The motivation

Earthshine is the sunlight reflected from Earth striking the Moon and observed as reflected light. The intensity of the earthshine is a measure of the short-wave reflectivity, or albedo, of Planet Earth, and is therefore especially an important quantity to measure in terms of the climate change debate.

Accurate, precise and long-duration observing campaigns of earthshine in these years of accelerating climate change can become vital independent records of the state of Earth, in decades to come.

Measurement of earthshine intensity faces all the problems of classical photometry: detection sensitivity is central — without it, the accuracy of the observations is at stake. Precision (i.e. scatter) is important too, but fortunately, modern instrumentation has reached the level that averaging data is sufficient to beat random error down enough that climate-change studies can be performed.

It is in the accuracy (lack of biases, and particularly, the absence of time-varying bias) that the core of the problem lies. In this work we explore the possibility that observing earthshine from outside the atmosphere, here with the University of Stuttgart Flying Laptop MICS camera, can be superior to traditional telescopic photometry from below the clouds and dynamically unstable atmospheric layer. One can imagine dedicated earthshine satellite instruments could be deployed to space, provided the benefits and drawbacks of satellite optical instrumentation are fully understood.

The problem

Earthshine is weak and has to be measured very close to a bright source of light — the sun-side of the Moon — so that catter shed light becomes a problem. Under the atmosphere, the light scattered from the bright side of the Moon reaches the earth-side, by the Mie scattering in the air, has to be removed at the data-reduction stage. Light is also scattered and diffused by optics — how strong is typical atmospheric scattering compared to optics-induced scattering? Understanding is the question of the present poster, and our main tool for answering it is to compare images of the Moon obtained through the atmosphere, with images obtained from space.

The satellite “Flying Laptop”, and its MICS camera

The Flying Laptop (FLP) is a satellite developed by graduate and undergraduate students at the Institute of Space Systems of the University of Stuttgart with support by space industry and research institutions. The satellite weighs about 110 kg and has a size of 60 × 70 × 87 cm³. The main objective of its mission is earth observation, technology demonstration and education. Therefore, different payloads are used: The main one is the Multispectral Imaging Camera System (MICS), which consists of three identical cameras with different filters (see Figure 1 and 3). Other payloads include a wide angle camera (FemCam) and an automatic identification system (AIS) receiver for observation of ships. The satellite was launched in July 2017 and is now used for earth observation and for student education ([1], [2]). All operations are performed from the control room at the Institute of Space Systems and have been highly automated. The satellite bus has proven to be reliable and performs well.

Each camera in the MICS system has its own CCD detector, and each camera has its own main multi-element objective and baffles (located inside the satellite). The MICS has the following specifications ([3], [4]):

- Objective is a 5.5/50 mm.
- Aperture diameter 90 mm
- Focal length 360 mm, F/4.0
- Image sensor is a Kodak KAI-1003M CCD interline sensor, implying a global shutter.
- 12-bit dynamic range
- Bias-framing has a regular pattern (see Figure 3).

There are three broad-band interference filters for 530 nm to 580 nm (Green), 620 nm to 670 nm (Red), and 720 nm to 870 nm (NIR), see Figure 3.

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