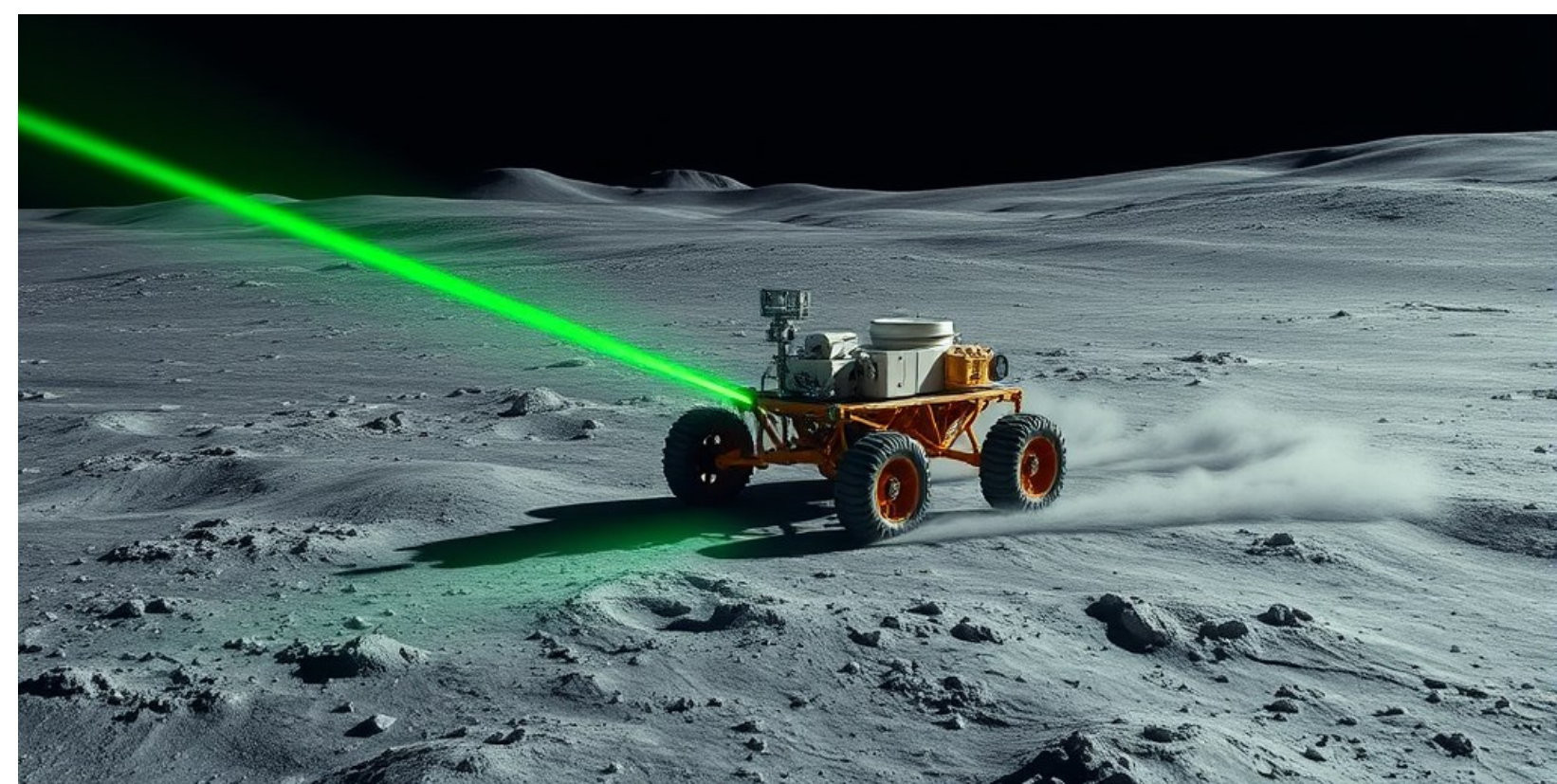


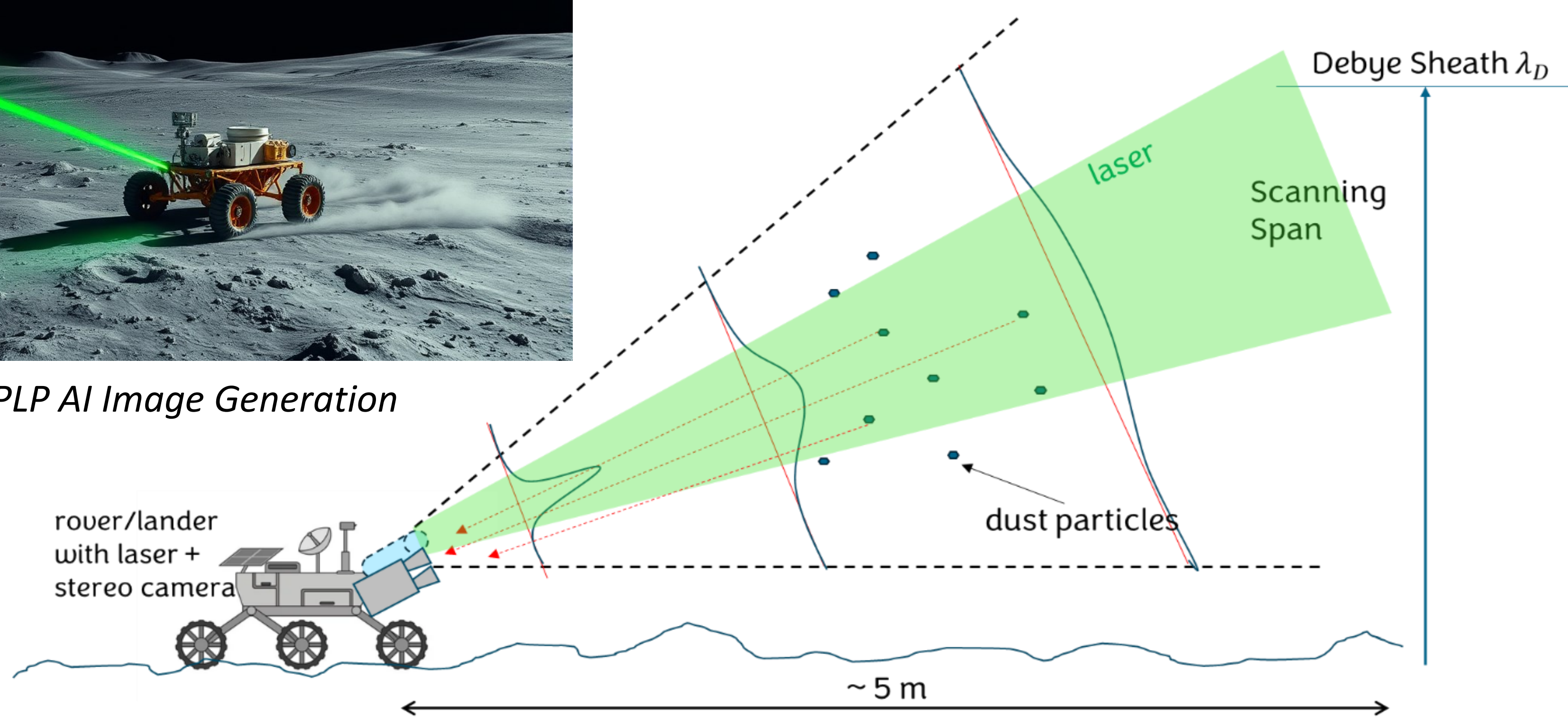
Laser-Assisted Dust Lunar Experiment: Investigating Electrostatic Dust Transport on the Moon

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Credits: PF-PLP AI Image Generation



Conceptual illustration of a rover-mounted laser scanning system on the lunar surface, showing how a projected laser beam interacts with suspended dust particles and how scattered light is collected by an onboard camera during forward scanning.

