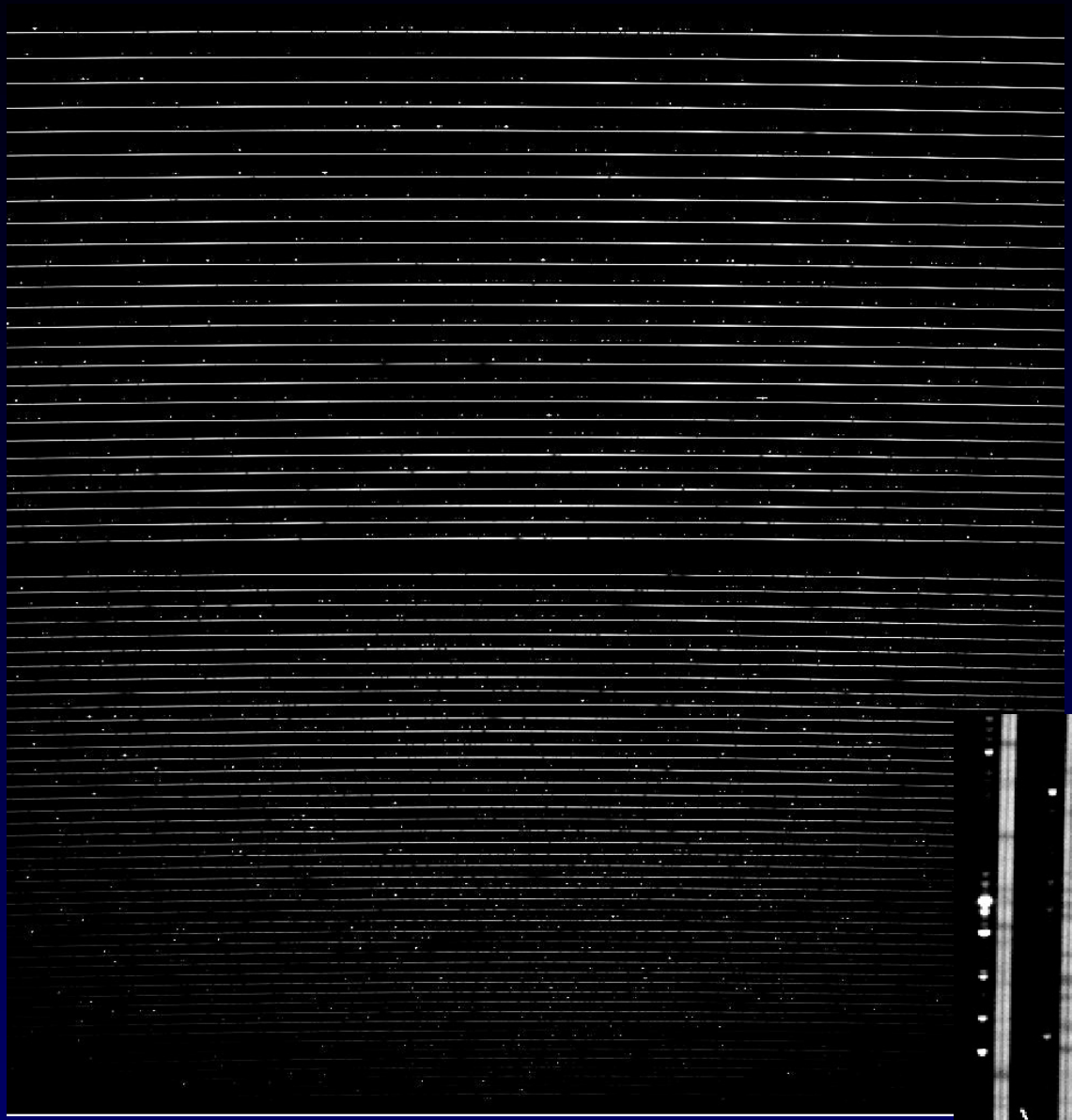

Modigliani et al. 2010

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




High-z QSO
Vernet et al. 2011

# HARPS-S



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

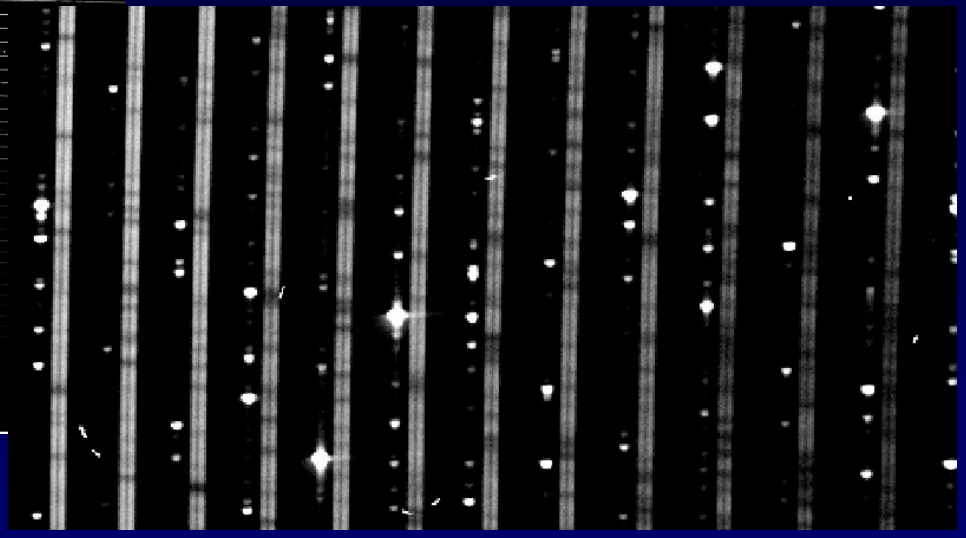
71 orders (89-161) – 115 not

3780-6910 A

R~115000

dRV~3m/s

Simultaneus ThAr/Laser comb/Fabry Perot



PlatoSpec simcal ThAr

# Overlapping Orders

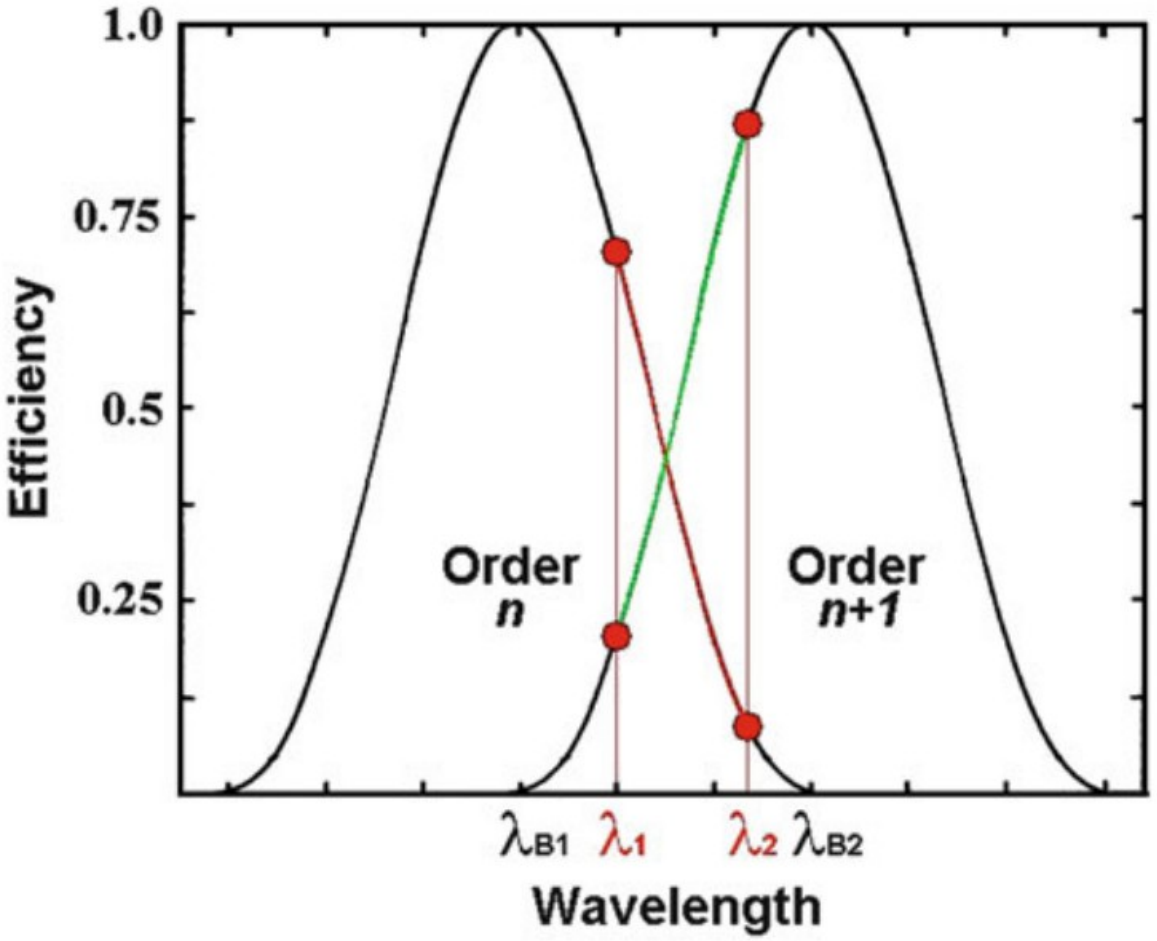
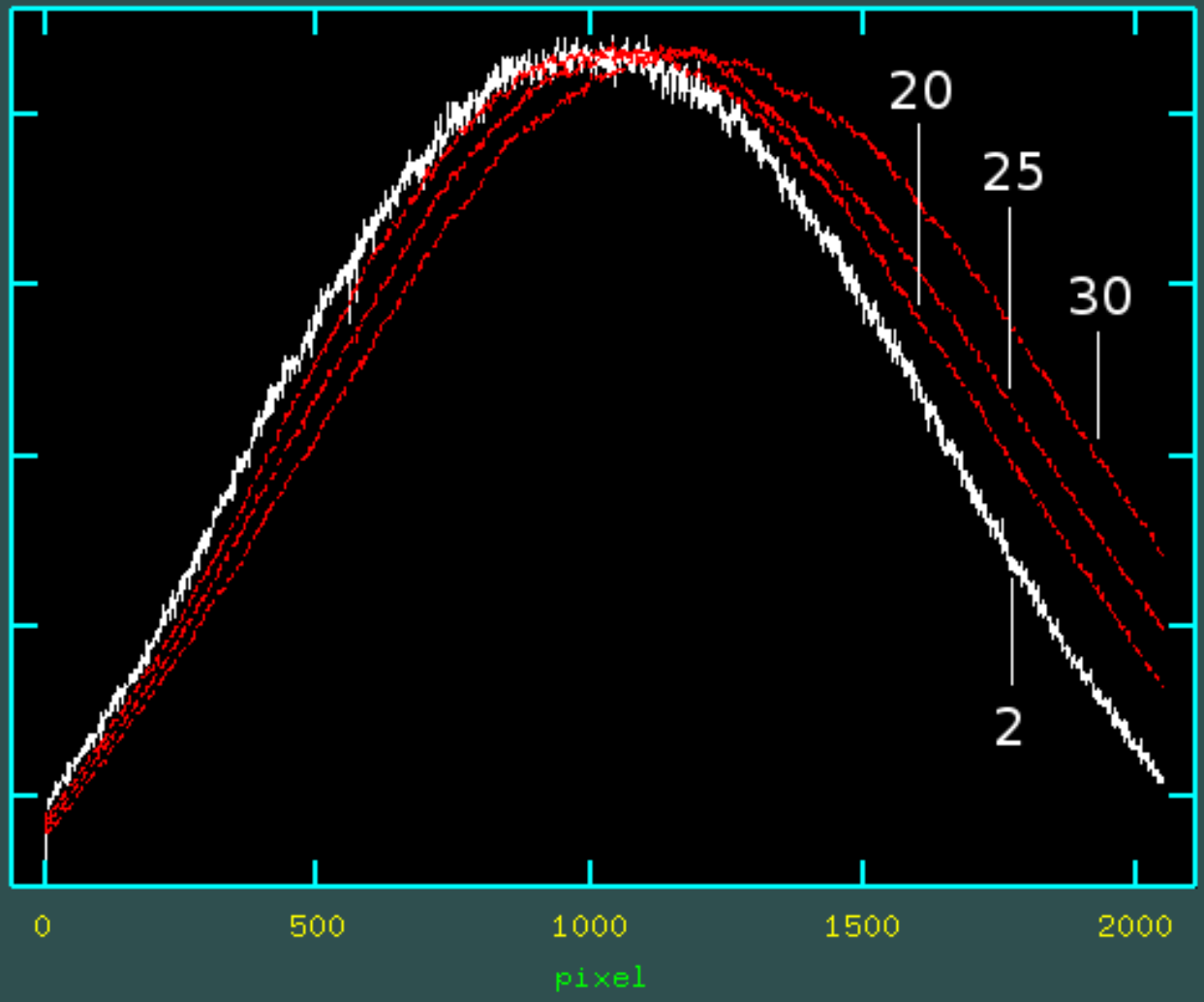



**Fig. 5.15** Sketch of the efficiencies in two adjacent orders. Identical wavelength intervals in the orders are indicated in *red* and *green*. Both wavelengths $\lambda_1$ and $\lambda_2$ are imaged in the two orders $n$ and $n + 1$. The two blaze peaks of the orders are positioned at $\lambda_{B_1}$ and $\lambda_{B_2}$

