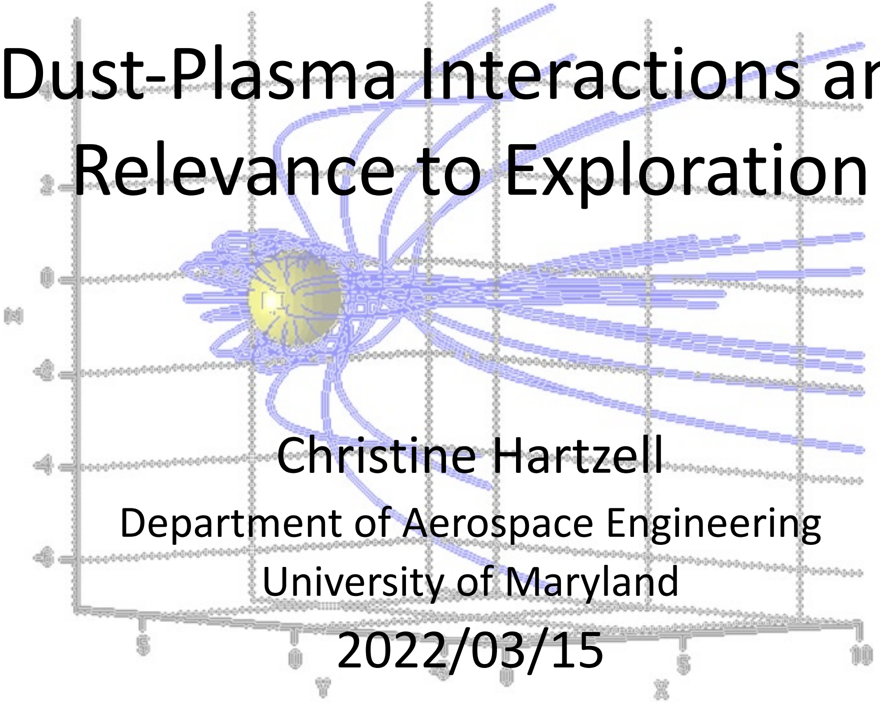

Dust-Plasma Interactions and Relevance to Exploration

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Motivation

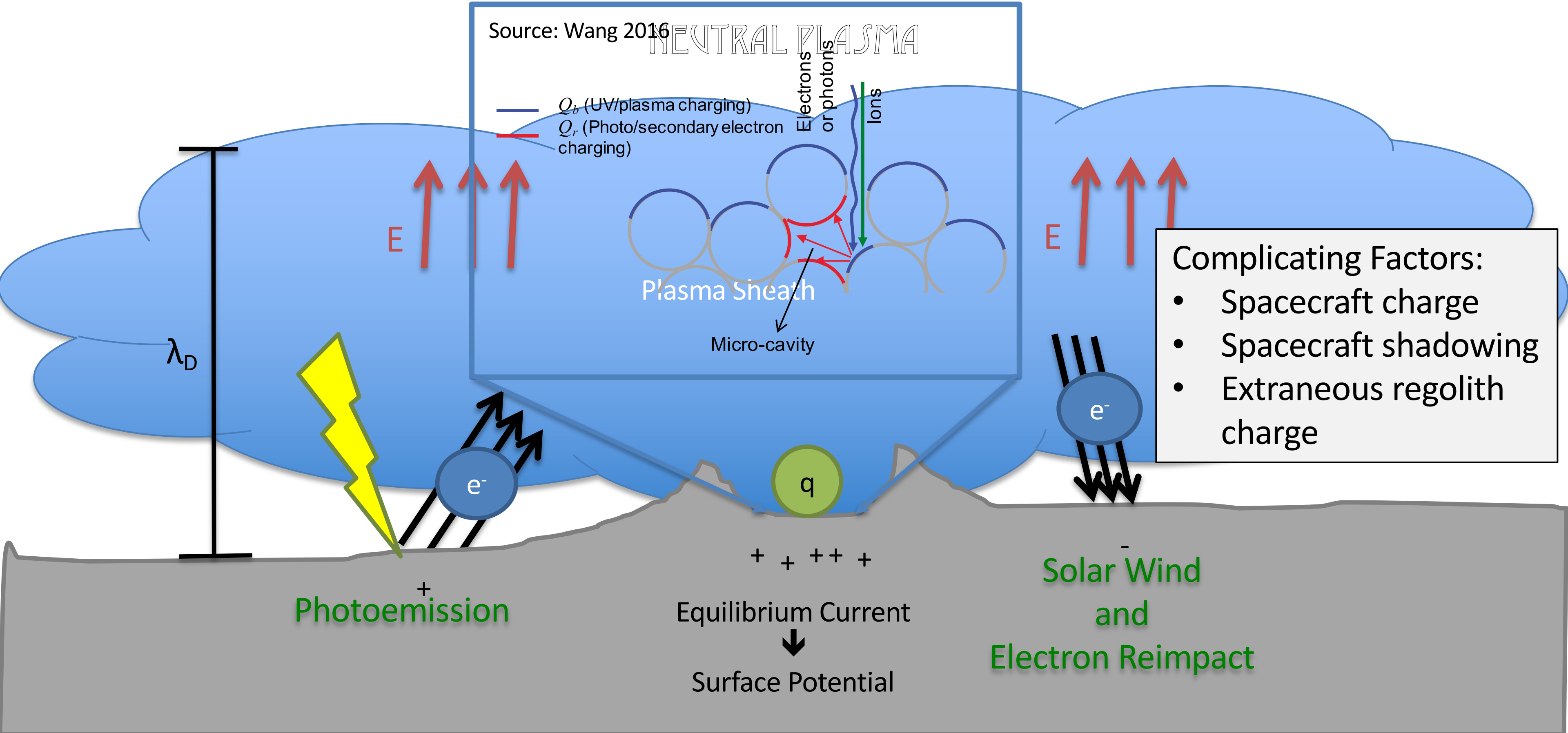
Dust-plasma interactions on the surface of the Moon are significant because:

- electrostatic dust motion is a surface process that may influence the evolution of the Moon's surface (and that of other small, airless planetary bodies especially asteroids)

- dust deposition on spacecraft poses a considerable threat to spacecraft

- the Moon is an ideal laboratory for some investigations of the fundamental physics of dust-plasma interactions

Intro to Lunar Dust-Plasma Interactions



Evidence (?) of Electrostatic Dust Motion

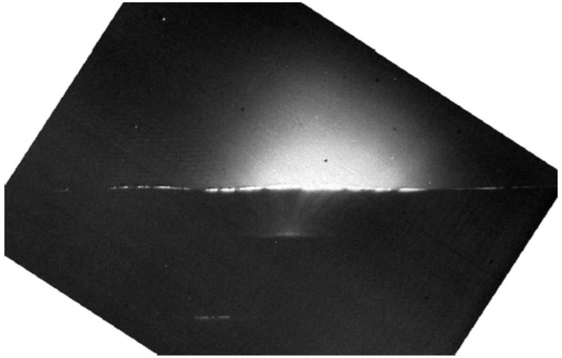


Figure Credit: Colwell et al. [3]

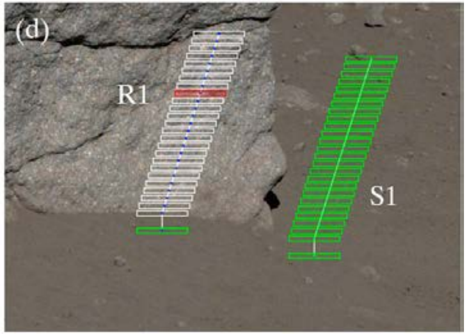


Figure Credit: Yan et al. [33]

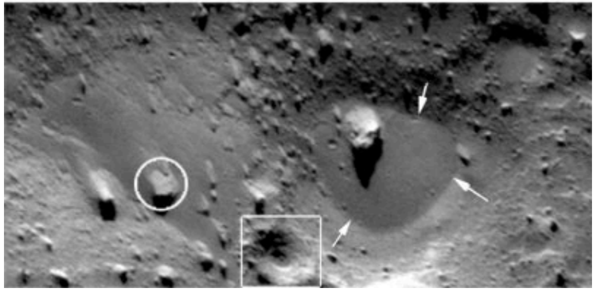


Figure Credit: Robinson et al. [11]

