

Southern African Large Telescope



Title: HRS pipeline for HR red-arm data
with MIDAS

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ABSTRACT

*In this report I present a pipeline for the High Resolution Spectrograph (HRS) red-arm data taken in High Resolution (HR) mode. This pipeline was implemented using standard system of astronomical data reduction MIDAS. All programs were written in MCL (MIDAS Command Language) and were developed and debugged by me within a total time of **twenty five minutes**. MCL programs are based on the standard MIDAS echelle packages FEROS and ECHELLE. I present here results of my work.*



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LT. JERRY MOUSE

1 Introduction

After making MIDAS working to reduce HRS red-arm data in LR and MR modes I make an experiment will it be possible for me to reduce HRS red-arm data taken in HR mode. I modified all procedures for work with HR mode. It took a total time of twenty five minutes. In the current report I will display shortly results of this work.

2 HRS HR red-arm data reduction implementation

2.1 Order Definition

It is absolutely similar to MR mode. Template was created using FLAT image for HRS HR red-arm data. With this template FEROS package program DEFINE/FEROS found 33 echelle orders in FLAT data.

2.2 Background Definition

It is absolutely similar to MR mode.

2.3 Order Extraction

It is absolutely similar to MR mode. I used solution I found for MR mode.

2.4 Flat Field Correction

I did the flat field correction for all objects from HRS data after their orders were extracted. This step is absolutely similar to MR mode.

2.5 Wavelength Calibration

SEARCH/EHELLE command finds ~ 800 lines in all 33 orders for each extracted fiber in case of HRS HR red-arm data.

I use the TWO-D method with initial interactive identification for the same 15 different not bright lines, which are located more or less uniformly across 2D ARC frame as I did for LR mode. Final solution was saved after that with SAVE/EHELLE procedure for each fiber and used for all next wavelength calibrations in GUESS mode, where new found line positions in extracted ARC spectra are cross-correlated with previous solution, identified and new solution is found automatically.

An examples for such solution for both object and sky fibers are shown in Figures 1 and 2.



This is the standard output from IDENTIFY/EHELLE procedure. It shows the absolute number of spectral order, amount of finally used lines to build wavelength solution, calculated starting and final wavelengths as well as the standard deviation. The output for the sky fiber shows that for the bluest spectral order with absolute number 85 the amount of finally identified lines is less than required and for that reason the global bivariate polynomial solution was used for this order.

Figure 3 shows the distribution in wavelength of residuals for each finally used lines from ARC. Blue lines show the standard deviation level.

Finally, the extracted orders, sampled to the constant wavelength step, which calculated during previous procedure and shown in Figures 1 and 2.

Figure 4 shows quality of the wavelength calibration in the way that edges of two adjacent orders are shown in the blue and red parts of spectra. It is easy to see that positions of emission lines are very accurate in all shown examples.

2.6 Order Merging

It is absolutely similar to MR mode.

Figure 5 shows an example of the final reduction of one velocity standard star after all 33 orders were merged in one spectrum. Some waves are still visible in the continuum that means that our flat-fielding does not remove the blaze to better than about 15%. *Different reasons could be for that and this question needs to be studied carefully.*

2.7 The Final Sky Subtraction

The sky subtraction was done in the same manner as it was explained in the previous report. Figure 6 shows examples how night sky lines were removed from HRS spectra after my reduction described in this report. Both panels show result of the night sky removing in the HRS spectrum for one of star observed for science program on 20160505. The top panel shows such result in the very blue order, spectral region of HeI $\lambda 5876$ line and two NaD $\lambda 5889.953, 5895.923$ lines. The spectrum from the fiber for object is shown with black color. Two emission from sky NaD $\lambda 5889.953, 5895.923$ are obvious. They are located at the blue edge of NaD lines, belong to the object or ISM in the object direction. The result of sky subtraction is shown with blue color. Both lines disappeared. Additionally, no any PCygni profiles is visible, that shows the quality of wavelength calibration for both fibers. The bottom panel shows result in the same manner, but for the very red order, practically in the reddest spectral region. All night sky lines were removed as well without any PCygni profiles. Unfortunately, *I can see some over-subtraction for some lines, so it is the field for the future study.*



