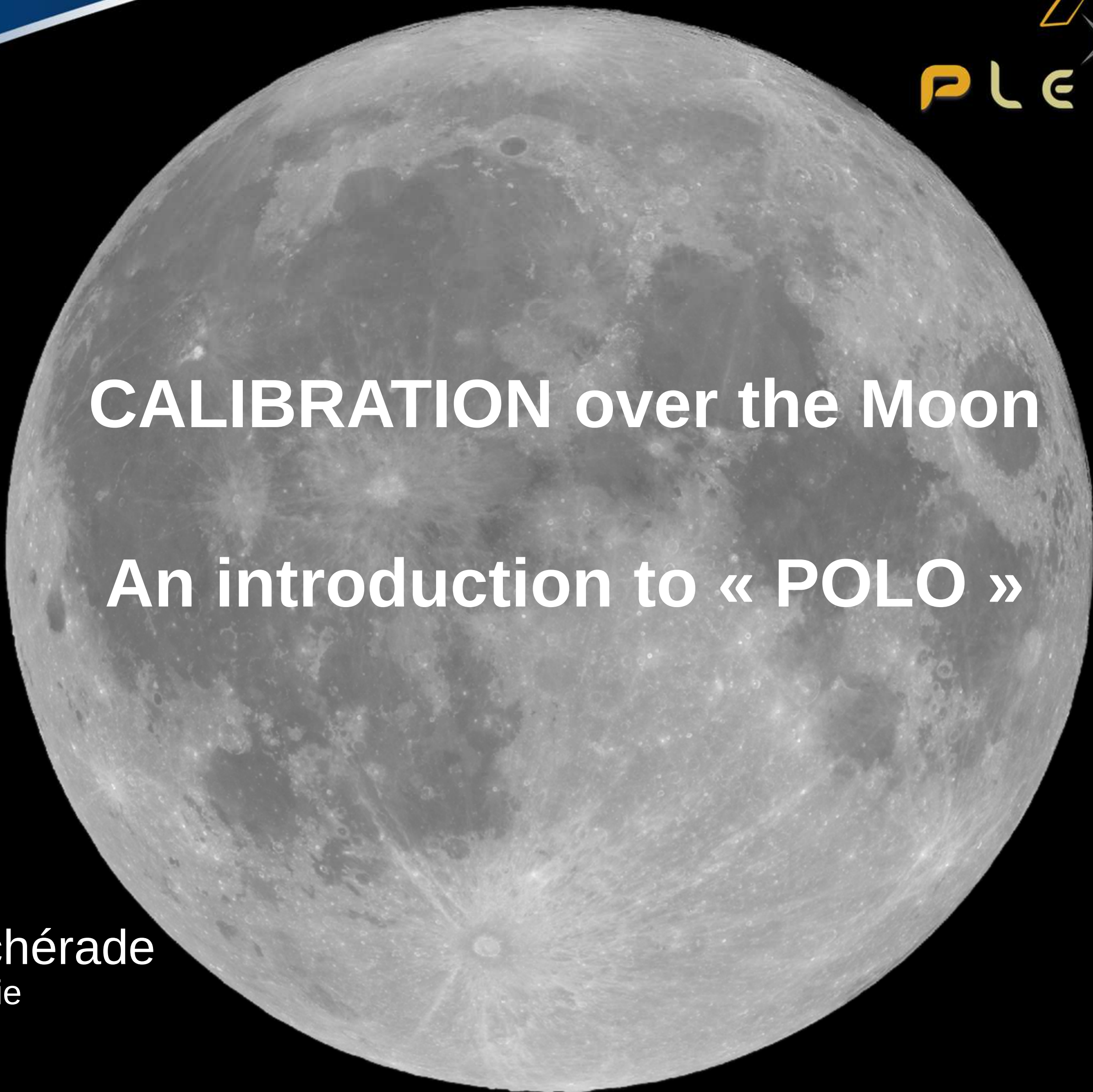
CALIBRATION over the Moon

An introduction to « POLO »



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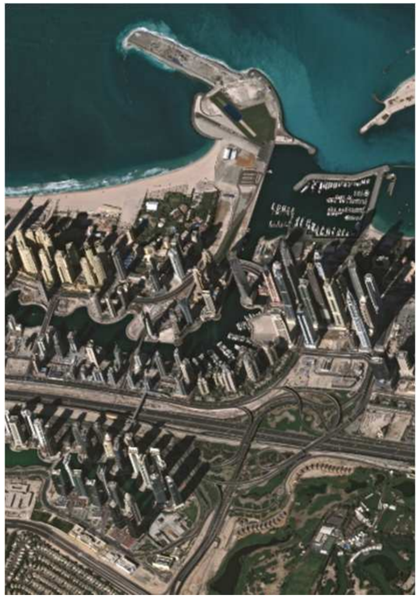
Introduction

- It has been demonstrated that the Moon is a very precious way to monitor in-orbit the radiometric drift of sensors
- Activity under development at CNES
  - Method implemented in the operational MUSCLE/SADE environment
  - Missions: PLEIADES, VENµS,…
- Starting of Pleiades 1A and 1B commissioning phases in Jan’12 and Jan’13
  - Strong ability to “catch” the moon
  - Intensive acquisitions have been performed (recom phase = 40)
    - » 1 moon every day during one lunar cycle
    - » various moon cycles
    - » several moons during the day : every orbit, 2 successively, several on the same orbit
    - » 1 moon simultaneously by PH1A and PH1B
- This defines the Pleiades Orbital Lunar Observations – “POLO”
  - Intensive in-orbit acquisitions in various conditions
  - Goals:
    - » to better understand the published ROLO model in its operational form
    - » to quantify the potential impact of the viewing and sun geometry, sampling and resampling
    - » to derive recommendations
    - » to contribute to improve the use of lunar acquisitions
    - » to develop sensors cross-calibration over the moon

