

Lunar Irradiance Model of ESA (LIME) and its application for PROBA-V radiometric calibration

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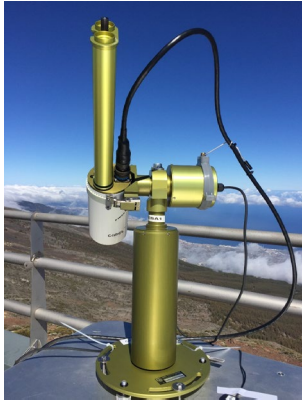


Overview

- LIME model
 - Instrument used
 - Calibration
 - Measurements
 - Modelling
- PROBA-V : usage of LIME



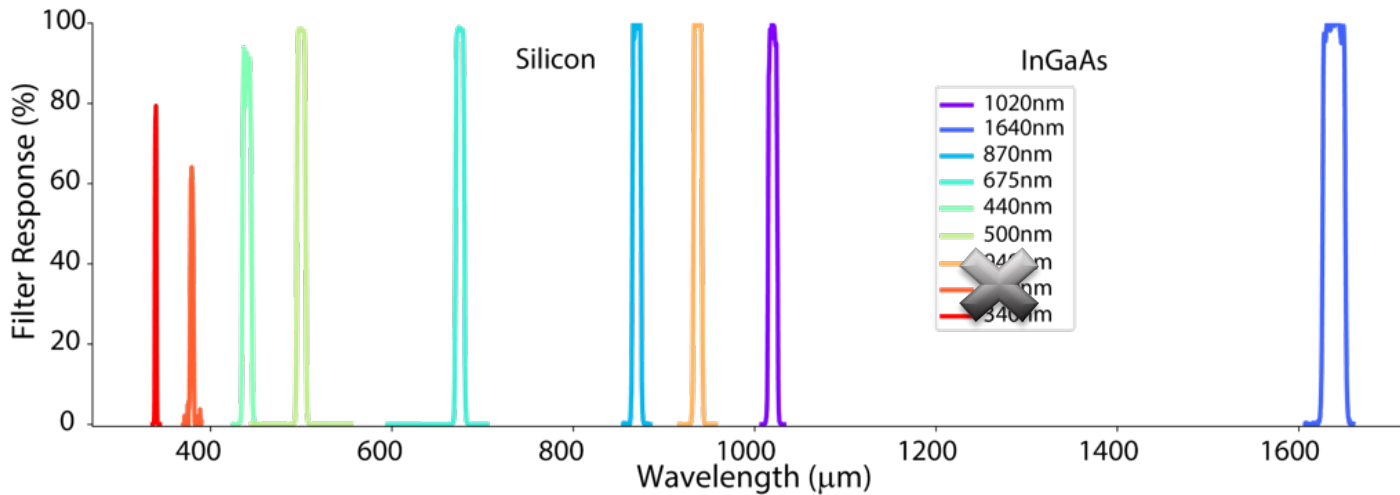
Model from Measurements



- In 2017 ESA launched the initiative to measure the total irradiance of the Moon, to build a new model for EO sensor calibration.
- A new instrument is installed at Izaña institute in Tenerife (Pico Teide) : CIMEL (CE318-TP9) in collaboration with AEMET
- Instrument calibration and characterisation at NPL and UVA
- Using the principle of night-time Langley to measure the exo-atmospheric irradiance
- Valid lunar phase angle ranges : $[-90^\circ; -2^\circ][2^\circ; 90^\circ]$



