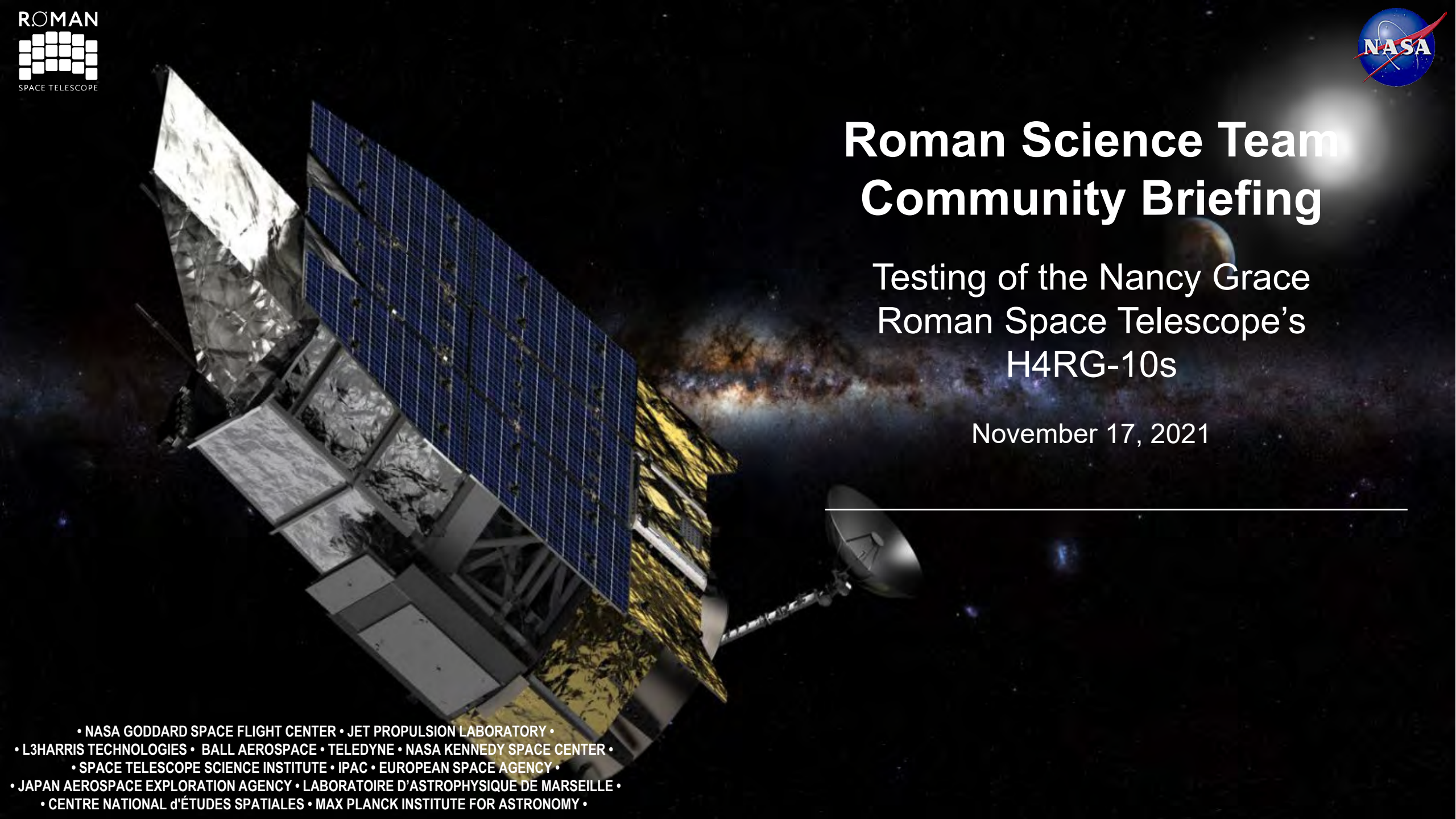

Roman Science Team Community Briefing

Testing of the Nancy Grace Roman Space Telescope's H4RG-10s

November 17, 2021

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Roman Science Team Community Briefing

Testing of the Nancy Grace Roman
Space Telescope's H4RG-10s

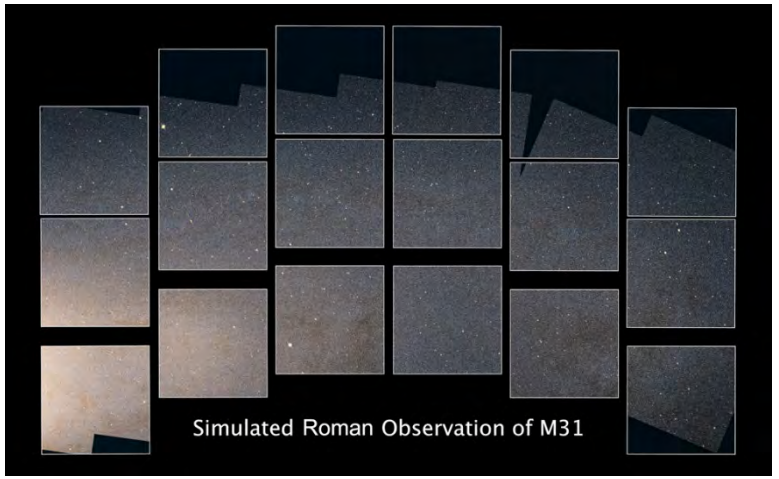
Greg Mosby with contributions from Bob Hill, and the
Goddard Detector Characterization Lab (DCL)

November 17, 2021

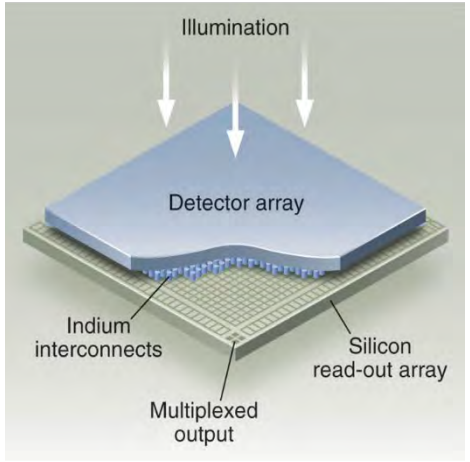
Overview

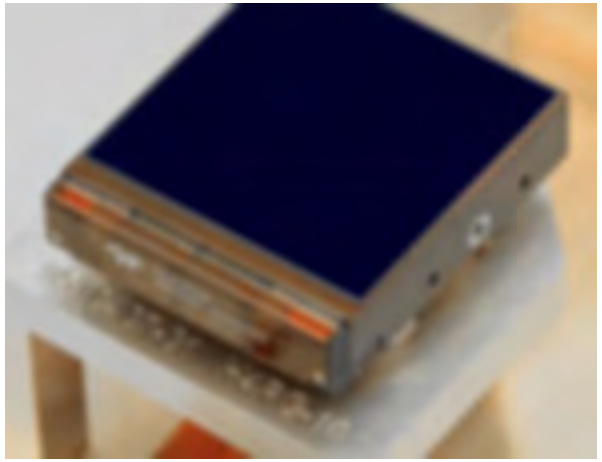
Nancy Grace Roman Space Telescope:

- Origin and evolution of dark energy
  - Exoplanet census of the Galaxy
    - General astrophysics
      - Wide Field of View and 18 detectors!

