Observation of Lunar Impact Flashes with the SPOSH Camera: System Parameters and Expected Performance

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1. Introduction

Observations of meteors in the atmosphere of the Earth have a long historic tradition and brought up knowledge of meteoroid population and streams in near Earth space (amongst others). Only recently observations of meteoroid impacts on the dark side of the Moon became technically possible. Since the first confirmed Earth based observation of a lunar impact flash in 1999 [e.g. 2] more than 50 impact flashes have been registered [1]. Meteoroids bombarding the Moon are not slowed down by an atmosphere and impact with high velocities of up to 70 km/s, causing a light flash of about 10 to 100 ms duration. Continuous observations of the dark hemisphere of the Moon enable the possibility to improve data of the meteoroid population as well as to determine impact time and location which can be used for seismic analysis and interior structure determination. Therefore, it is important to study the various system parameters that determine the possibility of a successful lunar impact flash detection, which we have implemented by numeric simulations. In particular, we want to evaluate the performance of the camera head of the SPOSH camera system [3] attached to a telescope.

2. Influence of System Parameters

In order to determine the limiting magnitude of an observational system we simulate the background signal seen during the observation. It consists mainly of two types of radiation: lunar thermal radiation and the sunlight reflected from Earth to the Moon and back to Earth, called Earthshine. Each type of radiation is emitted with a characteristic intensity in a certain wavelength. As CCD chips differ in their quantum efficiency depending on radiation wavelength, we evaluate the amount of background electrons by simulating the two main signal spectra as black body radiation. The wavelengths of maximum intensity can be calculated by Wien's displacement law for temperatures of 150 K (lunar surface temperature) and 5778 K (solar surface temperature):

$$\lambda_{max} = 2897.8\,\mu m\,K / T \qquad (1)$$

resulting in 19,300 nm infrared radiation and 500 nm visible light peaks, respectively. Thus, as the SPOSH camera system is most sensitive to visible light, Earthshine is the dominant background signal for our system.

The amount of background radiation recorded by one pixel depends on the background emitting area. The area covered by one pixel depends on the instantaneous field of view (IFOV) that can be calculated as:

$$IFOV = 2 * arctan(d_{Pixel}/2\,f) \qquad (2)$$

with d_{Pixel} being the size of a pixel (13,6 µm for the SPOSH camera) and f is the focal length of the telescope. Greater focal length and smaller pixel size result in a smaller IFOV, hence, in a smaller surface area covered by one detection unit and less background radiation. In this way, instrumental set-up influences the limiting magnitude for lunar impact flash detection. However, smaller IFOV results in a smaller coverage on the lunar surface and therefore in a lower probability of detecting lunar impacts.

Another important characteristic of the observational system is the integration time of the camera electronics and CCD. Fastest observations are done by systems with frame rates of up to 60 halfframes per second [e.g. 4]. Slower systems would collect more background signal instead of impact flashes and, thus, suffer from reduced signal-to-noise ratios. Binning of CCD's can increase frame rates on cost of resolution, but increases also the lunar surface per detection unit by the binning factor and thus compensates the lower integration times (see equations 2 and 3).

In contrast, changes in telescope aperture have an effect on the signal-to-noise ratio. A larger aperture directly increases the amount of collected photons per detection unit. The Poisson-distributed noise increases by the square root of the increased signal. Thus, doubling the diameter will approximately double the signal-to-noise ratio (3).

$$\frac{S}{N} \cong \frac{Flash\ (aperture)}{\sqrt{Flash(aperture) + Earthshine(t, IFOV, aperture)}} \quad (3)$$

3. Observational System

We are planning further observations with the SPOSH camera head at the Liebenhof observatory near Berlin. Two telescopes from the observatory and their specifications are shown in Fig. 1. Both allow complete coverage of the dark hemisphere of the Moon. Although the TEC Refractor has a smaller aperture, the system could be less sensitive to light reflections due to its conception as refractor and thus might suffer less from losses in signal-to-noise ratio due to reflections from the bright lunar hemisphere. In contrast, the Baker Ritchey Chrétien has a larger aperture and due to the larger focal length covers less lunar surface per pixel, resulting in reduced Earthshine background and better signal-to-noise ratio.

Fig. 1: Telescopes mounted at Liebenhof Observatory: TEC 140 Apo Refractor (left, 140 mm aperture, 980 mm focal length, 0,81° field of view) and Baker Ritchey Chrétien (right, 250 mm aperture, 1268 mm focal length, 0,62° field of view).

4. Summary

Evaluating all observational system parameters is important for understanding measurements of lunar impact flashes and background noise. Impact flash measurements will shed light on the properties of the impacting objects for studies of the origin of the meteoroid population and for assessments of collision hazards. Successful observations rely on improving the signal-to-noise ratio and balancing of lunar impact probability which depends on the system limiting magnitude as well as lunar surface coverage.

At the conference, we will present further parameters of our observational system and will discuss its performance for flash detections.

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