Field Photometry/Flat fielding: May 2013

SALT Board Meeting: May 2013

CAMK, Warsaw

Darragh O'Donoghue

SALT Instrumentation Director

1. **Field photometry / Flat fielding with SALT**
2. **SALTICAM Optics**

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 1:

We would like to know:

- **How can we correct for illumination variations over the science field on large pixel scales (~several arcmin)?**

- **How can we determine properties of targets distributed over the science field of view:**

  - ❖ **Differential photometry over the field**
  - ❖ **Fabry-Perot**
  - ❖ **Spectroscopic properties (e.g. emission line strengths across large extended objects)**

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 2:

Previous results:

- **Flats from the calibration system are no good. We know now that that is because the CALSYS optics are not "as designed back in 2003-2004"; the light does NOT follow the same path through the SAC as celestial light.**
- **Twilight sky flats are no good either. Analyses by Luis Balona, Vijay Singh, Nic Loaring, DOD all agree. The cause is unknown but could be: (i) stray light on the focal plane; (ii) geometrical distortion, so pixels don't cover the same angular field on the sky (Tad & Ted explanation).**
- **Even sky in the science images is not good for estimating the illumination. Using the sky to scale the images, Petri Vaisanen and Alexei Kniazev found they could achieve differential photometry with rms error of 0.07 mag (perhaps 0.05 possible). I achieved a similar result. Is the cause the same explanation as in the previous bullet?**

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 3:

In mid 2012, Tad Pryor and Ted Williams (Rutgers) obtained SALTICAM imaging over a track of fields of stars with known magnitudes. The aim was to see if photometry of point sources could determine the illumination across the science FoV:

- **V images of Selected Area 107 on 24 and 28 July 2012, and R images on 30 July. They got accuracy of peak-to-peak 0.05 mag (much better than Petri and Alexei / DOD) using vignetting models of the telescope computed by DOD.**
- **Recently Ted and I obtained RSS imaging over a track too: Selected Area 98 on 2 Mar and NGC2670 on 25 April.**
- **This talk presents the results of this investigation which is not finished and is still "Work In Progress". Much progress has been made.**

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 4:

- Data are repeat images in a single filter over an entire track, of fields with many stars of known magnitudes. These are ~10-20 sec exposures with SCAM (SA107 in 2012 Jul) and RSS (SA98 and NGC2670 in 2013 Mar & Apr).

- Instrumental mags were extracted using DAOPhot, SExtractor and my custom photometry – all gave same answers.

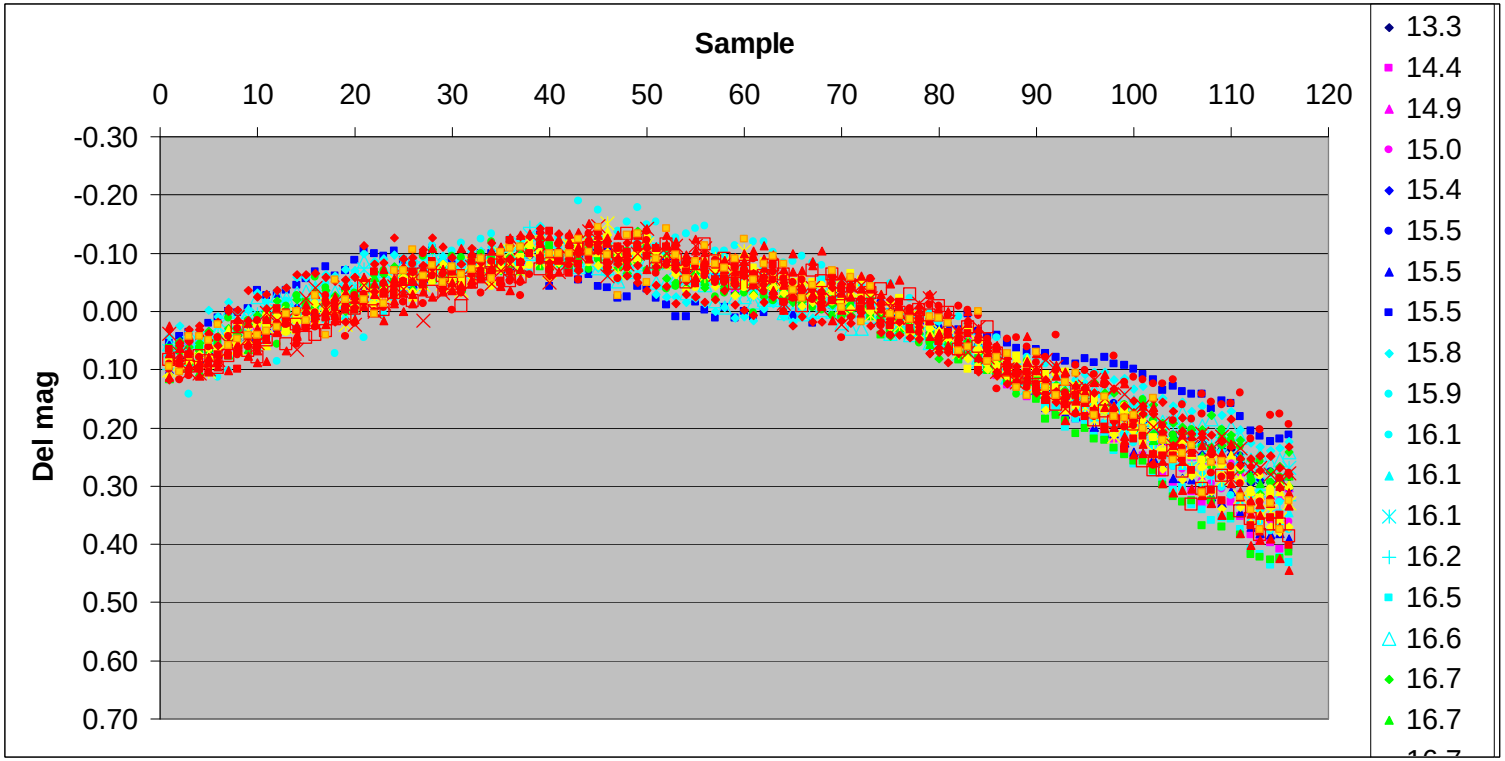
- You will see two kinds of plots:
  - ❖ Photometry of all stars during the track with the median of each individual star's magnitudes subtracted on a star by star basis separately. This shows how stars vary during the track.
  - ❖ Known V magnitudes were subtracted from the instrumental magnitudes with the hope that accurate differential photometry over the field could be achieved. One frame analysed in detail.

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 5:

Selected Area 98: 2013 March 2 116 x 30 sec exposures in PI5060

Median subtracted instrument. mag.



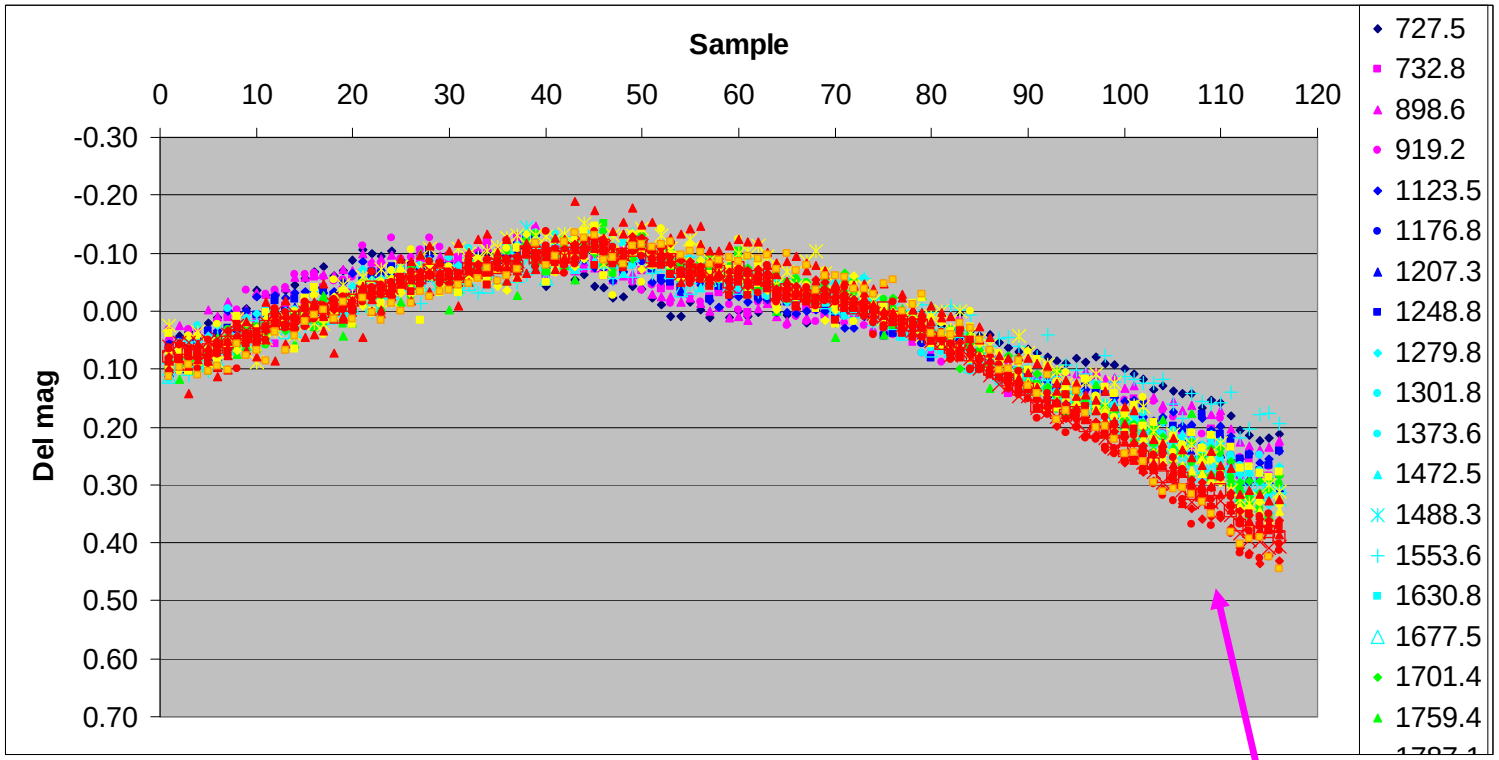
Frame No.