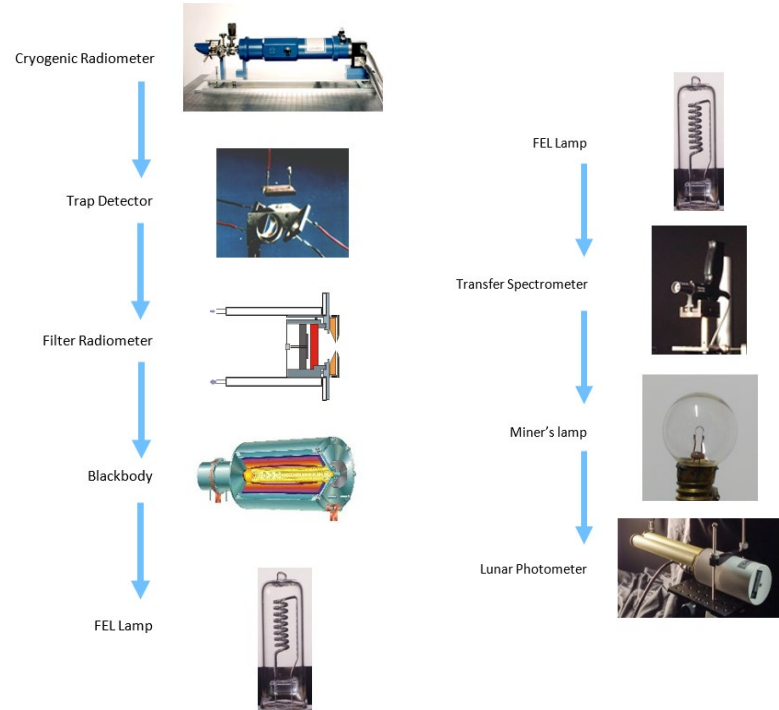
Instrument Spectral bands





Instrument calibration

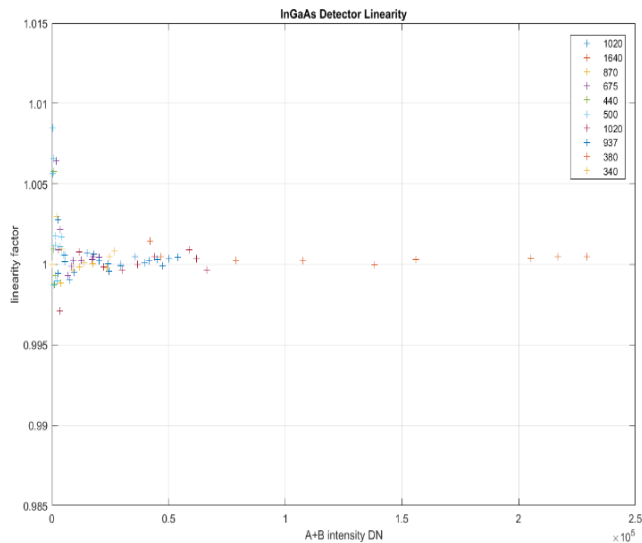
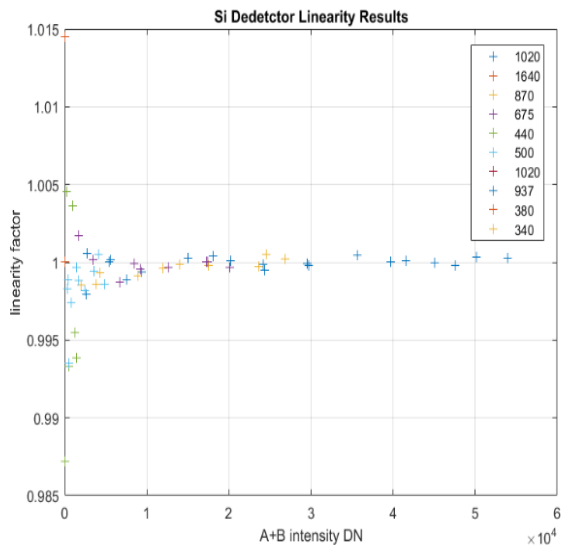
- Temperature characterization (Uva)
- Linearity factor per filter (NPL)
- Irradiance responsivity (NPL)
 - FEL lamp (standard)
 - Miners lamp (lunar irradiance levels)
- Radiance Responsivity (NPL)
 - diffuser
- NPL Full traceability of characterization of the calibration sources





Instrument calibration : Linearity NPL

Two apertures are applied separately (V_A and V_B) and combined (V_{A+B})



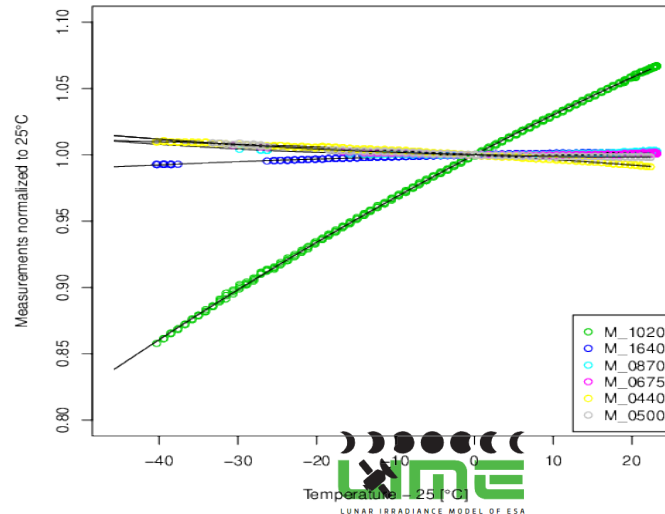
$$L(V_{A+B}) = \frac{V_{A+B}}{(V_A + V_B)}$$

Linearity achieved when $L = 1.0$



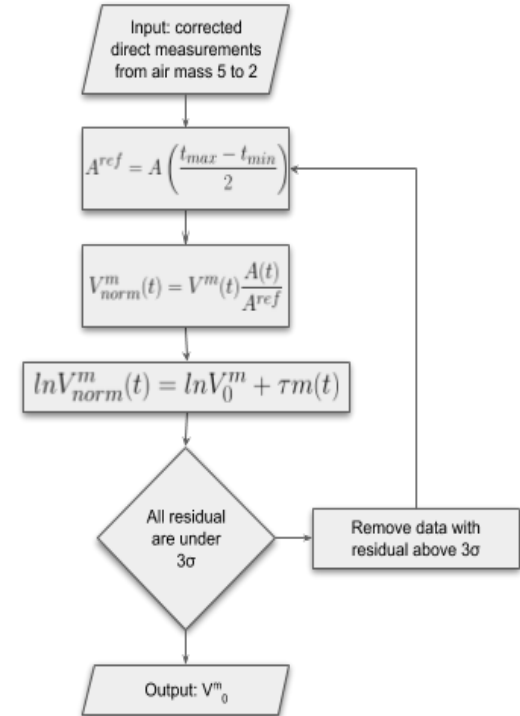
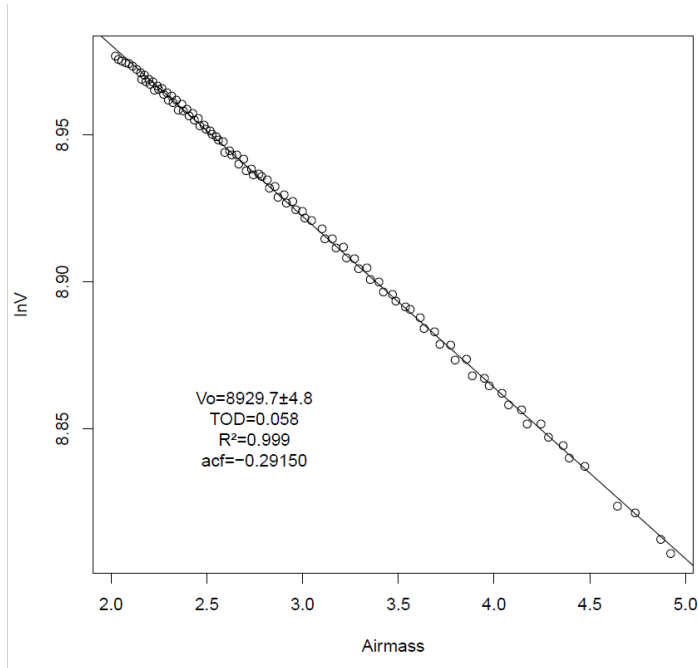
Instrument calibration : temperature UVa