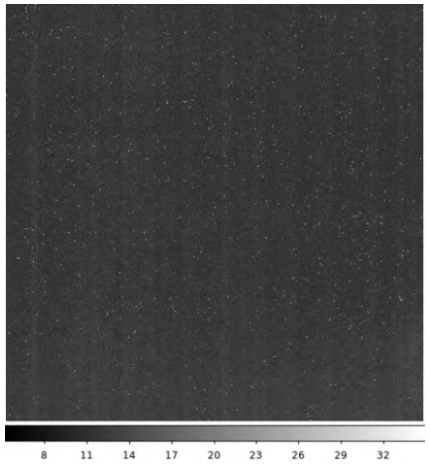


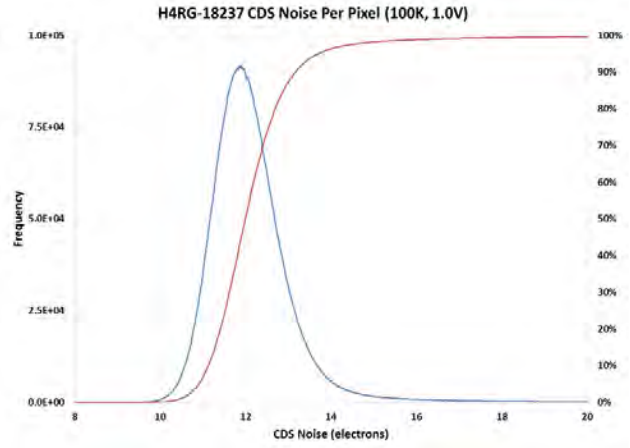
Each detector is a complex piece of electronics that must be tested to verify its performance.





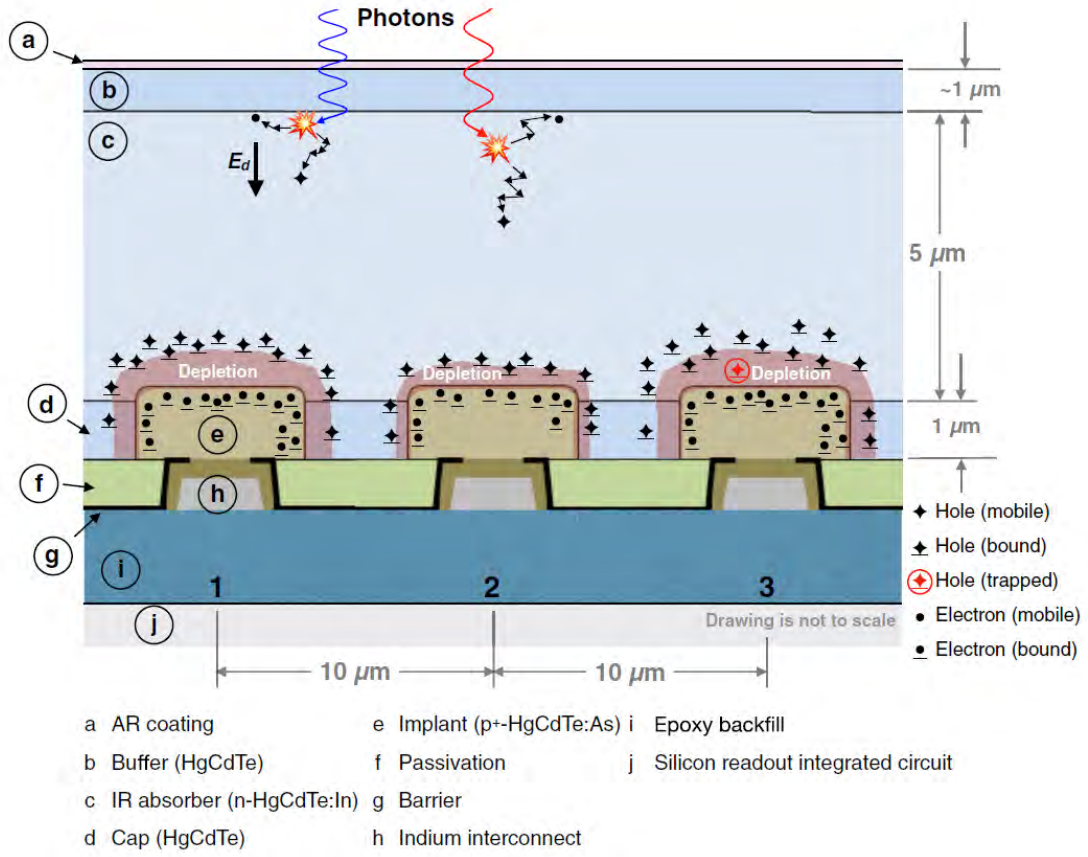
We share the characterization efforts of RST's flight detectors.





