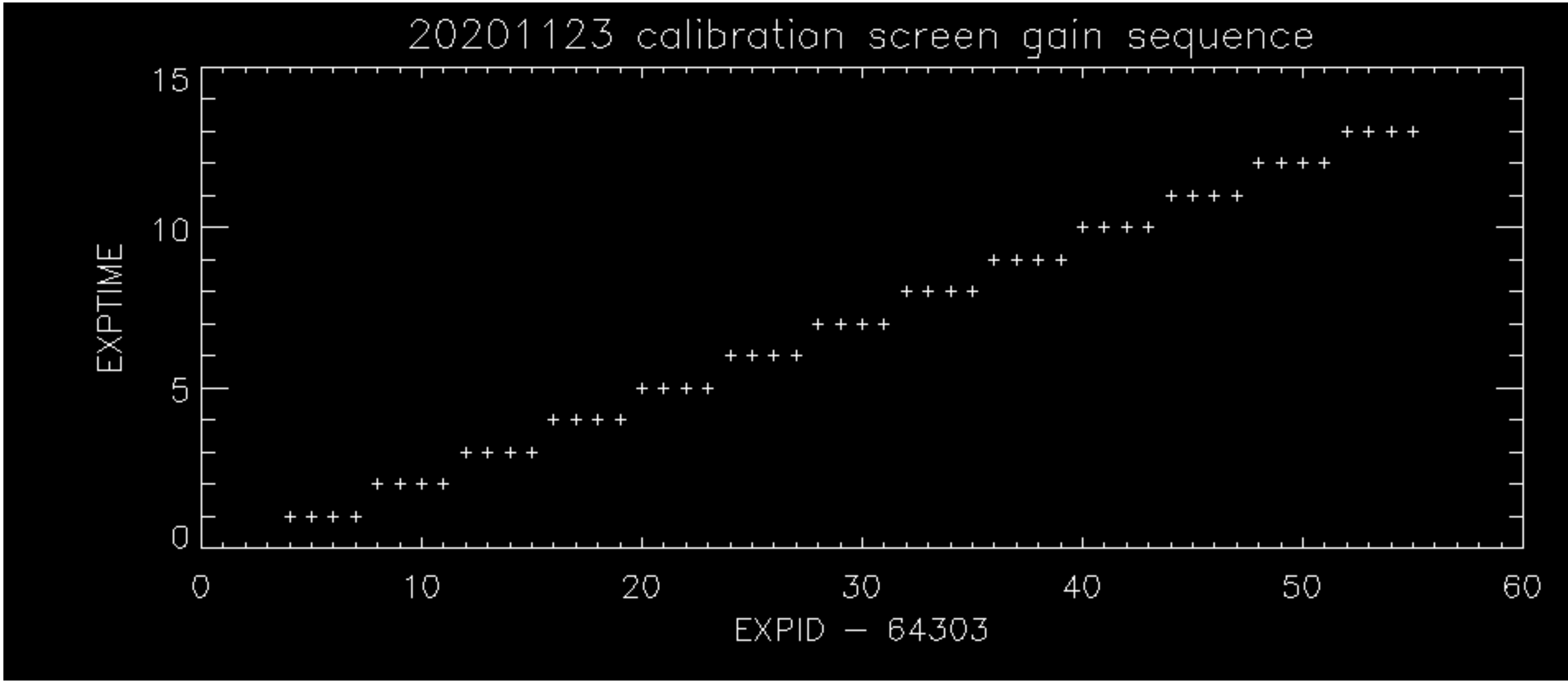
# GFA re-characterization report

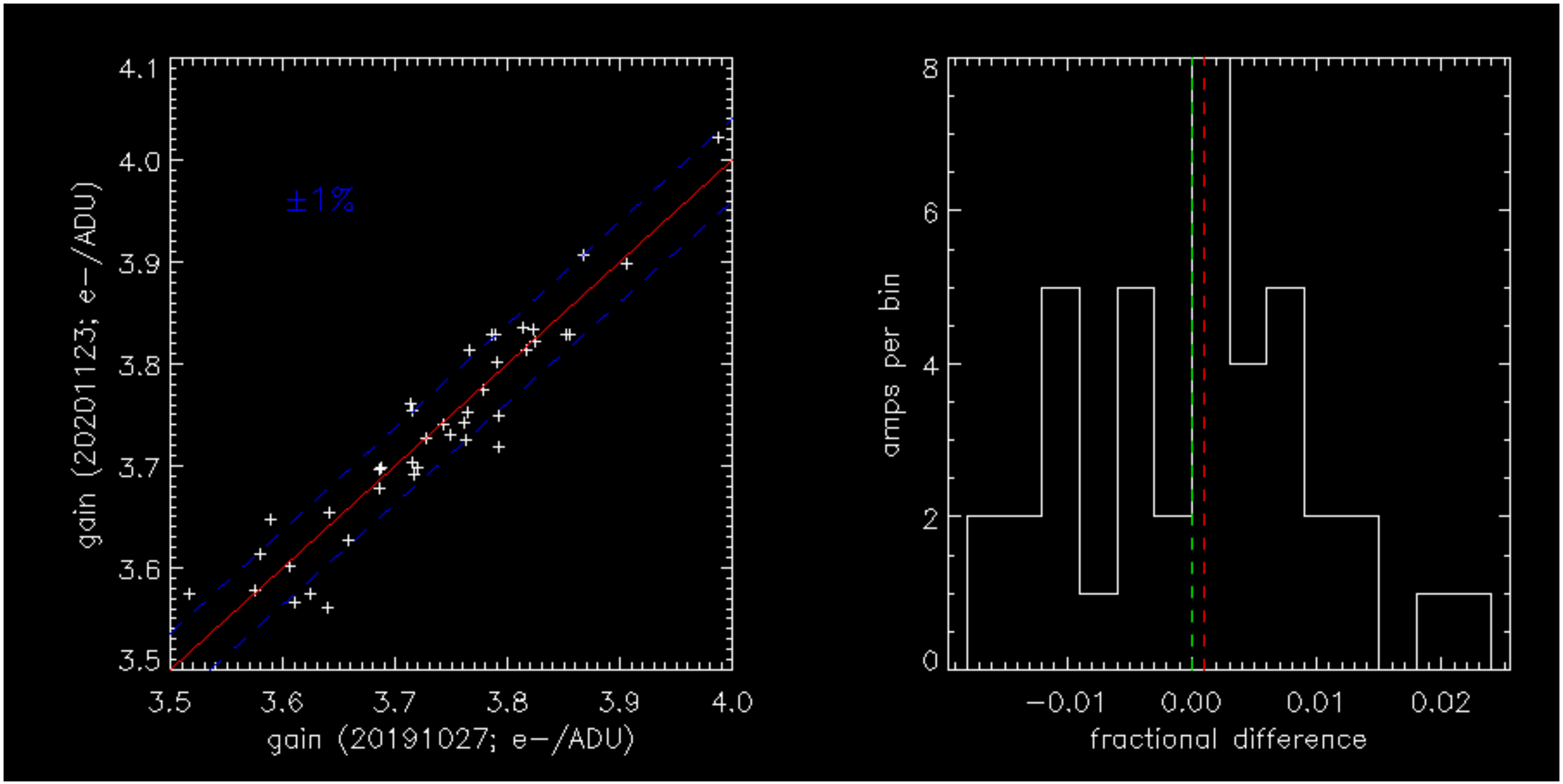
Aaron Meisner

# GFA gain re-measurement



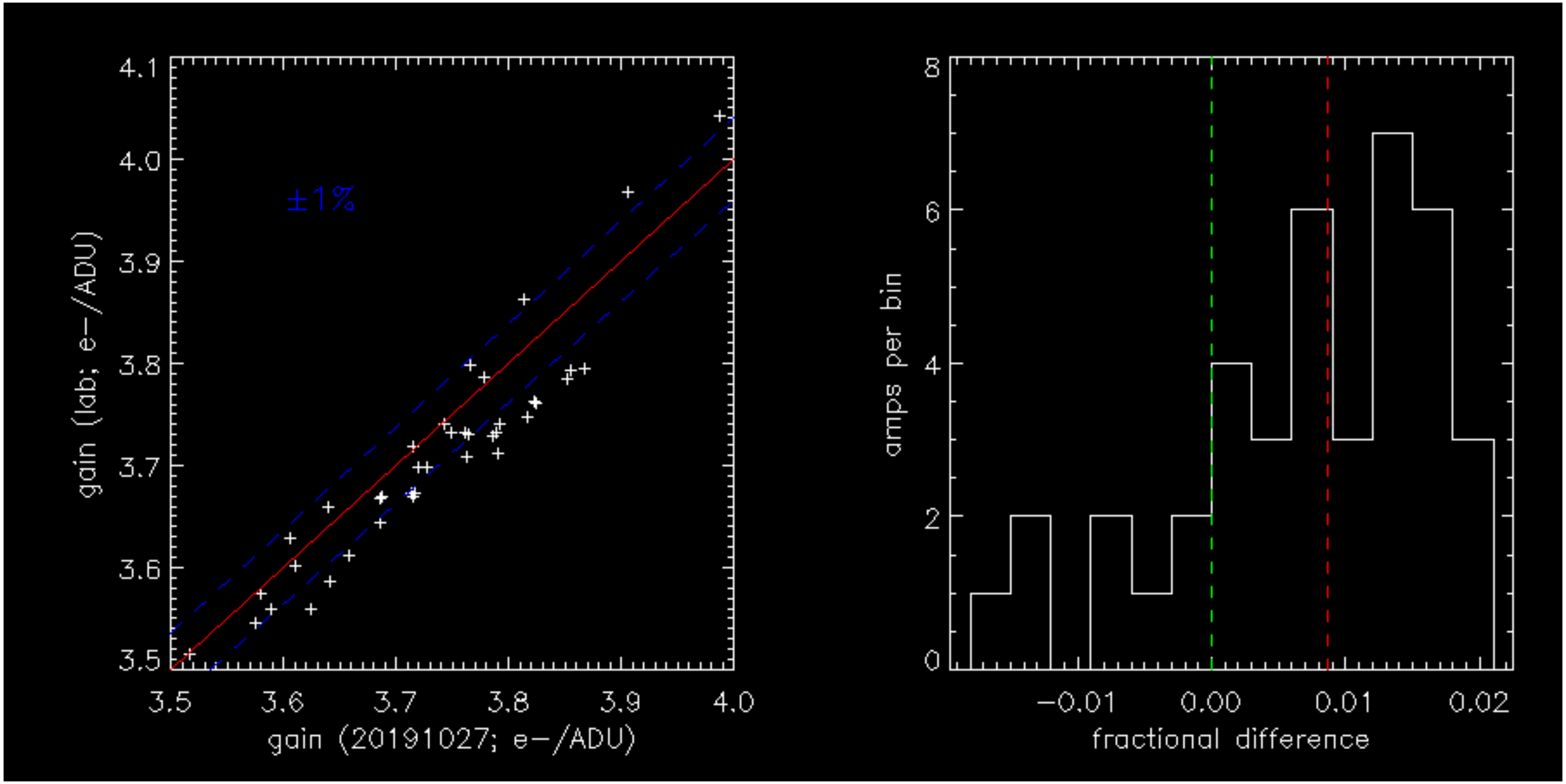

- On night 20201123 I took a set of calibration screen data using all stations of the LED lamps for illumination. This configuration gives ~3k ADU of signal per second.
- I ramped the exposure time from 0 s to 13 s in steps of 1 second, with four consecutive exposures at each unique exposure time (to enable pairwise differencing).
- EXPID = 64303-64358, PROGRAM = 'GFA gain test LED illumination'.
- The goal was to check consistency of the post-restart gains with the pre-restart gains measured on 20191027 (the 20191027 data set used Ne lamps rather than LED lamps for illumination).

# 20191027 vs. 20201123



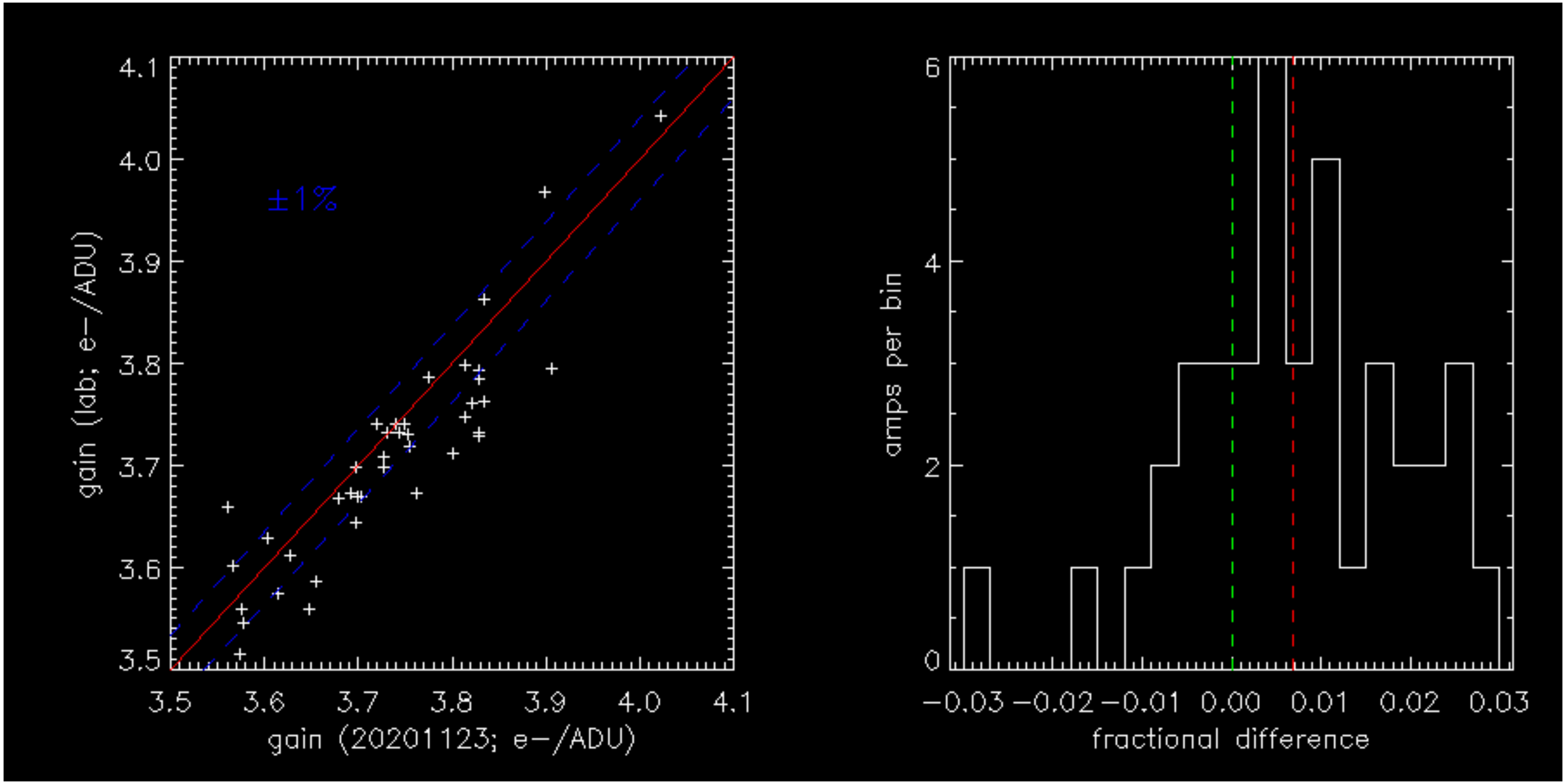

- median fractional difference = 0.0010
- mean fractional difference = 0.0002
- stddev fractional difference = 0.0091

# 20191027 vs. lab



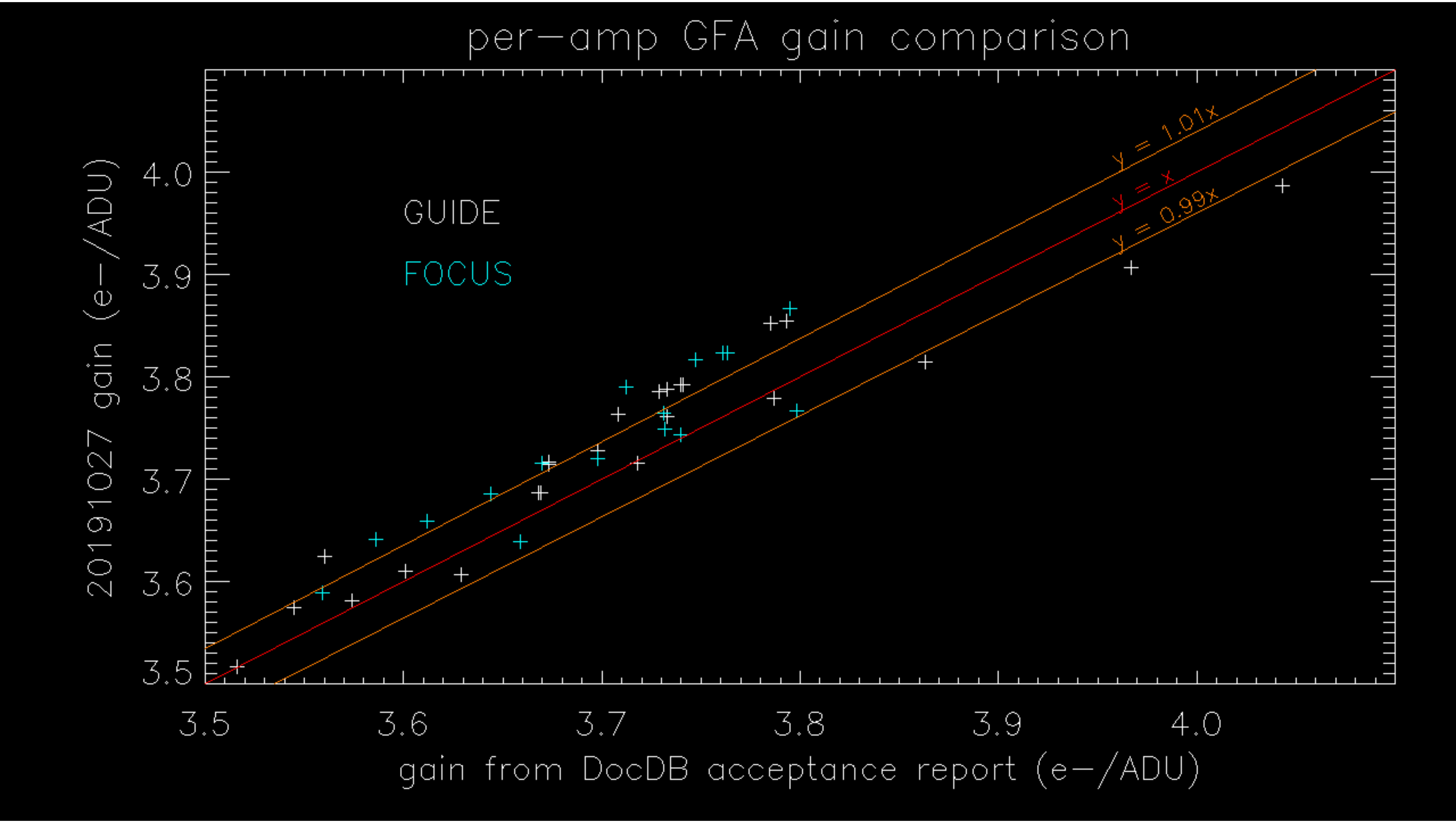

- median fractional difference = 0.0087
- mean fractional difference = 0.0072
- stddev fractional difference = 0.0096

# 20201123 vs. lab

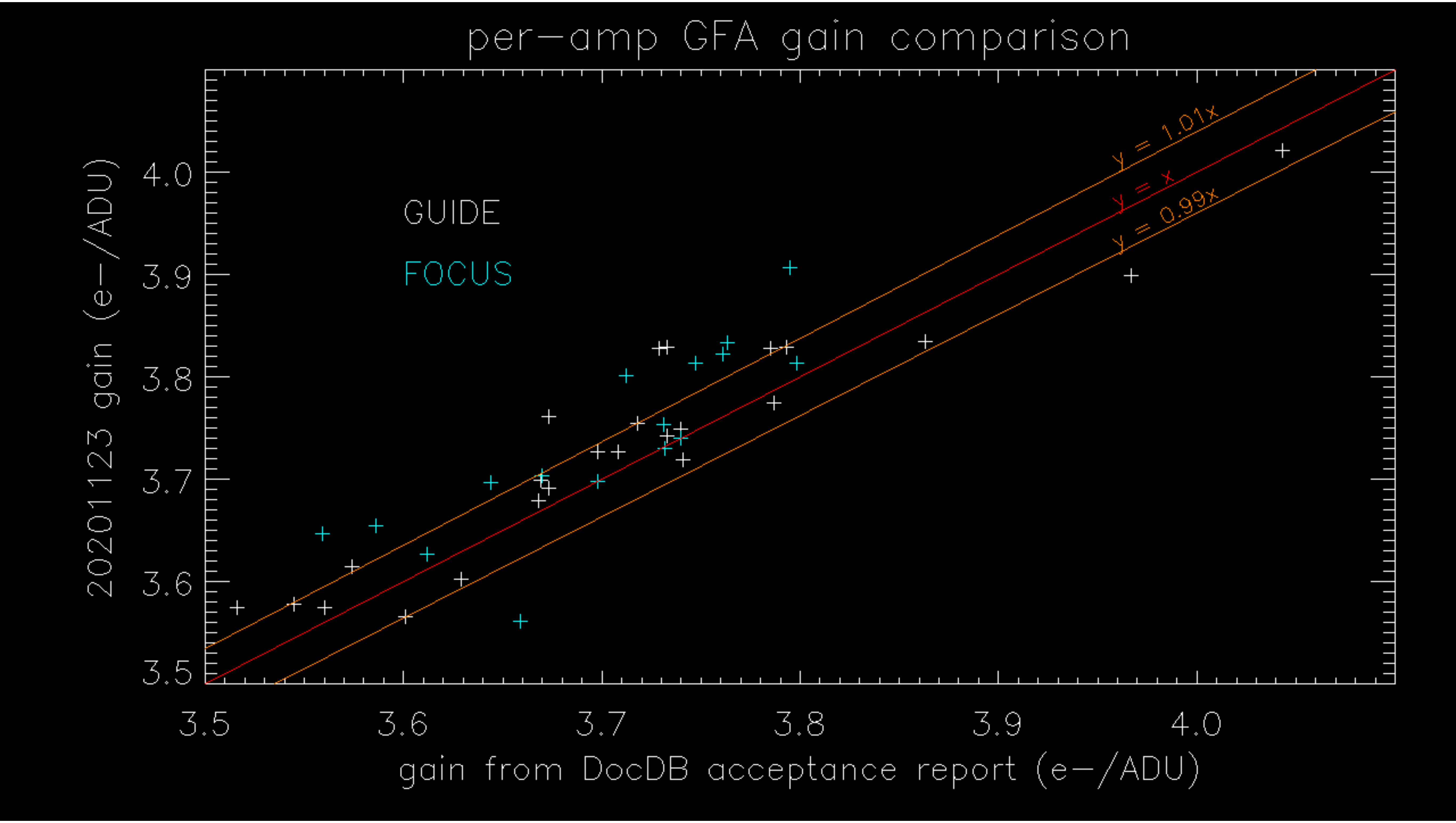



- median fractional difference = 0.0068
- mean fractional difference = 0.0069
- stddev fractional difference = 0.0122

# 20191027 vs. lab



# 20191123 vs. lab



# GFA gain re-measurement

- The post-installation gains from 20191027 and 20201123 are quite consistent: they agree to within 0.1% in the mean, with a per-camera scatter of 0.9%.

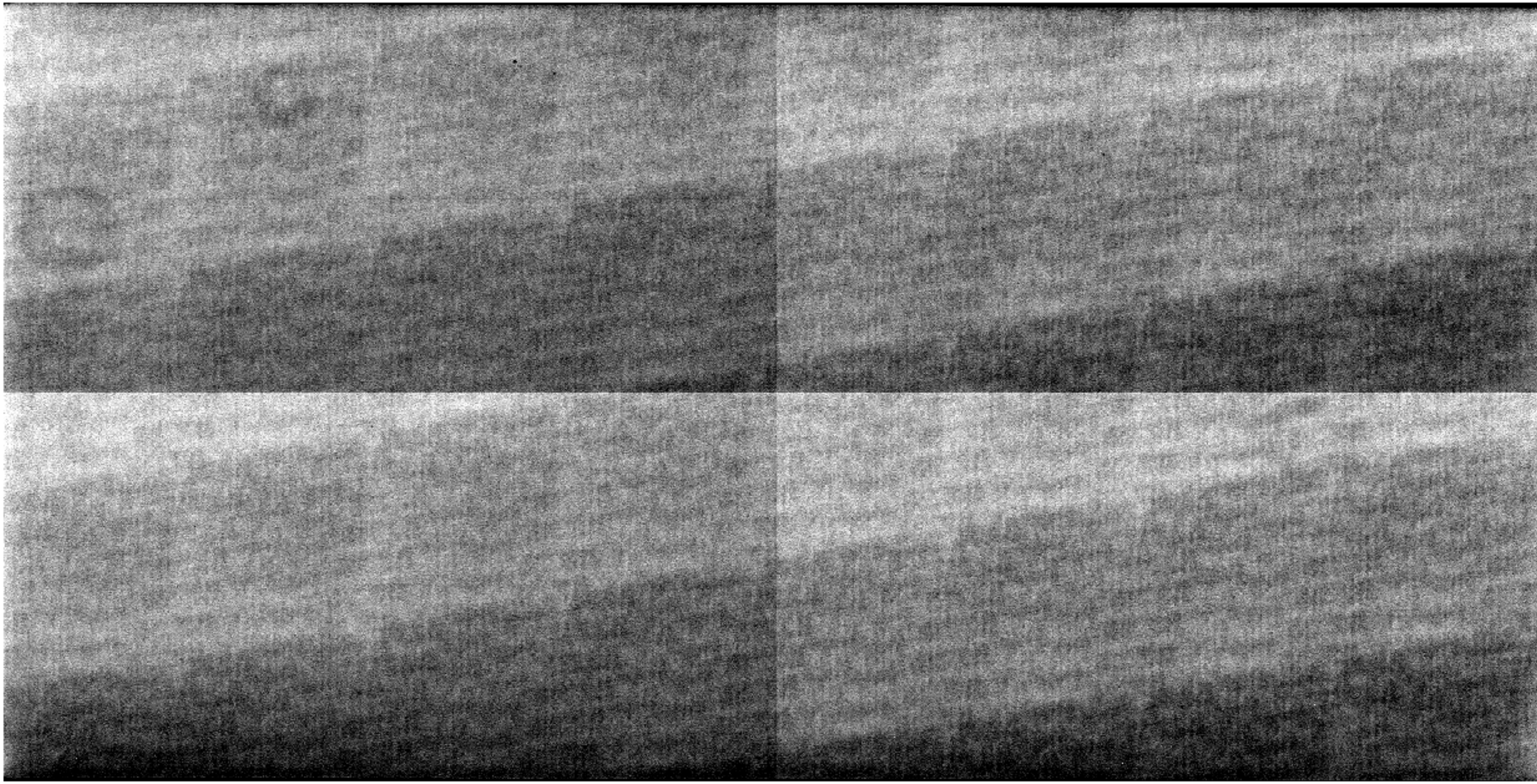
- We had only done one post-installation GFA gain measurement sequence in the past (20191027), so this is the first post-installation characterization of the stability of the GFA gains.

- The LED calibration screen data from 20201123 can also be used to compare the post-restart GFA flat fields to the those from earlier in 2020.

- I don’t see any salient new features (e.g. dust donuts appearing/disappearing) when blinking between the 20200115 and 20201123 LED-based GFA flat field images.

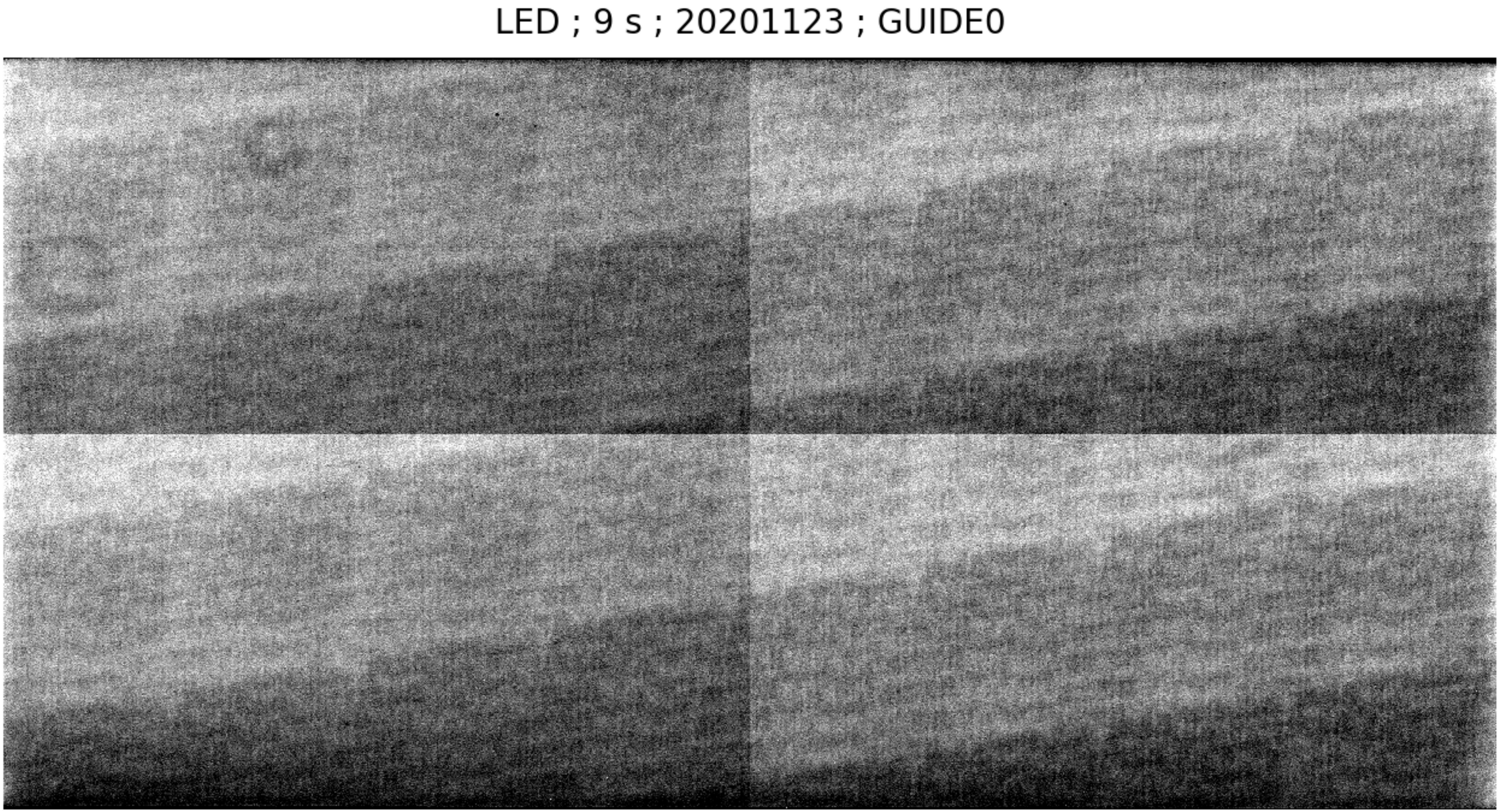
# flat field: GUIDE0

LED ; 5 s ; 20200115 ; GUIDE0



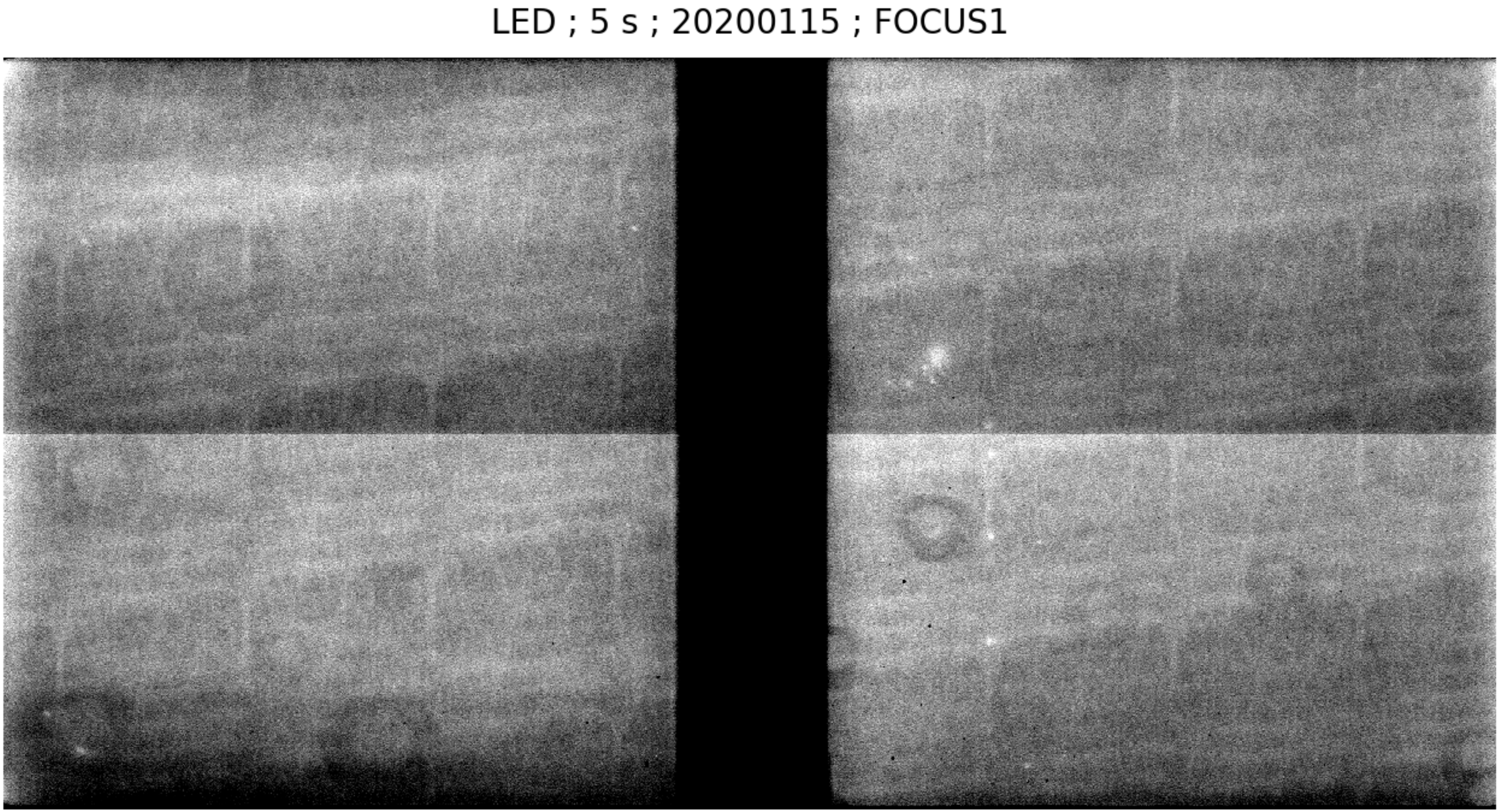
**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: GUIDE0



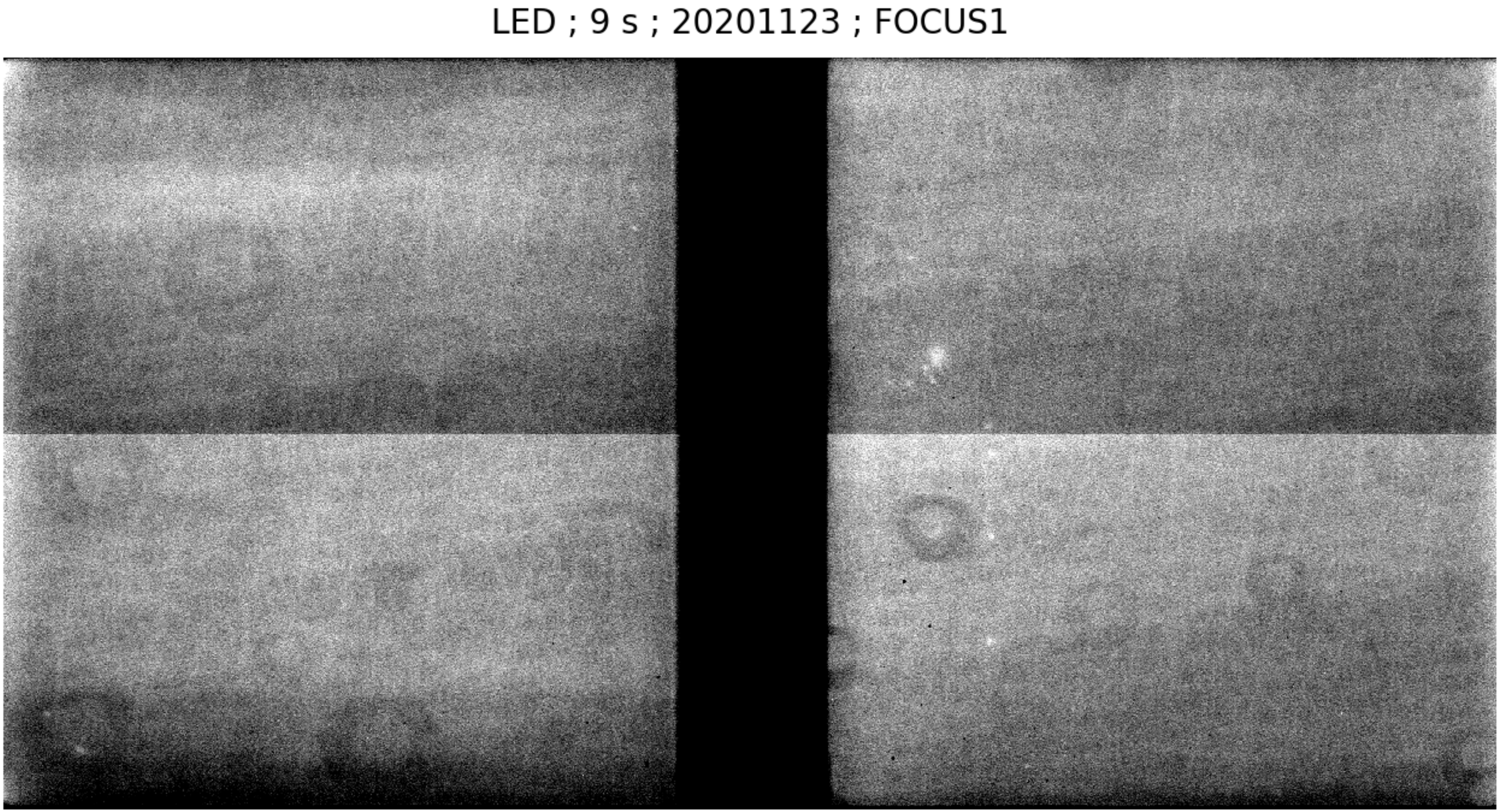

**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: FOCUS1




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

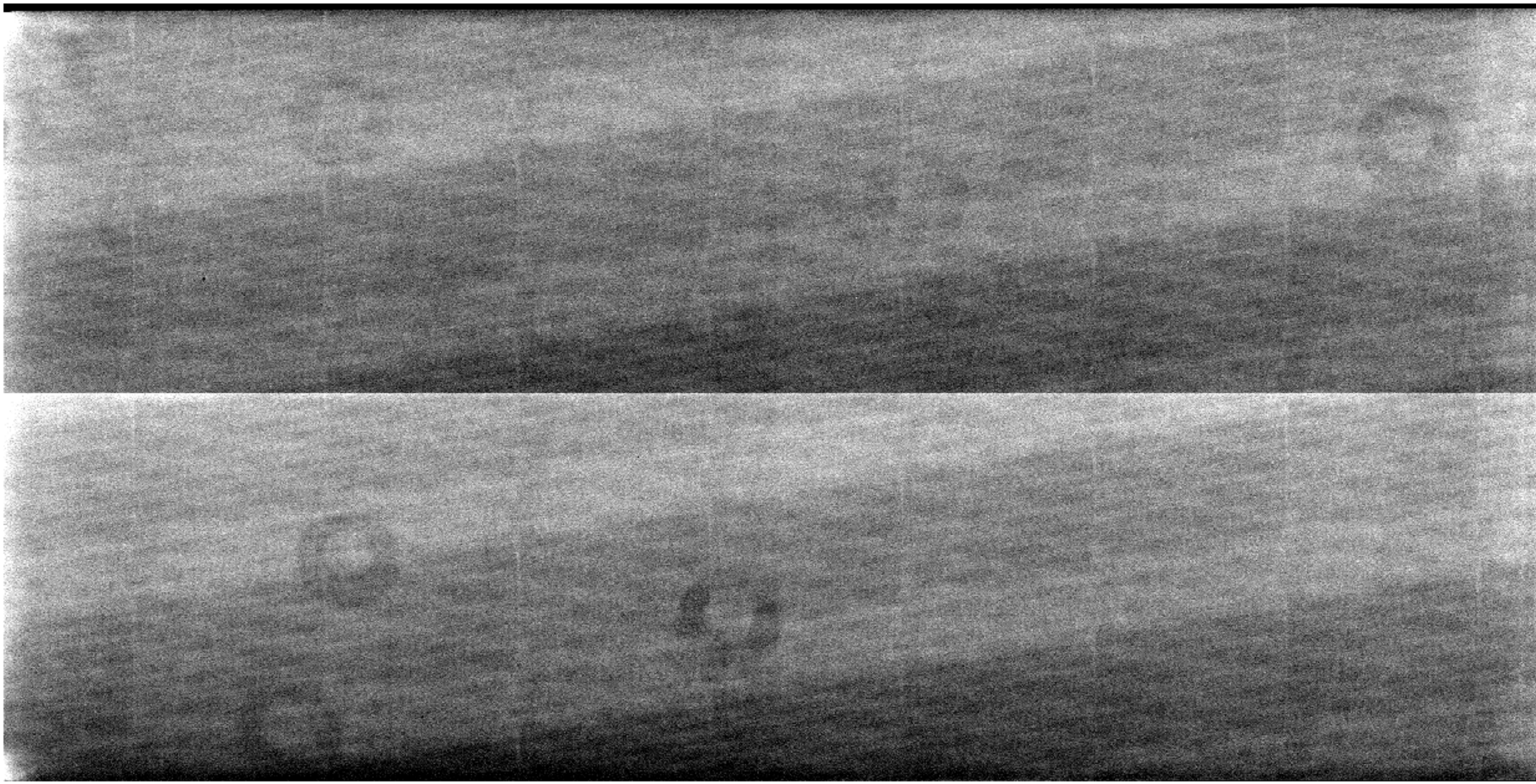
# flat field: FOCUS1




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

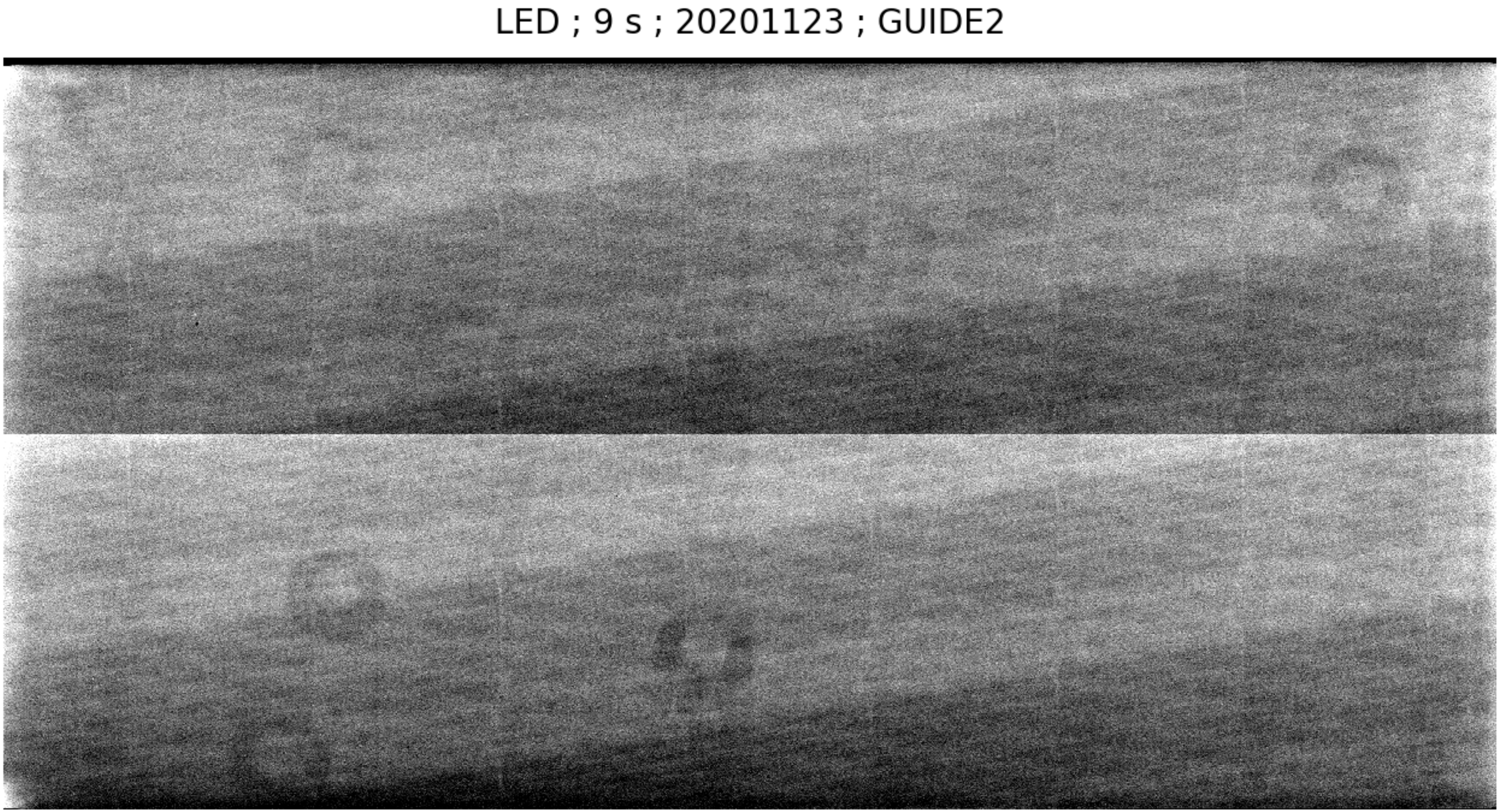
# flat field: GUIDE2

LED ; 5 s ; 20200115 ; GUIDE2



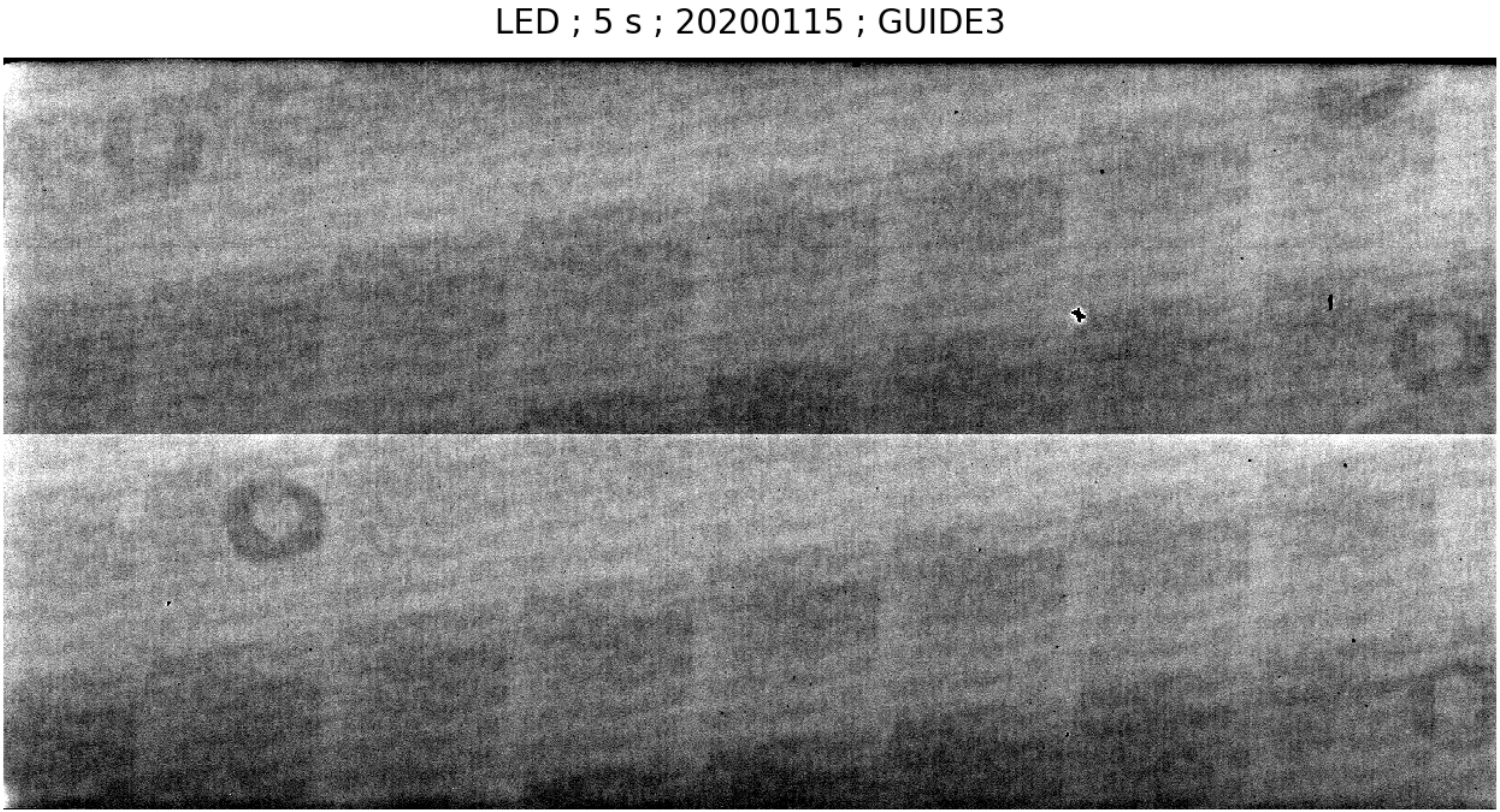
**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: GUIDE2




