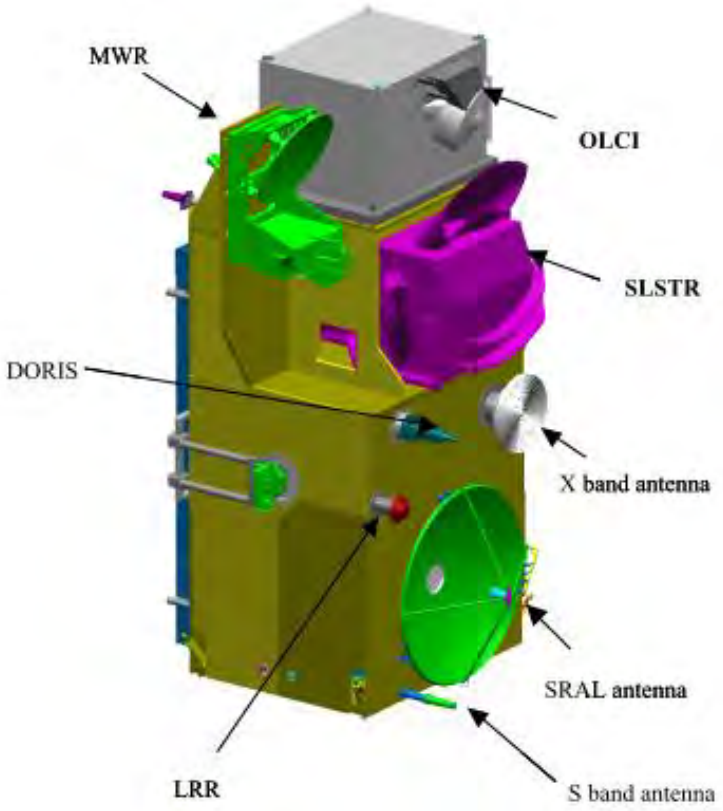
OLCI Stray-light correction: Performance assessment using Moon observations

L. Bourg

& the S3-MPC L1 ESL team



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Overview

- Instrument Overview
  - Principle & sub-systems
  - Straylight sources
- Straylight characterization and correction principle
- Moon Observation and related constraints
- Results

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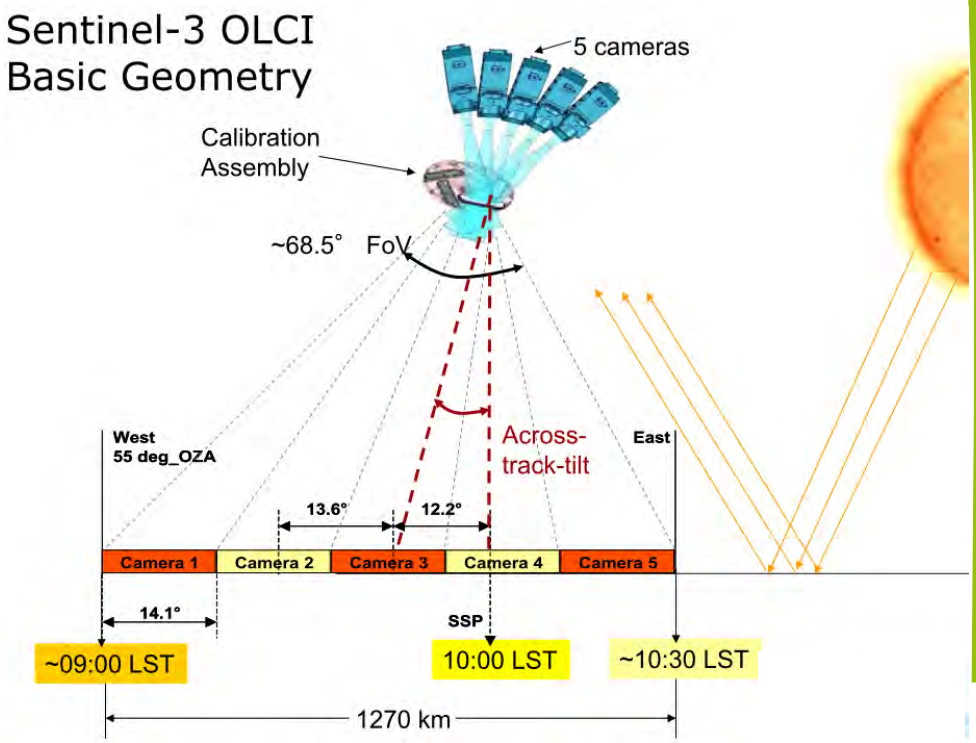
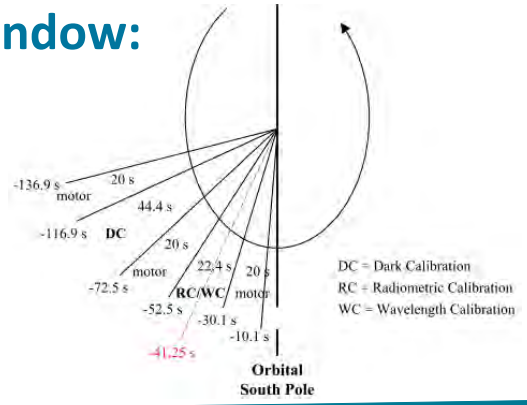
OLCI, successor to MERIS

- Push-broom imaging spectrometer, 5 fan-arranged cameras
- Radiometric calibration based on on-board diffuser(s)
- Spectral calibration using dedicated on-board diffuser

+ 12 degrees westward tilt to minimize Sun glint and increase swath to 1250km
+ number of bands increased to 21
+ technological improvements…



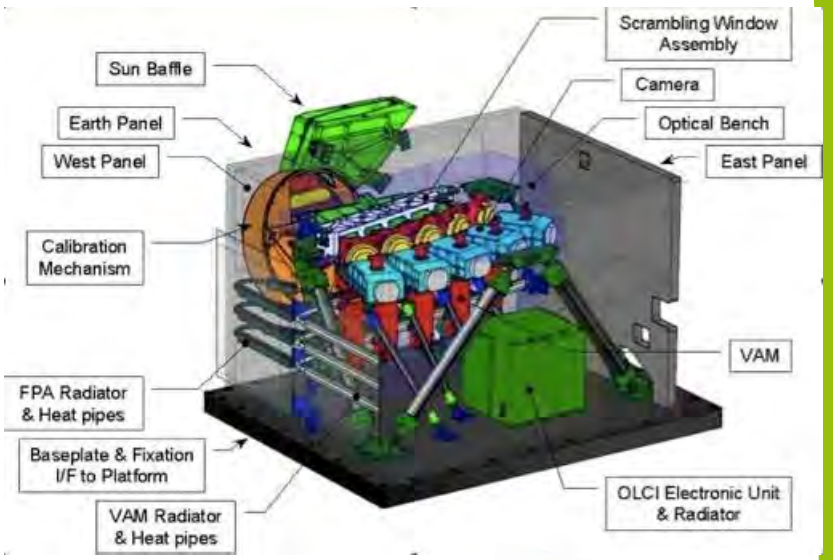
Radiometric calibration outside EO observation window:

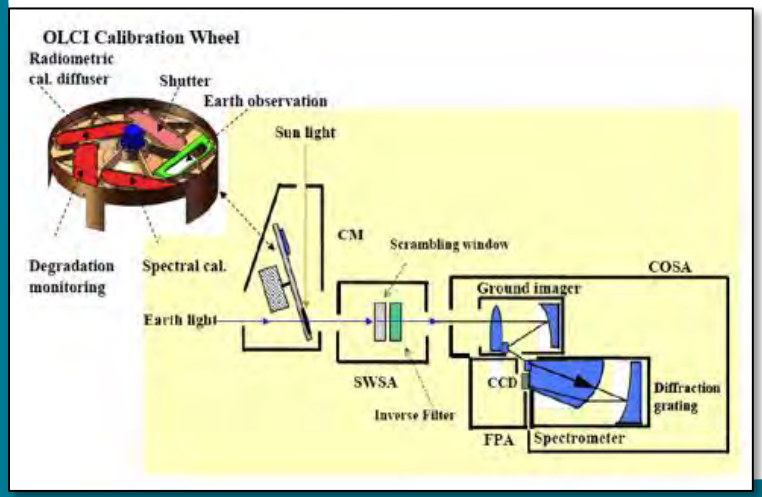


S3 OLCI: Technical details

Basic configuration similar to MERIS:

- 5 Camera Optical Sub Assemblies (COSA),
- 5 Focal Plane Assemblies (FPA),
- 5 Video Acquisition Modules (VAM),
- 1 Scrambling Window Assembly (SWA),
- 1 OLCI Electronic Unit (OEU) managing all the instrument functions,
- 1 calibration assembly allowing radiometric and spectral calibration.





