WFI Calibration Working Group Report

Roman Science Team
Community Briefing
November 17, 2021

Stefano Casertano, Neil Zimmerman,
and the Calibration WG

• NASA GODDARD SPACE FLIGHT CENTER • JET PROPULSION LABORATORY •
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The WFI Calibration Working Group

- **Started in February 2016 as one of the Project-wide working groups empaneled by the Formulation Science Working Group**
- **Co-chairs: Stefano Casertano, Dan Scolnic (through 2020), Neil Zimmerman (starting 2021)**
- **Spectroscopy lead: Phil Appleton**
- **Over 50 members: GSFC, SOC, SSC, most Science Teams, other experts**
  - Membership open; regular invites issued during FSWG telecons
  - Close collaboration with Detector Working Group
  - Meeting virtually on a weekly basis (currently Tuesdays 2pm EST/EDT)
    - Typical attendance 20-25 people
    - Notes and presentations available on Outerspace
  - Four in-person Calibration Workshops (1-2 days each, 2018-2019)
- **Main responsibilities:**
  - Advise Project on issues concerning WFI performance and data quality
  - Maintain knowledge of expected calibration accuracies
  - Follow ground tests and support evaluation of their results as appropriate
  - Develop on-orbit calibration plan tailored to meeting Mission science objectives, including resource estimates
  - Create ad-hoc study teams to address specific questions (e.g., RCS performance requirements)
  - Report regularly to broader Roman community
    - Status reports at in-person FSWG meetings
    - Since 2020, brief updates at FSWG telecons (approximately bimonthly)

Main activities in 2021

- **Support development of Calibration Overview Document**
  - Provides more detailed breakdown of specific Science Requirements; complementary to Calibration Plan
- **Review plans for simplified Relative Calibration System**
  - New hardware presented in June 2021; different approach to direct flux measurement
- **Flat field analysis**
  - Review plans for flat field quality during ground test
    - Issues include smoothness, S/N, number of wavelengths
    - Wil be revisited in greater detail during TVAC plans
- **Review of reference pixel information in Level 2 (calibrated) data**
  - WG requested that Level 2 data contain reference pixels (used in first stage of calibration pipeline)
  - Proposal for data organization from SOC DMS reviewed and approved
- **Triplet Test review (see presentation by Mosby for more information)**
- **Discussion on handling of reference pixel correction**
- **In-depth view (separate slides)**
  - Major update of the on-orbit Calibration Plan
  - Touchstone Fields concept
  - Calibration Peer Review
  - Placement of detectors in focal plane
  - Bright object observations and Defocus mode test

Flight Calibration Plan update

- **Describes in-flight calibration activities**
  - Targeted to meet Mission Science Requirements
  - Uses currently available estimates of detector/instrument properties, experience from previous Missions to estimate calibration frequency
  - Error budgets developed for some cases (complement Calibration Overview document)
  - Detailed program descriptions, but in most cases no end-to-end simulation of calibration process
    - Astrometry is the exception
- **Earlier versions developed in 2017 and 2019**
  - 2017 version had more extensive descriptions and justifications, less detailed program definition
  - 2019 version used for Mission PDR, included detailed program breakdown and time estimates
- **2021 update revisited several key areas**
  - Major updates in spectroscopy (led by SSC)
  - Additional darks due to difference in timing between imaging and spectroscopy
  - More emphasis on touchstone fields
  - Uniform accounting for observing overheads (including slews)
  - Other minor adjustments and improvements
- **Total time requirements for 5 year mission is 113.6 days – 6.2%**
  - In addition, most calibrations will take advantage of regular science data
- **Caveat: Calibration Program does not yet account for changes in RCS**
  - Wait for finalized design before redefining the necessary calibrations

Flight Calibration time estimates

	Calibration	Time per execution (hours)	Cadence	Average time / year (hours)	Total time over mission (days)
Detector	Imaging darks	3.1/2.0	Weekly	146.9	30.6
	Spectroscopy darks	2.0	Weekly	80.0	16.7
	Pixel-level Flat Field	2.3	Monthly	27.8	5.8
	Subpixel response	180.6 (Yr 1) / 60.6	Yearly	84.6	17.6
	CRNL (to be revisited)	Varies	Varies	87.0	18.1
Imaging	Small-scale photometric uniformity	8.3	Yearly	8.3	1.7
	Bandpass Uniformity	8.3	Twice in 5 yr	3.3	0.7
	Spectrophotometric flux calibration	17.3	Yearly	17.3	3.6
	Temporal Stability	1.0	Quarterly	4.0	0.8
	Cross-survey Calibration	7.8	Twice per year	15.6	3.3
	Geometric Distortion	23.4	Yearly	23.4	4.9
Spectroscopy	Pointing Reconstruction	2.0	Twice in 5 yr	0.8	0.2
	Wavelength solution	1.3	Twice per year	2.5	0.5
	Wavelength validation (PN)	7.5	Twice in 5 years	3.0	0.6
	Spectroscopic touchstone fields	4.7	Monthly	33.6	7.0
	Absolute flux calibration	8.3	Yearly	8.3	1.7
	Total			**546.6**	**113.6**