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

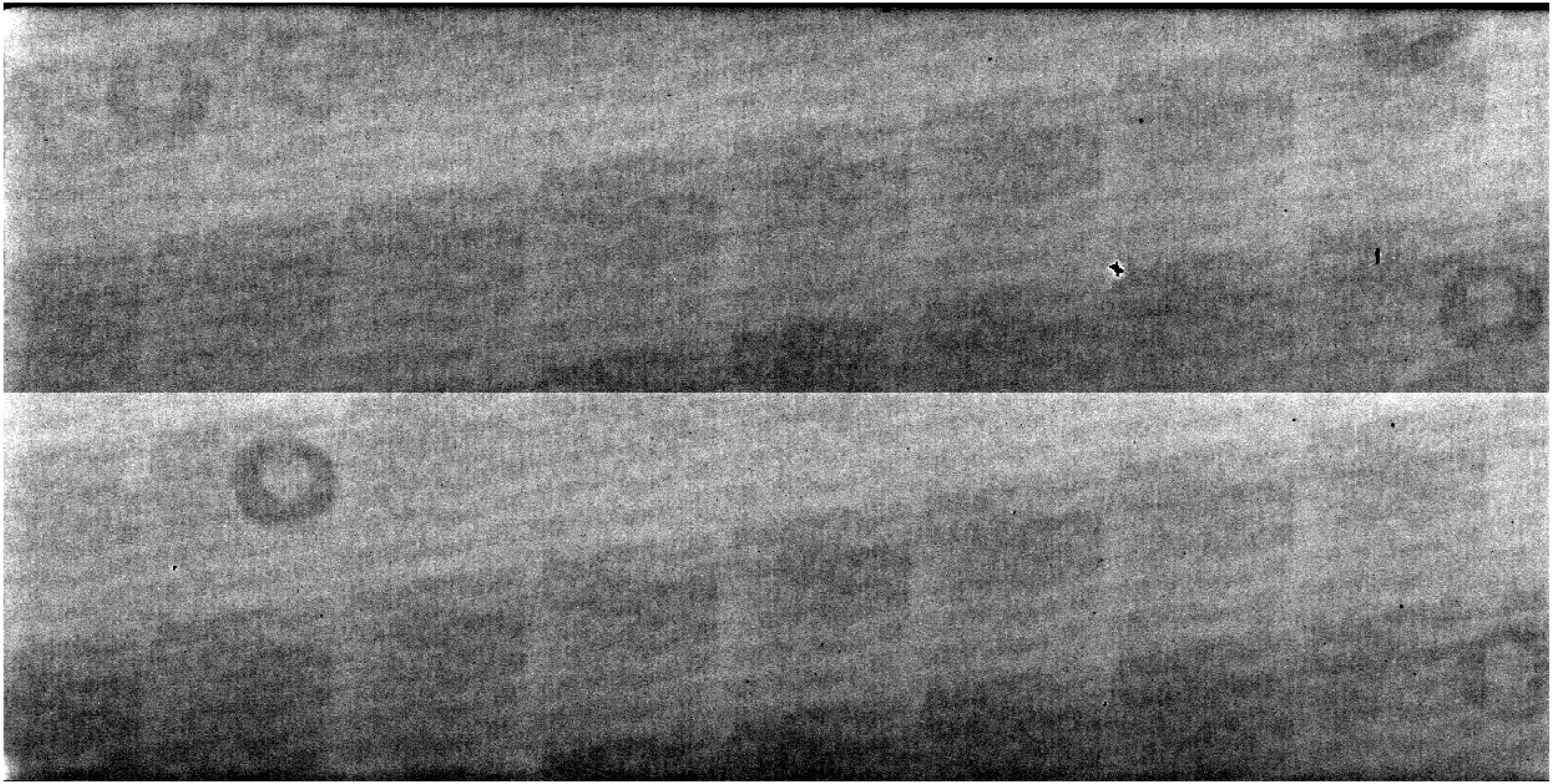
# flat field: GUIDE3




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: GUIDE3

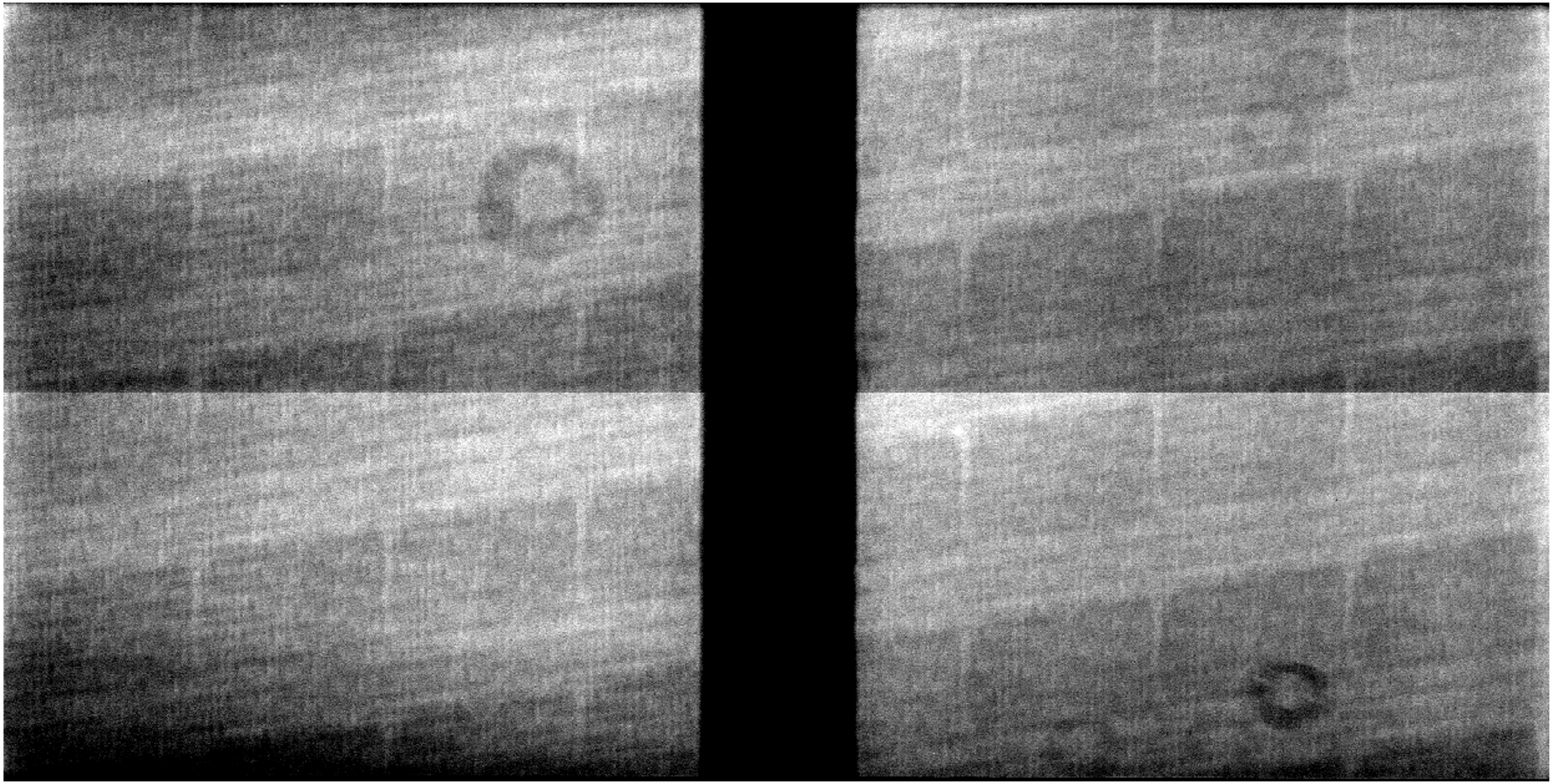
LED ; 9 s ; 20201123 ; GUIDE3



**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

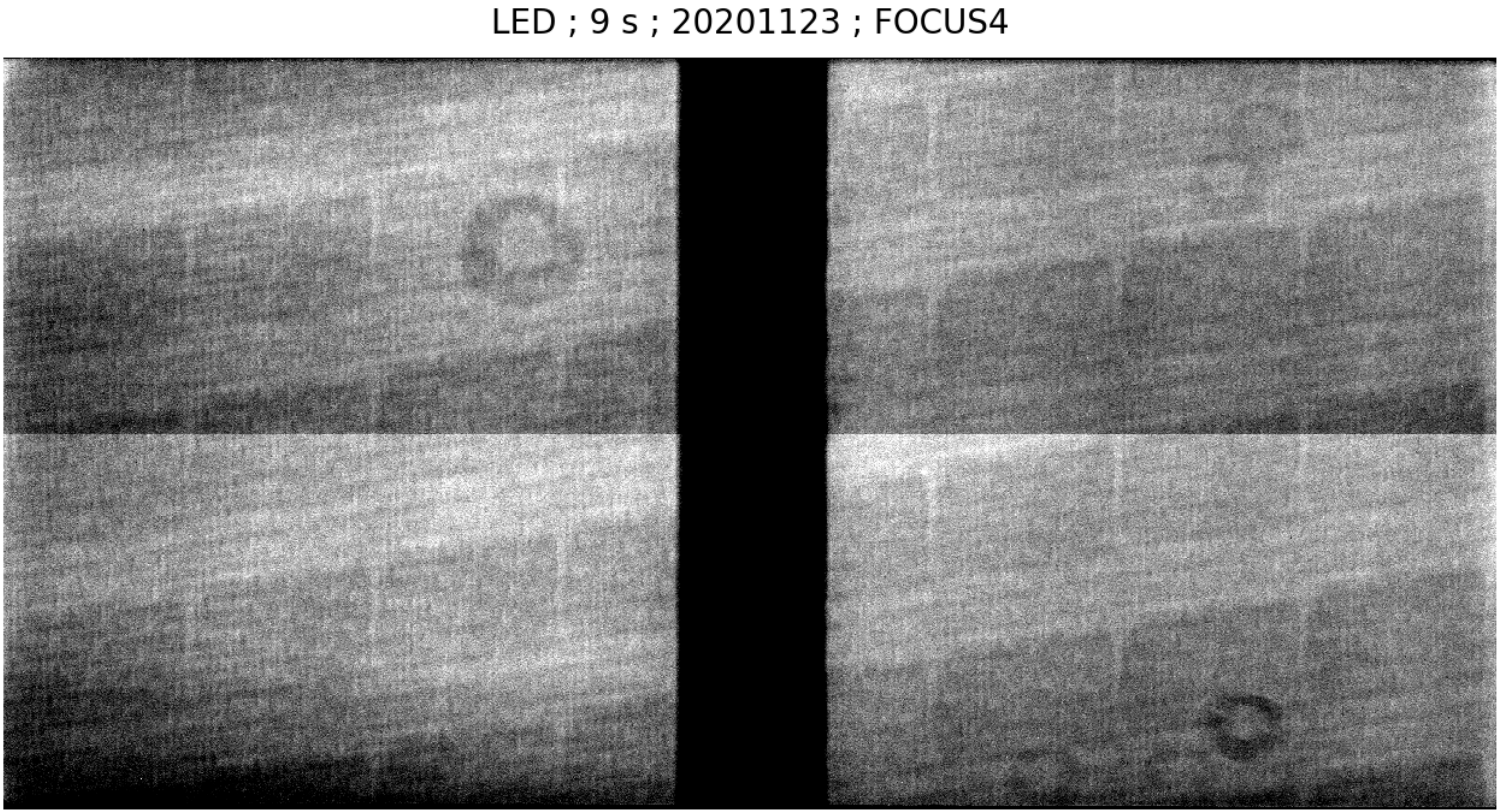
# flat field: FOCUS4

LED ; 5 s ; 20200115 ; FOCUS4



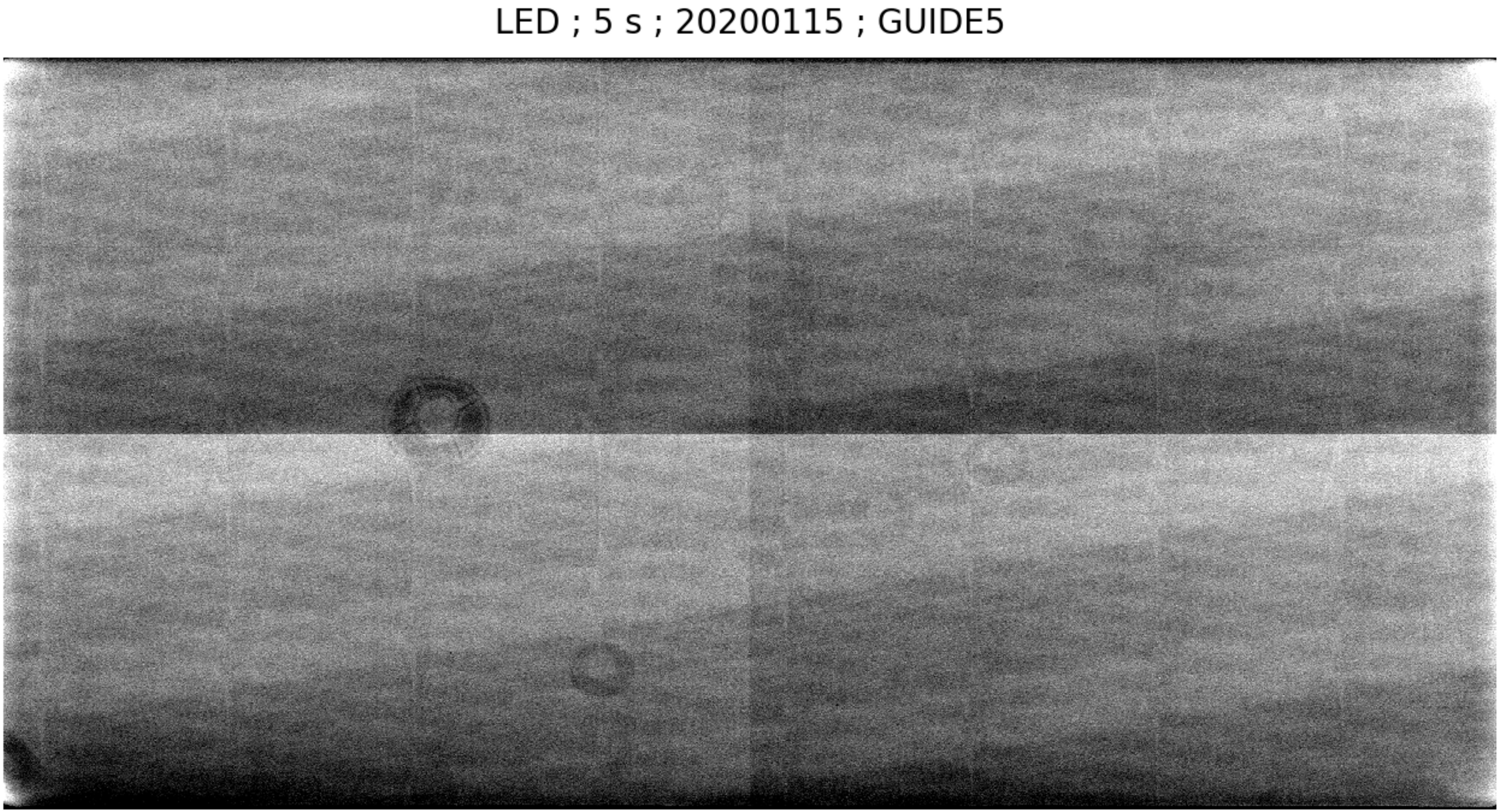
**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: FOCUS4



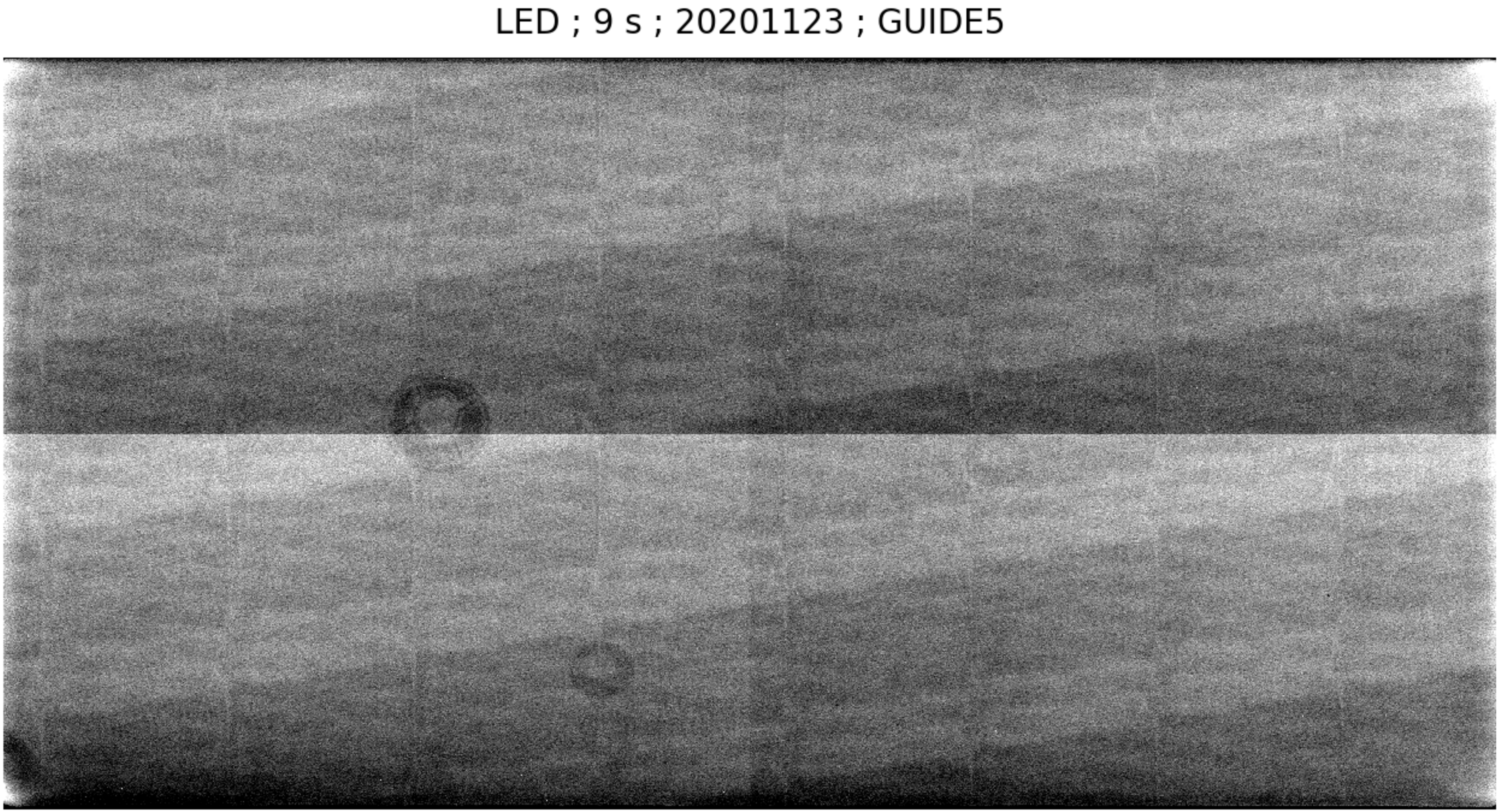

**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: GUIDE5



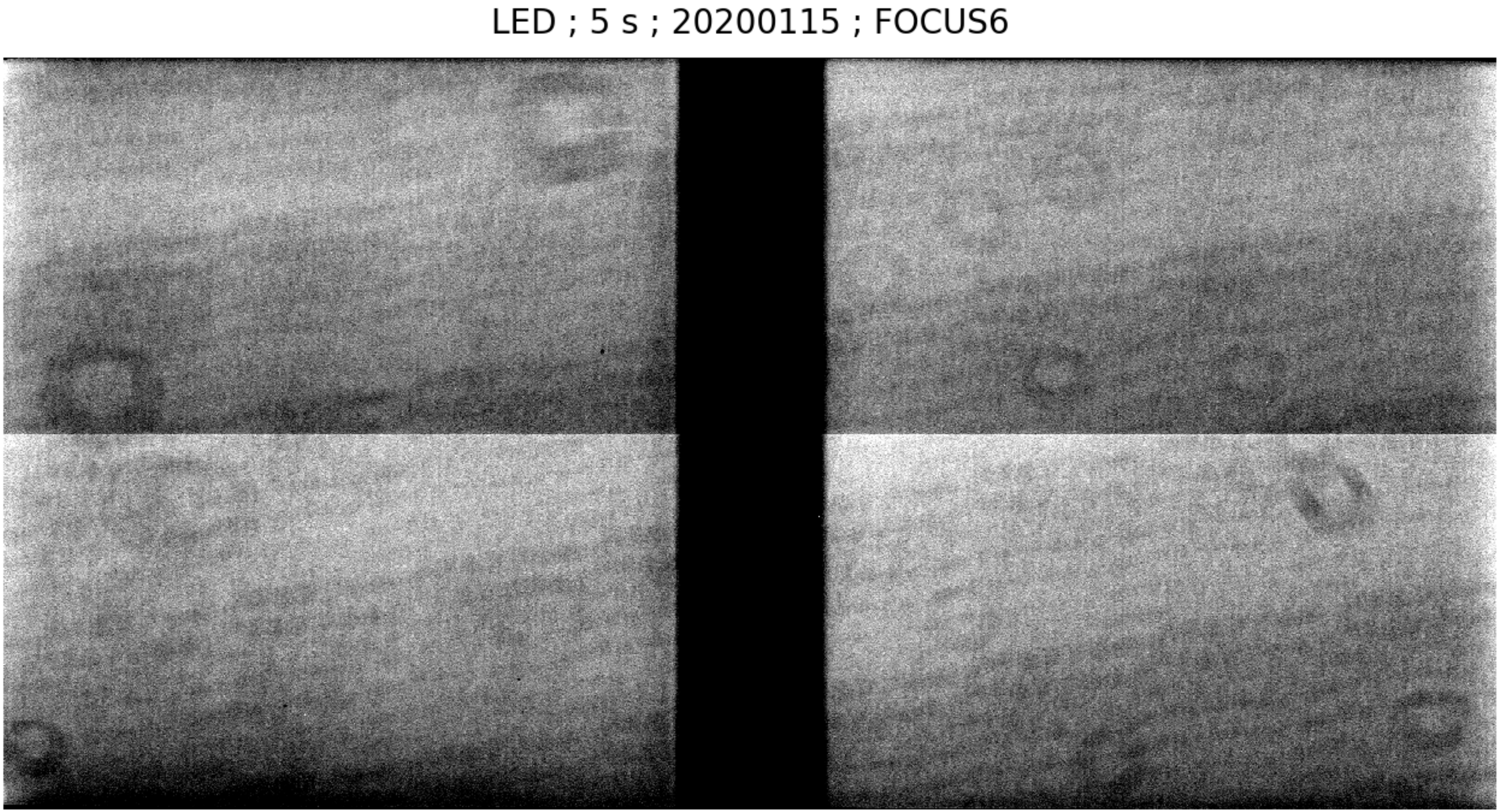

**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: GUIDE5




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

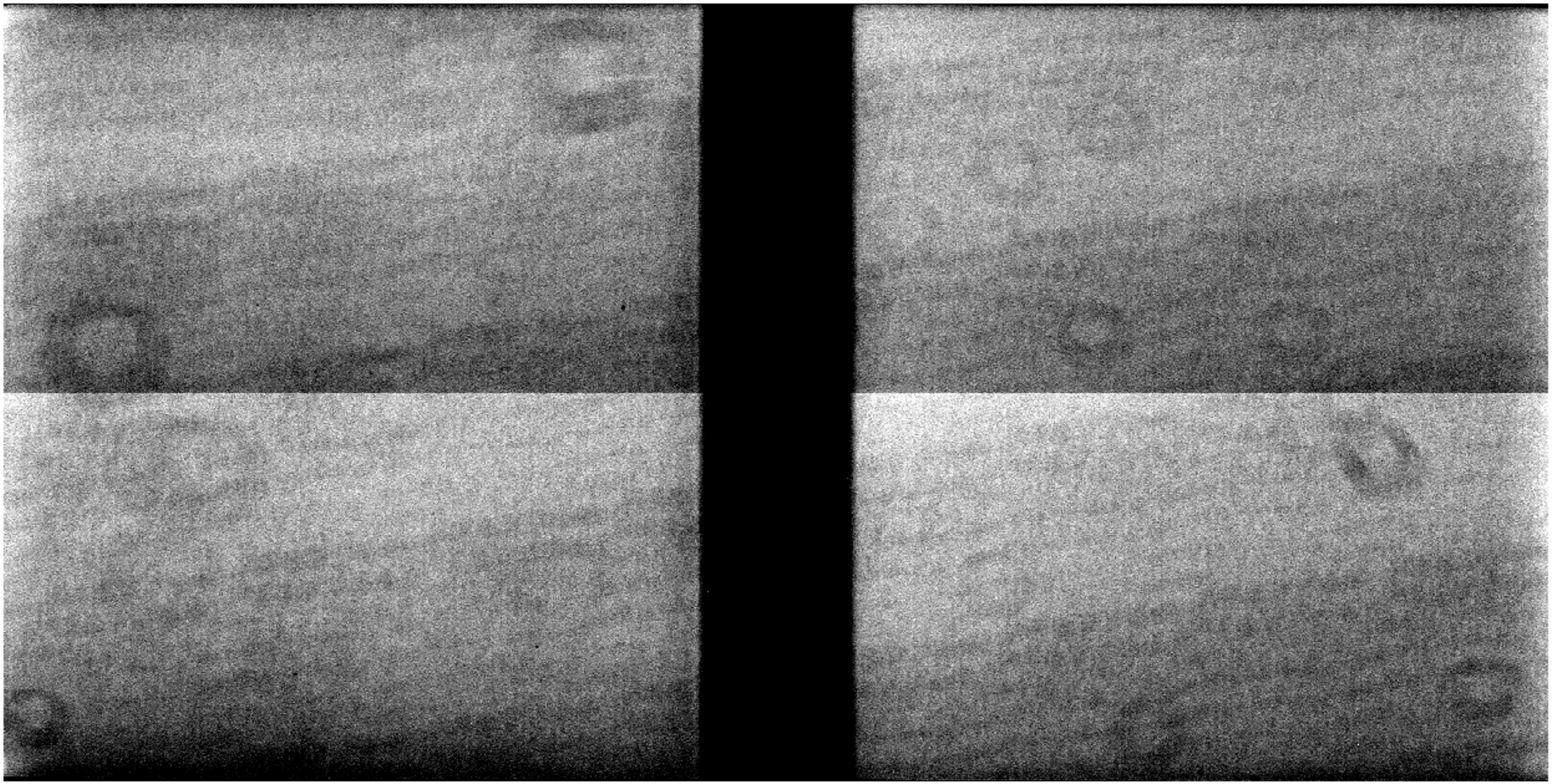
# flat field: FOCUS6




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: FOCUS6

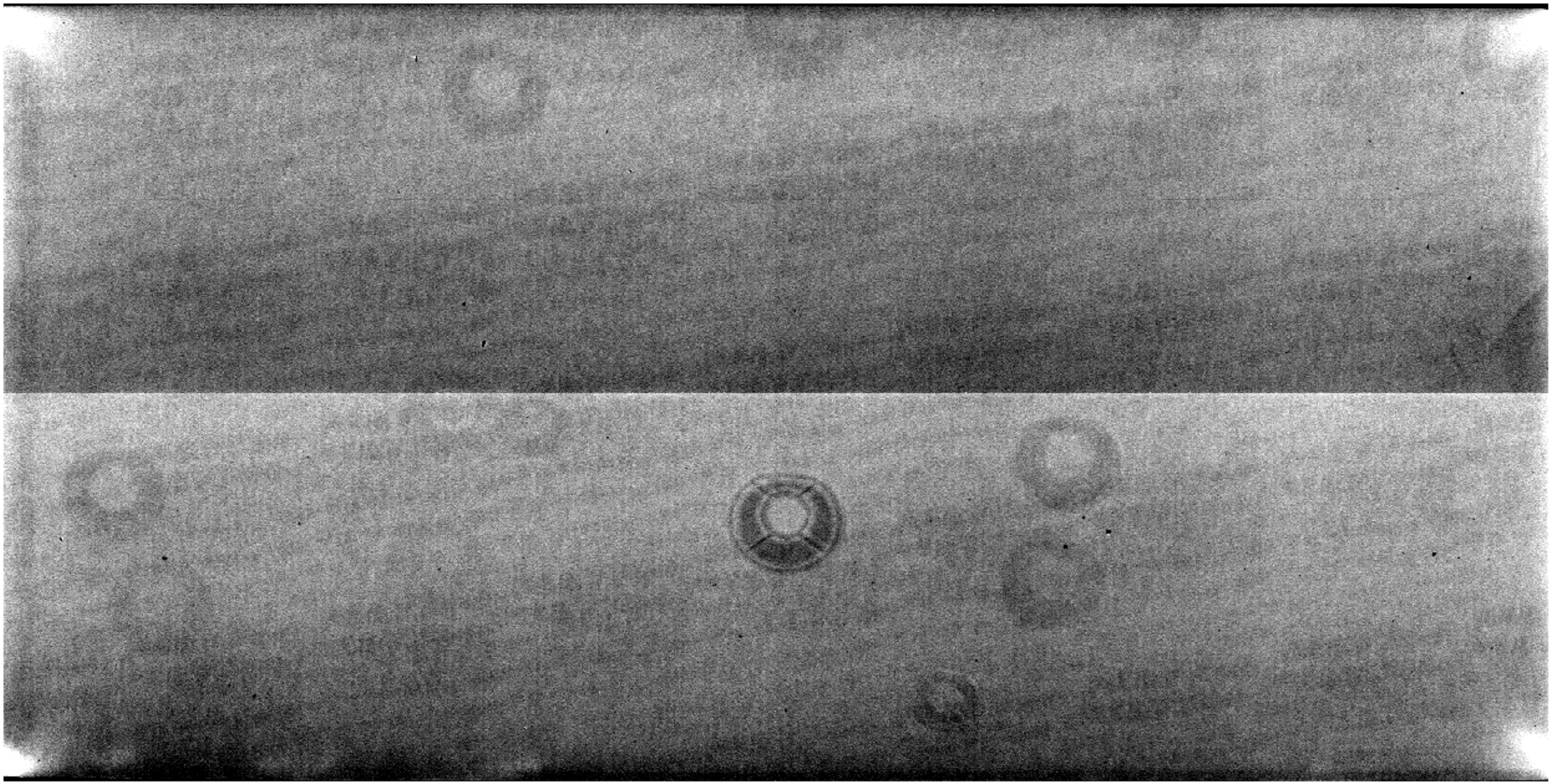
LED ; 9 s ; 20201123 ; FOCUS6



**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

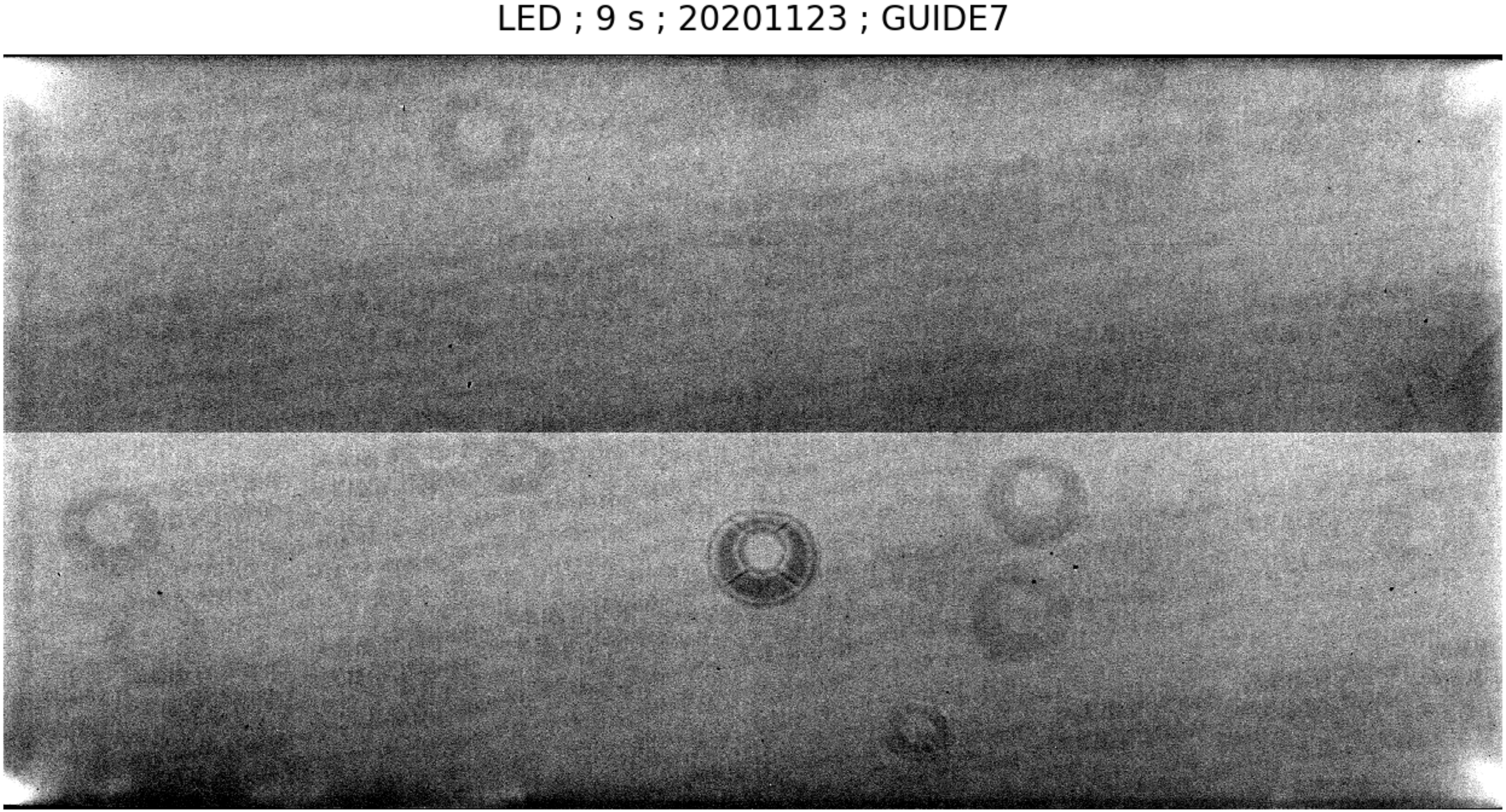
# flat field: GUIDE7

LED ; 5 s ; 20200115 ; GUIDE7



**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

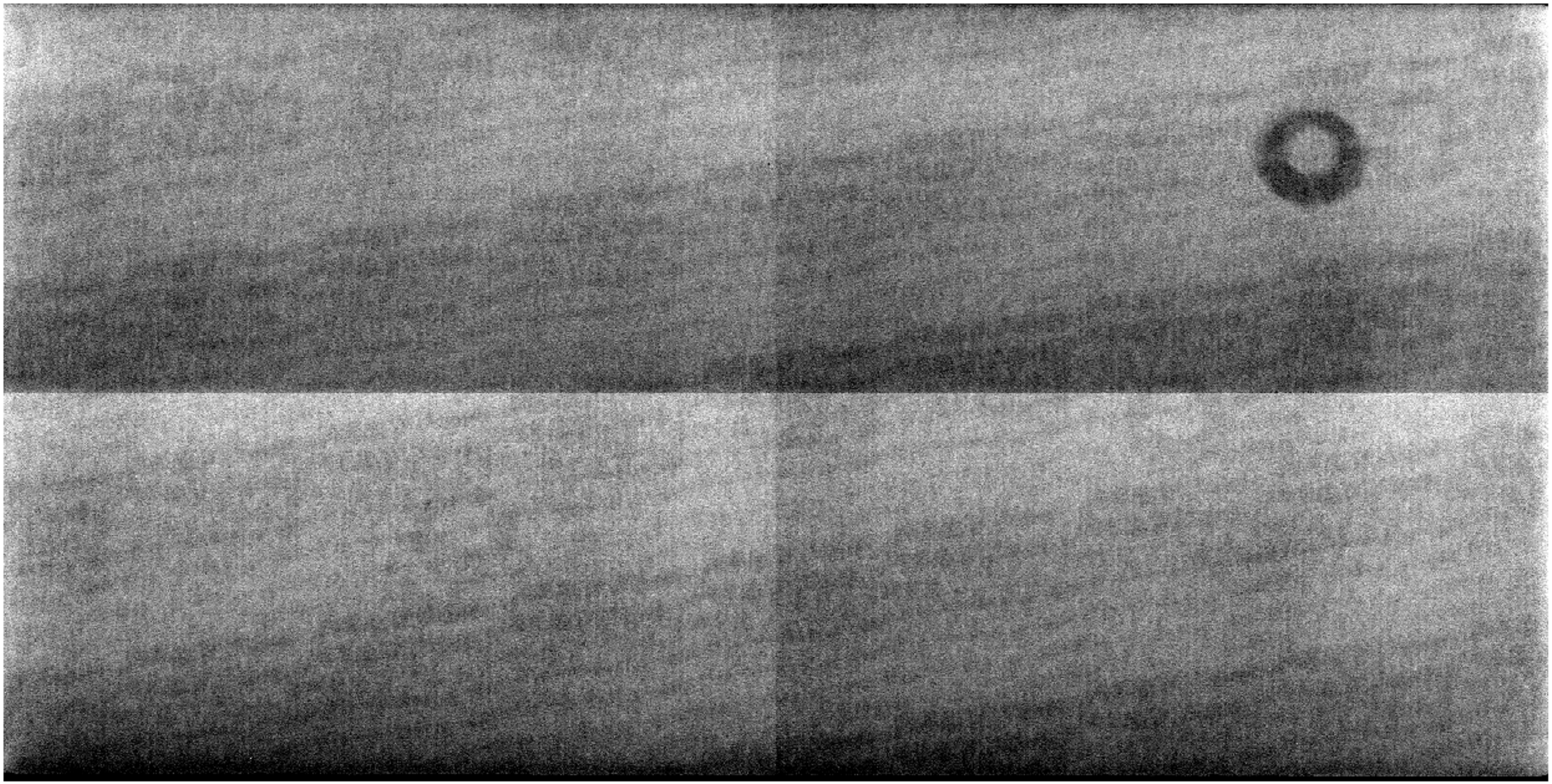
# flat field: GUIDE7




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

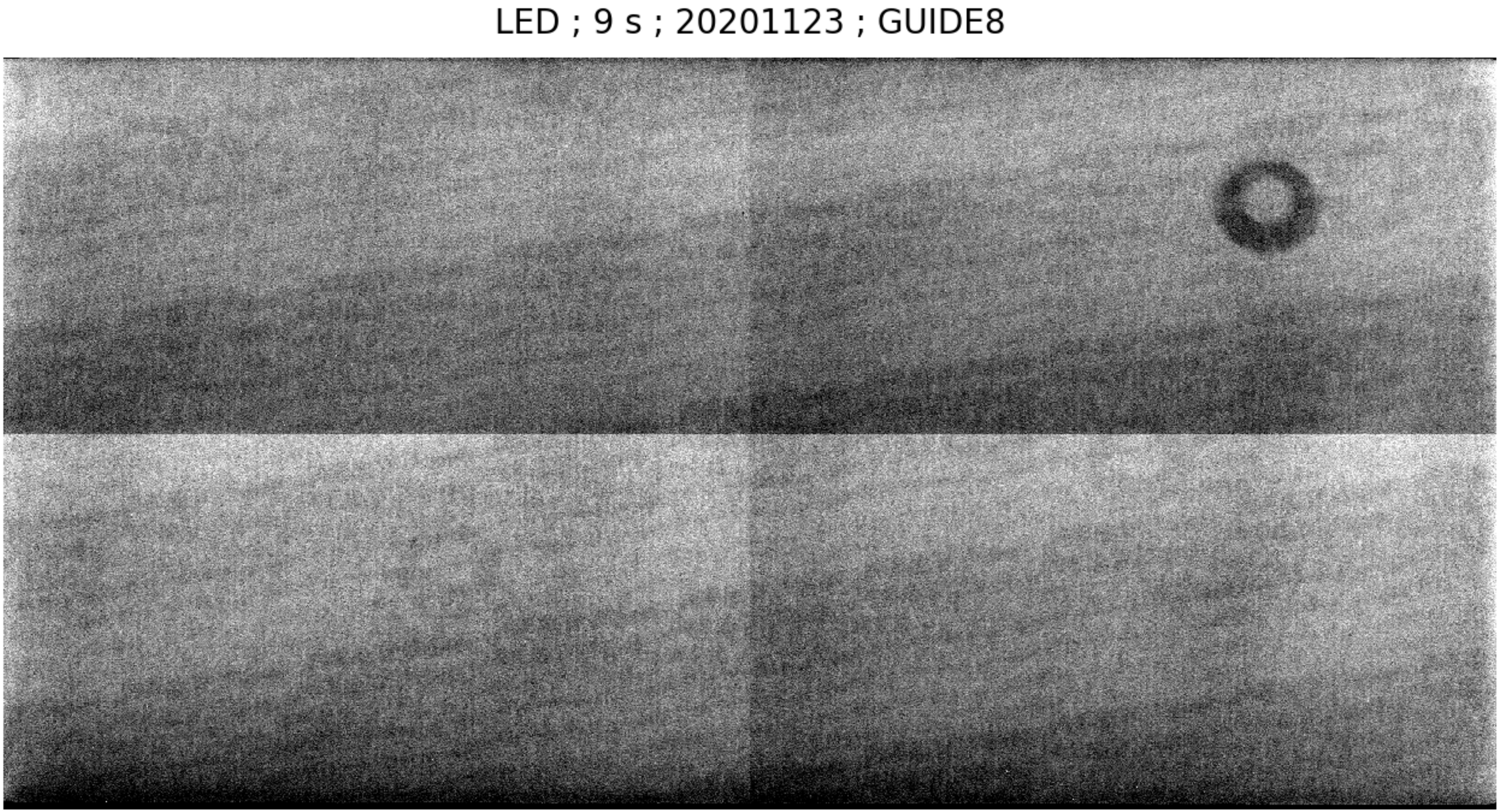
# flat field: GUIDE8

LED ; 5 s ; 20200115 ; GUIDE8



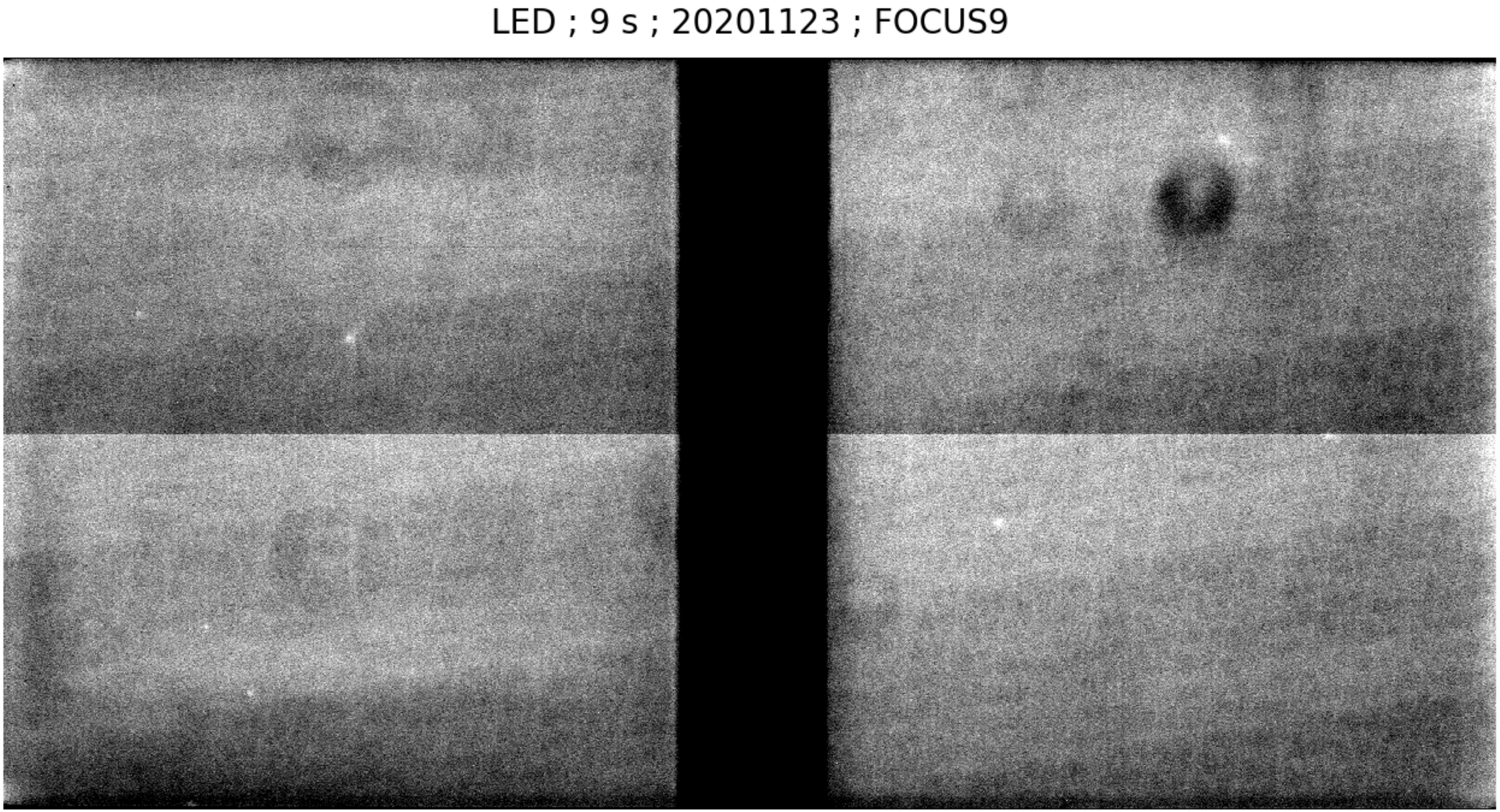
**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: GUIDE8