Roman Space Telescope Detectors – H4RG-10

- **H4RG-10 developed for RST to have low noise, low persistence.**
  - Detector material
    - HgCdTe (tunable cutoff wavelength)
    - Same photodiode material as JWST
    - Different passivation
  - Format
    - 4096 x 4096 vs 2048 x 2048
  - Pixel pitch
    - 10 micron size vs 18 micron size for JWST
  - Cutoff wavelength
    - 2.5 microns
  - Operating temperature
    - 95 K
  - Reverse bias
    - Using 1 V bias vs 0.5 V bias commonly seen
  - Readout Electronics
    - New ACADIA (ASIC for Control And Digitization of Imagers for Astronomy) ASIC



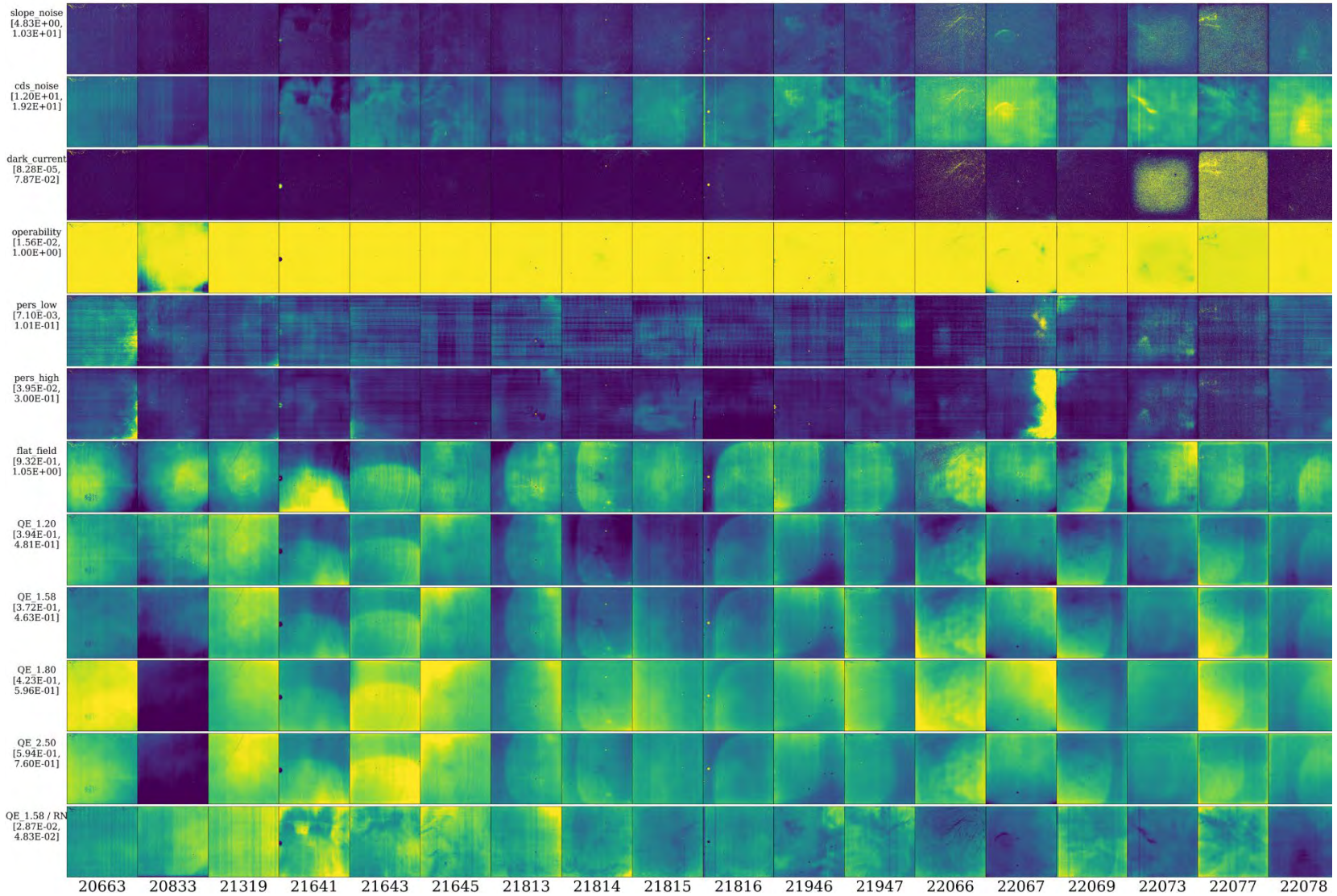
Mosby et al 2020 https://doi.org/10.1117/1.JATIS.6.4.046001

Acceptance Testing for RST Detectors

- **Each device from Teledyne that passes cold functional tests at Teledyne tested at Goddard DCL to assess flight candidate status.**
- **Provides most detailed information on detector (Sensor Chip Assembly) with non-flight readout electronics.**
- **Tests generate information on:**
  - SCA noise
    - CDS noise
    - Total noise
  - SCA dark current
  - SCA Quantum Efficiency (QE)
    - ~450 nm – 2600 nm
  - SCA disconnected pixels
  - SCA persistence
    - After stimulus of ~50 ke-
    - After stimulus of ~300 ke-
  - SCA interpixel capacitance

Test Parameter	Requirement	SCA Req. #	Test Results			
Power Dissipation	<20mW	RSCA-011	Measured Power Dissipation (mW)			
			7.70			
CDS Noise	N/A	N/A	Median (e)	Mean (e)	Modal (e)	
			13.94	14.41	13.89	
Total Noise	< 6.5 e- median < 12 e- per px	RSCA-030 RSCA-021	Median (e)	Mean (e)	Modal (e)	(%) Pixels passing
			5.14	5.92	5.07	98.19
QE	>40% for 0.48-0.6µm >60% for 0.6-0.8µm >80% for 0.8-2.1µm > 70 % per px	RSCA-024 RSCA-021	(%) Pixels passing			
			99.75			
Linearity	>80 ke Can be linearized to < 1% for > 97% of px	RSCA-021	(%) Pixels passing			
			99.71			
Dark Current	< 0.05 e-/s median < 0.5 e- /s per px	RSCA-033 RSCA-021	Median (e/s)	Mean (e/s)	Modal (e/s)	(%) Pixels passing
			0.000	0.030	0.000	98.20
Persistence 10 min (50 ke)	< 0.15 e-/s median	RSCA-039	Median (e/s)	Mean (e/s)	Modal (e/s)	
			0.026	0.019	0.024	
Persistence 10 min (300 ke)	< 0.50 e-/s median; < 0.8e-/s per px	RSCA-038	Median (e/s)	Mean (e/s)	Modal (e/s)	(%) Pixels passing
			0.062	0.061	0.059	99.66
Inter-pixel Capacitance	<2.5%	RSCA-035	Mean (%)	Maximum (%)		
			1.641	1.683		
Pixel Crosstalk: Cosmic Rays	< 1% above IPC	RSCA-034	Mean (%)	Maximum (%)		
			2.206	2.249		
Guide mode Functionality	Guide Window size, position, illumination level, shape	RSCA-067	pass			

Flight Candidate Detectors and Some Acceptance Testing Data



Flight SCAs

20663
20833
21319
21641
21643
21645
21813
21814
21815
21816
21946
21947
22066
22067
22069
22073
22077
22078

