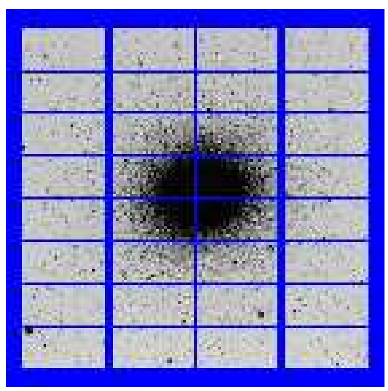
OmegaCAM Commissioning 1B - DFS

Record 26 April - 9 May, 2011

OmegaCAM Instrument Consortium



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Contents

1 Summary

The commissioning plan (VST-PLA-OCM-23100-3100) for OCAM1 has been fully executed.

In addition to the plan, PR images on M17, Omega Centauri, Leo Triplet and the Hercules cluster have been taken.

The work is on schedule and during the last nights already an OCAM2 OB could be exercised: pointing the standard field SA110 on each of the 32 chips in the g band.

The establishment of the settings of the amplifiers and final configuration of hardware was achieved only 2 nights before the end of the run. This was not scheduled, but during the last two days and nights most critical calibration observations could be repeated, leading to a first internally consistent set. Observations taken earlier then the last two nights should be avoided for characterization purposes, when possible.

The various pipelines were successfully applied to the data and the data analysis was executed as planned. The unplanned much shorter period between OCAM1 and OCAM2 implied a prime attention to those issues possibly impacting on the OCAM2 programme. Also, a full report was not planned at this state and should await the final characterization. The present writings in the following sections are preliminary and are a draft or incomplete. In fact, the full internal documentation is residing on the consortium Wiki pages. We have copied some of this information here.

Many of the detector/amplifyer test were already done in OCAM1A (see report VST-TRE-OCM-23100-3601) and indicated an overall very good performance, conform the lab testing in Garching (see report VST-TRE-OCM-23100-3358). No major non-conformances were noted in COM1B, though the slightly higher nominal readnoise (5.2 e^-, 2.1 ADU) implies that for u band exposures extra attention should be paid to optimizing integration times and number of dithers (perhaps N=4 is preferred over N=5).

Significant crosstalk was observed between CCDs 93,94,95 and 96 (right-half of mosaic). First analysis indicates that these can be suppressed quite will in the datahandling.

The overall ghosting is certainly not worse than expected. A few anomalies were observed and further characterized when a bright star is positioned on or near the crosses of segmented filters, or near, but outside, the edge of the field - see report VST-TRE-OCM-23100-3602

In OCAM1B the instrument was for the very first time exposed to the dome screen of the calibration lamps (calibration unit) and the twilight sky. A thorough analysis indicates:

- The illumination of the screen by the lamps is quite homogenous, better than 5% and with little straylight gradients
- The illumination in u is very poor, as expected, (no output of lamp) and dominated by straylight- its useage in u is questionable.
- The overall performance of the calibration unit is very good and promising. Considerable straylight gradients on the sky have been deduced from the data: at least 15% (center-corner) circular symmetric in g and with more substructure, non-symmetric but with a smaller amplitude in r,i,z . In B,V the straylight gradients are much less. The interference filters are much more sensitive to the gradients, due to the input angle criterion of FPs. Perhaps we are the first to observe with such large interference filters.
- Three different methods give consistent straylight gradient results, confirming that the ratio of raw dome-to-sky images provide a good insight on the sky straylight gradients.

Zeropoints have been derived from the standard fields and are in agreement when compared to the ETC.

The OBs of the calibration templates have been all handled over to Paranal staff and parameter values have been fine tuned and executed. The current and subsequent characterization observations were and are to be done with this set of OBs/templates.

At large Zenit distance fields with overlapping images have been observed as a start to settling optimal field center separation, how much overlap is required to obtain photometric cross-checks over fields and what is the influence of the large straylight gradients in the corners.

It was noted that for longer visit of a field at large ZD (45 degrees) it was difficult and time consuming to maintain the AO of the telescope. While DIM seeing reported 0.7-0.8 arcsec a lot of effort was required to achieve 1.1 arcsec images, while originally the observations gave 1.4 arcsec. Obviously, faster and better acquisition would help to improve on this. During OCAM2 the improvements on the VST AO and/or OmegaCAM AO will be assessed again.

The relatively long acquisition times and the uncertainties on the improvements thereof dominate the effective verification of ETCs and this should wait for OCAM2. The zeropoints will be affected by the straylight gradients, but the strategy to characterize 32 independent chips is in our favour (as the gross of the affect will be absorbed in individual chip zeropoints).

For OCAM2 the original Com plan is applicable and will be executed as such. Extra attention will be given to observations putting standard fields (SA107, SA 104, SA 110SA 113) on 32 chips to maximize our understanding of the substantial straylight, the handling over of the real-time health check (lamp and monitor on the sky), large ZD fields and survey overlaps. We will have plenty opportunity to observe the straylight from the moon.

2 Req 5.2.1/CP 8.1 - Cat I: CCD Read noise - doit

Required accuracy, constraints:

- Readout noise less than 5e$^-$
- Variation in readout noise w.r.t. reference value less than 0.5e$^-$

Results:

Read-out noise [ADU] and [e^-]							
ccd #89	ccd #90	ccd #91	ccd #92	ccd #93	ccd #94	ccd #95	ccd #96
ccd #81	ccd #82	ccd #83	ccd #84	ccd #85	ccd #86	ccd #87	ccd #88
ccd #73	ccd #74	ccd #75	ccd #76	ccd #77	ccd #78	ccd #79	ccd #80
ccd #65	ccd #66	ccd #67	ccd #68	ccd #69	ccd #70	ccd #71	ccd #72
Template: 2011-05-07 13:03:16 [ADU]							
2.75	2.47	2.28	2.36	2.01	2.02	2.53	2.19
2.03	1.97	2.04	2.05	2.16	2.08	2.14	2.07
1.96	2.08	2.03	2.04	2.24	1.96	2.01	2.01
1.98	1.97	2.09	2.13	2.12	2.10	2.00	2.02
Template: 2011-05-07 13:03:16 [e^-]							
6.52	6.23	5.98	6.03	5.15	5.61	6.90	5.17
5.20	5.05	5.22	5.06	5.19	4.82	5.10	5.22
4.70	5.18	5.12	4.97	5.95	5.31	5.36	5.17
4.73	5.10	5.20	5.42	5.28	4.69	5.08	4.83

Remarks:

- The read-out noise values are roughly 2.1 ADU, consistent with earlier lab tests.
- Using the gain to convert to read-out noise in electrons are roughly 5.2 e^- with 5 CCDs having read-out noise between 6 and 7 e^-.

Conclusions:

- The read-out noise is slightly outside specs. Significant time was spent during this commissioning period to try to change CCD firmware settings to bring this noise down. The results in the table show the situation at the final settings.

3 Req 5.2.2/CP 8.25 - Cat I: Hot pixels

Required accuracy, constraints:

- Number of hot pixels to be determined by experience/lab values.
- The total number of bad pixels (hot pixels + cold pixels) is less than 80000 (checked in req.535 Cold pixels)
- Difference in number of hot pixels w.r.t. reference value, less than 100.

Results:

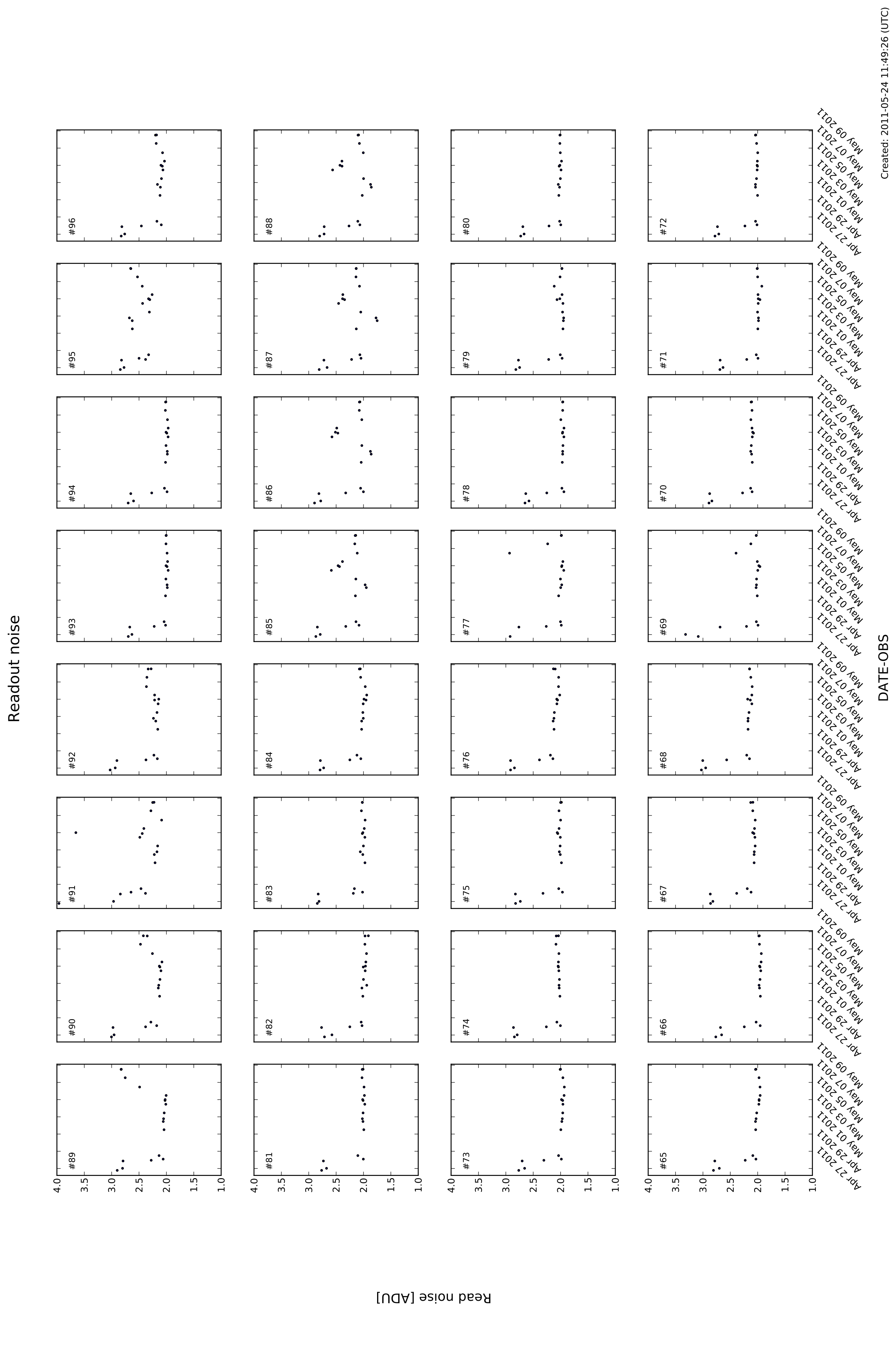

Figure 1: Trend of read-out noise value over time

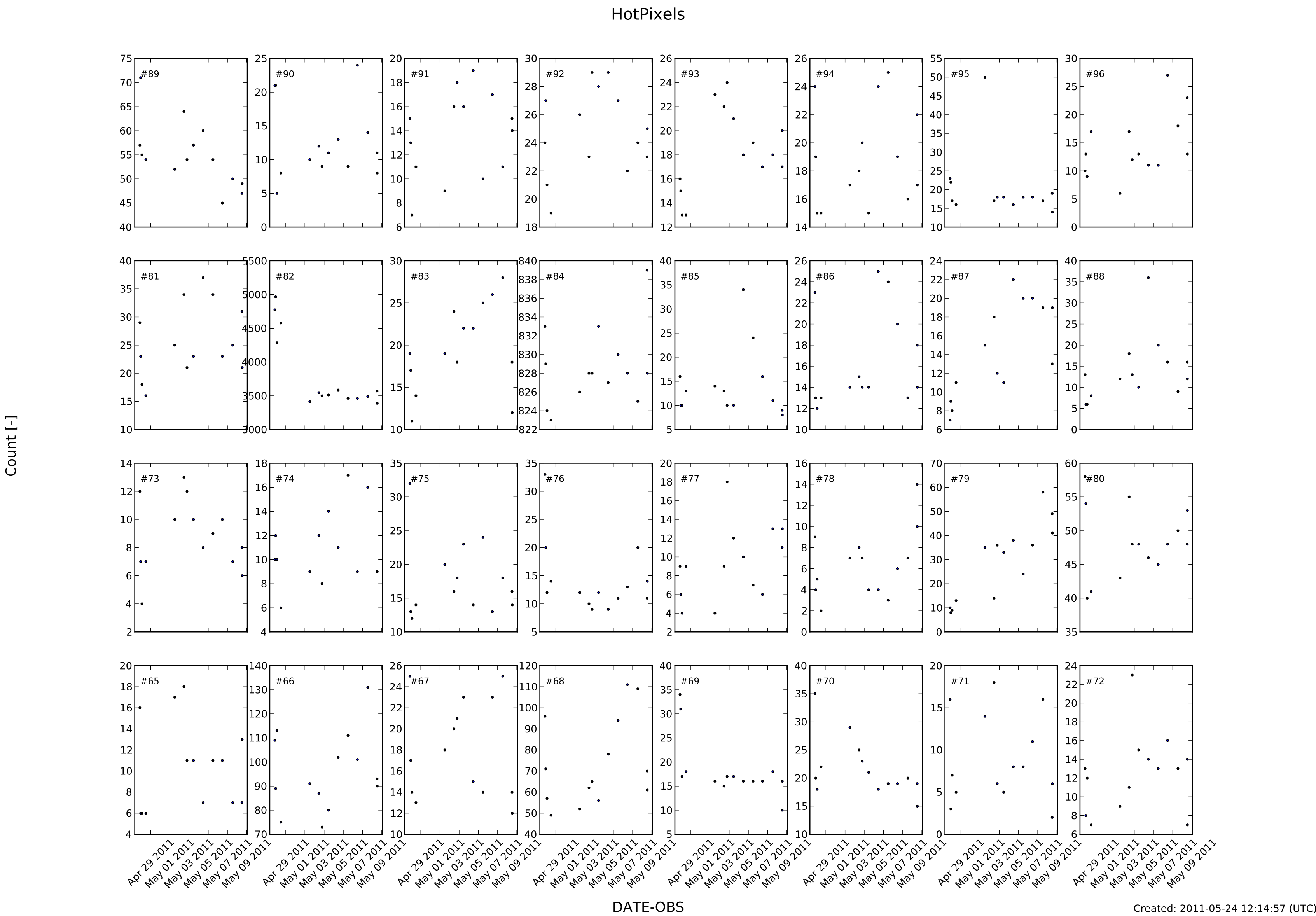

Figure 2: Trend of hot pixel counts over time

Hot pixel counts							
ccd #89	ccd #90	ccd #91	ccd #92	ccd #93	ccd #94	ccd #95	ccd #96
ccd #81	ccd #82	ccd #83	ccd #84	ccd #85	ccd #86	ccd #87	ccd #88
ccd #73	ccd #74	ccd #75	ccd #76	ccd #77	ccd #78	ccd #79	ccd #80
ccd #65	ccd #66	ccd #67	ccd #68	ccd #69	ccd #70	ccd #71	ccd #72
Template: 2011-05-07 13:07:01							
50	14	11	24	18	16	17	18
25	3490	28	825	11	13	19	9
7	16	18	20	13	7	58	50
7	131	25	109	18	20	16	13

Remarks:

- From visual inspection of raw bias images the hot pixels appear very few in number; the CCDs look excellent in this regard.

Conclusions:

- Very few hot pixels are seen; well within specs.

4 Req 5.2.3/CP 8.6 - Cat I: CCD Gain

Required accuracy, constraints:

- Accuracy: In units of e^-/ADU, from lab values or found empirically. Variation in time less than 1%.

Results:

Gain $[e^-/ADU]$							
ccd #89	ccd #90	ccd #91	ccd #92	ccd #93	ccd #94	ccd #95	ccd #96
ccd #81	ccd #82	ccd #83	ccd #84	ccd #85	ccd #86	ccd #87	ccd #88
ccd #73	ccd #74	ccd #75	ccd #76	ccd #77	ccd #78	ccd #79	ccd #80
ccd #65	ccd #66	ccd #67	ccd #68	ccd #69	ccd #70	ccd #71	ccd #72
Date: 2011-05-06 11:57:32							
2.37	2.52	2.62	2.56	2.56	2.78	2.73	2.37
2.57	2.56	2.56	2.46	2.40	2.32	2.39	2.52
2.40	2.48	2.52	2.44	2.66	2.71	2.67	2.57
2.39	2.59	2.49	2.55	2.48	2.23	2.54	2.39

Remarks:

- During commissioning 1A it was noticed that the saturation level was below 60000ADU and depedent on the local background. Tweaks to the firmware of the CCDs were made with three settings:
  - Settings from commissioning 1A (gain ∼1.6 e^-/ADU).
  - Settings from lab tests in 2005 (gain ∼2.2 e^-/ADU).
  - Settings from commissioning 1A + increased preamp gain (gain ∼2.5 e^-/ADU).
  - In addition, CCDs 85-88 were used to test additional settings, including hardware (a change of capacitors on the videoboard). This is reflected in figure 3.