Touchstone Fields

- **Instrument stability is a key component of reliable calibration**
- **Thanks to its large field of view, WFI can observe wide fields and lots of targets efficiently**
- **To take advantage of this capability, the Calibration WG has developed the concept of Touchstone Fields**
  - Special regions of the sky with the right mix of target brightness and density
  - Different regions may be needed for different calibration properties and modes
  - Each region is observed repeatedly (monthly to yearly) for high precision checks of instrument stability
- **Touchstone fields complement, do not replace other calibrations**
- **At least four different categories:**
  - Astrometric (yearly)
  - Photometric (quarterly)
  - Spectroscopic (grism, monthly)
  - Spectroscopic (prism, monthly)
  - Some categories may use more than one field; some fields could overlap
- **Group consensus reached on the *properties* needed for each field**
  - Specific fields not identified, although candidates exist (e.g., LMC for astrometry, Euclid Deep Field for spectroscopy)
  - Some fields might benefit from pre-launch, ground-based characterization (not required)

Calibration Peer Review

- **Review took place July 16+19, 2021; review panel led by Randy Kimble**
- **Two afternoons of presentations:**
  - Mission science requirements
  - Calibration Overview document (requirement breakdown)
  - Ground testing plans
  - On-orbit calibration plan
  - Touchstone fields
- **Major updates to key documents (Calibration Overview and Calibration Plan), provided to Review Panel in advance**
- **Report received late August**
  - 10 RfA, 3 Advisories, 4 Comments
- **Major findings:**
  - Error budgets need further review for completeness and reasonability
    - Insufficient time to evaluate individual error budgets with the level of detail the panel felt necessary
    - Follow-up reviews needed each focused on a single critical error budget
  - Subpixel characterization needs more detail
    - Current plans include on-orbit subpixel response tests
    - Additional targeted ground tests recommended
- **Response to RfAs submitted October 27**
  - Response to Advisories and Comments in progress

Summary of RfAs

Requests for Action		
RFA #	Originator	Topic
01	Panel (Finding 1)	Review of error budgets for completeness and reasonability
02	Panel (Finding 2)	Intrapixel sensitivity calibration: integration of test plans and error budgets
03	Rieke	Achieving absolute calibration to required level
04	Brown	Optical ghosts
05	Brown	Integration of flat field methodologies
06	Brown	Proper motions
07	Brown	Detector tip/tilt calibration plan
08	Sloan	Separating components of the spectrophotometric calibration
09	Sloan	Observations of spectroscopic standard stars
10	Kimble	Filter witness samples

Bright source calibration

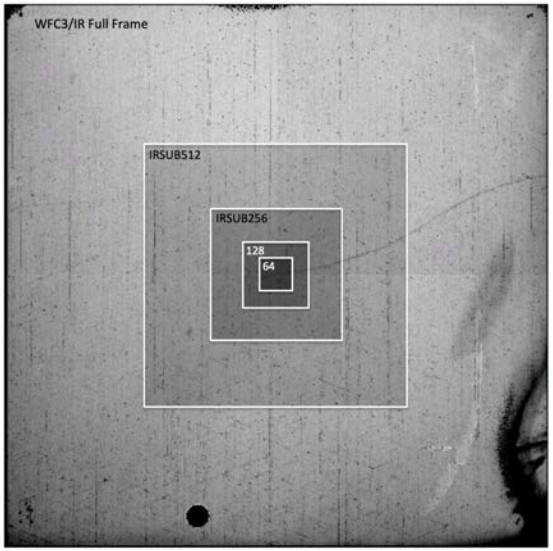
- Established white dwarf photometric standard stars are too bright for direct observation (count rates > 15k e/s) => poses challenge for meeting absolute flux and color calibration requirements.

