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EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

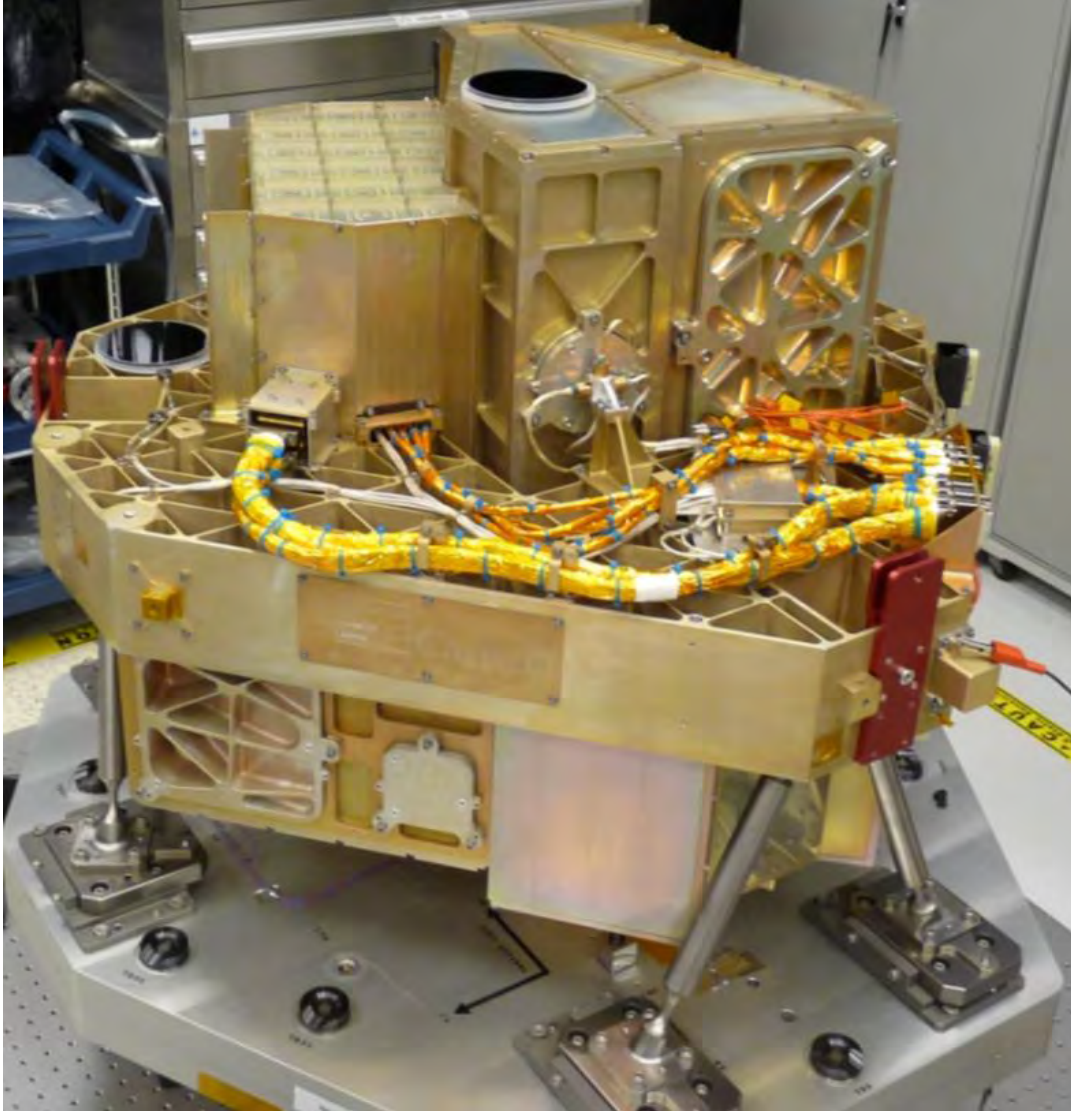
Near Infrared Imager and Slitless Spectrograph (**NIRISS**) Performance

Stephanie LaMassa (NIRISS Branch Manager) and Paul Goudfrooij (NIRISS Deputy)
on behalf of the AMAZING NIRISS Team

Feb 28, 2023



NIRISS & FGS provided by Canadian Space Agency



Principle Investigator:

Prof. René Doyon



Prime Contractor:

Honeywell



Technical Development:

National Research Council
of Canada (NRC)