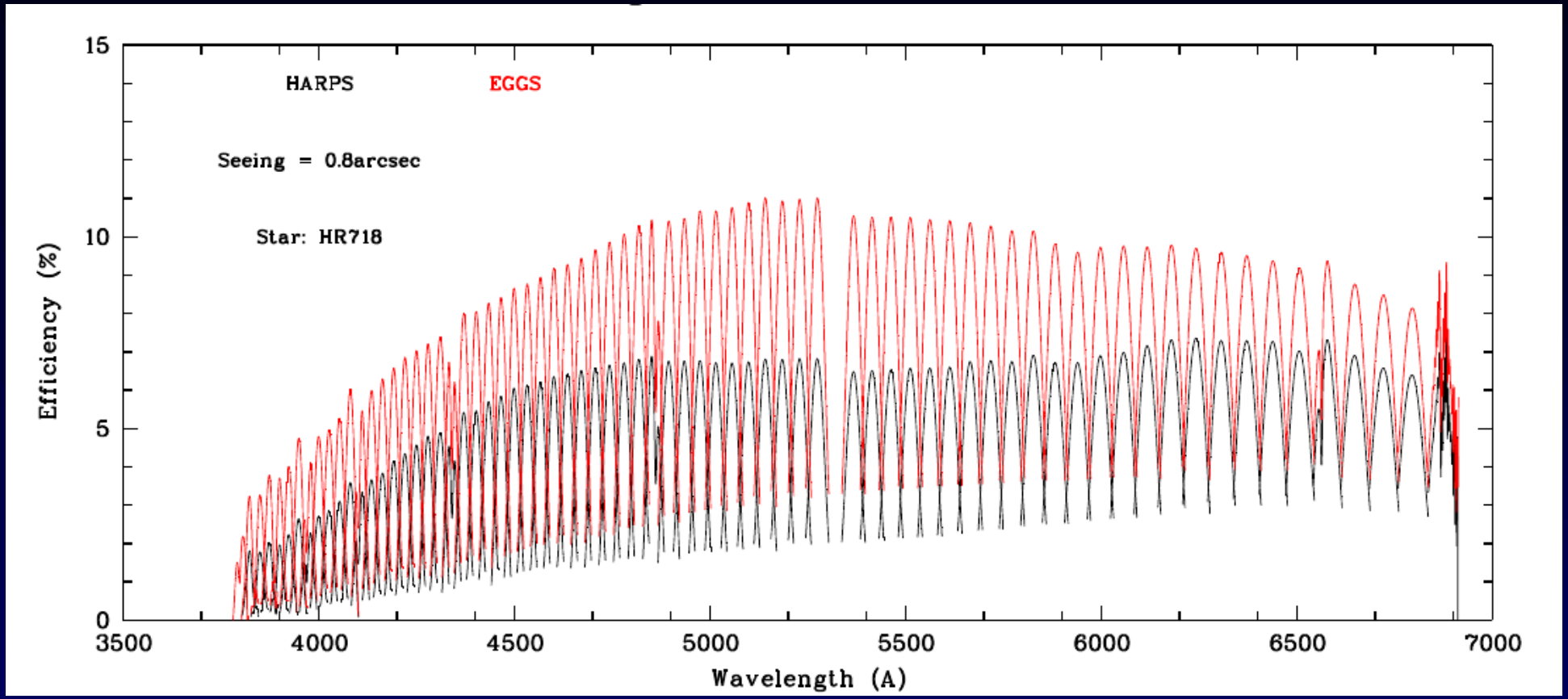
Eversberg, Vollmann. Spectroscopic Instrumentation 2015

# OES Blaze shift

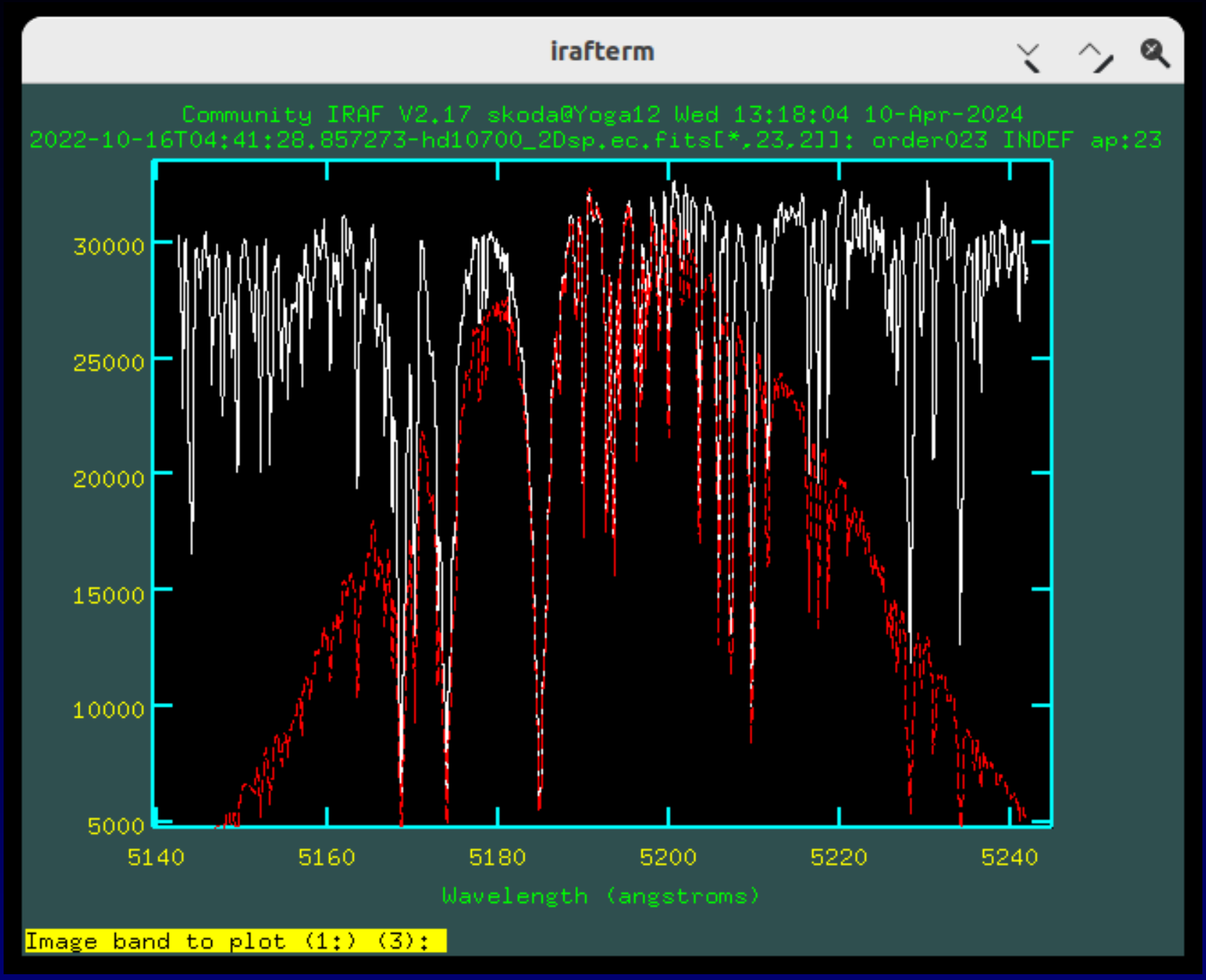



Šlechta

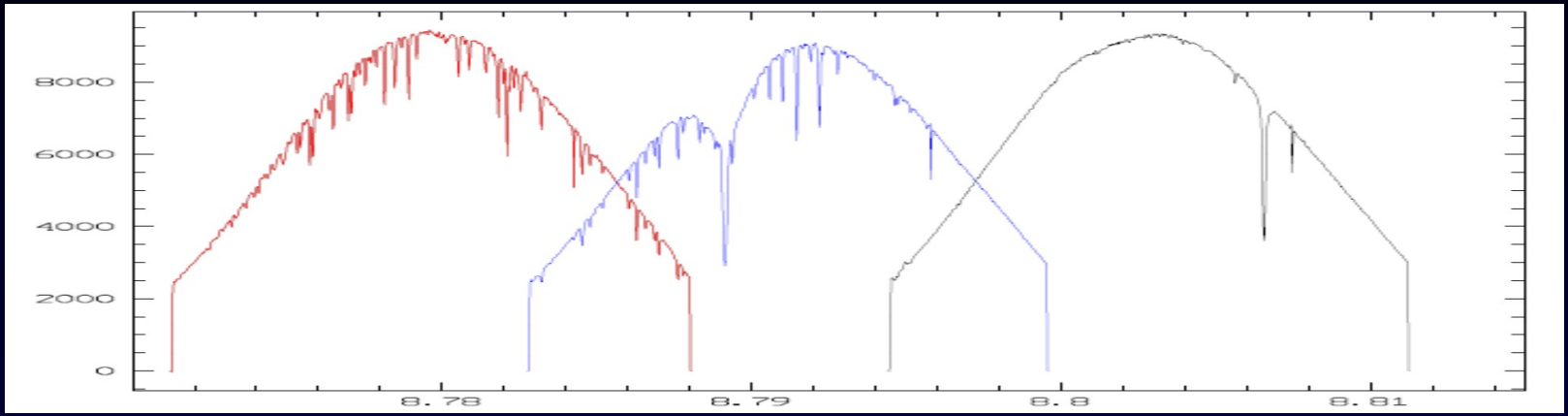
# HARPS-S

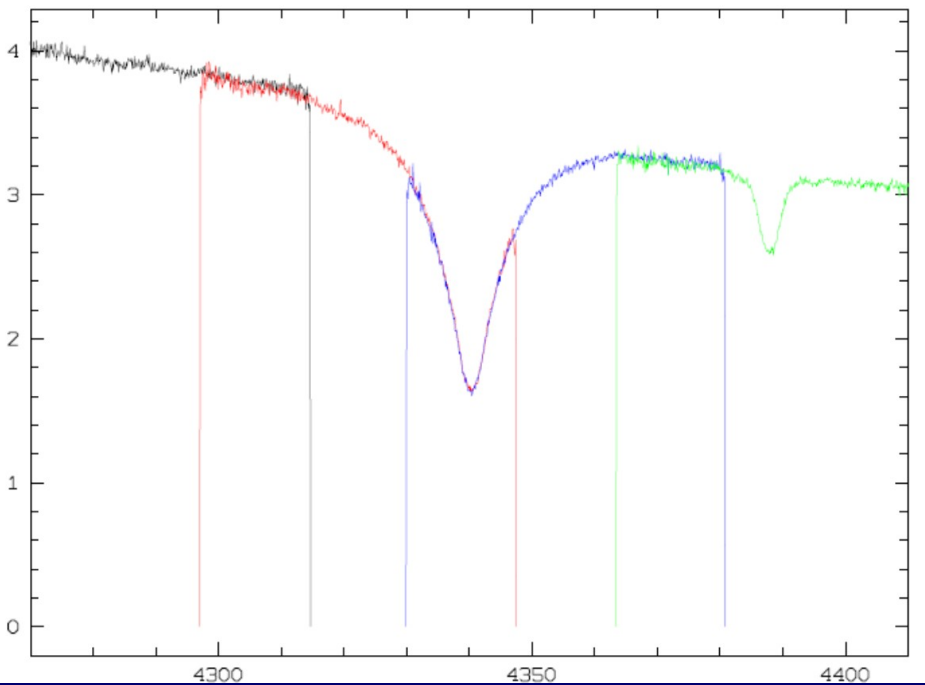

HARPS
EGGS
Seeing = 0.8arcsec
Star: HR718
Efficiency (%)
Wavelength (A)
0
5
10
15
3500
4000
4500
5000
5500
6000
6500
7000

