PHOTOELECTRIC CHARGE PUMPING OF DUST PARTICLES BY SOLAR WIND PLASMA. J. L. Richmond[1], J. H. Pagán Muñoz[2,3], X. Wang[2,3], M. Horanyi[2,3], J. Machacek[1], C. Charles[1] and R.W. Boswell[1], [1]Space Plasma, Power, and Propulsion Laboratory (SP3), Australian National University, Canberra, Australia; [2]Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder, CO 80303; [3]NASA SSERVI's Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT), University of Colorado, Boulder, CO 80303. (Email: Josef.Richmond@anu.edu.au).

Introduction: Electrostatic dust charging and transport on the lunar surface is a longstanding problem that was first indicated by Apollo observations of the lunar horizon glow and high-altitude streamers. Since then, this electrostatic process has been related to observations on other airless bodies, such as dust ponds on asteroid 433 Eros and radial spokes on Saturn's rings. Understanding this universal phenomenon on airless bodies is important for its role in surface processes on these bodies. As NASA moves forward with its Artemis program, the importance of understanding the dust-plasma environment and efficient mitigation solutions becomes increasingly important for a sustained human presence on the Lunar surface.

Though lunar dust electrodynamics has been extensively studied through modelling, the fundamentals of initial dust charging on the lunar surface and subsequent lofting have remained unresolved for decades. In 2016, a novel patched charge model [1] made a breakthrough, explaining that photoelectrons and/or secondary electrons induced by the solar UV or solar wind plasma can generate large charges within microcavities in the regolith surface, leading to dust lofting due to strong repulsive forces (Fig. 1 left A). Based on this charging model, here we show new lab results of a charge pumping mechanism of dust particles under UV exposure in the presence of a plasma.

Experiment and Results: The experiment was performed in a vacuum chamber at the IMPACT lab at the University of Colorado Boulder (Fig. 1, right). Dust particles 38 – 45 μm in diameter were loaded on an insulating surface that was exposed to UV light from the top of the chamber. A plasma source was located below the insulating surface to generate ambient plasma. It was shown that the dust lofting rate increased by about a factor of 4 in the UV + plasma case compared to the UV only case.

A charge pumping mechanism is developed to explain the results. As described in the patched charge model, a potential difference is created across a microcavity between particles that emit and collect photoelectrons. The collection of additional ambient plasma electrons lowers the potential on the photoemitting surfaces, resulting in more photoelectrons being emitted and "pumped" onto the surrounding particles and subsequently, resulting in increased dust repulsive forces and enhanced lofting (Fig. 1 left B). This mechanism, which was first proposed in [2], was quantitatively verified experimentally in this work, as described below.

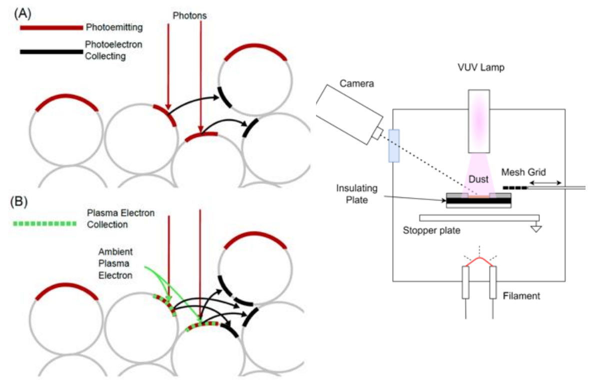

Fig. 1 Left: (A) Patched charge model under UV exposure; (B) Charge pumping of photoelectrons by ambient plasma electrons; Right: Experimental Setup.

We applied an external electric field by introducing a mesh electrode over the dust particles (Fig. 1 right) after they underwent the charging process in each case. It was found that the electric field required to lift off the dust particles in the UV + Plasma case is 2× lower than that in the UV only case, indicating the dust charge in the UV + plasma case is 2× larger than the UV only case. Subsequently, the dust-dust repulsive force is increased by a factor of 4 in the UV + plasma case, in agreement with the dust lofting rate measurements. These results verified the charge pumping mechanism.

Conclusion and Discussion: Based on the patched charge model, a charge pumping mechanism is developed and verified experimentally, showing photoelectric charging within microcavities between dust particles is enhanced by the collection of ambient plasma electrons. The laboratory results indicate that the solar wind plasma may contribute to enhanced dust charging, which is dominated by photoelectrons on the lunar dayside, and subsequent lofting.

References: [1] Wang et al (2016), GRL, 43, 6103; [2] Yeo et al (2022), Phys. Rev. E106, L013203.