## Virtual Observatory as a Tool for Stellar Spectroscopy

Petr Skoda Astronomical Institute of the Academy of Sciences of the Czech Republic

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## VO paradigma

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

## The reality in stellar spectroscopy

What stellar astronomers do most of time? Inefficient, tedious, target oriented work No revolutionary changes for 100 years ;-) What poor astronomers are they (those stellar ones)

## The reality in stellar spectroscopy

- lookup in journals (catalogues) -> SIMBAD (Vizier)
- measurement of plates scanning, (Aladin) (and NED as well)
- spectral plates -> FITS (ASCII) files (binary FITS tables - space missions)
- tables, nomograms -> online calculation (curve of growth)
- rulers, mm paper -> graphic tools, IRAF, MIDAS, STARLINK

## The reality in stellar spectroscopy

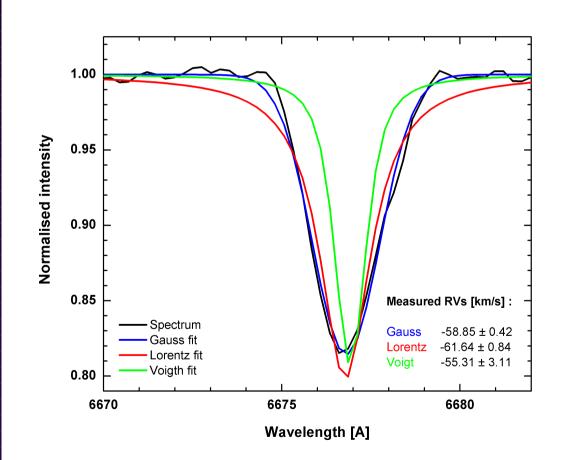
- Still switching different tools, packages, homewritten custom scripts
- Conversion of formats, interpolation, axis transformation, tables of values from FITS headers ...
- Measurement analysis export publication
- Tables (LaTeX output), graphs (PS)

## Simple Spectral Analysis

- (Over) Ploting spectra
- Different objects
- Different ranges (UV over IR)
- Different time (RV, profile changes)
- All heritage packages (bplot, splot, specplot, spectool, DIPSO, XALICE) can do this
- And VO-enabled as well !

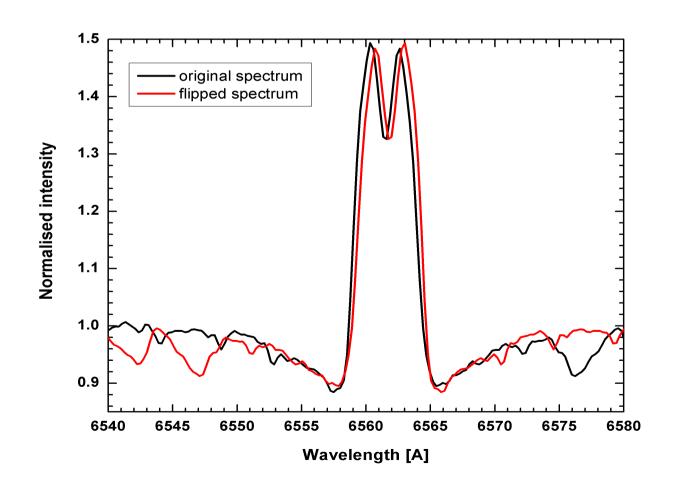
## **Measurement of RV, z**

- Individual spectra
- Normalization
- Fits of Gauss, Maxwell, Voigt
- Cross correlation
  - Good template



## Measurement of RV, z

Mirroring method



## Mirroring method

- Shift until best match of direct and flipped profile
- From old oscilloscopic comparator
- Complicated profiles (Be)
- Adjustable region of interest (wing/core)
- Interactive
- Needs reference line position
- Only SPEFO and SPLAT

## **Bisector Analysis**

- Quantitative study of LPV
- Searching exoplanets
- High resolution echelle
- Rectified (normalized) spectra
- Various smoothing
- Cuts in relative depth of line half of span
- Zoom of bisectors position
- Results in 3D cube (time, line, depth)

## Advanced Tools for Spectral Analysis

Require several variables from FITS headers

JD, time, epoch and derived variables

RV, line position, period – phase

and PROCESSED spectrum (normalization, log lambda)