MOTIVATION & BACKGROUND

Why Lunar Dust Matters

Lunar dust poses a major challenge for future exploration. Fine regolith particles adhere to surfaces, degrade optics, contaminate mechanisms, and pose health risks. Mission observations (Surveyor, Apollo, LADEE) suggest electrostatic dust lofting, but near-surface dust dynamics and detectability remain poorly constrained.

Knowledge Gap

Orbital data indicate low-density dust populations, yet direct optical measurements of individual suspended particles near the surface are missing. The link between particle size, scattering intensity, and detectability under realistic illumination is still uncertain.

SCIENTIFIC OBJECTIVES

Can suspended lunar dust analogs be optically detected and sized using laser backscattering?

- Detect individual dust particles (~1–100 μm)
- Quantify particle size and backscattered signal
- Compare measurements with Mie scattering theory
- Assess detection limits for future lunar instruments

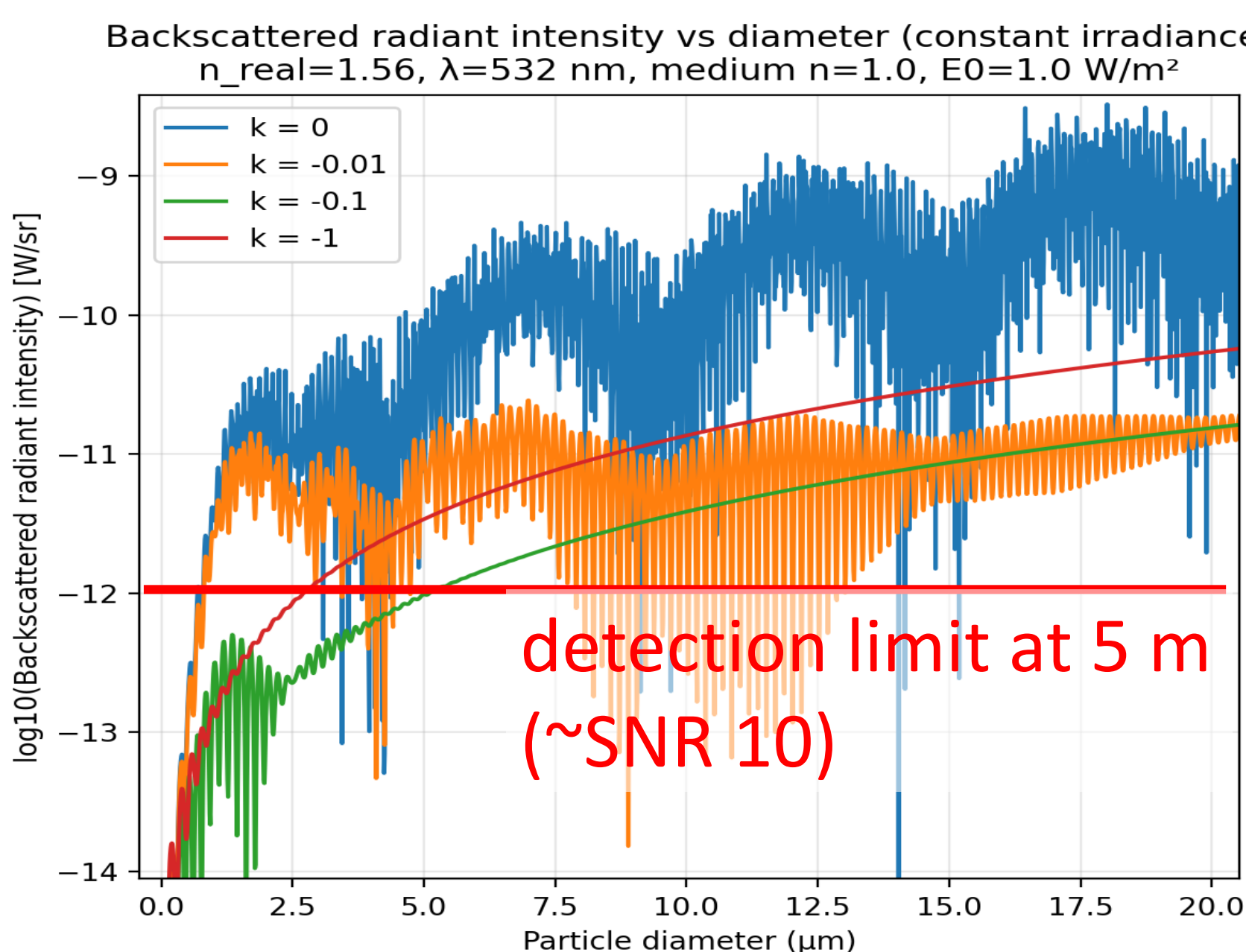
THEORETICAL FRAMEWORK

Electrostatic Dust Lofting

Dust on airless bodies is charged by photoemission, plasma collection, and secondary electron emission. Electrostatic forces can exceed lunar gravity, lofting particles into ballistic trajectories [Stubbs et al. (2005)]. Smaller particles reach higher altitudes and are optically more detectable.