Pico Teide Meteo	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Percentile 98 [°C]	7.7	8.0	8.7	11.7	14.1	16.6	18.7	18.8	15.1	13.0	9.9	7.5
Percentile 2 [°C]	-9.5	-12.0	-8.1	-5.7	-2.7	1.8	5.0	5.0	1.9	-3.5	-5.9	-8.2



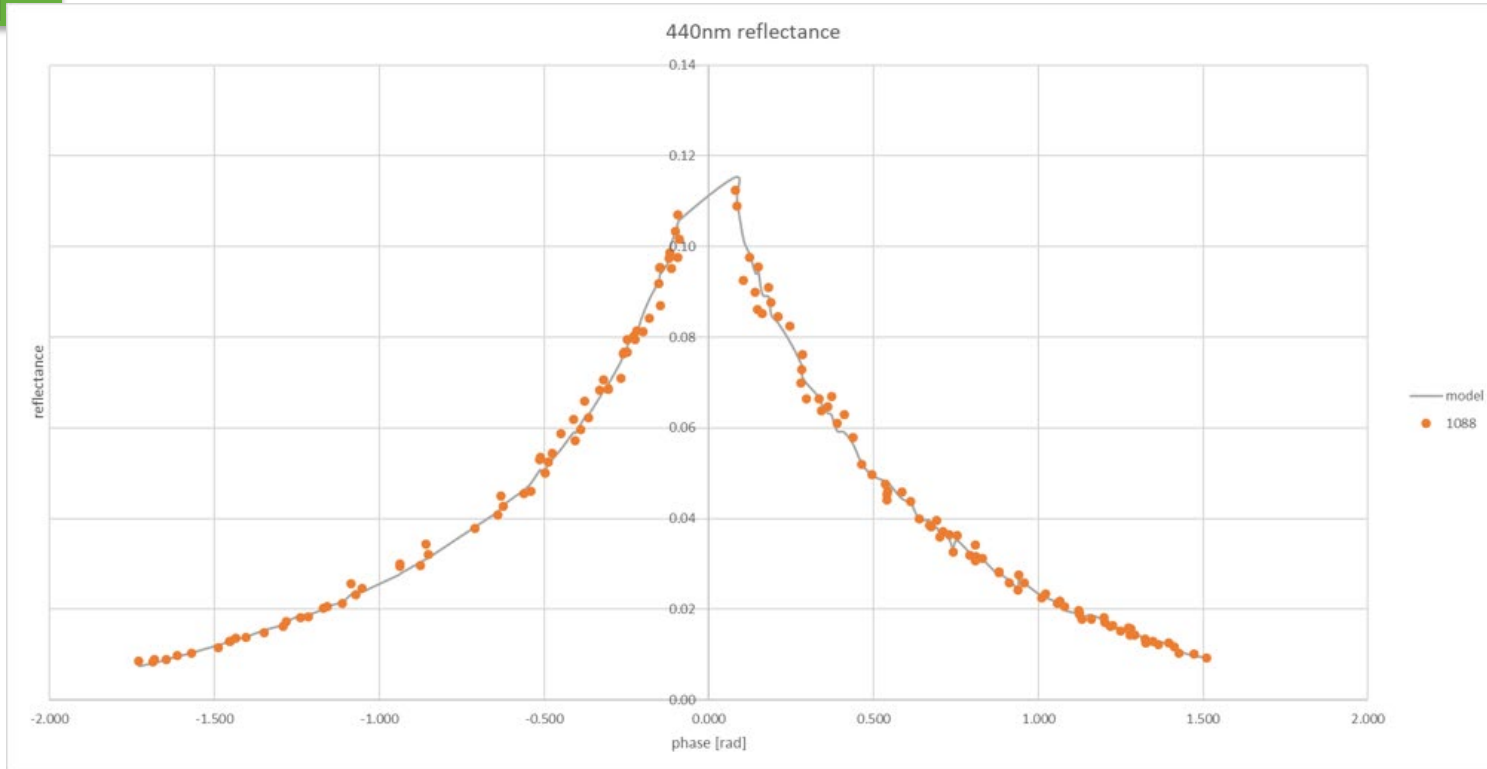


Measurements





Measurement





Model

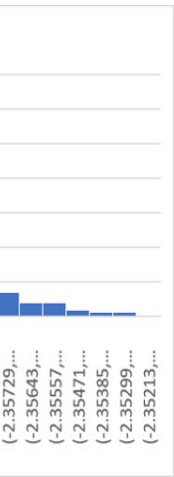
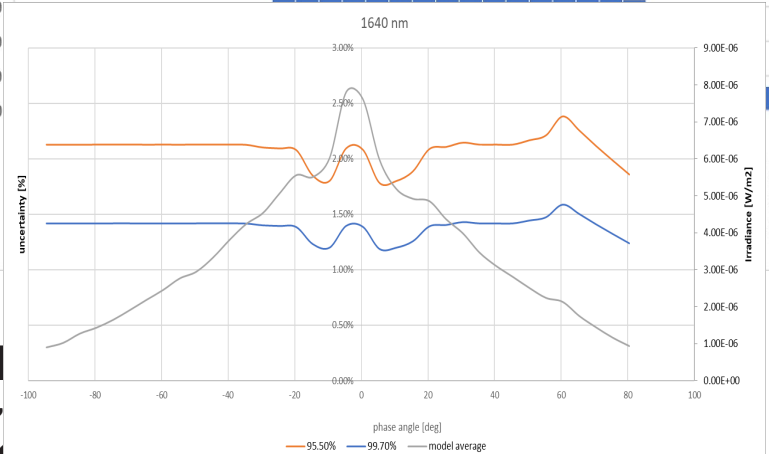
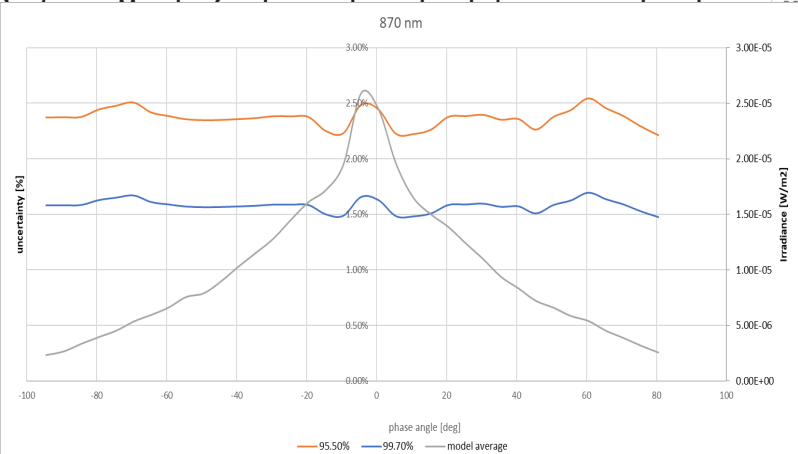
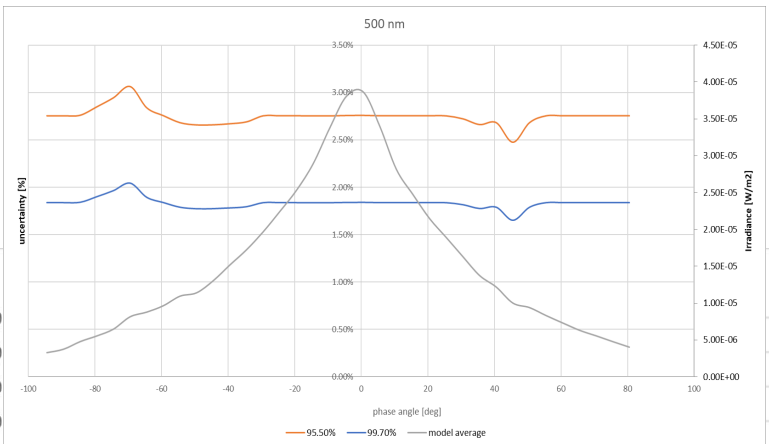
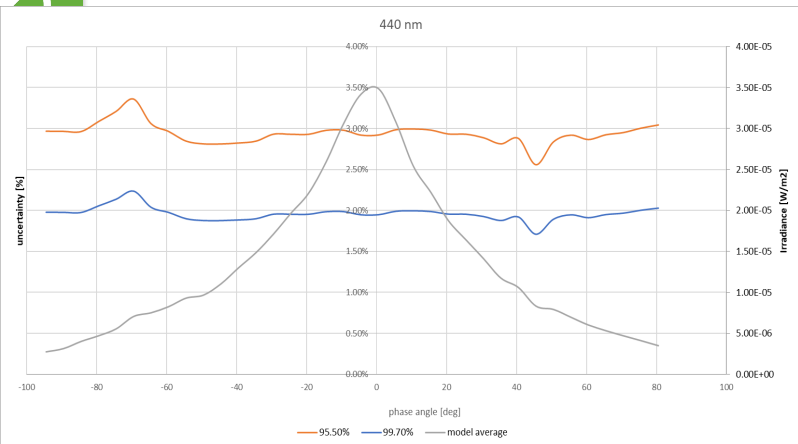
Based upon the work done by Kieffer and Stone