Overview of PLEIADES HR mission & satellite

MISSION

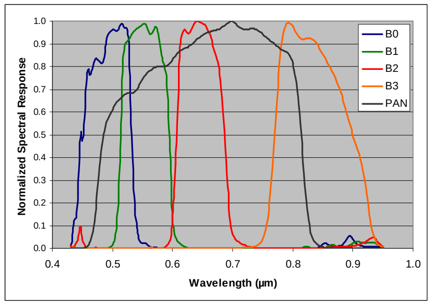


Dubaï from PHR1A ©CNES 2011

Spatial resolution

Panchromatic : 70 cm
XS (B, G, R, NIR): 2.80 m

Simultaneous PA + XS acquisition
Swath: 20 km

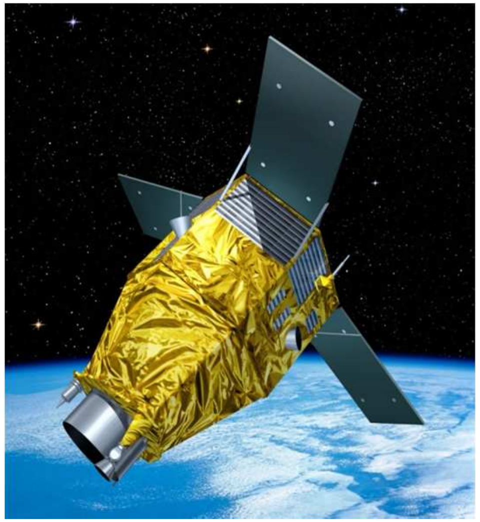


SATELLITE

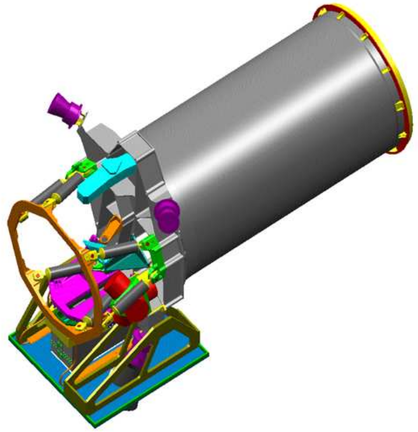
- Mass : < 1 T
- Power : Lithium-ion batteries
Rigid AsGa solar panels

- AOCS : Gyro actuators
Star sensors
Optical fiber gyros

- Image telemetry at 600 Mbps
- 600-Gbit mass memory



INSTRUMENT



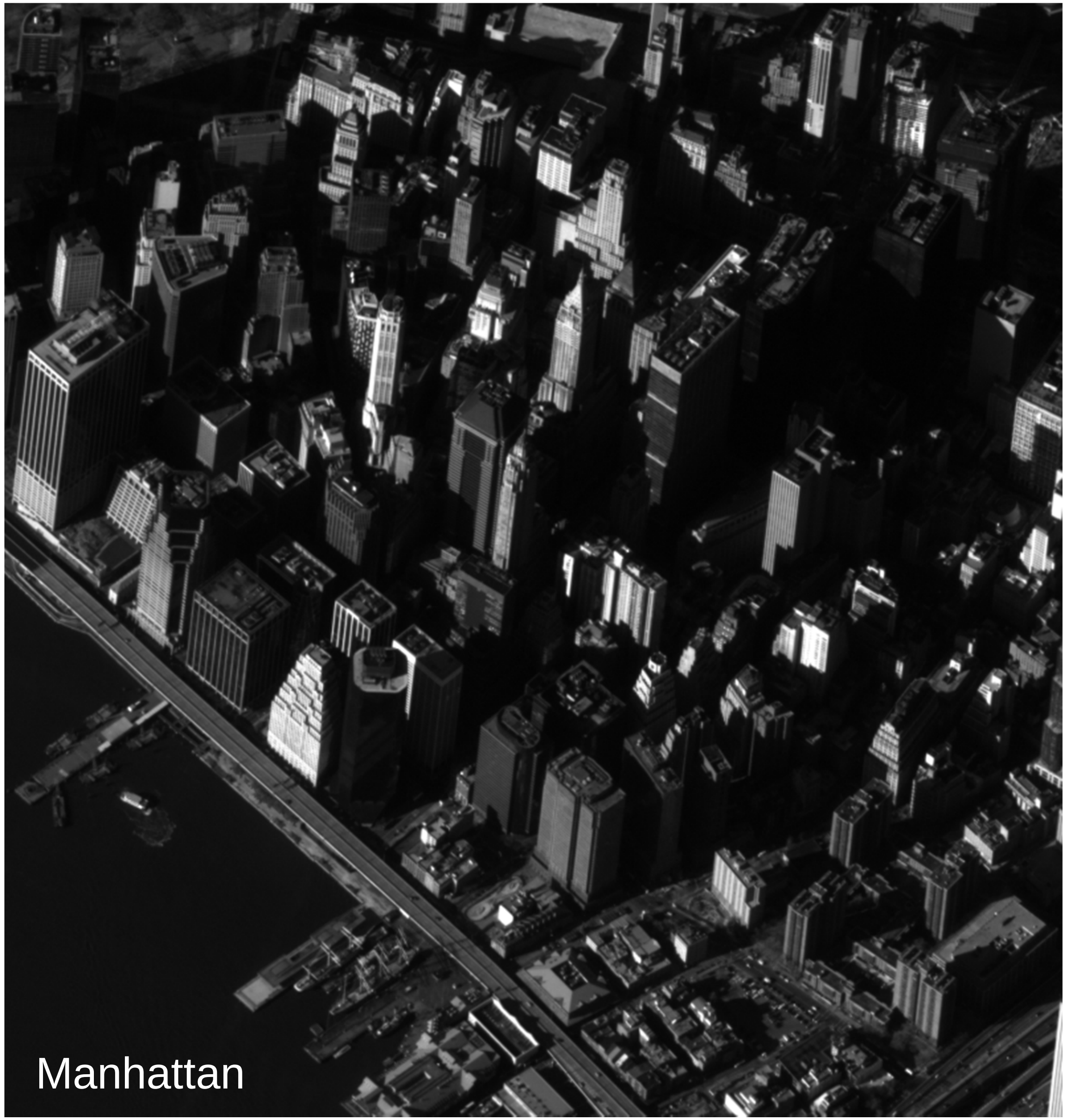
- Korsch camera
- Focal length 12.90m
- Diameter 0.65m