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 6:

Selected Area 98: 2013 March 2 116 x 30 sec exposures in PI5060

Median subtracted instrument. mag.



Frame

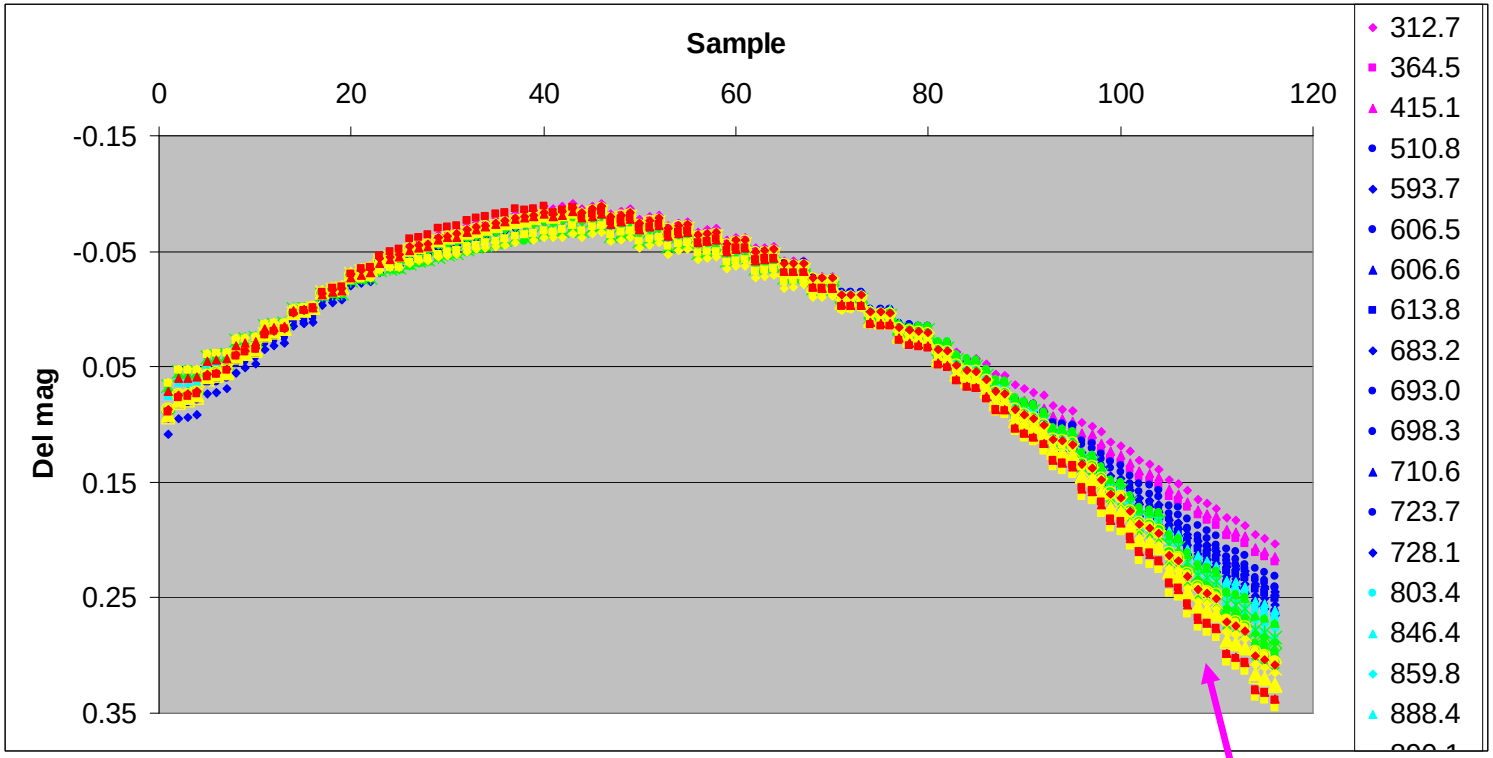
Colour code (red-blue) by X position on CCD

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 7:

Models computed for same track as 2013 March 2 data

Throughput from optical model of SALT: pupil variations in a track and vignetting in the SAC



Frame No.

X dependence seen in models as well

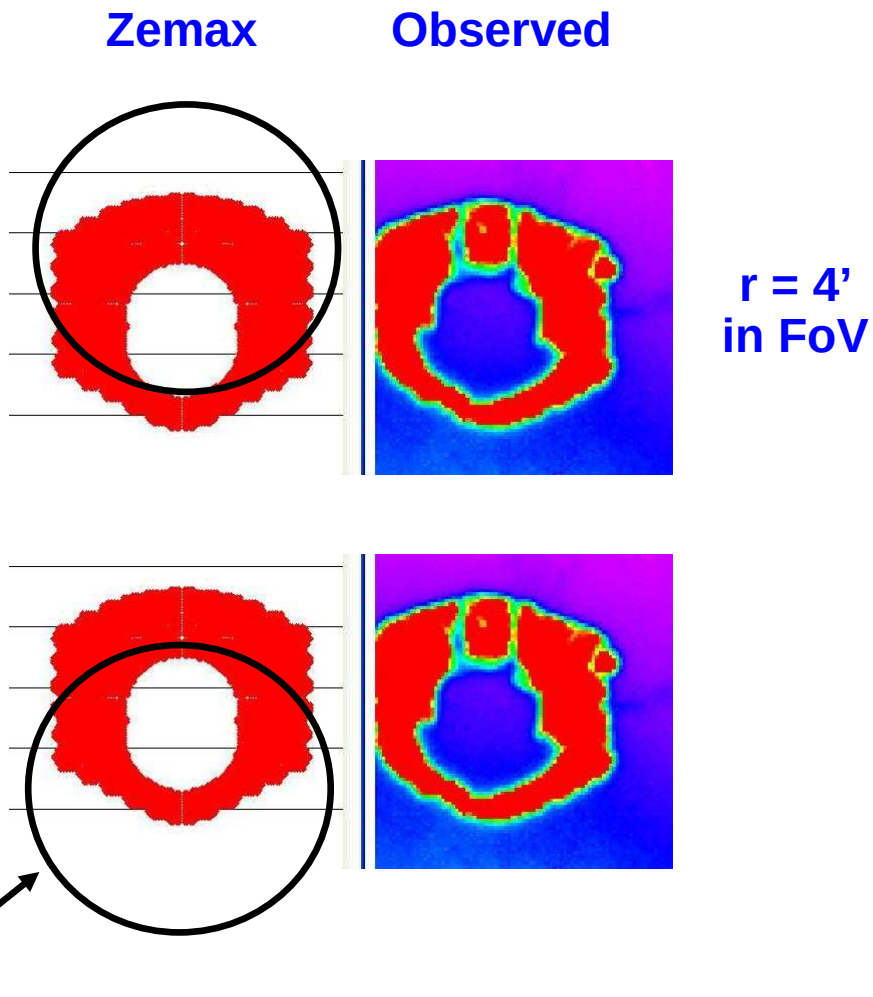
Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 8:

At edge of Science FoV:

- If pupil “goes off” the primary mirror on one side, only little light is lost

- If pupil “goes off” the primary mirror from the other side, lots of light is lost



Field Photometry/Flat fielding: May 2013

If you subtract the known V magnitude of each star, you should get scatter as small as you do when subtracting the median of each star separately