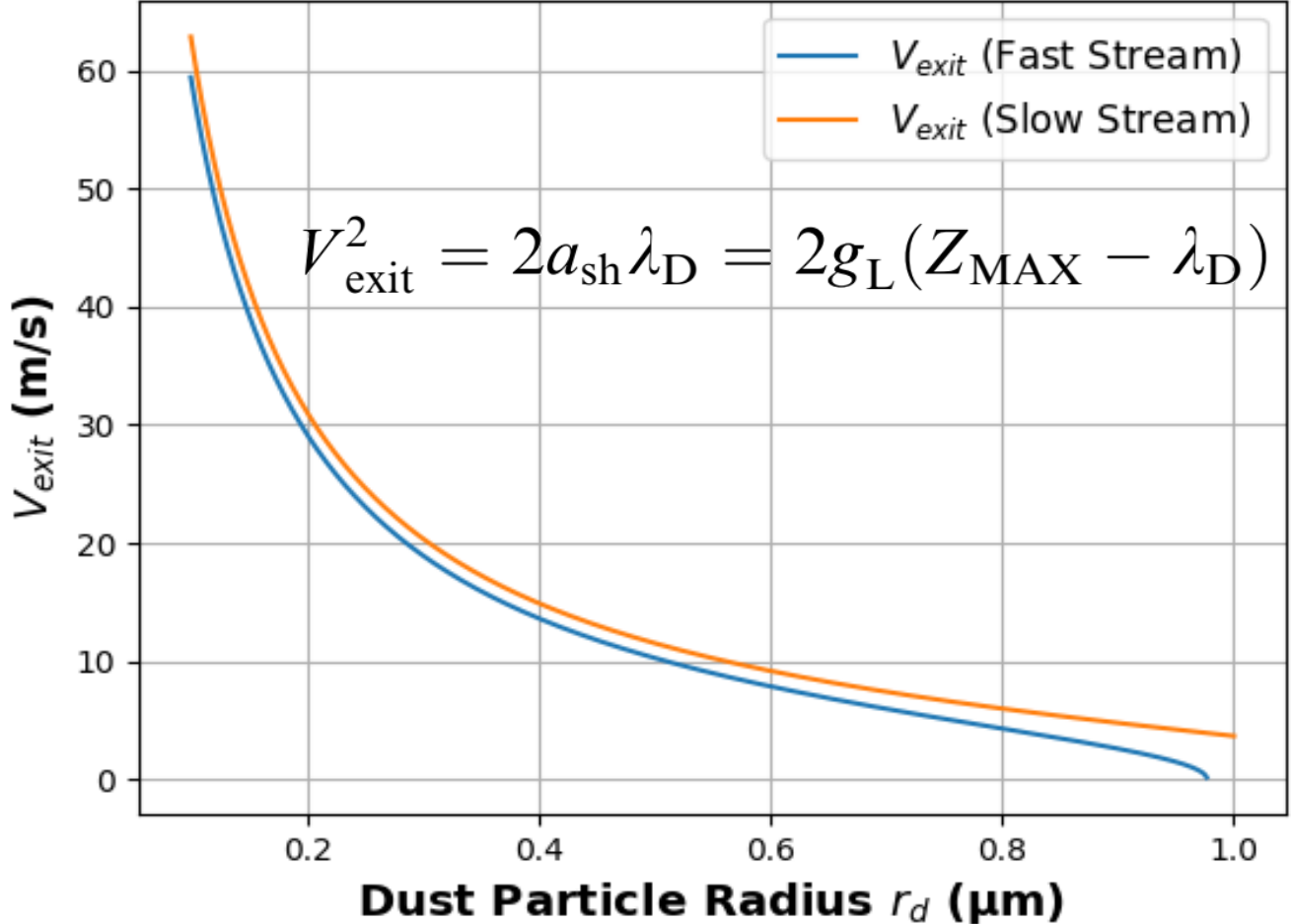
Optical Scattering

Laser detection is governed by Mie scattering, applicable when particle size is comparable to the laser wavelength. Backscattered intensity depends on particle size, refractive index, illumination geometry, and detector noise.

