Laboratory investigation of the electrical environment and dust transport within craters on airless bodies

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Electric environment within craters

- Solar wind – Moon interaction has been mainly studied globally. However, the lunar surface is not flat but has topographic features, for example, mountains, large boulders, and craters.
- The local plasma environment at these topographic features is interesting and could be important for dust transport.

Measurements of local lunar plasma environment are not capable with orbiters.

Electrical environment within permanently shadowed lunar craters

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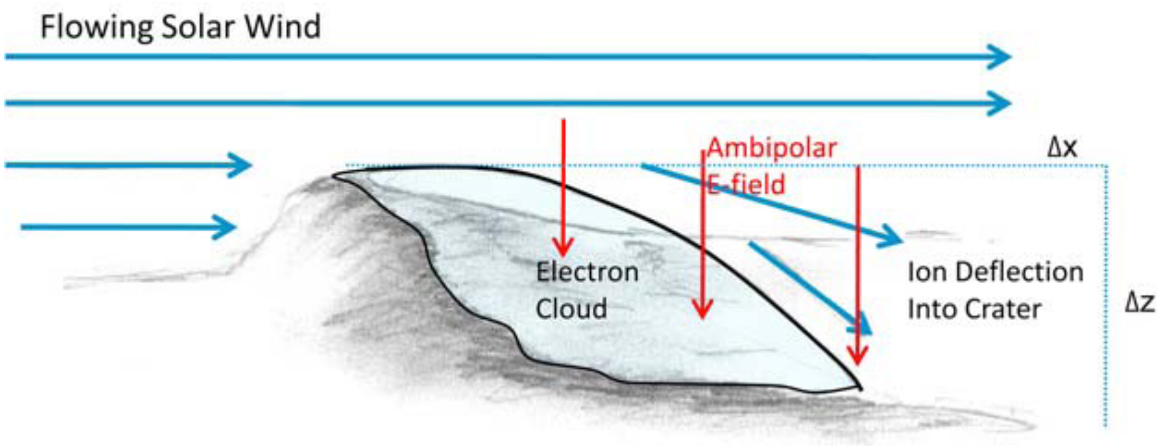
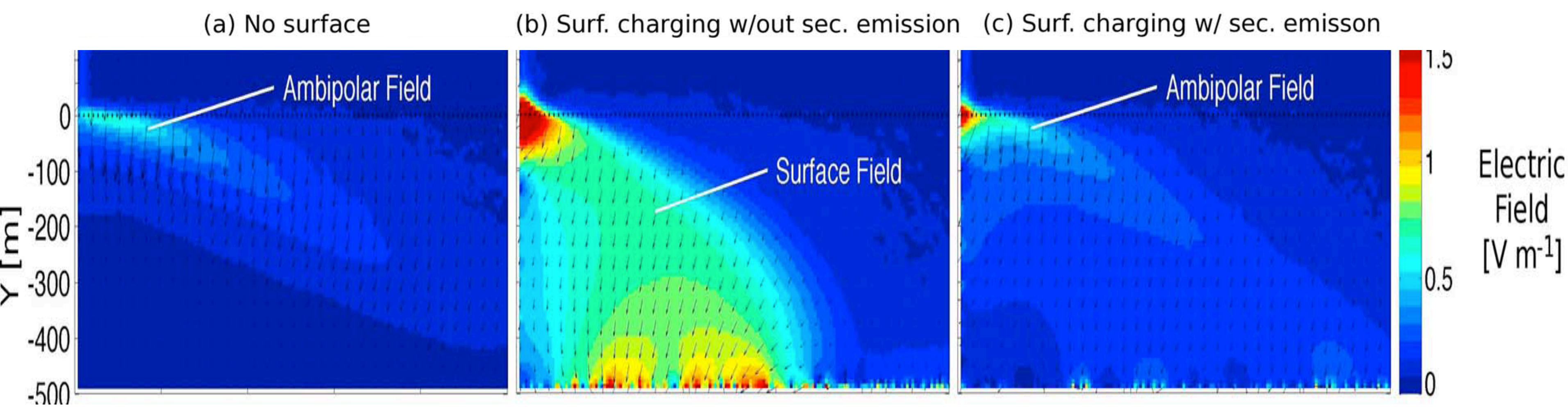


Farrell et al., J. Geophys. Res. (2010).

