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Astronomical Instrument Centre

Report #4: Washing CCD's

Report on an attempt to re-vitalize the W11-4 CCD for the DFOSC

by

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1 Introduction

The DFOSC spectrograph/focal reducer mounted at the Danish 1.54m telescope at La Silla is currently equipped with a Loral $2k^2$ CCD detector, serial number W11-4. In order to achieve the required sensitivity in the 300nm - 500nm wavelength range, the chip needs UV-flooding.

Due to problems with maintaining a stable UV-flooded quantum efficiency and vacuum, the dewar was in June 1996 sent to Garching for leak testing, baking, cleaning and mechanical modifications, to be performed by Sebastian Deiries (ESO) and Niels Michaelsen (CUO). The CCD was removed and sent to Copenhagen University Observatory in order to measure the performance before re-installation in the DFOSC dewar.

2 Baking

The CCD was contaminated by a considerable layer, possibly oil, covering the entire surface.

In an attempt to remove the contamination, the CCD was baked in vacuum. Pumping was started at room temperature, and a pressure of $10^{-2} mBar$ was reached quickly. During the following four hours, the temperature was gradually increased to $+116°\ C$, the pressure decreasing to $10^{-3} mBar$. The temperature was kept constant for 18 hours, during which the pressure decreased to $2.6 \cdot 10^{-4} mBar$. The heating was stopped, and after two hours, at a temperature of $+60°\ C$, dry synthetic air at room temperature was slowly let in to reach ambient pressure.

Visual inspection after baking revealed that little, if any, change had occurred. The CCD was still severely contaminated.

3 Performance after baking

The CCD was installed in the dewar for the ALFOSC and the camera was cooled to $-100°\ C$ in order to measure the unflooded quantum efficiency in the passbands of eleven filters ranging from $334nm$ to $1060nm$. The overall QE is measured from the sigma-clipped average level of the central 600 by 600 pixels. This measurement is plotted in figure 1. An unusually high blue sensitivity is found: 30% in the $334nm$ to $405nm$ range.

The dewar was then allowed to warm up to room temperature and filled to atmospheric pressure with dry synthetic air. The chip was UV-flooded for 15 minutes and pumped and cooled immediately after.

The QE measured immediately after cooling, also shown in figure 1, is in the $300nm$ to $700nm$ range about 10% lower than what was measured by Mike Lesser (Steward Observatory CCD lab.) and [Sørensen, H. J. 95] on the same chip earlier. H.J.S. had to use a flooding time of 45 minutes to reach full sensitivity, though.

The sensitivity was monitored at regular intervals in the following days. A rapid decrease was found: About 8% was lost during the first day after flooding, whereafter the decrease slowed somewhat, probably changing exponentially towards the un-flooded QE. The change in time can be seen in figure 1, and more clearly in figure 2.

The structure of the flat field can be examined in figure 3 for exposures at $405nm$. Before flooding, the sensitivity dropped rapidly near the edges. Immediately after flooding, the QE is higher at the edges, indicating a more effective flooding there. All over the CCD, small specks with high sensitivity are seen. In time, the non-uniformities grows stronger, as the central area looses sensitivity while the edges and specks decays at a slower rate. While the exact same pattern of specks was registered by H.J.S., the decay of QE was earlier first seen at the edges. The current pattern of decay seems to be caused by the oil contamination, inhibiting UV-flooding and speeding up the decay in the central region.