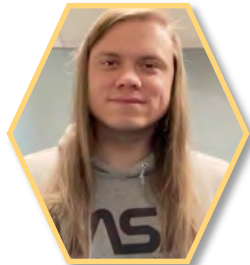
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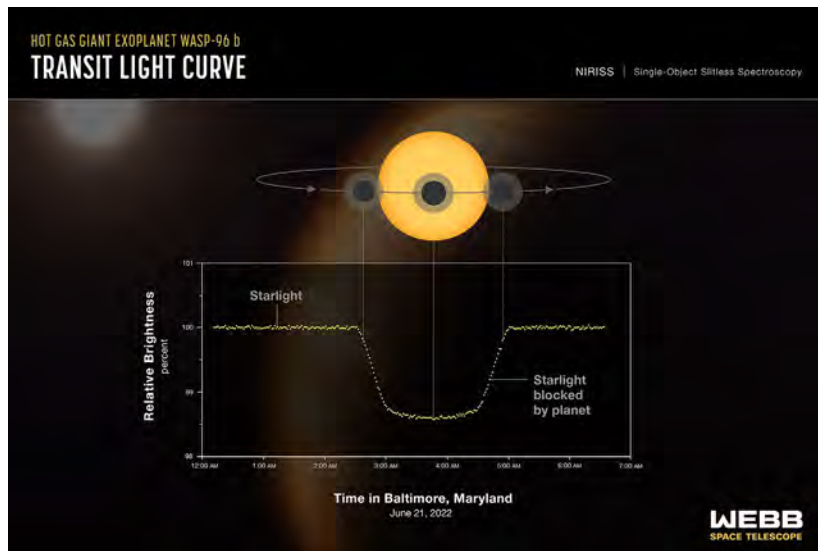
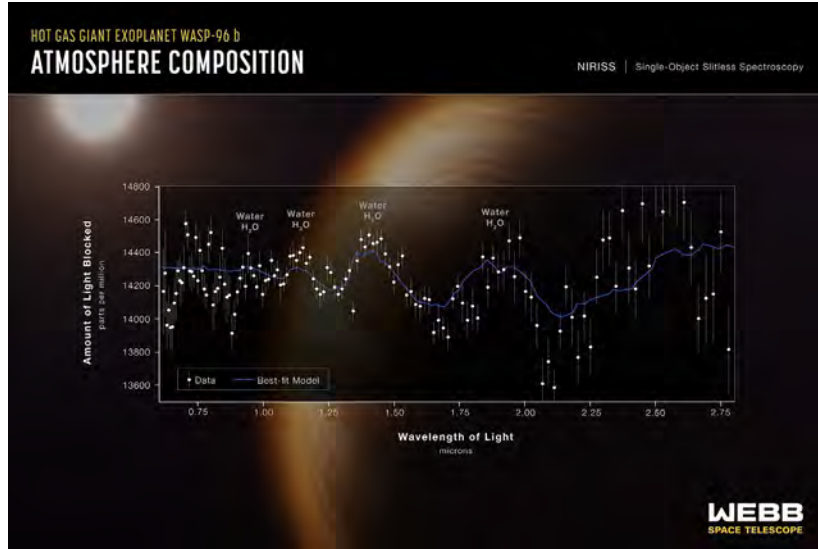
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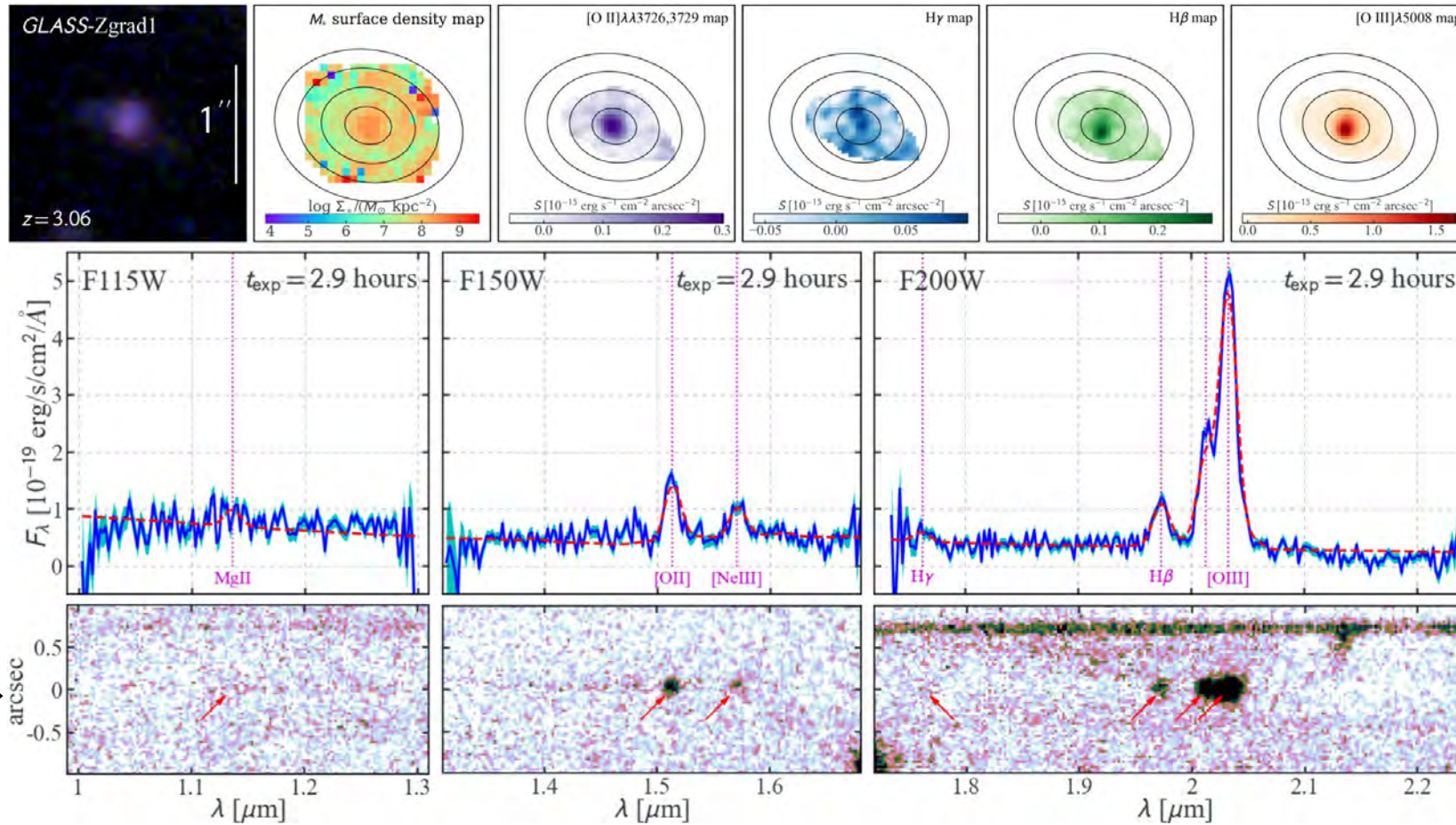
A Token of NIRISS Science Results