Simulation of solar wind past a step-like lunar crater



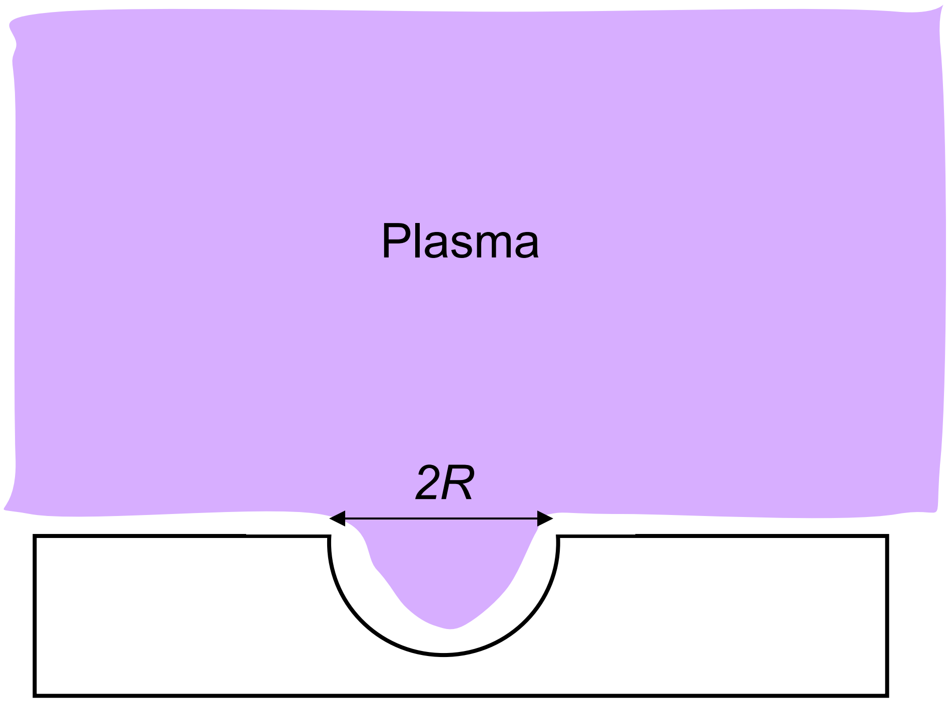
Zimmerman et al., Geophys. Res. Lett. (2011).

Crater size *vs.* plasma shielding distance

- There are various sizes of craters (m to km in diameter) relative to the ambient plasma shielding distance (several Debye lengths, m to hundred meters)

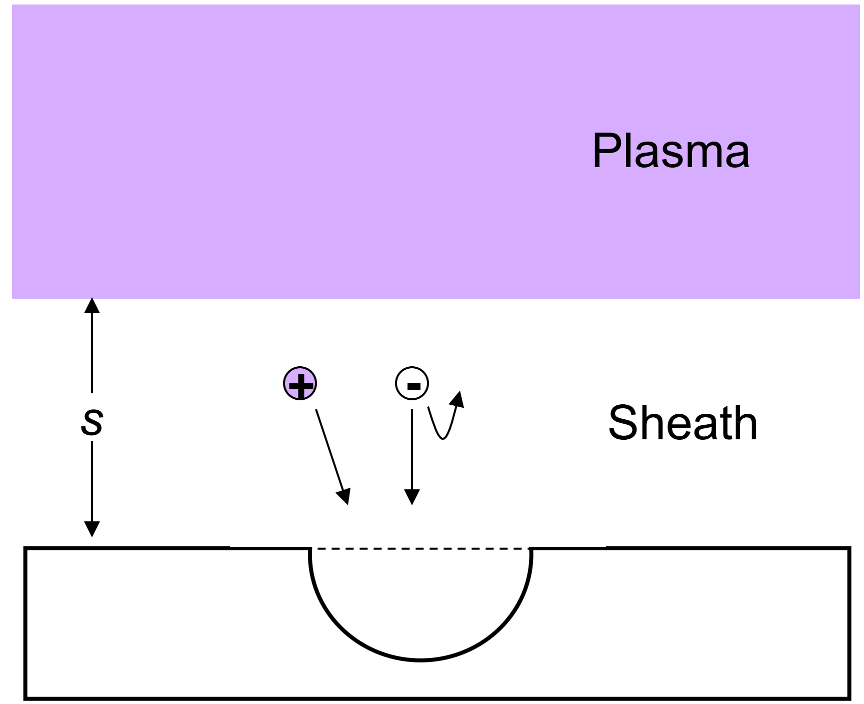
- Electric field distributions within different sized craters are expected to be very different, resulting in different dust transport processes.

