HRS Data Reduction

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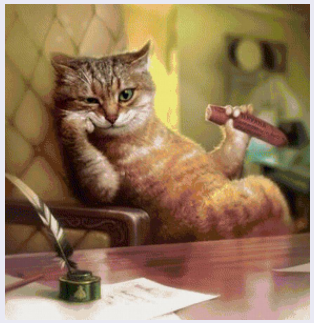
Aim of this talk



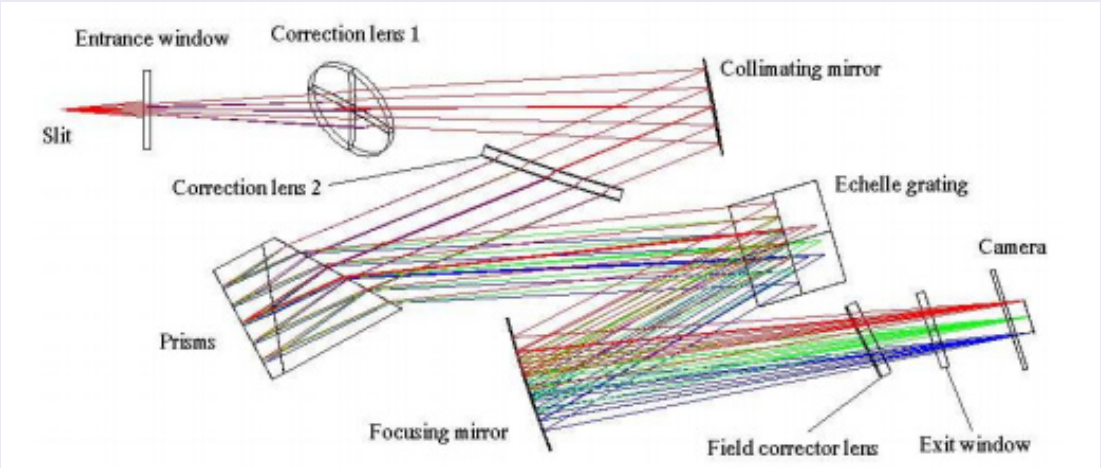
1. To give you an overview of the èchelle data reduction
2. To show you these steps with HRS data reduction as an example

If you would like to read more HRS reports, please, look into
https://www.saao.ac.za/~akniazev/pub/HRS_MIDAS/

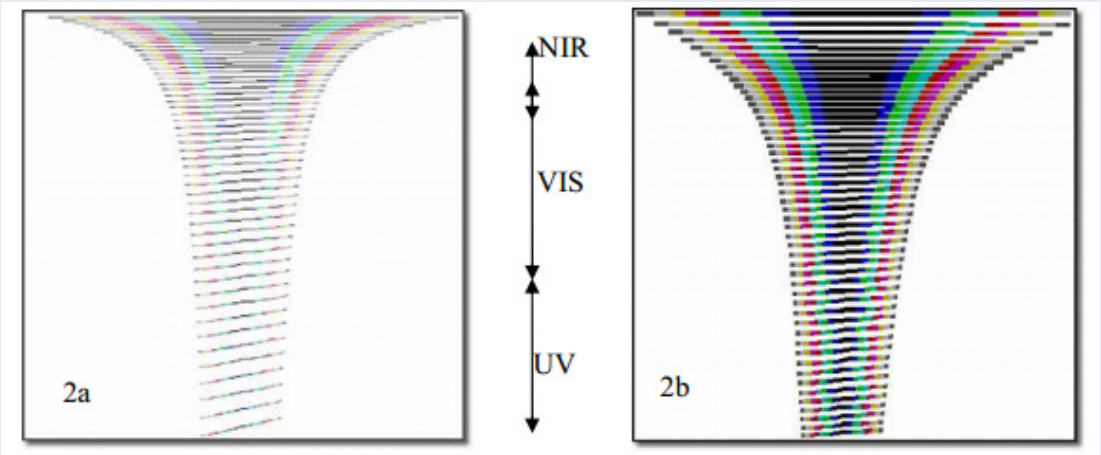
Particular implementation of èchelle data reduction for HRS was done by me with use of MIDAS (FEROS+ECHELLE packages) + Unix Shell. Sources of this pipeline are here:
https://bitbucket.org/akn_zdes_i_seichas/hrs_midas_pipeline/

General information about échelle spectrograph

Work in high orders



Second dispersing element split the in the vertical direction

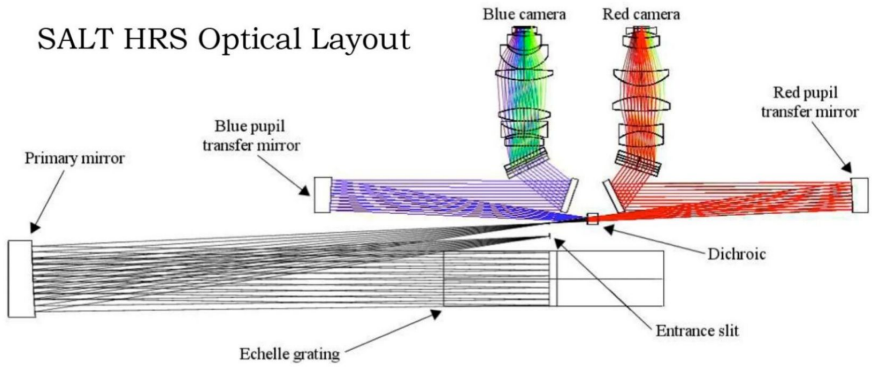


General Information about HRS (1)

HRS: High Resolution Spectrograph

Durham University

- Low Resolution (LR)
  - R ~ 15000
- Medium Resolution (MR)
  - R ~ 40000
- High Resolution (HR)
  - R ~ 65000



- High Stability Mode – same as HR, but with highest wavelength accuracy, in principle down to few m/s [exoplanet science]

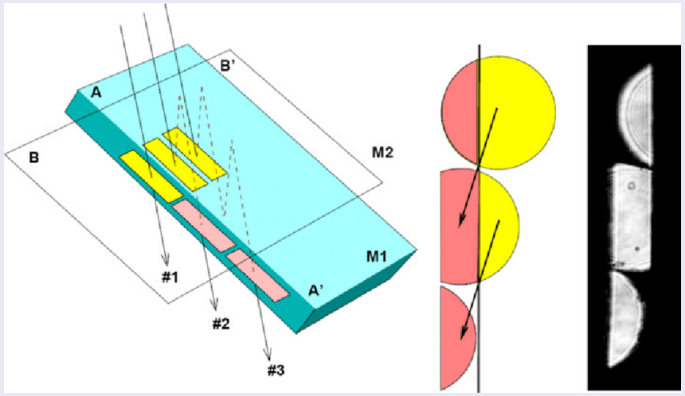
Pipeline now available! Wavelength calibrated extracted spectra.
Out-of-the box velocity accuracy <200 m/s for all modes.