Average Flight Candidate Properties

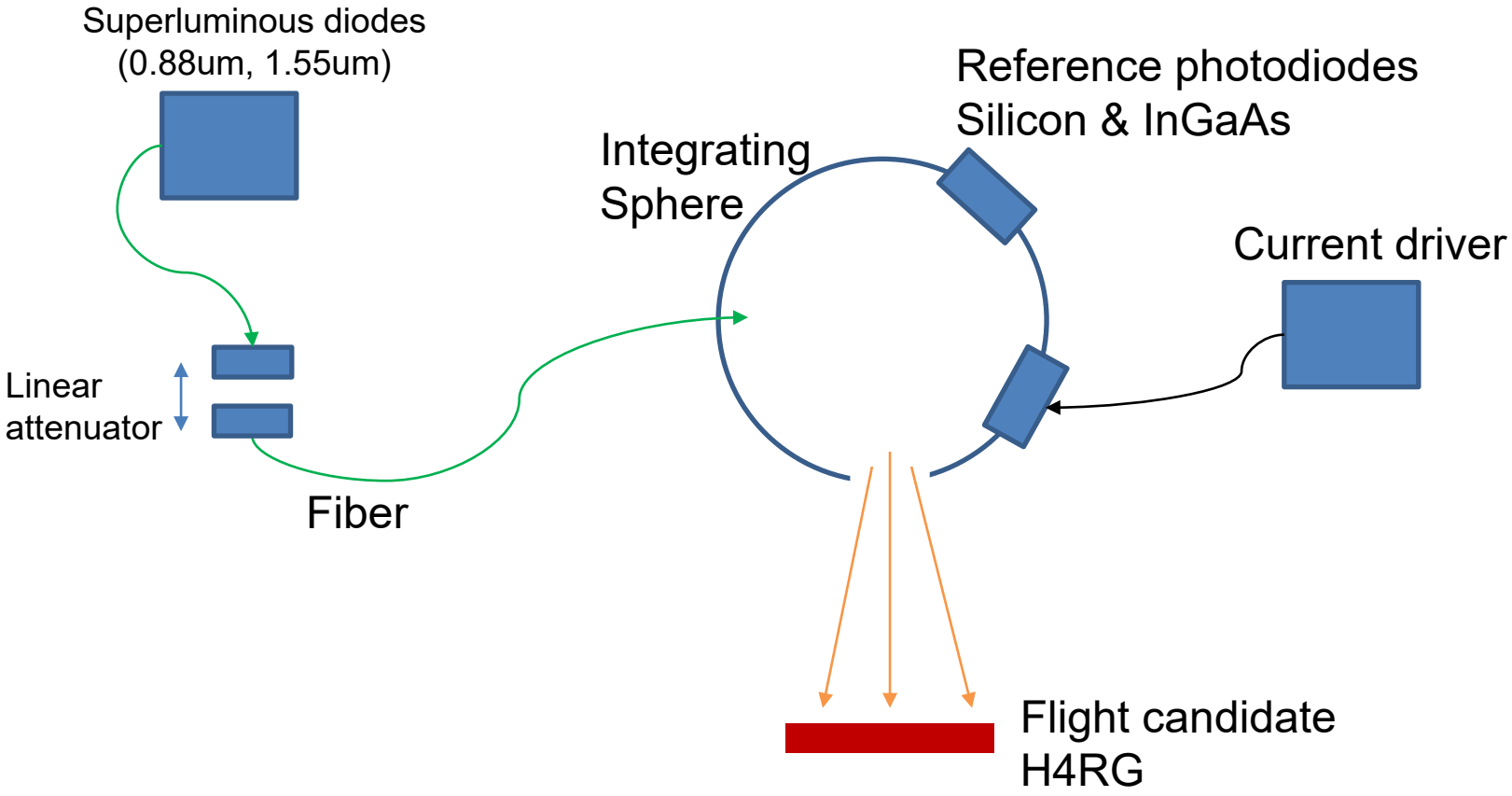
- **Noise**
  - Total Noise
    - Measures uncertainty in estimating signal observed using up-the-ramp sampling per pixel
    - Depends on number of frames up-the-ramp
  - CDS Noise
    - Measure uncertainty in estimating signal from frame differences per pixel
    - Typically used for bright objects
- **Dark Current**
  - Electrical signal in absence of illumination per pixel
  - A background signal, typically below zodi
- **Quantum Efficiency**
  - Response as a function of wavelength per pixel
- **Persistence**
  - Persistence signal in 10 mins after illumination per pixel

	CDS Noise	Total Noise		QE	Dark Current		Persistence 10 min (50 ke)	Persistence 10 min (300 ke)	
	Median (e)	Median (e)	(%) Pixels passing	(%) Pixels passing	Median (e/s)	(%) Pixels passing	Median (e/s)	Median (e/s)	(%) Pixels passing
21645	14.08	5.21	99.53	99.95	0.000	99.90	0.020	0.060	99.99
22073	16.27	5.90	97.98	99.26	0.001	98.44	0.024	0.073	99.57
21641	13.43	5.04	99.51	99.67	0.000	99.90	0.033	0.071	99.99
21814	14.30	5.33	99.44	99.76	0.000	99.91	0.020	0.060	99.98
22069	14.21	5.18	99.26	99.36	0.001	99.77	0.029	0.062	99.88
21947	14.71	5.60	99.29	99.73	0.001	99.82	0.037	0.075	99.98
22077	14.84	5.46	96.42	99.91	0.001	96.85	0.017	0.062	99.25
21643	14.60	5.42	99.50	99.96	0.000	99.89	0.030	0.070	99.96
21946	15.47	5.80	99.26	99.52	0.001	99.90	0.025	0.065	99.92
22078	17.18	6.28	99.10	99.92	0.000	99.75	0.034	0.093	99.91
20663	14.55	5.48	99.43	99.85	0.000	99.82	0.053	0.100	99.88
21815	15.10	5.59	99.48	99.82	0.001	99.94	0.030	0.080	99.98
22067	17.24	6.23	99.19	99.23	0.001	99.81	0.030	0.110	99.79
21816	14.69	5.39	99.26	99.87	0.002	99.80	0.019	0.046	99.98
21813	13.95	5.25	99.50	99.84	0.000	99.95	0.031	0.072	99.98
20833	13.14	4.97	99.64	98.86	0.000	99.94	0.027	0.074	99.93
21319	13.85	5.14	99.39	99.91	0.000	99.96	0.029	0.075	99.96
22066	16.30	5.92	98.93	99.81	0.001	99.60	0.010	0.060	99.89
Mean	14.88	5.51	99.12	99.68	0.00	99.61	0.03	0.07	99.88
Median	14.65	5.44	99.34	99.82	0.00	99.86	0.03	0.07	99.95
Std. Dev	1.187	0.384	0.767	0.310	0.001	0.770	0.009	0.016	0.187