- PA retina : TDI detector
- XS retina : four color CCD

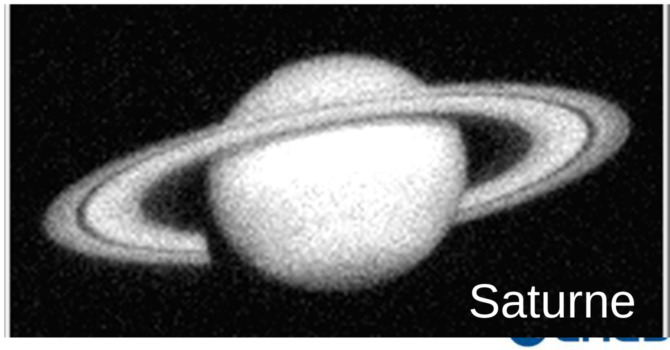
- 12 bit quantization
- On-board detectors normalization
- Wavelet compression:
  from 1.4 to 3.33 bits/pixel

PHR1A launch: December 17, 2011
PHR1B launch: December 2, 2012

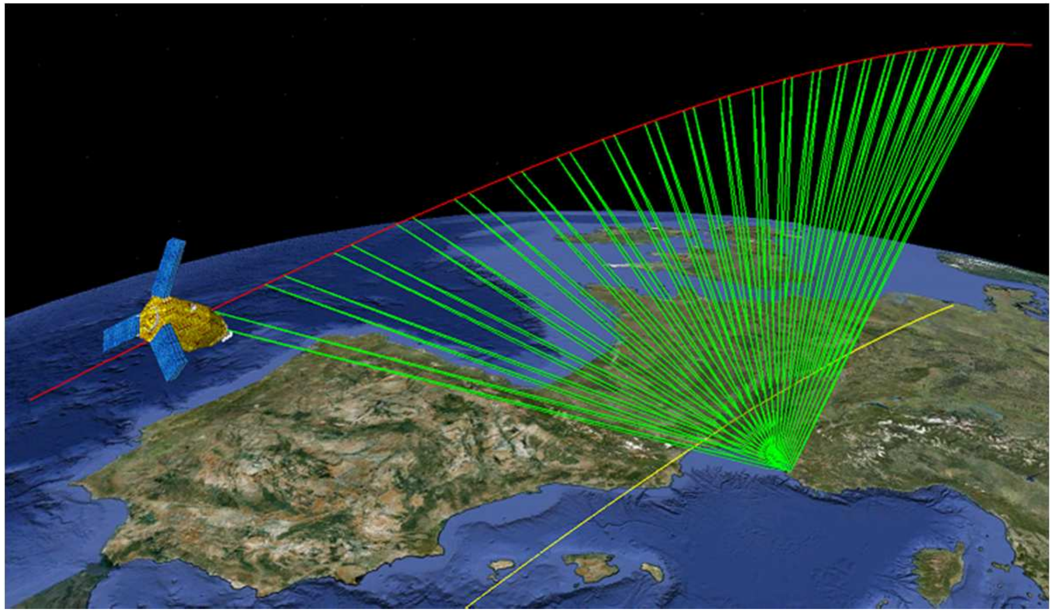
The PLEIADES system

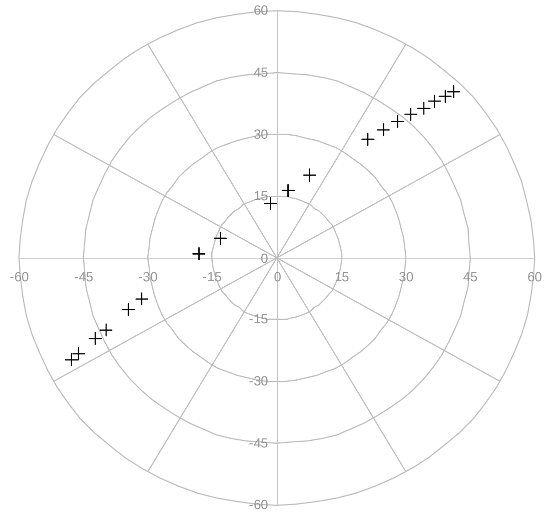


Satellites with a very high level of agility (60 in 25s) !