Conclusions:

-

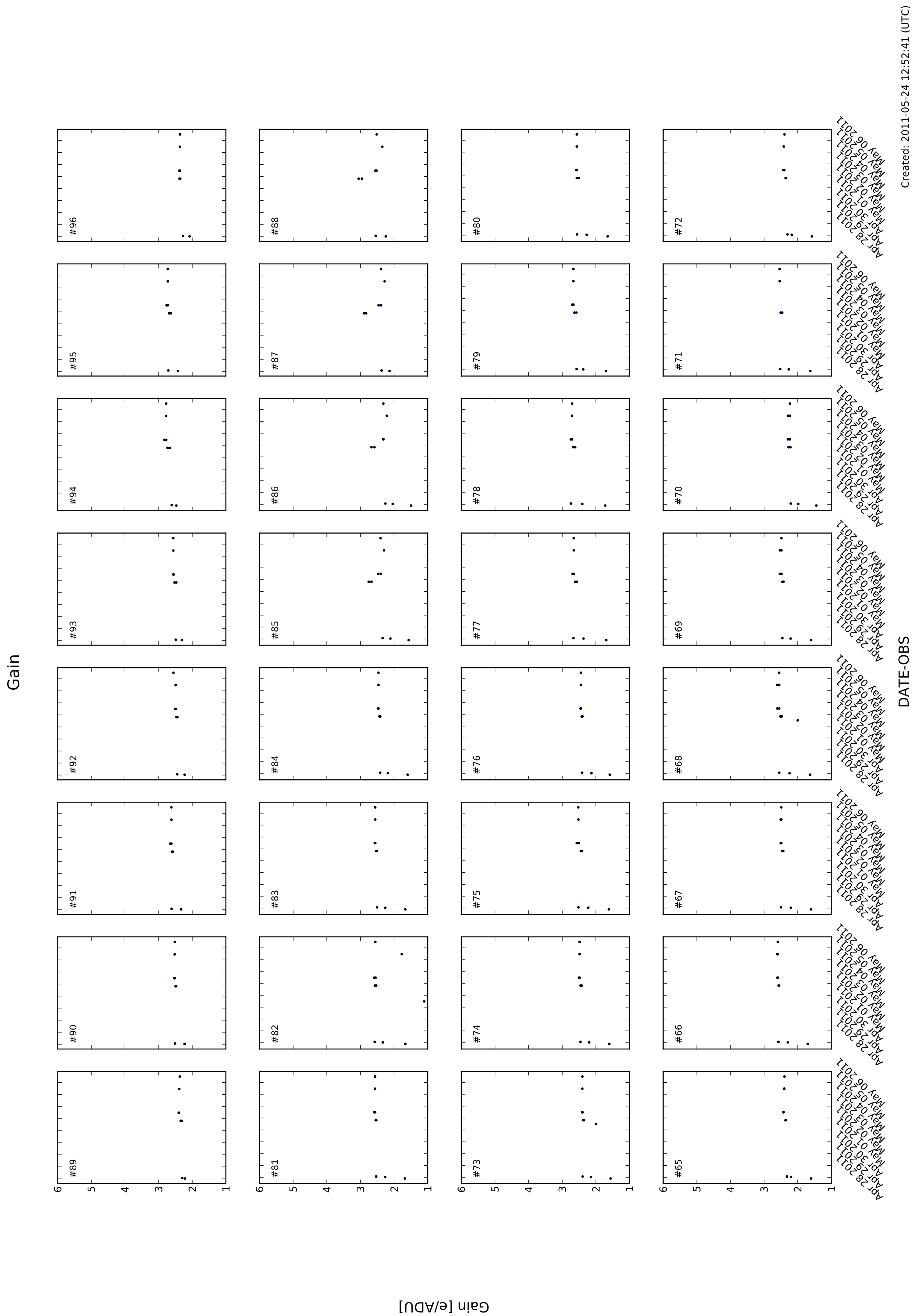

Figure 3: Trend of gain value (in e^{-}/ADU) over time

5 Req 5.2.4/CP 8.19 - Cat III: Electromagnetic Compatibility

Required accuracy, constraints:

- Difference between read noise under operational conditions and the standard read noise measurement should be smaller than 20% for external and 10% for internal causes of interference

Remarks:

- See report "Commissioning 1B - Technical Tasks" (VST-TRE-OCM-23100-3602).

Conclusions:

- No significant EMC noted for dome and telescope movements. No other serendipious EMC noted during runs.

6 Req 5.2.5/CP 8.20 - Cat III: CCD Electrical cross talk

Required accuracy, constraints:

- 10^{-5}

Remarks:

- *Notes by Dietrich Baade:*

  Electronic crosstalk between CCDs

  - CCDs #93-#95 are known to suffer some electronic crosstalk. Since crosstalk has not been found down to very low levels in any of the other CCDs, the explanation lies either in the CCDs concerned themselves or some manufacturing problem of the detector-head electronics. Because the overall behaviour seems to be stable, remedial action was not attempted as any intervention in the detector head entails a high risk.
  - The crosstalk has its origin in bright objects. The threshold for triggering crosstalk depends on the CCD and time. Typically, the exposure level is above 25,000 ADUs and often requires sources saturating the A/D converter (65535 ADUs).
  - The crosstalk can be both positive (bright) and negative (dark) with a range of up to 0.4%; it is the weaker the larger the distance between source and target CCD is. The ghost images always occur at the same relative pixel coordinates in the target CCD, at which the star in the source CCD is located.
  - The crosstalk pattern present in any image consists of several sub- patterns. The most common ones are:
  - 1. Negative crosstalk from #96 to #95. This is always present.
    2. Positive crosstalk from #94 to #95 and on to #96. It seems that #95 may sometimes be skipped over.
    3. Positive crosstalk from #96 to #95 to #94 and, very rarely, to #93.
  - In images with large-scale illumination, such as flat fields, the threshold for the triggering of crosstalk can be as low as a few 1000 ADUs.

Conclusions:

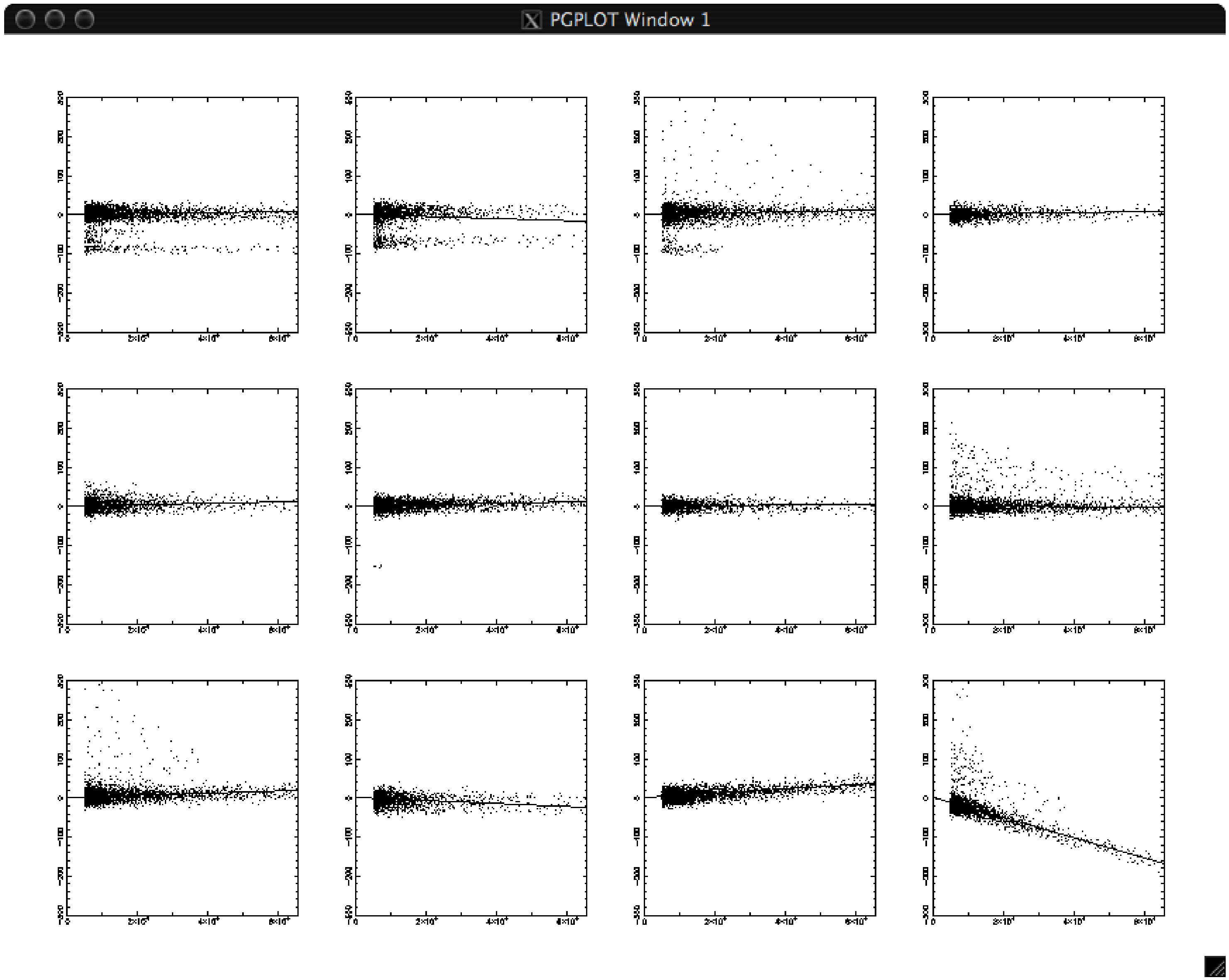

Figure 4: Correlation between pixel values of CCD93-96. Horizontally: ccd93 vs 94, 95, 96; ccd 94 vs 93, 95, 96; ccd 95 vs 93,94,96; and ccd96 vs 93,94,95. Horizontally the full ADU range is plotted, vertically the range is a few 100 ADU about the median value.

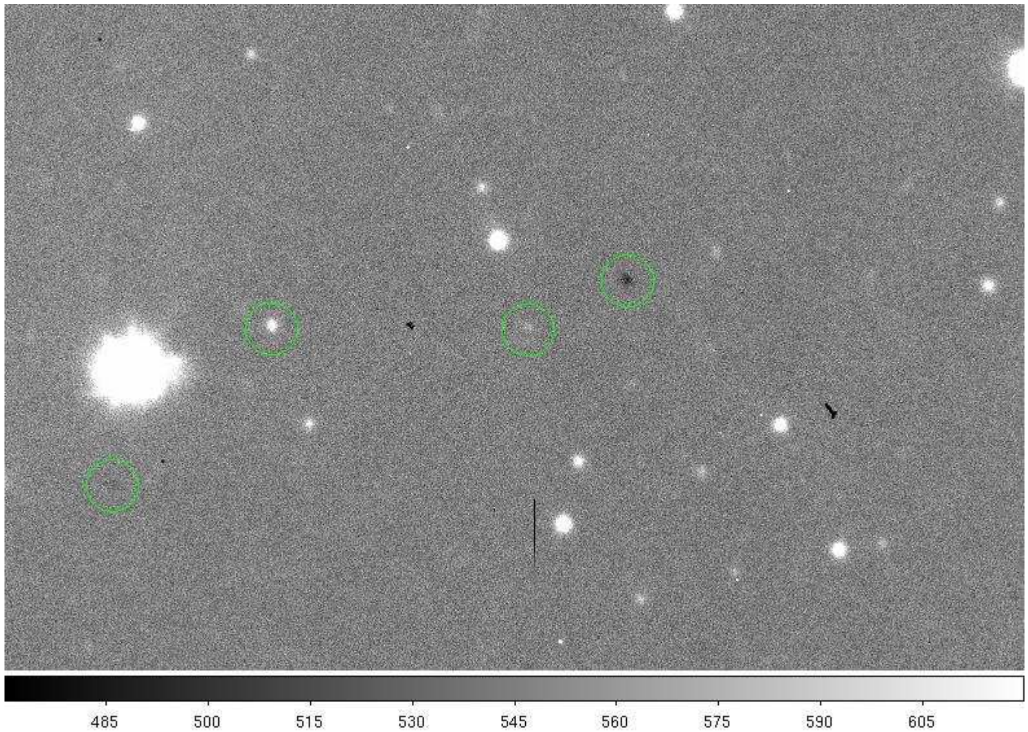

Figure 5: CCD 96 before crosstalk correction

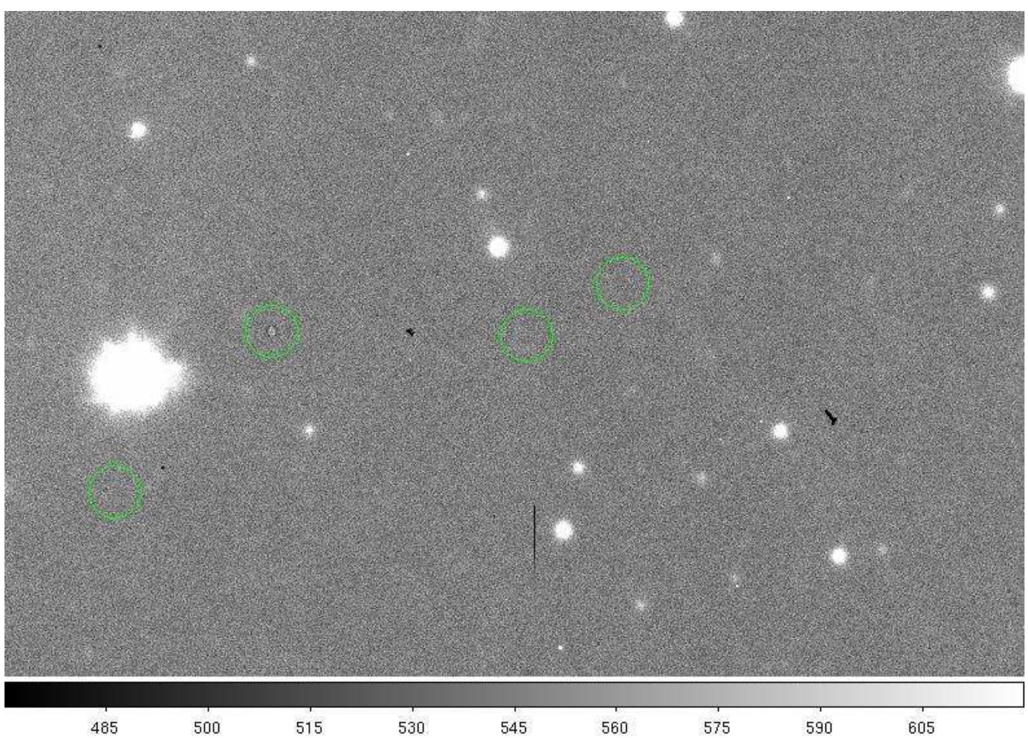

Figure 6: CCD 96 after crosstalk correction

- Figure 4 is a plot indicating the correlation between pixel values of CCDs 93-96.
- CCD 96 shows crosstalk from non-saturated pixels on 94 and 95. The other CCDs show crosstalk only from saturated pixels, not plotted here.
- A simple recipe to try to correct for the trends shown removes the worst effects of the ghosts.

  As an example see the before/after results on CCD 96: figures 5 and 6. (Some of the ghosts are from ccd 95, some from 94.) It's not perfect yet: saturated ghosts leave an edge which will need a bit more work. Probably it is from the part of the ghost which is saturated in ADU but not in electrons (i.e., saturation of the AtoD convertor, not of the chip itself).

7 Req 5.3.1/CP 8.7 - Cat I: CCD Dark Current - doit

Required accuracy, constraints:

- Dark count rate should be less than 1.5 ADU/pixel/hour.

Results:

Dark current [$ADU/pixel/hour$]							
ccd #89	ccd #90	ccd #91	ccd #92	ccd #93	ccd #94	ccd #95	ccd #96
ccd #81	ccd #82	ccd #83	ccd #84	ccd #85	ccd #86	ccd #87	ccd #88
ccd #73	ccd #74	ccd #75	ccd #76	ccd #77	ccd #78	ccd #79	ccd #80
ccd #65	ccd #66	ccd #67	ccd #68	ccd #69	ccd #70	ccd #71	ccd #72
Template: 2011-05-08 05:57:20							
0.50	0.46	0.36	0.47	0.27	0.37	0.15	0.34
0.36	0.28	0.41	0.31	0.33	0.40	0.37	0.38
0.35	0.22	0.21	0.28	0.33	0.26	0.24	0.29
0.30	0.36	0.26	0.30	0.25	0.31	0.27	0.28

Remarks:

- Dark current is less than 0.5 ADU/pixel/hour.

Conclusions:

- Well within specs.

8 Req 5.3.2/CP 8.26 - Cat I: CCD Particle Event Rate

Required accuracy, constraints:

- better than 1 particle/cm^2/hour.
- Particle event rates should be identical for each chip.

Results:

Particle event rate [$particles(events)/cm^2/hour$]							
ccd #89	ccd #90	ccd #91	ccd #92	ccd #93	ccd #94	ccd #95	ccd #96
ccd #81	ccd #82	ccd #83	ccd #84	ccd #85	ccd #86	ccd #87	ccd #88
ccd #73	ccd #74	ccd #75	ccd #76	ccd #77	ccd #78	ccd #79	ccd #80
ccd #65	ccd #66	ccd #67	ccd #68	ccd #69	ccd #70	ccd #71	ccd #72
Template: 2011-05-08 05:57:20							
122.55	111.12	117.79	116.20	114.12	119.41	113.02	116.45
114.96	113.20	117.12	117.61	122.02	119.30	118.60	108.93
116.80	113.91	111.82	113.73	115.07	112.99	108.79	110.41
111.68	168.14	110.98	114.15	108.97	110.73	112.21	111.93

Remarks:

- Particle events were high (∼600 events/cm^2/hour) during lab tests, when we had a temporary dewar window which was a source of high energy particles. When replaced by the actual window, the rates dropped to ∼175 counts. Counts now are actually lower: ∼115 events/cm^2/hour.
- CCD 66 shows ∼50% higher counts than the other CCDs in two separate templates. Cause TBD.

