# Identification of Important VO Spectral Services benefitting from deployment on the GRID

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# Outline of the Talk

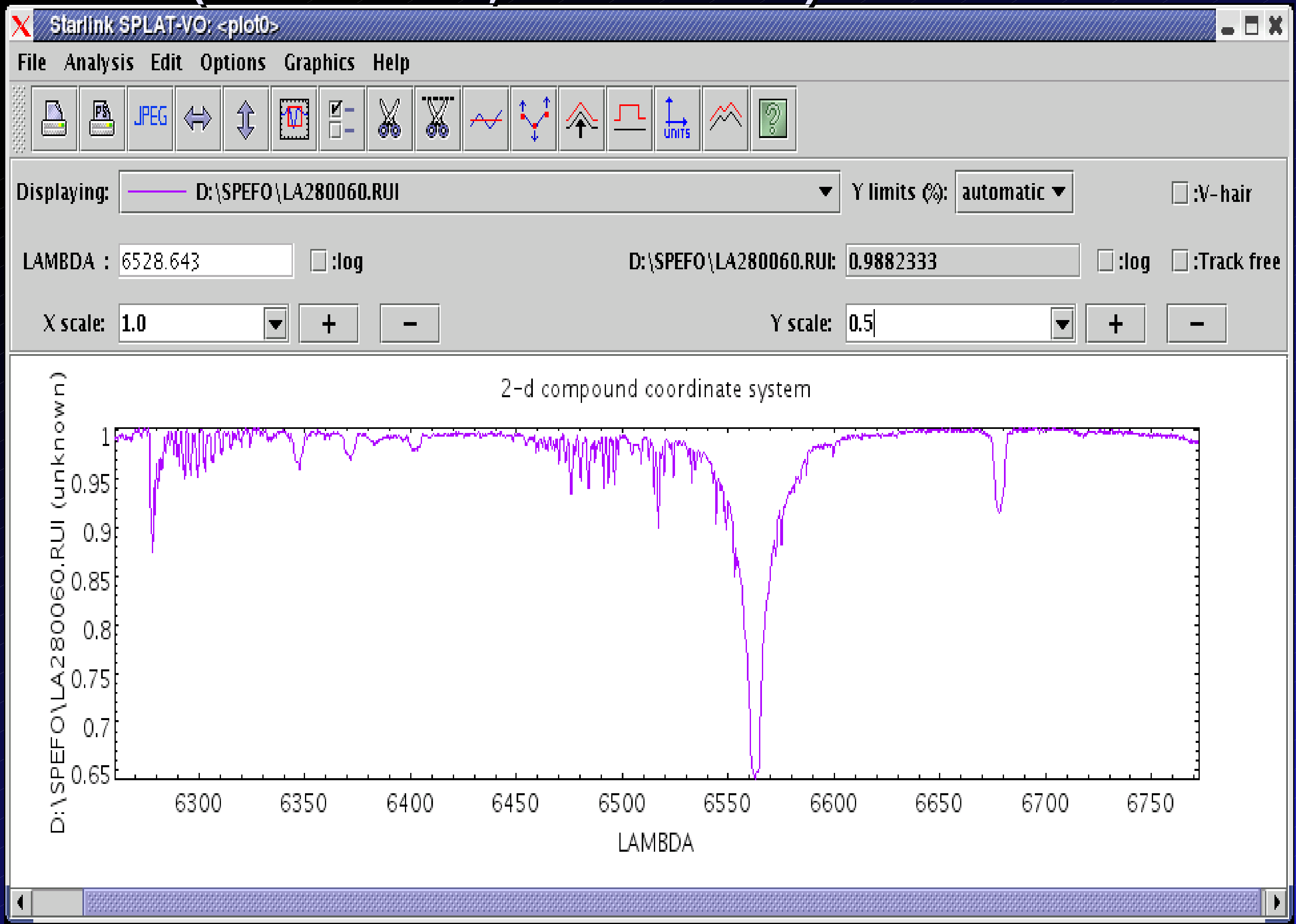
- Current support for spectra in VO
  - Clients (basic analysis)
- The proper VO way
  - Services
  - Postprocessing of spectra – on server
  - From individual programs to workflows
  - Why GRID (not VOrg but workflows)
  - Massive spectra reduction

# Outline of the Talk

- Advanced methods of spectra analysis
  - Detection of ES planets in spectra
  - Automatic spectra classification
  - Disentangling of spectra
  - Variability – Period analysis
  - Doppler imaging, tomography
  - Magnetic fields (Zeeman-Doppler imaging)
  - Week signatures of Mg field (Lorentz force)
- Conclusions for future development of VO

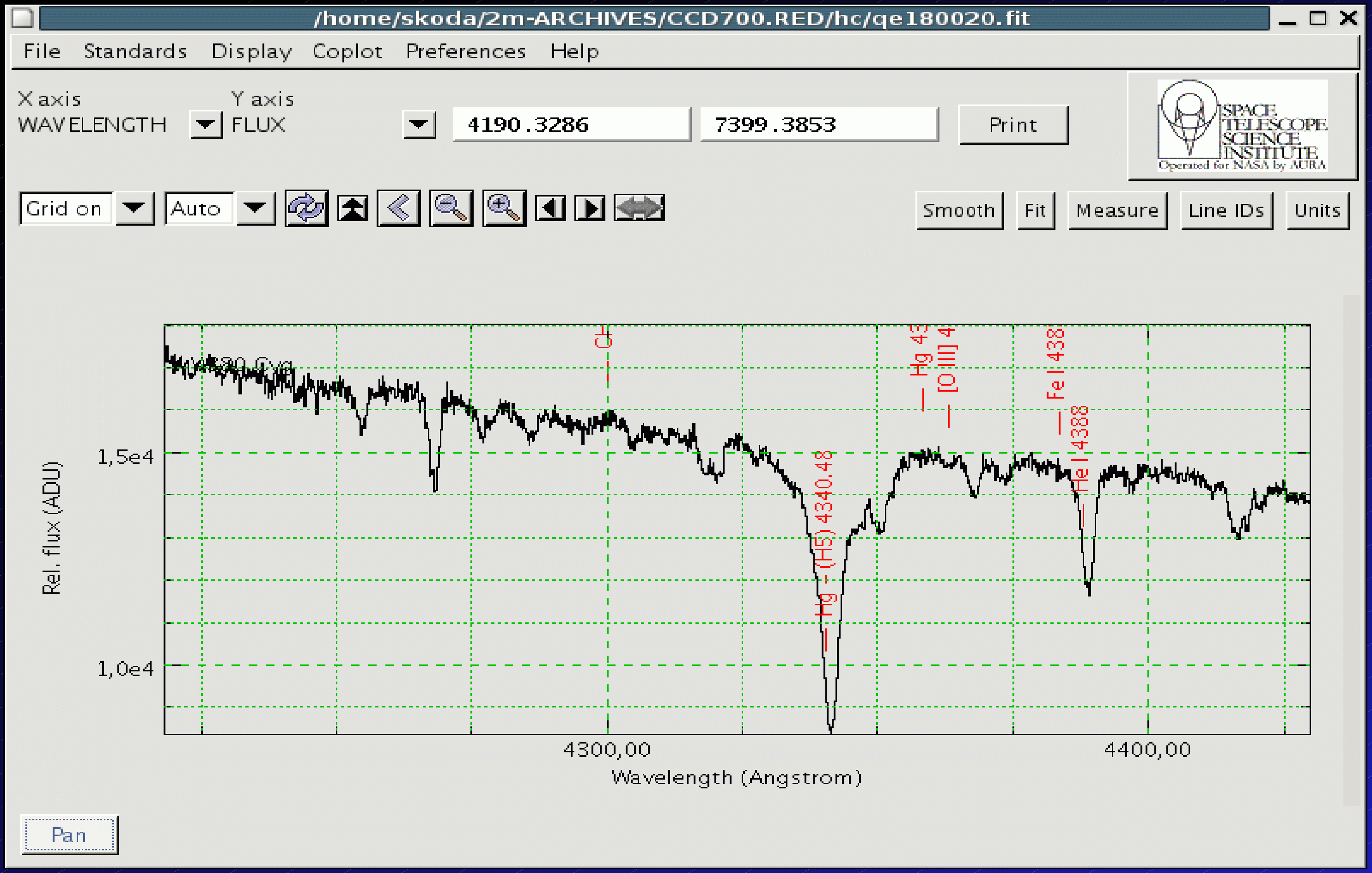
# SPLAT-VO

- VO Client for analysis (SSA and local files) 1D FITS (CRVAL1, CDELT1)

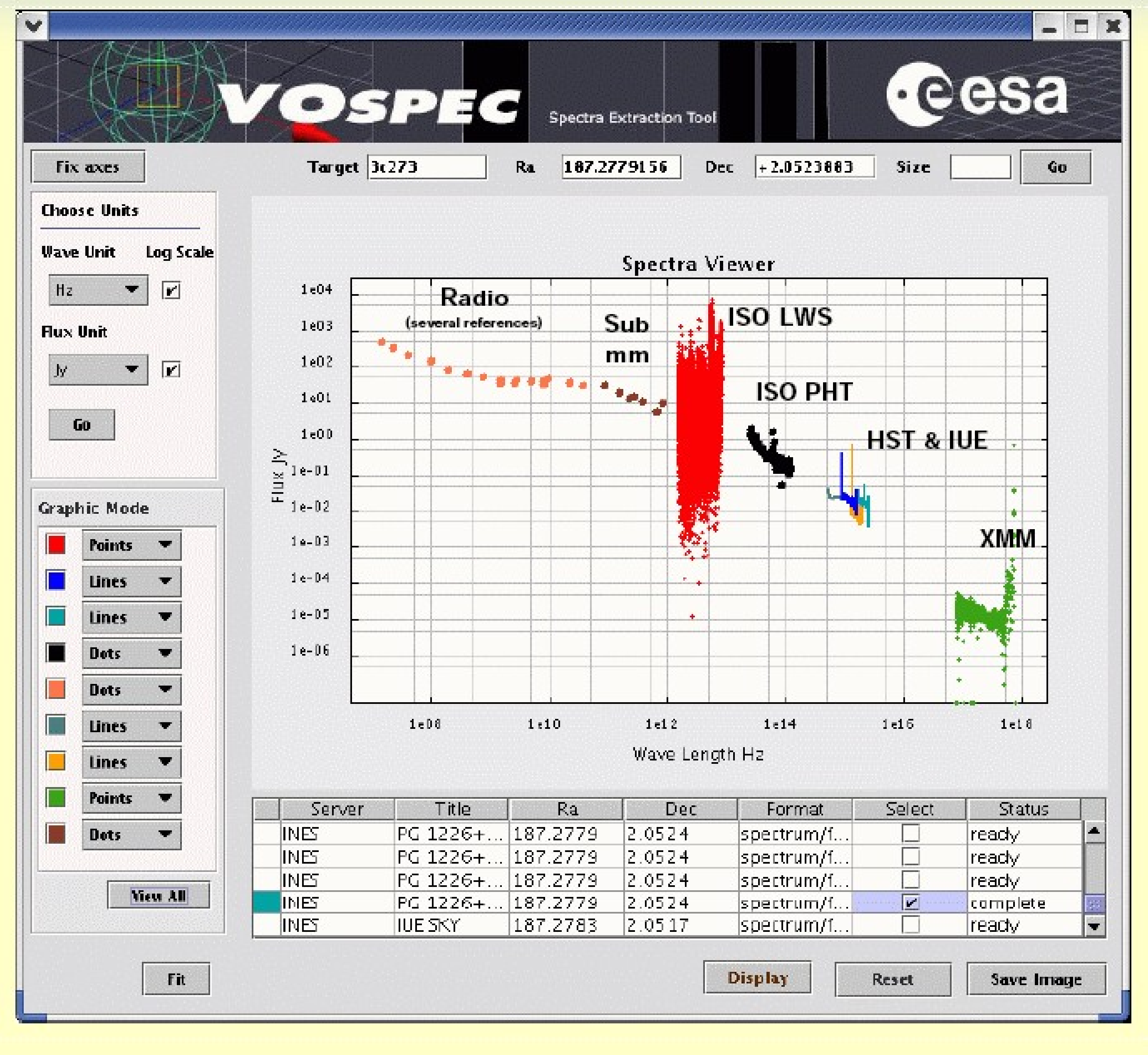


# SpecView

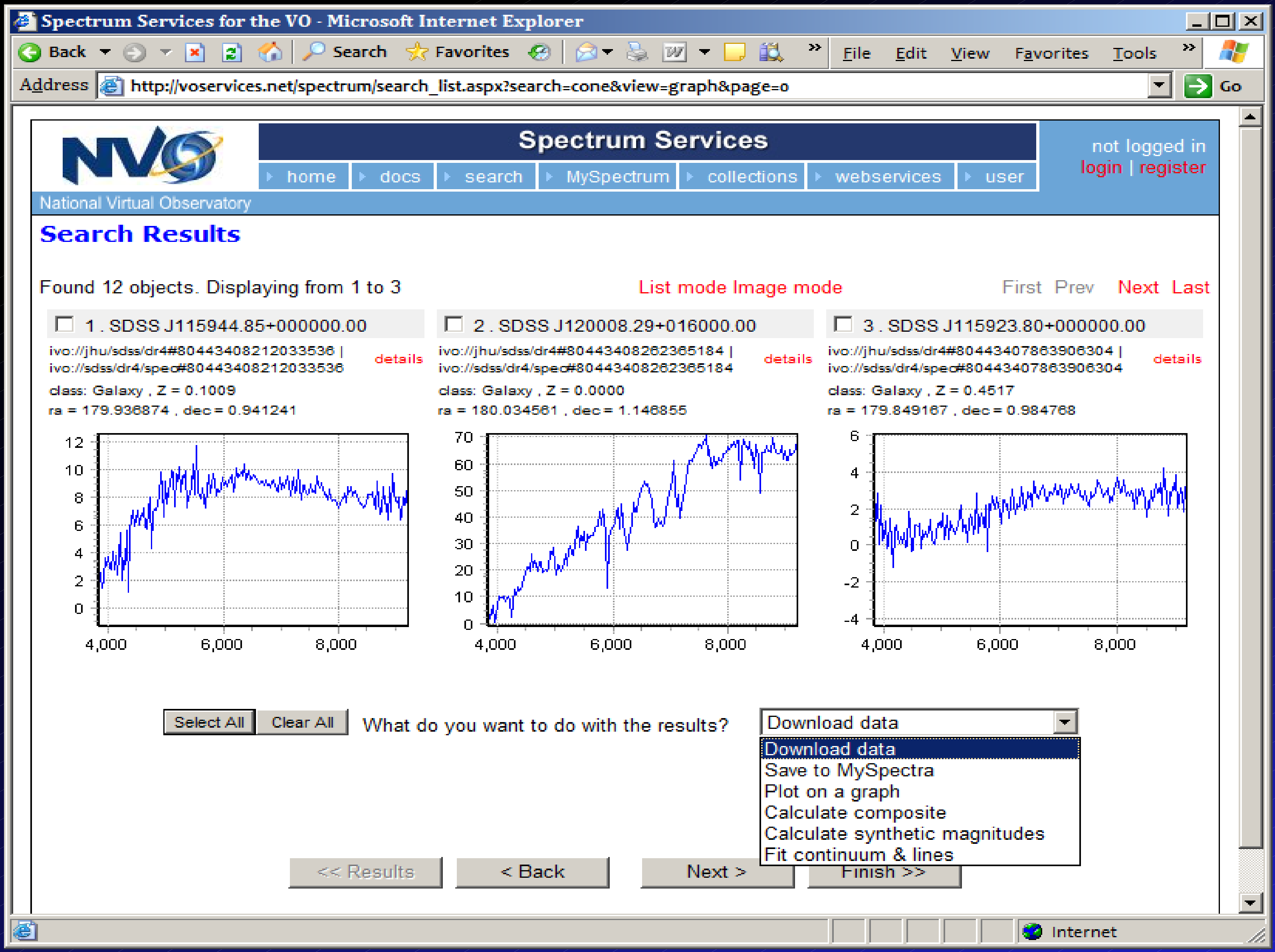
- VO Client for analysis (SSA and local files) 1D FITS (CRVAL1, CDELT1), models