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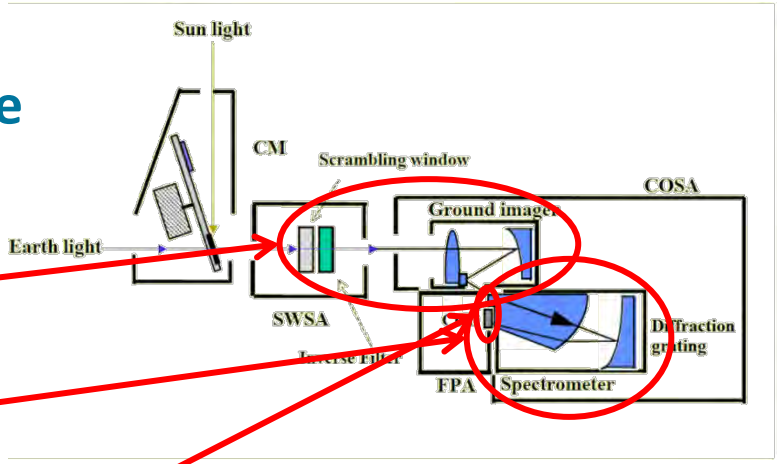
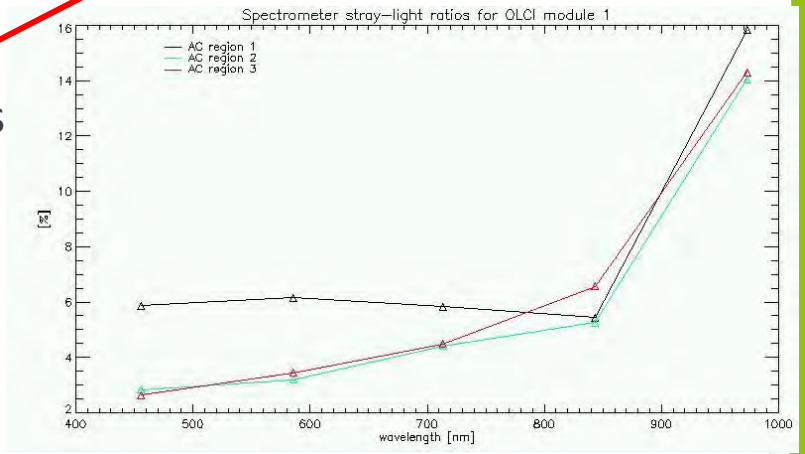
OLCI Straylight characteristics

- As all spectro-imagers, OLCI is sensitive to straylight
- Straylight sources:
  - Imaging optics
    - ✓ Straylight higher at short wavelengths
  - Spectrometer
    - ✓ Dominant term
    - ✓ Straylight increases at long wavelengths
  - CCD especially above 900





Ratio straylight / total signal
For 3 spatial regions, as a function of the wavelength

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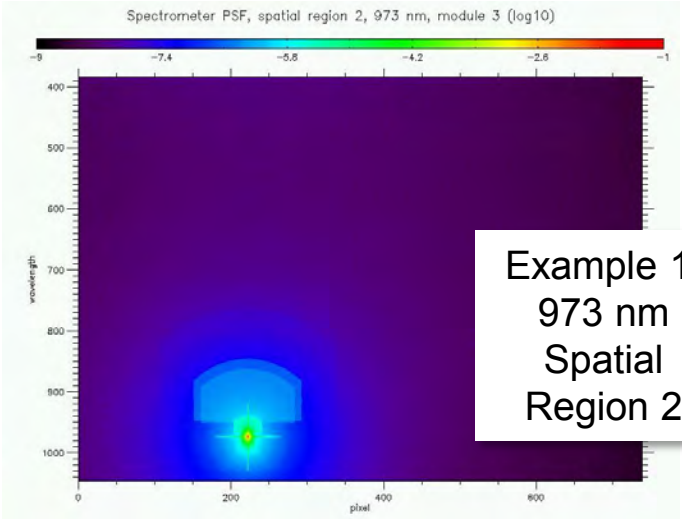
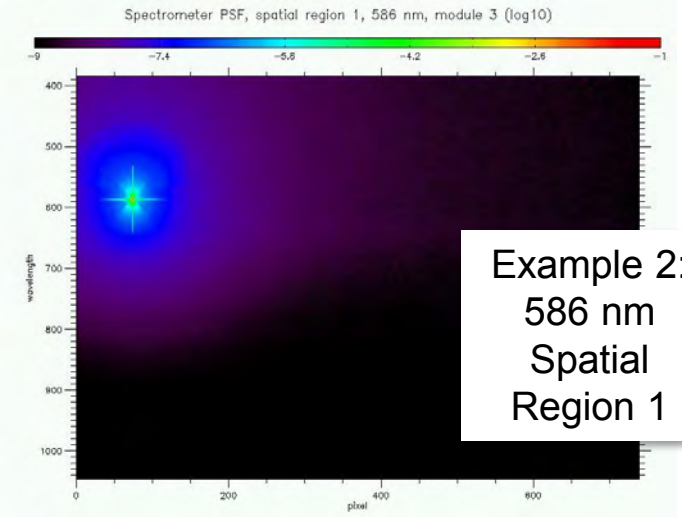
OLCI Straylight characterisation

On-ground characterization methodology

- **Simulation with ray tracing to generate PSF**
  - ✓ The simulation uses the ground characterization database for each camera
  - ✓ Simulations at several wavelengths and positions in the Field of View
- **Characterization with knife-edge set-up with feedback on simulation to adjust model parameters**
- **The Straylight PSF is obtained by subtracting the straylight-free PSF (no scatter, no reflections) from the full simulation PSF**



Example 1: 973 nm Spatial Region 2



Example 2: 586 nm Spatial Region 1

OLCI Straylight correction algorithm

Correction algorithm

- $(1+\varepsilon)^2 \approx (1+2\varepsilon)$ → SL from SL contaminated signal ≈ SL from clean signal
- Characterized by PSFs → convolutive process (implement by FFTs)
- Correction applied for each component following the light path backwards
- Spectrometer correction (for each camera)
  - ✓ Spatial x spectral whole CCD image rebuilt ([390, 1040] @1.25 resolution)
  - ✓ NxM PSFs (5 λ, 5 θ), assumed to vary bi-linearly in-between, interpolation implemented in the Fourier space
- GI correction
  - ✓ 2D spatial convolutions
  - ✓ N PSFs (3 λ), selected as closest to corrected channel