Conclusions:

- Particle event rate is ok.

9 Req 5.3.3/CP 8.27 - Cat I: CCD Linearity

Required accuracy, constraints:

- Better than 1% on the photometric scale

Results:

- See figures 7 and 8.

Remarks:

- Linearity is between 0.25% and 3%, depending on the CCD (see figures 7 and 8).
- Blinking the figures mentioned above, one can see variation for CCDs 82, 87, 88 and 92. Variation is within 1.5% for all but CCD 82.

Conclusions:

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10 Req 5.3.4/CP 8.21 - Cat III: CCD Charge Transfer Efficiency

Required accuracy, constraints:

- CTE > 0.999995 per parallel of serial shift

Remarks:

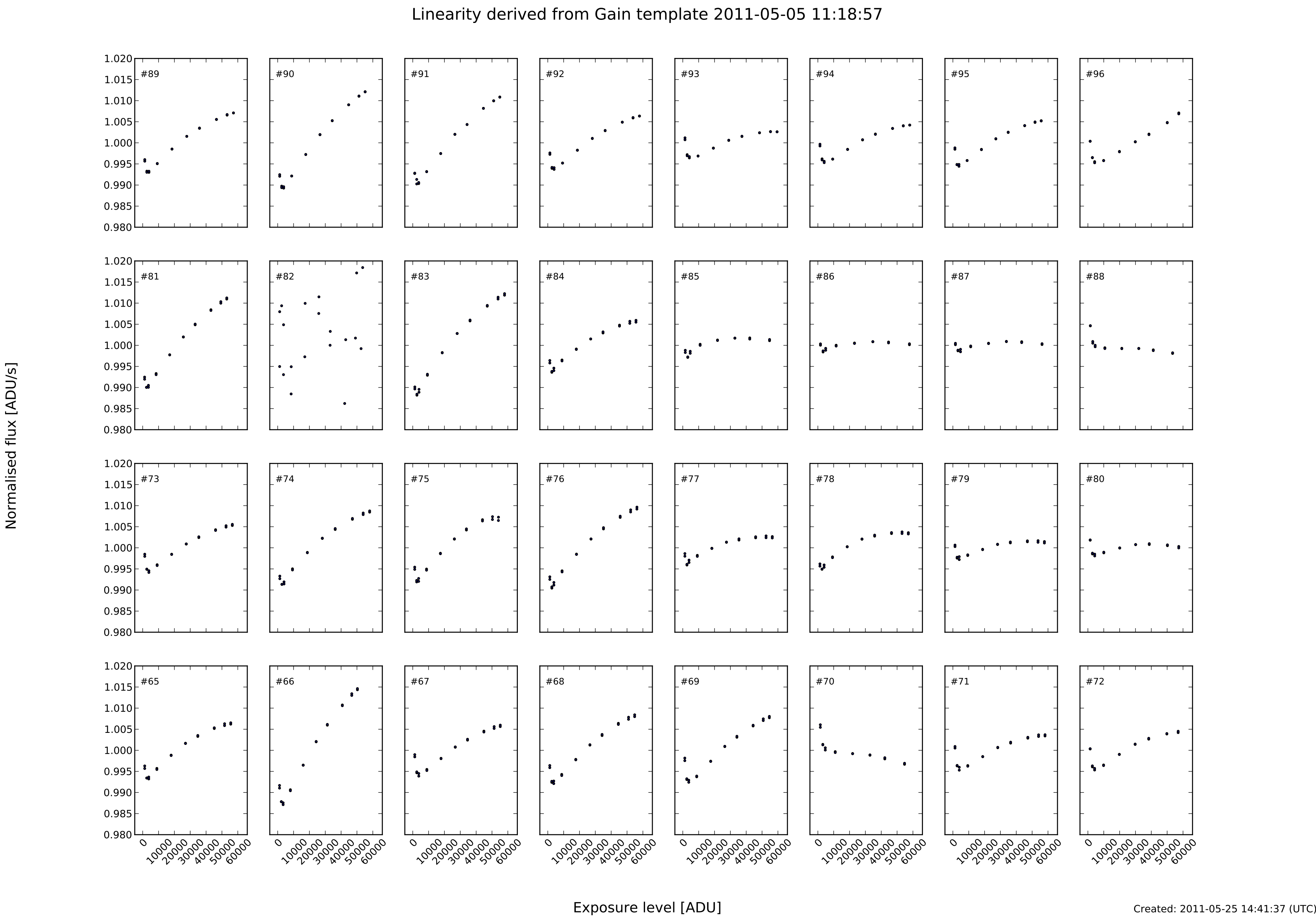

Figure 7: Linearity plot for gain template on 5 May.

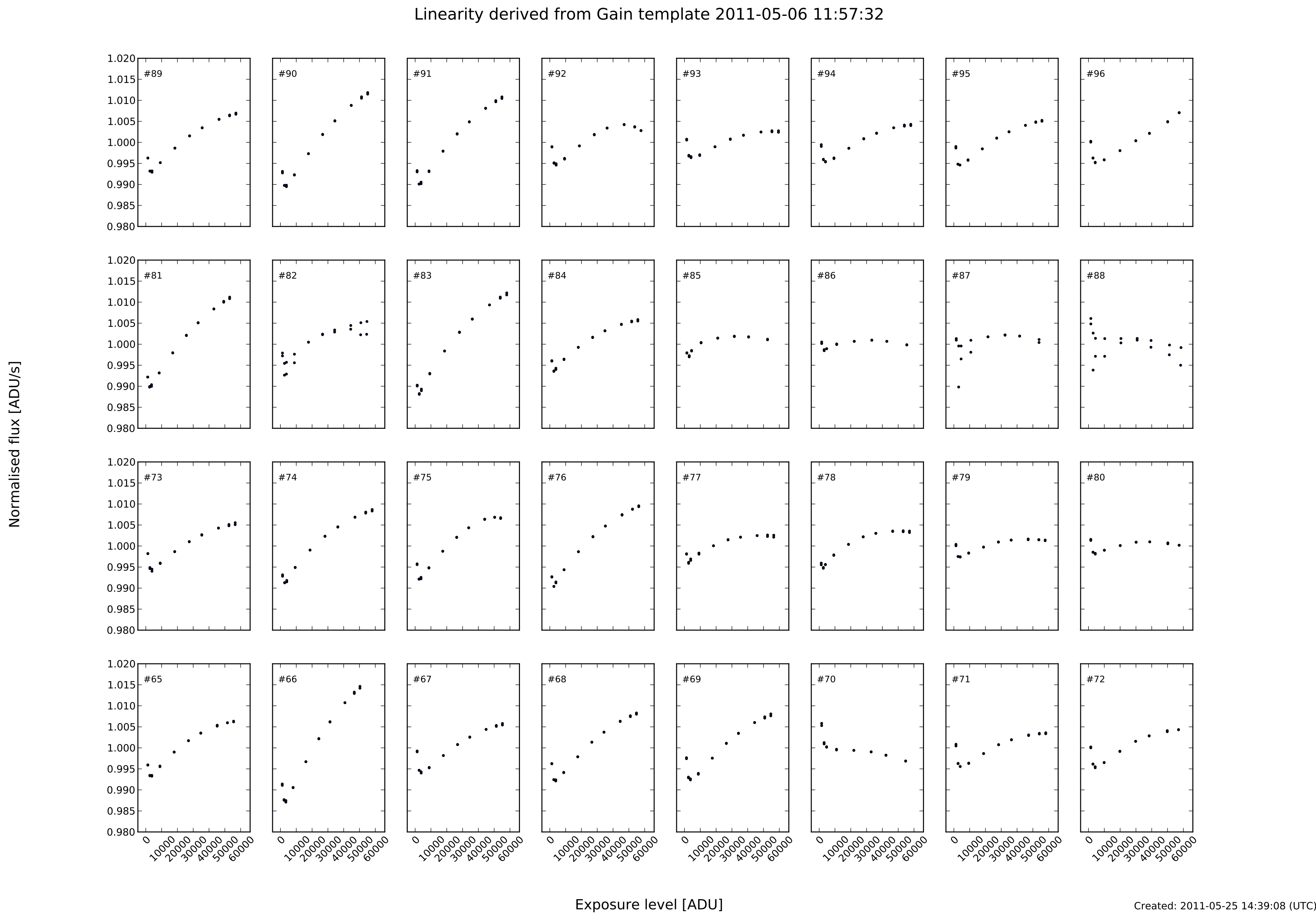

Figure 8: Linearity plot for gain template on 6 May.

- The report "Notes on OmegaCAM bias level - nov 2003)" shows that there is significant reminiscence in the detector/amplifier chain with typical time scale of about a second. Therefore both the vertical and the horizontal overscan regions are affected by this reminiscent signal (only the upper 50 rows of the Y-overscan region are free from this signal).

  Thus the method described in the Requirement is not expected to deliver very useful information on CTE.

  Alternative: it might be more practical and informative to inspect the tails in X and Y of very bright stars.

Conclusions:

- No trails (other than diffraction spikes and overflowing wells) are seen around saturated stars.
- *Idea for OCAM 2:* compare the photometry of objects in the same field rotated 180 degrees.

11 Req 5.3.5/CP 8.28 - Cat I: CCD Cold Pixels

Required accuracy, constraints:

- Quality Check: Number of hot pixels to be determined by experience/lab values. The total number of bad pixels (hot pixels + cold pixels) is less than 80000. Difference in number of cold pixels w.r.t. reference version less than 100.

Results:

Cold pixel counts							
ccd #89	ccd #90	ccd #91	ccd #92	ccd #93	ccd #94	ccd #95	ccd #96
ccd #81	ccd #82	ccd #83	ccd #84	ccd #85	ccd #86	ccd #87	ccd #88
ccd #73	ccd #74	ccd #75	ccd #76	ccd #77	ccd #78	ccd #79	ccd #80
ccd #65	ccd #66	ccd #67	ccd #68	ccd #69	ccd #70	ccd #71	ccd #72
Template: 2011-05-07 12:15:57							
3143	16719	8891	4926	7037	15038	10134	7222
8698	2816	9611	5713	9742	6420	8570	9553
3811	2692	2765	2802	2683	2660	2911	4329
2807	5363	2956	4163	3003	5783	7371	4191

Remarks:

- Visual inspection shows that cold pixels are far more numerous than hot pixels.
- Replacement of defective CCD 66 introduced significant dust into the dewar, as evidenced by considerable number of sharp and small artifacts that show up in flat-fields (and the cold pixel maps).
- Various artifacts are visible (it is tempting to describe them as hairs and scratches), particularly in CCDs 90 and 95.
- The number of bad columns is higher in the top two rows of detectors than in the bottom two rows.

Conclusions:

- Variation over time may tell whether the dust travels around inside the dewar.

12 Req 5.3.6/CP 8.22 - Cat III: CCD Hysteresis, strong signal

Required accuracy, constraints:

Results:

Remarks:

- Visual inspection: has not been noted.

Conclusions:

-

13 Req 5.4.1/CP 8.2 - Cat I: Bias - doit

Required accuracy, constraints:

- The required accuracy per pixel in the master bias frame is "nominal read-out noise/$\sqrt{N}$", where N is the number of input raw bias images. For the quality check: Since an overscan correction is performed, the deviation of the mean level of the master bias (bias level) from zero, should be less than TBD.

Results:

- See figure 9.

Remarks:

- FIERA restarts can give rise to jumps in the bias level.

Conclusions:

- Make sure a new bias template is observed after every FIERA restart.

14 Req 5.4.2/CP 8.41 - Cat I: Flat-field - dome key bands + user bands - doit

Required accuracy, constraints:

- Accuracy measuring pixel-to-pixel gain variations as small as 1%. Re-insertion of the filter shall not alter the flat field structure by more than 0.3% (rms, measured over the full detector area).

Results:

-

Remarks:

- **u**: 'Diamond' structure with characteristic scales of $\sim$ 400 pixels is as seen by Christen (PhD thesis).

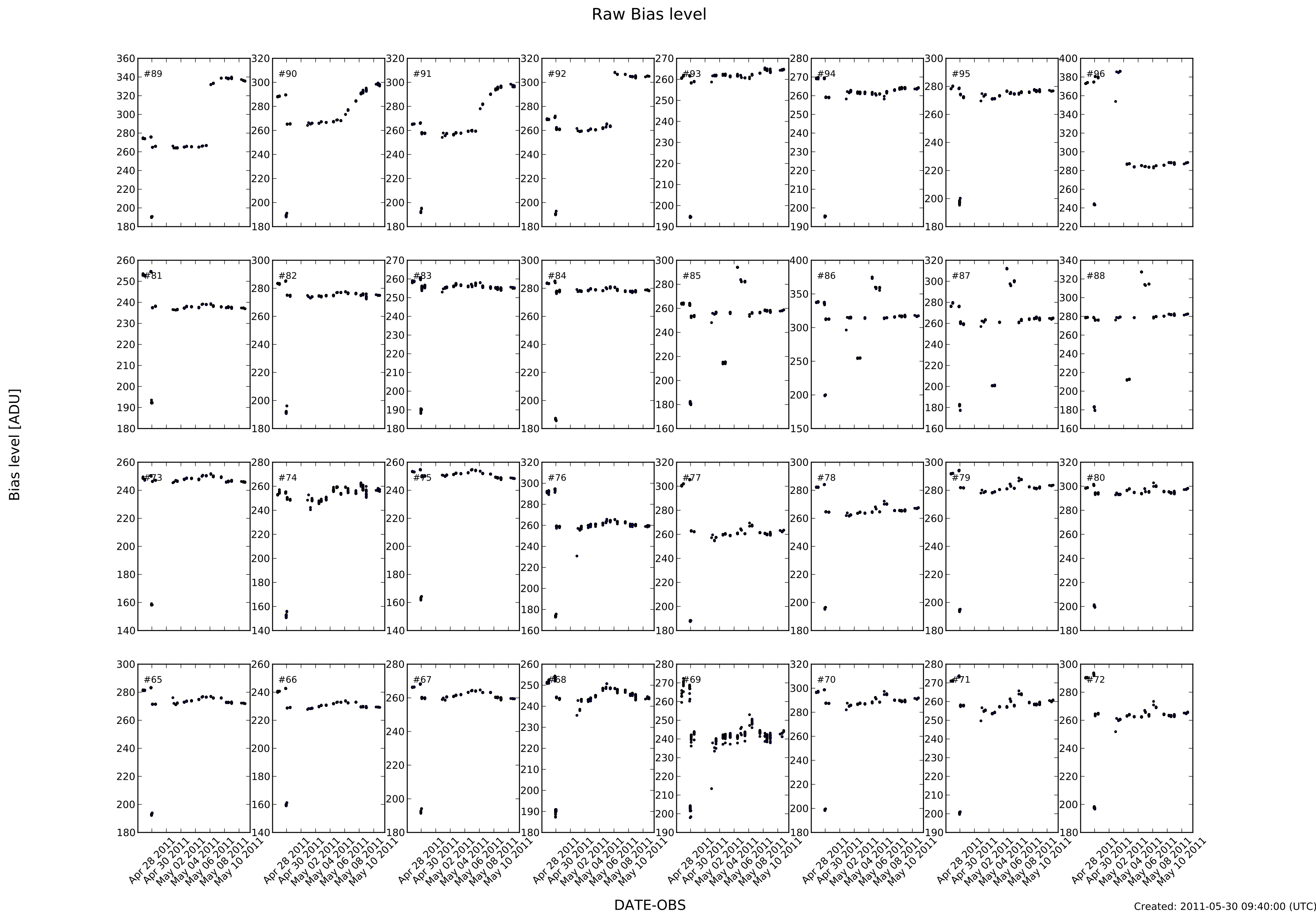

Figure 9: Trend of raw bias level over time

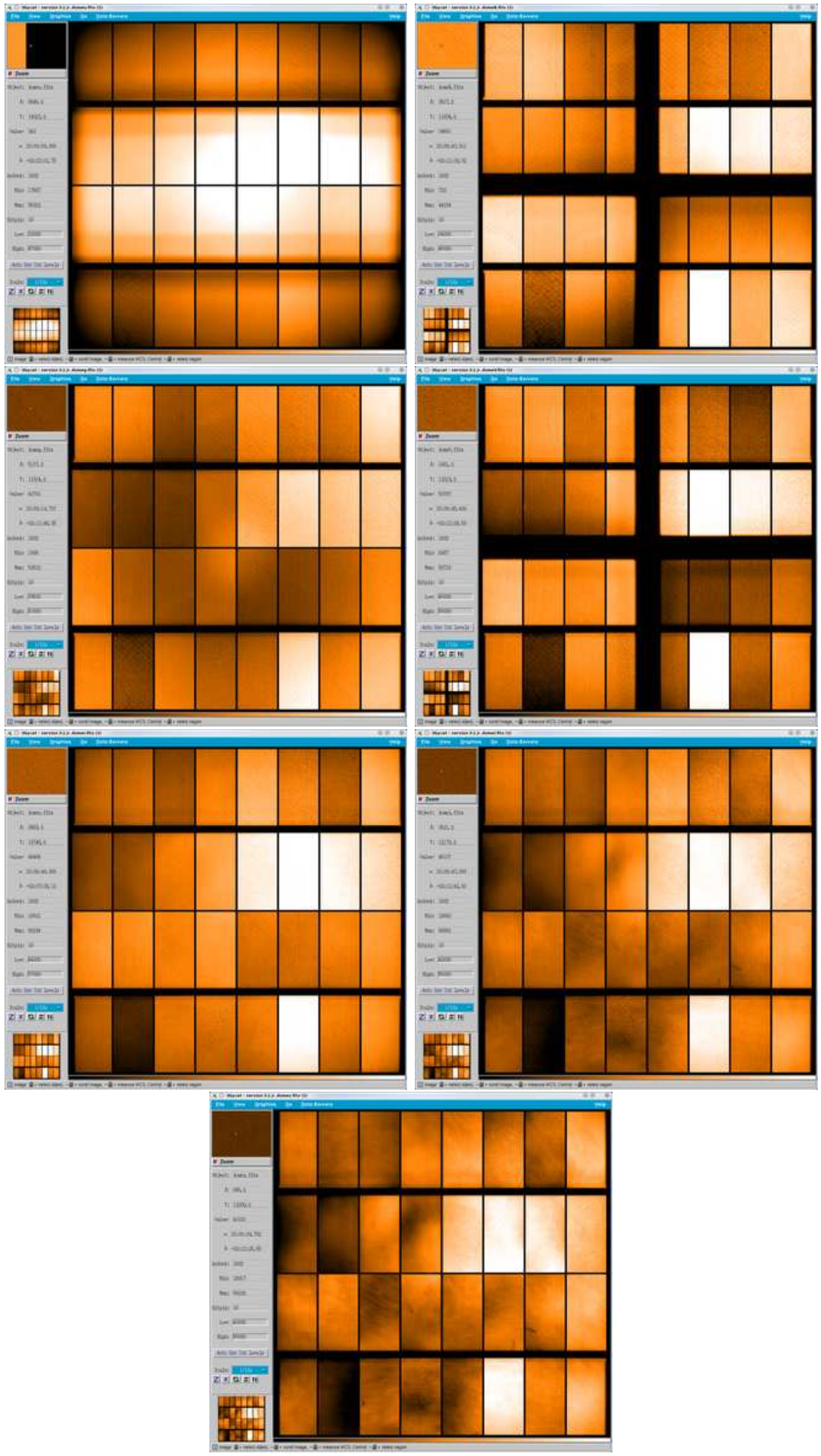

Figure 10: Images of raw domeflats (in ADU). From left to right and top to bottom: exposures with u,B,g,V,r,i and z filter.

