Study on validation of spectral band adjustment factors using lunar hyperspectral measurements

Activity 4: GOME2

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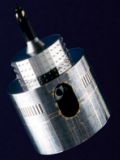
EARTH SPACE SOLUTIONS

Study funded by EUMETSAT

THE GOME-2 LUNAR OBSERVATIONS

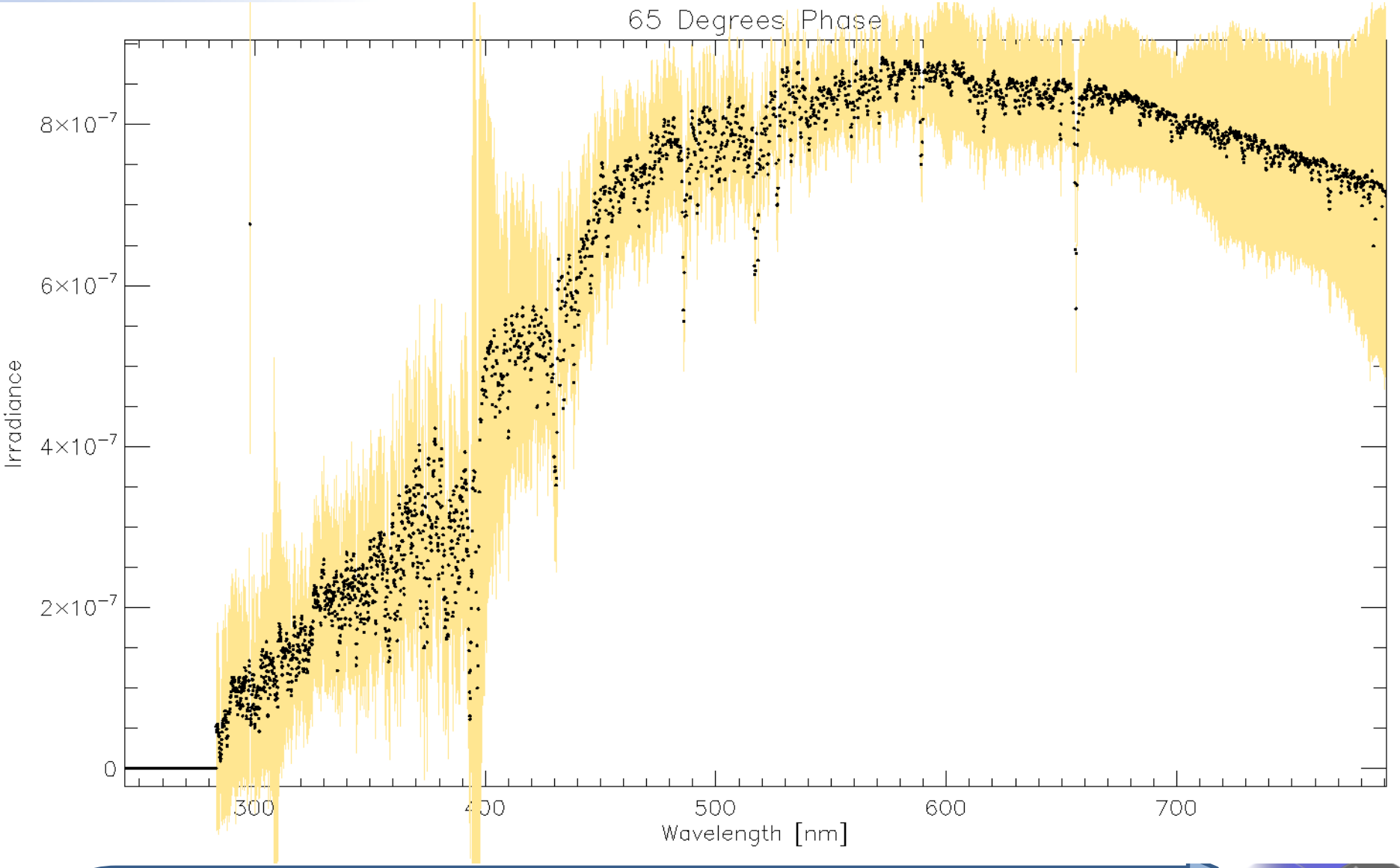
EUMETSAT

Ruediger Lang, Roger Huckle, Christian Retscher, Gabriele Poli, Rasmus Lindstrot, Antoine Lacan, Ed Trollope and Rosemary Munro



Teaser

Lunar Irradiance



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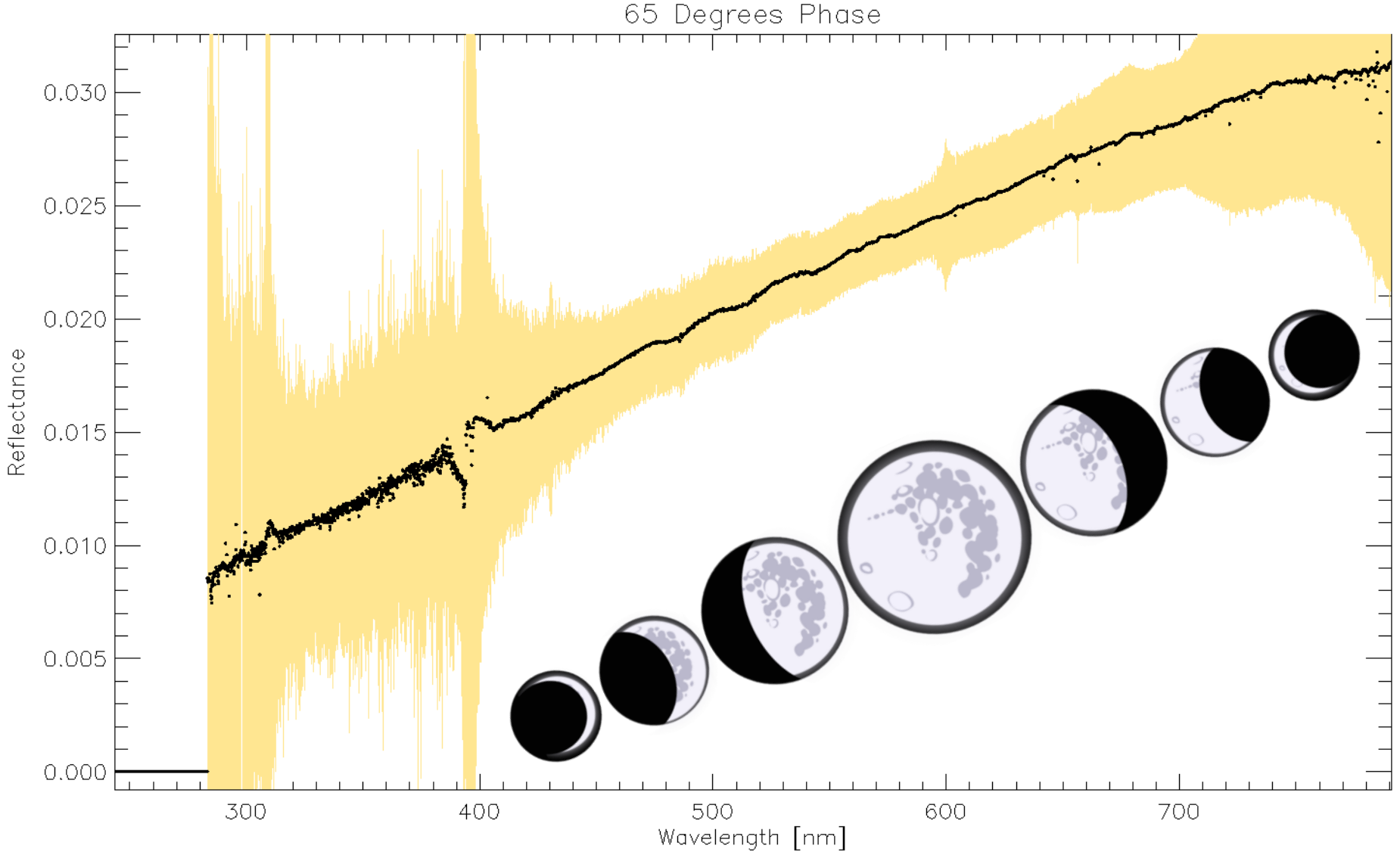
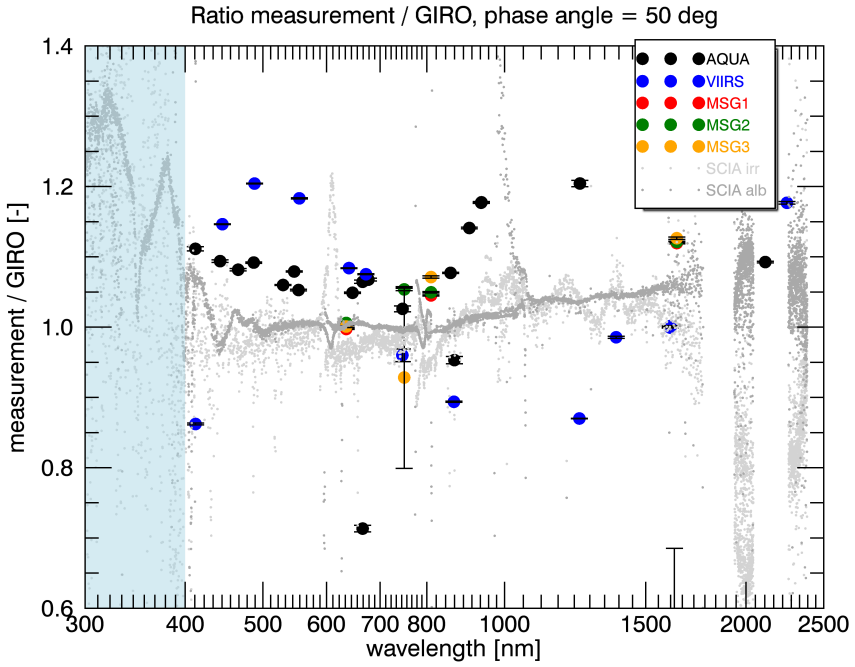
Lunar Reflectance



Content

- GOME2
- GOME2 Lunar observations
- Lunar Irradiance derivation
- Lunar variation model
- Issues
- Results
- Comparison GIRO

SCIAMACHY



EARTH SPACE SOLUTIONS

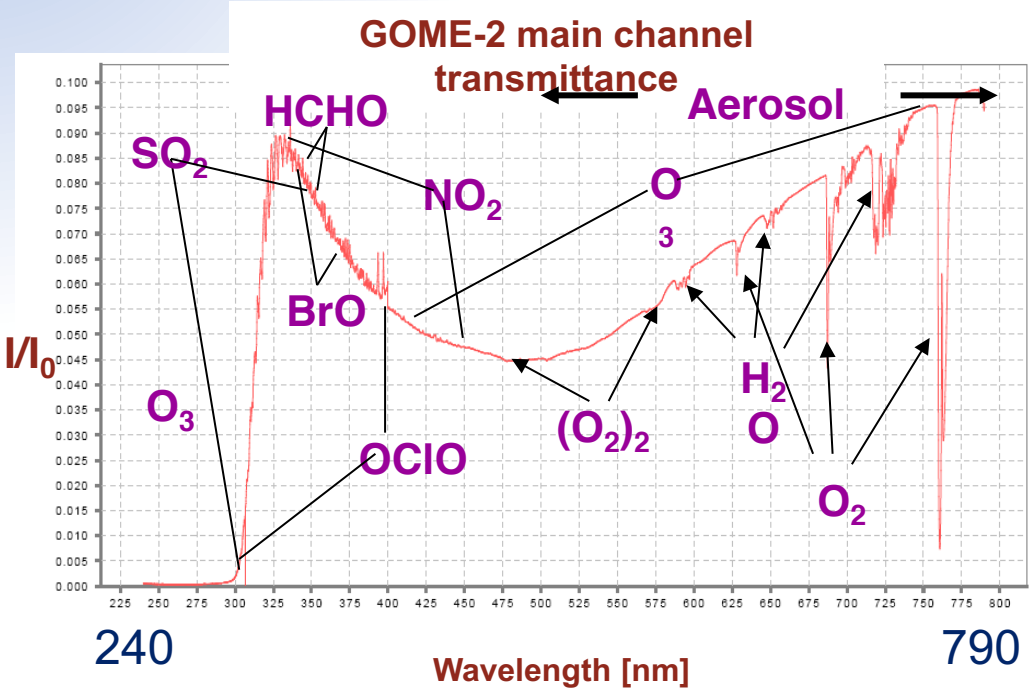
Objective Activity 4

- Derive stable lunar irradiance from GOME2

GOME2

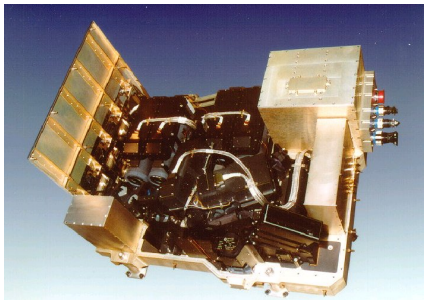
The GOME-2 UVN instrument on Metop

Measuring atmospheric composition



GOME-2:

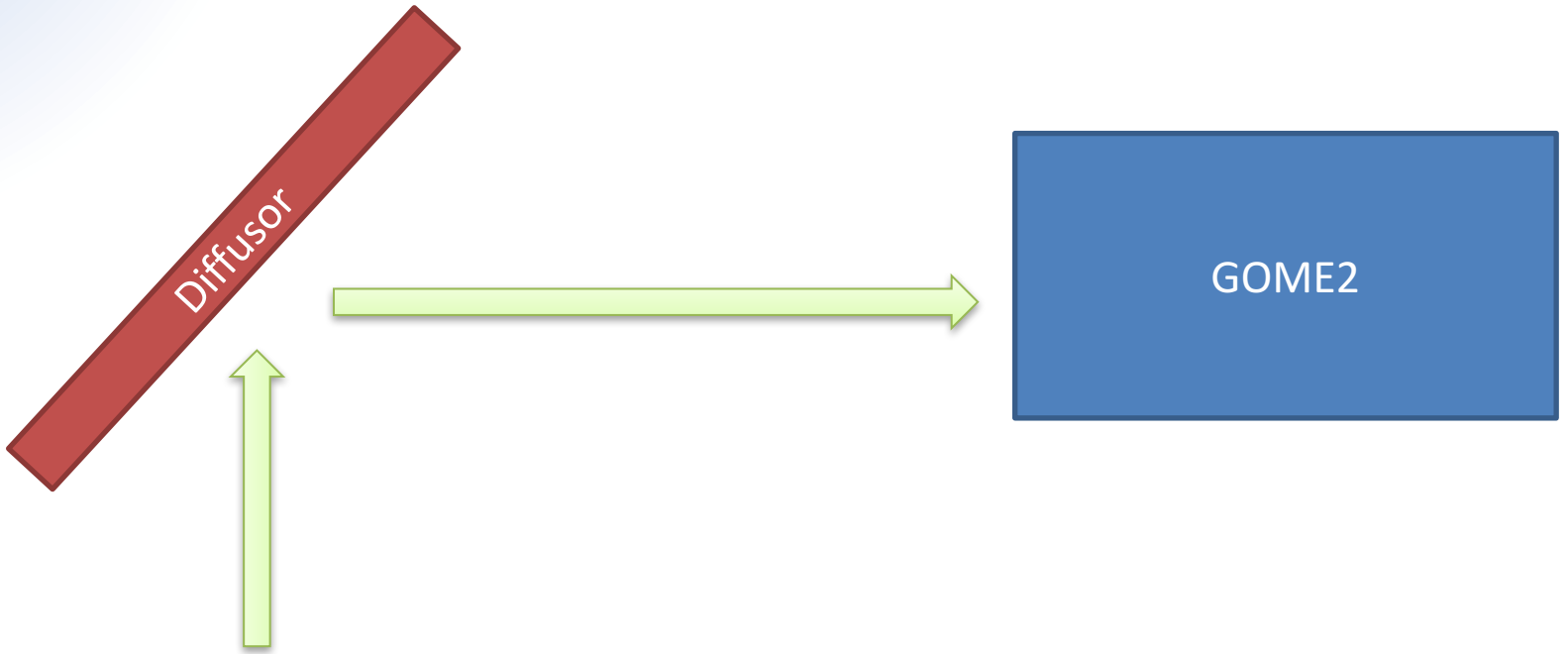
- series of 3 instruments on Metop (Metop A launched in 10/2006)
- sun-synchronous orbit, 09:30
- 412 orbits (29 days) repeat cycle
- Global coverage 1.5 days
- 240 nm to 800 nm
- 0.25 to 0. 5 nm spectral resolution (FWHM)
- 4 channels with 4098 energy measurements of polarisation corrected radiances (40 x 80 km^2)
- 2 channels with 512 energy measurements of linear polarised light in perpendicular direction (S/P) (40 x 10 km^2)