POLYNOMIAL DEGREE : 3

SEQ.NO	SPECTRAL ORDER	NO.LINES	WL START	WL END	STD. DEV. ANGSTROEM
1	85	6	5411.10	5532.83	0.00842
2	84	10	5479.82	5598.67	0.00457
3	83	10	5545.90	5666.09	0.00760
4	82	8	5609.28	5735.59	0.00625
5	81	11	5683.07	5805.93	0.00398
6	80	9	5754.06	5878.51	0.00585
7	79	16	5826.93	5952.87	0.00503
8	78	15	5901.67	6029.09	0.00895
9	77	17	5978.39	6107.37	0.00656
10	76	18	6057.06	6187.75	0.00719
11	75	23	6137.90	6270.23	0.00292
12	74	22	6220.88	6354.93	0.00762
13	73	17	6306.05	6441.95	0.00973
14	72	16	6393.73	6531.40	0.00523
15	71	18	6483.86	6623.33	0.00758
16	70	24	6576.50	6717.93	0.00469
17	69	12	6671.82	6815.42	0.00642
18	68	13	6770.06	6915.45	0.00747
19	67	14	6871.03	7018.75	0.00669
20	66	16	6975.20	7124.95	0.00763
21	65	24	7082.52	7234.53	0.00729
22	64	23	7193.26	7347.56	0.00609
23	63	23	7307.45	7464.19	0.00518
24	62	18	7425.33	7584.59	0.00563
25	61	18	7547.08	7708.82	0.00649
26	60	9	7672.92	7837.31	0.00271
27	59	15	7802.97	7970.16	0.00461
28	58	17	7937.55	8107.49	0.00653
29	57	11	8076.83	8248.28	0.00790
30	56	7	8221.10	8397.01	0.00290
31	55	15	8370.54	8549.69	0.00724
32	54	8	8525.57	8708.05	0.00401
33	53	9	8686.31	8874.40	0.00395

MEAN RMS: 0.00625

** TOTAL NUMBER OF LINES : 492 **

Set parameter SAMPLE=0.0430334806

Figure 1: Wavelength solution for fiber with object (fiber one in HR mode).



POLYNOMIAL DEGREE : 3

SEQ.NO	SPECTRAL ORDER	NO.LINES	WL START	WL END	STD. DEV. ANGSTROEM	
1	85	4	5415.36	5532.90	0.02005	*NOT ENOUGH LINES*
2	84	8	5479.91	5598.77	0.00433	
3	83	8	5546.01	5666.10	0.00721	
4	82	8	5613.65	5735.29	0.00265	
5	81	11	5683.15	5806.03	0.00243	
6	80	9	5754.17	5878.62	0.00542	
7	79	15	5827.00	5952.98	0.00611	
8	78	14	5901.78	6029.18	0.00573	
9	77	20	5978.46	6107.47	0.00958	
10	76	18	6057.16	6187.85	0.00687	
11	75	22	6137.94	6270.36	0.00685	
12	74	20	6220.99	6355.04	0.00642	
13	73	18	6306.17	6442.04	0.00829	
14	72	14	6393.85	6531.49	0.00560	
15	71	16	6483.99	6623.44	0.00656	
16	70	19	6576.61	6718.04	0.00330	
17	69	11	6671.94	6815.52	0.00599	
18	68	13	6770.23	6915.56	0.00646	
19	67	16	6871.16	7018.85	0.00906	
20	66	18	6975.32	7125.06	0.00685	
21	65	23	7082.64	7234.65	0.00651	
22	64	18	7193.37	7347.68	0.00688	
23	63	23	7307.56	7464.31	0.00569	
24	62	15	7425.46	7584.69	0.00389	
25	61	16	7547.24	7708.94	0.00443	
26	60	7	7673.04	7837.44	0.00377	
27	59	13	7803.10	7970.31	0.00397	
28	58	18	7937.68	8107.62	0.00868	
29	57	10	8076.96	8248.32	0.00693	
30	56	7	8221.22	8397.14	0.00370	
31	55	13	8370.66	8549.91	0.00296	
32	54	7	8525.76	8708.13	0.00136	
33	53	6	8686.88	8870.16	0.00204	

MEAN RMS: 0.00610

** TOTAL NUMBER OF LINES : 458 **

Set parameter SAMPLE=0.0431021601

Figure 2: Wavelength solution for fiber with sky (fiber two in HR mode).

