Optical Flash Expansion Geometry in Hypervelocity Impact Events

INVESTIGATION OF IMPACT FLASH POLARIZATION EFFECT

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Source: NASA, Near Earth Impact.

Source: CNN

D = 10 km


D = 3 mm to 10 cm
Fine grain sand 0.0161 g @ 4.65 km/s
impacting a differentially charged target ~ ± 145V
Hypervelocity Impact Phenomenon

Radiation Mechanisms in Plasma

Problem Overview

Science Question
How do the meteoroids and debris connect to the impact flash?

Optical Impact Flash
Measured optical spectrum

Plasma Parameters
Temperature, Density, Mobility...

Impactor Characteristics
Mass, Velocity, Composition
Multi-Physics Sensor Suite

- All Wavelength Photodiode Tube (PD)
- Transient Plasma Analyzer (TPA)
- Retarding Potential Analyzer (RPA)
- Color Filtered Photomultiplier Tubes (PMT)
- Radio Frequency (RF) Patch Antennas

Sensor Suite Front View
Impact Flash Spatial Measurement

**All Wavelength Photodiode**

- Raw
- Smoothed

**Spatial PMTs**

- Intensity, V
- Time, s

- 17 μs
- 34 μs
- 51 μs
AVGR Optical Expansion Polarization

Plasma Sensor

Grounded Target

Negatively Biased [ -50V ]

Floating Target

Positively Biased [ +50V ]

RF Sensors

Grounded Target

Negatively Biased [ -50V ]

Floating Target

Positively Biased [ +50V ]
CCLDAS Dust Accelerator Impact Flash

Geometry

LEFT
CENTER
RIGHT

Target

\[ \frac{\text{E}_{\text{ext}}}{\text{Ratio}} \]

Right/Center

Positive Bias

Left/Center

Negative Bias

Left/Right

\[ \text{Time, } \mu^s \]

\[ \text{Intensity} \]

\[ 15.42 \text{ fg @ } 25.92 \text{ km/s} \]

Eext

Geometry
Summary

• Potential **Polarization effect** observed in impact events at both dust accelerator and light gas gun facilities

• Impact Plasma Flash can be used as a diagnostic tool for hypervelocity impactors in space
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The Society of Taiwan Women in Science and Technology

Stanford Graduate Fellowship
Ongoing Work: Temperature Measurement

- All Wavelength Photodiode
  - Intensity, V
  - Time, s
  - Raw
  - Smoothed

- Continuum Temperature
  - Temperature, K
  - Time, s
  - ×10^{-5}

- PMT Signal
  - Intensity, V
  - Time, s
  - ×10^{-5}
Hypervelocity Impact Plasma Proposed Model

(a) Impact
(b) Plasma formation
(c) Initial expansion
(d) RF emission

Hypervelocity Impact Facilities

Different Bias Types

- **Negative Bias**
- **Positive Bias**
- **Grounded Bias**

Graphs showing the ratio over time for different bias types with legends R/C, L/C, and L/R.
Measured Emission Radiation Evolution

Optical Signal Intensity

Time

Continuum Dominant → Continuum Weaken → Line (Spectral) Dominant
Hypervelocity Impact Radiation Model

- Non-ideal / Collisional
- LTE
- Optically thick
- Ideal / Collisionless
- LTE breakdown
- Optically thin
Optical Sensor Setup for AVGR
NGDC Database

- NGDC database
  - NOAA Anomaly database for US satellites in MEO and GEO orbits
  - ~ 5000 satellite anomalies 1972 – 1992
  - Gives local time at impact, solar longitude etc.
  - Gives orbit type but not orbital parameters

<table>
<thead>
<tr>
<th>Anomaly Diagnosis</th>
<th>Count</th>
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<tbody>
<tr>
<td>Electron Caused EM Pulse (Deep Dielectric Charging)</td>
<td>490</td>
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<tr>
<td>Electrostatic Discharge (Surface Charging)</td>
<td>1072</td>
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<tr>
<td>Single Event Upset</td>
<td>822</td>
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<td>Radio Frequency Interference</td>
<td>8</td>
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<tr>
<td>Unknown</td>
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AVGR : Floating Target
AVGR : Floating Target
Biased to Negative 50 V
Grounded Target
Positively Biased