

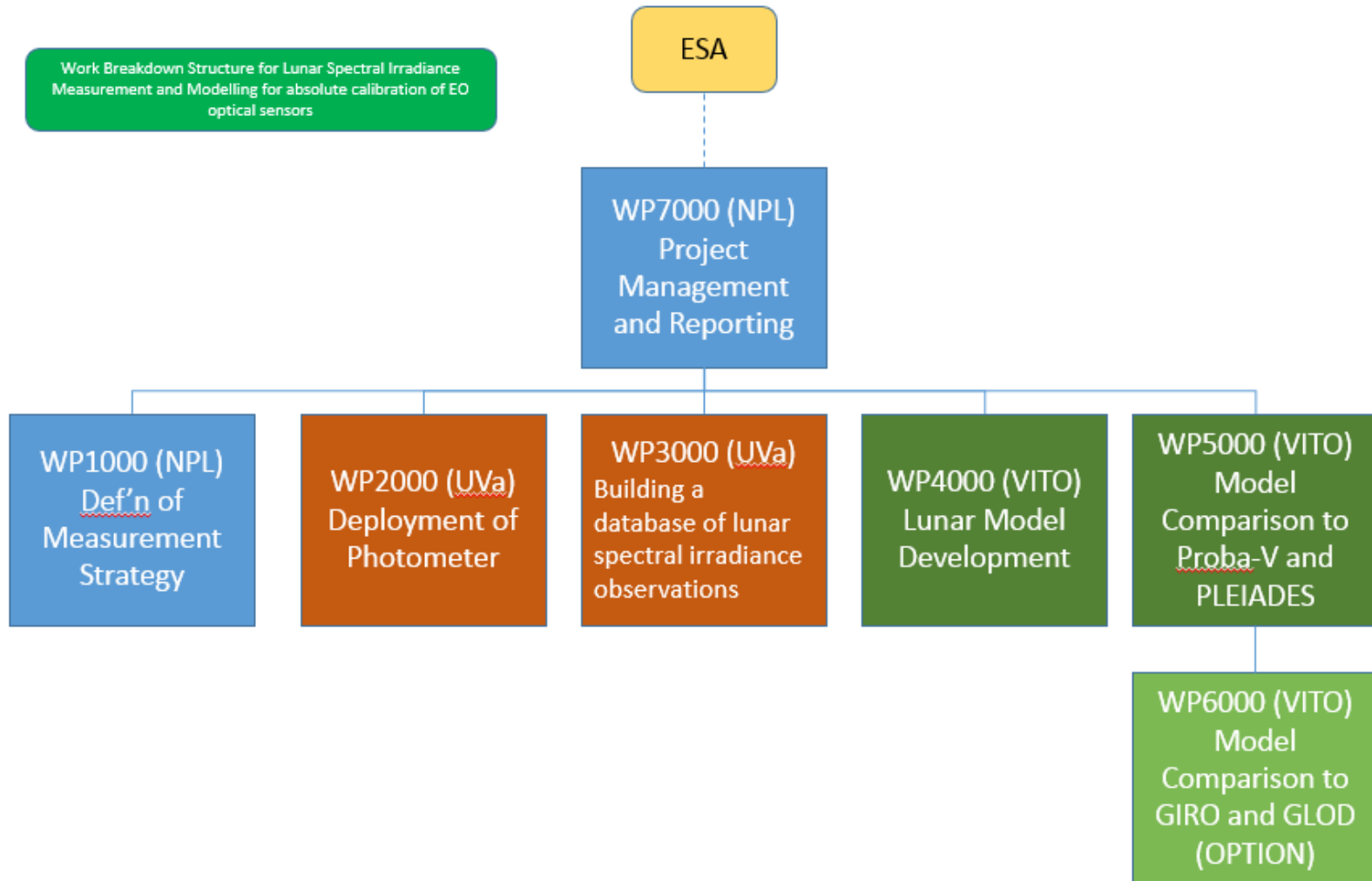
# Lunar irradiance measurement and modelling for absolute radiometric calibration of EO sensors

*M. Bouvet (ESA), Emma Woolliams (NPL), Claire Greenwell (NPL), Maria Garcia Miranda(NPL), Carlos Toledano (Univ. Valladolid), Alberto Berjón (Univ. Valladolid), África Baretto (Univ. Valladolid), Stefan Adriaensen (VITO)*

