Southern African Large Telescope

Title: **Stability of the HRS HS mode. The Red arm data**

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ABSTRACT

In this report I present results of the study of stability of the HS HRS mode. This analysis was done for the red arm HS data. The final result of this study shows that the HRS red arm instrument drift is about 2 m/s without taking into account the temperature dependence. After correction for the temperature dependence the final number for the HRS red arm instrument drift drops down to 0.00021 pixel that relates to the accuracy of about 40 cm/s at the wavelength of Hα line (6562.8 Å) that is absolutely the same accuracy ***as for the blue arm data****.*

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1 Introduction

I was requested to analyze HRS HS-mode stability in the way to check at what level do the object and sky/calibration fibers begin to deviate from one another. In this report I present results of my study of the red arm data. Explanations about used data and the primary data reduction, please, see in my previous report Kniazev (2020).

2 Method for selected lines

The second way I have tried was the same way I have used for the reduction of HRS data taken in LR, MR and HR modes. I have modified my programs in the following way:

1. to detect 33 echelle orders at the red arm data as the first step. This step was done with use of five echelle flats taken in HS mode on September 21st;

2. 2d background was fitted and subtracted to remove scatter light in between orders;

3. all 33 orders for each fiber from all 71 echelle arcs were extracted;

4. in each extracted fiber for each spectrum all emission lines were detected with use of the standard selection method in the `echelle` package of MIDAS that uses criteria of the FWHM and the threshold. I need to note here that the MIDAS standard selection method gives the fast possibility to select lines, but since it does NOT produce the accurate gaussian fitting its line positions it could be used as THE PRELIMINARY information in our case.

   All ~ 2700 emission lines detected in the first fiber of one 2D ThAr spectrum are shown in Figure 1. The distribution of the peak intensities of these detected lines is shown in Figure 3. All lines with the peak intensities in between $1 \cdot 10^5 - 4 \cdot 10^6$ counts were selected for the following analysis. Finally, 300 lines were selected with this criterion.

   The X-Y pixel distribution of all finally selected 300 ThAr lines is shown in Figure 2 with red filled circles.

5. For each line of the finally selected 300 lines in each order for all 71 spectra the Gaussian fit was done and 300 tables were formed. All analysis that was done for the blue arm data was repeated for the red arm data. Finally, only 208 lines out of 300 were used for the final analysis.

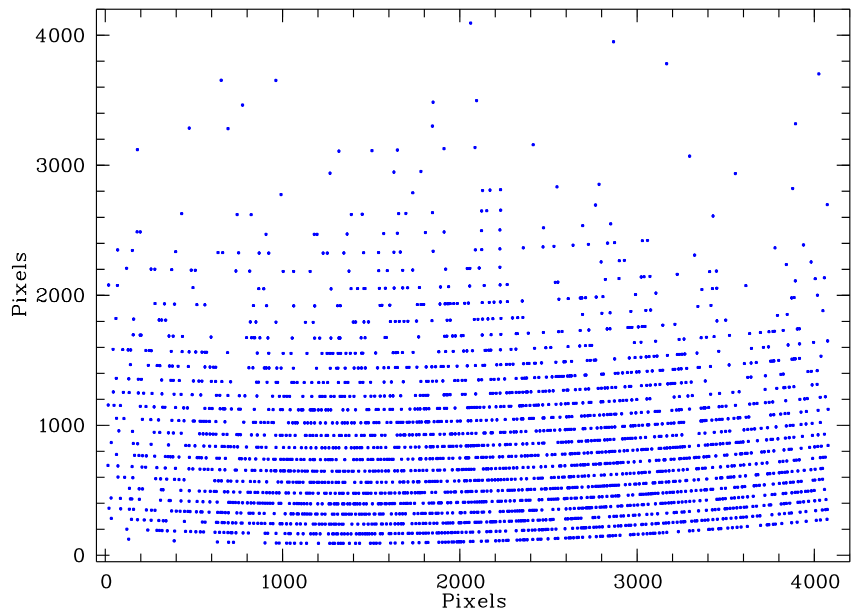

Figure 1: The XY-distribution of all found $\sim$ 2700 emission lines in the arc spectrum of the first fiber. Found lines from the second fiber are not shown because the difference in Y-coordinate is very small.