General Information about HRS (2)

HRS modes:

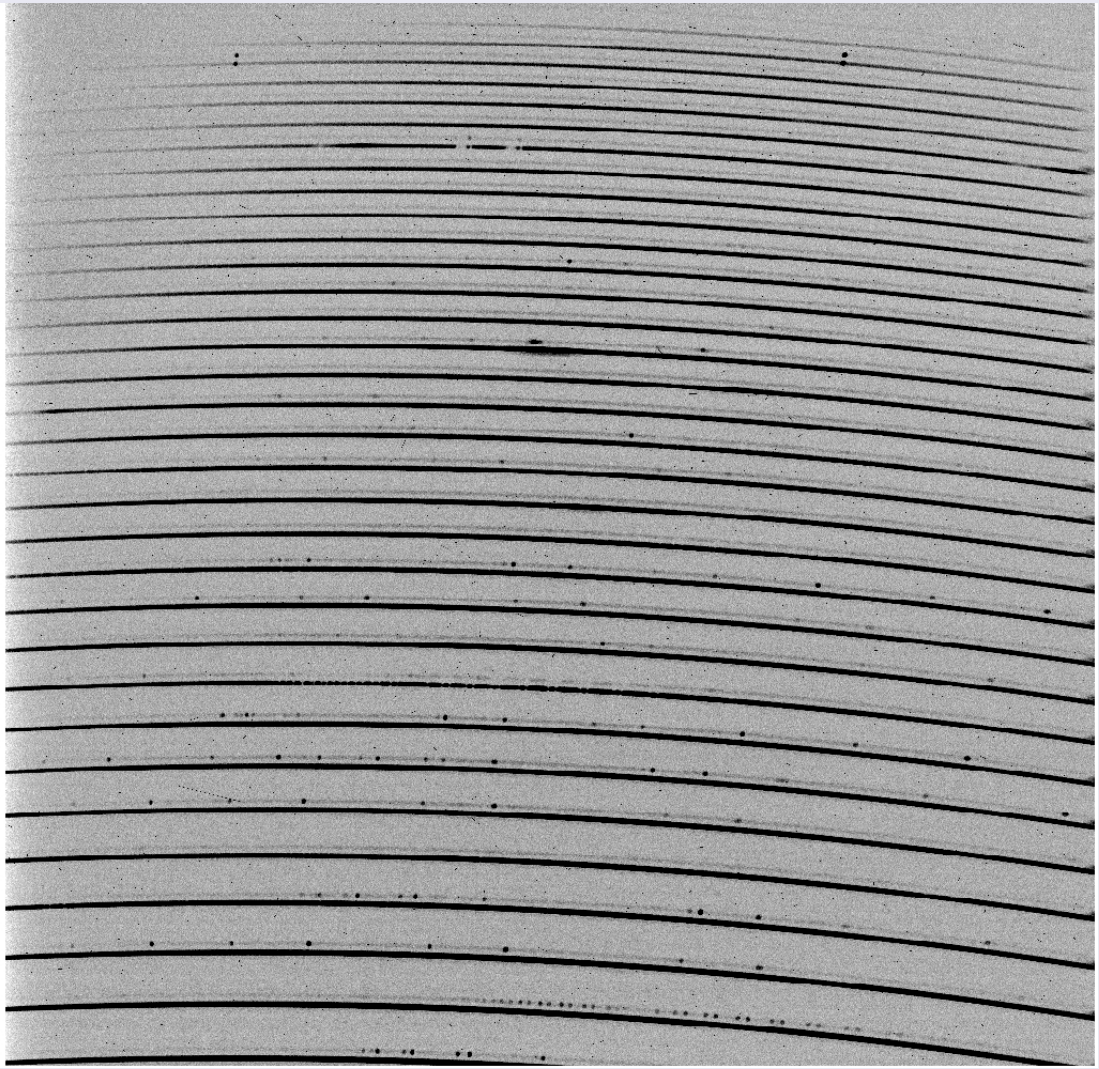
Parameter	Low Resolution Mode	Medium Resolution Mode	High Resolution Mode	High Stability Mode
Fibre Diameter (μm)	500	500	350	350
Fibre Diameter (arcsec)	2.23	2.23	1.56	1.56
Slit width (arcsecs)	1.673	0.710	0.355	0.355
Image Slicers	No	3 slices	3 slices	3 slices
Blue arm resolution	15000	43000	65000	65000
Red arm resolution	14000	40000	74000	65000

Image slicer idea:



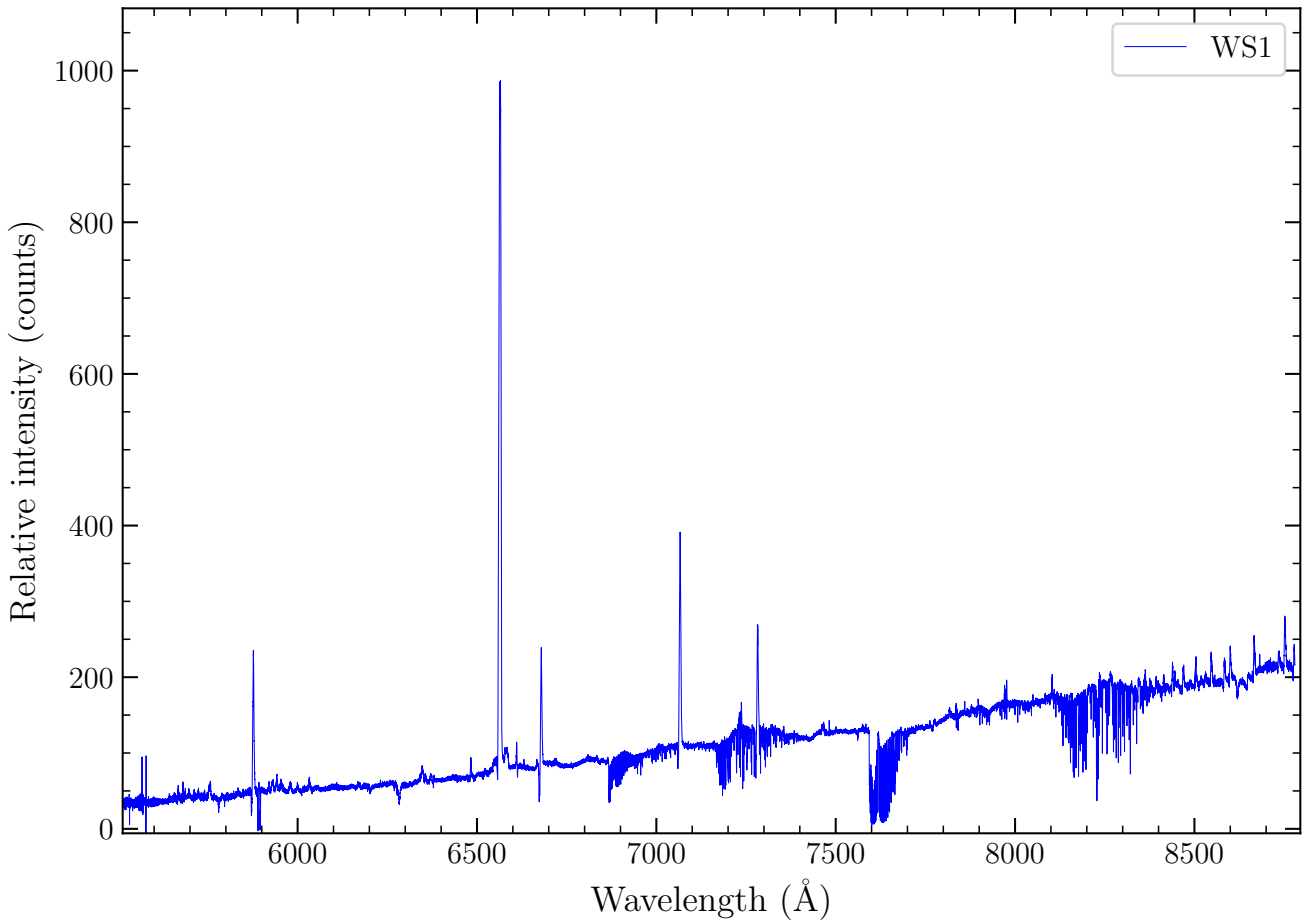
What do we want? (1)