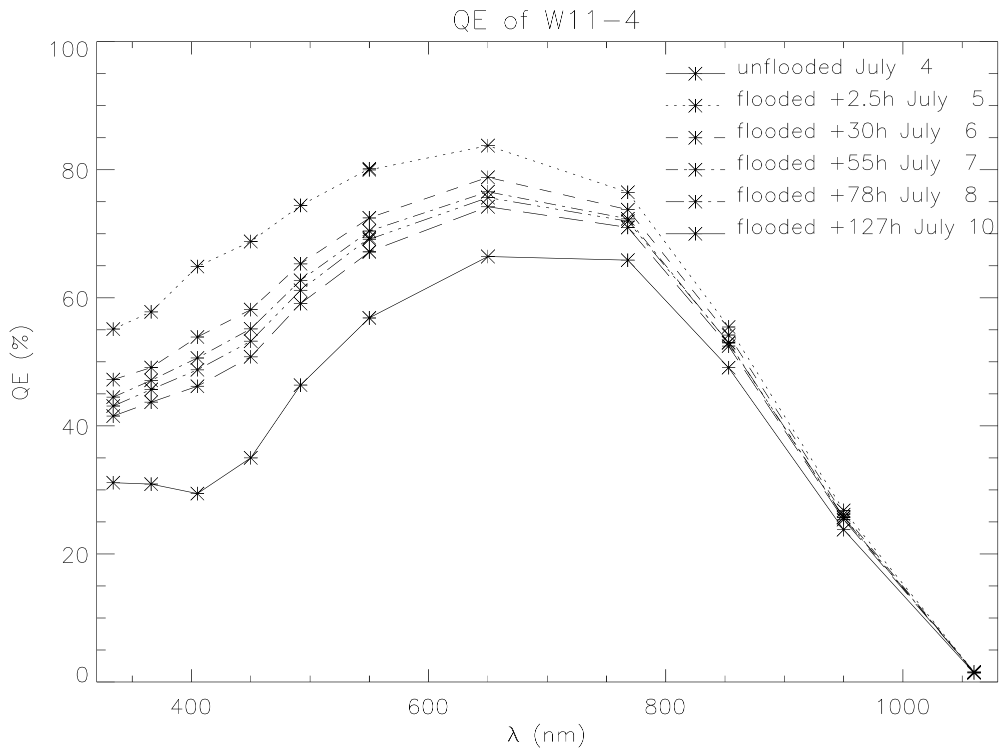

Figure 1: Plots of QE of W11-4 at different wavelengths, measured during a few days. First measurement is made before UV-flooding, the second immediately after cooling down after flooding. The development of the QE is then monitored, displaying a severe lack of stability.

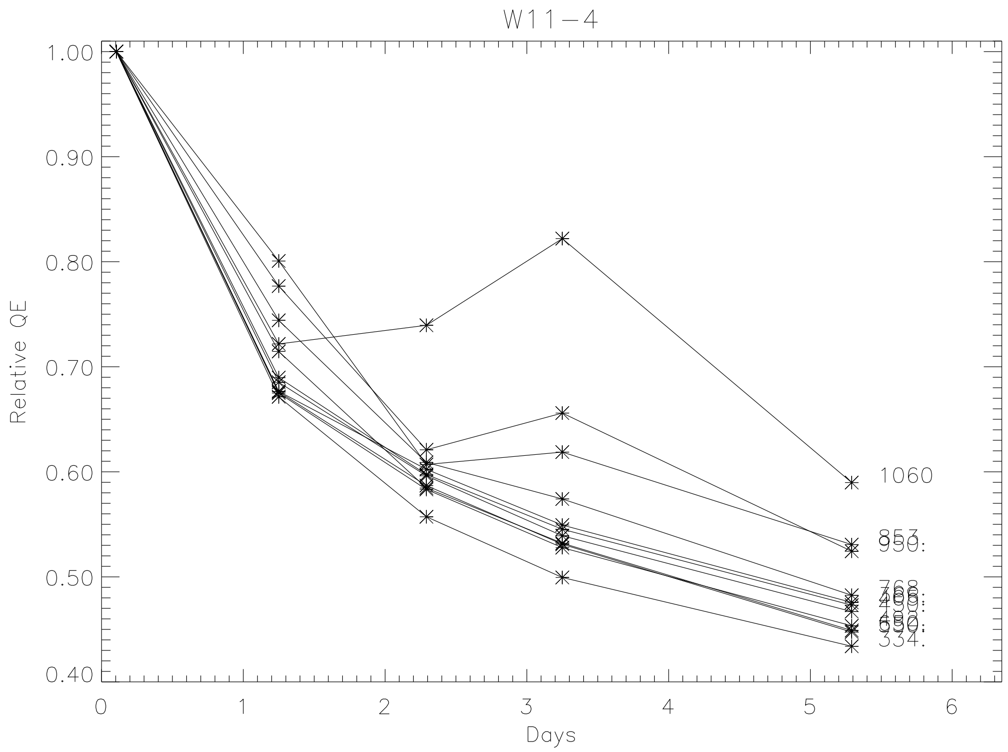

Figure 2: Relative decay of QE with time. Normalized to 1 for the measurement immediately after flooding, and un-flooded QE is scaled to 0. The decay appears exponentially with a half-time of about four days. The decay speed seems independent of color, when the near-IR points are excluded. In the near-IR, the effect of flooding is very small, so the relative decay is strongly affected by measurement errors.