The PLEIADES system





Example of video over Melbourne (Australia)

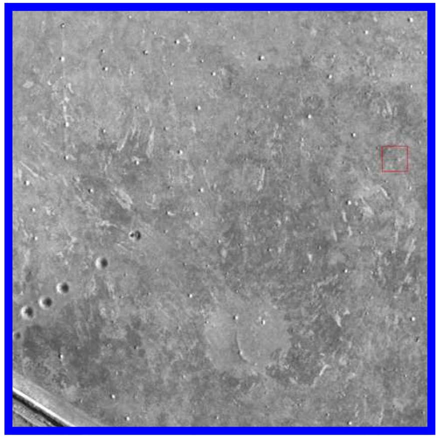
..\..\..\PLEIADES\PHR-1A\IMAGES\PHR_VIDEO\MELBOURNE\2600_8400.exe

The PLEIADES absolute calibration

Goal: radiometric absolute calibration better than 5%

Methods:

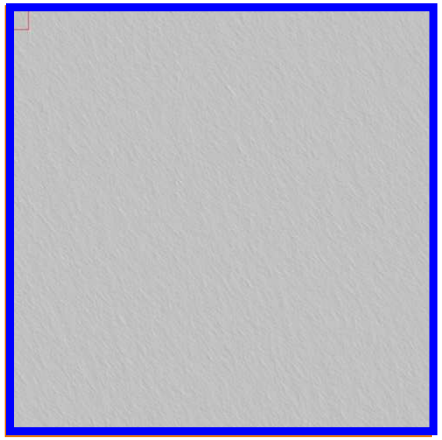
African Desert sites



La Crau

Moon

Oceans



Dome

Calibration over the moon

Lunar calibration is a multi-temporal calibration method

→ Based on ROLO *

Digital count of the instrument

→ Considering than the radio $I_{obs} = \dfrac{\sum_{i=1}^{N_p} L_i \cdot \Omega_i}{A_l(\alpha_l)} \cdot \left(\dfrac{D_{l-obs}}{384400}\right)^2 \left(\dfrac{D_{l-s}}{1AU}\right)^2$ is constant

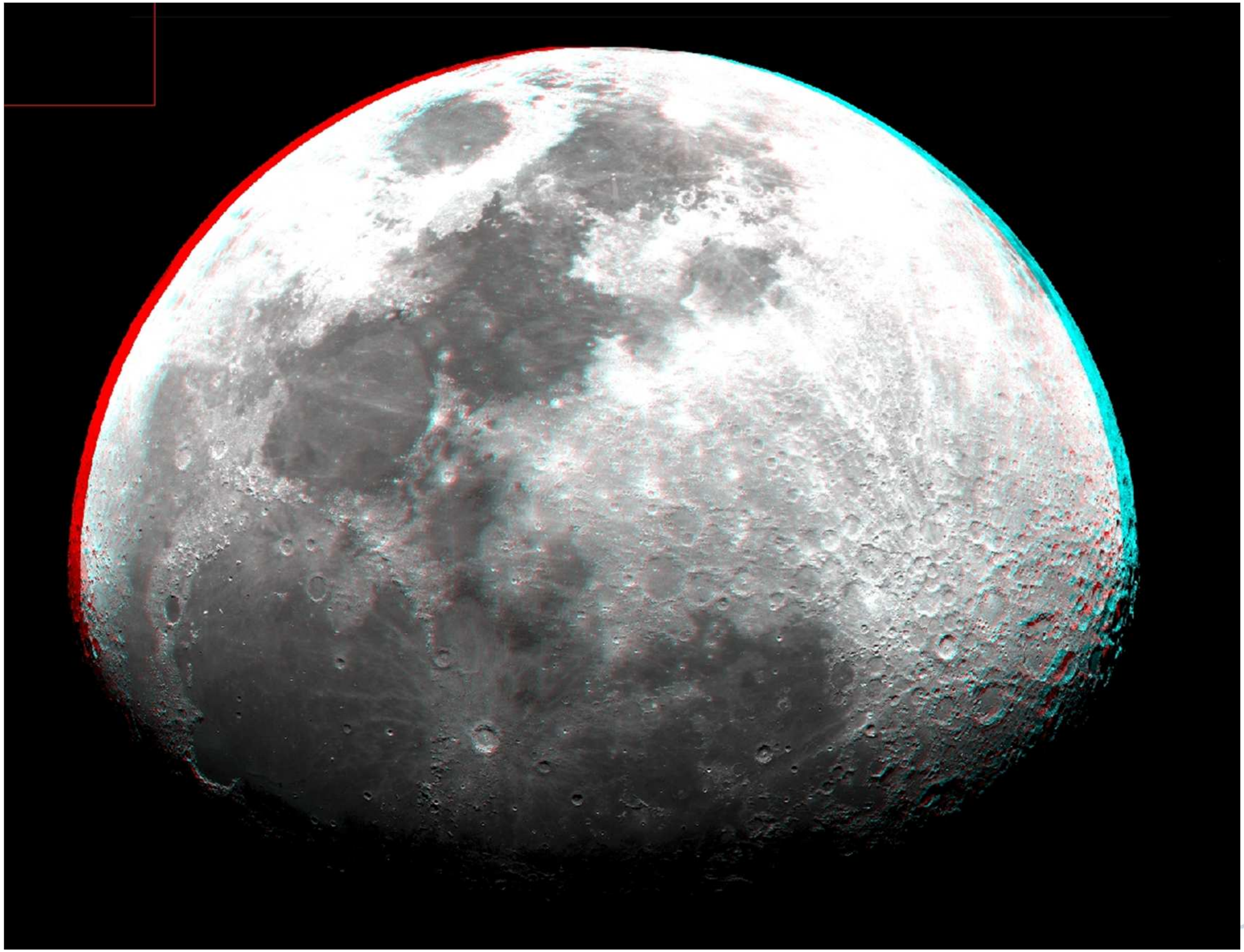
ROLO Albedo integrated in the PHR spectral bands