HRS LR red-arm observation:



What do we want? (2)

HRS LR totally reduced spectrum:



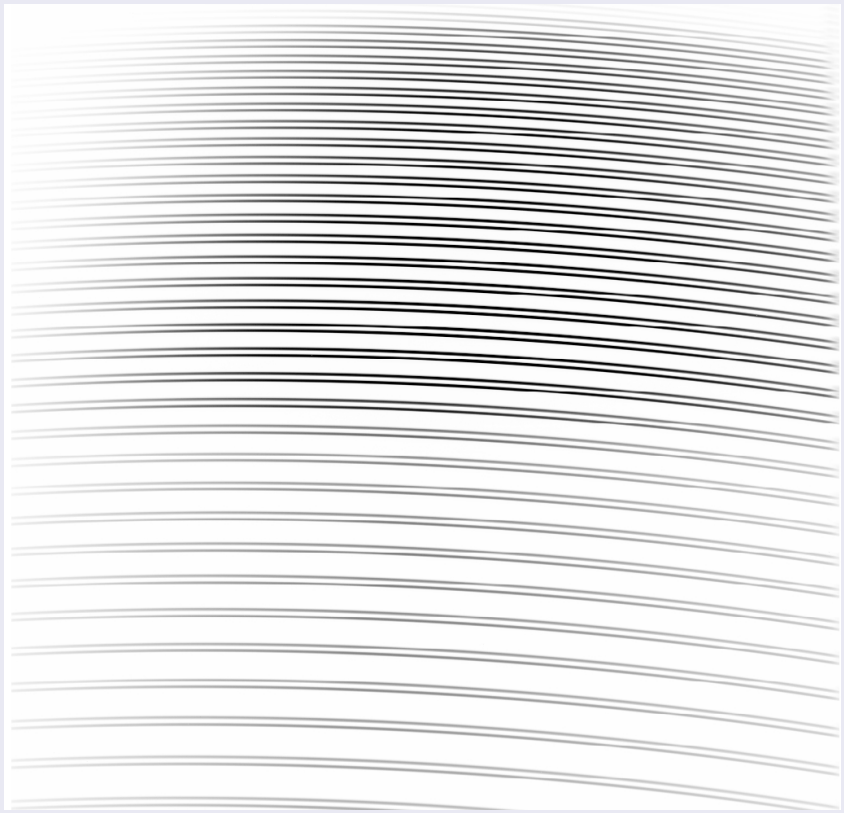
How to reduce 2D échelle spectrum of object

Flow chart for échelle reduction

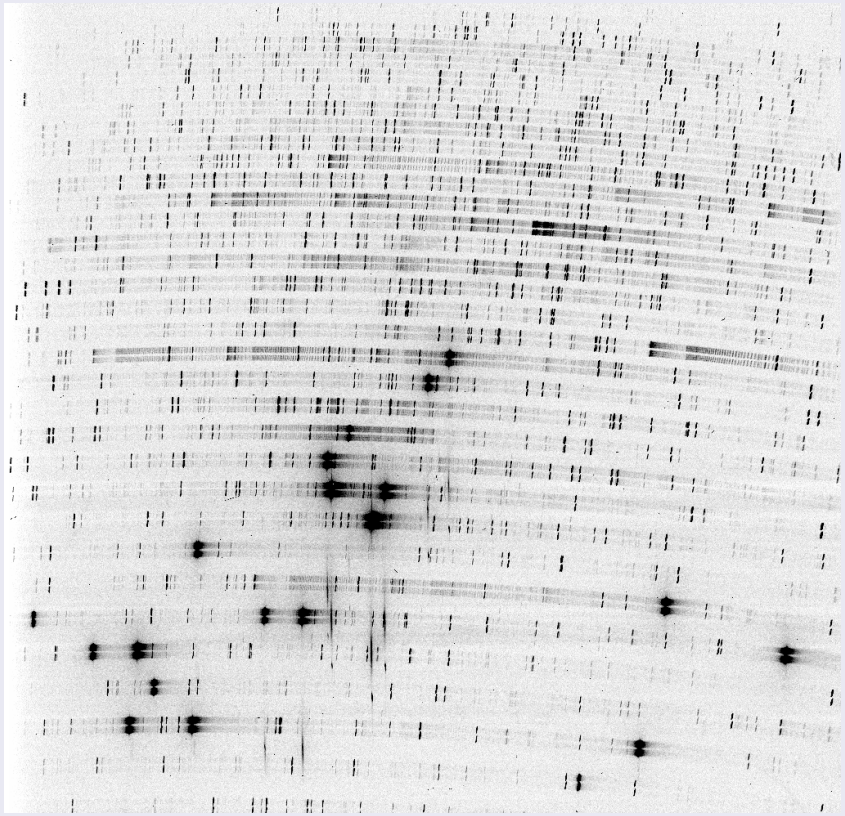
FLAT	ARC	OBJECT
⇓	⇓	⇓
SUBTRACT BACKGROUND	SUBTRACT BACKGROUND	SUBTRACT BACKGROUND
⇓	⇓	⇓
FIND ORDER POSITIONS	EXTRACT ORDERS	EXTRACT ORDERS
⇓	⇓	⇓
EXTRACT ORDERS	IDENTIFY LINES	BLAZE CORRECTION
⇓	⇓	⇓
BLAZE FUNCTION	COMPUTE DISP. COEFFS.	SAMPLE IN WAVELENGTH
		⇓
		MERGE ORDERS