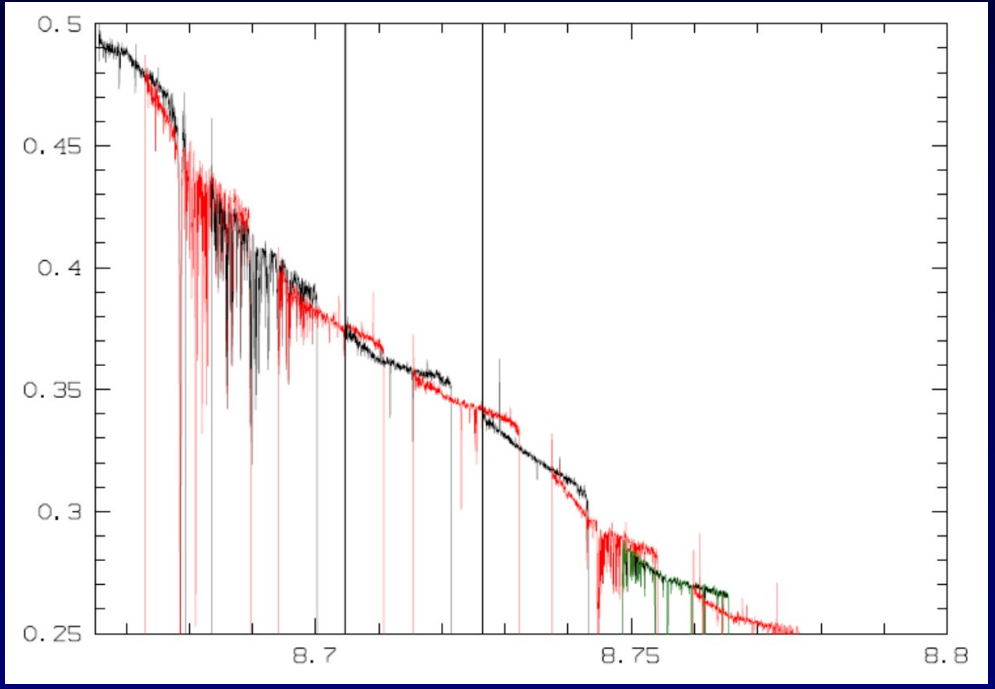
# PUCHEROS+ in IRAF



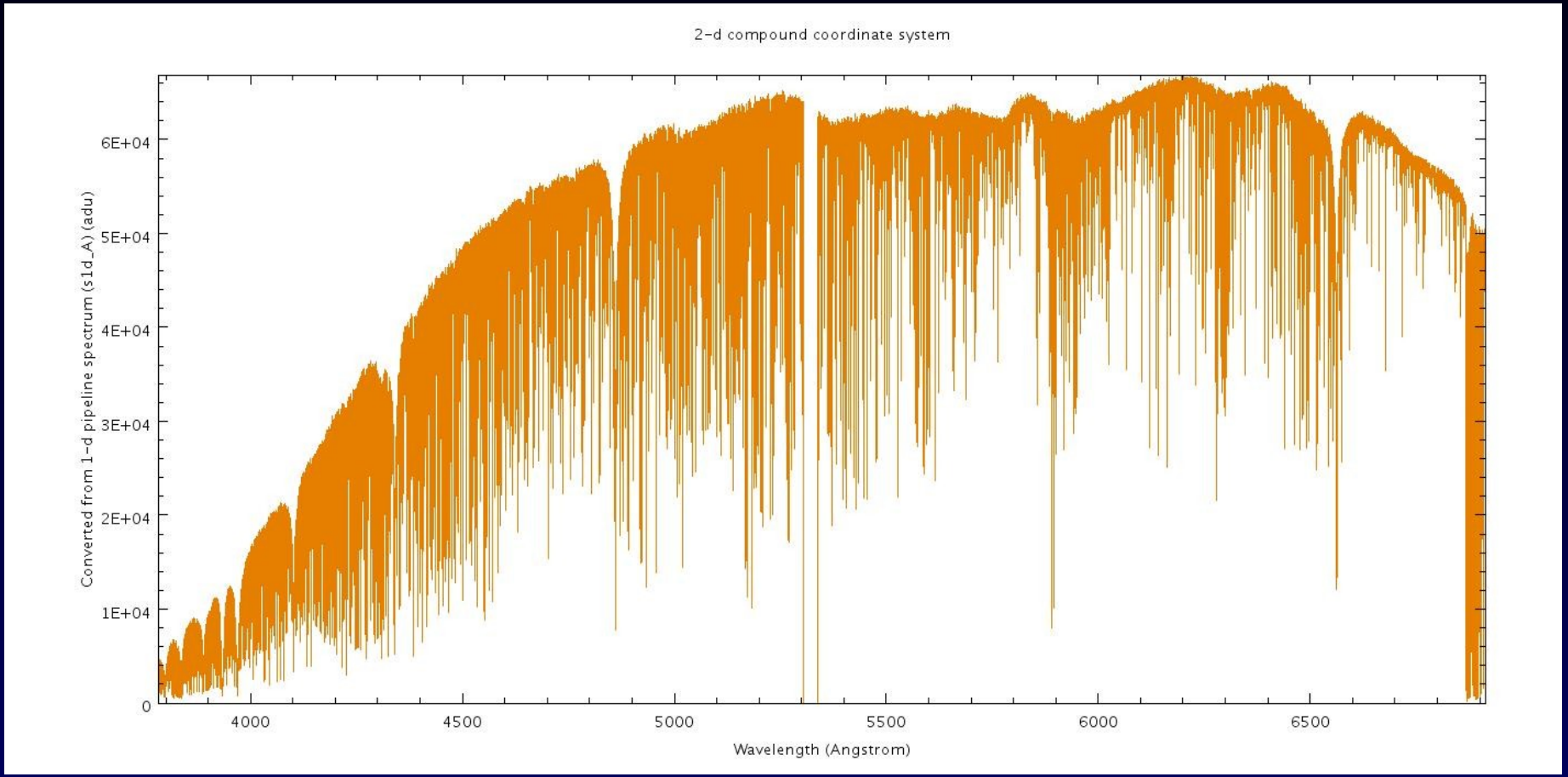
# Echelle Spectra Problems in Hot Stars



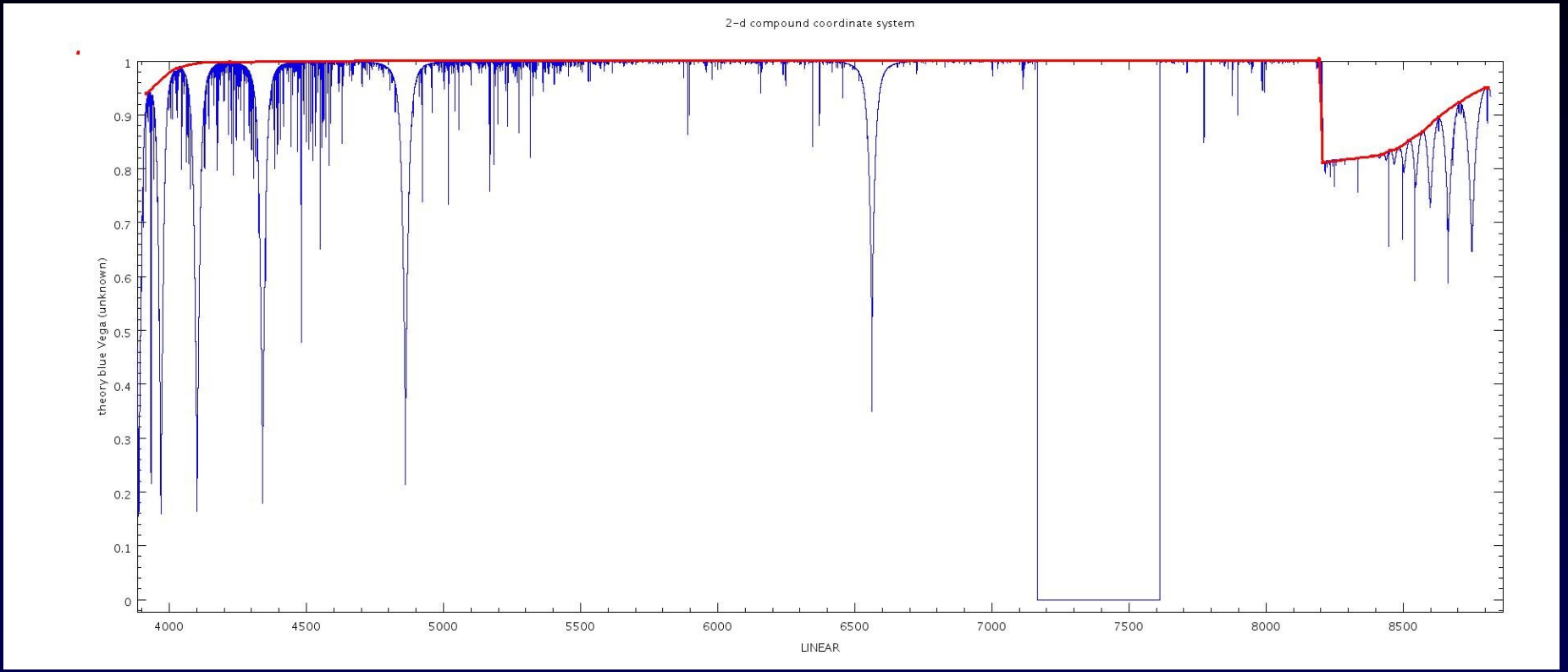
# HARPS-S in SPLAT




313138 points

Procyon

# Continuum Normalisation



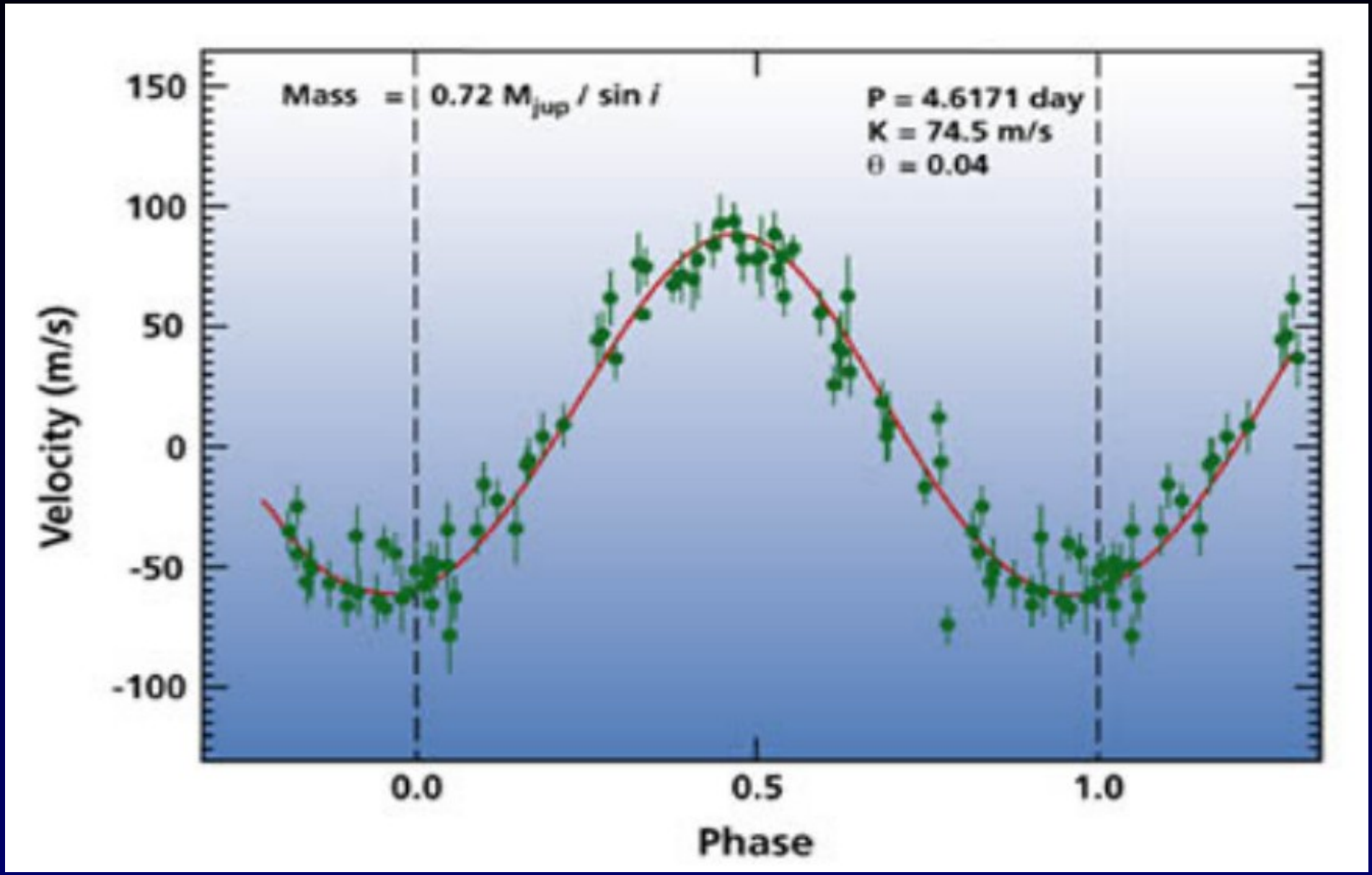

Theoretical spectrum of Vega

The continuum is NOT ALWAYS at 1.0 !