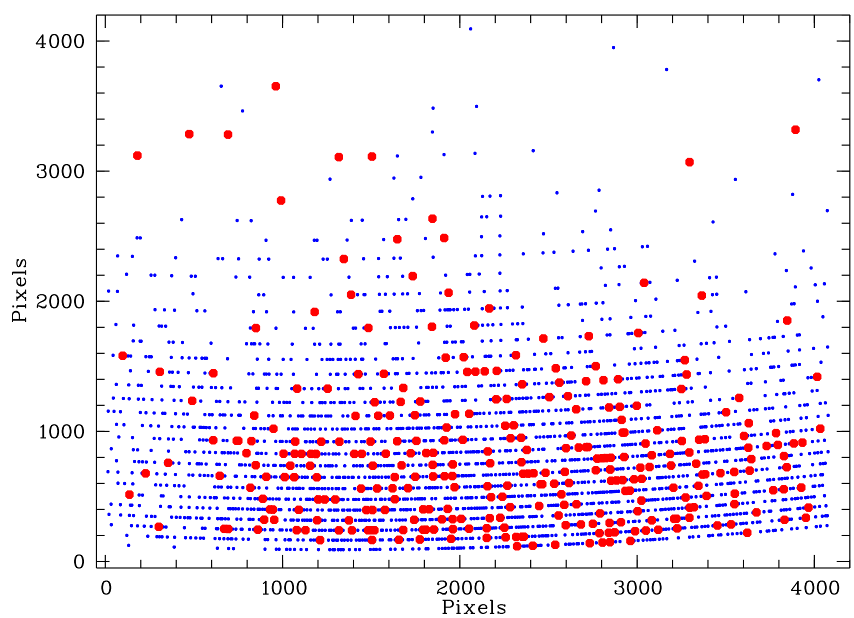

Figure 2: The distribution of finally selected lines is shown with red filled circles.

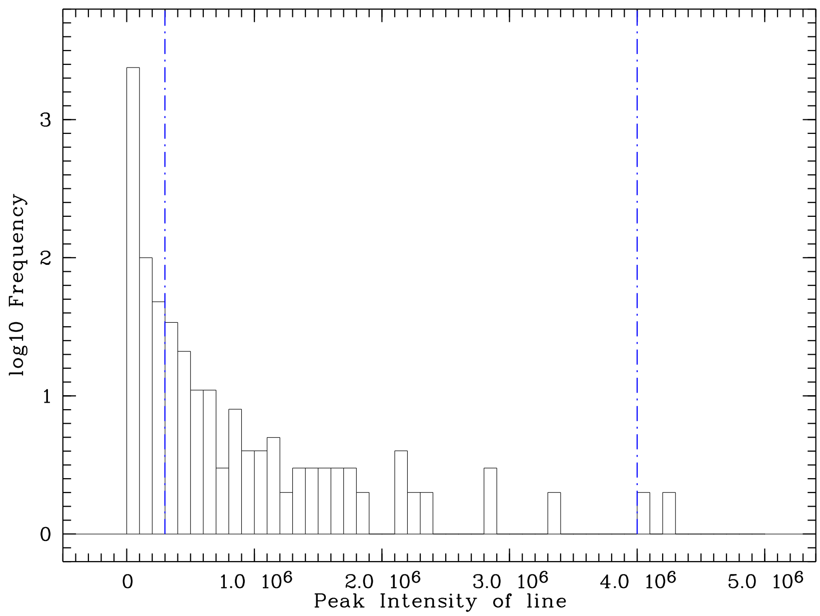

Figure 3: The range of the peak intensities for all found ~ 2700 emission lines. 300 lines were selected finally with the selection criterion of the peak intensities $1 \cdot 10^5 - 4 \cdot 10^6$ counts. This range of the peak intensities is shown with vertical blue lines.

2.1 Stability with the line-by-line analysis

The same way of the analysis was done as for the blue arm data for the line-by-line method. Figure 4 presents the distribution of standard deviations from the peak intensity of our analyzed lines. For the each intensity range plotted with blue lines I show the median value plotted with a red filled circle.