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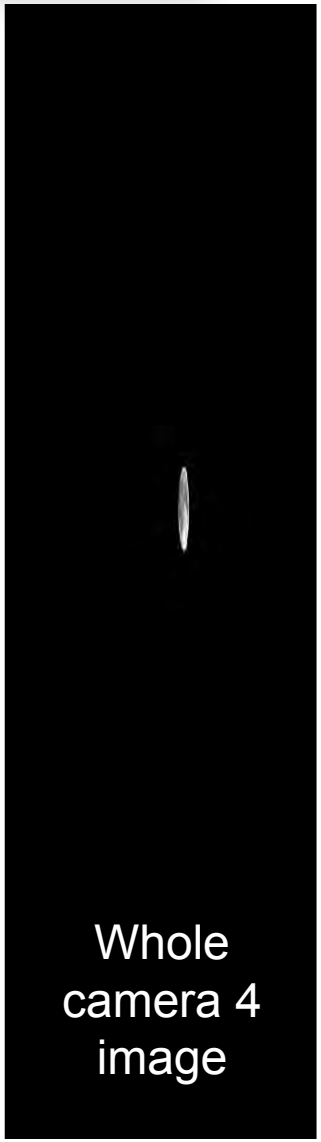
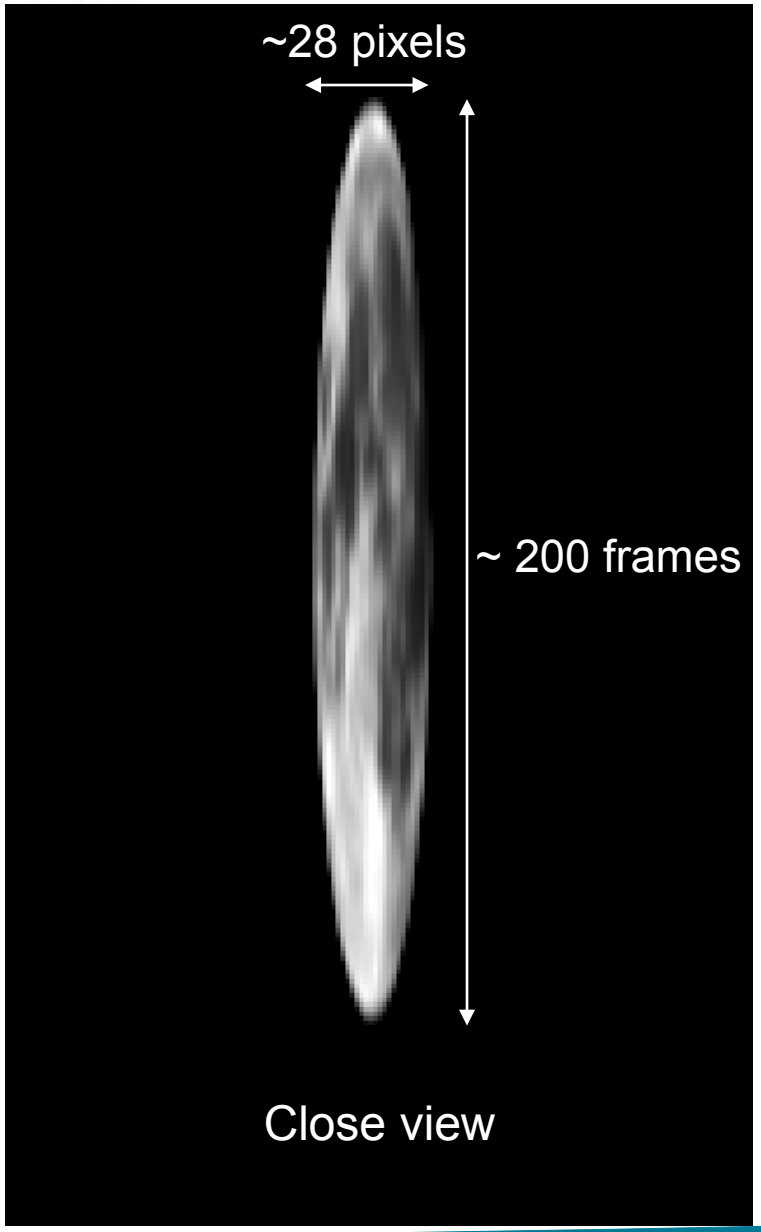
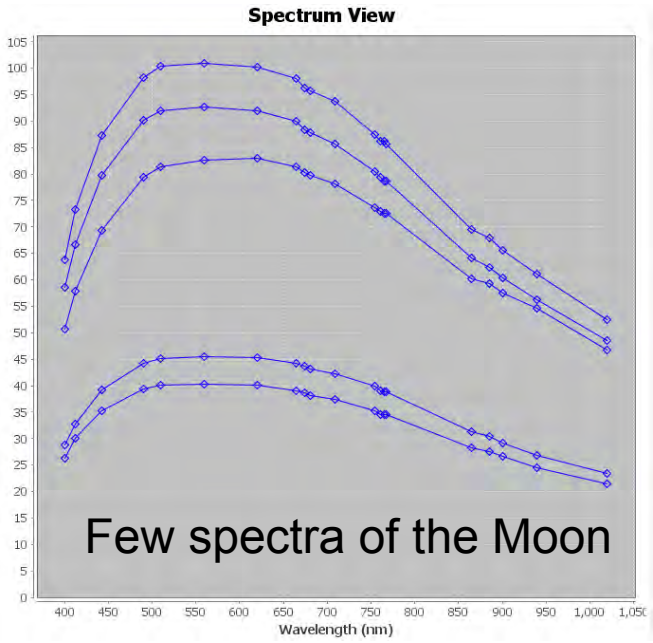
Moon observation





- **Acquired with Camera 4, 27/07/2018**
- **Flyby velocity introduces time (along-track) oversampling factor x7.225**
- **Up to ~100 $mW.m^{-2}.sr^{-1}.^{-1}$**



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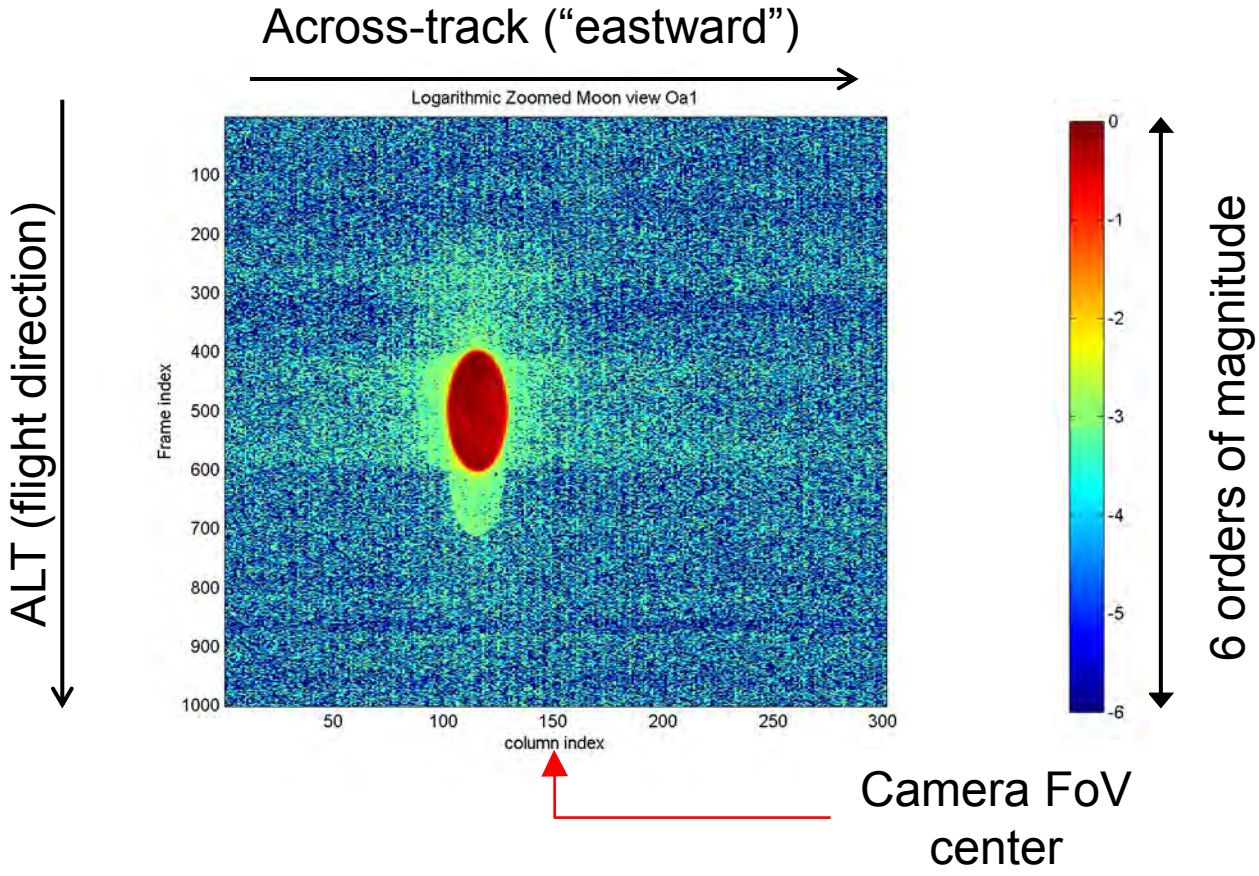
  - Correction performance

In-orbit straylight verification using Moon scene

Qualitative assessment before on-ground correction (OLCI-B, camera FM1-R)

Interpretation courtesy Thales-Alenia-Space France

log-scaled radiance, normalized to max



In-orbit straylight verification using Moon scene

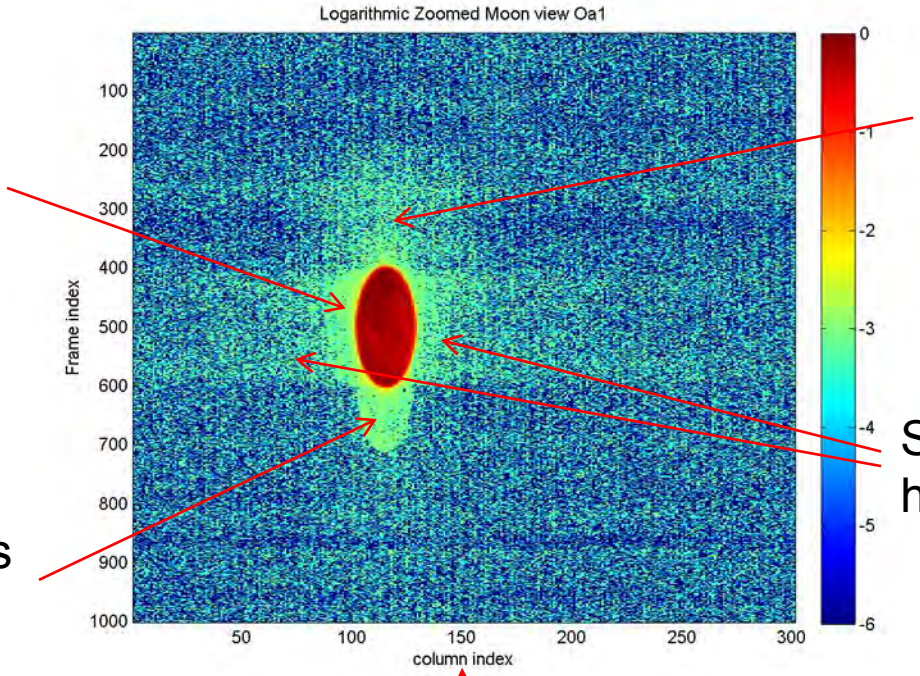
Qualitative assessment before on-ground correction (OLCI-B, camera FM1-R)

