Luminous Efficiency of Hypervelocity Meteoroid Impacts on the Moon
Derived from the 2006 Geminids, 2007 Lyrids, and 2008 Taurids

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Abstract
Since early 2006 the Meteoroid Environment Office (MEO) at NASA Marshall Space Flight Center has been consistently monitoring the Moon for impact flashes produced by meteoroids striking the lunar surface. During this time, several events have been observed at multiple sites, including the 2006 Geminids, 2007 Lyrids, and 2008 Taurids. These flashes are similar to those observed in 1999-2000 by Bolte, Rubielo, Loza, and Boffelli (2006). The luminous efficiency and energy of the lunar impactors can be calculated from these data.

Introduction
When a meteoroid impacts the Moon, a large portion of the impact energy is converted into heat and plasma production. A small fraction goes into generating visible light, which results in a brilliant flash at the point of impact that can be seen from Earth. The luminous efficiency (\(\eta\)) of how much of the meteoroid’s kinetic energy (\(K\)) is converted into luminous energy (\(L\)) in a particular wavelength range (\(\lambda\)) is given by:

\[ L(\lambda) = \eta K(\lambda), \]

The luminous efficiency plays a vital role in understanding observations and constraining models. Experiments into lunar regolith simulate a low-velocity (<10 km/s) have been performed at hypervelocity gun test ranges in order to determine \(\eta\) (Swift et al., 2008), but high-velocity meteoroid experiments are impossible to replicate in the laboratory. Since the properties of showers are unknown better than that of space meteoroids, observations of lunar impact flashes can assist in estimating \(\eta\) at high velocities.

The MEO has conducted observations of the 2006-2008 mm wavelength range during the 2006 Geminids, 2007 Lyrids, and 2008 Taurids. Multiple impact flashes were detected, allowing for a luminous efficiency analysis that produced Bolte Rubielo et al. (2006) in the 1999-2000. It is estimated from a comparison of the total number of events observed to be a factor depending on the shower’s spatial density and distribution in size. Using the derived luminous efficiency and velocity, the mass of the impactors is estimated.

Setup
Observing Facilities
- Automated Lunar and Meteorite Observatory (ALMOTO) in Huntsville, Alabama (52° N, 86° W)
- Walker County Observatory (WCO) near Chickamauga, Georgia (34° N, 85° W), -125 km away

Telescopes
- 20 cm, 2.5 m, and 4.0 m telescopes
- One 1-D 5-20% diameter Ritchey-Chrétien telescope

Data Reduction
- With focal reducer, 20 frames per second, interlaced; FWHM = 400-800 nm
- Derived from the 2006 Geminids, 2007 Lyrids, and 2008 Taurids

Observations

<table>
<thead>
<tr>
<th>Date</th>
<th>Shower</th>
<th>Telescopes</th>
<th>Obs Timespan (UT)</th>
<th>Obs Time (hr)</th>
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<tbody>
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<td>04/22/07</td>
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</tr>
</tbody>
</table>

Summary
- The luminous energy at the Moon is related to the energy released at Earth (\(L\)) and \(E\) is the impact energy (in mm range for the 1999-2000 Lyrids). Results are shown in Table 2.

References
- Bolte, Rubielo, Loza, and Boffelli (2006)
- Swift, Suggs, and Bolte (2008)
- Rubio et al. (2000)