Time-resolved Emission Characteristics of Hypervelocity Impact Generated Flash

Meteoroids and orbital debris, collectively referred to as hypervelocity impactors, travel between 7 and 70 km/s in free space. Upon their impact onto the spacecraft, the energy conversion from kinetic to ionization/vaporization occurs within a very brief timescale and results in a small and dense expanding plasma with a very strong optical flash alongside. This plasma can produce radio frequency (RF) emission that could potentially lead to electrical anomalies within the spacecraft. Additionally, space weather, such as solar activity and background plasma, can set up spacecraft conditions that can amplify the damages done by these impacts.

In this presentation, we will present the optical data from our recent hypervelocity impact (HVI) experiment at the 3 MV electrostatic dust accelerator at the Colorado Center for Lunar Dust and Atmospheric Studies (CCLDAS). The facility is capable of accelerating micron or sub-micron charged particle to various velocities from 5 km/s to 100 km/s, which resemble the impact condition in free space. The optical sensor suite consists of three photomultiplier tubes (PMT) with three different interference color filters, i.e. 450 nm, 550nm, and 600 nm. Using the three-color PMT setup, we are able to achieve a time-resolved emission spectroscopy on the impact-generated flash. The spectroscopic data have revealed a near continuum emission spectrum. By blackbody radiation approximation, we can estimate the impact generated gas cloud/plasma temperature via Plank's formula. However, the spectrum experiences a less blackbody like emission spectrum in certain part of the time window. An optical model is thus derived to explain the time dependent behavior of the emission spectrum by considering all possible emission and absorption effects in the impact generated plasma, i.e. free-free emission, free-bond emission, line radiation, Pseudocontinum effects. This project will facilitate the understanding of hypervelocity impact generated plasma by connecting the impact generated flash with the plasma properties, i.e. temperature. Additionally, the optical method provides a less intrusive detection when compared to traditional plasma sensors, which might distort the electromagnetic fields around the plasma, used in previous experiments.