## **Period Analysis**

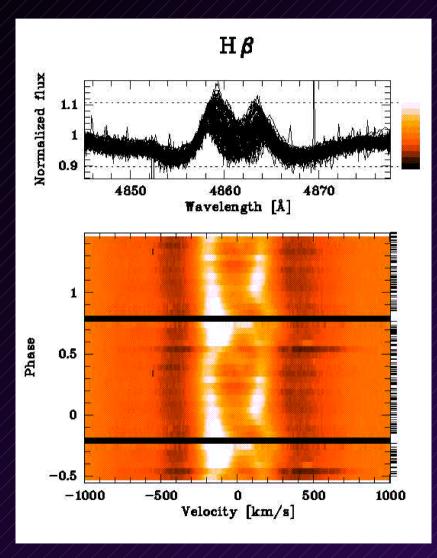
- Time series
- Various variables
  - EW
  - Moments (asteroseismology)
- PDM, Fourier (CLEAN), many others
- Requires
  - Rectified spectrum
  - Time
  - Ranges
  - Initial estimate of period

## **Period Analysis**

#### Period98, Period04 (java), FROG ?

	Period04: BiCMi-l	Example.p04		
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Time String Fit Log				
Main Goodness of Fit				Fourier Calculation Settings
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Export frequencies     Zero point:     Export frequencies     Residuals:		2.93355749 0.00880255096	From: 0 Step rate: High 🕶 0.000458885312	
Settings for the Least-Squares Fit Calculation			0.00000255050	To: 50 Nyquist: 139.806
Fitting formula: $\mathbf{Z} + \mathbf{\Sigma} \mathbf{A}_i \sin(2\pi (\Omega_i \mathbf{t} + \Phi_i))$				Use Weights: none Edit weight settings
· · · ·				Calculations based on:
			justed data	Original data     Residuals at original     Spectral window
Use weights: none Edit weight settings				○ Adjusted data ○ Residuals at adjusted
Use Freq# Frequency Amplitude Phase				Compact mode:   Peaks only  All
F1	8.24552165	0.0365499379	0.304163	Highest Peak at: Frequency = 8.24525129 Amplitude = 0.0349032041
✓ F2	8.86629795	0.0308253197	0.236373	Calculate
F3	8.51400244	0.00953713984	0.0260293	My Fourier calculation ( F=8.24525129, A=0.0349032041 )
▶ F4	7.4244122	0.00788237406	0.300239	My Fourier calculation (F=8.86612312, A=0.0349052417)
₽ F5	10.427036	0.00544374494		aph: My Fourier calculation
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## **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)
- Custom packages
  - D. Massa IDL
  - MIDAS TSA (Stahl, Rivinius)
- Multiple lines at the same time

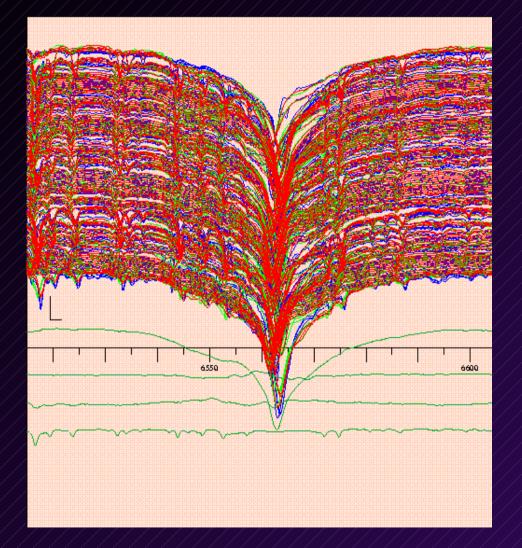
## Spectral Disentangling

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

## Spectra Disentangling

- Show all spectra overploted
- Remove bad same cut, regions
- KOREL (P. Hadrava), FDBinary (S. Ilijic)
- Batch processing on GRID, interactive control of iteration, plug-in optimization methods (agents - genetic, insects cloud, NN)
- Iterative Interactive refeed results (orbit) as parameters