Orbit file sizes

GOME-2 L1B ~ 1GB
IASI L1C ~ 2GB

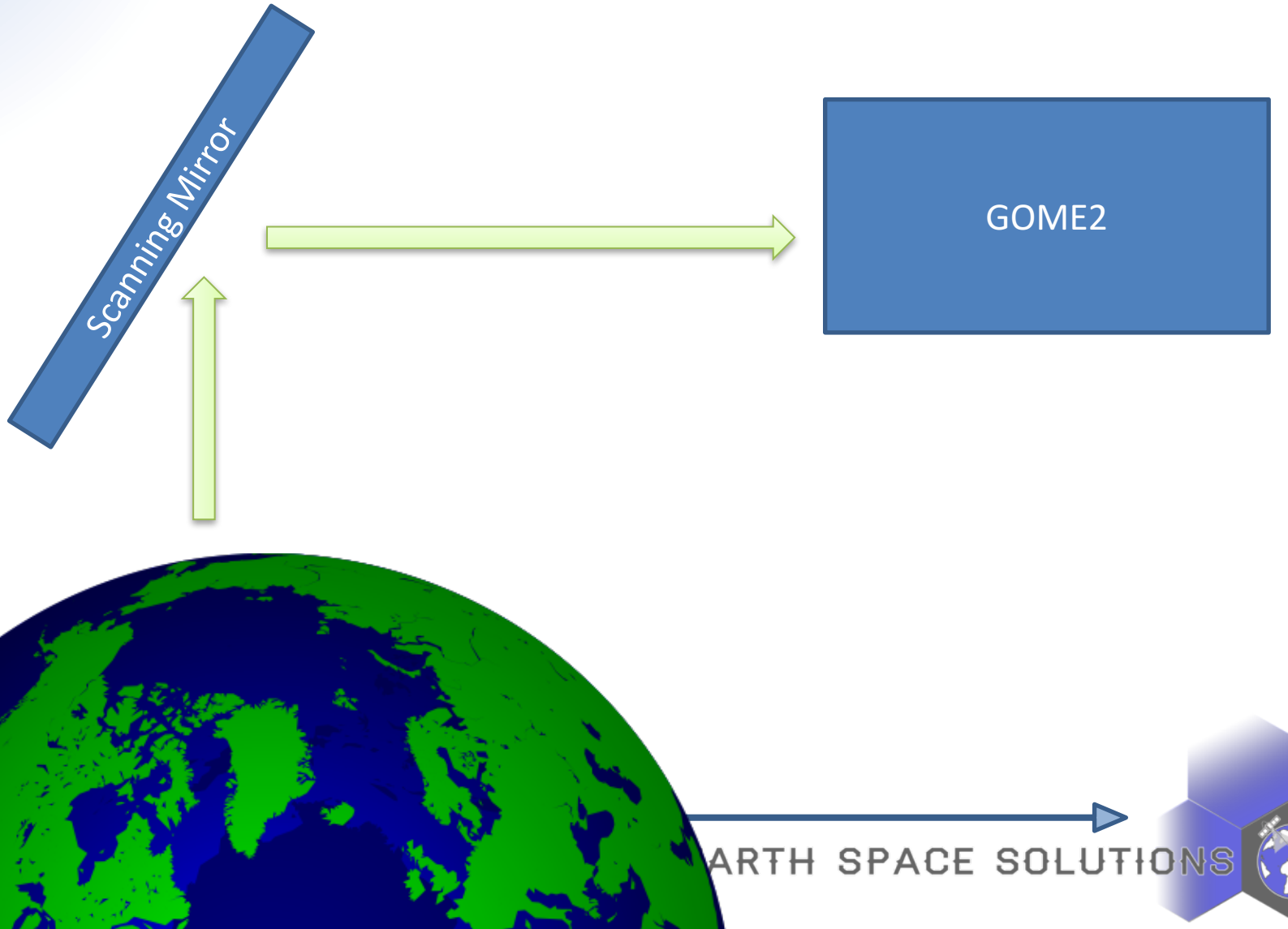
Sun Mode



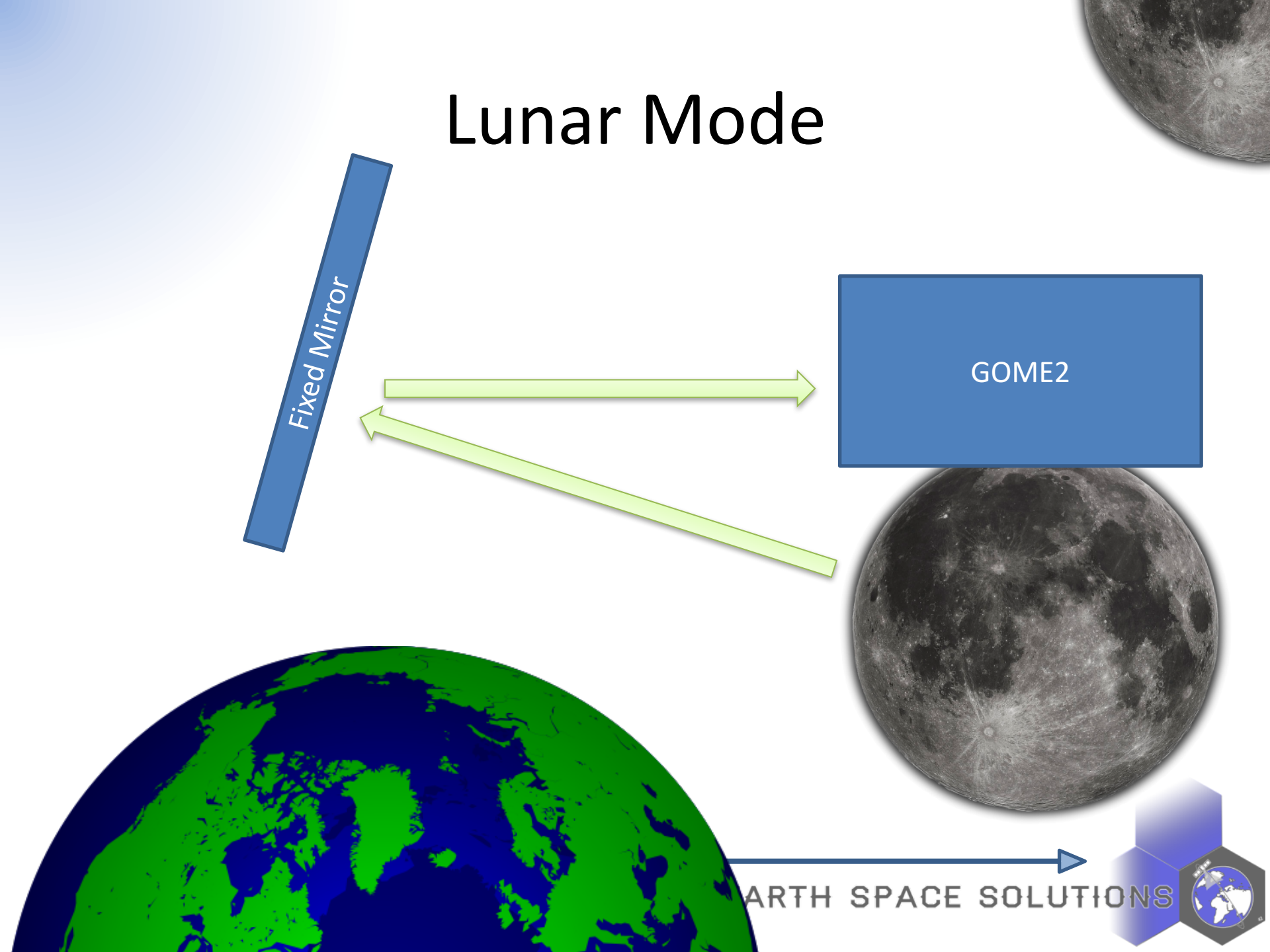
NOTE:
“Irradiance” is Lunar Irradiance
not solar irradiance unless explicit