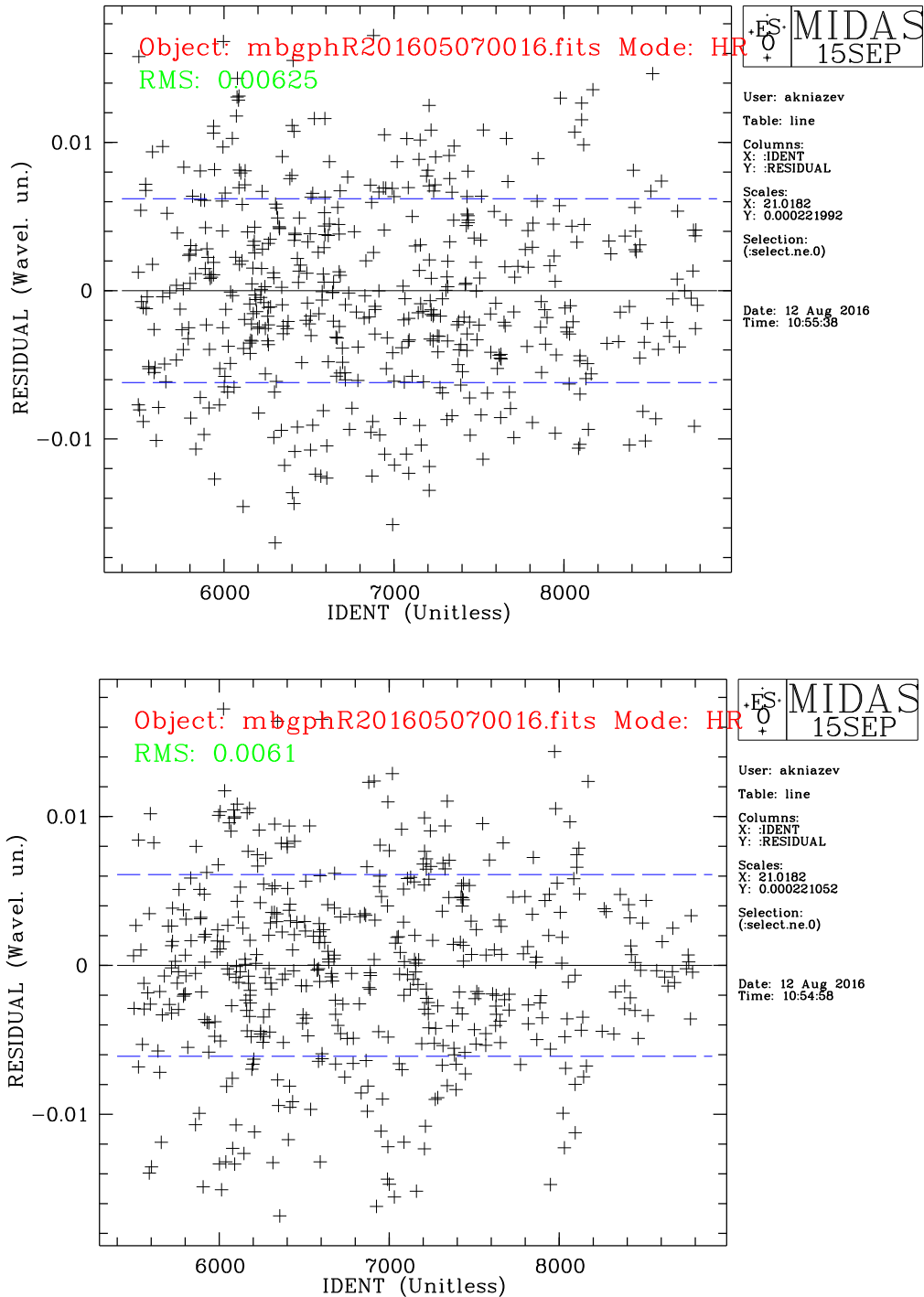


Figure 3: The distribution in wavelength of residuals for each finally used lines from ARC. Blue lines show the standard deviation level. The top panel shows this distribution for the first fiber and the bottom panel shows is for the second fiber.