## **Spectra Disentangling**



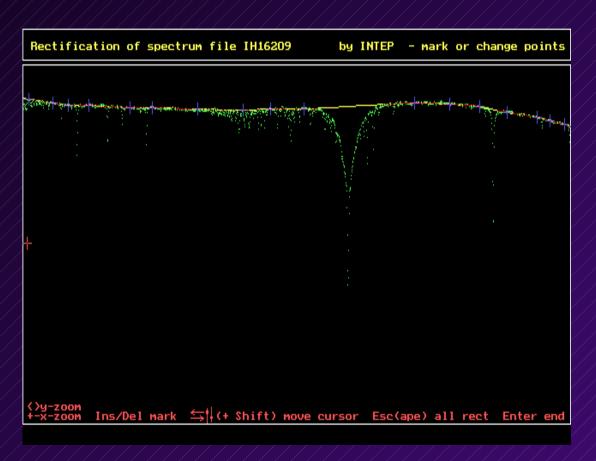
- Example of triple star P. Hadrava
- Poster S240-121 next week
- Telluric line removal

## Benefits of implementing as VO services

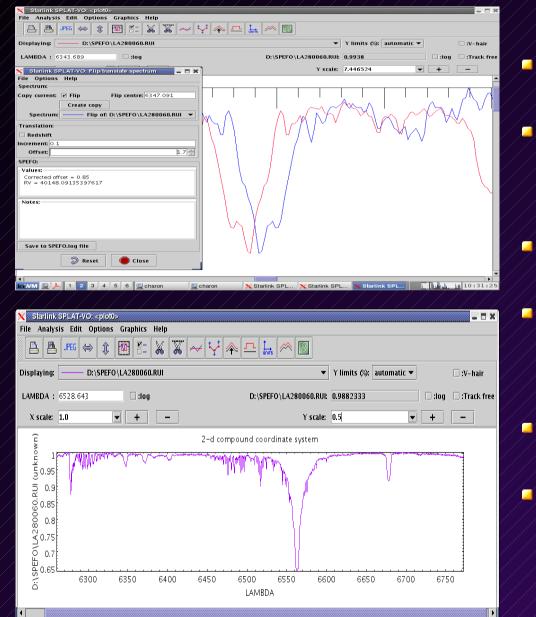
- Unified data format (VO-Table, semantics of variables)
- Transparent data conversion, homogenization, rescaling
- Powerful presentation with remote data (URI)
- Large spectral survey feasible
- Serendipitious research click on star in the image of cluster to see its dynamic spectra (many observation)

# Present VO - enabled spectral analysis tools

- Complicated stars Be, Symbiotic, Novae ...
- Flexible Fitting of Continua (INTEP, Akima)
- RV measurement (mirroring, fitting)



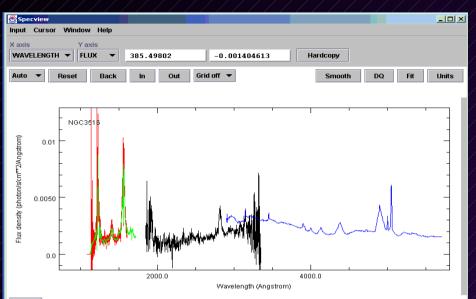
### SPLAT



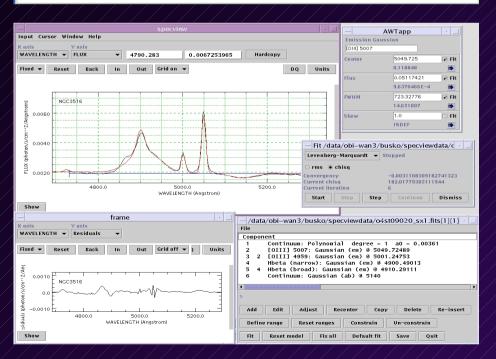
Has all features

- VO registry hardcoded
- Custom line list
- Development not justified
- Most advanced
- P. Draper (JCMT)

## SpecView (STScl)



Pan



- Fitting profiles from models
- Simple polynomials
- Analysis strong (deredening, CLOUDY)
- Supported !!
- Not good for IRAF WCS (1D FITS)



- Very simple
- Polynomial fits
- No RV measurement
- No complex operations
- In VizieR now
- Can work with SLAP!
- Theoretical VO supported

## Conclusions

#### Present state:

- VO enabled tools lacks features necessary to replace local analysis tools
- Simple rectification
- RV only fit of Gauss...
- Only few spectral archives of optical stellar spectra (Elodie)

- What to do ?
- 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 !