HRS FLAT and ARC data

Flat for LR mode and red arm



Arc for MR mode and red arm



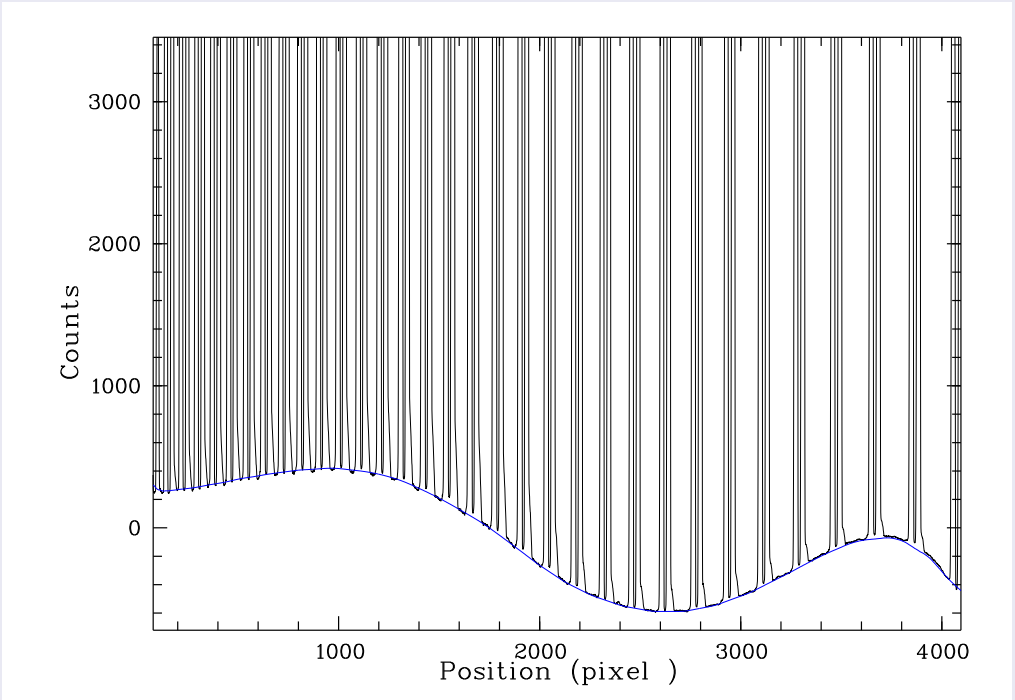
Background Definition

Background is multiplicative signal and it is consist of:

- bad bias subtraction (mostly data 2014–2016 years – up to 500 counts!!!)
- general scattered light
- diffuse light in the interorder space coming from adjacent orders

For algorithm see
1996AN....317...95S

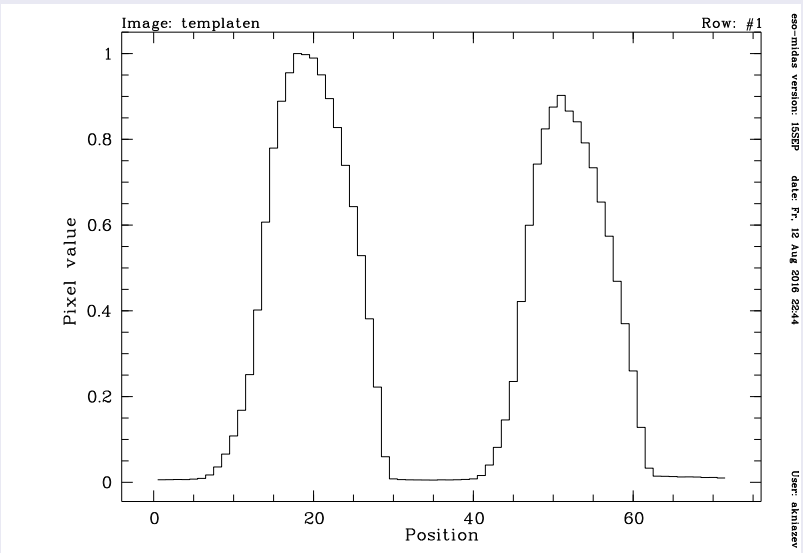
Background definition for one central row of FLAT



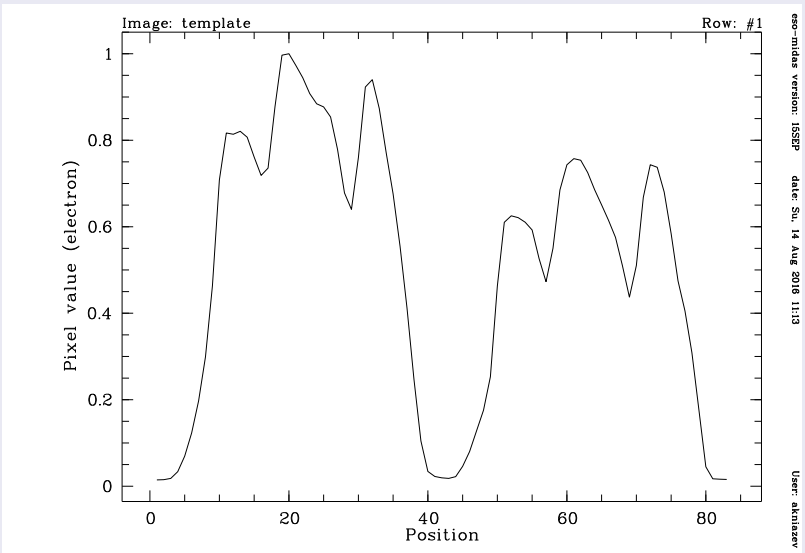
Order Positions (1)

The easiest way to find the centers of orders with the complex profile is a convolution with template of this profile