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

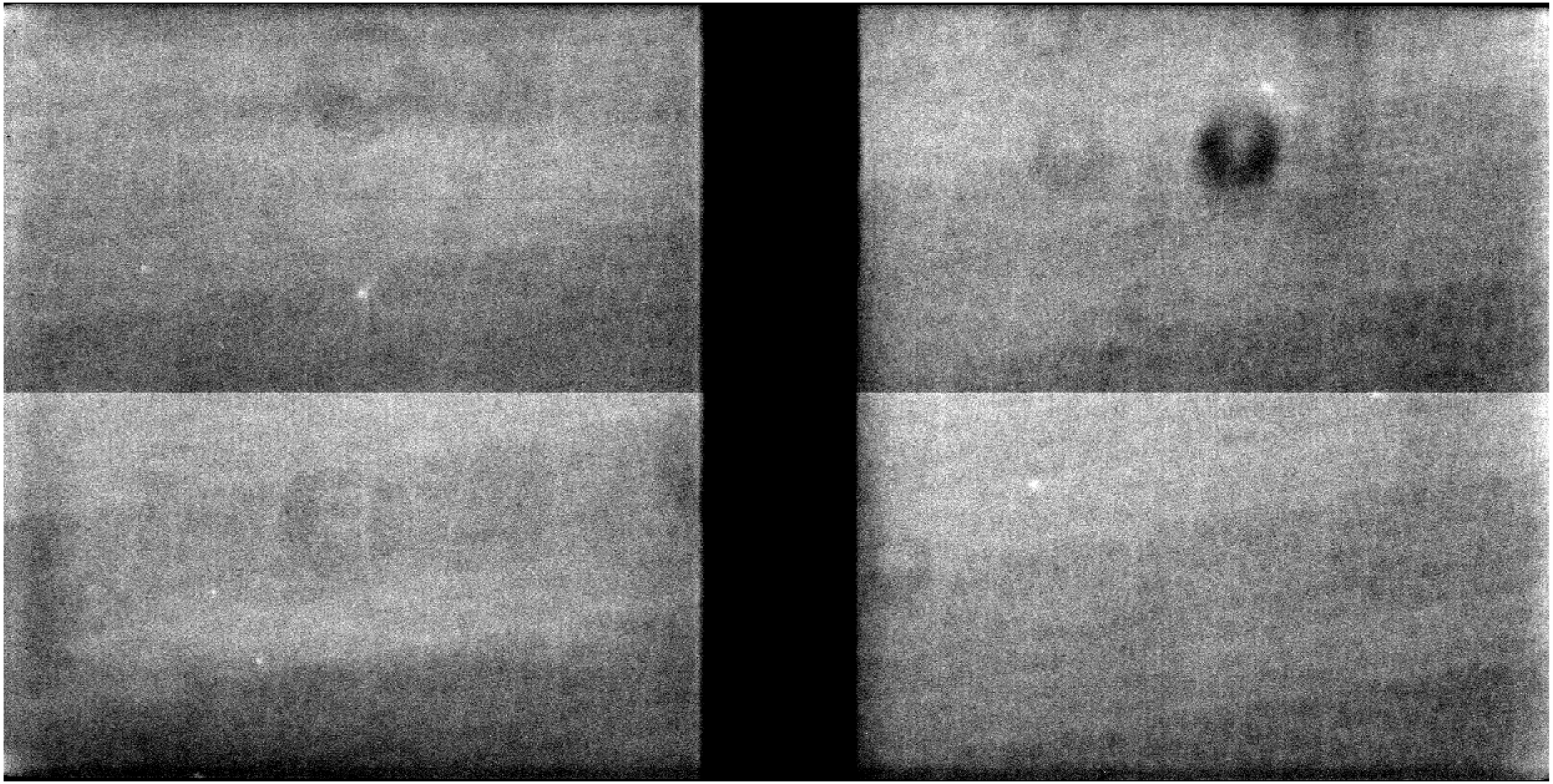
# flat field: FOCUS9




**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# flat field: FOCUS9

LED ; 9 s ; 20201123 ; FOCUS9



**The four amps are shown rescaled to have the same median value, in order to highlight small-scale structures.**

# GFA zeropoints at zenith

| night | airmass | EXPTIME | # exp | ZP0 | ZP2 | ZP3 | ZP5 | ZP7 | ZP8 |
|---|---|---|---|---|---|---|---|---|---|
| 20191025 | 1.003 | 60 s | 21 | 25.678 | 25.642 | 25.642 | 25.634 | 25.551 | 25.599 |
| 20201125 | 1.020 | 60 s | 16 | 25.684 | 25.622 | 25.627 | 25.637 | 25.547 | 25.614 |
| 20201125 | 1.010 | 30 s | 11 | 25.688 | 25.623 | 25.629 | 25.630 | 25.538 | 25.622 |

**all processings run with same version of gfa_reduce**

# GFA zeropoints at zenith

- In the previous table, ZP0 is the GUIDE0 r-band mag for a source with total detected flux of 1 ADU/second. Then ZP2 corresponds to GUIDE2 and so forth…

- The same sky location at (ra, dec) ~ (80, 30) was used for all three rows of the previous slide's table. Arcminute scale dithers were applied from one exposure to another.

- The 20201125 minus 20191025 zeropoint differences (60 s EXPTIME) are 0.005, -0.019, -0.015, 0.003, -0.004, 0.015 mags. These differences have a median within 1 mmag of zero and a standard deviation of 0.013 mag.

# GFA zeropoints at zenith

- The 20201125 zeropoints for EXPTIME = 30 seconds versus EXPTIME = 60 seconds are highly consistent.
- The differences are 5 mmag, 1 mmag, 2 mmag, -7 mmag, -9 mmag, 8 mmag.

# Measuring the GFA k-term?

- Night 20201125 was photometric, so we decided to also measure zeropoints in another dense field near airmass of 2.
- This alternative dense field is at (ra, dec) = (25, 65).
- 10 x 60 second exposures were taken with a mean airmass of 1.97 (EXPID = 64754-64763).
- On 20201125, the 60 second airmass = 1.02 zeropoints are 0.039 mag deeper than the 60 second airmass = 1.97 zeropoints, with a scatter of 0.019 mmag.
- This would imply a k-term coefficient of k = 0.041.

# Measuring the GFA k-term?

- k = 0.041 for r-band seems like it’s on the low side.
- In DESI-5418, I predicted k = 0.114 based on my GFA throughput curve.
- DESI pre-imaging codes mosstat.pro, bokstat.pro, and decstat.pro all use k = 0.1 for r band.
- PS1 range from https://arxiv.org/pdf/1201.2208.pdf is k = 0.085 +/-  0.03 for r band.
- Further data analysis could be done to try to standardize for source color (in these dense fields there may be a lot of heavily reddened stars).
- Holistic analysis of existing GFA data set might be able to further constrain the GFA k coefficient and/or color-terms.

# 20201123 GFA darks

- on 20201123 we attempted to take some GFA darks, since between night 20201122 and 20201123 the amount of light contamination in the dome had been decreased dramatically.

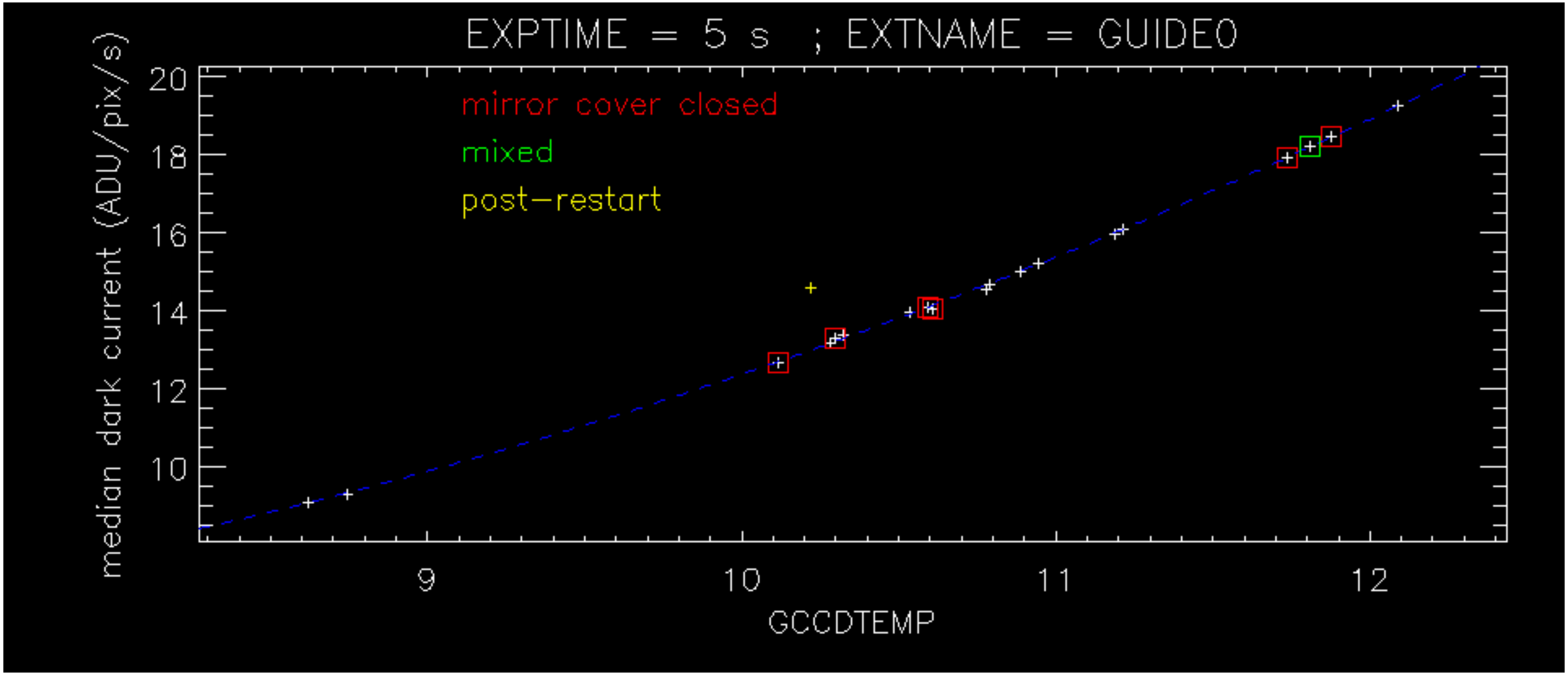
- However, it appears that there was still some residual light contamination in the dome on 20201123, since the GFA dark count rate is a little bit higher than expected.

- In any case, the 20201123 dark count rates agree at the ~10-20% level with pre-restart darks, so these 20201123 GFA still validate that the GFA dark current is similar to what it was during the 10/2019-3/2020 commissioning time period.

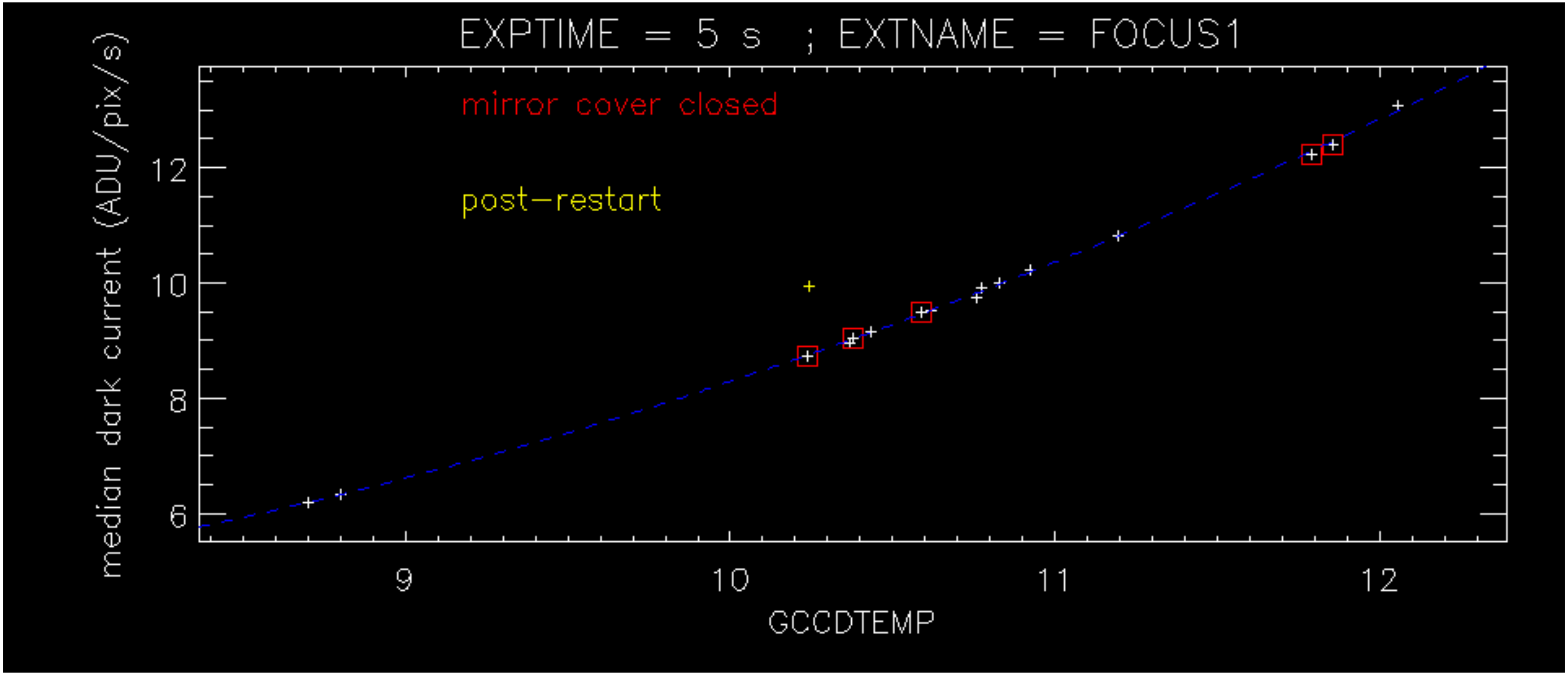
- The light contamination is ~1.5 ADU/pix/sec, which translates to r ~ 21.7 mag per sq. asec AB

- We should retake 100 x 5 seconds and 50 x 20 seconds GFA darks at some point.