This distribution obviously shows that the final accuracy depends on the intensity of analyzed lines that is logic. The accuracy for centers of faintest lines is in about two times worse than for the medium intensity lines because any random factor changes the measured position of their centers drastically. Lines is the middle of the intensity range are the best ones and there is a range of line intensities exist where accuracy could be as high as about 0.0010–0.0016 pixel. However, starting from some intensity lines started to be saturated and accuracy started to be worse again.

I have plotted with the green line some level of the standard deviations (accuracy), which I was never able to reach with my method of analysis. **This level is about 0.0008 pixel or about 1.5 m/s for Hα line (6562.8 Å).**

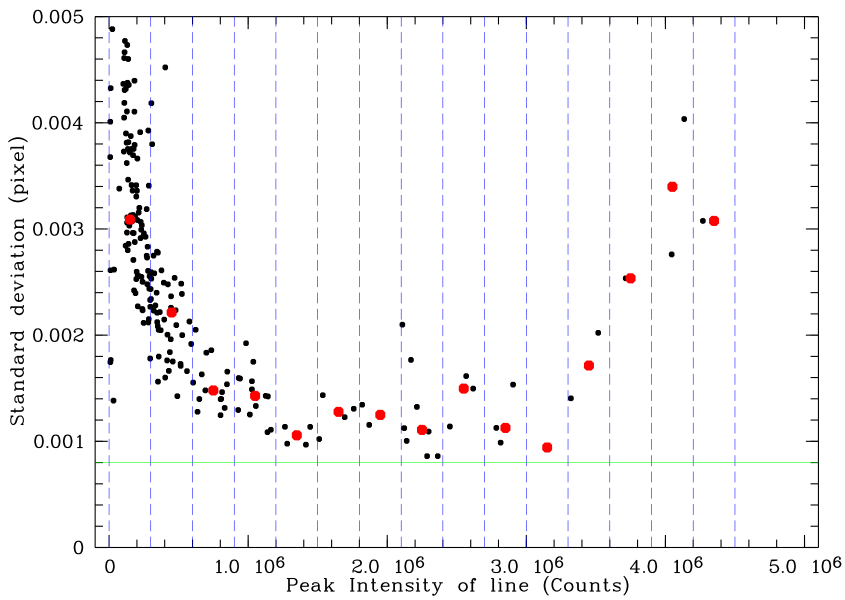

Figure 4: The final distribution of standard deviations of all analyzed lines depending on the Peak Intensity of line. For the each intensity range plotted with blue lines the median value is plotted with the red filled circle.

3 Stability with the frame-by-frame analysis

The second way I have tried was suggested by Dr. Arpita Roy and consist of the general idea to check the stability of the whole system of lines from one fiber relatively to another and check this stability with time for the whole system of our set of data.

The general algorithm of this test could be explained in the following steps:

1. I used all analysis results explained in Section 2 for the selection of 208 lines, positions of which could be measured very accurate, since they are separate and not blended lines in the very good range of their intensities.

2. The first frame was assign as a reference frame.

3. I calculated the difference in line position between each frame and the reference frame for all selected lines of the first fiber, and take the median and/or mean value of that. This is the absolute drift of the first fiber.

4. Repeat above step for the second fiber. This is the absolute drift of the second fiber. This absolute drift of the mean position is plotted in Figure 5 and shows that each fiber has absolute drift of the mean value at about 0.04 pixel during these two days of tests or about 75 m/s at the wavelength of Hα line (6562.8 Å). The plot of the median value shows absolute the same tendency and amplitude.