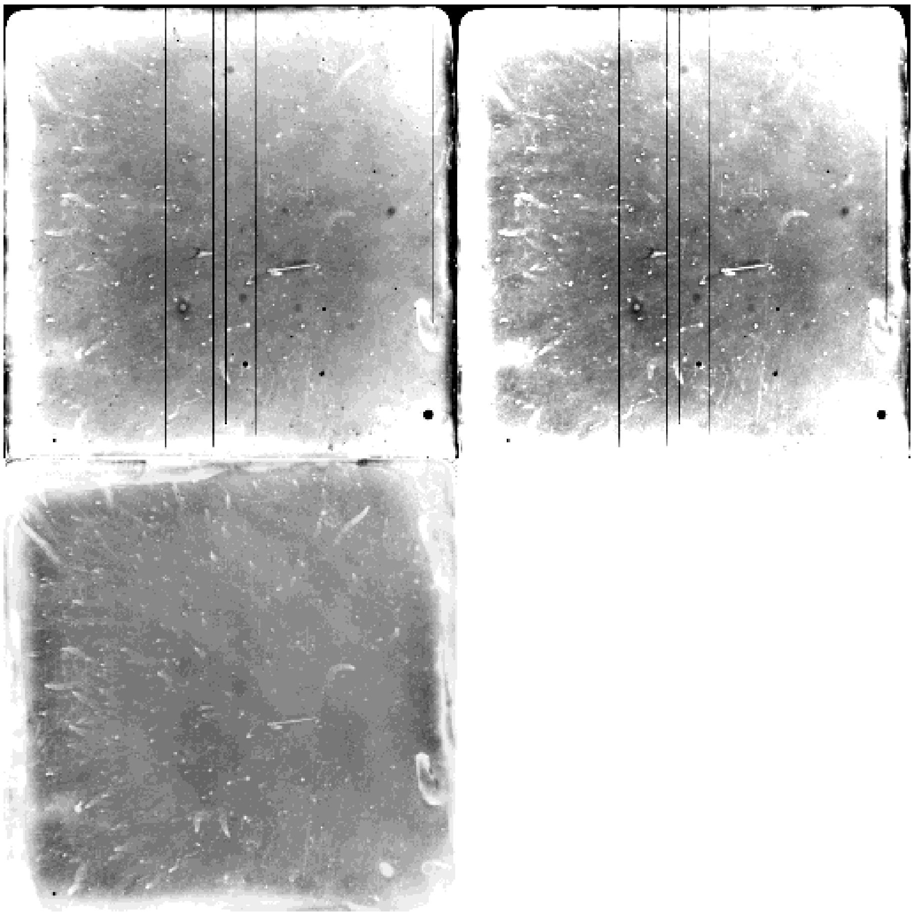

Figure 3: *Upper left:* Full frame flat field at 405 nm immediately after UV flooding. *Upper right:* Full frame flat field at 405 nm 28 hours later. *Lower left:* Ratio of the two flat fields. The white and black corresponds to deviations of 20% from the median level. The flat field is strongly non-uniform with higher sensitivity at the edges and and in specks of the size of a few pixels. The flat field acquired later shows even stronger irregularities with the sensitivity falling off most rapidly in the central region.

4 Washing

As the oil coating seemed the most probable cause of the lack of QE-stability, this had to be removed by washing the CCD.

A procedure for washing was provided by Mike Lesser. Due to lack of time, some deviations from the procedure were necessary.

Another CCD, W11-3, was selected to be the first subject to the washing process , in order to prevent damage from improper handling to the W11-4. W11-3 had previously suffered damage to the coating and had also been demonstrating lack of UV-flooded QE stability. Because of this, it is used for test purposes only.

Acetone and isopropylalcohol (IPA) was purchased from a pharmacy. Liquids of higher purity had been ordered, but did not arrive in time for the washing. Bottles of each liquid were heated in a bath of 50° C warm water, corks slightly loosened in order to avoid a pressure buildup. The temperature of the liquids were not measured directly, but seemed after an hour still to be significantly cooler than the bath due to vaporization cooling. Two 60 milliliter injection syringes without needles were filled with each of the liquids. Before, the plastic of the syringe was confirmed not to react with either acetone or IPA.