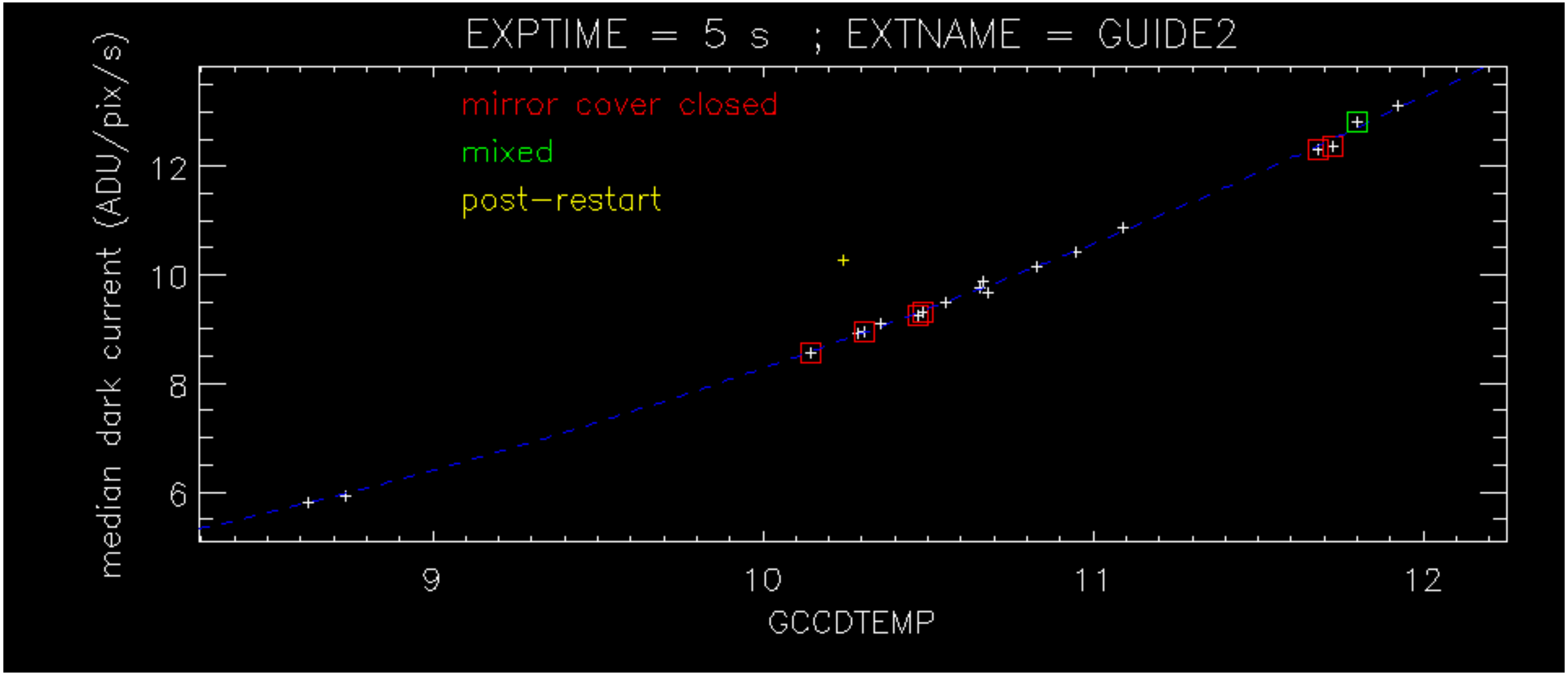
# 20201123 GFA darks



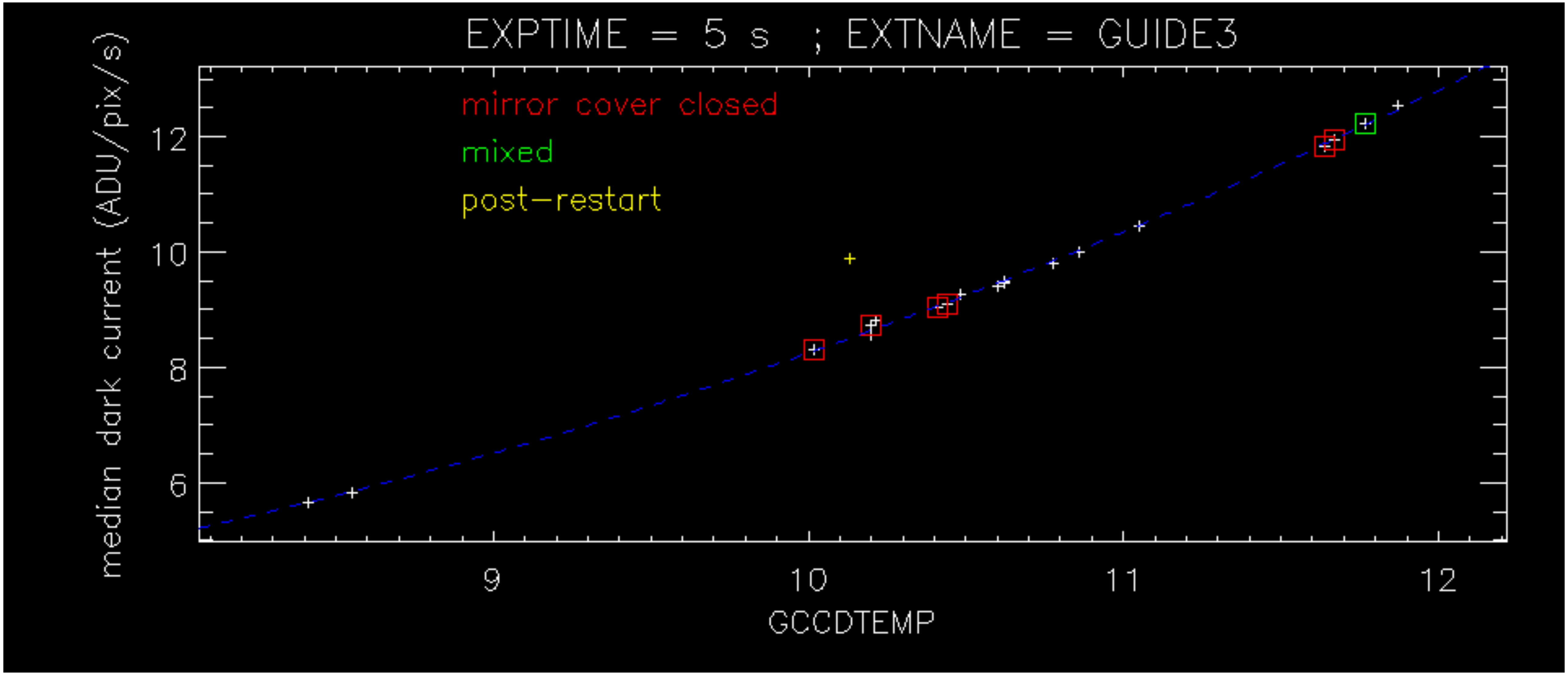
# 20201123 GFA darks



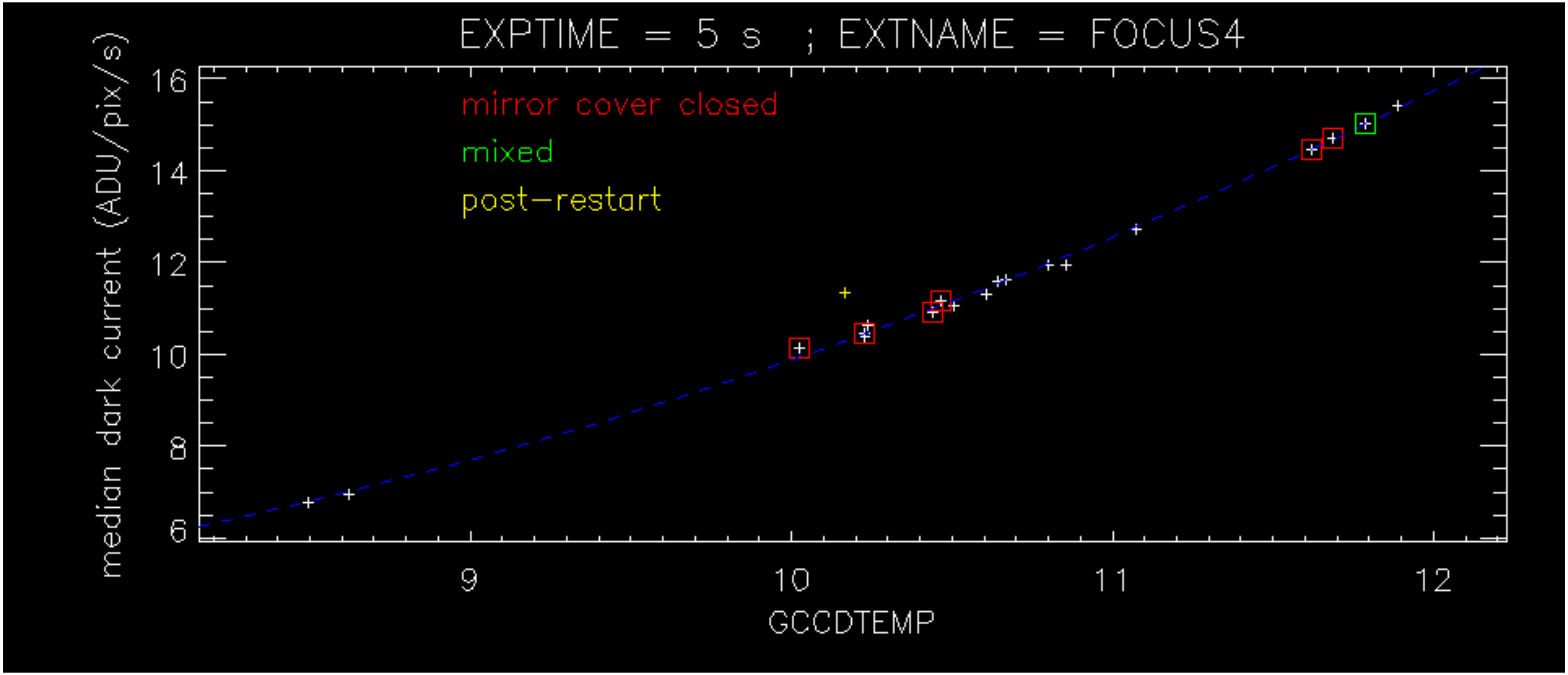
# 20201123 GFA darks



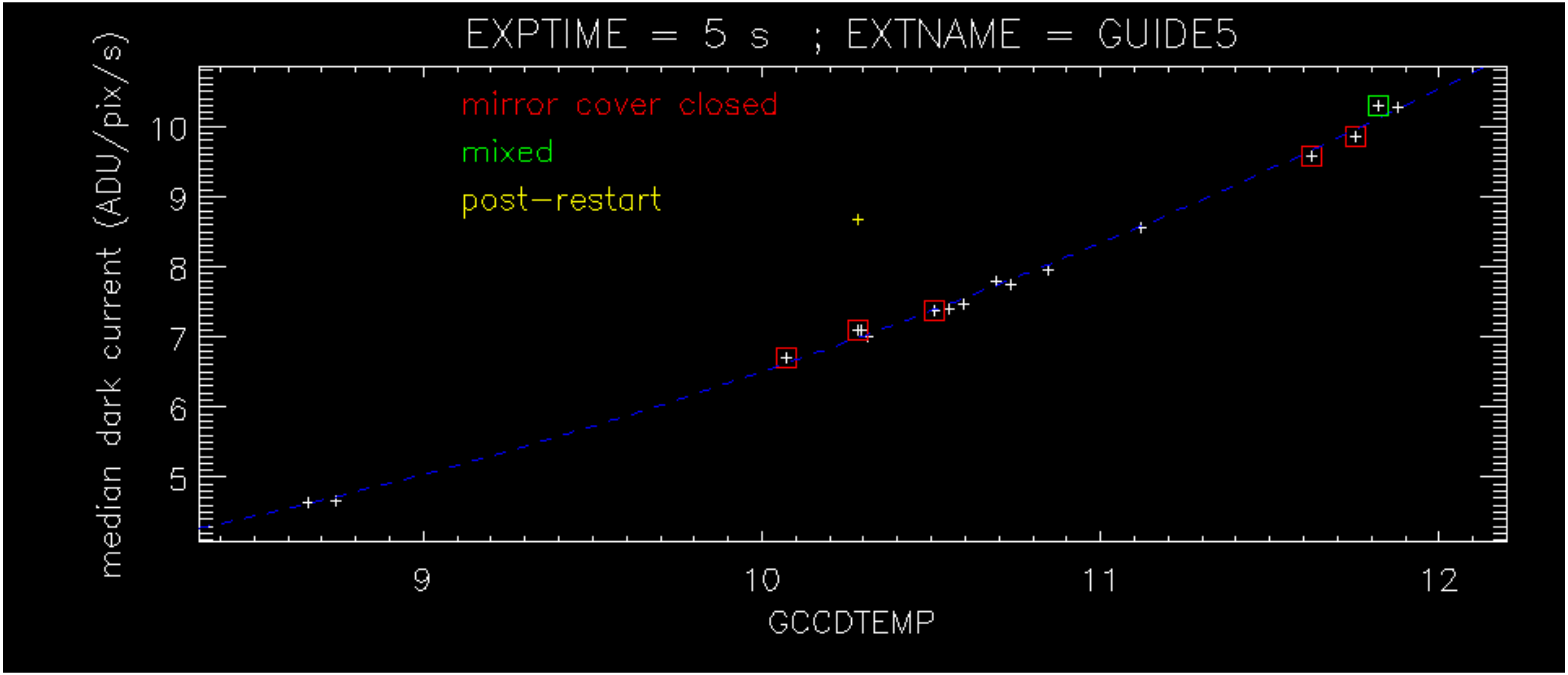
# 20201123 GFA darks



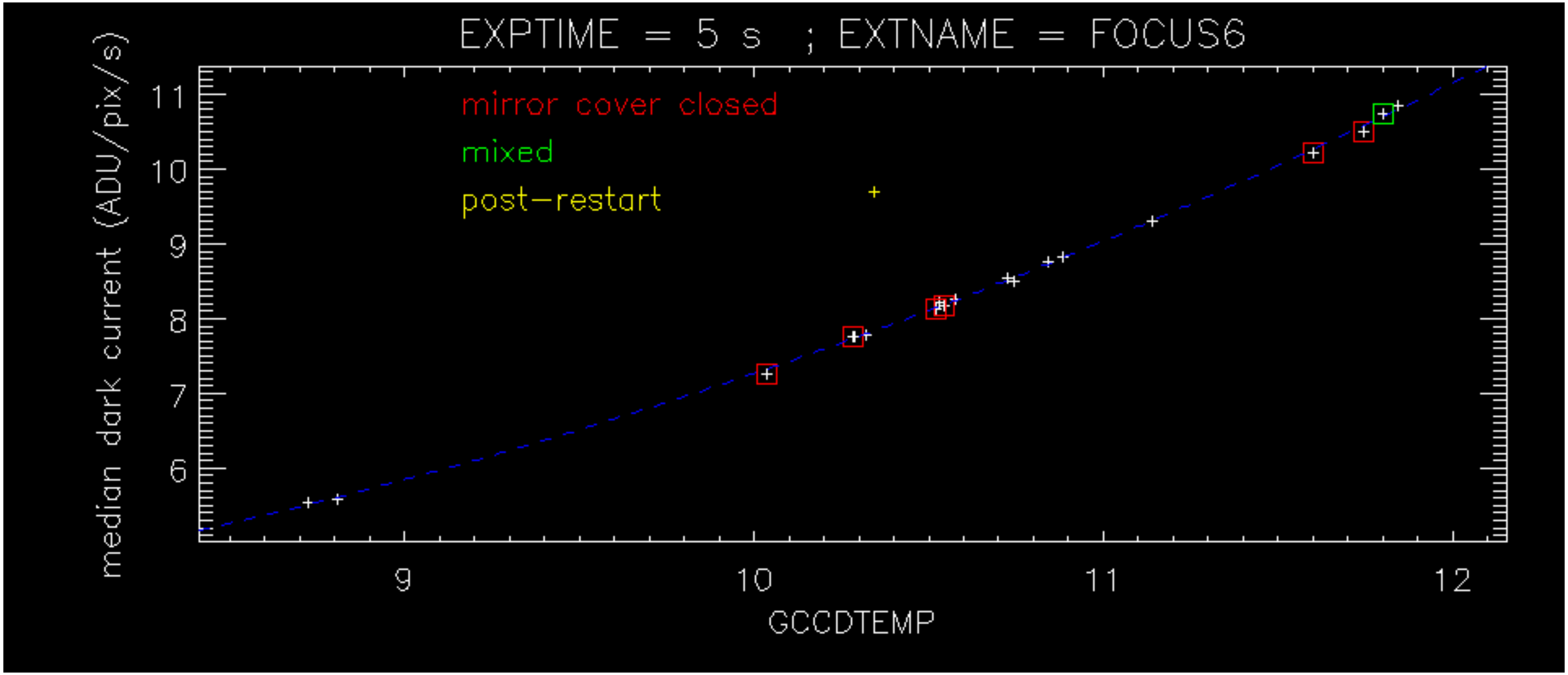
# 20201123 GFA darks



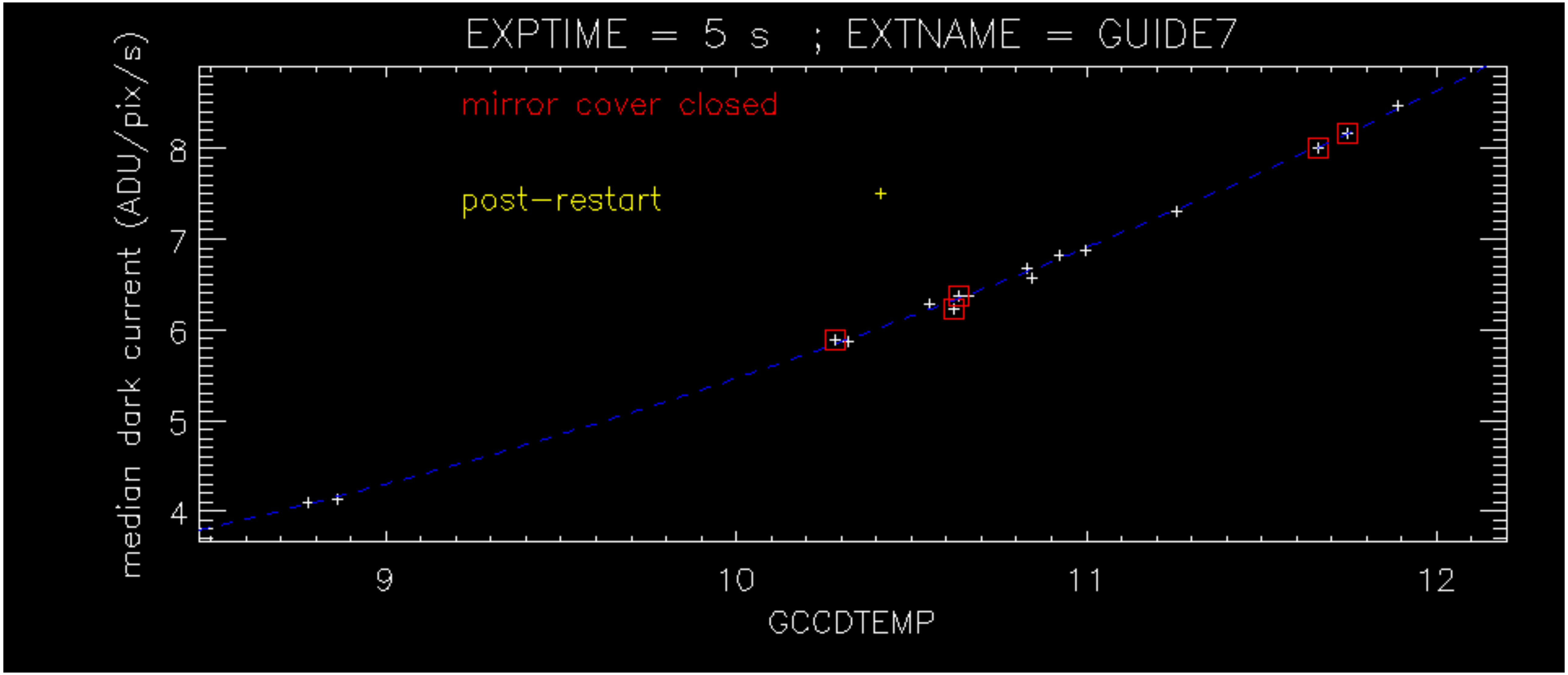
# 20201123 GFA darks



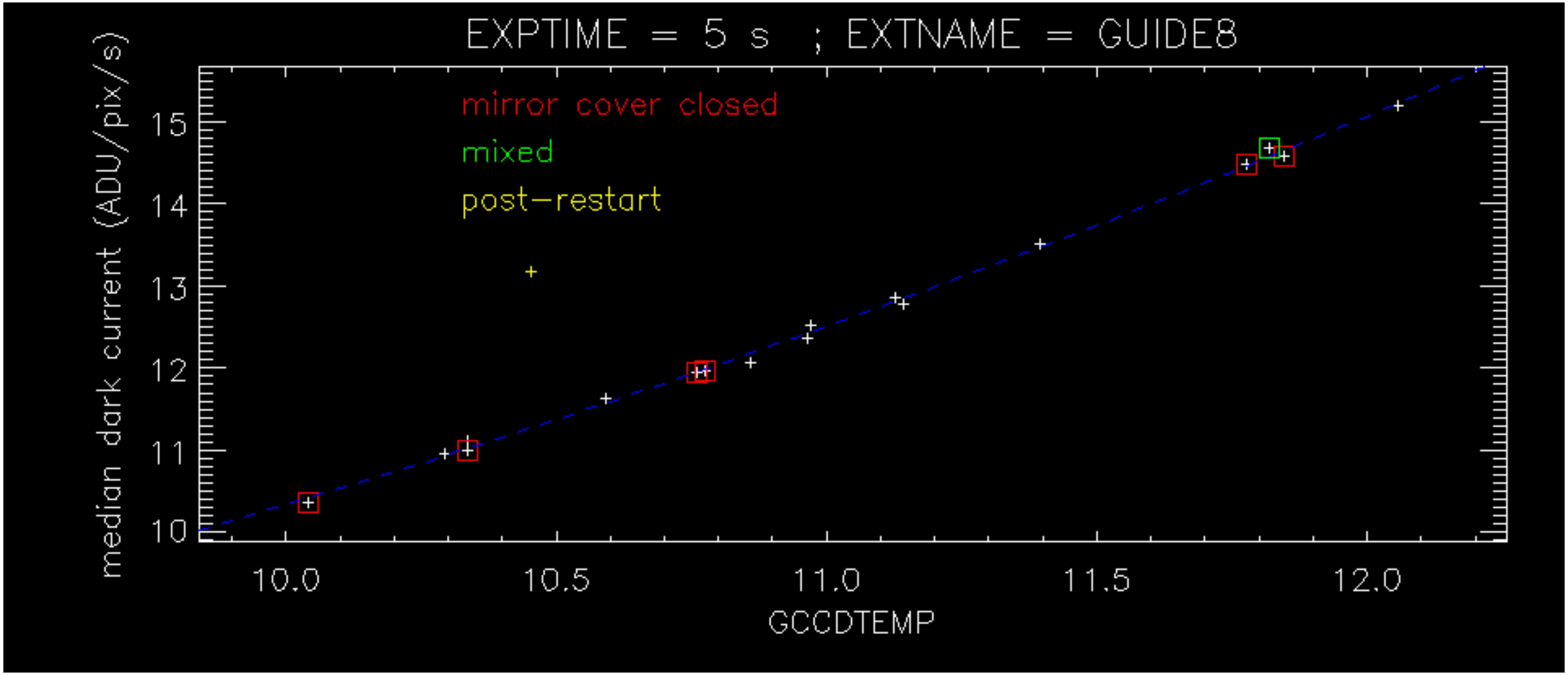
# 20201123 GFA darks



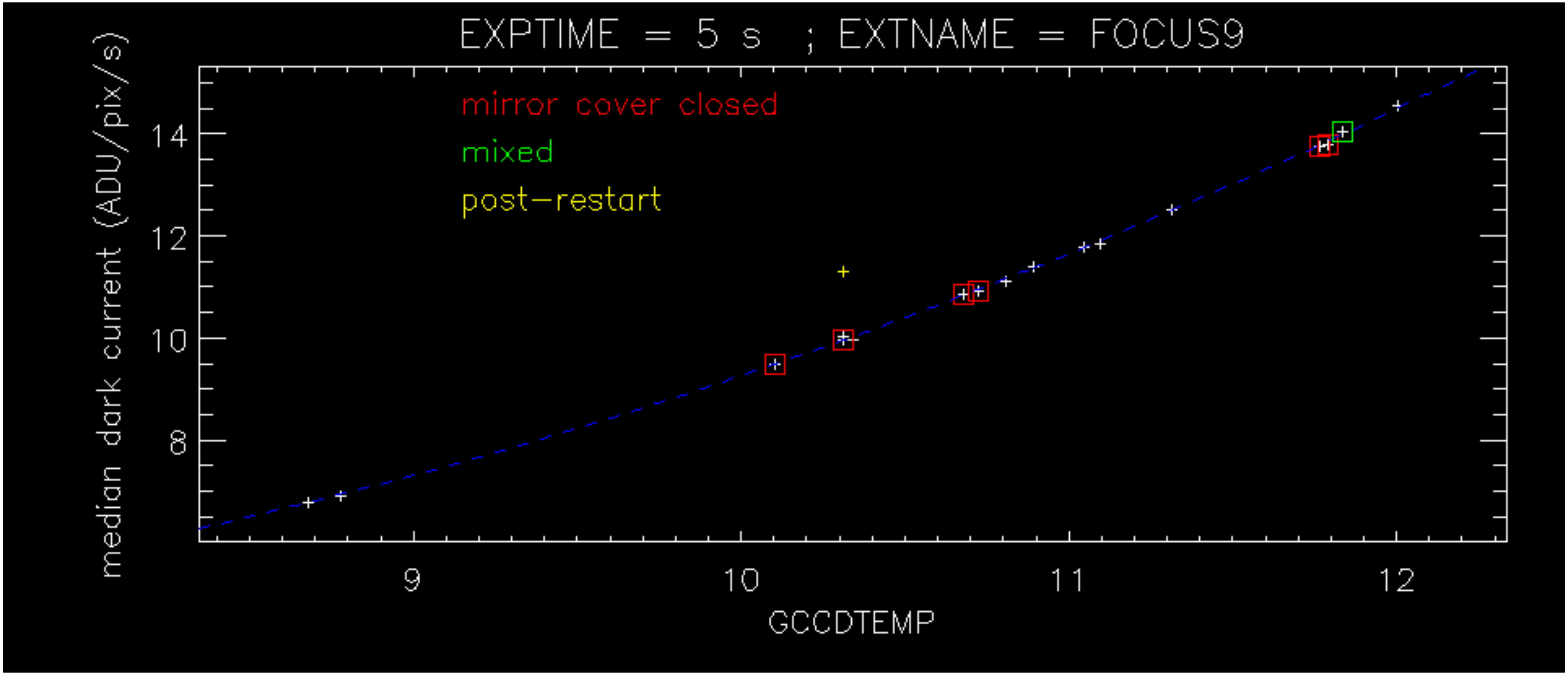
# 20201123 GFA darks



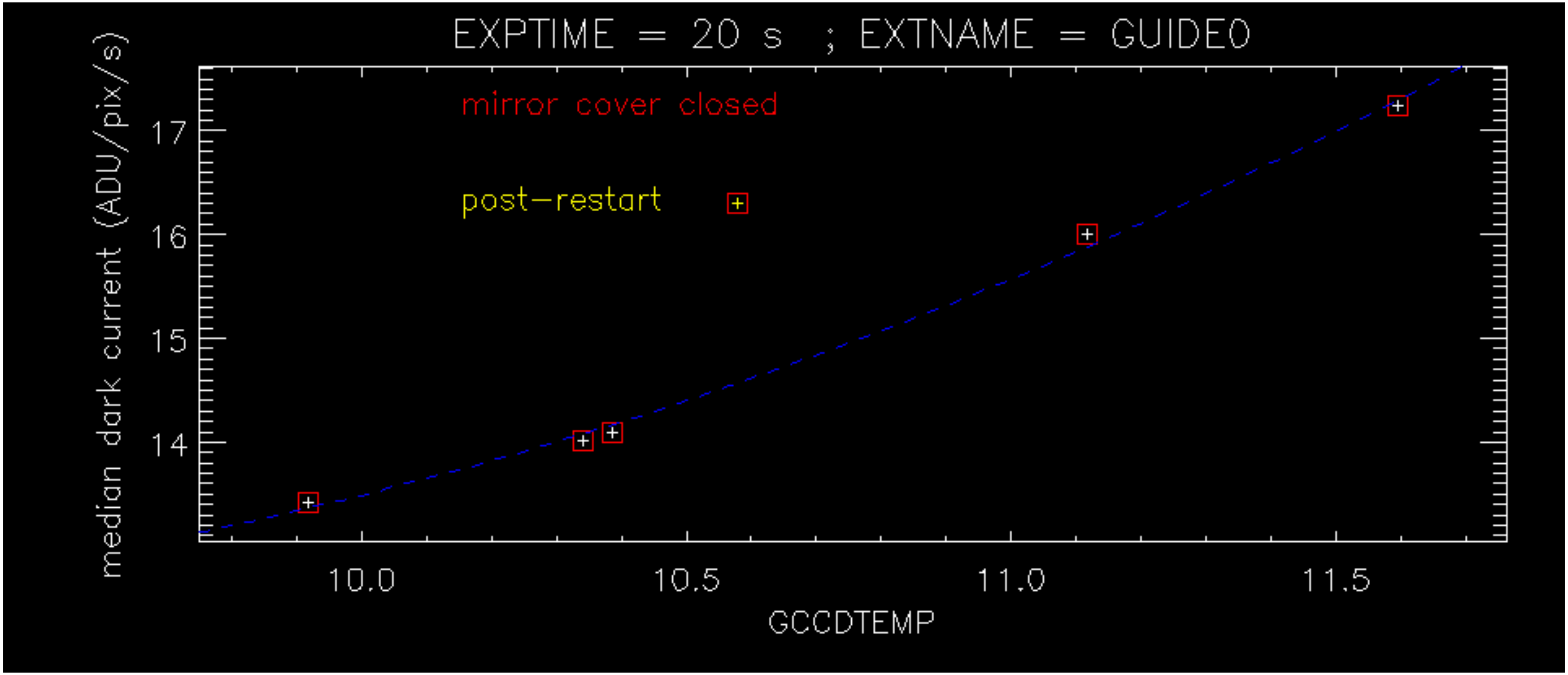
# 20201123 GFA darks



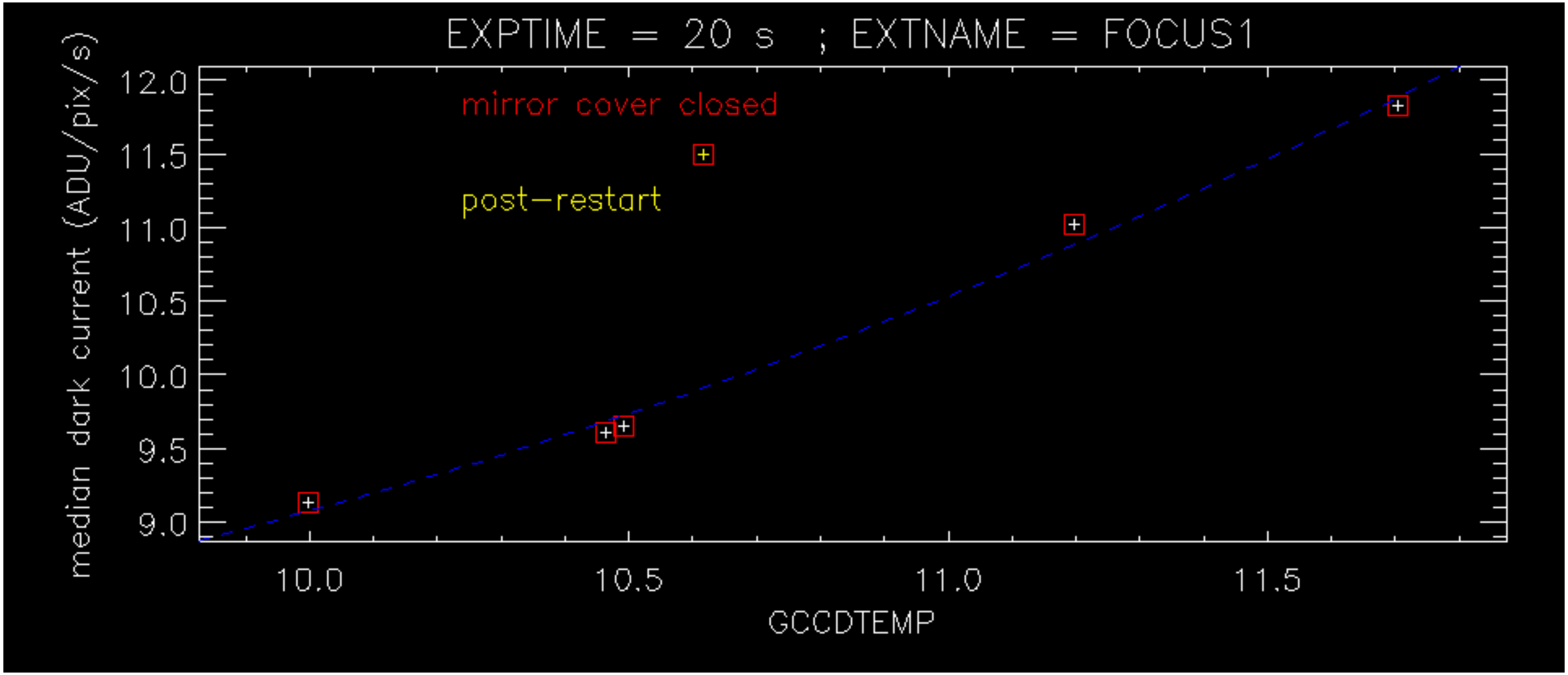
# 20201123 GFA darks



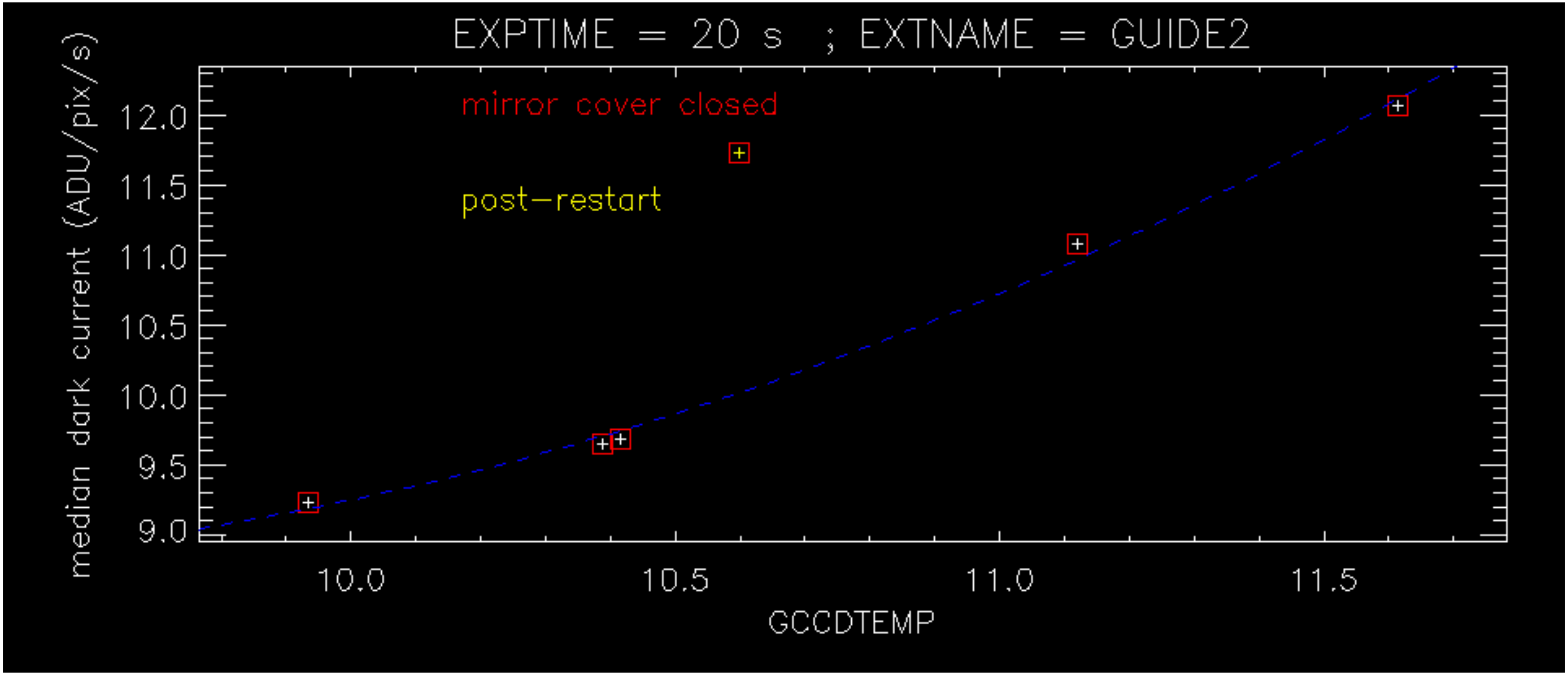
# 20201123 GFA darks



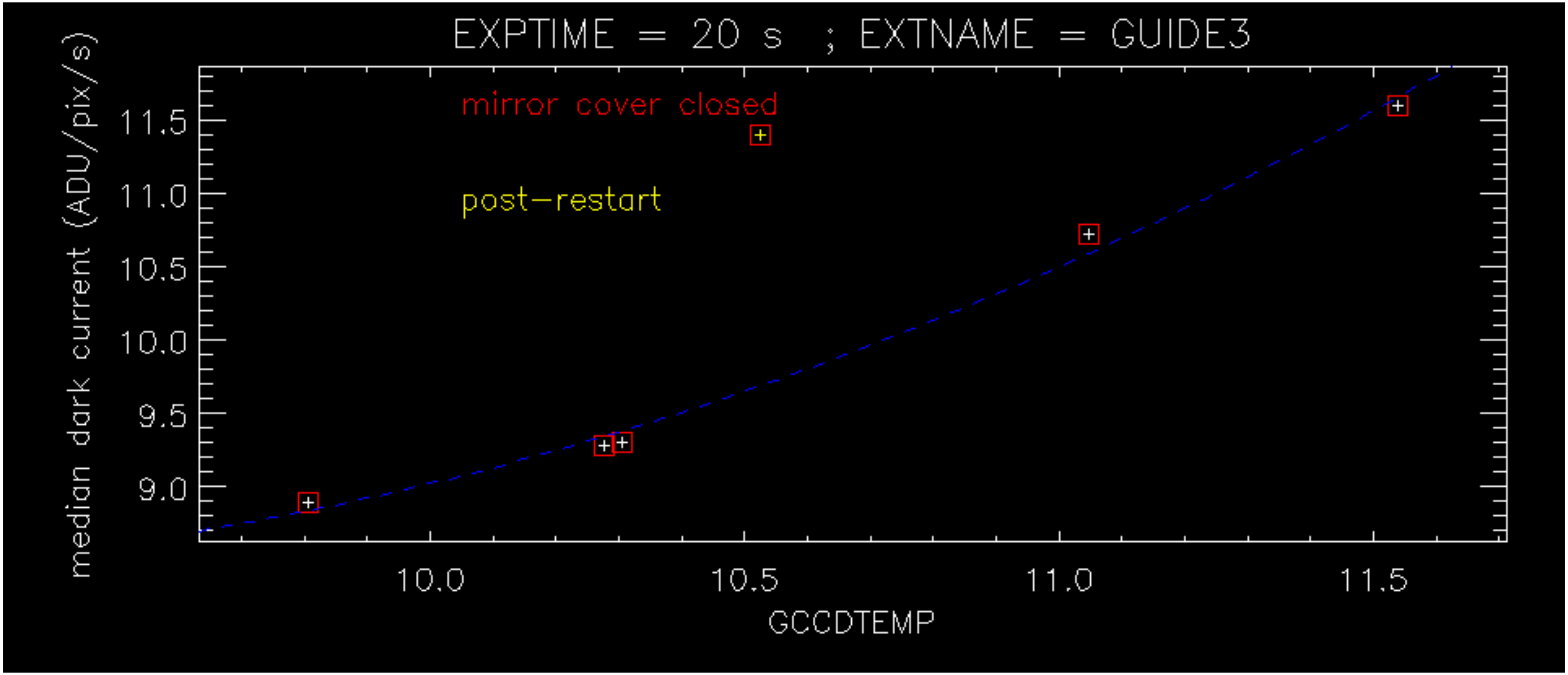
# 20201123 GFA darks



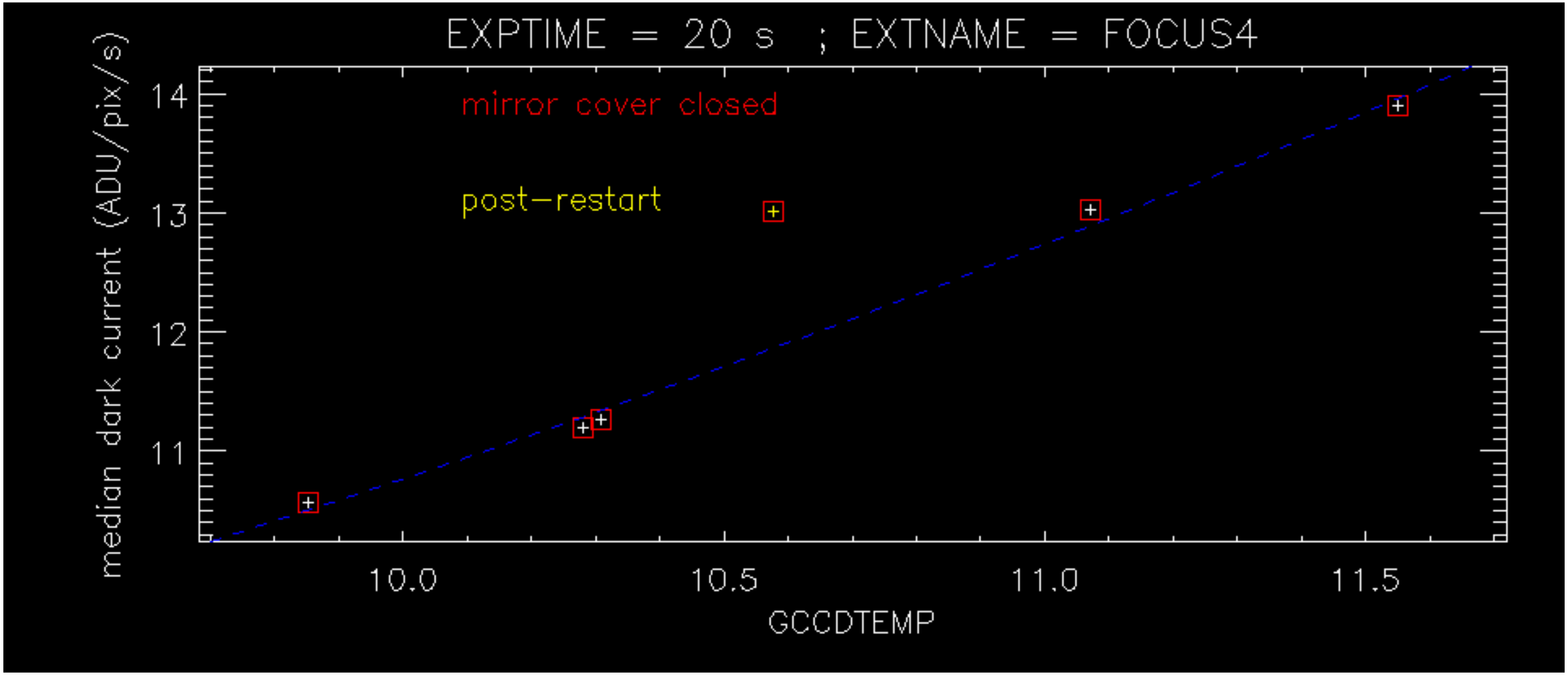
# 20201123 GFA darks



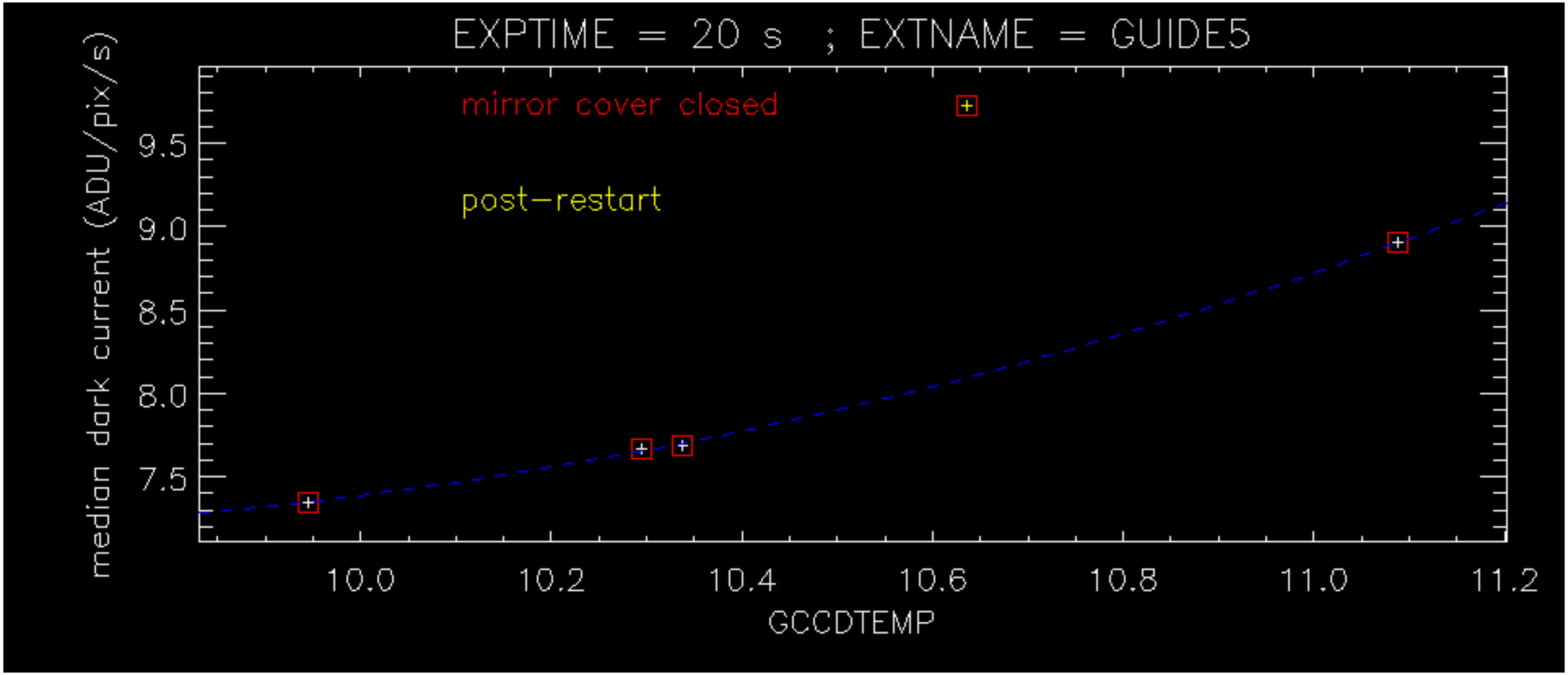
# 20201123 GFA darks



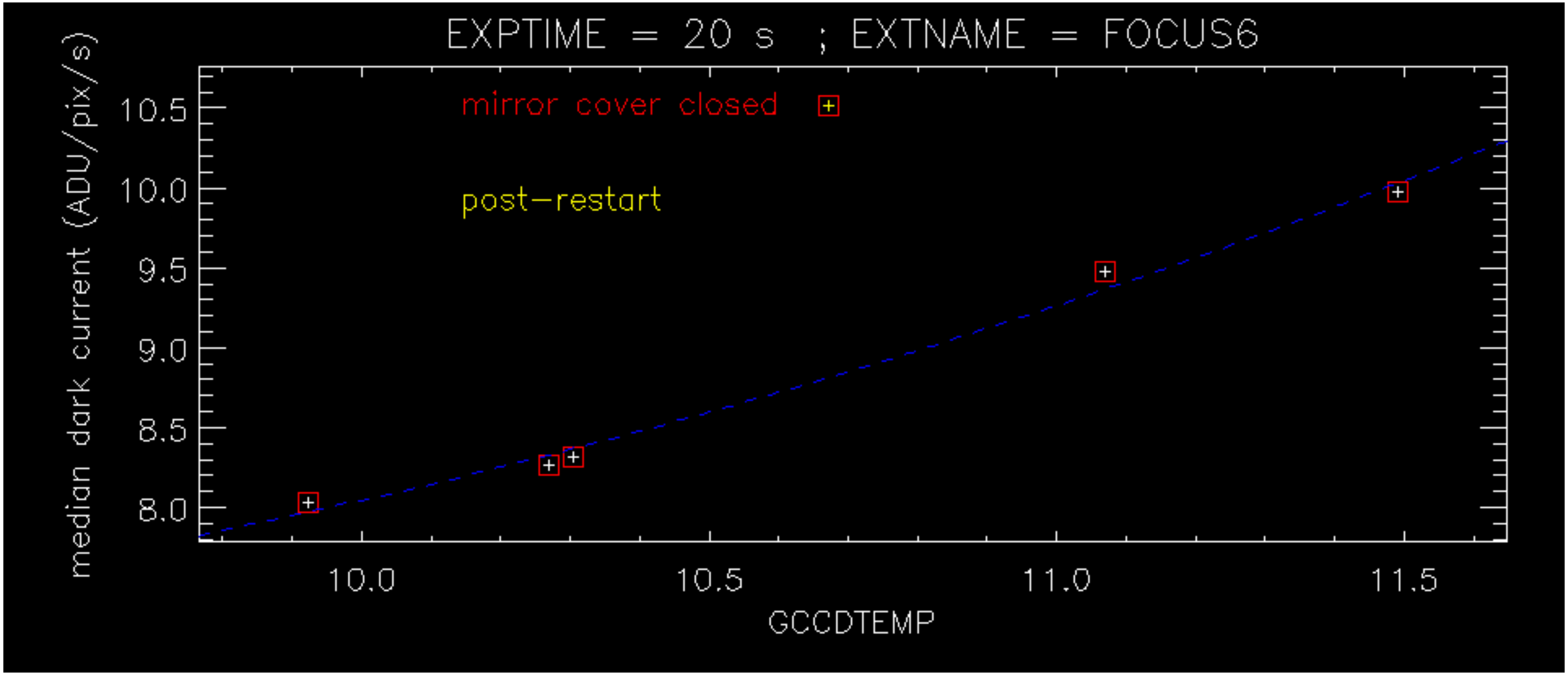
# 20201123 GFA darks



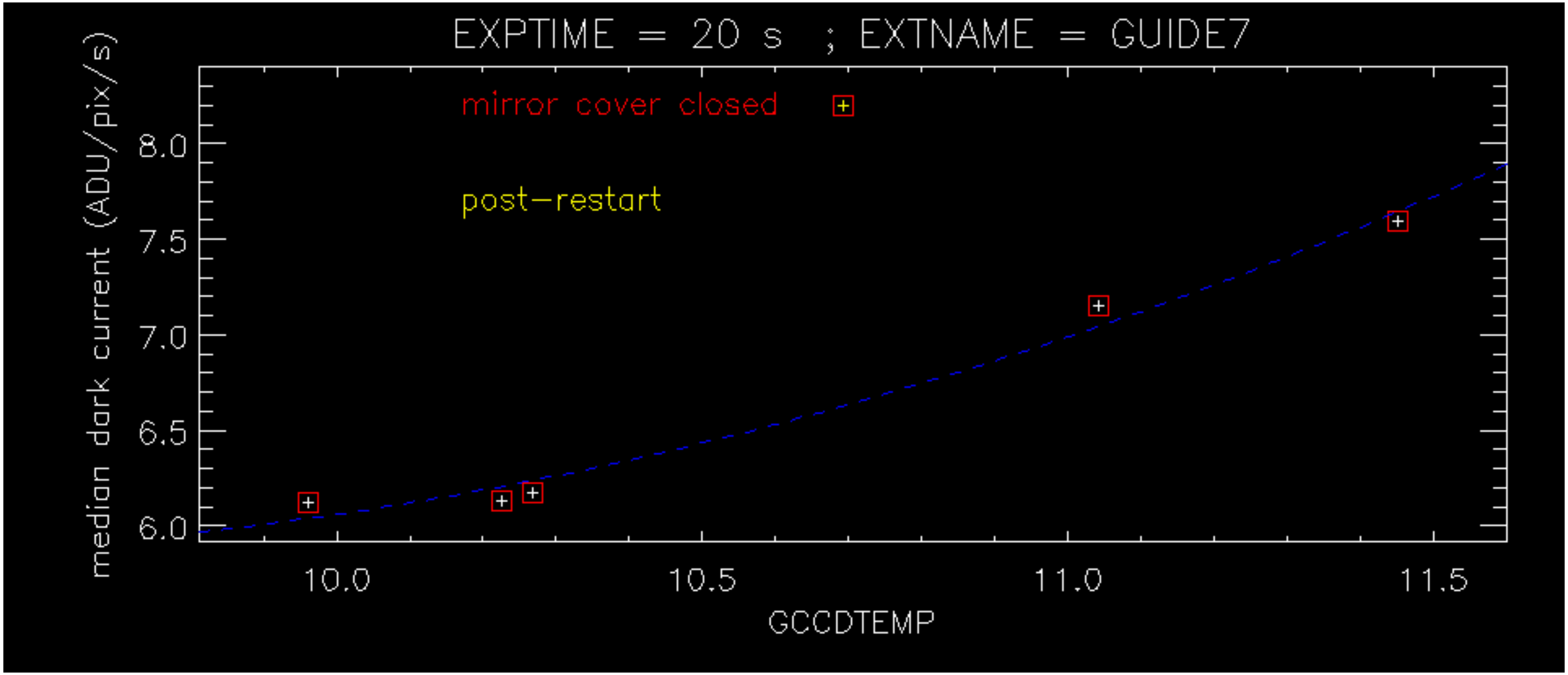
# 20201123 GFA darks



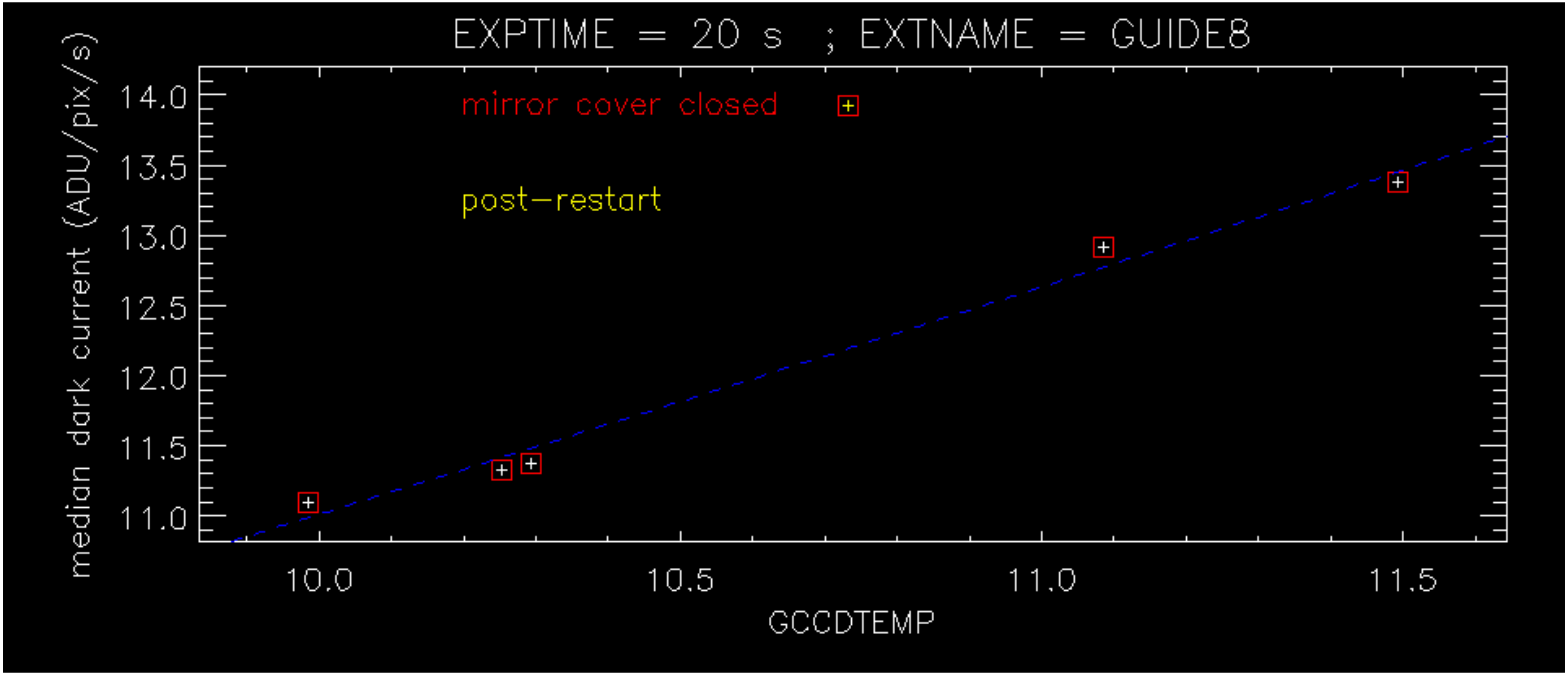
# 20201123 GFA darks



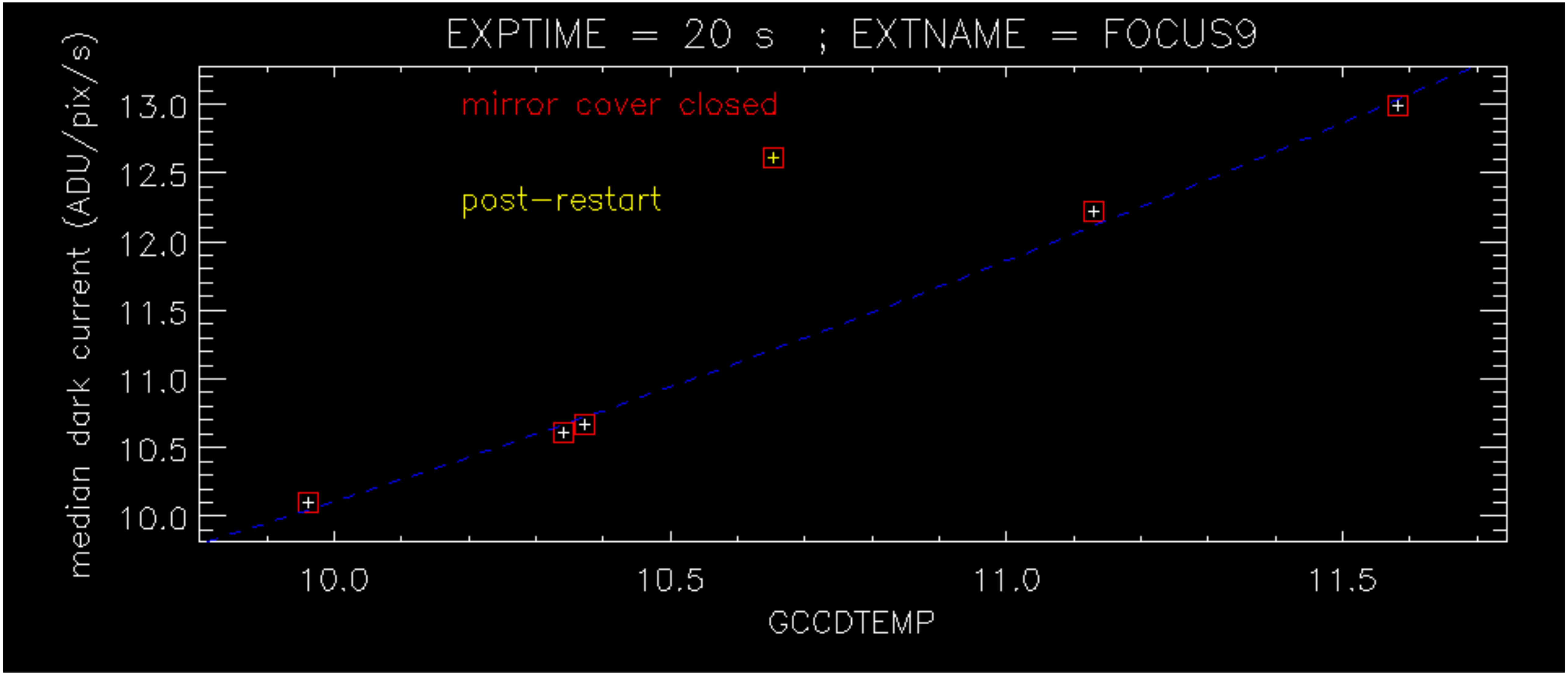
# 20201123 GFA darks



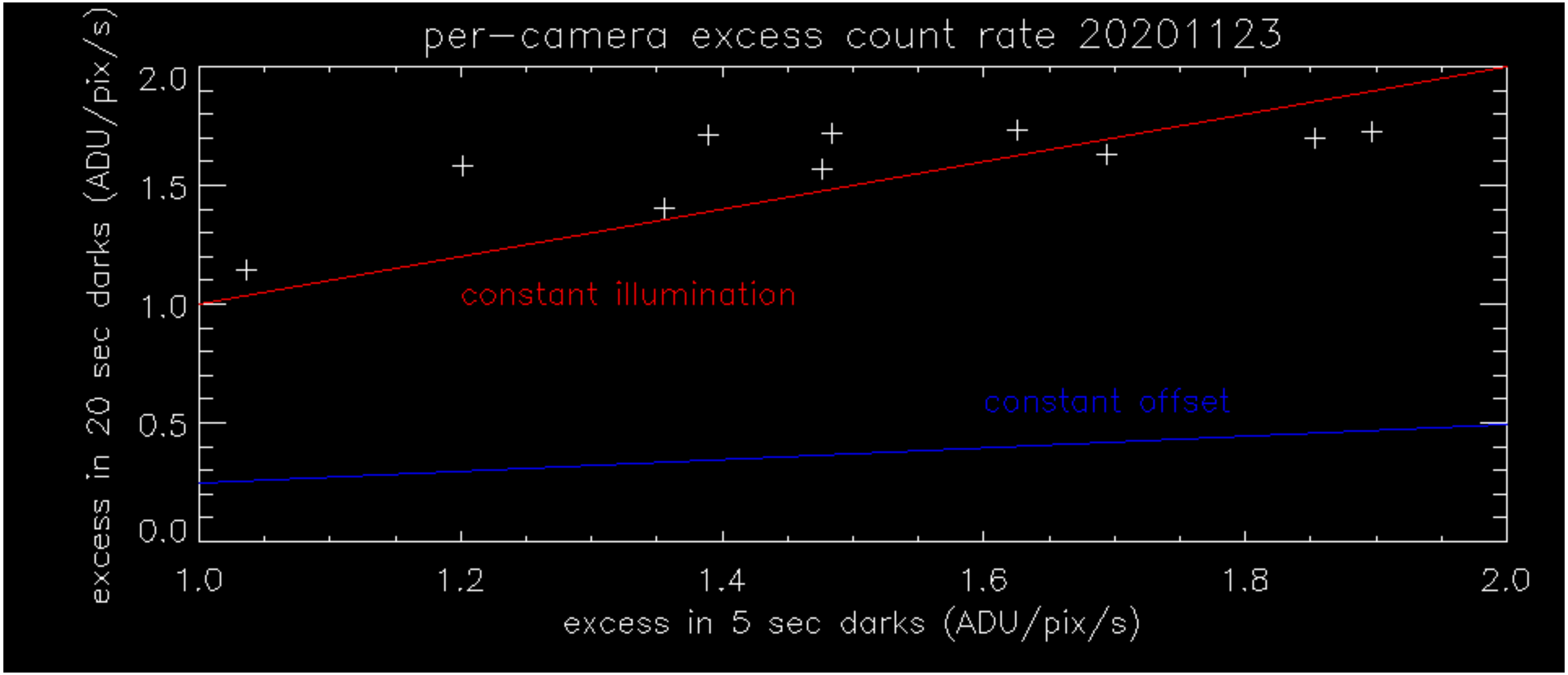
# 20201123 GFA darks



# 20201123 GFA darks



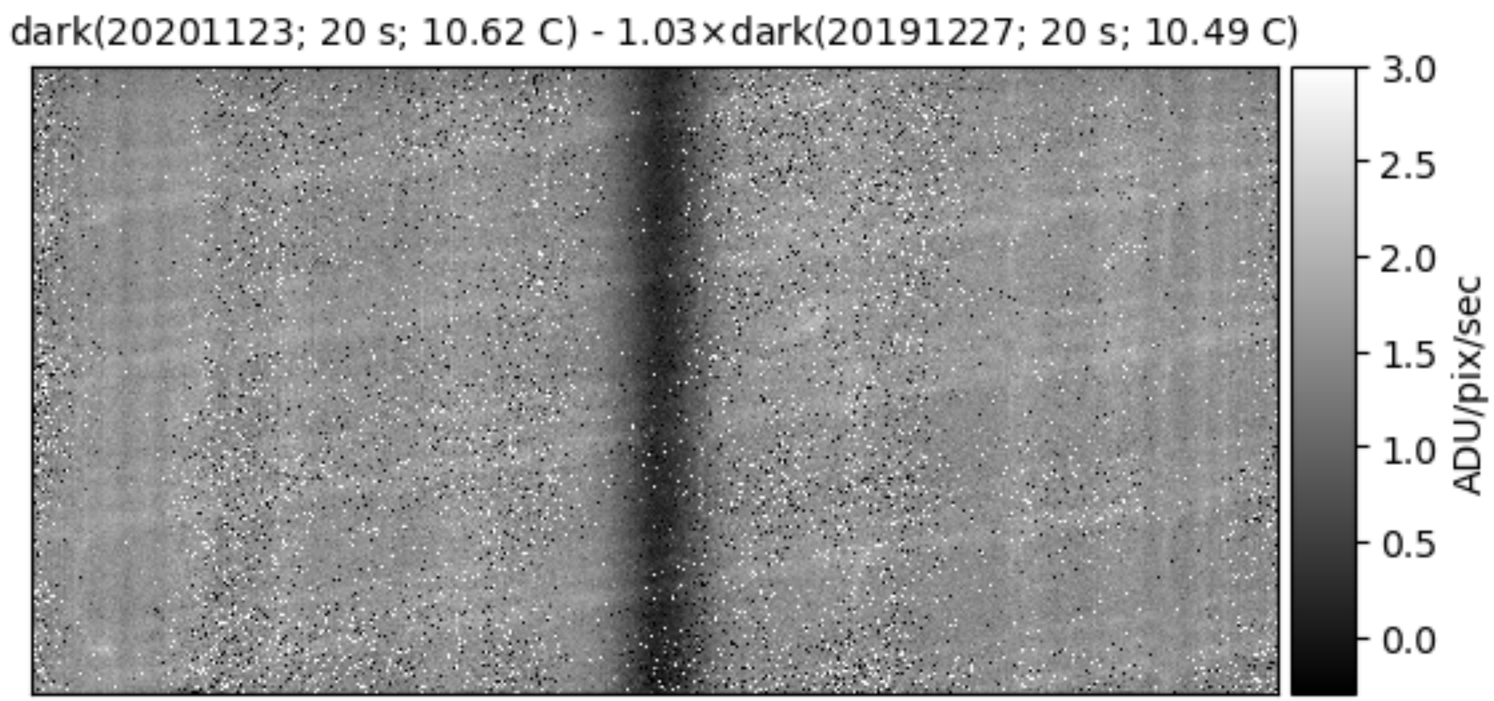
# 20201123 GFA darks




- Comparing the 20 s versus 5 s darks, the 20201123 excess in dark count rate is more consistent with constant illumination than a constant offset due to e.g., imperfect bias subtraction

