Technical work with eShel

Report – October 2017

The 28/3-2017 the throughput of eShel suddenly decreased significantly, for which we thing the explanation is

1. That the fiber is damaged or broken. This would agree the a strong bend of the object fiber seen on several images after the the setup.
2. If not the object fiber, then the problem is related to the spectrograph or the FIGU.

Procedure

Simon Holmbo and I discussed how we effectively could check the above mentioned problems

- First a direct comparison between the "Old" Object Fiber (OOF) and a New Object Fiber (NOF) is needed. As both the calibration unit and spectrograph is placed in the container, an easy first test is to take a flat spectrum with the NOF (hence, simply connecting the NOF directly from the calibration unit to the spectrograph). Afterwards the OOF needs testing in isolation. To do this the OOF needs to connected to the spectrograph, and bring the calibration unit (without ThAr power supply) to the dome floor, in order to not move the OOF. The calibration unit uses a 12 V adapter which I will bring. If the two flats are different it is most likely that the OOF is damaged.
- Alternative the OOF can manually be bend/stretched at the points where is it suspected to be damaged, meanwhile flats are taking. If clear intensity differences appear on these images, the fiber is broken.
- In cases of equal flats between OOF and NOF, another test could be to connect the Calibration Fiber (CF) directly to the spectrograph. As the fiber-head diameter is 200 µm (compared to 50 µm for the object fibers) a higher throughput should be seen, and hence this can be compared to the expectations. It might be that some impurities within the spectrograph is the cause.
- Another test can be made is to send light through the OOF and take an image with the guide camera of the fiber-hole. There may be impurities close or at the fiber entrance to the object fiber.
- If none of the above mentioned bullet points do not give a clear result, creative thinking is needed.

Extra work if time permits

- If the throughput problem is solved right away, Simon is requesting me to look for, and bring back to Aarhus, a small device that can focus the spectrograph remotely. Hence, with this different orders can be focused without anybody which can be used for the second spectrograph in Aarhus. This device should be within the service building next to the SONG telescope.

- Seen in Fig. 1, which shows a guide camera image while taking a flat, three problems needs attention. First the light is casted into a coma-like shape, hence, there is a misalignment between the outgoing light from the CF and the flip mirror. This problem should be serviced first as an alignment will move the illumination source. Secondly, hereafter the fiber-tip of the object fiber needs to be adjusted to the COF of the flat (and ThAr) illumination. This can easily be done by adjusting some bolts on the side on FIGU. Thirdly, dust is visible on the mirror which needs cleaning by blowing it with clear air.
- Observe either a KIC star or θ Cyg to test the modifications.

Results

2017-10-03: Mentioned above the testing was done using flats exposures seen in Fig. 2. Seen in the two upper plots a initial comparison between a flat between the 6/2-2017 and the 3/10-2017 was made. It can be seen that the flux apparently have decreased a bit. The two middle plots is the direct comparison between the OOF and NOF, which shows no intensity difference, meaning the fiber is not broken. The lower left plot is after I mounted the OOF back into the spectrograph, and a big difference can already be seen, meaning the fiber most haven been mounted wrong. The lower right image is after I optimized the fiber illumination inside the FIGU. This optimization can be seen in Fig. 1.
To make the changes more clear Fig. 3 shows three flux-cuts through the cross dispersion for the 6/2 (—), the initial image from the 3/10 (—), and the final image from the 3/10 (—). The right-hand plot shows a zoom-in on the spectral oder of interest, and here is it clear that the intensity of this order have increased by a factor 10 from the initial to final image of the 3/10-2017.
I likewise made a check with the ThAr lamp as seen in Fig. 7. From top to bottom is seen an image from the 6/2, 29/2 (the day the flux-drop was noticed), and 3/10 (after the optimization). We here confirm the clear improvement by an increase of flux (likewise with an increase in flux of a factor of 10 from the 29/3 to the 3/10).

