Report on the HAWK-I sky subtraction problems

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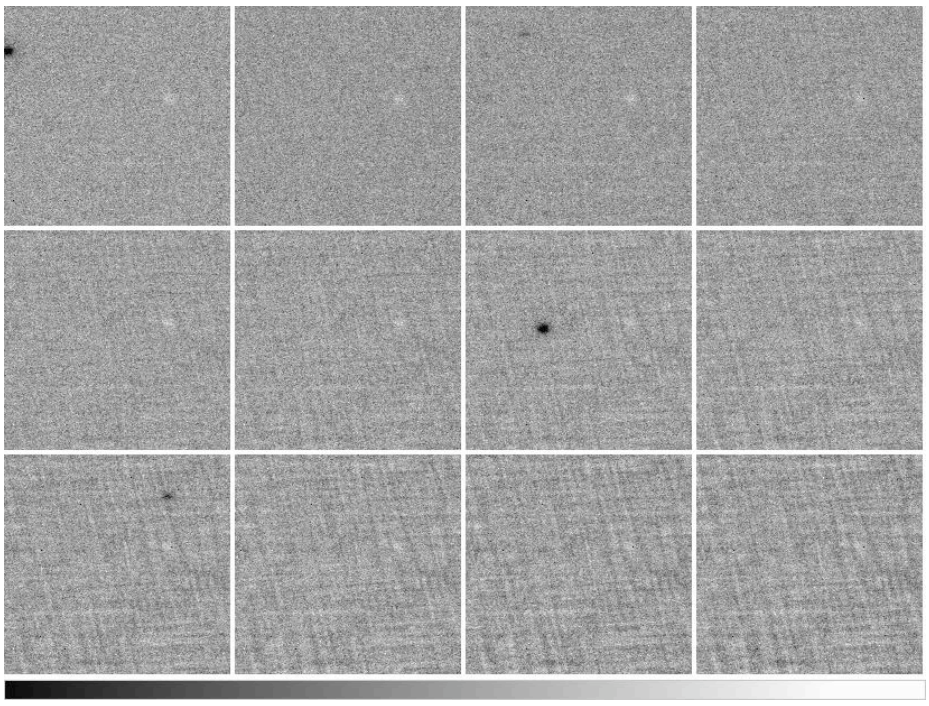
1. Description of the problem.

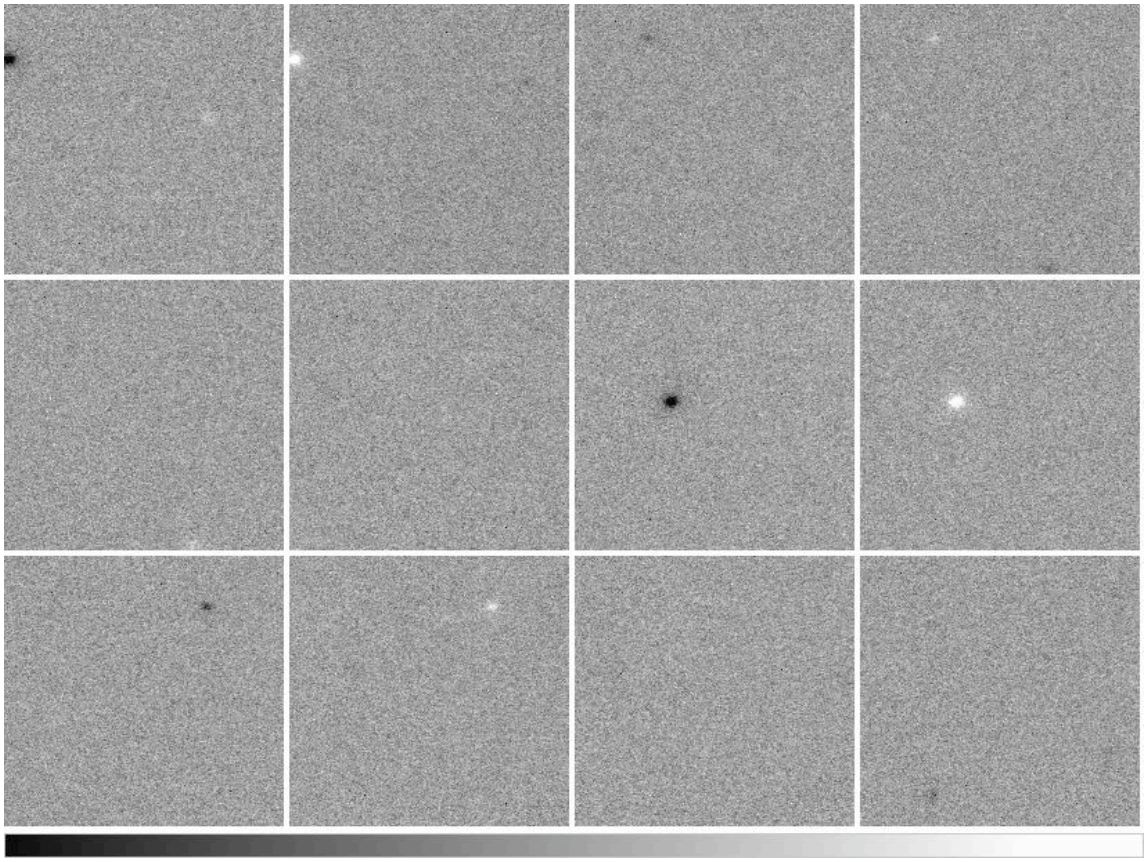
During the first run of HAWK-I observations a problem with sky subtraction was uncovered. The following set of frames show the effect:



The figure shows the differences of a set of frames with DIT*NDIT=60 s, the first tile shows frame 2 – frame 1, subsequent tiles show 3-1, 4-1, etc. We can see a rapidly deteriorating quality of the sky subtraction, and the appearance of a cross-hatched pattern.

2. A possible post-processing solution

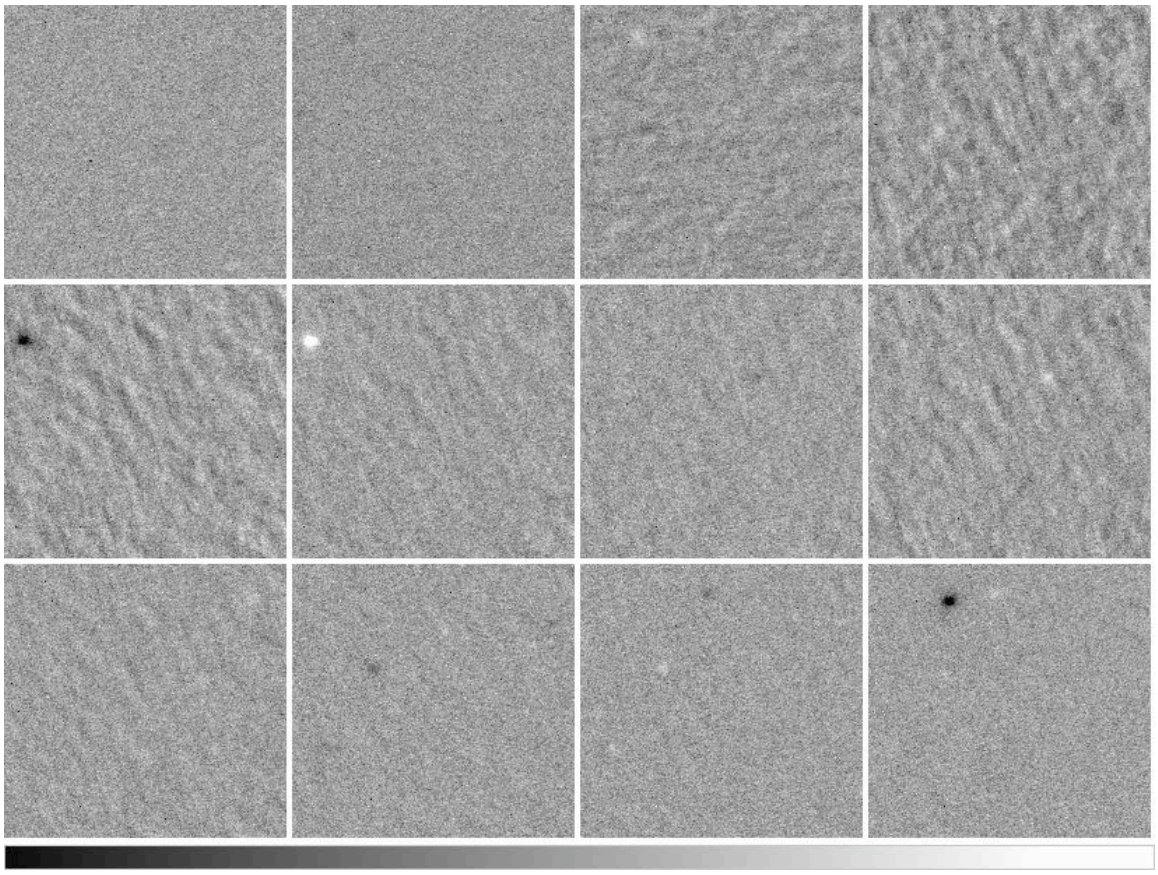
When the set of frames is shown by subtracting consecutive frames, that is, frame N+1 – frame N, we obtain the figure that follow:



At the data reduction stage one can limit the frames used for sky estimation to a window including the immediate neighbours or at most the next set of frames. However, this solution only works well if the pupil rotation between consecutive frames is less than ~0.5 degrees.

3. Caveat emptor

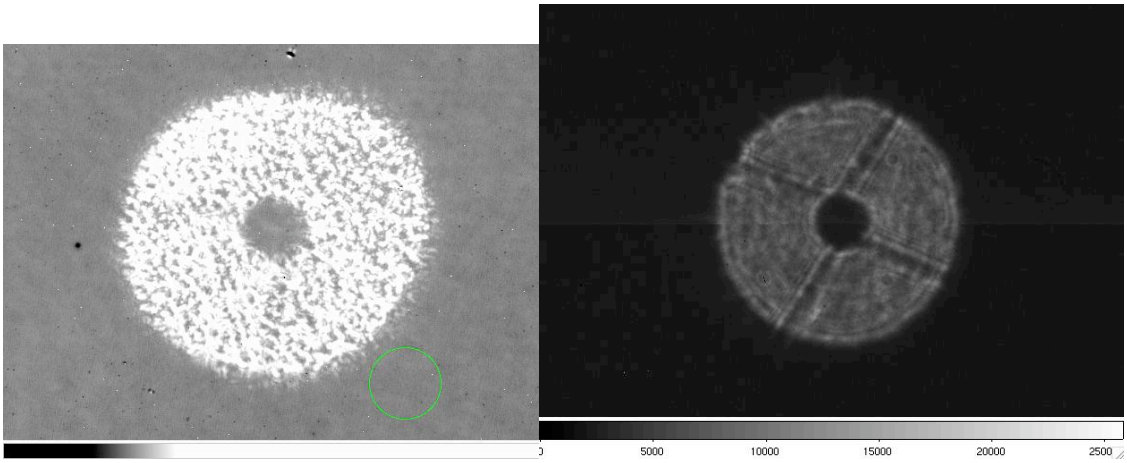
The reduction of the data in this way in which images are subtracted pair-wise can increase the noise in the final product by at most 40%. Nevertheless, the problem is a bit more serious as the following set of consecutive differences show: once in a while a sudden increase in the sky noise is observed (as a mottled pattern). This appears to indicate a sudden shift of the field with respect to the entrance window.