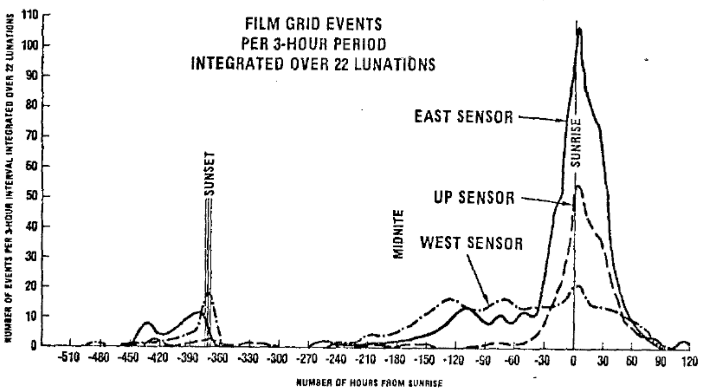


Figure Credit: Berg et al. [1]

BUT:

- LADEE's LDEX instrument saw no evidence of high altitude dust other than that released by micrometeoroid bombardment.
- Reanalysis of Apollo 15 LHG observations are consistent with zodiacal light

Terrestrial Work on ES Dust Motion

- Plasma sheath structure: semi-analytical and computational, near-surface and global (Nitter 1998, Zimmerman 2014, Poppe 2010, 2012)
- Dust charge: computational and experimental (Zimmerman 2016, Wang 2016, Schwan 2017)
- Dust lofting feasibility, considering cohesion (Hartzell 2013, Wang 2009)
- Altitudes and particle sizes of levitating (Hartzell 2013)
- Dust transport into craters (Hughes 2008)
- Experimental levitation in plasma sheath (Sickafoose 2002)

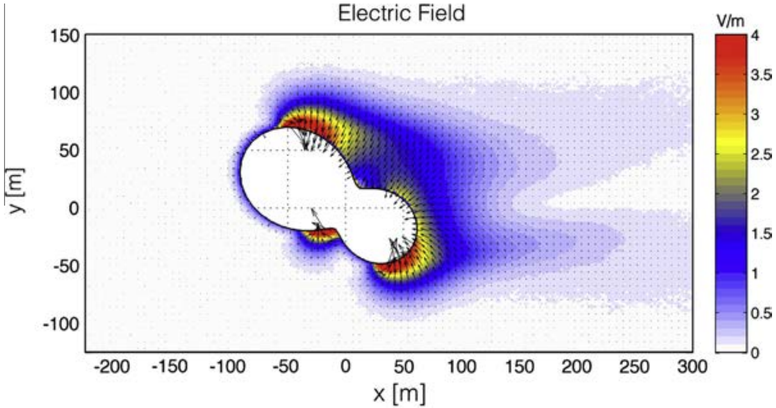
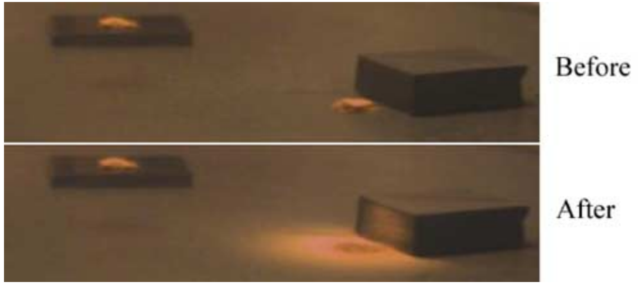


Figure Credit: Zimmerman et al 2014 [30] (above), Wang et al 2009 [19] (below)