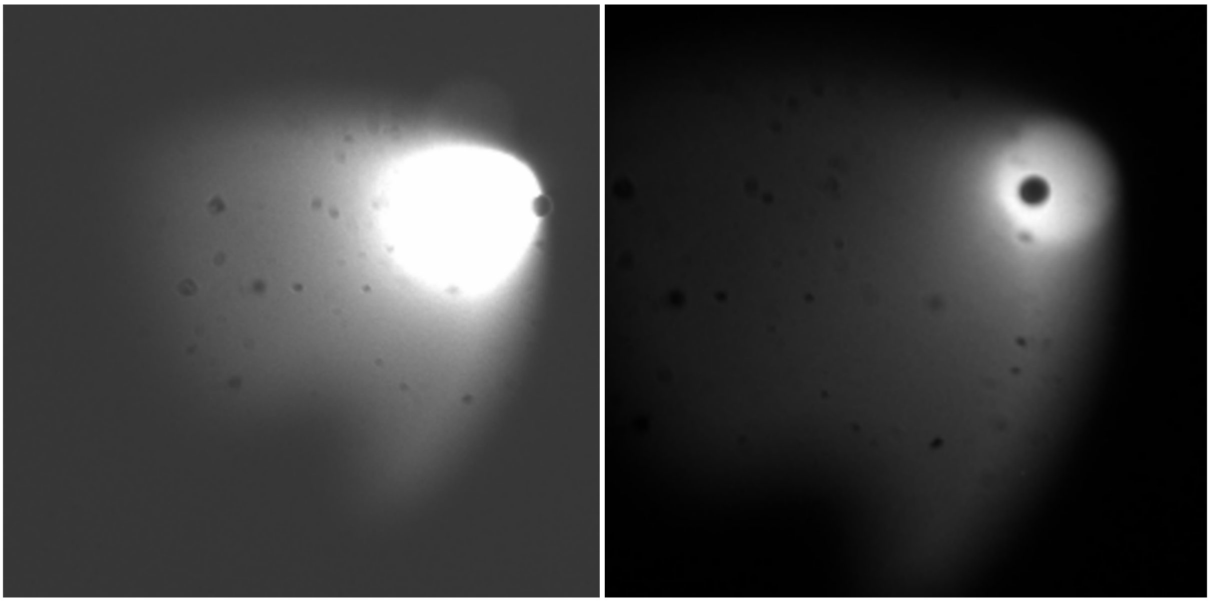

Figure 1: Two flats images taking with the guide camera showing the object fiber (or more precise the whole in the mirror) as a black dot and the reflected light from the flip-mirror. Left shows a guide image before the correction, and right shows after the correction.

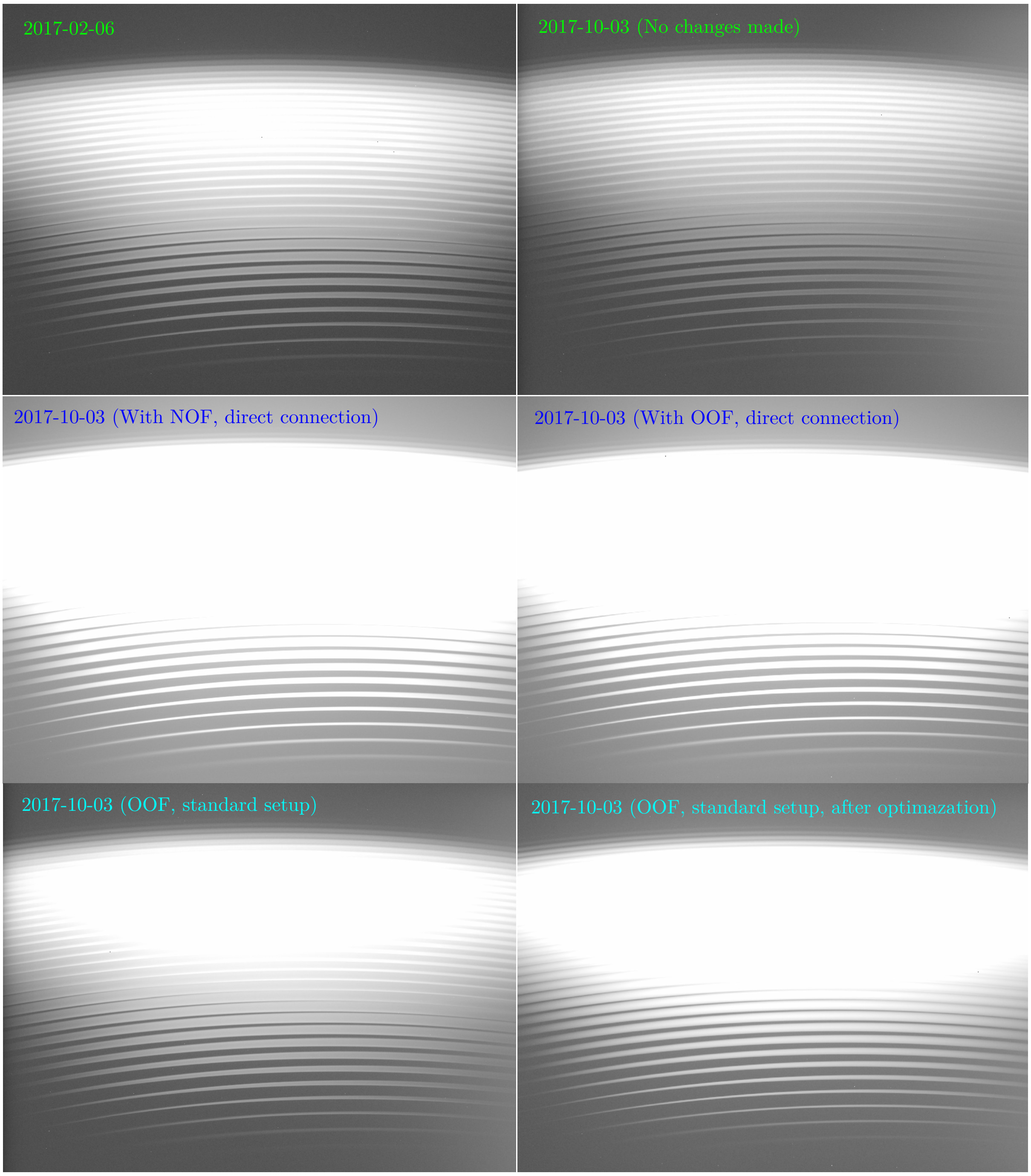

Figure 2: All images uses the same scale and with exposure times of 600 s. Top: left is from the 6/2-2017 and right from the 3/10-2017, where the standard setup was used. Middle: left is with the NOF and right is with the OOF both with direct connection between the calibration unit and spectrograph. Bottom: left are the OOF was remounted and right after the illumination of the object fiber was optimization by adjusted the flip-mirror (this was done by eye).

