GALEX GR1 Instrument Performance and Calibration Review

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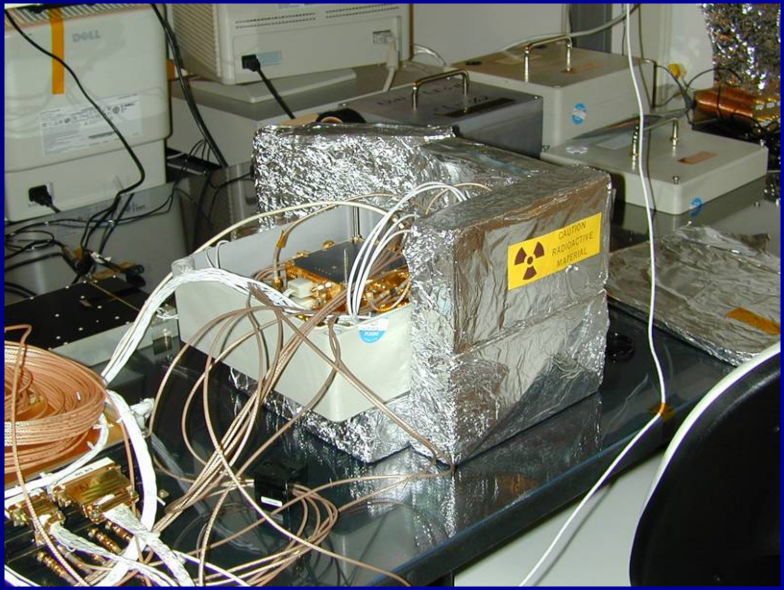
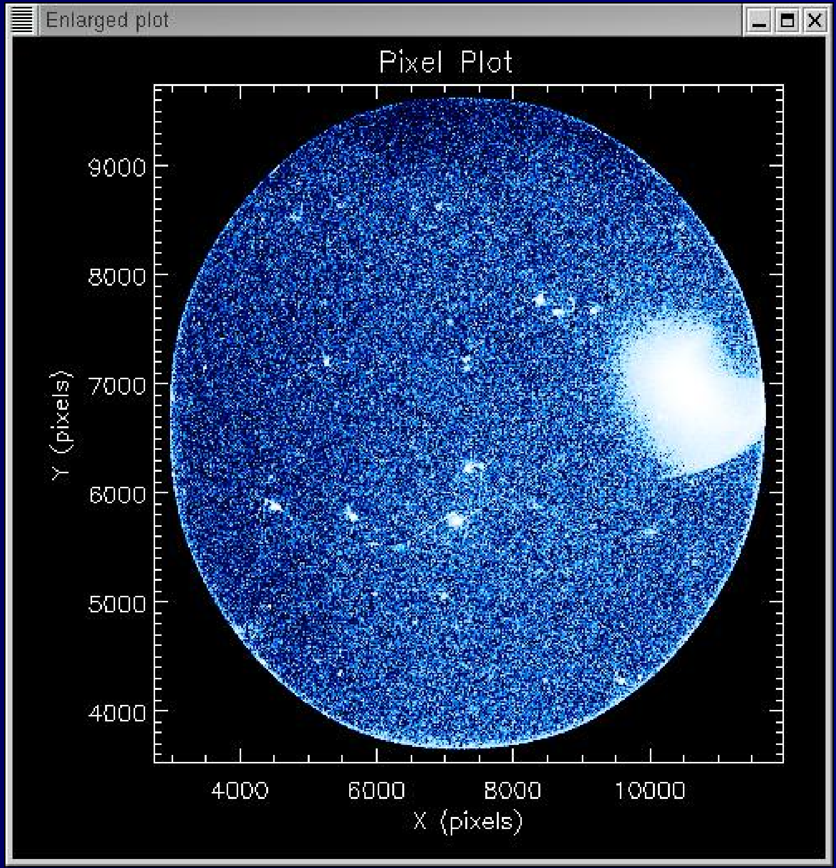
Caltech

Operations Overview

- GALEX is operating quite smoothly in 2004.
  - Active space weather has mostly dissipated.
  - FUV is shut down approximately monthly to discharge the window.
    - Shutdowns these days are almost all by ground command, rather than instrument fault response, resulting in approximately 15% down-time.
    - A software patch is in development to reduce this further.



FUV Background (Window Charging)



- The FUV detector window charges on orbit, and unlike the NUV detector, does not have a uniform metallization on the inside of the window to help define the field in the gap region between the window and MCP.
- Window charging appears to cause field emission from the window, which appears as a bright patch of light in the image.
- For the most part, ground monitoring of the background has prevented recurrence.

Calibration Priorities for GR1

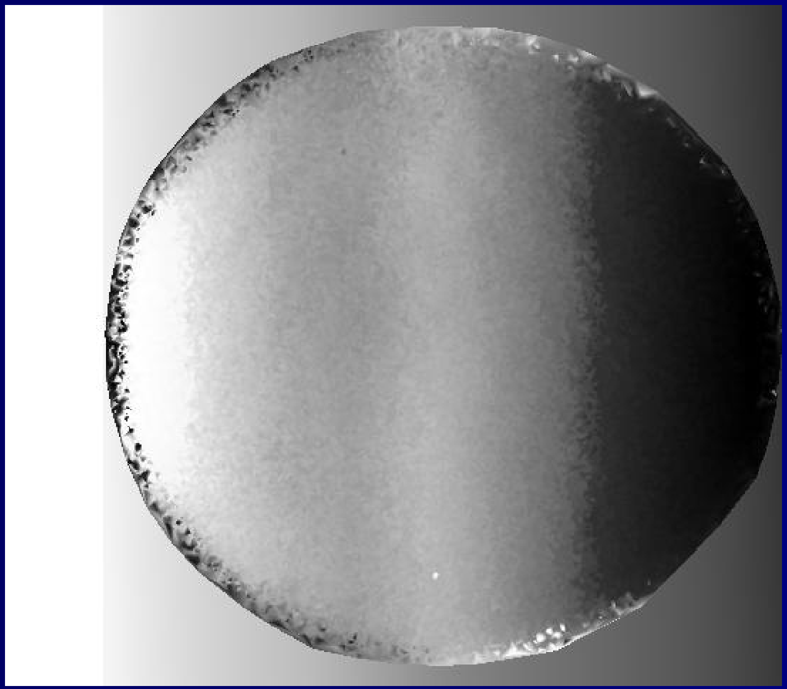
- Astrometry
  - Distortion maps (Morrissey)
  - Walk and Wiggle (Schiminovich)
- Photometry
  - Dead time correction (Conrow)
  - Zero Point (Morrissey)
  - Flat Field (Morrissey)

