COE CST Eleventh Annual Technical Meeting

Task 186: Space Environment MMOD Modeling and Prediction

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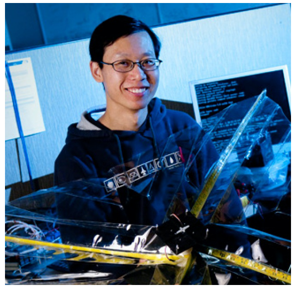
Center of Excellence for Commercial Space Transportation

Agenda

- Team Members
- Task Description
- Goals
- Methodology
- Results
- Conclusions and Future Work

Team Members

- **PI: Sigrid Close**
- **Research Staff: Nicolas Lee**

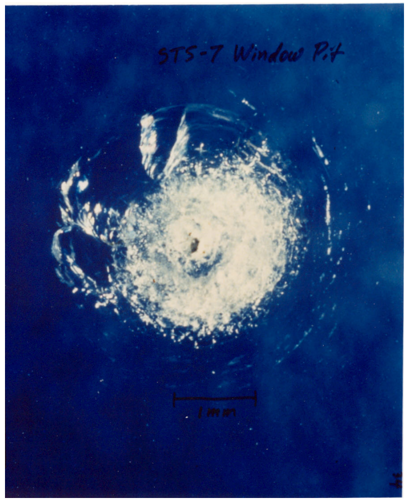

- **Graduate Students**
  - Alan Li (now at NASA Ames)
  - Diana Juarez (now at Raytheon)
  - Lorenzo Limonta (now at End-to-End Analytics)
  - Glenn Sugar (now at JHU Applied Physics Lab)

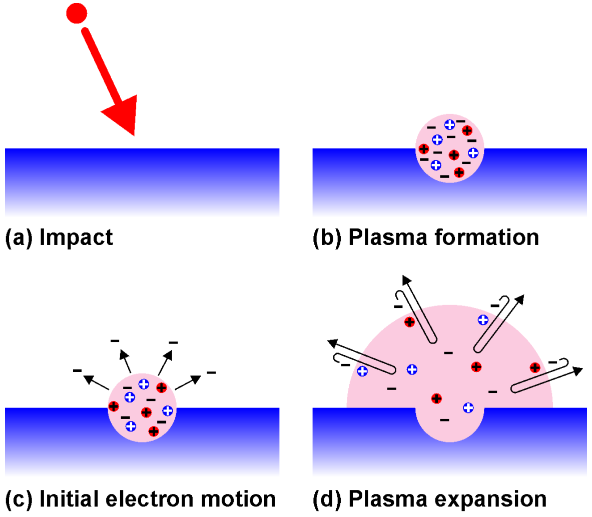


- **Collaborators**
  - University of Western Ontario
  - NASA Marshall Space Flight Center

Task Description

- **Spacecraft are routinely impacted by meteoroids and orbital debris (MOD)**
  - Mechanical damage: “well-known”, larger (> 120 microns), rare
  - Electrical damage: “unknown”, smaller/fast, more numerous

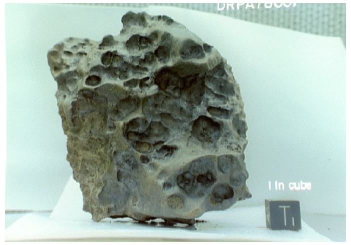




- **Growing need to characterize MOD down to smaller sizes and provide predictive threat assessment**

Meteoroids and Orbital Debris

- **Meteoroids**
  - **Speeds**
    - 11 to 72.8 km/s (interplanetary)
    - 30-60 km/s (average)
  - **Densities**
    - ≤1 g/cm^3 (icy) or > 1 g/cm^3 (rocky/stony)
  - **Sizes**
    - < 0.3 m (meteoroid)
    - < 62 μm (dust)



- **Orbital debris**
  - **Speeds in LEO**
    - < 12 km/s
    - 7-10 km/s (average)
  - **Densities**
    - > 2 g/cm^3
  - **Sizes**
    - < 10 cm (small)

Goals

- Particle impacts in atmosphere: probability of impact
- Particle impacts on spacecraft: effects of impact