Orders profile in LR mode

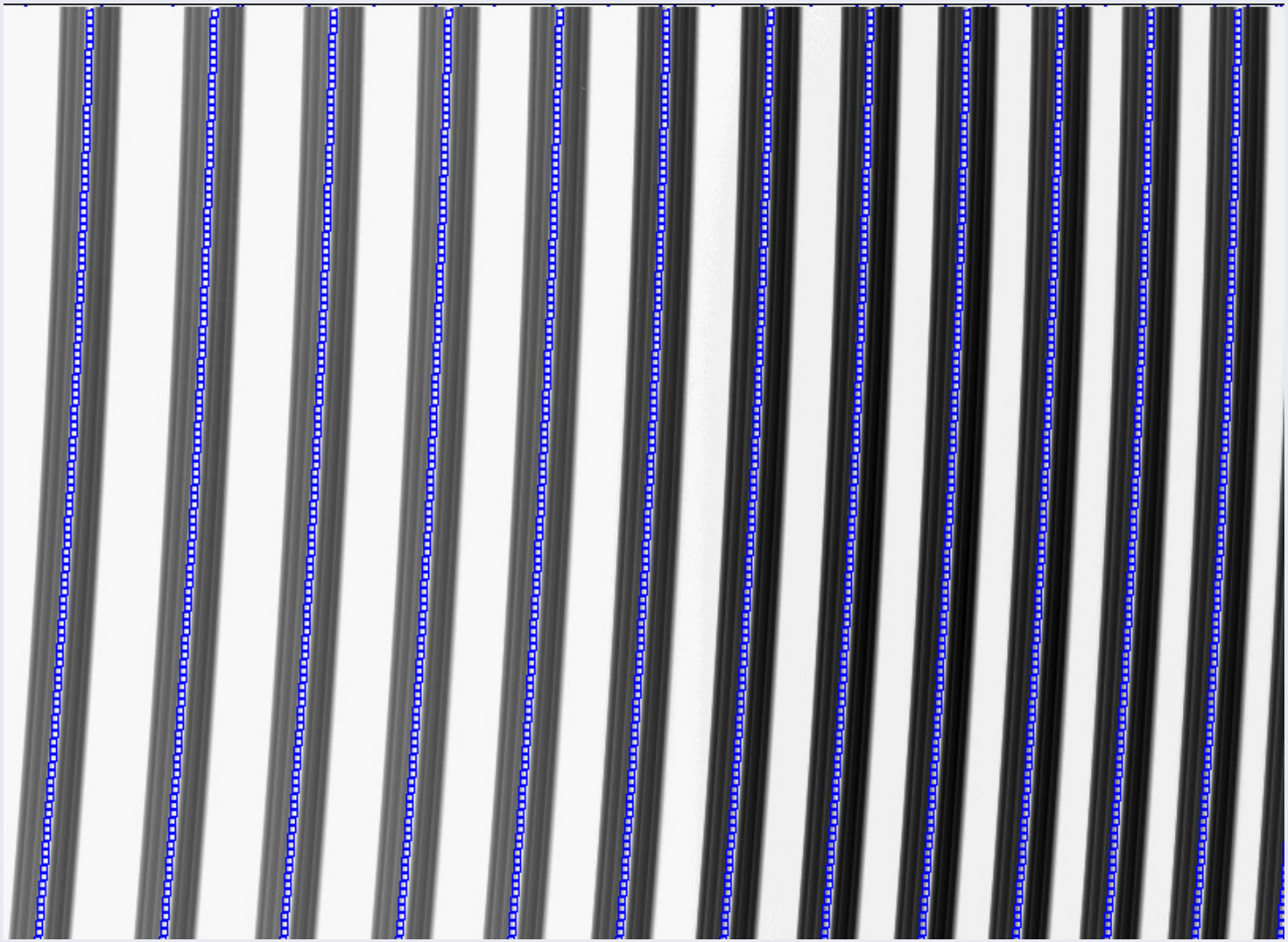


Orders profile in LR mode



Order Positions (2)

Orders positions with MR mode (complex profile)



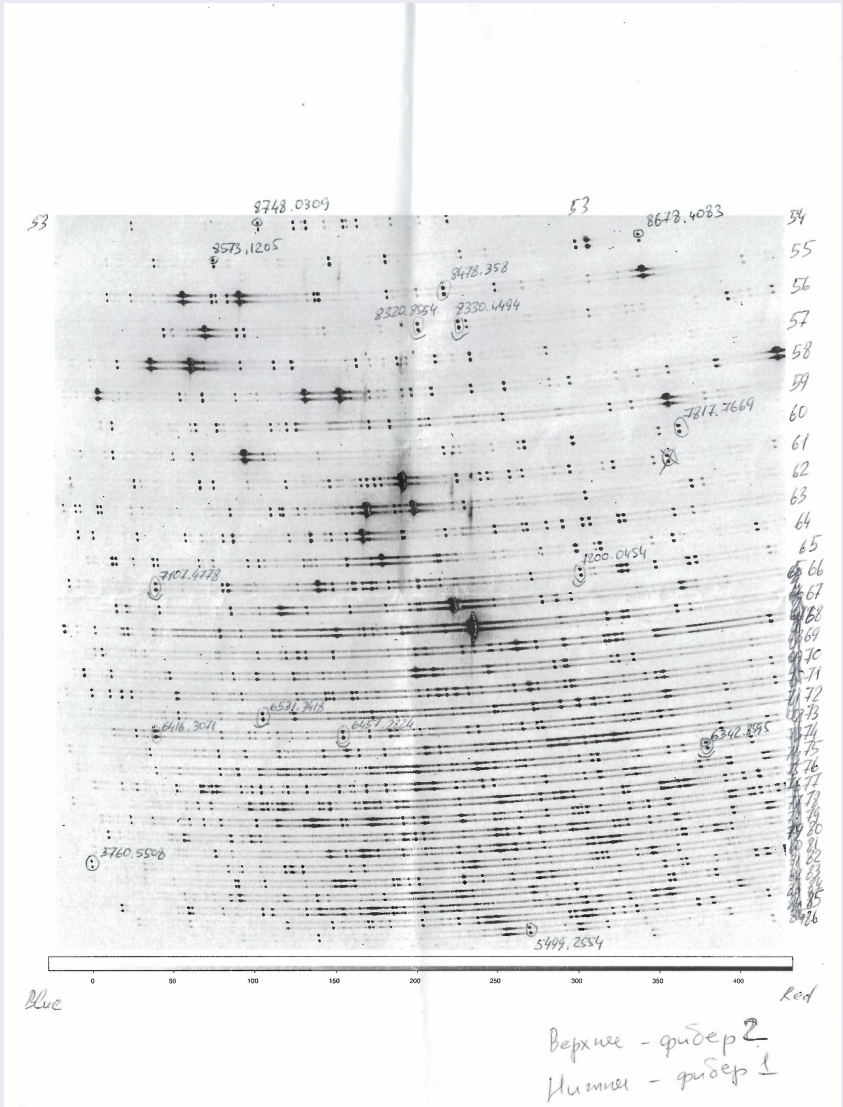
Reference Spectra Reduction (1)

For 2D solution we need 2D identification:

- MIDAS can produce 2D identification automatically, but for the primordial identification I was need to identify as minimum 9 lines that are located in the different orders and MIDAS needs to be informed about the accurate wavelength and the absolute échelle order number for these lines.
- Once done you save this solution and NEVER do it again!!!
- Each time during calibration procedure your identification will be used as the first iteration for the preliminary raw identification which will followed the accurate one.
- For above reasons:
  HRS info + GOOGLE + Arc lines lists + Rock Music + Coffee + Time