… BUT YOU DON'T …

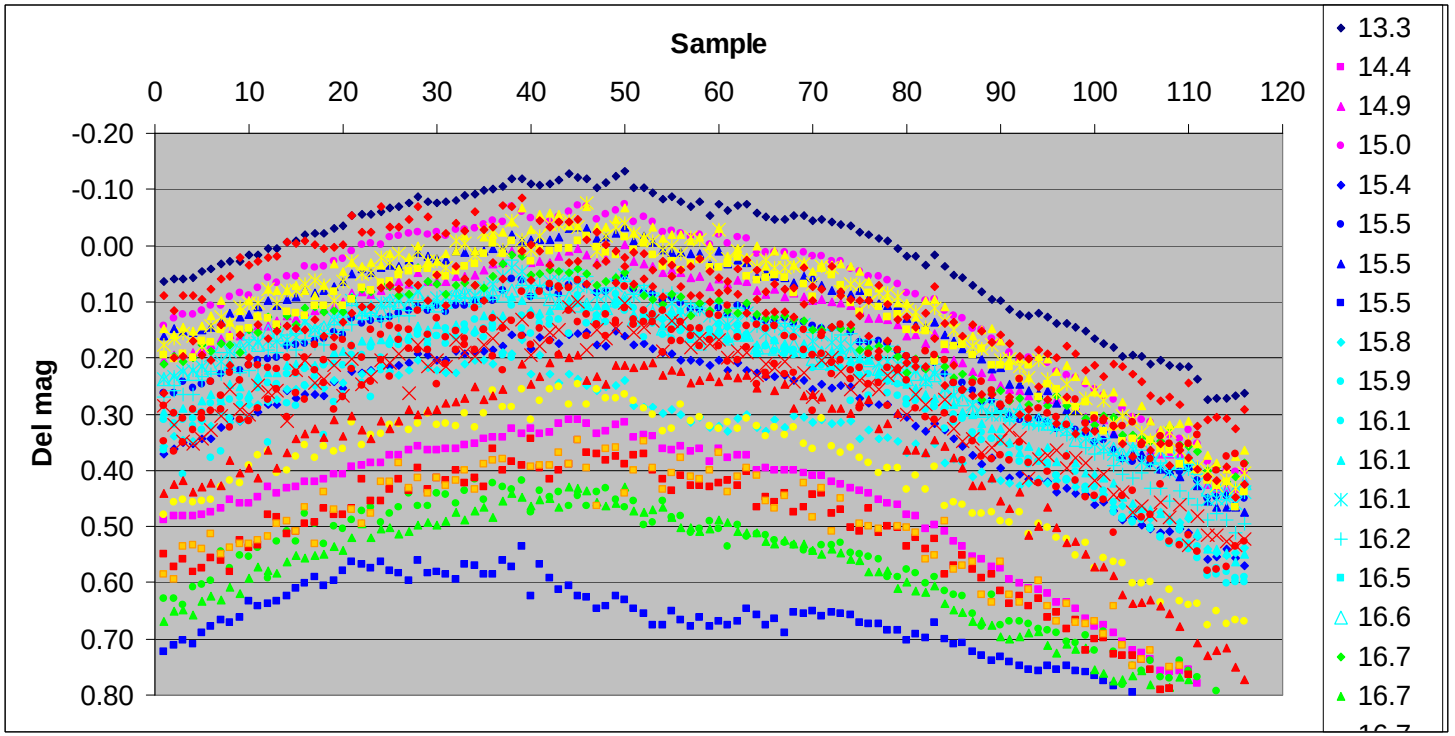
Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 9:

Selected Area 98: 2013 March 2 116 x 30 sec exposures in PI5060

Instrumental mag With known V mag subtracted

(and single zero pt added)

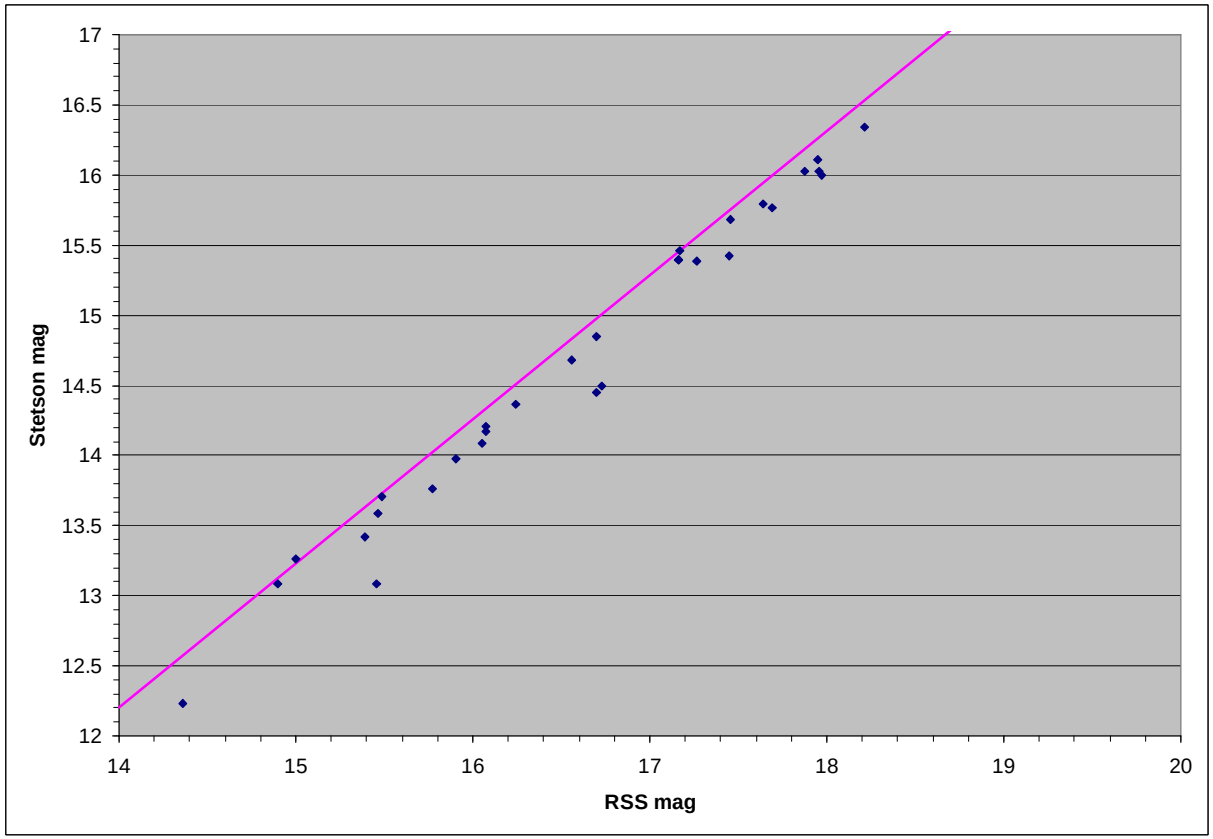


Frame No.

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 10:

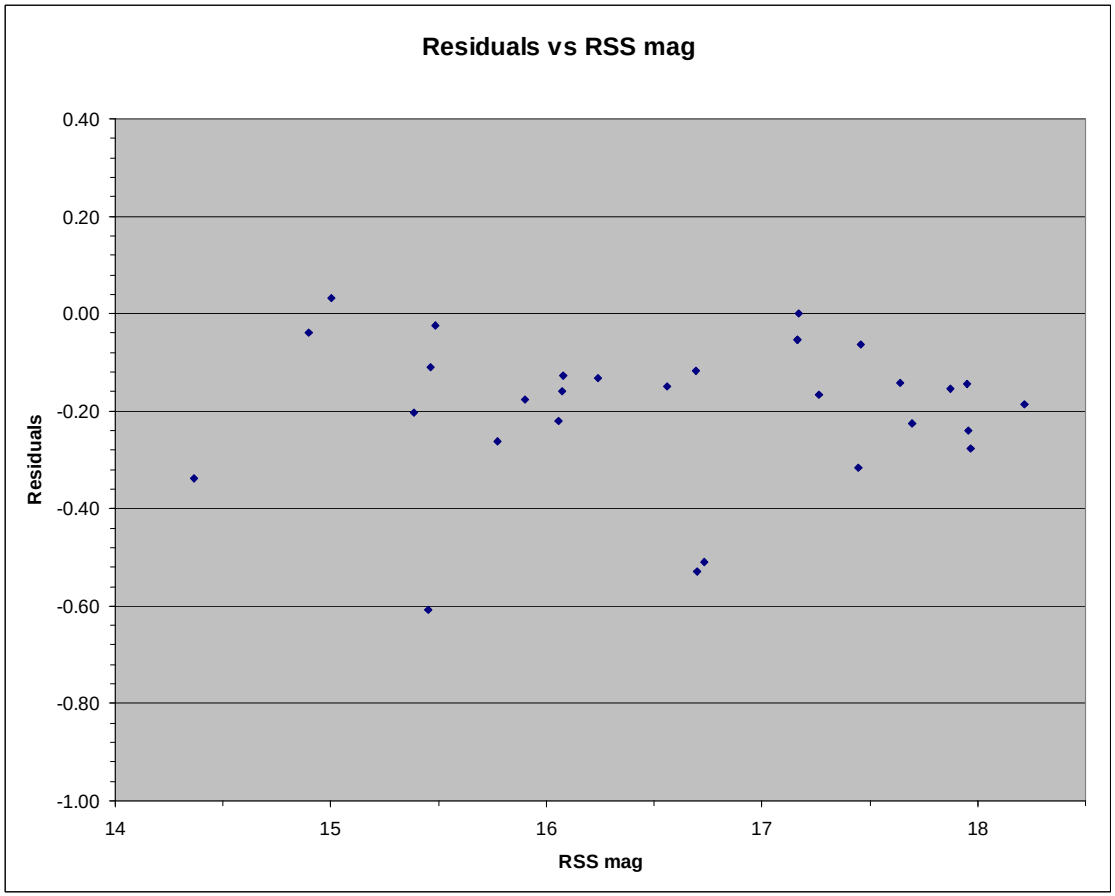
Selected Area 98: 2013 March 2 1 frame at centre of track



Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 11:

Selected Area 98: 2013 March 2 1 frame at centre of track

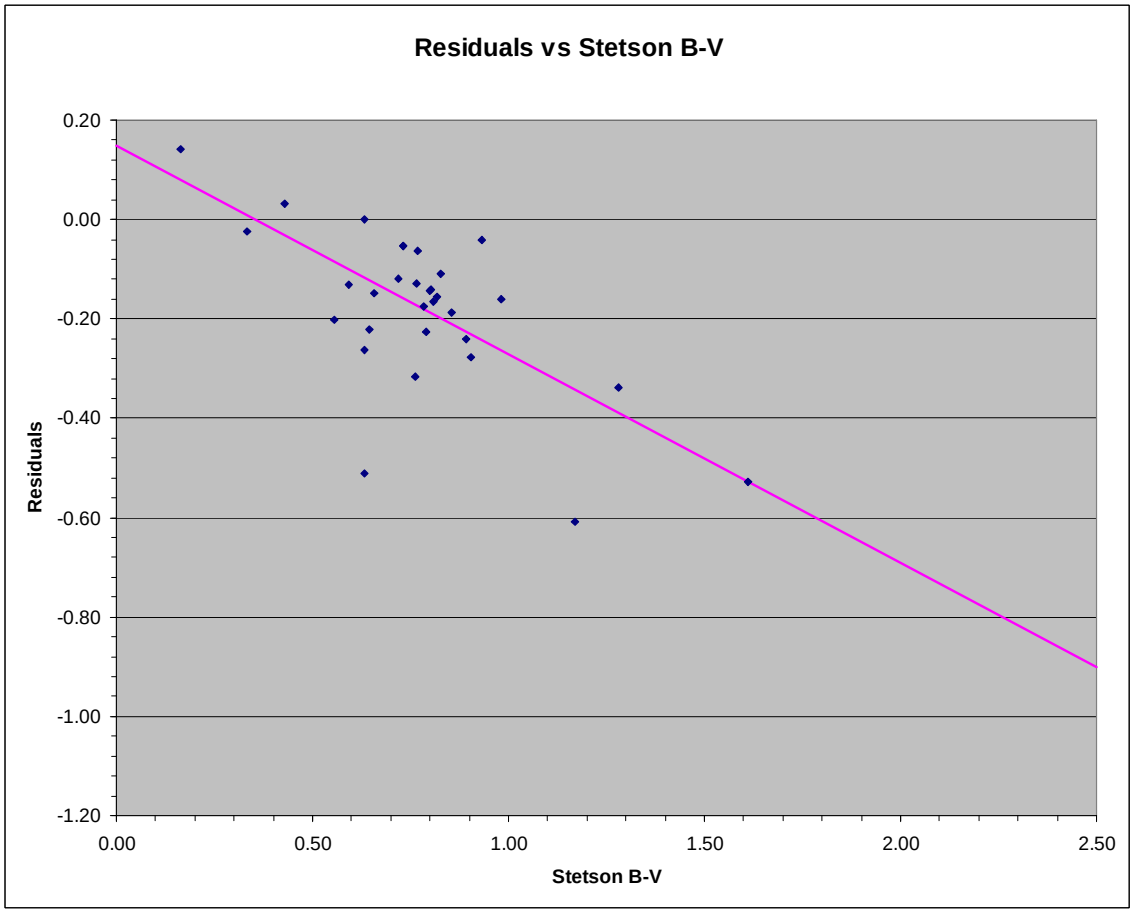


Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 12:

Selected Area 98: **2013 March 2** **1 frame at centre of track**

Colour correction needed because filter was at central lambda of 5060 nm.



Field Photometry/Flat fielding: May 2013

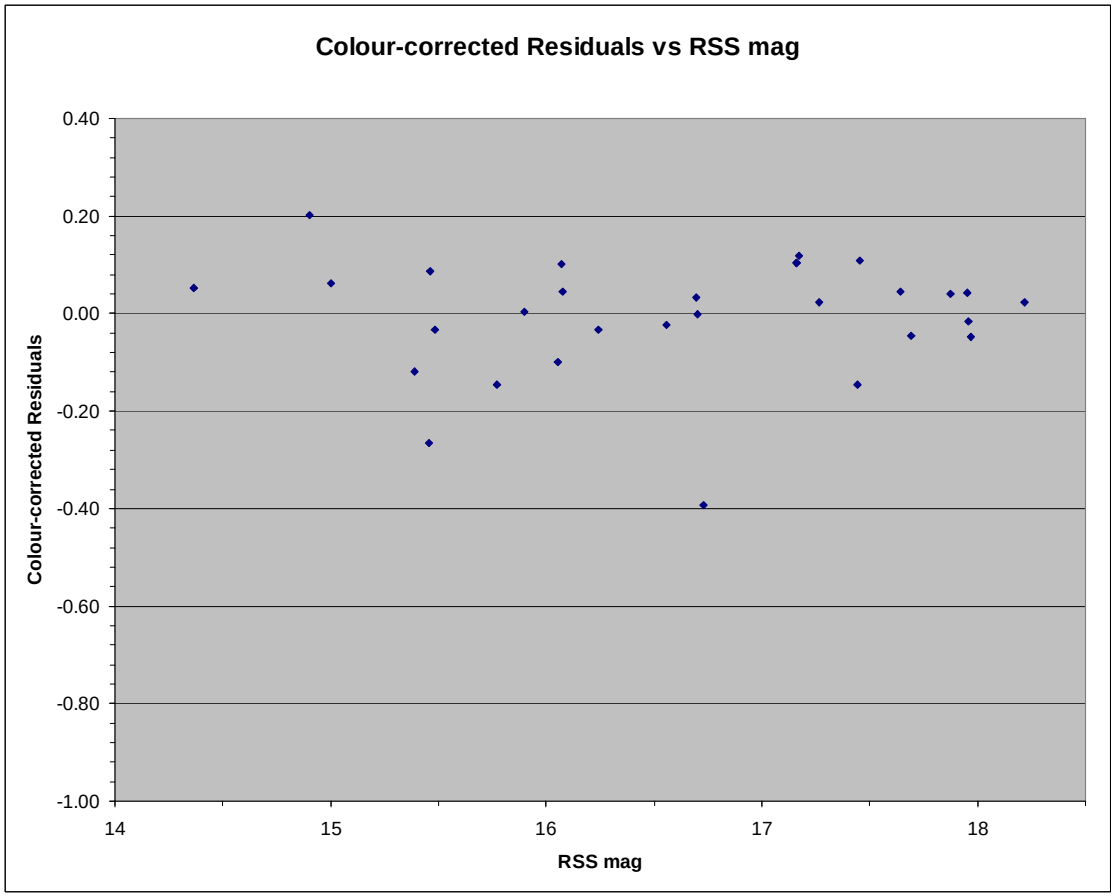
Flatfielding and Field Photometry 13:

Selected Area 98: **2013 March 2** **1 frame at centre of track**

Peak to peak scatter of ~0.3 mag with rms of 0.06 mag !!

WHY?

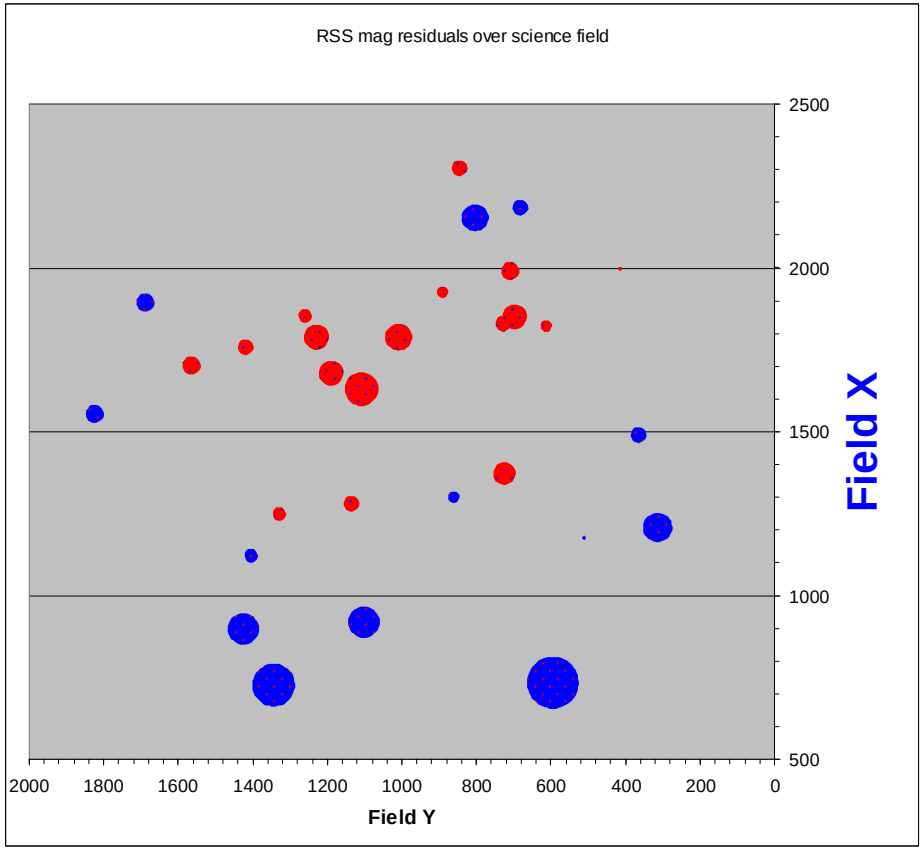
Amateur astronomers with their eyeball achieve 0.1 mag.