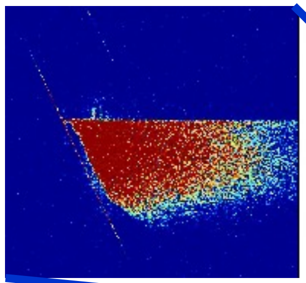
Threat Characterization

Spacecraft Specifications

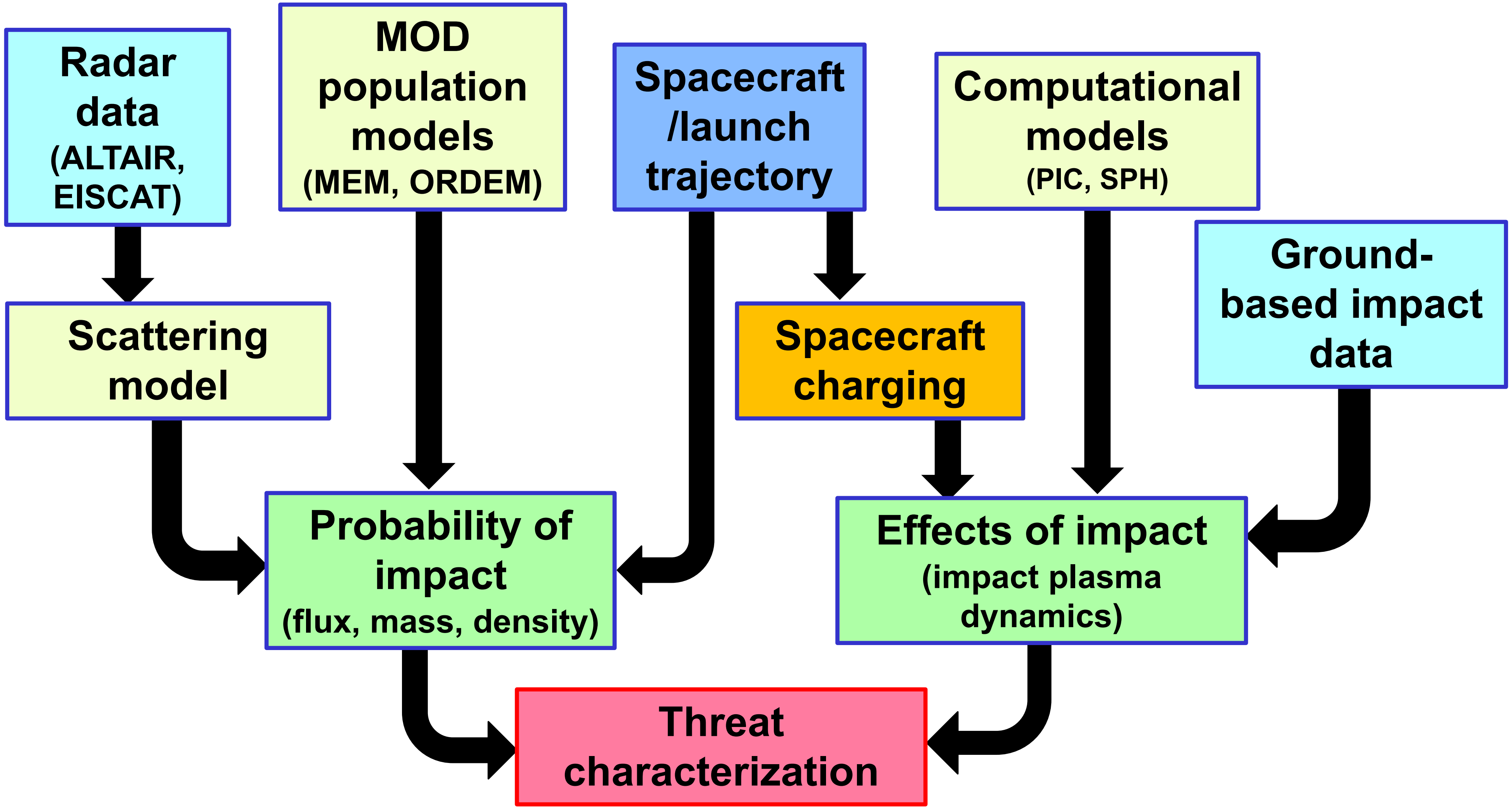