The same night Mads and I took a 300 s exposure of the start θ Cyg, which can be seen in the right-hand plot of Fig. 5. The left plot shows a 900 s exposure before my visit the 7/7-2017 (where almost no throughput can be seen). Clearly a big difference can be seen, and now the Ca II H & K lines is visible in the spectrum (•).

2017-10-04: I started the day by taking some flats of 600 s exposures to check that everything was working as it should. Surprisingly, the flats now showed a much lower flux than the day

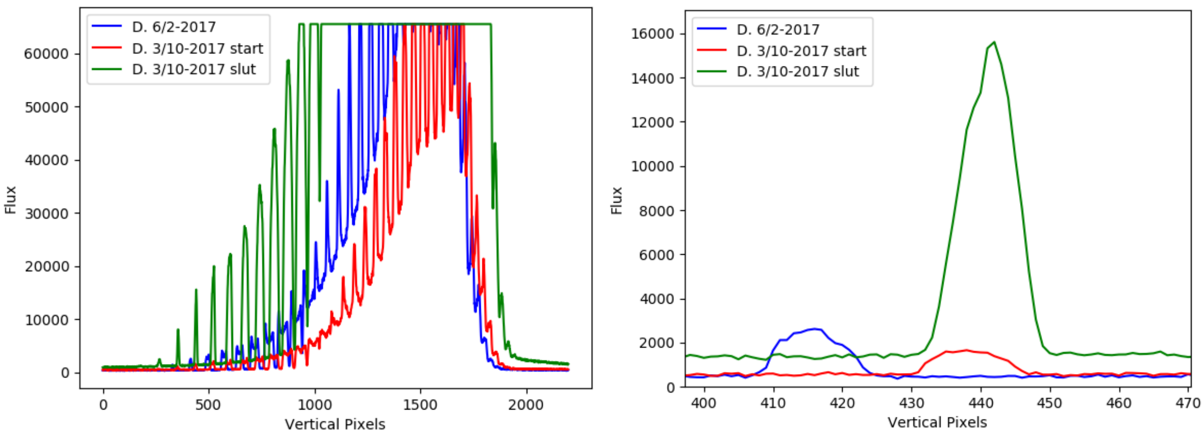

Figure 3: Flux cut through cross dispersion at mid pixel dispersion. Left image shows the total cross-cut whereas the right is a zoom-in on the order containing the Ca II H & K lines. The offset of the spectral order from the 6/2 (—), compared to the 3/10 (—) and (—), is due to a unknown physical drift-offset.

before. I made a direct test between the OOF and NOF, and both showed the decreased flux. Hereafter I tried to move around the setup to see if anything changed, however, it did not. I also power cycled the CCD and restarted the INDI server, but with no use. I then dismounted the fiber and looked at the illumination coming out of the fiber socket. Here is was clear that the Tungsten lamp did not work at all, and only 2 out of 6 LED lamps was functional. Seen in Fig. 6 our finding was confirmed looking at the PC board on the backside of the lamp electronics was burned (the green board). I write to Shelyak and they confirmed the finding from the images I took. They reasoned it to be because of an lamp use for an extended time period. Usually 10–30 second flat exposure is needed to get a good flat, but I was testing a very long time. As I tested most of the 4/10 without turning off the lights, this the board burned. However, no indications in the Shelyak manual says that he lamps cannot be used for an extended period of time.
Mads and I would like to remove the LED + Tungsten lamps from the calibration unit, as one then still could use the ThAr lamp after my travel back home, however, we estimated it to be too risky and it should be left for Shelyak to do. I thus took the whole calibration unit with me home to Aarhus for then send it to Shelyak the 10/10-2017.
2017-10-05: On my last day I tested the ThAr lamp, and likewise found an flux decrease from the 3/10 to the 5/10. This can clearly be seen in Fig. 7. Looking at a ThAr spectral line (•) I measured a flux decrease of around 41% (which agreed with comparing a flux summation of the images). I regularly took exposures the whole day of the 5/10, and observed a further decrease of about 15% in the flux level from the beginning to the end of this day. Hence, the ThAr lamp is dying and need to be replaced.
To test the setup of eShel was fine I tried to observe θ Cyg once again, to compare with the spectrum from the 3/10, however, we experienced some technical difficulties during the observation on the 4/10 and the 5/10. Hence, I will write a updated observing manual which is more specific. I will talk to Simon when coming back home.

Conclusion and Future work

- In total I solved the purpose of the trip, namely, increase the throughput to the eShel spectrograph, which was clear from the spectrum of θ Cyg. The improvement was most likely due to a wrong mount of the object fiber. Likewise, I improved the illumination of the object fiber inside FIGU meaning a higher flux (or lower exposure time needed) for flats or ThAr images

- The backside of the coin was that all the testing burned all the calibration lamps (LED + Tungsten). While this writing I have send the calibration unit back to Shelyak (France). The received it the 11/10, and will spend a few days repairing is.
- Also the ThAr lamp needs to be replaced and I will write a small manual in how to do so, as collaborator to SONG will do this on the site.

