SI-traceable Calibration of Suitcase SOLARIS for CLARREO Pathfinder Mission

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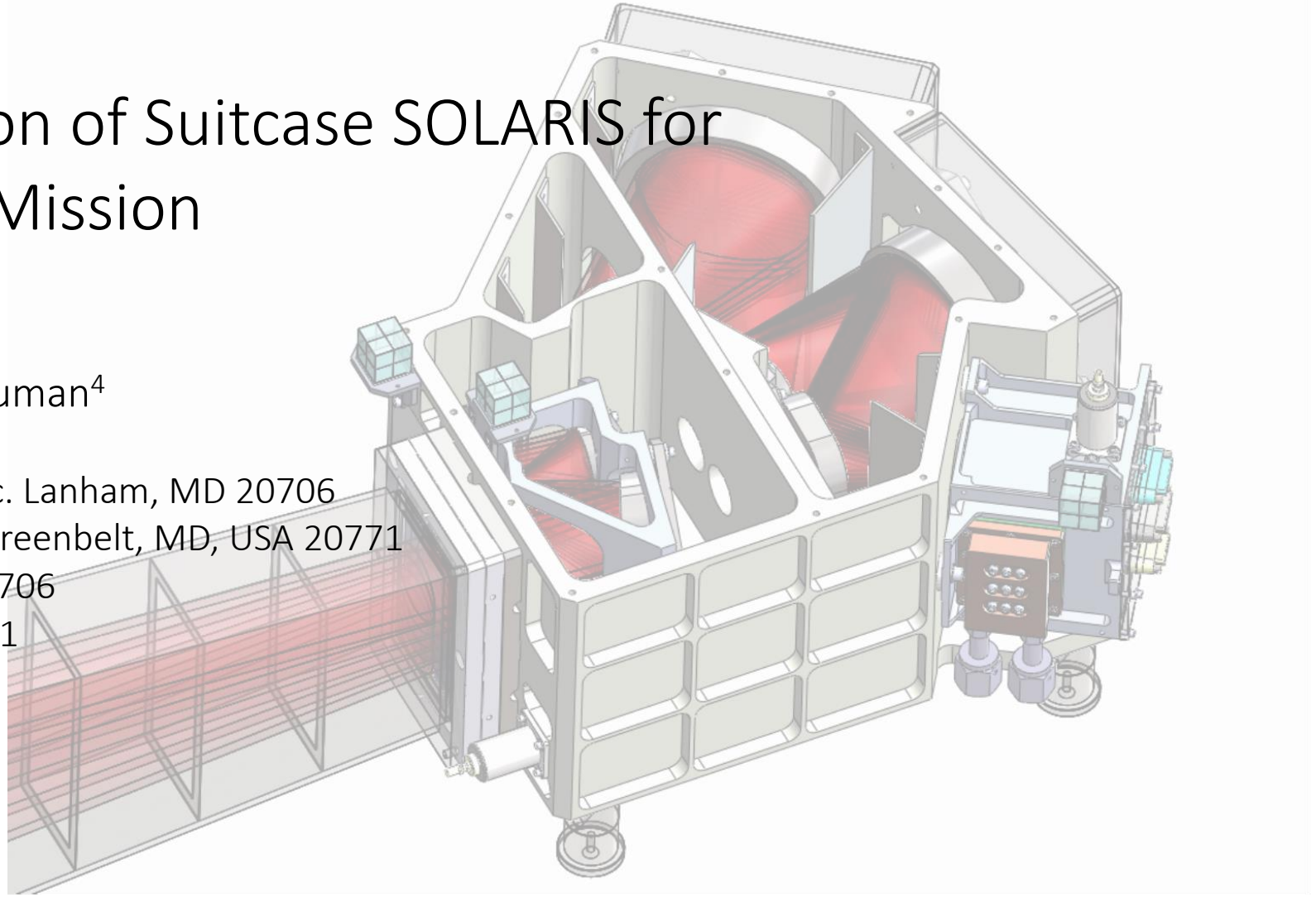
[2]NASA Goddard Space Flight Center, Greenbelt, MD, USA 20771
[3]Ball Aerospace, Lanham, MD, USA 20706
[4]Fibertek, Inc. Herndon, VA, USA 20171

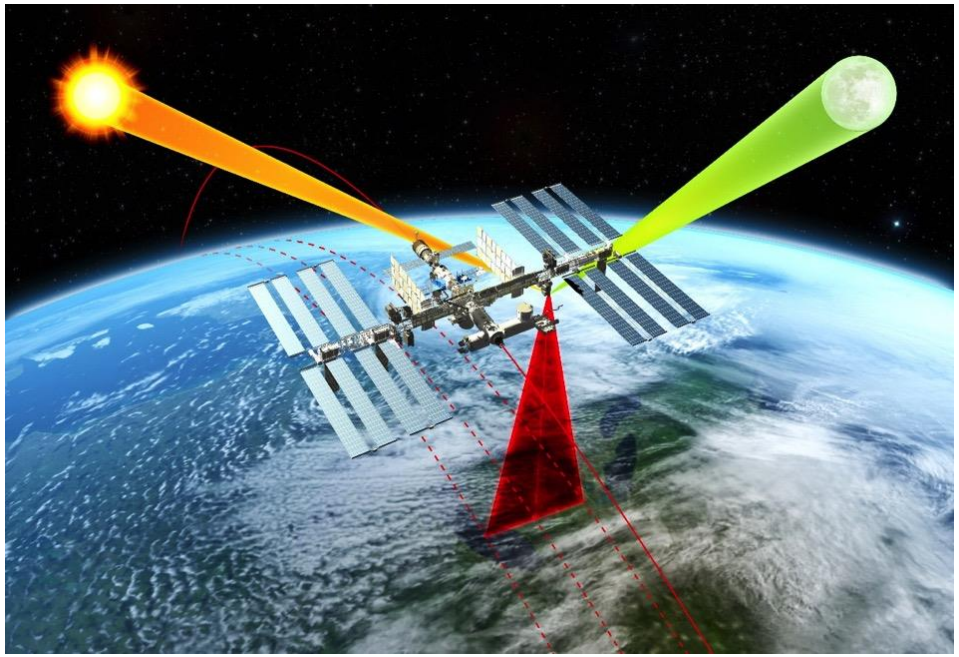


Suitcase SOLARIS v.2: Motivation

SOlar, Lunar Absolute Reflectance Imaging Spectroradiometer is developed as a sensor testbed for the original CLARREO mission

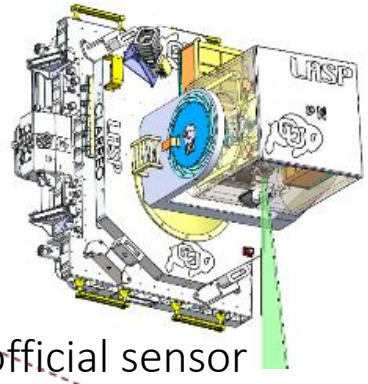
CLimate Absolute Refractivity and Reflectance Observatory (CLARREO) Pathfinder (CPF) mission objectives are in two folds:

1) Demonstrate High Accuracy SI-Traceable Radiance Measurements (0.3%, k=1)
2) Demonstrate Inter-Calibration Capabilities



Mission Description:

- Shortwave (SW) Spectrometer to be mounted on the International Space Station (ISS)
- Nominal 1-year mission life + 1 year science data analysis Category 3 / Class D Mission
- Launch Readiness Date: 2023



CLARREO Pathfinder Independent Cali

- ceability than official sensor
- ent e-launch
- Olar, Lu flectance Imaging Spectroradiomet ed
- Include field-based studie tly-planned on-orbit charact s to evaluate model

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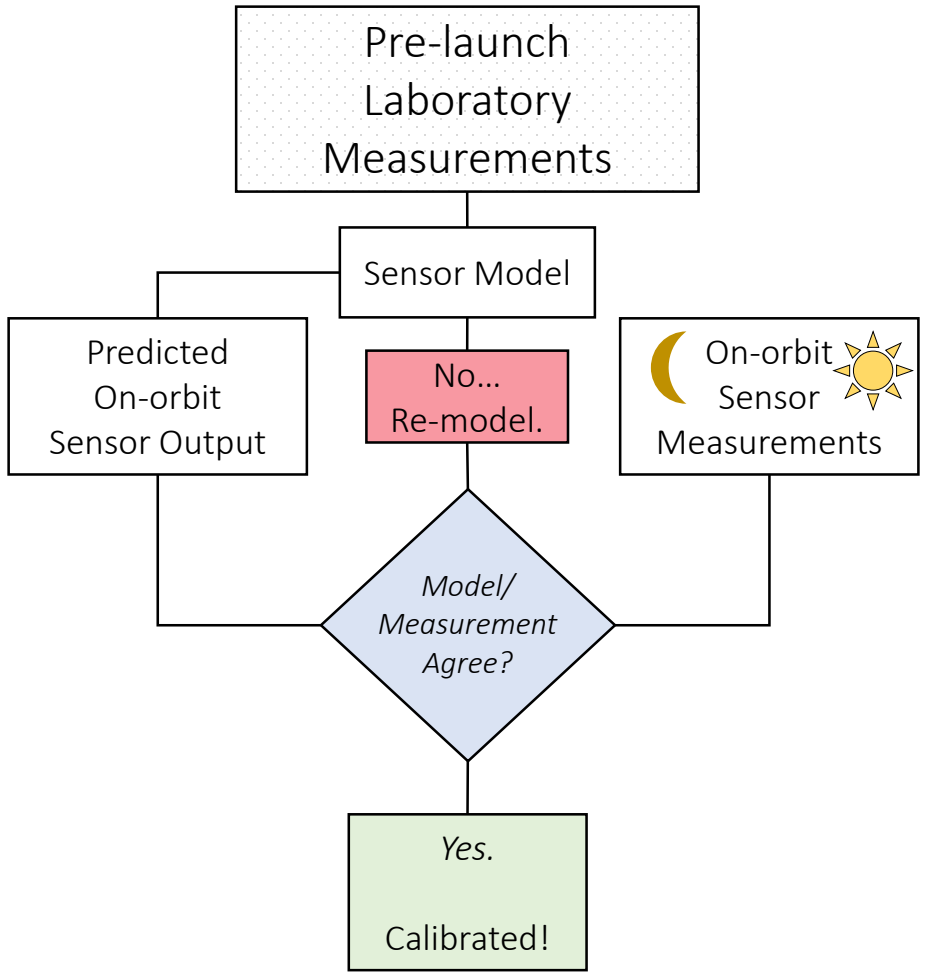

*Angal, Amit, Joel McCorkel, and Kurt Thome. Earth Observing Systems XXI. Vol. 9972. International Society for Optics and Photonics, **2016**.

*Wielicki, B. A., et al. "CLARREO pathfinder mission: Enabling faster observation of climate change." AGU Fall Meeting Abstracts. **2015**.

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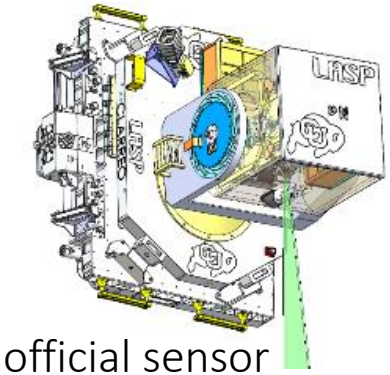
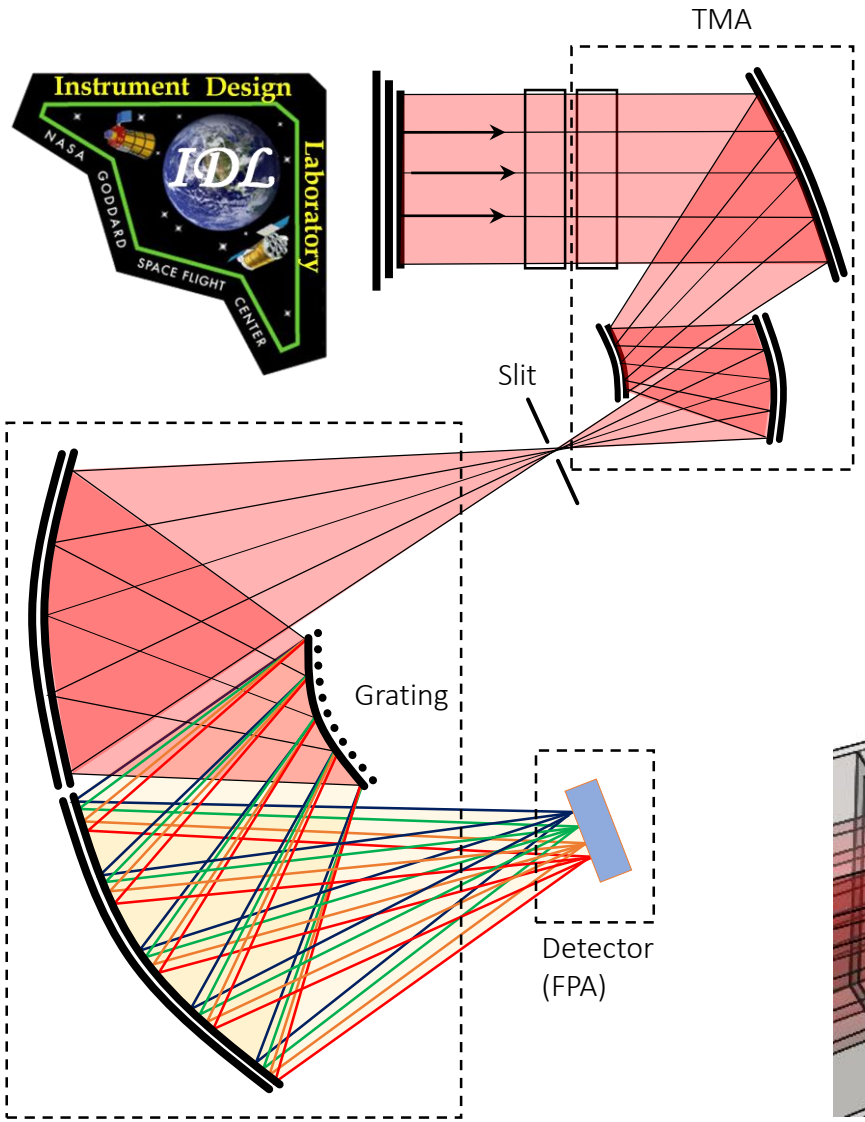


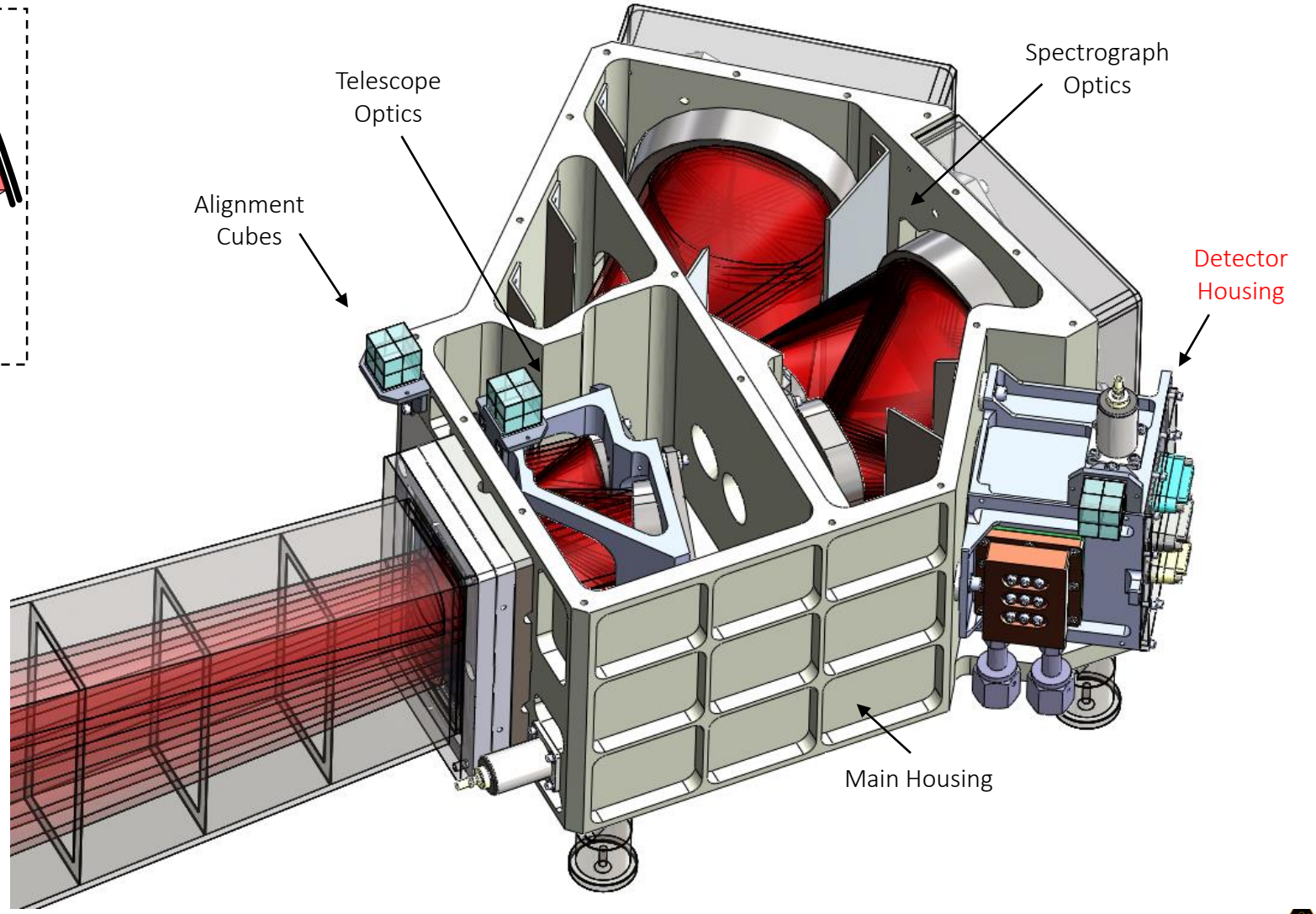
CLARREO Pathfinder Independent Calibration Efforts:

- Follows a different traceability than official sensor characterization
- Coupled with instrument model based on pre-launch characterization data
- Make use of the SOlar, Lunar for Absolute Reflectance Imaging Spectroradiometer for lessons learned
- Include field-based studies as well as currently-planned on-orbit characterization collections to evaluate model

Suitcase SOLARIS v.2: Design

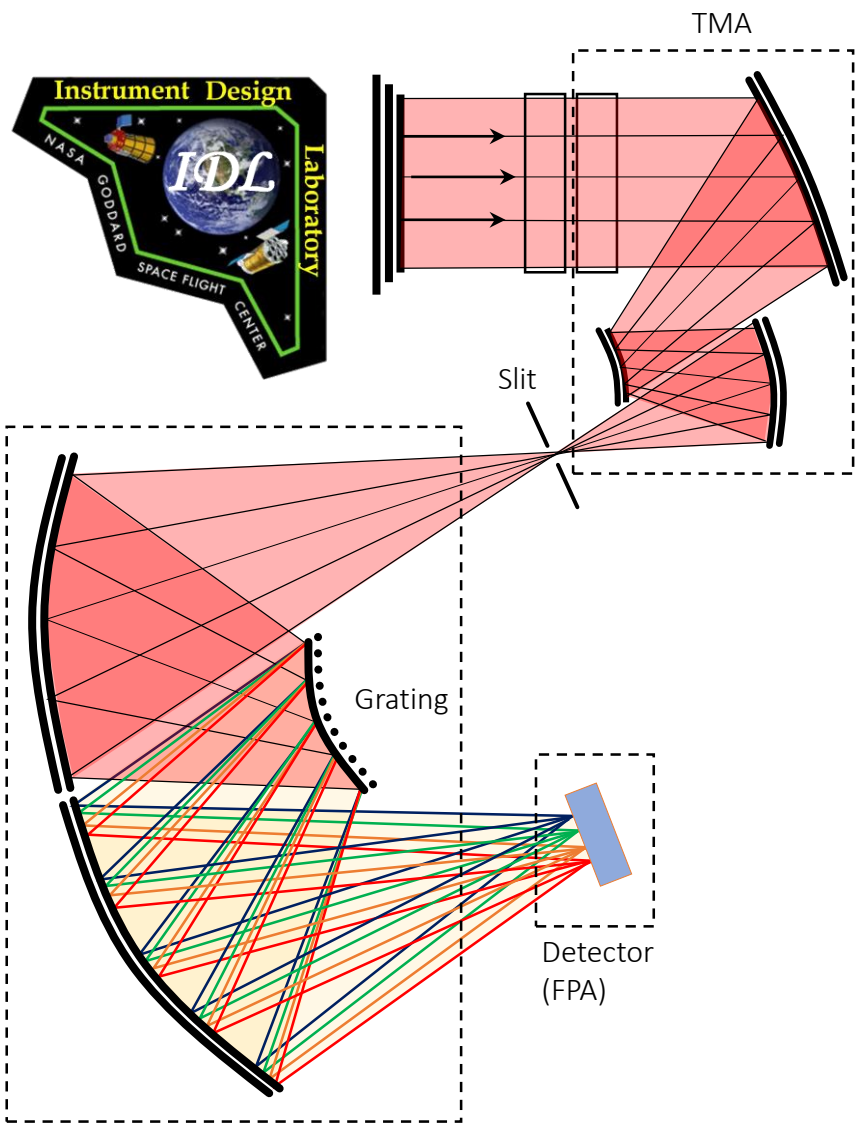
A portable, broadband, push-broom style imager operates from 350 nm to 1000 nm spectral region



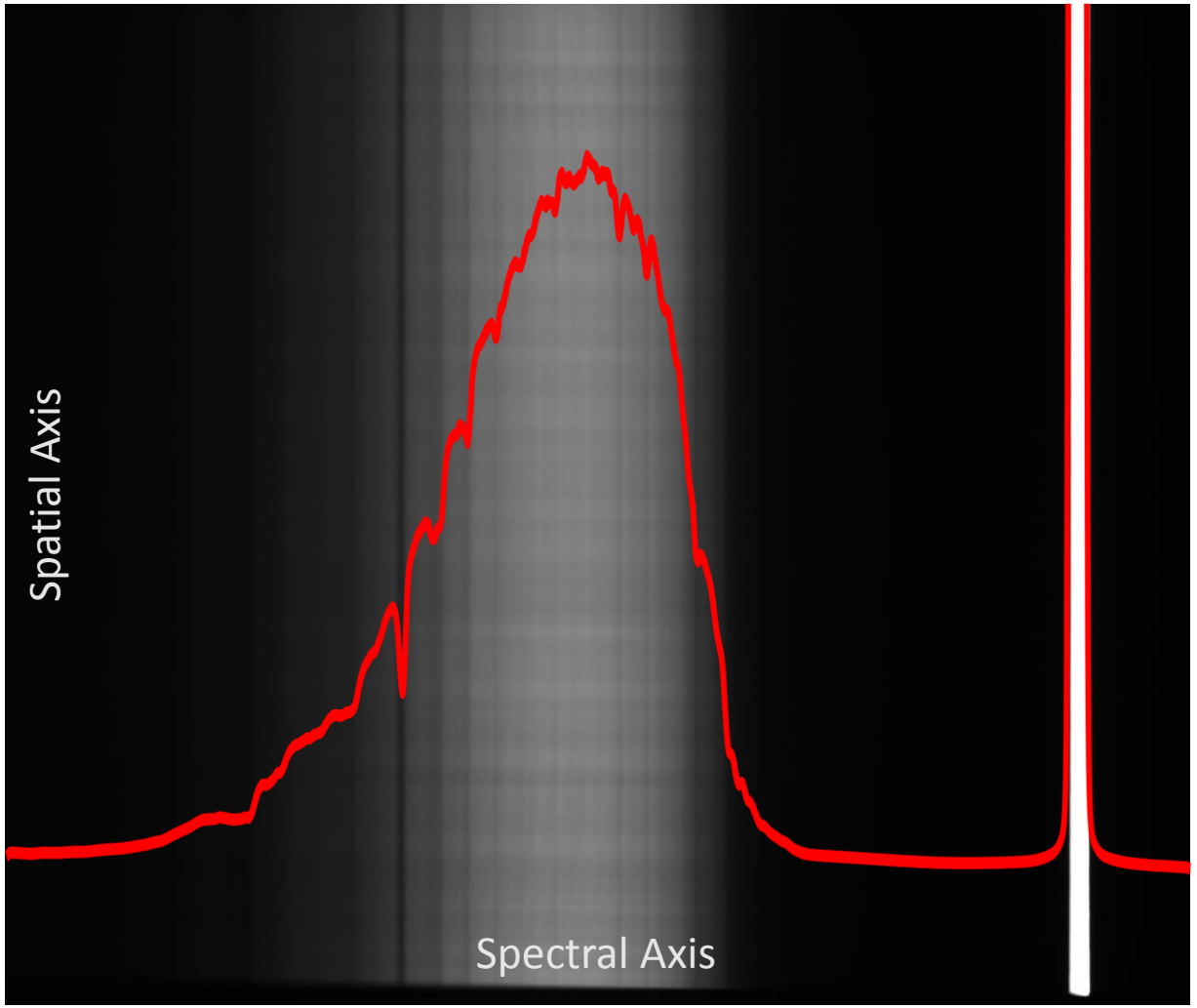


*Prieto-Blanco, X., et al. "Analytical design of an Offner imaging spectrometer." Optics Express 14.20 (**2006**): 9156-9168.

Suitcase SOLARIS v.2: Design

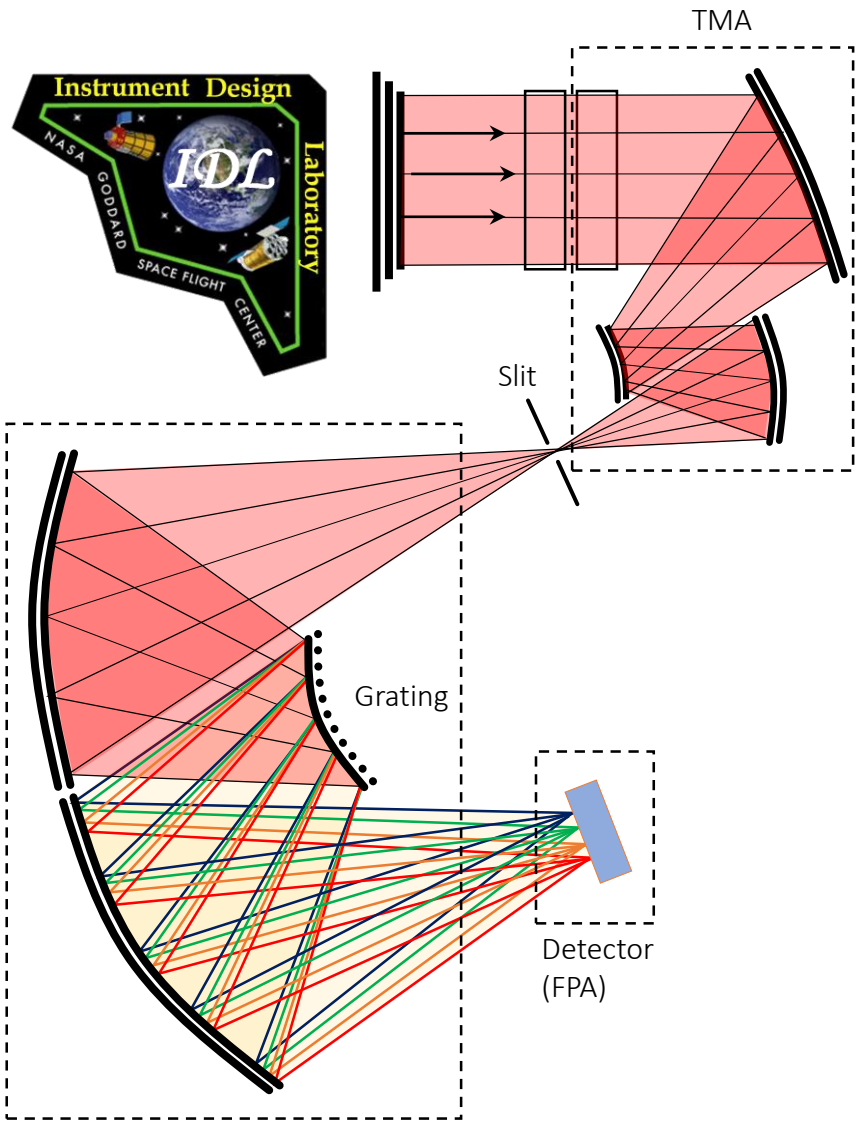


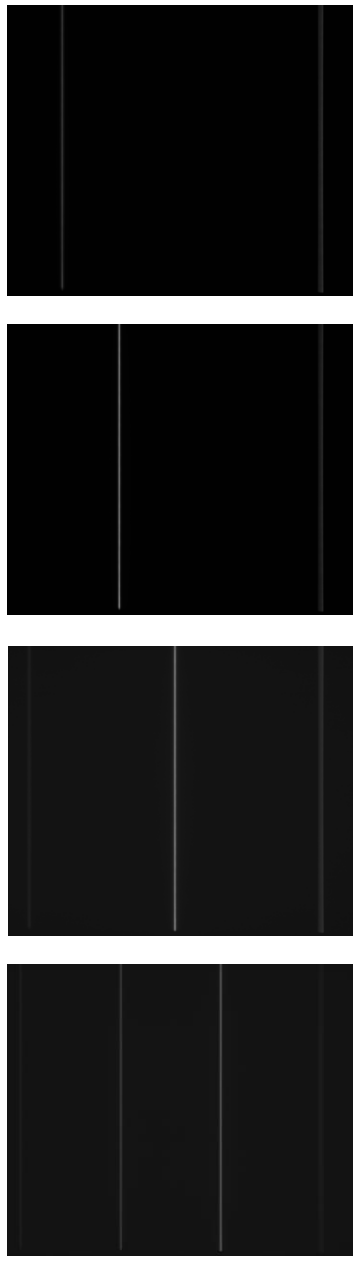
SS2's sCMOS generates 2560x2160 (.tiff) images

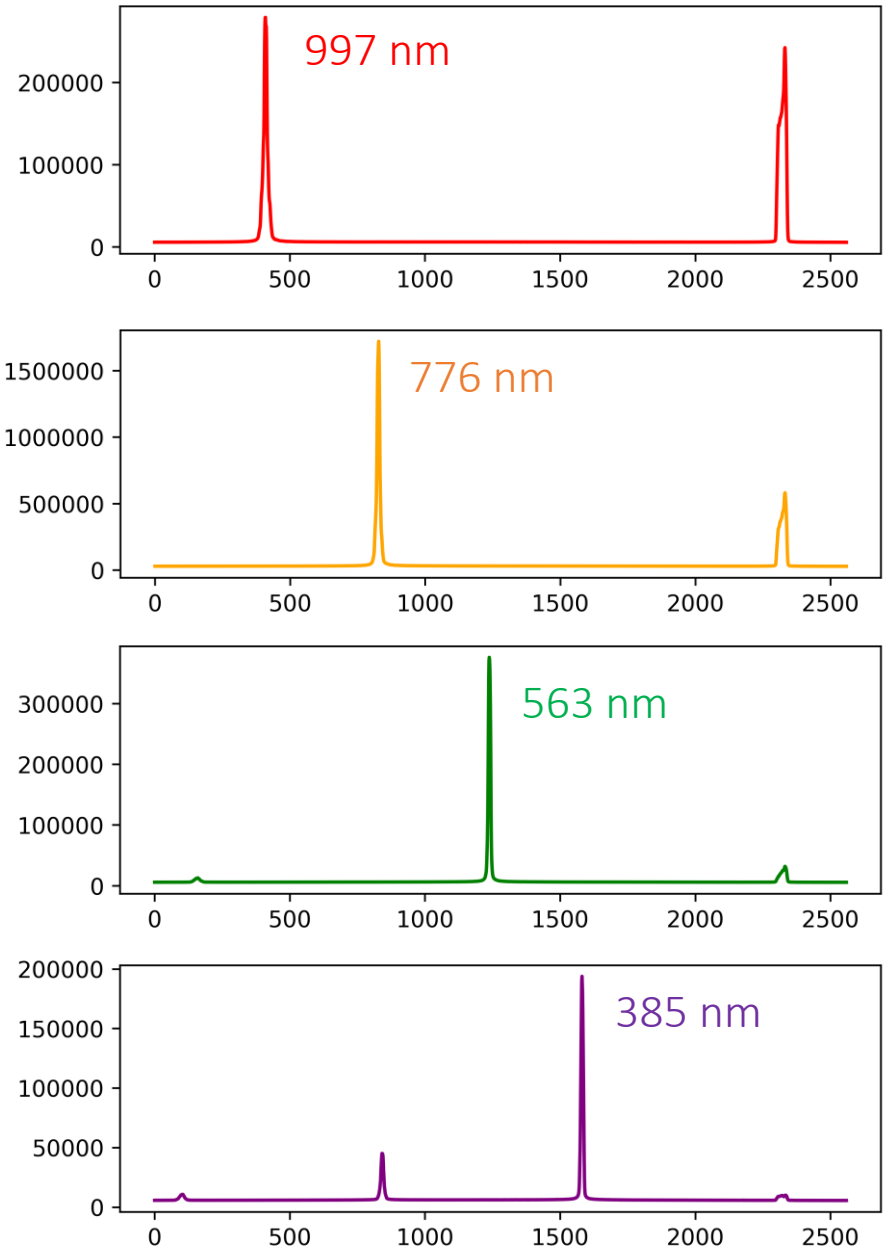


Reflected solar radiation from panel (Goddard, Nov 9, 2018)
5 ms integration time