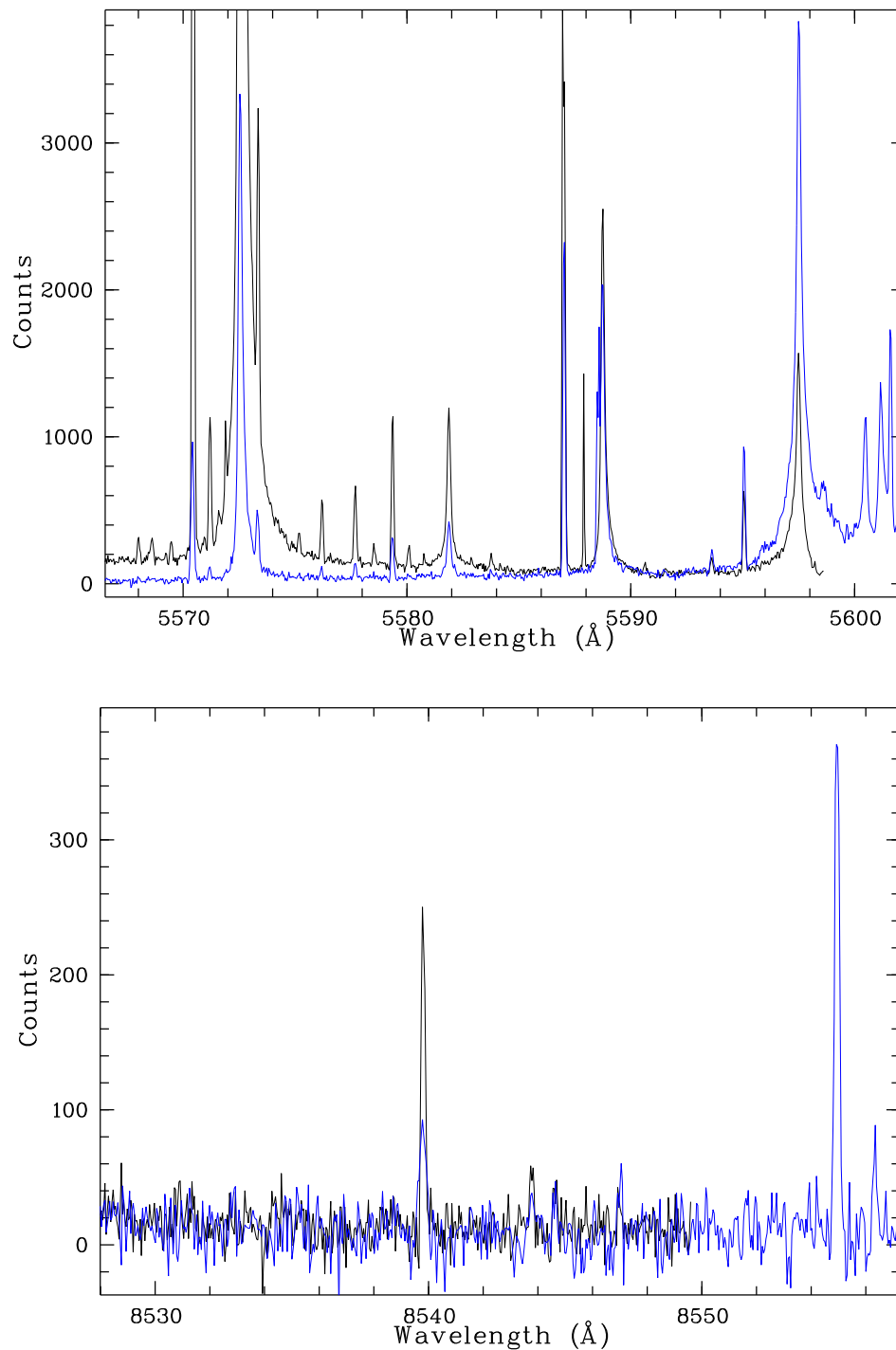


Figure 4: Two examples of edges for adjacent orders from wavelength calibrated ARC spectrum. Different orders are shown with different color. Blue (top) and red (bottom) spectral regions are shown.