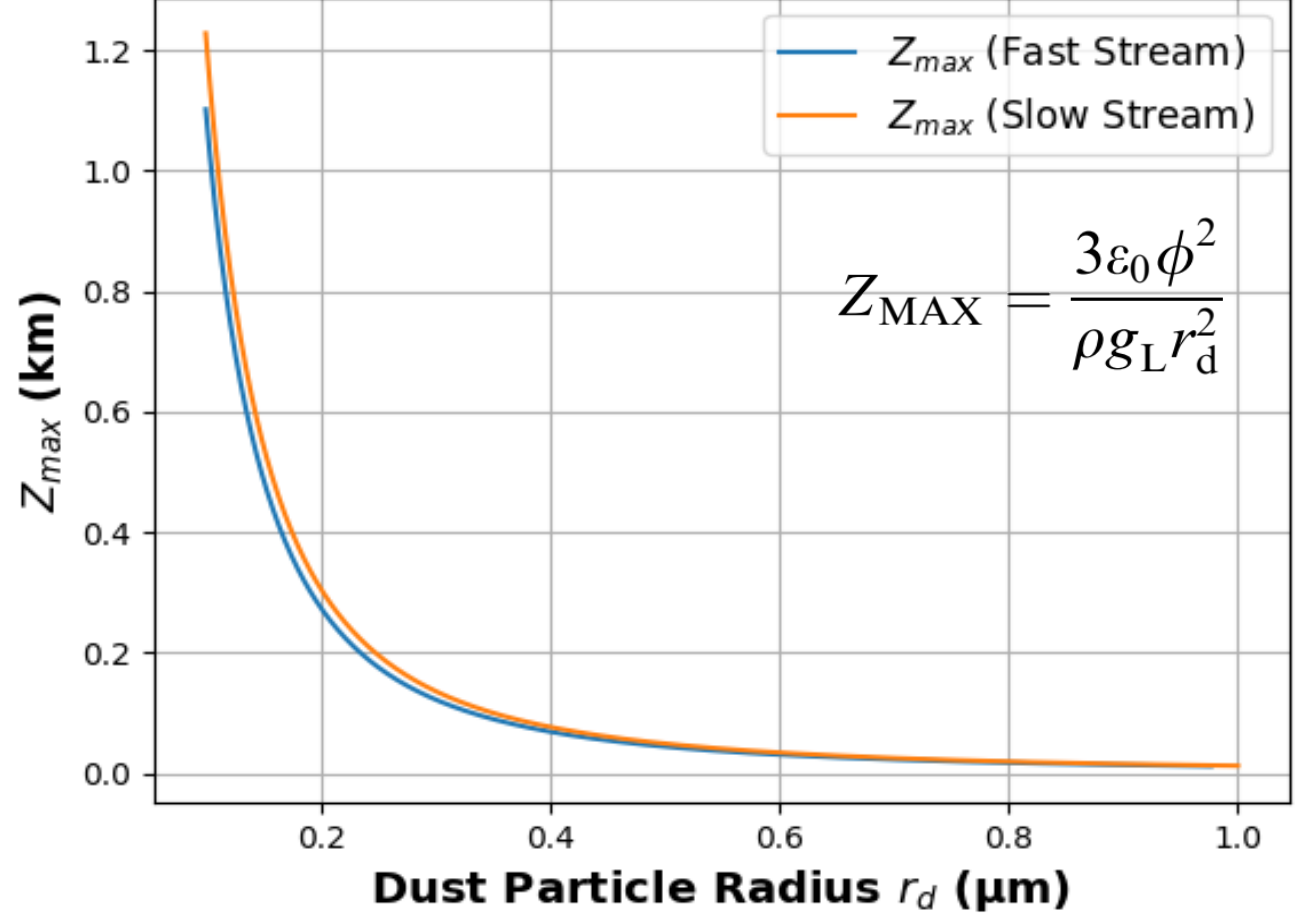


Simulated backscattered light from dust particles over particle diameter according to Mie Theory.

Exit Velocity of Dust Particles vs. Radius



Maximum Height of Dust Particles vs. Radius



Top: Exit Velocity above the plasma sheath region for Lunar Dust Particle of radius 0.1-1 μm. Bottom: Maximum height reached for Lunar Dust Particle of radius 0.1-1 μm [T.J. Stubbs et al. (2014)].