Flux Dependent Nonlinearity Testing for RST Detectors

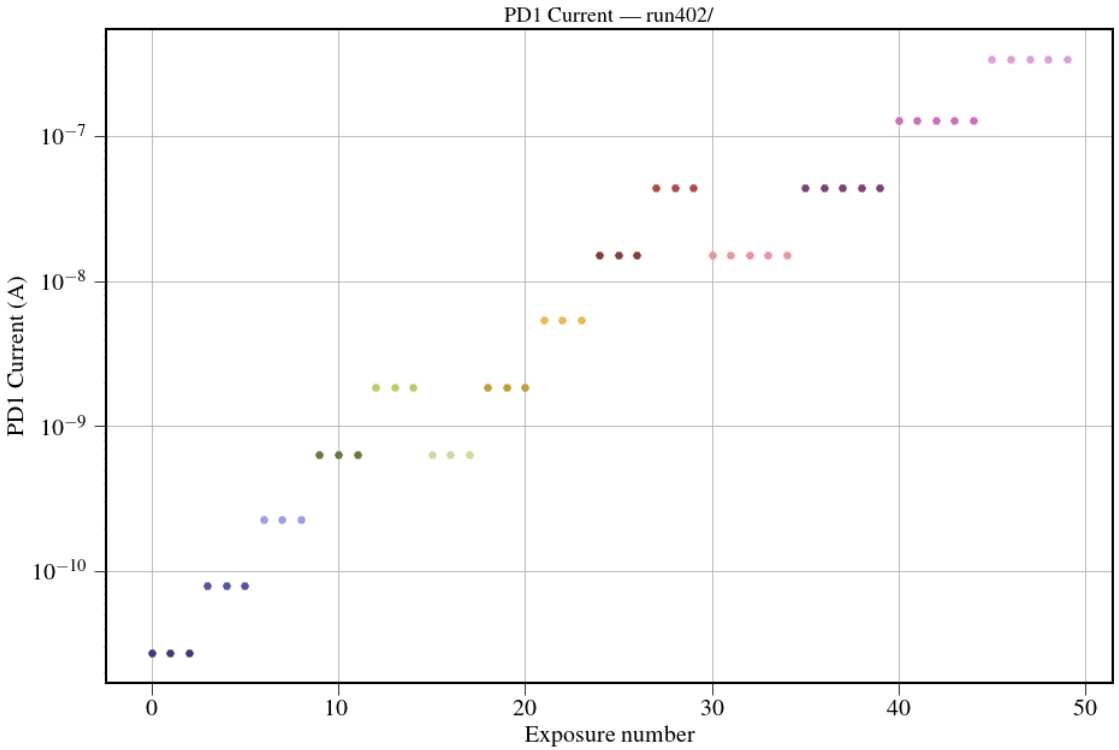
- **Flux dependent nonlinearity (also reciprocity failure, count-rate nonlinearity) is dependence of SCA response to the incident flux level.**
- **Important for precision photometry**
  - Example
    - Faint sources have underestimated fluxes -> shape errors due to PSF underestimation and overestimation of SN luminosity distance
  - Historical measurements of the magnitude and color dependence of CRNL in HgCdTe devices have varied due to device architecture
    - e.g NICMOS's large color dependence seen vs WFC3's lack of apparent color dependence
- **All flight candidate detectors undergo characterization for this in the Goddad DCL at two wavelengths (880 nm and 1550 nm)**

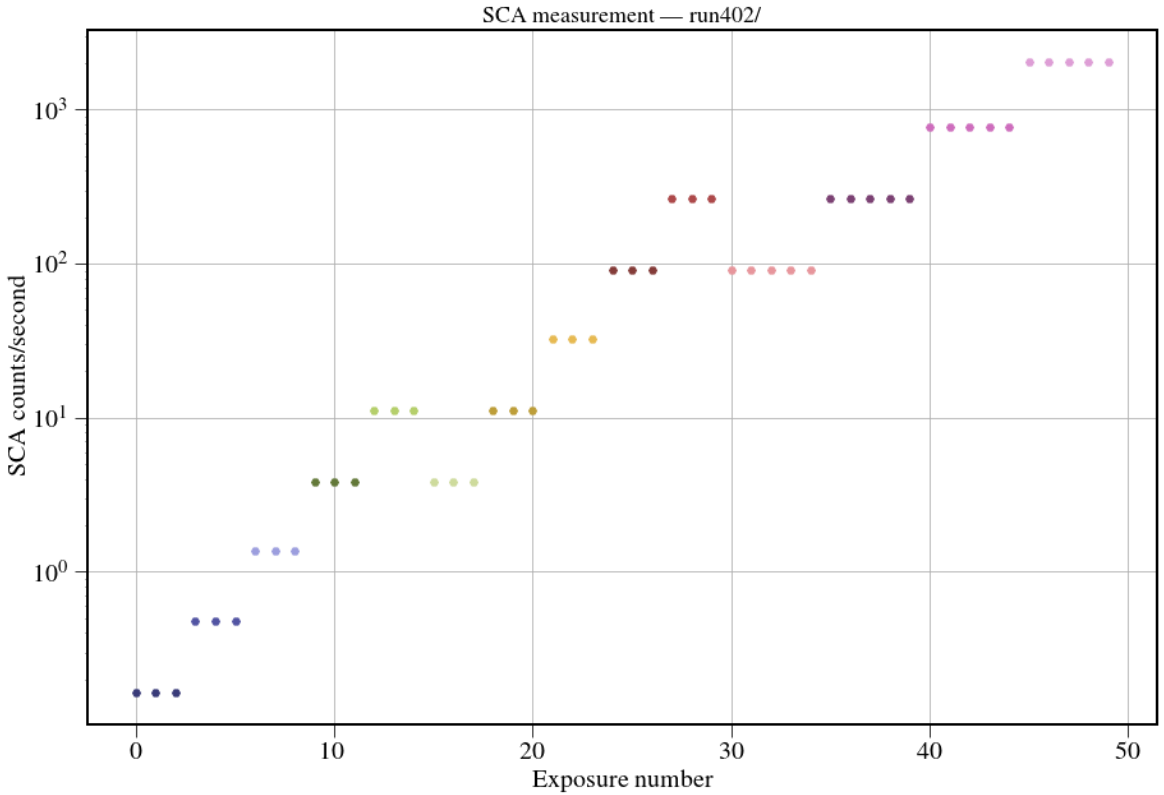
FDNL Testing Setup



The current plan is to measure CRNL for all flight candidates at 0.88um and 1.55um