Astrometry for GR1

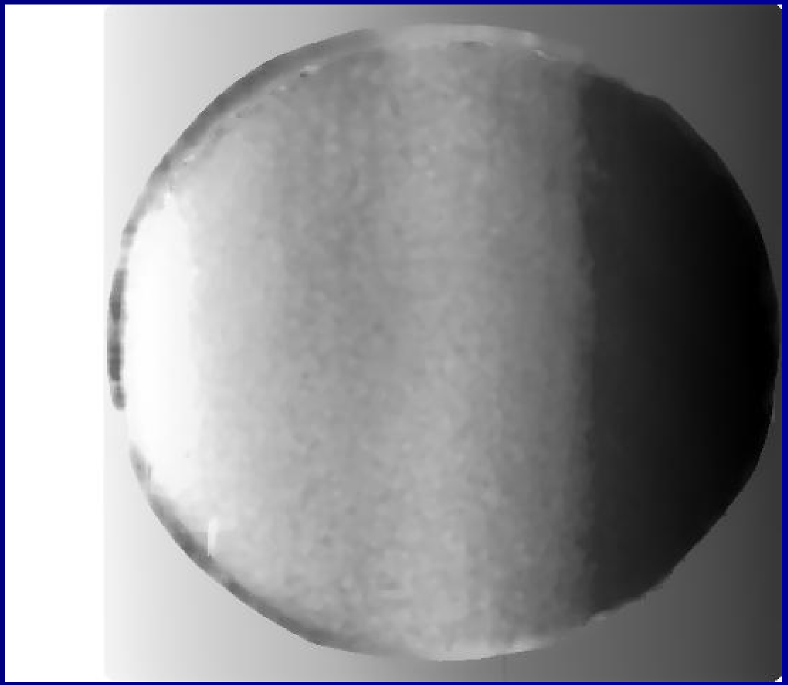
- We extracted the positions of thousands of ACT (Tycho) stars from the GALEX catalogs.
  - Eventually we had about 40,000 NUV stars and 10,000 FUV stars from the IR0.9 fields.
  - RA/Dec were transformed to the detector coordinate space, where position errors were accumulated to refine the 10” resolution non-linearity map.
  - This process was iterated by re-running the pipeline on each field, and then re-extracting all of the stars.
    - EXTREMELY time consuming!
  - Astrometric errors are improved significantly for GR1.
    - **80% of stars now are found within 1.1-1.2” for the entire field (compared to 1.5-2.8” for the middle 1 degree previously).**