Field Photometry/Flat fielding: May 2013

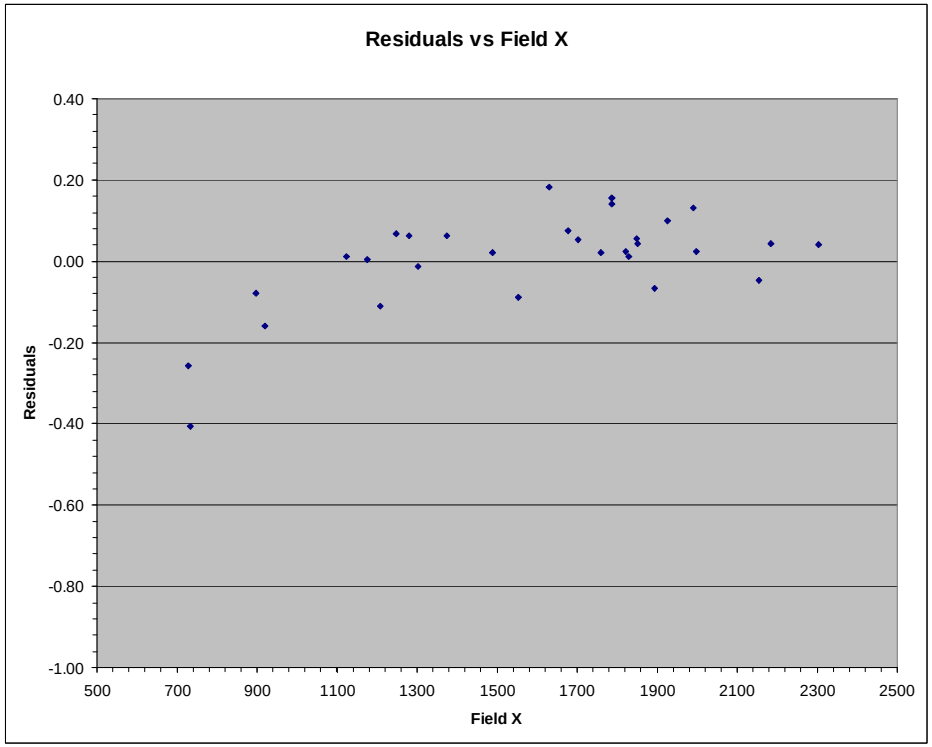
Flatfielding and Field Photometry 14:

Size of symbol proportional to residual and red & blue indicate opposite sign



Field Y

Plot of residuals vs X



Field X

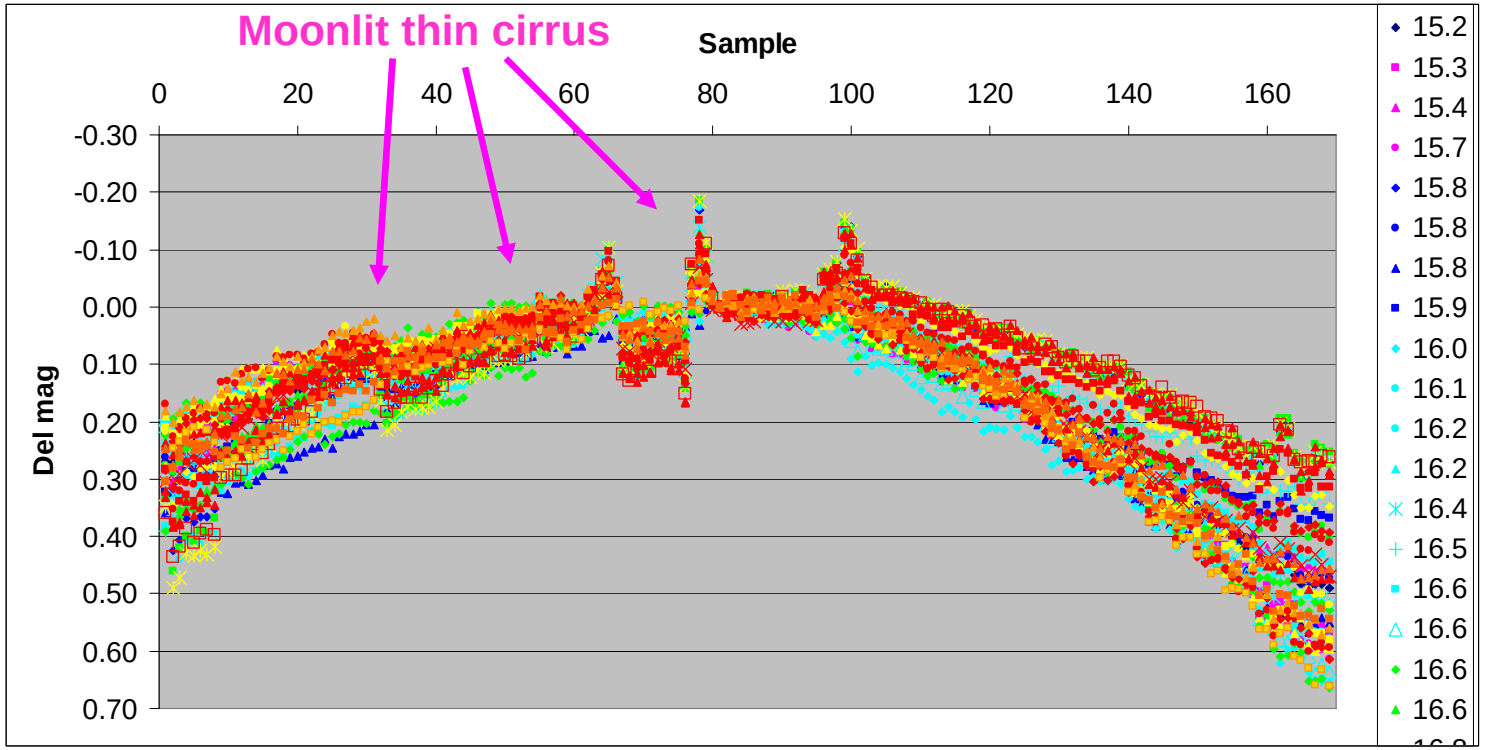
Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 15:

New field: NGC2670 with photometry by Kubiak

NGC2670 2013 Apr 25 169 x 30 sec exposures in PI5060

Median subtracted instrument. mag.