[Kieffer and Stone, 2005]

Minor adaptations to the model formulation

$$\ln(A_k) = \sum_{i=0}^3 a_{ik} g^i + \sum_{i=1}^3 b_{ik} \Phi^{2i-1} + c_{1k} \theta + c_{2k} \phi + c_{3k} \Phi \theta + c_{4k} \Phi \phi + d_{1k} e^{-\frac{g}{p_1}} + d_{2k} e^{-\frac{g}{p_2}} + d_{3k} \cos\left(\frac{g - p_3}{p_4}\right)$$

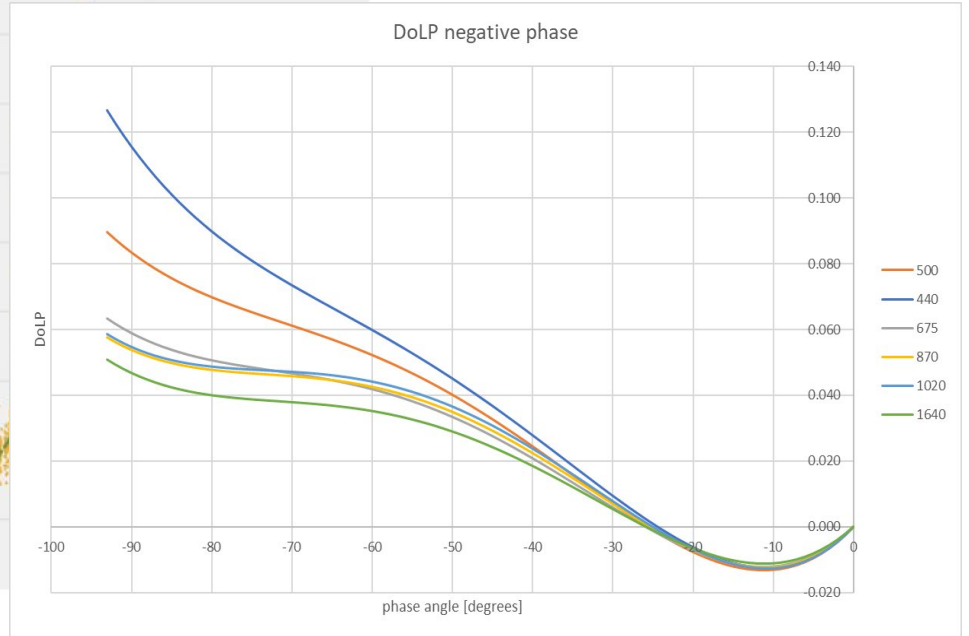
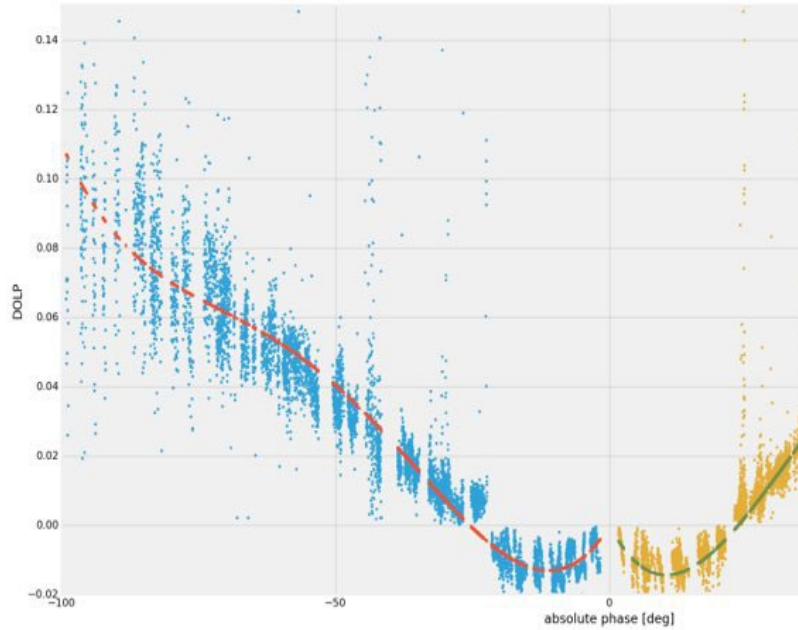
Model is based on the lunar irradiance measurements done at Izaña : currently 4 years of measurements available, approx. 100 meas / yr