FUV-X-DET-TO-SKY-480

Ground Map

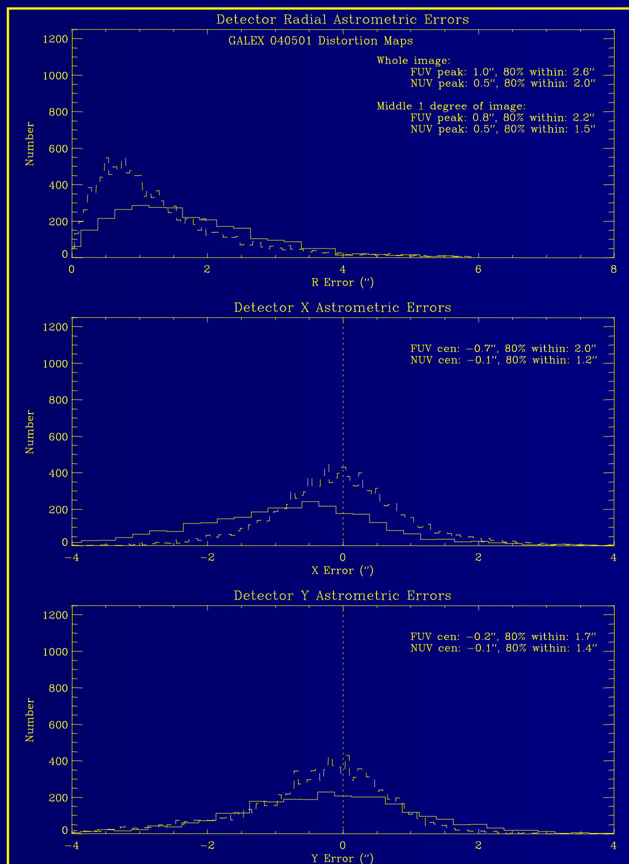


Flight Map

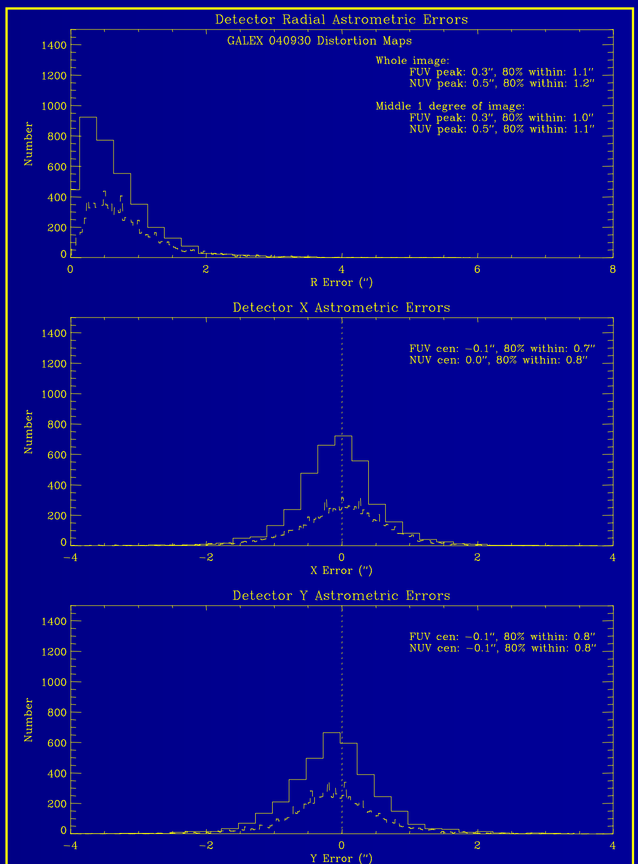


Astrometry results for GR1

Ground



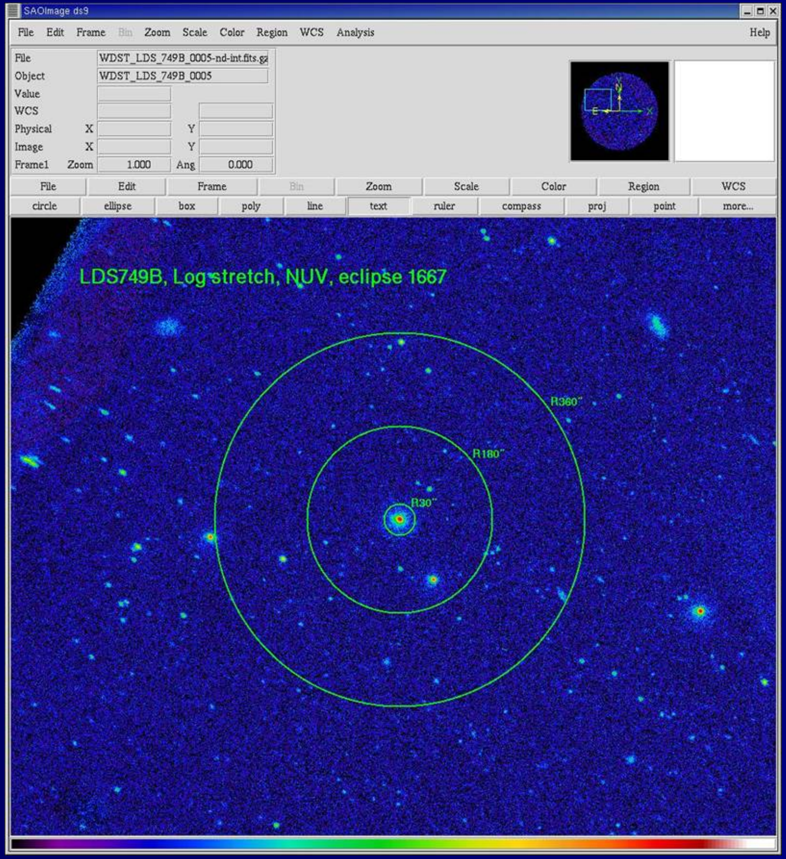
Flight



Photometry for GR1

- Our main goals were to:
  - Correct the GALEX zero point using white dwarf calibrators
  - Improve the photometric scatter among measurements by improving the flat field.
  - Fix a software application that was mis-correcting the global electronic deadtime in the FUV data.

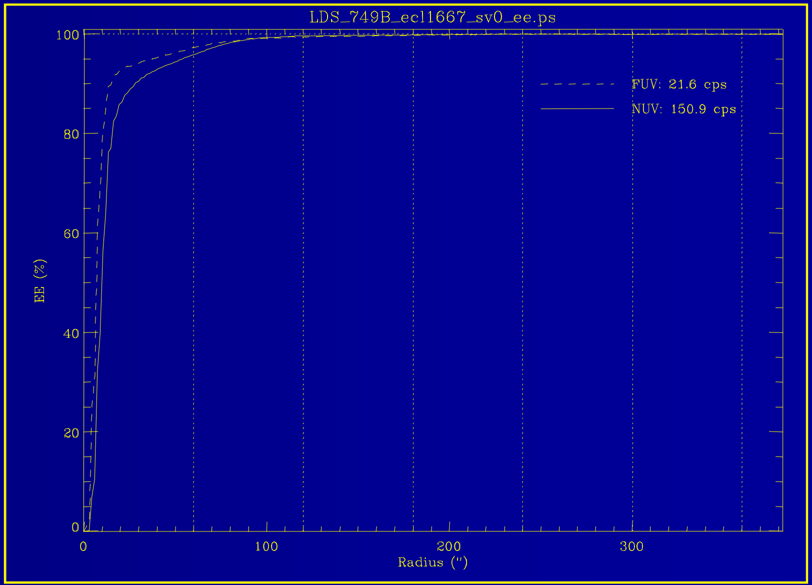
GALEX White Dwarf Calibrators



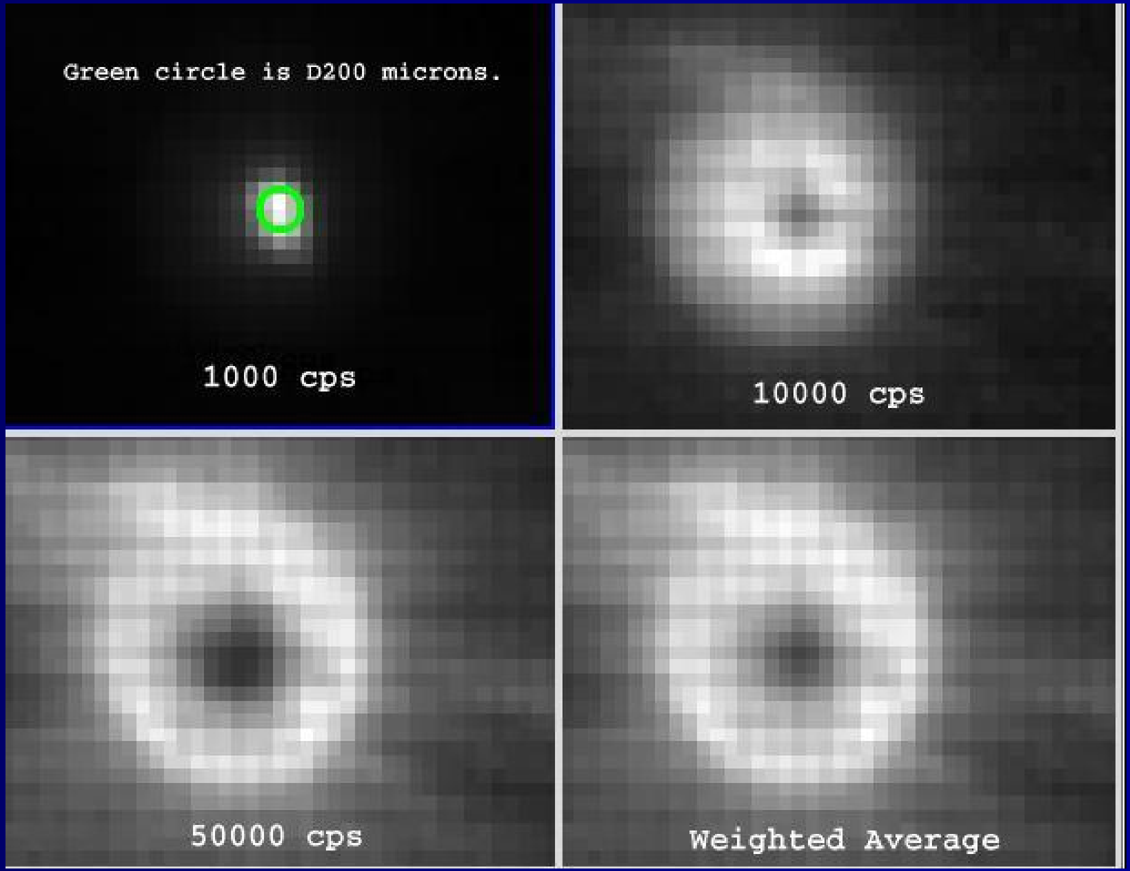
- The GALEX calibration program includes a regular series of white dwarf observations, however most of the white dwarfs in the HST database are much too bright (only useful for non-linearity measurements!)
- LDS749b is a good calibrator for GALEX because it does not saturate either detector.
- One weakness of the current photometric zero point setting is that it relies on 45 measurements of one white dwarf. We recently observed HZ4, which is similar to LDS749B, and are planning additional measurements.