# VOspec (SLAP,TSAP)



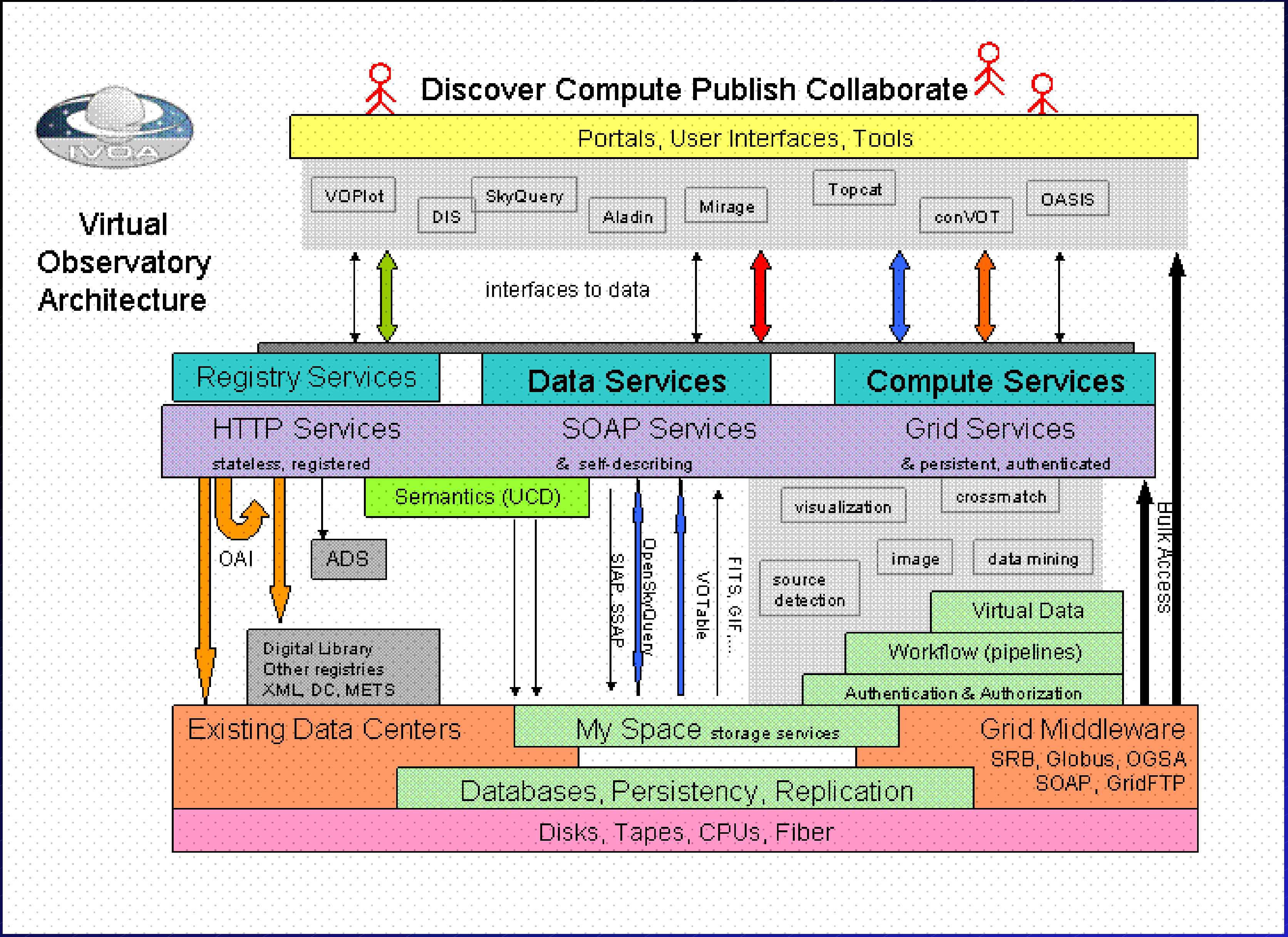
# SDSS Spectrum Services
# PCA similar spectra



# VO key feature

- Interoperability
- All current work of an astronomer done in ONE GUI
- Transparent  search, download, conversion
- Unified presentation - different relations
- Background computing on GRIDS
  - results in WS or DB
- Remote control - batch observation - robotic telescope
  - results DB
- ADASS quotation : The telescope is a database with very long time access

# Architecture of VO



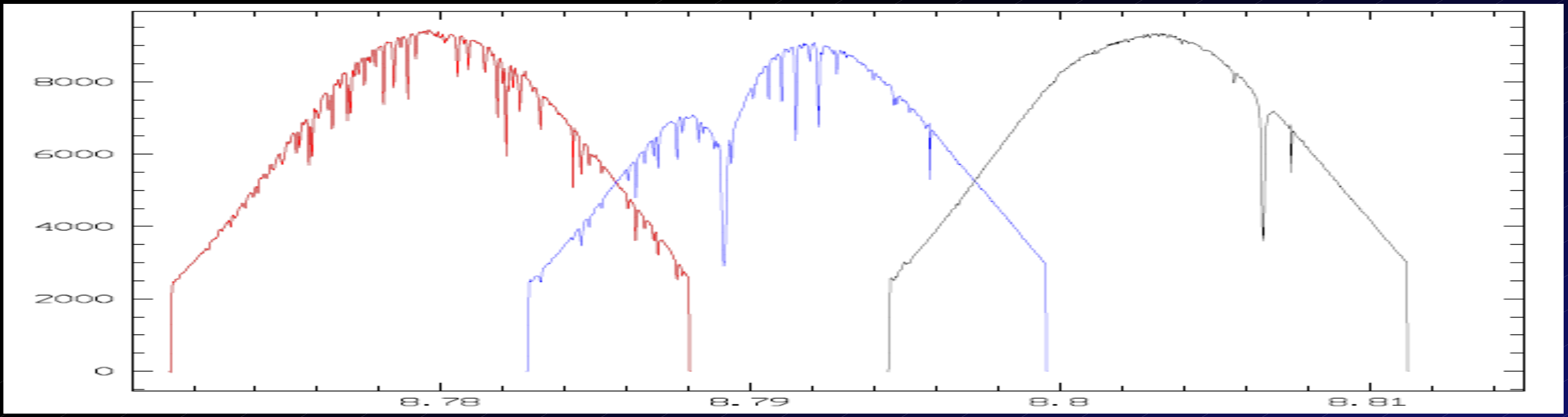
# Spectra postprocessing

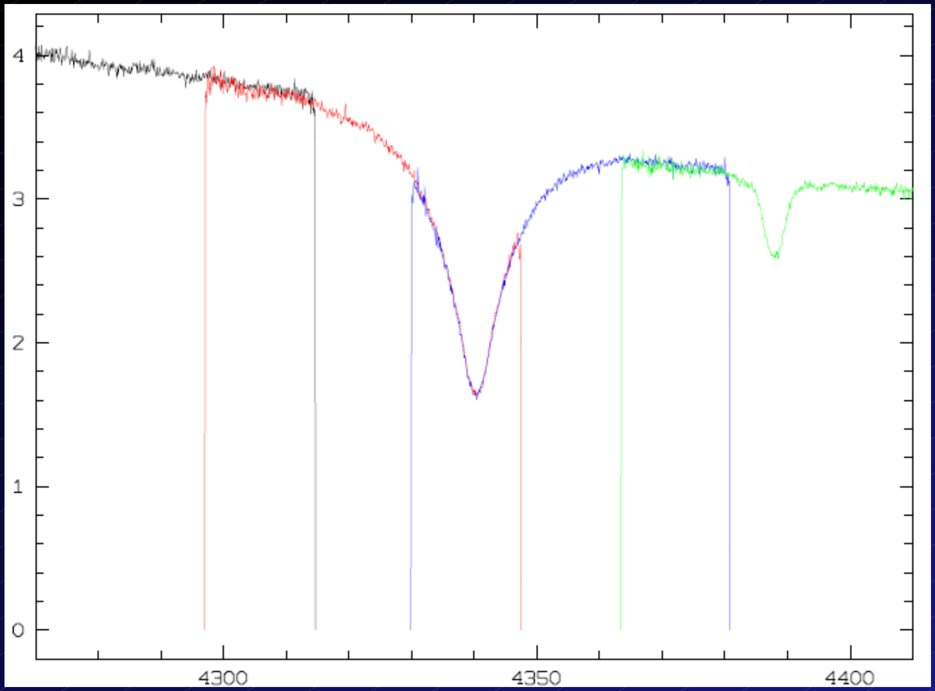
- cutout service (ranges in SSAP )
  - echelle spectra – orders, overlap lacking
  - certain line (in SSAP – names of photometric regions  - how wide ? )
- Rebinning (change od dlambda in echelle)
- Instrument profile (de)convolution
- Broadening functions (rotation, limb dark)
- RV shift
- on server side (Pleinpot WWW pipeline)

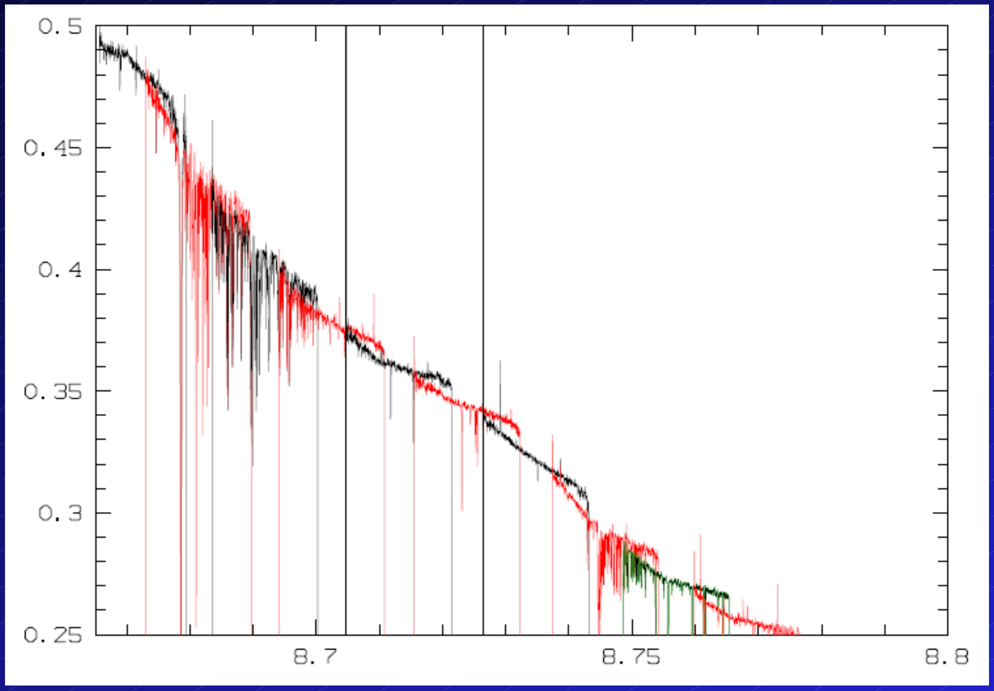
# Workflows - Pipelines

- From programs on local PC
- to distributed network (batch queue)
- Condor - GRID?
- legacy applications
  - parameters, filenames
  - need to run in proper order
    - (setairmass - rvcorr)
  - waiting for files (usually quick)
- Workflows natural but conservatism !

# Echelle Spectra Problems



# Massive parallel spectra reduction

- Workflows – Gasgano (UVES)
- Using theoretical spectra to reduce echelle spectra
  - continuum points – real 1.0
  - shape of blaze function in Balmer lines (convolution with instrument profile)
- Complex echelle spectra reduction
  - (Piskunov 2002 – clustering, COP solved – not supposed)
  - Background model - HAMSCAT

# Advanced Tools for Spectral Analysis

Simple tasks – done by VO clients
visualisaton, overplot, RV, cont. fitting?
experienced user, spectrum by spectrum

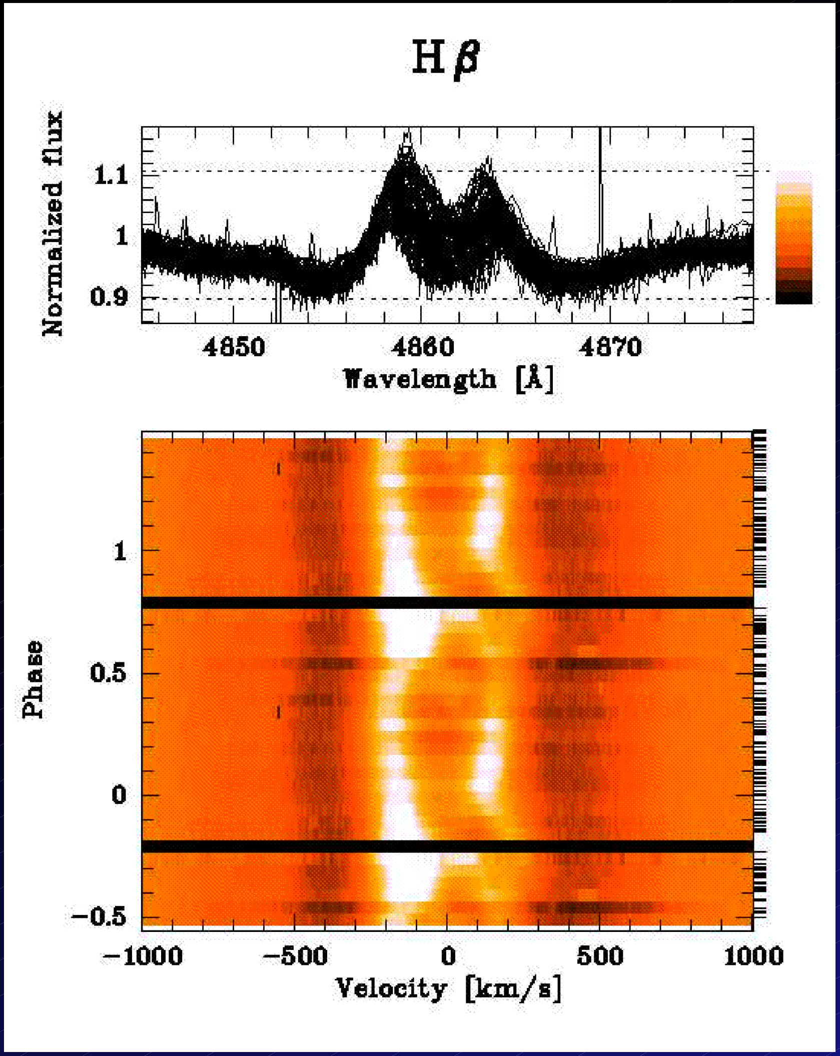
Require several variables from FITS

JD, time, epoch and derived variables

RV, line position, period – phase

and POST-PROCESSED spectrum

# 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)

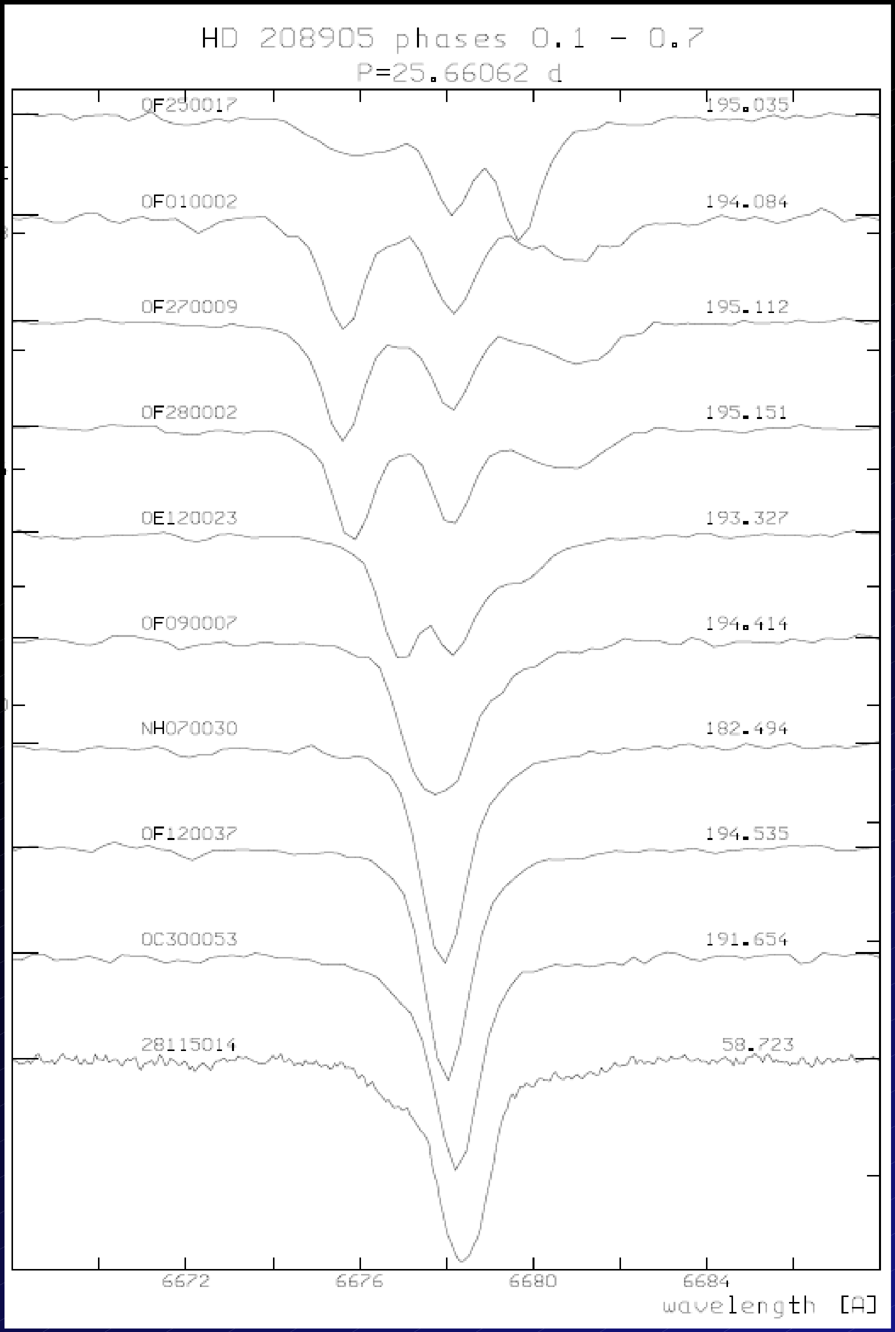
# Dynamic Spectra

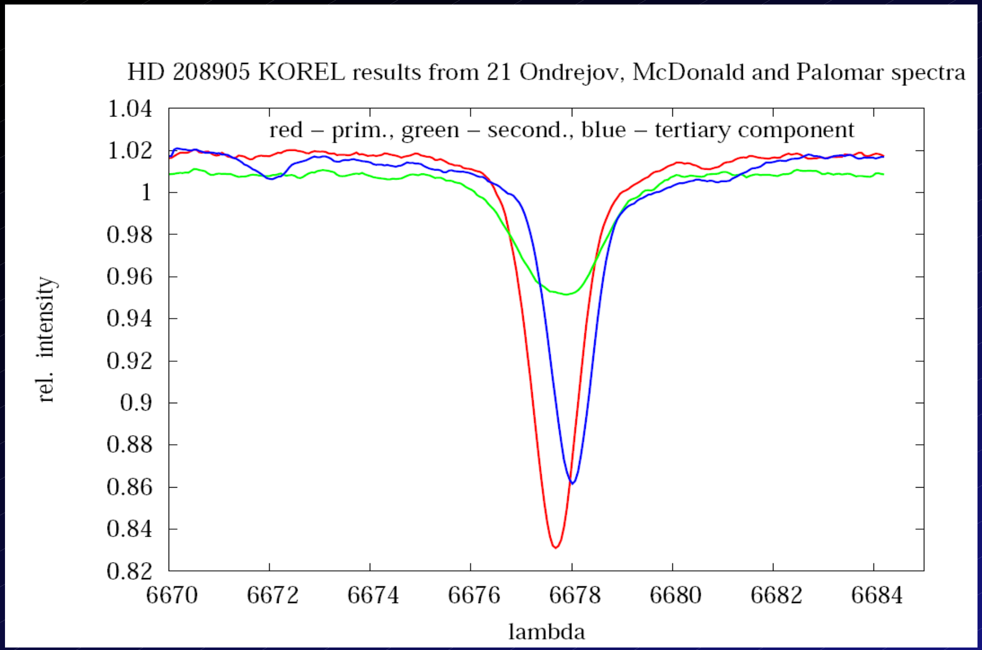
- Interactive features, color cuts, LUT
- GRID (many stars)
- legacy packages, custom tasks
  - D. Massa – IDL
  - MIDAS TSA - (Stahl, Rivinius)
- Multiple lines at the same time
  - Not yet molecular lines !