# Products derived from spectra

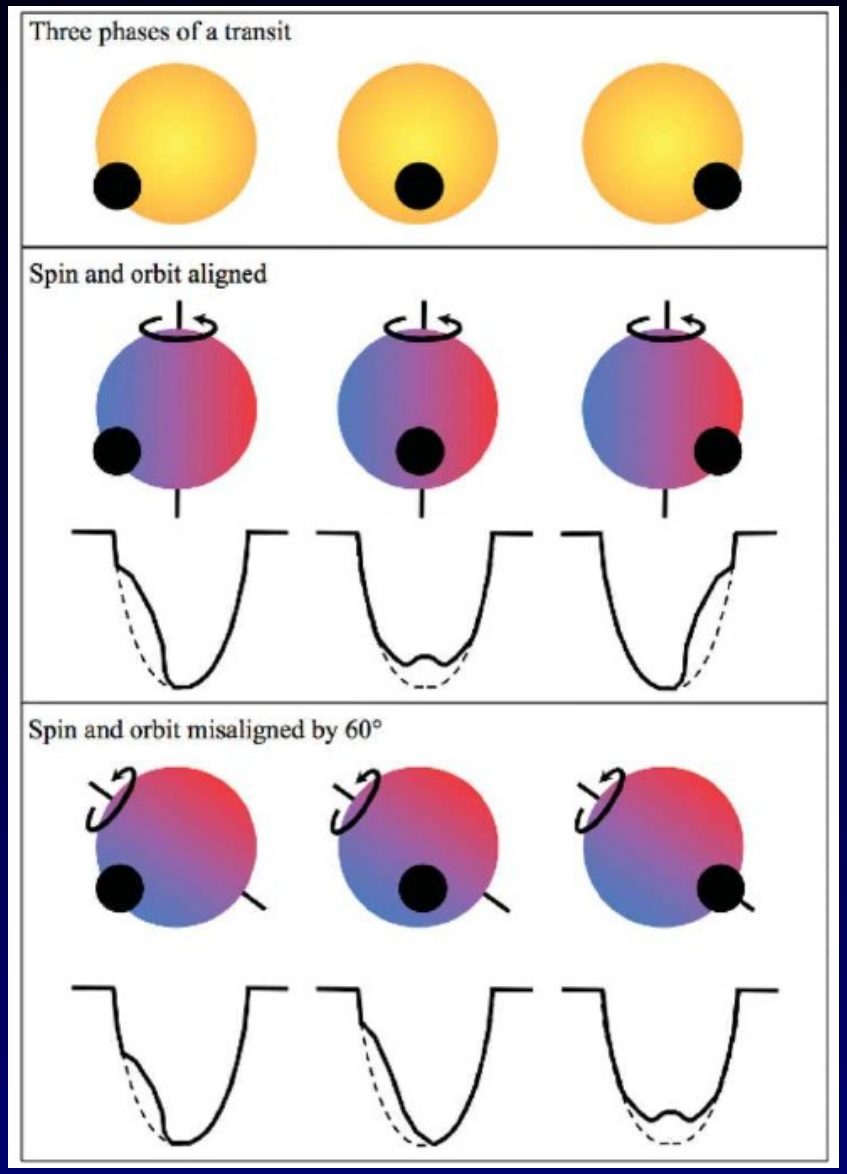
# Radial Velocity Curve

# Radial Velocity Curve



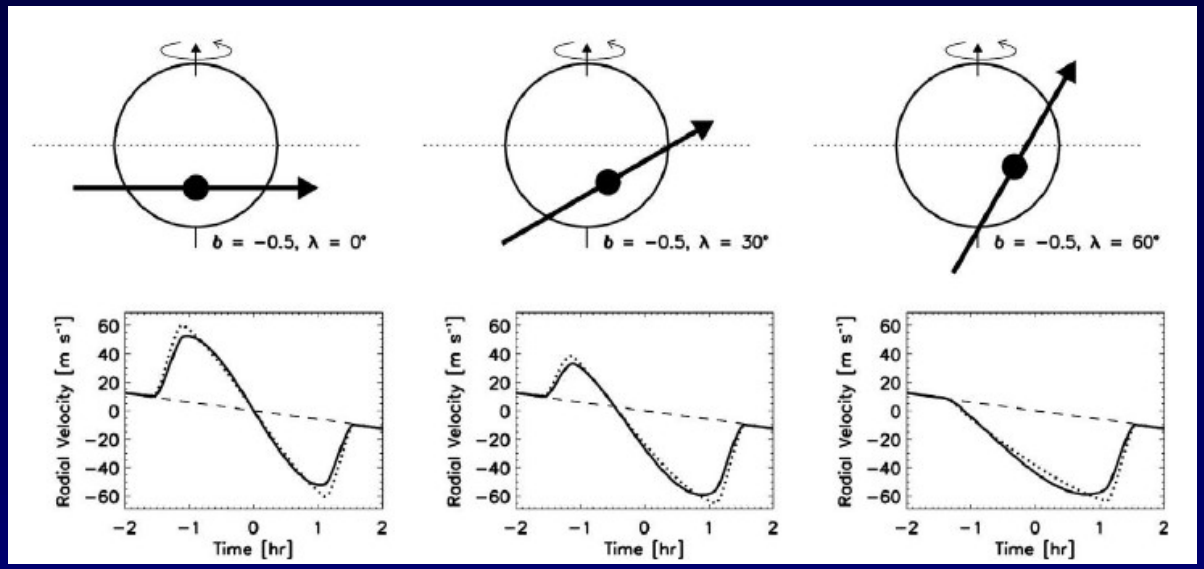

51 Peg b, Mayer and Queloz 1995

# Rossiter-McLaughlin effect




RV Curve – time series of RV

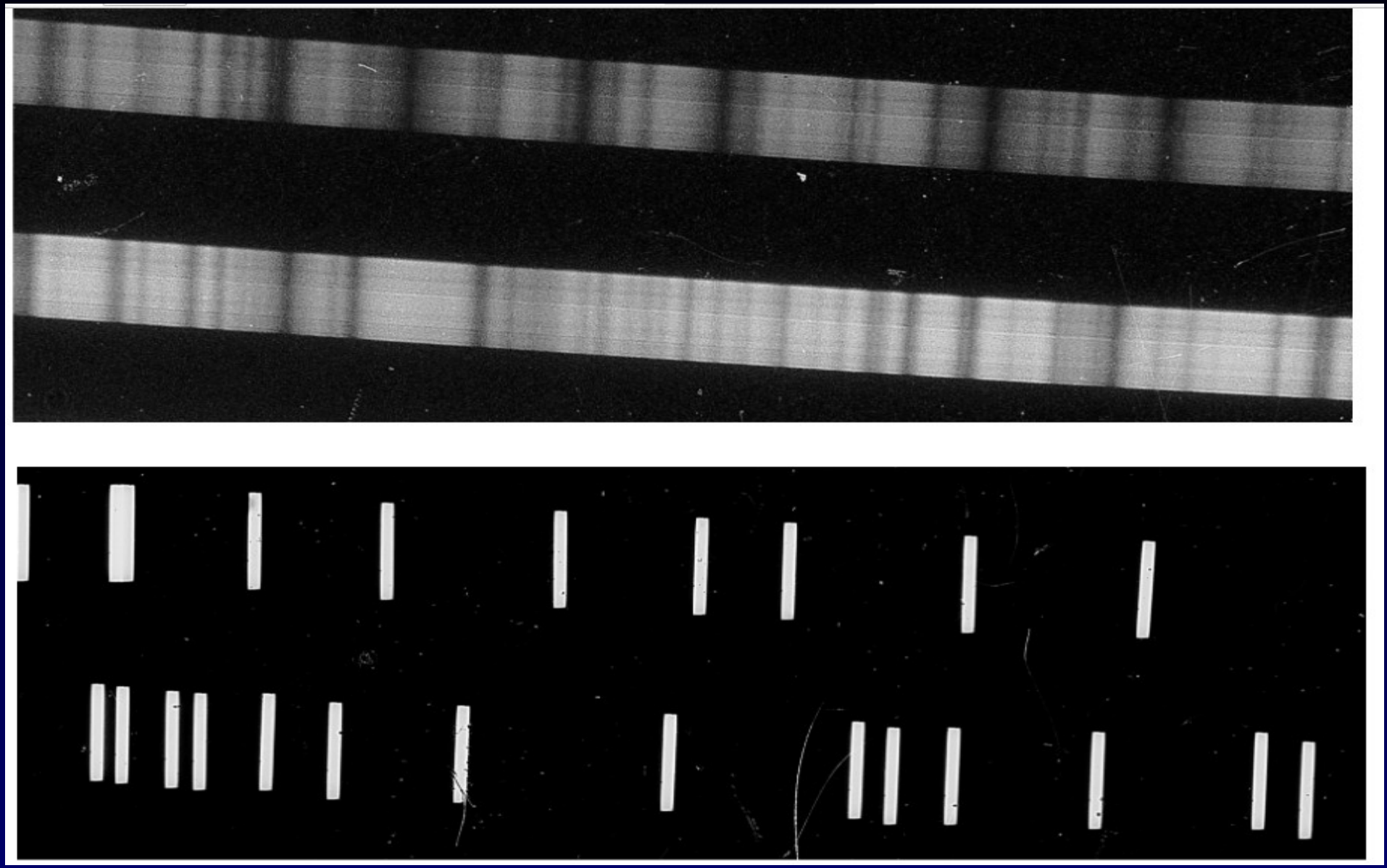
Only for direct occultation




Winn 2010

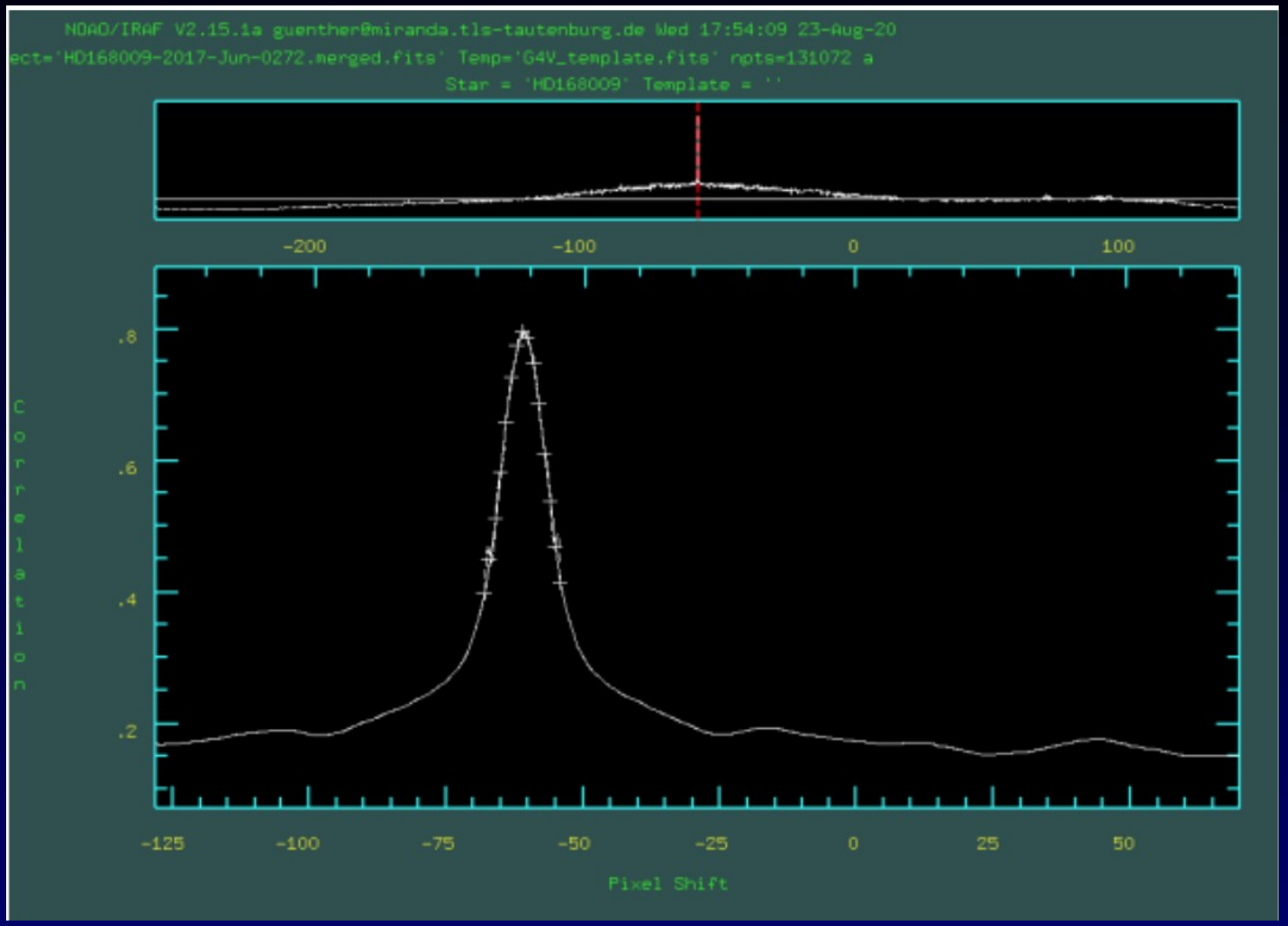
# Cross Correlation Function

# Analogue Technique



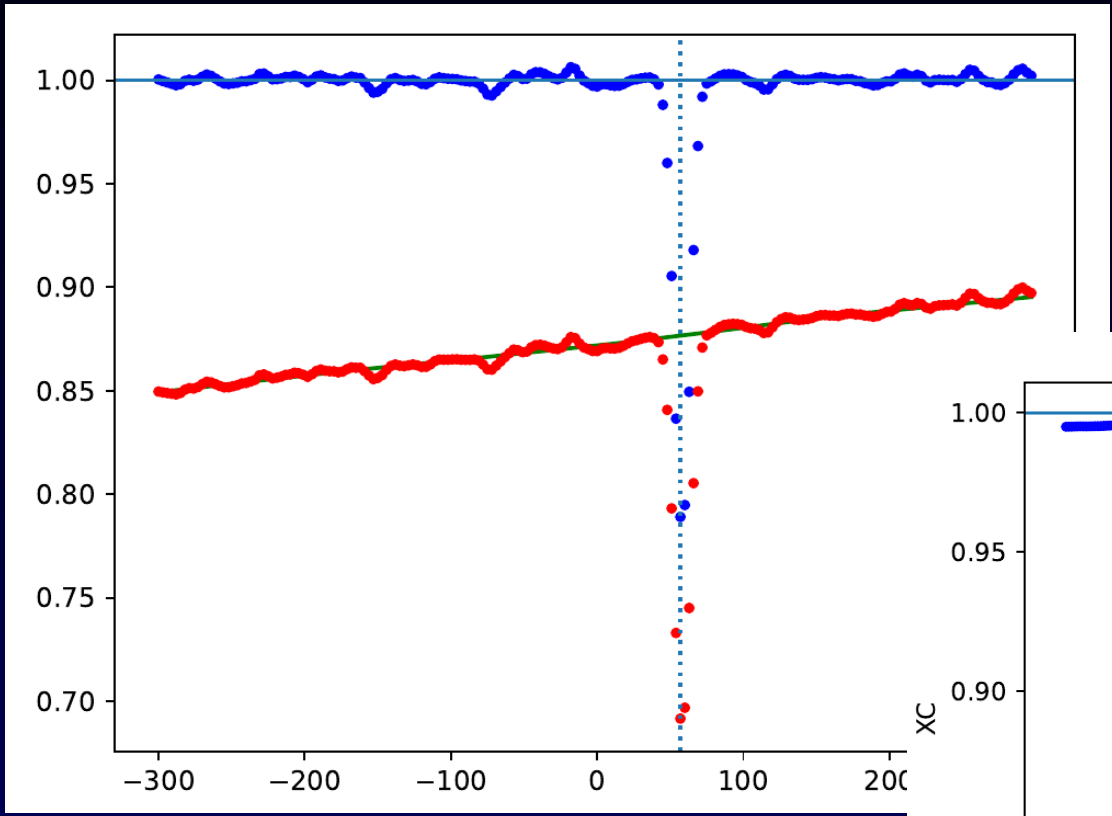
First principle  Griffin 1967, DAO 122, CORAVEL ESO D154 1981