Flux
Mass
Velocity

+

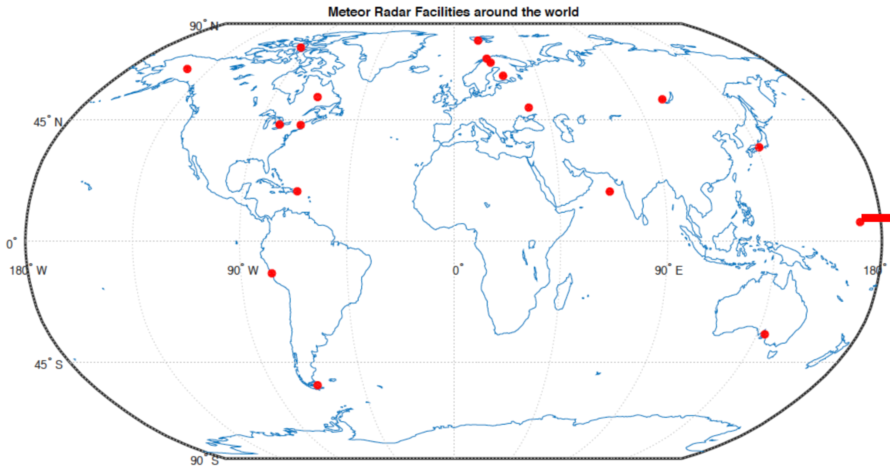
Plasma
Optical emission
RF emission

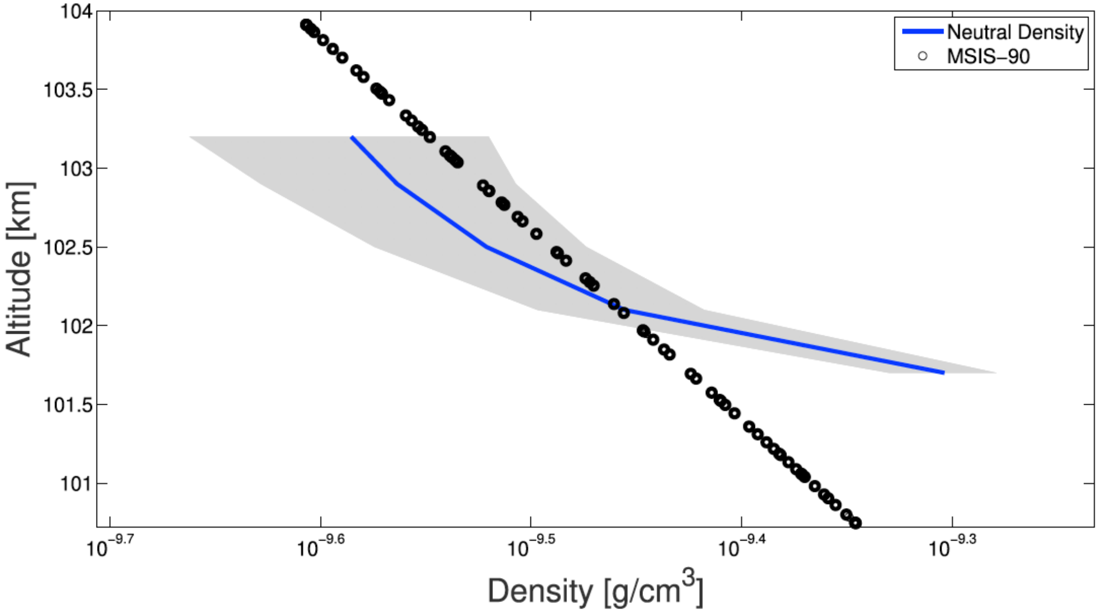