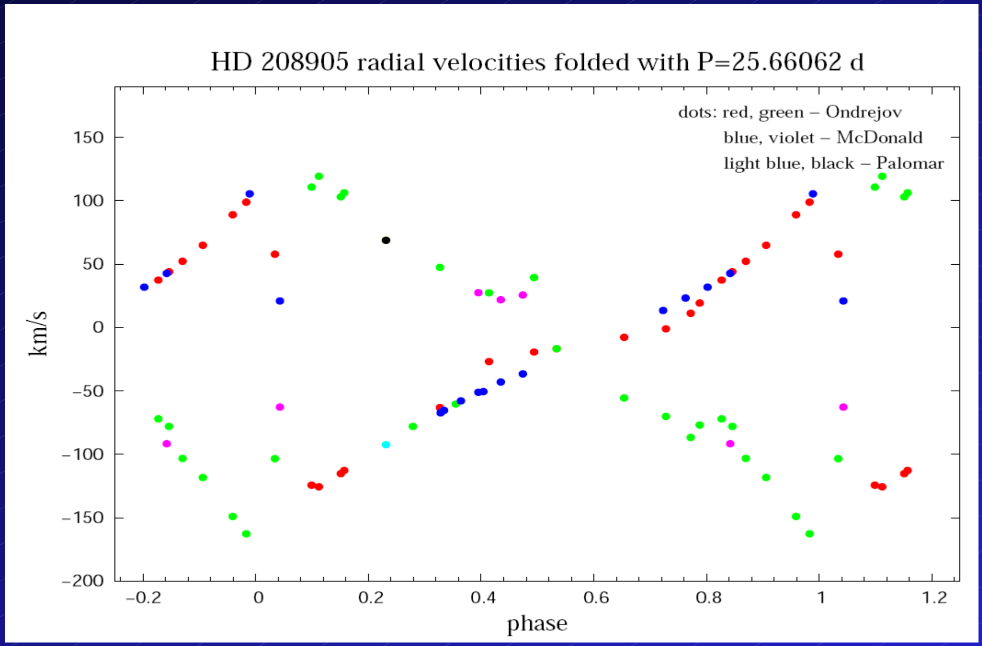
# Spectral Disentangling

- For blended spectra of binary (multiple) stars
- Very powerful
- Requires good orbital coverage, estimate of orbital parameters (SIMBAD)
- Wavelength space disentangling - computing power, space (Simon&Sturm)
- Fourier disentangling - perfect continuum, cut regions, log lambda (Hadrava)

# Spectra Disentangling in Fourier Space - KOREL

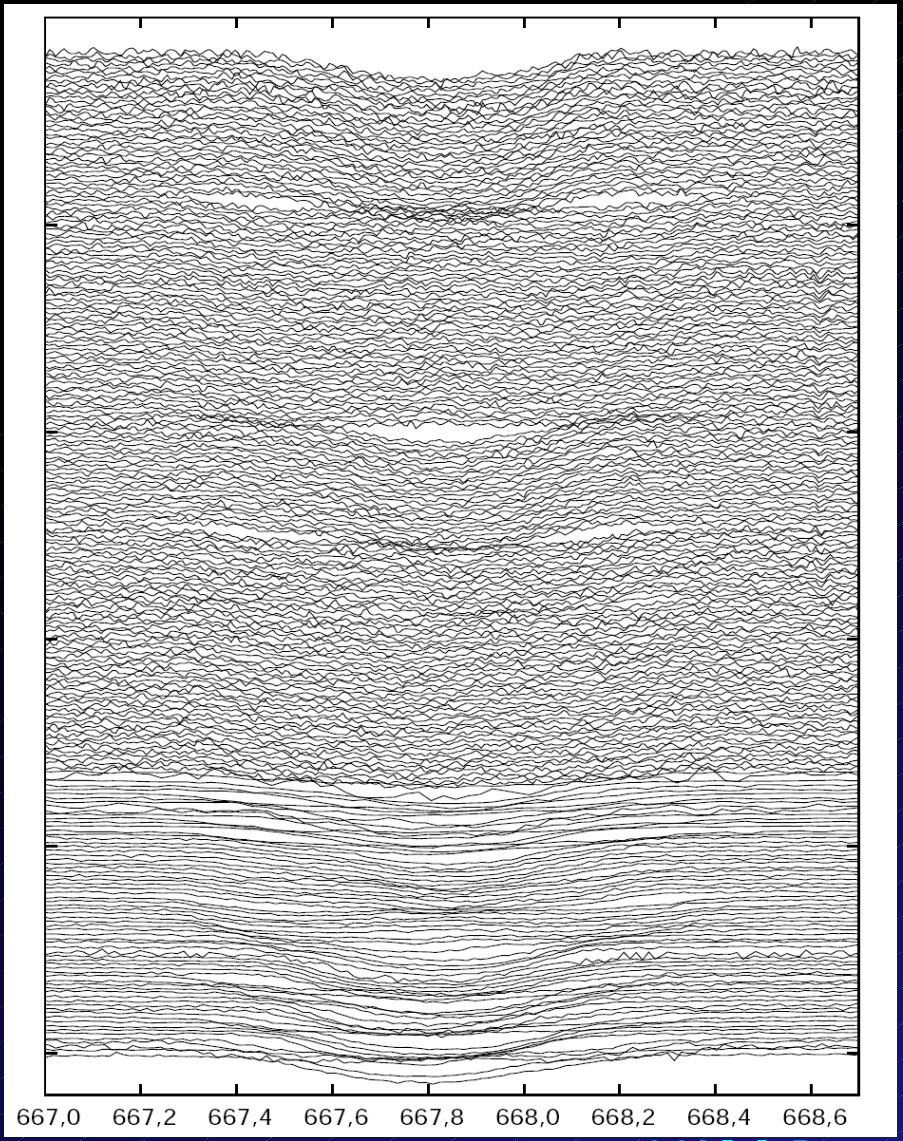


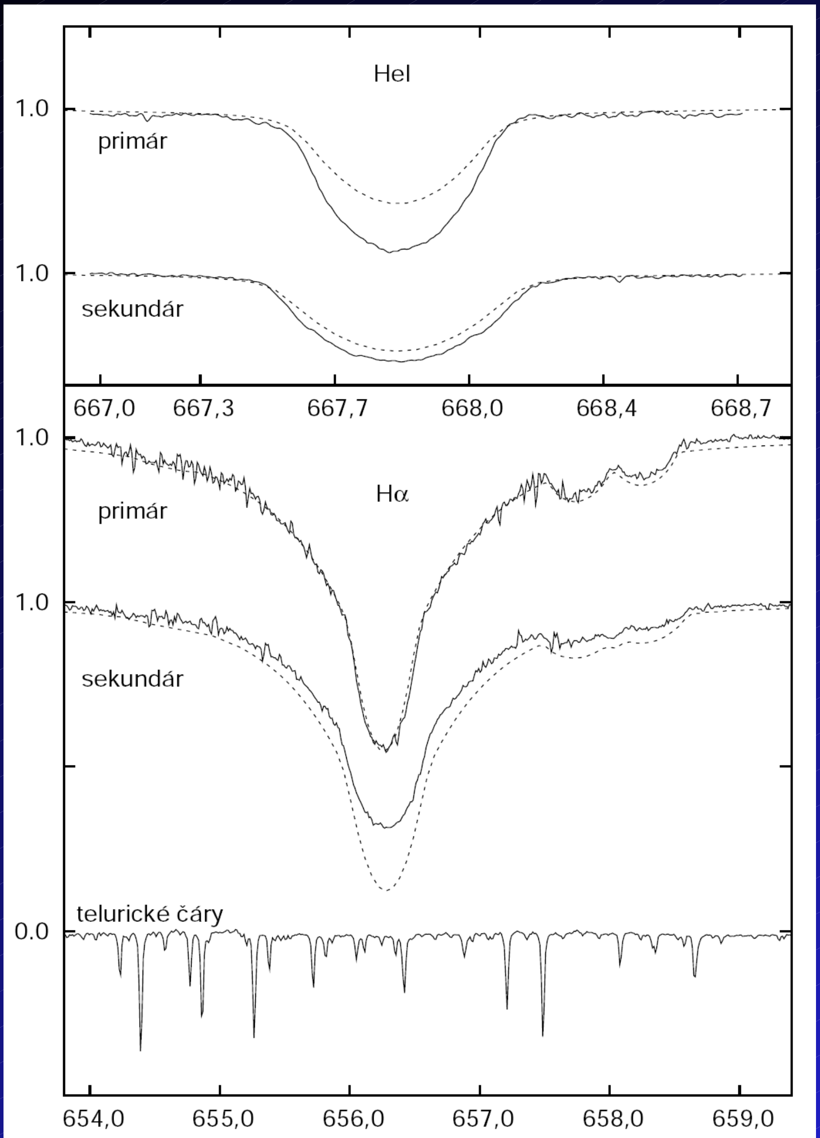




HD208905: Koubsky et al. 2006

# KOREL - Many Spectra Overploted




V436 Per Janík 2003

# Seaching ES Planets

- Planet search on spectra (x photometry)
- precise RV
  - Iodine cells
- Changes in Line Profiles
  - Bisector  (different turbulence, flows, granulation)
  - spots
  - Another light !

# Deconvolution of Iodine Lines

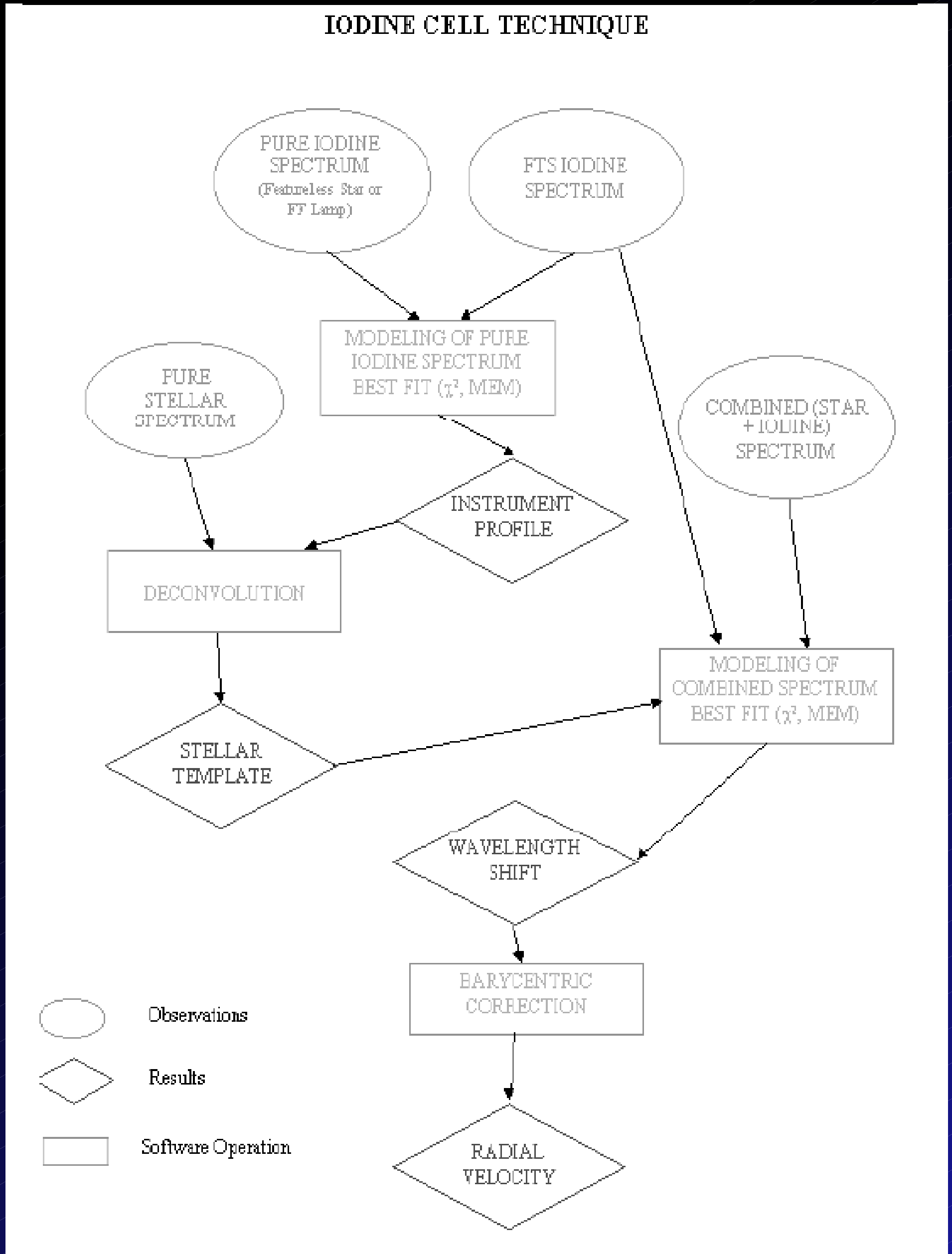


Figure 3.2: Diagram of the analysis in the process to measure radial velocities from stellar spectra (from Desidera 1996).

Desidera 1996

Models

Computation

Observation (different instruments - FTS)