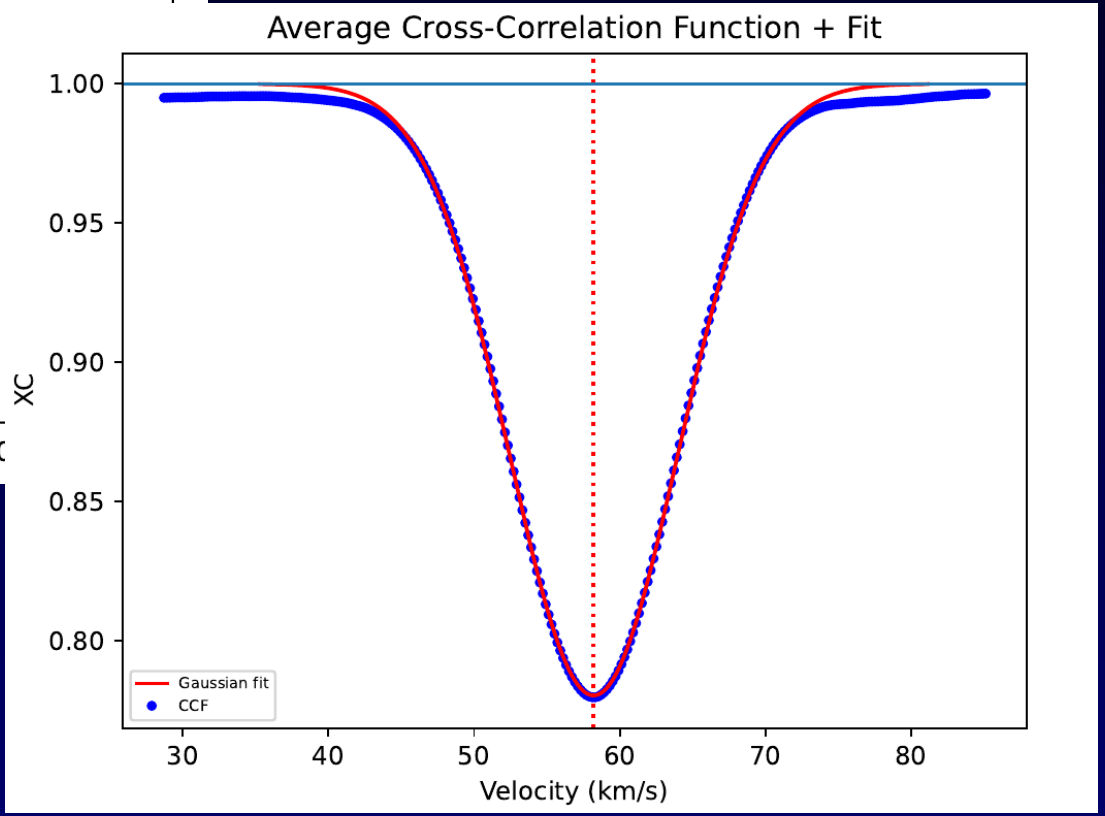
# Cross Correlation Function




IRAF fxcor task

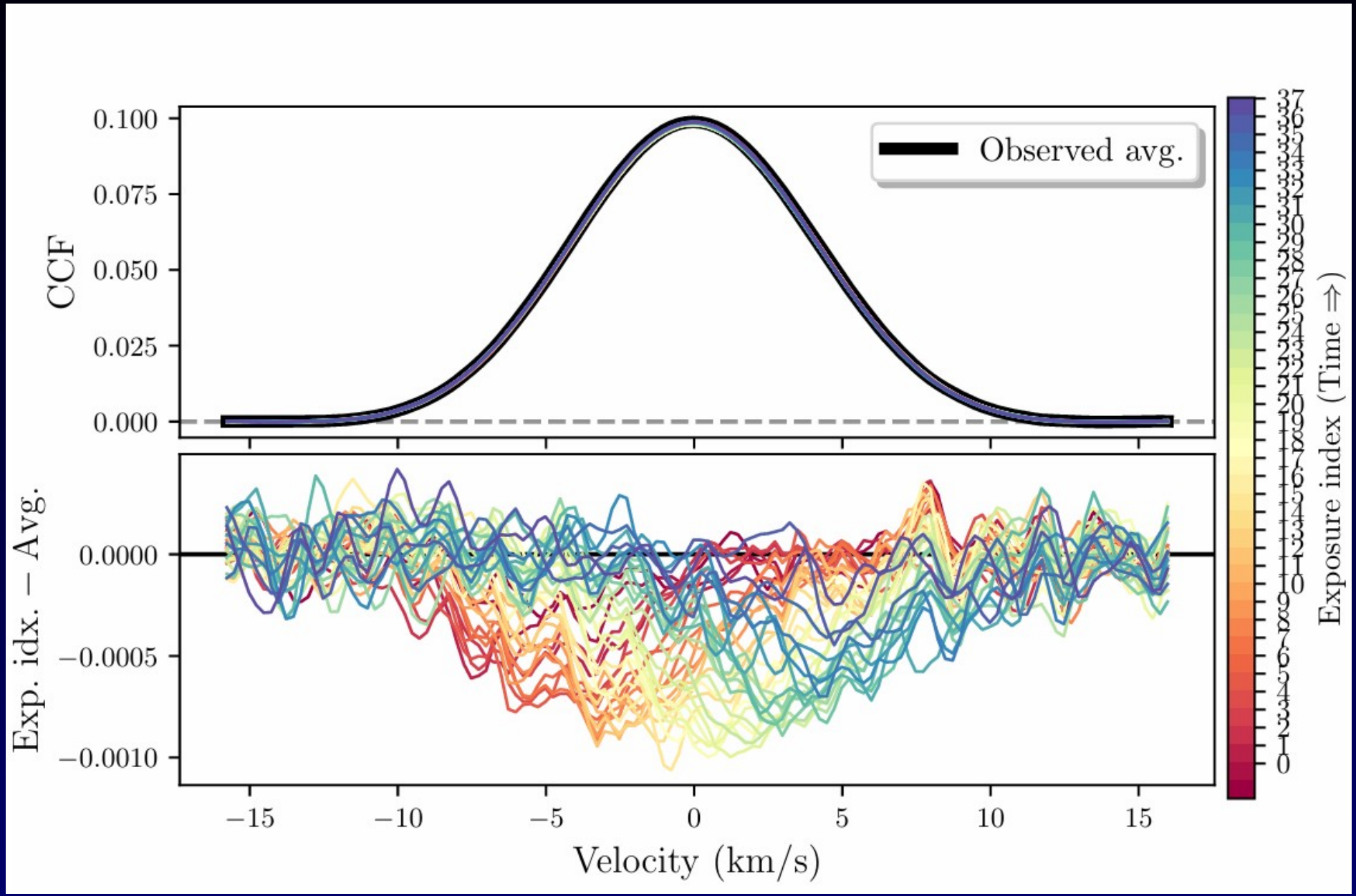
# Cross Correlation Function - CCF



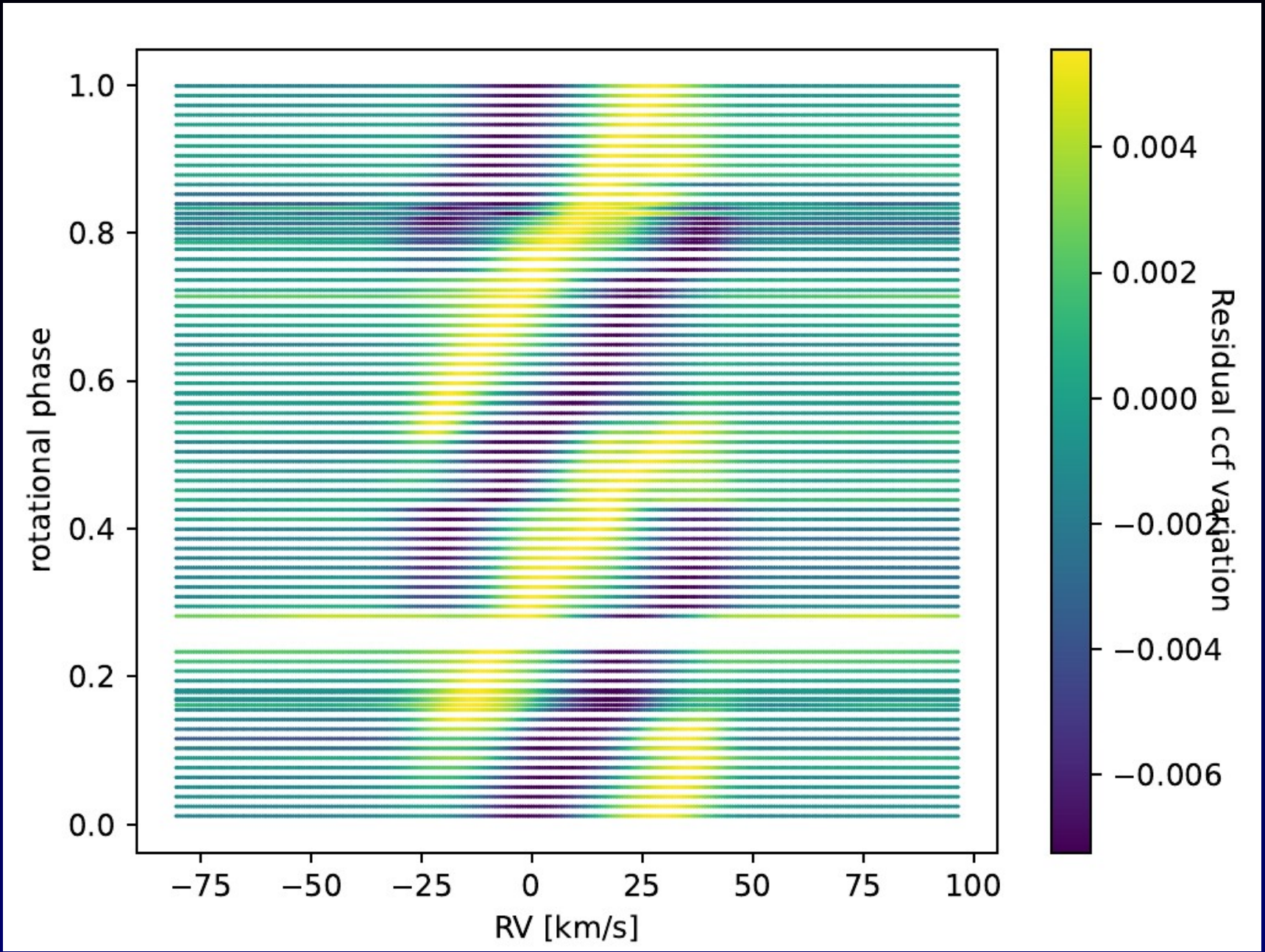




Example of PlatoSpec data reduced by CERES+

# Residual CCF



# Dynamic spectra – CCF




Lipták 2025, private comm.

# (Simple) Spectra in VO

# Simple Spectra Access Protocol
# Spectral Data Model




International Virtual Observatory Alliance

## Simple Spectral Access Protocol

## Version 1.04

## IVOA Recommendation Feb 01, 2008

**This version:**
http://www.ivoa.net/Documents/REC/DAL/SSA-20080201.html
**Latest version:**
http://www.ivoa.net/Documents/latest/SSA.html
**Previous version(s):**
Version 1.03, December 2007
Version 1.02, September 2007
Version 1.01, June 2007
Version 1.00, May 2007
Version 0.97, November 2006
Version 0.96, September 2006
Version 0.95 May 2006
Version 0.91 October 2005
Version 0.90 May 2005
**Editors:**
D.Tody, M. Dolensky
**Authors:**
D.Tody, M. Dolensky, J. McDowell, F. Bonnarel, T.Budavari, I.Busko, A. Micol, P.Osuna, J.Salgado, P.Skoda, R.Thompson, F.Valdes, and the data access layer working group.


International Virtual Observatory Alliance

## IVOA Spectral Data Model

## Version 1.03

## IVOA Recommendation 2007-10-29

**This version (Recommendation Rev 1)**
http://www.ivoa.net/Documents/REC/DM/SpectrumDM-20071029.pdf
**Latest version:**
http://www.ivoa.net/Documents/latest/SpectrumDM.html
**Previous versions:**
http://www.ivoa.net/Documents/PR/DM/SpectrumDM-20070913.html

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

# SSAP Parameters

### 4.1.1 Mandatory Query Parameters

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

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

### 4.1.2 Recommended and Optional Query Parameters

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

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

# 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.

| *UTYPE* | *Description* | *Req* | *Default* |
|---|---|---|---|
| **Dataset.DataModel** | Datamodel name and version | MAN | Spectrum-1.0 |
| Dataset.Type | Type of dataset | OPT | Spectrum |
| **Dataset.Length** | 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.

| *UTYPE* | *Description* | *Req* | *Default* |
|---|---|---|---|
| Char.FluxAxis.Ucd | ucd for flux | REC | |
| Char.SpectralAxis.Ucd | ucd for spectral coord | REC | |

# Spectra - query output and previews

CZVO Czech Virtual Observatory

## 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

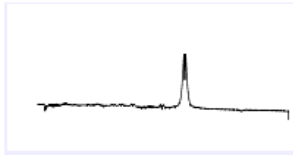
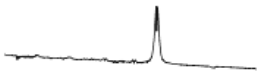
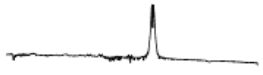
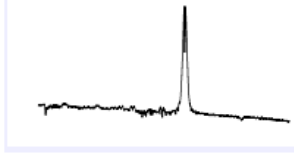
### Parameters

- Object standard name: ['psiper']