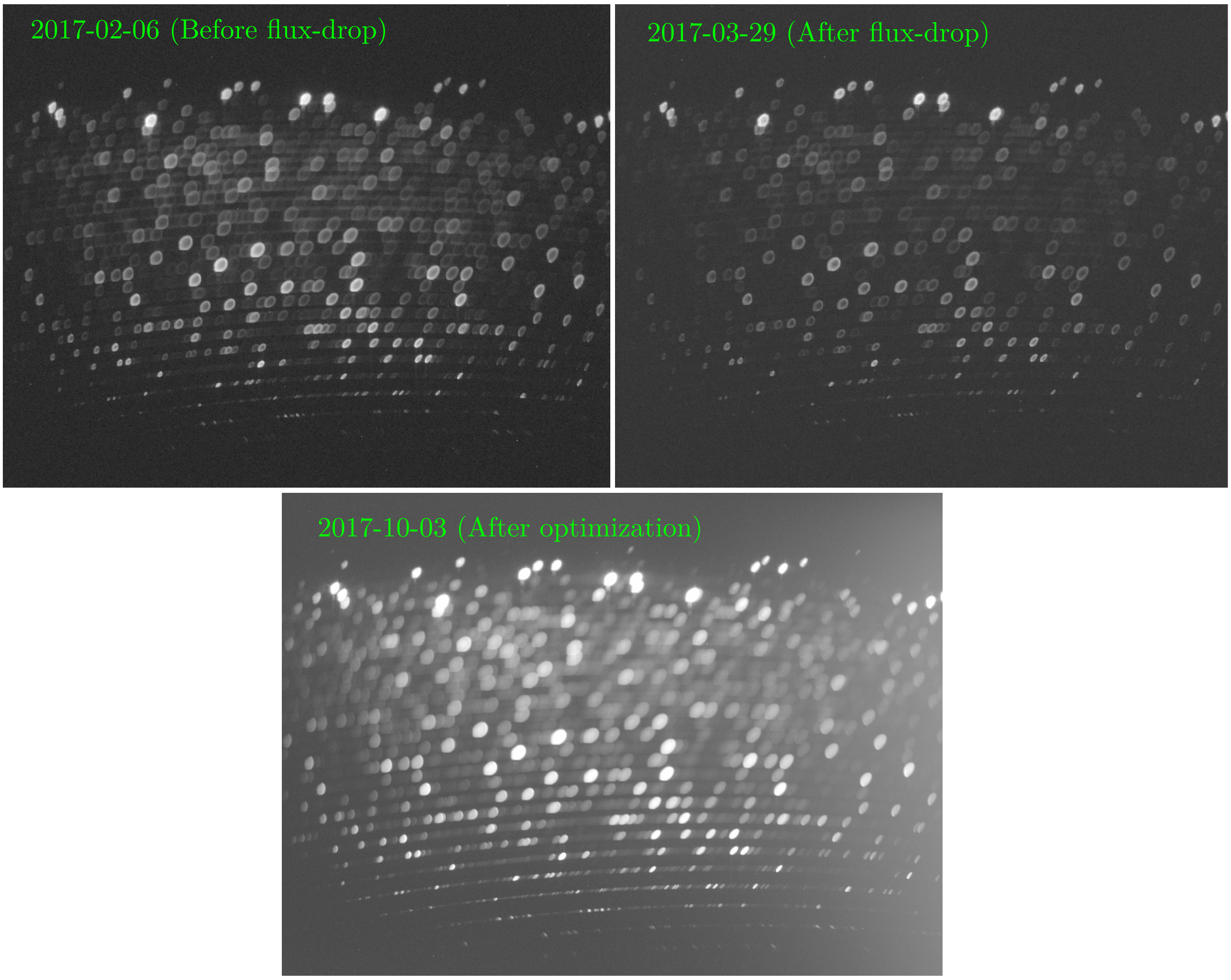

Figure 4: All images uses the same scale and an exposure time of 600 s. From the top left to bottom image a ThAr image from the 6/2 (before flux-drop), 29/3 (after flux-drop), and 3/10 (after optimization of object fiber illumination. Between the 29/3 and the 3/10 a factor 10 of flux excess is gained.

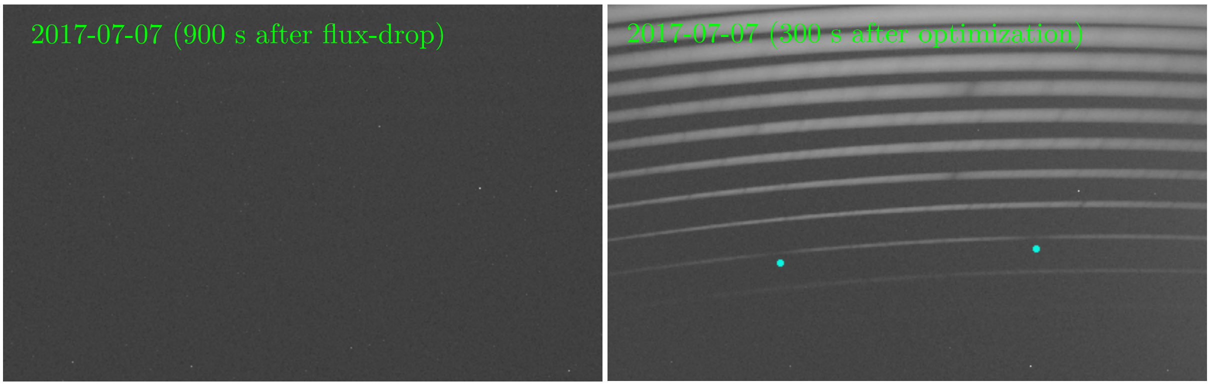

Figure 5: Two spectra of θ Cyg. Left is a 900 s exposure from the 7/7 (after the flux-drop) and right is a 300 s exposure from the 3/10 after optimization. Clearly, a big improvement can be seen and the Ca II H & K lines are now clearly visible (•).