Holding the CCD with the connector at the bottom, pointing approx. 45° downwards, the CCD was first flushed with acetone applied to the upper edge in a sweeping motion. Most of the syringe was emptied in this way during about ten seconds. Immediately afterwards, before the acetone dries, flushing was done with IPA in the same manner. Then, the CCD was dried with a jet of dry air, initially directed from above to force the majority of the remaining liquid off the chip before drying. Mike Lesser's instructions were to use nitrogen instead of air.

The chip was then baked for at least an hour at $+45^\circ$ C in vacuum before installing in a dewar.

No change to the the visual appearance of the surface of the W11-3 CCD was noticed after washing.

The W11-3 was then UV-flooded, and a QE measurement was made immediately after and a day after. The rate of decay in sensitivity seemed unchanged as compared to measurements before washing. Neither were any changes in the flat-field structure seen.

The QE immediately after flooding did not reach the level from a previous, measurement but was about 10% lower. As no other changes of the properties were seen and the measurement setup had been modified in the mean time, a flux calibration error seemed a possible explanation for the discrepancy. It was then concluded, that the washing process was not harmful to the CCD.

The W11-4 chip was then washed following the same procedure. The majority of the visible oil layer was removed, but a few faint streaks were left. As nothing similar was seen on the W11-3, the streaks probably consists of oil that was dissolved, but not completely flushed off.

After baking, the CCD was installed in the cleaned DFOSC dewar, now at CUO, by Preben Nørregaard (CUO).

5 Performance after washing

The CCD was UV-flooded for 20 minutes in dry air at atmospheric pressure immediately after installation in the dewar. After evacuating the dewar for one hour, cooling to -100° C was started.

QE measurement was made immediately after operating temperature was reached and during the following three days. The results are displayed in figure 4. The initial qe is higher than measured before washing and is within a few percent of the measurements by Lesser and by H.J.S. Change in sensitivity is apparent during time, but is much smaller than seen before washing. The change is now chromatic. No decay longwards of $800nm$ is seen. In the $500nm$ to $700nm$ range, a decay of approx. 2% per day is occurring, with no convergence towards a stable level seen during the short monitoring time. Around $400nm$, a tendency towards increasing sensitivity is seen. The measurement errors are relatively large here, but the change seems significant.

Due to the rather different color dependence, we may be observing a phenomenon unrelated to the surface charge. While a significant decay of the sensitivity at wavelenghts longer than $800nm$ was observed before washing, no decay is seen now. From this it is concluded that the UV-flooding is stable, but the QE is now changing due do other factors.

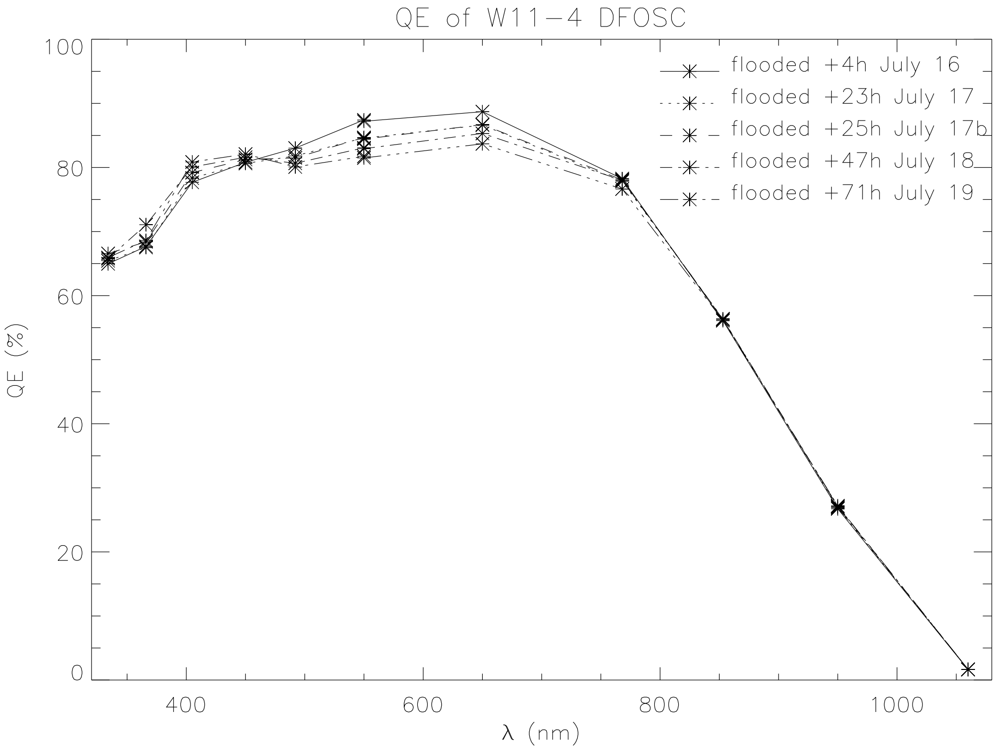

Figure 4: QE of the washed W11-4 immediately after UV-flooding and during the three following days. The QE has increased and the stability has improved, but still shows a considerable chromatic change.