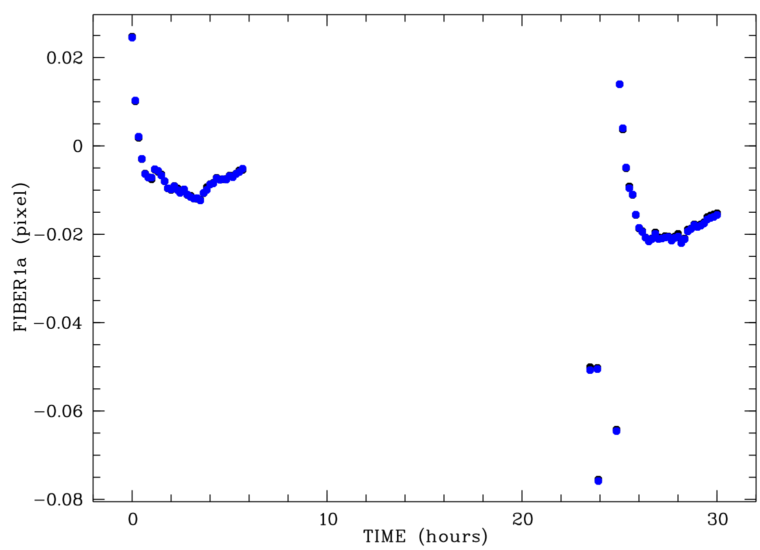

Figure 5: The absolute drift of the mean (median shows the same) position with time of each fiber. The mean position for the first fiber is shown with black symbols and for the second fiber is shown with blue symbols. Practically in all cases blue symbols are on the top on black ones. Time is shown in hours and covers two days with night of observations in between them.

5. Now, plot the drift of the first fiber minus drift of the second fiber. This is the instrument drift and it is plotted in Figure 6 and has amplitude of ∼0.001 pixel that is ∼40 times less compare to the drift of each fiber.

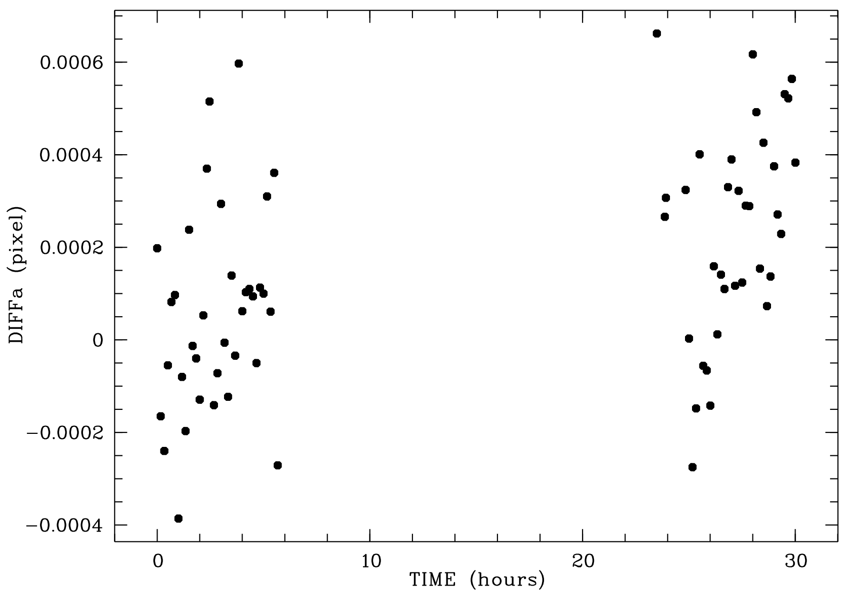

Figure 6: The instrument drift calculated for the set of test data.

3.1 Results

The above result (Figure 6) shows that the absolute drift of the HRS red arm is about 0.001 pixel that could be recalculated as 2 m/s at the wavelength of Hα line (6562.8 Å). At the same time all data obviously show some systematic trend.

Can we remove this trend out of our data? I analyzed this dependency on the different temperatures specified in FITS-headers for all HRS data: (1) SDSU controller temperature, (2) HRS environment air temperature, (3) Red camera temperature, (4) Collimator mount temperature, (5) Echelle mount temperature, (6) Optical bench temperature, (7) Vacuum chamber wall temperature. All these parameters shows about the same dependence and finally I have selected "Red camera temperature" as the most obvious for me. Such a dependence and its approximation with the first order polynomial is shown in Figure 7. Point from two different days of tests are plotted with different color to show that all data belong to the same dependence. The rms of approximation is 0.00021 pixel.

The final Figure 8 shows the instrumental drift with red symbols and the same drift after I subtracted the temperature dependence approximation from it (blue symbols). The final distribution has mean value as zero with very high accuracy and rms 0.000213 pixel that means is is dominated by the accuracy of approximation of the temperature dependence. The rms 0.000213 pixel relates to the accuracy of about 40 cm/s at the wavelength of Hα line (6562.8 Å).