Adding up the Light

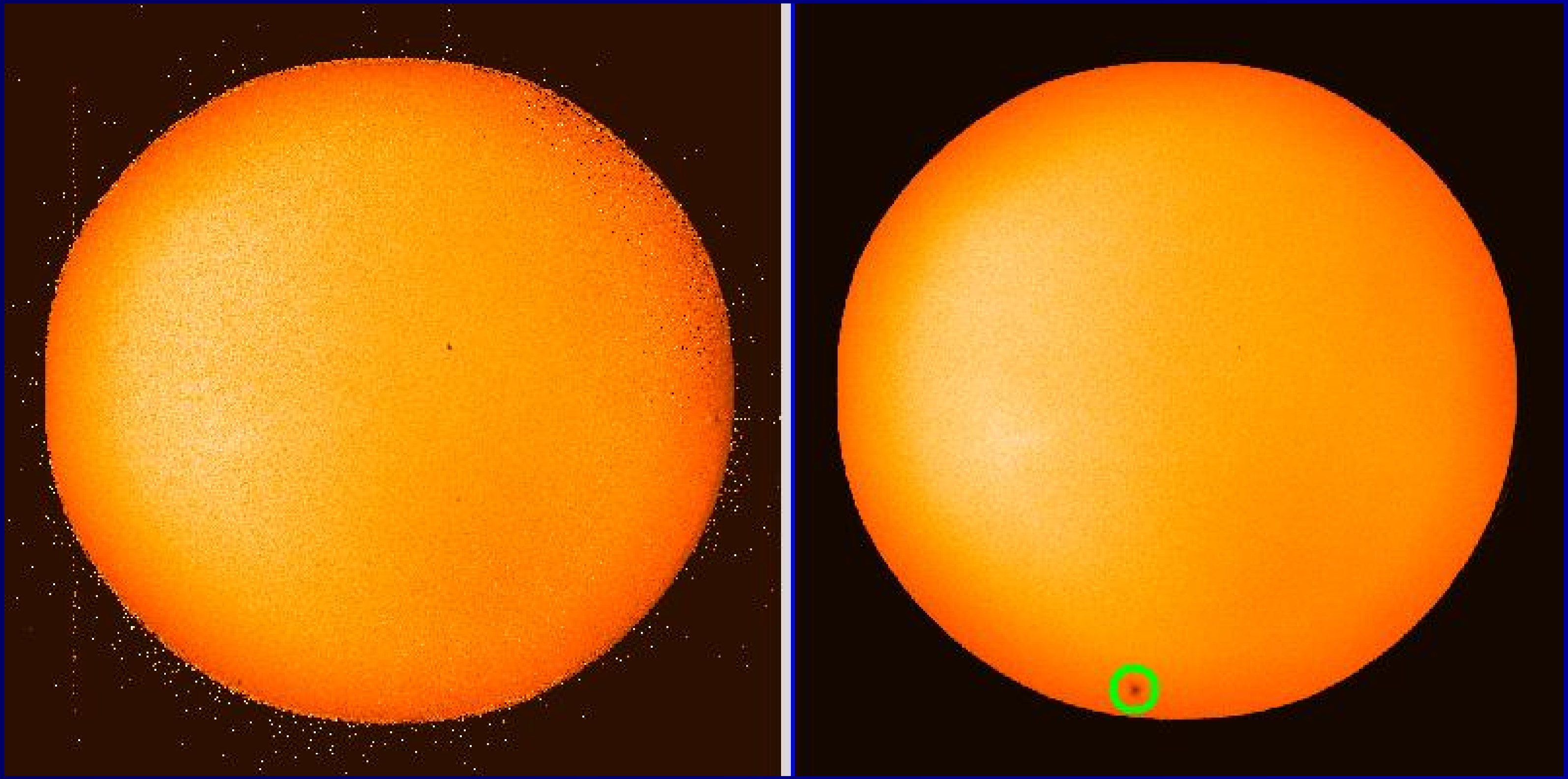
- For the GALEX zero point, a large aperture was used around each image of LDS749b, adding up all the light within and “swiss cheesing” sources identified from the catalog.
- Background is estimated from the outer portion of the aperture.
- For critical work, the aperture must extend at least an arc-minute in radius.



Local Non-linearity



Things to Avoid
(Changing the Calibration)