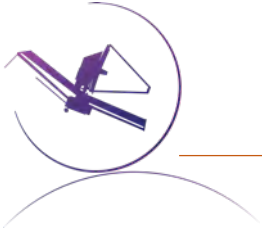
ERO Images: NASA, ESA, CSA, STScI



A Token of NIRISS Science Results



Star-forming dwarf galaxy ($M_* \sim 10^{8.6} M_\odot$) at $z = 3.1$ with NIRISS/WFSS (from GLASS-JWST ERS program; Wang et al. 2022)



NIRISS anomaly: unavailable from Jan 15 – Jan 27



Summary of NIRISS Anomaly

- NIRISS unavailable for observations (science & calibration) from *Jan 15 – Jan 27*
- Logic in the FPGA (field programmable gate array) electronics was scrambled
- Root cause: likely radiation event. Galactic cosmic ray seen as culprit since no clear correlation with solar radiation and timing of anomaly
- Fixed via rebooting NIRISS
- NIRISS Flight Ops Team (*Miranda Link, Amanda Marrione, Bruce Barringer*), GSFC engineers (*Begoña Vila, Julie Van Campen, Chris Dailey, ++*), & Honeywell engineers (*Neil Rowlands, Julia Zhou, Gerry Warner, ++*) are phenomenal!
 - We owe the successful recovery to their dedication, careful investigations, teamwork, and perseverance
- Impact on science: 1 of 2 NGDEEP survey observations was deferred to following year due to position angle constraint
 - Some PIs asked about removing parallel NIRISS observations to allow prime NIRCам observations to proceed, but we recovered NIRISS in enough time this wasn't necessary