In figure 5, the structure of the flat field after washing is displayed. The uniformity of the flat field has improved, leaving only a small fraction of the pixels outside 3% of the median level. A modest drop in sensitivity is seen at the edges, and the high-sensitivity spots are difficult to detect.

During the next three days, some small scale structure appears, partly the specks seen before, partly a pattern consistent with the residual contamination observed visually. The largest change occurs along one edge of the CCD, where the relative difference in sensitivity is 5% at the extreme edge. Inspection of day-to-day changes shows the largest change in structure occurs during the first day, while the difference from day 2 to 3 is very small.

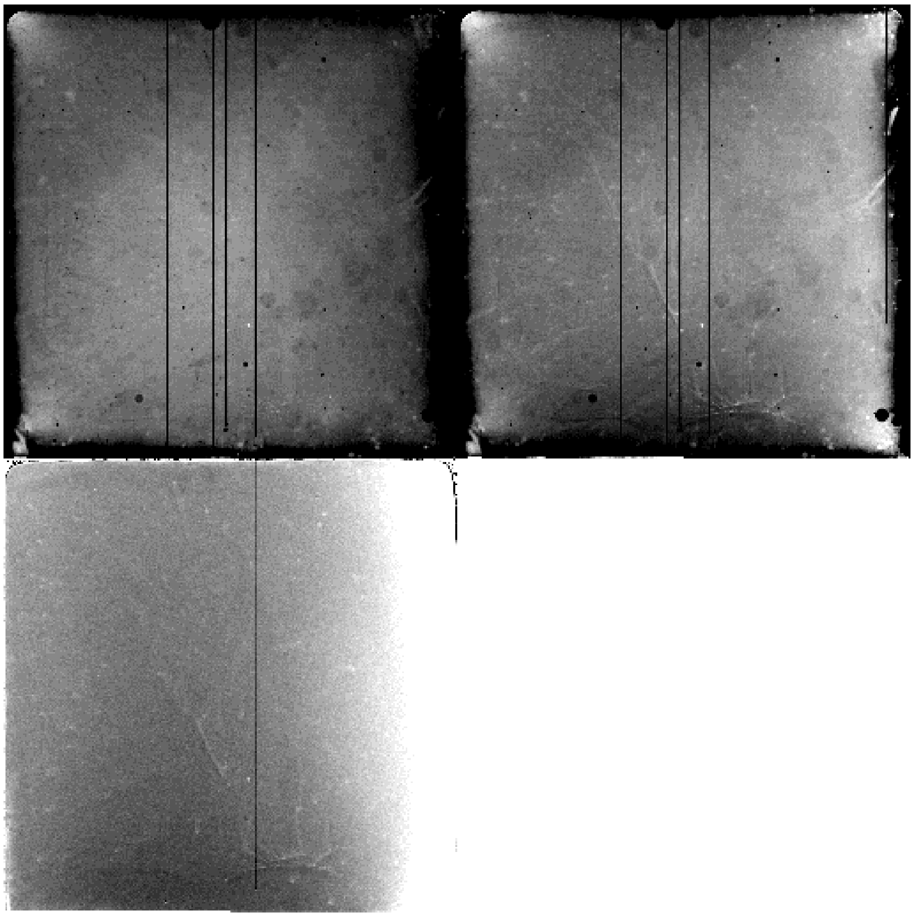

Figure 5: *Upper left:* Full frame flat field at 405 nm immediately after UV flooding. *Upper right:* Full frame flat field at 405 nm three days later. *Lower left:* Ratio of the two flat fields. The white and black corresponds to deviations of 3% from the median level.

6 Performance after installation on the DFOSC

The camera was heated to room temperature while pumping, and then transported to La Silla. Upon arrival, after about 4 days, the pressure was of the order $10^{-2} mBar$.