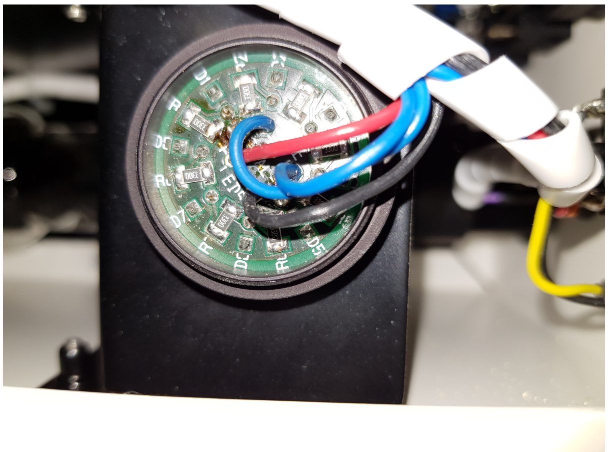

Figure 6: Electronics on the backside of the LED lamps + Tungsten lamp. It can be seen that the PCB is burned.

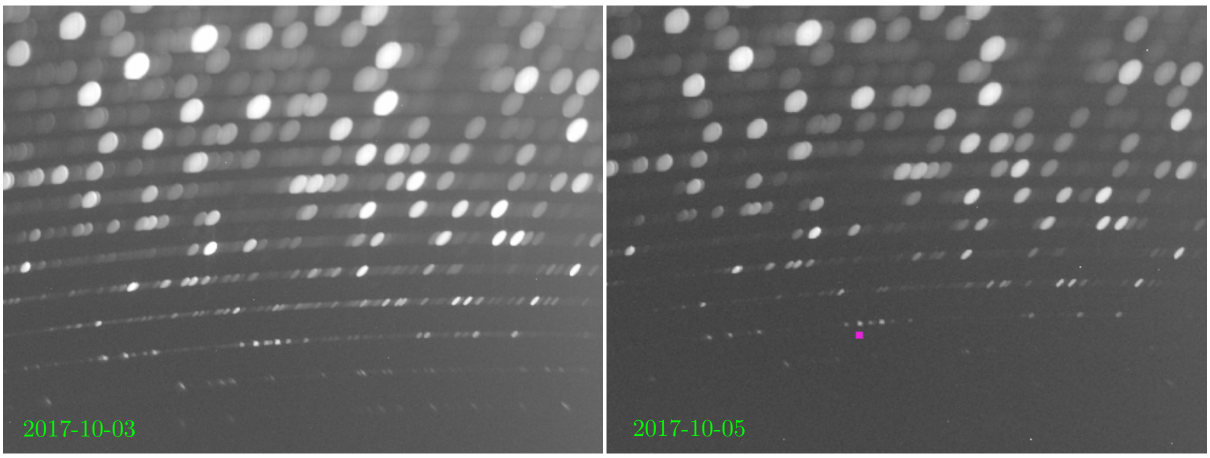

Figure 7: ThAr images from the the 3/10 after the optimization (left) and from the 5/10 end of day (right).

Future work

- A second image of θ Cyg is needed to verify the improvements.
- When the calibration unit is back it needs to be installed as fast as possible again. Likewise the ThAr needs to be replaced at the same time.
- As the connection to Atik 460ex was lost several times, we might need to test if there is a loose connection or a malfunction of the camera.

Guide to replace arc lamp (January 2018)

This is a guide short guide, for whom it may concern, to replace a arc lamp. The relevant setup can be seen in Fig. 8, and is physical placed beneath the main SONG spectrograph in the container. The complete setup is the calibration unit, the ThAr power supply, and the eShel spectrograph. The setup is currently shielded from its surroundings by a wooden box as seen in the upper-left image. As seen from the bottom images all the relevant wires, the fiber etc. is placed inside the wooden box. Next continue with the following steps to the calibration unit to the setup:

1. First step is to dismount the current ThAr lamp (if not already done). Now unpack the ThAr lamp and install this in the calibration unit by rotating the black socket labeled (1) in bottom-right image to the left until its unmounted. Now place the ThAr into the socket and replace it in the calibration unit.
2. Place the calibration unit beneath the ThAr power supply inside the wooden box and beside the spectrograph (just like displayed in the upper-right image.
3. Connect all electronics into the calibration units back-side, as seen in the lower-right image. Wire (1) connects to the ThAr power supply. Wire (2) connects to the 12 V power supply. Wire (3) connects also to the ThAr power supply. Wire (4) is an external power.
4. Turn on all the switches: *On*, *Mirror*, *LED*, *ThAr* and *Tung.*. For each a green light should indicate that each function is working. You can also try to turn each lamp on separately and look into the fiber outlet (dismount fiber if mounted) at the front side of the unit. White, blue, and purple light should be seen when turning on the LED, Tungsten, and ThAr lamp, respectively. IMPORTANT: When done switch off the *Mirror*, *LED*, *ThAr* and *Tung.*!
5. Now connect all electronics into the calibrations units front side, as seen in the bottom-right image. Wire (1) is the network, wire (2) the power to the guide unit, and (3) the optical fiber. When placing the optical fiber, first remove the black cap (OBS: do not touch the white outlet of the fiber). To connect the fiber properly, rotate the fiber until a small metal knot is visible on top of the metallic outlet. In this way it should be possible to put in the fiber and rotate it slightly (either to the left or right) to fasten it properly. Now rotate the ring of metal at the outlet to secure the fiber.
6. Lastly, make a quality check that everything is working as it should by following "How to take calibration images with kstars" in the *BlueSONG Cookbook*.

Figure 8: Setup of Eshel spectrograph (Spec), ThAr power supply (ThAr Power and the calibration unit (Calibration Unit). This was the previously working setup. ...Setup of Eshel spectrograph (Spec) and ThAr power supply (ThAr Power. The wooden box shields the current working setup. ....Upper panel: backside of calibration unit. The yellow and red numbers corresponds to the electronincs that needs to be connected. Lower panel display the network wire (1), power to guide unit (2) and the optical fiber (3). When connected it is important that all frontside swithces is turned on (*On*, *Mirror*, *LED*, *ThAr* and *Tung.*). Also, when attaching the fiber, only the right angle will fasten the fiber properly.

Report – Marts 2018

While working on an routine to find the optimal focus for eShel, I noticed the 2018-03-15 that the focus has changed. The change was so small that by visual inspection, after the ThAr replacement the 2018-01-11, is was not noticed.
Mads will travel to Tenerife around the 2018-03-20 and will shift the focus while I measure the focus remotely.

Results and Conclusion

The first thing Mads did was just remove and replace the object fiber. Seen from Fig. 9 this clearly made a big difference – actually there is also an clear improvement from my service visit the 2017-10-03 (—) to the current adjustments the 2018-03-22 (—). From the lower panel in Fig. 9 this is an improvement of the 20% in flux throughput for the internal eShel system (without the losses that might relates to coupling efficiency and the path before reaching FIGU). This immediately tells us that the fiber or spectrograph is very sensitive to changes. A ThAr image showed on the other hand that the focus is pretty much the same, however, the throughput is less compared to my service visit the 2017-10-03. This indicates that the previous lamp was more luminous (perhaps also warmer from many ThAr acquisitions that day, and hence warmer emitting more light?). I decided to settle with the initial improvement Mads delivered. Mads and Frank will used the object fiber the 2018-03-17 to test if this is suitable for the new node in Australia. Mads reattached the fiber the 2018-03-22. The focus remained the same and everything looked okay using similar test as mentioned above.
Perhaps by pure accident, it seems like Mads tuned the focus for the better just by removing and replace the fiber. If this is the case, this means that either this fiber, the fibers in general, or the spectrograph is very sensitive to changes.

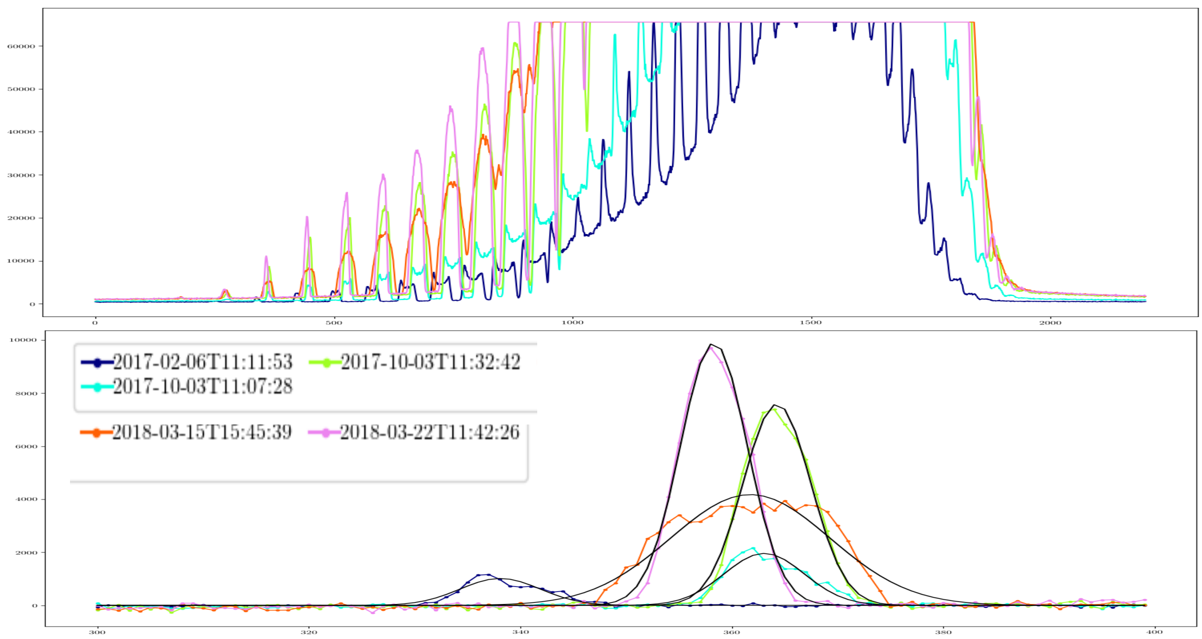

Figure 9: Flux slices in cross dispersion at mid dispersion for different important dates. Upper plot is for entire cross dispersion and lower plot is a zoom-in of the order containing the Ca II H & K lines with Gaussian fits to measure height and FWHM.