Interpretation courtesy Thales-Alenia-Space France

Channel Oa1 – 400, log-scaled radiance

Ghost „C", shifted ≈ 16 pixels

(grating order 0 → reflection by corrector block → grating order -1 → detector)



Ghost between slit and field lens + scatter

Scatter + ghost from higher wavelengths

Ghost between scrambler/filters and Ground Imager

Camera FoV center

In-orbit straylight verification using Moon scene

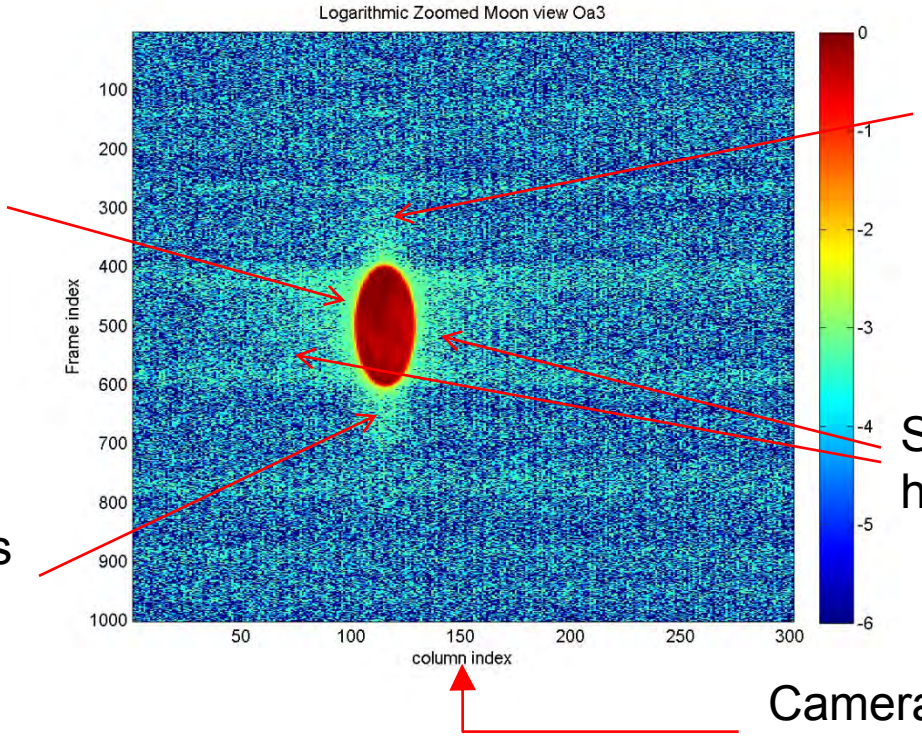
Qualitative assessment before on-ground correction (OLCI-B, camera FM1-R)

Interpretation courtesy Thales-Alenia-Space France

Channel Oa3 – 443, log-scaled radiance

Ghost „C", shifted ≈ 16 pixels

(grating order 0 → reflection by corrector block → grating order -1 → detector)



Ghost between slit and field lens + scatter

Channel Oa3 exhibits the lowest straylight level

Scatter + ghost from higher wavelengths

Ghost between scrambler/filters and Ground Imager

Camera FoV center

In-orbit straylight verification using Moon scene

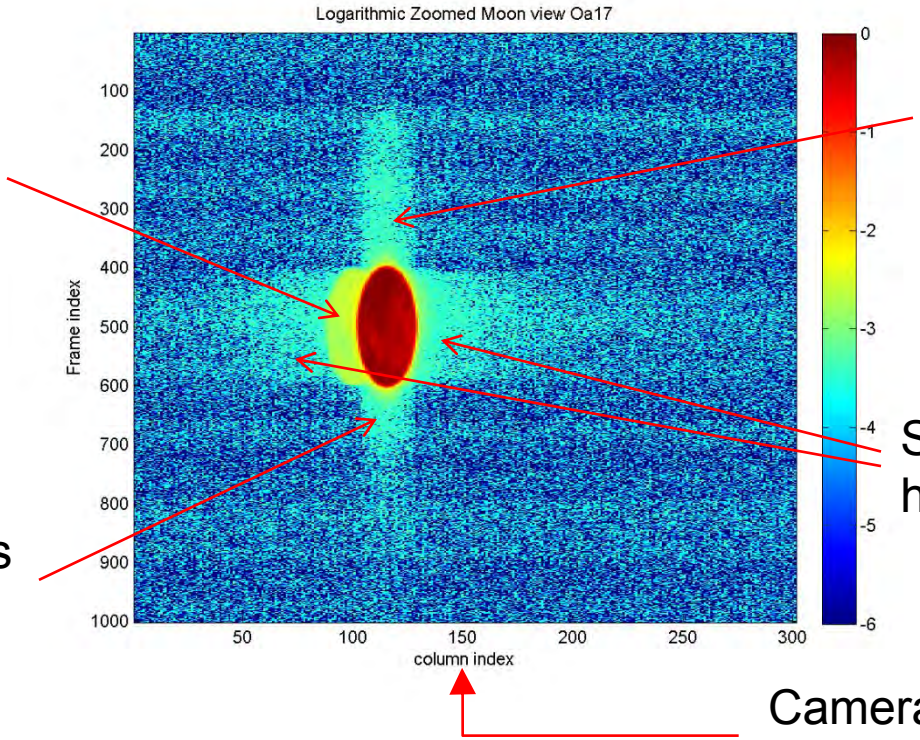
Qualitative assessment before on-ground correction (OLCI-B, camera FM1-R)

Interpretation courtesy Thales-Alenia-Space France

Channel Oa17 – 865 , log-scaled radiance

Ghost „C", shifted ≈ 16 pixels

(grating order 0 → reflection by corrector block → grating order -1 → detector)



Ghost between slit and field lens + scatter

Scatter + ghost from higher wavelengths

Ghost between scrambler/filters and Ground Imager

Camera FoV center

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In-orbit straylight verification using Moon scene

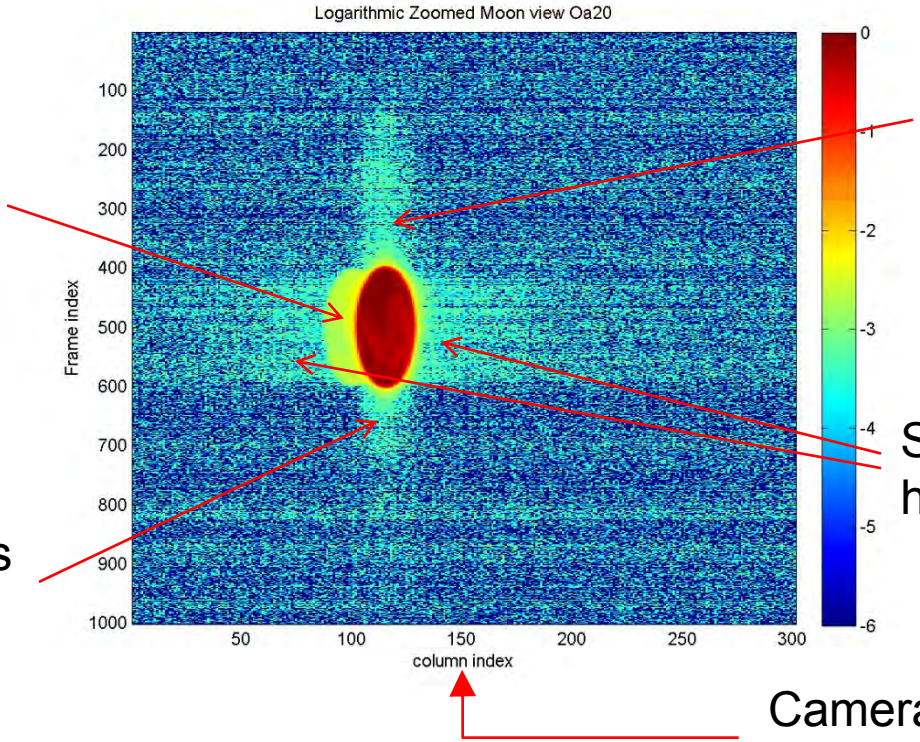
Qualitative assessment before on-ground correction (OLCI-B, camera FM1-R)

Interpretation courtesy Thales-Alenia-Space France

Channel Oa20 – 940 , log-scaled radiance

Ghost „C", shifted ≈ 16 pixels

(grating order 0 → reflection by corrector block → grating order -1 → detector)