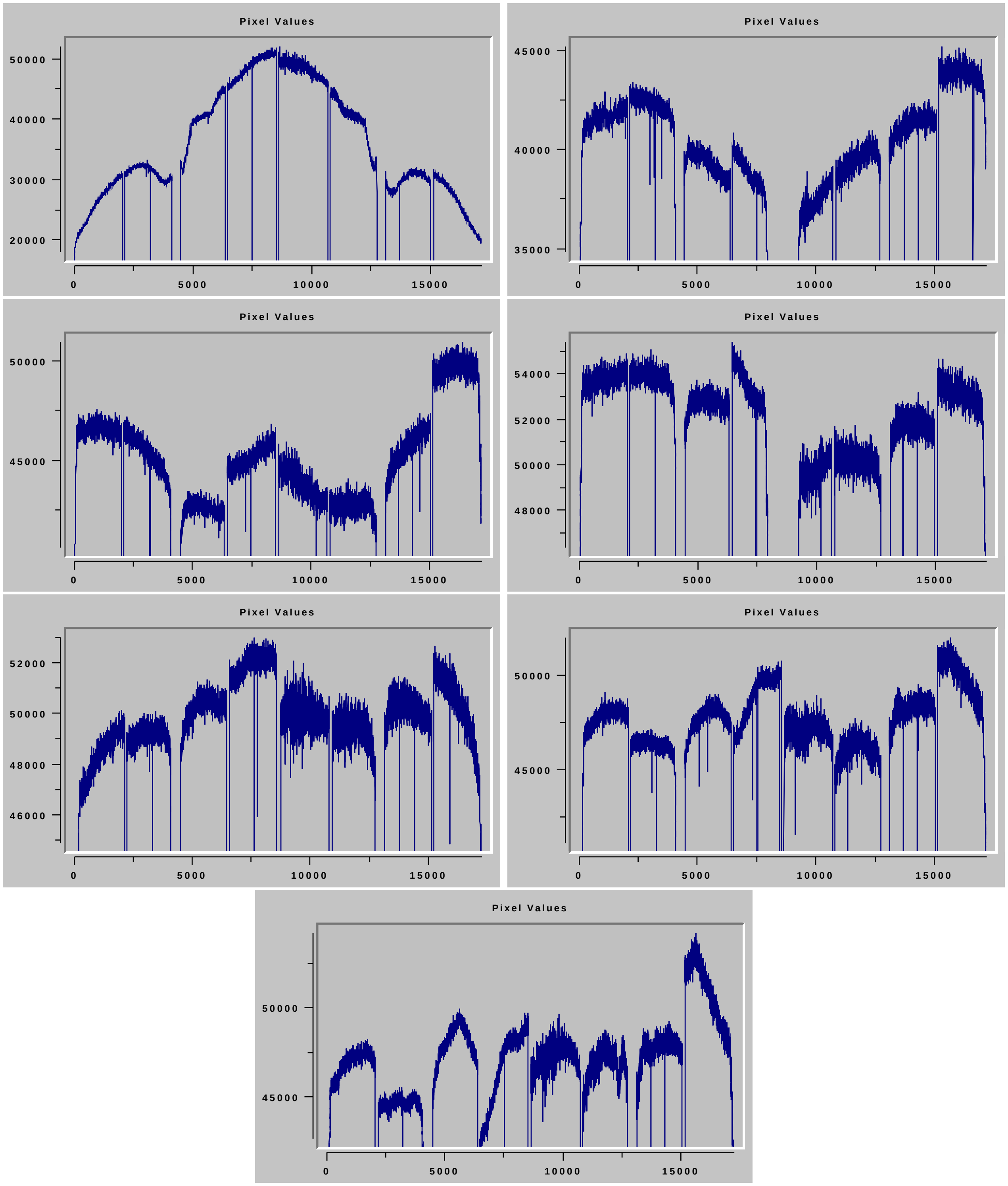

Figure 11: Diagonal cross-cuts through raw domeflats (in ADU). From left to right and top to bottom: exposures with u,B,g,V,r,i and z filter.

- **B and V**: vignetting cross in B and V is from support structure for 4 glass quadrants.
- **g,r,i,z**: cross-cuts and image inspection indicate similar domeflat illumination pattern for all these filters.
- Filter reinsertion to be further studied using scratches and dust on filters.

Conclusions:

- **Illumination uniformity:** we have analyzed illumination variations on the dome flats in 2 ways. Analysis of the raw dome flats in electrons and absolute domeflats. The methods yield a consistent picture in which the illumination variation across in domeflats amount to $\sim 5\%$ or less. This is in agreement with Quick Illumination analysis (see Req. 5.4.8). The exception is the non-uniform illumination of the u band.
- **Deviant u band**: in the u band, the very deviant light distribution is most likely due to the very low u-band output of the calibration lamp: the illumination of the domeflat in u is then dominated by scattered light.

15 Req 5.4.3/CP 8.42 - Cat I: Flat-field - twilight

Required accuracy, constraints:

- Mean levels should be approximately 20000 ADU.

Results:

- See figures 12, 13 (raw images and associated crosscuts) and 14, 15 (ratio images of raw dome divided by raw twilight, and associated crosscuts).

Remarks:

-

Conclusions:

- **Illumination variation**: Inspection of the twilight flats (in electrons) and absolute twilight flats indicate significant illumination variation (at least 15% amplitude from center to corner) in the twilight flats. This must be due to a stray-light gradient. The dome flat illumination is flat within $\sim 5\%$ (see req 5.4.2). Thus the ratio'd dome/twilight images give a good first impression on the straylight gradients when observing on sky. These ratio images show the largest amplitde in g, and being circular symmetric. In r,i and z the amplitude is less but the variation is non-symmetric with more substructure. In B and V the amplitude of the straylight gradients is much less than in g. Finally, the inferred illumination variations from the flat field analysis are consistent with the Quick Illumination analysis (see Req. 5.4.8).

16 Req 5.4.7/CP 8.3 - Cat I: Quick detector responsivity check - doit

Required accuracy, constraints:

Results:

- See figure 16.

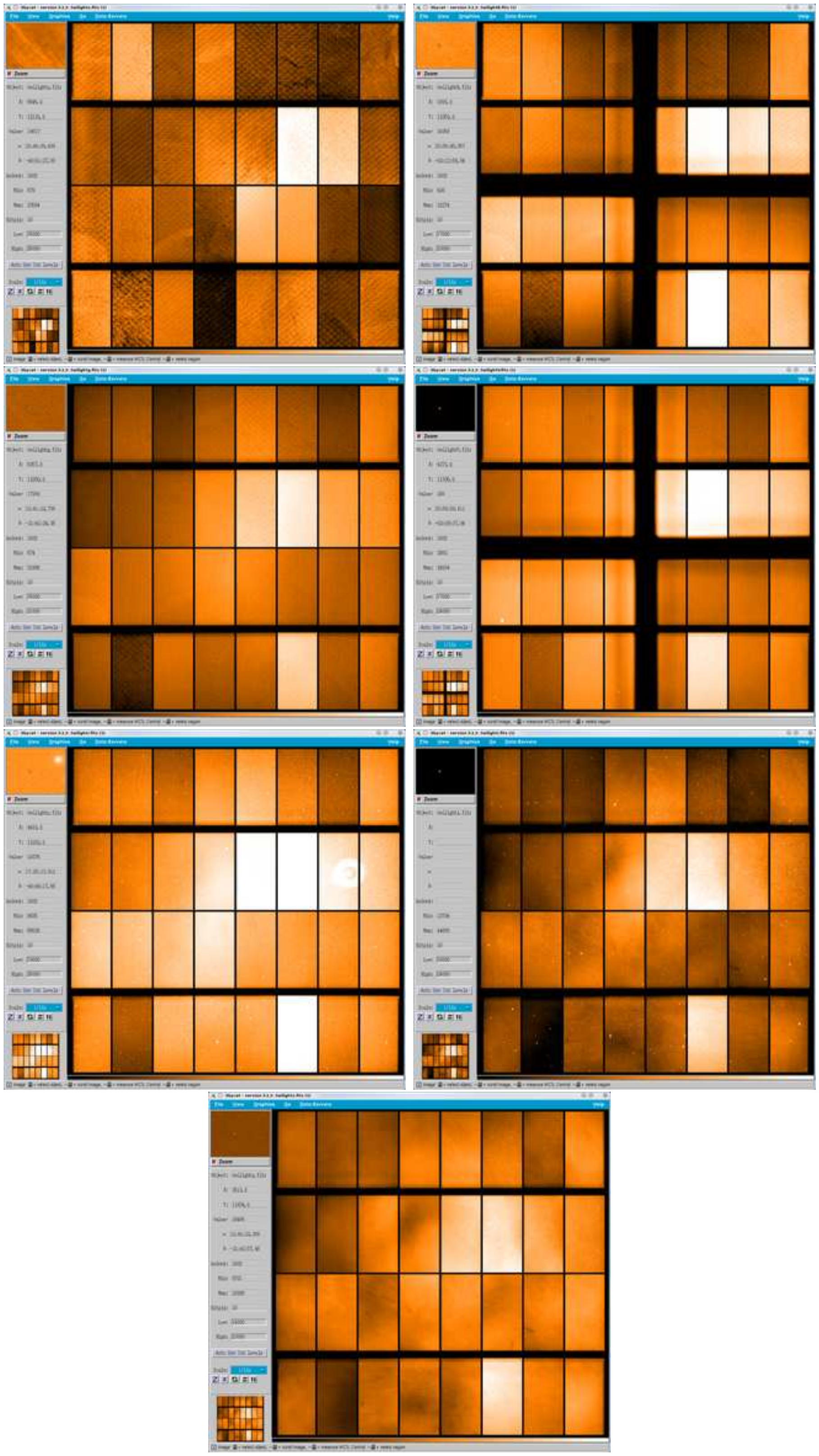

Figure 12: Images of raw twilightflats (in ADU). From left to right and top to bottom: exposures with u,B,g,V,r, i and z filter.

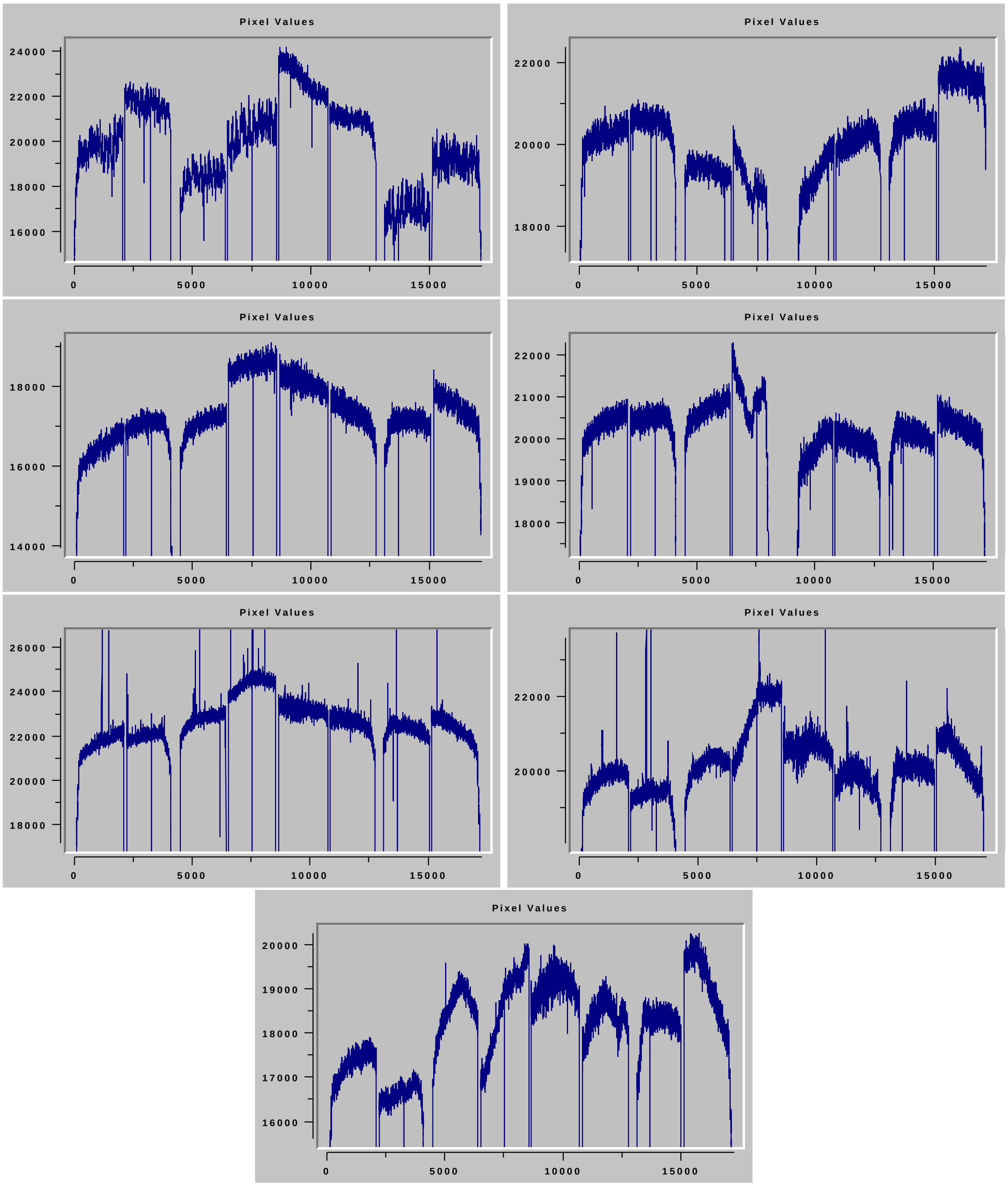

Figure 13: Diagonal cross-cuts through raw twilightflats (in ADU). From left to right and top to bottom: exposures with u,B,g,V,r, i and z filter.