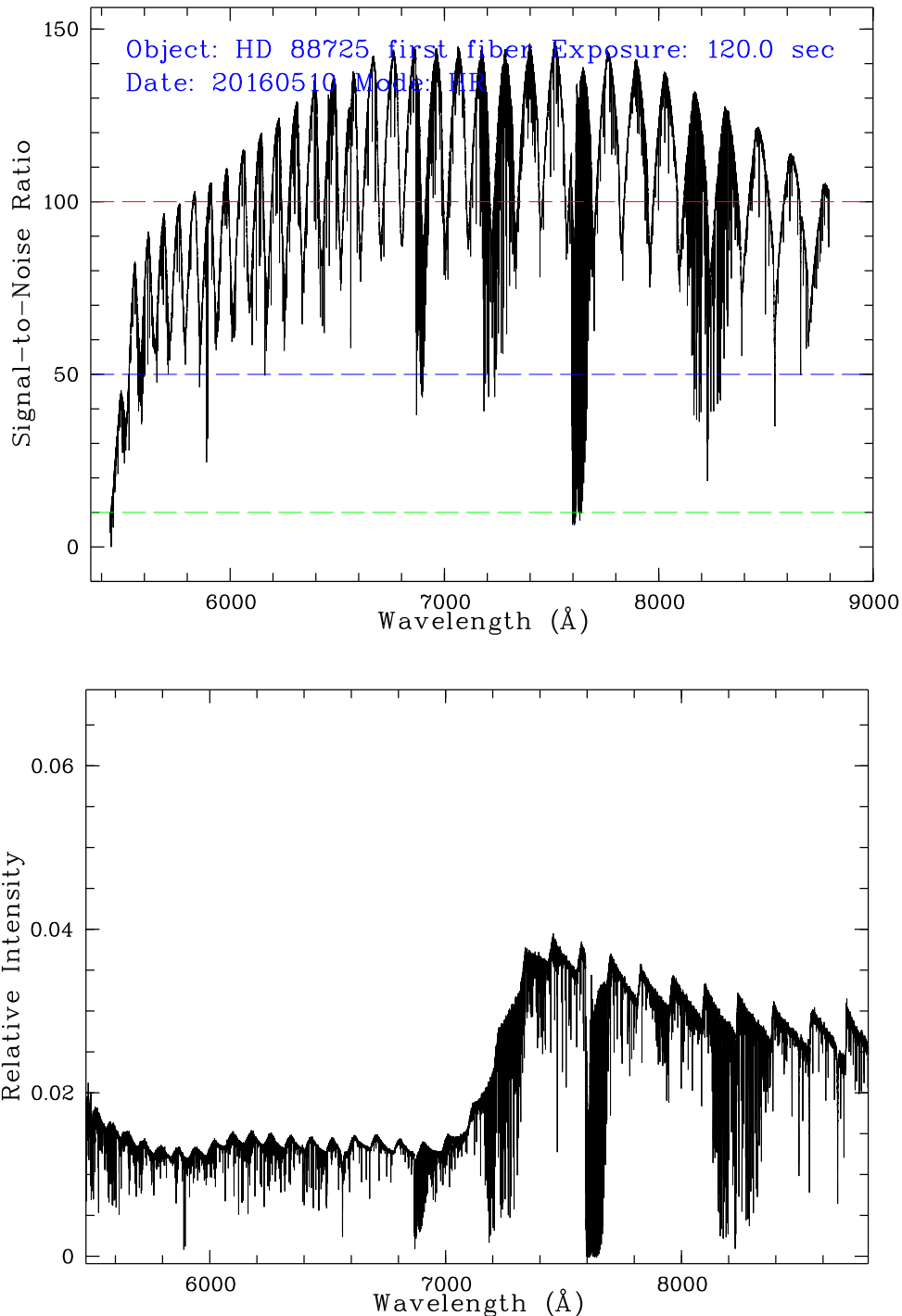


Figure 5: *Top*: Merged spectrum of the velocity standard without flat-field correction. My standard procedure for estimation of SNR for observed spectrum. *Bottom*: An example of the final HRS data reduction for the velocity standard, but after flat-field correction. There is obvious systematic slope of the distribution for each order after flat-field correction. This effect is about 15%.