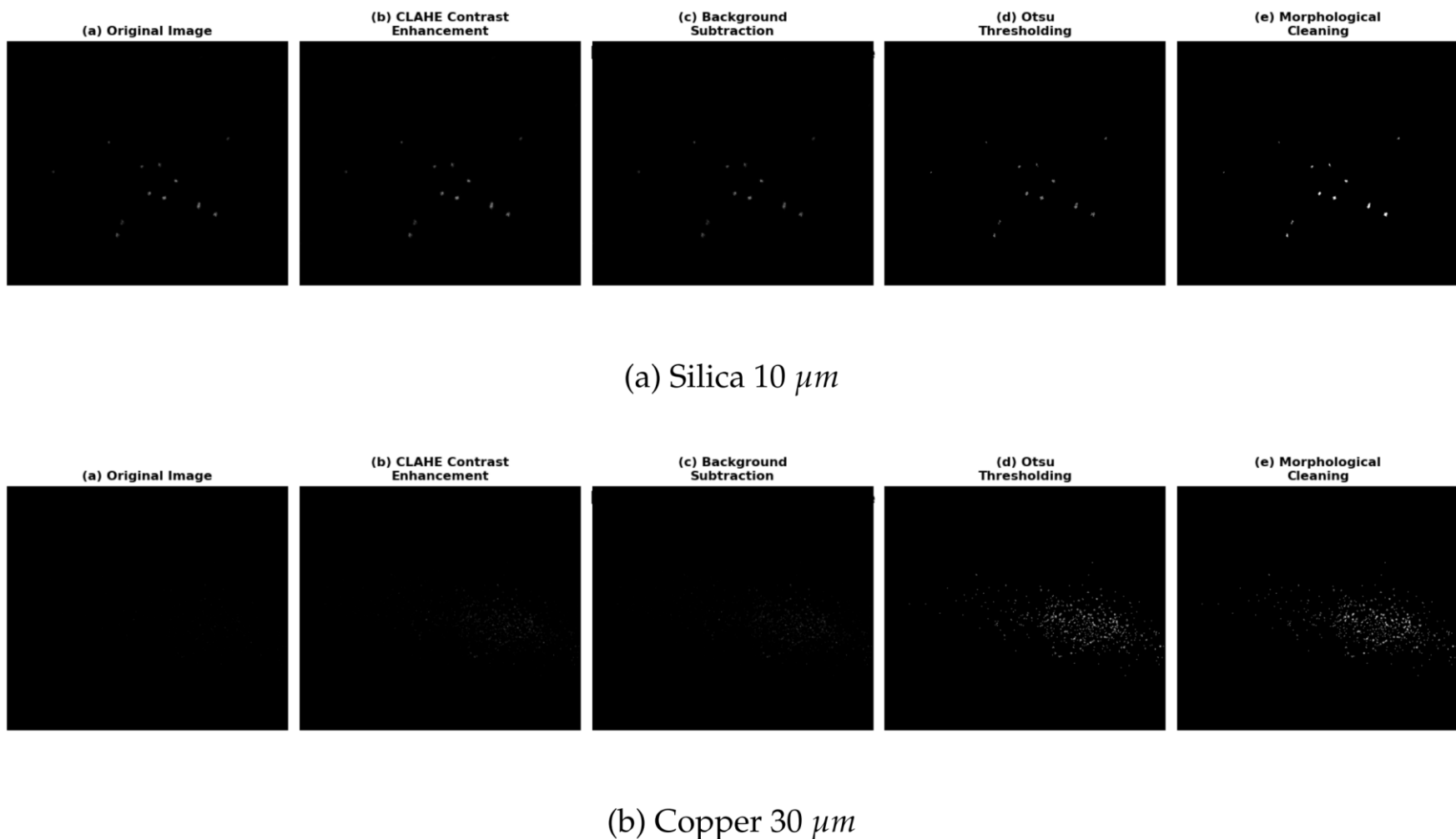
EXPERIMENTAL SETUP

Laboratory Concept

A controlled setup simulates isolated dust particles crossing a laser beam for direct optical detection.

Key Components

- Pulsed laser (visible / 532 nm)
- CMOS imaging detector
- Defined illumination geometry
- Free-fall dust release (dust chamber abandoned due to agglomeration)
- Silica and metal-coated particles were used as lunar dust analogs [Li, Yanwei et al. (2023)].



Acquired and processed images of dust test spheres at 1.4 m distance.

DATA PROCESSING & ANALYSIS

Image Processing

- Dark-frame subtraction
- Background normalization
- Contrast enhancement
- Threshold-based detection

Extracted Parameters

- Particle size
- Particle shape
- Backscattered intensity
- Particle velocity

Results were validated using multi-frame statistics.