EARTH SPACE SOLUTIONS

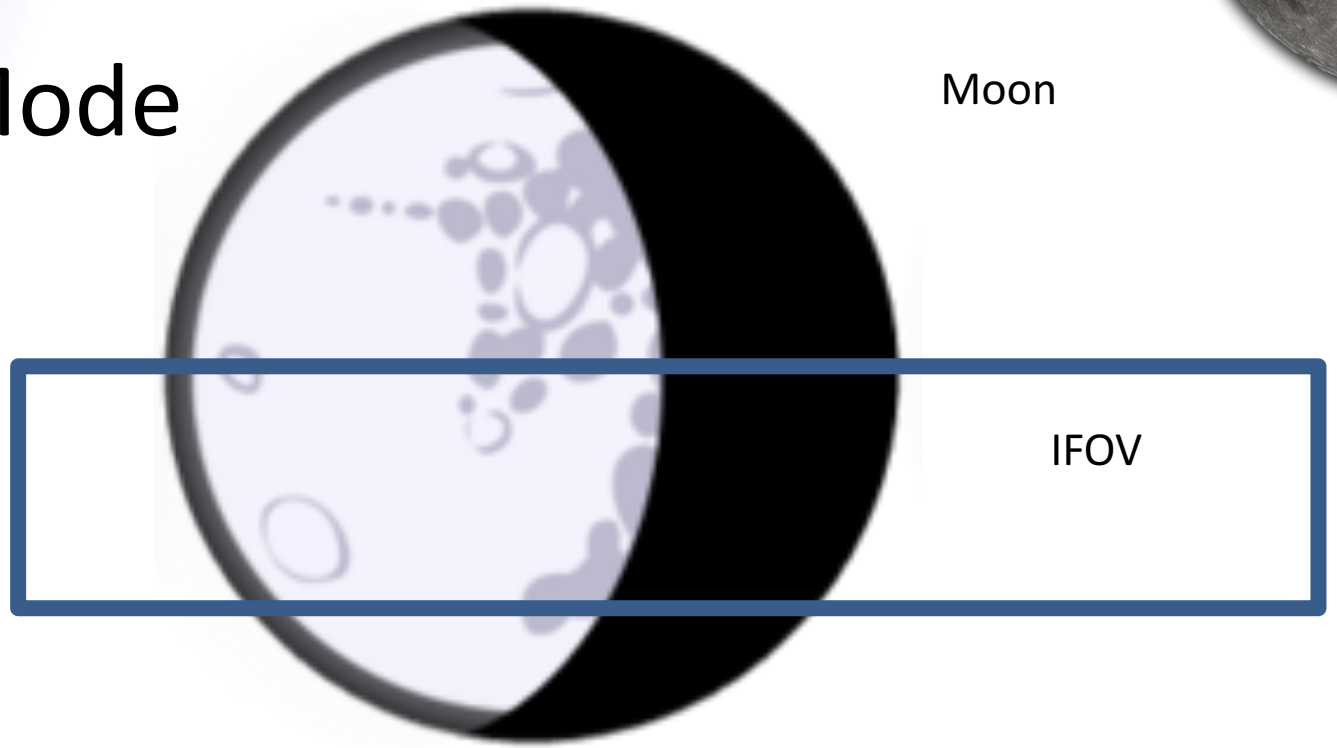
Earth Mode



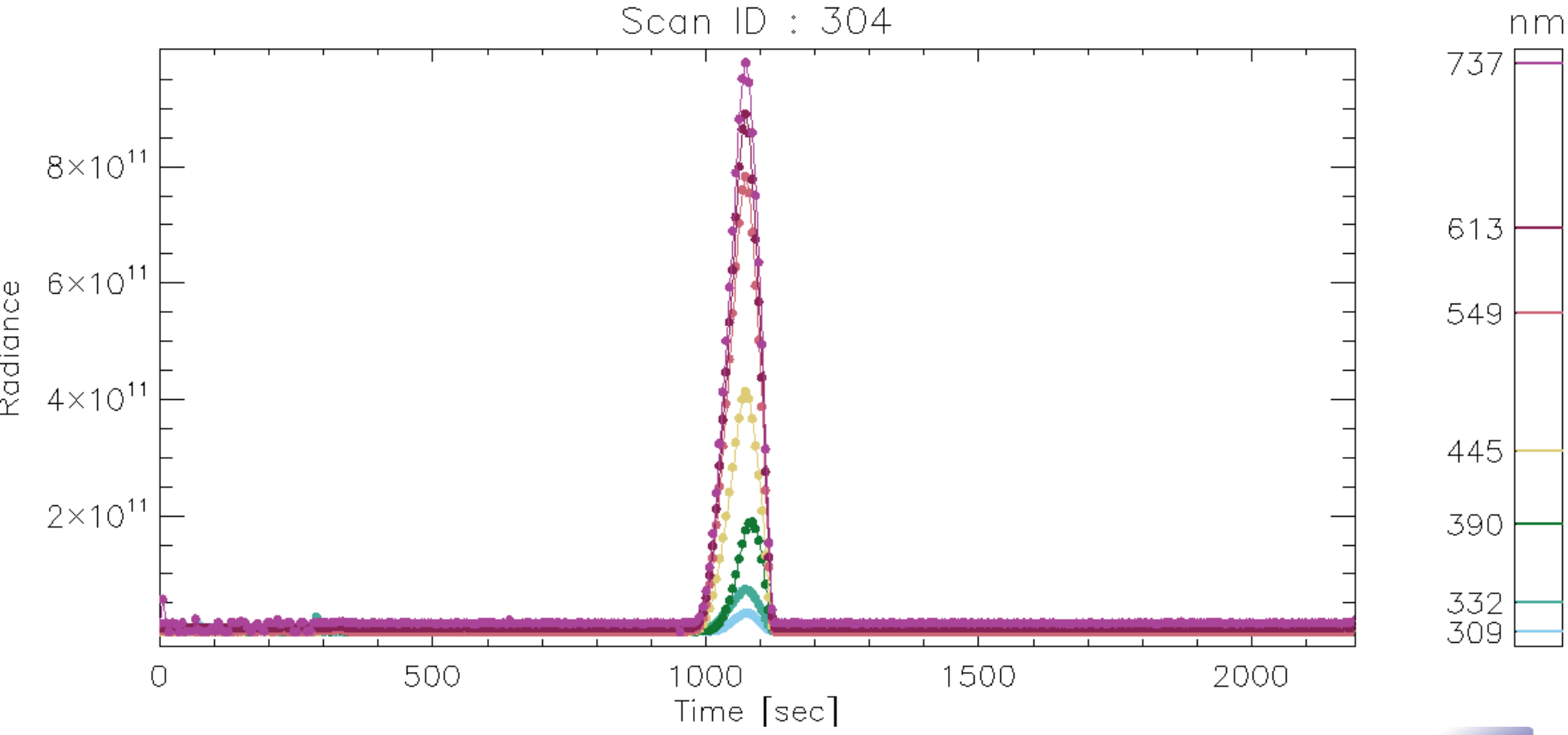
Lunar Mode



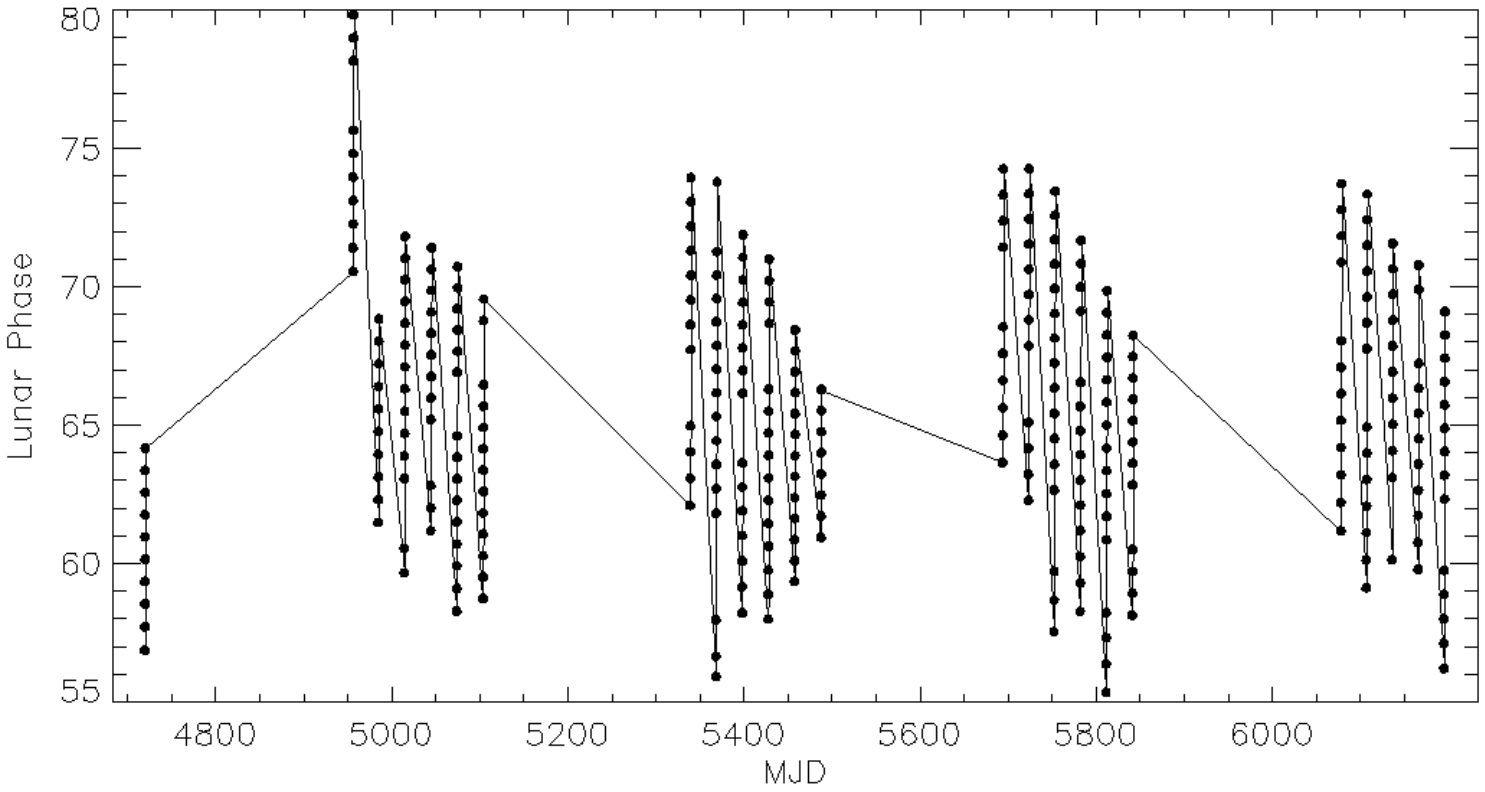
Lunar Mode



Nominal Lunar Measurement

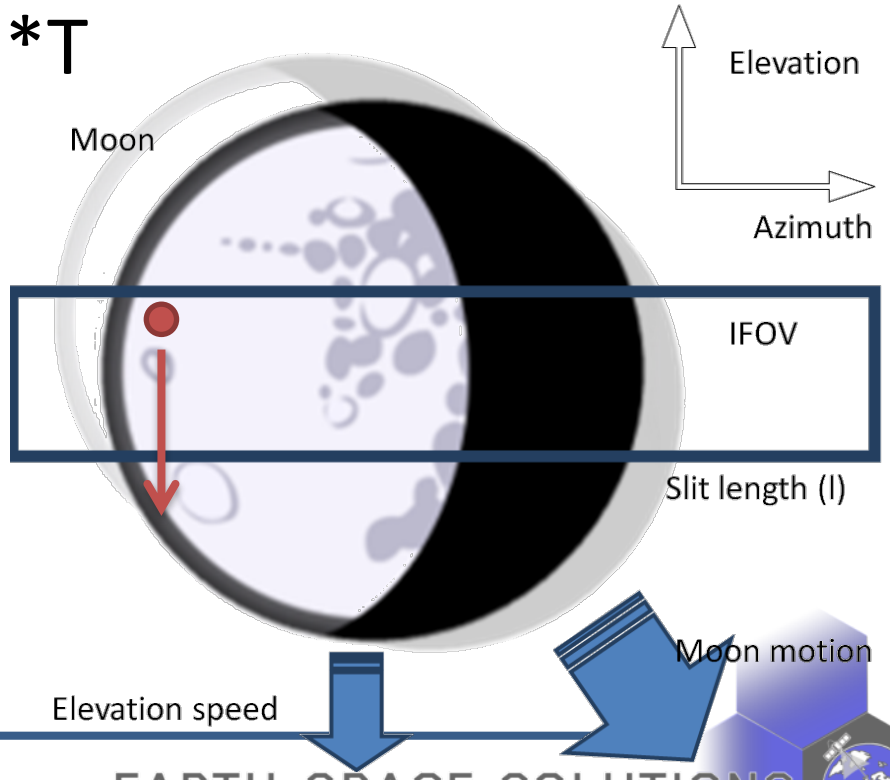


Measurements



Irradiance Derivation

- (all per nm per m2)
- R = #photons/sec/sr
- S = #photons = R*(L*B)*T
- Sum Scan ΣR
- I = #photons/sec
- I = ΣS / (B/V)
- I = ΣR*L*B*T / (B/V)
- I = ΣR*L*V*T



Modelling Lunar Variation

4 Models

- GOME2 Irradiance
- GOME2 Reflectance
- GOME2/GIRO Irradiance
- GOME2/GIRO Reflectances

Reproduces GIRO

Model (for each wavelength)

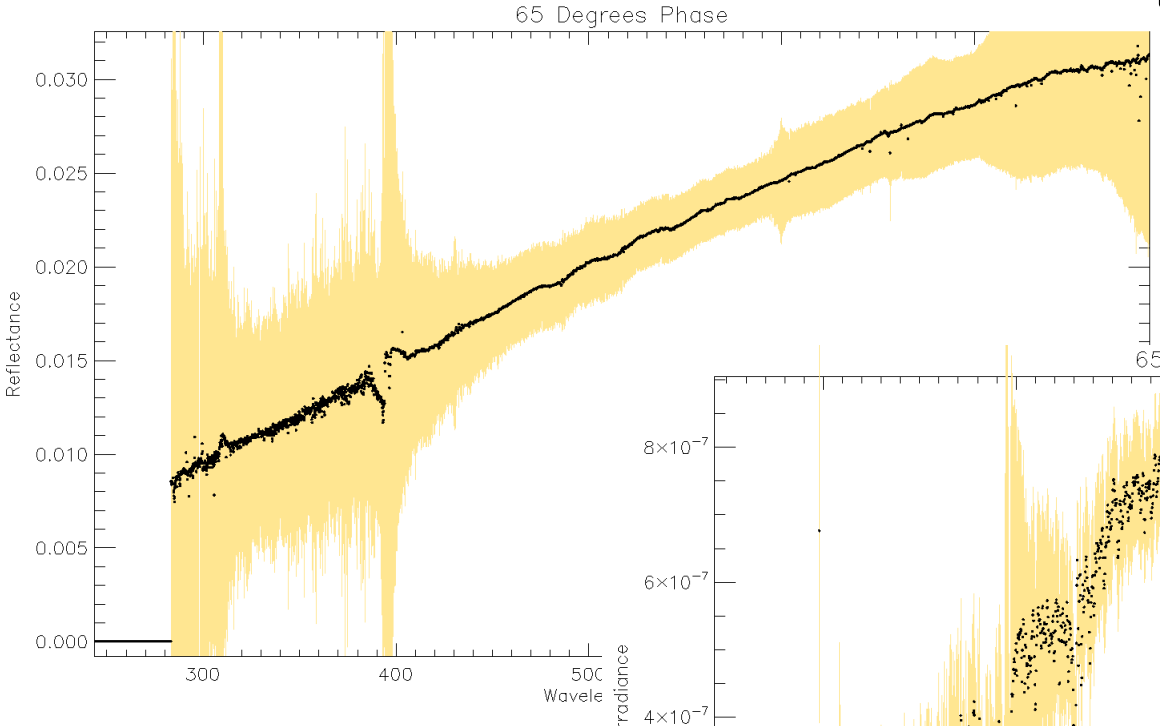
- P[0]*
- 1+P[1]* (√(lunar_phase)- √(65°))
- 1+P[2]*Libration_latitiude
- 1+P[3]*Libration_longitude
- 1+P[4]*Solar_longitude Not used
- Exp(MJD*P[5]+MJD^2*P[6]*MJD^3*P[7]) MJD-4720 (Dec 2012)
- Distance_sun_moon^P[8] Fixed
- Distance_sat_moon^P[9] Fixed

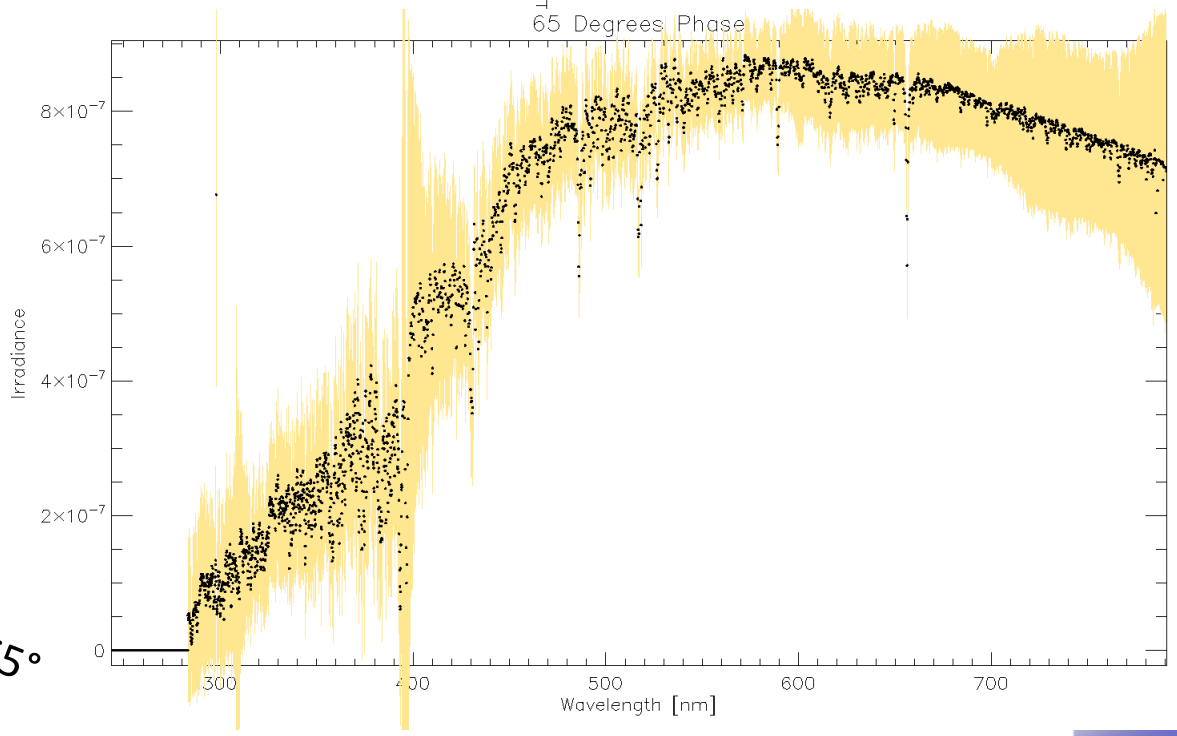
Fitting

- Weight invalid measurements to zero
- Fit degradation relative to GIRO (seed)
- Fit model (incl degradation) relative to GIRO
- Add distance dependence (P[8:9]=-2)
- Fit model (incl degradation) to data
- Remove channel overlaps

Both for Reflectance and Irradiance

P[0]





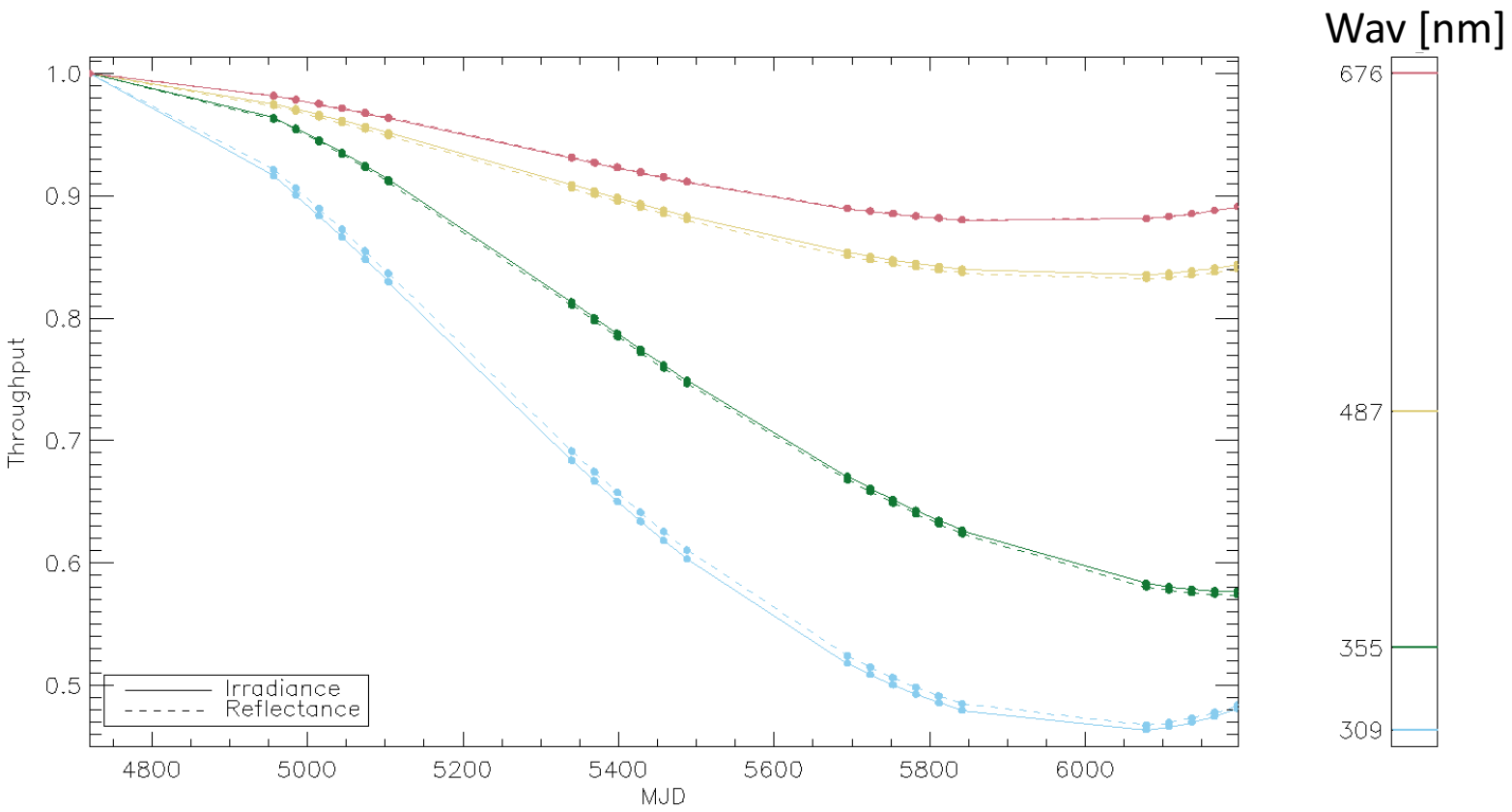
MJD 4720, No libration, Phase 65°

Issues

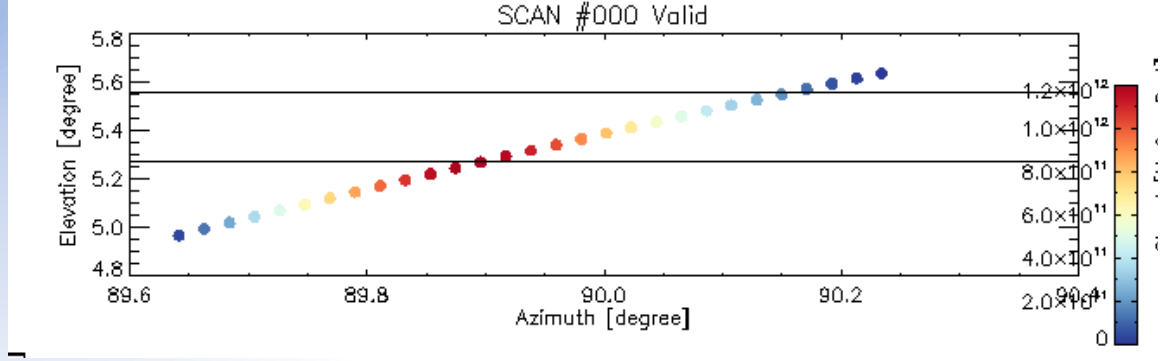
- **Degradation**
- Missing Data
- Pointing
- Duration
- Background
- **Straylight**