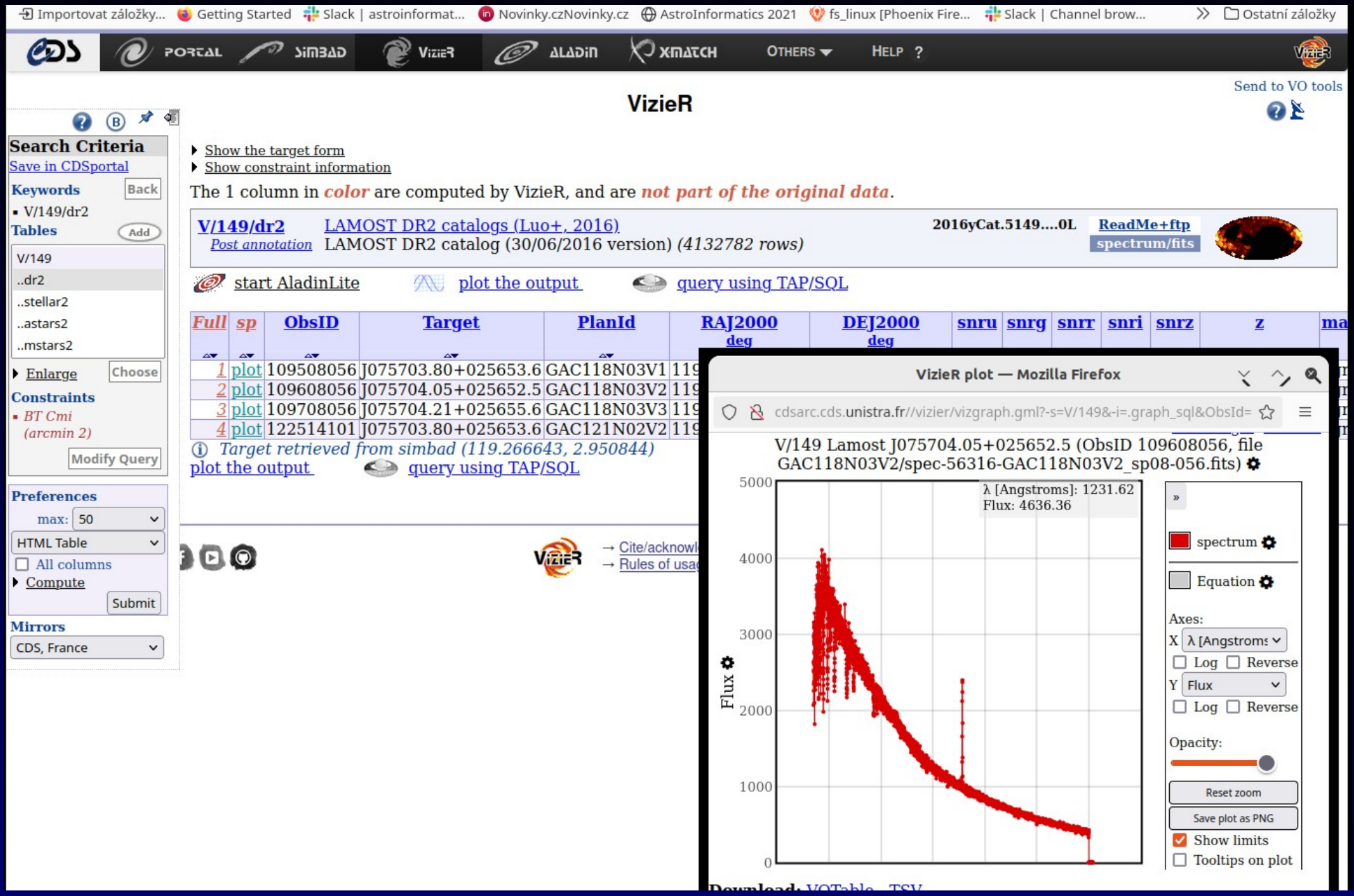
### Result

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

# Spectra in Vizier (VO)



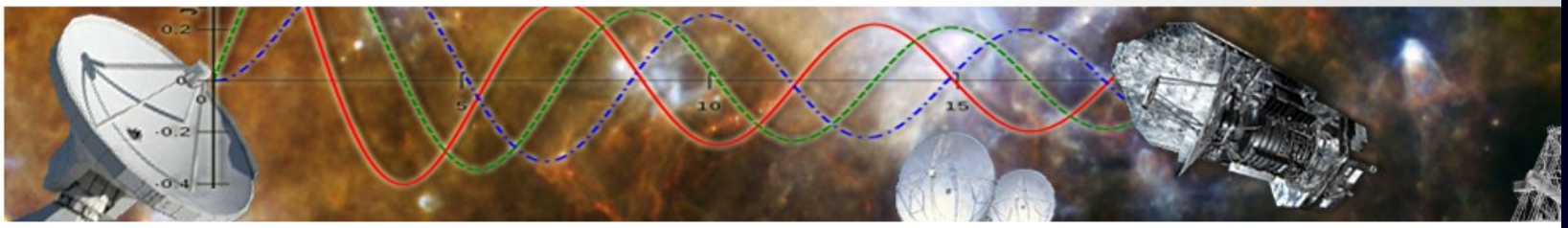
# VO Tools

- 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
- Cassis 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**
  - Sandrine Bottinelli: Sandrine.Bottinelli{at}irap.omp.eu
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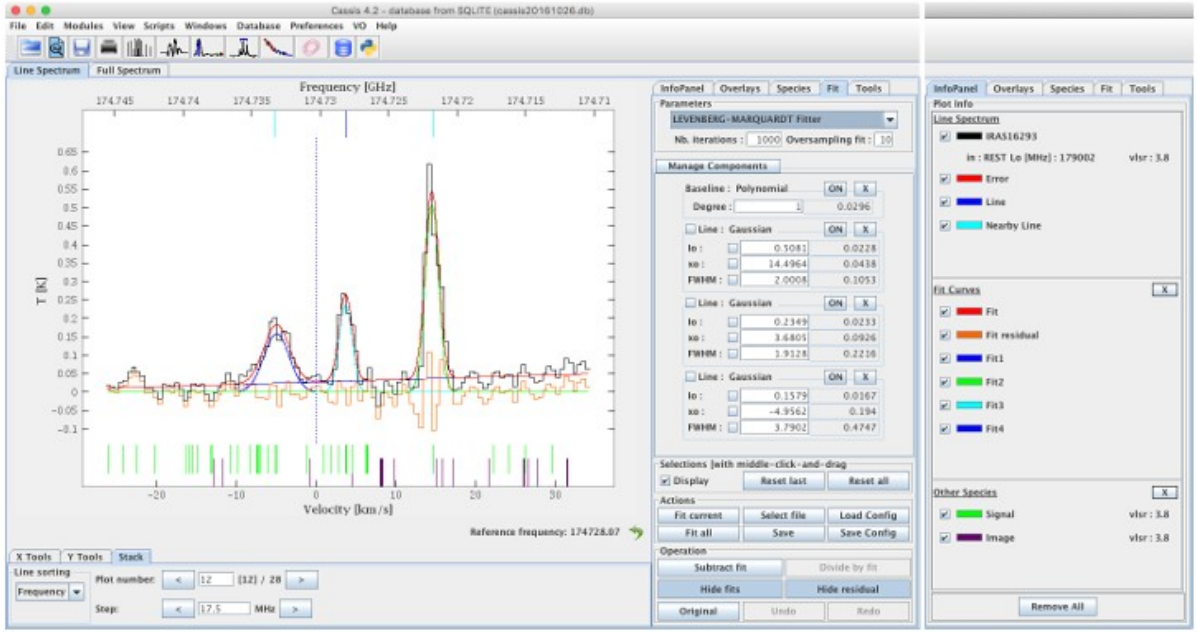
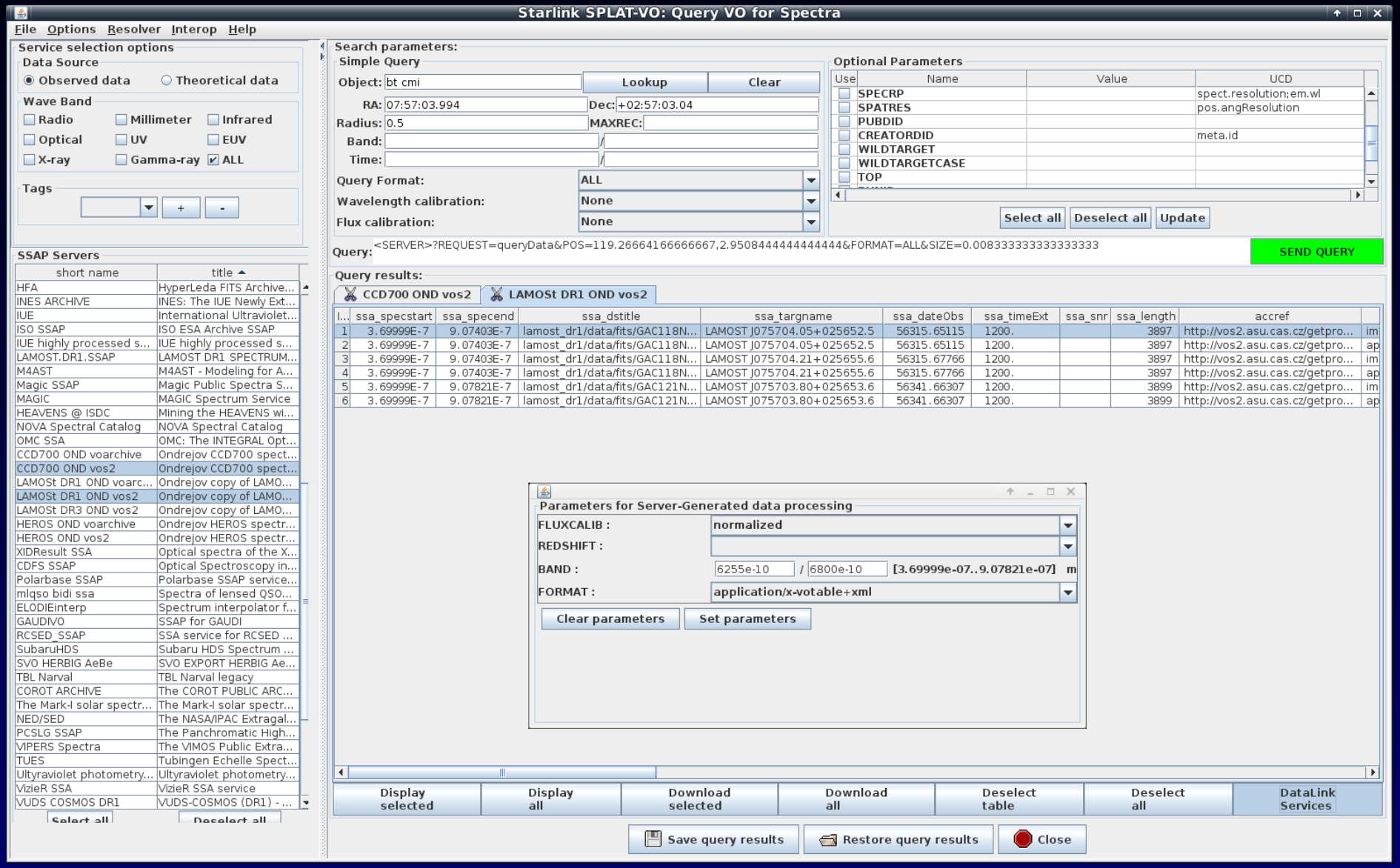
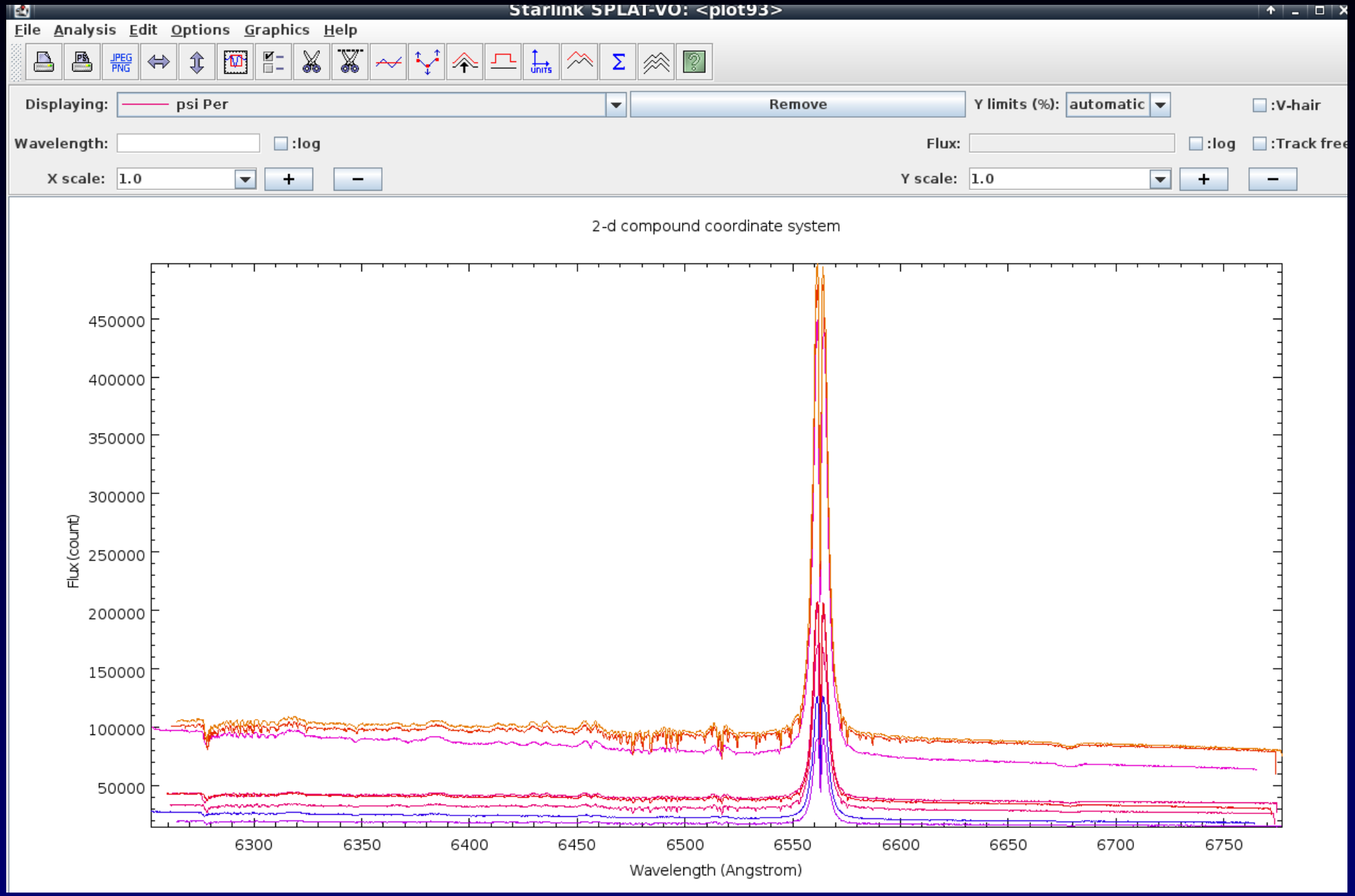
  - Jean-Michel Glorian : Jean-Michel.Glorian{at}irap.omp.eu
- **Developer**
  - Mickaël Boiziot : Mickael.Boiziot{at}irap.omp.eu