Details to be found on <https://calvalportal.ceos.org/lime>





Degree of Linear Polarisation





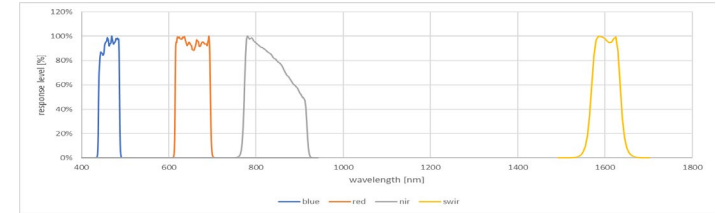
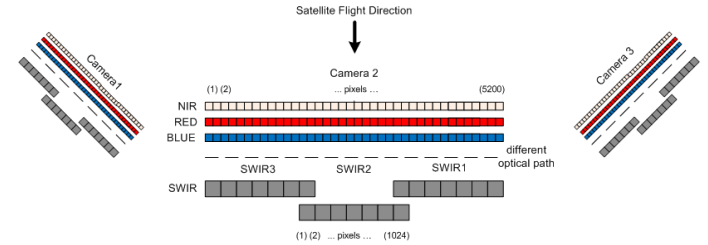
LIME Improvement

- Improving the model :
 - Upgrade CIMEL : extra filters
 - Hyperspectral reflectance measurements : currently ongoing at Pico Teide
 - Improving the interpolation
 - Uncertainties propagated
 - Evaluate the formulation of the model
- Development of reference implementation
- Application of the model
 - Sensor comparison (i.e. AIR-LUSI)
 - Nightly Aerosol (Africa Barreto)
- <https://calvalportal.ceos.org/lime>



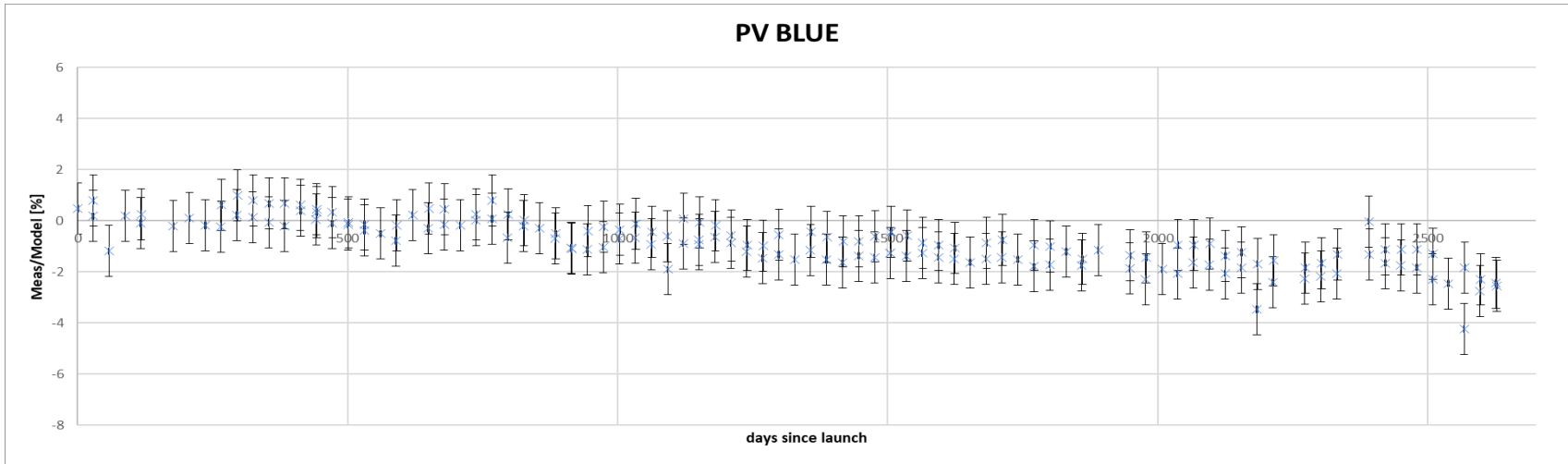
PROBA-V calibration

- In orbit since 2013
- MSI : 4 broad spectral bands
- Pushbroom - 2000km swat
- Daily global VGT monitoring
 - Until November 2021
- Calibrated based upon vicarious methods
 - Lunar acquisitions from November 2014
 - +/- 7 degrees phase angle
 - Trend modelling
- Still active in experimental mode :
 - Moon acquisitions : full cycles [-90,90] (support to LIME development)
 - Dark Current
 - Railroad valley