Suitcase SOLARIS v.2: Design



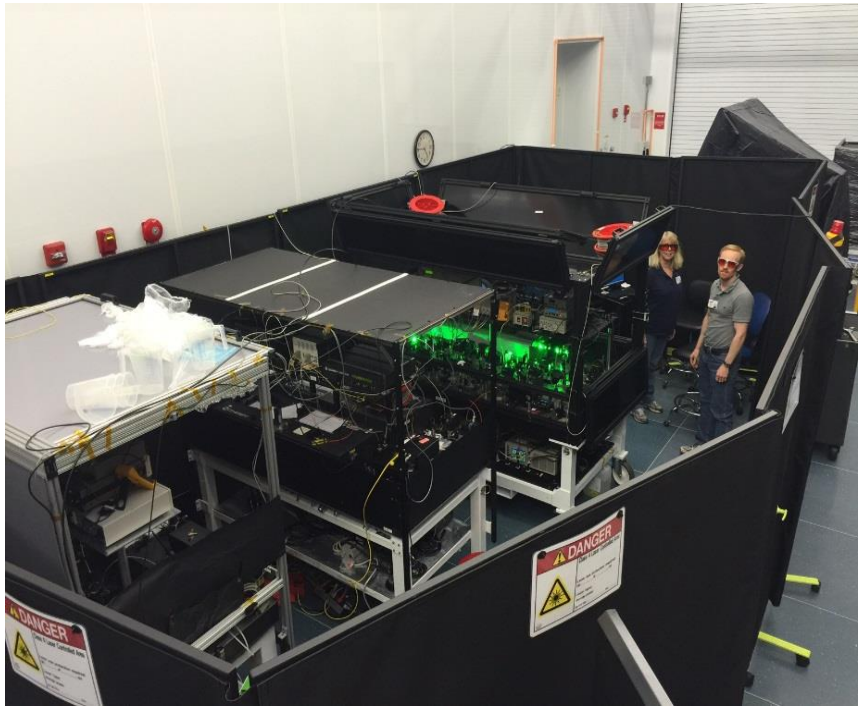


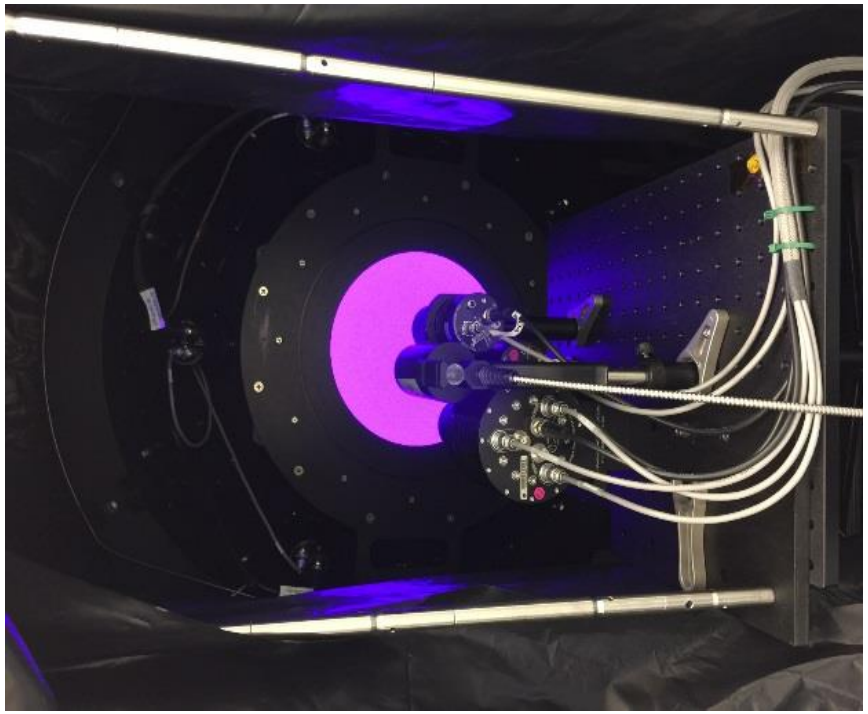


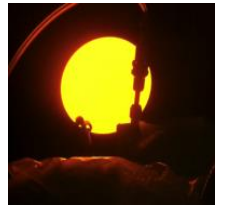
GLAMR

Goddard
Laser for
Absolute
Measurement of
Radiance

- Based on a frequency doubled neodymium doped yttrium vanadate at 532 nm pump operated at 80 MHz repetition rate which is used to pump an optical parametric oscillator (OPO)
- The monochromatic, broadband, and high-intensity output of the parametric conversion output is coupled to a multi-mode fiber that is mated to an integrating sphere
- NIST-calibrated transfer radiometers and the DUT are positioned side-by-side at the exit port of the integrating sphere to during the radiometric calibration







*McAndrew, Brendan, et al. 2018 Conference on Lasers and Electro-Optics (CLEO). IEEE, **2018**.

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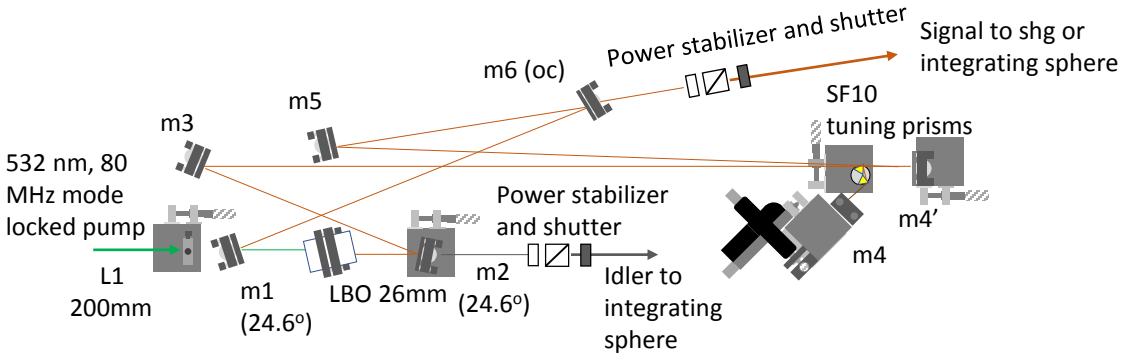
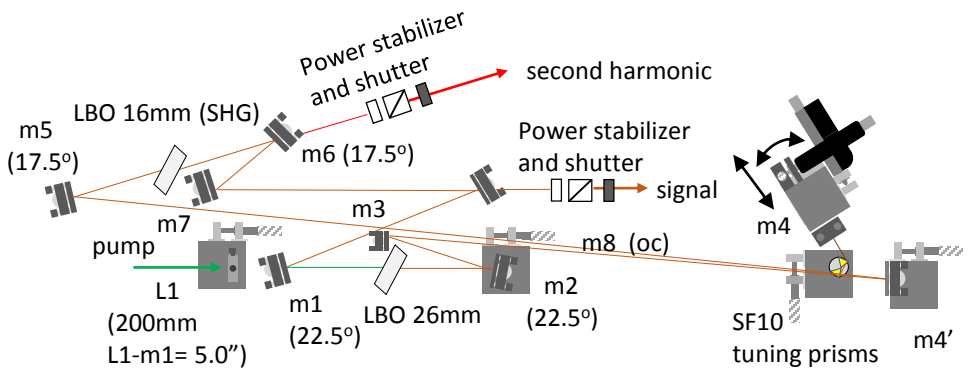


NIR-OPO 680-1100 nm + 1200-2200 nm



SWIR-OPO 1080-1400 nm + 540-700 nm

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GLAMR

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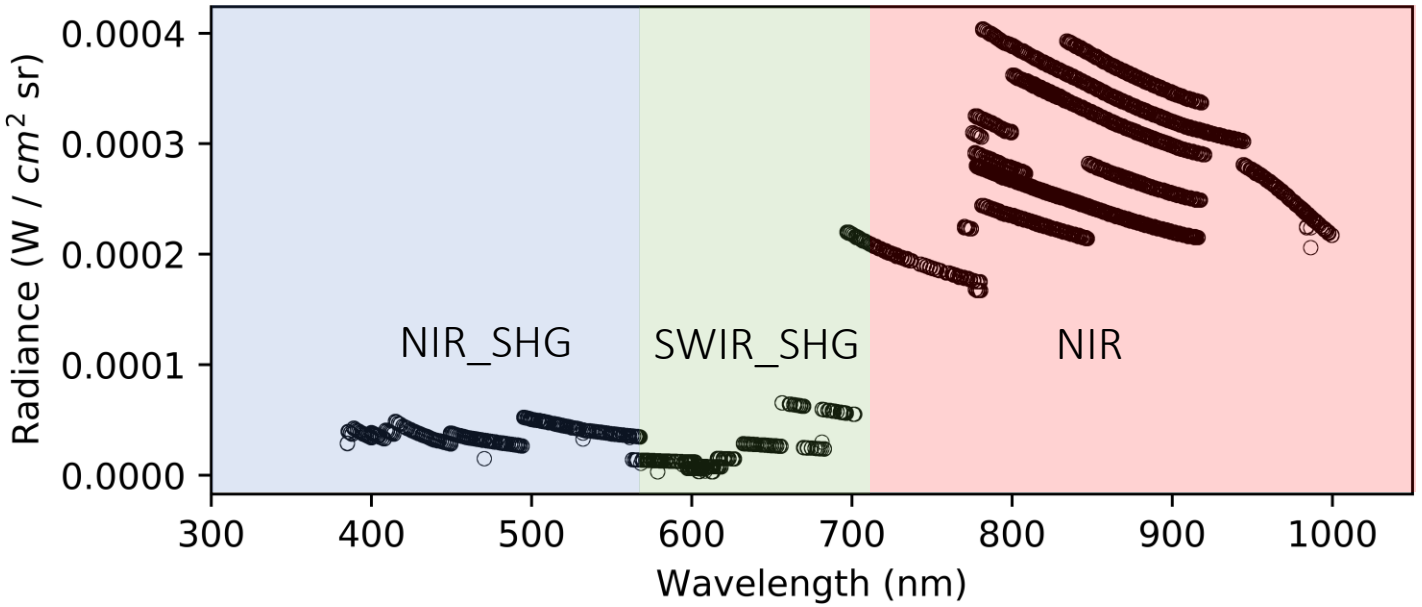

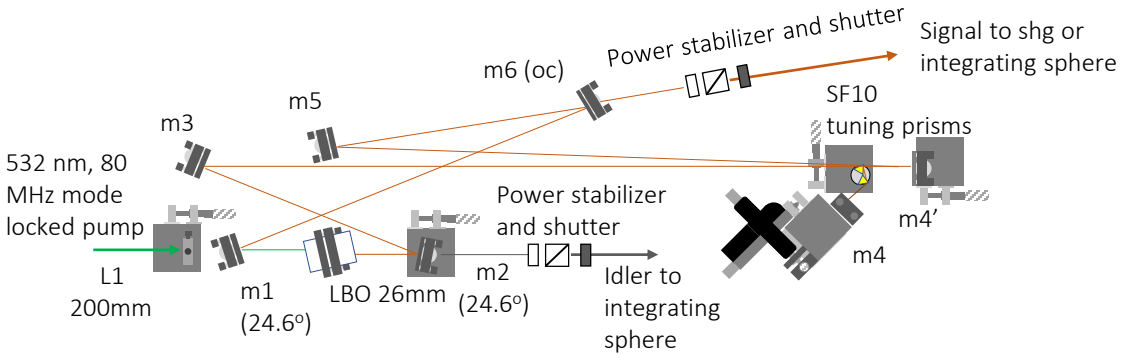

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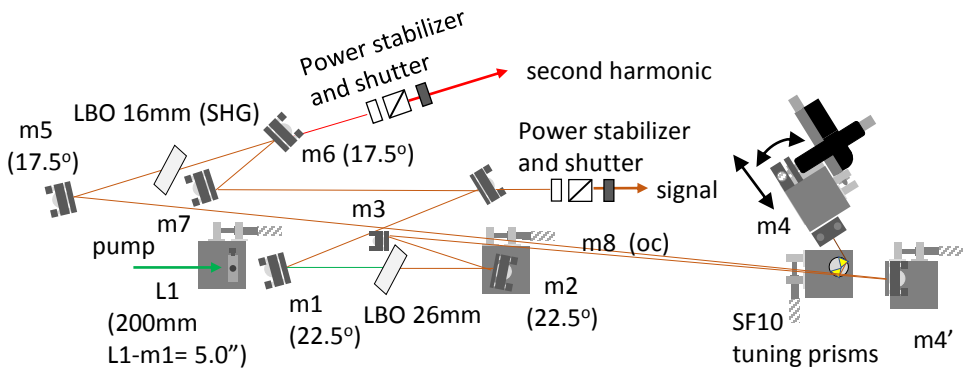