Report – April to November 2019

While starting the observations of a few target from HK-survey during the beginning of April, it was noticed that the Tungsten lamp died the 23/2-2019. Also meanwhile working on my thesis, several problems with the setup have been found by looking at the calibration frames for each day. For this reason a bigger service operation is needed to bring eShel to professional standards. I here divide the problems into each element of the eShel-SONG spectroscopic system:

Procedure

- **Object-fiber illumination:** (see Fig. 1)
  - **Alignment:** The light is casted into a comet-like shape, hence, there is a misalignment between the light from outlet of the calibration fiber and the flip mirror. This problem should be serviced first as an alignment will move the illumination source.
  - **Focus:** Hereafter the fiber-tip of the object fiber needs to be adjusted to the COF of the flat (and ThAr) illumination. This will increase both the efficiency of flat and ThAr acquisition and hence lowering the exposure time for these, which ultimately will mean the lamps last longer.
  - **Dust cleaning:** Lastly, dust is visible on the mirror(s) inside the FIGU which needs cleaning. While at it, the mirror reflecting the collimated light from SONG into the FIGU should also be cleaned.
- **eShel:**
  - **CCD efficiency:** To exploit the best CCD efficiency, the orders of interest should be placed centrally on the CCD image.
  - **Moving CCD frame:** On the other hand moving the spectrum centrally means that the camera focus needs to be changed. This might be good news, since we do not need to defocus it. This would mean the order would be more well defined also at the order edges, and less scattered light from defused consecutive orders will be present.
  - **Alignment problems:** Three alignment problems exist: (1) From the extracted stellar spectra so far, it is clear that the blaze function is affecting the spectra at the edges: at the order edge there is simply too little light (especially in the left order end). The sparse amount of light is most likely caused by a combination of vignetting of light (as the order is physically placed very low on the CCD) and because the Ca II H & K lines is dispersed in a very high order with generally lower efficiency (hence this we cannot change). (2) The maximum of the blaze lies into the H line core profile, and this should be changed such it lies in between the K and H lines. (3) Most easily seen in flat images, the order width is increasing with higher dispersion. The problem probably originates from the fact that the CCD is not exactly 90° angled in respect to the incoming light.
  - **eShel is leaky:** In late October 2018 I noticed eShel is extremely leaky, meaning when the light inside the container is on, this contaminate the calibration images. Obviously this effect is visible in darks, flats, and ThAr images, but have the strongest impact on dark images, which basically are useless as one begins to see more scattered light! This is a severe problem if we want integrate eShel into a fully automatic observing mode with SONG.
  - **Scattered light:** From the extraction procedure of `Blues` a high amount of scattered light can be seen in especially flats images. I noticed that the inside of eShel is wide open allowing light to scatter easily.
- **Calibration unit:**

- **Tungsten lamp upgrade:** The Tungsten lamp used has a Planck profile temperature of around 2800 K which leaves almost no light in the spectral domain of 4000 Å. If possible a lamp of $T \sim 6500$ K would give the desired peak intensity in the Ca II H & K order.
- **Tungsten detachment:** Just as for the ThAr lamp, it would be a great advantage if we could detach the Tungsten lamp from the PC board, such we easily can replace a new lamp ourself (instead sending it back to Shelyak).

Results

The second eShel spectrograph placed at ORO in Aarhus was collected and transported to La Palma for testing. The setup was not complete; a adapter frame (between the Atik 460ex camera the Canon objective lens, and a mini-USB cable were missing, which was bough ordered from ThorLab and borrowed from a student, Abel, respectively. For guiding this setup uses a QHY guide camera. Luckily both cameras can used within the acquisition software *kstars* (`Tools` → `Devices` → `Device Manager` → Under `Local/Server` choose `CCDs` → Select camera type and `Run Service`).

Object-fiber illumination:
From the eSehl manual the reflective mirror inside the FIGU can be adjusting by two screws close to the power cable connector. This mirror determines the angle upon light from the fiber enters to the guide camera, hence, with a given focus, the same flux will enter the hole in the mirror and the object-fiber. The real issue is the off-the-shelf F-ratio between the incoming bean from the calib-fiber and the mirror-slit. At the end of the calib-fiber mount there seem to be some optics to produce the desired F-ratio. Since only the angle, and not the distance, of the mirror-slit can be adjusted in respect to the calib-fiber outlet, the F-ratio can only be changed by moving the calib-fiber. Thus the socket for the calib-fiber needs to be changed. The idea of having FIGU is brilliant, but unfortunately it do not leave much freedom for adjusting. One possible test is simply to gently grind the metal off the calib-fiber outlet, such that the fiber can go further in the socket. Little by little a good focus might be possible to find. Fig. 10 shows the defocused guide image with the LED+Tungsten lamp on and the mirror-slit as the small dark spot. By simply turning screws the posioning of the hole can be adjusted but not the focus.