# 20201123 light contamination

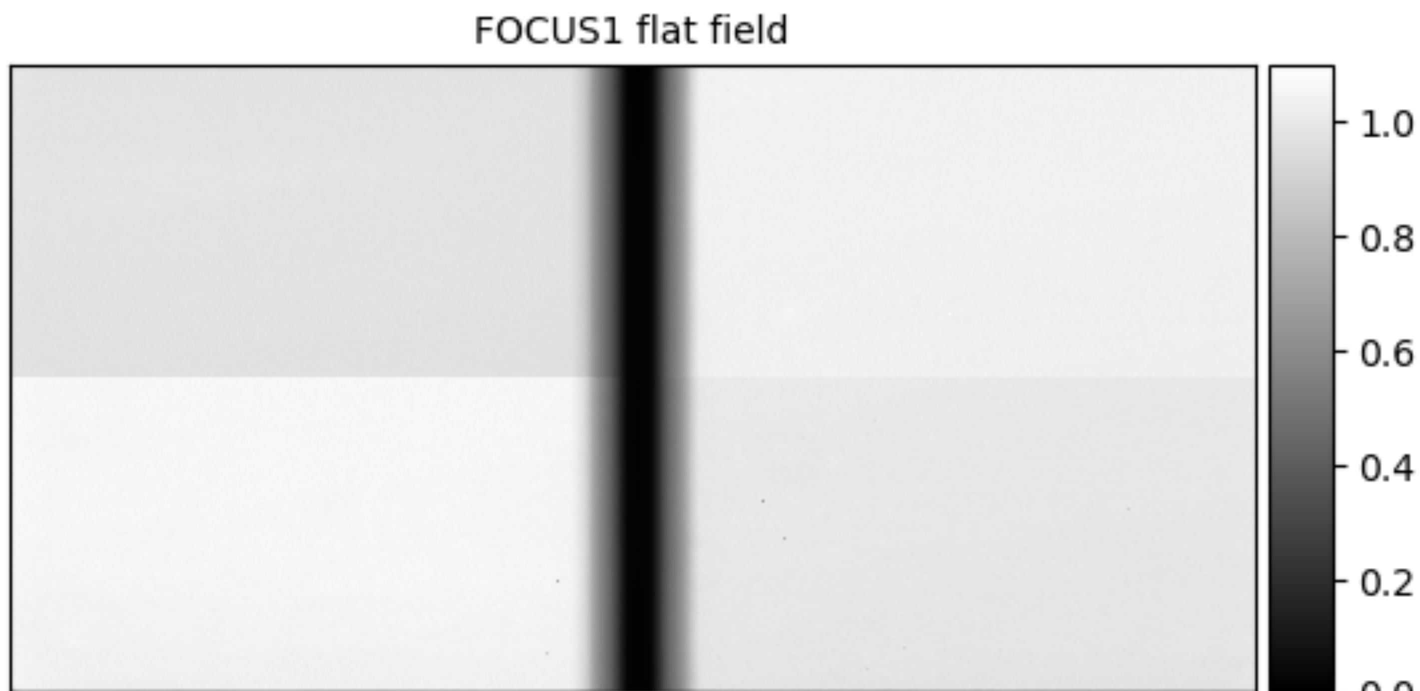
**FOCUS1**




- The excess in the 20201123 ‘darks’ looks like the flat field

# 20201123 light contamination

**FOCUS1**

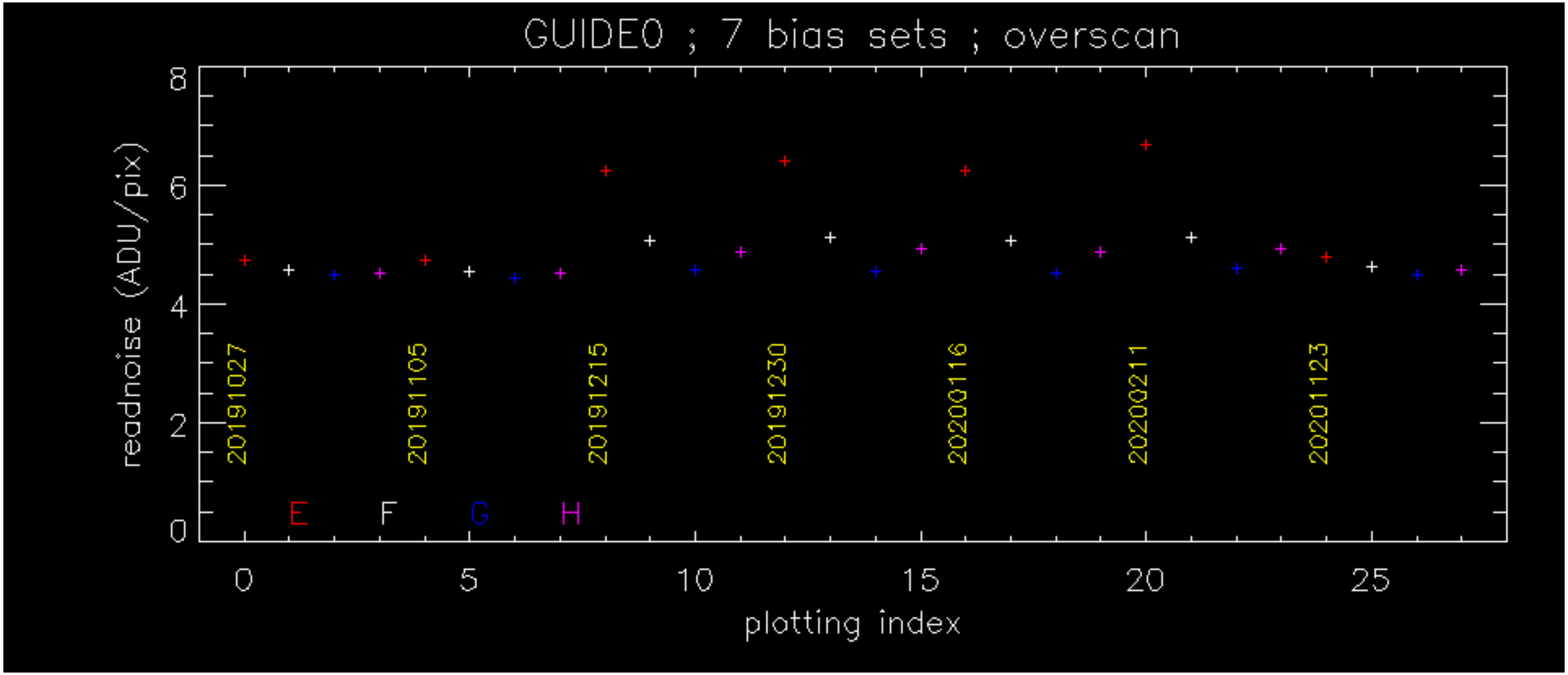



- The excess in the 20201123 ‘darks’ looks like the flat field

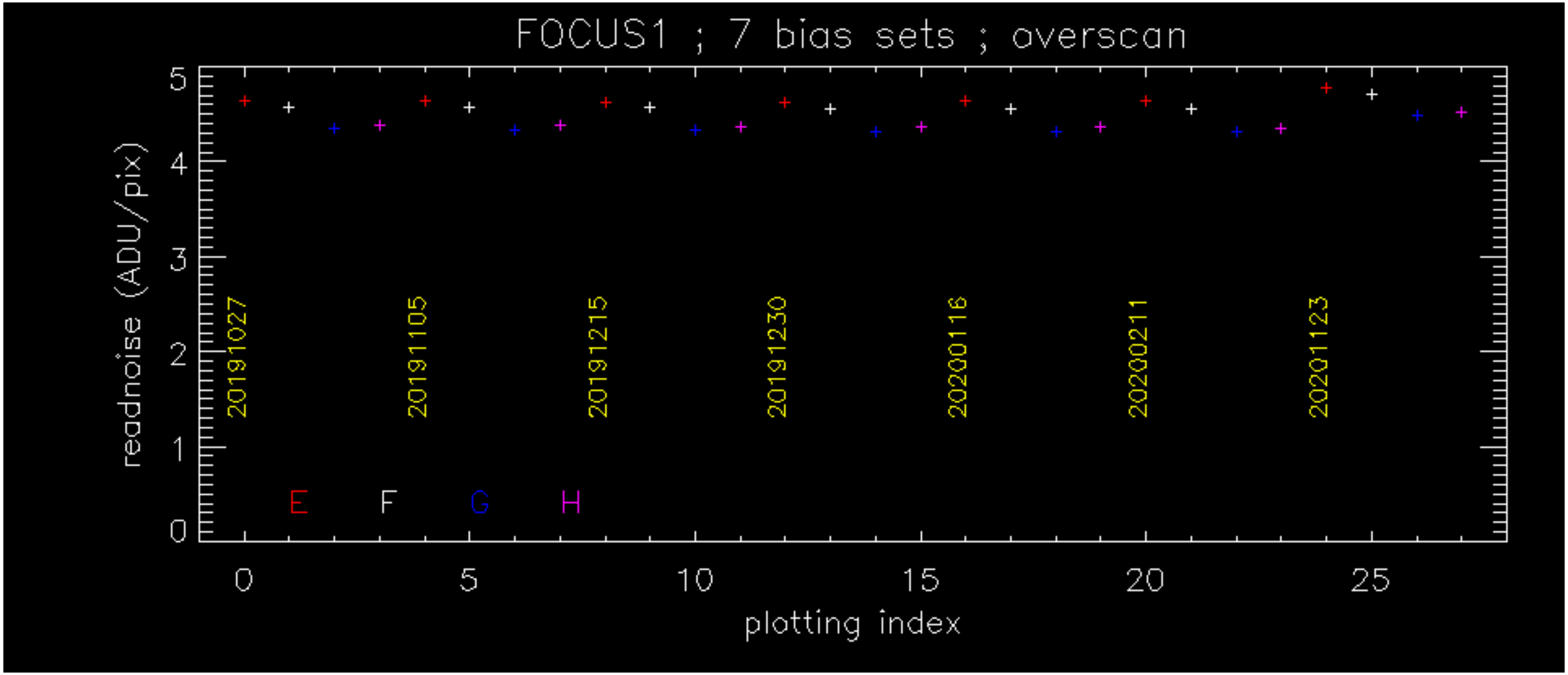
# readnoise

- Measure readnoise with pairwise differences from 50 GFA zeros taken with the dome (almost entirely) dark on 20201123
    - EXPID = 63914-63963, PROGRAM = ‘Zeros with dome dark’
- As with pre-restart GFA readnoise measurements, the readnoise values are affected by electronic pattern noise that shifts around from one zero to the next
    - My interpretation is therefore that most variation of the measured GFA readnoise values shown in the following slides is not actual variation of the readnoise, but rather variation in the amplitude/behavior of electronic pattern noise from one night to another.
- As shown by the following plots, the measured readnoise values from 20201123 are within the range seen in 6 pre-restart sets of GFA biases taken at KPNO between 2019 October and 2020 February