(A Few) Open Questions

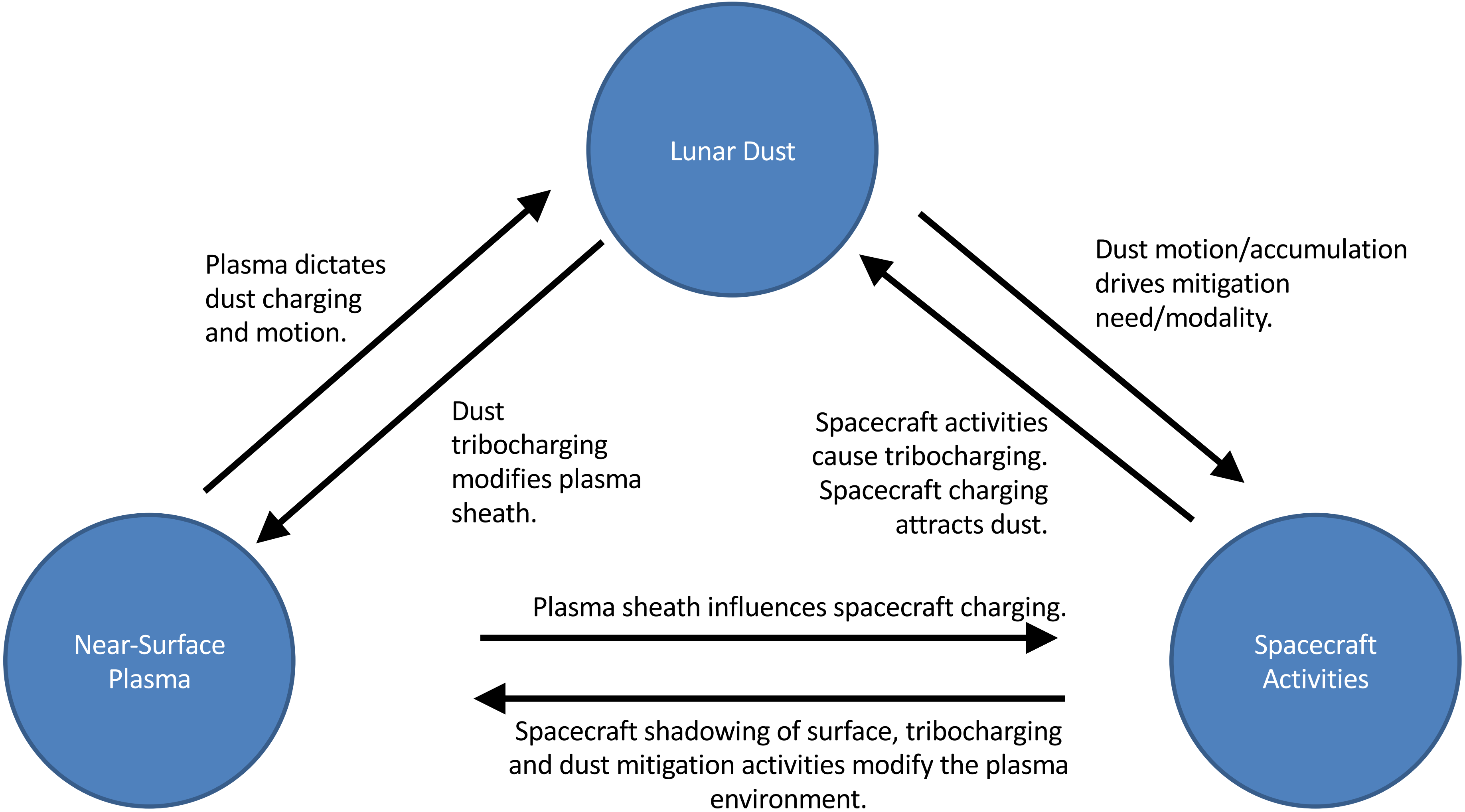
Fundamental Physics:

- What is the charge on a dust particle on a solid surface in a plasma?
- What is the charge on a dust particle in a bed of other particles in a plasma (e.g. a single regolith particle on the lunar surface)?
- How does dust charging on a surface or in a plasma sheath depend on the particle's chemical composition and shape?

Planetary Science:

- Does electrostatic lofting occur on the Moon? When? Where? At what rate? What are the characteristics of these particles?
- Does electrostatic levitation occur on the Moon? (see above)