Normalization of the distances

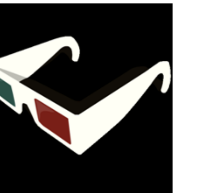
→ Regular acquisition of the moon – fixed phase of 40 every month
2 views per day to allow stereoscopic acquisitions

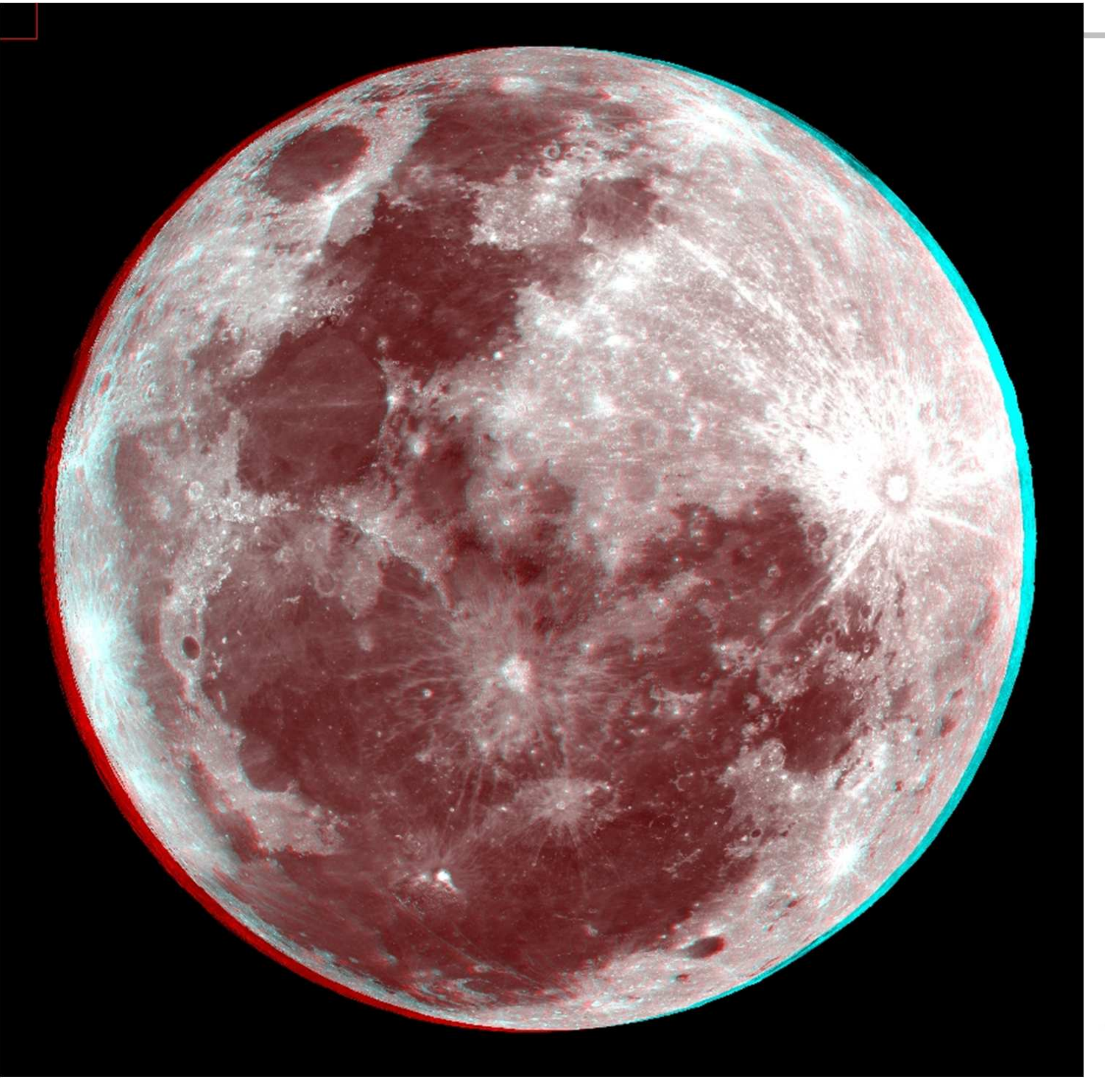
* H.H. Kieffer, T.C. Stone, R.A. Barnes, S. Bender, R.E. Eplee, J. Mendenhall, L. Ong
On-orbit radiometric calibration over time and between spacecraft using the moon
SPIE 4881, pp. 287-298, 2003.