Ghost between slit and field lens + scatter

Scatter + ghost from higher wavelengths

Ghost between scrambler/filters and Ground Imager

Camera FoV center

In-orbit straylight verification using Moon scene

Qualitative assessment before on-ground correction (OLCI-B, camera FM1-R)

Interpretation courtesy Thales-Alenia-Space France

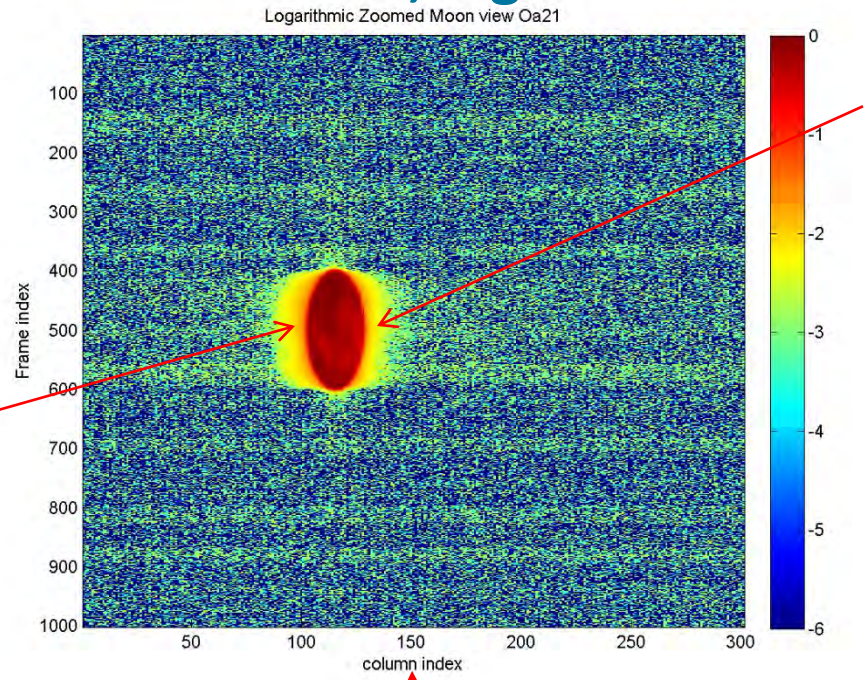
Channel Oa21 – 1020 , log-scaled radiance

Ghost „C", shifted ≈ 16 pixels

(grating order 0 → reflection by corrector block → grating order -1 → detector)

+

Photon diffusion



Photon diffusion

Unlike other channels, Oa21 is dominated by ghost 'C' and photon diffusion within the CCD

Camera FoV center

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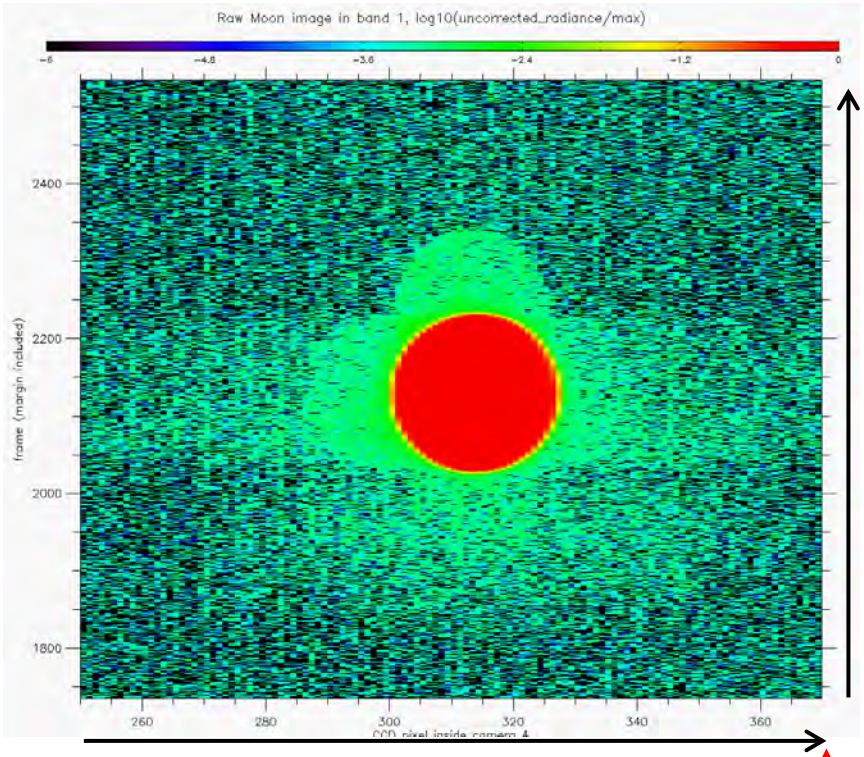
  - **Correction performance**

What will we look at ?

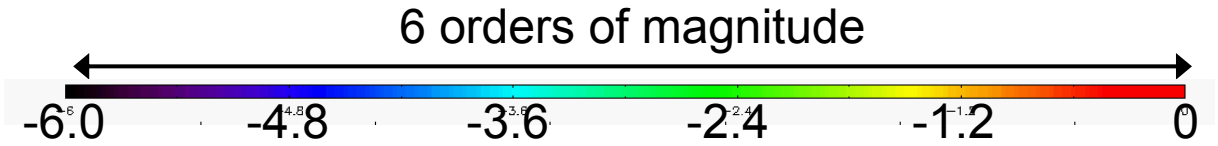
log-scaled radiance, normalized to max $log_{10}\left(\frac{L(\lambda)}{L_{max}(\lambda)}\right)$