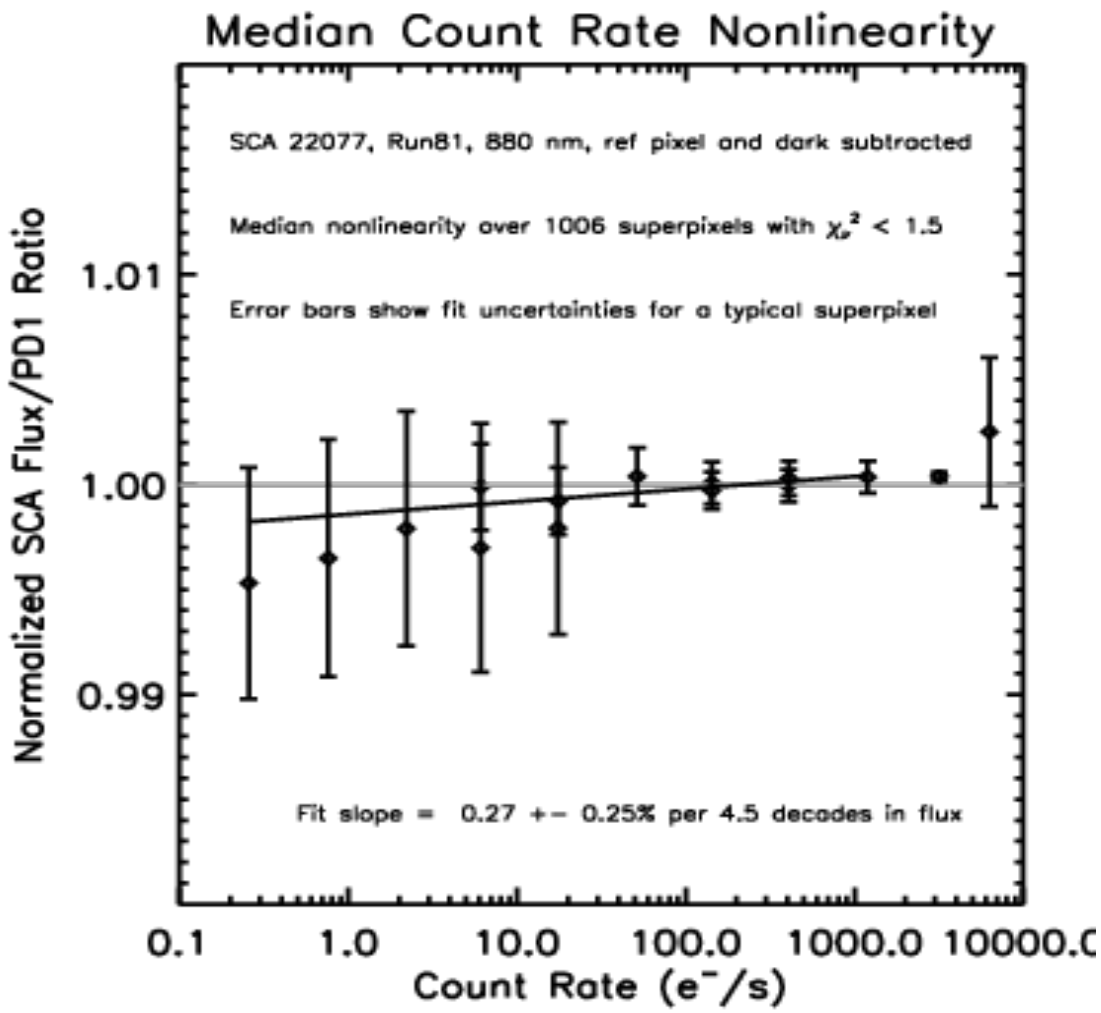
The data acquisition is a series of exposures at different fluxes.