# Line Profile- Bisectors

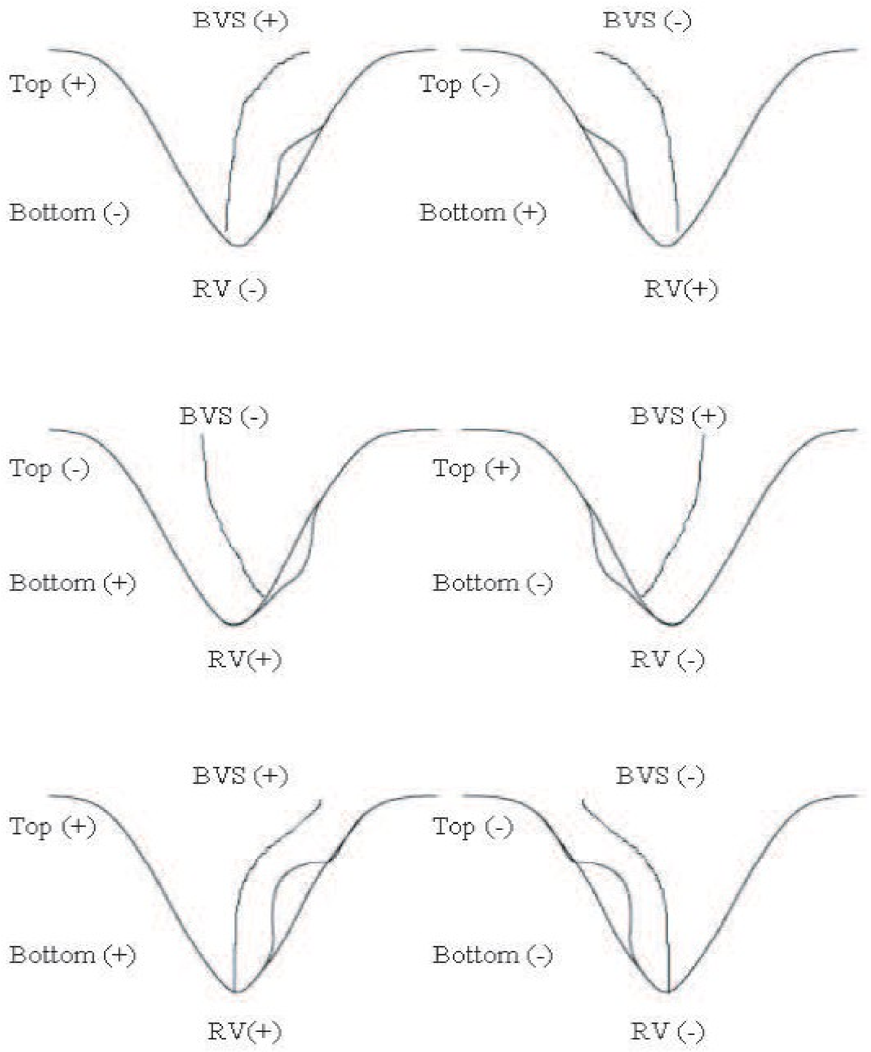
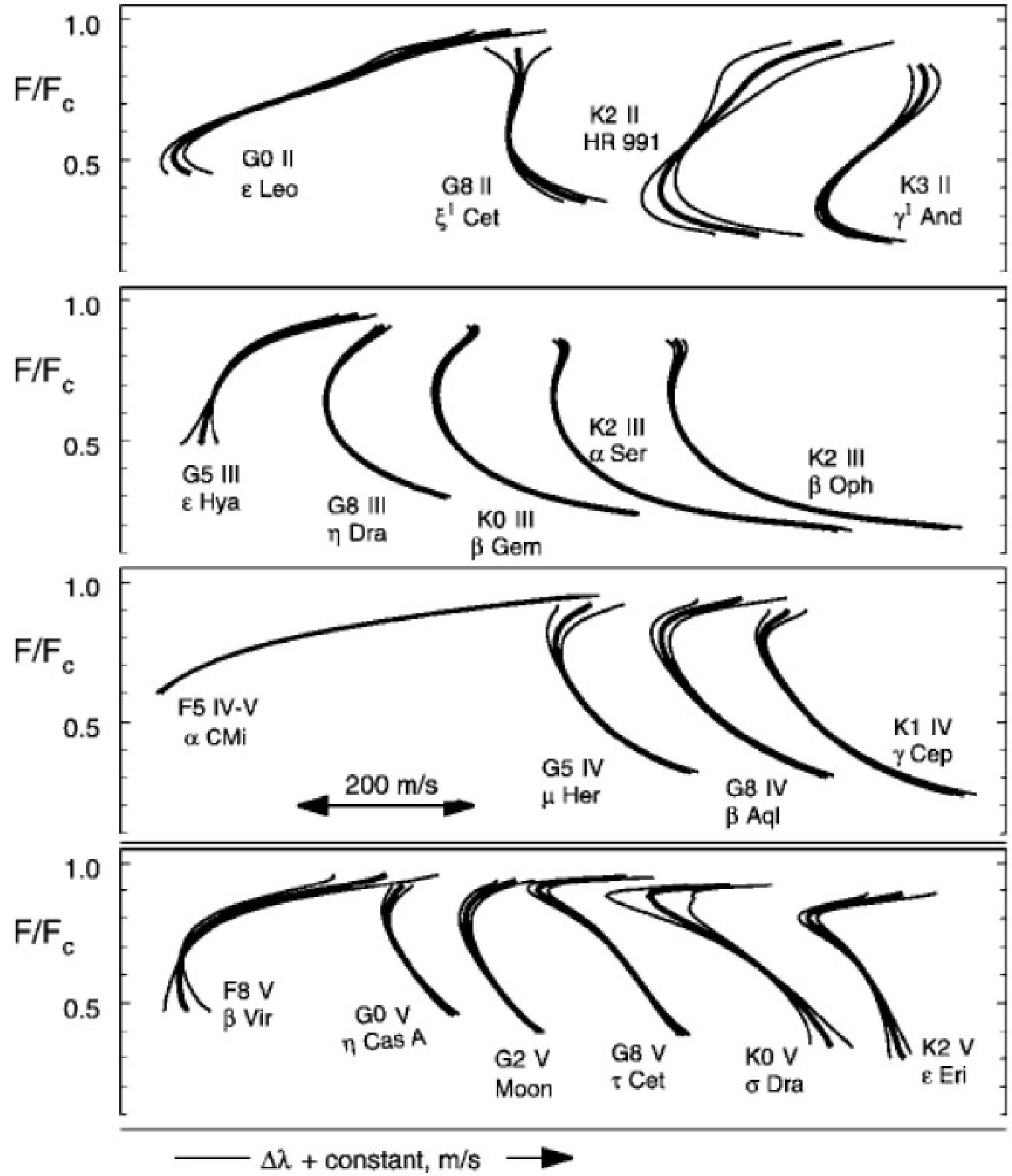



Figure 8.1: Schematic representation of different absorption profiles and their line bisectors, see text. Up: asymmetric absorptions due to spots (upward dip). Middle: asymmetric absorptions due to feculae (downward dip). Low: asymmetric absorptions due to light from a nearby object contaminating the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



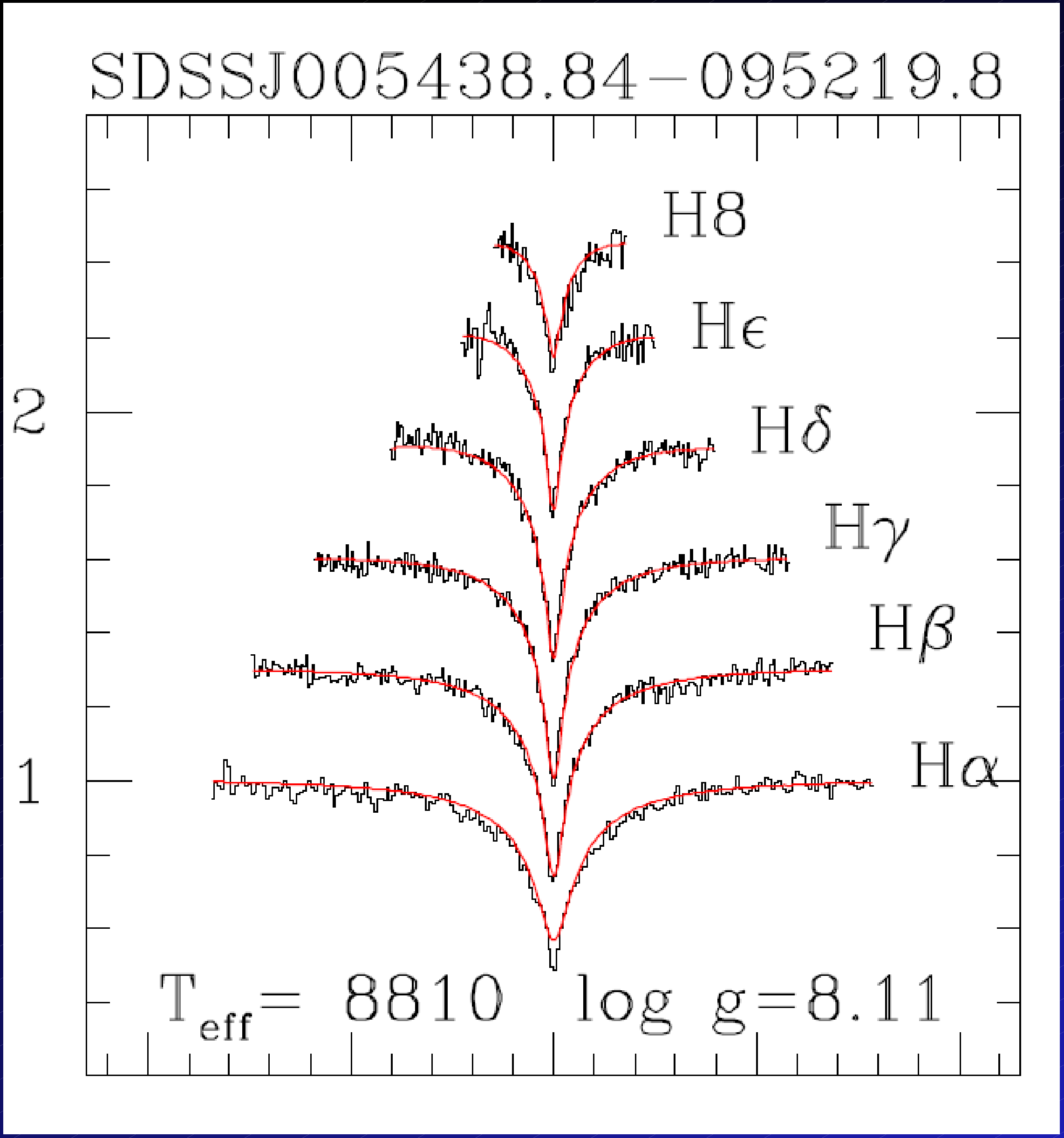

Fiorenzano PhD 2006

Gray 2005

# Classification of Stellar Spectra

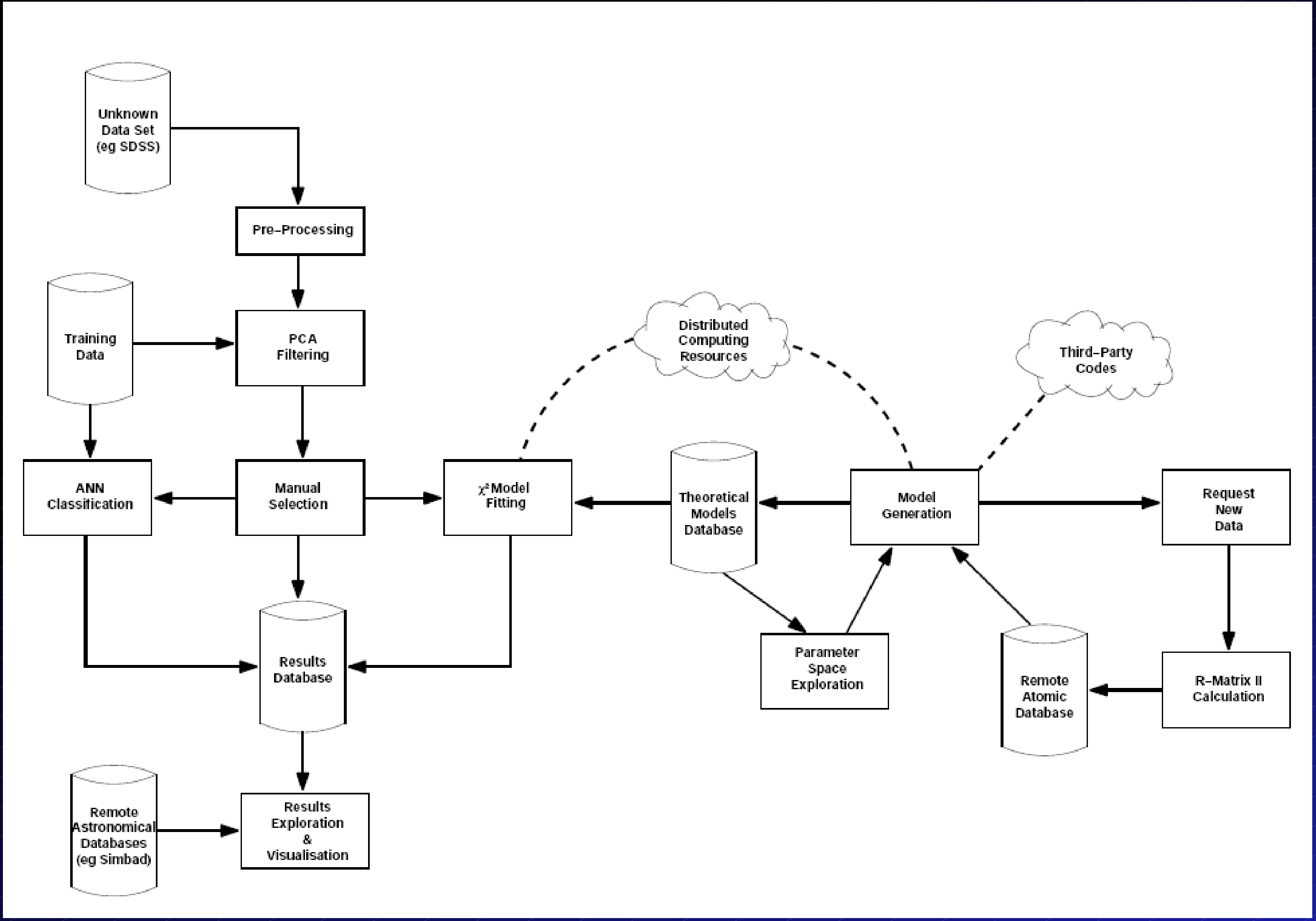
- automatic classification of stellar spectra
  - direct chi^2 minimization (SFIT code, line broadening – Jefferey 2001) Simplex AMOEBA or Levenberg-Marquardt)
  - Genetic Algorithm)
  - Artificial Neural networks
  - PCA – template spectrum + differences
- example – Hot subdwarf filter
  - Ch. Winter 2006 – PhD thesis

# WD models by manual fitting interpolation by experience




Kawka, Vennes 2005

# Automatic classification engine




Winter 2006

Workflow

Parallel

# Classification od hot subdwarfs

Winter 2006

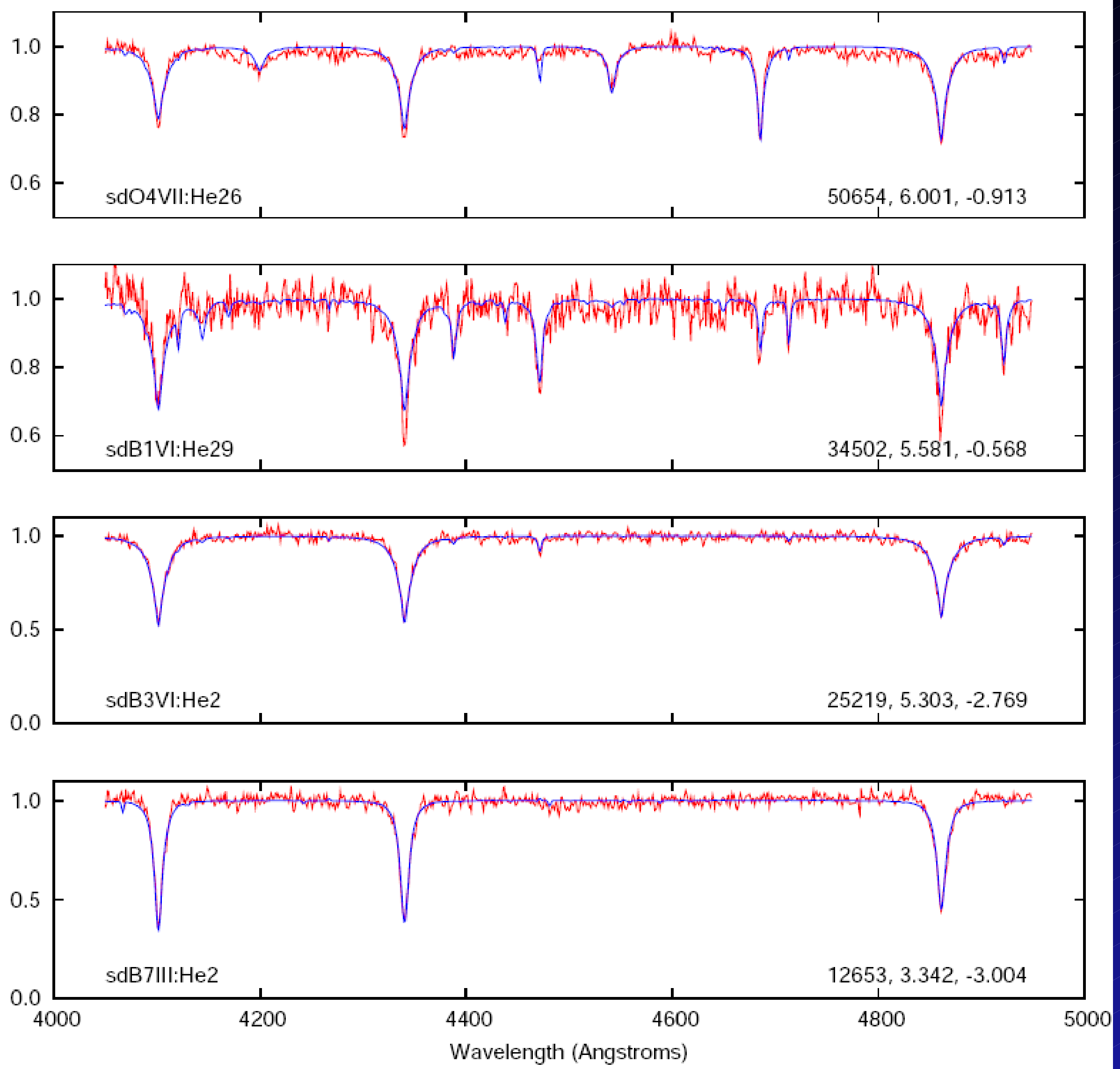



**Figure 5.3**: Four example fits from the 282 SDSS hot subdwarfs. The classificatior and physical parameters ($T_{\rm eff}$ (K), $\log g$, $\log(n_{\rm He}/n_{\rm H})$) obtained for each star are printec in the lower corners of each plot.

# Automatic EW measurement

**Automatic Normalization and Equivalent-Width Measurement of High-Resolution Stellar Spectra** *

Jing-Kun Zhao, Gang Zhao, Yu-Qin Chen, Jian-Rong Shi, Yu-Juan Liu and Ju-Yong Zhang

National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012; *zjk@yac.bao.ac.cn*

Received 2006 February 15; accepted 2006 April 10

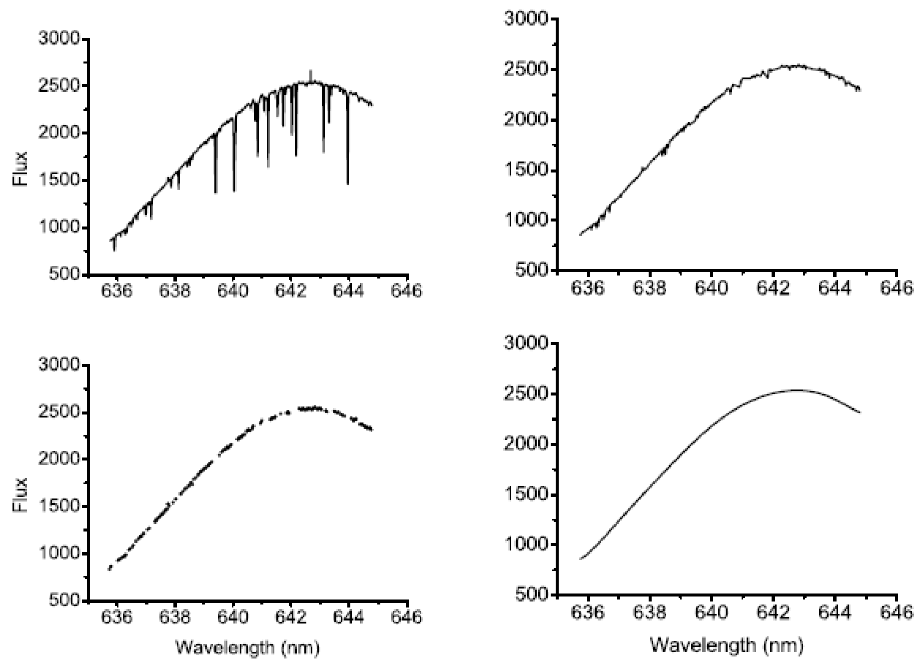



**Fig. 1** An example of the procedure for obtaining the continuum. Upper left: the original spectrum; upper right: strong lines are removed; lower left: 'high points' are determined; lower right: the continuum.