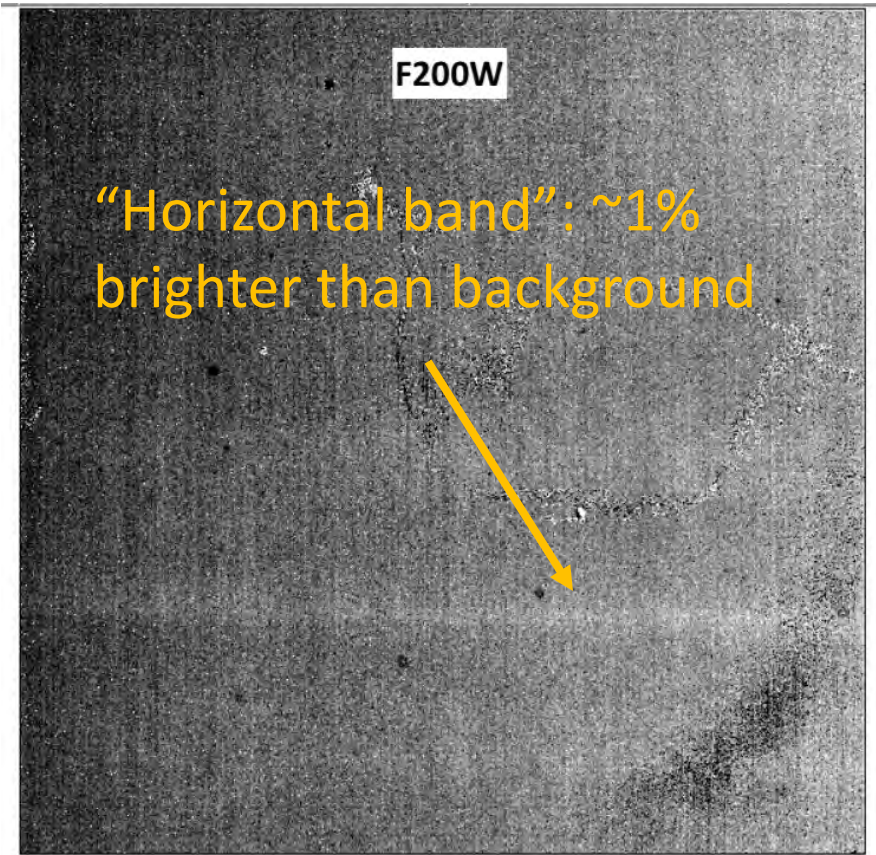


Detector Features: light saber

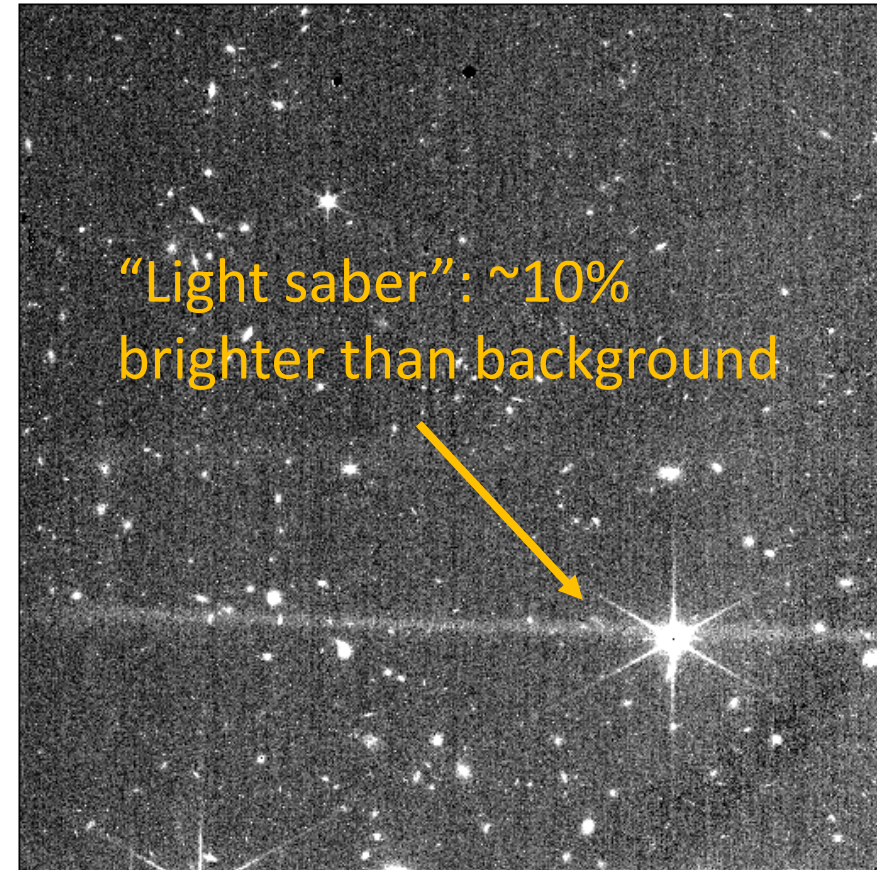


Discovery of horizontal light band during commissioning

Flat field image



Sky image



Credit: Loïc Albert, Chris Willott, Etienne Artigau (Data from APT 1063)



Origin of horizontal band & light saber

- Ray tracing model from Scott Rohrbach (GSFC) identified a susceptibility region: light enters NIRISS through “rogue path”, ~ 12.5 degrees off nominal pointing (!)
- *Horizontal band* (\sim **1% brighter than background**) from zodiacal light & fainter stars in susceptibility region
 - Will always be present in imaging & WFSS observations: preparing model to subtract out in pipeline processing
- *Light saber* (\sim **10% brighter than background**) from bright star in region ($K < 2$ mag, Vega)
 - Can mostly avoid this feature by setting aperture angle constraints

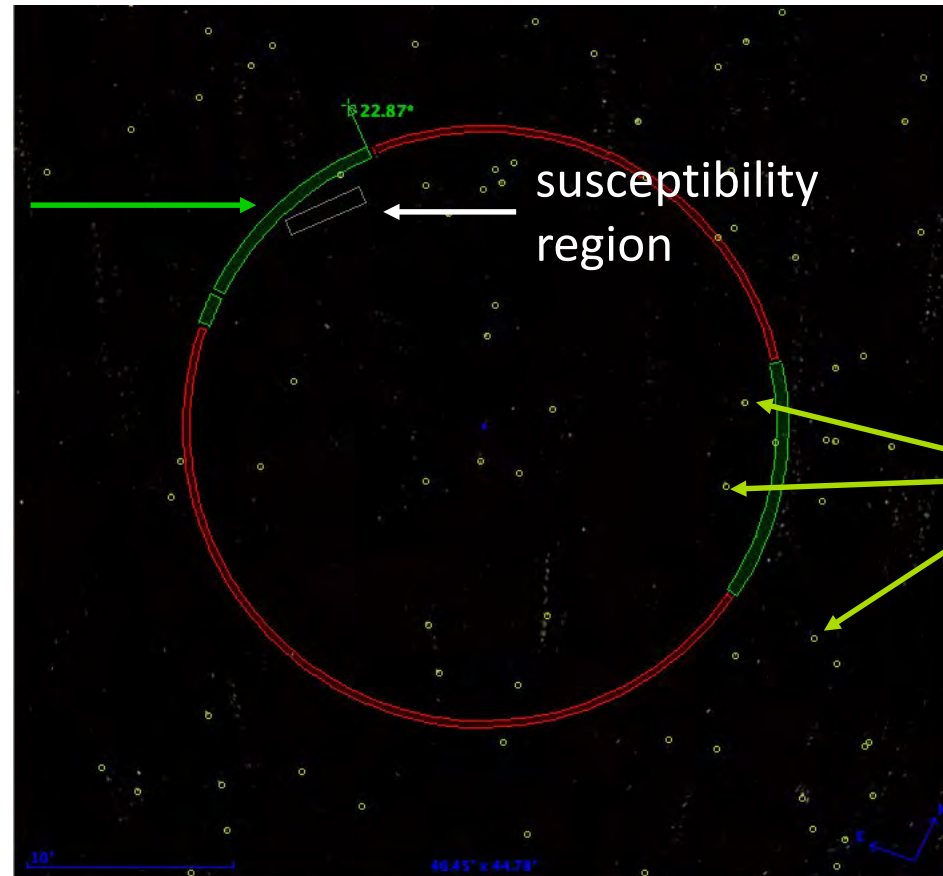
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Light saber mitigation

- Cycles 1 & 2:
 - Technical reviews of proposals to identify spoiler stars in susceptibility region likely to cause light saber ($K \lesssim 2$, Vega; brighter stars more of a problem)
 - Aladin overlay of susceptibility region in APT 2023.1

Permitted position angles



spoiler stars



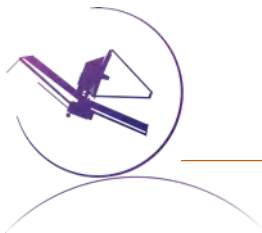
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 - Aladin overlay of susceptibility region in APT 2023.1
 - Reviewers can identify whether spoiler stars enter susceptibility region during permitted position angles for observation (from special requirements or field-of-regard restrictions)
 - Reviewers will alert PI if spoiler stars are present at specific position angles
 - PI may choose to add a viewing angle constraint to avoid spoiler star
- Cycle 3 & onward:
 - JDox will have information about how to use Aladin to identify spoiler stars in susceptibility region so PIs can plan observations to avoid spoilers.
 - Reviewers will continue to check for spoiler stars as part of technical review of accepted programs