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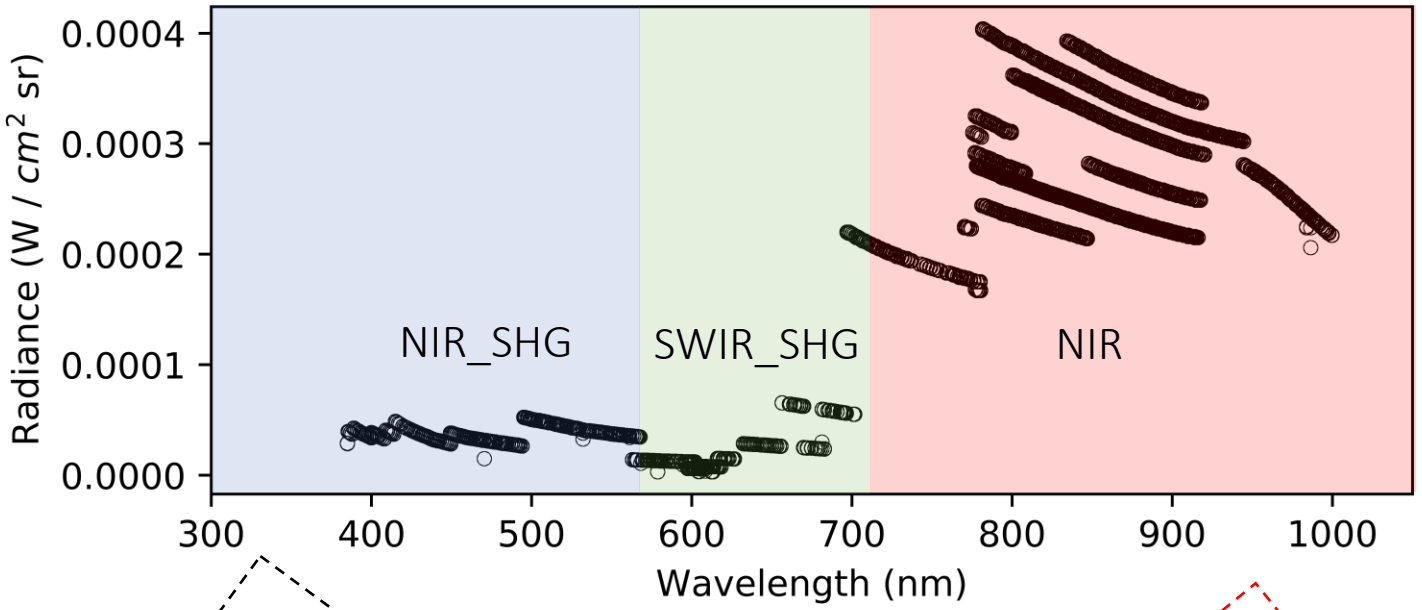
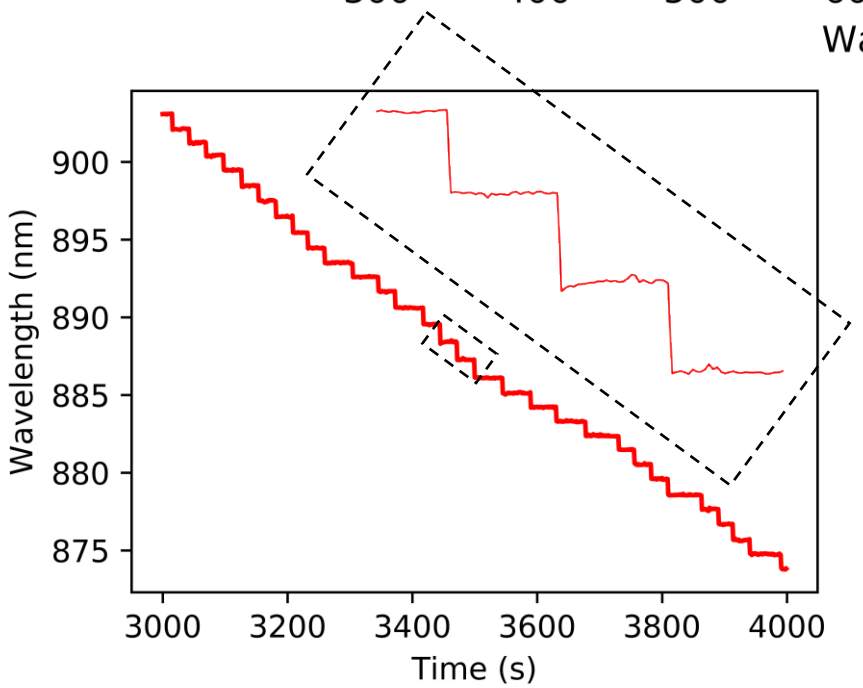
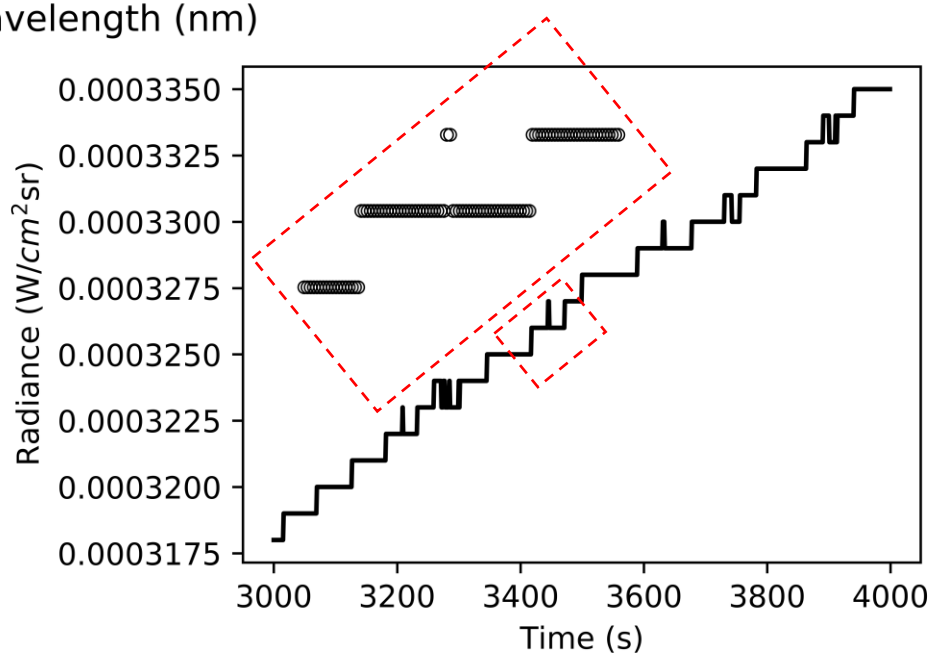
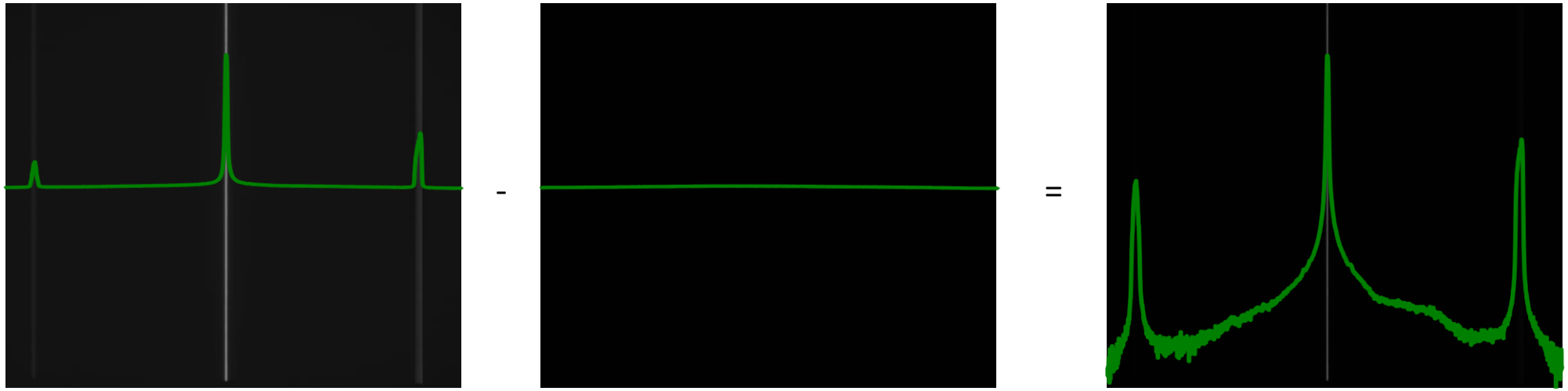






SS2 GLAMR Test Data Acquisition



Shutter Open (light) - Shutter Close (dark) = Background Free

1 Hz:

20190313_221818_SS2_00016_GLAMR_0563nm_LIGHT_50ms

20190313_221730_SS2_00002_GLAMR_0564nm_DARK_50ms

5 Hz:

['Light_DateTime(UTC)', 'Light_JD', 'Light_Date', 'Light_Time', 'Dark_DateTimeStart(UTC)', 'Dark_DateTimeEnd(UTC)', 'Dark_JD_start', 'Dark_JD_end', 'WLmean_air(nm)', 'WLsd(nm)', 'LWmean_air(nm)', 'LWsd(nm)', 'Radiance(W/cm^2/sr)', 'SphereCal(TR/SM)', 'TransRadCal', 'SMpcurrmean(A)', 'SMdark(A)', 'SMdarksd(A)', 'Name-SphMon', 'Laser', 'Original_data_filename', 'TransRadCalfile', 'Table']

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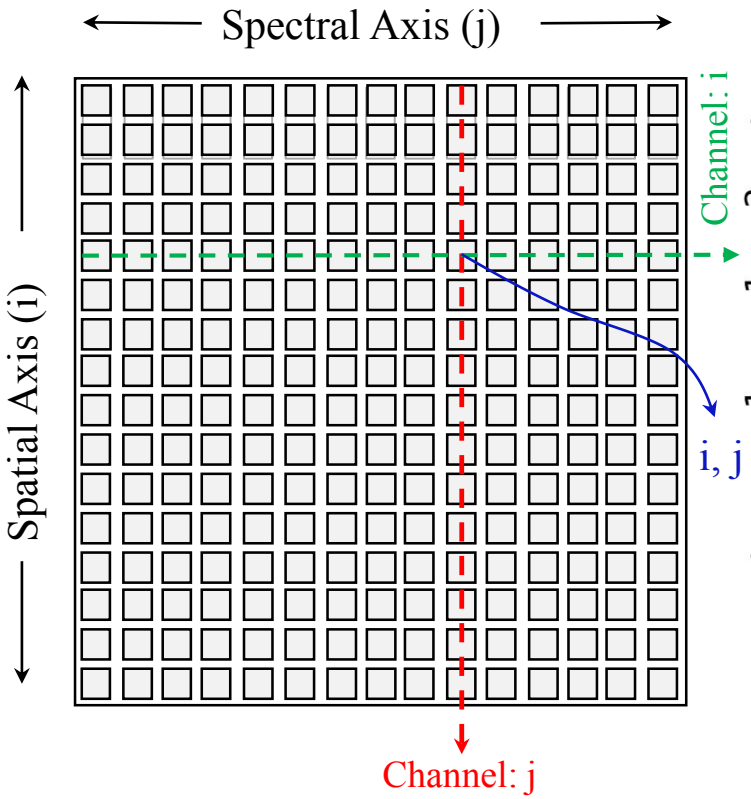
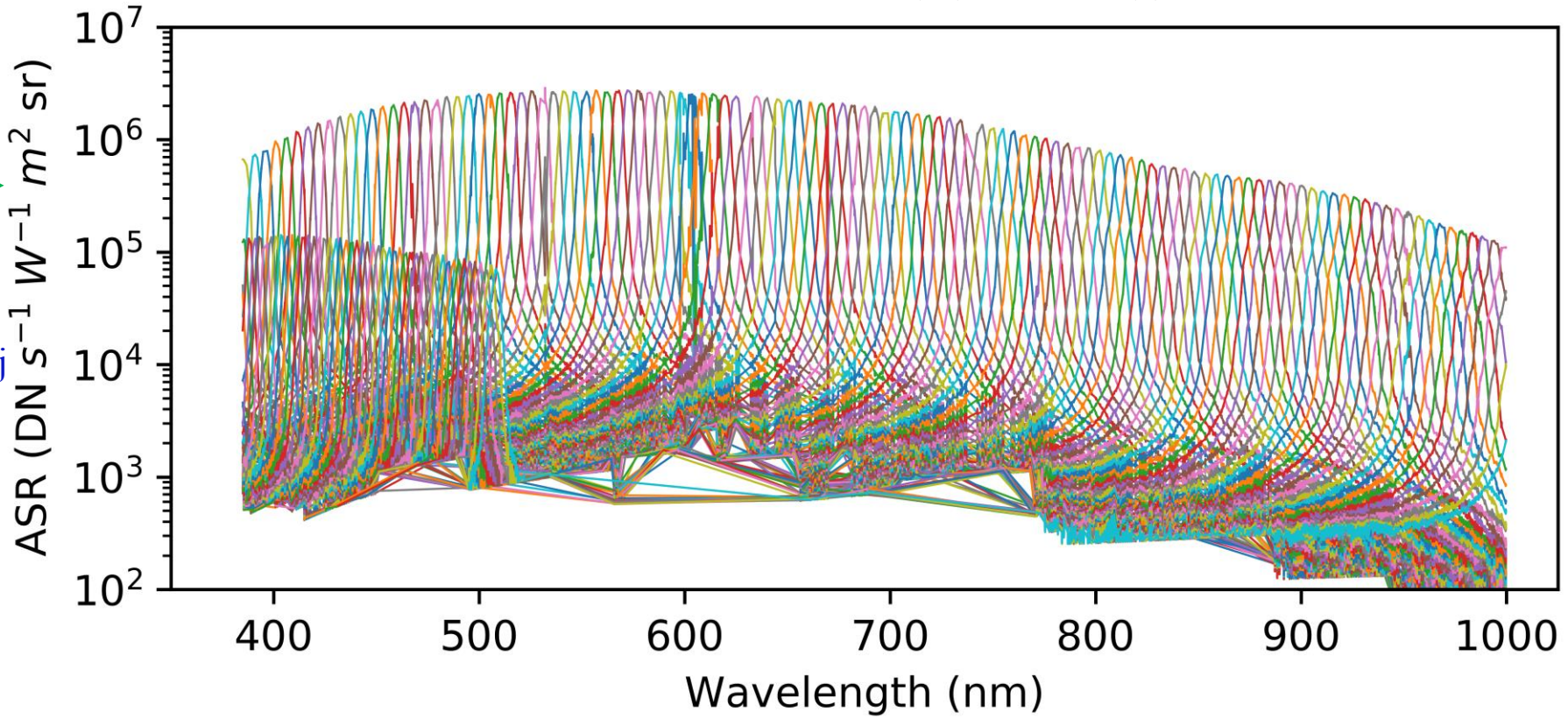


$$ASR(i,j,\lambda) \coloneqq DN\ s^{-1}(i,j)/Radiance(\lambda).$$



- GLAMR scans are done from 390 nm to 995 nm wavelength range with 1 nm intervals
- 30 sec. shutter open, 15 sec. shutter close configuration with 1 Hz (frame/sec.)
- Integration time of the sCMOS is set to 5 ms, 25 ms, 50 ms, 100 ms depending on the SNR of the image

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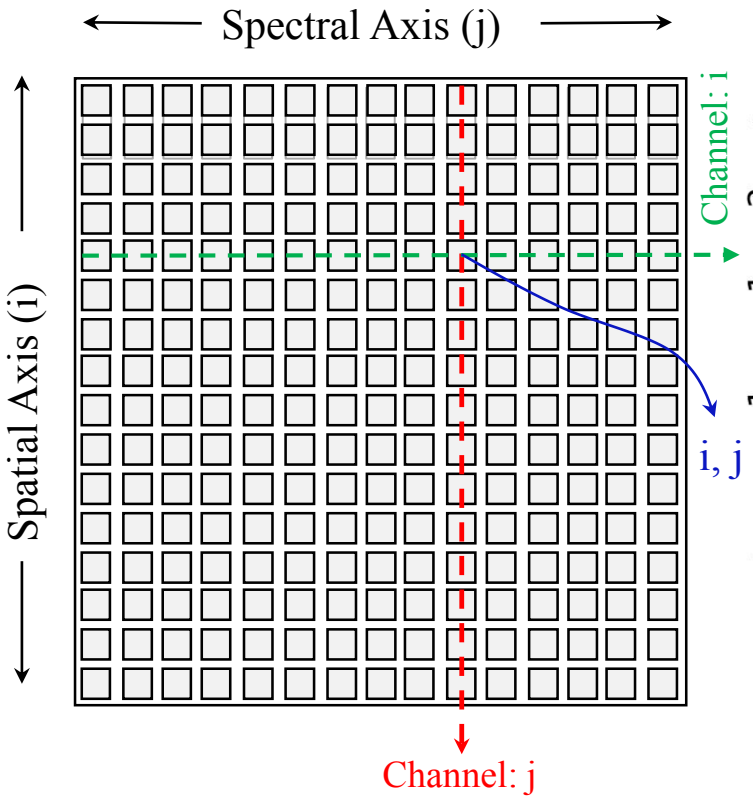

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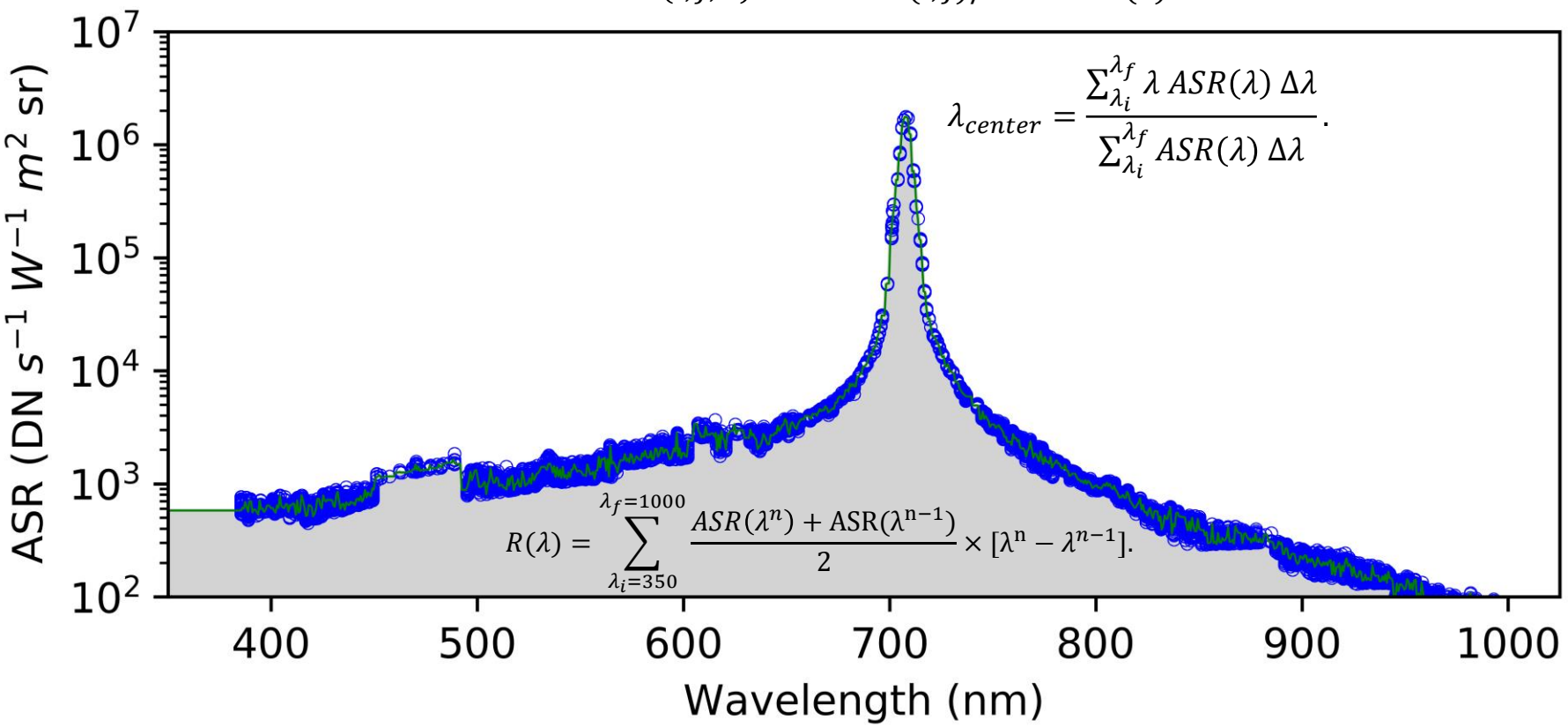