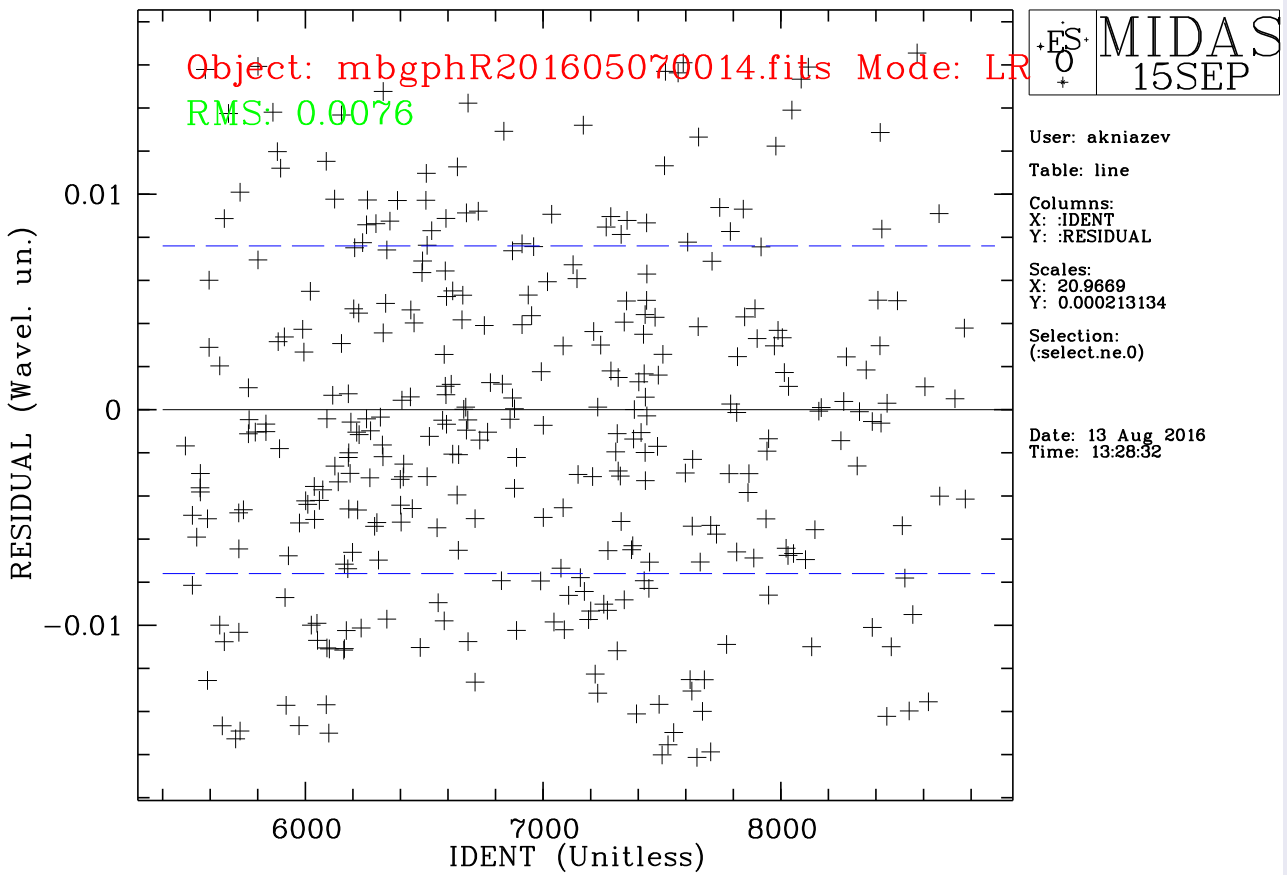
Reference Spectra Reduction (2)

First ARC ThAr+Ar identification:



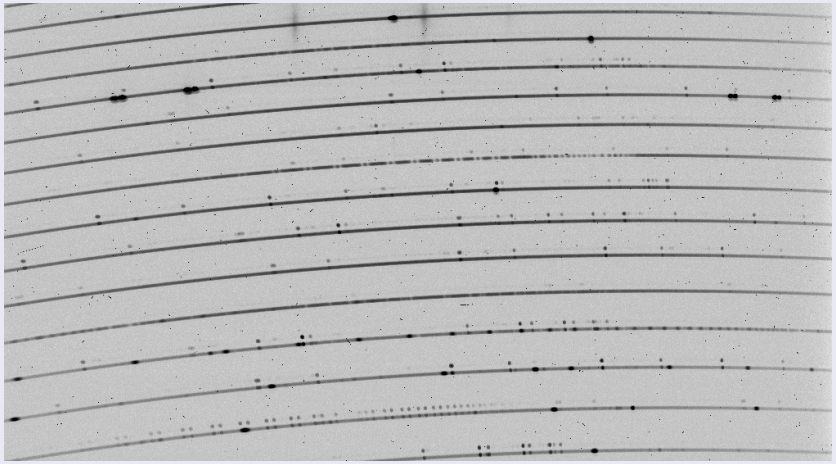
Reference Spectra Reduction (3)

The final solution for the red arm LR (∼ 340 m/s):