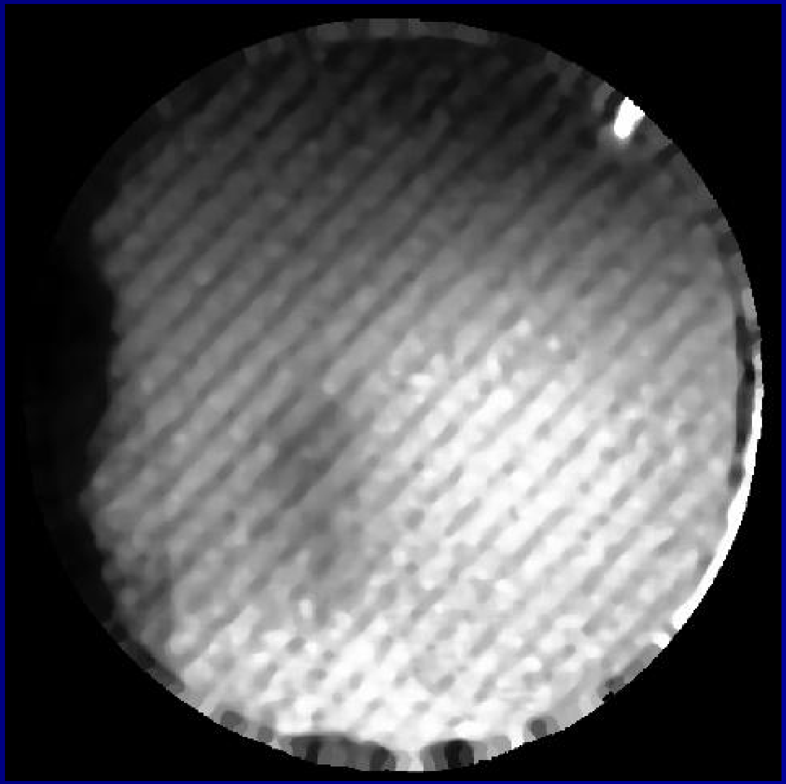
Flat Field Construction

- The ground flat field map was constructed by moving point images around the field and tracking their intensity.
  - The amount of data collected in ground calibration was only sufficient for a ~10' resolution map.
  - It can not capture the finer details of the instrument response, such as FUV grid wire shadows.
  - It worked remarkably well!
- The flight flat field map was constructed by building stacks of images with similar exposure rotated to detector coordinates, and then determining the median value for each "arrow" through the stack.
  - Captures much more detail than the ground map.
  - The new flat is scaled so that the original zero points (18.82 FUV and 20.08 NUV) provide correct magnitudes.
  - But there is something else going on, because the scatter (about 7%) is not greatly improved over the original.

FUV Ground vs Flight Comparison

Ground

Flight



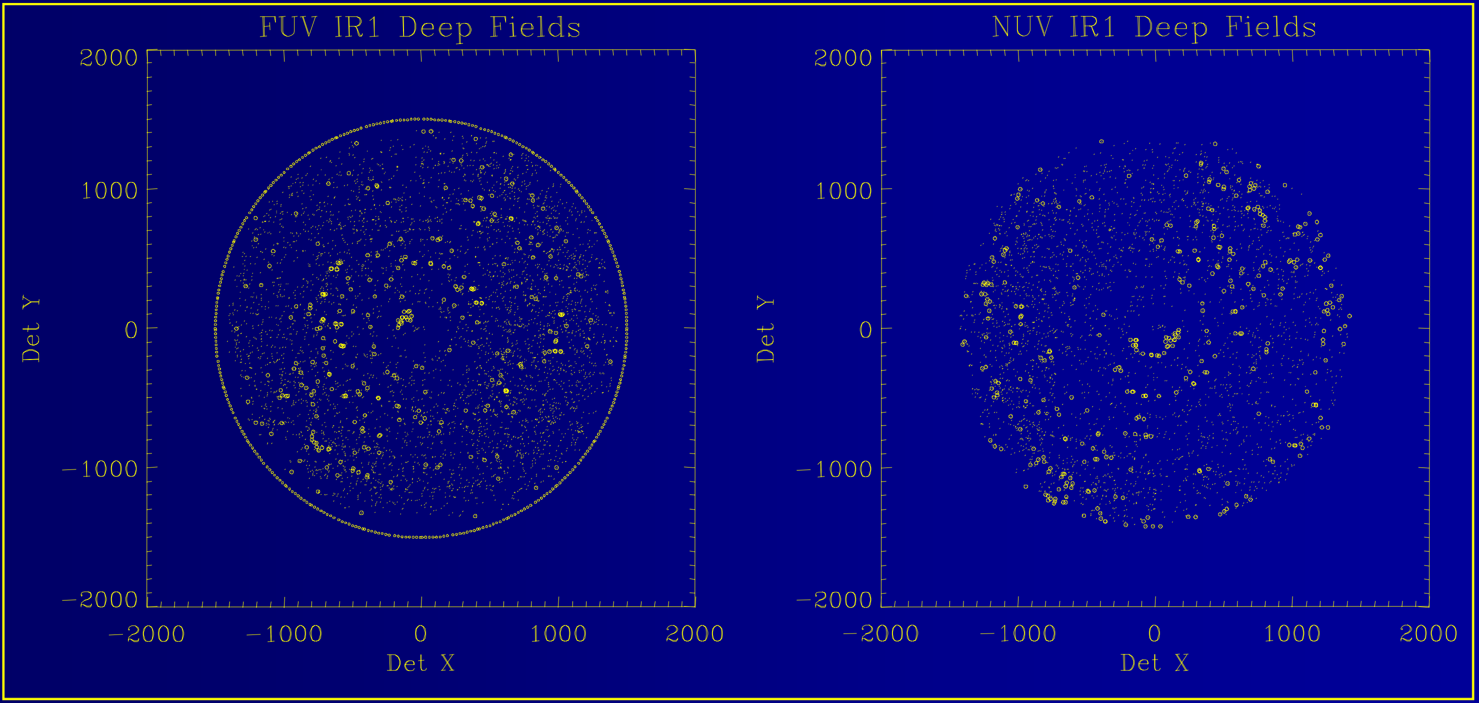
GR1 White Dwarf LDS749B

FLIGHT	2003 (20 measurements)	2004 (15 measurements)	ALL data (35 measurements)
FUV (15.57)	15.56+/-0.09	15.57+/-0.03	15.56+/-0.07
NUV (14.71)	14.70+/-0.08	14.72+/-0.07	14.71+/-0.08
GROUND	2003 (19 measurements)	2004 (15 measurements)	ALL data (34 measurements)
FUV (15.57)	15.49+/-0.10	15.51+/-0.04	15.50+/-0.08
NUV (14.71)	14.75+/-0.04	14.78+/-0.07	14.76+/-0.06