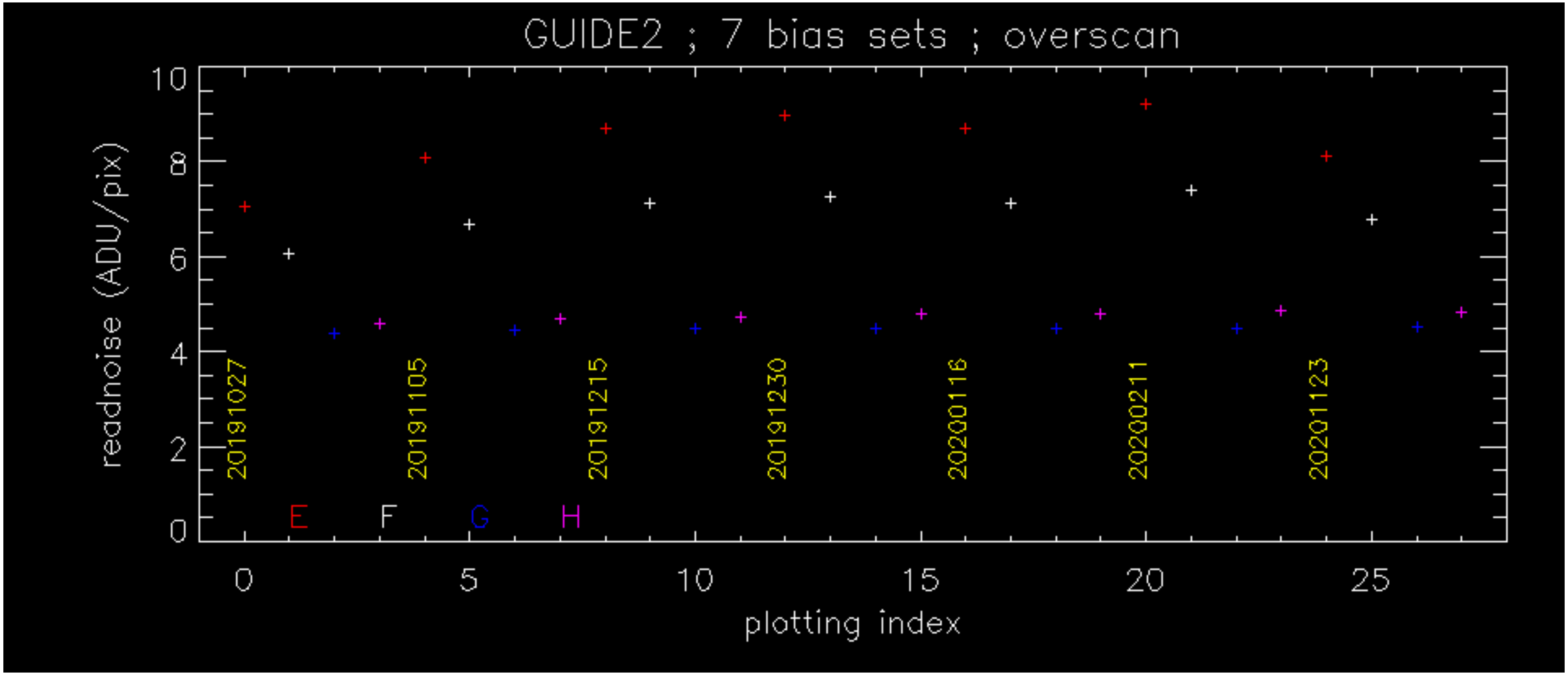
# readnoise per amp; overscan



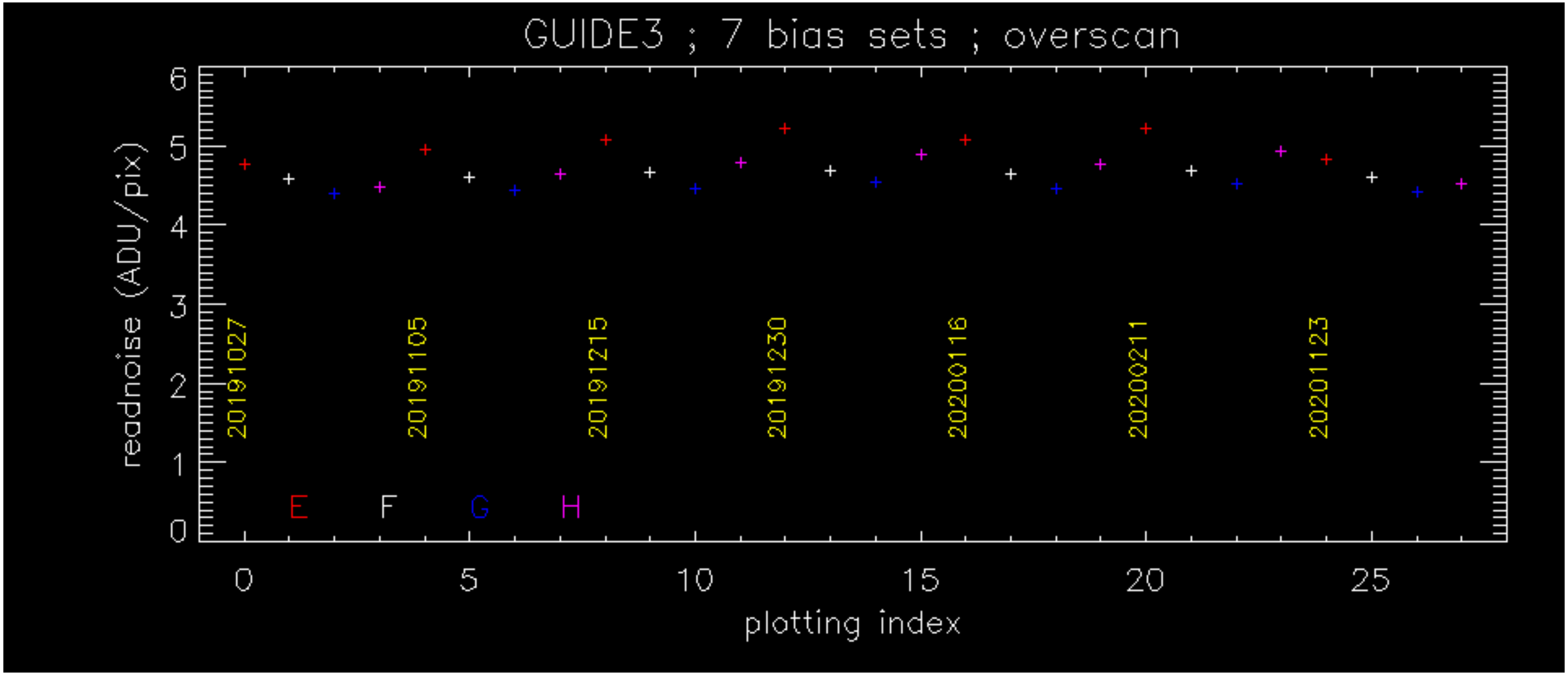
# readnoise per amp; overscan



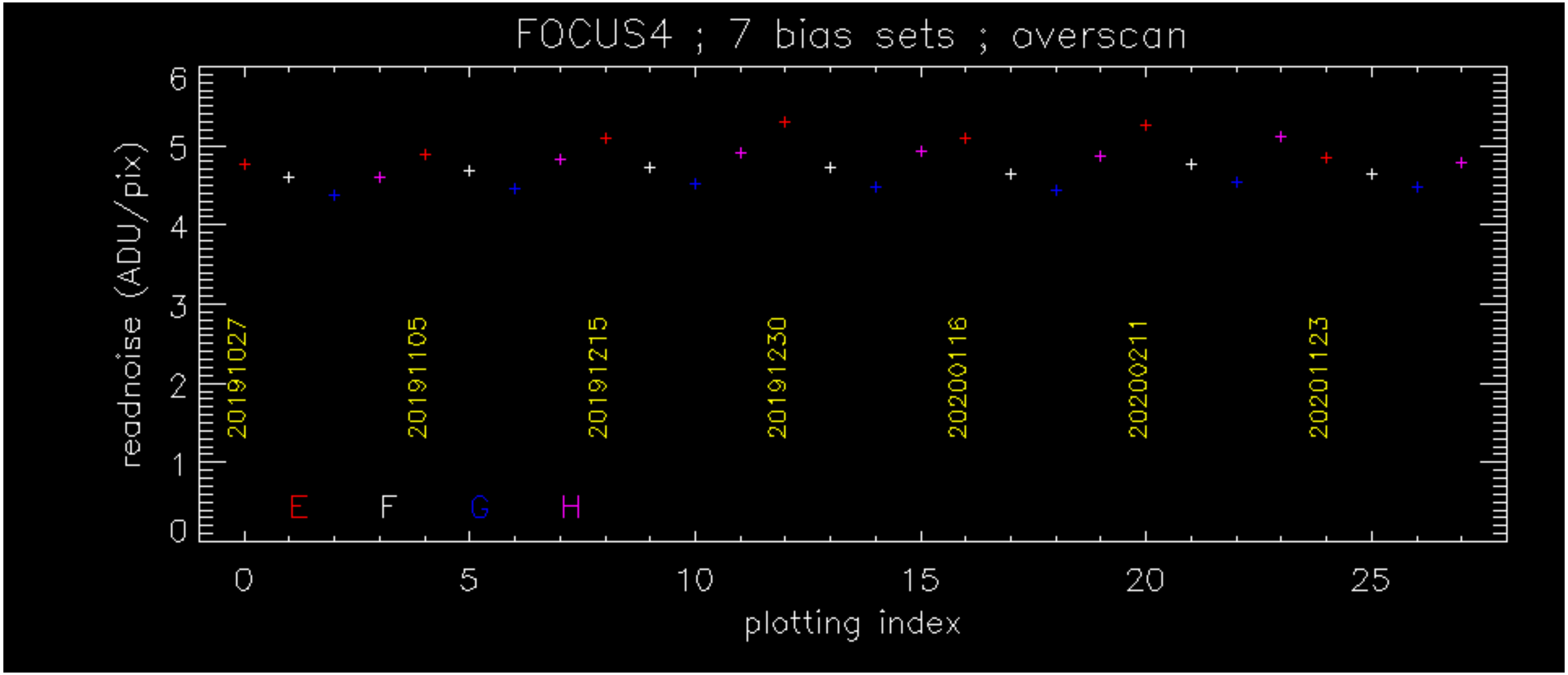
# readnoise per amp; overscan



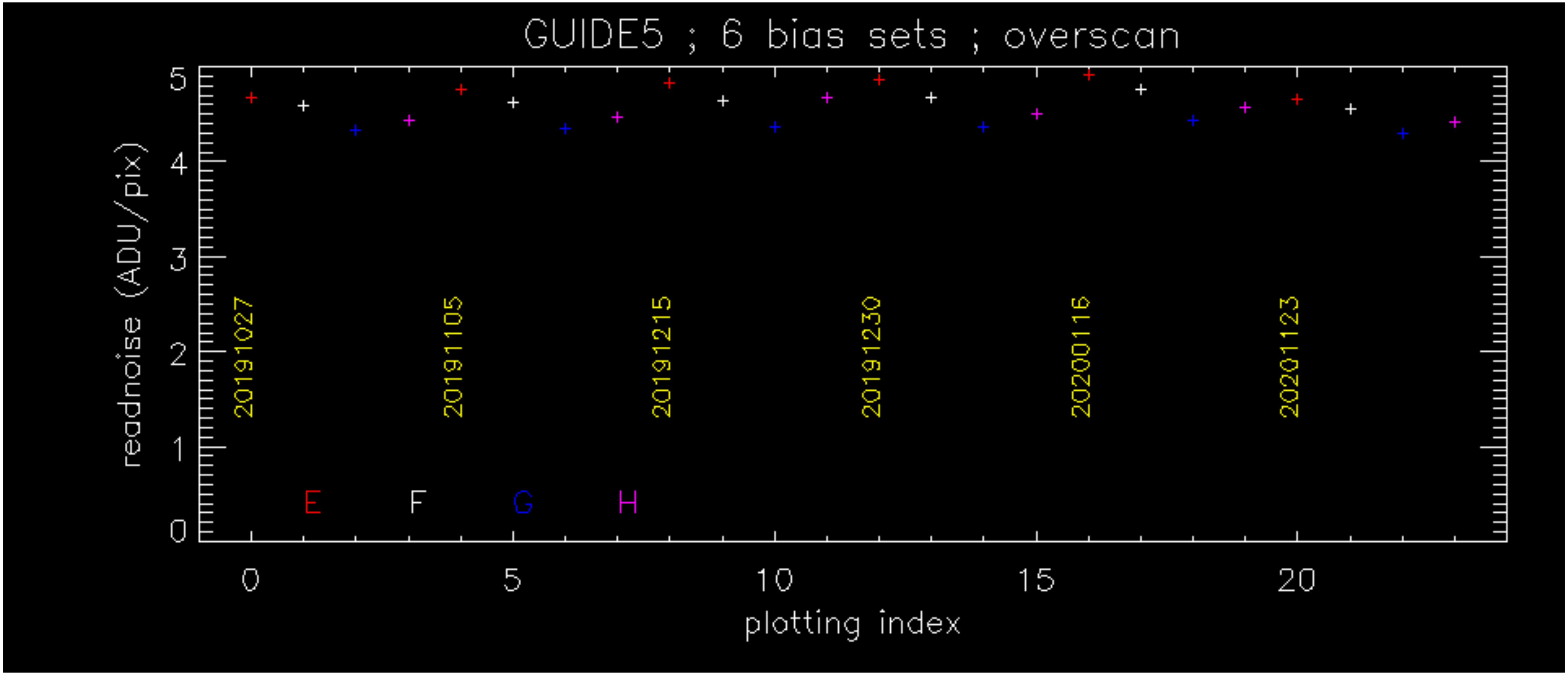
# readnoise per amp; overscan



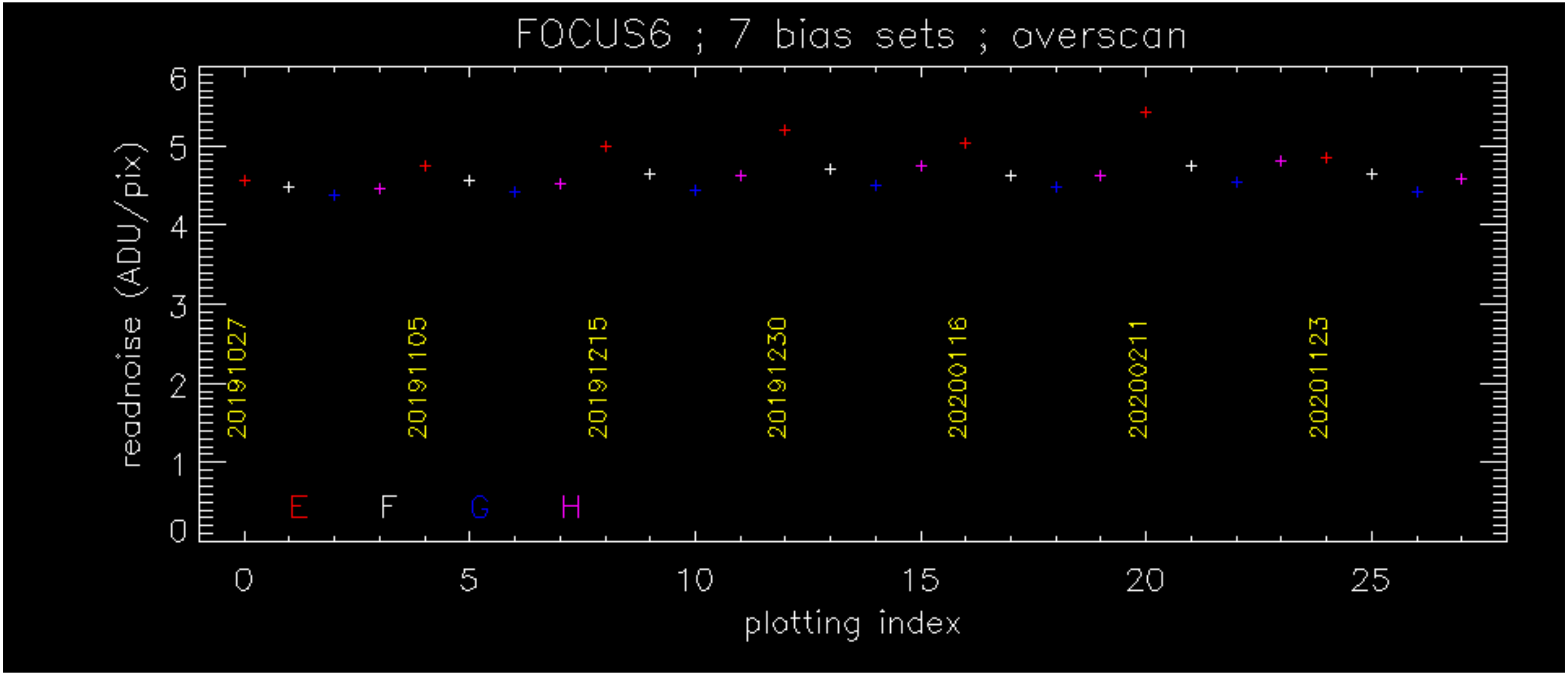
# readnoise per amp; overscan



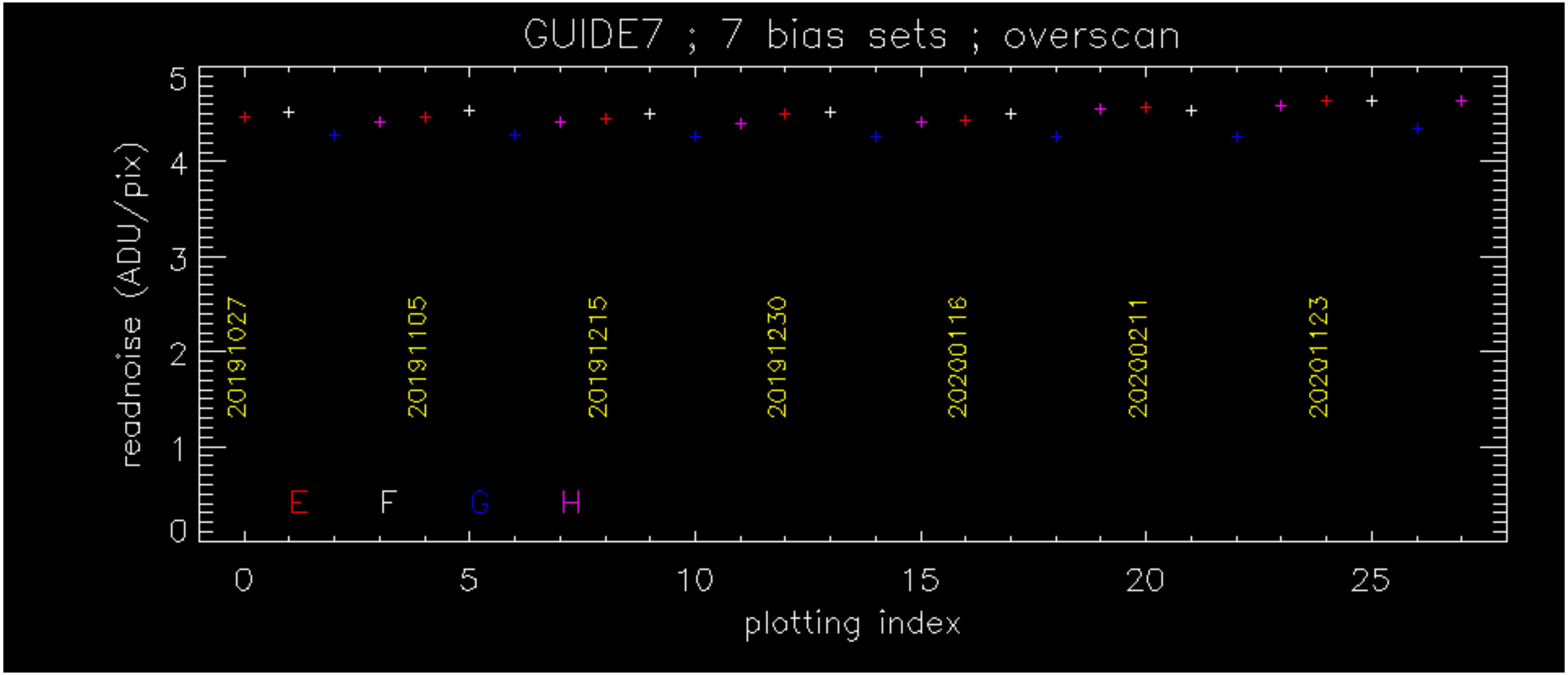
# readnoise per amp; overscan



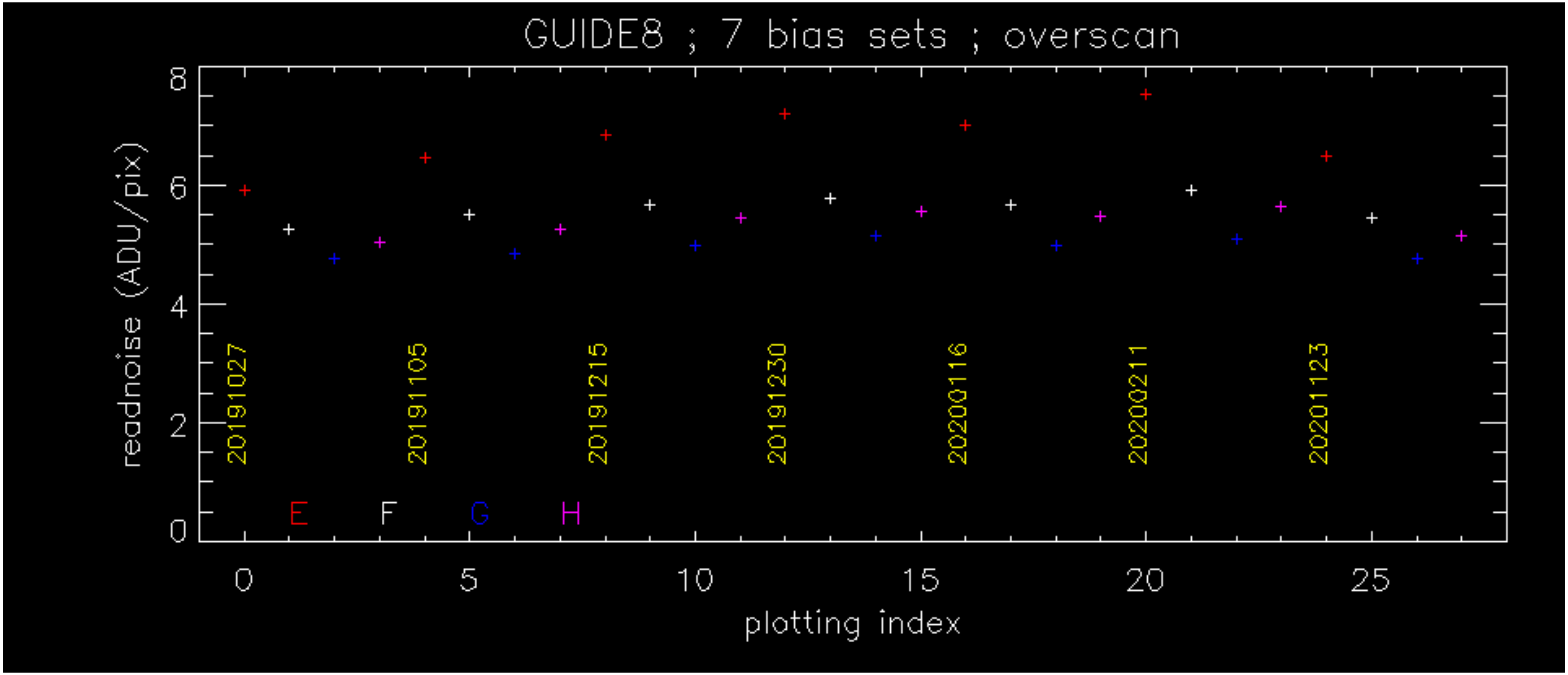
# readnoise per amp; overscan



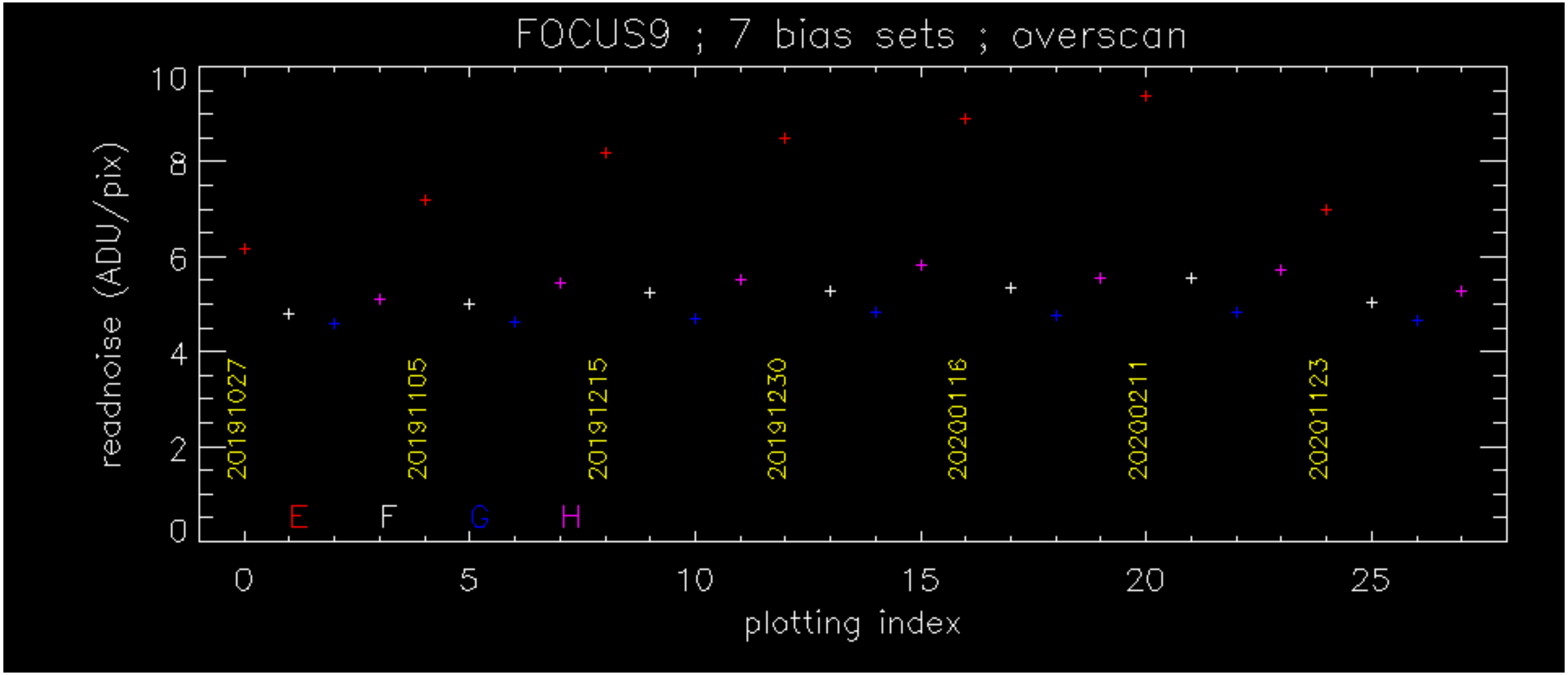
# readnoise per amp; overscan



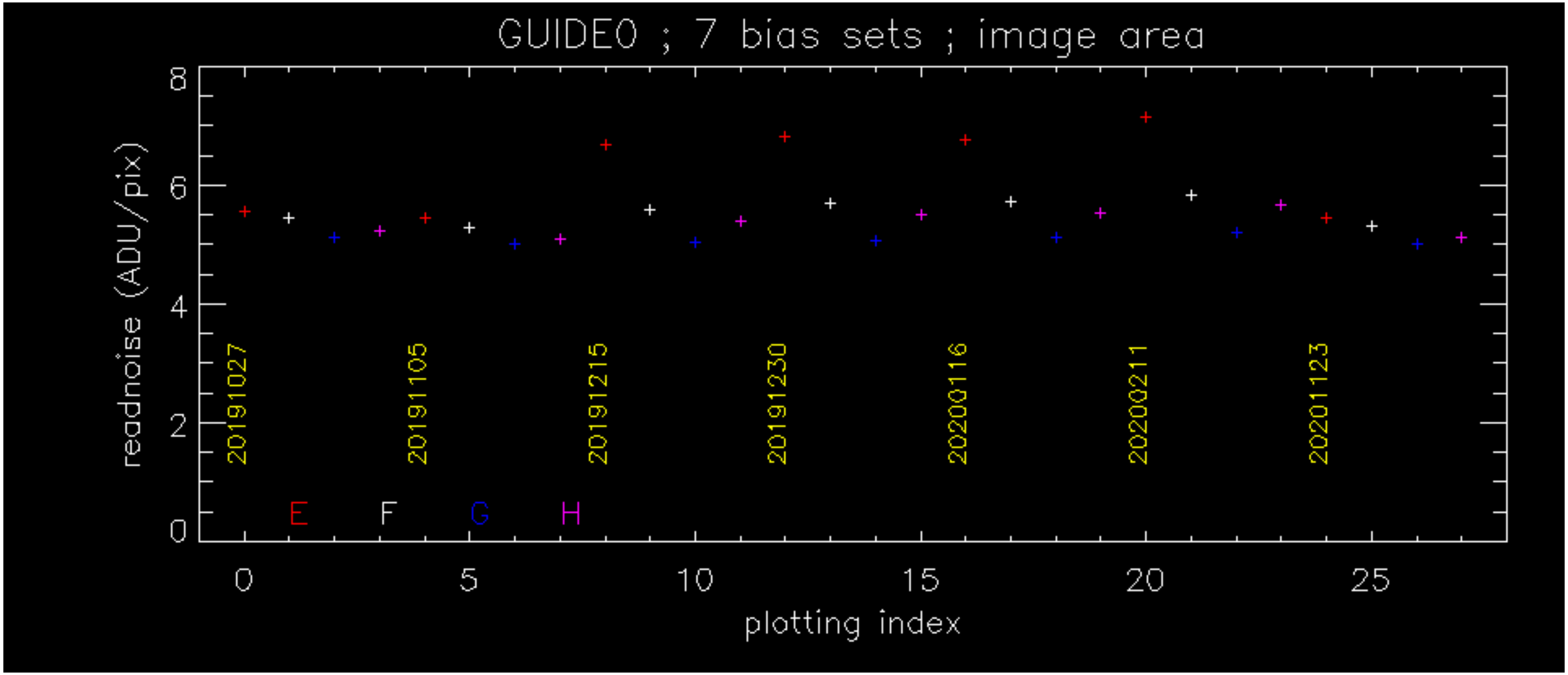
# readnoise per amp; overscan



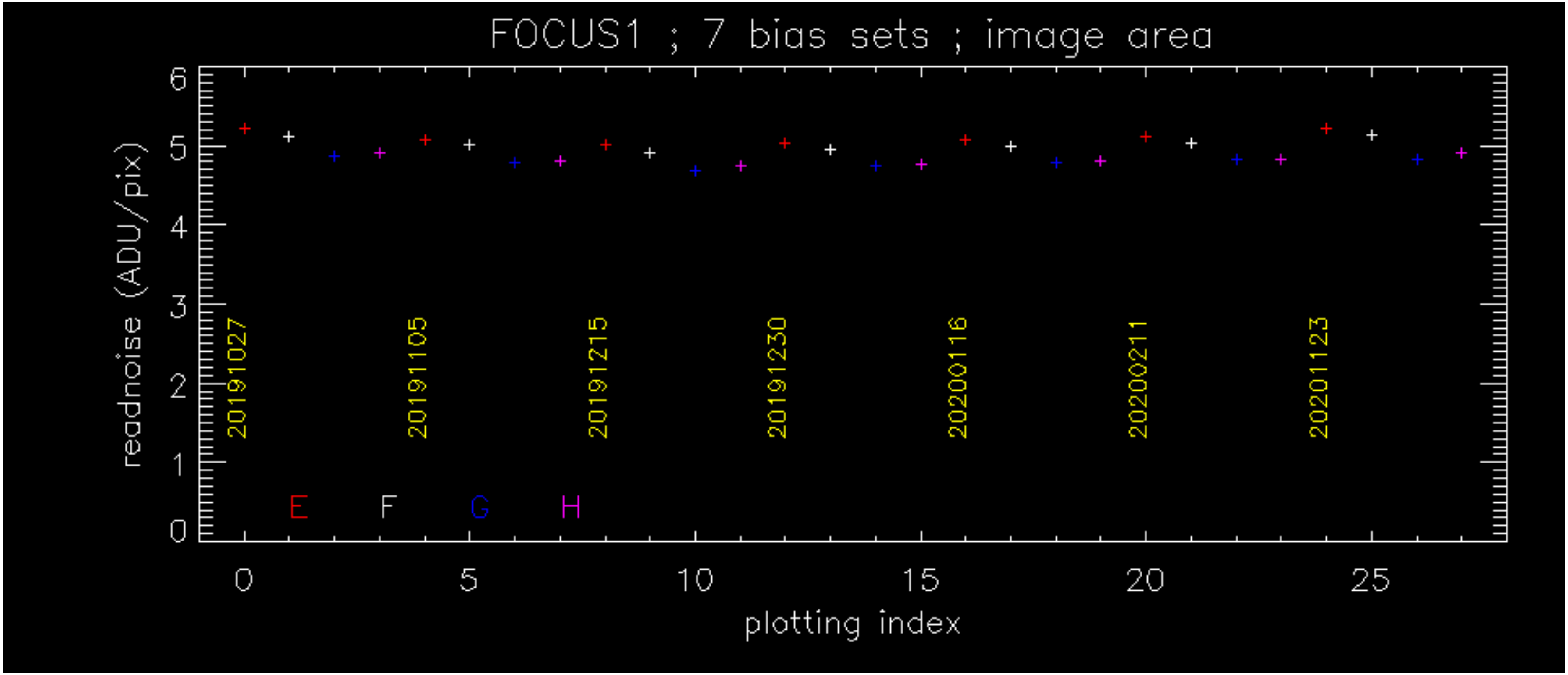
# readnoise per amp; overscan



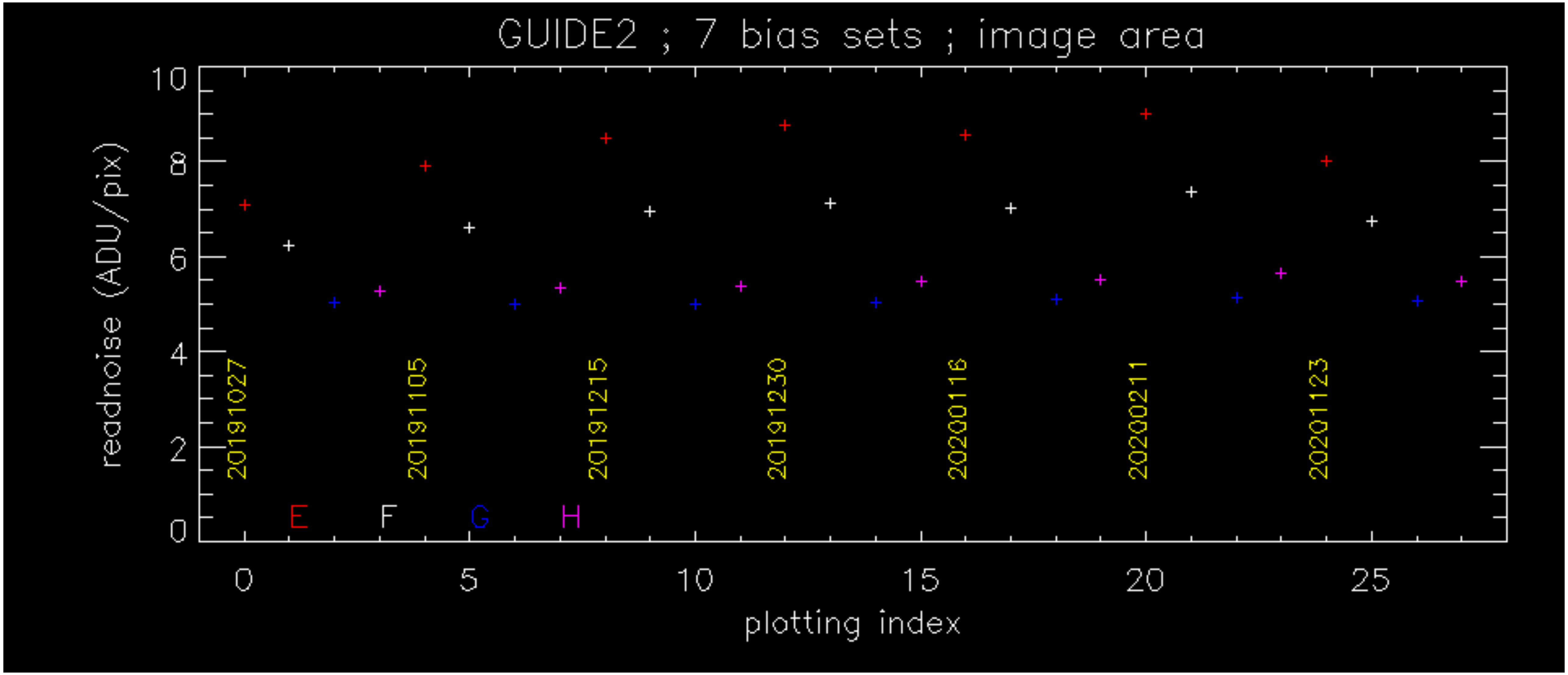
# readnoise per amp; image area



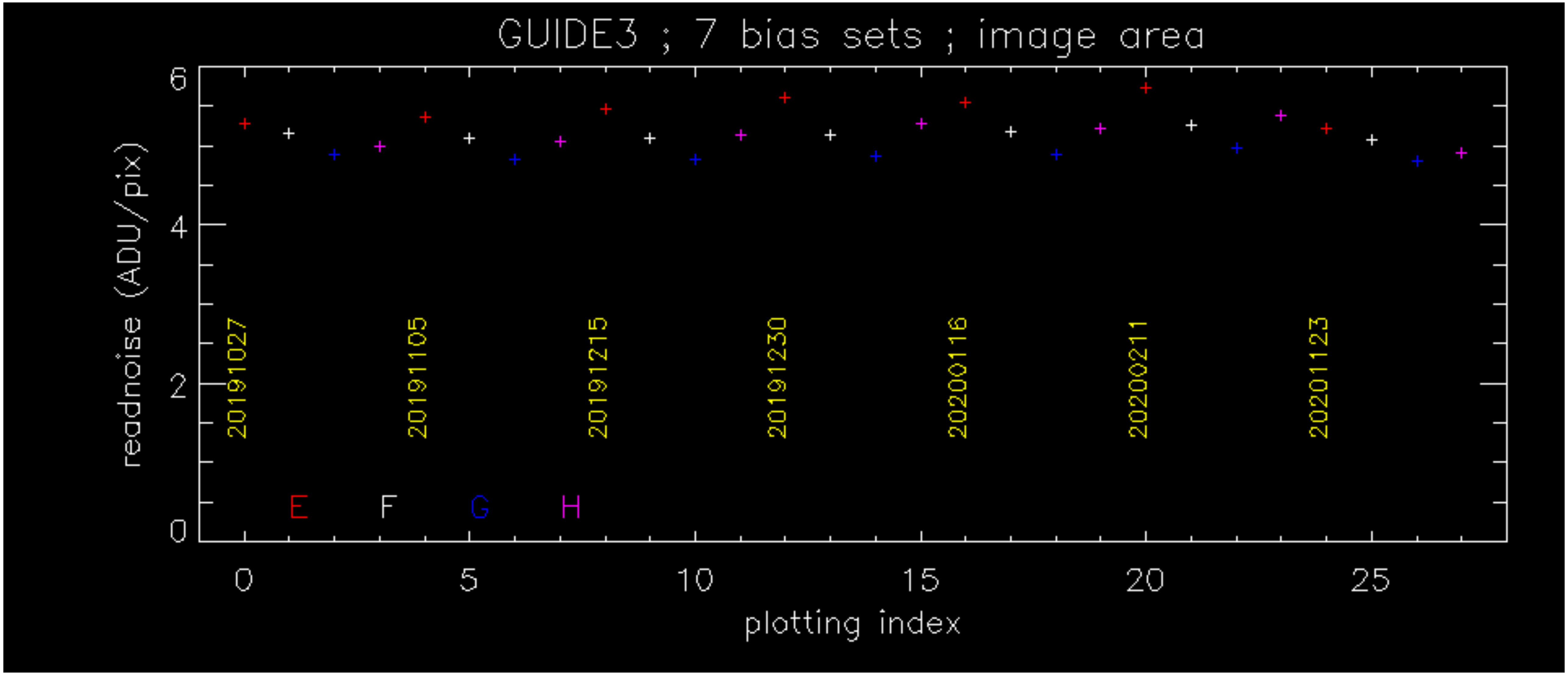
# readnoise per amp; image area



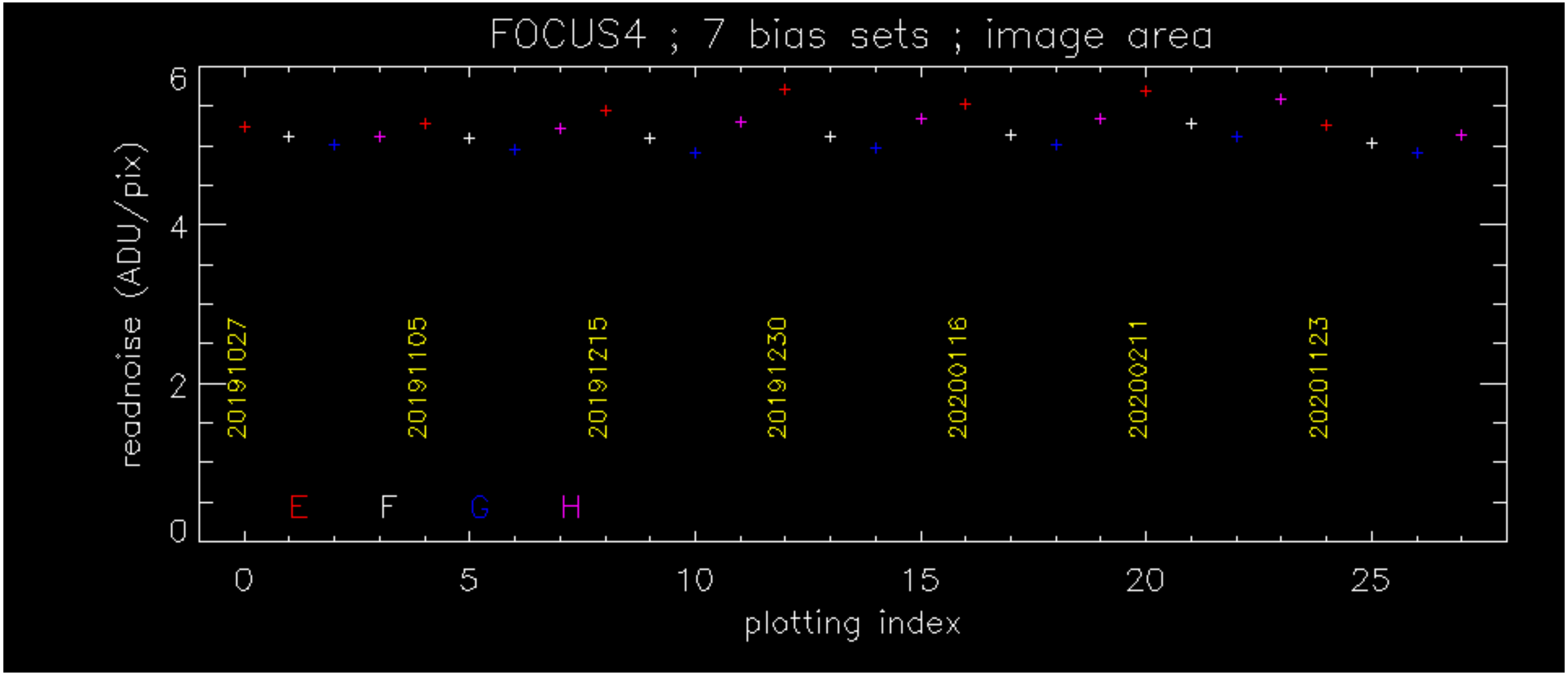
# readnoise per amp; image area



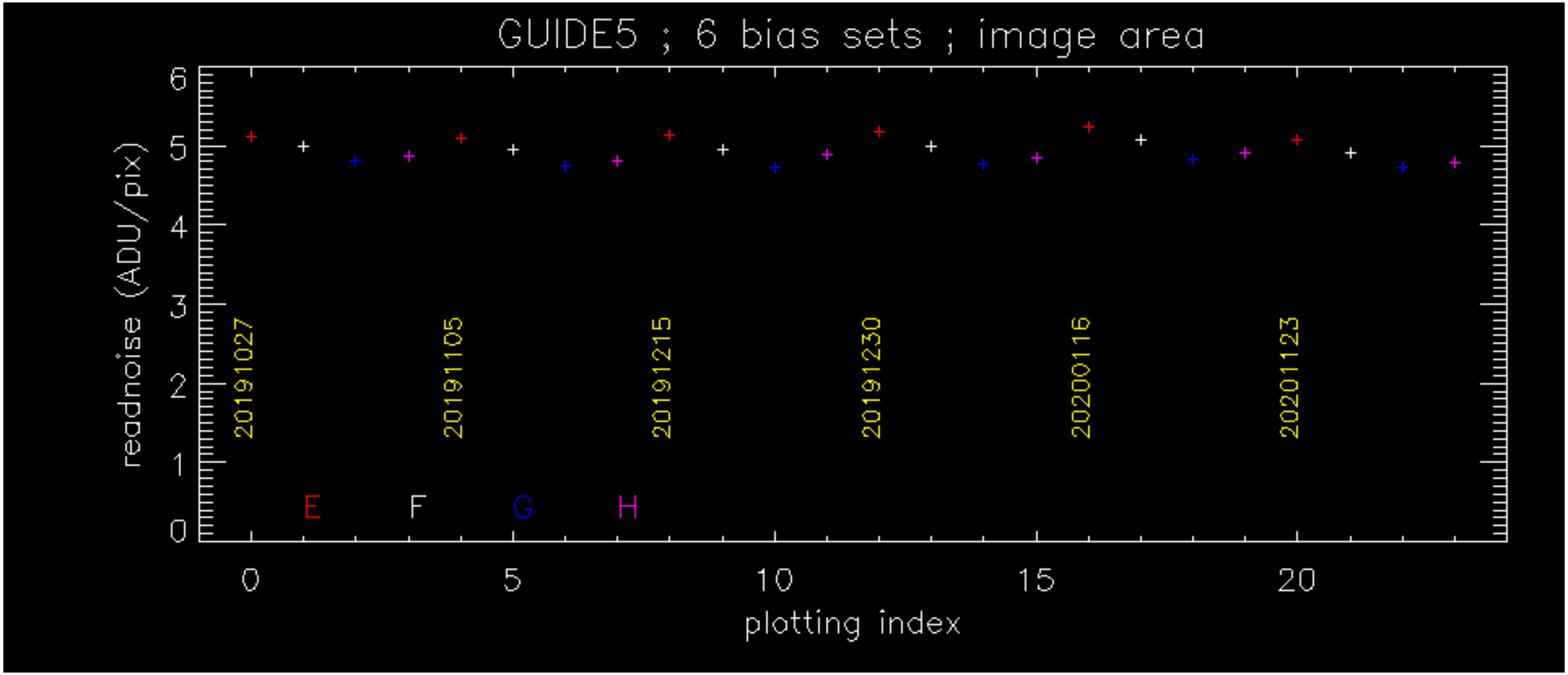
# readnoise per amp; image area



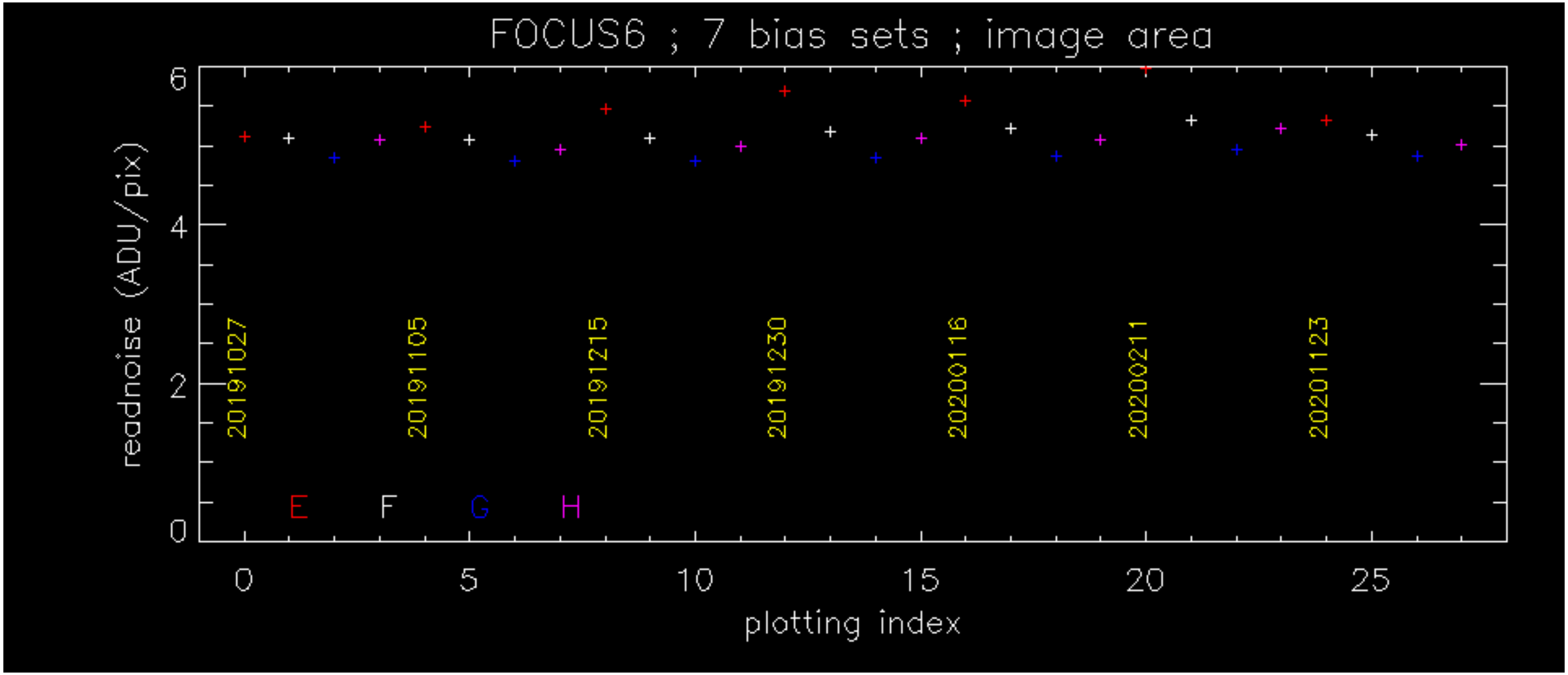
# readnoise per amp; image area



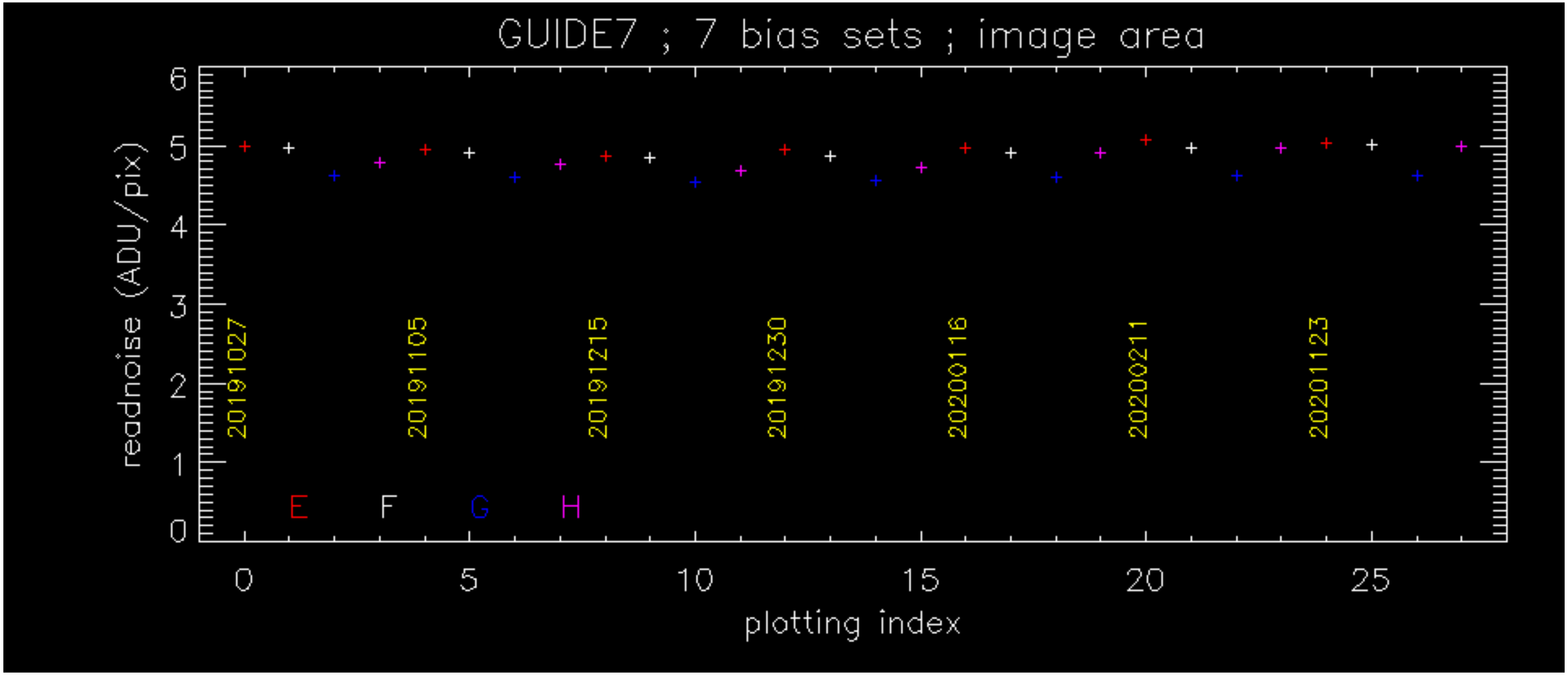
# readnoise per amp; image area



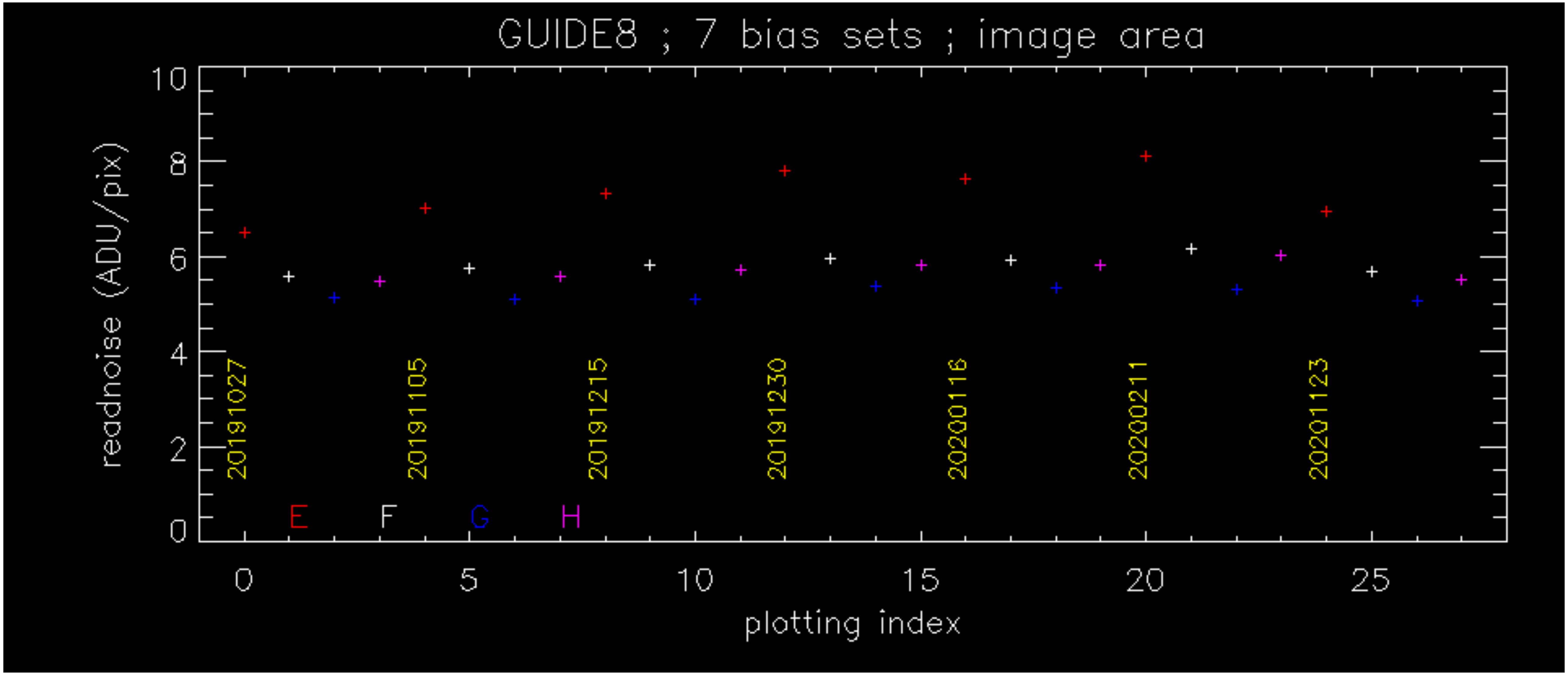
# readnoise per amp; image area



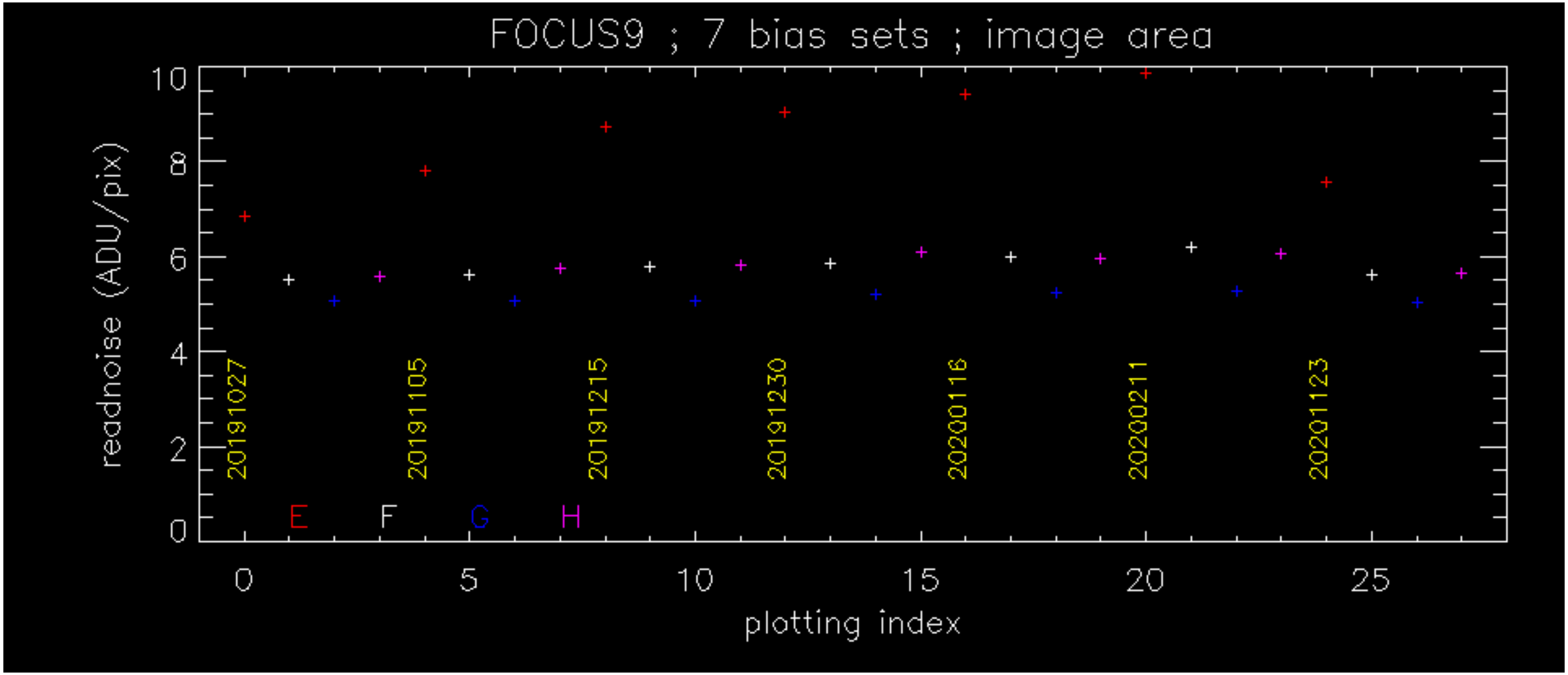
# readnoise per amp; image area



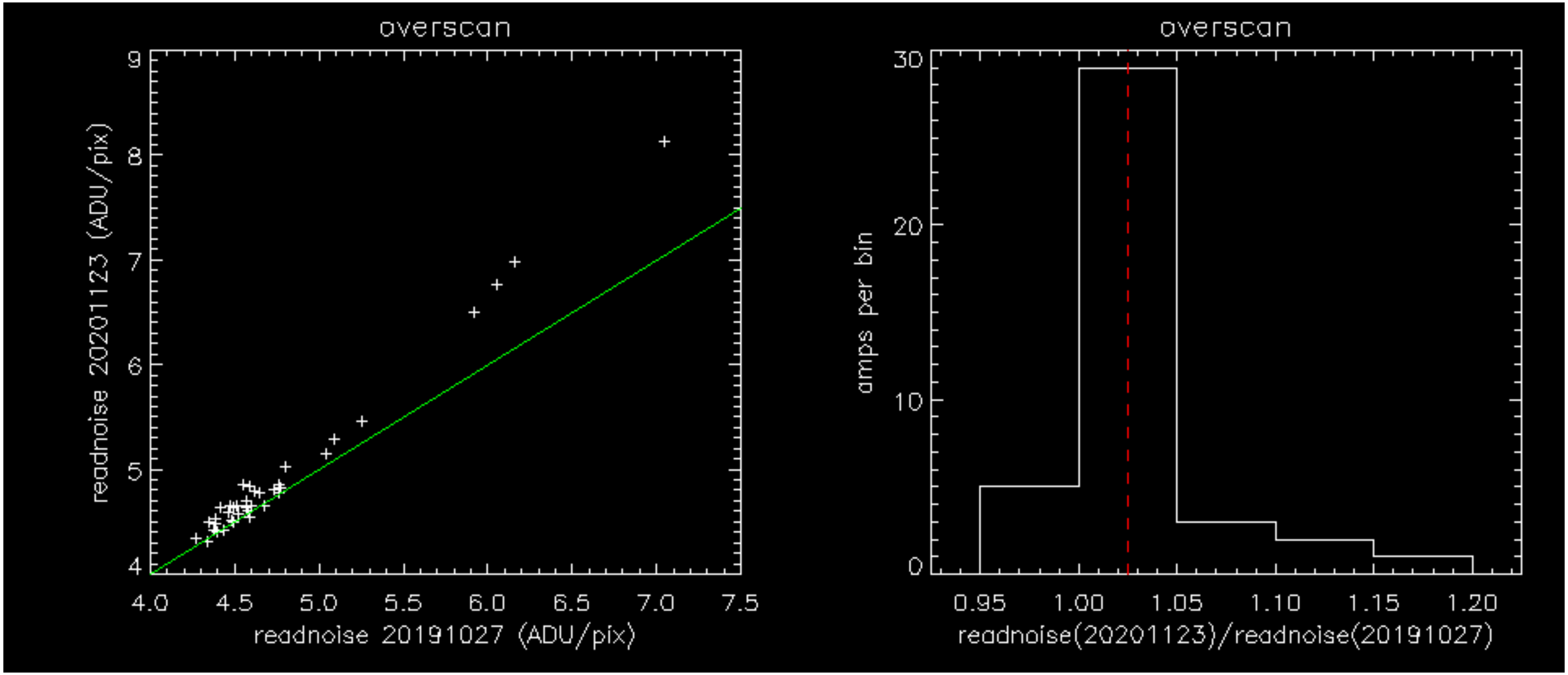
# readnoise per amp; image area



# readnoise per amp; image area

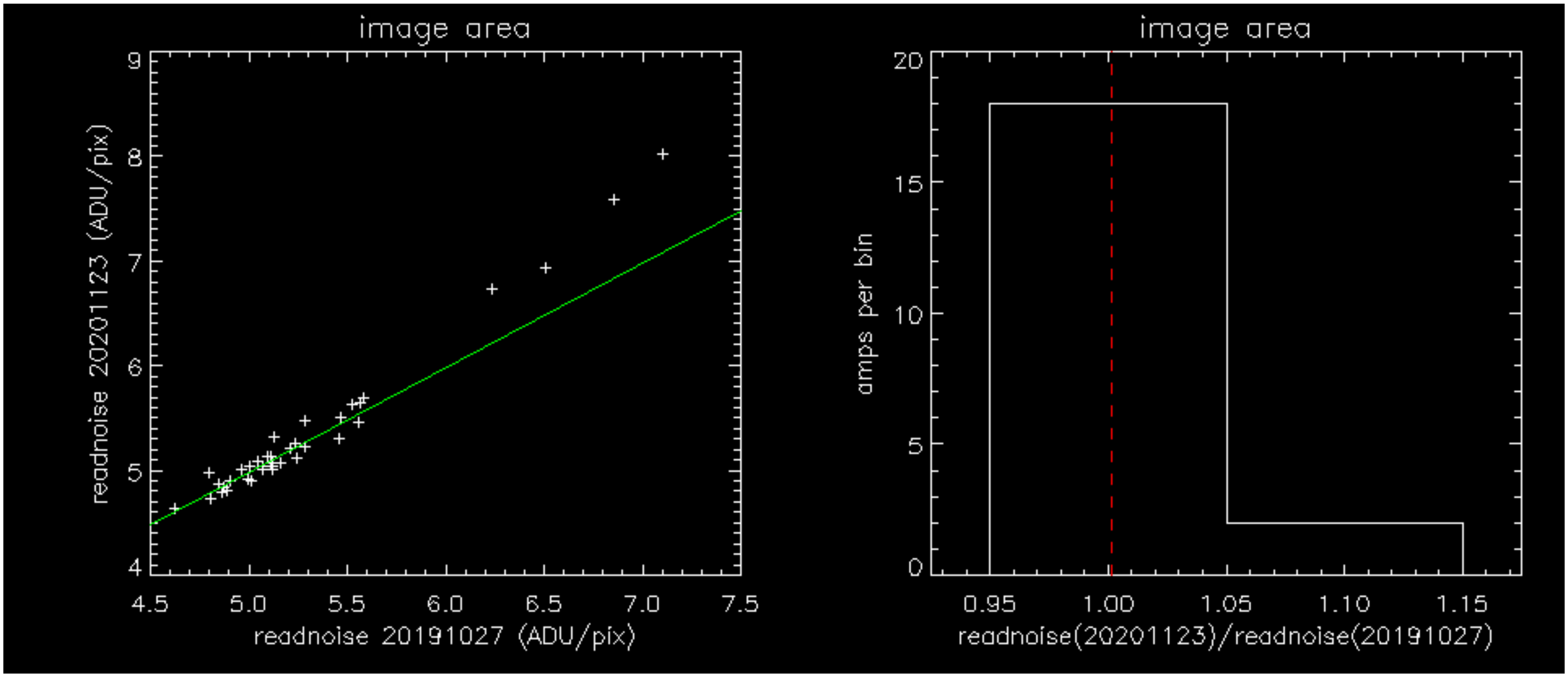


# readnoise summary; overscan




# 20191027 versus 20201123

# readnoise summary; image area



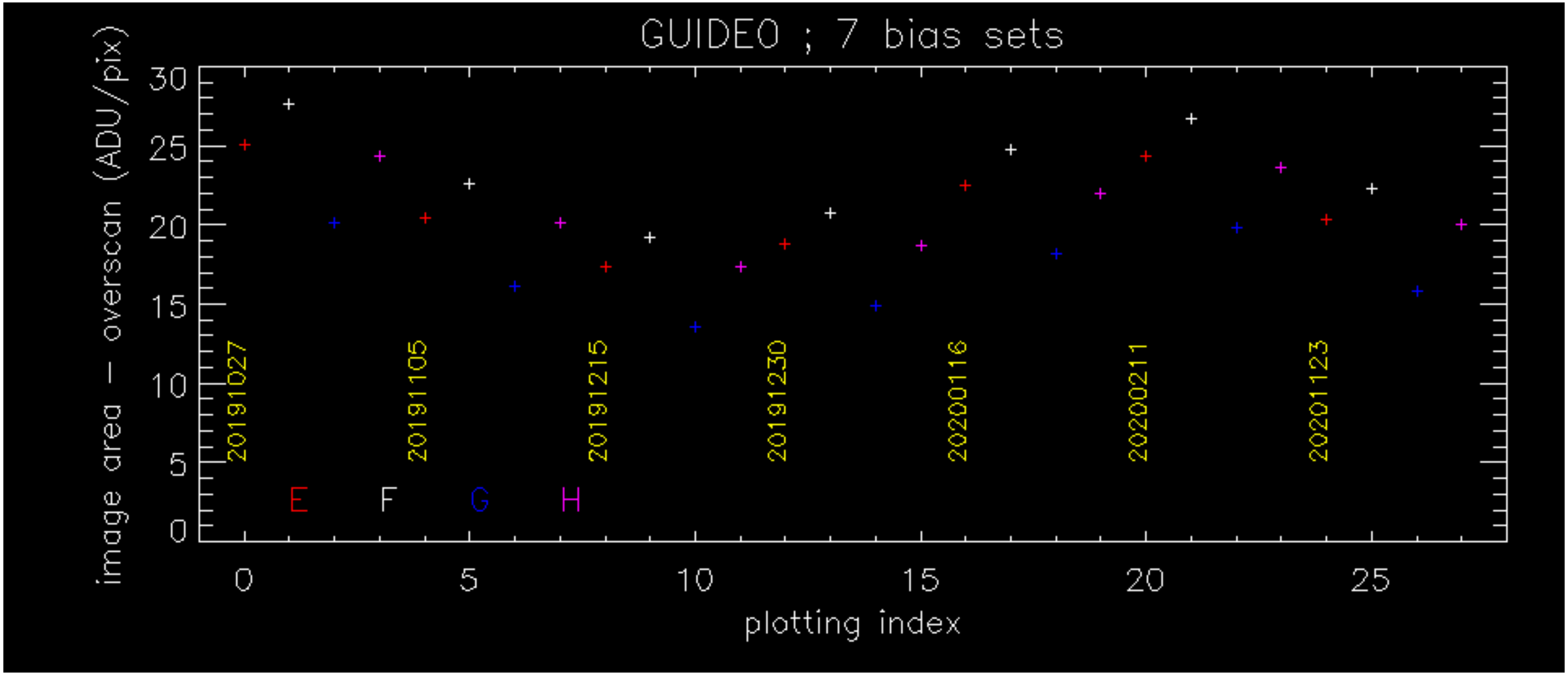

# 20191027 versus 20201123

# bias: image area versus overscan

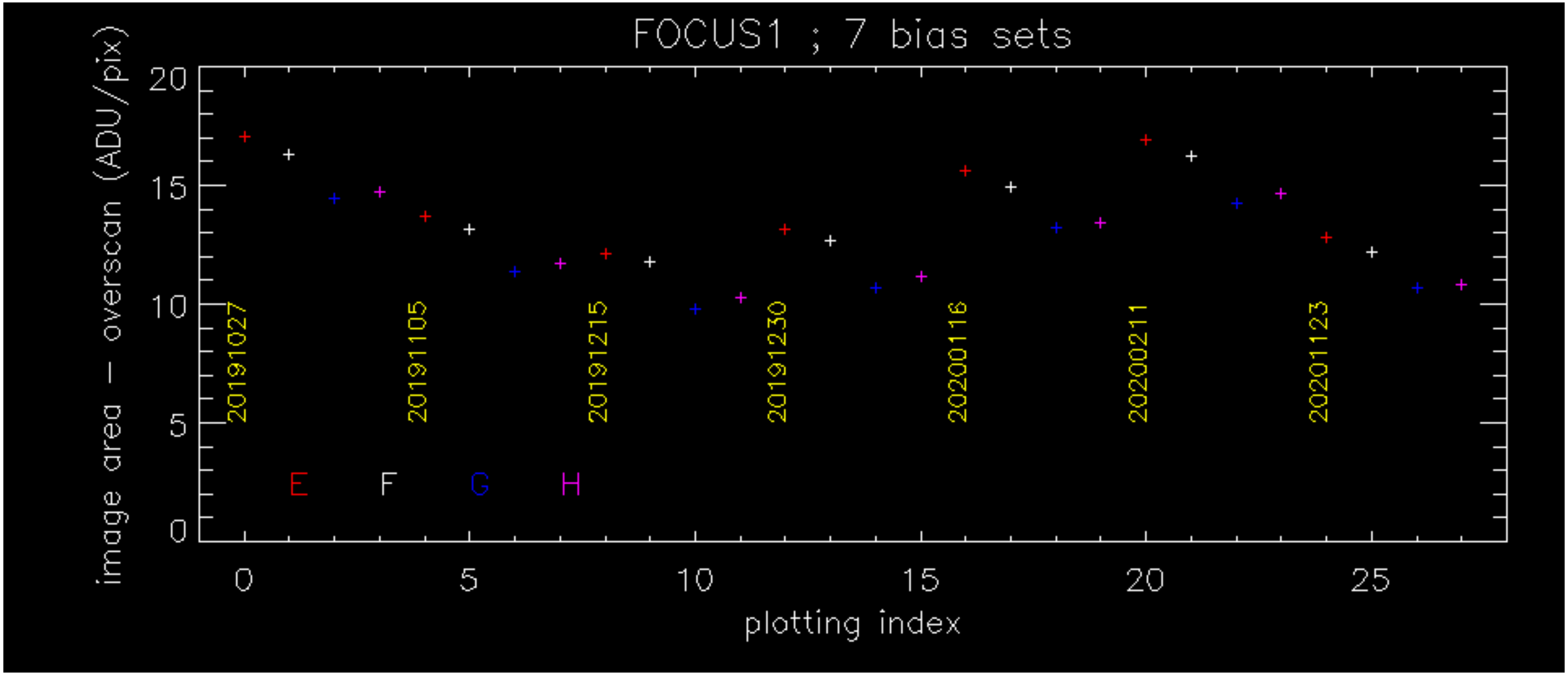
- The following plots show the offset between the image area and overscan for each amp of each camera, in each of 7 good sets of biases spanning 20191027-20201123

- The 20201123 offsets fall within reasonable ranges considering the offsets seen pre-restart at KPNO.