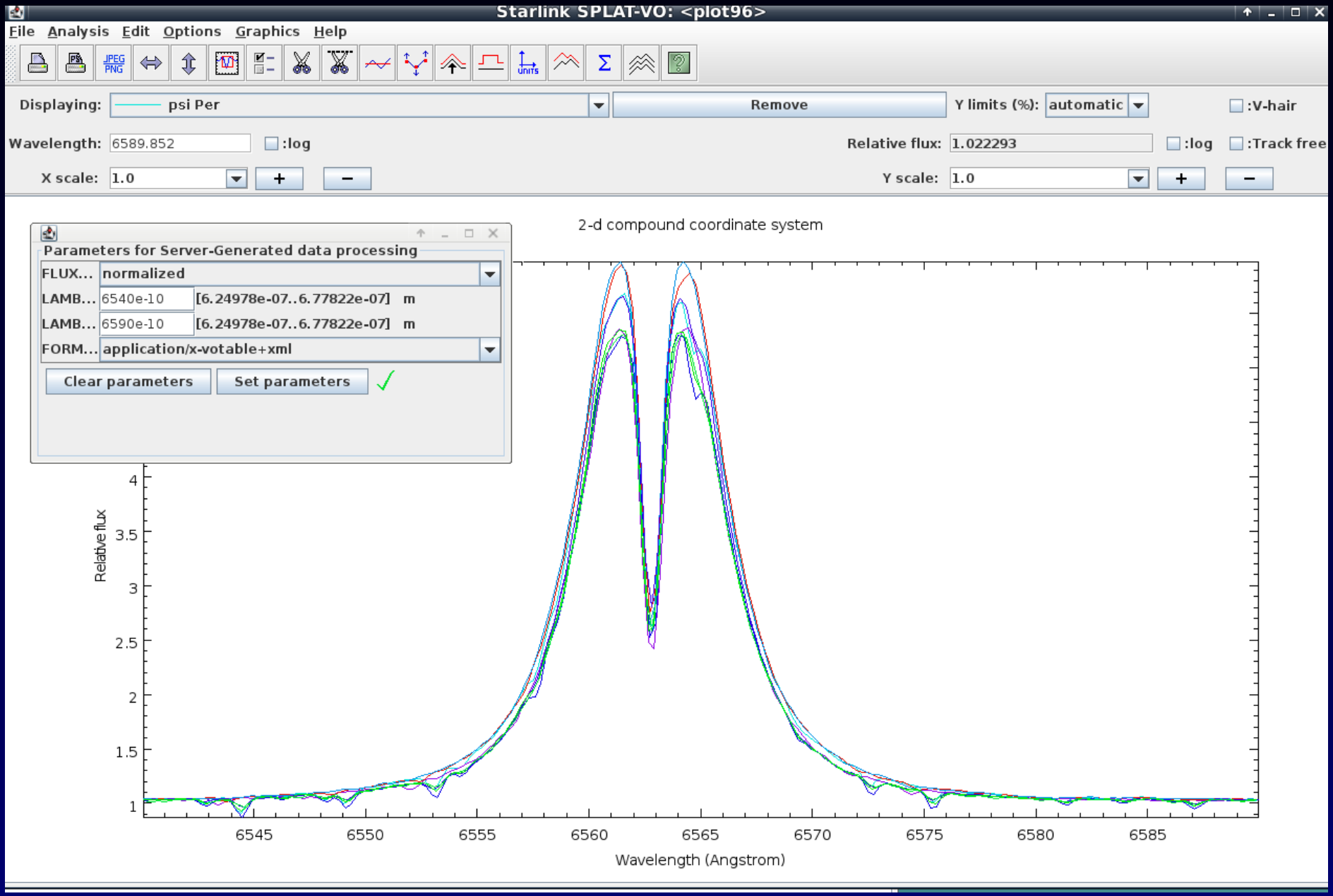
# LAMOST Query  Ha region



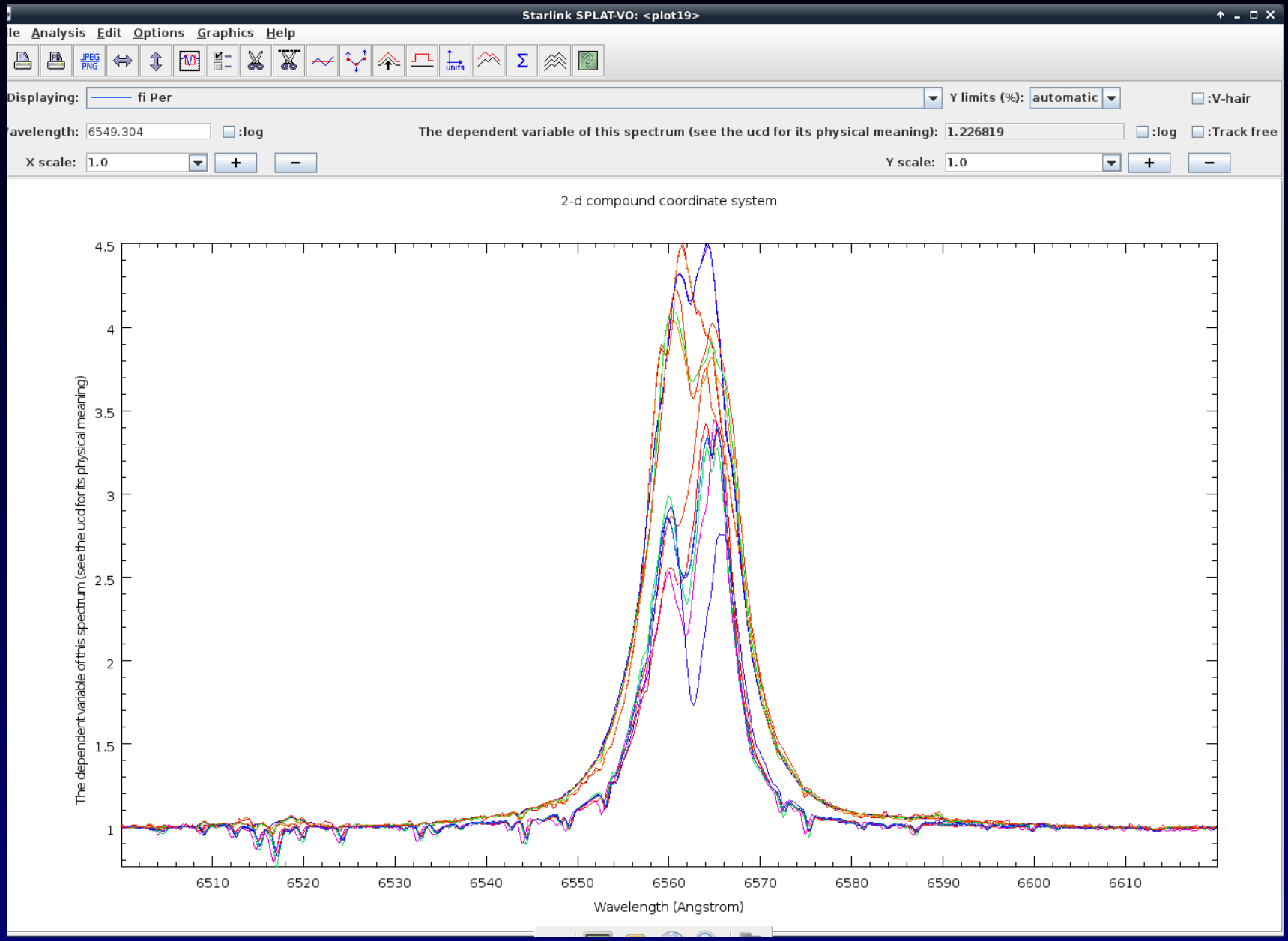
# Spectra in SPLAT-VO direct access



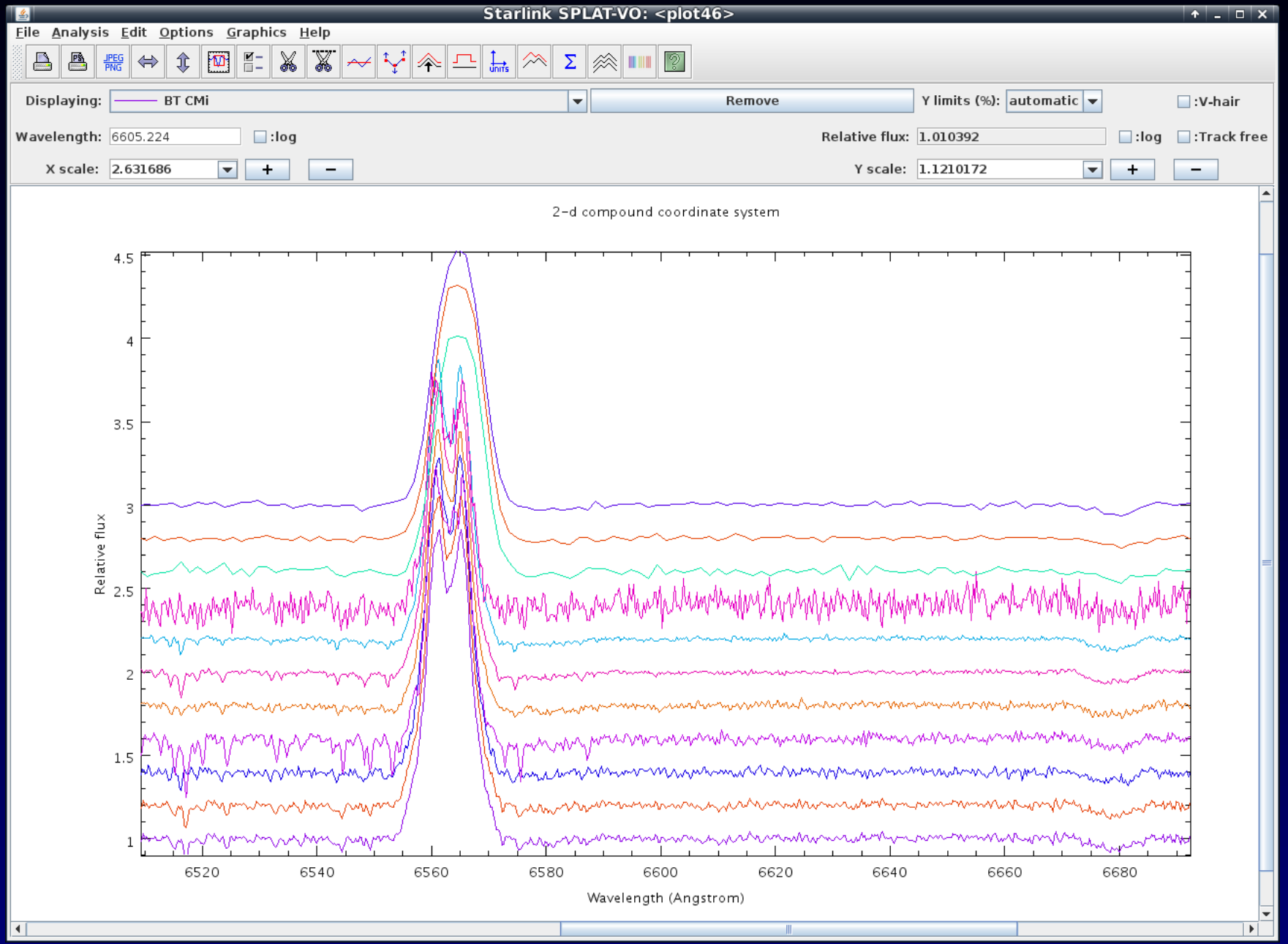
# Spectra in SPLAT-VO - DataLink



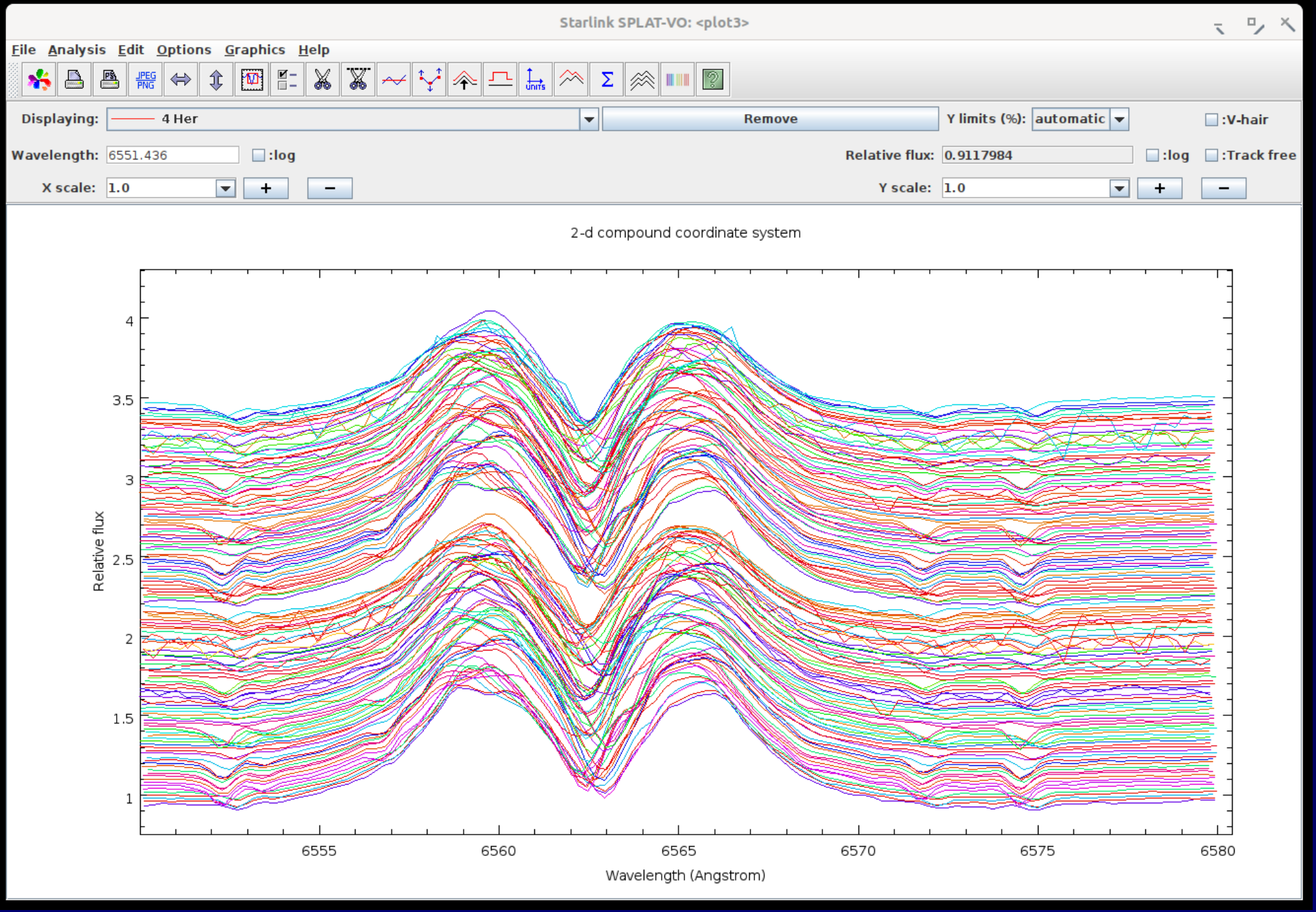
# Variability of Line Profile on Be star



# LAMOST emission candidate



# Series of Spectra – LPV



# 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.
```

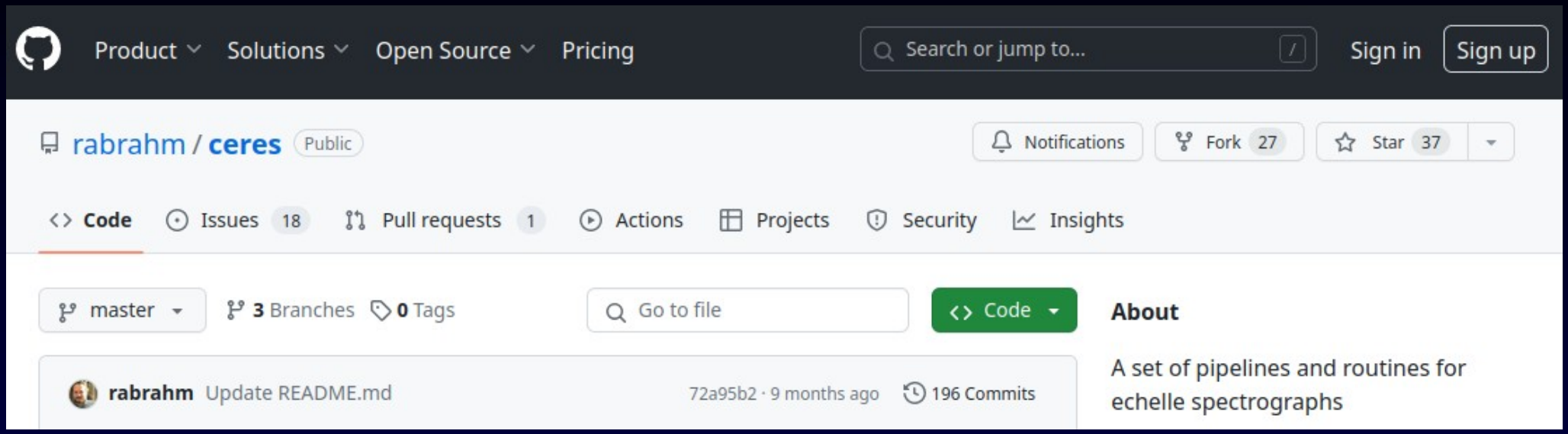
5.6 Pixel Array Dispersion Function

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




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(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-  Continumm normalized flux multiplied by the derivative of the wavelengt
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 $= \frac{1}{\sqrt{(variance(FLUX))}}$
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 contiuum 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 | DataType | 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_DESCRIPT | 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_COR |
| 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_ |
| 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 ….)

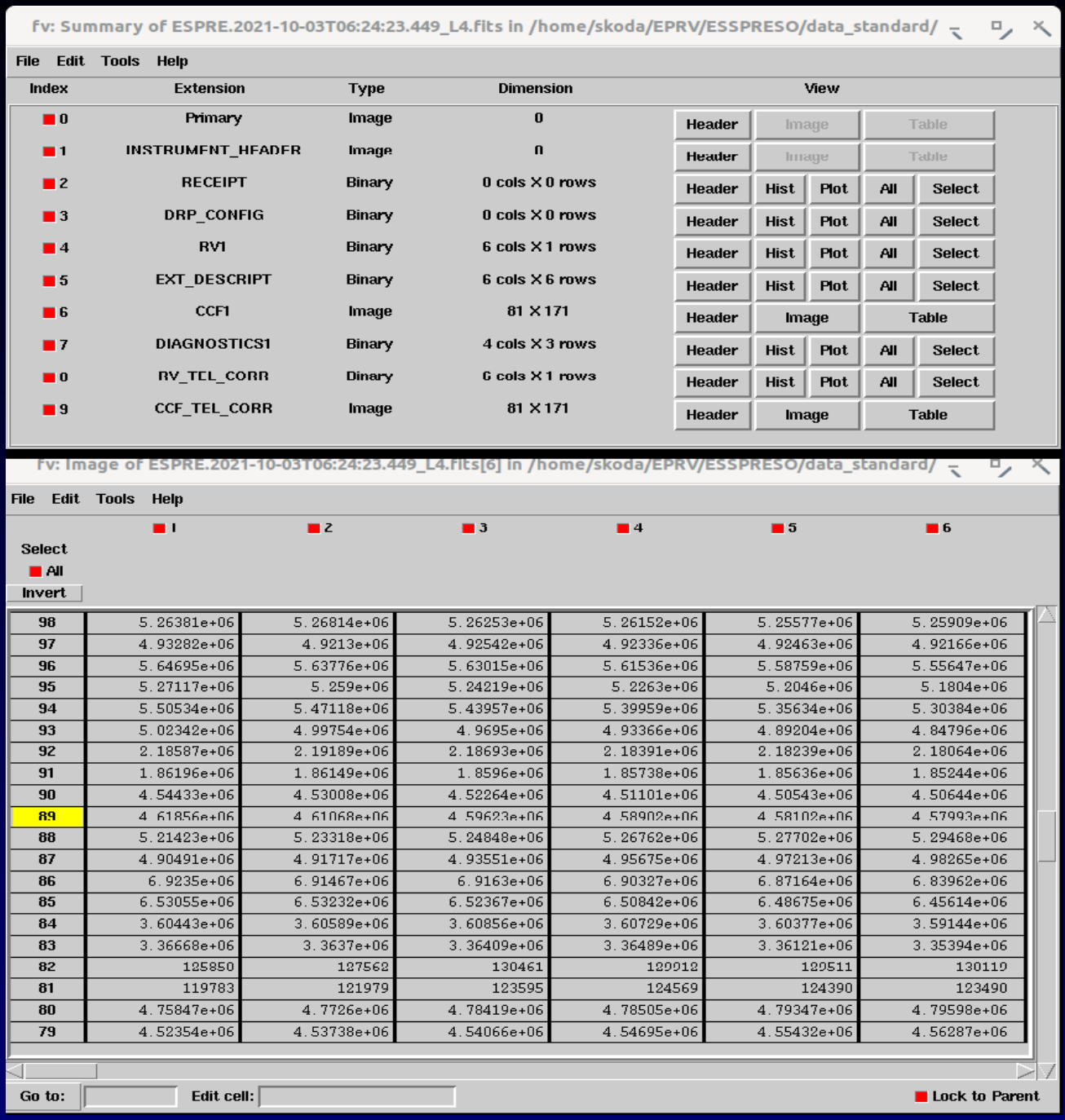
It is the most important output of pipeline

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 | 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 | 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




Thanks:
E.Fontanet
2025 priv.com.

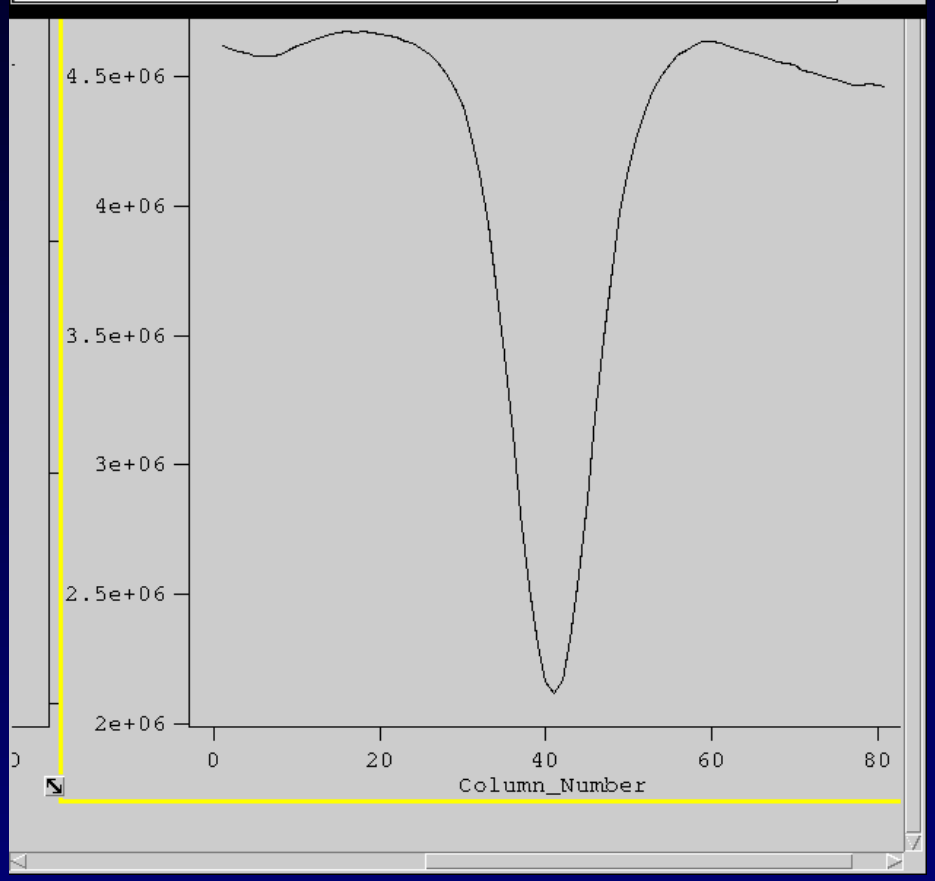
# EPRV L4 CCF in fv

fv: Header of ESPRE.2021-10-03T06:24:23.449_L4.fits[6] in /home/skoda/...

File Edit Tools Help

Search for: Find Case sensitive? No