Pleiades on the moon



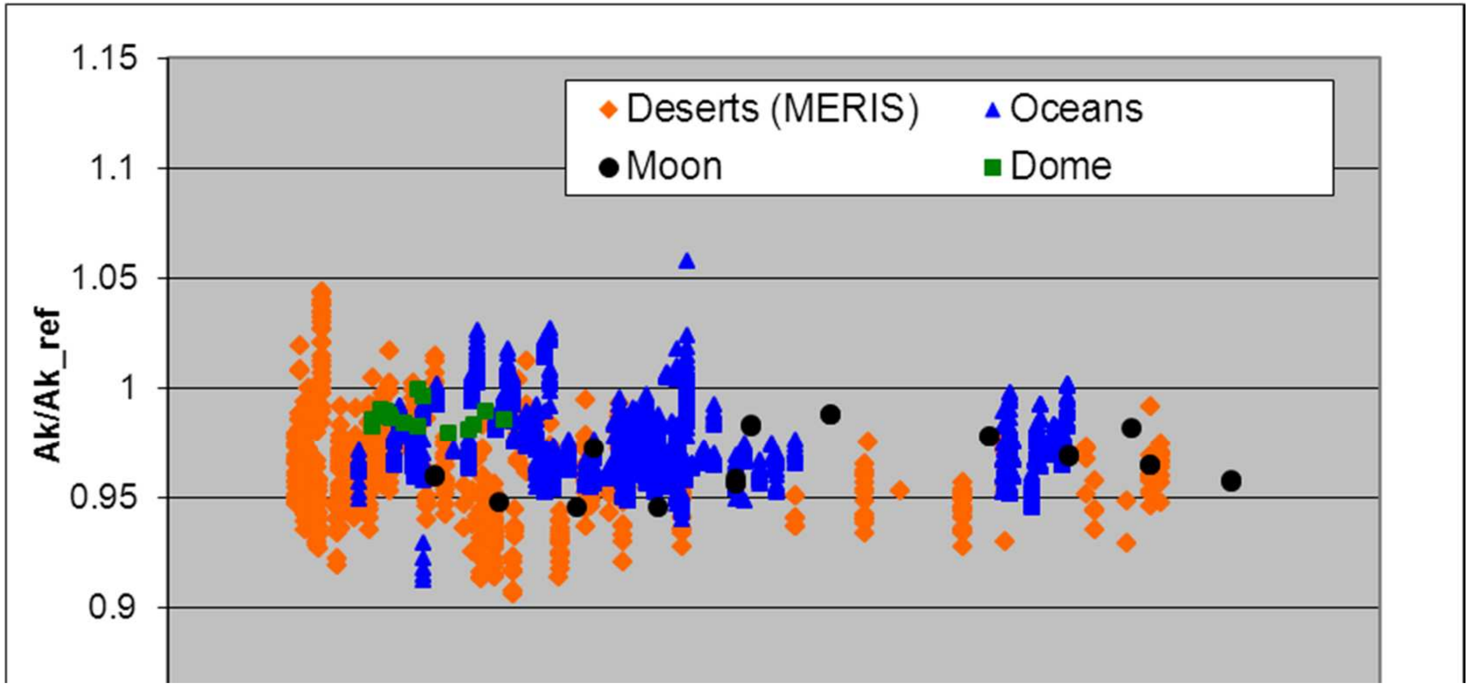
Pleiades on the moon





Focus on the LUNAR acquisitions

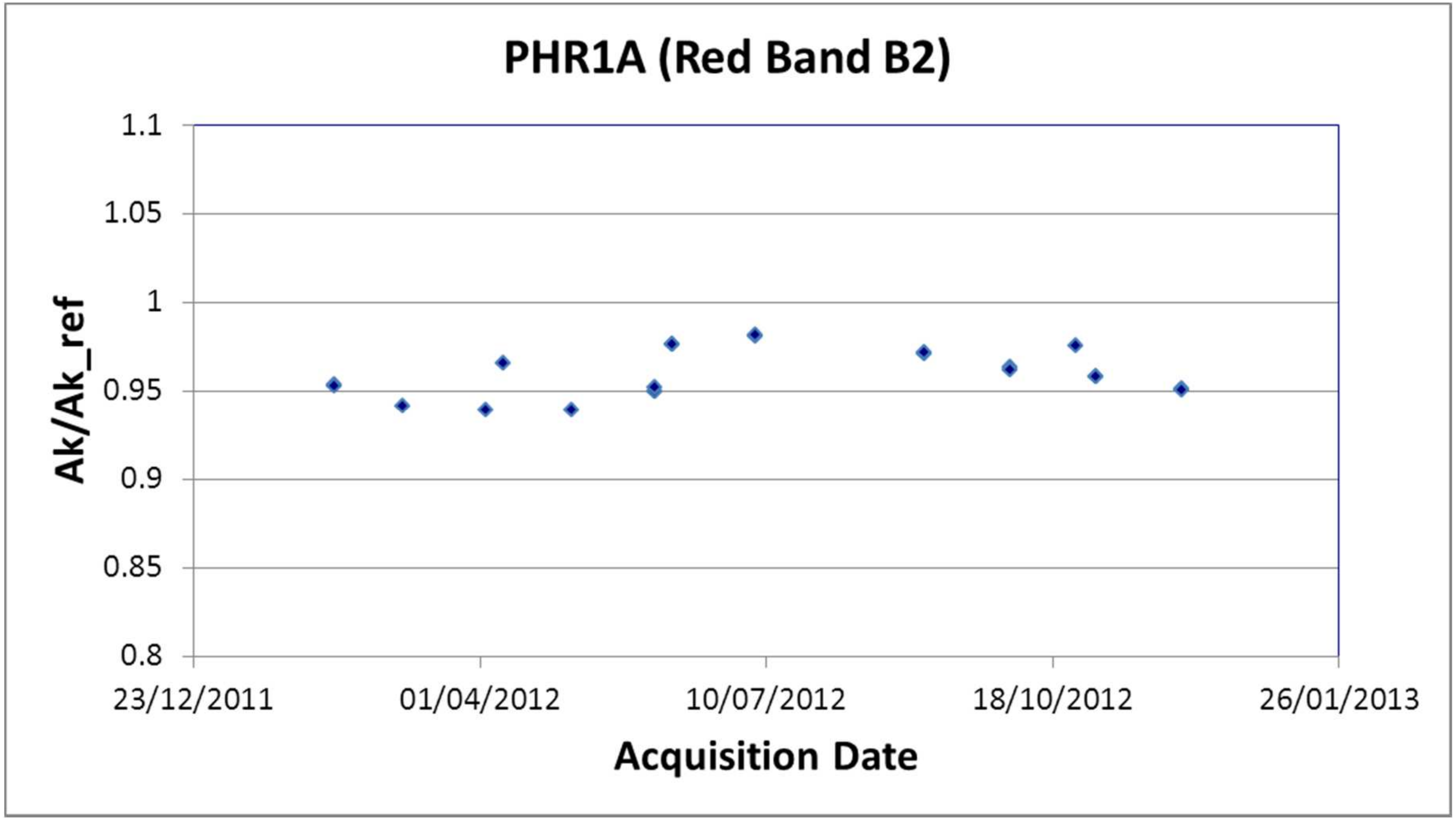
→ Multi-temporal calibration based on Moon with a phase of 40