- Define a strategy for the measurement of the lunar spectral irradiance variation from the ground
- Demonstrate the feasibility of such measurements
- Compile a database of such measurements and on that basis improve the modelling of the lunar disk irradiance variations through its cycles (targeting sub-2 % absolute radiometric accuracy)
- Compare the improved lunar disk irradiance model to various independent sources of lunar observations from space

- ✓ KO of activity in Sept. 2017
- ✓ KO+2 months: definition and procurement of lunar photometer
- ✓ KO+6 months (19<sup>th</sup> of March 2018): Review of instrument characterisation (spectral, geometric and radiometric), calibration and derivation of measurement uncertainties.
- KO+6 months (19<sup>th</sup> of March 2018) to end:
  - ✓ Lunar data collection at Pico Teide / Izana (Spain)
  - ✓ Development of a model of lunar irradiance
- KO+12 month to end: comparison of the model of lunar irradiance to:
  - ✓ lunar observations: from Proba-V, PLEIADES and a subset of the GLOD
  - ✓ Other lunar model(s): GIRO

Duration: 21 months

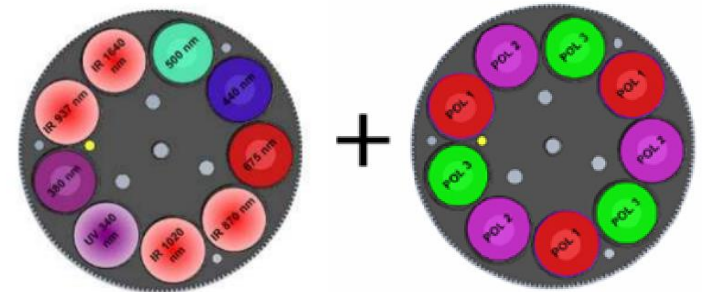






Instrument selected is the Sun-Sky-Lunar photometer CE318 from CIMEL designed for night aerosol retrieval and specifically for this project:

- Spectral channels: 340, 380, 440, 500, 670, 870, 936, 1020, 1640 nm
- Double filter wheel for polarimetric measurements
- Modification of firmware for polarimetric capabilities in direct lunar observation configuration



# WP 1000: Instrument specification, characterisation, calibration and uncertainty budget



- Temperature characterization (Uva)
- Irradiance / radiance responsivity (NPL/Uva)
- Linearity of the instrument (NPL)
- Final tests at Izana Observatory (Uva)