- Calibration WG is pursuing several mitigation approaches in parallel:
  - Cultivate new, fainter standards (projects led by Susana Deustua and Phil Appleton)
  - Develop special, bright object observing modes

Bright source calibration

Bright source observation methods under consideration:

1. Detector subarray



Kalirai, Deustua, et al., STScI Instrument Science Report WFC3 2011-08 (2011)

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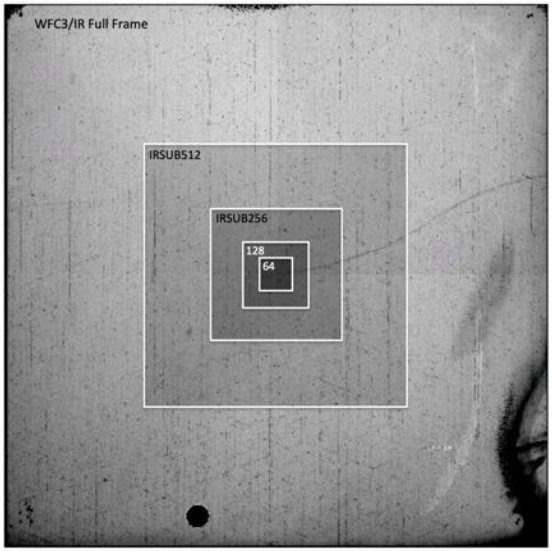

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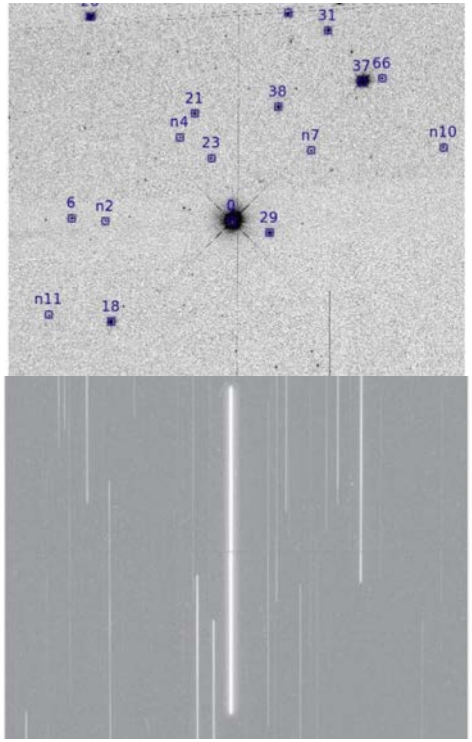
2. Spatial scan



Riess, Casertano, et al., ApJ 861, 126 (2018)

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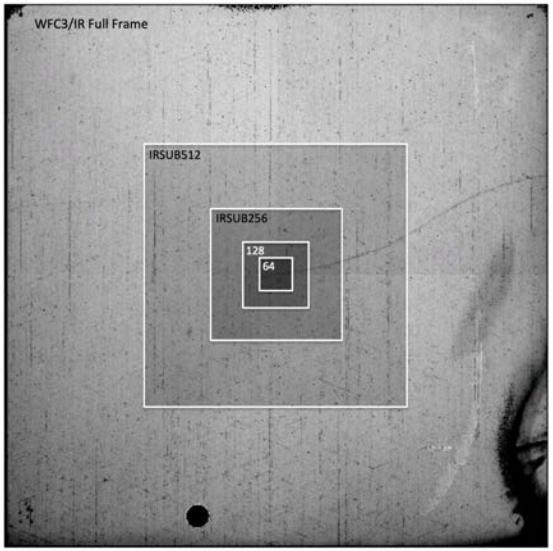

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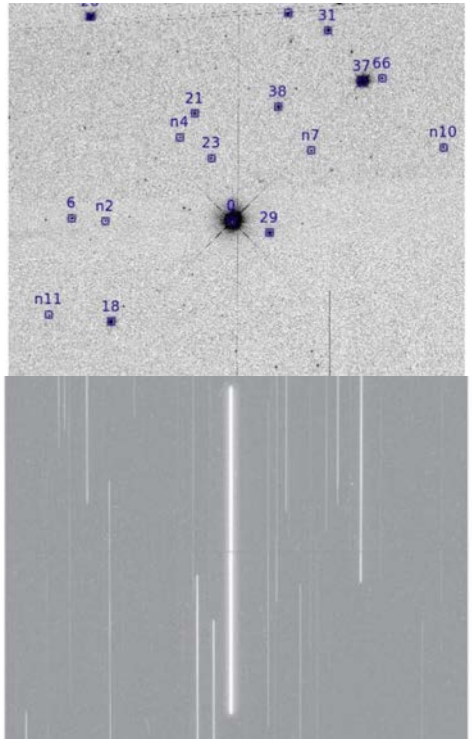