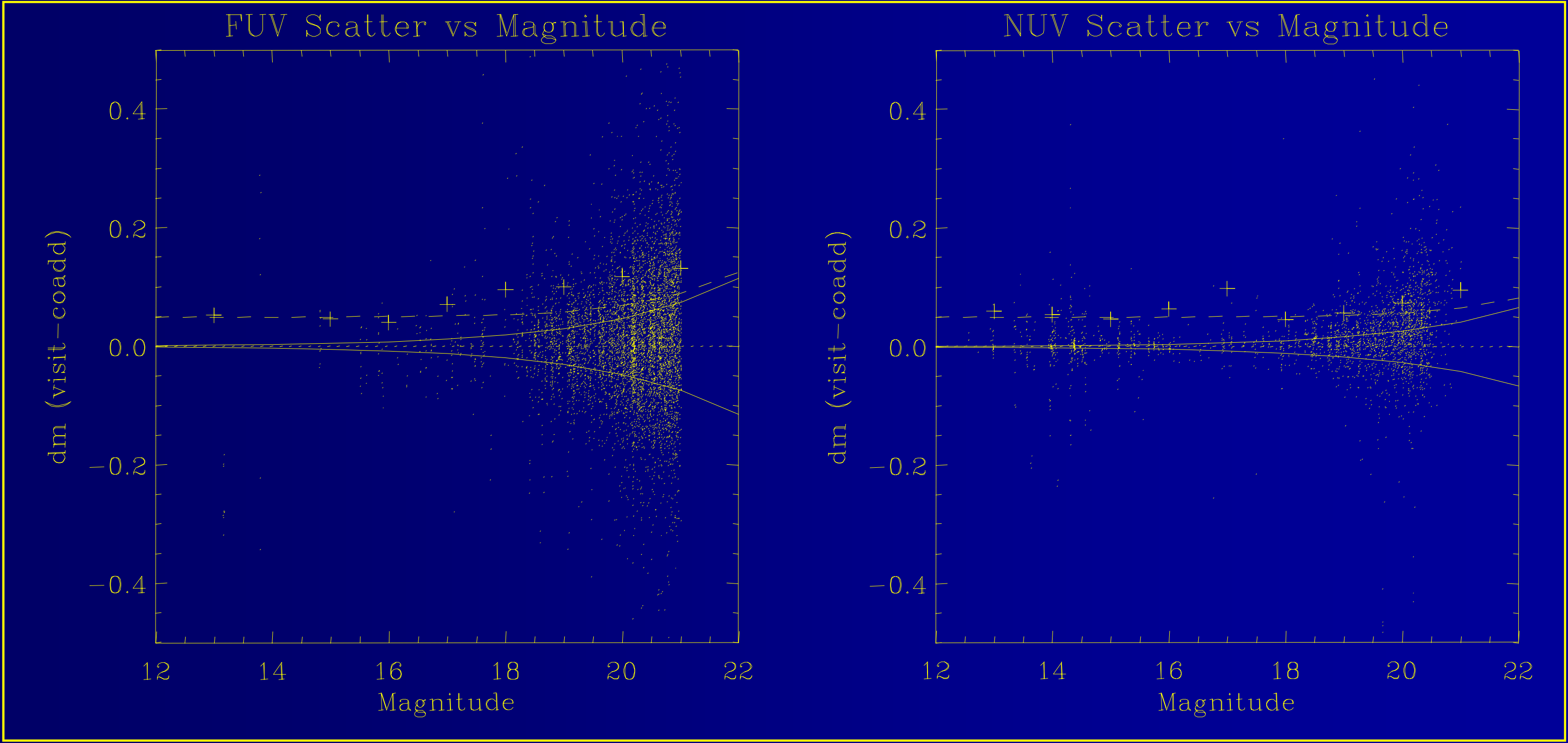
GALEX Deep Field Analysis

- Match sources in GR1 deep field co-adds that are smaller than 10” FWHM and brighter than M21.
  - Match these to each deep field visit and compare the results
  - Basically, the new flats appear to be performing at the 5% level, but in order to achieve Poisson-limited performance at m<21, they will need to be improved to more like 1%.
    - Even so, there appears to be an additional systematic not explainable with flat field errors that contributes significantly to photometric scatter at the faint end.