# WP 2000: Deployment at Tenerife



- Summer at Pico Teide



- Winter at Izana Observatory





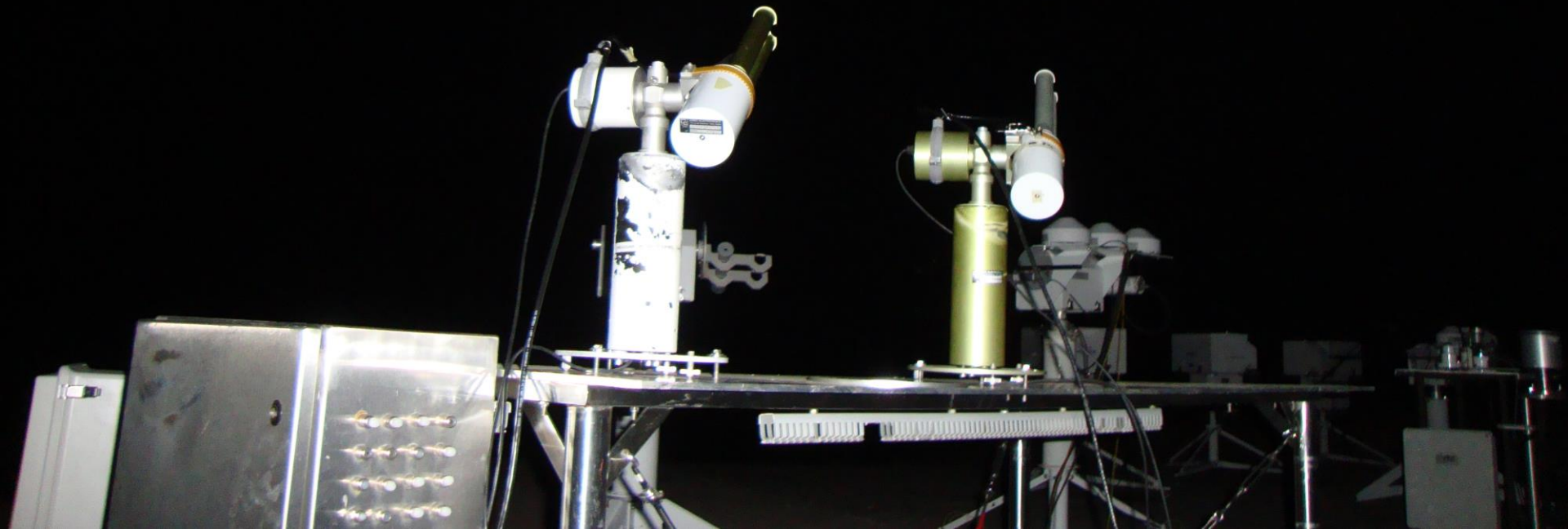
# WP 2000: Deployment at Tenerife



# WP 2000: Deployment at Tenerife

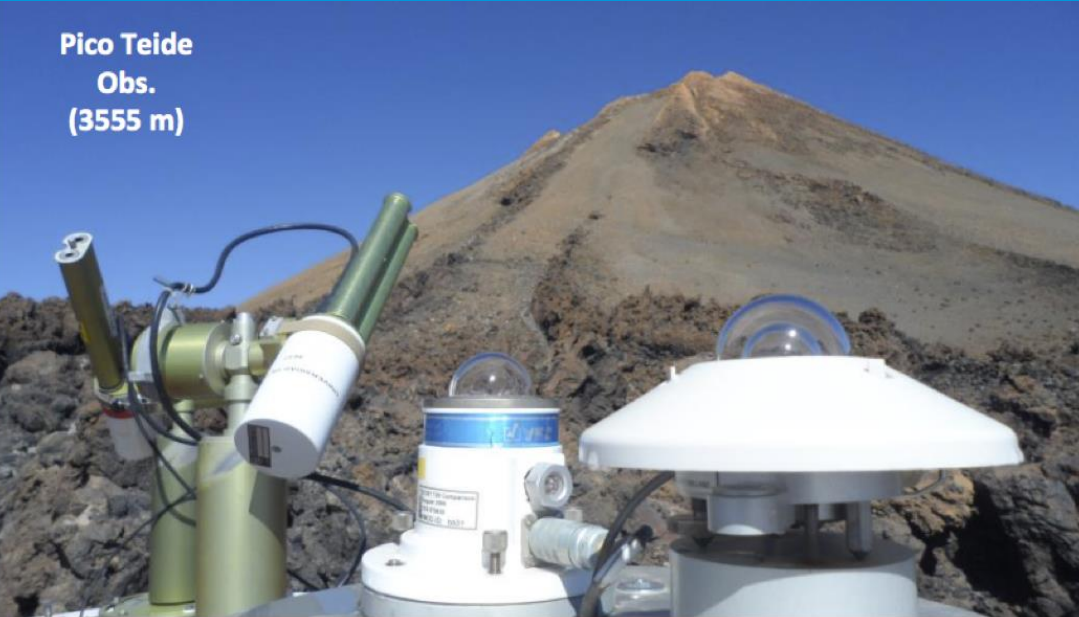
## Measurement principle

- Lunar Langley plots for AOD and TOA lunar irradiance measurements
- Sun Langley plots used for radiometric calibration stability monitoring