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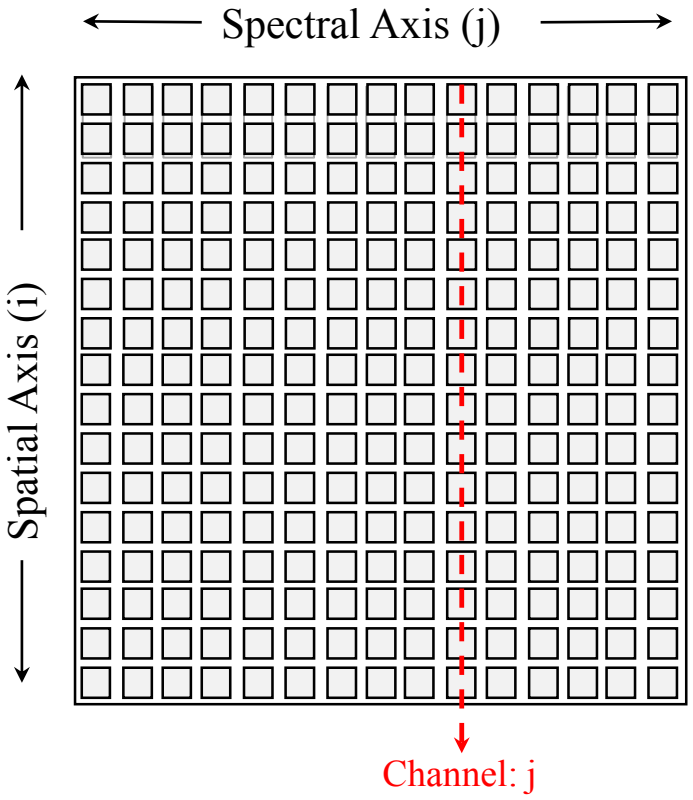

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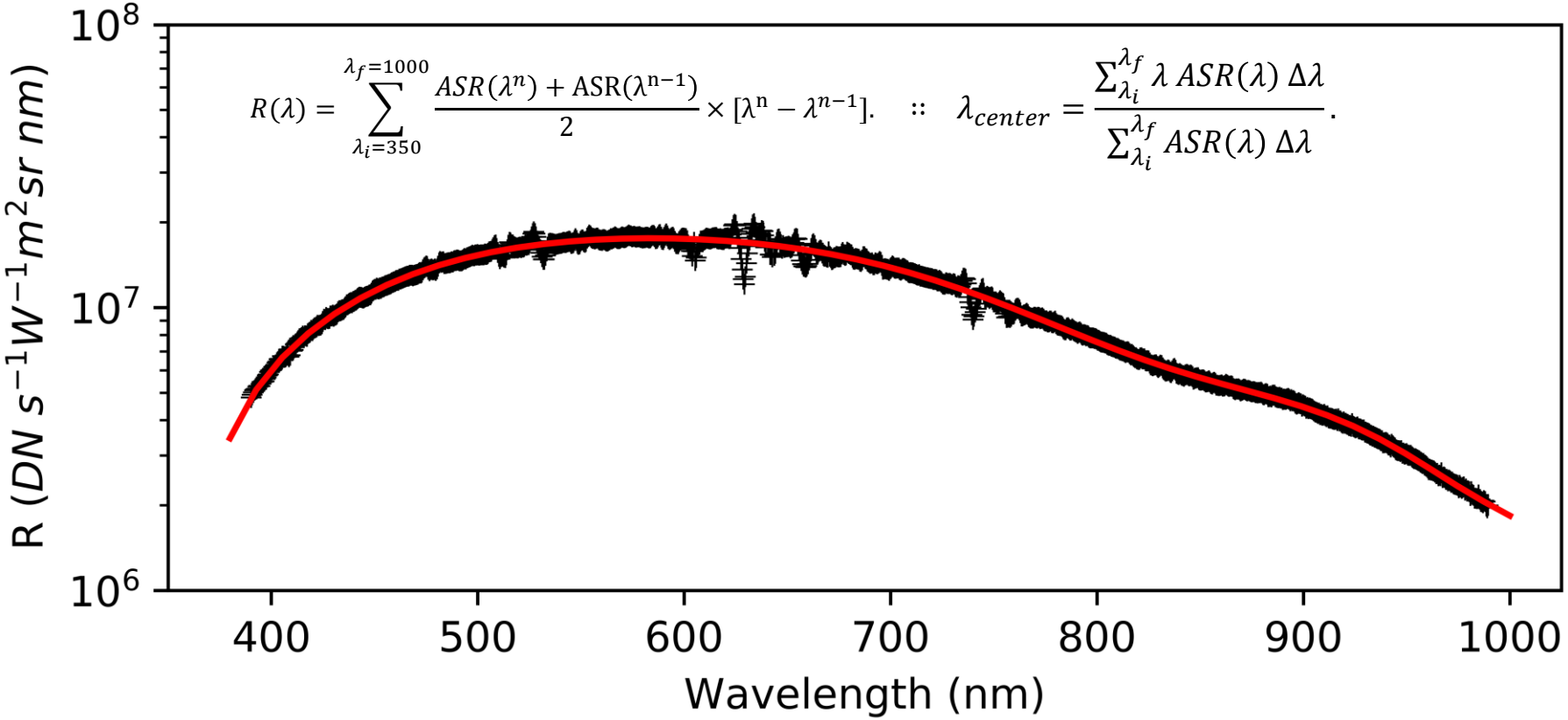

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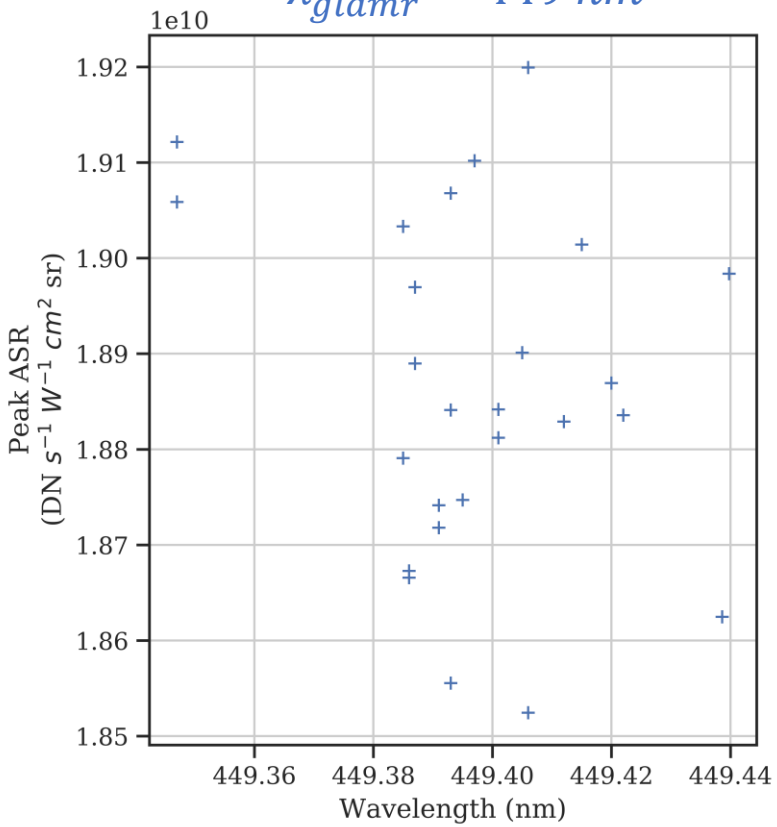
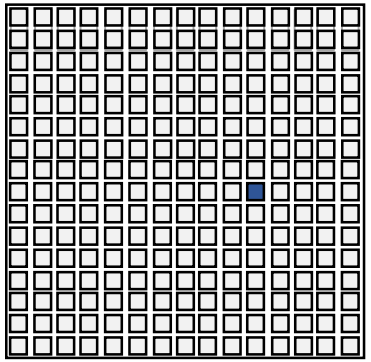
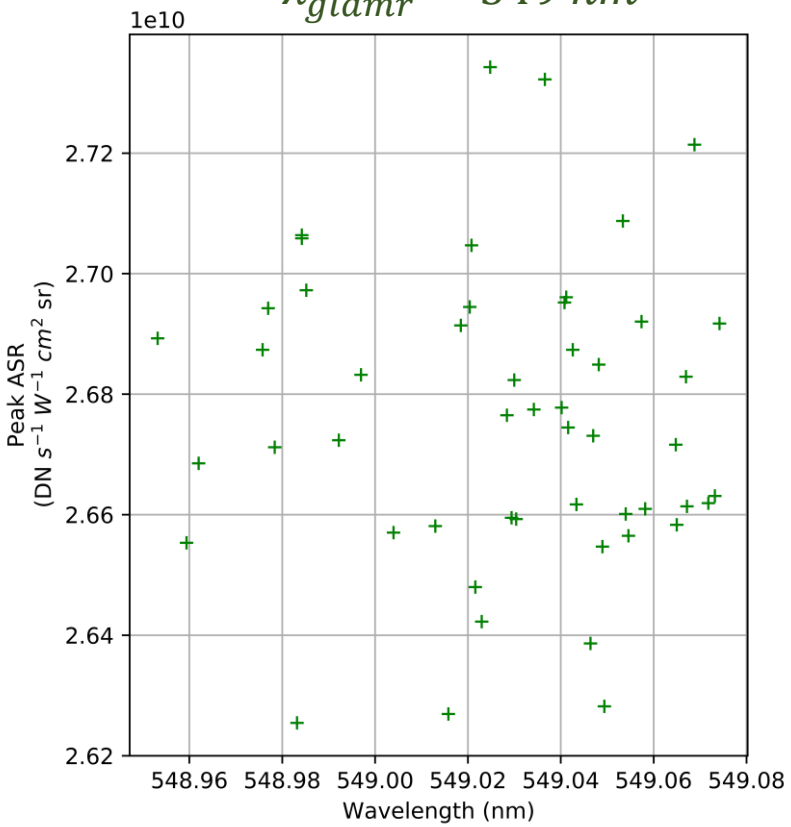
SS2 GLAMR Test Results