Light saber future work

- Test background models for removing horizontal band → light saber in pipeline for imaging and WFSS
- Gather statistics of light saber detections via JWST Quick Look (JWQL) inspections of data:
 - Investigate whether coordinates of susceptibility region and/or limiting magnitude of spoiler star should be adjusted



NIRISS Calibration



High level summary

- *All* current calibration reference files were created based on analysis of in-flight data from commissioning
 - Those reference files have been active since Sep 2022
- NIRISS team analyzing Cycle 1 calibration data and assessing what updates may be needed



Detector level calibration files

- New bad pixel map using darks data obtained through Nov 27
 - Number of “DO_NOT_USE” bad pixels increased to 1.101% from 0.918%
- Current flat fields are accurate to $< 2 - 3\%$ (depending on filter)
 - Cycle 1 calibration data for filters F090W, F115W, F150W, F200W, F444W
 - Observations not yet executed.
 - Will update flat fields in those filters if we see S/N is good enough to improve results
- Geometric distortion accurate to ~ 3 mas per axis, repeatability of solution < 1 mas
 - Preliminary analysis of calibration data indicates no changes are needed to distortion map
 - Plans being developed to implement look-up table corrections to correct for residuals across detector (similar to Hubble)
- Analysis of darks is on-going



Detector level improvements: charge migration

- Charge migration: electrons spill into neighboring pixels at a certain signal limit at $\lesssim 50\%$ of the saturation limit.
- Identified algorithm enhancements in pipeline to deal with charge migration, especially in NIRISS modes where the PSF is strongly peaked (short-wave imaging; AMI).
 - Ramp slope determinations (flux) are biased low without any corrections.
 - After the signal limit is reached, the slope of integration ramp decreases, causing some earlier groups to be flagged as “jumps.”



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- Pipeline updates: “undersampling correction” step being implemented in pipeline to improve ramp fitting for bright objects
 - New data quality (DQ) flag of “UNDERSAMP” for groups above the signal limit. Groups will also be flagged “DO_NOT_USE”.
 - Flagged groups will be excluded from ramp fitting step, but will be used in read noise variance computation (relevant to weights in resample step).



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- Calibration analysis to potentially revise current threshold (30,000 ADU) underway
 - Aperture Masking Interferometry (AMI) mode especially sensitive to charge migration
 - Proposal planning mitigation: advice to stay below signal limit in an integration ramp



Quality of Stage 3 Pipeline Products for NIRISS

- Generally in quite good shape already
- (Direct) Imaging:
 - `Tweakreg`: Requested switch from DAOSStarFinder to IRAFStarFinder for source detection
 - More accurate centroids for stars near pixel boundaries for undersampled PSFs
 - Mainly important for relatively sparse fields
 - `Outlier_detection`: in good shape
 - Parameter Reference Files for all filters already determined and created from commissioning data
 - `Resample`: Defaults are OK for pipeline purposes
 - `Source_catalog`: Defaults are OK for pipeline purposes
- WFSS and SOSS:
 - `Extract1d`: Tweaking of parameter values TBD, waiting on analysis of Cycle 1 Calibration data
- AMI:
 - Working on rendering stage 3 AMI pipeline consistent with [ImPlaneIA package on GitHub](#)
 - Cycle 1 AMI teams aware of and using *ImPlaneIA*



Wavelength calibration – Wide Field Slitless Spectroscopy (WFSS)

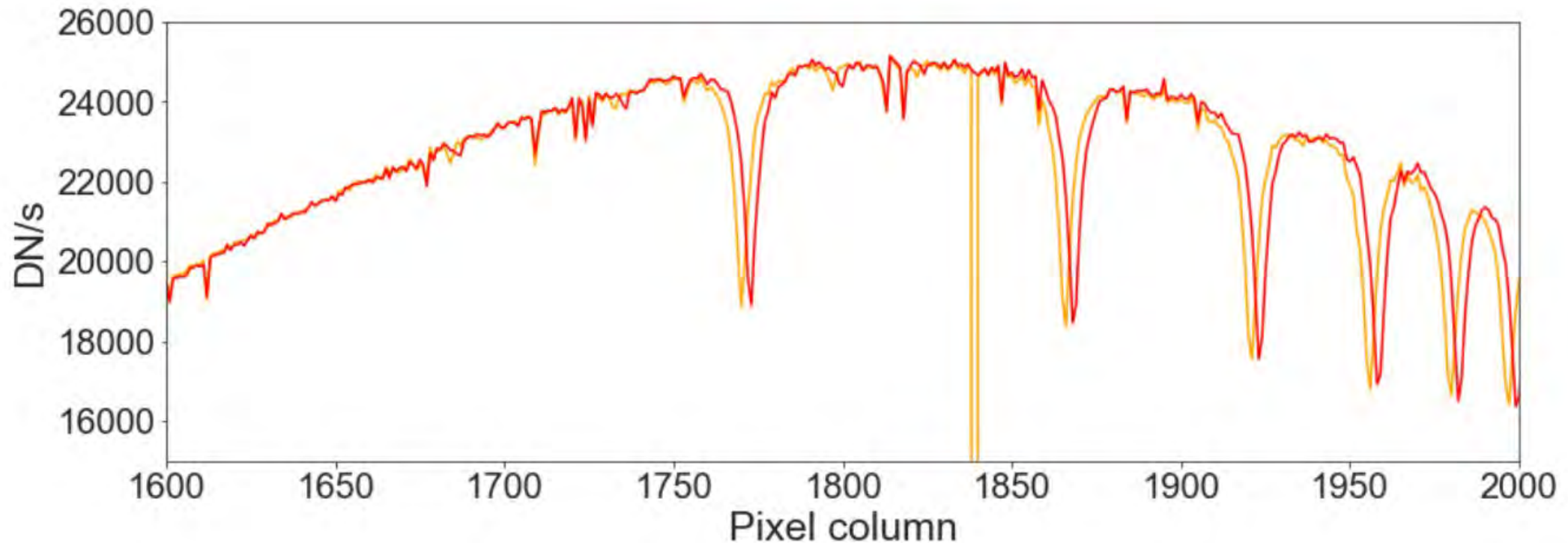
- Commissioning: wavelength dispersion solution uncertainty less than 5-10% of resolution element
 - ✓ Requirements: “shall be known within $1/10^{\text{th}}$ of a resolution element”
 - Measured at center of detector
- On-going analysis from Cycle 1: implement detector position-dependent solution
 - Mosaic observation to place calibration source at different positions in detector