Degradation

Fitted Degradation

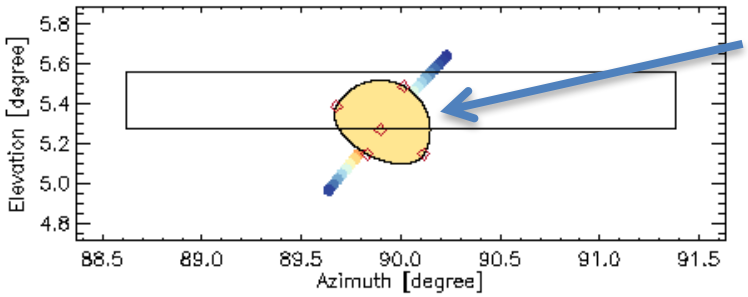


Conclusion: Degradation is there, but can be fitted

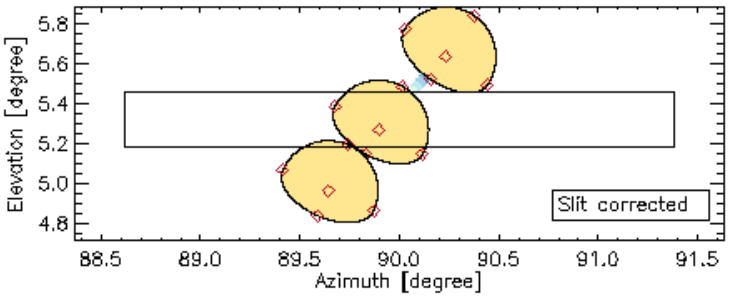


Model

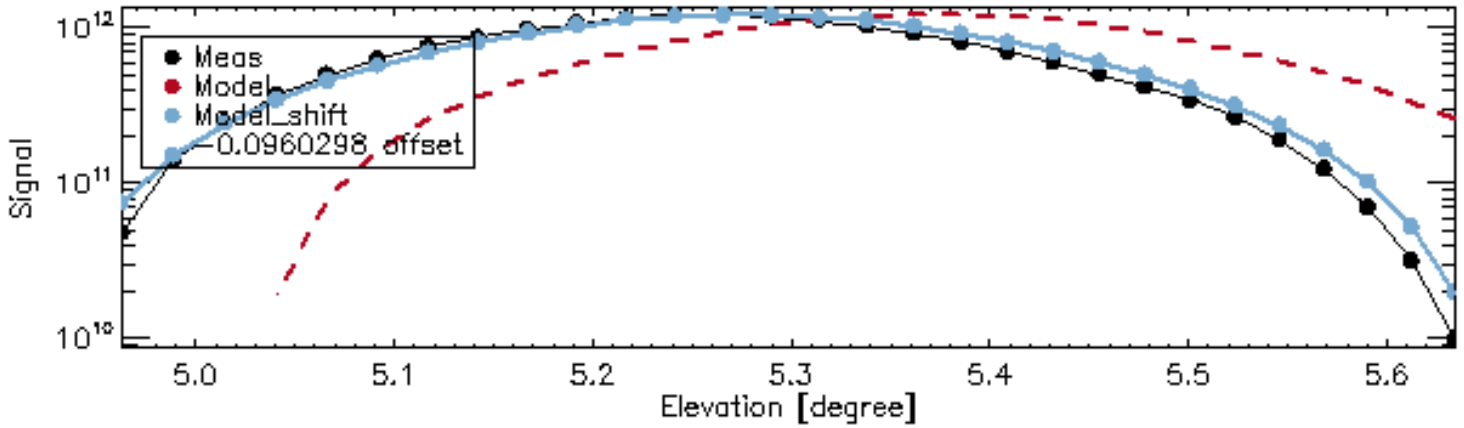
as verification



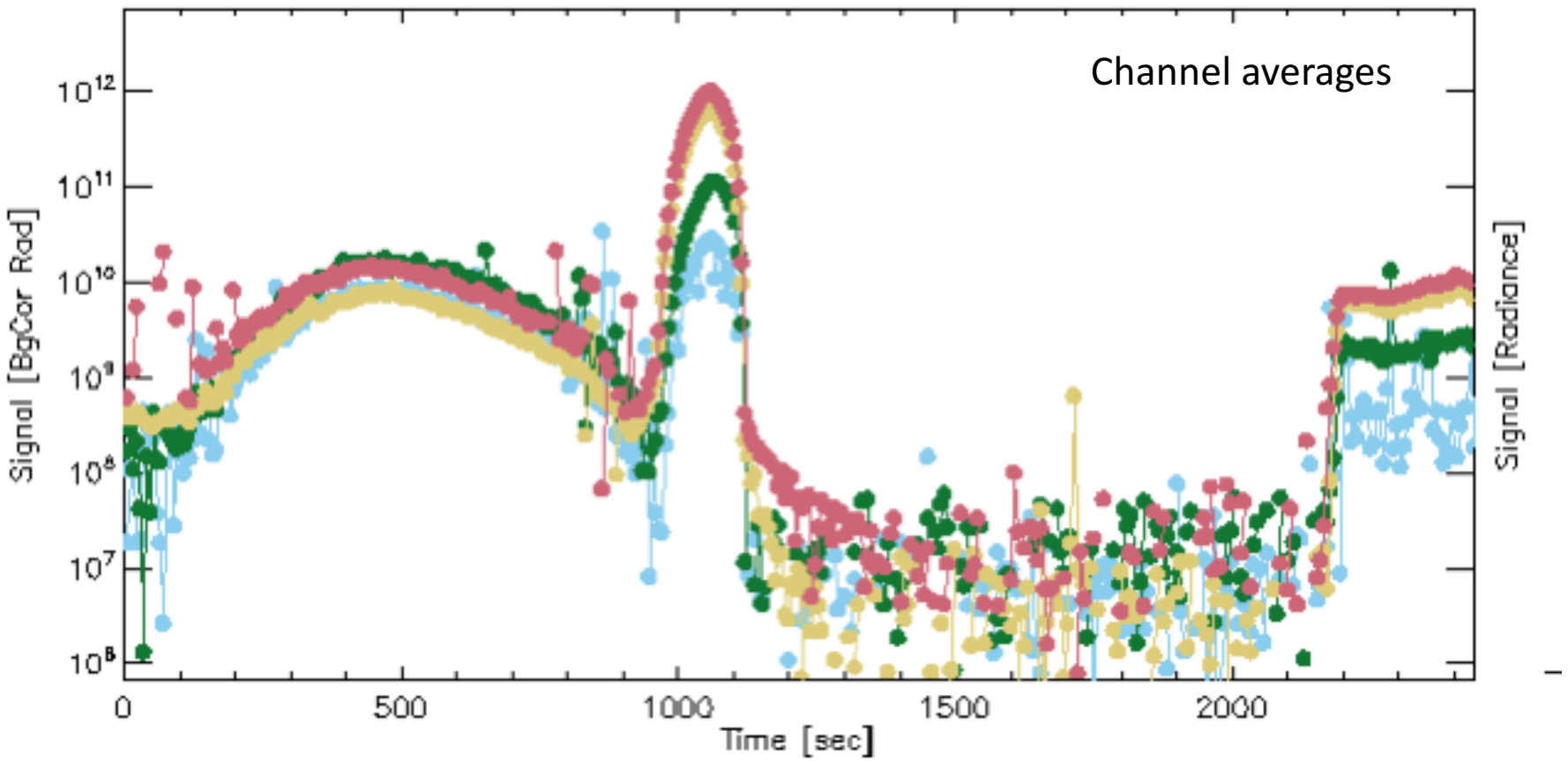
Max
lunar signal



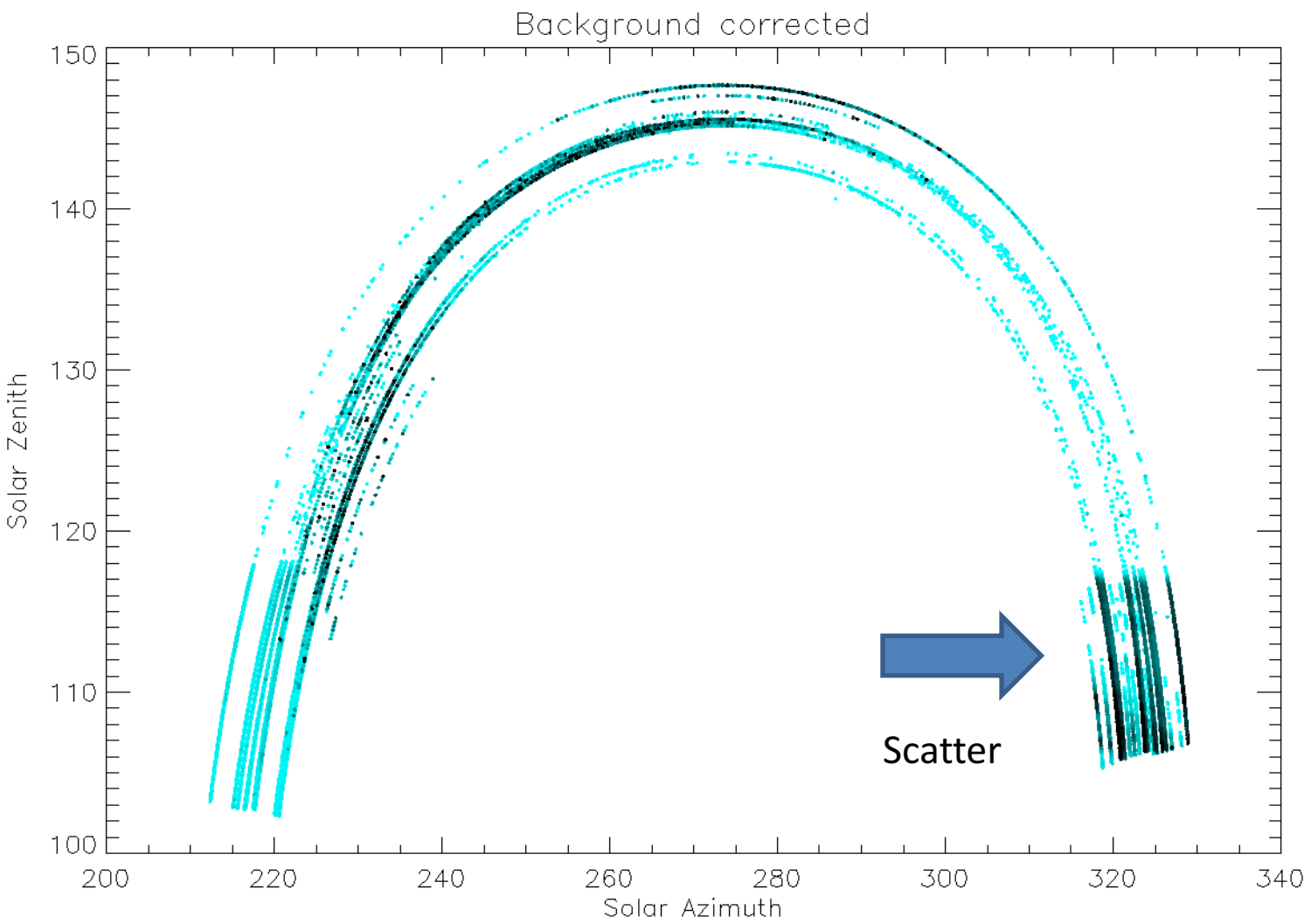
Lunar Slit Model



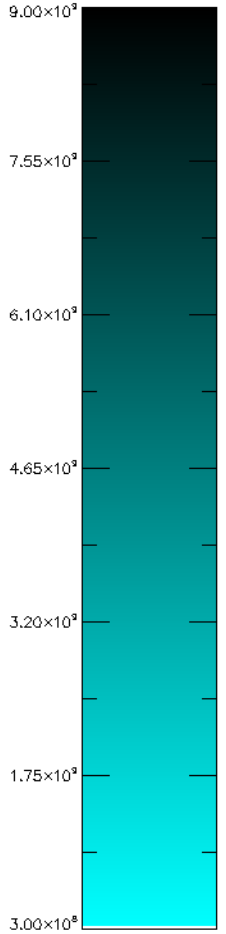
Sample contaminated Lunar measurement



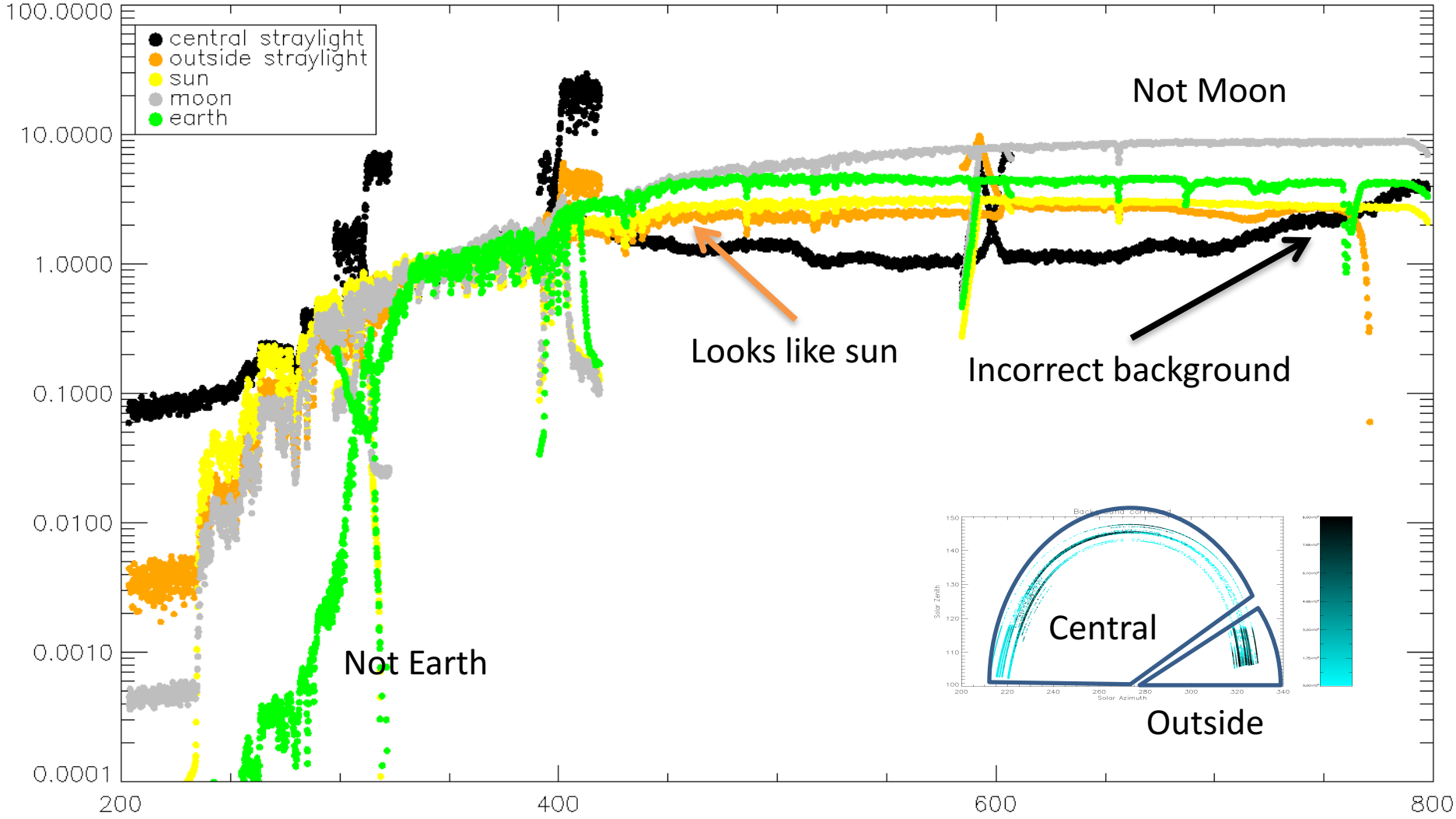
Signal as function of solar position relative to satellite