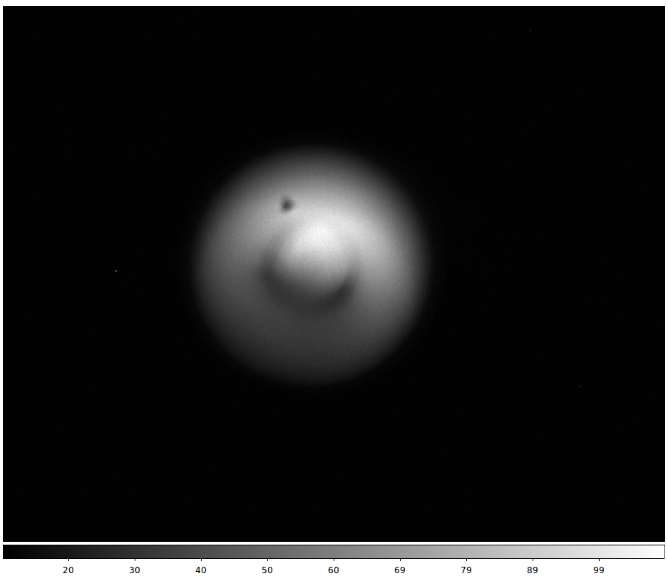

Figure 10: Guide image showing the object-fiber illumination (dark hole) with LED+Tungsten light, which clearly is out of focus.

eShel:
First the spectral orientation on the CCD was secured by changing the orientation of the Atik CCD itself. It is not possible to physically move the camera, as it has a fixed socket, hence the grating angle α (vertical displacement) and shifting angle γ (horizontal displacement) can be tuned. Seen in Fig. 11 (a) shows the bias frame gradient in electronic thermal exitation without cooling and (b) an initial flat. Thus an optimal displacement of the échelle orders are onto the low noise CCD area. (c) shows this spectral displacement after tuning α, and since we are only interested in a few orders (d) shows the read-out of these. This test showed that it is possible to move grating, and hence the orders onto the CCD, without any big loss of intensity. This means that we both get a efficiency for taking exposures (the read-out time is approx 1/4 lower) and storing data on the server (from 12.1 MB to 3.3 MB in this example).

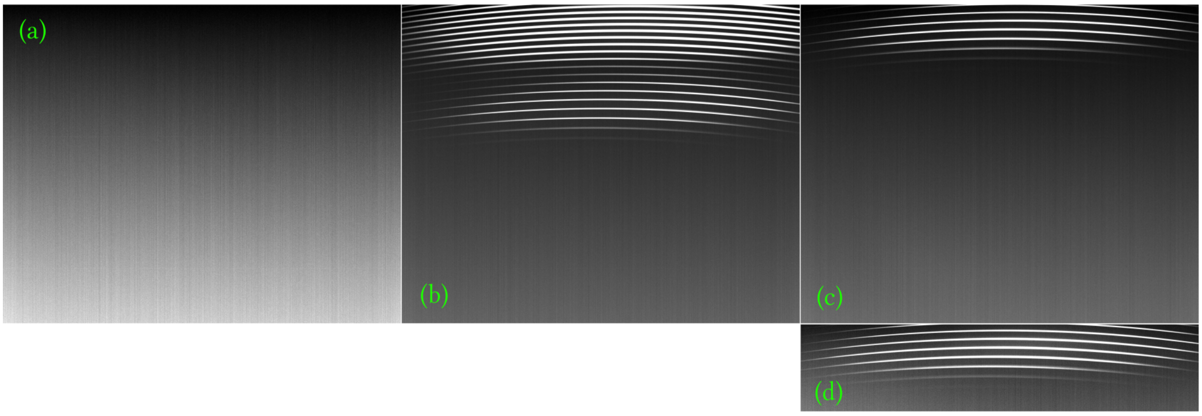

Figure 11: Spectral displacement of the ećhelle orders; (a) raw bias showing gradient in electronic thermal exitation without cooling, (b) Initial flat before changing α, (c) after tuning α for placing spectrum in low noise area of the CCD, and (d) only reading out relevant part of CCD.

Future Work

- FIGU: further work is needed to confirm if it's possible to focus the calibration light onto the object-fiber.
- Tungsten lamp upgrade: The Tungsten lamp used has a Planck profile temperature of around 2800 K which leaves almost no light in the spectral domain of 4000 Å. If possible a lamp of $T \sim 6500$ K would give the desired peak intensity in the Ca II H & K order.
- Tungsten detachment: Just as for the ThAr lamp, it would be a great advantage if we could detach the Tungsten lamp from the PC board, such we easily can replace a new lamp ourself (instead sending it back to Shelyak).
- test for horizontal displacement when ThAr lamp is working.
- Scattered light: scattered light could be minimized by simply building small metal plates working as "baffles" and place them on the inside of eShel's shell. However, if we can avoid opening eShel this is preferred.
- eShel is leaky: when all internal test have been performed, one can simply put gaffa-tape around all edges and test with dark exposures until there is no difference from when the light is on and off.