- **Stability of the instrument since the Launch**
- **Consistency of the 3 methods for the temporal evolution of the sensor**

Calibration over the moon

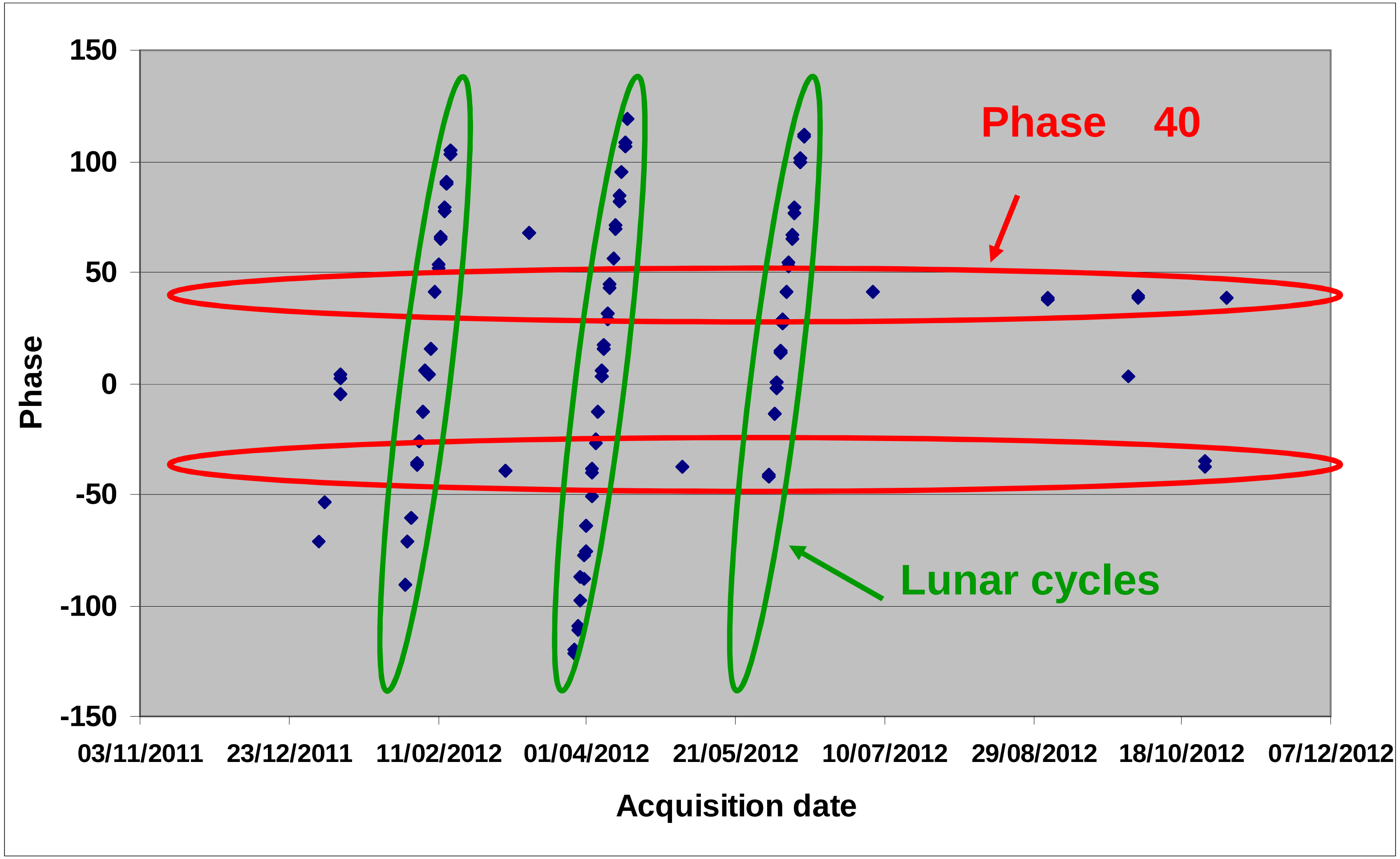
How to explain the dispersion of the lunar acquisitions (2%) ?



