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Lunar impact flashes: estimation of their temperatures.

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Abstract

Here we present the calculation of the temperatures of the impact flashes detected on the lunar surface. This is done for the first time since the beginning of the lunar obervations, thanks to an ESA-funded project. We believe that these observations in combination with on-going hypervelocity impact experiments will lead to a better understanding of the collissional processes.

1. Lunar Impact flashes

Almost 20 years ago the lunar surface started to be monitored with small telescopes for the detection of collisions by recording the produced light [1]. The initial purpose was to understand the flux of impactors on Earth. Since the Earth's atmosphere is a great interference and the sky monitoring systems for bolides did not have so large detection area, the lunar surface provides an extended area for numerous detections. The estimation of the flux of near Earth Objects (NEOs) is important not only for the prevention of human civilisation (meter-sized, see Chelyabinsk event in 2013) but also for the protection of the space assets (cm-sized objects). Apart from the NEO flux per se, the lunar surface becomes a *large-scale impact laboratory*, considering both the impactor sizes and speeds compared to the indoor laboratory hypervelocity experiments [2] where the sizes of impactors are typically a few mm and the speeds below 10 km/s.

Impact flash data are valuable for several other purposes [3].

- Find the coordinates on the lunar surface that the flash occured and earch for the crater afterwards.
- Calculate the luminous efficiency of a flash.
- Estimate the mass of the NEO, when a safe assumption of the impact speed can be made. This can be more safelly done from flashes caused by a meteor stream, where the impact speed can be better constained.

2. Observations

The European Space Agency (ESA) is directing and funding lunar observations at Kryoneri in Peloponnese, Greece [4]. The facilities that belong to the National Observatory of Athens, were recently upgraded. An 1.2 m telescope is equiped with two identical Andor Zyla sCMOS cameras. A dichroic beam-splitter directs the light on to the two cameras, that observe in visible and inrfared wavelengths using R_c and I_c Cousin filters respectively. Currently it is the largest telescope in the world that performs dedicated observations, surveying lunar impact flashes. The novelty of this instrumentation setup is that it aquaires data from two detectors simultaneously. In that way there is no need anymore of using two different telescopes to perform sychronous observations, in order to reject the false detections (e.g.cosmic rays).

Observations are scheduled and performed each month when the Moon is in favorable phase. Data are stored and callibrated immediately after the end of the observations. Each night standard stars at similar airmass are also observed in both filters. This procedure is executed by the specialised NELIOTA pipeline that was developed for this particular type of observations.

After obtainining the lunar data and the raw data of the standard stars we used our own routines for data reduction and photometry deriving the fluxes for the flash and standard stars. Our analysis is primarily focused on the calculation of the flash temperatures for a first time using data from big scale impacts via telescopic observations.

3. Temperature Estimations

To begin with, because the first data obtained come from sporadic objects we focused on the flash temperature, T_f calculation. This is now possible for a first time after the beginning of the lunar observations, since obervations are performed in two wavelengths. Although an impact flash is not a product of the same physics laws as the luminocity of a star, we will work on our analysis by assuming a black body behaviour. By using the fluxes of the standard star in both wavelengths we can callibrate the fluxes of the flash and solving the Planck equation derive the T_f.

4. Implications

Generally, when a collision occurs there is a partitioning of the kinetic energy of the impactor. However there are a numerous parameters that play a role on that and thus we are still not fully aware of this procedure. So far scientists had to use as flash temperatures values from literature that were usually obtained from laboratory experiments. Now we can have a better understaning, especially when the T_f is coupled with mass and speed estimation of the impactor. In addition, the observations are done with high time resolution (30 fps) and this enables us to detect any "anomalies" in the flash light-curve tail (and also evolution of the temperature) during the cooling phase of the hot plasma in the ejecta. This will help to get insight and try to assign this phenomenon to a natural cause, e.g. either to secondary impacts by the ejecta or to the changes of the opacity of the ejecta plum. Finally from this work we can have a first idea, in large scales, how the mass and/or speed of the colliding body affects the flash duration and the difference we detect in visible and infrared wavelengths. Complementary hypervelocity impact experiments are designed by us in order to mimic the observations.

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