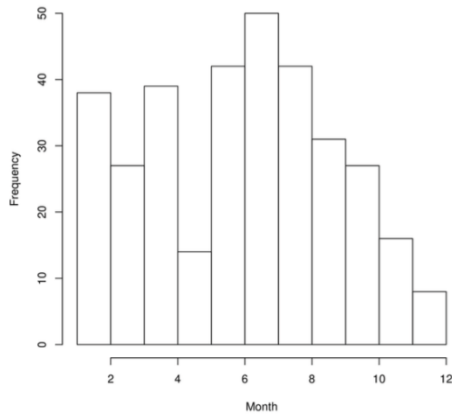
# WP 2000: Deployment at Tenerife

**Pico Teide  
Obs.  
(3555 m)**



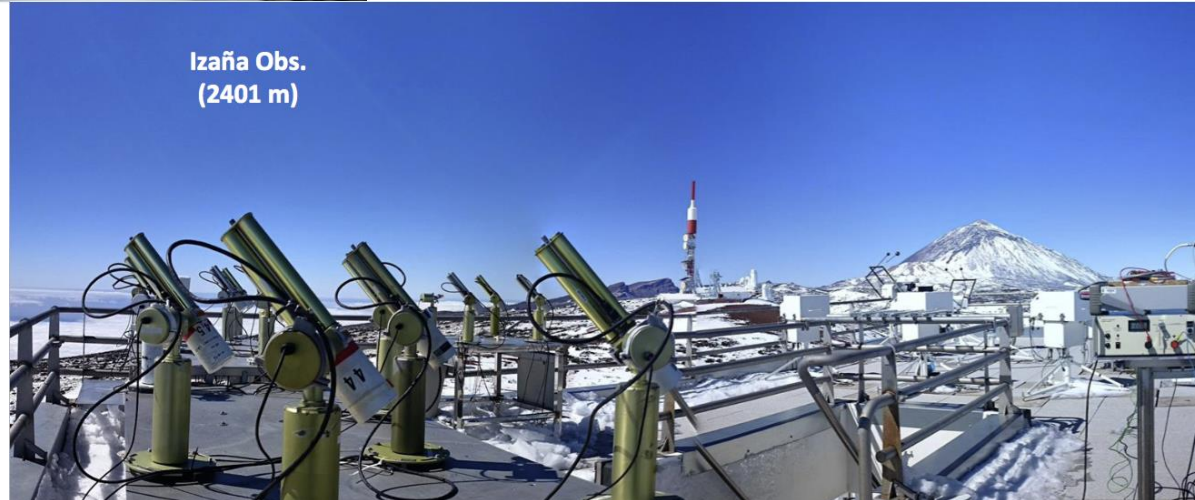
	$\tau_{a500}$	sigma
JAN	...	...
FEB	...	...
MAR	...	...
APR	...	...
MAY	0.020	0.009
JUN	0.042	0.085
JUL	0.091	0.160
AUG	0.078	0.082
SEP	0.018	0.021
OCT	0.010	0.005
NOV	0.009	0.004
DEC	0.007	0.000

**Number of Langley plots by month  
(June, 2014/ April, 2017)**



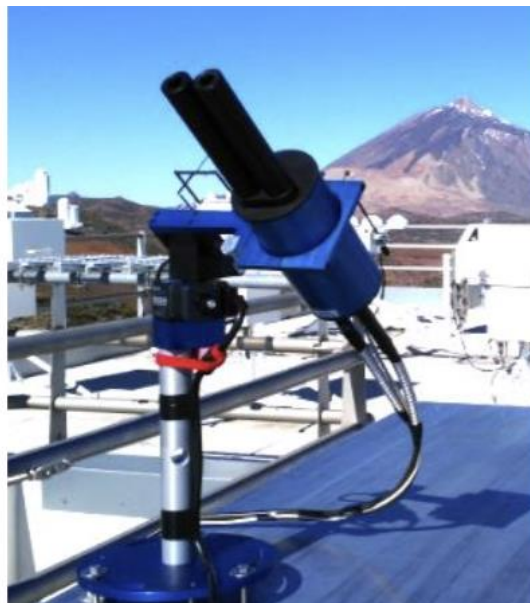
334 Langleys plots  
in 3 years!