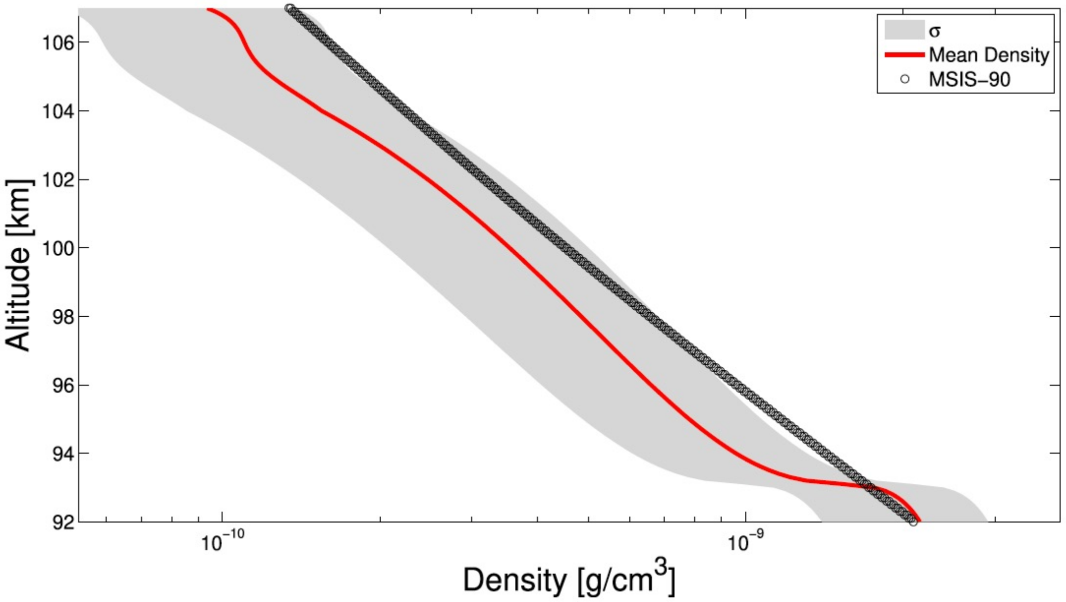
Methodology



Results: Neutral Densities



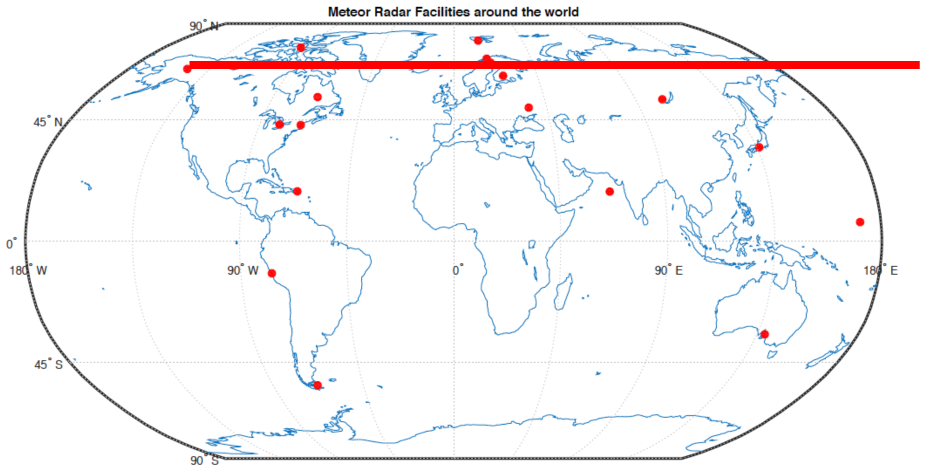


