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Future Concepts for Impact Flash Observing

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Abstract

With Earth-based impact flash detection becoming more common place, enhancements to existing observing techniques are discussed that could improve impact flash light curve sensitivity, time resolution, measure the impact fireball temperature, and extend observing opportunities to the dayside of the Moon. The possibility of searching for impact events, from spacecraft orbiting around the Moon, planets, or indeed from the surface, are also considered.

1. Introduction

Impact events on the Moon have been actively searched for since the 1940's, but the first confirmed impact flashes were videoed confirmed by a team of amateur astronomers during the 1999 Leonid meteor shower [1]. Since 2005 NASA's MSFC has catalogued nearly 300 impact flashes using two or more telescopes [2]. Other research groups involved with impact flash detection are in Spain [3], Japan [3], France [3], and Germany [6]. Amateur astronomers continue to attempt to video impact flashes through IOTA, ALPO, and GLR [1].

Most observations of impact flashes have been made with broad band photometric filters, or in white light, utilizing low light level CCTV cameras, such as the Watec 902H [1], with PAL/NTSC image resolutions, with TV field rates of 1/50th/1/160th sec, and a flash magnitude limit of ~11 under ideal conditions. However this is affected greatly by scattered light within our atmosphere and telescope optics, especially as the lunar phase increases, and has limited observing to < 60% lunar phases. The brightest impact flash recorded so far was of 5th magnitude, and the longest duration flash was 1.4 seconds, although most are about 0.1 seconds or less [2,7]. One area of potential concern is how atmospheric seeing and scintillation may affect the light curve and colour of impact flashes, and this does not feature much in publications, although in an analogous technique of high speed occultation photometry it is a well known issue [8].

Impact flashes are highly desirable to observe because, during meteor showers of known velocity, the observed flashes can provide information on the luminous efficiency of the impacts, and help to characterize the impact process, They can also assist in determining cratering flux rates beyond the era of the Apollo seismometers [9], and provide target locations for future missions to search for fresh non-space weathered metre scale impact craters. However issues remain, such as how to improve sensitivity and time resolution. Little work has been done on attempting to measure the temperature of the flashes or capturing a flash spectrum, and so far all observations have been confined to the night side of the Moon. Lastly, could the Earth-based techniques be applied to spacecraft in orbit around the Moon and other planets?

2. Improving Sensitivity

The key this improvement is to increase the amount of simultaneous observation of a flash, beyond the typical 2-3 telescopes that are used at present. The more simultaneous light curves that can be obtained, the greater the ability to identify and eliminate atmospheric turbulence effects [8] from flash light curves. The averaging of light curves together, weighted according to atmospheric turbulence effects, would improve the photometric resolution of the build-up of the impact flash and subsequent decay.

3. Improving Time Resolution

Higher frame rate cameras are expensive, balky, and have yet to be tested for impact flash sensitivity. Two low cost alternatives are available: 1) A vibrating glass plate could be placed into the optical path – this would refract the light from any part of the an impact flash (and the lunar surface), around a locus. So if the locus path was a circle of 100 pixels circumference, and the TV field rate was 50 fps then the time resolution of the flash over 1 pixel of length would be 1/5000th second. The high time resolution would be at a cost though because the flash exposure would be reduced, but the background earthshine exposure would remain 1/50th sec. 2) If several observers used CCTV exposures set say 1/10th of the field rate, then we would end up with several sub-sampled light curves, with large gaps between each time sample. By fitting these to each other, in brightness, but offsetting them in time, it should be possible to reconstruct a higher time resolution light curve.

4. Improving Spectral Sensitivity

Impact flash fireballs emit black body radiation; therefore by measuring dual waveband brightness, the temperature as a function of time can be determined. Alternatively the same information could be derived using a single camera with a very low resolution diffraction grating placed over the CCD window, as well as the detection of any spectral emission lines. Figure 1, although not of an impact flash, demonstrates the technique, although in practice a much lower spectral dispersion grating would have to be used to avoid spreading photons from already weak impact flashes over too many pixels, and flashes would need to be at least 6th magnitude or brighter to be detected.

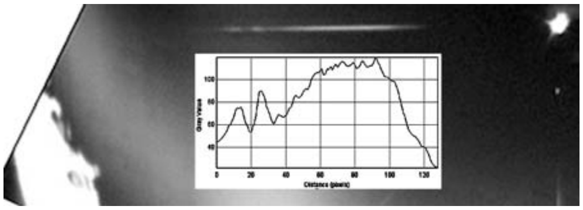

Figure 1. Absorption bands from an uncalibrated flash spectra produced from an aircraft strobe light, in chance alignment with earthshine, from a telescope equipped with a diffraction grating placed over the CCD camera window.

5. Dayside Impact Events

Although the mean surface brightness of the Full Moon is +3.2 mag/arcsec^2, if we assume that we can measure a brightness changes as small as 10% of the background, then the faintest flash that could be detected would be m_v=+5.8. At a 50% phase Moon, the mean surface brightness would permit flashes as faint as m_v = +7.8 to be captured. The practicalities of dayside monitoring would be optimized by imaging in the near IR (the black body radiation peaks here), at an image scale equivalent to the atmospheric seeing disk, targeting lower intensity terminator region, and concentrating on featureless dark mare areas, masking out edges of surface features which might cause false detection triggers from atmospheric turbulence. This approach would at least permit the study of impacts from meteor showers when they do not happen to strike conveniently the earthshine region, albeit with a lower detection rate due to a smaller field of view, and less sensitivity.

6. Spacecraft-Based Observing

A lunar orbiter at an altitude of 100 km, equipped with a 120° field of view camera would expect to detect 9 impact flashes of magnitude 6, or brighter, per hour of operation [6]. This is a significant increase of detection over Earth-based observations [7]. The idea has been used in at least a couple of lunar spacecraft proposals [6,10]. However the power and data storage requirements for running 1, or even 2 (to help discriminate impact flashes from cosmic rays), CCTV continuously over the night side of a planet would be untenable. Instead, a single camera could be used with a lower frame rate and longer exposures, to avoid a high power drain and excessive data accumulation. A low resolution diffraction grating placed over the CCD would eliminate false cosmic ray detections, and provide spectral information about the flash. The disadvantage of a long exposure though would be a loss of positional information of a flash along the ground track. Therefore it is proposed that an on-board radio monitor experiment is run, looking for radio spikes that maybe associated with impacts [11]. The spacecraft ephemeris time of the radio spike could then be used in conjunction with spacecraft and camera SPICE data to determine the most likely location of the impact, in the image, on the planetary surface.

An alternative method would to be to compare thermal imagery of the night side of the Moon, with imagery taken under the same lunar phase looking for differences that could be attributed to the thermal decay from heat from the impact site. The thermal imagery on a particular orbit should overlap so that the same area of the Moon is imaged at least twice, so as to help eliminate cosmic ray detections. Thermal impact detection has been demonstrated successfully during Deep Impact [12] and LCROSS [13].

6. Discussion

The adaptation of a wide angle spacecraft camera for planetary night side impact flash detection would just require the placement of a low resolution diffraction grating into a filter wheel, and adequate power and storage requirements to take long exposure images at night. A similar adaptation could be used for landers/rovers to look for impact flashes from micrometeorites at the surface. Observing impact events is a versatile way to study the meteoroid population local to a planet, and to compare impact rates with any concurrent seismic data. It can also be used to assess safety risks to astronauts from the ejecta. Once fresh impact sites are located, the resulting craters could be explored by future surface missions to analyze recently non-space weathered excavated material.

References

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