Normalisation ! (highest points)

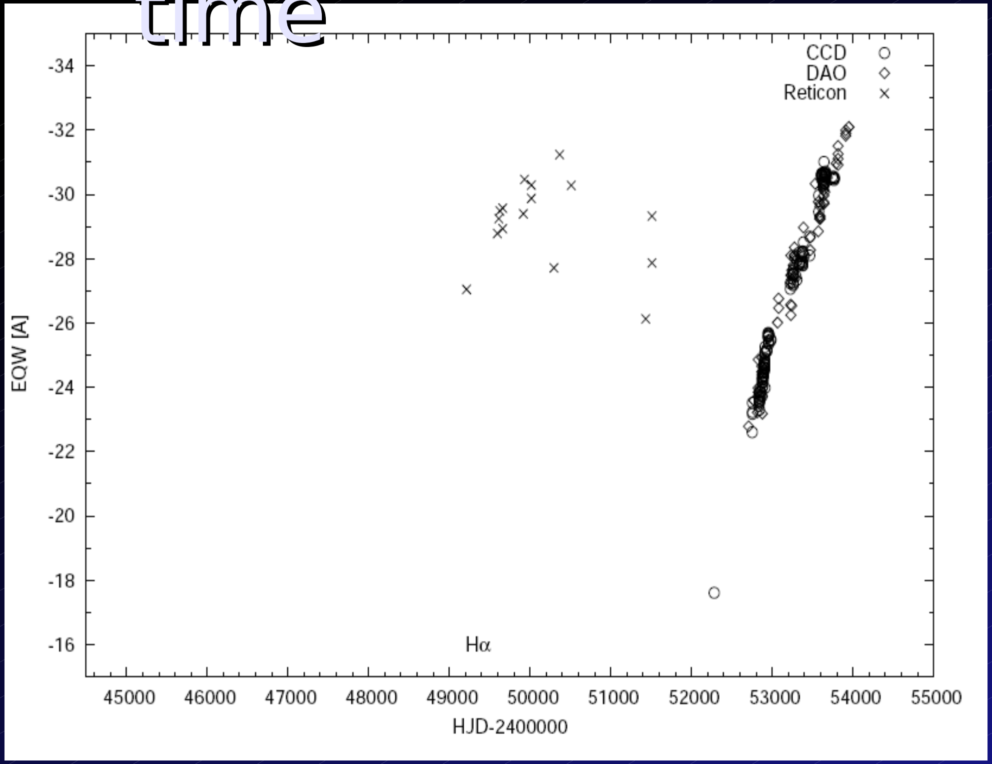
tricky on hot stars

(on echelles) require synt. spectrum

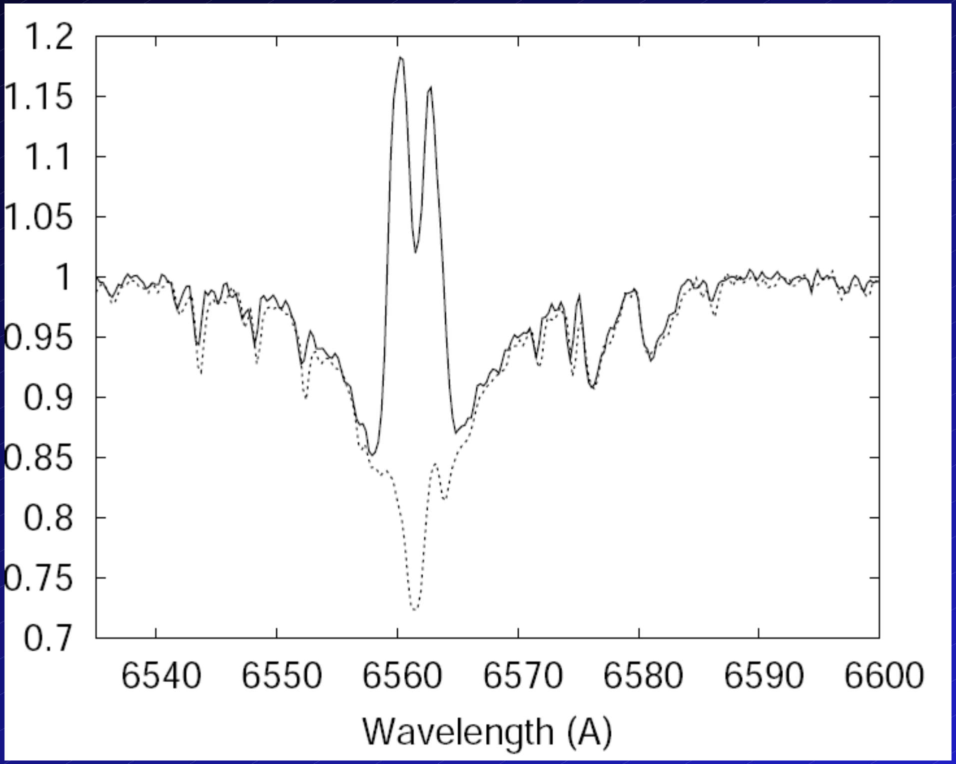
Zhao et al. 2006

# Changes of EW in Time

- Batchmode processing, workflows
- Intrinsically parallel – simple algorithm
- Result – one number – plot for each line in time



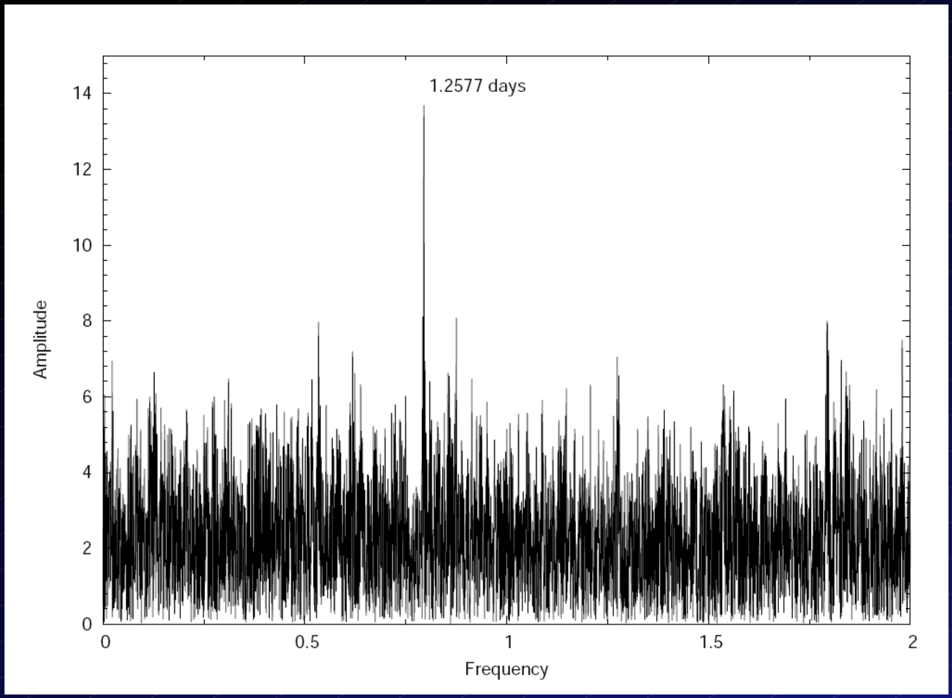

Omi Cas : Koubsky et al. 2004



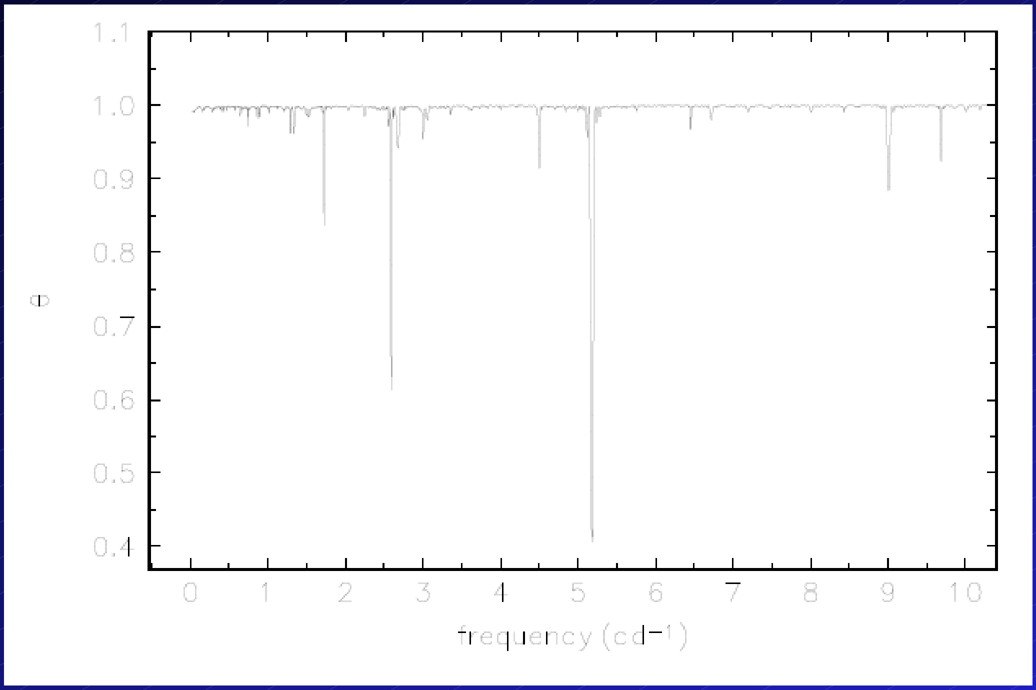

HD6226 : Slechta and Skoda 2004

# Time variability - Current VO Support

- Period analysis – NONE but
  - SIGSPEC (P. Regen) – used to MOST
  - Period04 (P. Lentz)