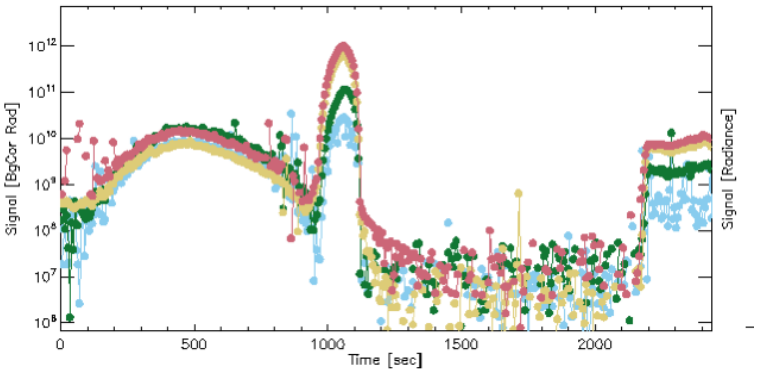
Remaining signal

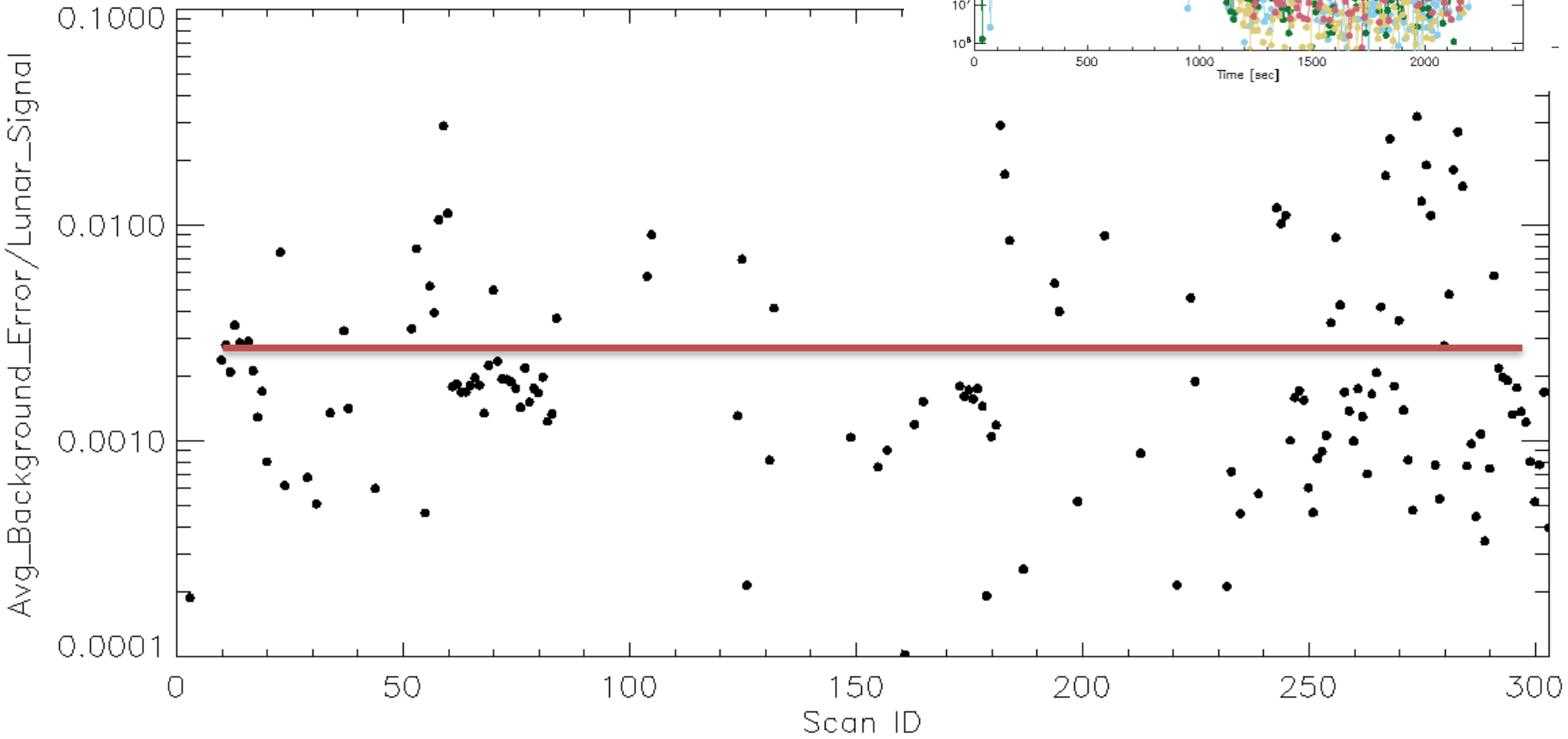


Straylight Spectra compared to know sources



Impact estimate





Conclusion: Straylight will impact relative accuracy

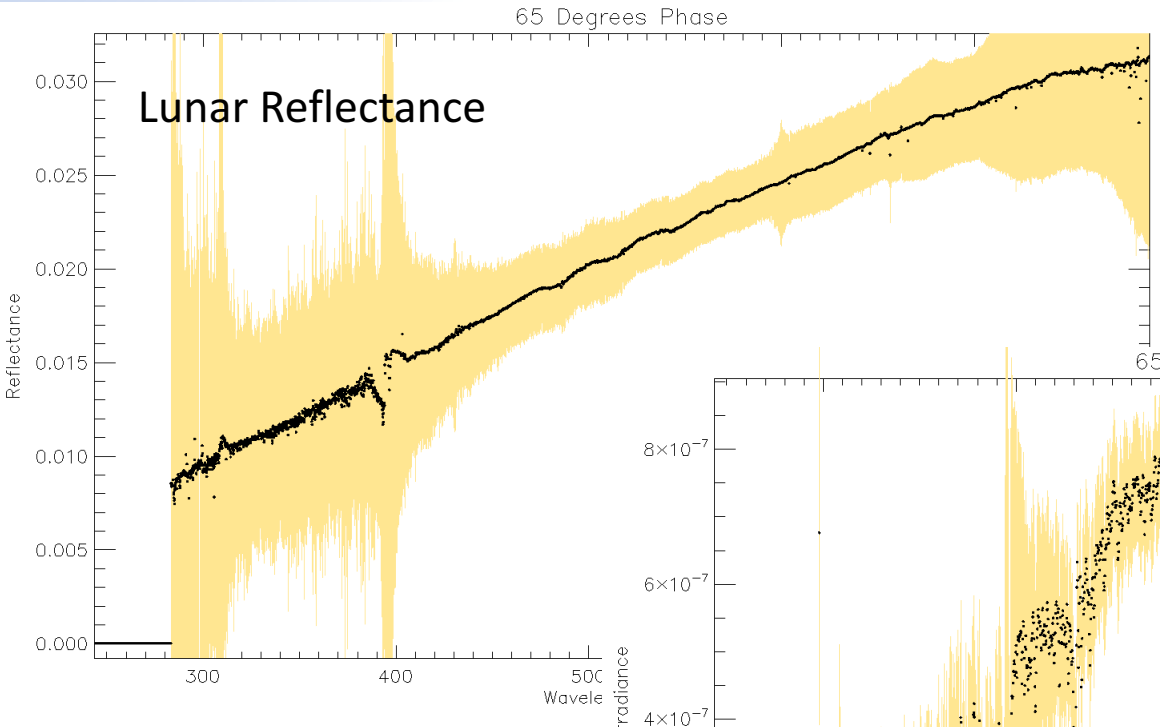
Note: Straylight not random error!

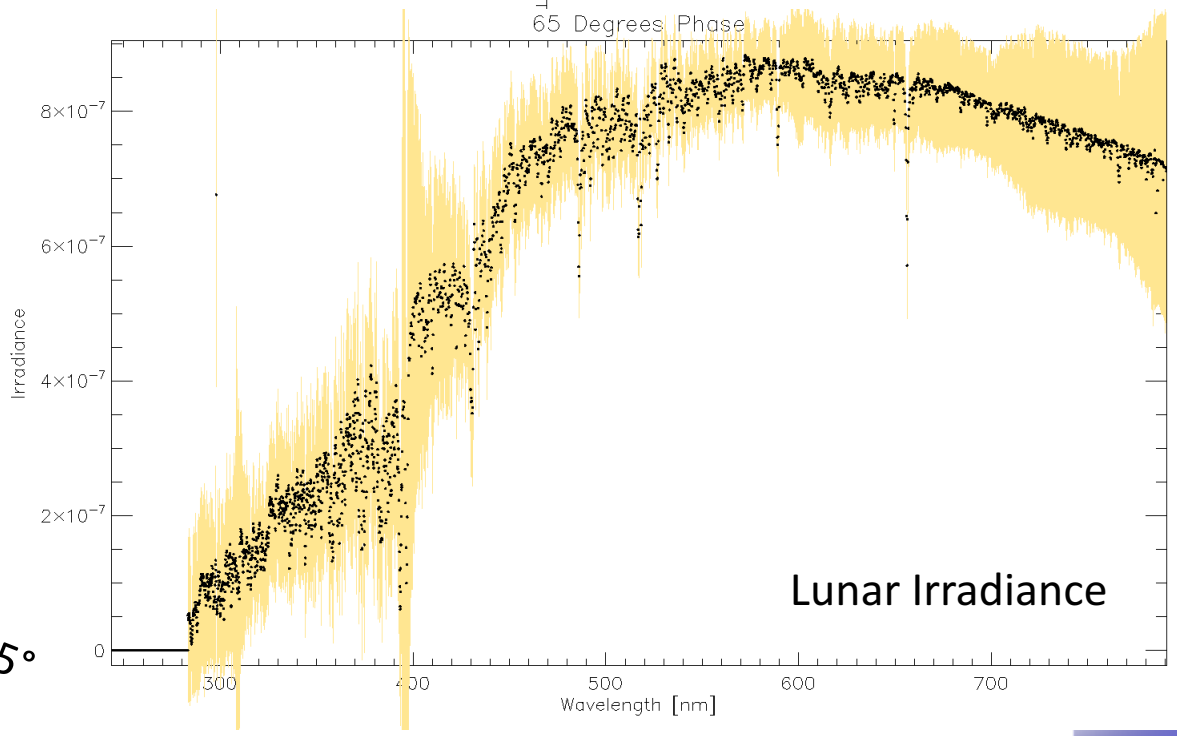
Results

Reproduces GIRO

Model (for each wavelength)

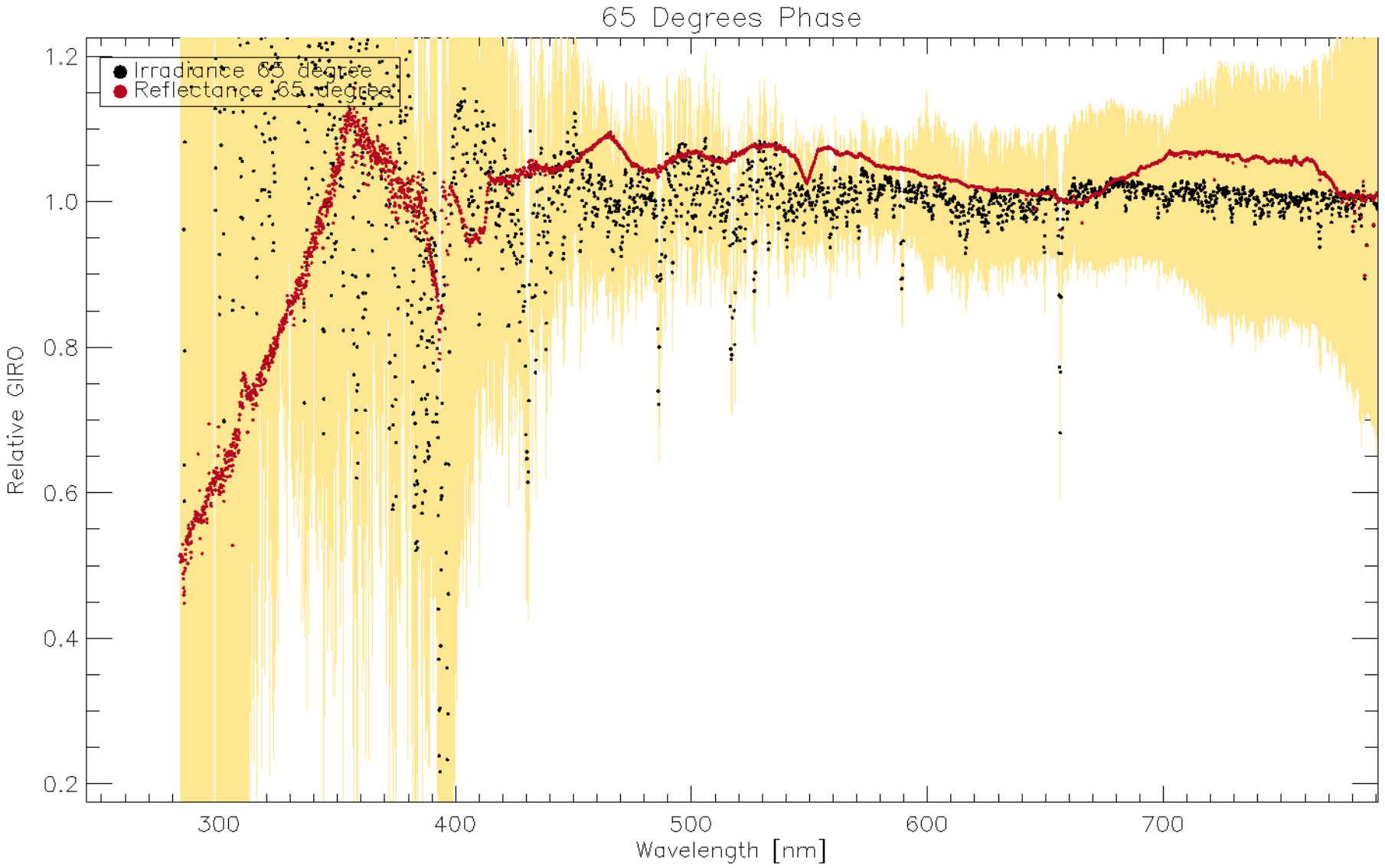
- P[0]*
- 1+P[1]* (√(lunar_phase)- √(65°)) [radians]
- 1+P[2]*Libration_latitiude [degrees]
- 1+P[3]*Libration_longitude [degrees]
- 1+P[4]*Solar_longitude Not used
- Exp(MJD*P[5]+MJD^2*P[6]*MJD^3*P[7]) MJD-4720 (Dec 2012)
- Distance_sun_moon^P[8] Fixed
- Distance_sat_moon^P[9] Fixed