Wavelength calibration – Single Object Slitless Spectroscopy (SOSS)

- Commissioning: wavelength solution shifts from visit-to-visit by a few pixels

GR700XD spectrum of BD+60-1753 observed at 2 epochs

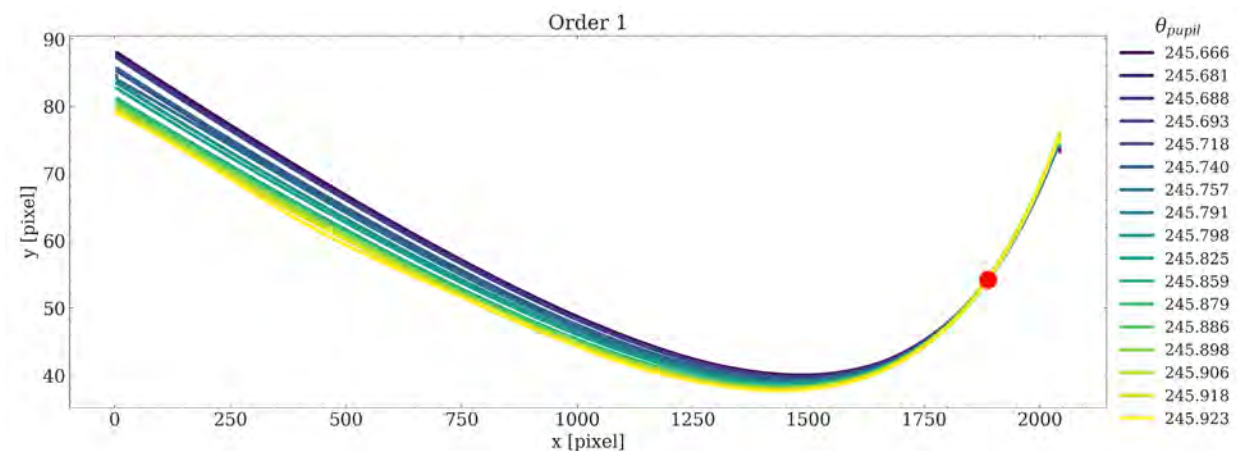


Credit: Baines & Espinoza (in prep.)

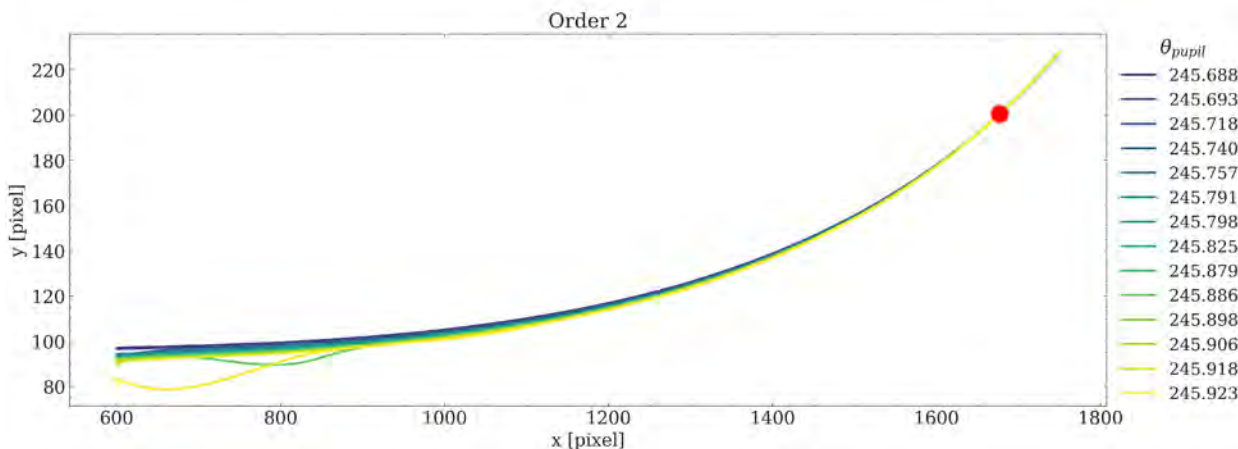


Wavelength calibration - SOSS

- Commissioning: wavelength solution shifts from visit-to-visit by a few pixels
- Spectral traces rotate between visits – related to Pupil Wheel position of GR700XD grism



- Actual position of pupil wheel can be $\pm 0.1651^\circ$ from commanded position