ALT (flight direction)
~800 oversampled frames
or ~110 “nominal” ones

Across-track (“eastward”): 120 pixels

Camera FoV center



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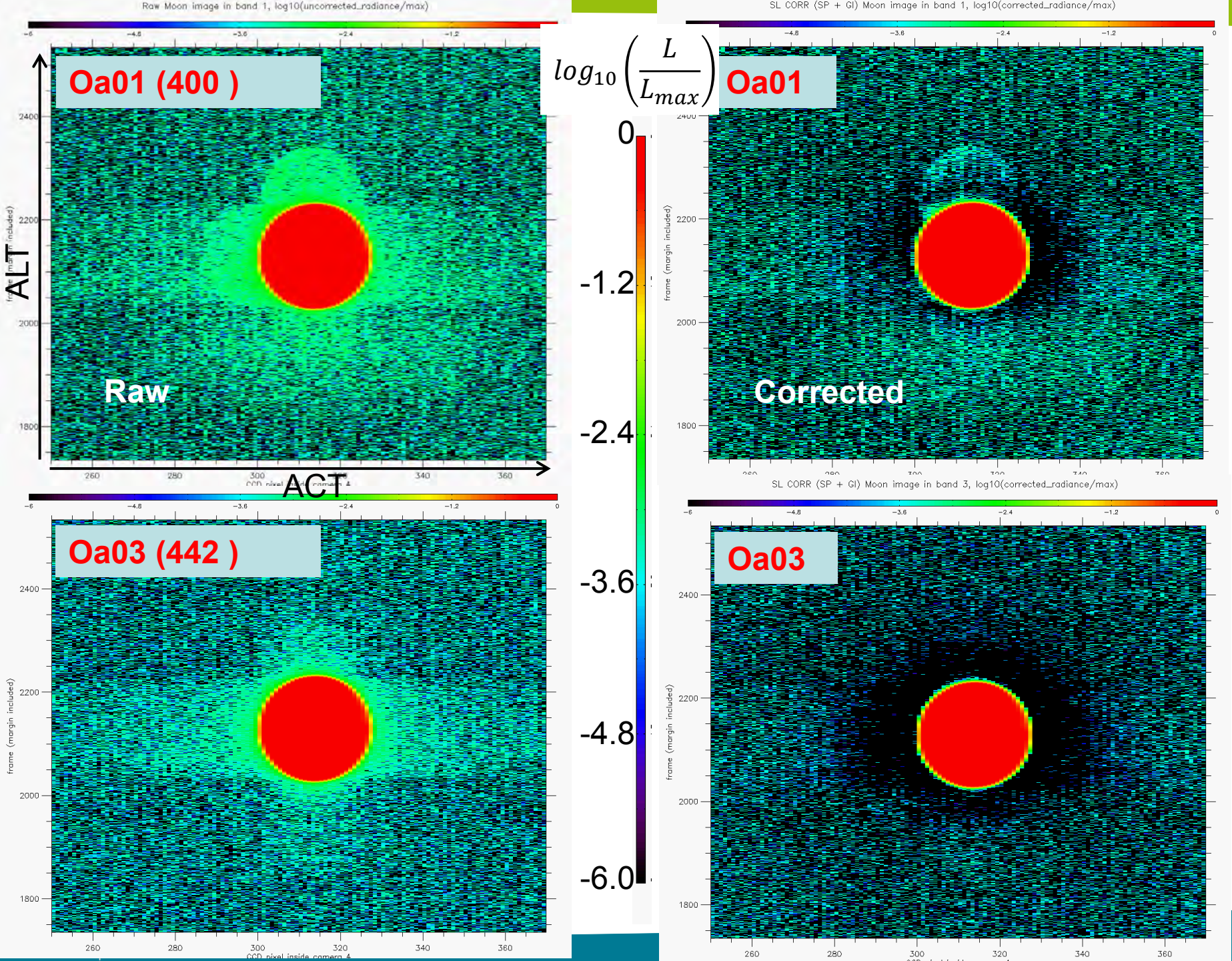
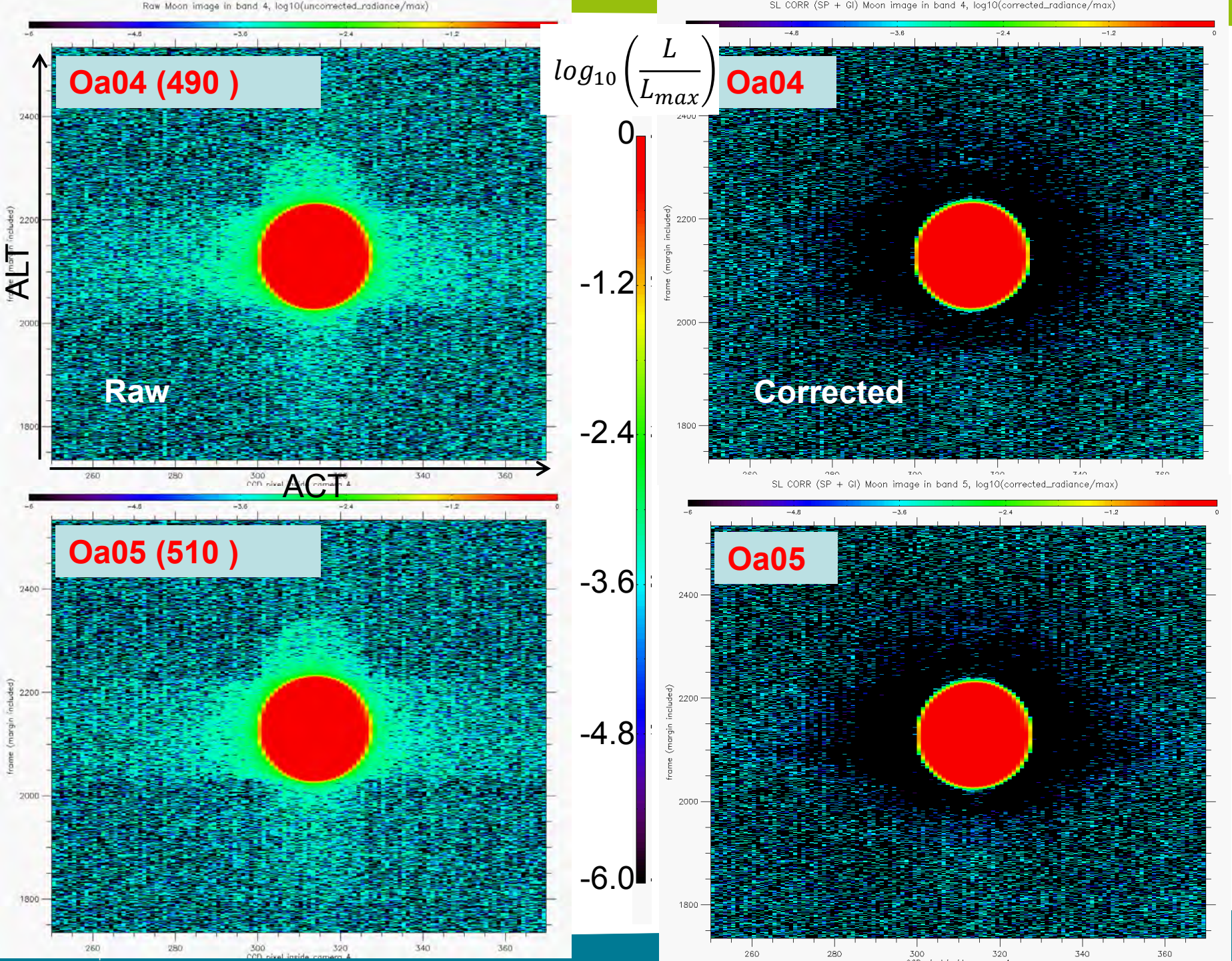
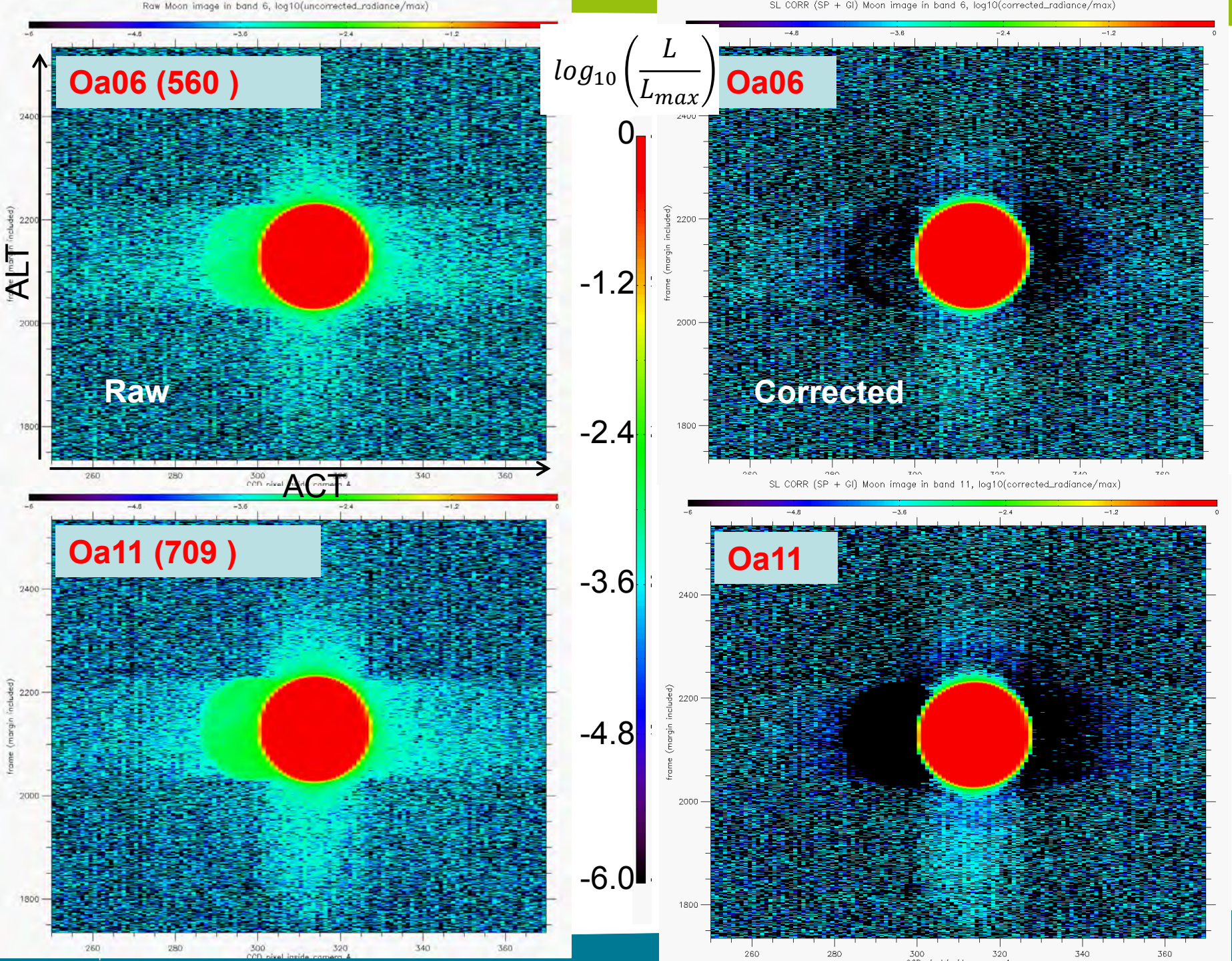
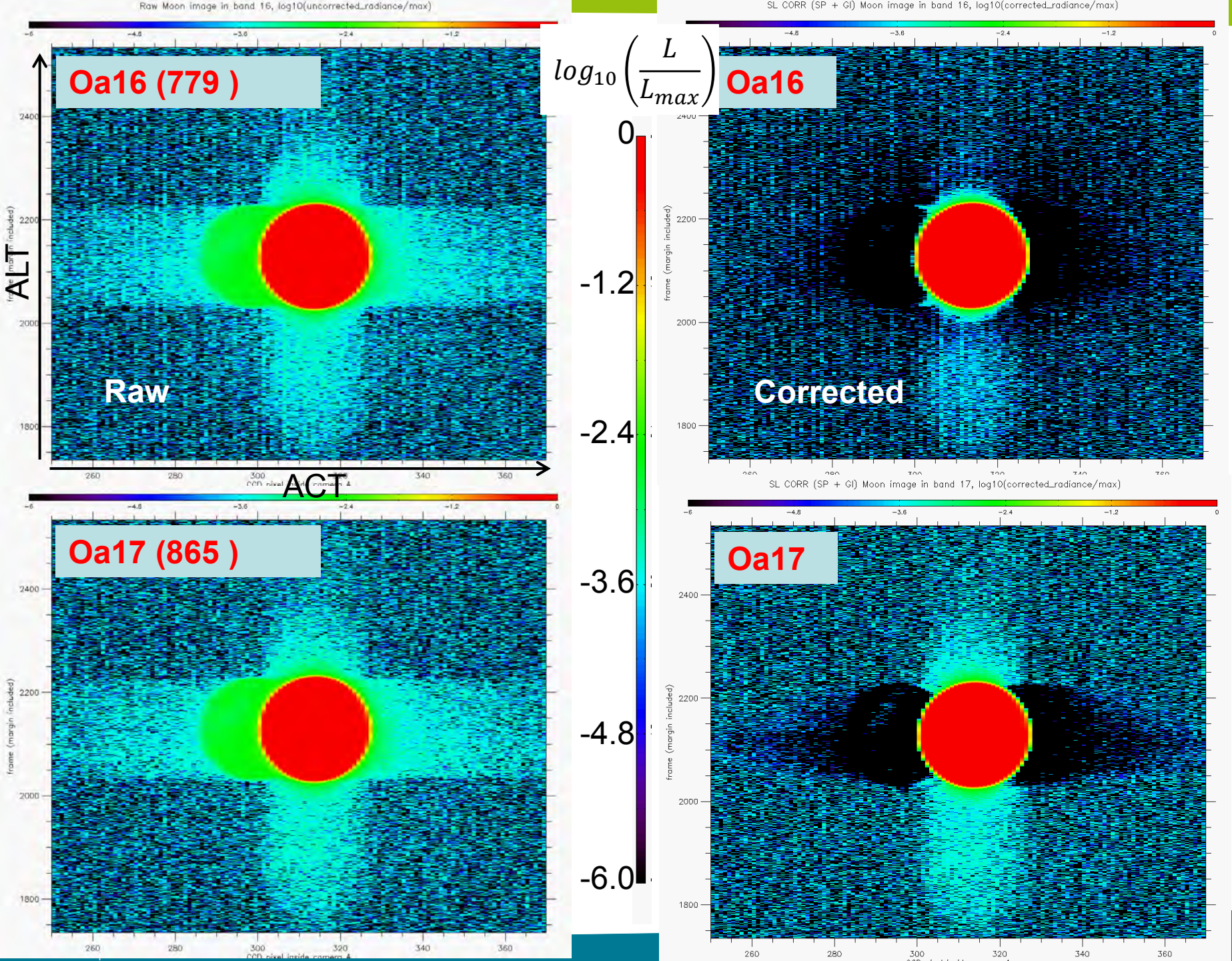
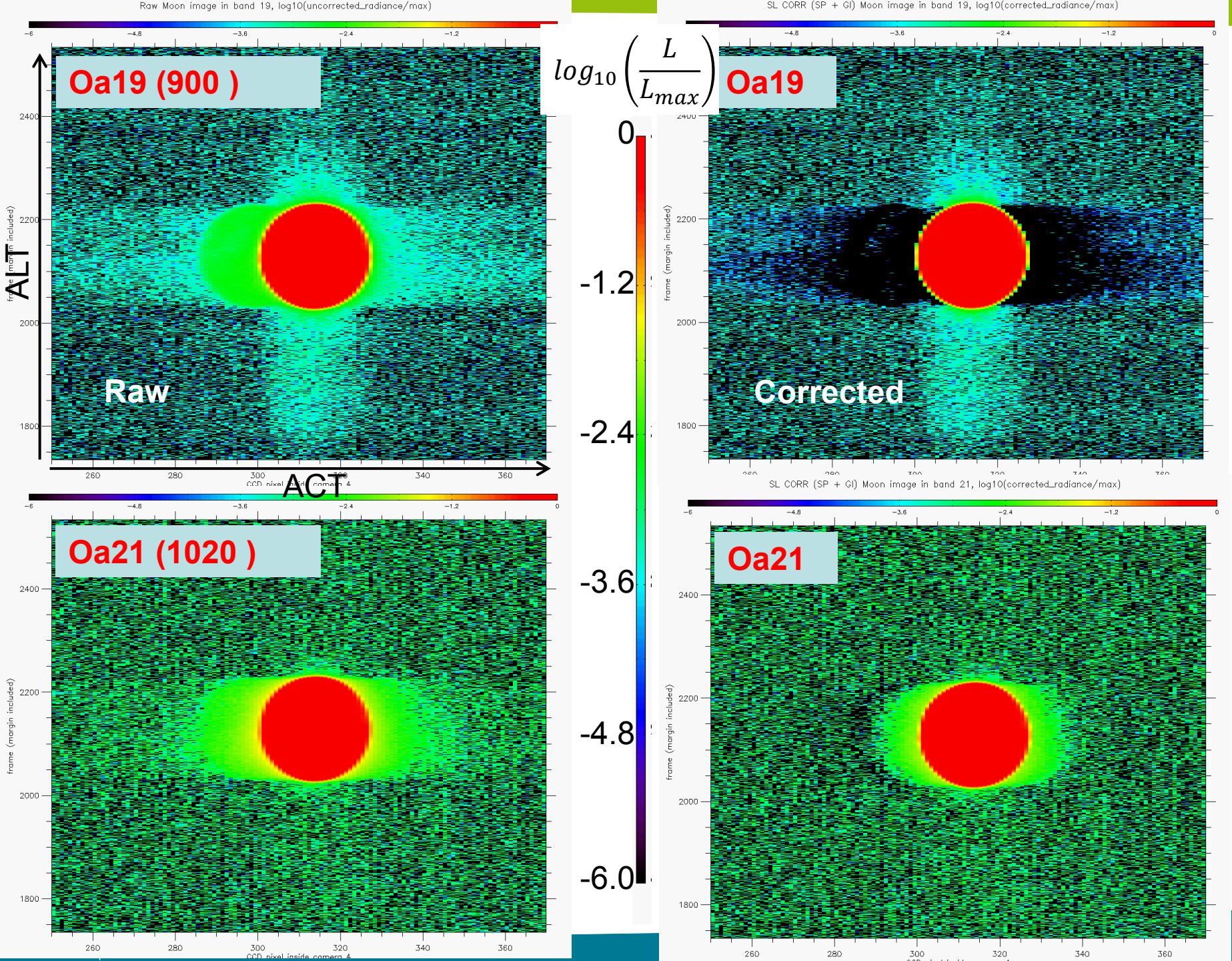