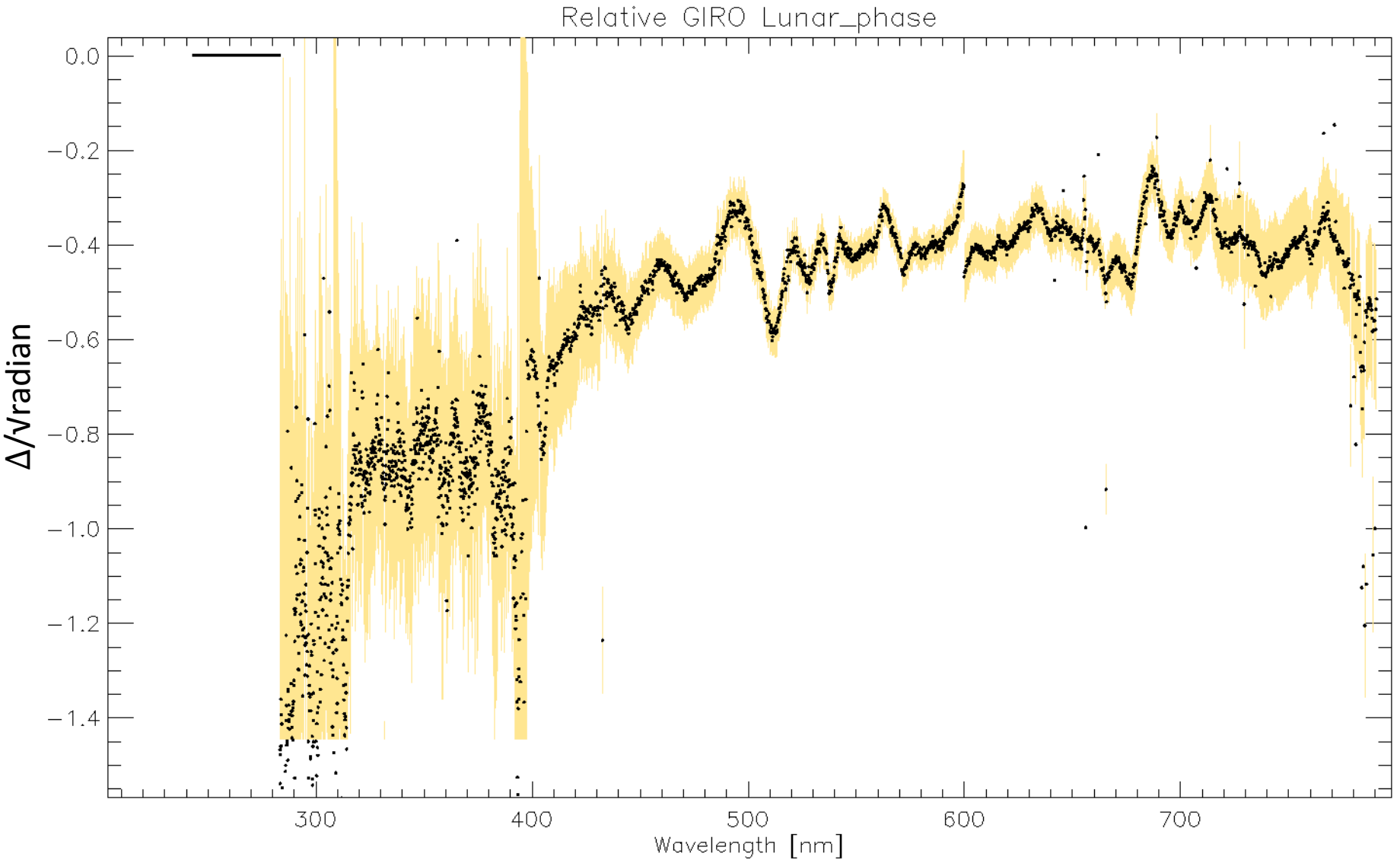


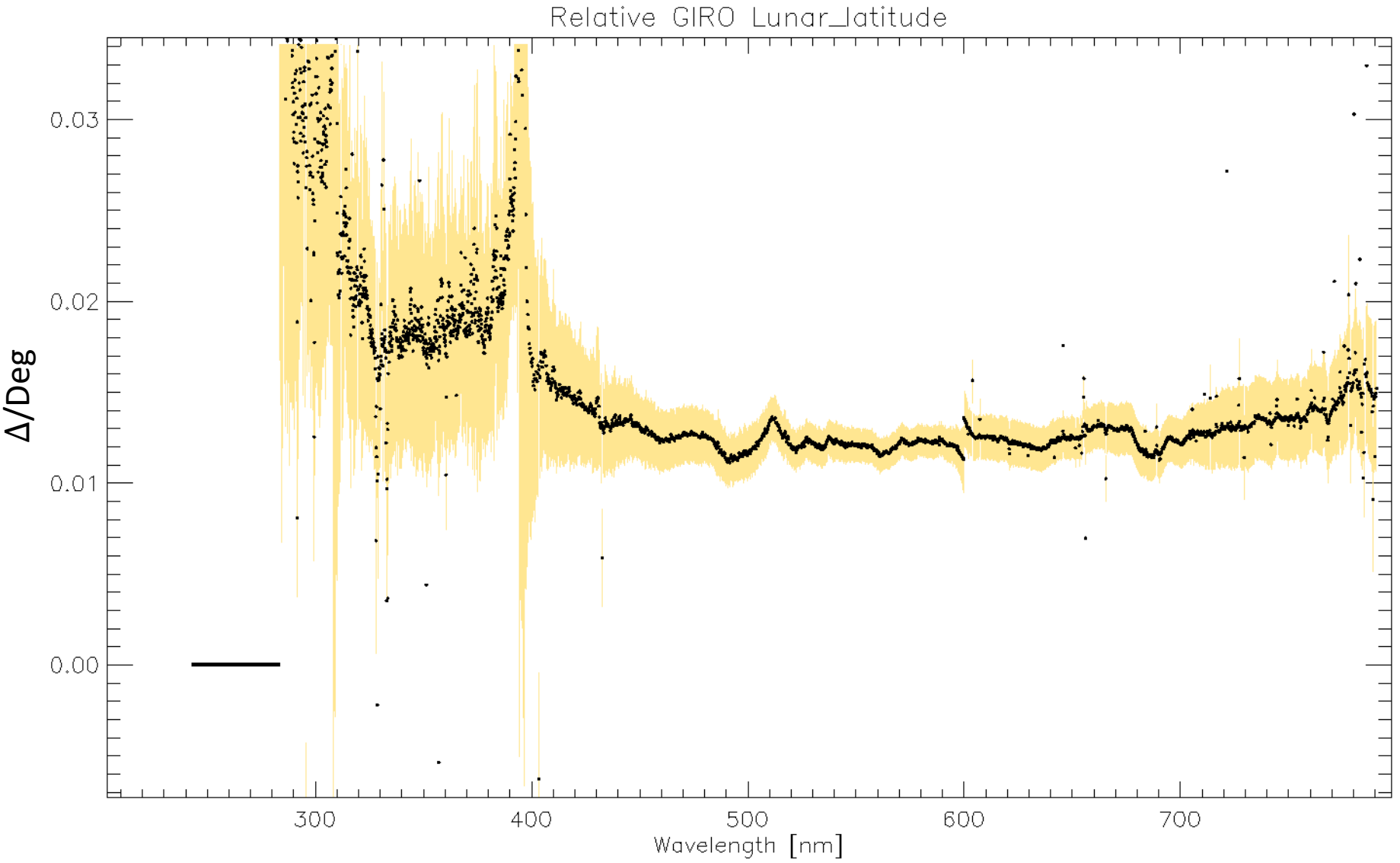


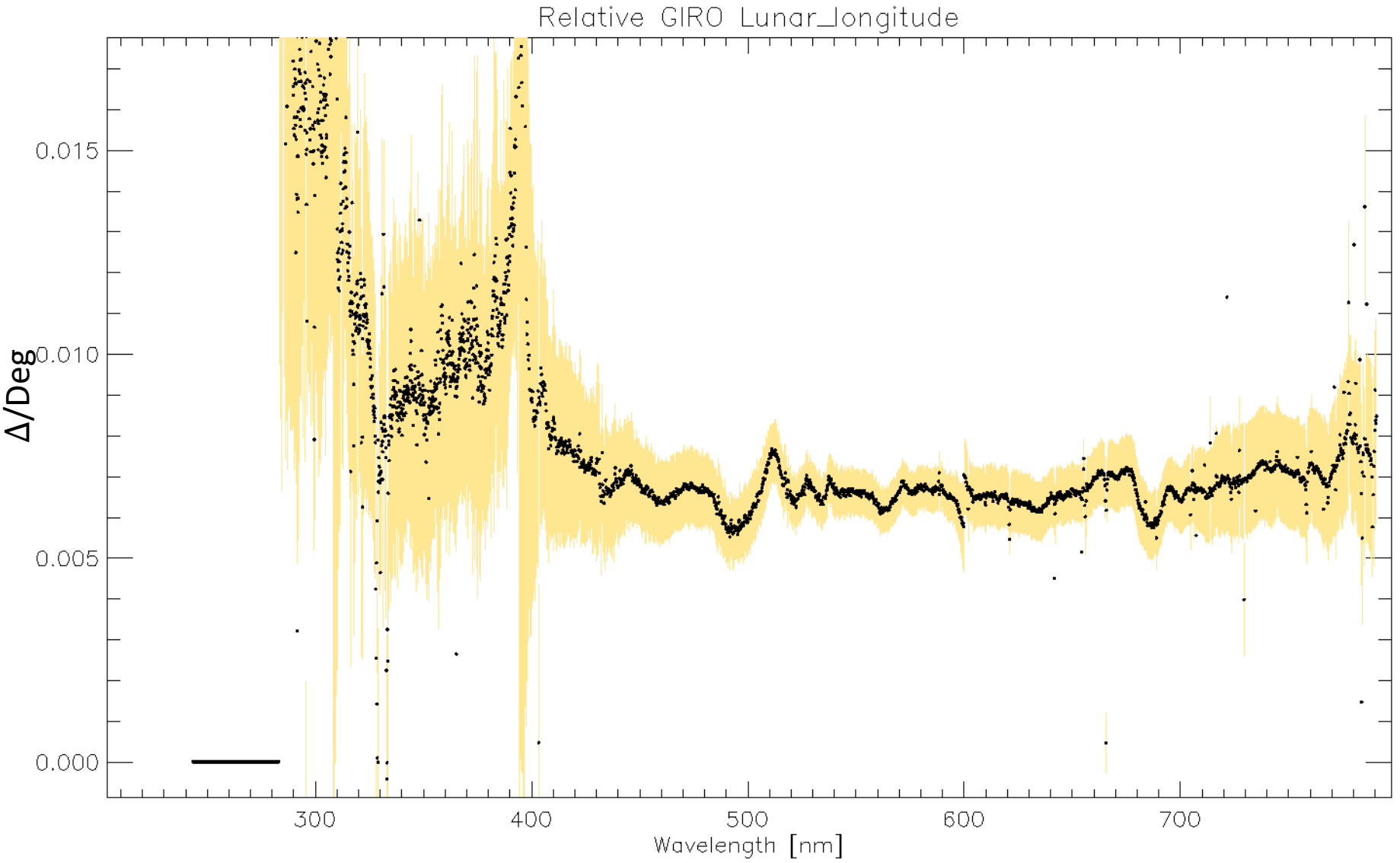
Dec 2012, No libration, Phase 65°

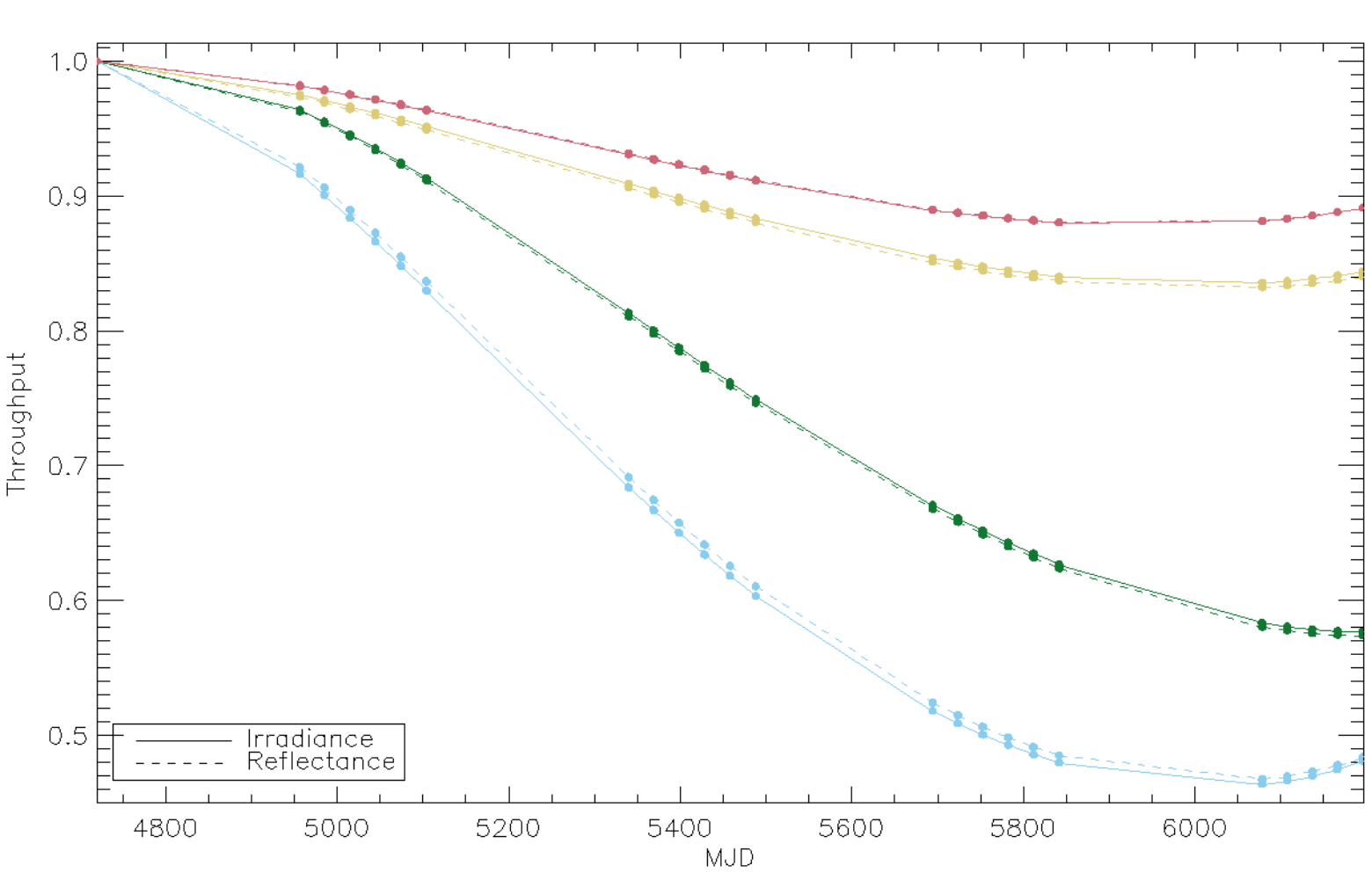
Compare to GIRO

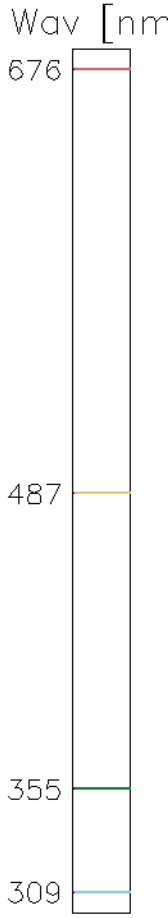

65 Degrees Phase
Irradiance 65 degree
Reflectance 65 degree
Relative GIRO
1.2
1.0
0.8
0.6
0.4
0.2
300
400
500
600
700
Wavelength [nm]


Relative GIRO Lunar_phase
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
Δ/Vradian
300
400
500
600
700
Wavelength [nm]