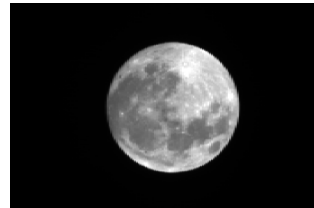
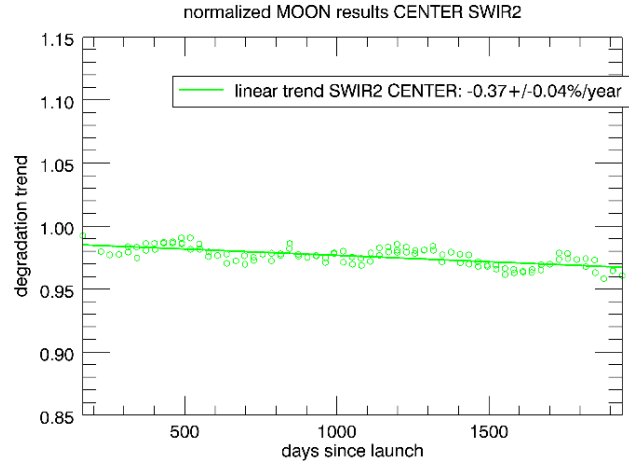
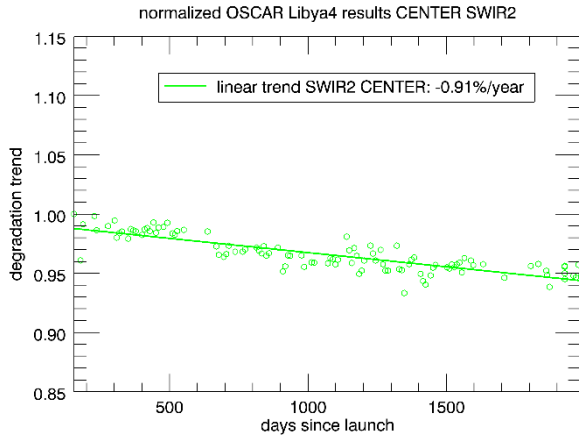
PROBA-V operational calibration