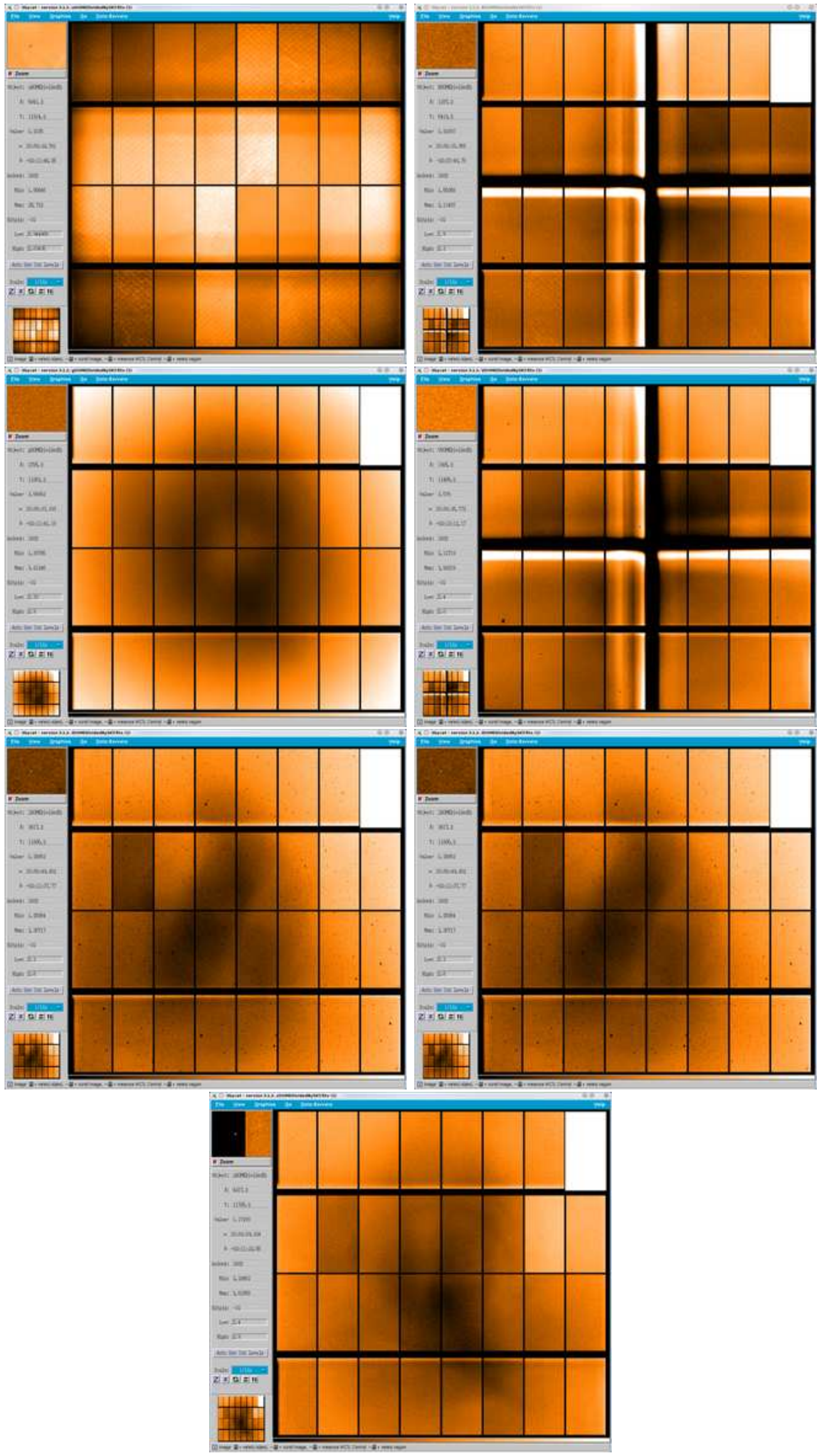

Figure 14: Images of raw domeflats divided by twilightflats. From left to right and top to bottom: exposures with u,B,g,V,r, i and z filter.

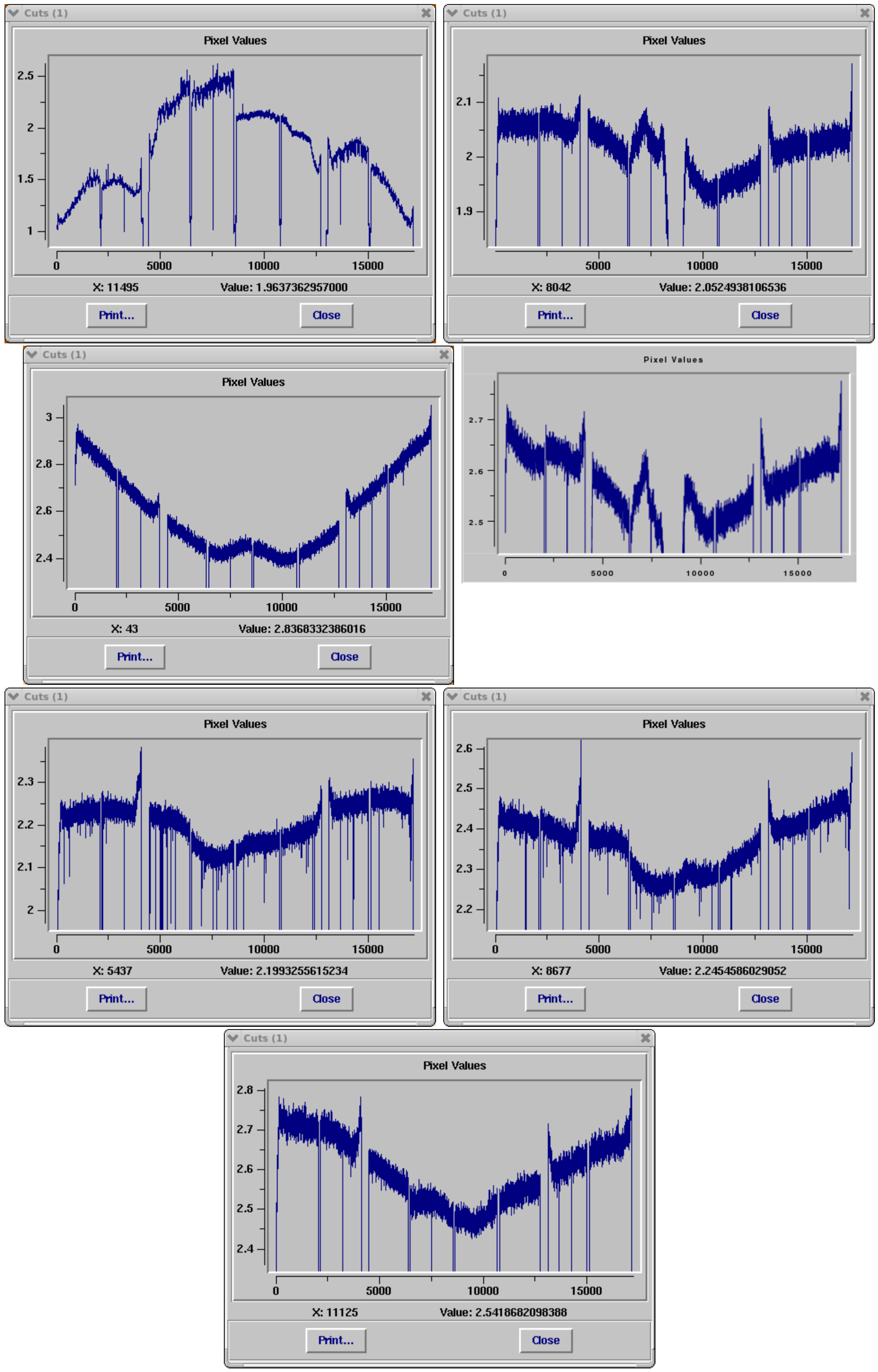

Figure 15: Diagonal cross-cuts through raw domeflats divided by twilightflats. From left to right and top to bottom: exposures with u,B,g,V,r, i and z filter.

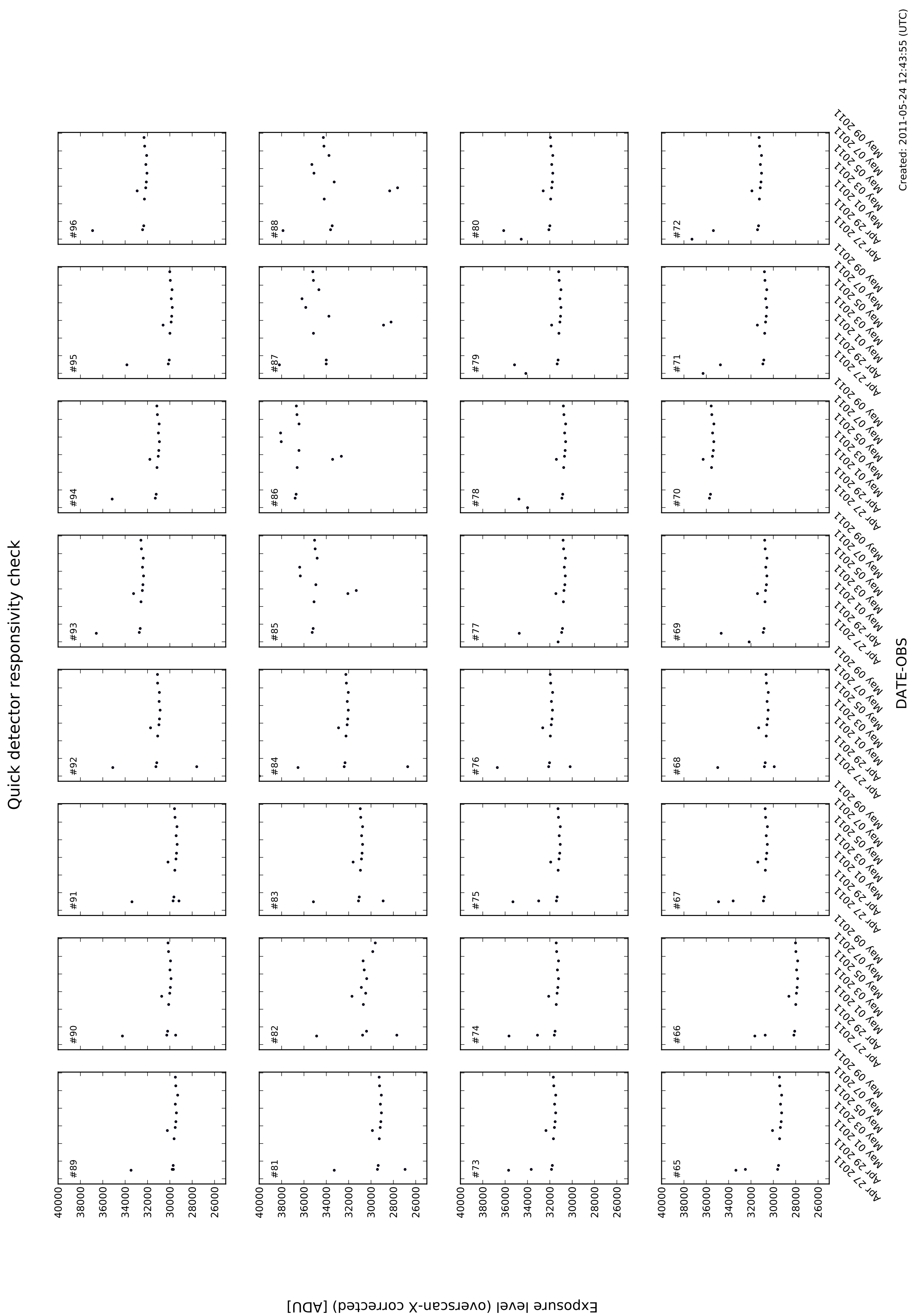

Figure 16: Quick detector responsivity check: trend of de-biassed raw domeflat level of fixed exposure time.

Remarks:

- One purpose of this check is to indicate changes in gain. The tweaks of firmware settings intended to improve the saturation can be easily seen here.
- CCDs 85-88 were singled out for final changes to the firmware.
- Excepting those, and looking at the points from 3-9 May the stability of the entire system is much better than 1%, which is remarkable.

Conclusions:

- Calibration lamp stability is very good.

17 Req 5.4.8/CP 8.17 - Cat II: Illumination correction - part 1 Quick

Required accuracy, constraints:

- Better than 1% for the amplitude over a single CCD.

Results:

Remarks:

- Illumination variations estimated from flatfield analysis are in agreement with the Quick Illumination analysis.

Conclusions:

- The illumination of the screen by the lamps is quite homogenous, better than 5% and with little straylight gradients
- Considerable straylight gradients on the sky have been deduced from the data: at least 15% (center-corner) circular symmetric in g and with more substructure, non-symmetric but with a smaller amplitude in r,i,z . In B,V the straylight gradients are much less. The interference filters are much more sensitive to the gradients, due to the input angle criterion of FPs. The ratio'd dome/twilight images give a good first impression on the straylight gradients observed on the sky.

18 Req 5.5.1/CP 8.14 - Cat III: Position of Camera in focal plane

Required accuracy, constraints:

- Internal precision: 0.3 pixel. External precision limited by reference catalog.

Results:

- Initial values were determined, that are good enough to achieve astrometric solutions with. See table 18.

Remarks:

- Initial values have been determined, and these values are now written in the headers by the IWS.

Conclusions:

-

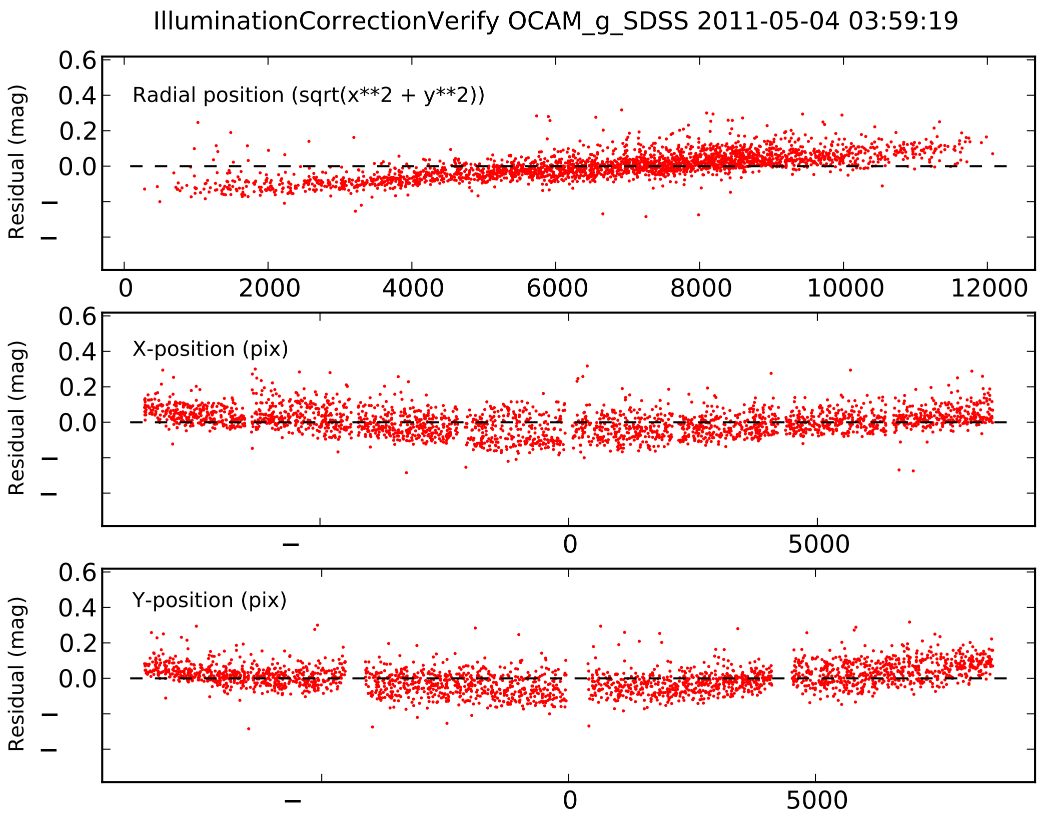

Figure 17: Illumination correction: residuals (SA107, g') as a function of radius (top) X (middle) and Y (bottom). Flatfielding is done with twilight flatfields only.

19 Req 5.5.2/CP 8.10 - Cat III: Telescope Pointing and offsetting

Required accuracy, constraints:

- 1 arc second

Results:
Remarks:

-

Conclusions:

-

20 Req 5.5.3/CP 8.11 - Cat III: Telescope and Field Rotator tracking

Required accuracy, constraints:

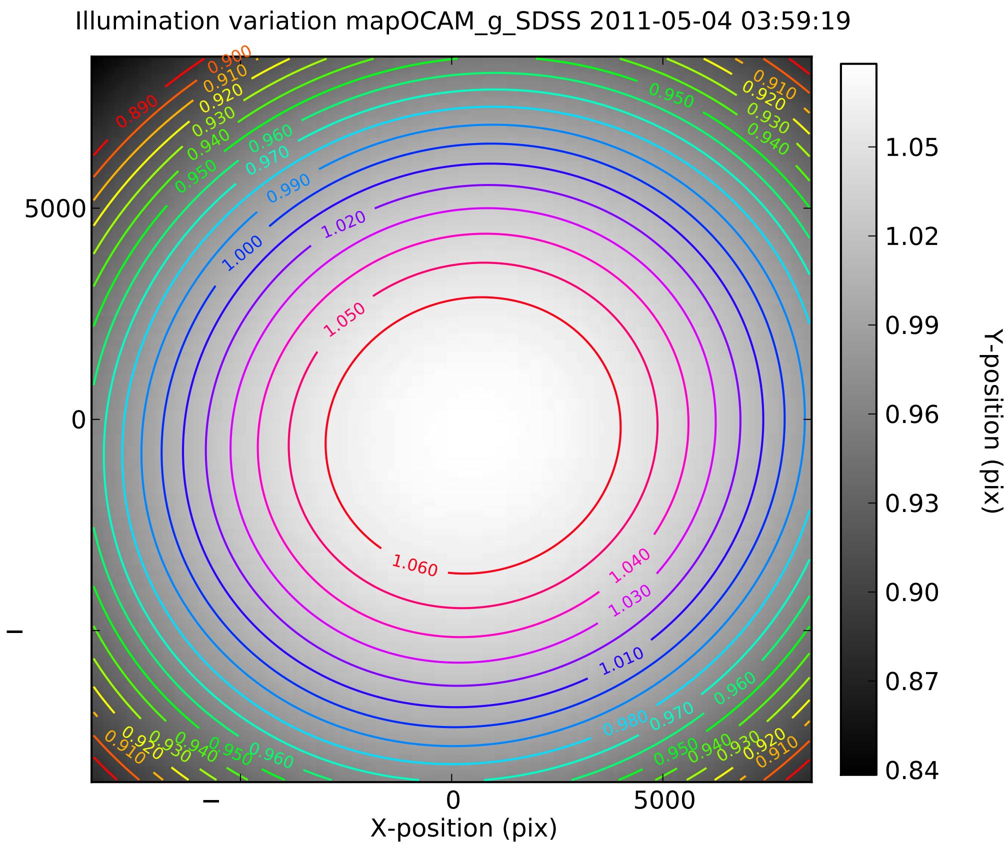

Figure 18: Illumination correction: 2nd order 2-d polynomial fit to (SA107, g') residuals in plot above

VST requirements:

- free tracking better than 0.2 arcsec r.m.s.
- autoguiding tracking better than 0.05 arcsec

Results:

Remarks:

- Verification indicates that tracking without autoguiding is better than 0.1 arcsec in 300 seconds exposures.