Raw Moon image in band 1, log10(uncorrected_radiance/max)
Oa01 (400)
Raw
ALT
ACT
$log_{10}\left(\frac{L}{L_{max}}\right)$
0
-1.2
-2.4
-3.6
-4.8
-6.0
SL CORR (SP + GI) Moon image in band 1, log10(corrected_radiance/max)
Oa01
Corrected
SL CORR (SP + GI) Moon image in band 3, log10(corrected_radiance/max)
Oa03 (442)
Oa03
frame (margin included)
CCD pixel inside camera 4


Raw Moon image in band 4, log10(uncorrected_radiance/max)
Oa04 (490)
Raw
ALT
ACT
frame (margin included)
CCD pixel inside camera 4
$log_{10}\left(\frac{L}{L_{max}}\right)$
0
-1.2
-2.4
-3.6
-4.8
-6.0
SL CORR (SP + GI) Moon image in band 4, log10(corrected_radiance/max)
Oa04
Corrected
SL CORR (SP + GI) Moon image in band 5, log10(corrected_radiance/max)
Oa05 (510)
Oa05


Raw Moon image in band 6, log10(uncorrected_radiance/max)
Oa06 (560)
ALT
ACT
Raw
$log_{10}\left(\frac{L}{L_{max}}\right)$
0
-1.2
-2.4
-3.6
-4.8
-6.0
SL CORR (SP + GI) Moon image in band 6, log10(corrected_radiance/max)
Oa06
Corrected
Oa11 (709)
SL CORR (SP + GI) Moon image in band 11, log10(corrected_radiance/max)
Oa11
frame (margin included)