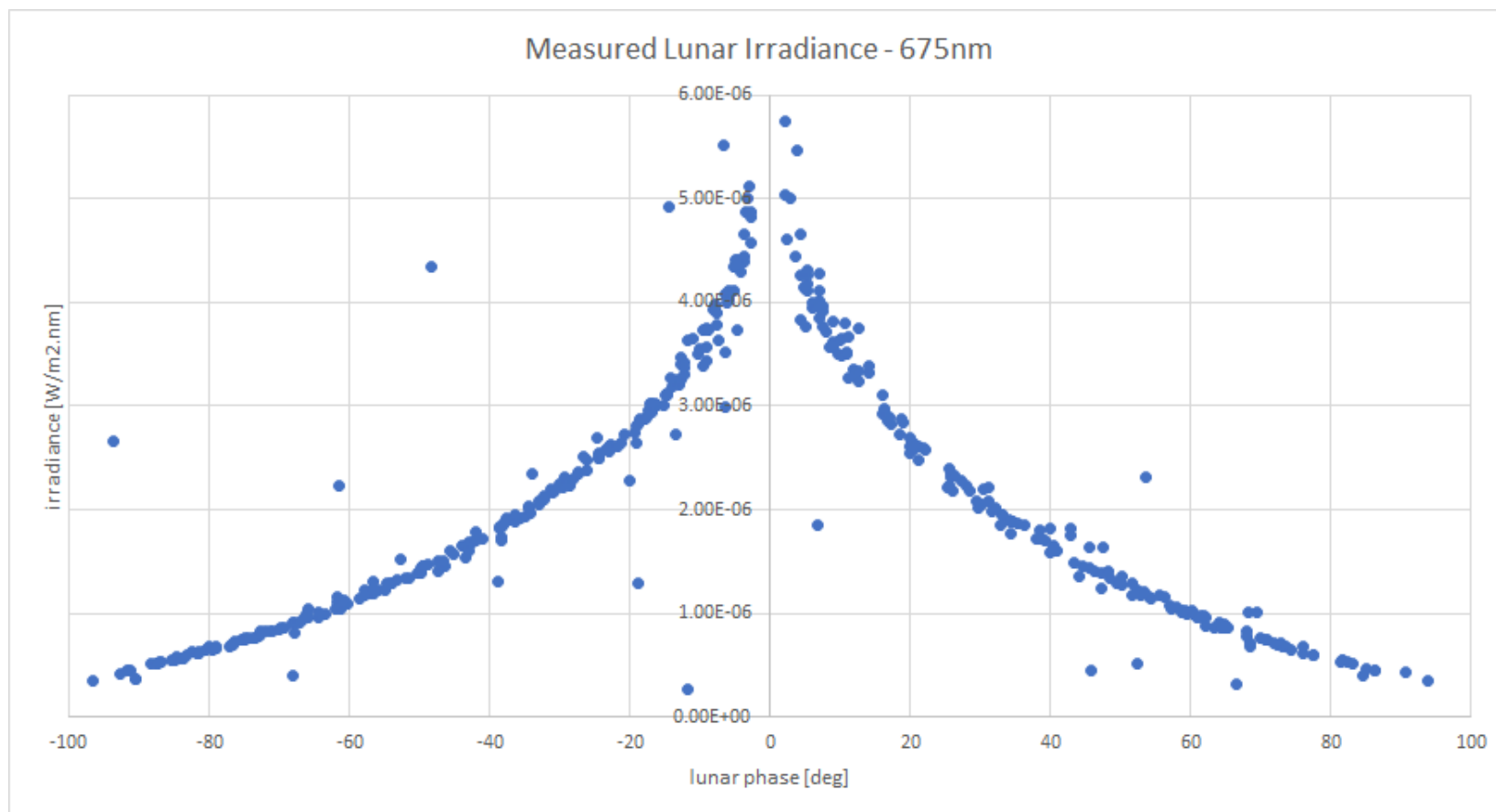
**Izaña Obs.  
(2401 m)**



Additional instrument (already previously) deployed will include:

- Standard lunar photometer CIMEL (no polarimetric capabilities) => 3 years of lunar irradiance measurements available for this project
- ASD spectrometer + Pandora-2S with lunar tracking capabilities => will support the hyperspectral interpolation of multi-spectral photometer irradiance measurements





- Develop an automated processing scheme for the derivation of lunar spectral irradiance measurements
- Archive the raw data
- Process the raw data into lunar spectral irradiance measurements
- Build a database of lunar spectral irradiance measurements

## Photometer DB: CÆLIS

UVa

- Network management tool
- Database archive for raw data
- Quality control in real-time
- Meta-data: site information, calibration coefficients, configuration parameters, interference filter response, etc.
- Digests ancillary data
- Data processing

### Alarms

Show: Valladoid | Ph | All | Roma | Photons | Hide Lab/box

Select date: 2016-08-16

IP#	2016-08-16 Tuesday	2016-08-15 Monday	2016-08-14 Sunday	2016-08-13 Saturday	2016-08-12 Friday	2016-08-11 Thursday
#18	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!
#382	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!	Valladoid calibration #Received 5 OK!
#412	Valladoid calibration #Received 6 OK!	Valladoid calibration #Received 6 OK!	Valladoid calibration #Received 6 OK!	Valladoid calibration #Received 6 OK!	Valladoid calibration #Received 6 OK!	Valladoid calibration #Received 6 OK!
#421	Valladoid master #Received 5 Status 3	Valladoid master #Received 5 OK!	Valladoid master #Received 5 OK!	Valladoid master #Received 5 OK!	Valladoid master #Received 5 OK!	Valladoid master #Received 5 OK!