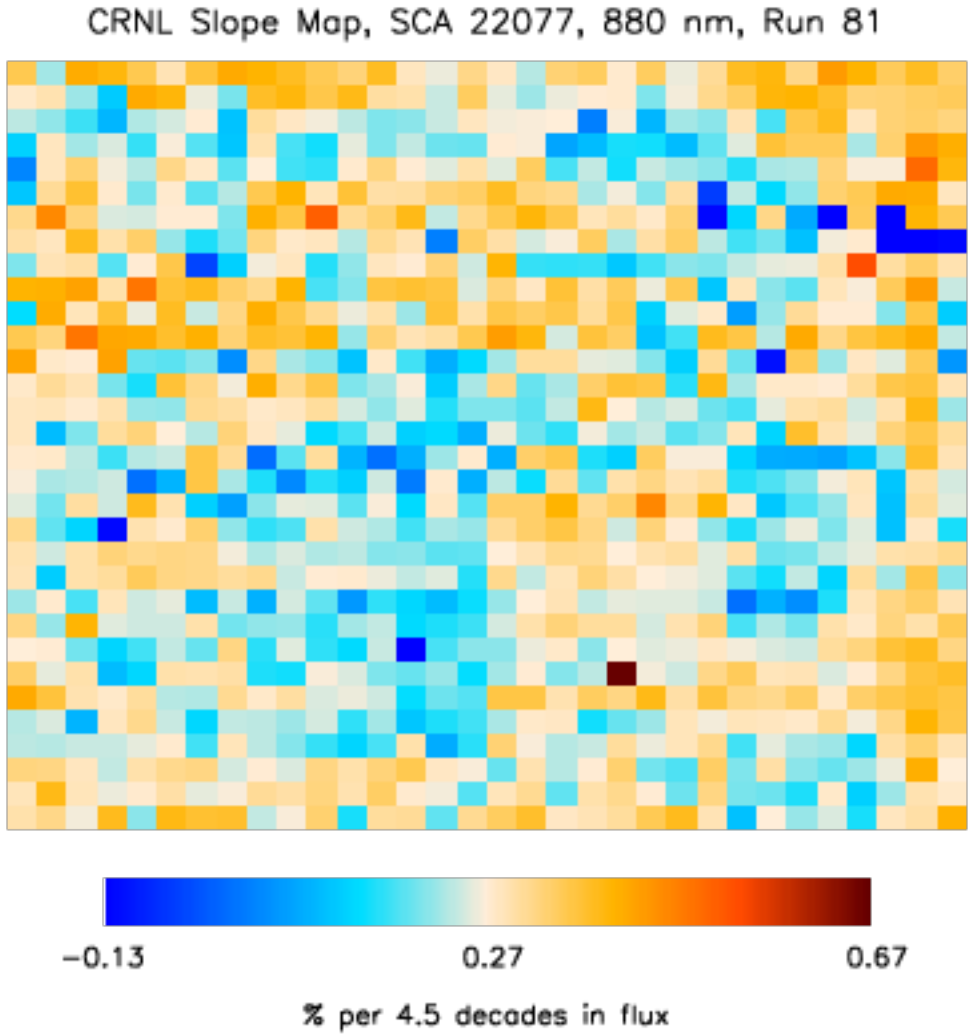




Each point corresponds to an average over a WFI detector (SCA) exposure; each color is a different LED flux

The response of the SCA is compared to a photodiode to estimate nonlinearity.





Triplet Testing of Flight Candidate SCAs

- **Triplet testing is the testing of 1 flight SCA, 1 flight cable, and 1 ACADIA ASIC (also called Sensor Control Electronics)**
- **Before focal plane integration, these tests represent the most flight-like environment for the RST detectors.**
- **Tests generate information on:**
  - Interpixel capacitance with flight SCE
  - Thermal sensitivity of SCA
  - Thermal sensitivity of SCE
  - Long term photometric stability
  - Crosstalk (output to output and SCA to SCA)
  - Triplet Noise
    - Total Noise with SCE
    - Total Noise with SCE and Guide Windows enabled
  - Second look at SCA properties
    - SCA Flatfield uniformity
    - SCA dark current

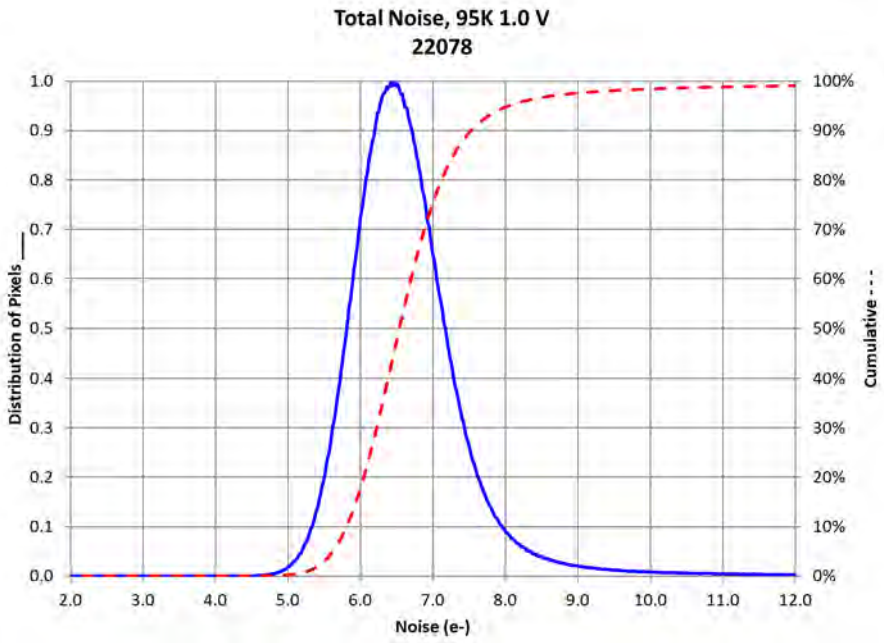
Triplet Testing of Flight Candidate SCAs

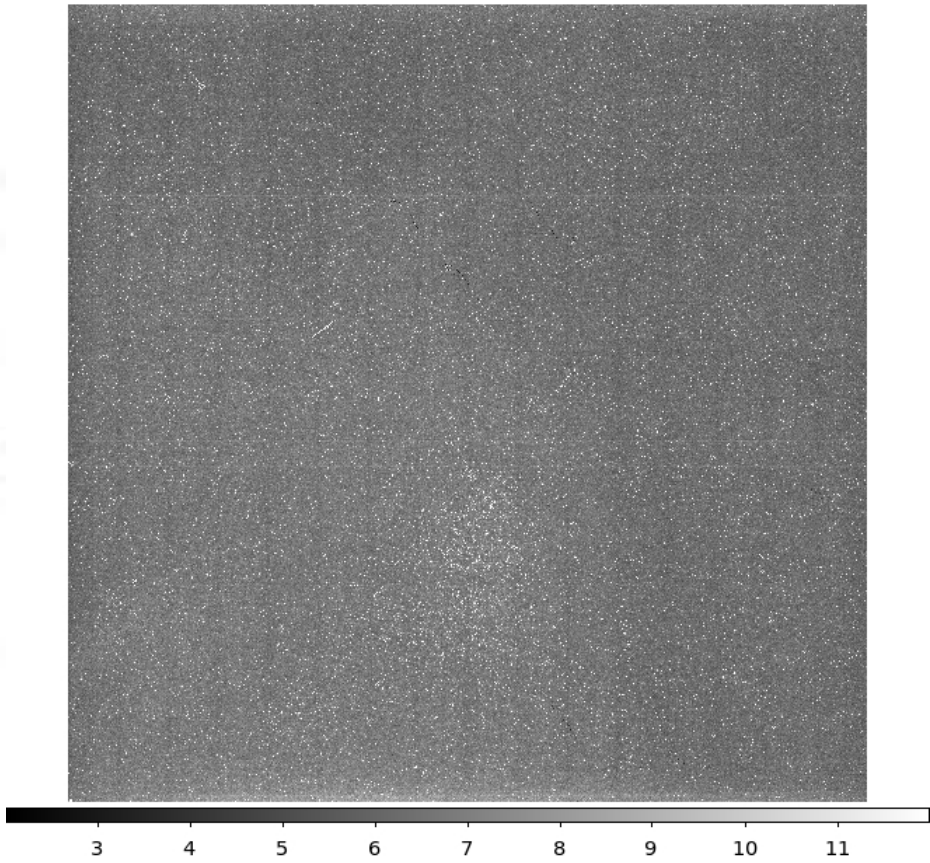
- **Triplet testing is the testing of 1 flight SCA, 1 flight cable, and 1 ACADIA ASIC (also called Sensor Control Electronics)**
- **Before focal plane integration, these tests represent the most flight-like environment for the RST detectors.**
- **Important differences between Acceptance Testing and Triplet Testing**
  - Use of ACADIA ASIC and flight like cable
  - Reset mode of detector in pixel by pixel reset for all tests if possible
    - Acceptance Testing used line by line reset early in test cycle
  - Use of Guide Windows
    - Acceptance Testing only tested GW functionality otherwise GW not enabled
  - Reference Output digitization is enabled
    - Acceptance Testing did not digitize reference output.
  - Operating in differential mode
    - Acceptance Testing in single-ended