Conclusions:

-

21 Req 5.5.4/CP 8.12 - Cat III: PSF Anisotropy

Required accuracy, constraints:

- Better than 1%.

Position of camera in focal plane		
CCD	**CRPIX1**	**CRPIX2**
#65	8568.26	8585.09
#66	6424.21	8589.89
#67	4281.92	8586.01
#68	2143.76	8586.22
#69	5.32	8580.92
#70	-2147.88	8581.78
#71	-4277.88	8592.05
#72	-6417.42	8596.44
#73	8565.72	4130.86
#74	6427.27	4121.32
#75	4287.68	4120.18
#76	2145.48	4122.55
#77	3.01	4124.68
#78	-2141.08	4121.44
#79	-4281.77	4131.00
#80	-6419.57	4134.60
#81	8571.09	76.27
#82	6427.07	68.31
#83	4284.95	79.06
#84	2143.53	75.50
#85	4.56	75.54
#86	-2139.69	79.52
#87	-4286.17	83.97
#88	-6423.44	64.30
#89	8569.19	-4385.37
#90	6429.16	-4391.55
#91	4279.49	-4390.24
#92	2136.77	-4389.19
#93	-2.71	-4388.17
#94	-2155.40	-4378.71
#95	-4286.84	-4382.25
#96	-6425.77	-4381.68

Table 1: **Initial** solutions for the position of the CCDs in the focal plane

Results:

- See figures 29-32 from section 30.

Remarks:

- After correction for the tilt of the instrument w.r.t. the rotator a residual anisotropy is found.
- This may be due to a tilt between telescope and rotator, or misalignment of the optical elements of the telescope.
- During observations at high airmass / low altitude, the stellar images can look triangular. This is a consequence of the Active Optics not maintaining the proper primary mirror shape.

Conclusions:

- There are non-conformances in the image quality at edges of the field.

22 Req 5.5.5/CP 8.50 - Cat I: The astrometric solution for templates -doit -see 6.3.4

Required accuracy, constraints:

-

Results:

- From three dither$_{N=5}$ observations at low, intermediate and high telescope pointing altitudes (Hercules 02, Leo Triplet and NGC 6822, respectively) in good to reasonable seeing, acceptable quality coadds were obtained.
- See figures 19, 20, 21. These plots contain 32 points; one for each CCD. They consist of the 5 pointings in a dither compared to the resulting coadded image.
- See figures 22 and 23.

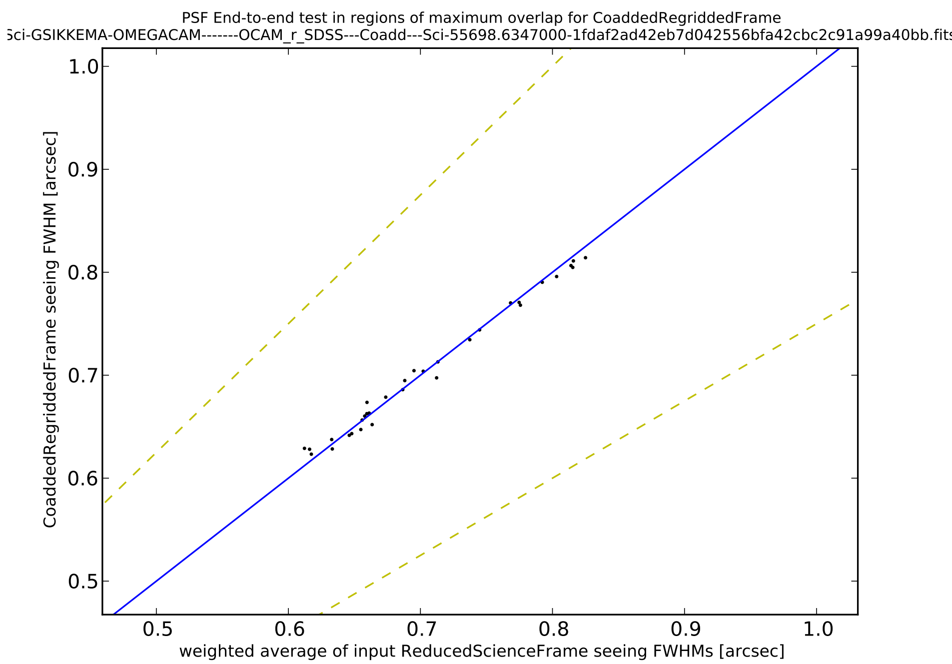

Figure 19: Hercules 02 (r') PSF end-to-end inspect figure

Remarks:

- The PSF end-to-end plots show how the coadded sources in regions covered by a single chip (whose area is common to all input frames and to the coadd) compare to the non-coadded sources in the same regions. The values compared are the mean of the said areas, so there are 32 points per plot.
- The Astrometric residuals plots show the internal and external residuals (Figures 22 & 23, respectively). In these representative plots can be seen the residuals of a given source position as measured from one chip to the source position measued on an overlapping chip (same or different CCD) for the internal comparison, and the residuals of a reference source position from the USNO-A2.0 catalog to the measured position of the same source on any given chip for the external comparison.

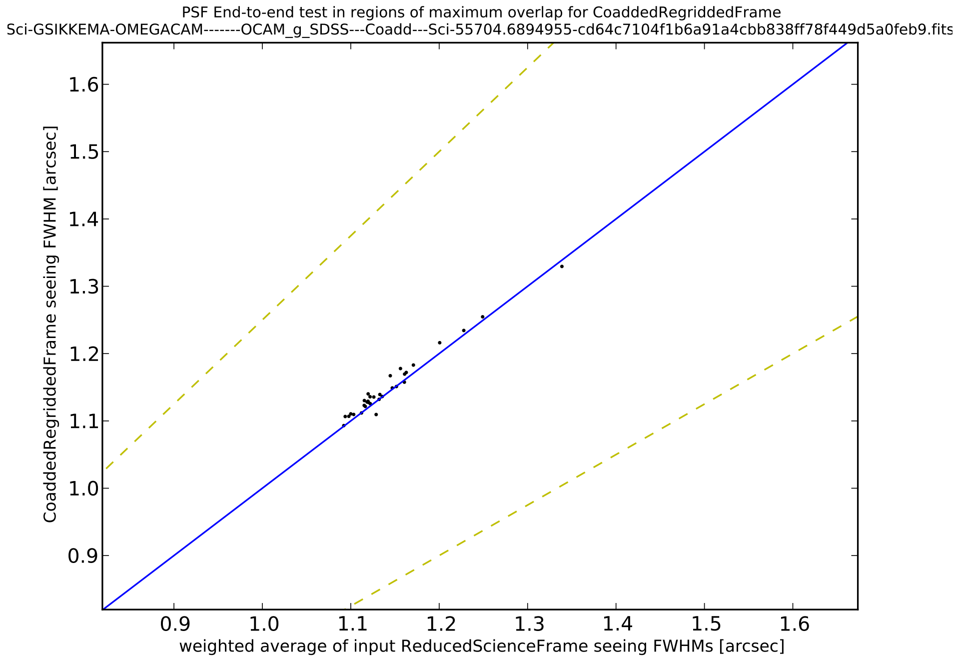

Figure 20: Leo triplet (g') PSF end-to-end inspect figure

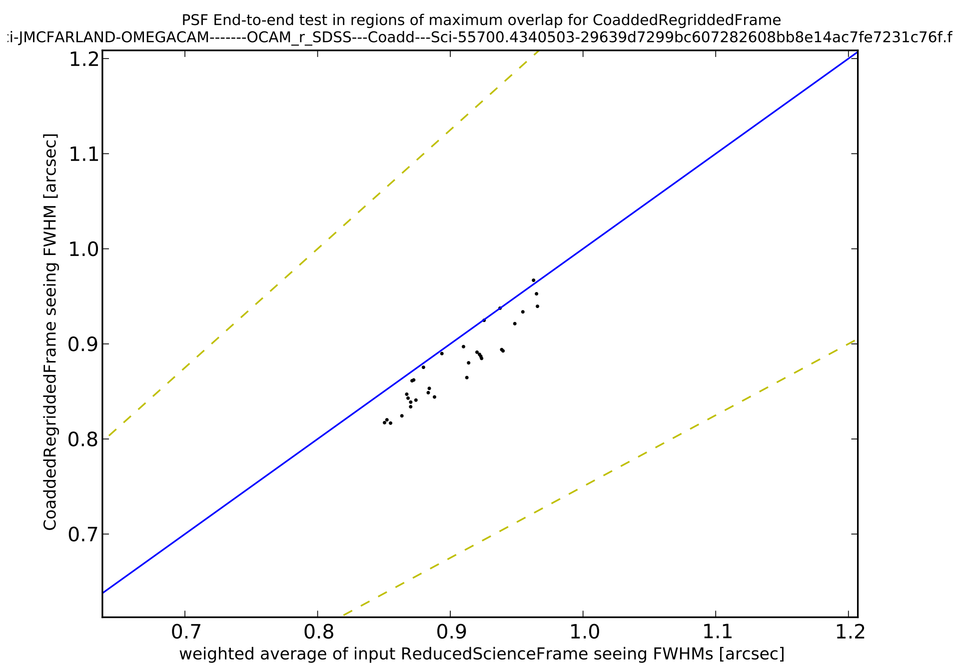

Figure 21: NGC 6822 (r') PSF end-to-end inspect figure

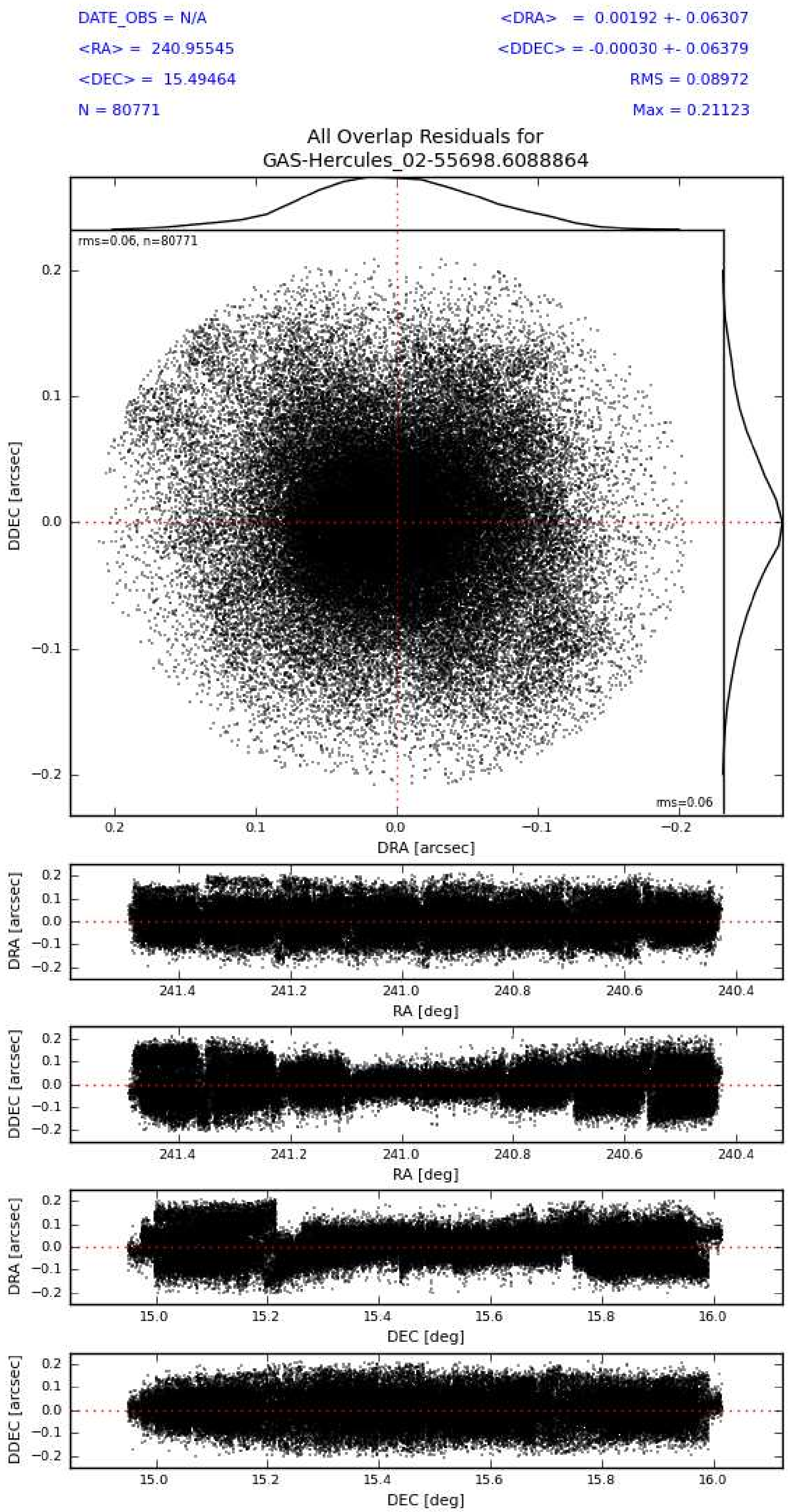

Figure 22: Hercules 02 astrometric overlap residuals figure

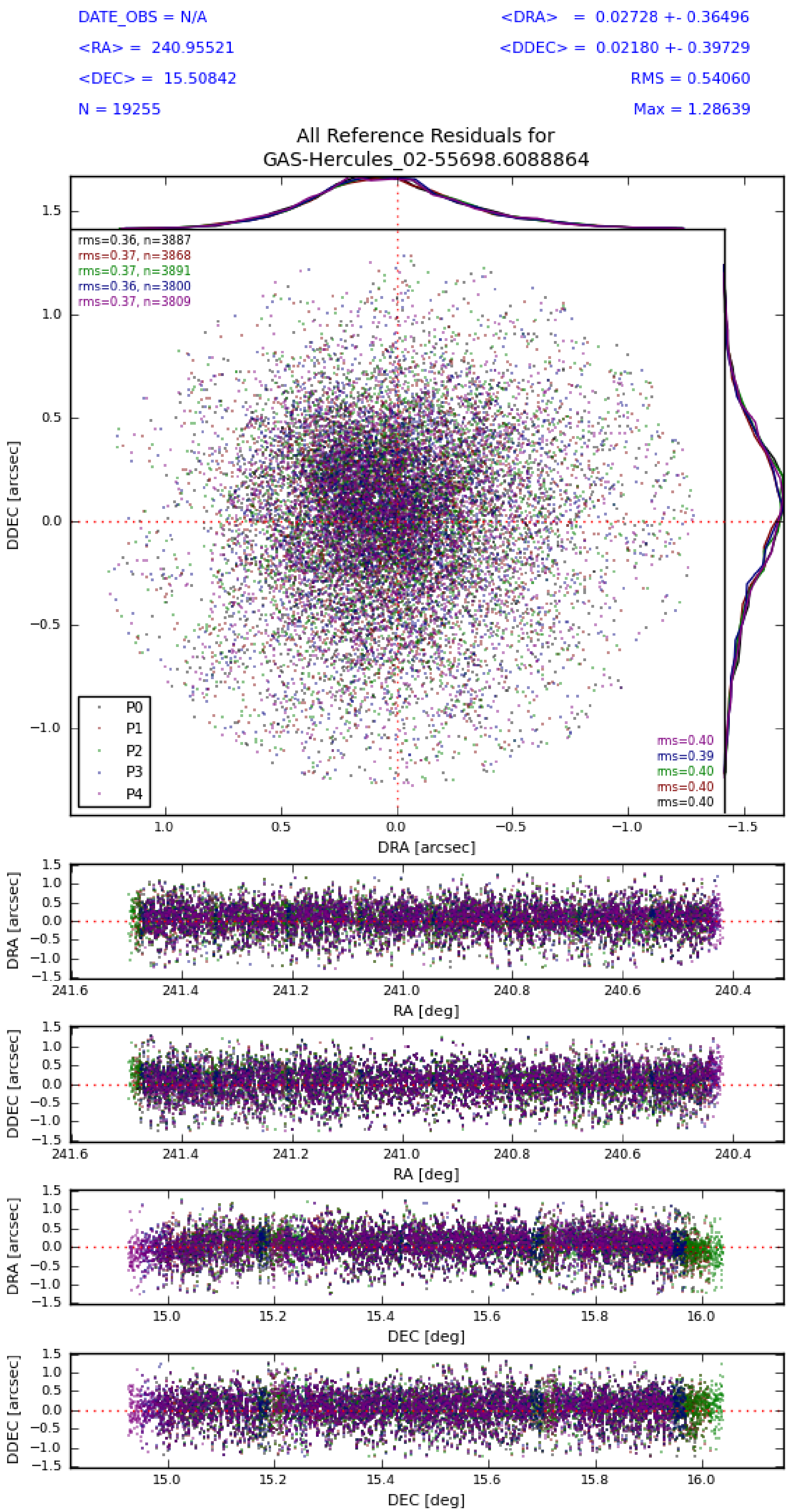

Figure 23: Hercules 02 astrometric reference residuals (USNO-A2.0) figure

- NOTE: The observations were taken after the detector plane tilt was compensated for. There remains a tilt of the focal plane caused by the telesope itself that has undoubtedly affected the results. It is also possible that the lack of active guiding is affecting the results as well. The results seen here can only improve in quality once this tilt is adequately corrected and active guiding is employed.

Conclusions:

- The PSF end-to-end plots show that the PSF difference is less than $\sim 5\%$, indicating that in general, the source positions have been matched by the global astrometric solution with good precision.
- The astrometric residual plots show an internal accuracy of ~ 0.1 arcsec and an external accuracy of ~ 0.5 arcsec. These values are a bit higher than required (nominally 0.07 arcsec and 0.3 arcsec, respectively). This is likely due to a number of factors, most notably the presence of residual focal plane tilt, and also the use of reference catalog which can have systematic offsets up to 1 arcsec.