```
XTENSION= 'IMAGE   '           / Image extension
BITPIX  =                  -32 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                   81
NAXIS2  =                  171
PCOUNT  =                    0 / number of parameters
GCOUNT  =                    1 / number of groups
EXTNAME = 'CCF1    '
CHECKSUM= 'XAQ9X6P8XAP8X5P8'   / HDU checksum updated 2025-05-27T05:20:30
DATASUM = '2322973122'         / data unit checksum updated 2025-05-27T05:20:30
VELSTART=                -36.6 / Coordinate at reference pixel
VELSTEP =                  0.5 / Coordinate increment per pixel
CCFMASK = 'G9      '           / CCF mask used
VELNSTEP=                   81 / Number of Steps in Velocity Grid
END
```




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

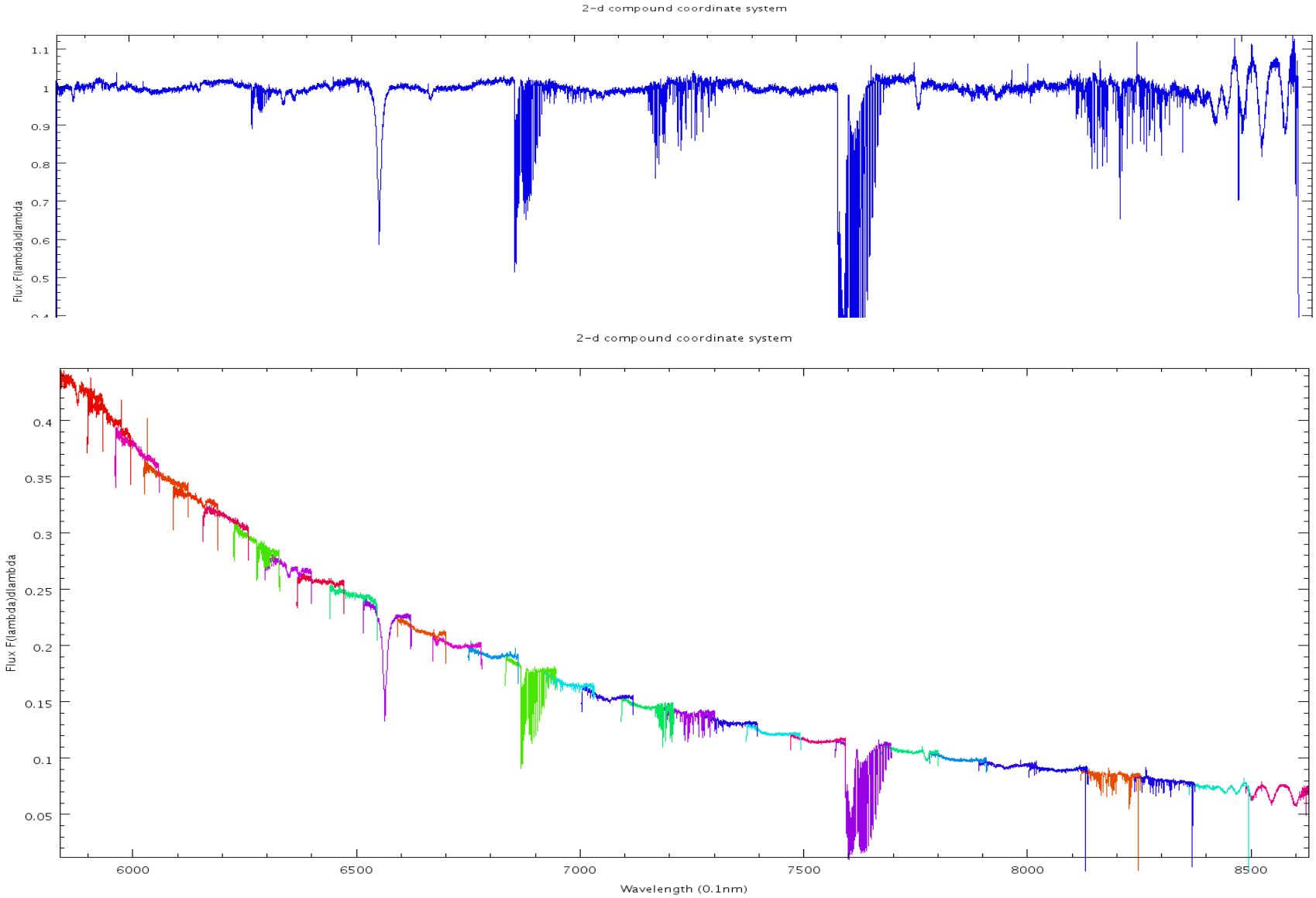
Center~41

-36.6+40*0.5=-16.6

| Astrometry | |
|---|---|
| **Radial velocity ($R_v$)** | −16.68 ± 0.05[5] km/s |
| **Proper motion (μ)** | RA: −1721.728 mas/yr[1] |
| | Dec.: +854.963 mas/yr[1] |
| **Parallax (π)** | 273.8097 ± 0.1701 mas[1] |

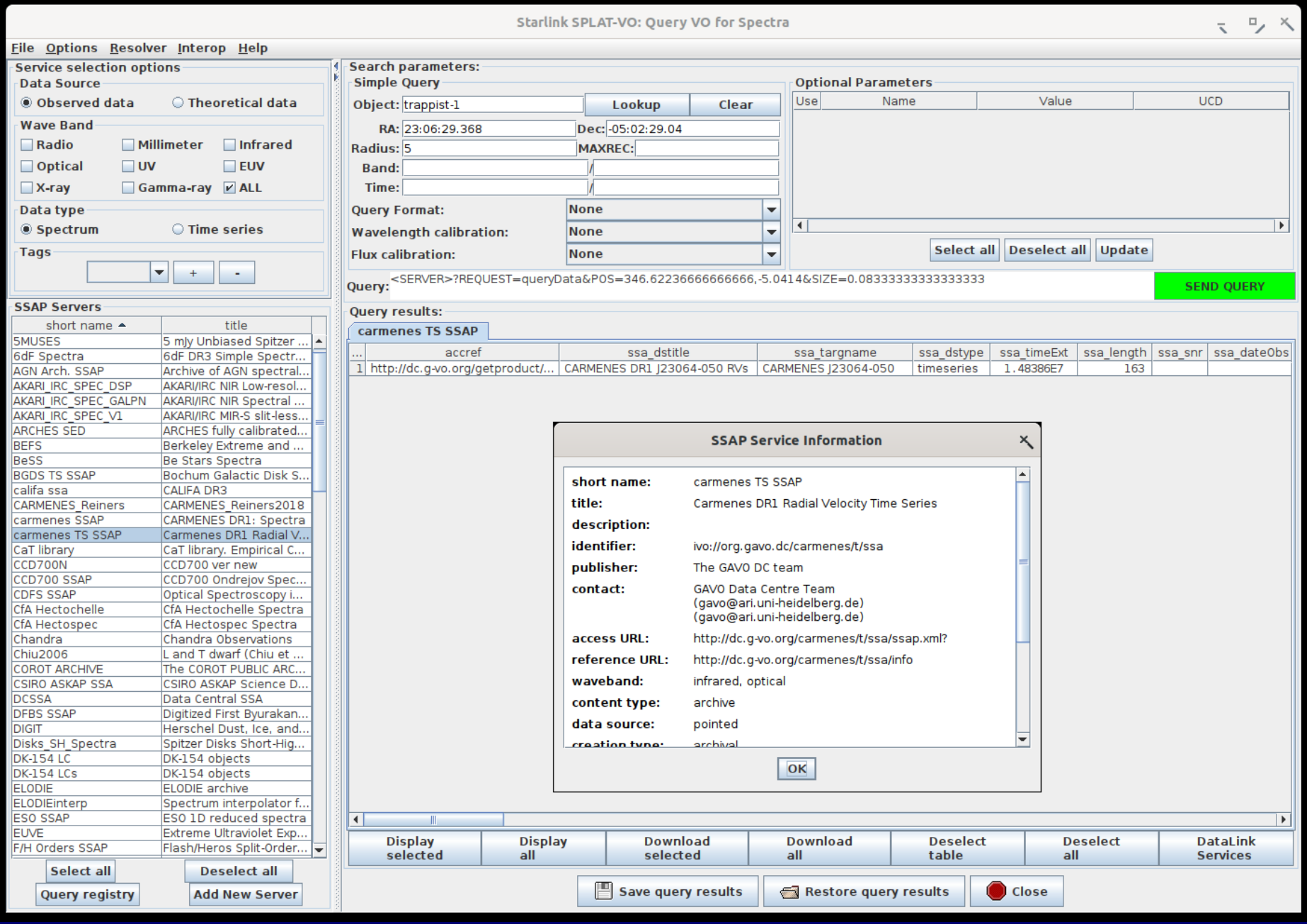
Thanks:
E.Fontanet
2025 priv.com.

# DaCHS Testbed Split-Order SSAP

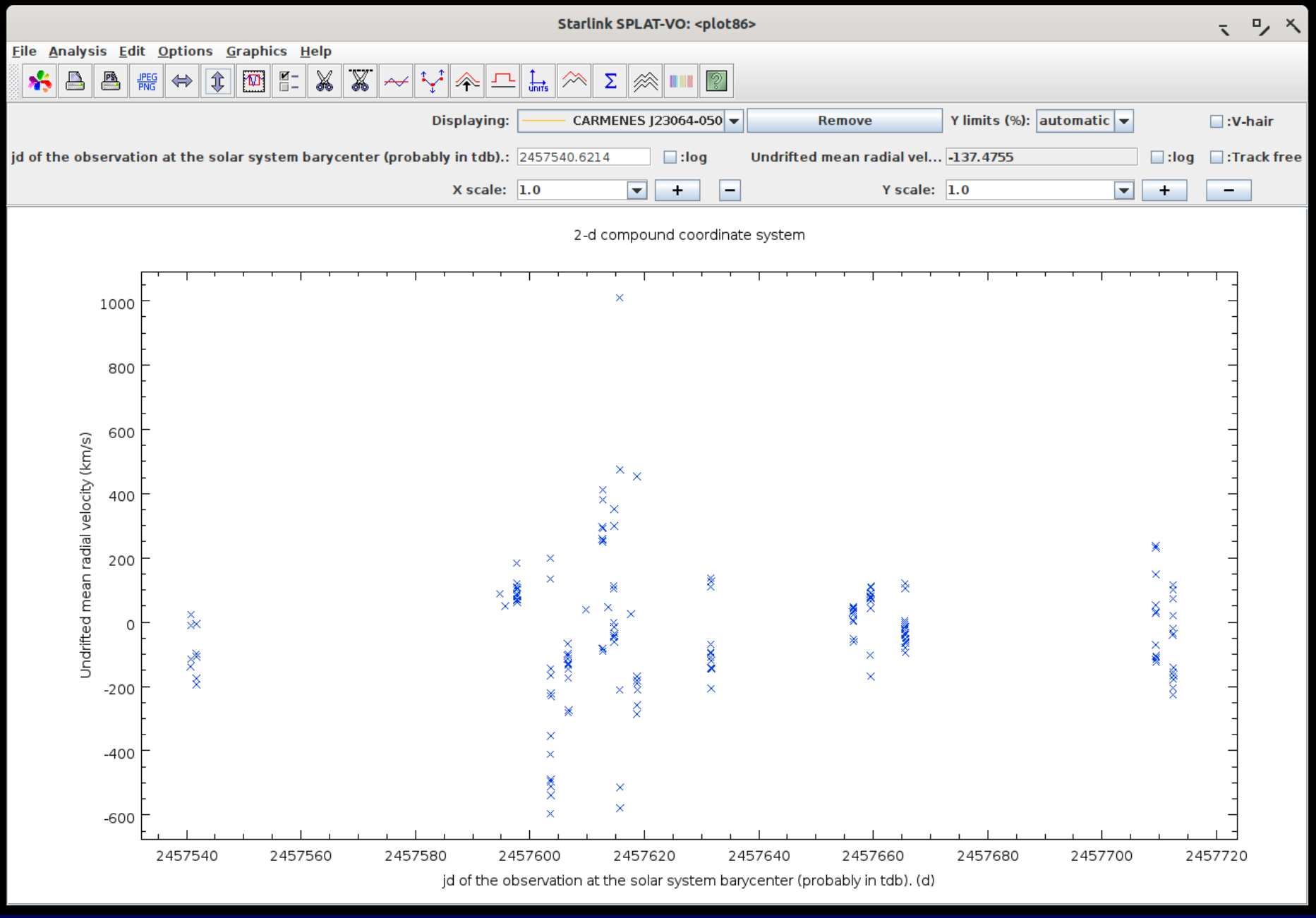



nu Pup HEROS red

# Trappist-1 RV Curve – Carmenes



# Trappist-1 RV Curve – Carmenes



Thank you