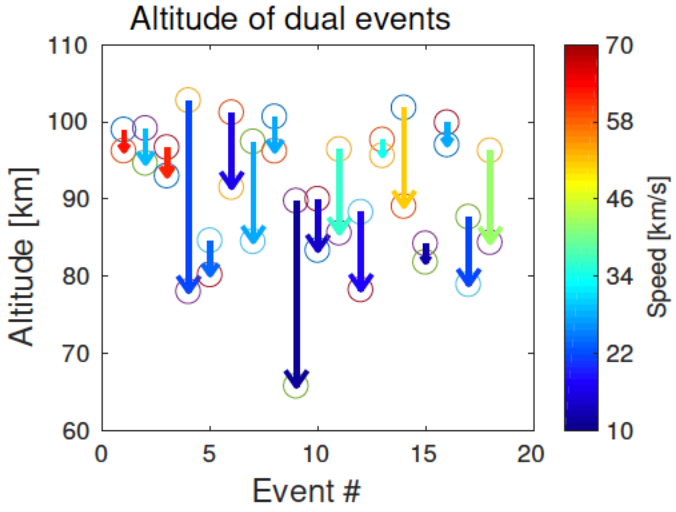


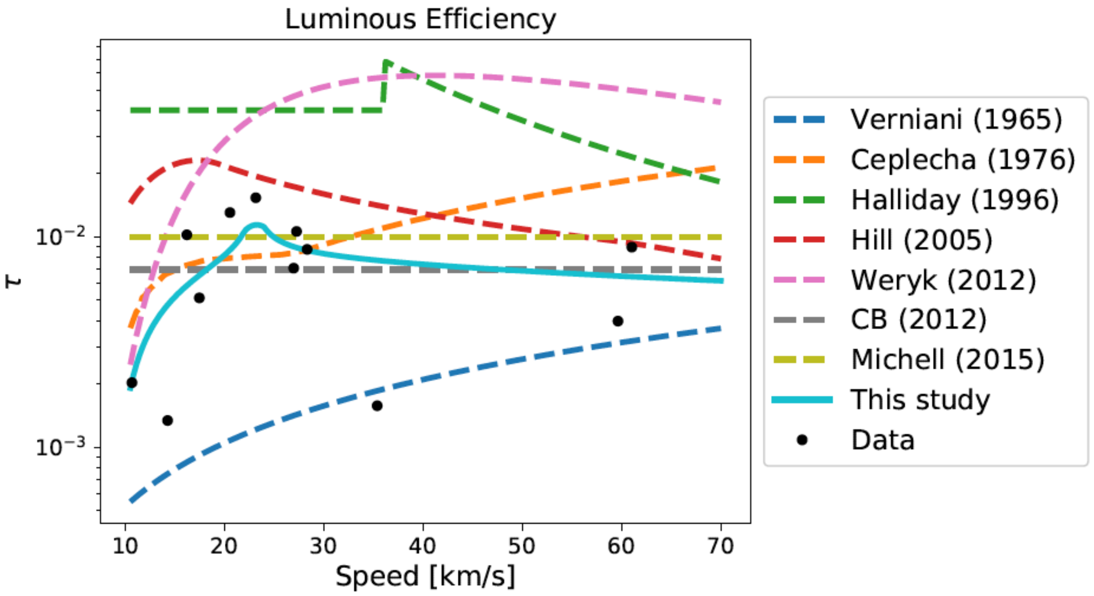
Results: Ionization and Luminous Efficiency