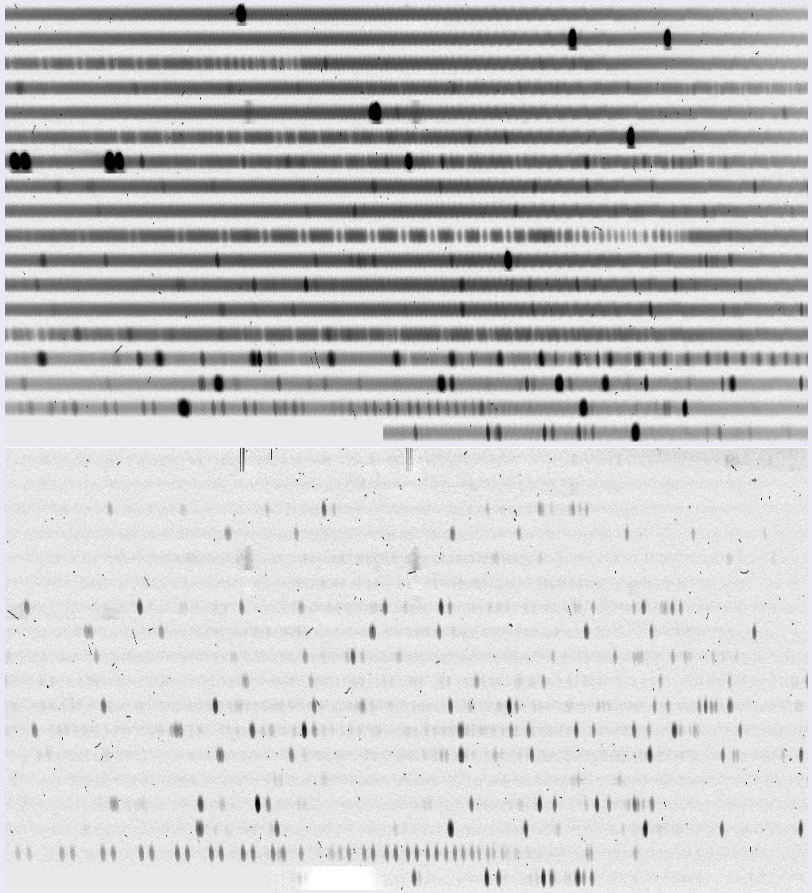


Spectra Extraction

2D spectrum



Rectified 2D spectrum

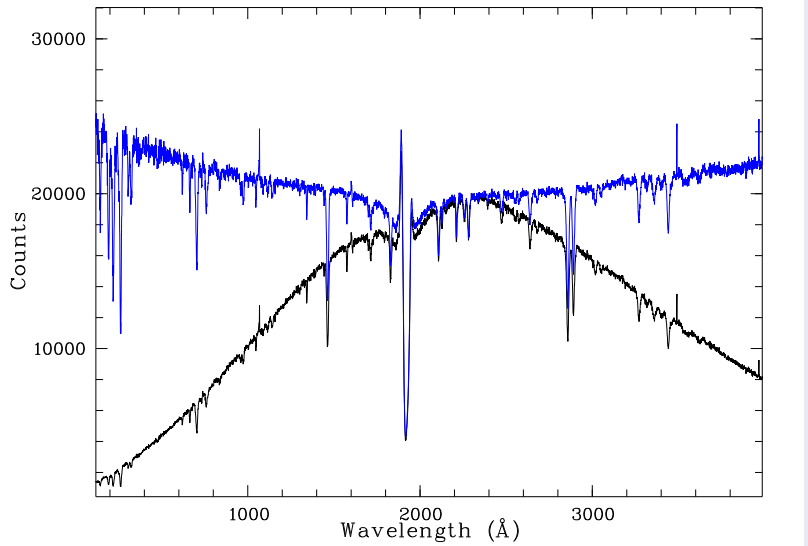


There is no worry about cosmic since extraction procedure used special iterative method to remove it very efficient.

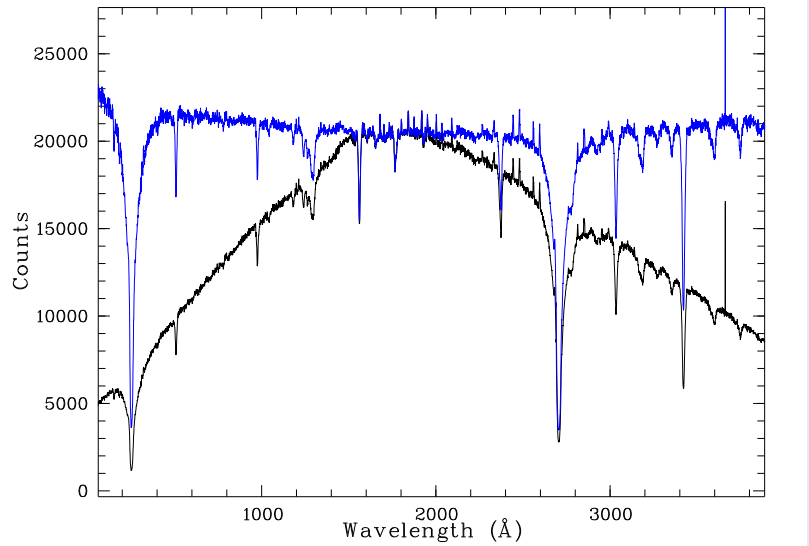
Blaze Correction

Blaze Correction in the HRS case (fiber èchelle spectrograph) is some sort of a flat-field correction

Èchelle order before and after



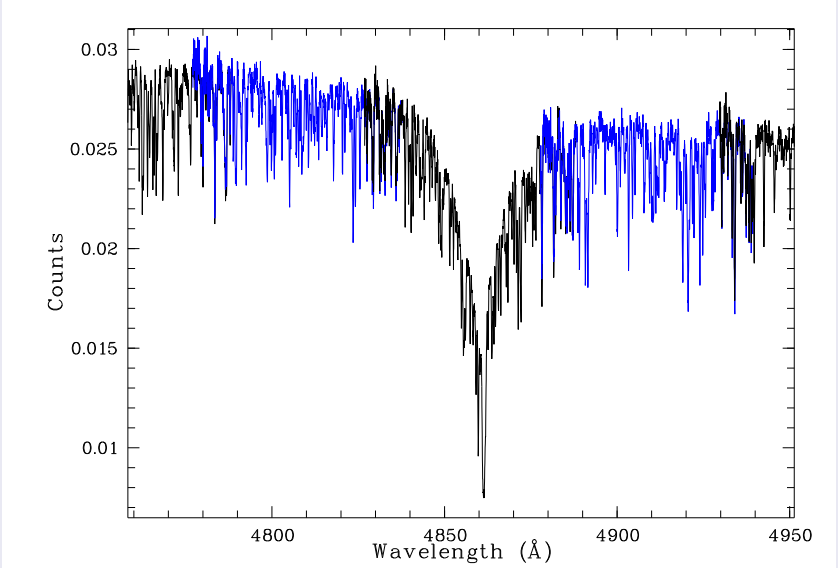
Èchelle order before and after



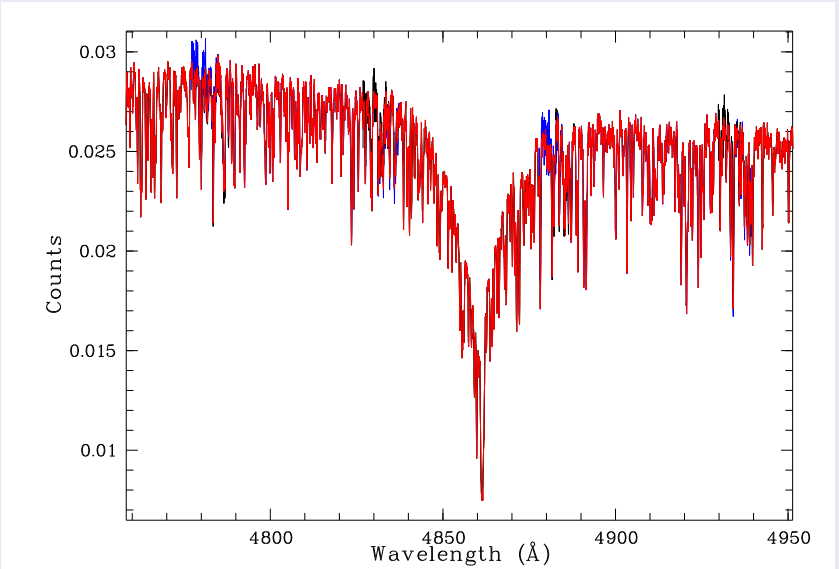
Transformation to wavelength and merging orders

The orders are merged into a 1D file. The algorithm computes a weighted average in the overlapping region of adjacent orders. The normalized weight is a linear ramp between 0 and 1 in the overlapping region.