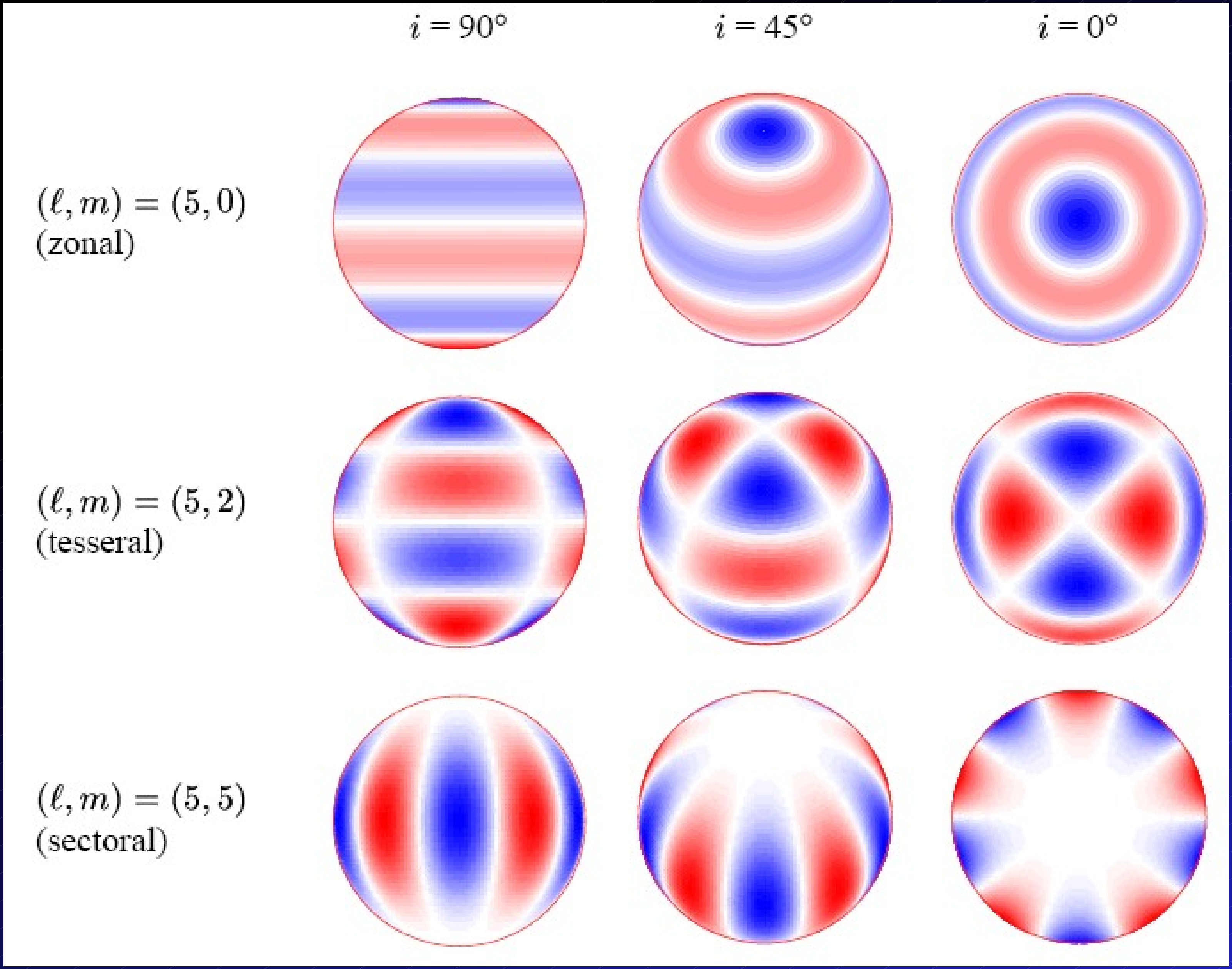



Power spectrum FT



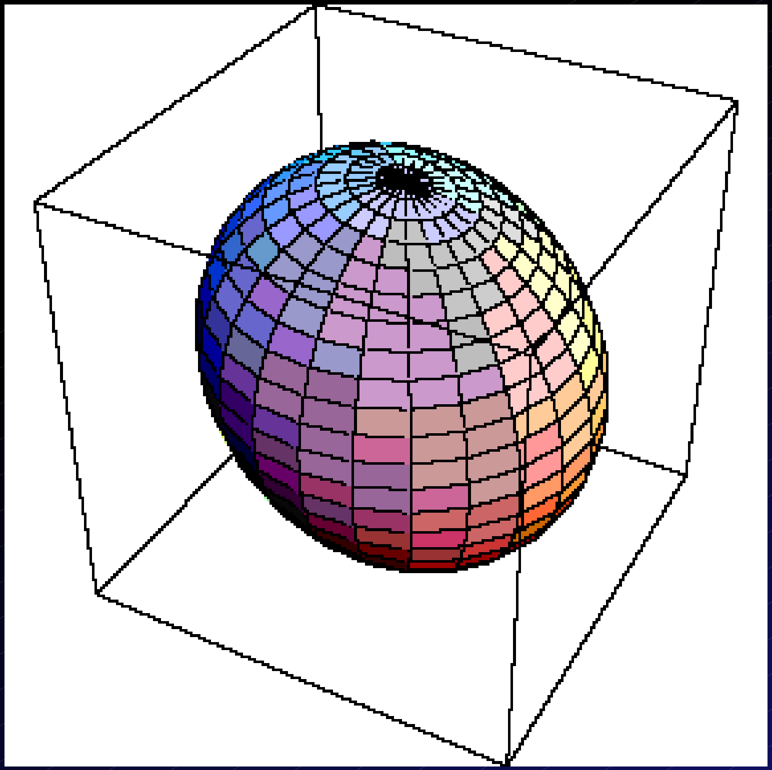

Theta statistics

# Non Radial Pulsations Modes

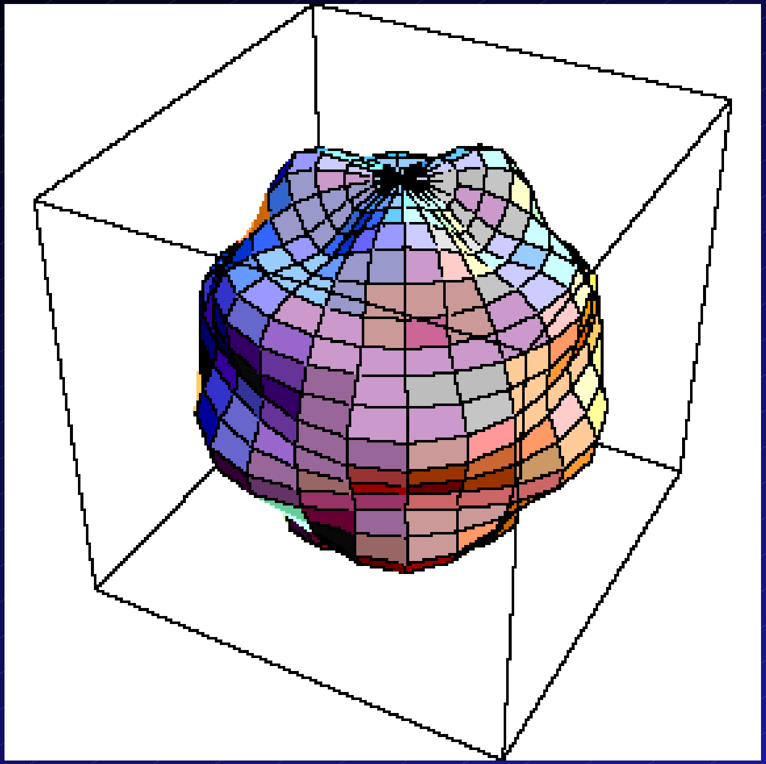



C. Schrijvers

# Non Radial Pulsation



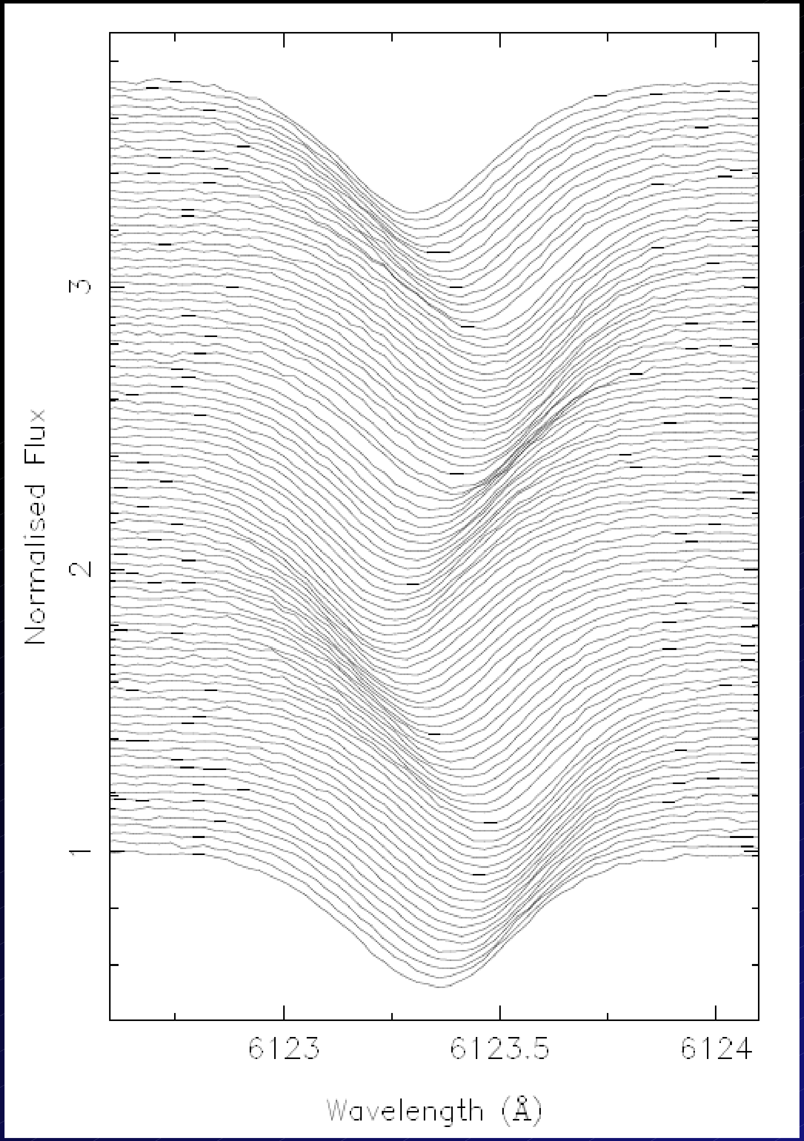
$\ell = 2, m=1$

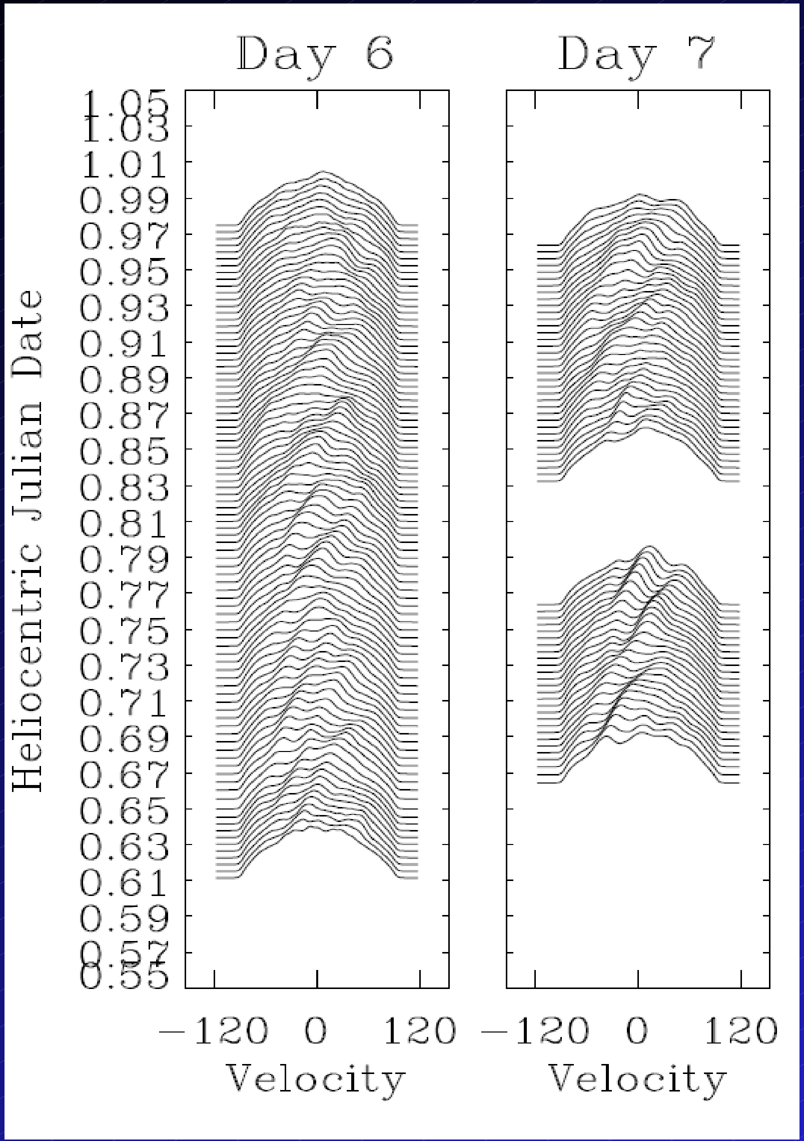


$\ell = 8, m=3$

*Tim Bedding*

# Measured Pulsations



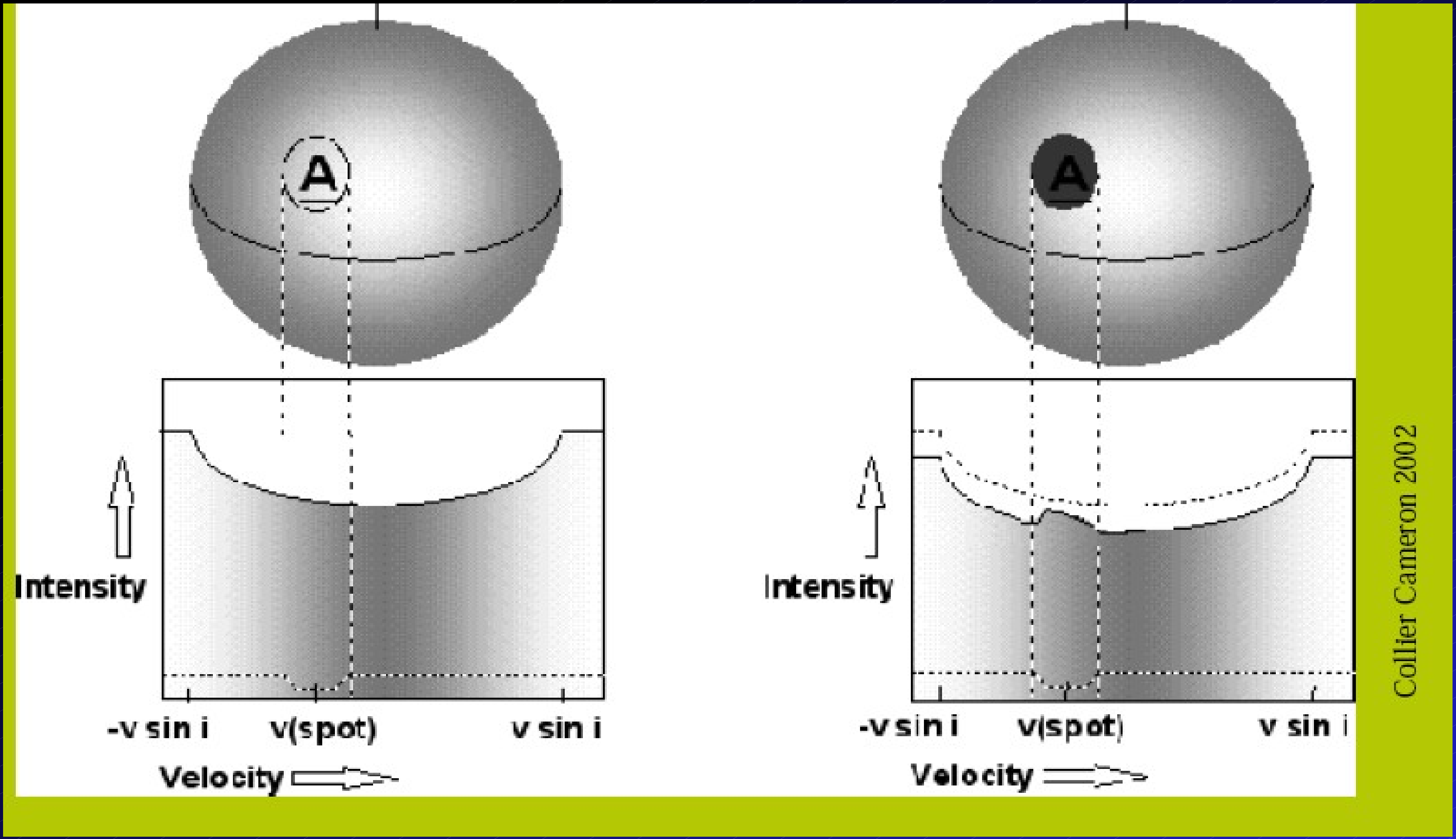




Rho Pup – del Sct type

Eps Cep - del Sct type

# Doppler Imaging

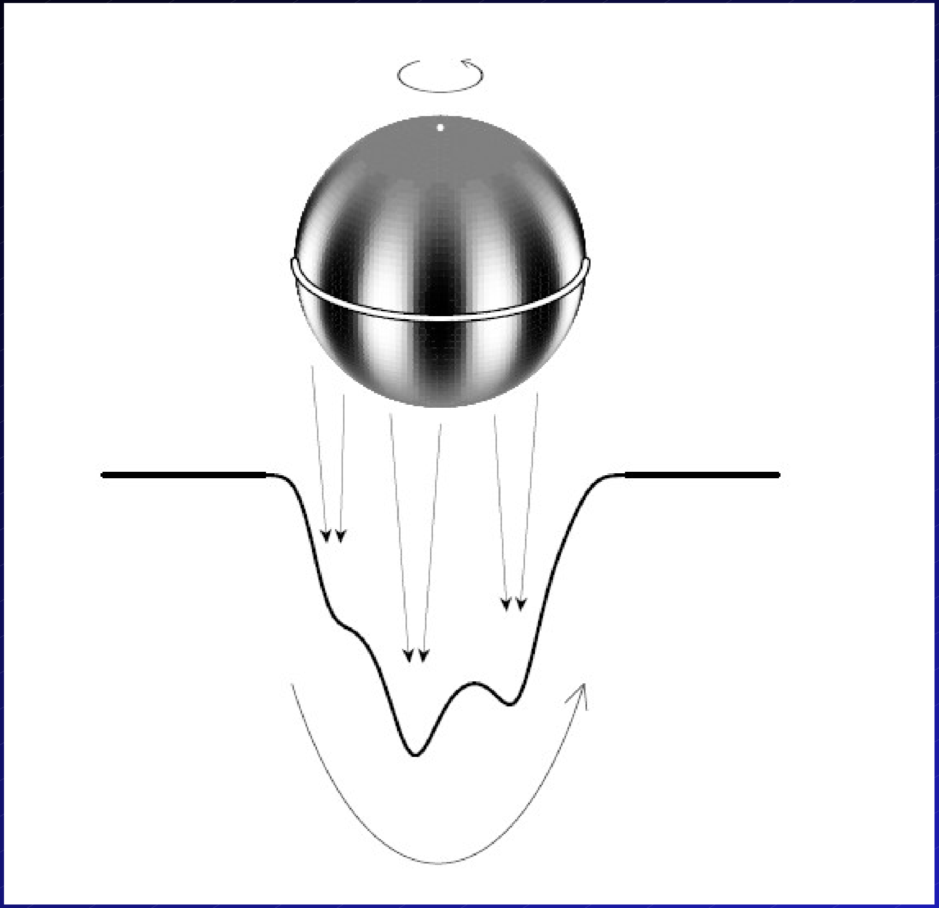
From LPV due to rotation
stellar Spots  - darker, brighter – chemical patch



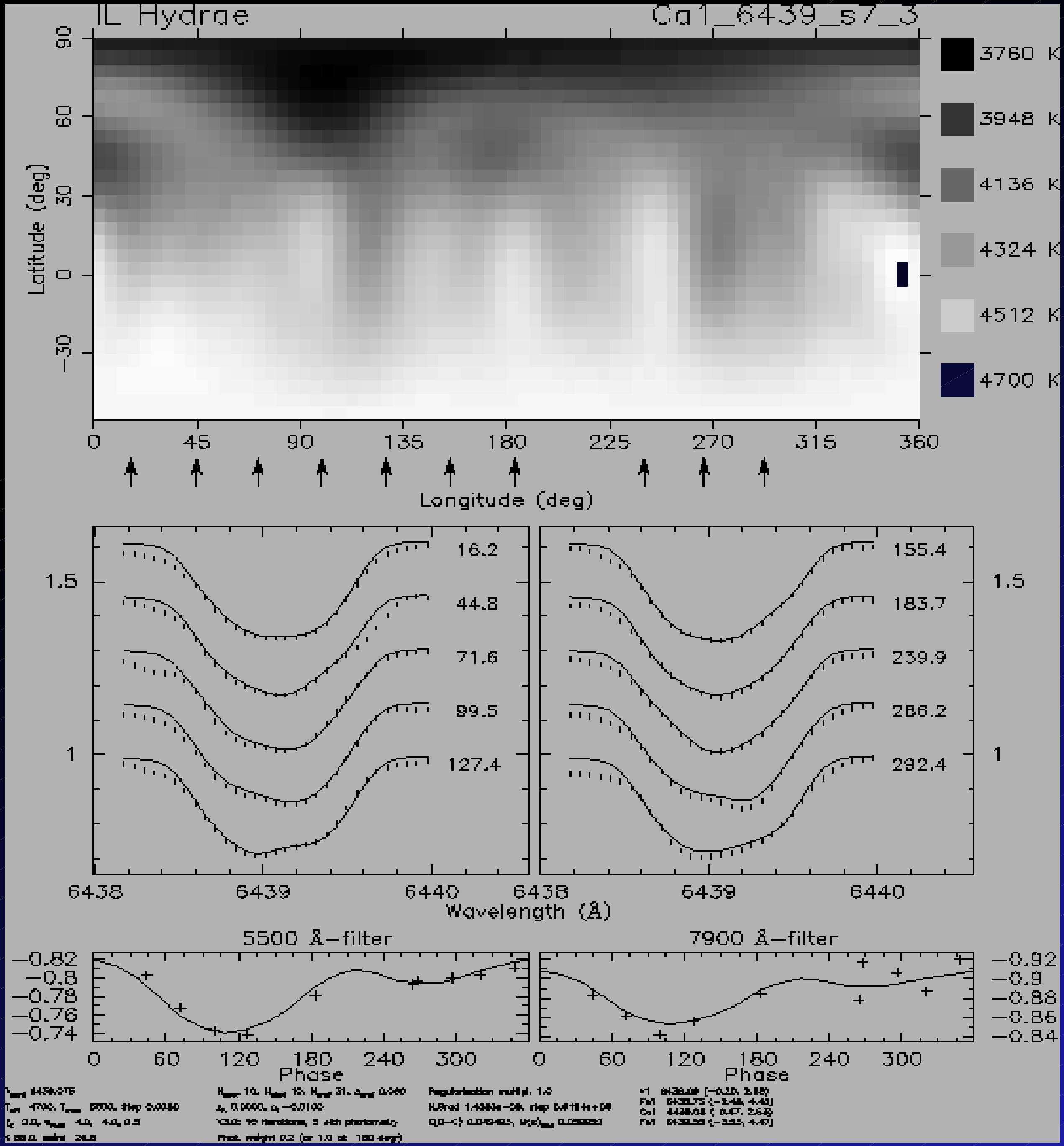
# Doppler Imaging - NRP

Vogt & Penrod -80s
Zet Oph

- Requires high SNR
  - (>300-500)
  - Perfect rotation coverage
  - Artefacts otherwise
  - NRP or solar spot
  -
- Doppler Tomography
  - Accretion jets  in Algols
  - Orbits in RV phase space