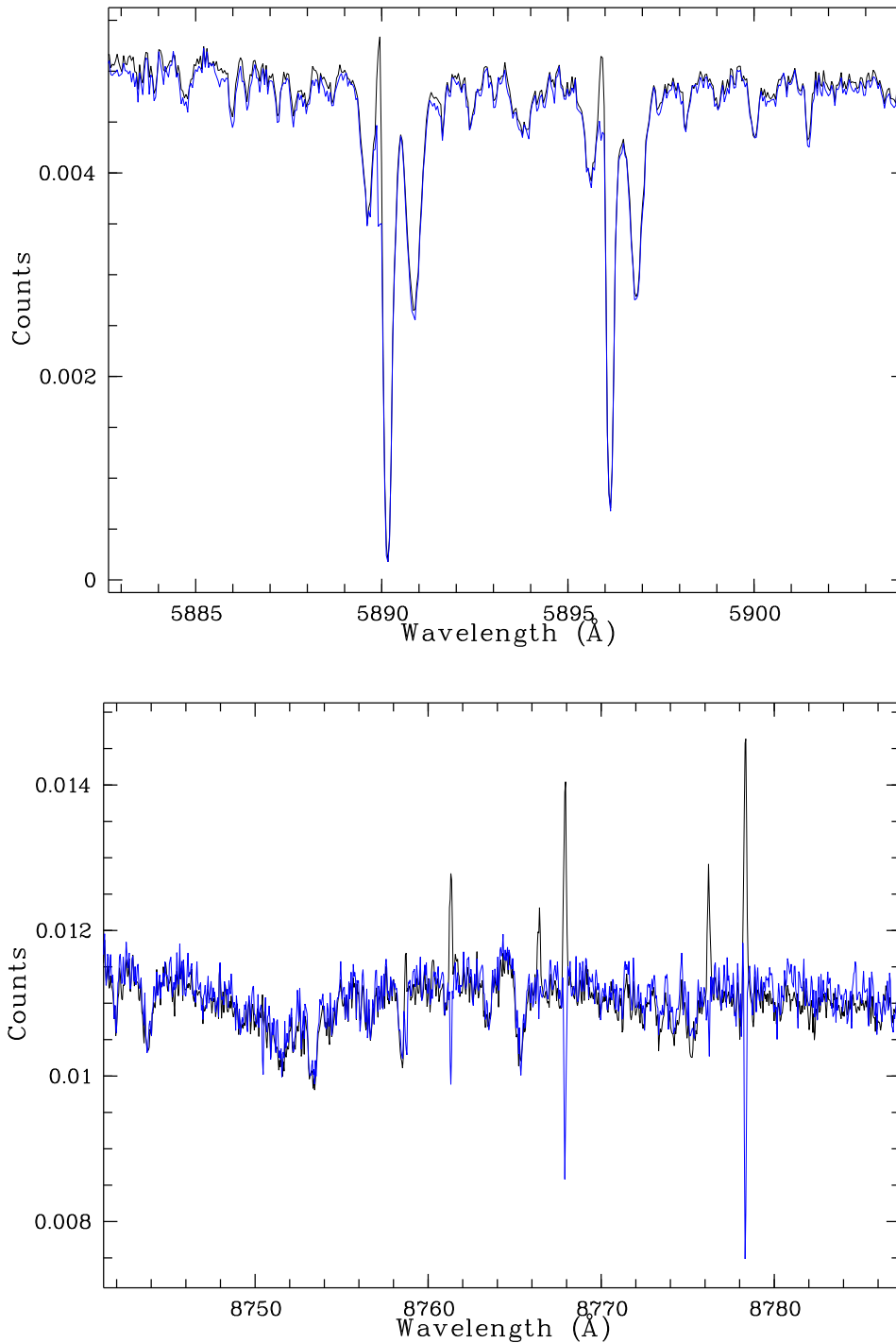


Figure 6: Examples of removing of night sky lines from HRS spectra after reduction with MIDAS. Both panels show result of the night sky removing in the HRS spectrum for one of star observed with SALT in HRS HR mode on 20160505. Exposure time was 1800 sec. The top panel shows such result in the very blue order, and the bottom panel shows such result in the very red order.



3 MIDAS pipeline for HRS HR red-arm data

All programs are written in MCL. The total length of the code is 450 MCL strings excluding comments. All steps are summarised into three main procedures:

1. **FLAT reduction**

During this step FLAT image is reduced. The output of this procedure consist of extracted and smoothed flats for both fibers and file with their ratio.

2. **ARC reduction**

During this step ARC image is reduced. The output consist of all tables, which are necessary for wavelength calibration of both fibers and extracted, calibrated and merged ThAr+Ar spectra for both fibers.

3. **Object reduction** The output consist of extracted, calibrated and merged spectra for both fibers and result of subtraction of the sky fiber from the object fiber as well as extracted, calibrated but not merged spectra for both fibers.

The output of all procedures is mostly FITS-files except configuration files, which are saved by system in the internal MIDAS format.

Each procedure has as minimum two modes of work: (1) **visualization mode**, when practically after each step user has a possibility to see and check the result of step, and (2) **silent mode**, when procedures work without any graphical output. Only the ARC reduction procedure has one more interactive mode for the possibility of re-identification of the reference spectrum.

Since the low level programs are implemented with C and FORTRAN code, reduction works very fast. The average time work of my procedures in silent mode on my laptop is ~ 25 sec for FLAT reduction, ~ 10 sec for ThAr reduction and ~ 30 sec for one OBJ.

4 Conclusions

HRS pipeline for HRS HR red-arm data is created and works.