Results

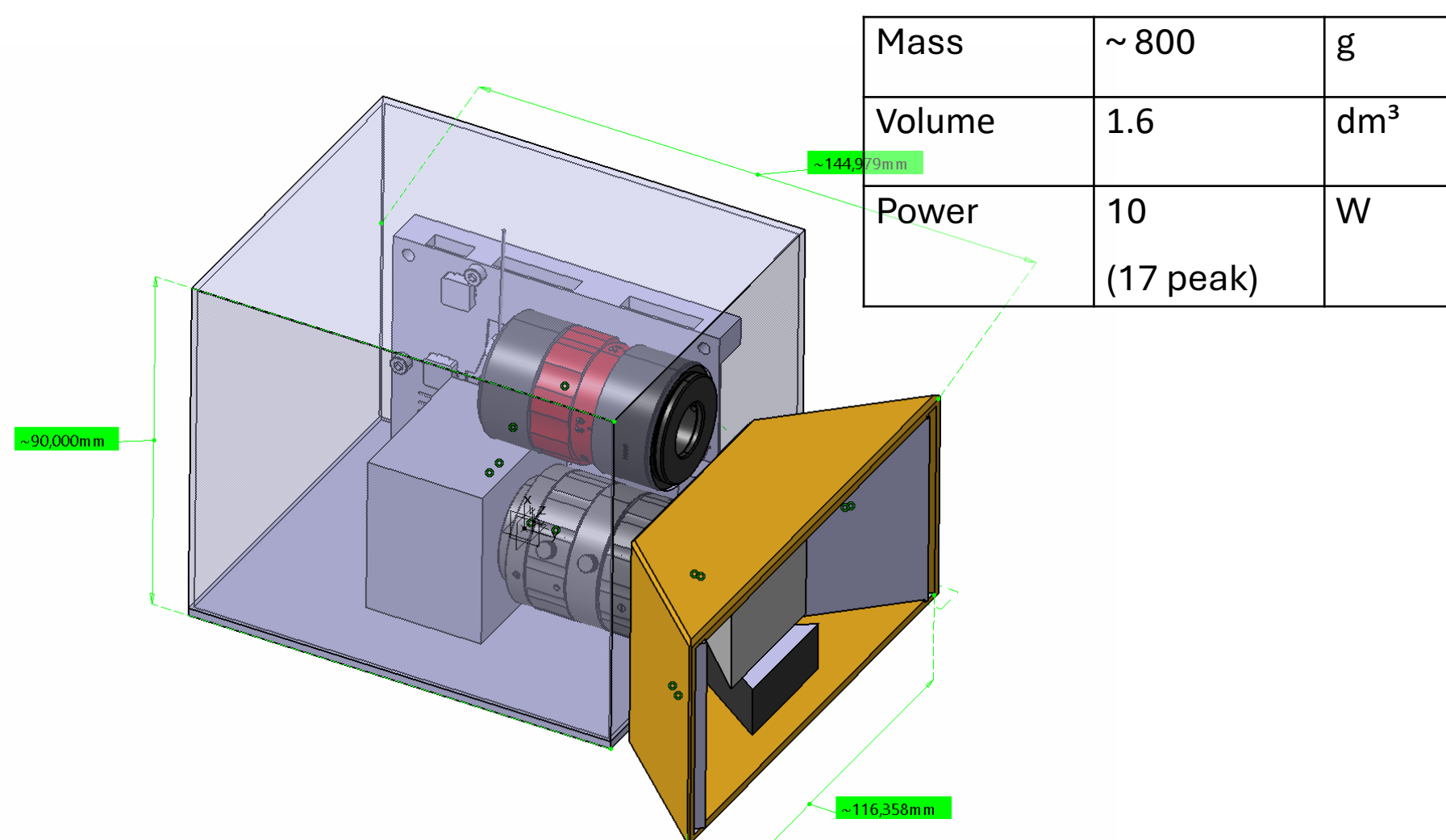
Key Findings

- Laser–optical detection of single dust particles is feasible
- Mie scattering is a valid first-order interpretation model
- Sensitivity is mainly limited by resolution and detector noise

Relevance for Lunar Missions

- In-situ dust monitoring on landers and rovers
- Optical studies of lunar horizon glow
- Validation of electrostatic dust transport models

Parameters	Value	Unit
f	~25	mm
f/#	> 5.6	-
FOV	1 to 10	°
E pulse	100	μJ
t pulse	< 100	μs
Frequency	> 50	Hz
Detector 3d Plus Cube	12	MP
	pp 3.45 x 3.45	μm
Range	up to 5	m
Particle sizes	> 1	μm
Particle velocities	up to 10	m/s



Envelope model of a payload design with diode laser and stereo camera.

CONCLUSIONS & OUTLOOK

Individual lunar dust analog particles can be detected using laser backscattering. Particles in the ~10–30 μm range show size-dependent signal strength consistent with Mie scattering. Detection performance is limited by optical resolution, noise, and agglomeration.

Future work should target vacuum and plasma environments, smaller particles, real lunar regolith, and compact, flight-representative optical systems to better constrain near-surface lunar dust dynamics.