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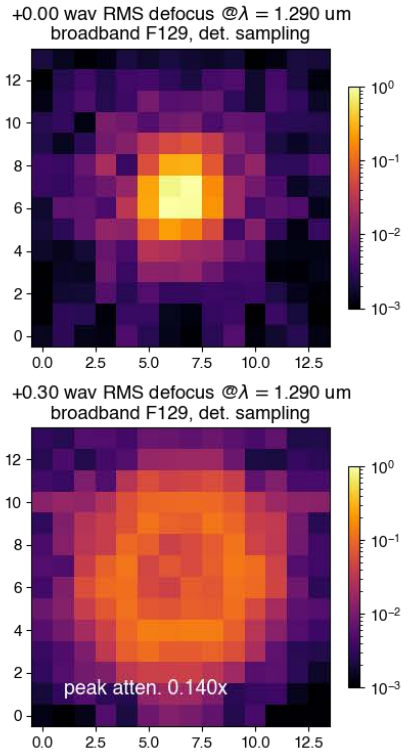
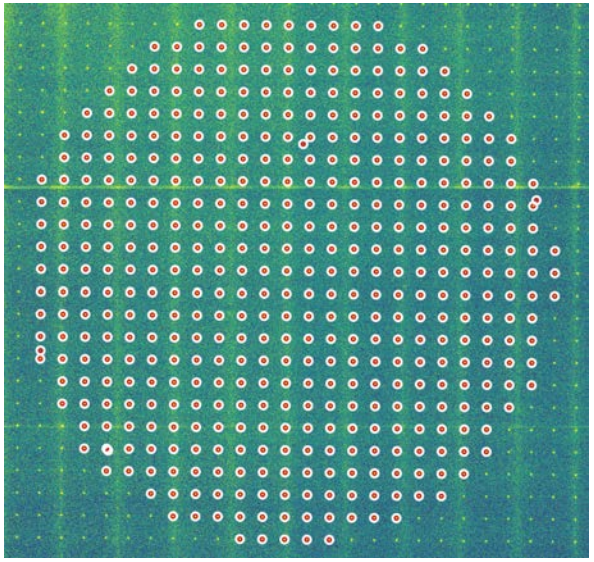
3. Defocused PSF

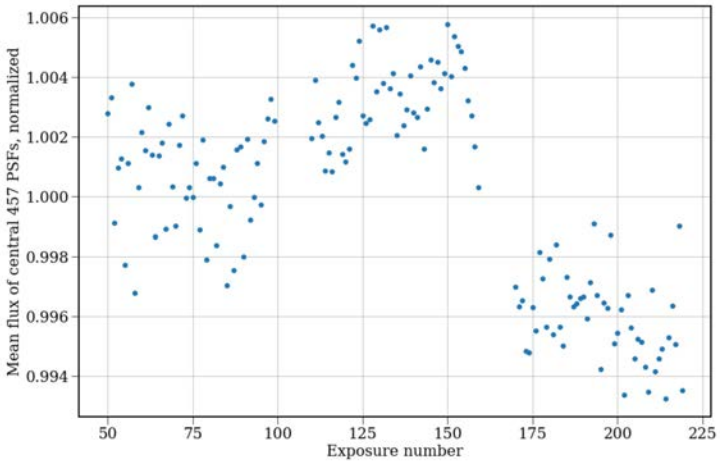


WebbPSF simulation

Defocused PSF test data

- Defocus test data obtained this year by Chaz Shapiro on JPL Precision Projector Lab testbed (*Shapiro et al., JATIS, 2019*).
- Grid of diffraction-limited Airy disk PSFs on H4RG detector, matched to WFI f/# and sampling, repeated in focus and defocused by +/- 0.4 waves.
- WG is currently analyzing photometric consistency between focus states.