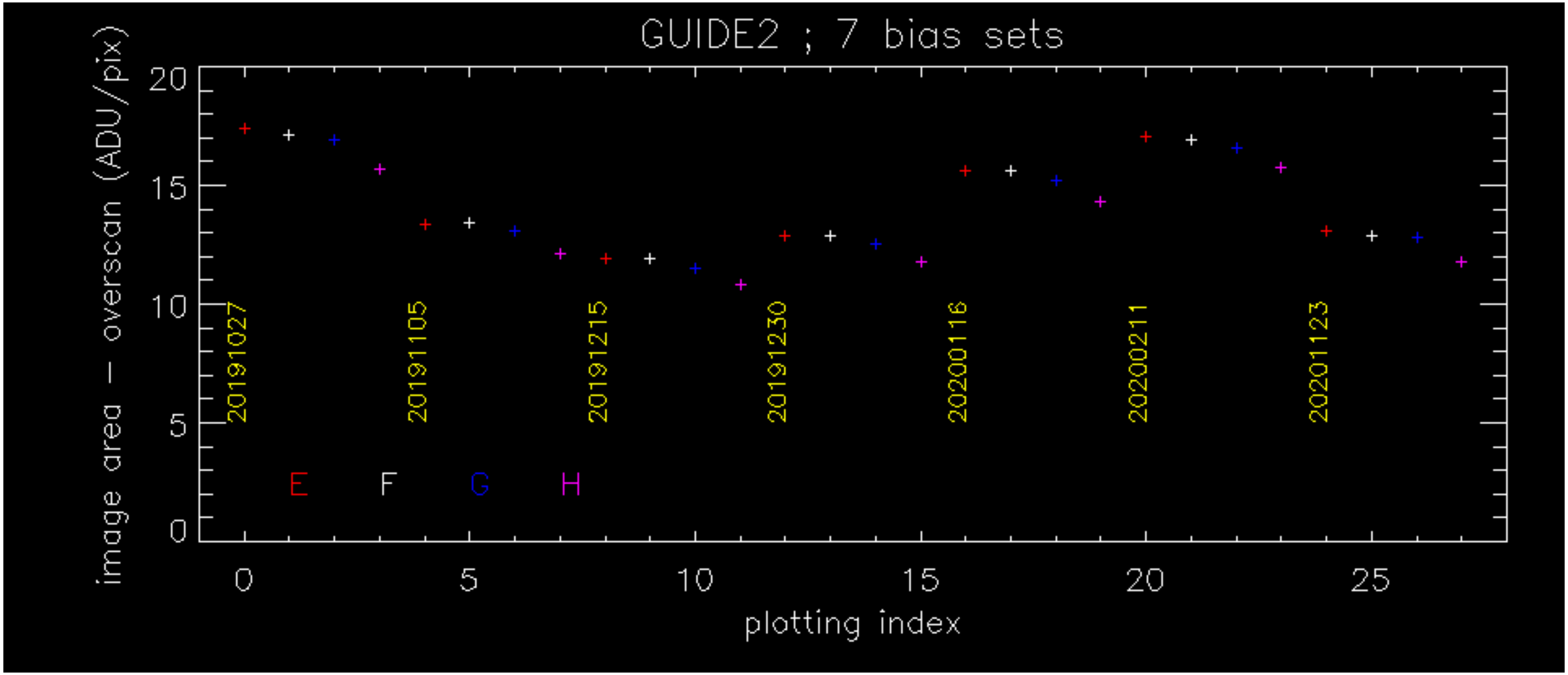
# bias: image area versus overscan



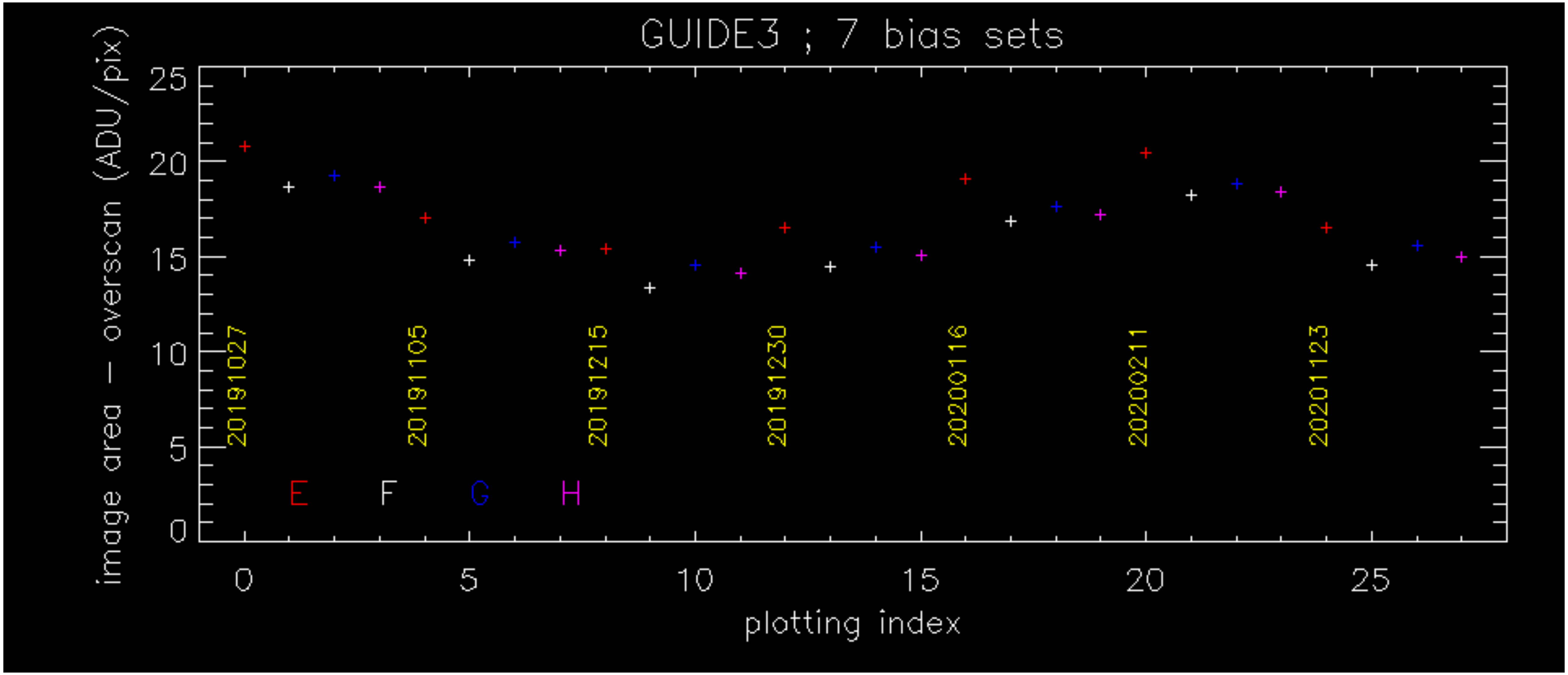
# bias: image area versus overscan



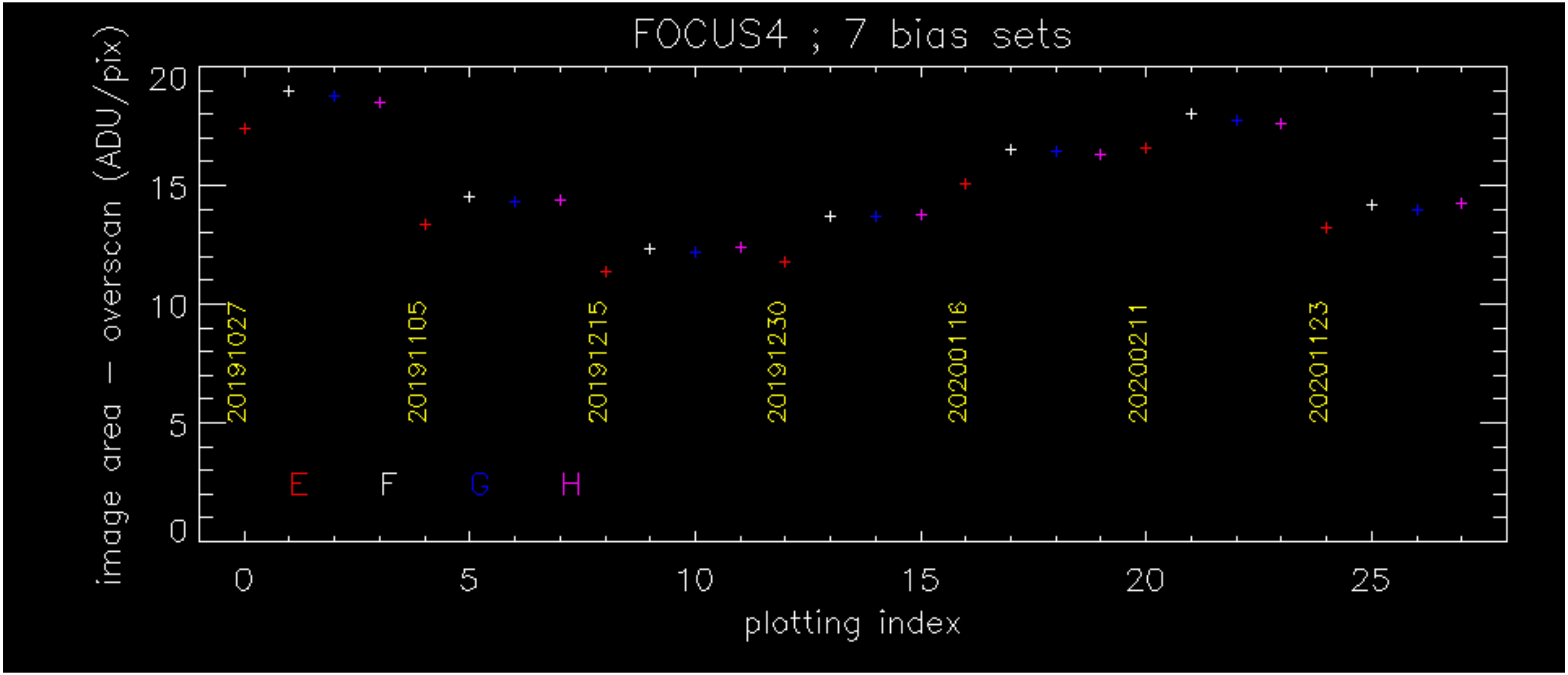
# bias: image area versus overscan



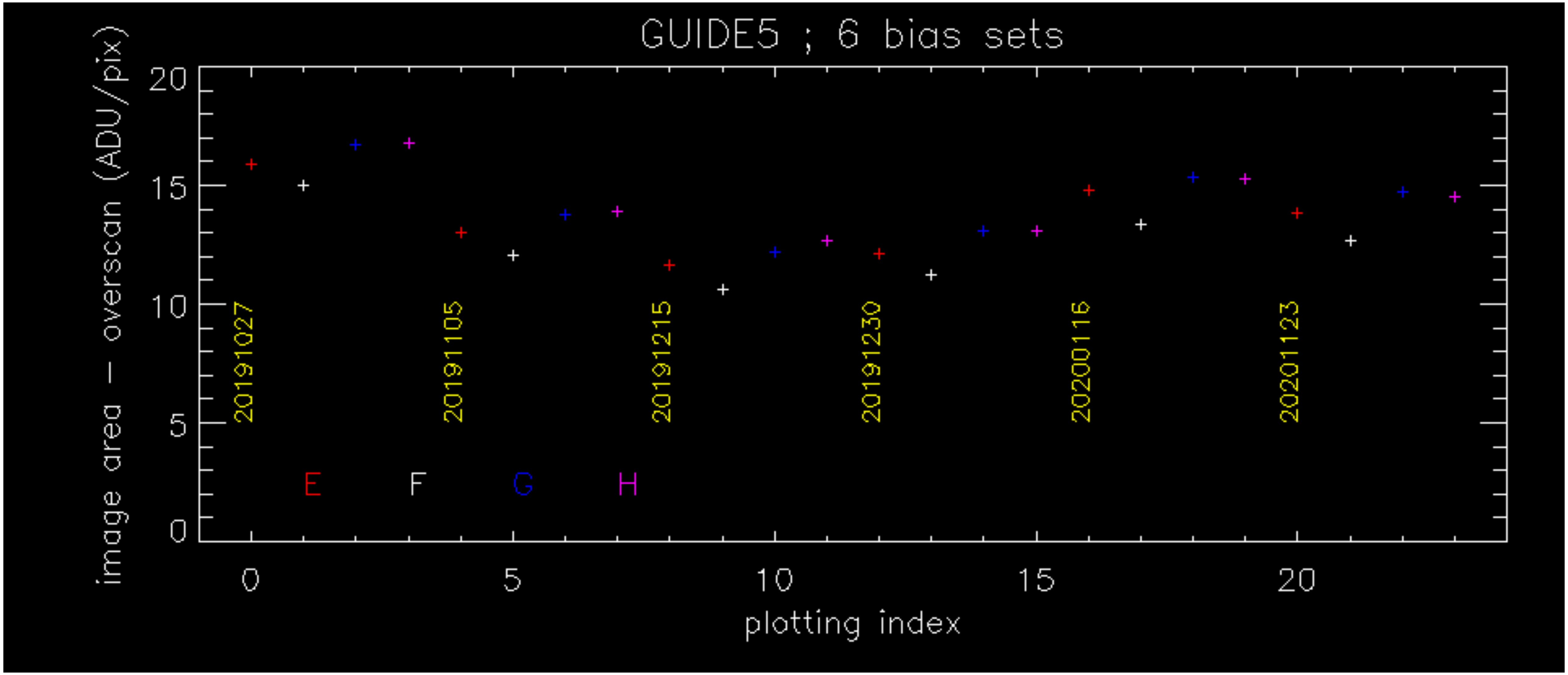
# bias: image area versus overscan



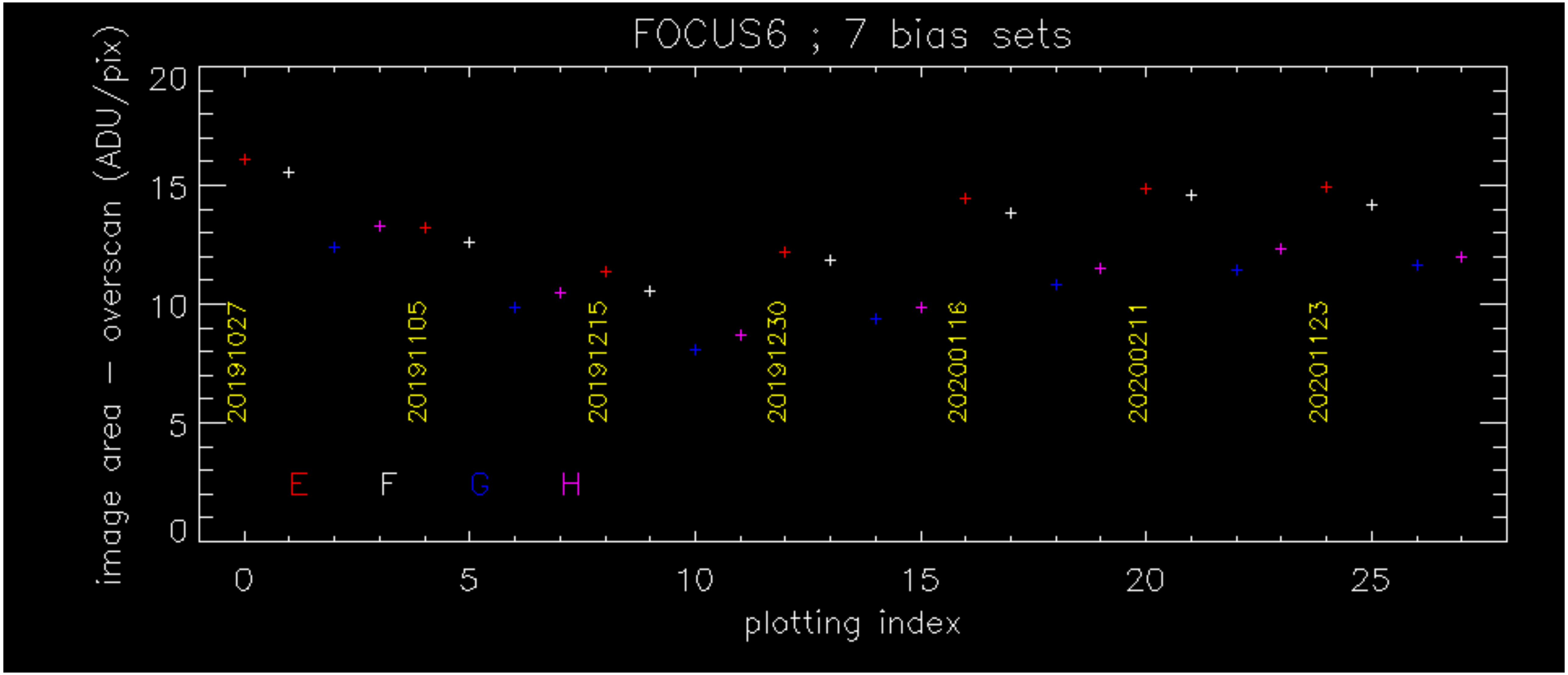
# bias: image area versus overscan



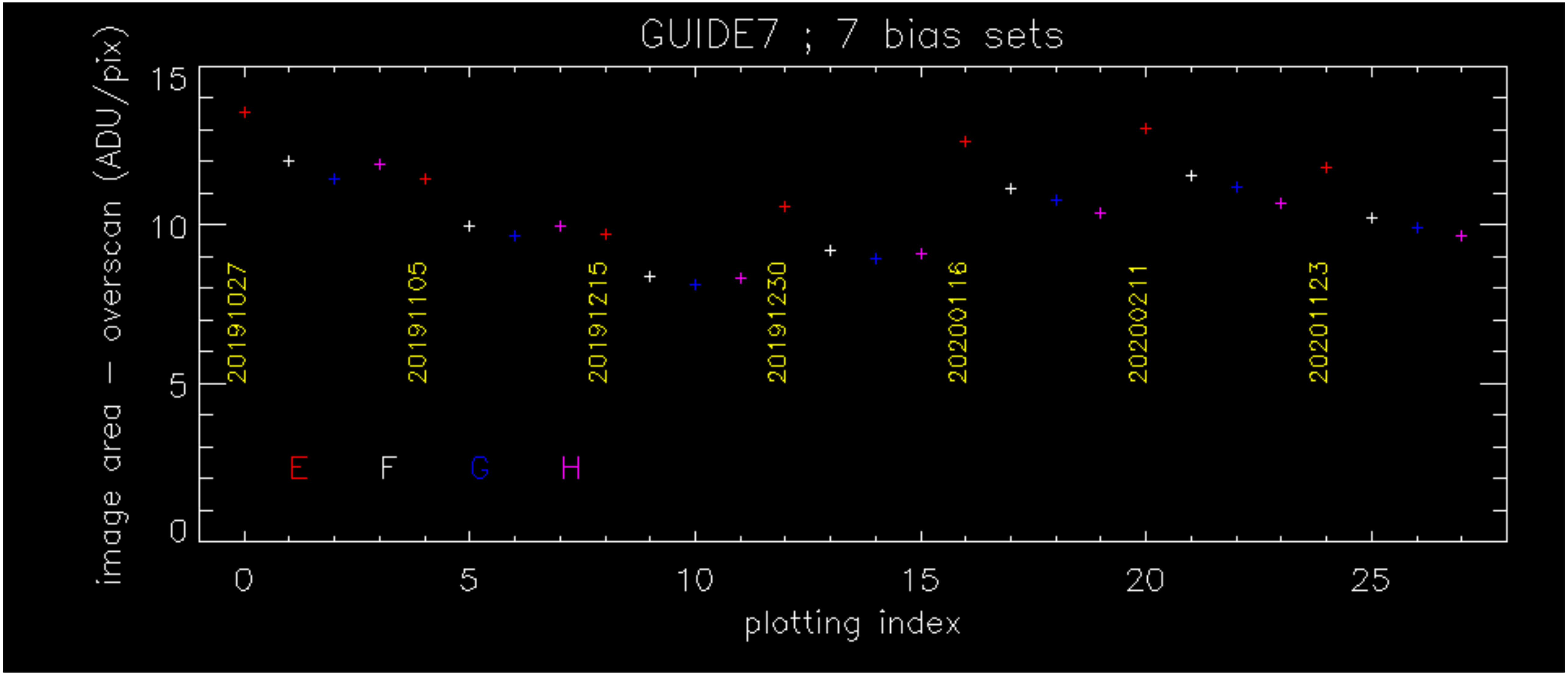
# bias: image area versus overscan



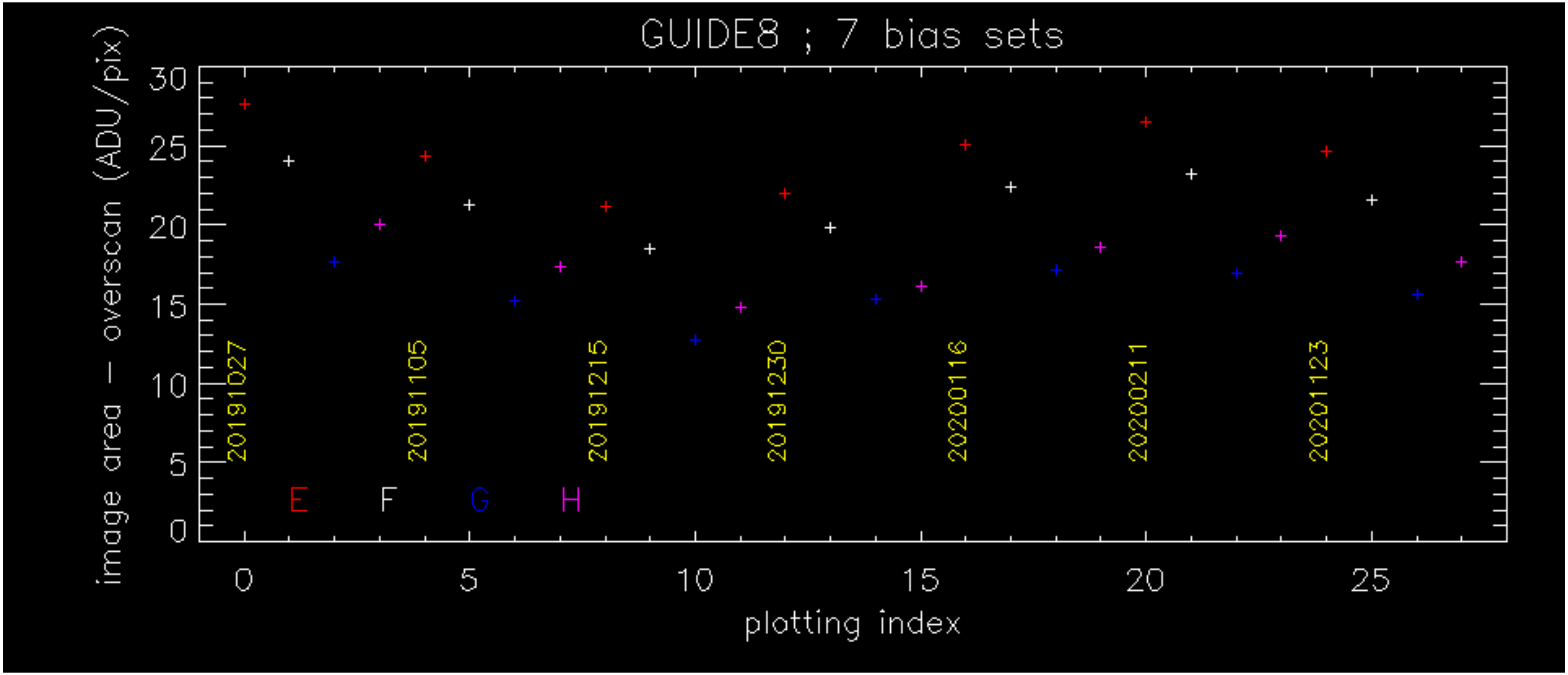
# bias: image area versus overscan



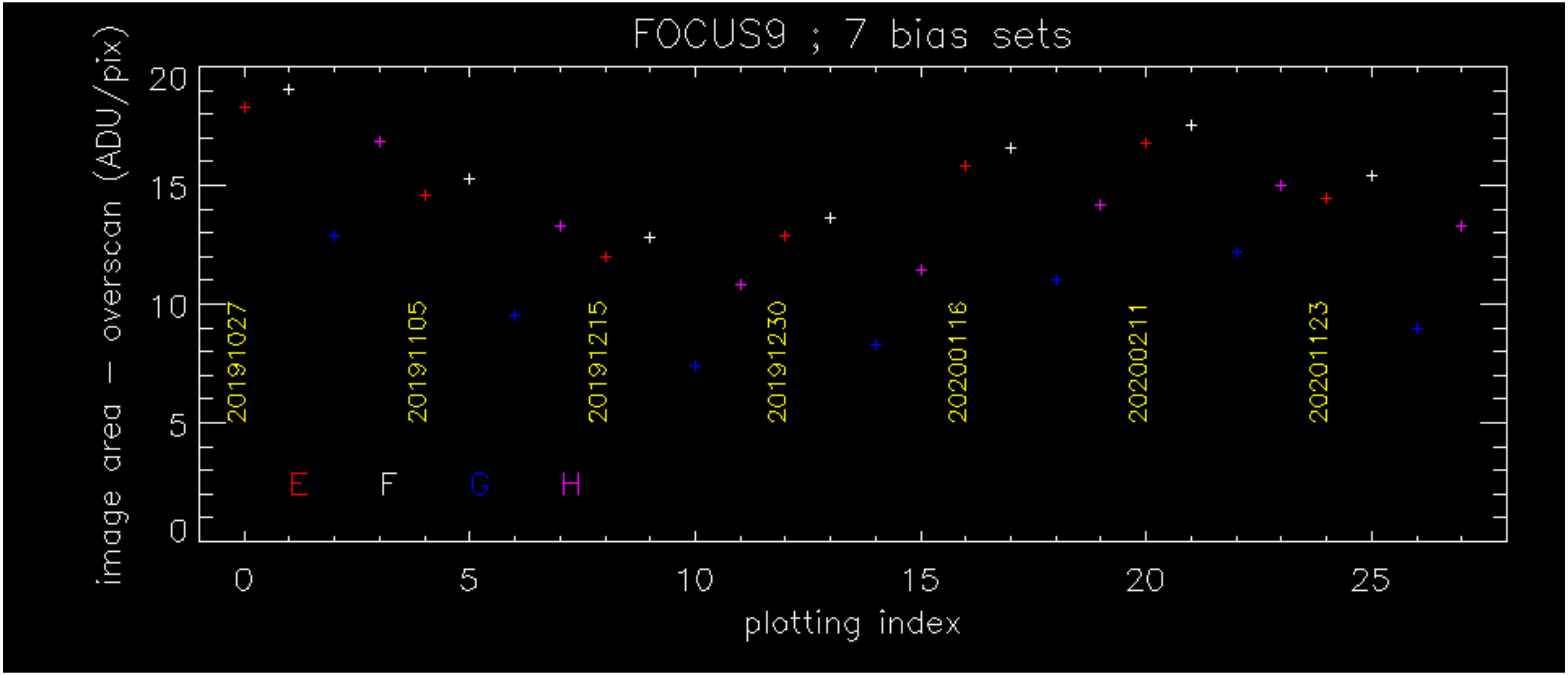
# bias: image area versus overscan



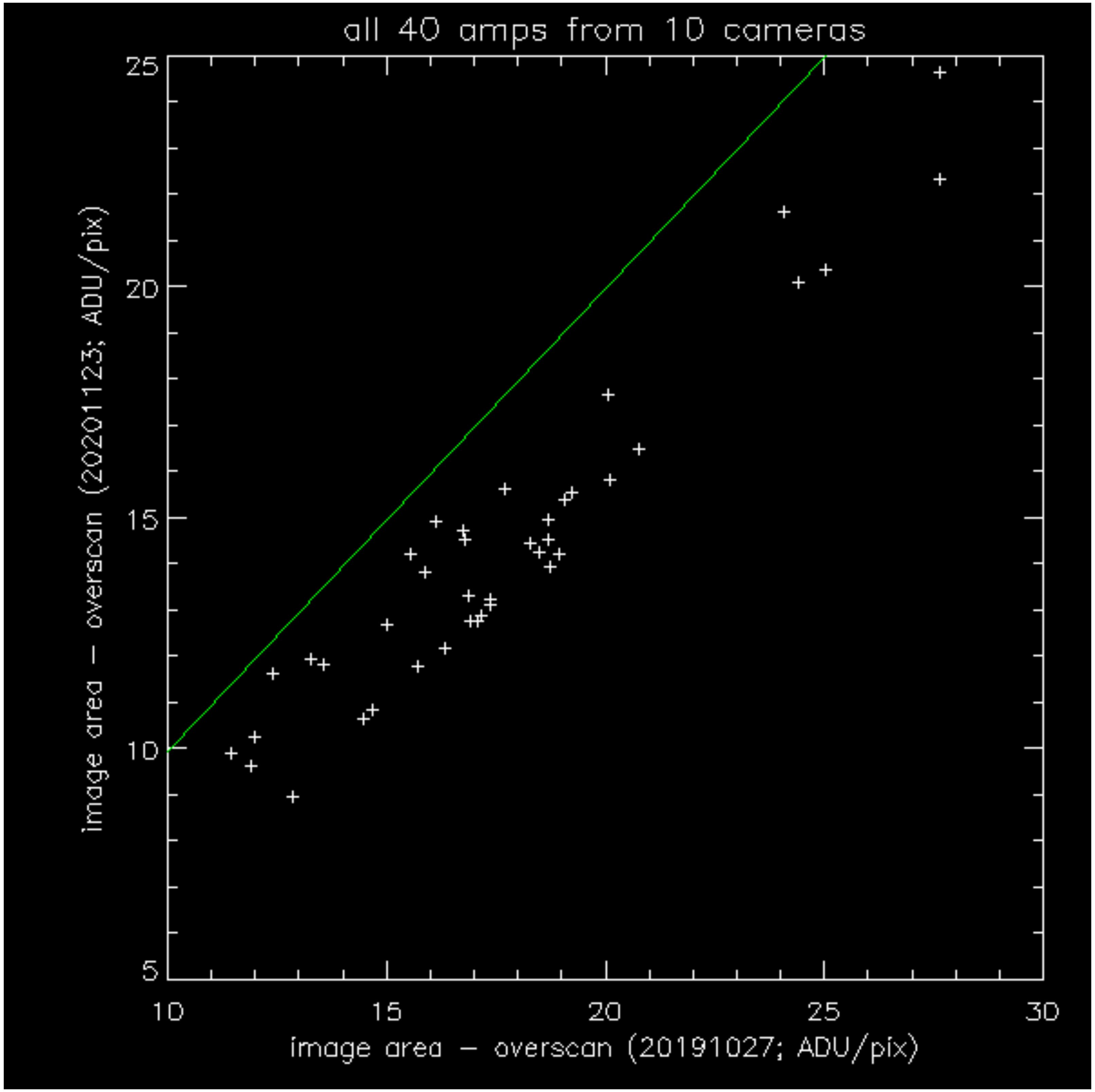
# bias: image area versus overscan



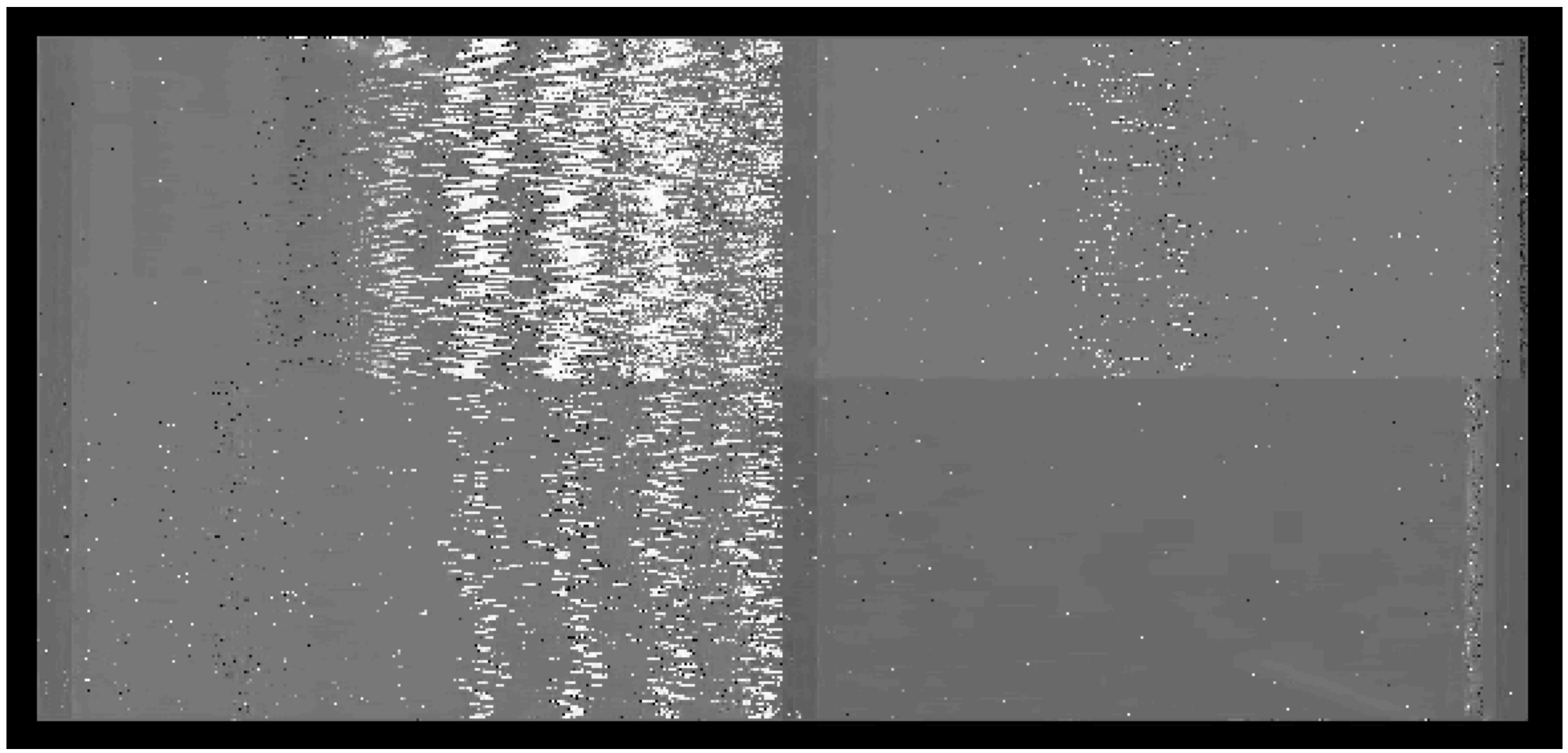
# bias: image area versus overscan



# bias: image area versus overscan

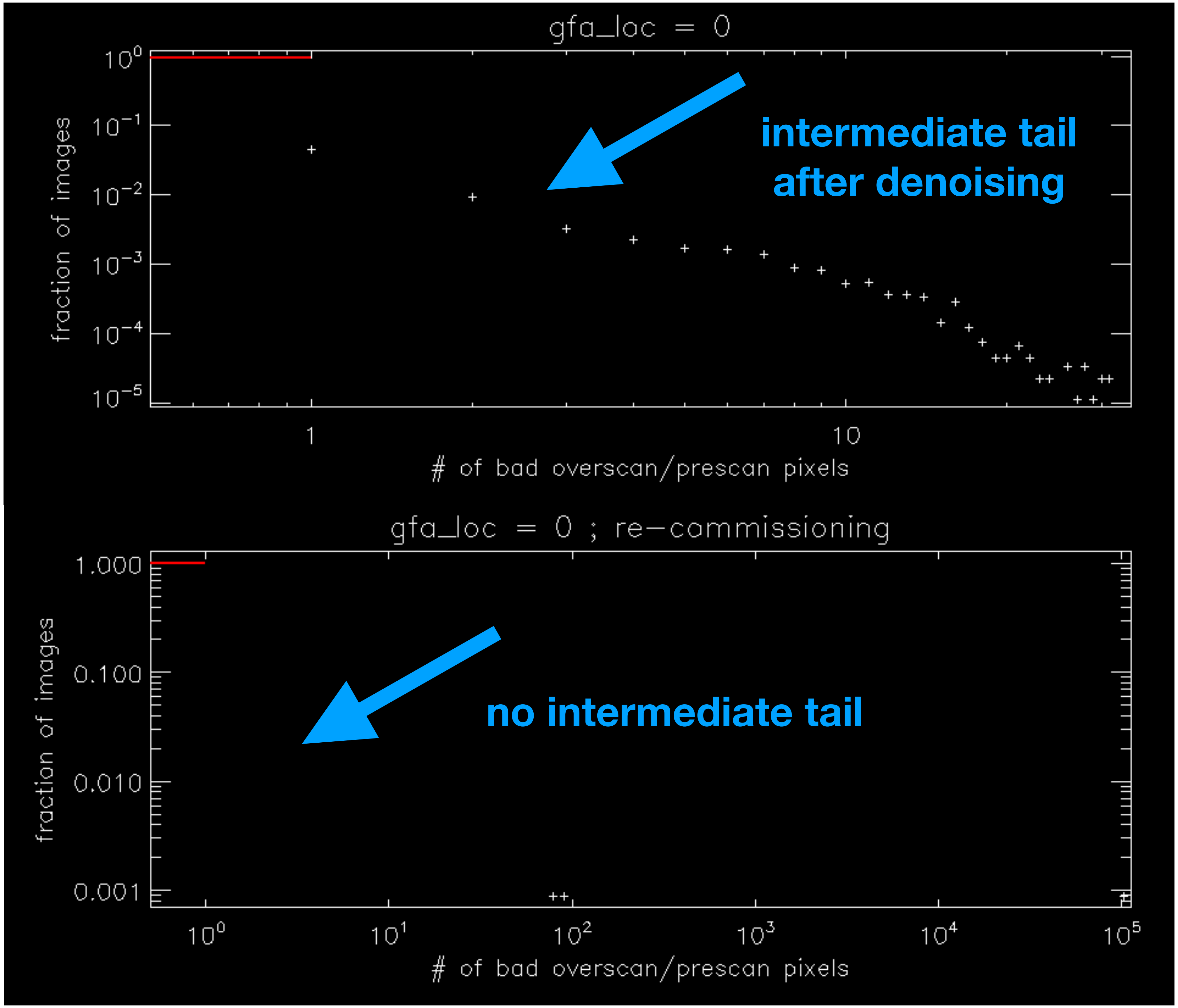


# denoising



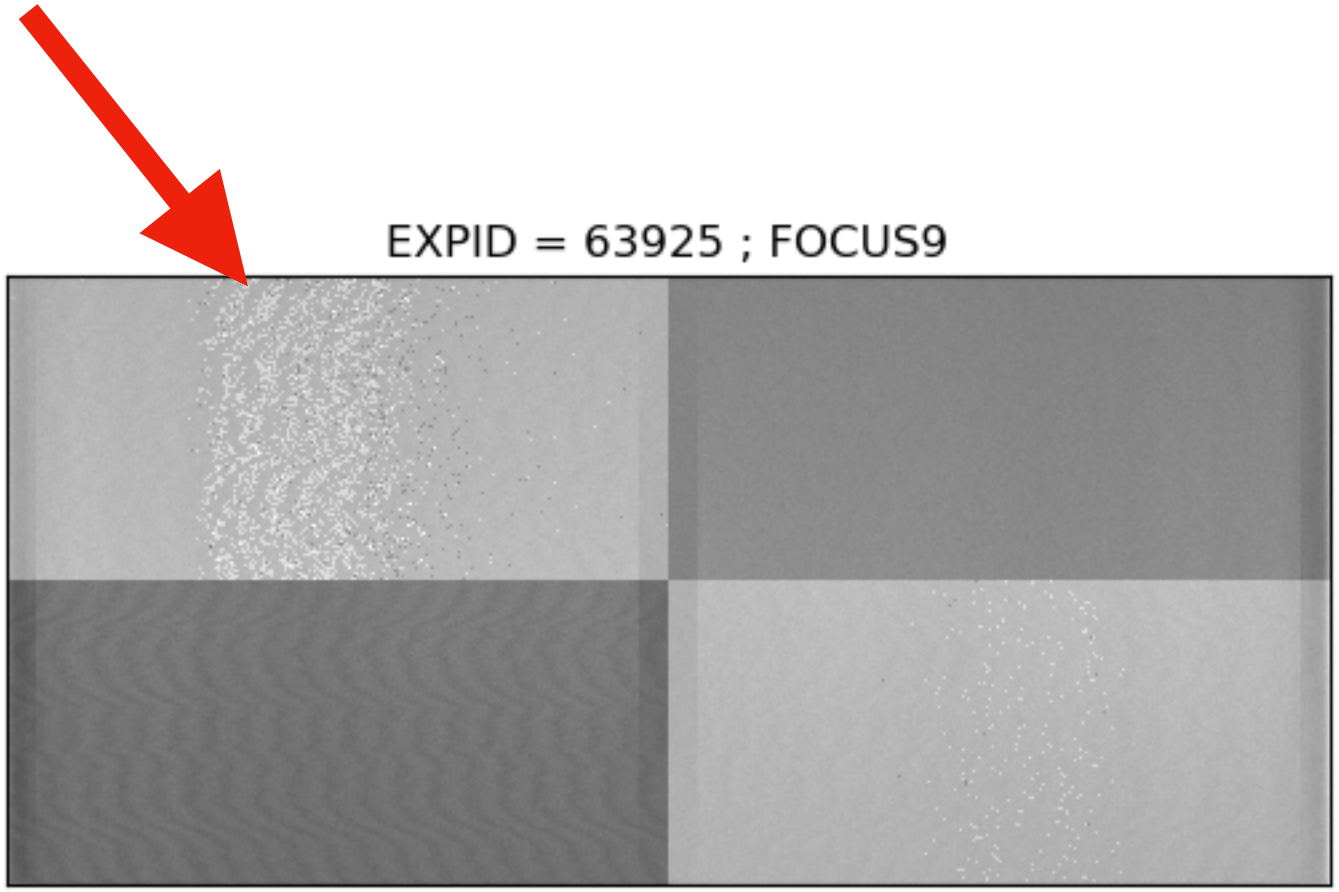
- A/D noise can still happen upon GFA startup
- The above image is from 20201122, GUIDE5, EXPID = 63735 (the second GFA exposure of observing night 20201122)

# denoising




- **When quantified/flagged in terms of extreme 'fake' bad pixels ( > 10k ADU) in the overscan regions, the post-restart behavior generally seems more 'binary' (i.e., either there are significant A/D problems or none at all)**

# denoising

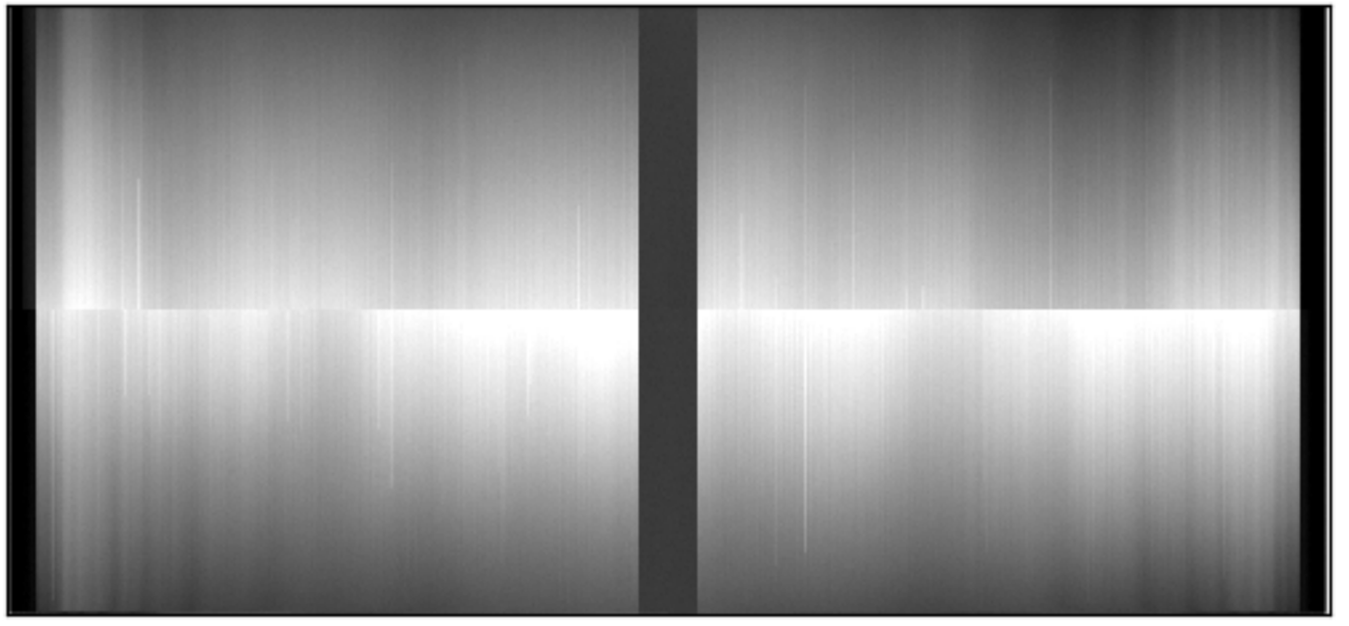



**Other such FOCUS9 examples from this set of biases: 63941, 63957**

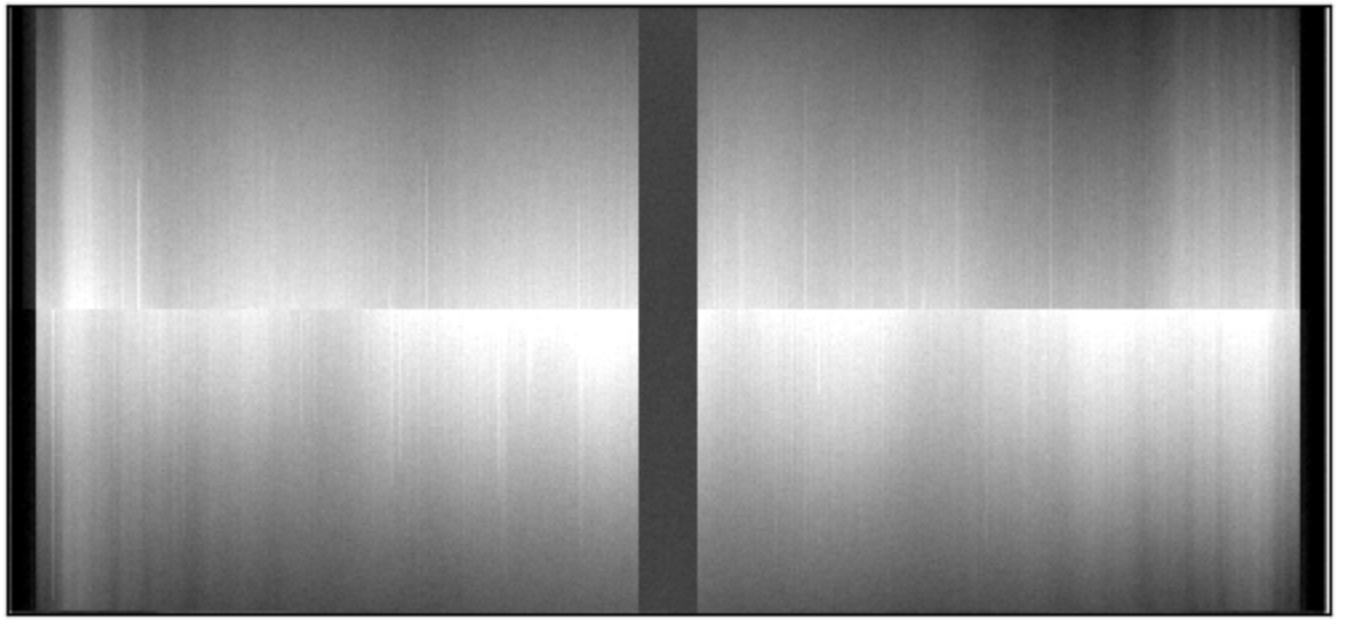
- **Stumbled onto some bad FOCUS9 reads during the bias sequence from 20201123 when we had thought that we were fully denoised**
- **In this case there are no extreme ( > 10k ADU) bad pixels in the overscan, but the readout is clearly corrupted, producing a large number of pixels spuriously offset at the order 100 ADU level in amp H**
  - **This suggests perhaps investigating tweaks to the way that I flag bad GFA readout**

# appendix: master bias comparison 20191027 versus 20201123

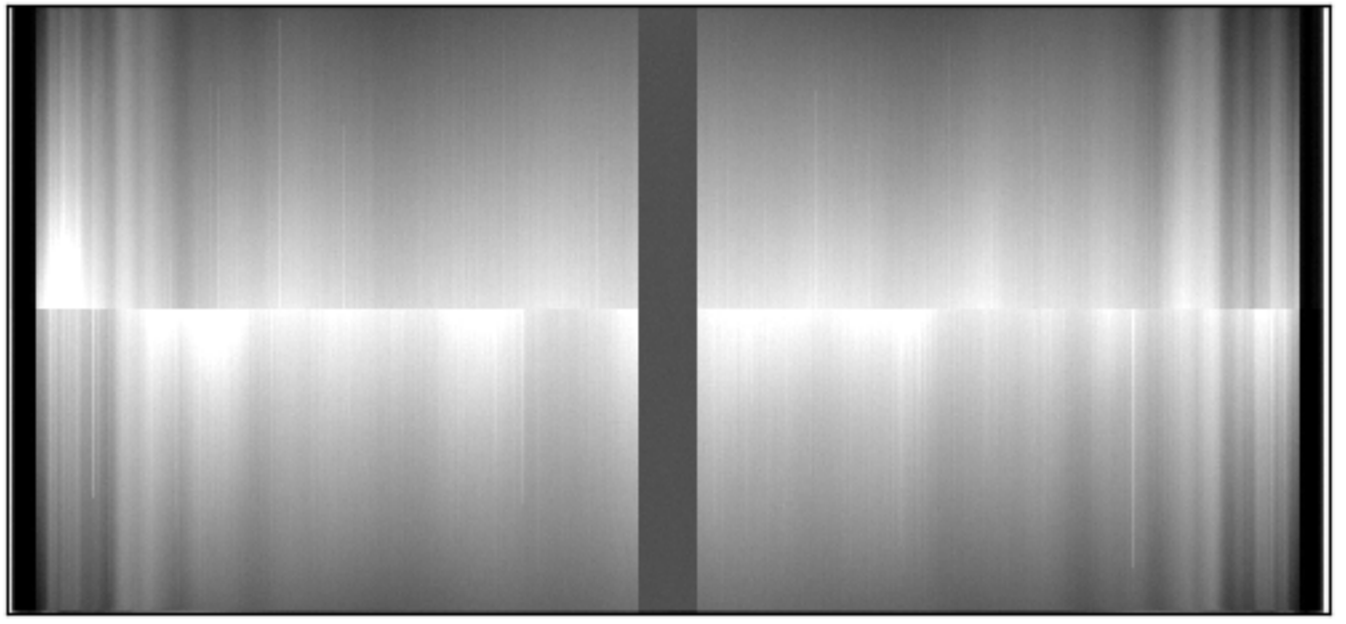
master bias ; overscan subtracted ; 20191027 ; GUIDE0