23 Req 5.5.6/CP 8.13 - Cat III: The astrometric solution for the Guide CCDs

Required accuracy, constraints:

- 1 arcsec rms for the accuracy with respect to the external standard;
- External precision is driven by the position of the reference catalog. This is in the case of the USNO-A2 catalog of the order 0.3" with possible systematic excursions to 1".

Results:

Position of the Auto Guide CCDs in the focal plane		
CCD	**CRPIX1**	**CRPIX2**
#G1	-9702.00	-27.33
#G2	11650.00	4229.33

Table 2: Initial **physical** solutions for the position of the Guide CCDs in the focal plane

Remarks:

- The CRPIXn values are with respect to the physical center of the mosaic (i.e., at the cross point between CCDs #76, #77, #84 and #85). The values above are for the nominal physical parameters (i.e., not as seen through the optics). [**The calculated values are expected from ERD.**]

Conclusions:

- Use of fully linear solution is inadequate to attain the required accuracy. Higher order terms will likely need to be used, but only after flexure induced variations (due to, for example, changing pointing altitude and temperature) are fully understood. An average linear solution should obtain on the order of 5 arcsec accuracy given the current conditions.

24 Req 5.6.1/CP 8.18 - Cat III: Shutter Timing

Required accuracy, constraints:

- Timing error less than 0.2%

Results:

- See figures 24 and 25.

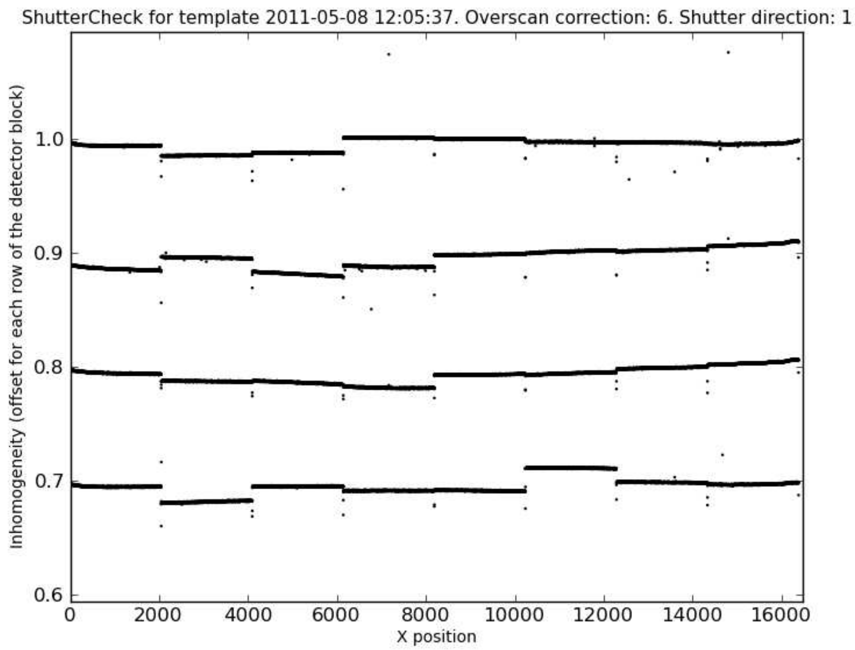

Figure 24: Shutter check for direction "1"

Remarks:

- The inhomogenuity of the effective exposure time as a function of pixel position is of the order of 1% (see figure 27).

Conclusions:

- Within specs.

25 Req 5.6.2/CP 8.37 - Cat I: Photometric Calibration - monitoring

Required accuracy, constraints:

- all photometry better than 1-2% on the photometric scale

Results: Remarks:

- To be exercised at OCAM2.

Conclusions:

-

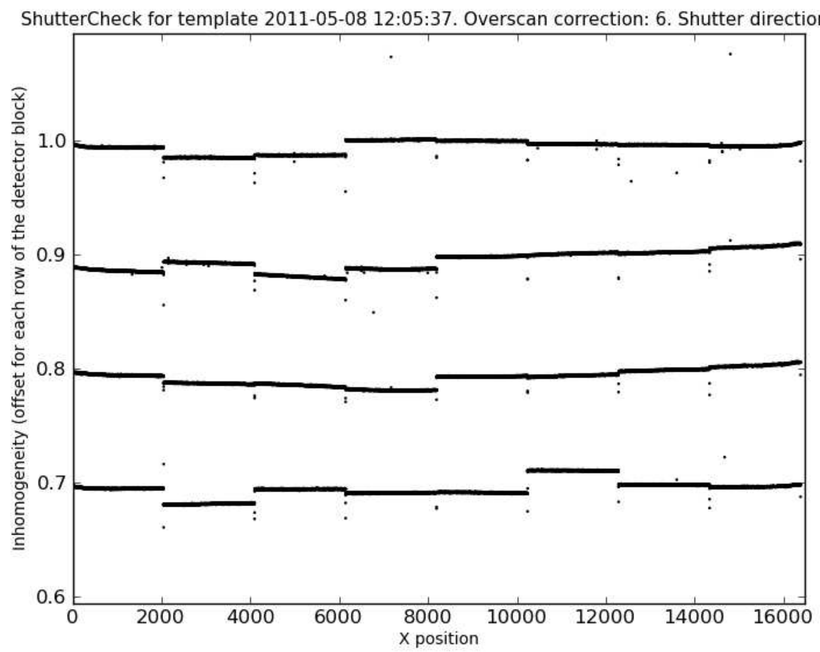

Figure 25: Shutter check for direction "-1"

26 Req 5.6.3/CP 8.38 - Cat I: Photometric Calibration - zeropoint keybands -doit

Required accuracy, constraints:

- 1% on the photometric scale

Results:

- Zeropoint results are presented in Tables 26 and 26. Figure 28 illustrates a zeropoint derivation.
- For SA110 we used Stetson, Landolt and standards from our prepatory secondary standards program.
- For SA107 we used the SDSS catalog of standard stars.
- Atmospheric extinction coefficients from Patat+2011 were applied.

Remarks:

-

Conclusions:

- **Zeropoint accuracy**: in g the measurement error in the zeropoint per chip is below 0.01mag. Extinction error is included in this budget.
- **Throughput consistent with expectations.** A comparison indicates that the observed zeropoints appear to agree with those effectively used in ESO's ETC, within 10%. In Sloan z preliminary results indicate an observed 20% greater throughput. This result is very preliminary, as it involves extrapolation from Johnson-Cousins I to z.

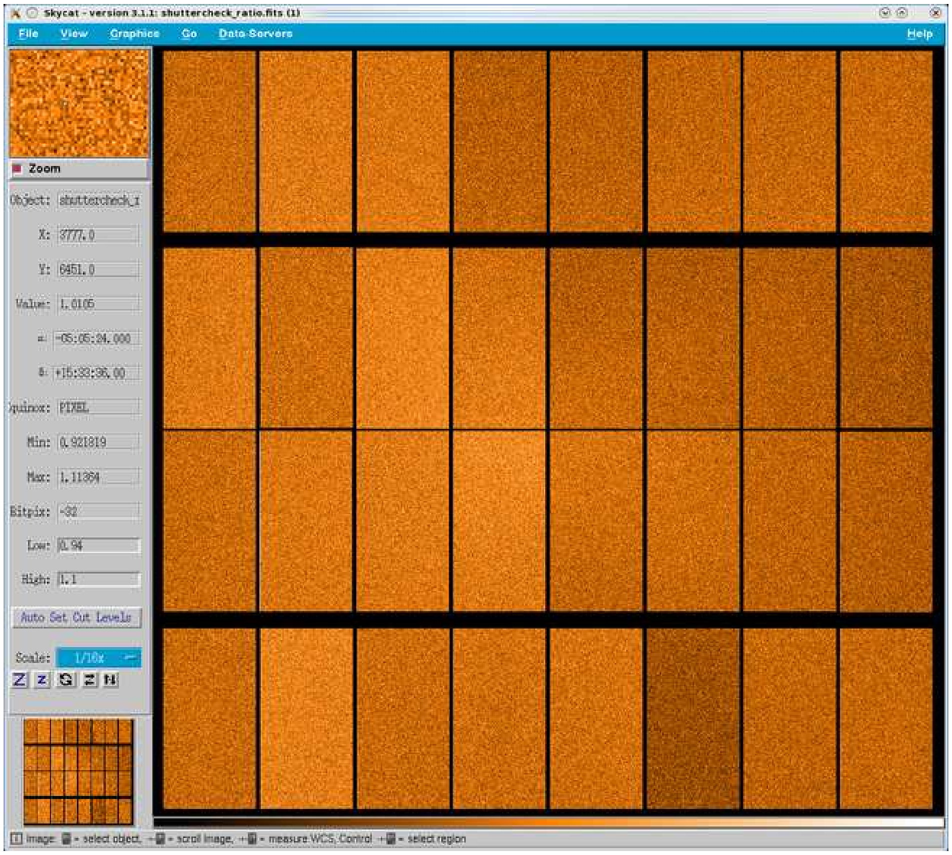

Figure 26: Ratio of overscan corrected short (0.1s) and long (3.5s) exposure.

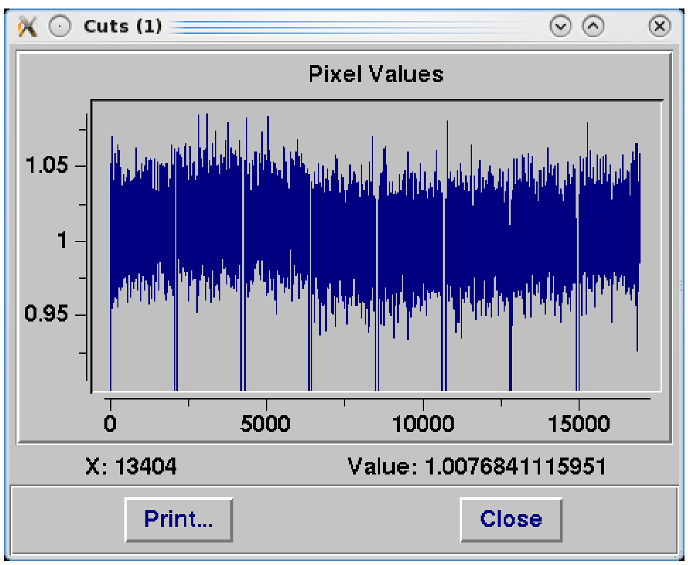

Figure 27: Cross cut of pixel values along the top row of CCDs in the ratio image

Table 3: Per chip zeropoints statistics for key- and user-band filters. Color range of Landolt stars in SA 110: B-V=[0.5-2.2] and in SA 107: B-V=[0.5-1.5].

filter	**SA**	**median(ZPT)**[a] airmass=0	**median(ZPT)** airmass=1	**variation**[b]	**DATE-OBS (UT)**
u (AB)	110	23.26	22.74	0.12	2011-05-09 10:03:29
u (AB)	107	23.46	22.95	0.12	2011-05-04 03:55:17
g (AB)	110	24.99	24.81	0.08	2011-05-09 10:11:12
g (AB)	107	24.97	24.79	0.07	2011-05-04 03:59:19
r (AB)	110	24.83	24.73	0.05	2011-05-09 10:14:06
i (AB)	110	24.23	24.18	0.06	2011-05-09 10:17:04
z (AB)	110	22.80	22.77	0.09	2011-05-09 10:21:06
B (Vega)	110	24.89	24.68	0.09	2011-05-09 09:52:04
V (Vega)	110	24.00	23.87	0.11	2011-05-09 09:56:44
V (Vega)	107	24.61	24.47	0.05	2011-05-03 05:52:49

[a]median value of single chip zeropoints
[b]standard deviation of distribution of single chip zeropoints

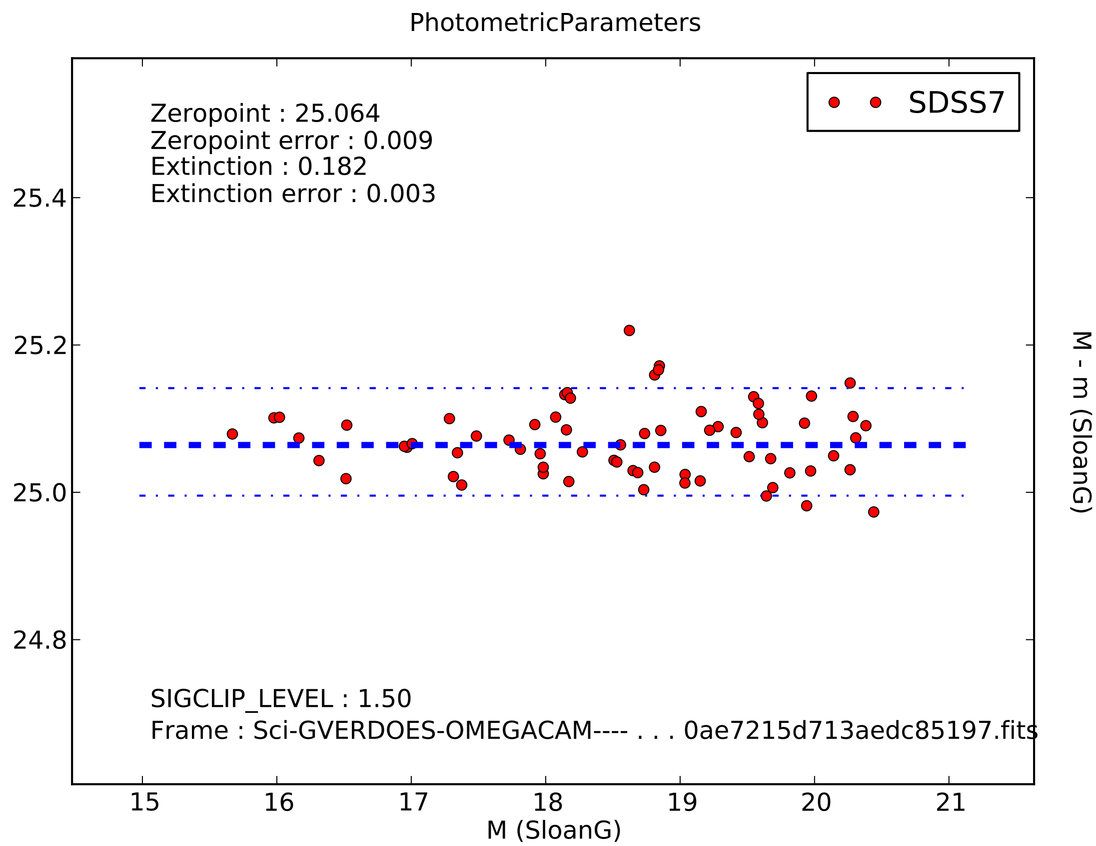

Figure 28: Example of a photometry inspect figure: zeropoint determination for a single CCD.

27 Req 5.6.4/CP 8.44 - Cat I: Photometric Calibration - zeropoint user bands

Required accuracy, constraints:

Table 4: Zeropoints per chip for SA107 OCAM_g_SDSS. [1] contains contribution from measurement errors in stellar photometry and error in atmospheric extinction coefficient.

chipname	zeropoint airmass=1	err(zeropoint)[a]	n standards
ESO CCD #65	24.841	0.006	85
ESO CCD #66	24.751	0.006	70
ESO CCD #67	24.837	0.008	85
ESO CCD #68	24.789	0.008	73
ESO CCD #69	24.793	0.009	65
ESO CCD #70	24.949	0.007	76
ESO CCD #71	24.816	0.006	79
ESO CCD #72	24.882	0.009	60
ESO CCD #73	24.863	0.007	70
ESO CCD #74	24.787	0.005	78
ESO CCD #75	24.757	0.006	63
ESO CCD #76	24.771	0.008	63
ESO CCD #77	24.745	0.005	69
ESO CCD #78	24.724	0.005	69
ESO CCD #79	24.771	0.009	85
ESO CCD #80	24.812	0.006	71
ESO CCD #81	24.759	0.006	57
ESO CCD #82	24.698	0.005	85
ESO CCD #83	24.704	0.005	54
ESO CCD #84	24.783	0.007	61
ESO CCD #85	24.888	0.006	63
ESO CCD #86	24.950	0.005	70
ESO CCD #87	24.895	0.006	72
ESO CCD #88	24.924	0.007	75
ESO CCD #89	24.820	0.009	86
ESO CCD #90	24.789	0.012	57
ESO CCD #91	24.734	0.007	77
ESO CCD #92	24.756	0.012	81
ESO CCD #93	24.829	0.010	69
ESO CCD #94	24.781	0.009	97
ESO CCD #95	24.759	0.009	74
ESO CCD #96	24.903	0.007	87

[a] contains contribution from measurement errors in stellar photometry and error in atmospheric extinction coefficient (0.003mag)

- 2% on the photometric scale for broad bands and 5% for narrow band filters

Results:

- See user bands included in previous section.

Remarks:

- OCAM2

Conclusions:

-

28 Req 5.6.6/CP 8.24 - Cat III: Dependency on angle - ADC, rotator/reproducibility

Required accuracy, constraints:

- 1% on the photometric scale

Results:

Remarks:

- Goal: Verify the dependency of the photometric calibration on the angle of the field rotator.
- Requires observations at 12 different rotator angles. Not available?