Example Total Noise Results from a Triplet

95 K 1.0 V	Triplet TLR ref px corr	Triplet Top ref px corr.	Triplet GW TLR ref px corr.	Triplet GW Top ref px corr.
Median (e-)	6.56	6.59	6.55	6.54
Mean (e-)	7.16	7.19	7.27	7.26
Gaussian Mean (e-)	6.51	6.53	6.50	6.48
% pxs passing requirements	99.05	99.04	99.03	99.03

Histogram Noise in GW mode
TLR px correction

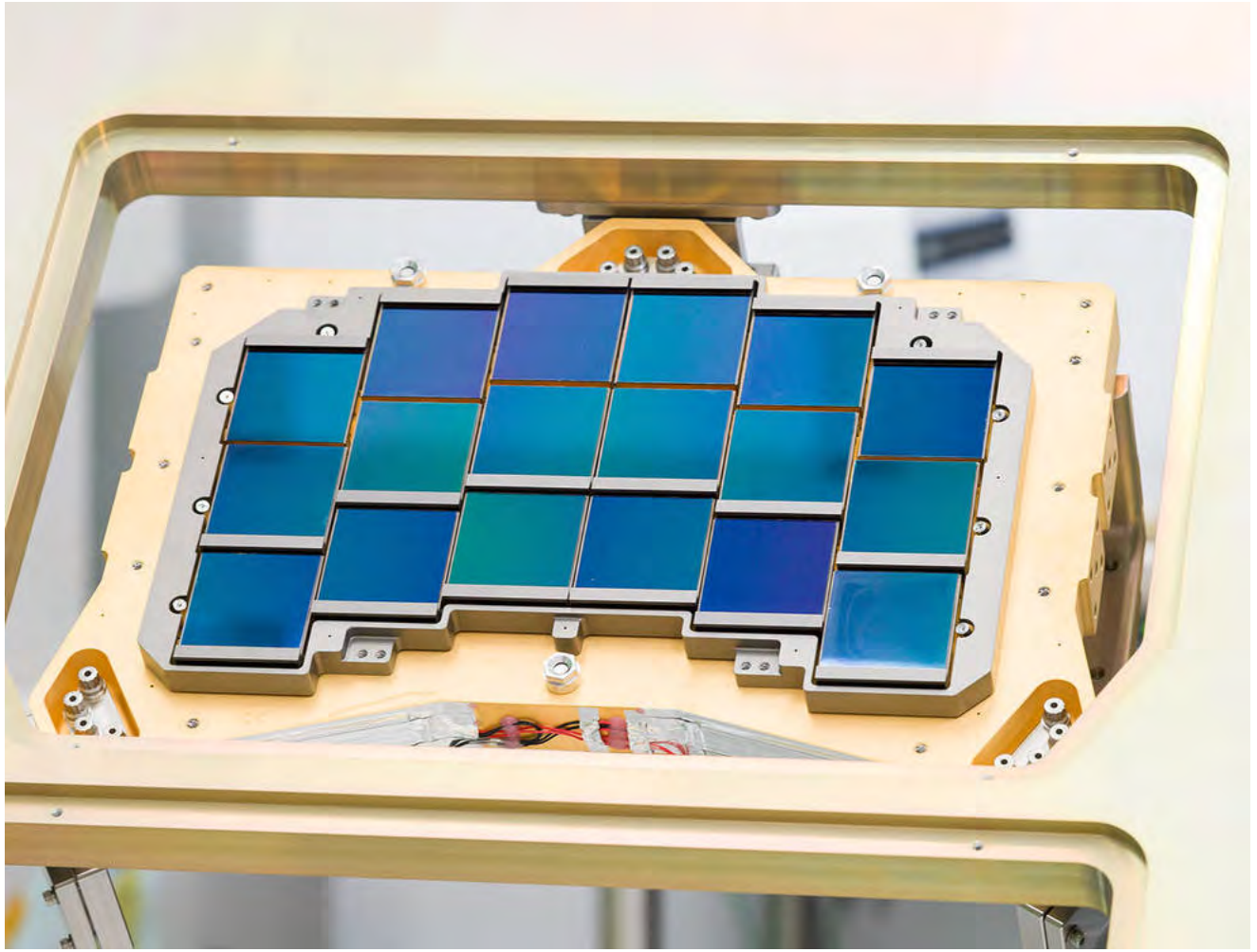




100 exposures triplet in GW mode

After triplet testing candidates installed into the focal plane.

- ETU Model of focal plane with non-flight candidates pictured.
  - The ETU focal plane has since completed thermal vacuum testing reading out all 18 devices.
- First 6 flight candidates being installed in middle row of flight mosaic plate after metrology and final spacer installation.
- After integration of flight SCAs & flight focal plane electronics, flight focal plane system will undergo TVAC.



Ongoing and Additional Testing on the Horizon

- **After flight triplet testing and installation of flight detectors complete, it is expected that additional work will continue to understand how best to operate and calibrate RST detectors**
  - Optimizing reference pixel correction to remove 1/f noise
    - Important for removing correlated noise
  - Characterizing sub-pixel response across SCAs
    - Important for assessing intra-pixel sensitivity variations that will be important to quantify for calibrations.
  - Carefully analyzing Classical Nonlinearity
    - Important in interpreting flux dependent nonlinearity results that depend on the classical nonlinearity correction used.
  - Examining cross talk in Roman Triplets
    - Some vertical crosstalk seen in triplets that must be investigated.

Data Archive

- **All test data being stored on NASA NCCS ADAPT system**
- **Data from Acceptance Testing uploaded as FITS cubes**
- **Data from Triplet Testing converted from raw tiff files and uploaded as FITS cubes**
  - Includes reference output in all image extensions
  - Includes guide window reads in a named extension
  - Includes reset frames in a named extension
- **Availability**
  - Contact me (gregory.mosby@nasa.gov) if you're interested in accessing Roman detector data.


Hubble
Nancy Grace Roman Space Telescope