$$\frac{dm_m}{dt} = \frac{\mu q v}{\beta}$$

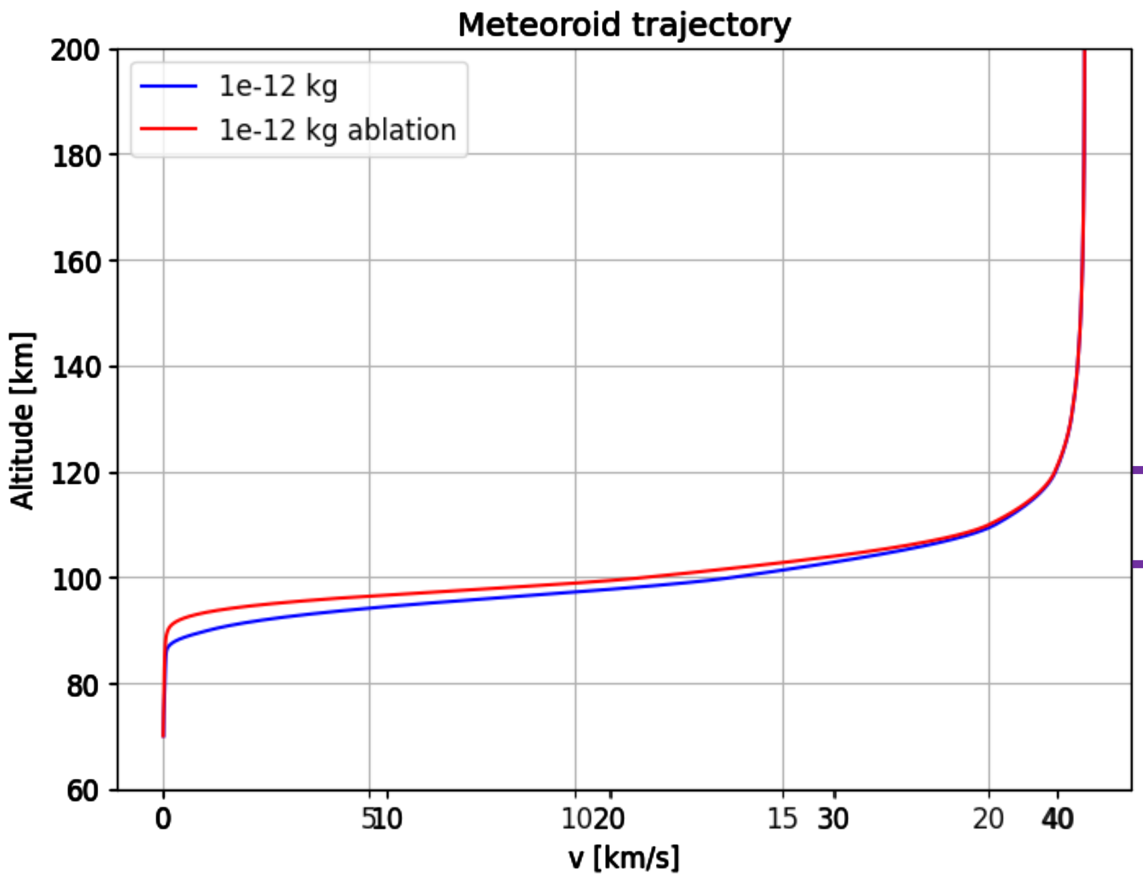
$$I = \frac{\tau}{2}\frac{d(m_m v^2)}{dt}$$