Conclusions:

-

29 Req 5.6.8/CP 8.52 - Cat III: Detection limit and ETC calibration

Required accuracy, constraints:

- 10% in detection limit

Results:

Table 5: Zeropoints observed vs predicted by ETC for key- and user-band filters.

filter	**ZPT obs** airmass=1	**ZPT ETC** airmass=1	**DATE-OBS (UT)**
u (AB)	22.95	22.8	2011-05-09 10:03:29
g (AB)	24.79	24.8	2011-05-09 10:11:12
r (AB)	24.73	24.6	2011-05-09 10:14:06
i (AB)	24.18	24.0	2011-05-09 10:17:04
z (AB)	22.77	22.0	2011-05-09 10:21:06
B (Vega)	24.68	24.63	2011-05-09 09:52:04
V (Vega)	23.87	24.42	2011-05-09 09:56:44
V (Vega)	24.47	24.42	2011-05-03 05:52:49

ZPT ETC: ZPT predicted by ESO's ETC. For Sloan bands nearest Johnsons-Cousins band (UBVRI) magnitude is converted to AB. ESO is adapting the ETC to allow a direct comparison for Sloan bands.

Remarks:

-

Conclusions:

- **Throughput consistent with expectations.** The zeropoints are a good measure of the end-to-end throughput of OmegaCAM+VST. The observed zeropoints are within 20% or better of ETC predictions. The exception is Sloan z where the observed throughput is 0.7 mag higher than predicted. This is a very preliminary result as it involves extrapolation from Johnson-Cousins I (see caption Table 29).

30 Req 5.7.1/CP 8.9 - Cat III: Camera focus/tilt

Required accuracy, constraints:

Results:

- See figures 29, 30, 31 and 32.

Remarks:

- A procedure to automatically analyse focus sequence images and calculate the tilt was written by K. Kuijken.
- The tilt was corrected by inserting shims in the instrument mountings.
- The PSF Anisotropy plots shown here are taken at rotator angles of 0, 90, 180, 270 degrees, after the tilt was corrected.

Conclusions:

- The plots show that the PSF anisotropy pattern stays the same as the instrument is rotated. This means that the instrument is properly aligned with the rotator.
- The image as provided by the telescope may still be improved.

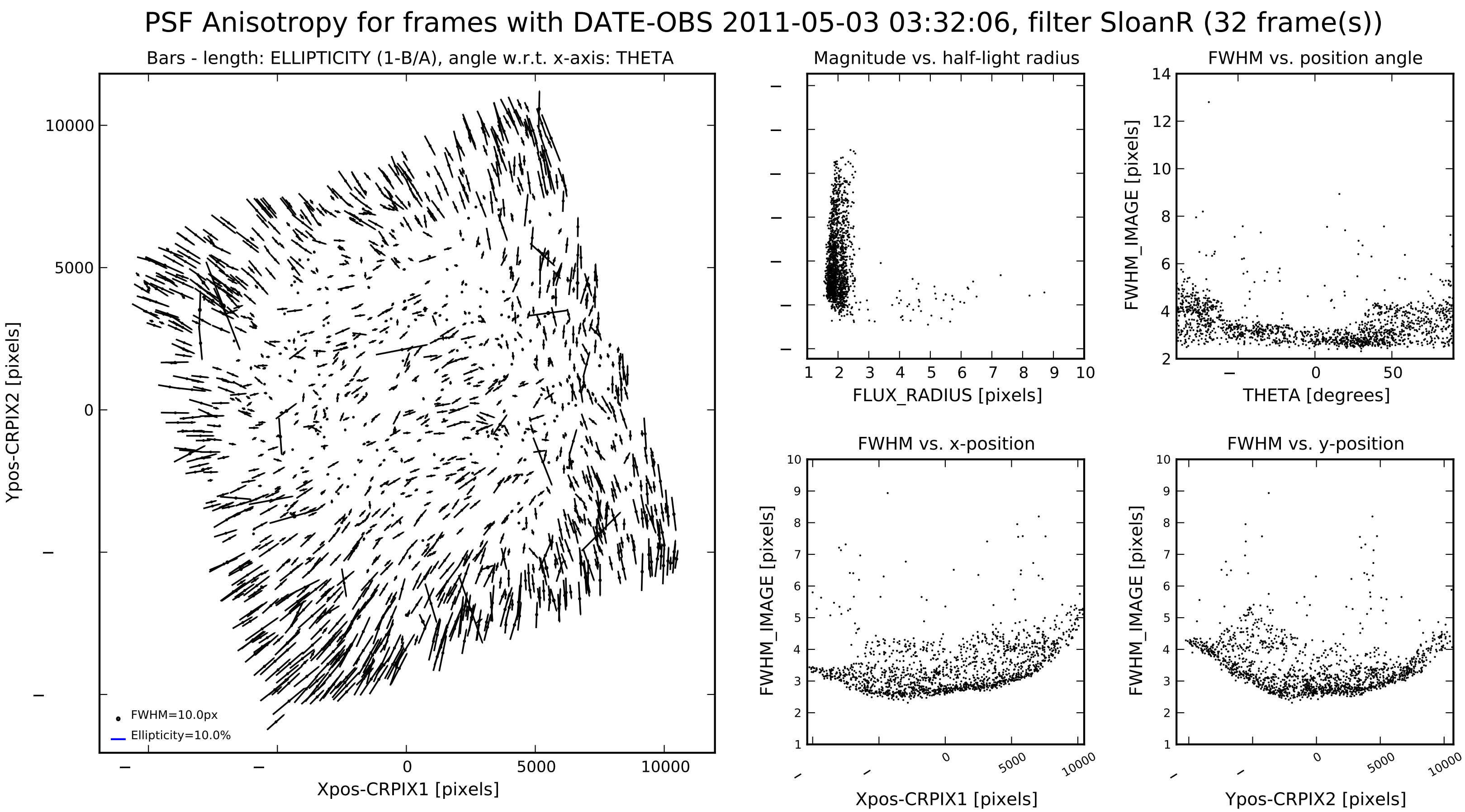

Figure 29: PSF Anisotropy at rotator angle 0.

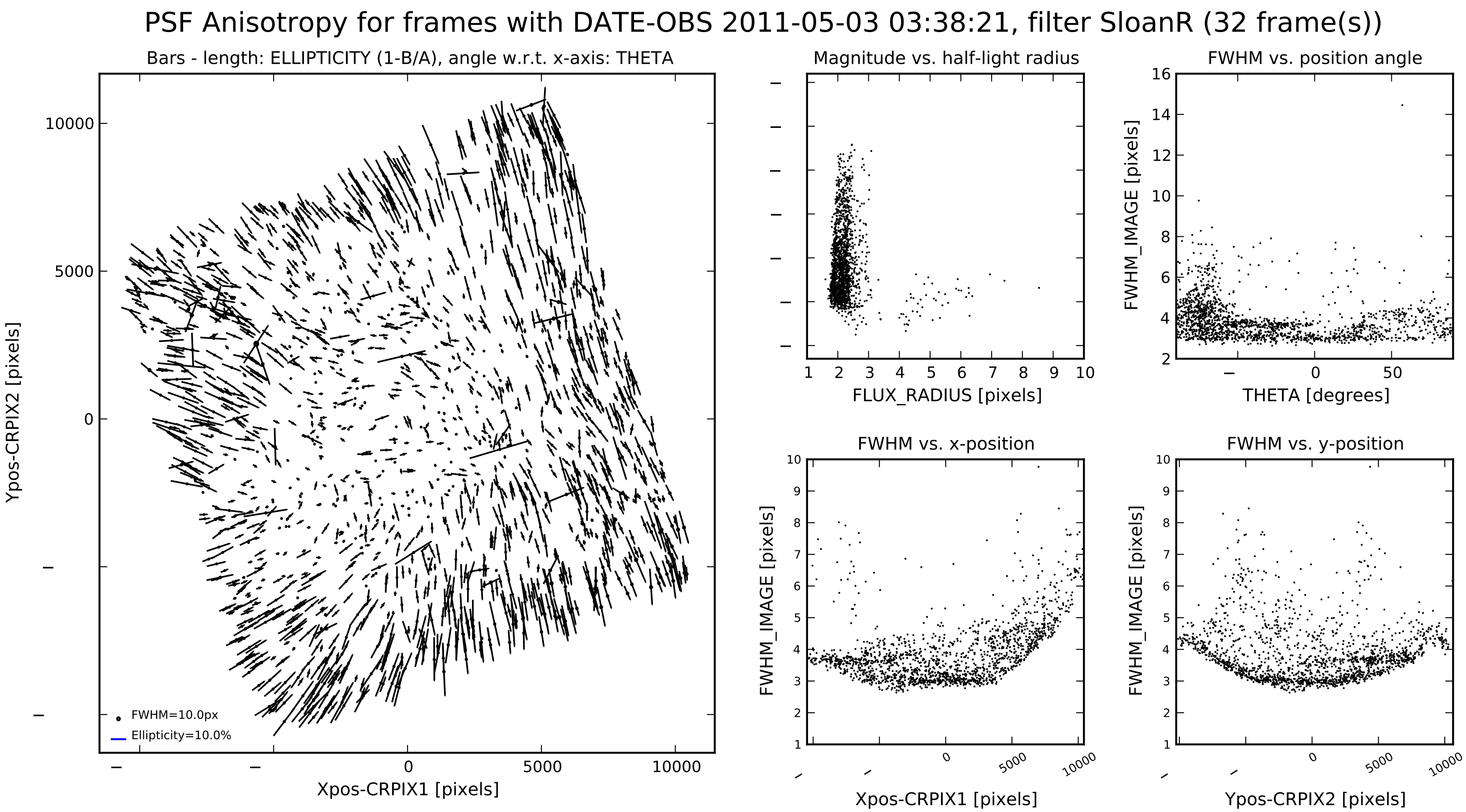

Figure 30: PSF Anisotropy at rotator angle 90.

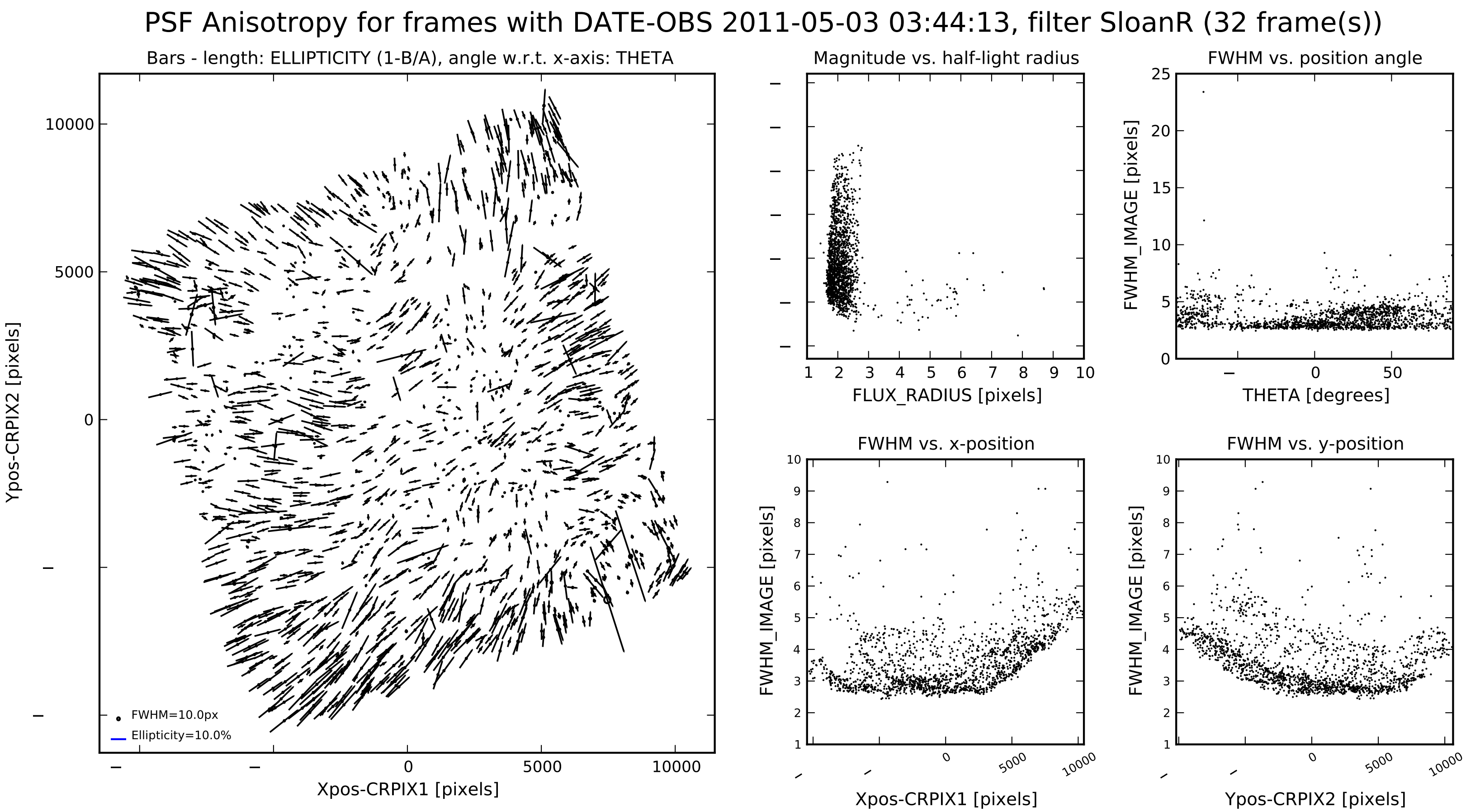

Figure 31: PSF Anisotropy at rotator angle 180.

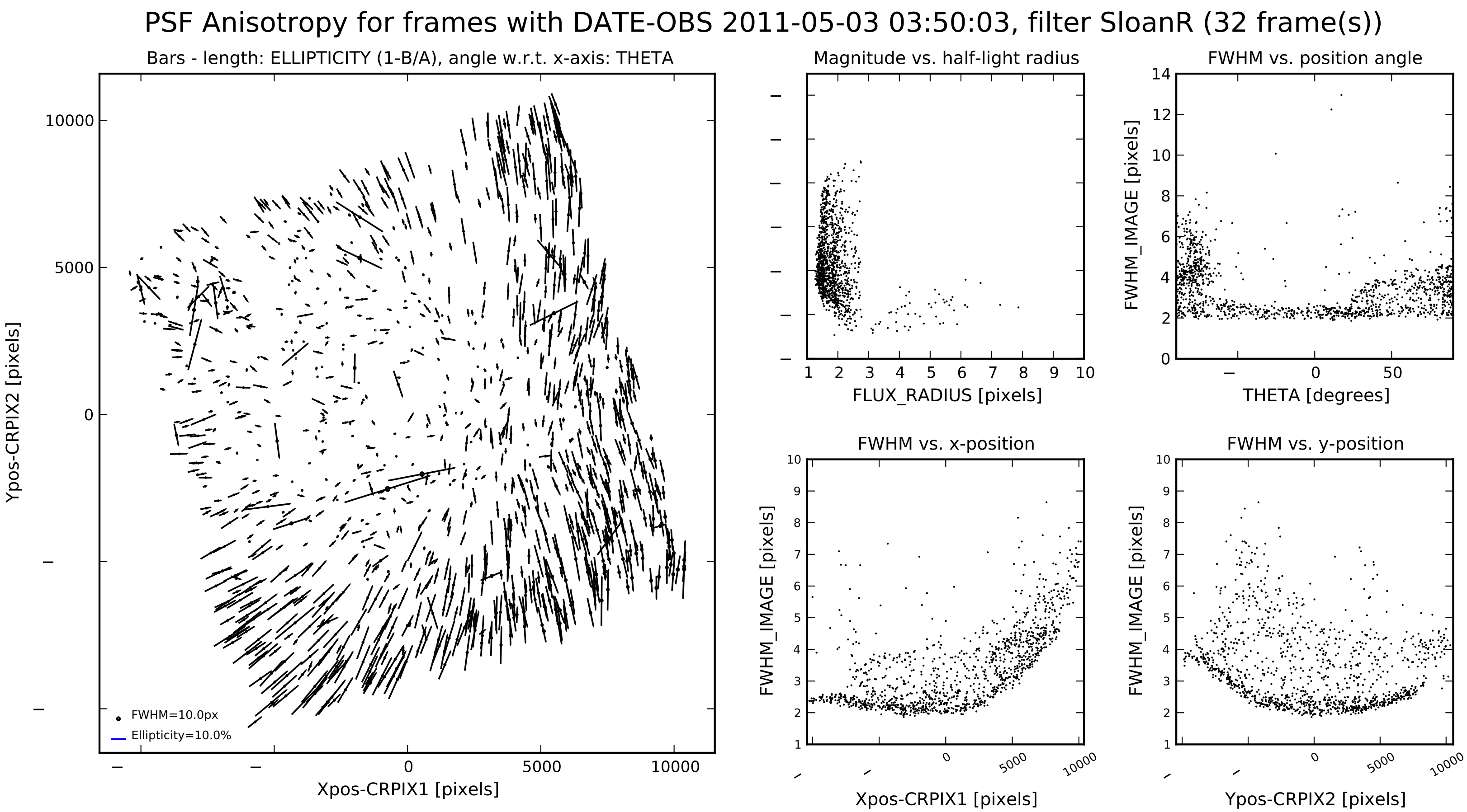

Figure 32: PSF Anisotropy at rotator angle 270.

31 Delivered scripts

Three scripts are to be delivered to Paranal:

- Quick Detector Responsivity Check (**ready**).
- PSF Anisotropy (**delivered**).
- Photometric Monitoring (**not ready**).

32 Tasks for Commissioning 2

See Commissioning Plan.

- Req. 5.4.8 Illumination Correction - part 2 complete
- Req. 5.6.4 Photometric Calibration - zeropoints user bands (extensive)
- Req. 5.6.5 Dependency on angle - ADC, rotator/reproducibility
- Req. 5.6.7 Linearity (as a function of flux)
- Req. 5.6.9 Secondary Standards