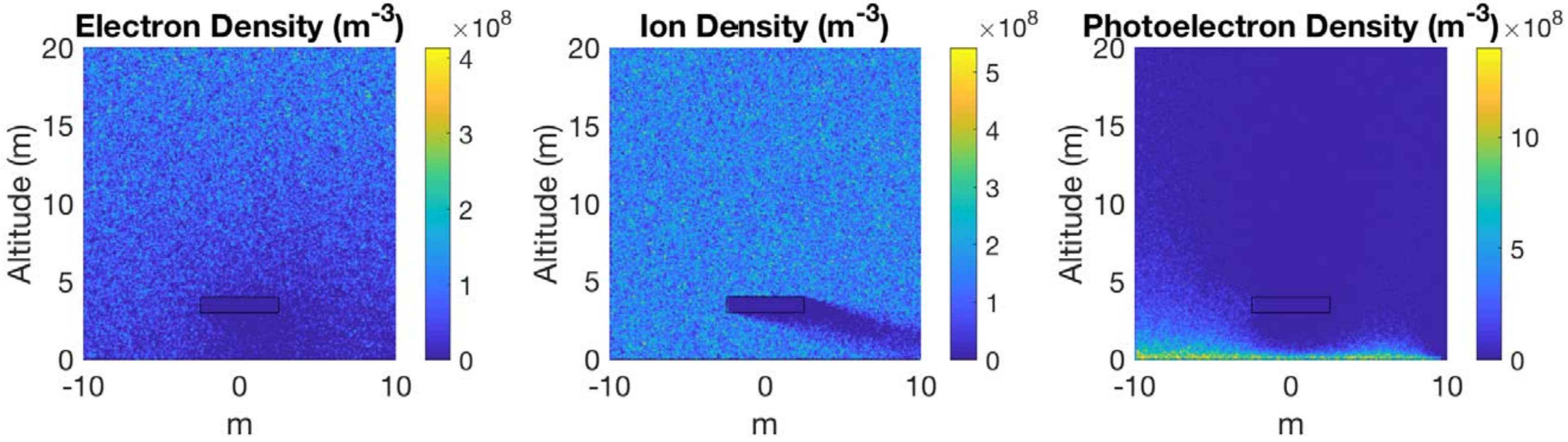
These observations would test modeling predictions and inform spacecraft design


Lunar Dust
Plasma dictates dust charging and motion.
Dust tribocharging modifies plasma sheath.
Dust motion/accumulation drives mitigation need/modality.
Spacecraft activities cause tribocharging. Spacecraft charging attracts dust.
Plasma sheath influences spacecraft charging.
Near-Surface Plasma
Spacecraft Activities
Spacecraft shadowing of surface, tribocharging and dust mitigation activities modify the plasma environment.

Practical Implications for Spacecraft/Mission Design

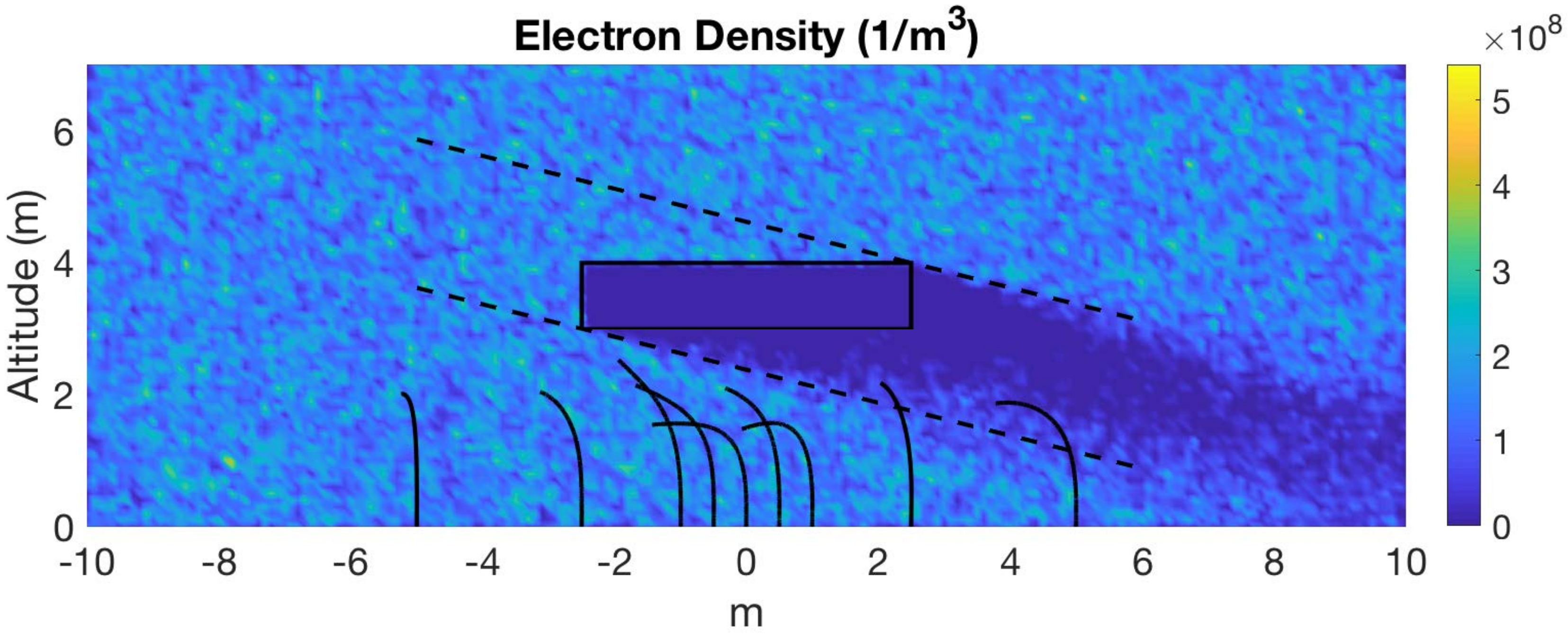
- What is the rate of dust accumulation on spacecraft?
  - Particle sizes?
  - Variation with time of day, landing location?
- How is dust accumulation influenced by tribocharging?
- How will the spacecraft charge?
  - Variation with time of day, landing location?