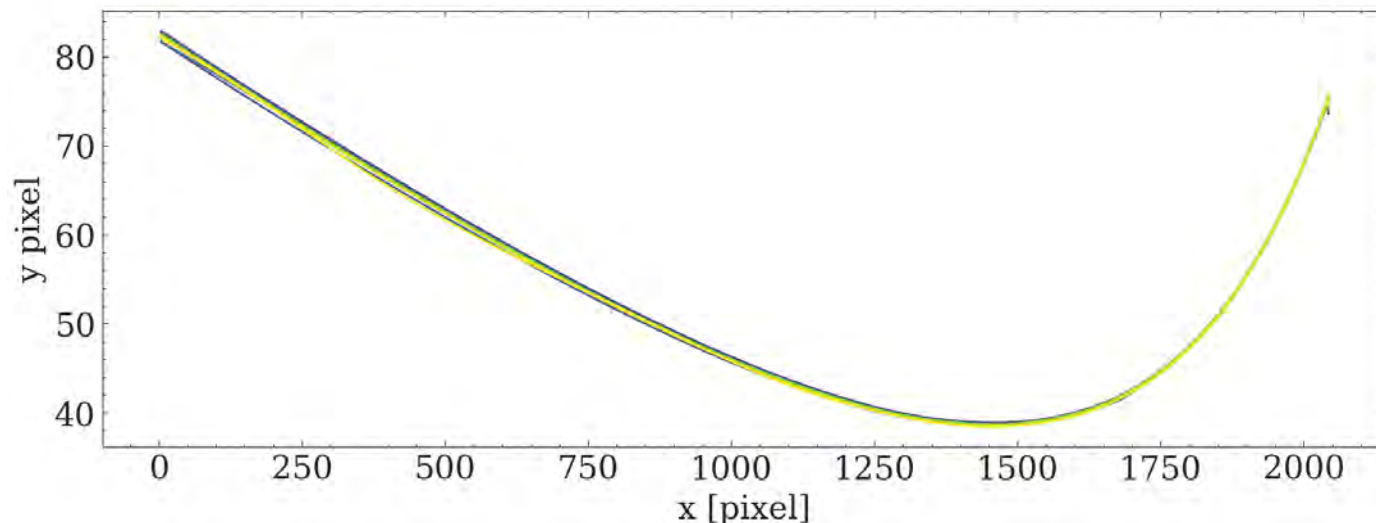


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Wavelength calibration - SOSS

- Commissioning: wavelength solution shifts from visit-to-visit by a few pixels
- Spectral traces rotate between visits – related to Pupil Wheel position of GR700XD grism
- Apply de-rotation → residuals between reference & de-rotated trace now at subpixel level



- Model to predict trace position given pupil position angle: to be released soon
→ Improve wavelength calibration accuracy



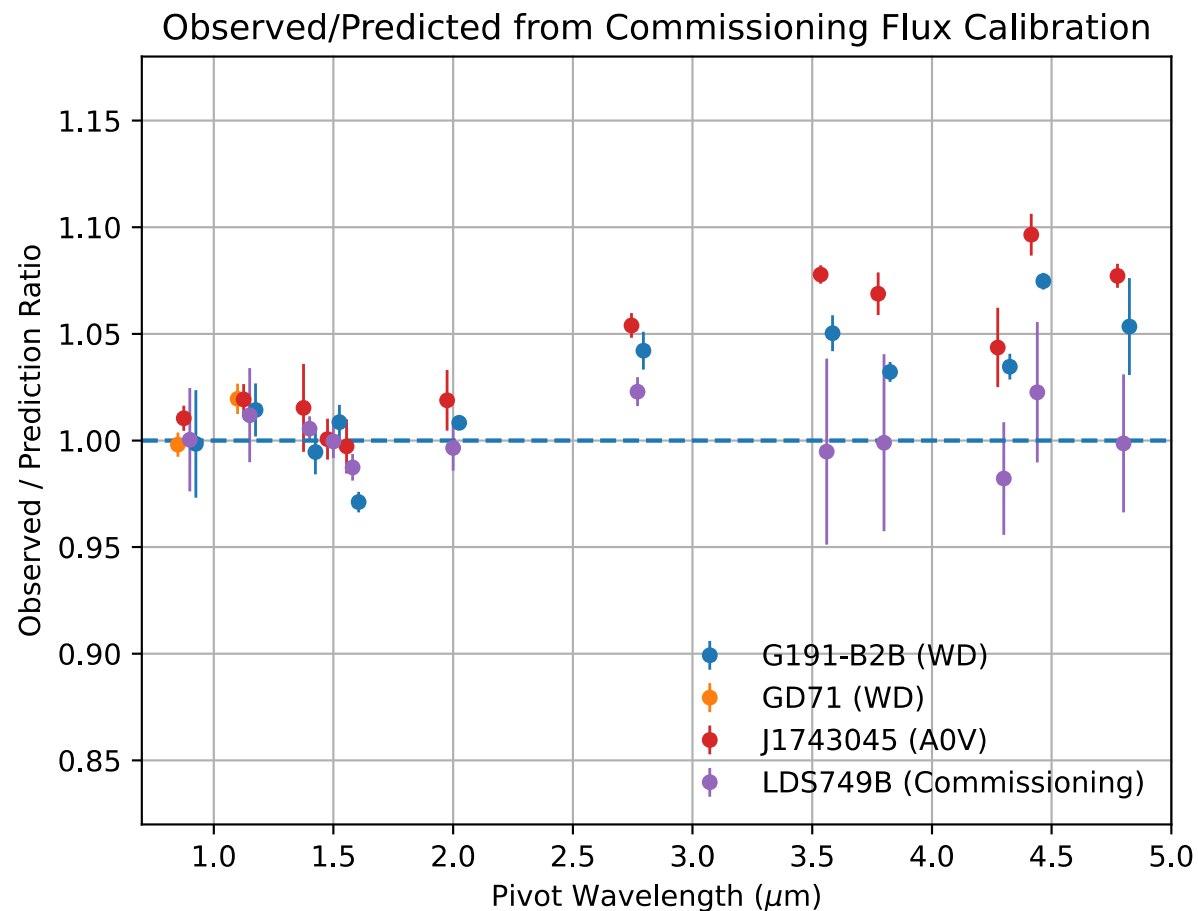
Absolute Flux Calibration

- Absolute Flux Calibration in commissioning was based on observations of one flux standard star in each mode
- Star selection based on observability of suitable stars around the time the commissioning program was scheduled
 - Single Object Slitless Spectroscopy (SOSS): BD+60 1753 (A1V)
 - Wide Field Slitless Spectroscopy (WFSS): WD 1657+343 (DA1)
 - Imaging: LDS 749B (DBQ4)
 - Dependencies of throughput calibration on spectral type, time dependence, etc, to be determined during Cycle 1-2
- So far, Cycle 1 Calibration data only observed and analyzed for Imaging mode (though not for all spectral types yet)