4. Possible origin of the problem

The origin of the effect has been traced to a damaged inside coating of the Dewar window, showing up as little spots in the following picture:

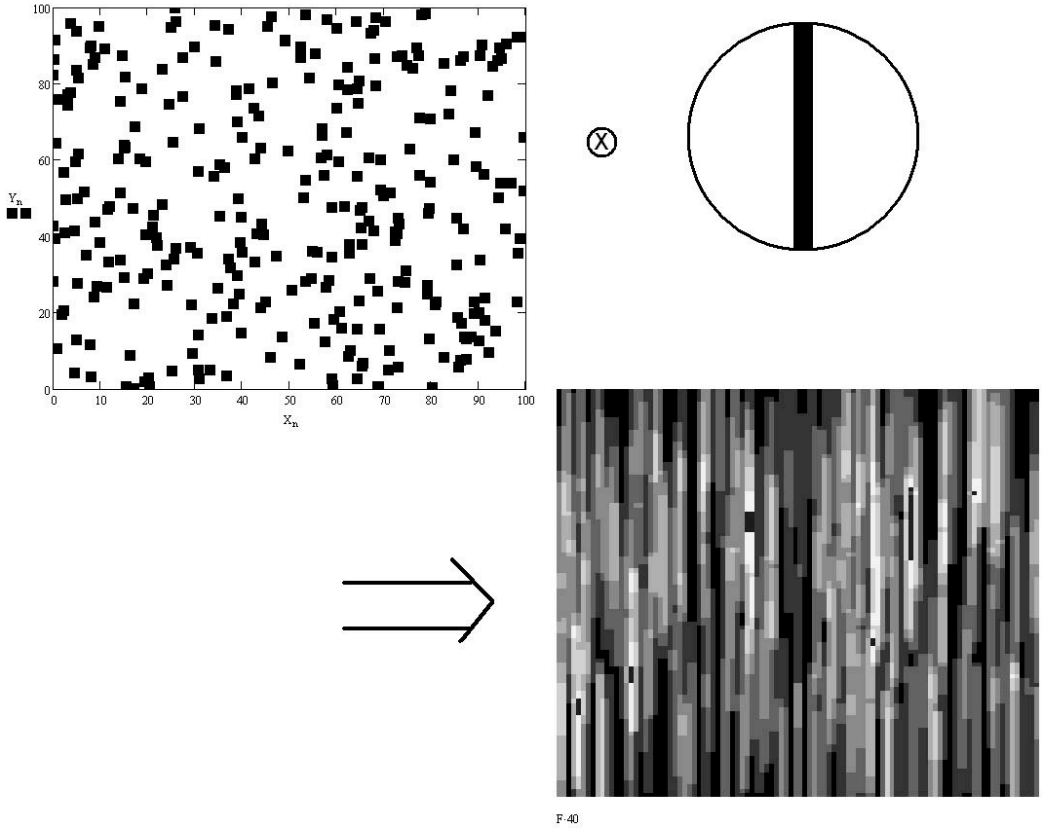
This is also illustrated by the “spotty” pupil image shown below (HAWKI left pupil image, ISAAC right pupil image):



Explanation of effect

The internal coating is approximately 150 mm from the f/15 Nasmyth focus giving a blur circle of 10mm at the internal coating (or about 160 pixels in the focal plane). The out of focus image from each point on the sky, will contain the shadow of the M2 and spider. The exact throughput for that field point will then depend on the coating defect relative to the spider shadow, e.g. if it is in the shadow there is no change, if it is outside the shadow it decreases the transmitted flux. Because of the symmetry of the M2 spider, field points along the spider directions tend to have similar flux levels - the net result is a correlated cross-hatching which mimics the spider symmetry. Basically the result is a convolution of the coating defect pattern with pupil image (see attachment [the Figure shown below] where only one spider arm was used for simplicity).

In a difference image this should all subtract off pretty well (focal plane flexure relative to the window is very small in short exposures). However the pupil rotates, so each little cross-shaped spider pattern will not subtract off, and will give rise to random hatched pattern over the difference images. This seems to match the images we have, which do not have long consistent stripes over the arrays but many short, slightly displaced parallel segments."



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Recommendations

There is a spare window available that nevertheless is currently being repaired. During the IOT Meeting on 03 July it was decided to replace the current, damaged, window with that spare window (*without coating*) once it is ready. The estimated time slot for such intervention is 23-26 August 2008. In the meantime we recommend visitors to:

- Keep DIT*NDIT < 60 s. If sky-subtraction is a fundamental issue for your programmes then the above should be DIT*NDIT< 30 s.
- Observe at a HA such that pupil rotation is kept to minimum