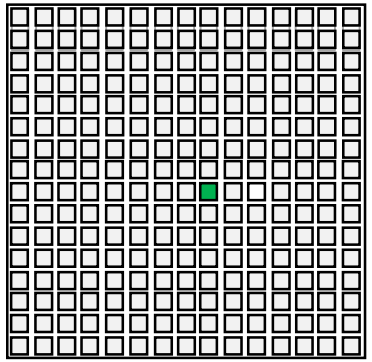
$\lambda_{glamr}^{set} = 449\ nm$



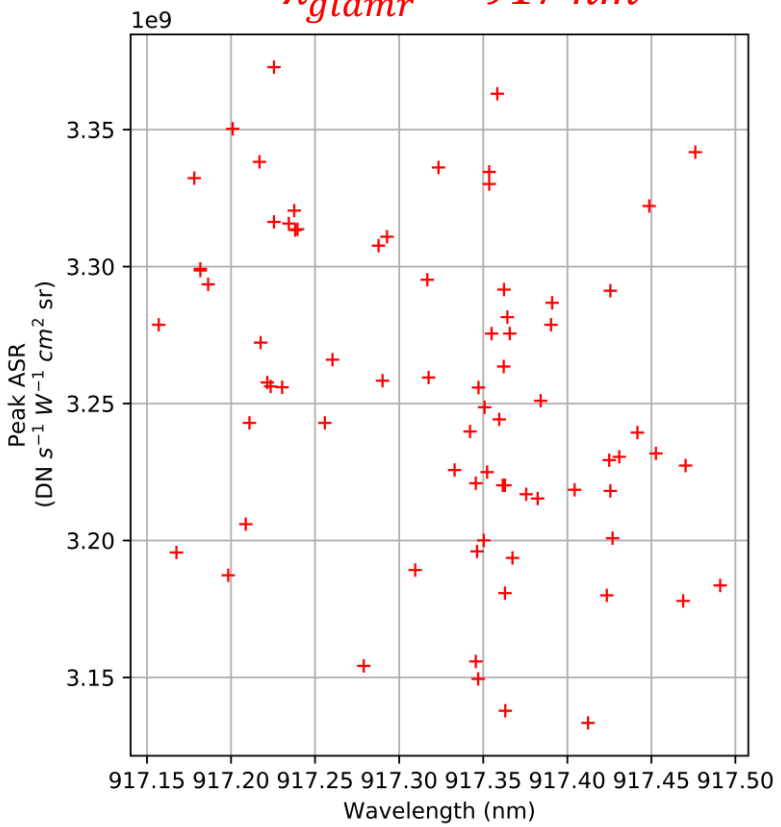


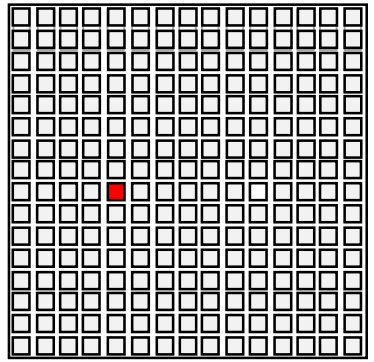
$\lambda_{glamr}^{set} = 549\ nm$





$\lambda_{glamr}^{set} = 917\ nm$





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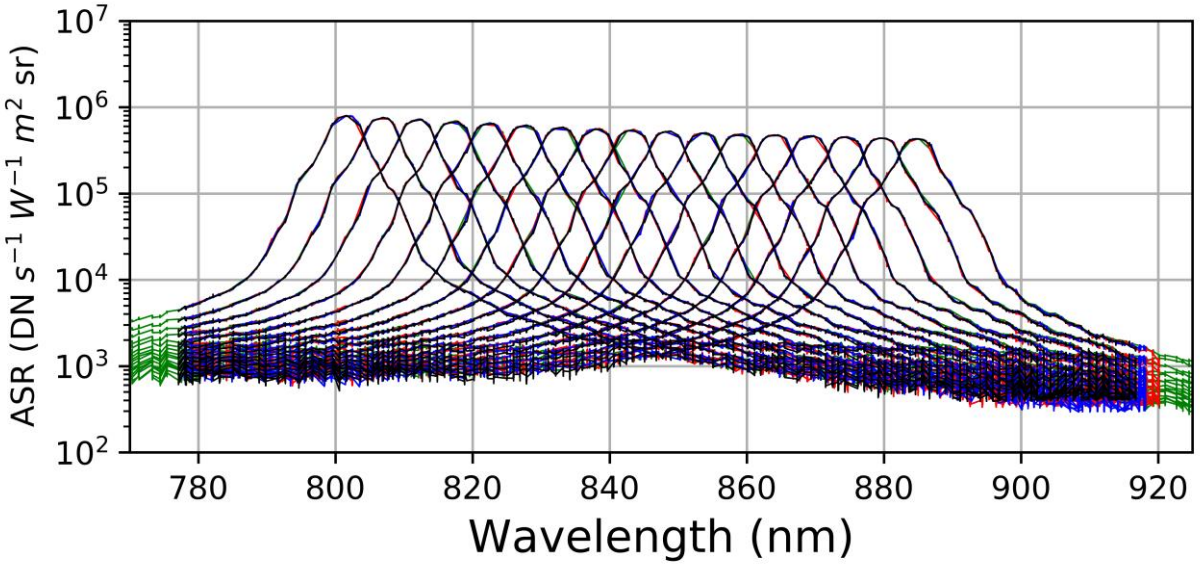
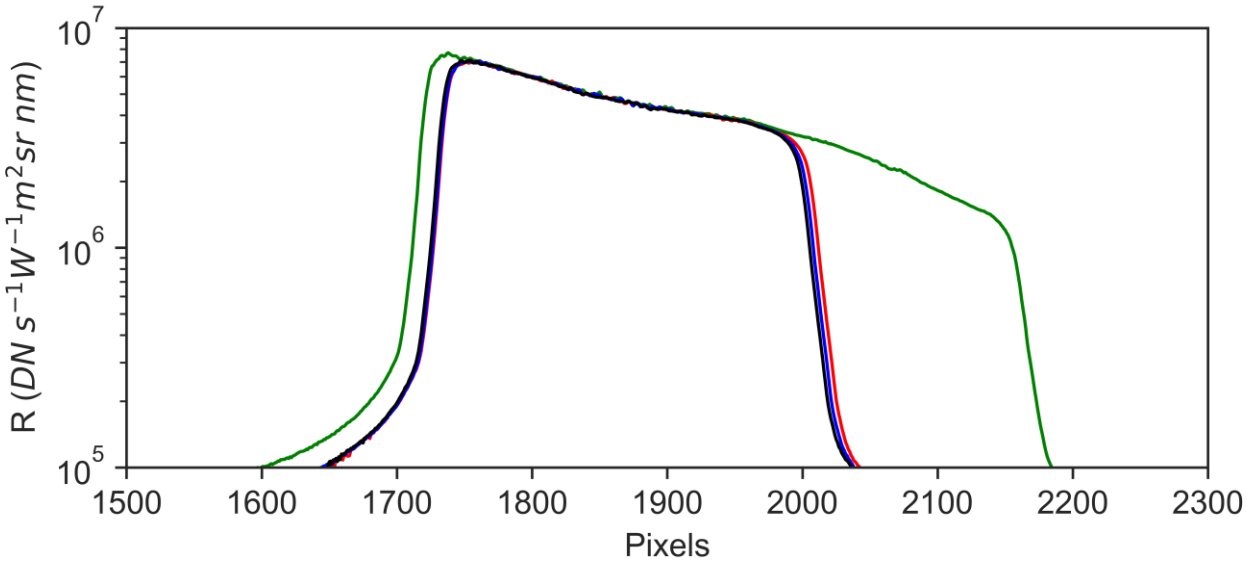
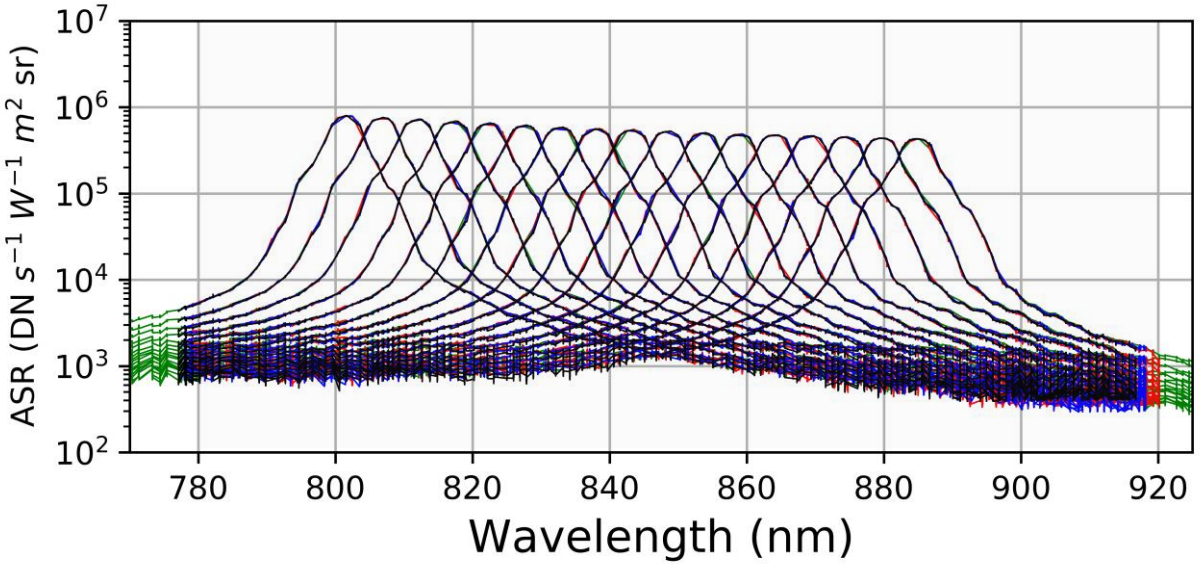


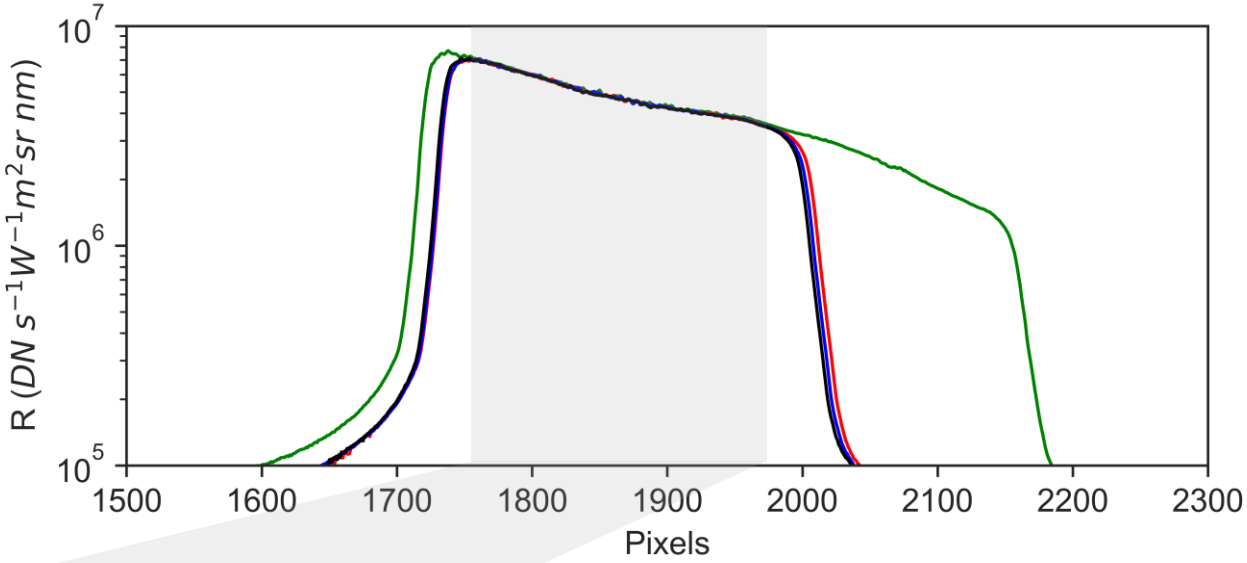


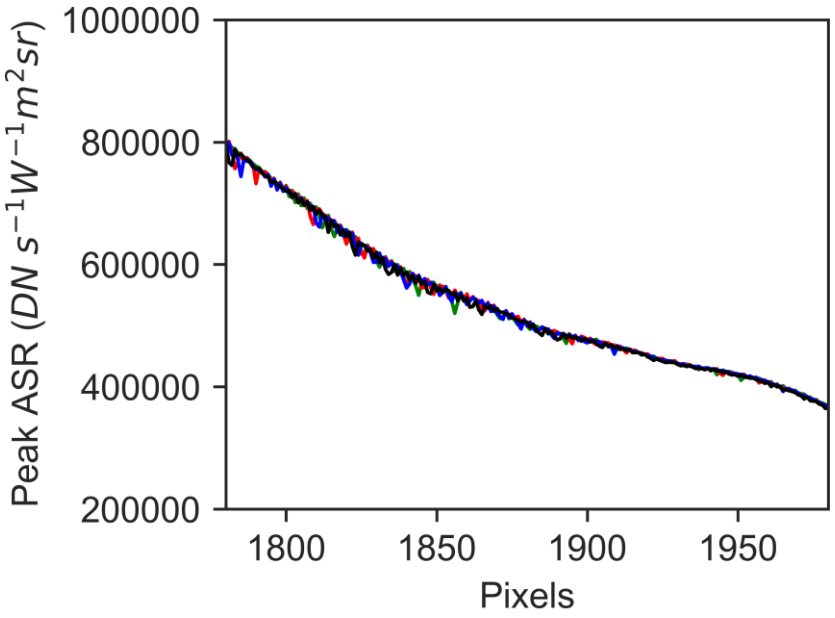
Repeatability Test:

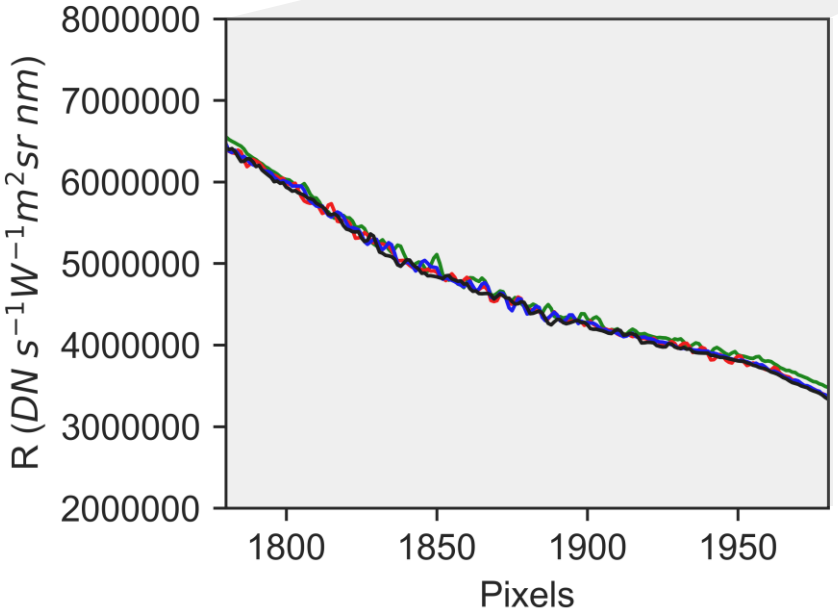
- Scanned 780 nm – 920 nm spectral range four times in two days
- The goal is to compare ASR, target wavelength, and the band averaged responses
- Checking the GLAMR conditions and repeatability as well