# Doppler Imaging

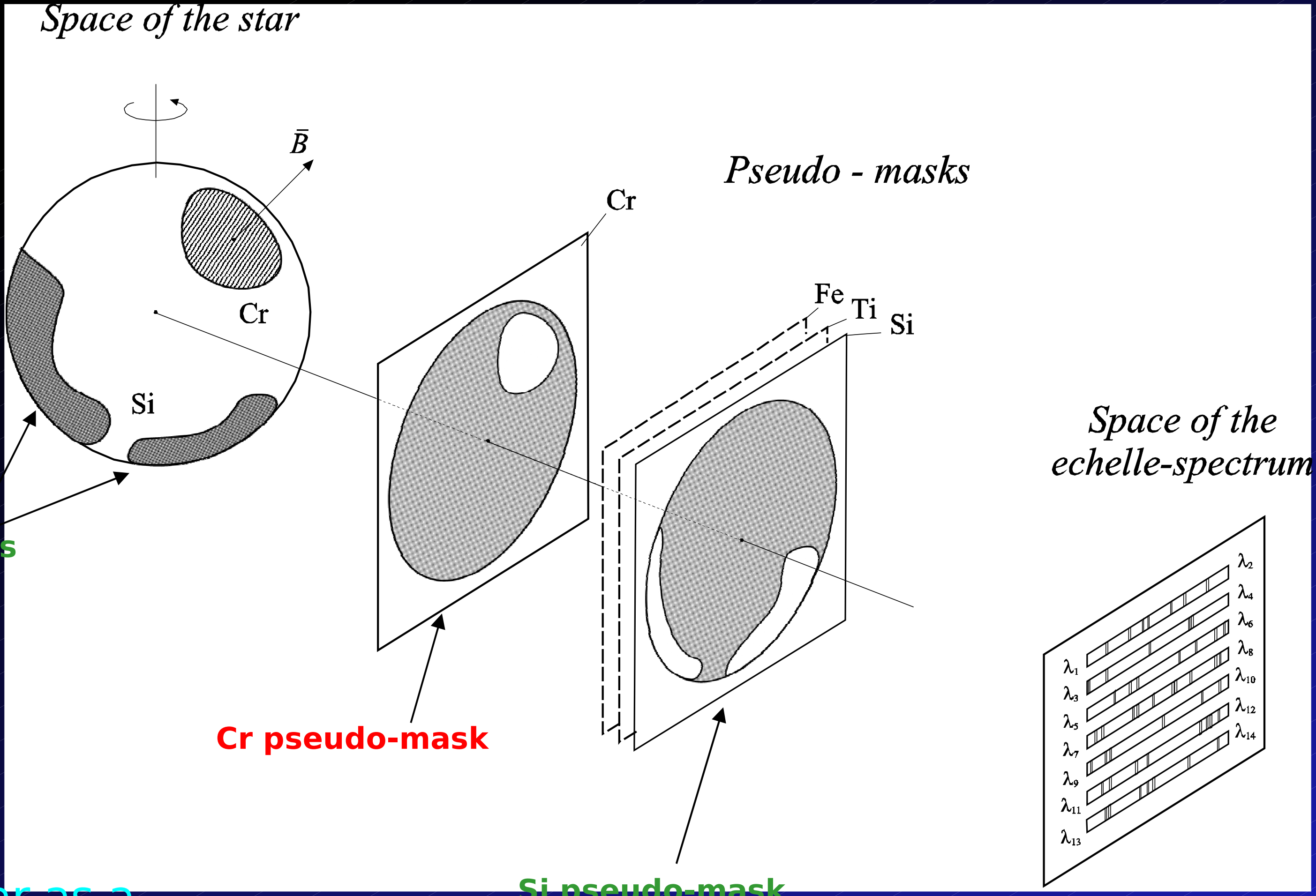



Different elements

temperature distribution

# Periodic spatial filter (PSF) concept for NRP mode detection (2-D concept)

**(Mkrtichian 1994, Solar Physics, 152, p.275)**

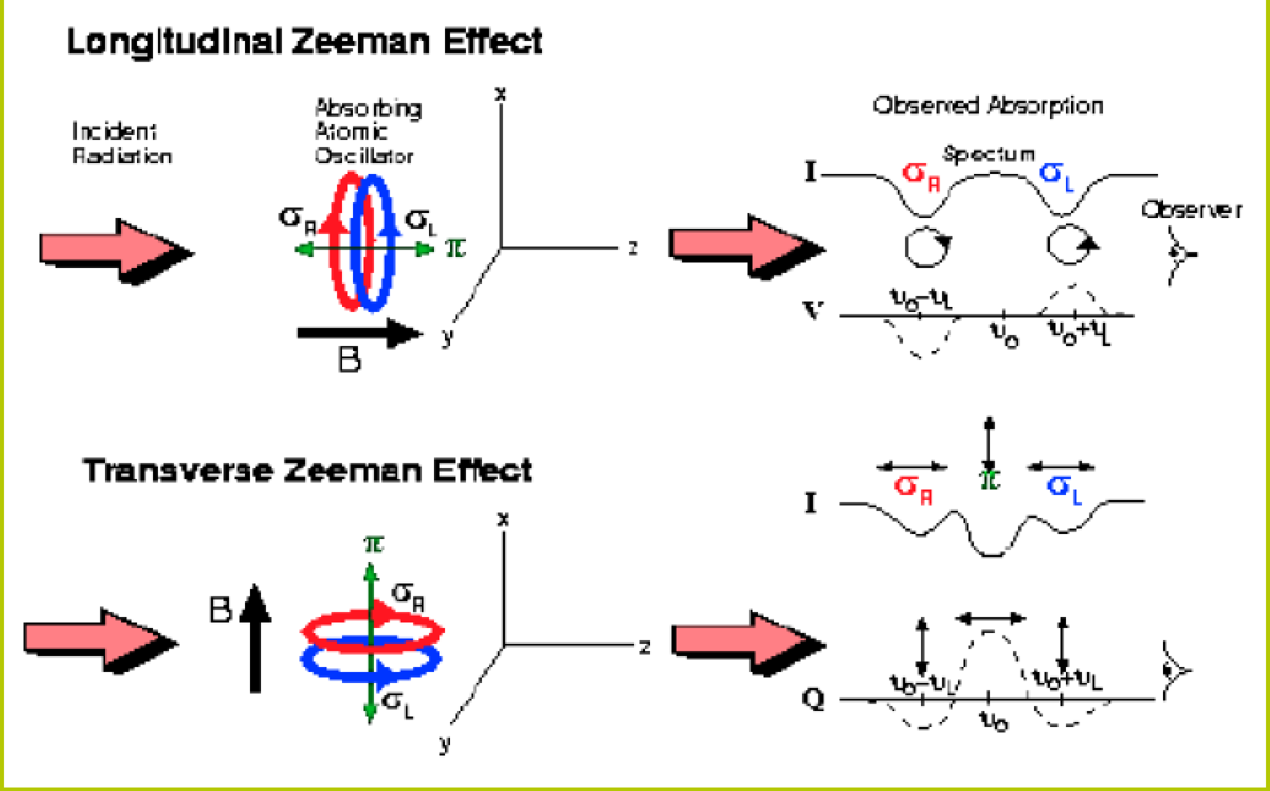



"roAp star as a Sun" observations:

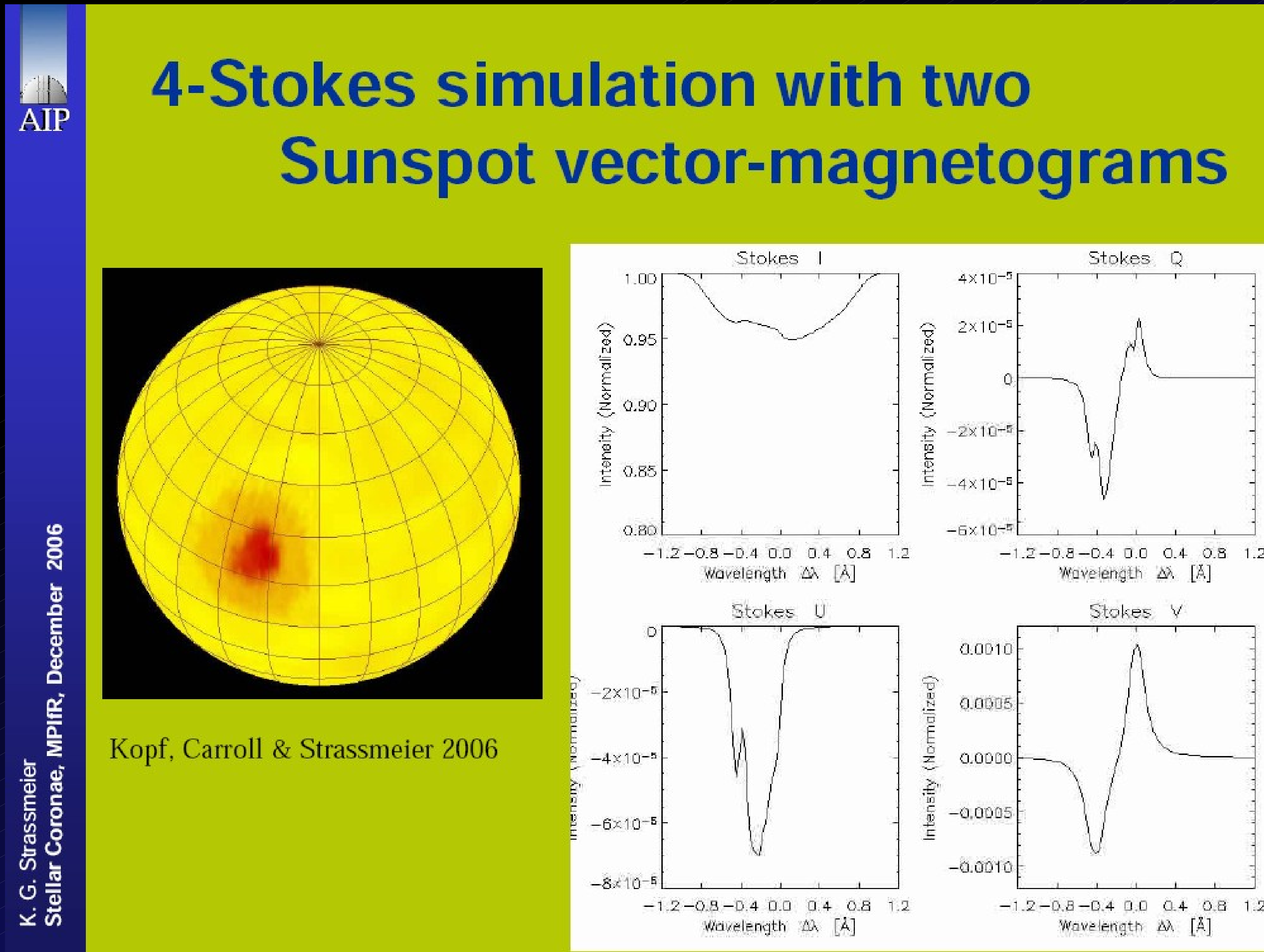
# Mg Field - Polarimetry

## „The holy grail“

### ... full-Stokes Zeeman-Doppler imaging



# Simulation of Stokes



# Simulated Magnetic stars - spectra

Kochukhov & Piskunov 2002

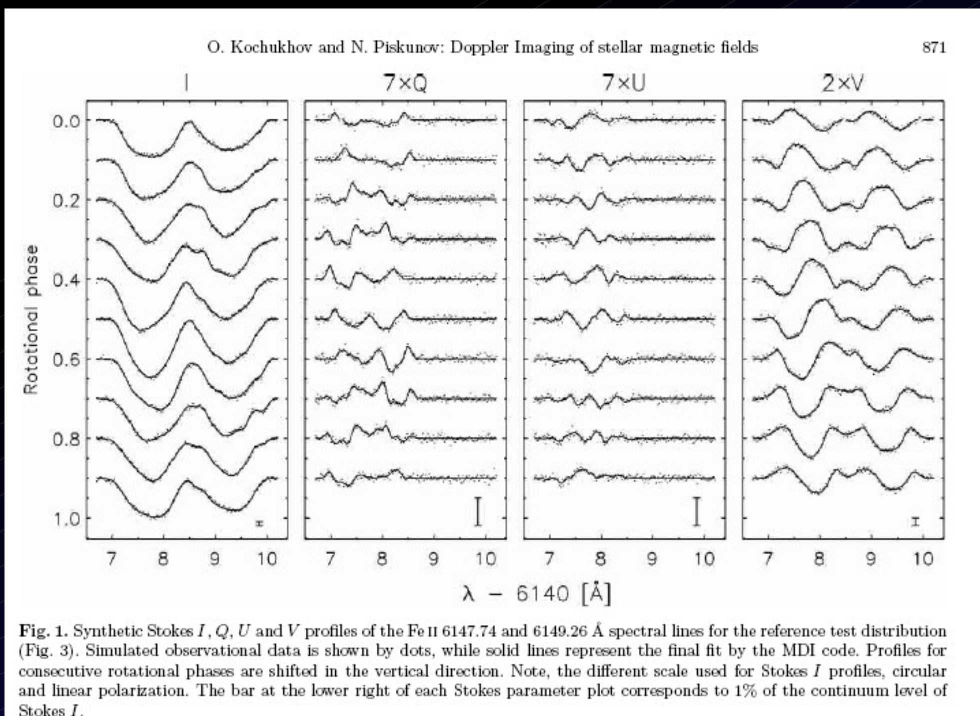



**Fig. 1.** Synthetic Stokes $I$, $Q$, $U$ and $V$ profiles of the Fe II 6147.74 and 6149.26 Å spectral lines for the reference test distribution (Fig. 3). Simulated observational data is shown by dots, while solid lines represent the final fit by the MDI code. Profiles for consecutive rotational phases are shifted in the vertical direction. Note, the different scale used for Stokes $I$ profiles, circular and linear polarization. The bar at the lower right of each Stokes parameter plot corresponds to 1% of the continuum level of Stokes $I$.

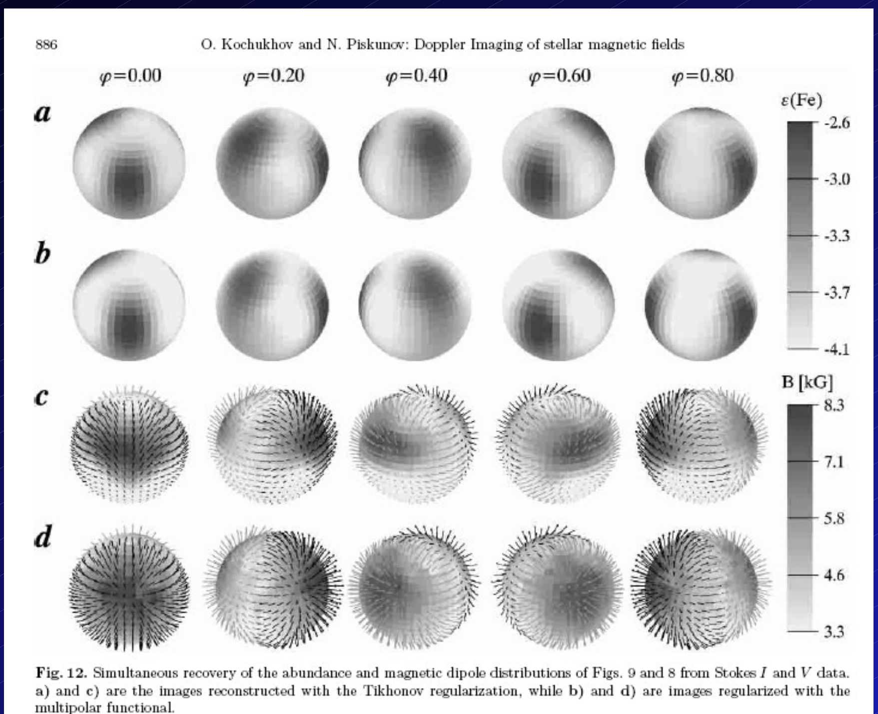
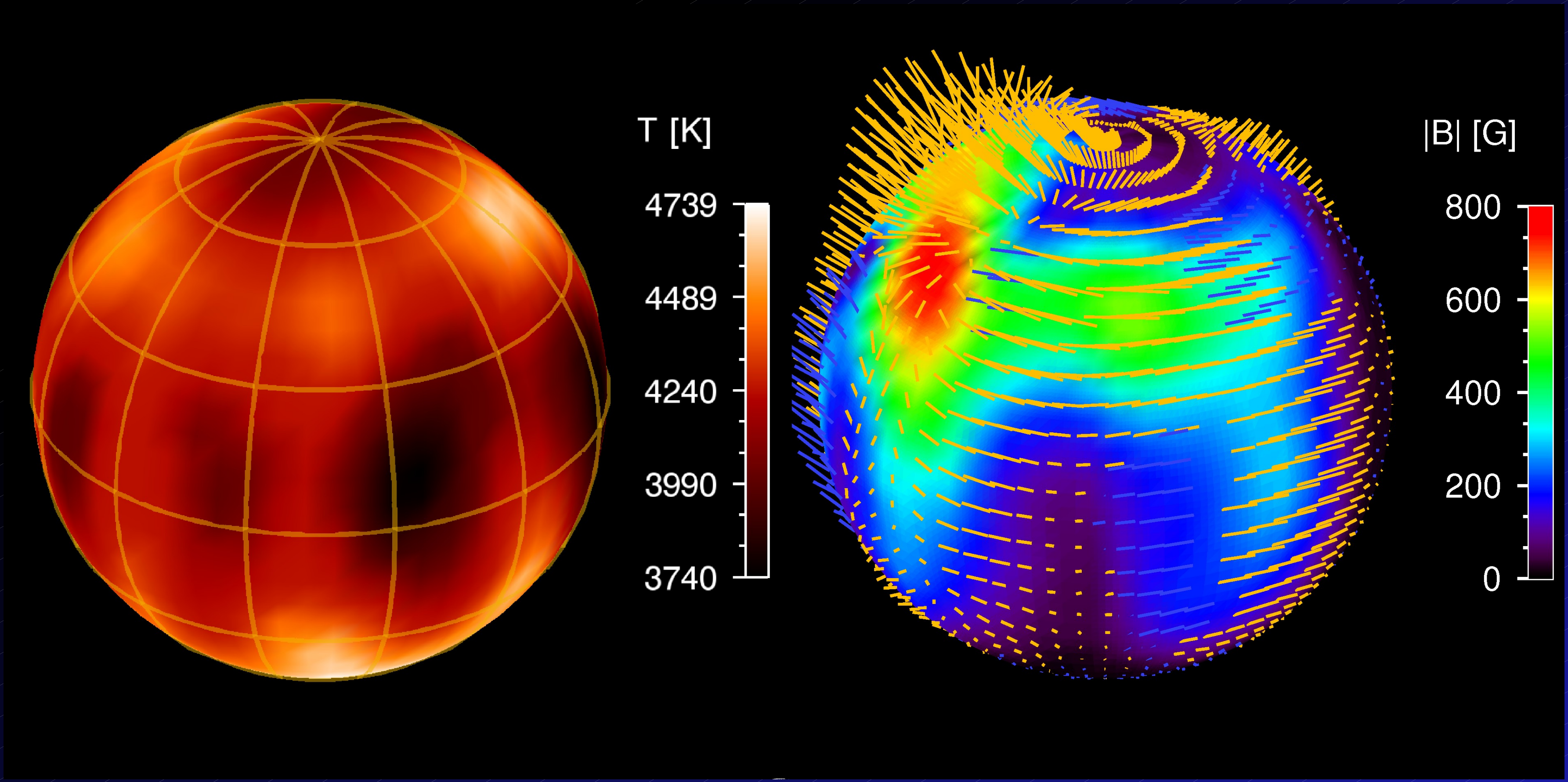



**Fig. 12.** Simultaneous recovery of the abundance and magnetic dipole distributions of Figs. 9 and 8 from Stokes $I$ and $V$ data. a) and c) are the images reconstructed with the Tikhonov regularization, while b) and d) are images regularized with the multipolar functional.