GR1 Source Locations in Detector Coordinates

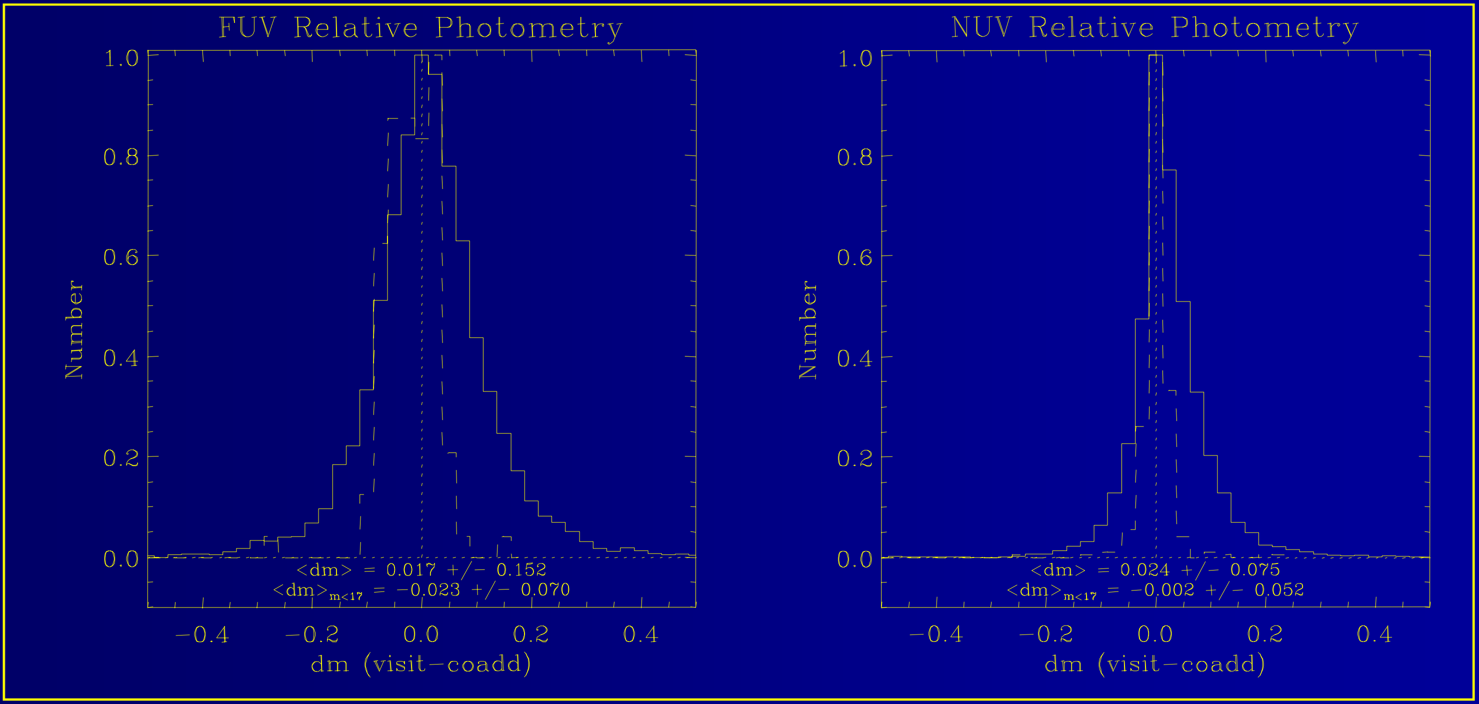


GR1: dm vs m

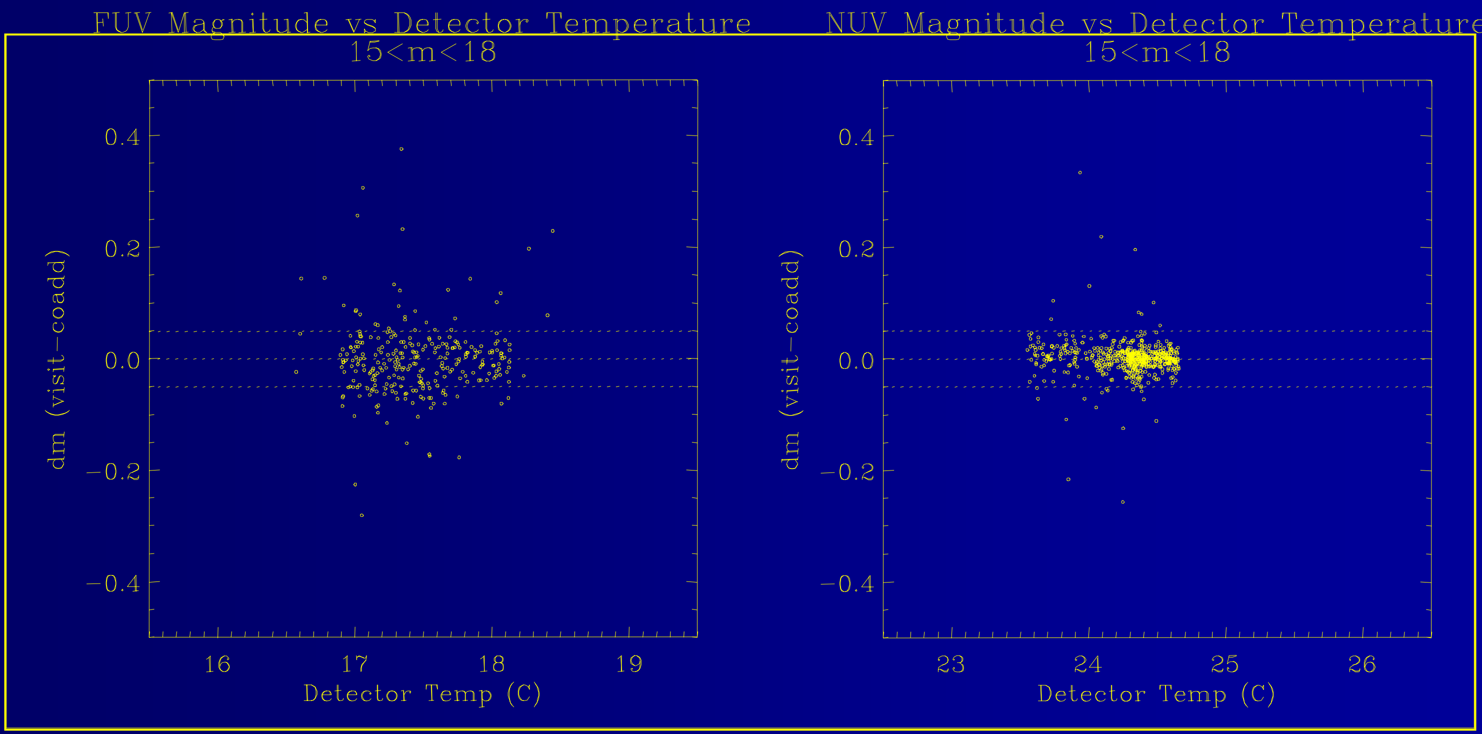


FUV Scatter vs Magnitude
dm (visit−coadd)
0.4
0.2
0.0
−0.2
−0.4
12
14
16
18
20
22
Magnitude
NUV Scatter vs Magnitude
dm (visit−coadd)
0.4
0.2
0.0
−0.2
−0.4
12
14
16
18
20
22
Magnitude