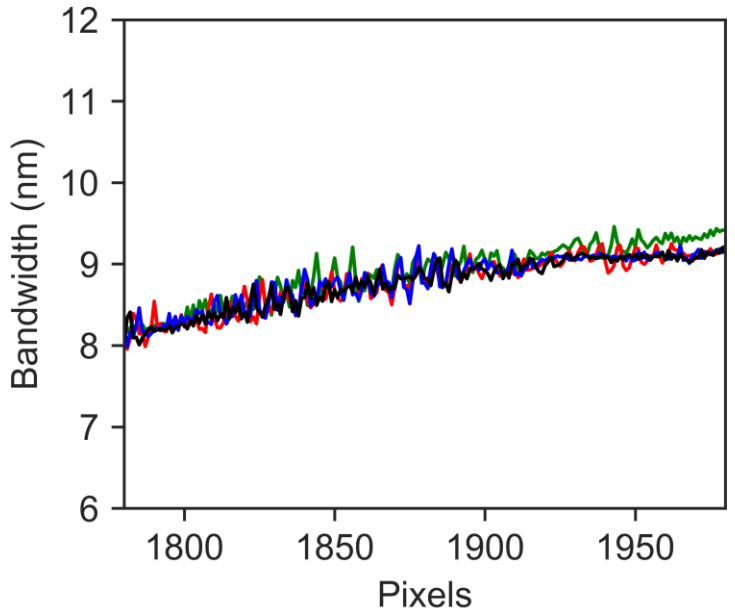
SS2 GLAMR Test Results



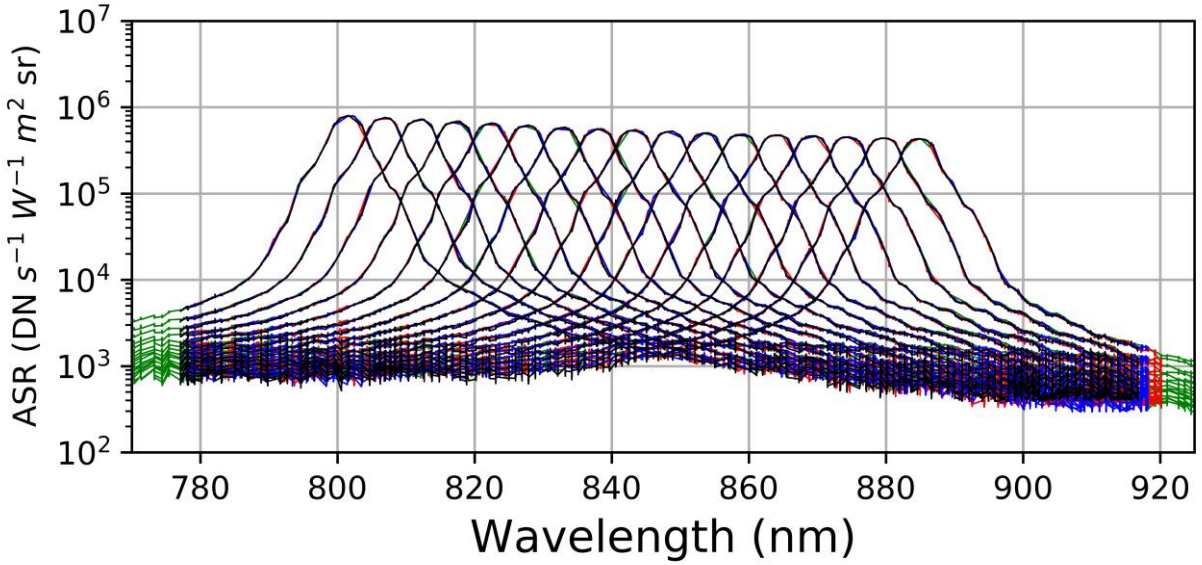


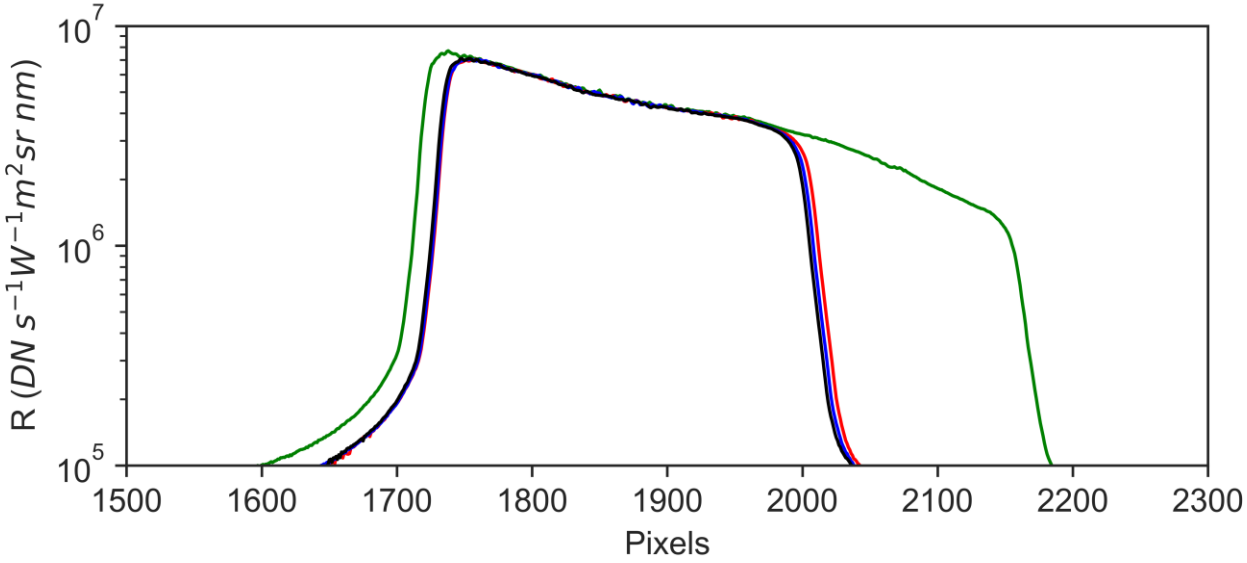


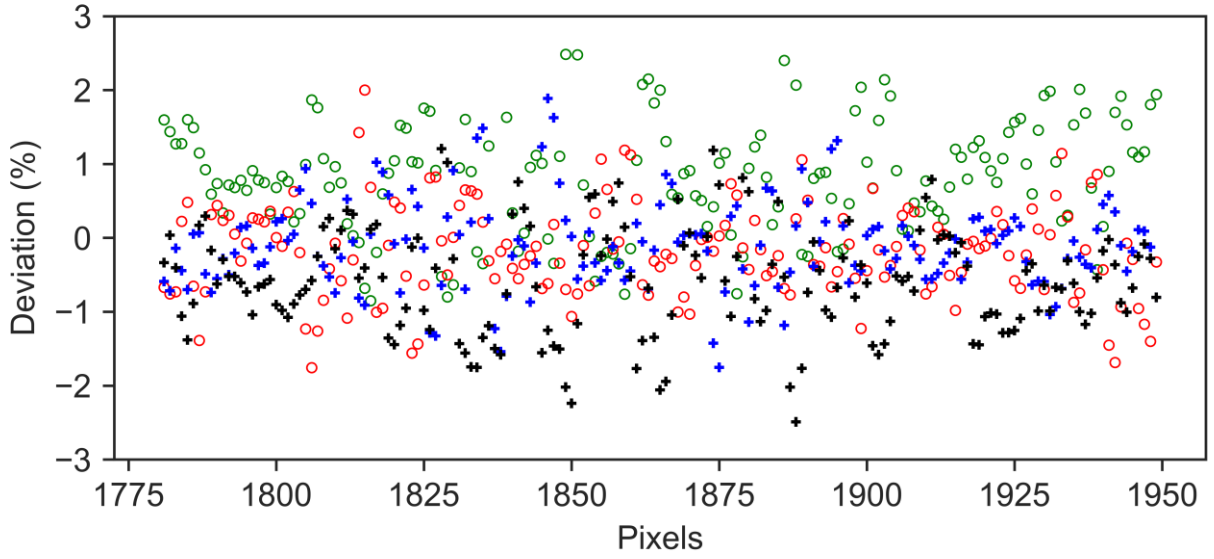


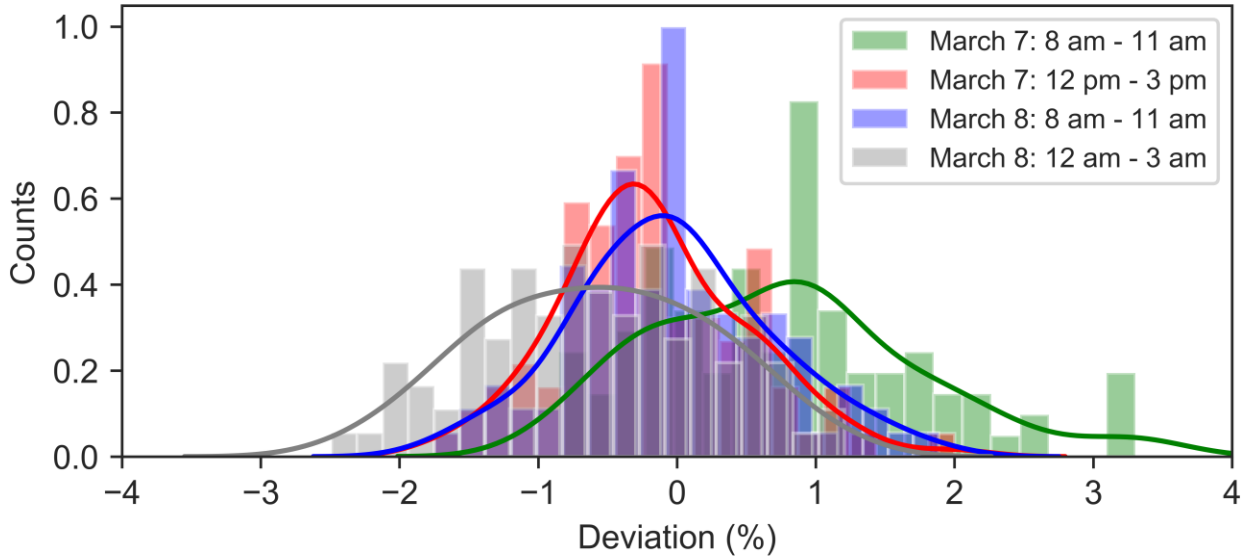


SS2 GLAMR Test Results

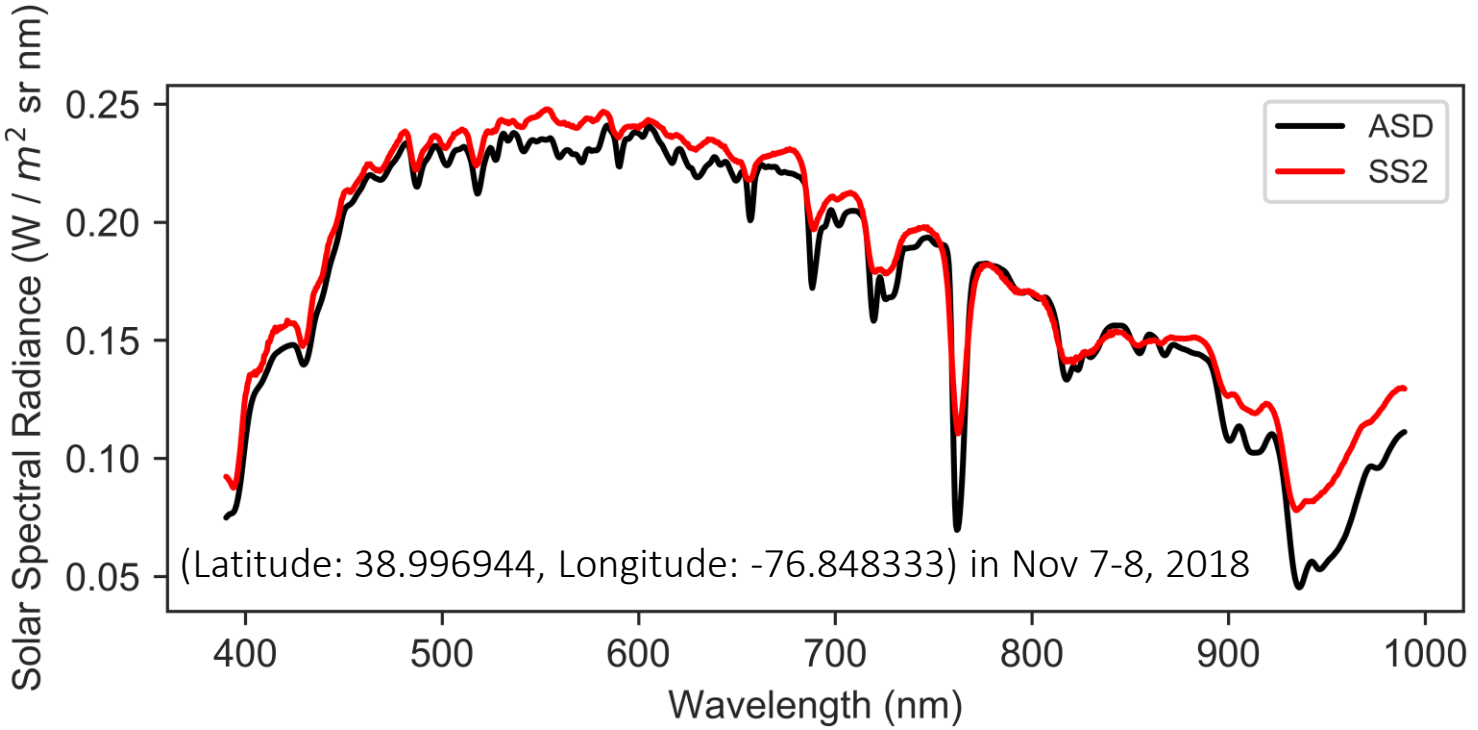


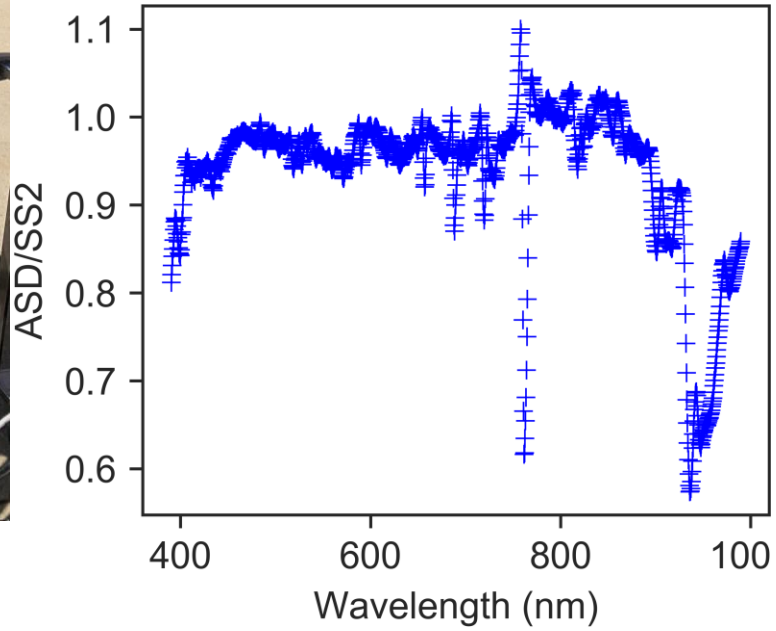


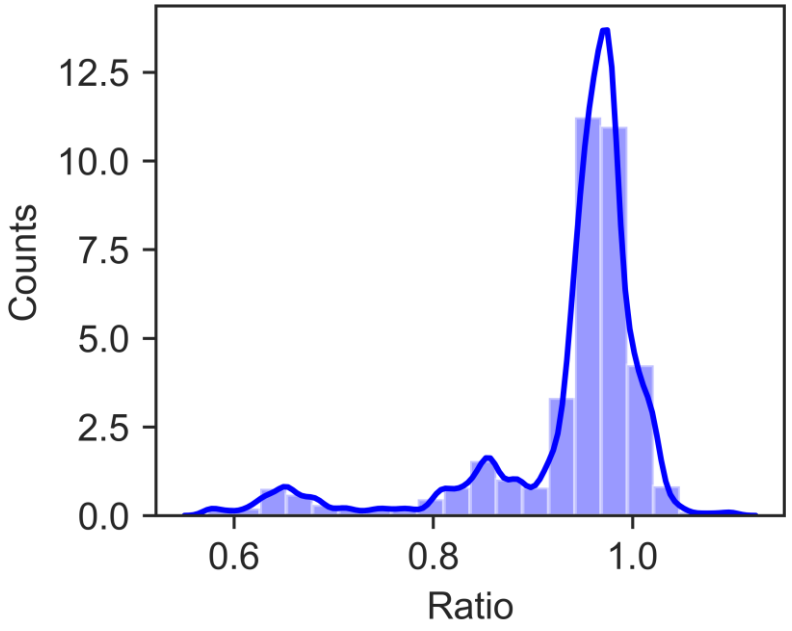




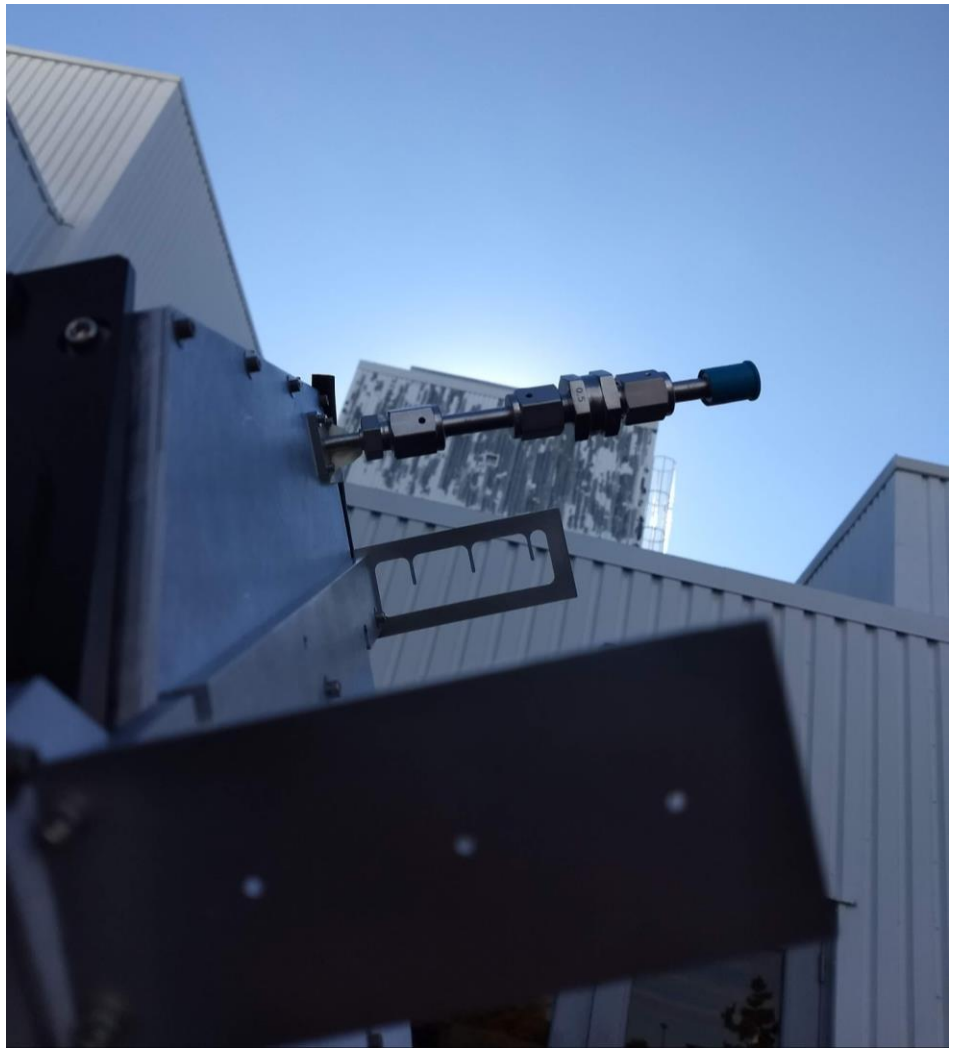
SS2 Outdoor Measurements

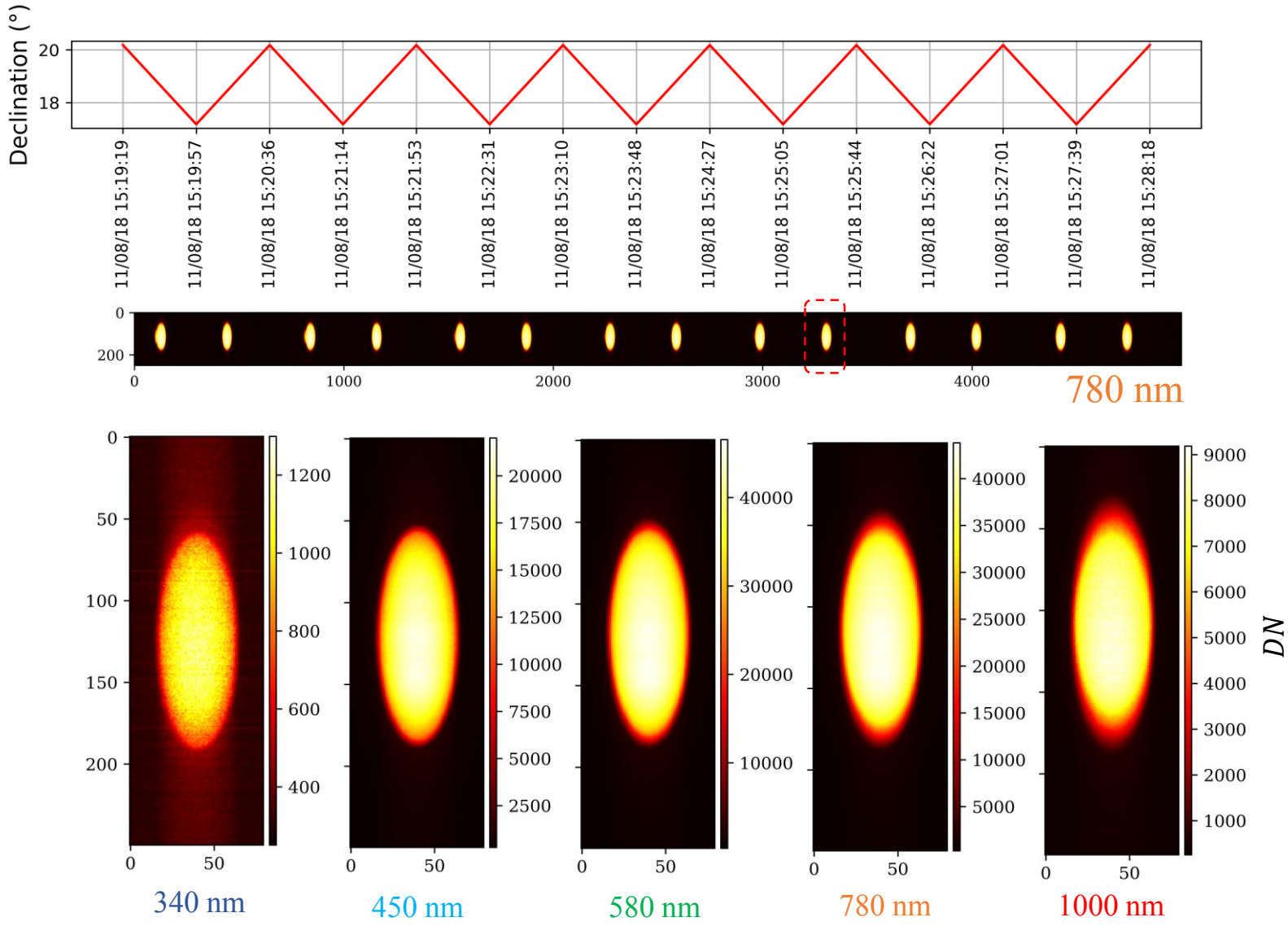






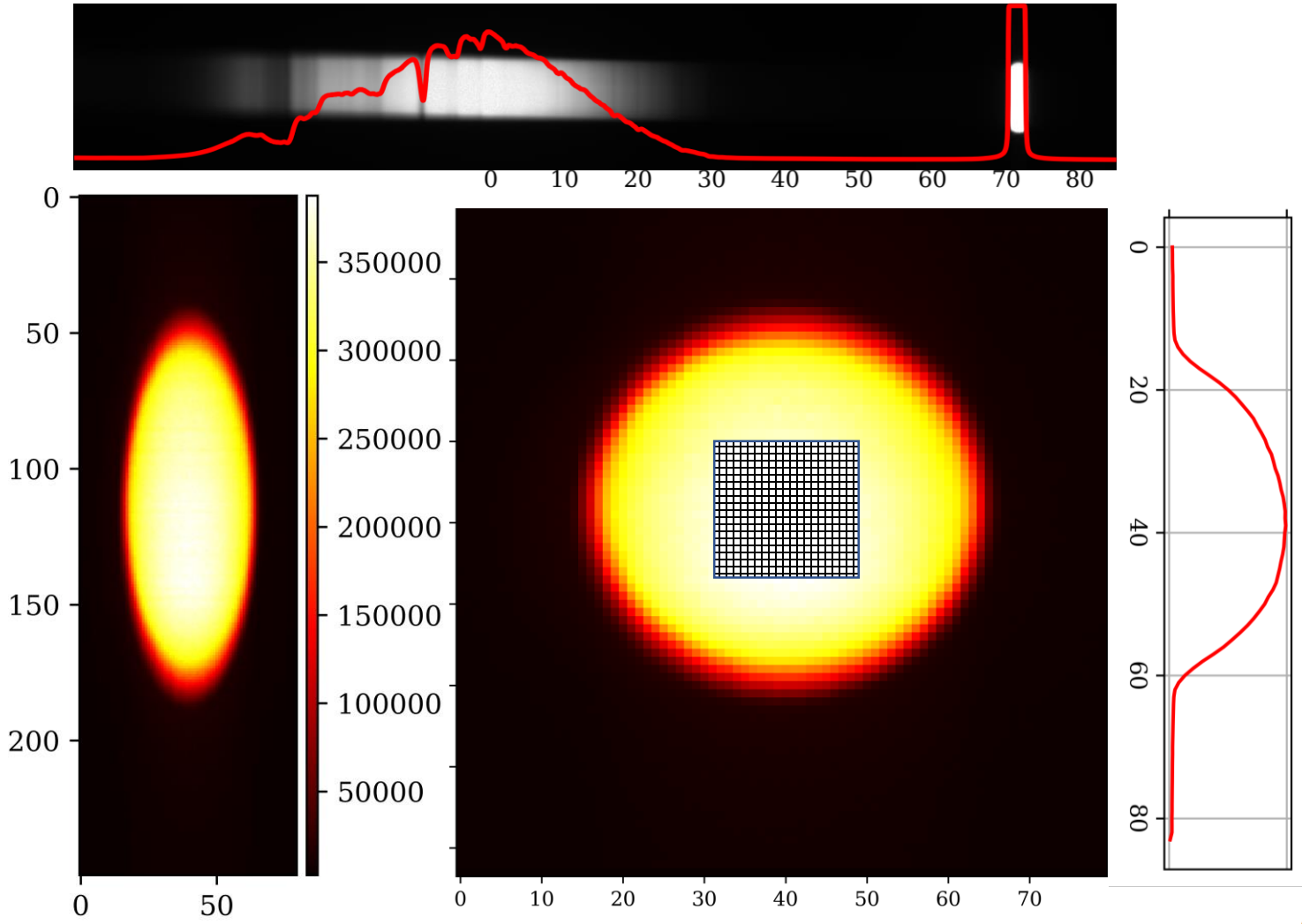
SS2 Outdoor Measurements





SS2 Outdoor Measurements

- Elliptical solar shape is due over sampling, and corrected by image downscaling algorithm
- At the spatial center of the image, solar radiation is calculated



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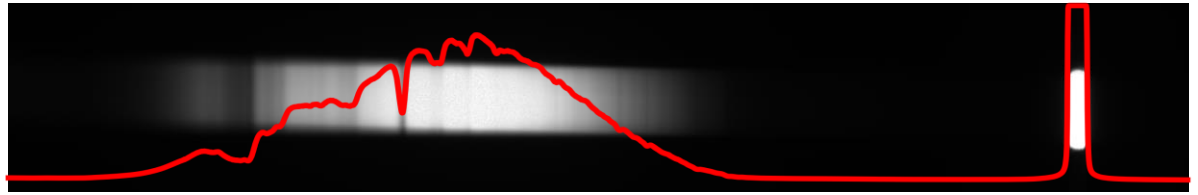

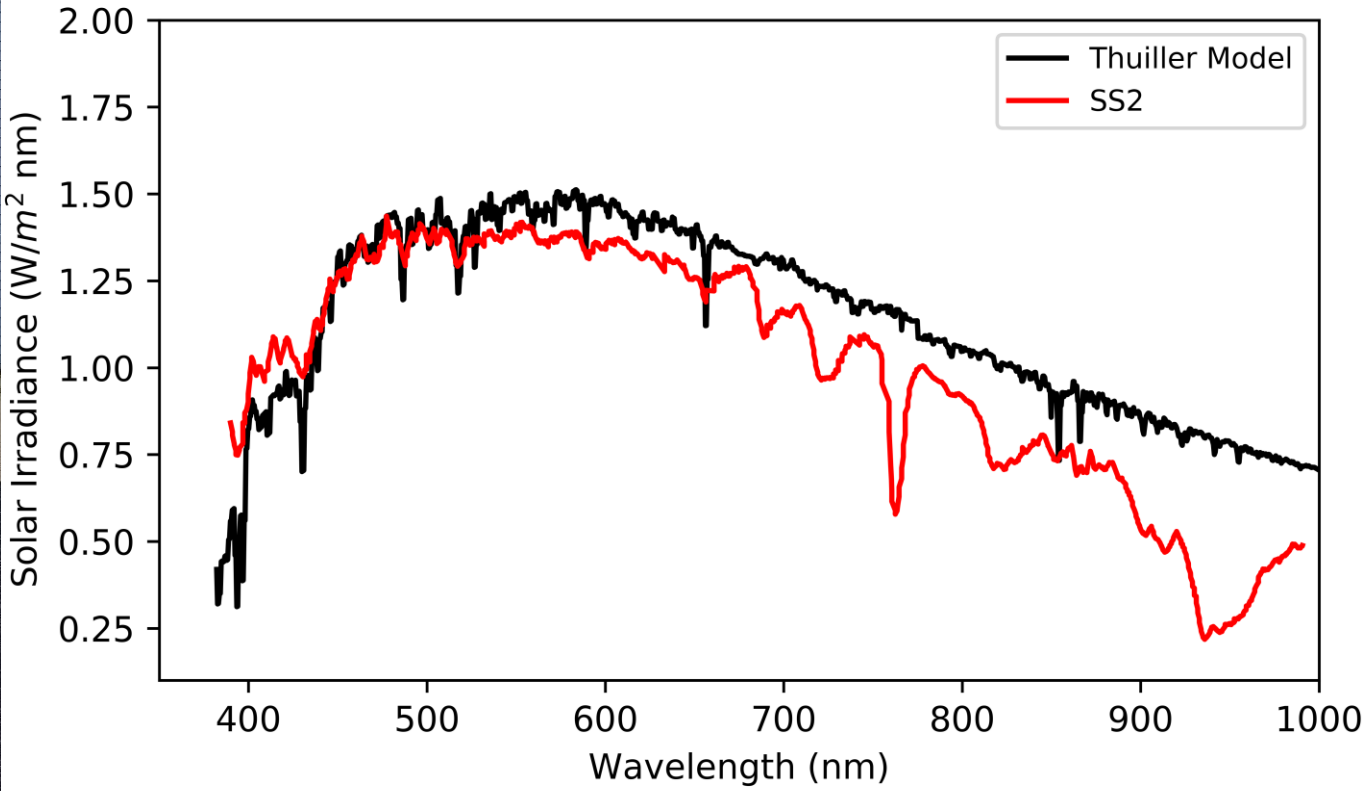

Conclusion

- SS2 is an easy-to-manage type test environment can be used both in laboratory and outside, while providing a high sensitivity sCMOS images

- GLAMR's advance calibration system is a unique test environment for characterizing spectroradiometers such as SS2, LandSat, HySICSs, etc.

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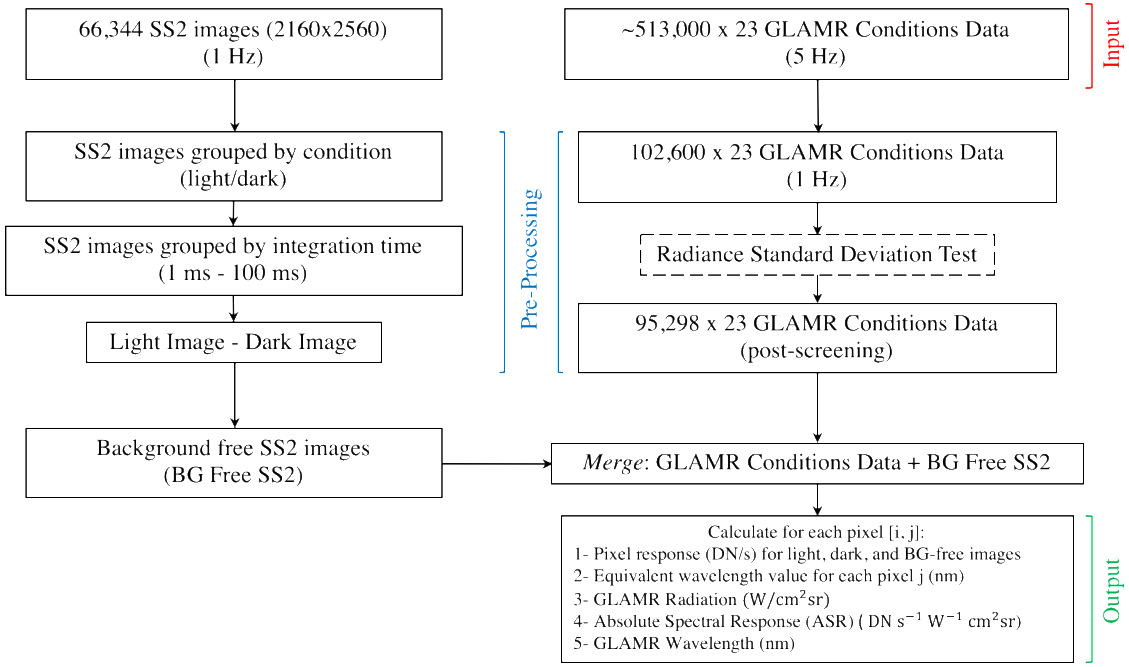
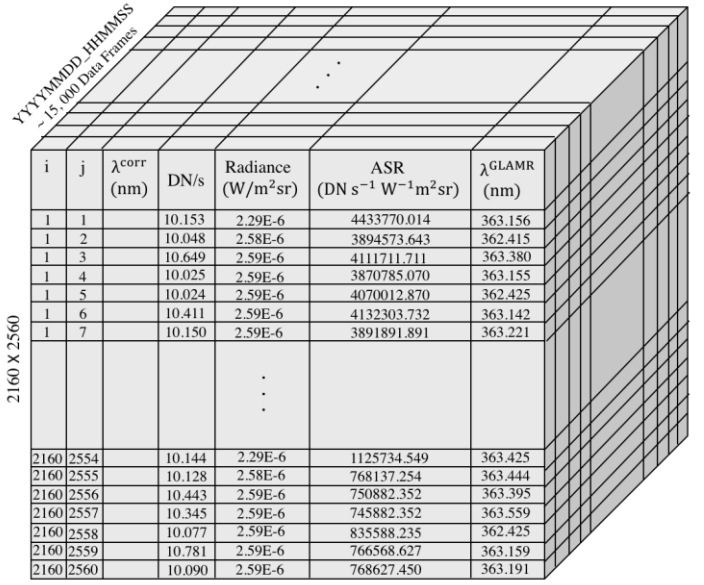