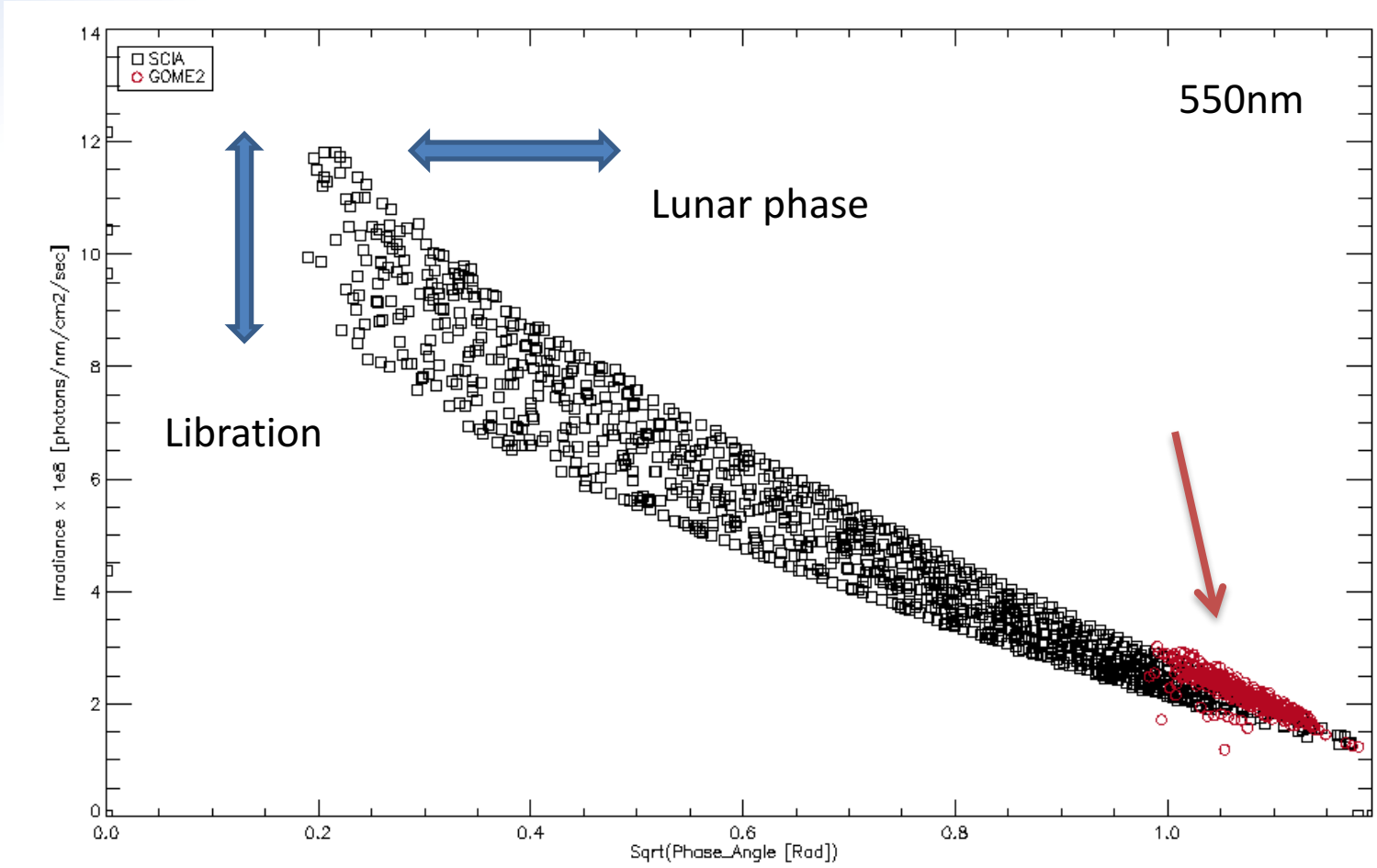

Relative GIRO Lunar_latitude
0.03
0.02
0.01
0.00
Δ/Deg
300
400
500
600
700
Wavelength [nm]

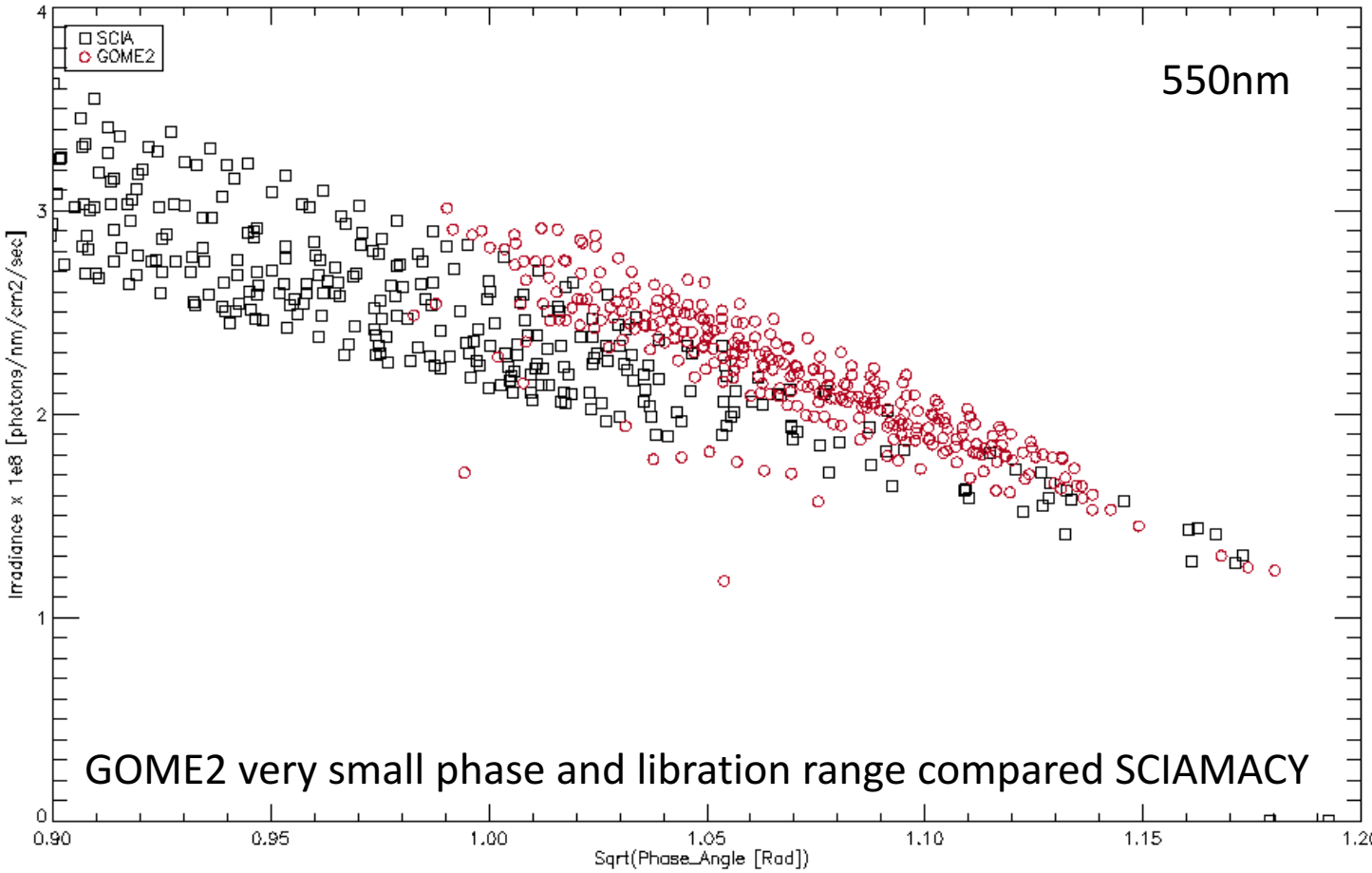

Relative GIRO Lunar_longitude
Δ/Deg
0.015
0.010
0.005
0.000
300
400
500
600
700
Wavelength [nm]


1.0
0.9
0.8
0.7
0.6
0.5
Throughput
4800
5000
5200
5400
5600
5800
6000
MJD
Irradiance
Reflectance


Wav [nm
676
487
355
309

SCIAMACHY vs GOME2





GOME2 very small phase and libration range compared SCIAMACY

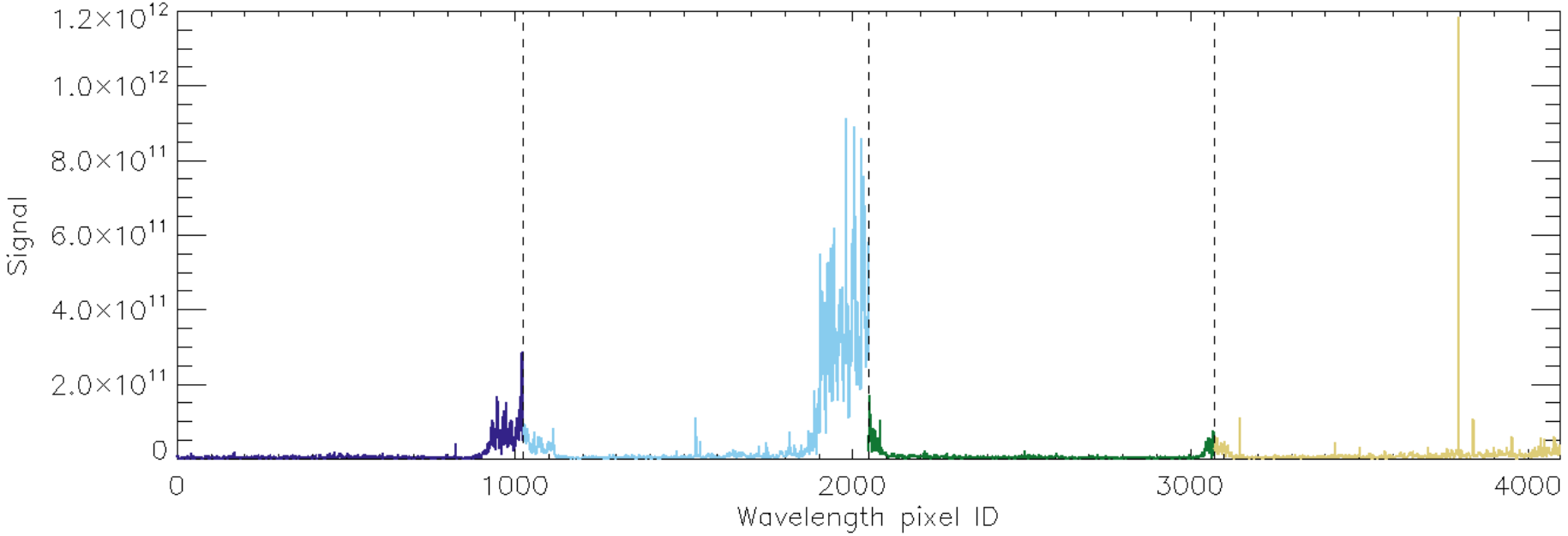
Conclusions

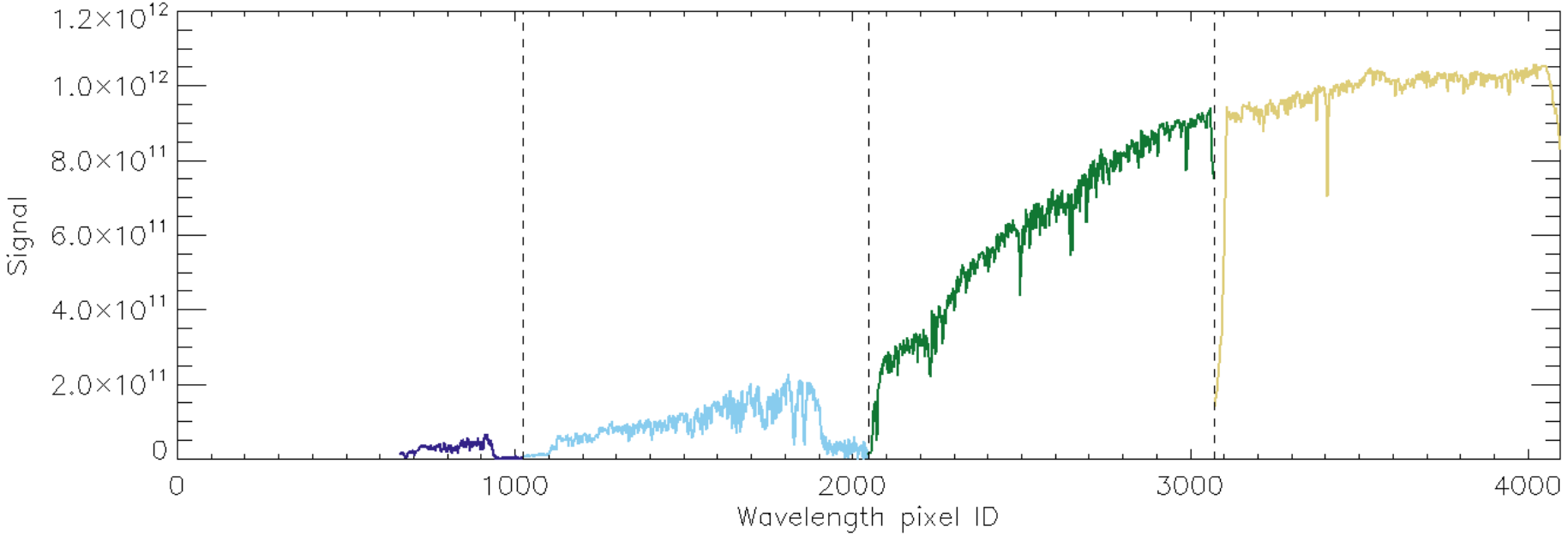
- Issues
  - Degradation
  - Missing Data
  - Pointing
  - Duration
  - Background
  - **Straylight**
- Stable lunar irradiance derived
- Differences relative GIRO due limited geometries

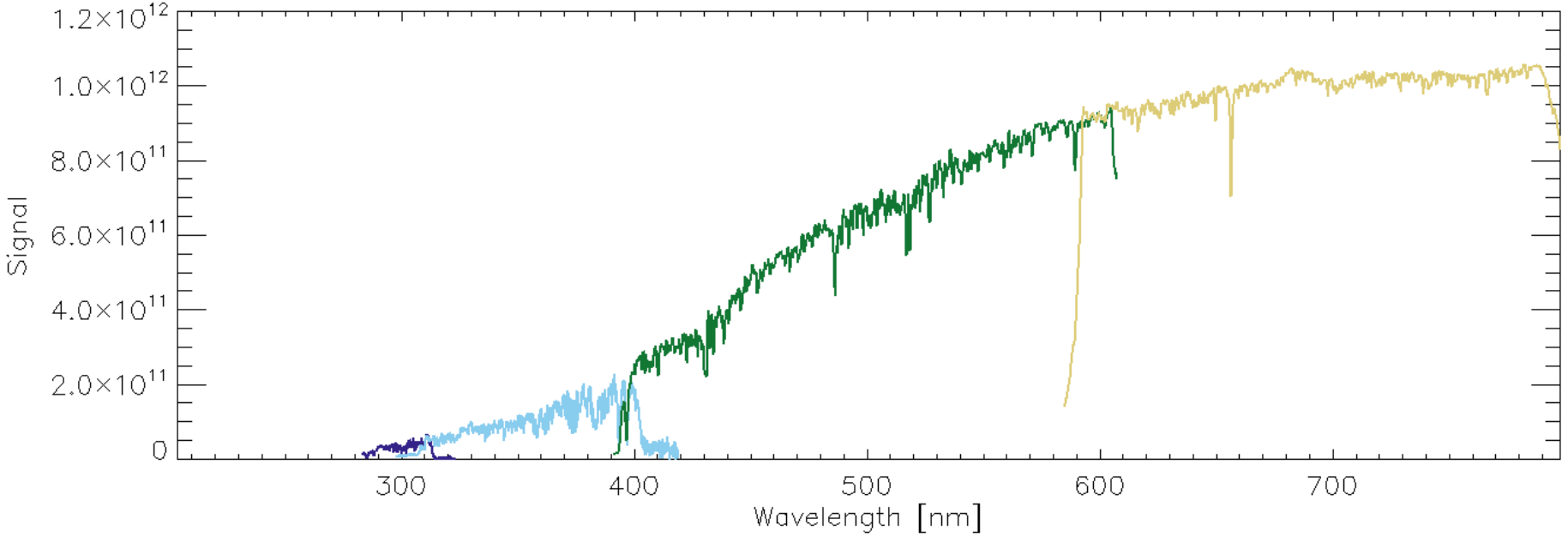
Thank you!