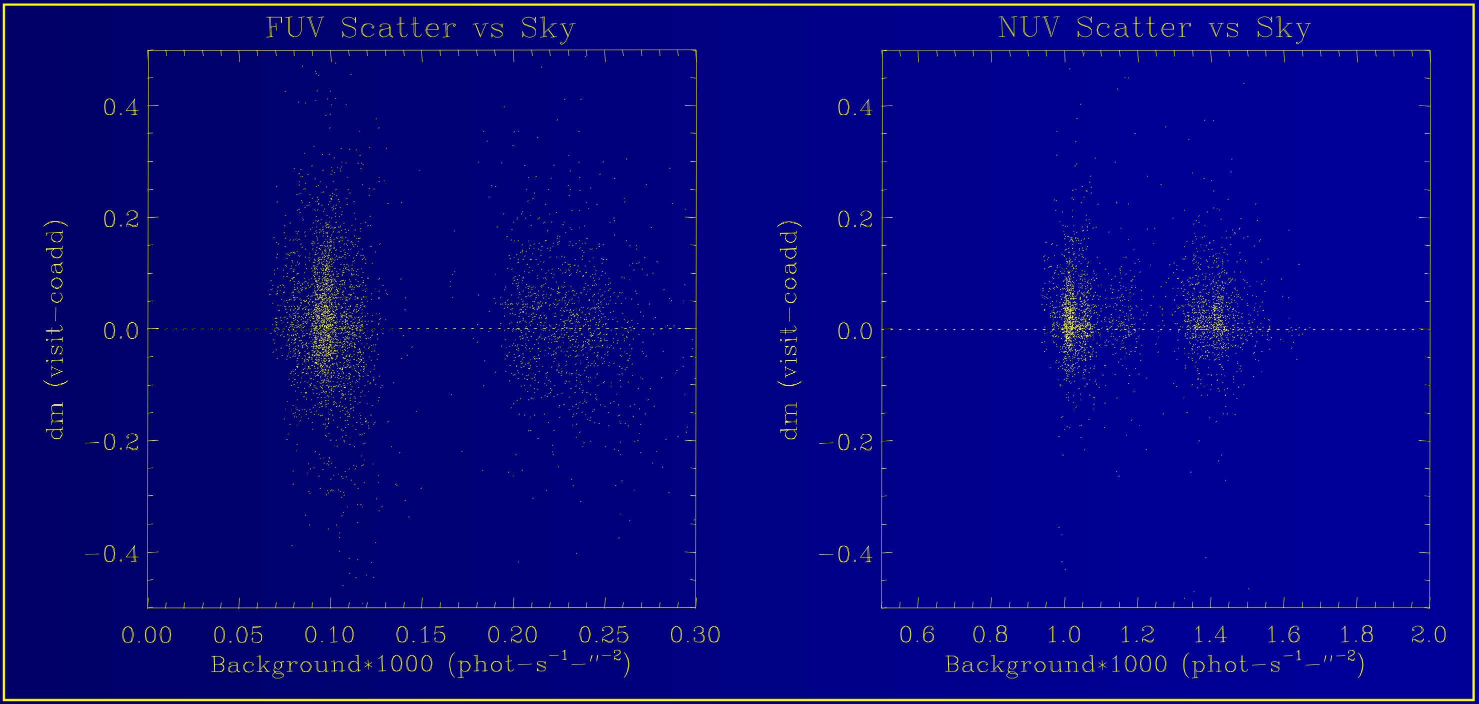
GR1: Photometric Scatter



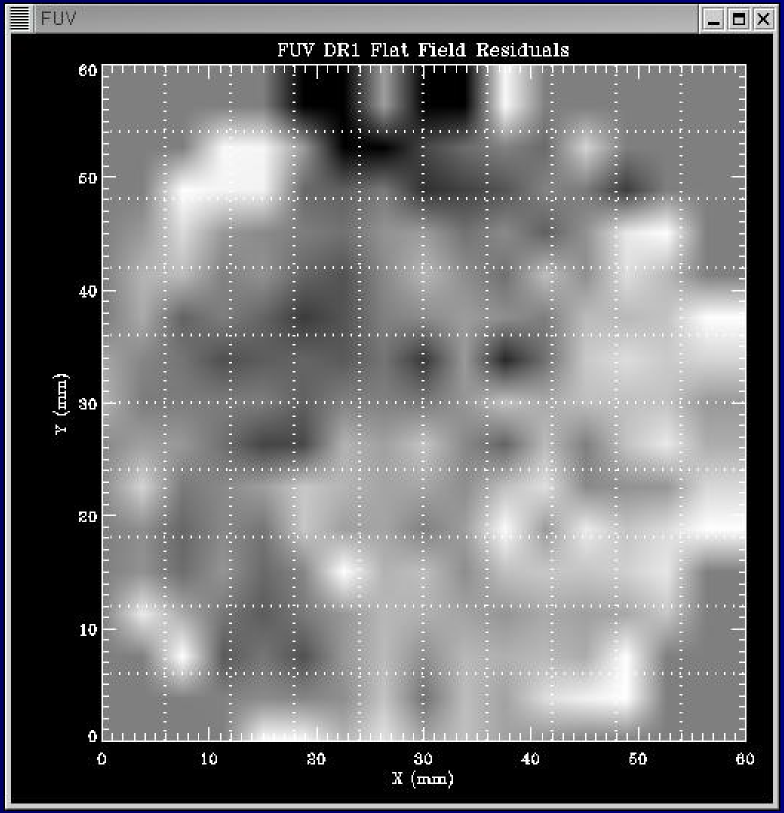
GR1: Thermal Variation?

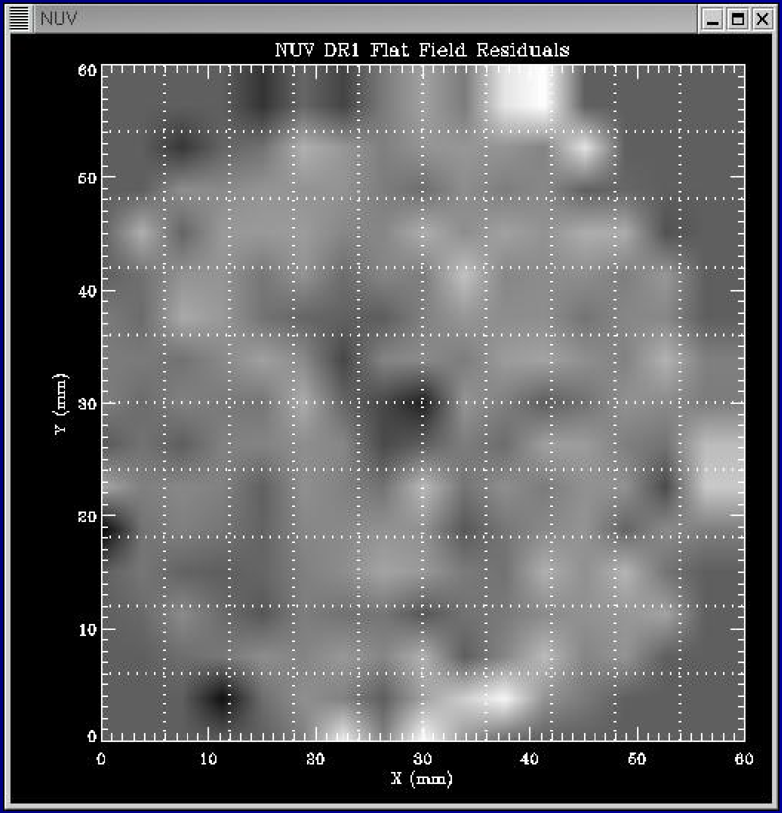


GR1: Sky Background Variation?



GR1: Flat Field Residuals for ~6000 Deep Field Sources





+/- 0.1 mag full scale

Conclusions

- Astrometry
  - Looks great, but the software is in place to iterate again and could be done for the next go-round.
- Photometry
  - Is performing well with respect to zero point as far as we can tell, but there continues to be scatter in the data, some explainable by the flat, **but not most** at faint magnitudes.
    - The inner machinations of SExtractor deserve some careful study.
  - Is it possible the flat has changed since launch, or could tweeking with additional residuals improve the results?
    - A flat performing at the 1% level would really help for m21 and brighter.