Plasma Densities (Mike Zimmerman)



- 5m spacecraft at 3m, SIA of 76 deg

Effect of Launch Location



- Trajectories generally similar, even those that enter the wake

Relevance to Mitigation

- Several mitigation efforts rely on electrostatic forces:
  - Electrodynamic dust shield from KSC
  - Electron beam developed at CU

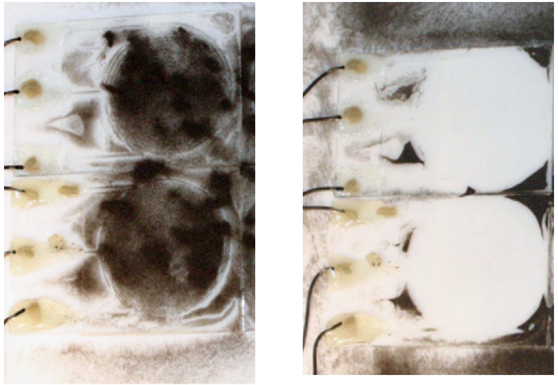
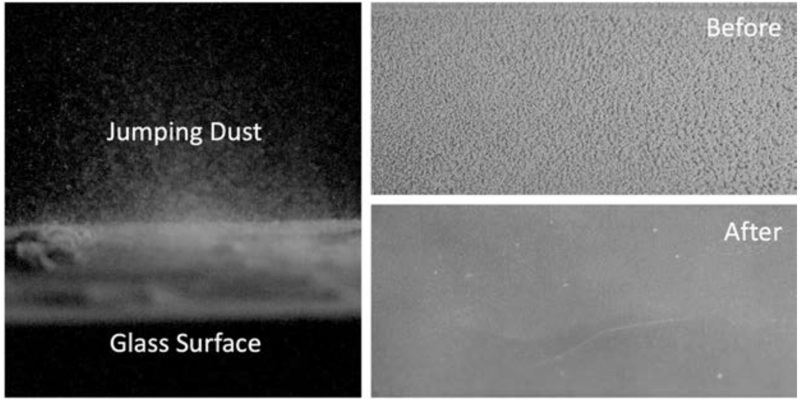


Figure Credit: Calle et al. [34] (above), Farr et al [35] (below)



- These mitigation efforts will change the local plasma environment
- Knowledge of particle charge would inform these mitigation efforts

Conclusions

- The Dust-Plasma-Spacecraft system is interconnected and ripe for experimental investigation

- There are a number of outstanding fundamental physics and planetary science questions that could be investigated, to test existing theories

- Dust-plasma interactions are relevant to spacecraft operations, especially mitigation

Questions?

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