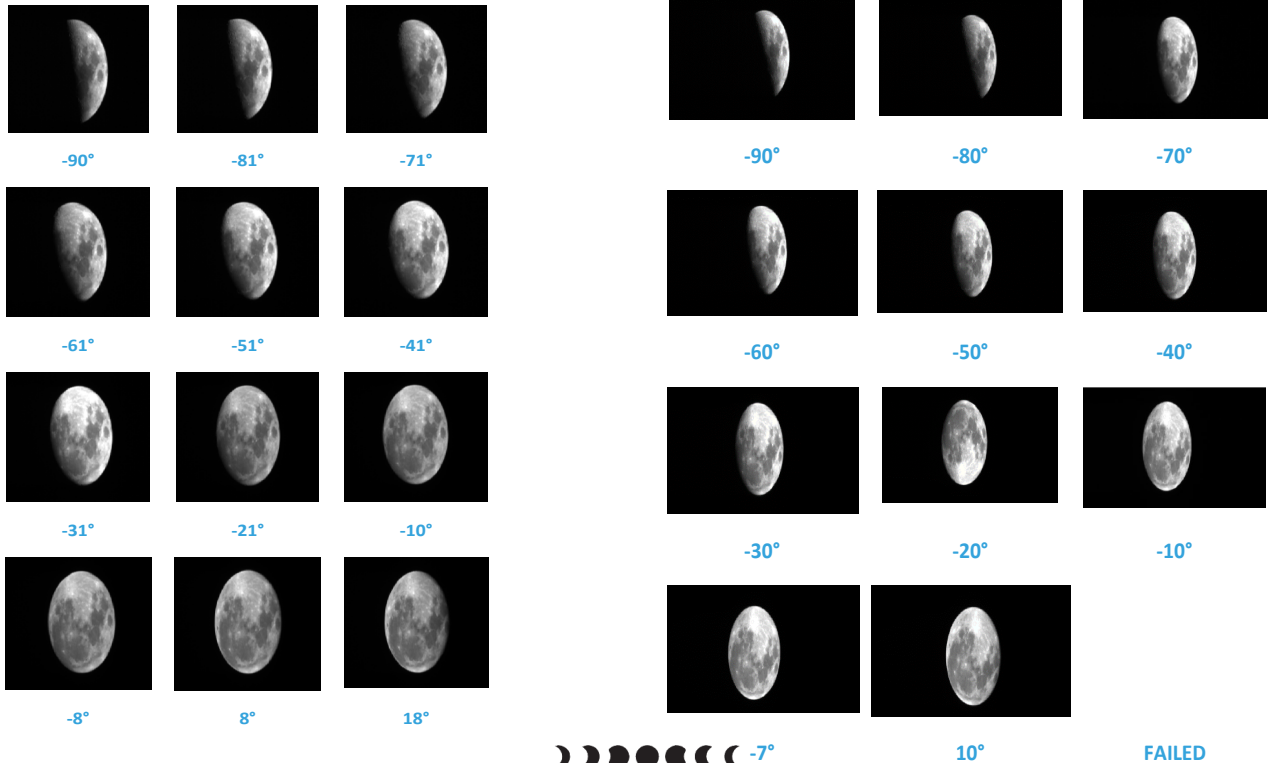
PROBA-V operational calibration

Routine lunar calibration : extra confidence on instrument stability



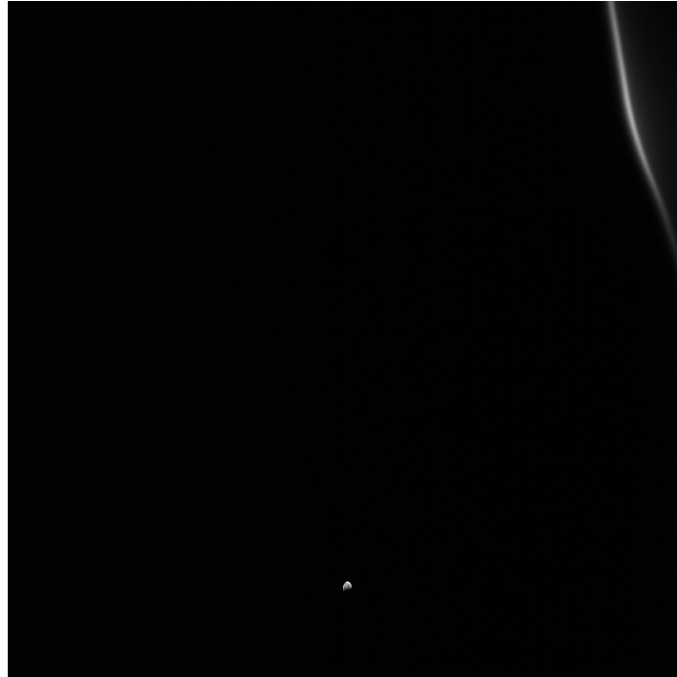
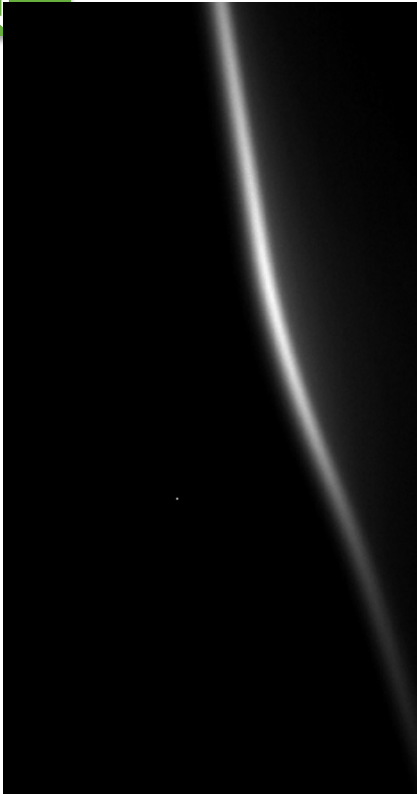