→ **Decision to extend the moon acquisitions to cover the entire Moon cycle (from -115 to 115) to better understand the method**

Calibration over the moon

⇒ 138 images acquired by PLEIADES1A since its launch (12/2011)



⇒ 150 images acquired by PLEIADES1B since its launch (12/2012)!

Calibration over the moon

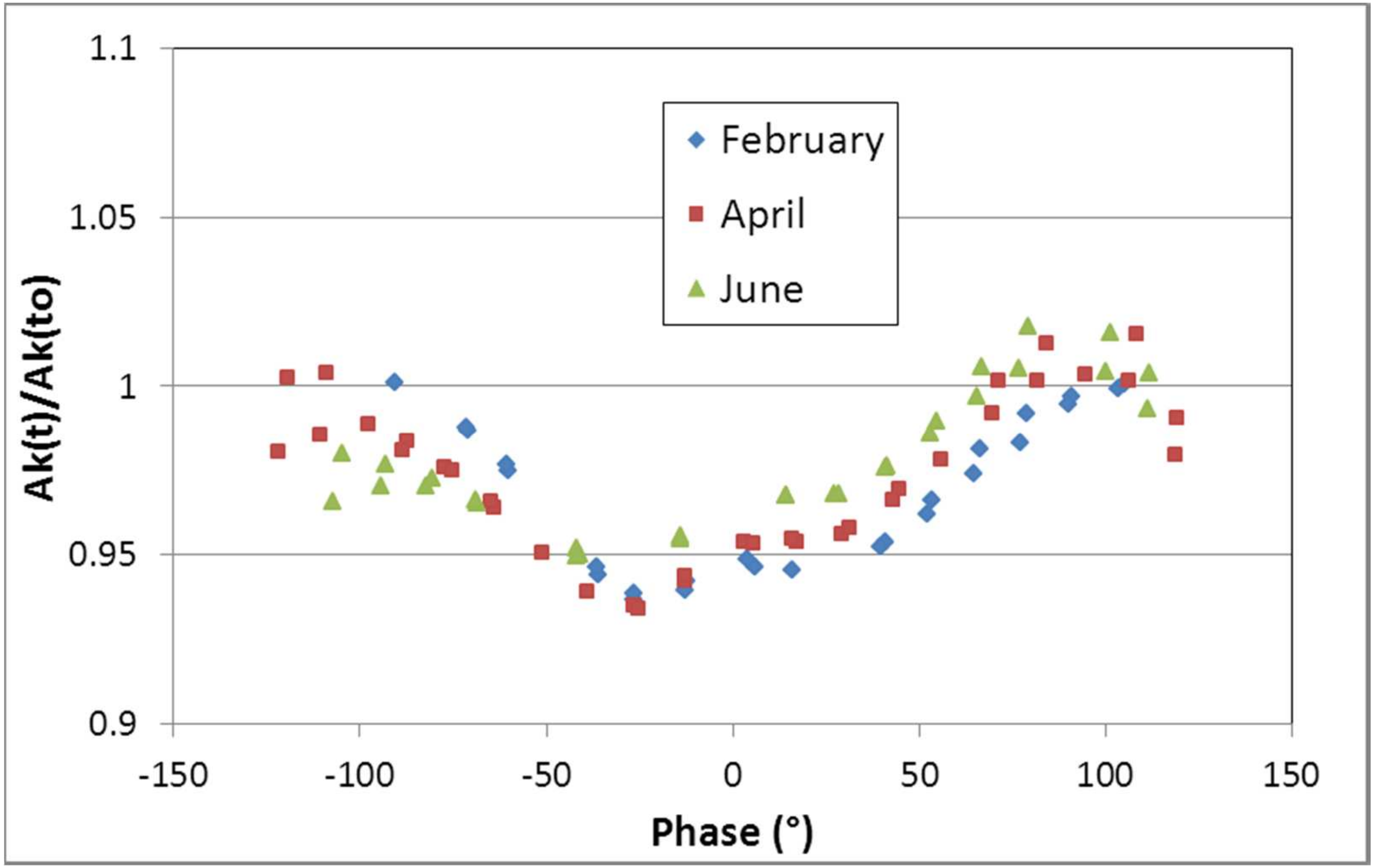
Focus on the LUNAR acquisitions

→ **Evolution of the moon with the phase**

Moon_PHR1A_April.exe

Calibration over the moon

Influence of the “phase” on the calibration results



⇒ **Sensitivity of the method with :**

- **conditions of acquisition**
- **the phase of the moon**

Conclusion

- Thanks to Pleiades satellites agility, and taking advantage of the commissioning phases, we performed intensive in-orbit moon acquisitions varying sun and viewing geometries

  → The “POLO” Pleiades Orbital Lunar Observations

- The analysis of this set of data is ongoing
  - To check the implemented ROLO model
  - To better understand the results sensitivity to the phase of the moon (residue modelization?)
  - To better analyze the impact of the viewing geometry on the calibration results (the yaw angle is not constraint)
  - To better consider the over/under-sampling impact regarding acquisition configuration
  - To demonstrate the moon interest for cross-calibration – tested for P1A and P1B : same date + same phase

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