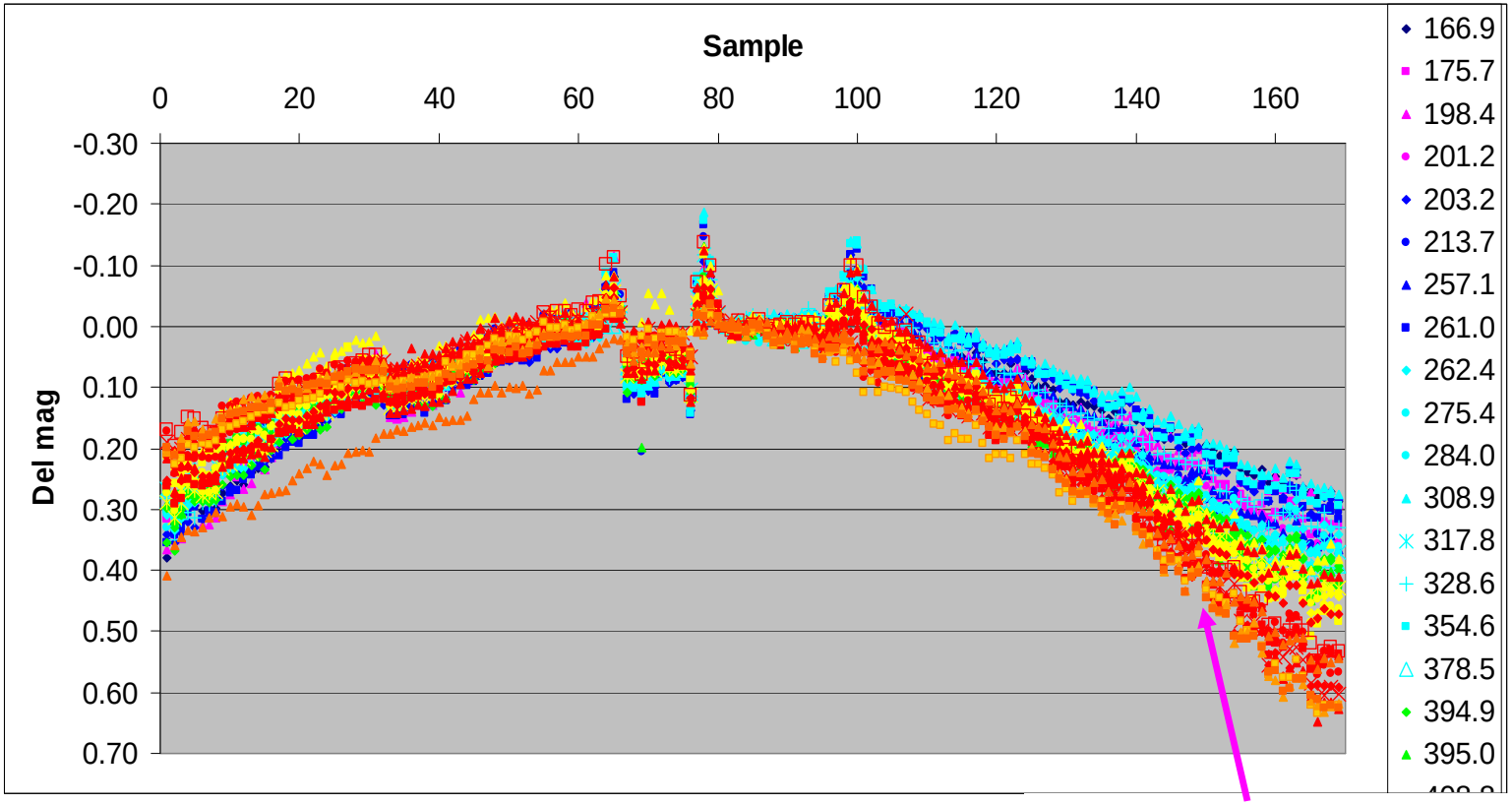
Frame

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 16:

NGC2670 2013 Apr 25 169 x 30 sec exposures in PI5060

Median subtracted instrument. mag.



Frame

Colour code (red-blue) by Y position on CCD

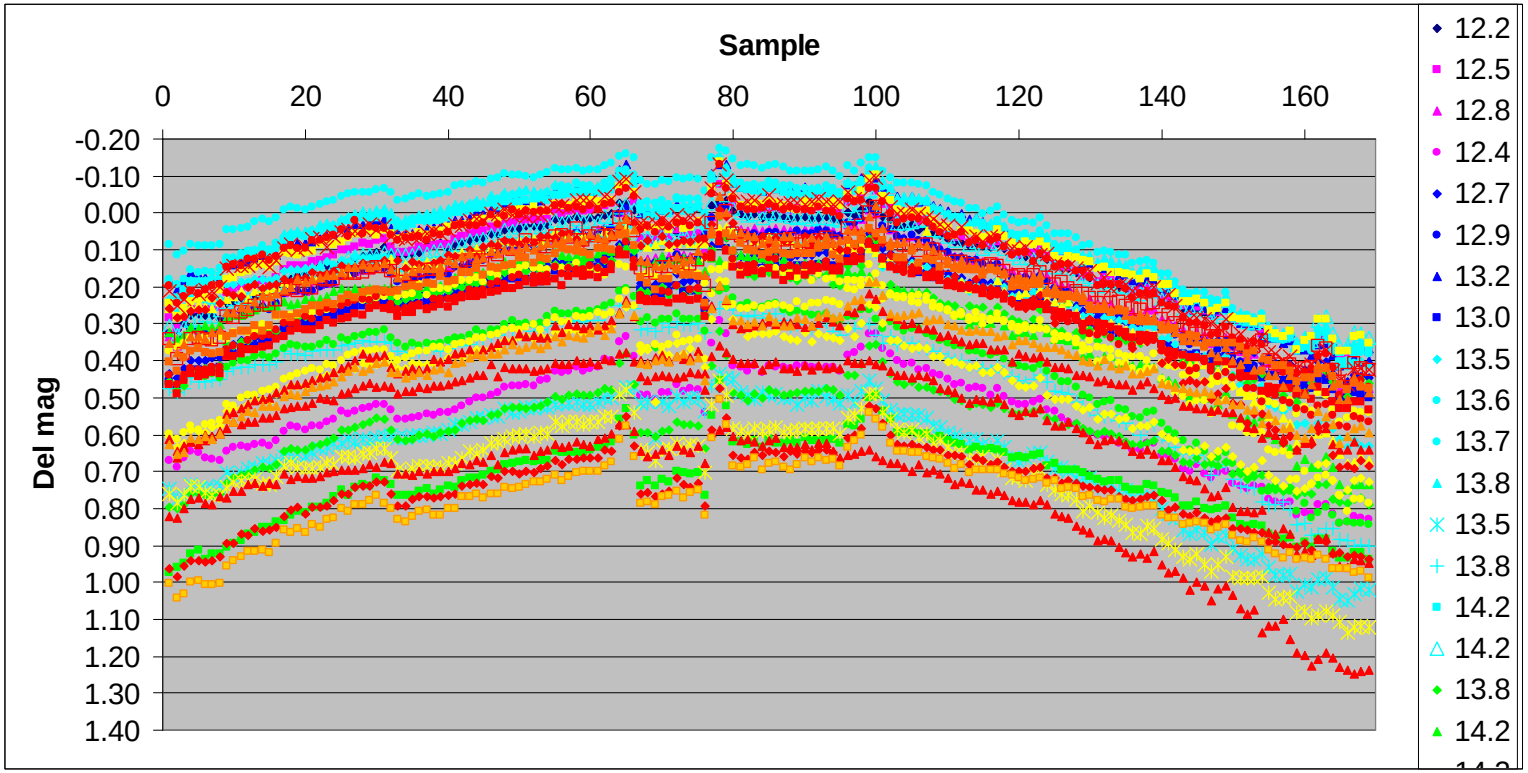
Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 17:

NGC2670: 2013 Apr 25 169 x 30 sec exposures in PI5060

Instrumental mag With known V mag subtracted

(and single zero pt added)



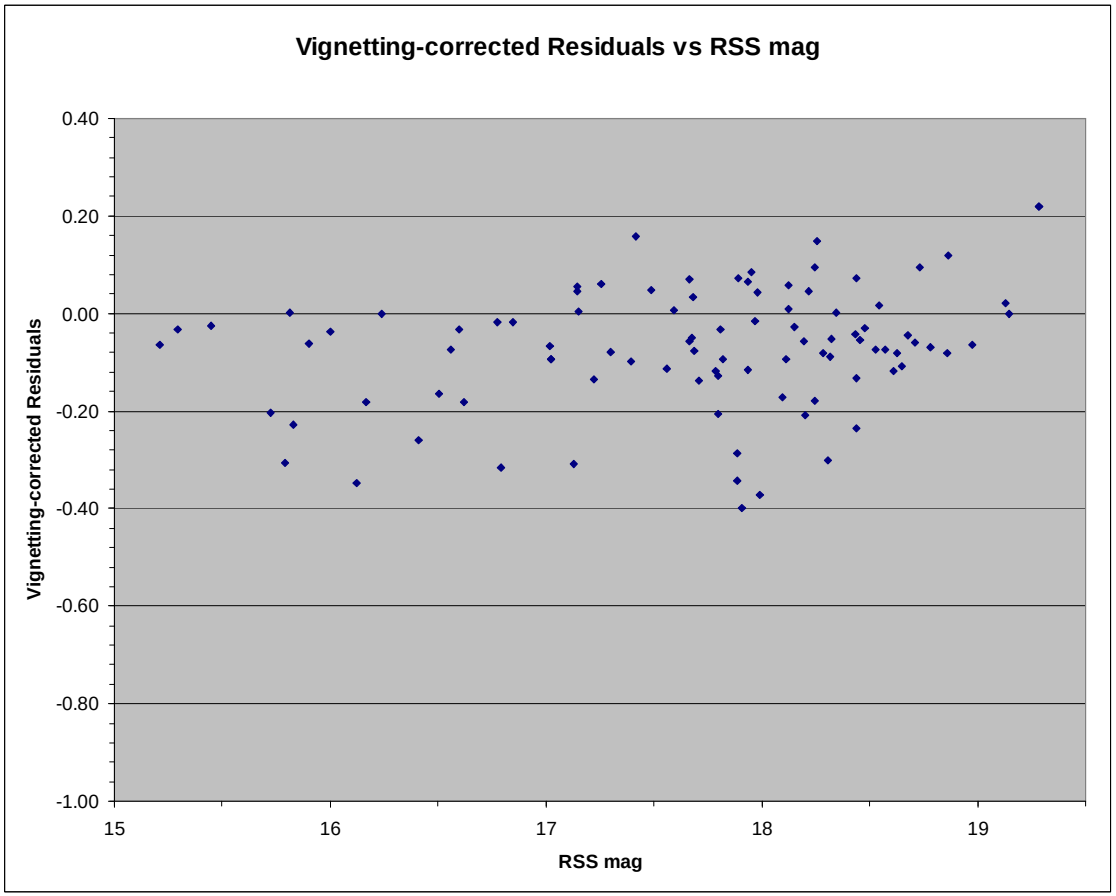
Frame No.