Absolute Flux Calibration

Imaging Mode: Cycle 1 Calibration results



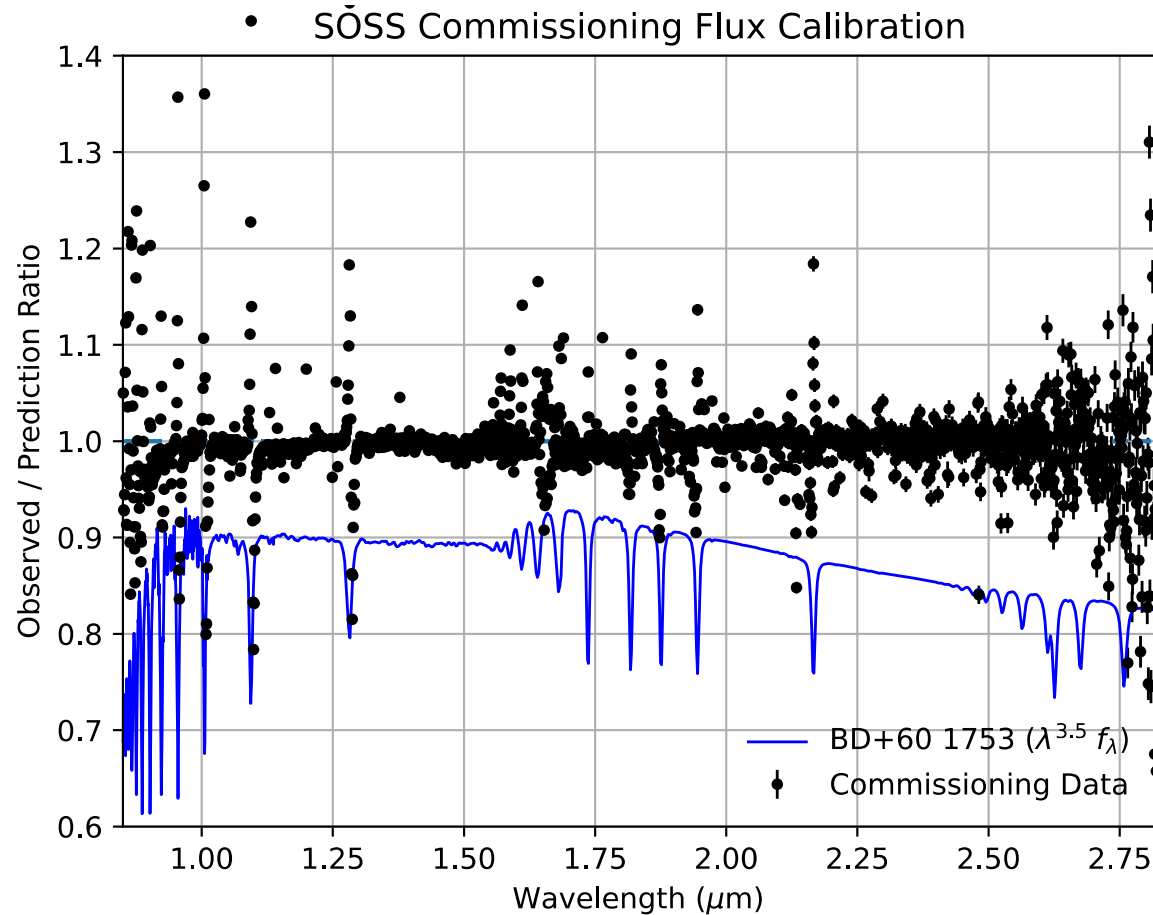
Credit:
Paul Goudfrooij & Kevin Volk

- Likely $\sim 5\%$ adjustment needed at $\geq 2 \mu\text{m}$, if confirmed by observation of solar-type standard star.



Absolute Flux Calibration

Flux Calibration – Single Object Slitless Spectroscopy



Credit:
Kevin Volk & Paul Goudfrooij

- Stellar continuum of standard star fit within $\sim 2\%$ (and similarly for WFSS)
- Cycle 1 Calibration data taken recently, not analyzed yet.



NIRISS Performance Summary

- Successfully recovered from anomaly via power cycling
 - Performance nominal
 - Some impact to science observations: 1 of 2 NGDEEP observations deferred for 1 year
- Effect of “light saber” on science performance
 - Handled via mitigation in observation planning.
 - Tool will be provided to user community to aid their observation planning for Cycle 3 onwards
 - NIRISS team will investigate optimizing background subtraction in pipeline & whether coordinates of susceptibility region and/or limiting magnitude of spoiler stars should be updated
- All calibration reference files use in-flight data from commissioning
 - Commissioning is only preliminary characterization
 - NIRISS team hard at work analyzing Cycle 1 calibration data to improve accuracy and update reference files
- NIRISS team working with Calibration WG and pipeline developers on pipeline algorithm improvements to better calibrate NIRISS data