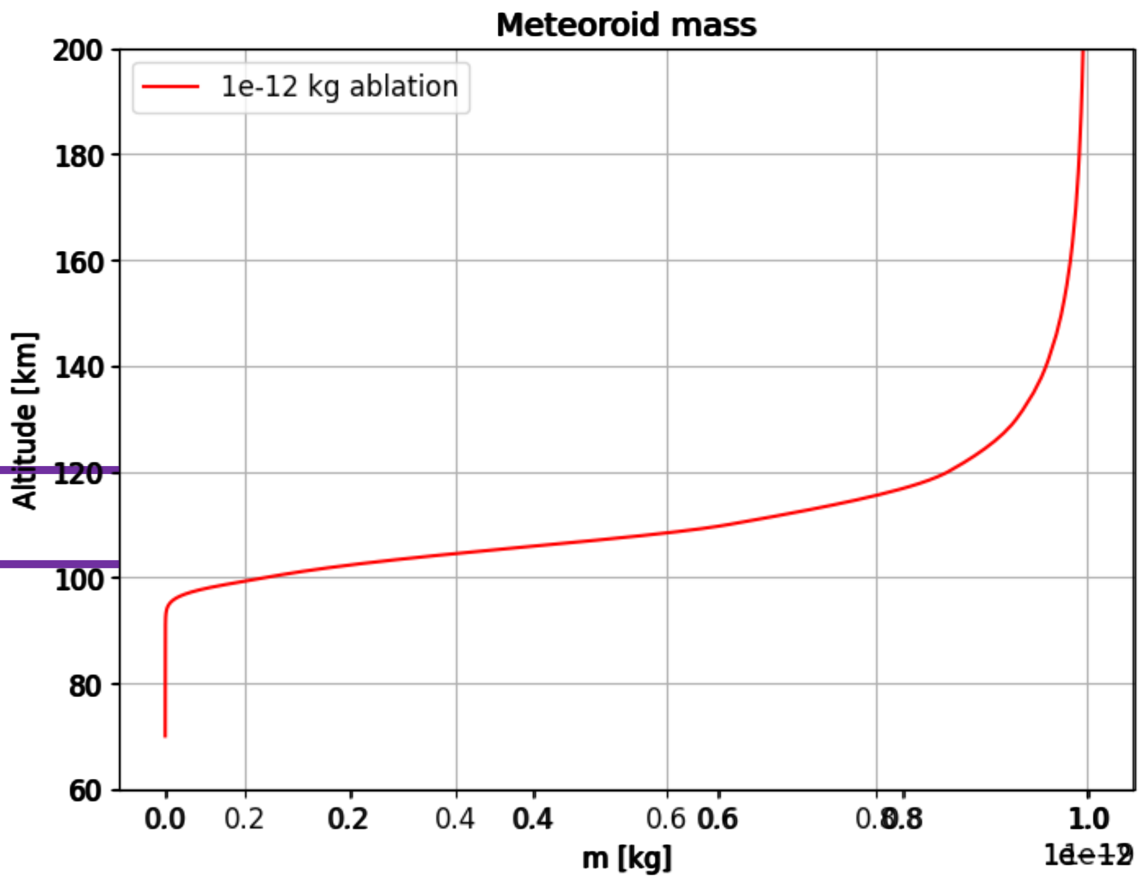






Results: Meteoroid Ablation





Recent Publications and Presentations

PUBLICATIONS

Sugar, G., M. M. Oppenheim, Y. S. Dimant and S. Close (2018), "Formation of plasma Around a small meteoroid: Simulation and theory", JGR Space Physics, Vol. 123(5), pp. 4080–4093, https://doi.org/10.1002/2018JA025265.

Sugar, G., M. M. Oppenheim, Y. S. Dimant and S. Close (2019), "Formation of plasma around a small meteoroid: Electrostatic simulations", JGR Space Physics, Vol. 124(5), pp. 3810–3826, https://doi.org/10.1029/2018JA026434.

Limonta, L., Close, S., and Marshall, R.A. (2020), A technique for inferring lower thermospheric neutral density from meteoroid ablation, Planetary and Space Science, Vol. 180, 104735, https://doi.org/10.1016/j.pss.2019.104735.

Limonta, L. (2018), "Experimentation and Simulation of Meteoroid Ablation", Ph.D. Thesis, Stanford University, purl.stanford.edu/wh601yb5230.

Sugar, G. (2019), "Meteoroid Mass from Head Echoes Using Particle-in-cell and Finite-difference Time-domain Simulations", PhD. Thesis, Stanford University, purl.stanford.edu/nz604gp3764.

PRESENTATIONS

Lee, N. and S. Close (2021), Effect of upper thermosphere flight on meteoroid ablation and deceleration prior to radar detection, AGU Fall Meeting, 13–17 Dec.

Lee, N., Hedges, T., and S. Close (2020), Estimating neutral density of the thermosphere from meteor trajectories, Abstract SA002-08, AGU Fall Meeting, 1–17 Dec.

Close, S. and Lee, N. (2020), Atmospheric neutral density dynamics through meteor observations, Science Highlight, CEDAR Workshop, online, June.

Lee, N. and Close, S. (2019), Neutral density measurement from simultaneous radar observation of meteors, Abstract SA43C-3218, AGU Fall Meeting, San Francisco, CA, 9–13 Dec.

Lee, N. (2019), Meteoroids, impact plasma, and atmospheric density, special seminar, Jicamarca Radio Observatory, Lima, Peru, October 10, 2019

Lee, N. (2019), Meteoroid impact plasma and atmospheric density, CEDAR Workshop, Santa Fe, NM, June 21.

Conclusions and Future Work

- **Characterize ablation parameters of MOD**
  - Meteoroid: remote sensing of plasma and scattering model provides flux, mass, bulk density and neutral density
  - Space debris: remote sensing of particles and shape modeling provides flux, mass
  - Simultaneous optical-radar experiments provide cross calibration of ionization and luminous efficiency
- **Future work**
  - Continue to refine new neutral density estimation algorithm
  - Apply orbital dynamics to correlate bulk density with source