Stokes parameters spectra

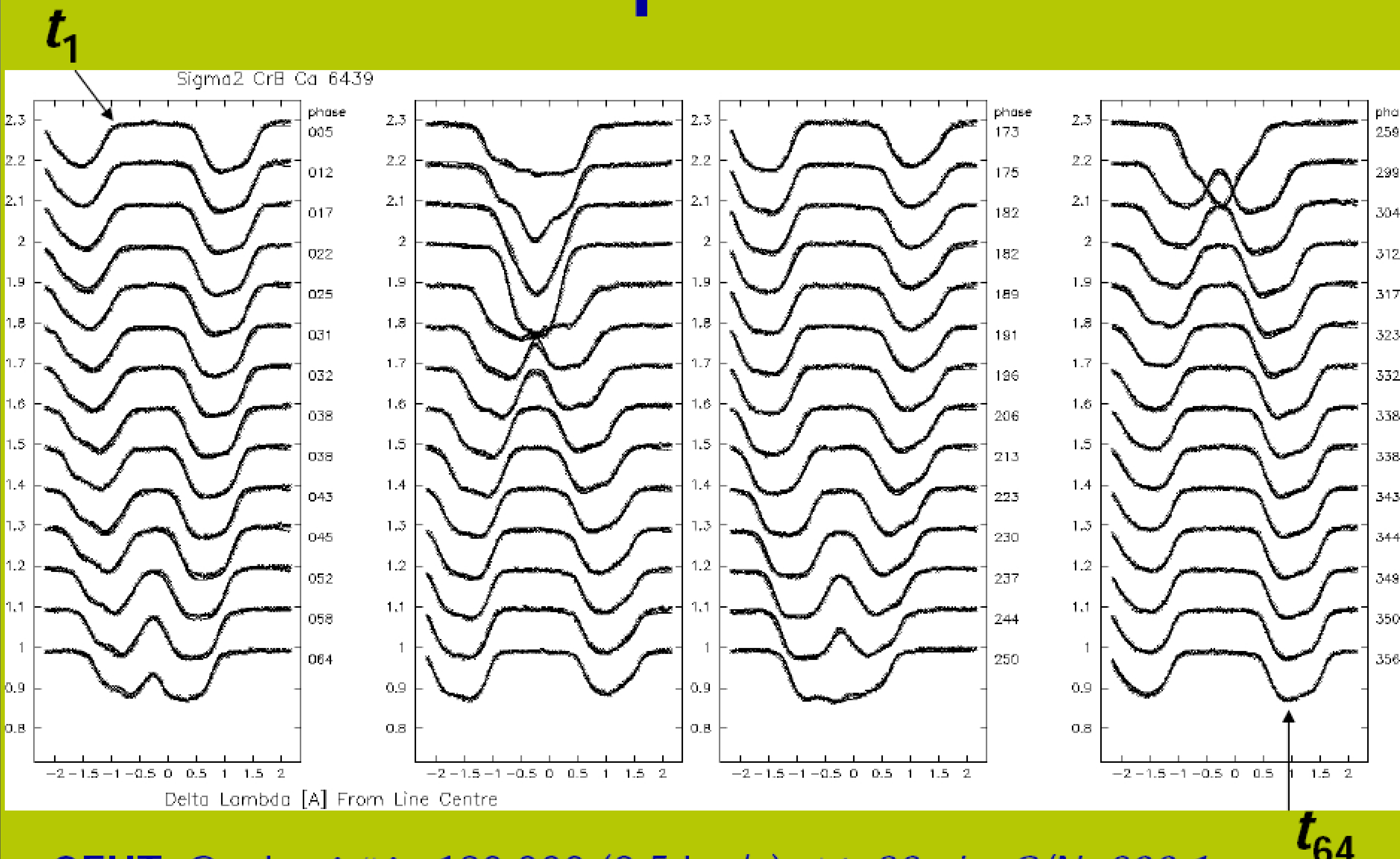
Abundances + Mg field

# Zeeman Doppler Imaging



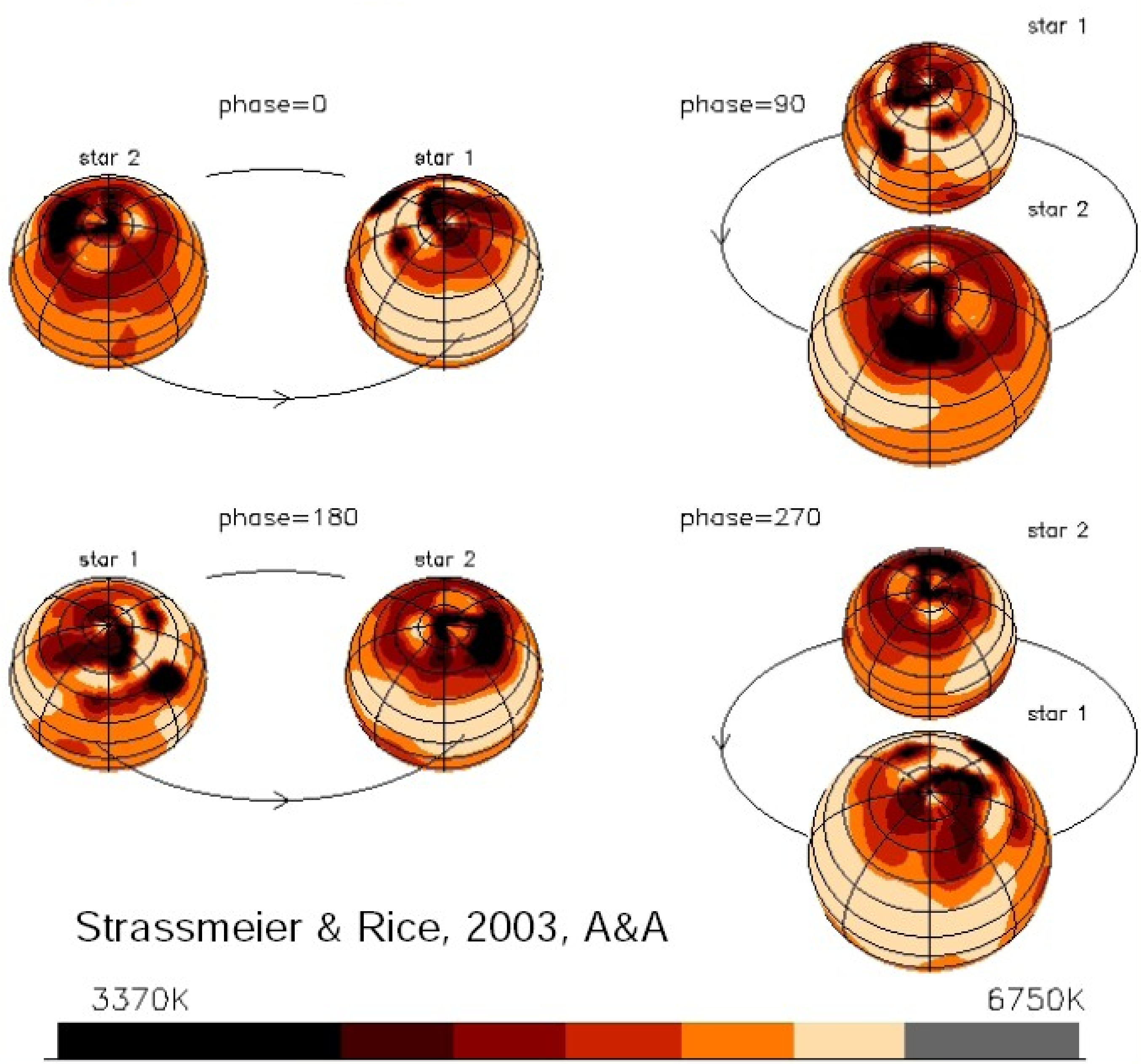

II Peg, Strassmeier 2007

# 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*

# Doppler images $\sigma^2$ CrB

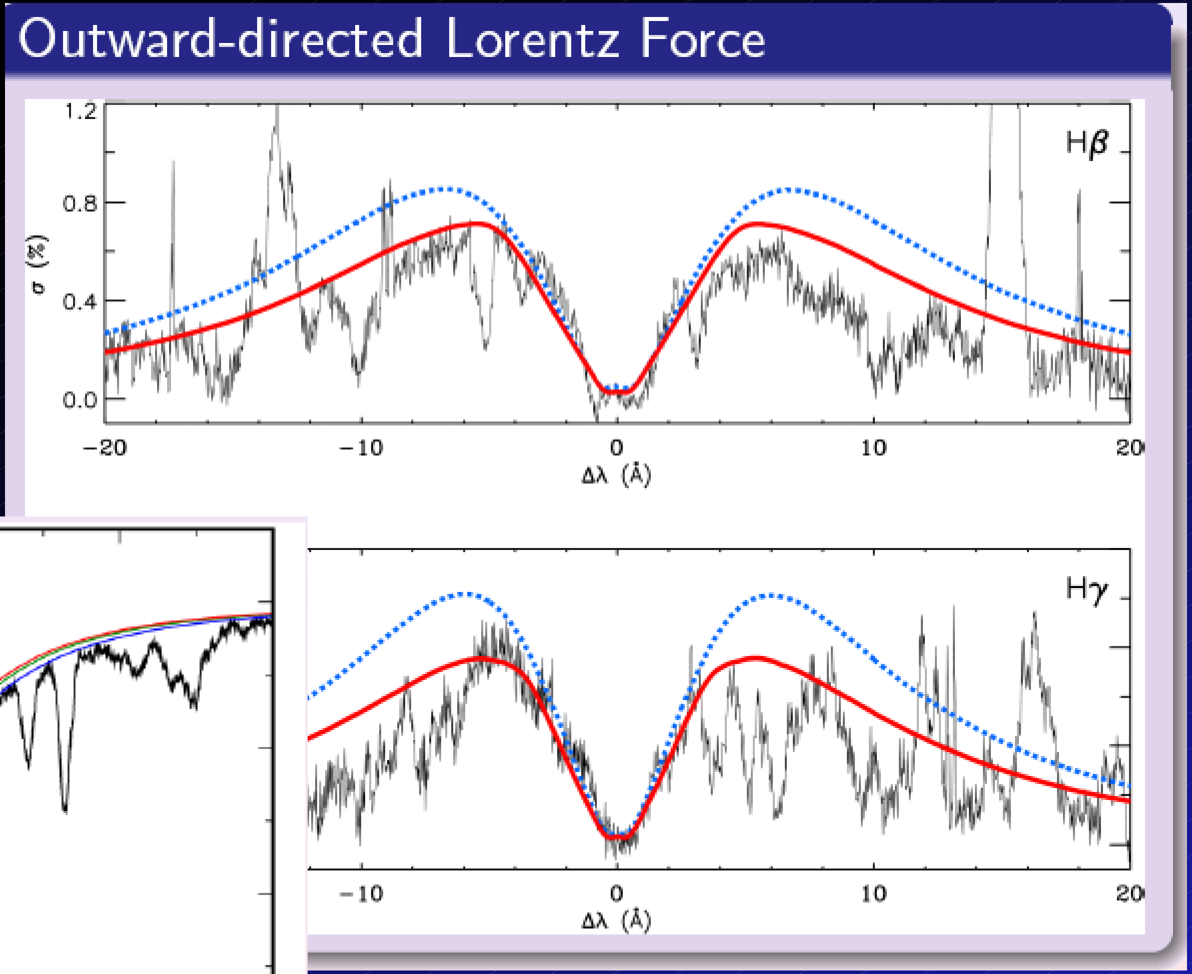


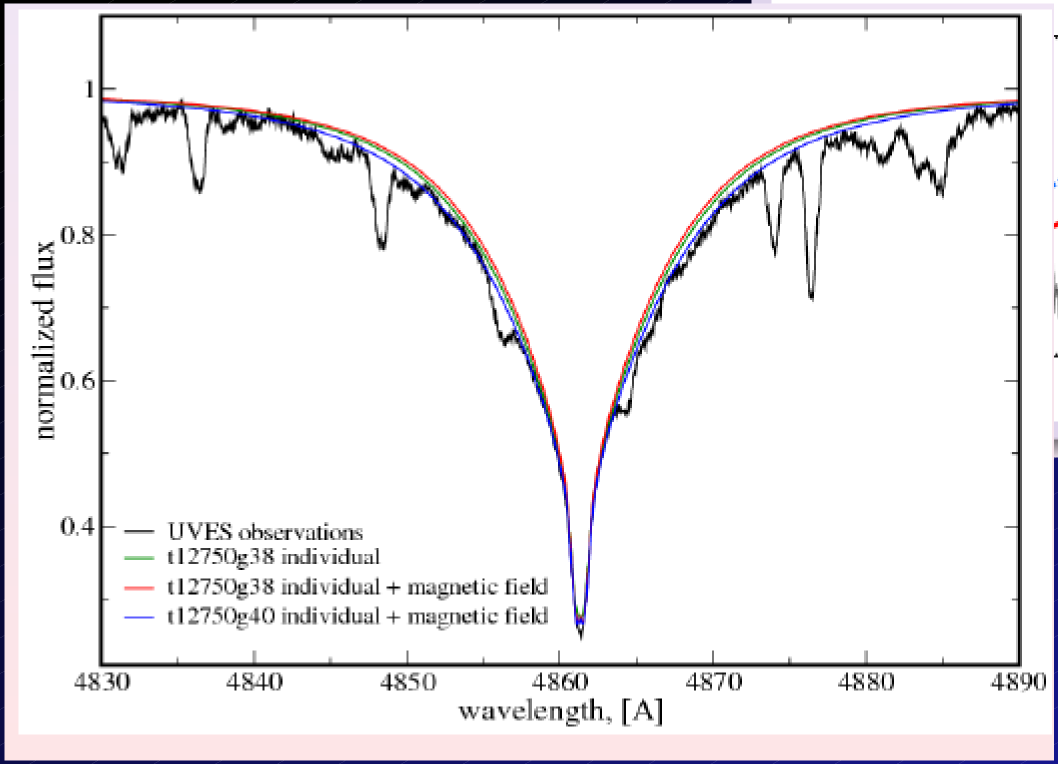

Strassmeier & Rice, 2003, A&A

# Lorentz Force Signatures

Balmer lines variability

Shulyak 2007



# Benefits of implementing as VO services

- Unified data format (VO-Table, semantics of variables)
- Transparent data conversion, homogenization, rescaling
- Powerful presentation with remote data (URI) + TVO results
- Large spectral survey feasible
- Serendipitious research - click on star in the  image of cluster to see its dynamic spectra (many observation)

# Killer spectral applications

- Use VO to find all stars with emission in given line (EW<0) – find the time when it was in em.
- Use VO to get 1000 spectra of the given object cut out regions arround given lines, plot the lines, make a gray dynamic spectrum folded in time
- The same – search period, fold by period
- Get the unknown line ID of piece of spectra from SLAP overploted over SSA data
- Create Light and RV curve for given period
- Fit the grid of models (Teff, log g) to the observed spectrum – for many stars

# Conclusions

- VO clients – basic functions
- Advanced work not supported in VO at all!
- Server side services
- switch to Workflows
- GRID
- Need  of  models
- TVO
- What to do ? - VO literacy
- More stellar spectra to VO archives
- VO portal using local private spectral server
- Write analysis tools with VO interface
- VO services for common tasks
- Ask astronomers !