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry 18:

NGC2670: **2013 Apr 25** **1 frame at centre of track**

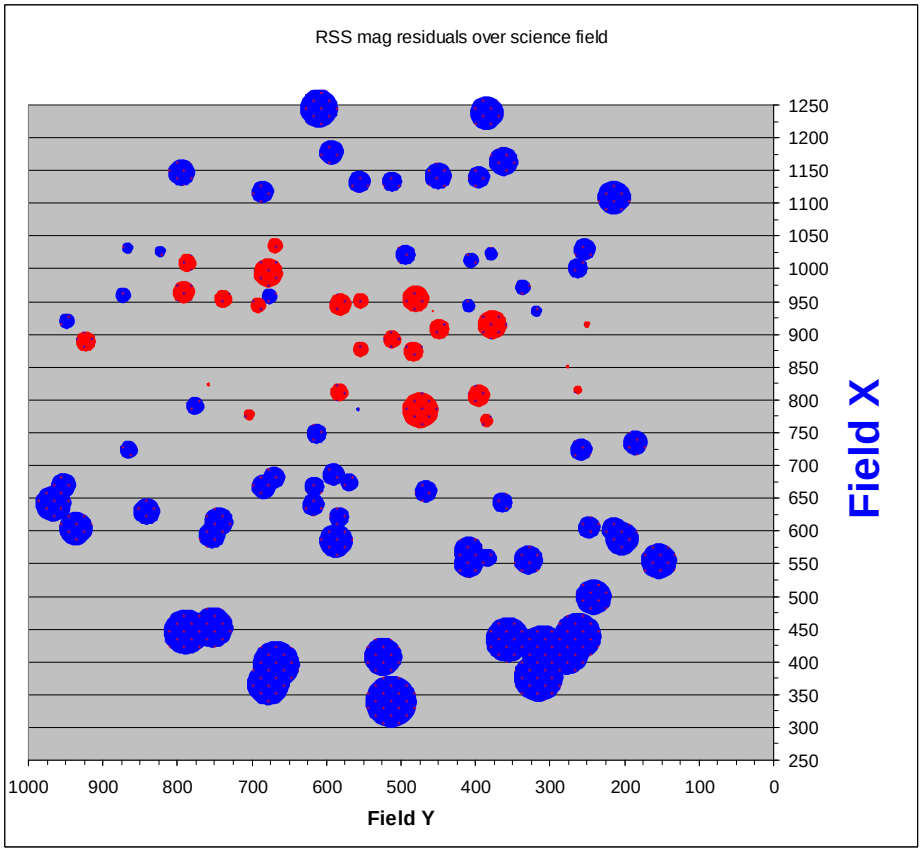
After all known corrections made, peak to peak scatter of ~0.45 mag with rms of 0.1 mag !!



Field Photometry/Flat fielding: May 2013

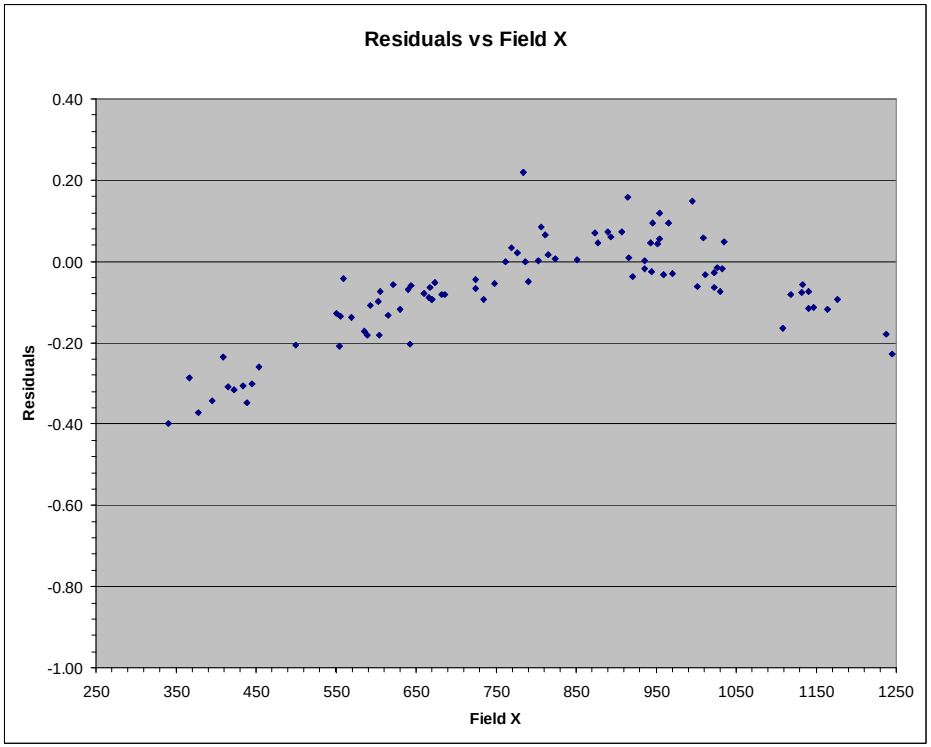
Flatfielding and Field Photometry 19:

Size of symbol proportional to residual and red & blue indicate opposite sign



Field Y

Plot of residuals vs X



Field X

Field Photometry/Flat fielding: May 2013

Flatfielding and Field Photometry Conclusions:

From 2 tracks of imaging with RSS:

- **Flatfielding during a track is accounted for by optical models (probably!)**
- **Within any one frame, and after all corrections, there is a systematic trend with field X (vignetting?).**
- **Worryingly large scatter over short separations in the field of view of ~0.1 mag.**

Next:

- **Compare with Tad and Ted's results with SALTICAM.**
- **Investigate 'vignetting' (remove ADC + baffling).**

Field Photometry/Flat fielding: May 2013

Post-coating damage to SALTICAM optics I:

We would like to know:

- **How badly has the throughput of the SALTICAM optics been degraded because of the damage to the lens coatings?**
- **What about scattered light?**

Field Photometry/Flat fielding: May 2013

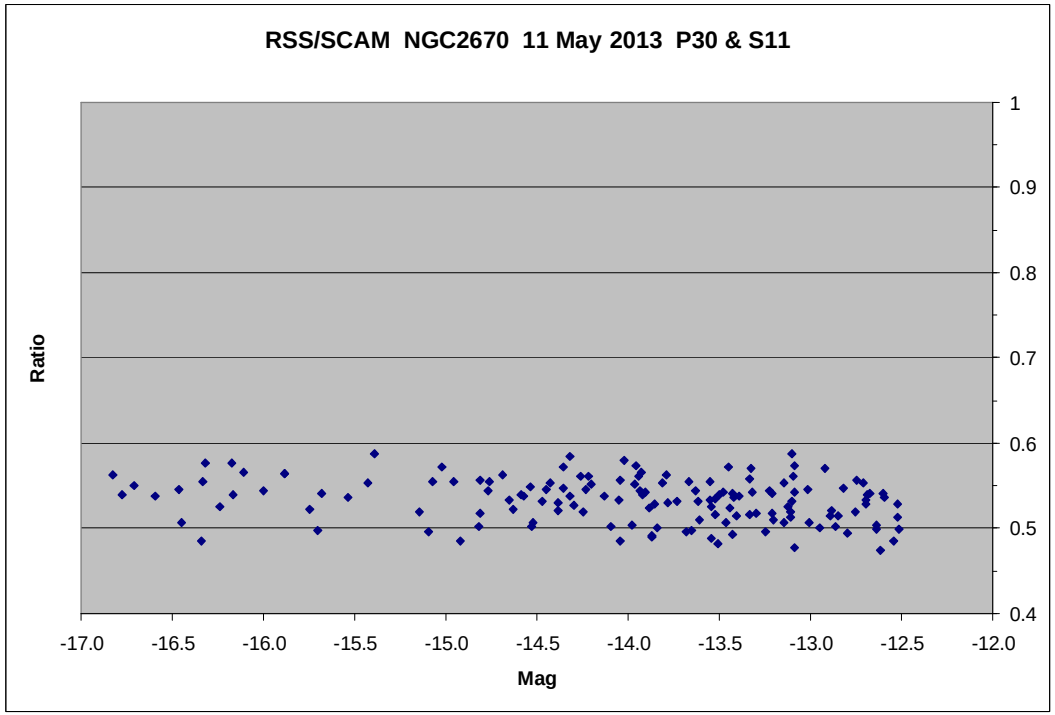
Post-coating damage to SALTICAM optics 2:

- **Instrument re-installed on telescope in 2nd week of May.**
- **Impossible to separate RSS and SCAM from telescope. Therefore, all throughput measurements are either (i) telescope + SCAM; (ii) telescope + RSS or (iii) RSS/SCAM.**
- **RSS / SCAM is determined by direct imaging through clear (fused silica) filters in each instrument.**
- **Wavelength dependence is determined by "burst" primary with filtered observations of spots from unvignetted primary mirror segments. Spectrophotometric standards are used. 'Absolute' result derived from knowing flux at top of atmosphere, atmospheric extinction, area of 1 mirror segment, filter response function, CCD QE. All the rest is throughput of optics of telescope and instrument.**

Field Photometry/Flat fielding: May 2013

Post-coating damage to SALTICAM optics 3:

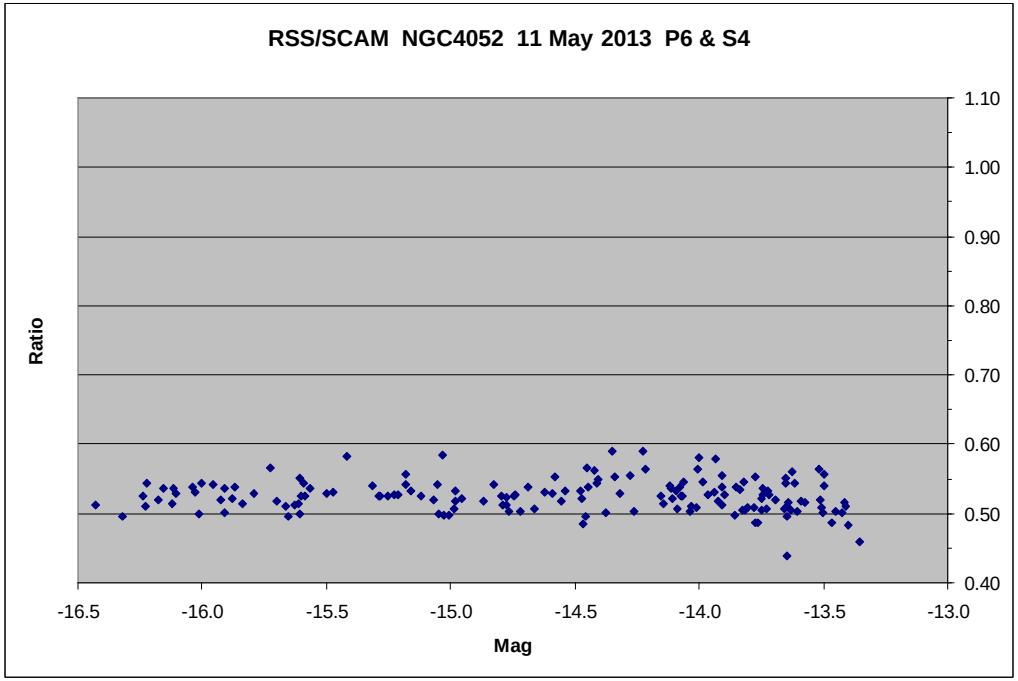
- First clear night was 11 May. Observations of open clusters NGC4052 and NGC2670.
- Photometry of stars all over field of view, gain-corrected ratios of photons for the same star in RSS and SCAM calculated.



Median: 0.54

Field Photometry/Flat fielding: May 2013

Post-coating damage to SALTICAM optics 4:



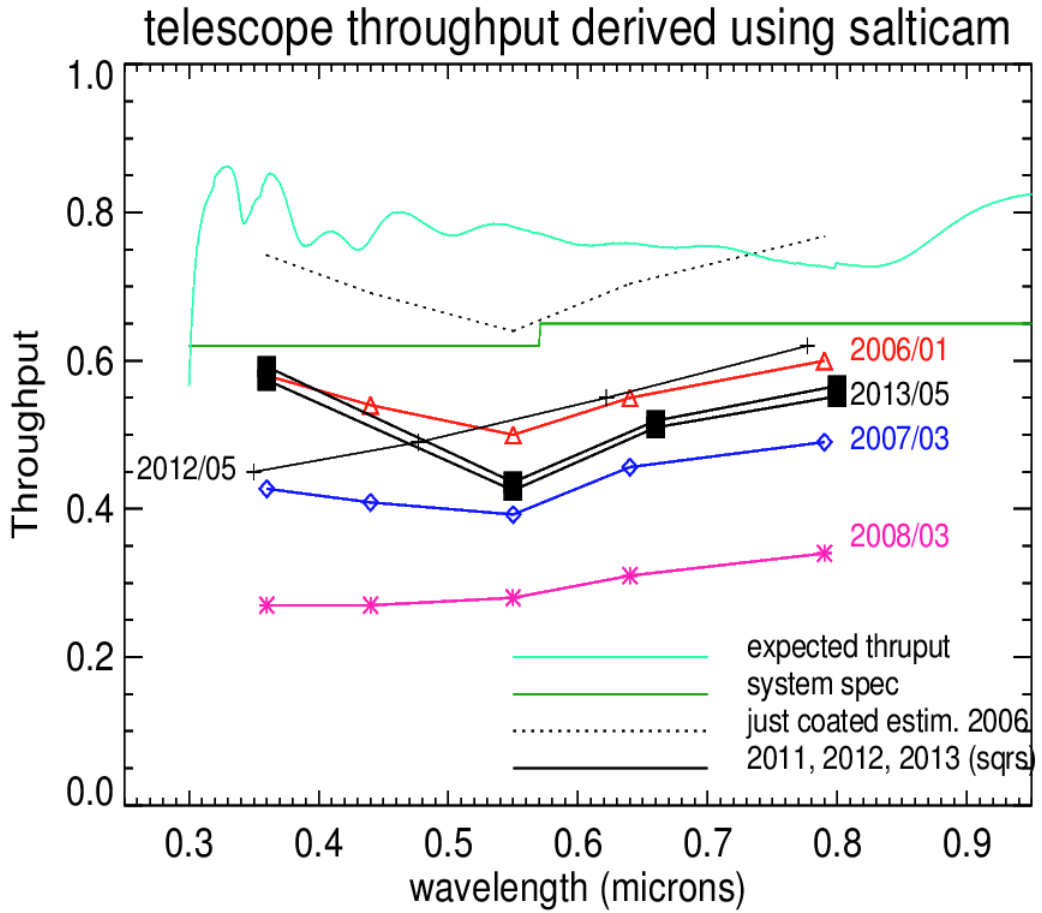
Median: 0.53

- **Summary: NGC4052: 0.53 NGC2670: 0.54**
- **Mid 2011: Value from 4 stars: 0.53**
- **No sign of degradation!**

Field Photometry/Flat fielding: May 2013

Post-coating damage to SALTICAM optics 5:

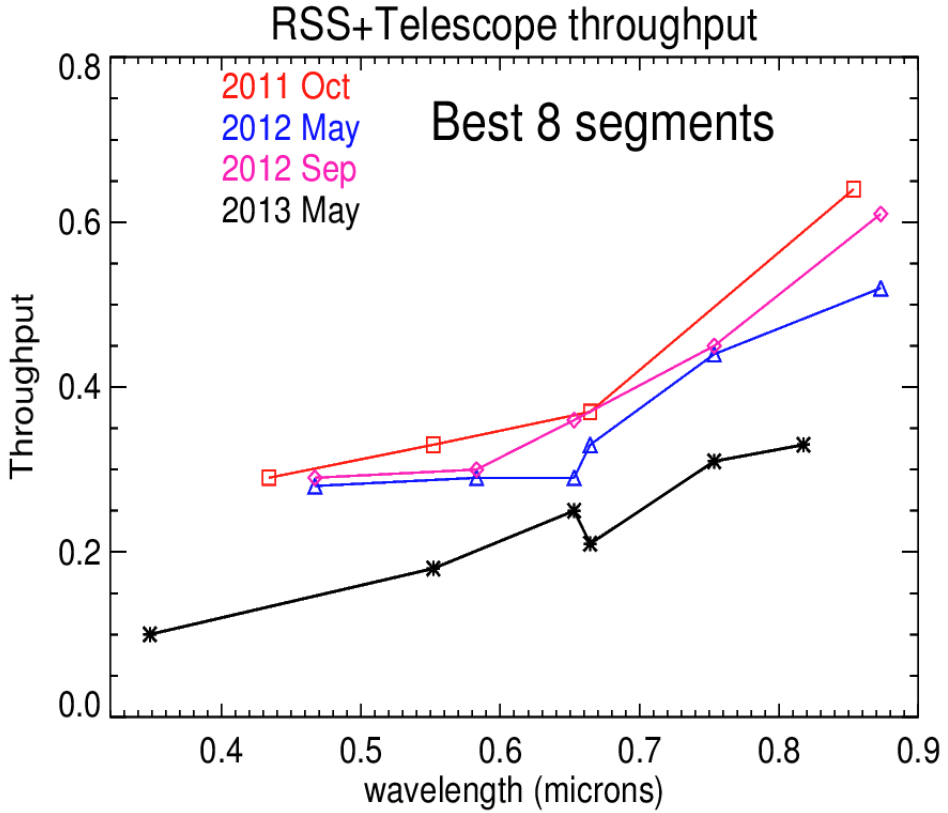
- **Multi-filter "burst" primary data from 17 May and last night. Both instruments measured with different filters.**



Field Photometry/Flat fielding: May 2013

Post-coating damage to SALTICAM optics 6:

- **BUT … RSS results are puzzling. Is telescope and/or RSS worse? (I think there MUST be something wrong with the RSS result)**



Field Photometry/Flat fielding: May 2013

Post-coating damage to SALTICAM conclusions:

- **Clear filter RSS/SCAM still seems to be ~0.54. This has removed the telescope-alone throughput.**
- **Filter burst images suggest SCAM is not worse than several per cent compared to before.**
- **BUT … RSS results are puzzling and influence the first result above.**
- **Nevertheless I LIKE MY RESULT**

Next:

More data to try and understand the puzzle (my "nice" result was spoiled by more data but scientists are supposed to believe in more data. Petri Vaisanen will get more data this week)