Extra Slides

Channel Edges


1.2×10^12
1.0×10^12
8.0×10^11
6.0×10^11
4.0×10^11
2.0×10^11
0
Signal
0
1000
2000
3000
4000
Wavelength pixel ID


1.2×10^12
1.0×10^12
8.0×10^11
6.0×10^11
4.0×10^11
2.0×10^11
0
Signal
0
1000
2000
3000
4000
Wavelength pixel ID


1.2×10^12
1.0×10^12
8.0×10^11
6.0×10^11
4.0×10^11
2.0×10^11
0
Signal
300
400
500
600
700
Wavelength [nm]

GOME-2 Level-0 to 1b specifications: PGS 7

Lunar observation geometry: Section 5.2.8

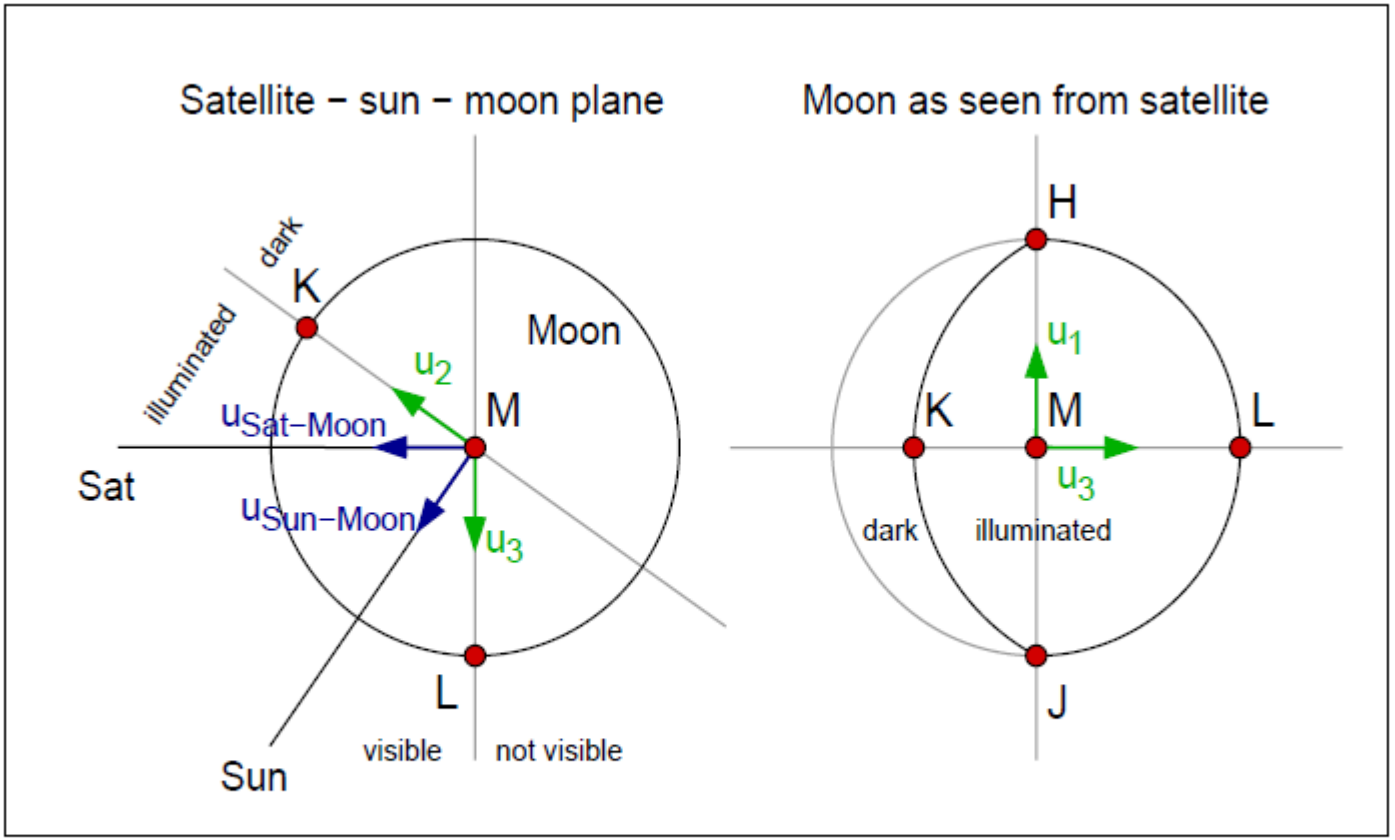


Figure 8: Geometry for lunar observations. Elevation and azimuth angles in the Satellite Relative Actual Reference CS are calculated for the four points HJKL delimiting the illuminated part of the lunar surface as seen from the satellite, and for point M, the centre of the moon.

ϕ_{Moon}	Azimuth of lunar points HJKLM (Satellite Relative Actual Reference CS)	d[5]	deg	o	A2.23.1	**MDR-1*-Moon** GEO_MOON LUNAR_ AZIMUTH *res*[12] Moon mode only
E_{Moon}	Elevation of lunar points HJKLM (Satellite Relative Actual Reference CS)	d[5]	deg	o	A2.23.1	**MDR-1*-Moon** GEO_MOON LUNAR_ ELEVATION *res*[13] Moon mode only
$D_{Sun\text{-}Moon}$	Distance between sun and moon	d	m	o	A2.23.1	**MDR-1*-Moon** GEO_MOON DISTANCE_SUN_ MOON Moon mode only
$D_{Sat\text{-}Moon}$	Distance between satellite and moon	d	m	o	A2.23.1	**MDR-1*-Moon** GEO_MOON DISTANCE_SAT_ MOON Moon mode only
ω	Lunar phase angle (geometrical)	d	deg	o	A2.23.1	**MDR-1*-Moon** GEO_MOON LUNAR_PHASE Moon mode only
A_{Moon}	Illuminated fraction of lunar disc (sunlit moon area divided by total moon area as seen from the satel-lite)	d	–	o	A2.23.1	**MDR-1*-Moon** GEO_MOON LUNAR_FRACTI ON Moon mode only

Geometries provided in the L1B product

MDR-1B-Moon / GEO_MOON

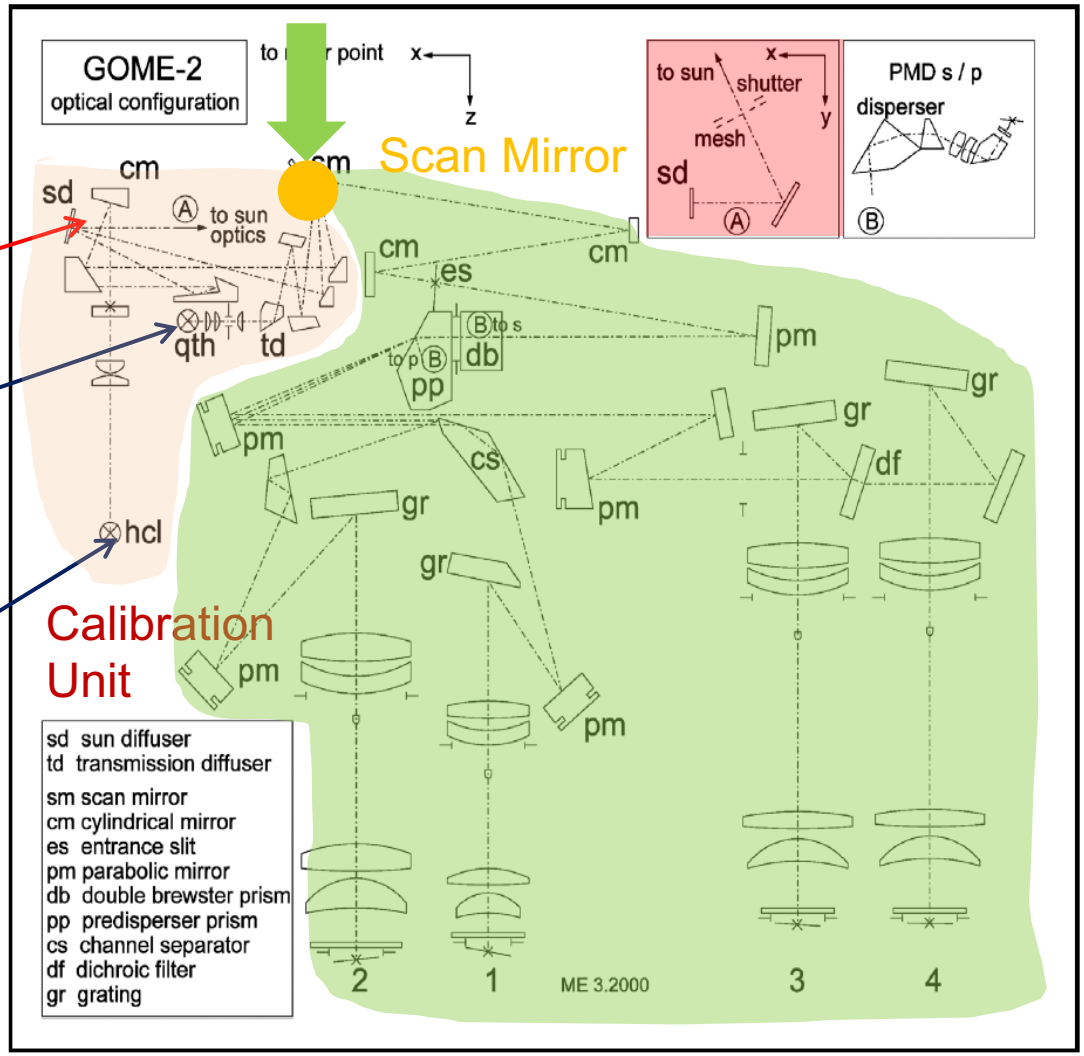
Earthshine

Sun I_0 (daily)

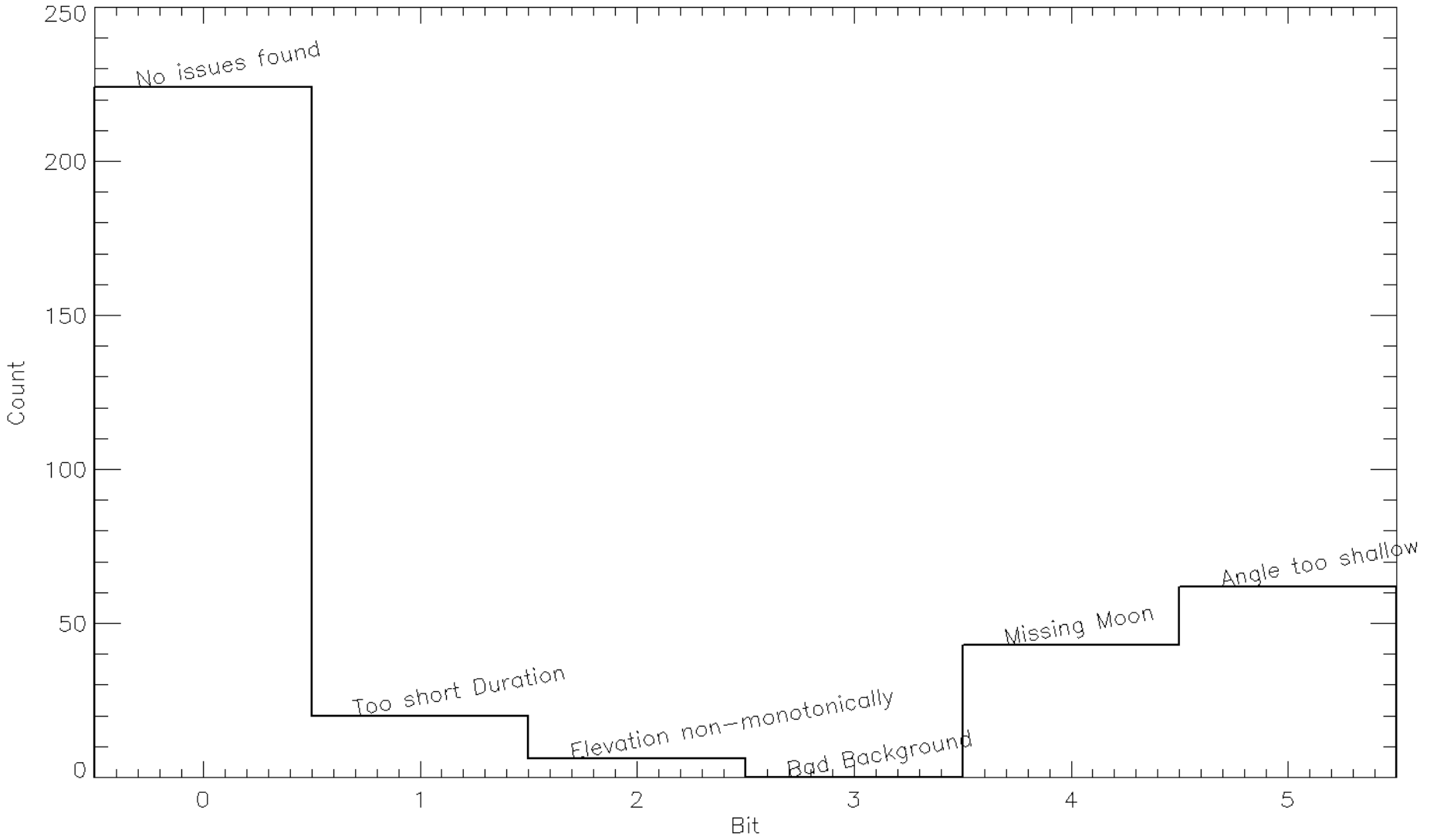
Solar diffuser

White Light Source WLS (daily)

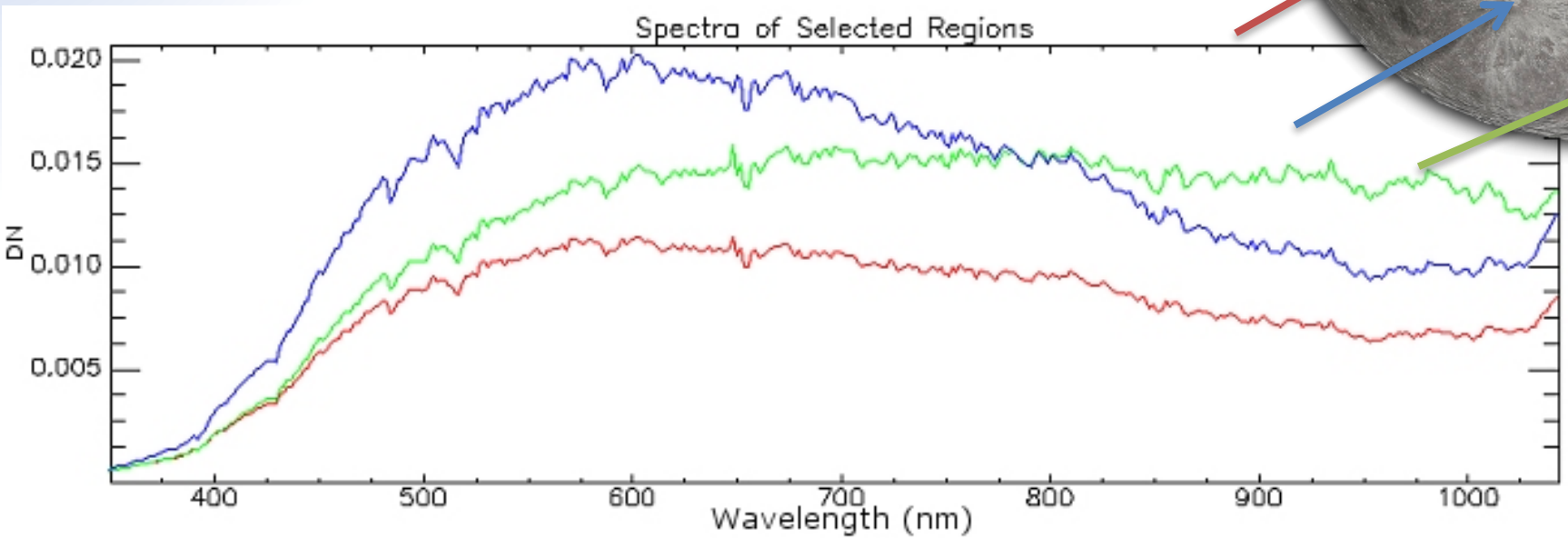
Spectral Light Source SLS (daily)



Common (Earth/Solar/Cal) path


250
200
150
100
50
0
Count
No issues found
Too short Duration
Elevation non-monotonically
Bad Background
Missing Moon
Angle too shallow
0
1
2
3
4
5
Bit

Spectral variation



Date: 04 March 2005
Satellite: Rosetta
Depicts: Three lunar spectra
Copyright: ESA
Three spectra of three different regions on the Moon:

Blue = Kepler crater

Green = Mare Humorum

Red = Oceanus Procellarum

GOME2A

- Simular results (not shown here)
- Additional uncertainty
  - Step-function degradation (2nd Throughput test)
  - Calibration problem early mission

Recommendations

- Degradation
  - Fact of life
- Missing Data
  - Check Lv0/1 for missing data
- Pointing
  - Check Flight Dynamics
- Duration
  - Extend lunar measurement by 30-60sec both direction
- Background
  - Investigate background from Lv0 (not Lv1)
- Straylight
  - Investigate straylight at Lv0