Some orders before merging



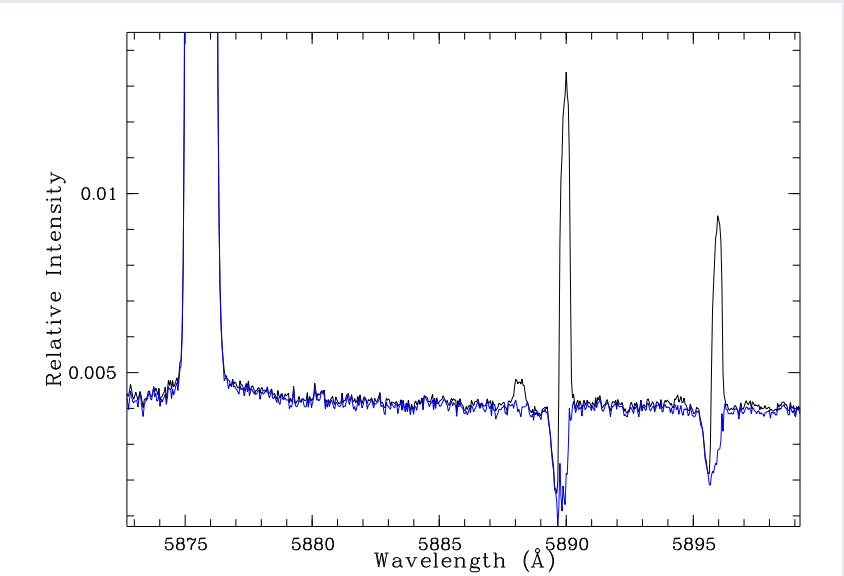
The same part but merged (red) on top



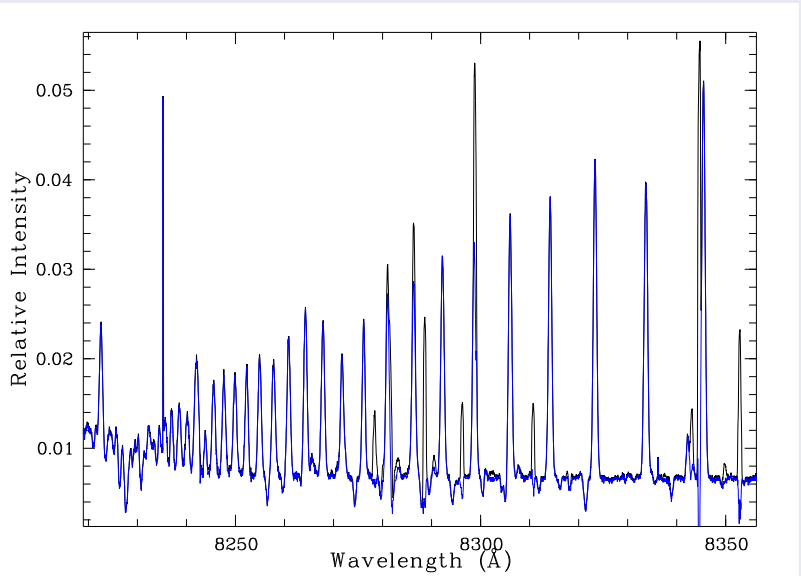
Object fiber and Sky fiber

Examples of removing of night sky lines from HRS spectra. Both panels show result of the night sky removing in the HRS spectrum for the central star SAO 244567 of young planetary nebulae. The final spectrum before sky fiber subtraction is plotted with black colour and after is plotted with blue colour.

First example



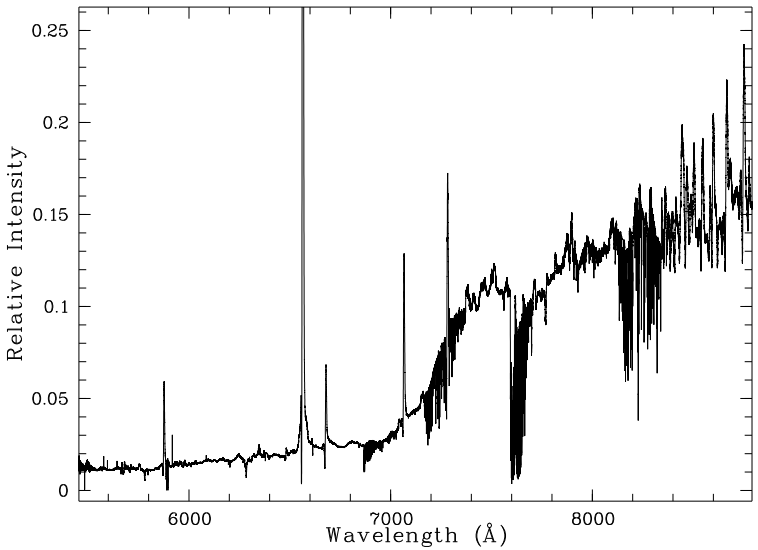
Second example



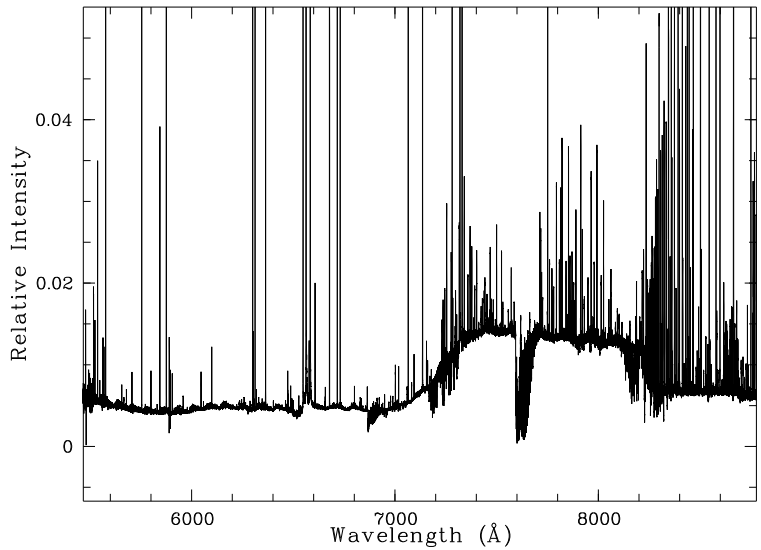
Sensitivity of the system

Finally we have spectra which need to be corrected for the sensitivity curve. Observations of HRS SPST are part of SALT calibration plan, but correction for the sensitivity is still not included in the HRS pipeline.

Merged 33 orders



Merged 33 orders



MIDAS HRS pipeline output data

Visit:
https://astronomers.salt.ac.za/software/hrs-pipeline/
and read
https://www.saao.ac.za/~akniazev/pub/HRS_MIDAS/HRS_pipeline.pdf

The end of story

Me

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