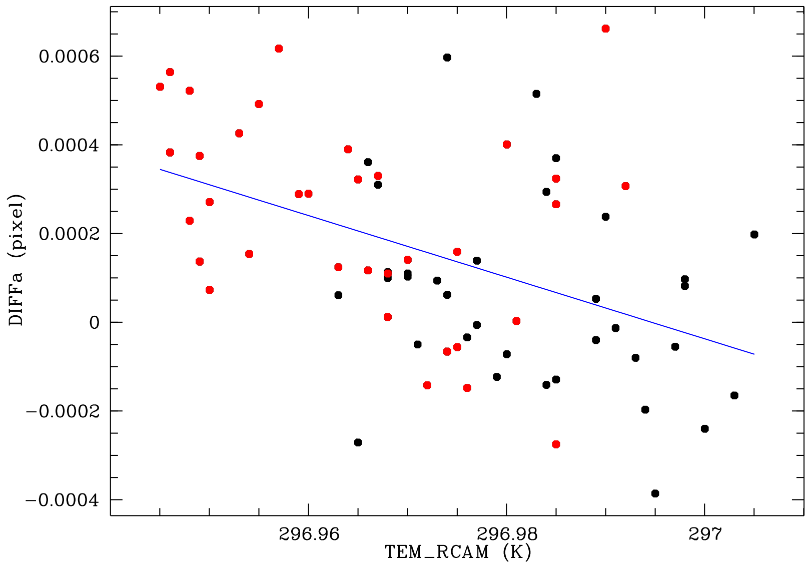

Figure 7: The dependence of the instrument drift on the red camera temperature for the HRS red arm data. Black and red points shows data taken during two different days of tests, where night time observations were taken in between. Blue curved line shows approximation with the first order polynomial.

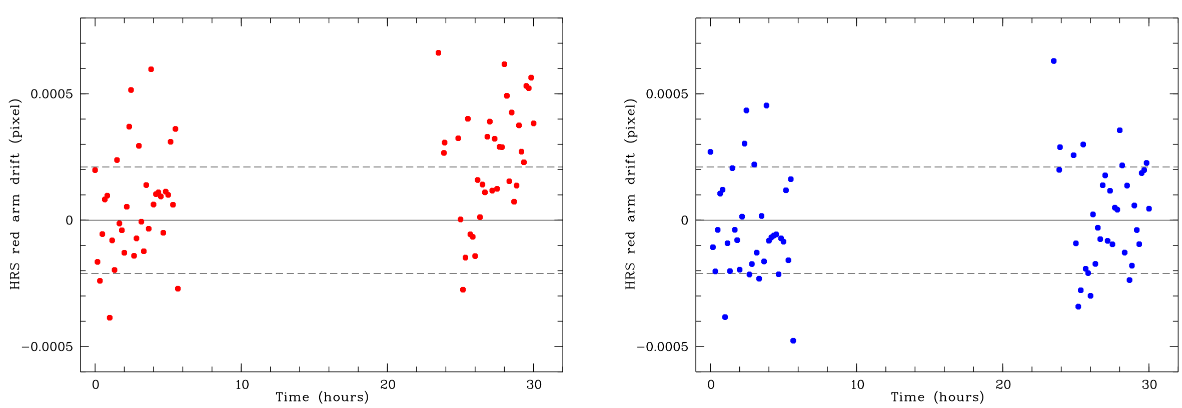

Figure 8: The final result. The left panel shows the instrumental drift with black symbols. The right panel shows the same drift after I subtracted the temperature dependence approximation from it with blue symbols. The final distribution has mean value as zero with very high accuracy and rms 0.000213 pixel that means is is dominated by the accuracy of approximation of the temperature dependence.

4 Conclusions

I see some conclusions as the result of my analysis:

1. The HRS blue arm instrument drift is about 2 m/s without taking into account the temperature dependence.

2. After correction for the temperature dependence that could be approximated by the first order polynomial, I found that the final number for the HRS blue arm instrument drift is 0.000213 pixel that relates to the accuracy of about 40 cm/s at the wavelength of Hα line (6562.8 Å) that is absolutely the same as for the blue arm.

References

Kniazev A. Y., 2020, "Stability of the HRS HS mode. The Blue arm data", SALT report HRS0000024, 1