PROBA-V experimental lunar observations



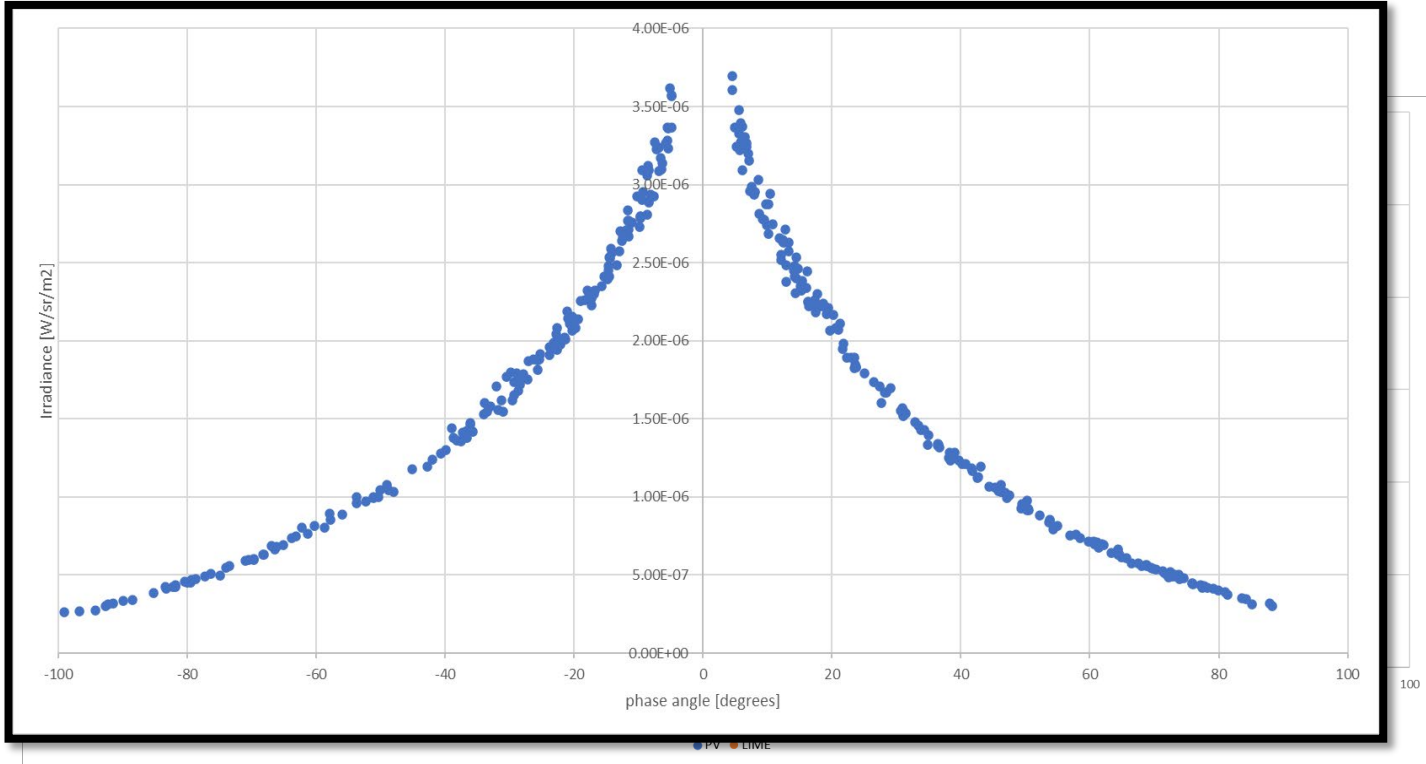


PROBA-V experimental lunar observations



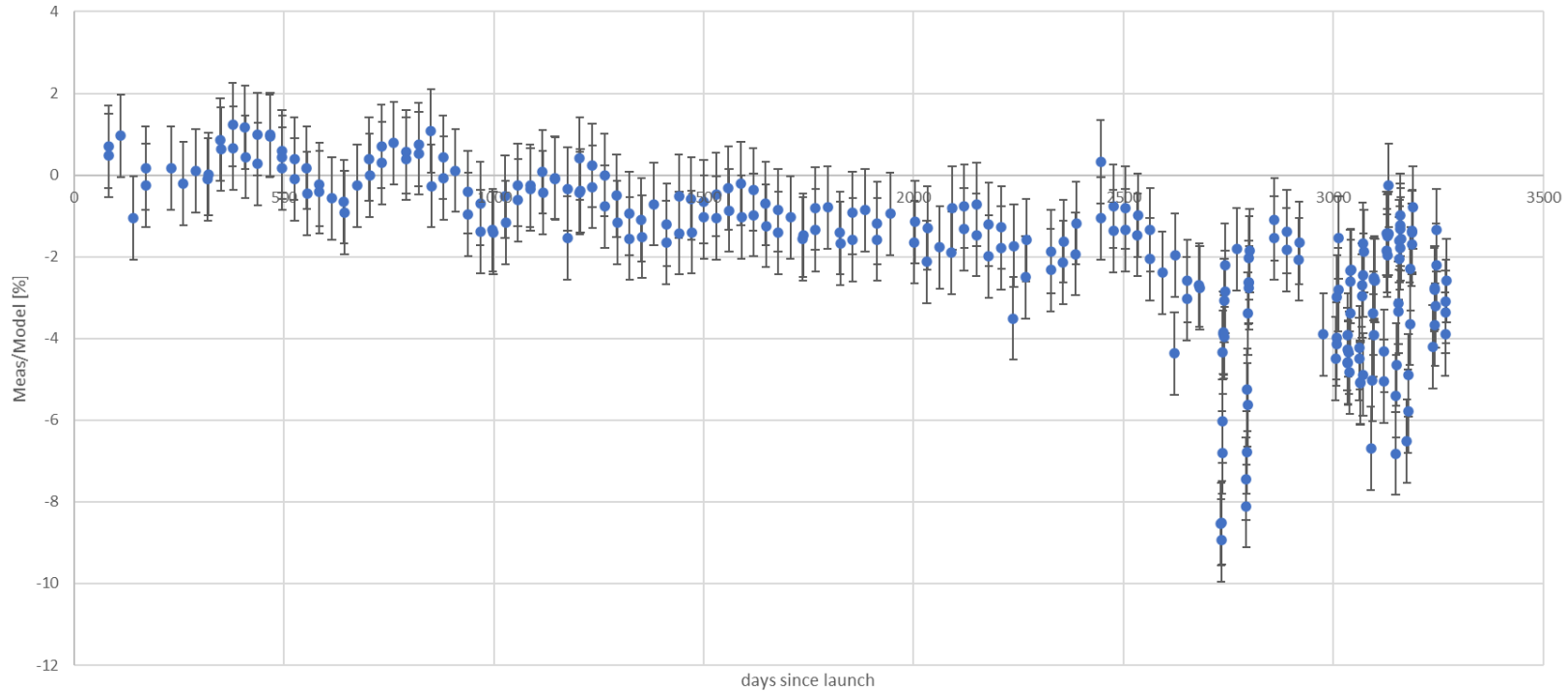


PROBA-V experimental lunar observations





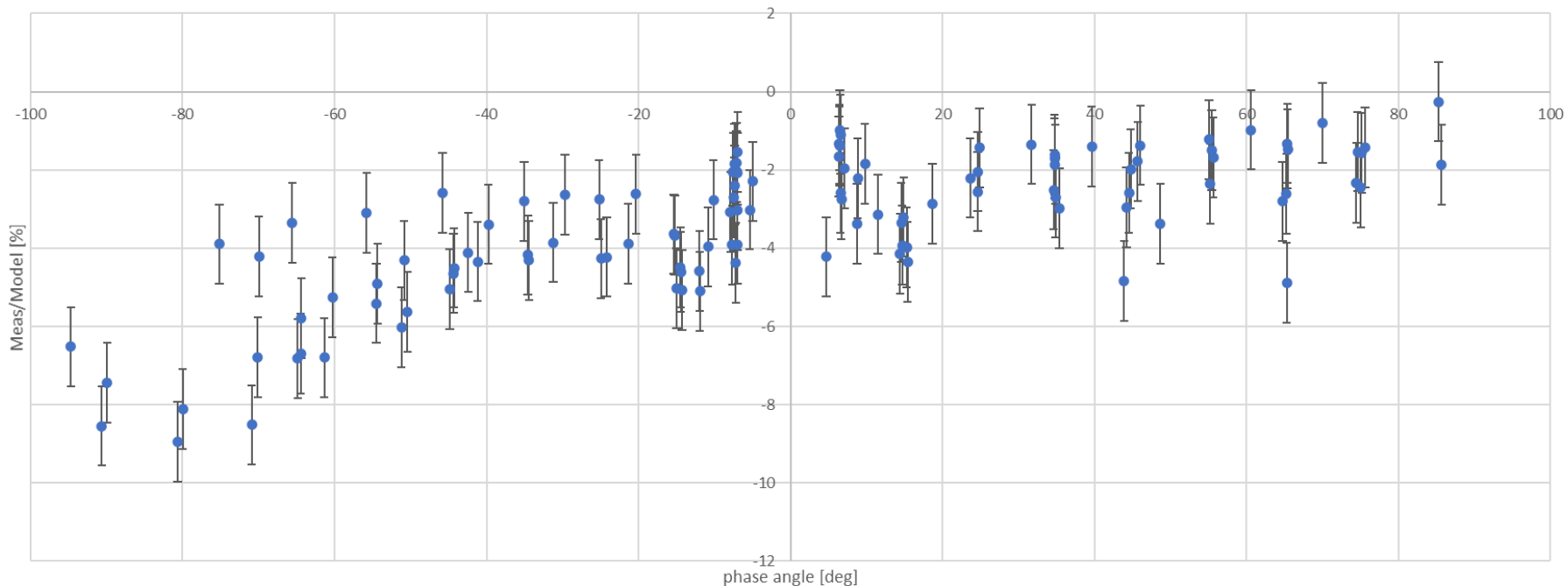
PROBA-V experimental lunar observations



● PV BLUE



PROBA-V experimental lunar observations





Conclusion

- LIME model development based upon the CIMEL measurements at Pico Teide was successful
- Model improvements are ongoing
- PROBA-V used LIME as calibration method for trending
- PROBA-V is serving the model improvements in experimental modus (and the community)



Thanks for your
attention