### Data Viewer

Select ph: 18 | Site: Valladoid  
 Select date: 2016-08-16 | Irradiation type: calibration  
 Since: 2016-07-20 09:00:00 | Photometer type: standard model (SP3000)

Tab: Light | Light Variability | Alarms | Alarms | Phot (up) | Plans | Status | Rates | TCD | GROUP | Test Files

Date	Type	Description
2016-08-18 06:20:37	STA	OK Status
2016-08-18 06:20:39	SSK	SUNAS30KYV4 S4 Fibre measurement
2016-08-18 06:24:05	STA	OK Status
2016-08-18 06:24:05	SSK	SUNAS30KYV4 S4 Fibre measurement
2016-08-18 06:26:57	STA	OK Status
2016-08-18 06:26:57	SSK	SUNAS30KYV4 S4 Fibre measurement
2016-08-18 06:28:10	SSK	SUNAS30KYV4 S4 Fibre measurement
2016-08-18 06:32:54	STA	OK Status
2016-08-18 06:32:54	SSK	SUNAS30KYV4 S4 Fibre measurement
2016-08-18 06:38:38	STA	OK Status
2016-08-18 06:38:40	SSK	SUNAS30KYV4 S4 Fibre measurement
2016-08-18 06:45:28	STA	OK Status
2016-08-18 06:45:43	SSK	SUNAS30KYV4 S4 Fibre measurement

### Photometer Description

Head	Collimator	Robot	Control Box
T203-1005-030C	CL211-0543-096	CE318-M 0911-904	CE318NEBSS-6
CE318NEBSS-7	A2: M103-0155-0024	Z6: M103-2167-0024	1006129UA395

#### Filters

Filter 1	Filter 2	Filter 3
Nominal WL: 1.520 Manufacturer: SARR-POC Ref. Lot: 4709 - #00 Exact WL: 1.520	Nominal WL: 0.870 Manufacturer: SARR-POC Ref. Lot: 4709 - #04 Exact WL: 0.869	Nominal WL: 0.675 Manufacturer: SARR-POC Ref. Lot: 4709 - #07 Exact WL: 0.677
Download Filter Response	Download Filter Response	Download Filter Response
Filter 4	Filter 5	Filter 6
Nominal WL: 0.440 Manufacturer: SPECTROGN Ref. Lot: 13-795 - #563 Exact WL: 0.439	Nominal WL: 0.500 Manufacturer: SARR-POC Ref. Lot: 4709 - #00 Exact WL: 0.500	Nominal WL: 1.640 Manufacturer: SPECTR Ref. Lot: 4-5147 - #1044 Exact WL: 1.637
Download Filter Response	Download Filter Response	Download Filter Response

### Filter description

CE318-01 0074  
 Manufacturer: SARR-POC  
 Lot Number: 1210  
 Filter Number: 18  
 Nominal Wavelength: 1.520  
 Central Wavelength: 1.52100  
 Wavelength Unit: nm

Full width at half maximum: 0.0021463  
 Maximum Transmittance: 0.9999  
 Type: Transmittance: 0.9999  
 Coefficient M20: 12.020  
 Coefficient M10: 0.020461  
 Coefficient B & W: Sign: 0  
 Coefficient B & W: Sign: 0  
 All Data Generated: 12/08/2016  
 When Data Generated: 12/08/2016  
 Add Data Generated: 12/08/2016  
 Subst Data Generated: 0

2007 Oct 12 00:00:00 UT



- Define a strategy to derive the model regression coefficients (ROLO based) from the lunar measurements
- Derive regression coefficients from database of measurements
- Measurements uncertainty propagation in to the model parameters / regression coefficients

*From wikipedia*



- Lunar observations:
  - ✓ Proba-V (ESA mission operated by VITO)
  - ✓ PLEIADES (through an agreement with CNES)
  - ✓ GLOD: access requested via EUMETSAT
- Other lunar model(s):
  - ✓ GIRO: access requested via EUMETSAT

Thank you for you attention