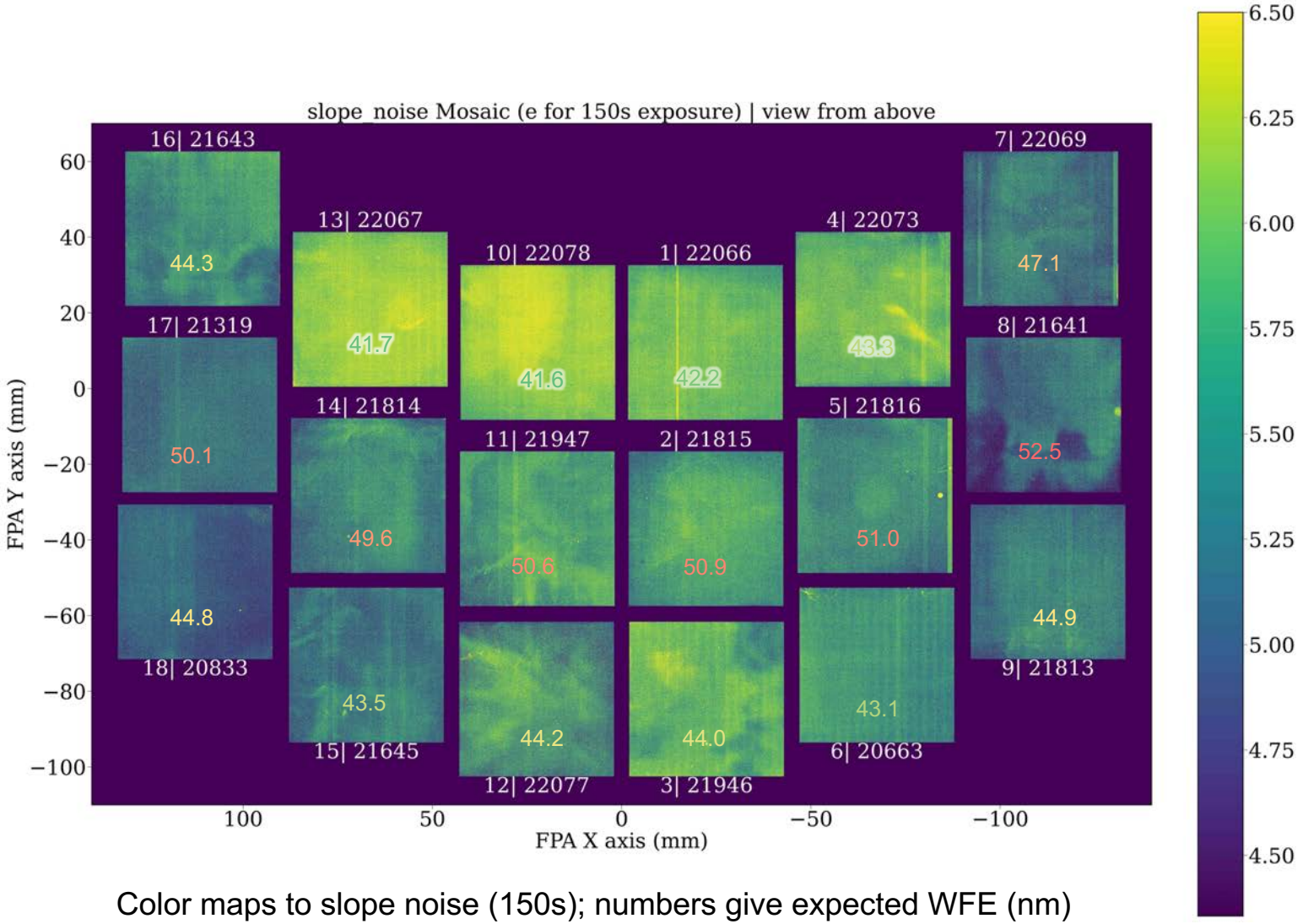
Plots courtesy of Maxime Rizzo

Detector Selection and Placement

- **Assisted the Project in reaching a consensus on the best 18 detectors (out of 28 candidates) for the flight focal plane**
  - Agreement in Calibration WG, Detector WG, with strong input from DCL and Science teams
  - Other detectors remain viable if new issues are found

- **Suggested priorities & criteria for detector placement**
  - Primary criterion: balance sensitivity, image quality to achieve better uniformity for surveys
  - Avoid placing regions with regions of bad pixels where optical performance is best or where they increase effective chip gaps

Detector Placement in the Focal Plane



Color maps to slope noise (150s); numbers give expected WFE (nm)
(Courtesy Josh Schlieder)

Future Plans

- **Calibration Working Group will continue to meet regularly (Tuesdays 2-3pm ET)**

- **Activities planned for next year**
  - Finalize recommendations on bright object observations
  - Continue reviewing performance from Triplet Test and Focal Plane System test
  - Iterate with Calibration Peer Review panel as needed
  - Support preparation for Instrument I&T and other ground tests
  - Support development of Commissioning Plan

- **Please ask one of us if you want to join the Working Group**
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  - neil.t.zimmerman@nasa.gov