Raw Moon image in band 16, log10(uncorrected_radiance/max)
Oa16 (779)
Raw
ALT
ACT
$log_{10}\left(\frac{L}{L_{max}}\right)$
0
-1.2
-2.4
-3.6
-4.8
-6.0
SL CORR (SP + GI) Moon image in band 16, log10(corrected_radiance/max)
Oa16
Corrected
SL CORR (SP + GI) Moon image in band 17, log10(corrected_radiance/max)
Oa17 (865)
Oa17
frame (margin included)


Raw Moon image in band 19, log10(uncorrected_radiance/max)
SL CORR (SP + GI) Moon image in band 19, log10(corrected_radiance/max)
SL CORR (SP + GI) Moon image in band 21, log10(corrected_radiance/max)
$log_{10}\left(\frac{L}{L_{max}}\right)$
Oa19 (900)
Oa19
Oa21 (1020)
Oa21
Raw
Corrected
ALT
ACT
frame (margin included)
CCD pixel inside camera 4
0
-1.2
-2.4
-3.6
-4.8
-6.0

Summary GI correction (from ALT direction)

Channel	Wavelength (nm)	used kernel	status
Oa1	400	1st GI Kernel 455.625 nm	≈ Ok
Oa2	412.5		
Oa3	442.5		Over corrected (over-correction increases with λ)
Oa4	490		
Oa5	510		
Oa6	560	2nd GI Kernel 634.375 nm	≈ Ok
Oa7	620		
Oa8	665		
Oa9	673.75		
Oa10	681.25		
Oa11	708.75		
Oa12	753.75		
Oa13	761.25		
Oa14	764.375		
Oa15	767.5		
Oa16	778.75		
Oa17	865	3rd GI Kernel 1019.375 nm	Under corrected
Oa18	885		
Oa19	900		
Oa20	940		
Oa21	1020		?

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Summary SP correction (from ACT direction)

Channel	Wavelength (nm)	used kernel	status
Oa1	400	1st SP Kernel 455.6 nm	Moderately over corrected
Oa2	412.5		
Oa3	442.5		
Oa4	490	1st + 2nd SP Kernels 455.6 & 585.7 nm	Moderately over corrected
Oa5	510		
Oa6	560		
Oa7	620	2nd + 3rd SP Kernels 585.7 & 713.1 nm	Moderately over corrected
Oa8	665		
Oa9	673.75		
Oa10	681.25		
Oa11	708.75		
Oa12	753.75	3rd & 4th SP Kernels 713.1 & 843.1 nm	Moderately over corrected (more important for narrow bands)
Oa13	761.25		
Oa14	764.375		
Oa15	767.5		
Oa16	778.75		
Oa17	865	4th & 5th SP Kernels 843.1 & 973.1 nm	Strongly over corrected
Oa18	885		
Oa19	900		
Oa20	940		
Oa21	1020	5th SP Kernel 973.1 nm	Under corrected

Increasing SL & over correction: ε^2 effect ?

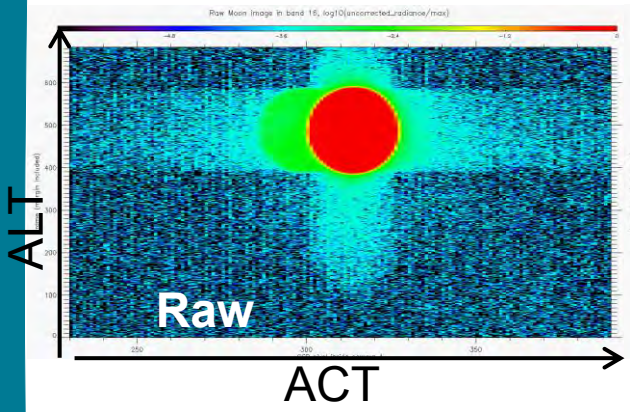
Correction performance qualitative conclusions

- **Spectrometer SL: systematic overcorrection where SL significant**
  - **➔ issue of the ε^2**
  - **➔ improved correction under test (including 2nd iteration: corrected L gives better SL estimate)**
- **Ground Imager SL: can be quite correct (400, 560 to 780), over-corrected (410-510 , slightly) or under-corrected (> 800)**
  - **➔ likely limited by number of characterised wavelength and nearest neighbour selection**
  - **➔ But also by (on purpose) exclusion of a ghost that varies across FOV, to be further investigated**

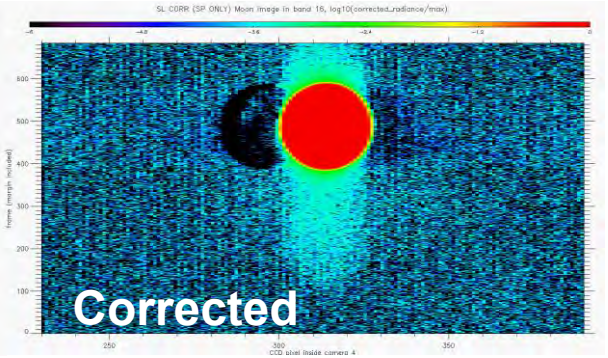
1st test of 2nd iteration (preliminary results)

CARE: only spectrometer correction applied!

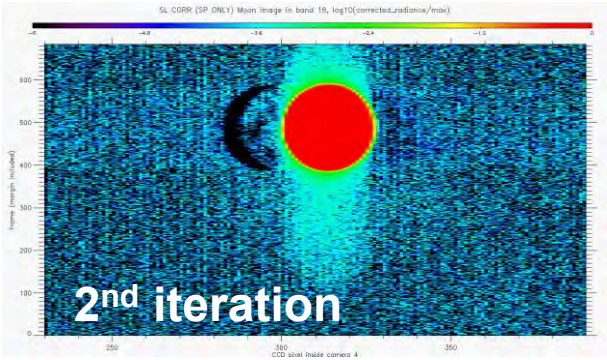
Oa16 (779)



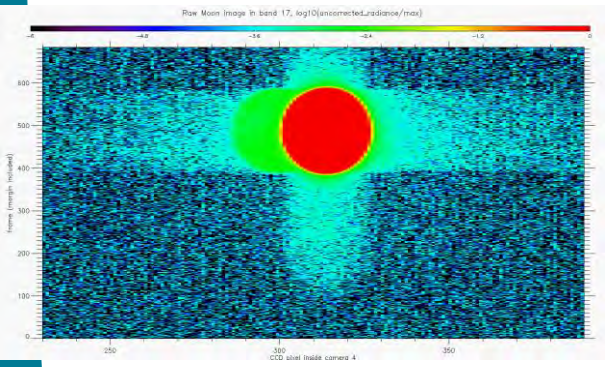
Oa16



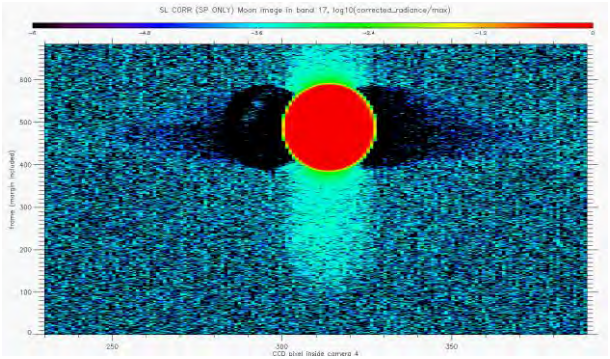
Oa16



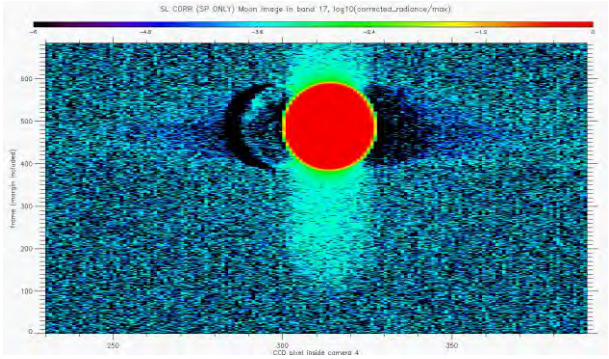
Oa17 (865)



Oa17



Oa17



+ Significantly improves over-correction but not perfect; remnants not fully understood

– 3rd iteration goes the wrong way, 4th and above insignificant

+ Can be implemented at “no cost” acting only on kernel pre-processing

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Conclusion

- Moon observations well adapted to straylight studies
- OLCI straylight is significant, various known sources can be observed and identified
- OLCI correction is efficient but not sufficient:
  - GI SL correction is limited by number of characterized wavelengths and kernel selection (closest). May try interpolation instead but raise memory issues
  - SP SL correction is limited by the amount of SL, for which assumption $\varepsilon^2 \approx 0$ becomes wrong and imply over-correction. Improvement (2nd iteration) under test, 1st results positive but limited.

THANKS FOR YOUR ATTENTION

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