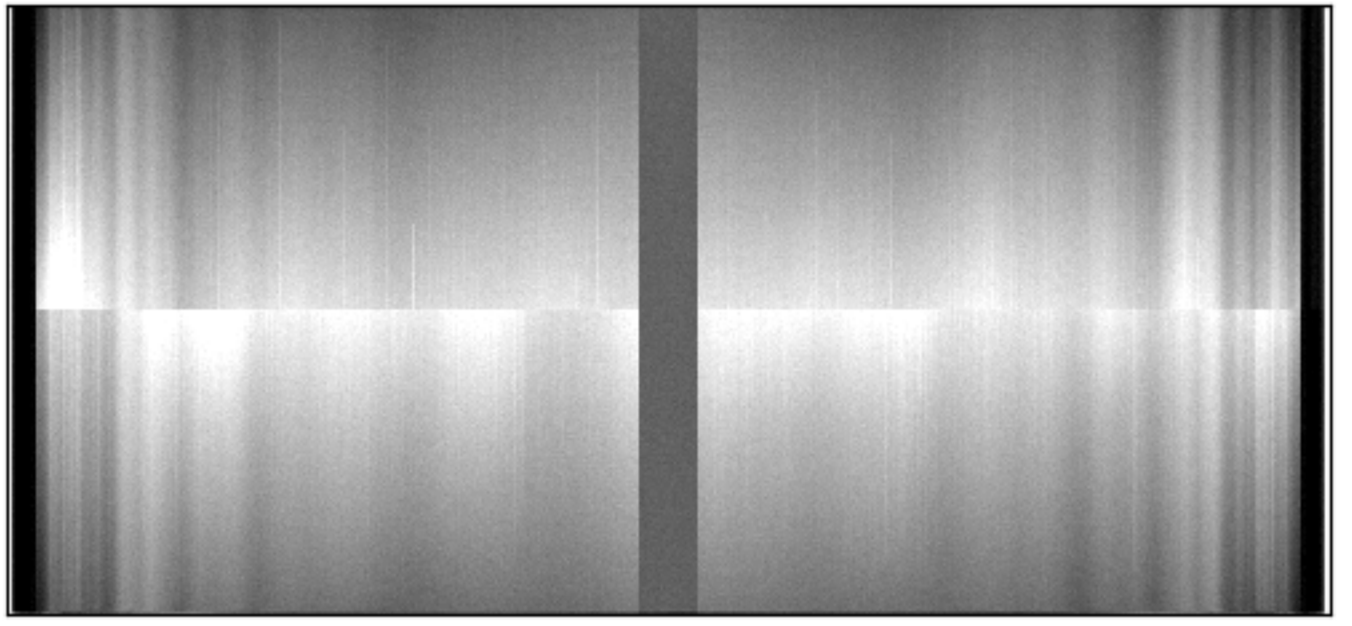
master bias ; overscan subtracted ; 20201123 ; GUIDE0



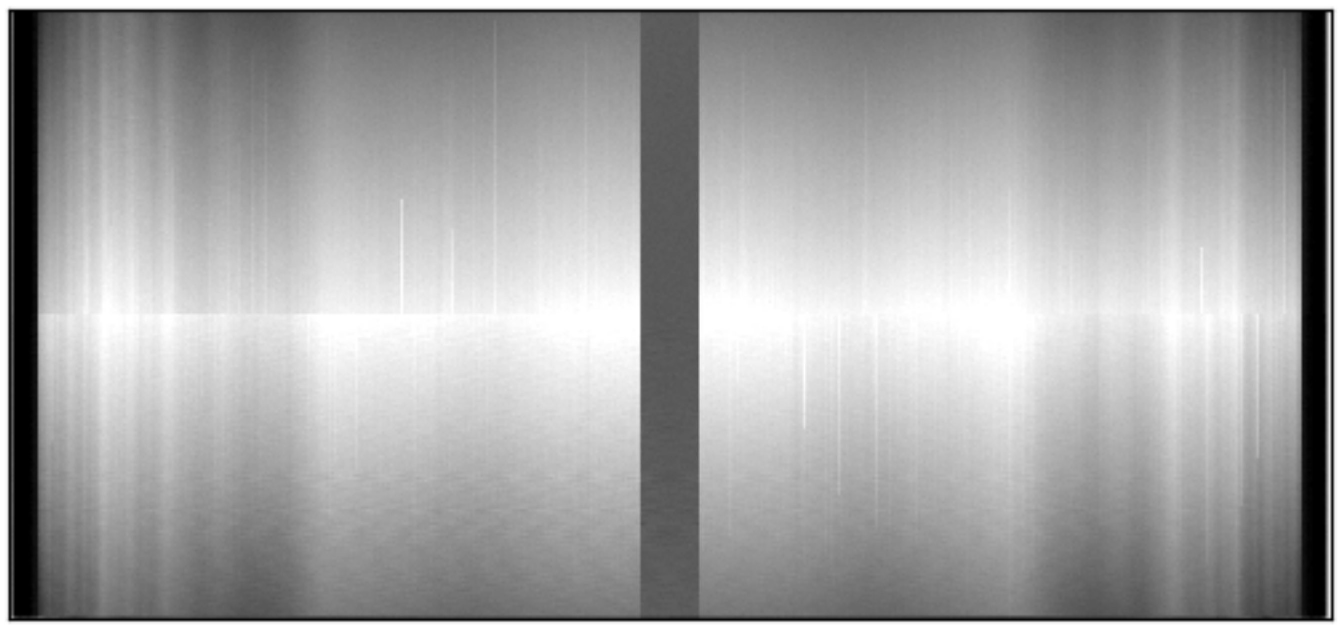
master bias ; overscan subtracted ; 20191027 ; FOCUS1



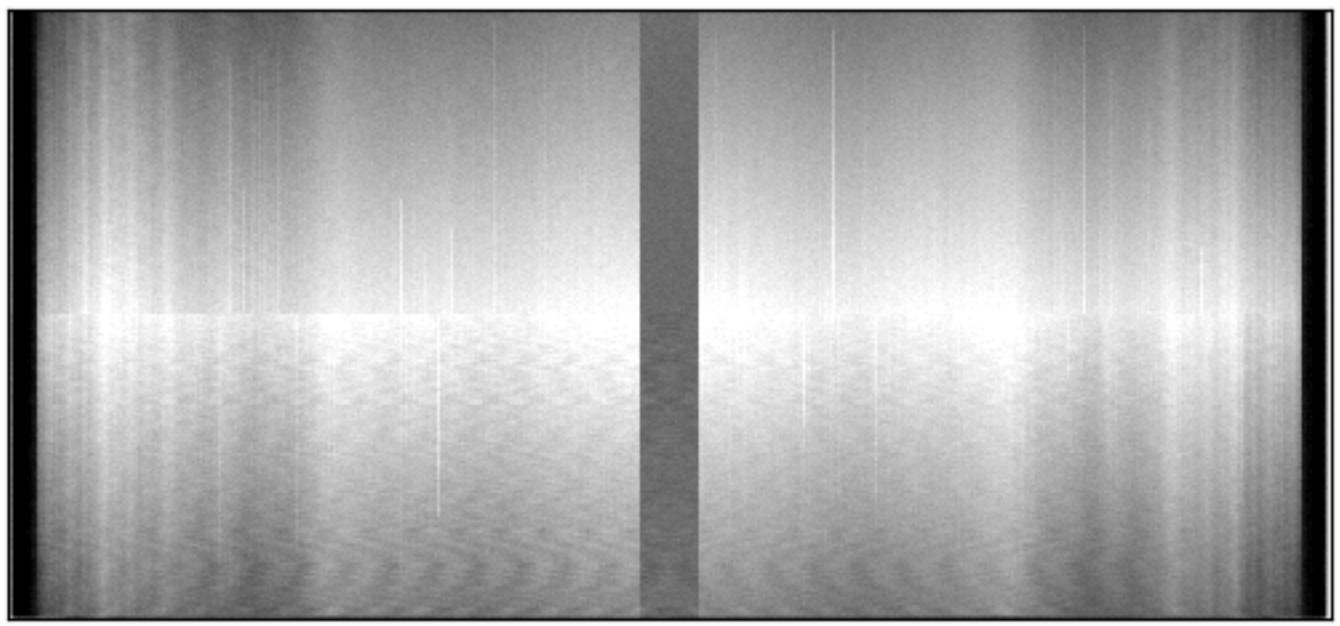
master bias ; overscan subtracted ; 20201123 ; FOCUS1



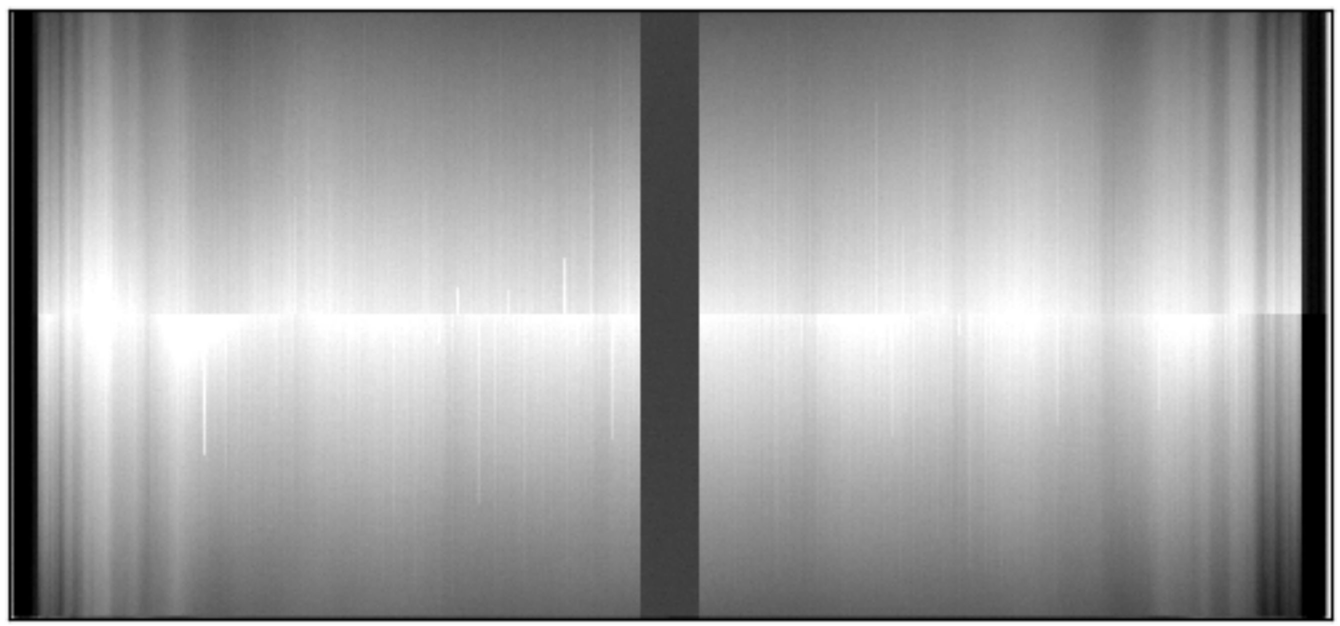
master bias ; overscan subtracted ; 20191027 ; GUIDE2



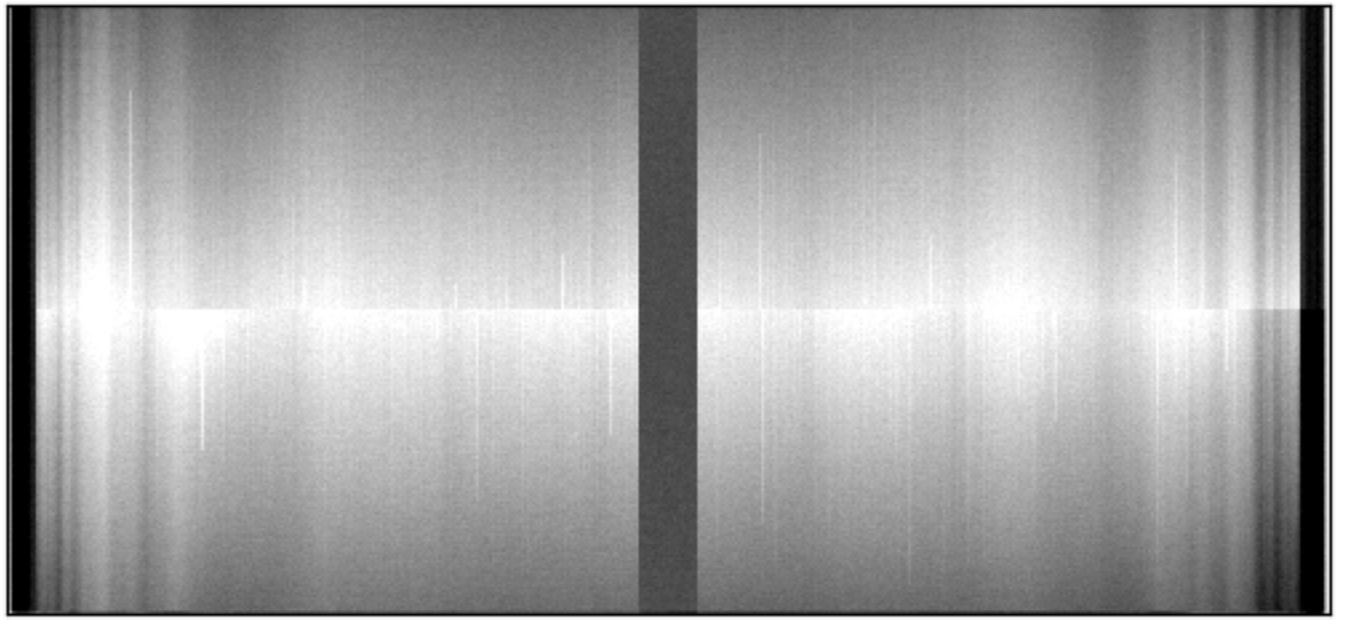
master bias ; overscan subtracted ; 20201123 ; GUIDE2



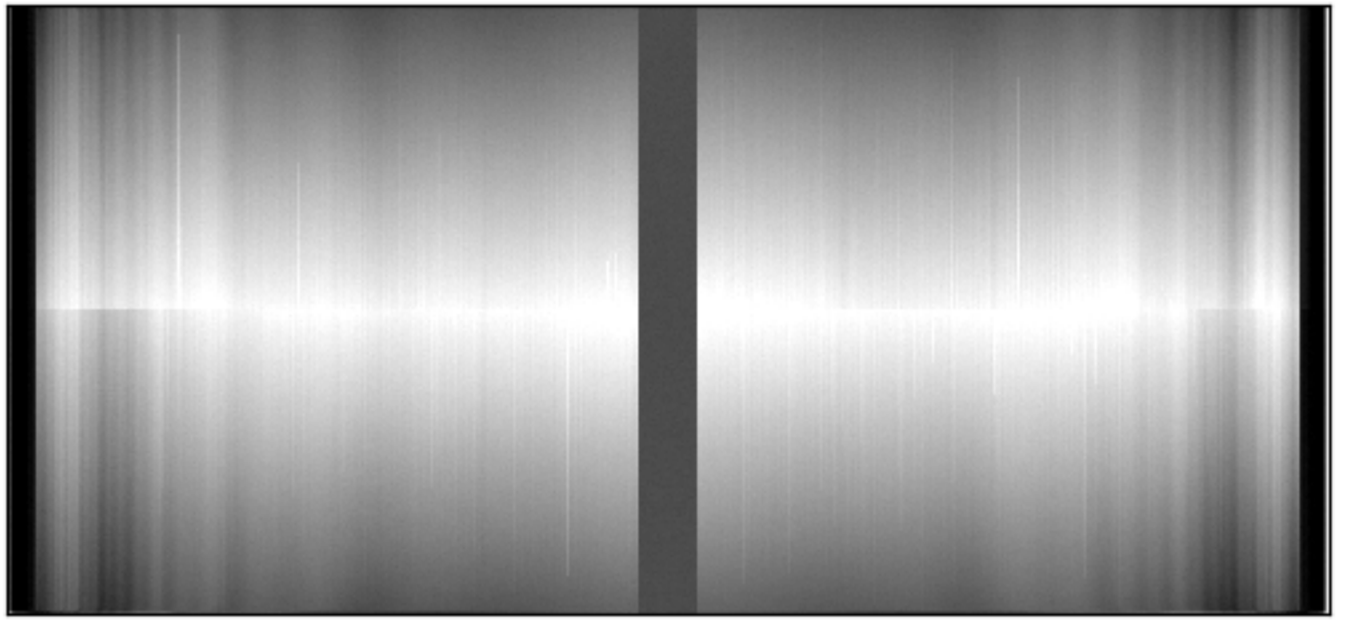
master bias ; overscan subtracted ; 20191027 ; GUIDE3



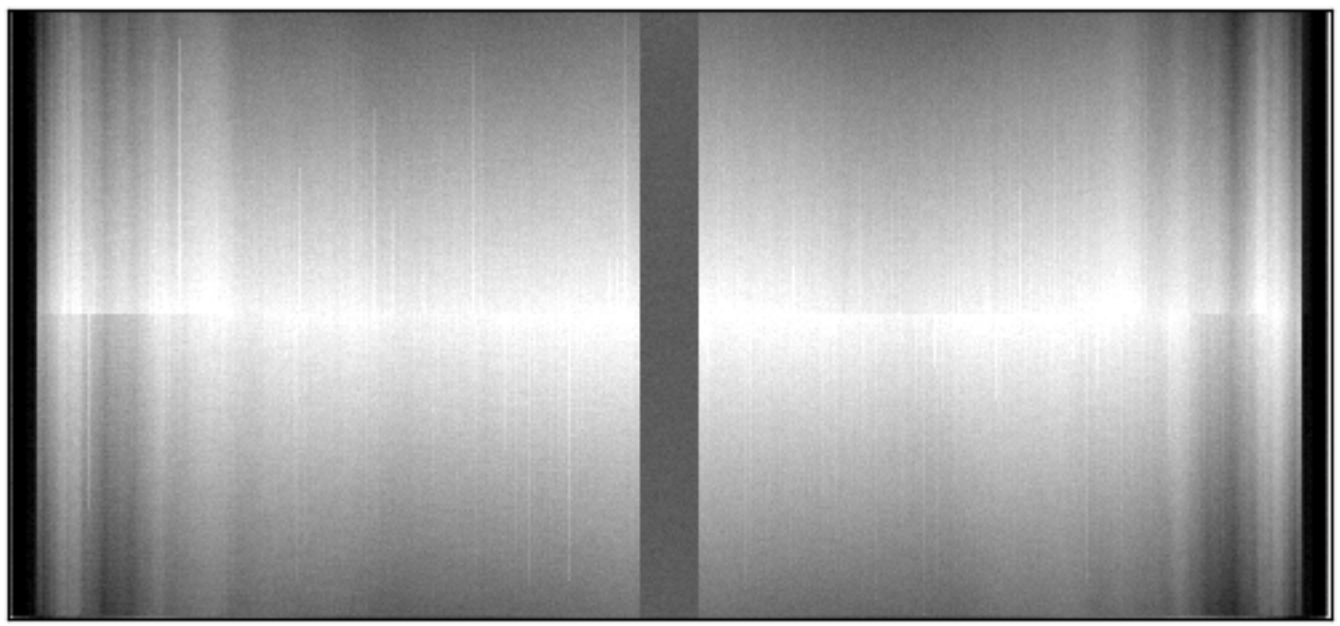
master bias ; overscan subtracted ; 20201123 ; GUIDE3



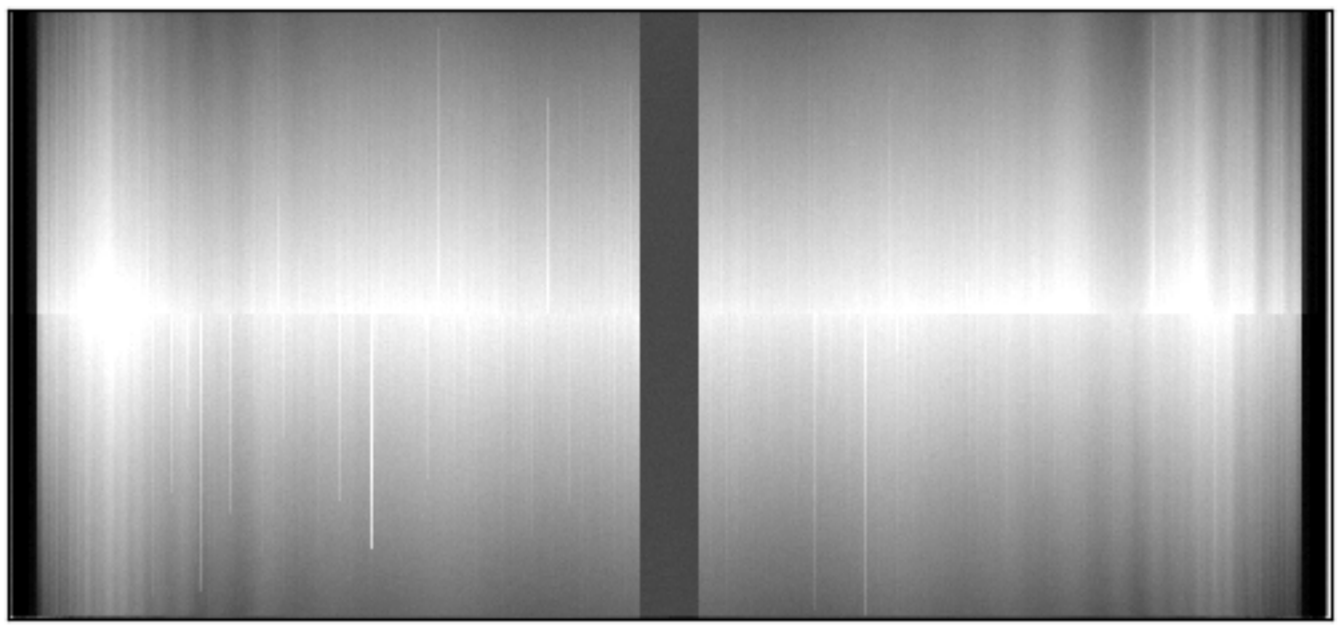
master bias ; overscan subtracted ; 20191027 ; FOCUS4



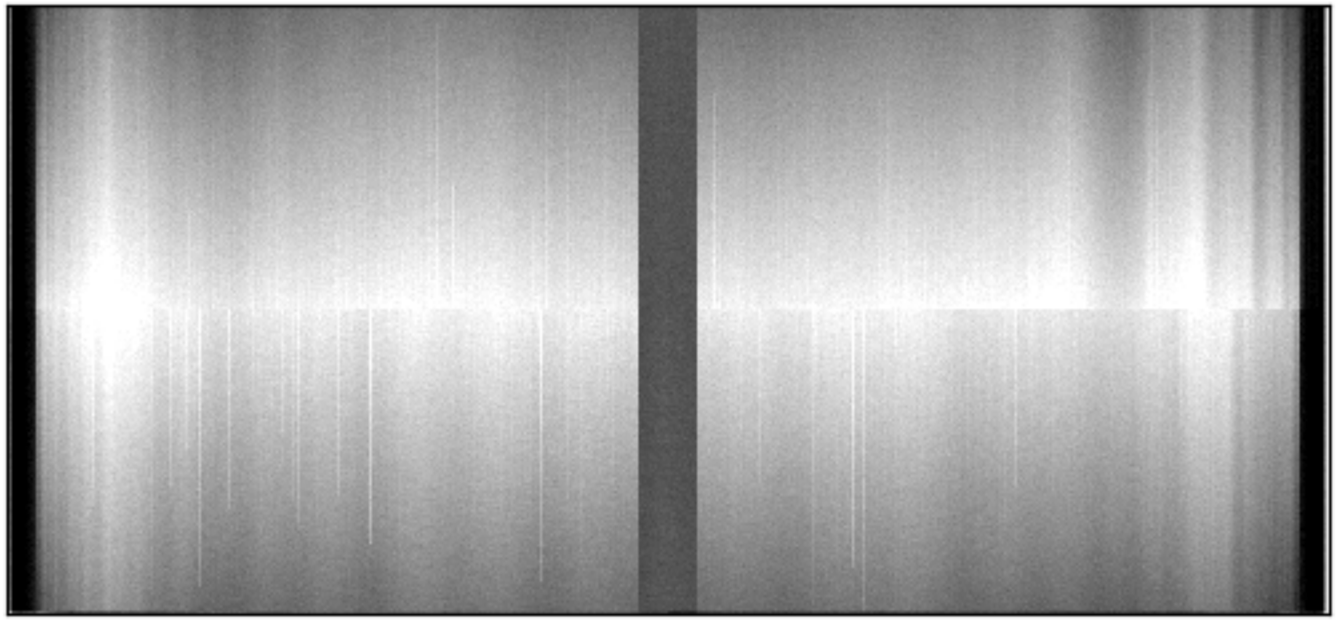
master bias ; overscan subtracted ; 20201123 ; FOCUS4



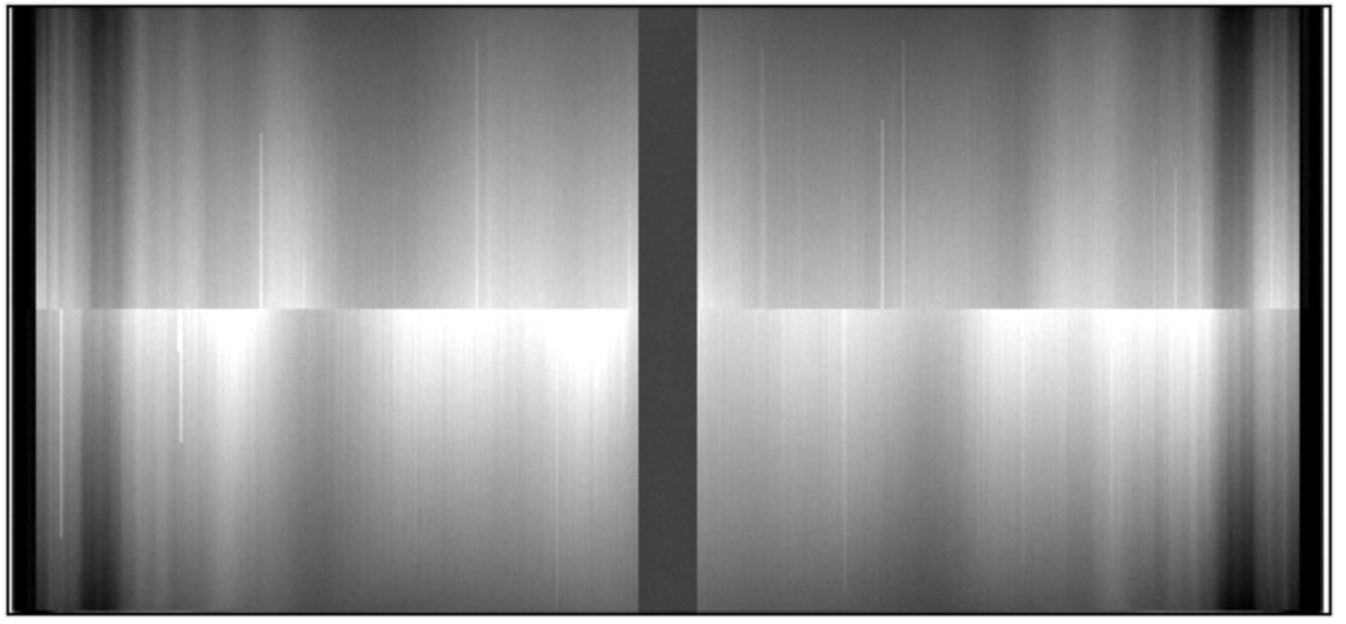
master bias ; overscan subtracted ; 20191027 ; GUIDE5



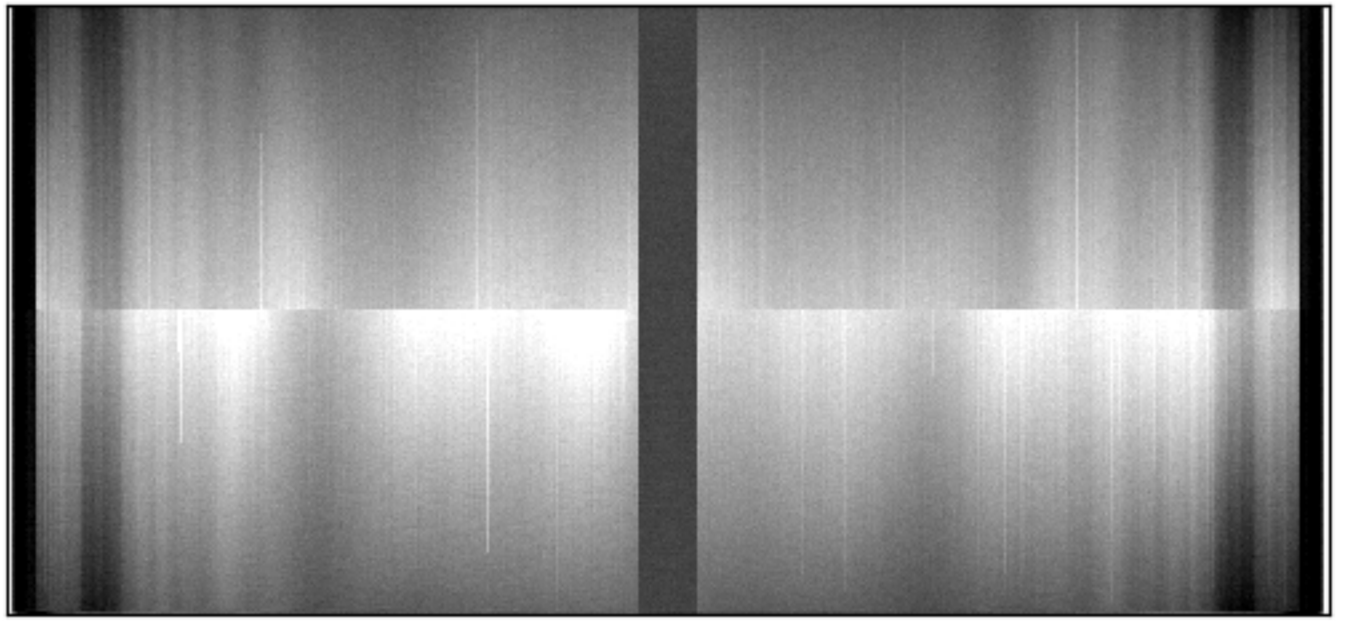
master bias ; overscan subtracted ; 20201123 ; GUIDE5



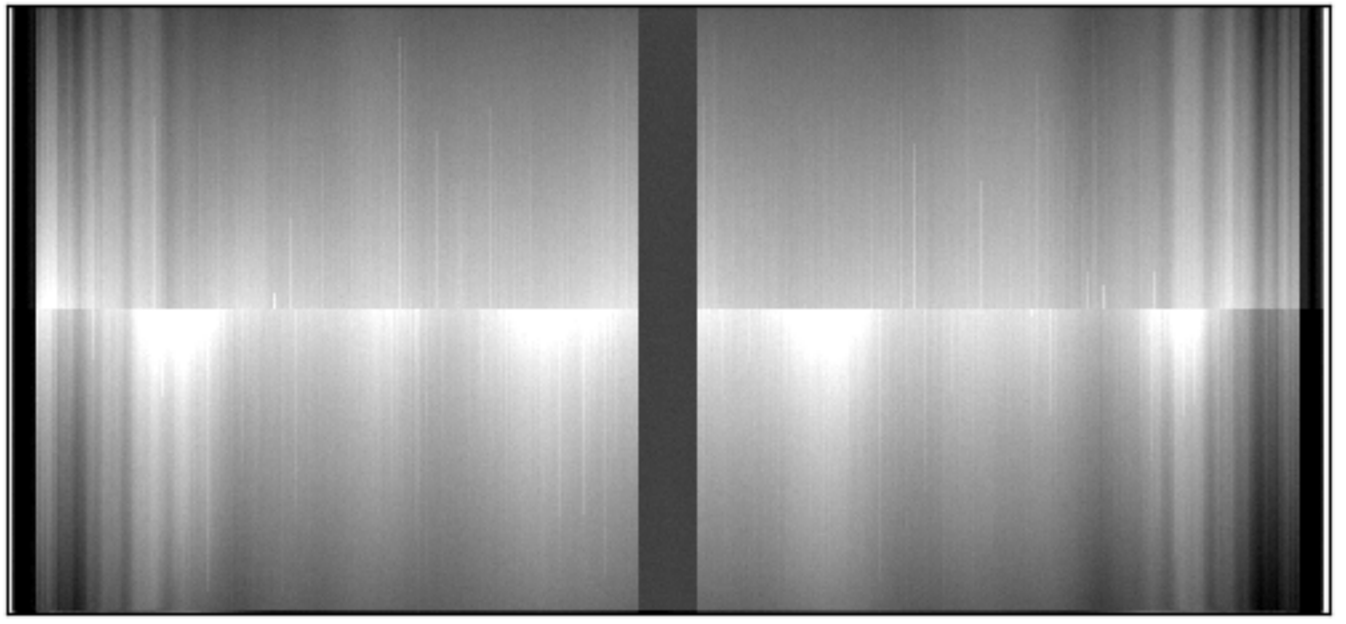
master bias ; overscan subtracted ; 20191027 ; FOCUS6



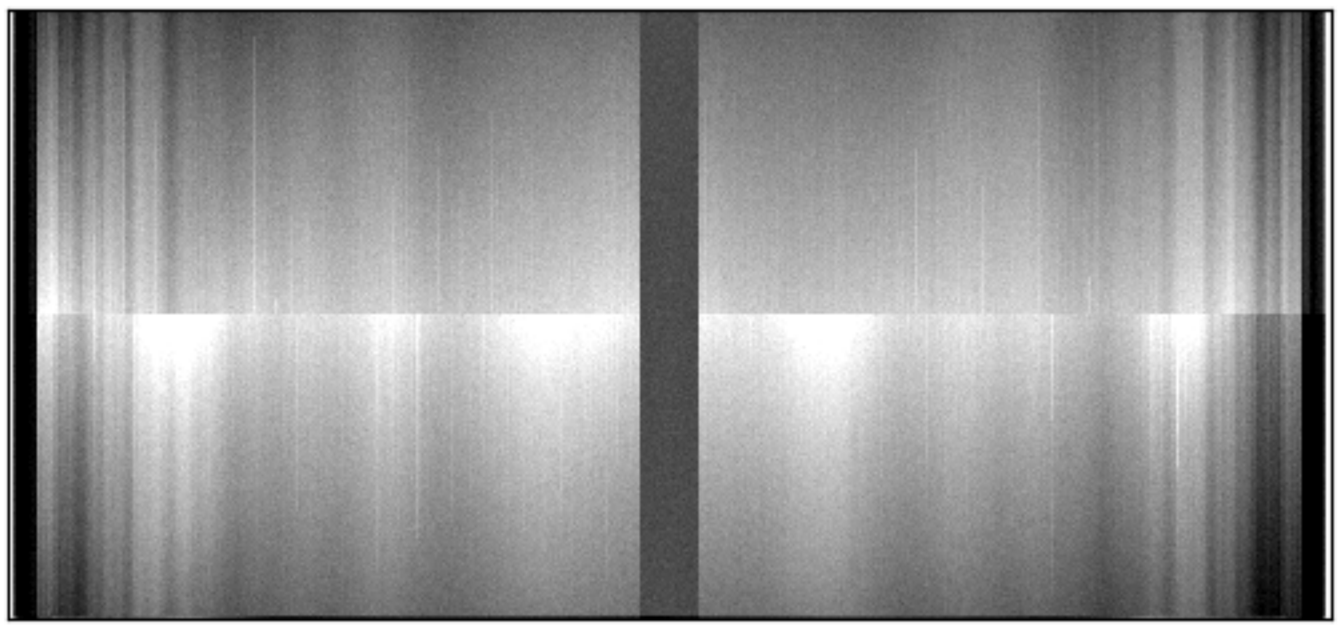
master bias ; overscan subtracted ; 20201123 ; FOCUS6



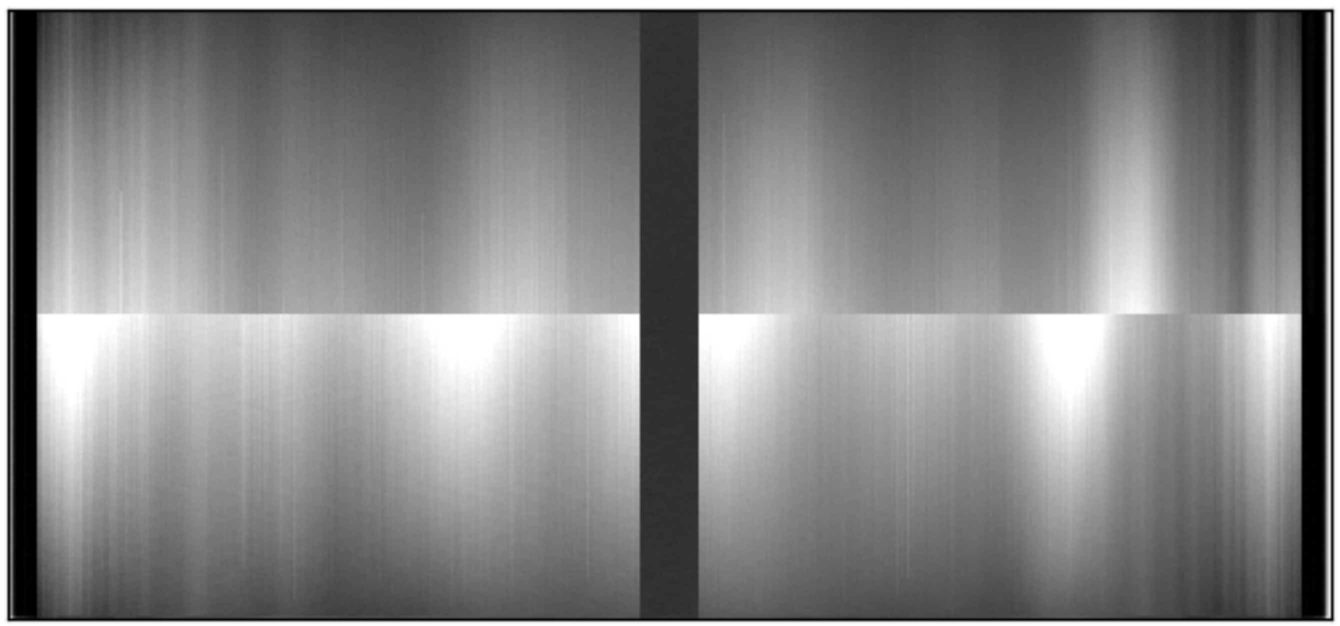
master bias ; overscan subtracted ; 20191027 ; GUIDE7



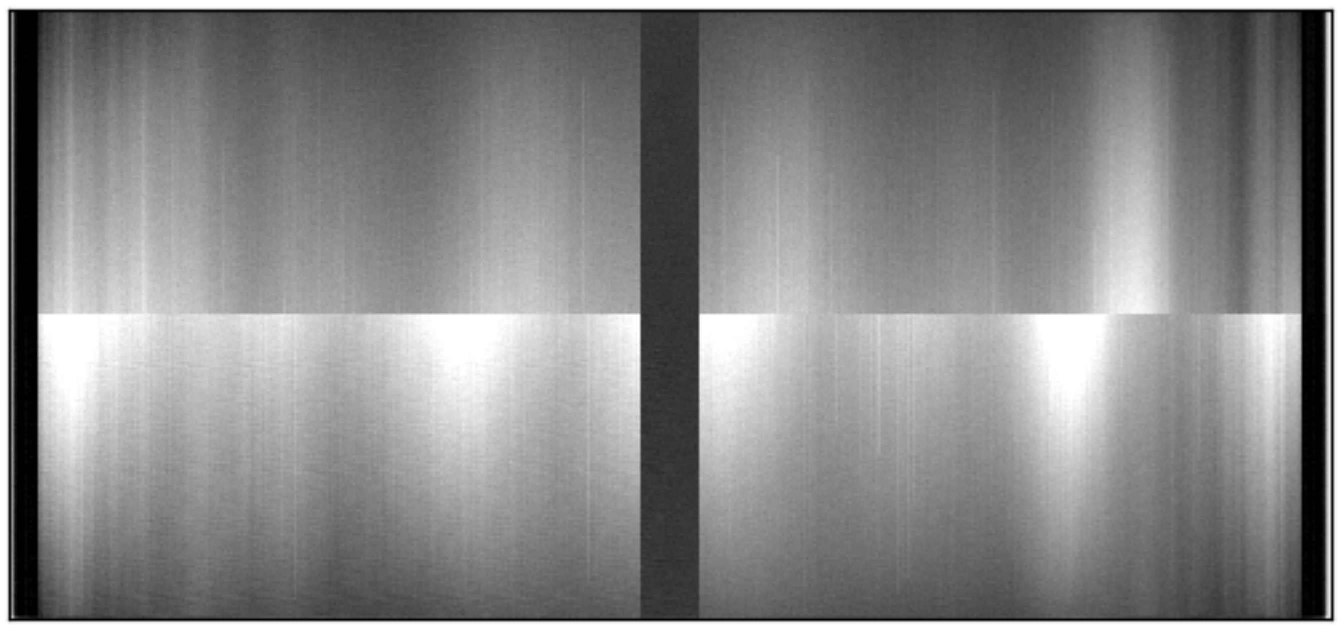
master bias ; overscan subtracted ; 20201123 ; GUIDE7



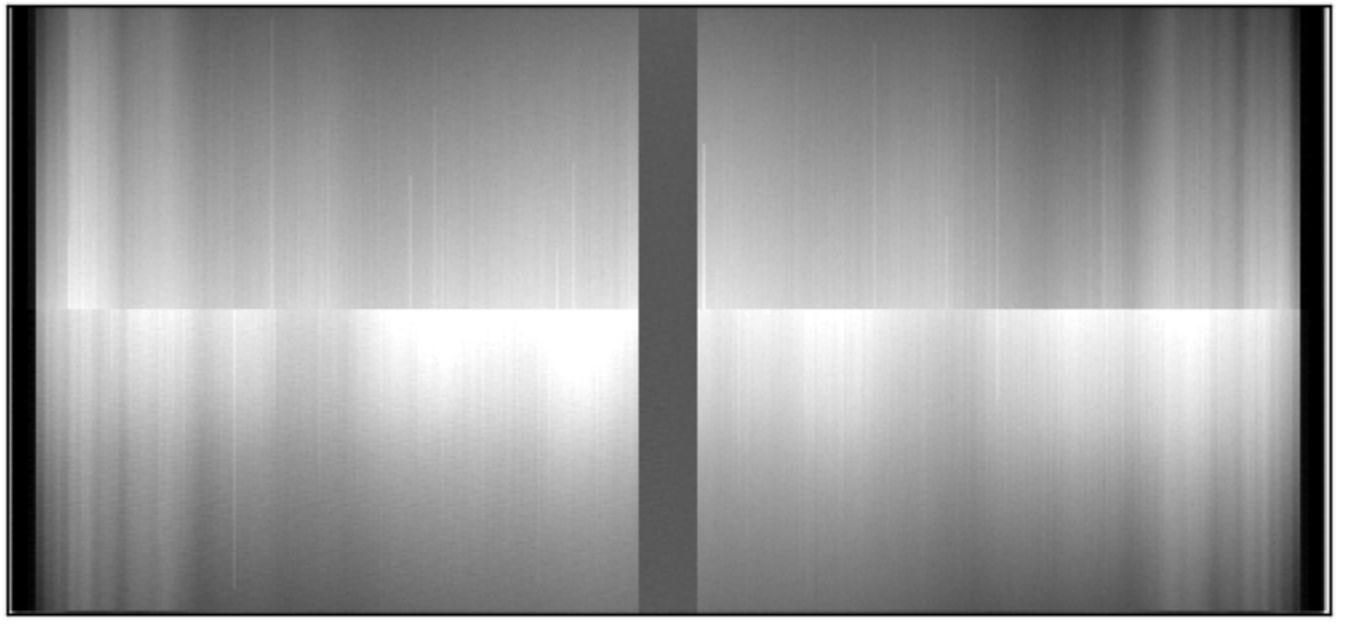
master bias ; overscan subtracted ; 20191027 ; GUIDE8



master bias ; overscan subtracted ; 20201123 ; GUIDE8



master bias ; overscan subtracted ; 20191027 ; FOCUS9



master bias ; overscan subtracted ; 20201123 ; FOCUS9