After installation and functional testing by Preben Nørregaard, the camera was pumped, filled with dry air, UV-flooded, pumped and then cooled to $-100° C$. While the QE could not be measured, the performance could be estimated from the appearance of flat fields, the count rate from a radioactive flouresence source. In addition, Jesper Storm (ESO) and Isabel Perez (ESO) acquired photometric data on standard stars.

During the first night of operation, the flat fields in all broad band filters were strongly non-uniform, and resembled the flat fields acquired after baking the chip in Copenhagen.

Apparently, the outgassing from the activated charcoal and other components normally occurring at room temperature had contaminated the CCD to a degree where uniform UV-flooding was not possible.

It was decided to un-flood the CCD, which was attempted by baking in vacuum at $+50° C$. Flat fields subsequently still showed strong non-uniformities and high sensitivity at the edges, indicating the partial UV-flooding still to be in effect. Monitoring of flat-fields and flouresence source counts showed the sensitivity to be decaying rapidly with changing structure during the following days.

The appearance of some of the specks with high sensitivity, a peak surrounded by an area with low sensitivity, caused some concern that possibly a lensing effect was involved. As the blobs were not seen after washing and were in the same positions as before washing, the effect could not be explained as droplets on the surface, but possibly as variations in the surface charge, causing migration of electrons parallel to the surface. Images of the slit with the edge passing over specks were made in order to detect geometric distortion associated with the lenses. No such effect was detected, but proper flat fielding seemed difficult. In figure 6 a speck with 80% higher than average sensitivity is shown. This was obtained after the attempt to un-flood the CCD. Assuming a nearly complete decay of the UV-flooding, the variation in sensitivity corresponds roughly to the difference between flooded and un-flooded average sensitivity. The speck of high sensitivity can then be explained as an area with a potential equivalent to a properly UV-flooded area, with no lensing required. The flat fielded image has an intensity error of approx. 5% at the location of the speck. The flat field was obtained a few minutes after the slit exposure, so a change of the flat field properties had not had time to occur.

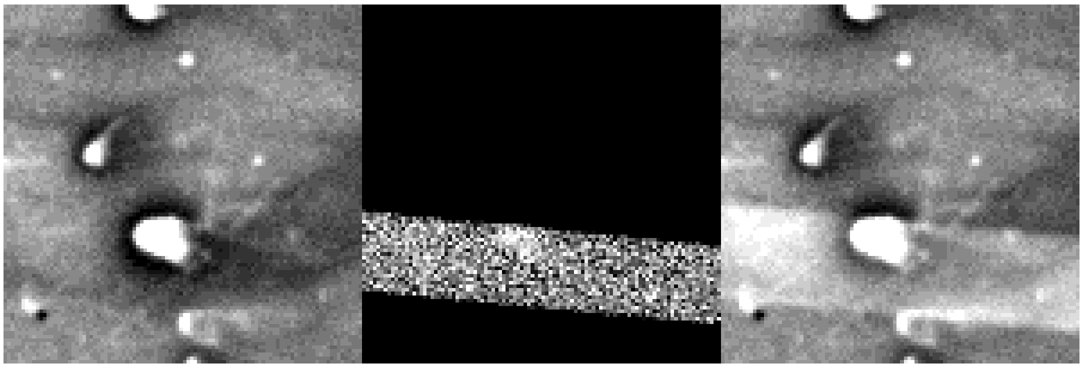

Figure 6: B-band images in the section [400:500,280:380] demonstrating flat field properties of specks with high sensitivity. *Left:* Dome illumination flat field. The white and black corresponds to deviations of 15% from the median level. *Middle:* Flat field corrected image of the slit. *Right:* Slit image and flat field superposed.

7 Conclusion

The attempt to bring the W11-4 CCD to the nominal performance at the DFOSC was a failure. The performance immediately after washing was satisfactory, but the CCD seems overly sensitive to even weak contamination as happened during the room-temperature transport. As a consequence, it can not be used in UV-flooded mode under observing conditions.

The improvement in performance immediately after washing is very encouraging, as the washing procedure seems effective in de-contaminating the CCD, without damaging it. This is suggested as a standard procedure as a more efficient alternative to baking, which has proved a dangerous method.

References

[Sørensen, H. J. 95] Sørensen, Helge Jønch : **DFOSC CCD-camera and Dewar test report**, September 1995, Copenhagen University Observatory.