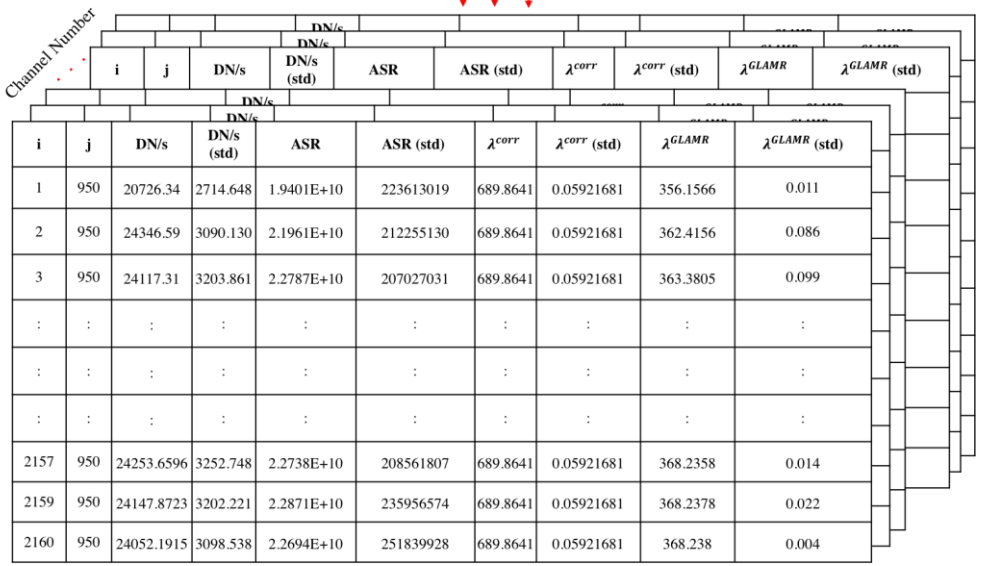




i	j	λ^{corr} (nm)	DN/s	Radiance (W/m²sr)	ASR (DN s⁻¹ W⁻¹m²sr)	λ^{GLAMR} (nm)
1	1		10.153	2.29E-6	4433770.014	363.156
1	2		10.048	2.58E-6	3894573.643	362.415
1	3		10.649	2.59E-6	4111711.711	363.380
1	4		10.025	2.59E-6	3870785.070	363.155
1	5		10.024	2.59E-6	4070012.870	362.425
1	6		10.411	2.59E-6	4132303.732	363.142
1	7		10.150	2.59E-6	3891891.891	363.221
2160	2554		10.144	2.29E-6	1125734.549	363.425
2160	2555		10.128	2.58E-6	768137.254	363.444
2160	2556		10.443	2.59E-6	750882.352	363.395
2160	2557		10.345	2.59E-6	745882.352	363.559
2160	2558		10.077	2.59E-6	835588.235	362.425
2160	2559		10.781	2.59E-6	766568.627	363.159
2160	2560		10.090	2.59E-6	768627.450	363.191



i	j	DN/s	DN/s (std)	ASR	ASR (std)	λ^{corr}	λ^{corr} (std)	λ^{GLAMR}	λ^{GLAMR} (std)
1	950	20726.34	2714.648	1.9401E+10	223613019	689.8641	0.05921681	356.1566	0.011
2	950	24346.59	3090.130	2.1961E+10	212255130	689.8641	0.05921681	362.4156	0.086
3	950	24117.31	3203.861	2.2787E+10	207027031	689.8641	0.05921681	363.3805	0.099
:	:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:	:
2157	950	24253.6596	3252.748	2.2738E+10	208561807	689.8641	0.05921681	368.2358	0.014
2159	950	24147.8723	3202.221	2.2871E+10	235956574	689.8641	0.05921681	368.2378	0.022
2160	950	24052.1915	3098.538	2.2694E+10	251839928	689.8641	0.05921681	368.238	0.004