Two extreme cases



$R >> S\ (\lambda_D)$

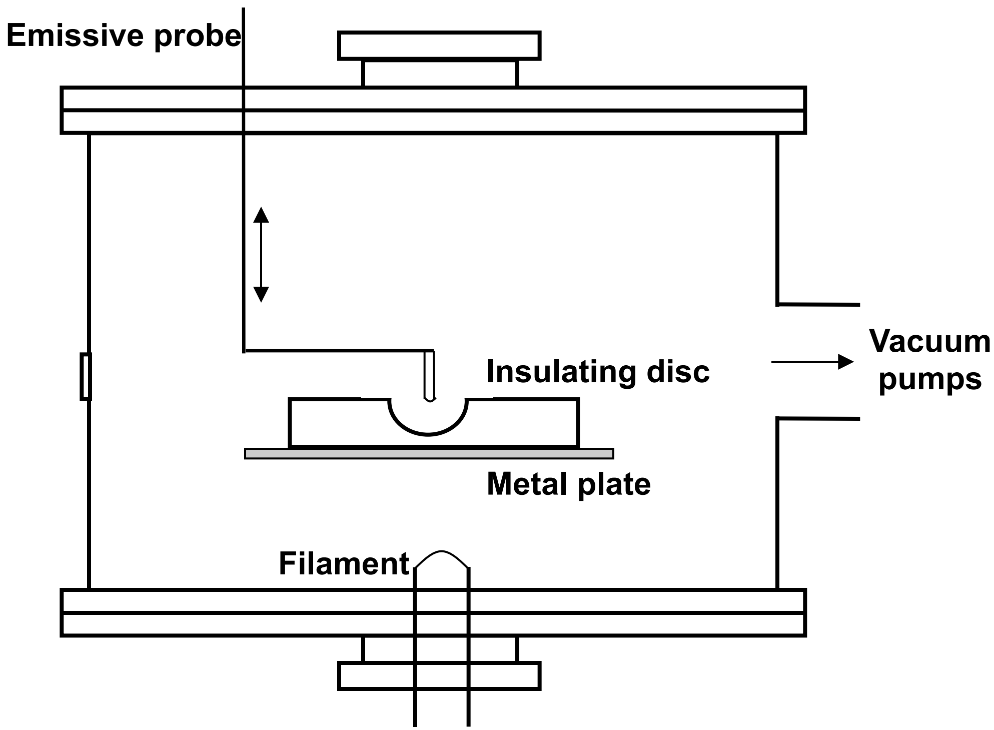
The plasma expands into the crater.

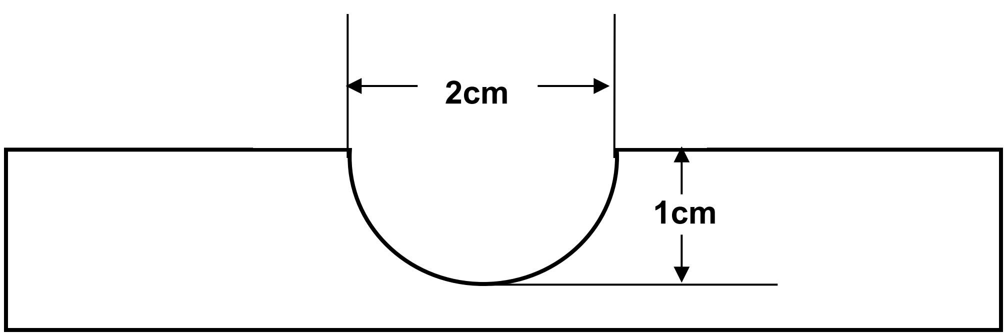


$R << S\ (\lambda_D)$

The crater is shielded out from the plasma.

Experiment



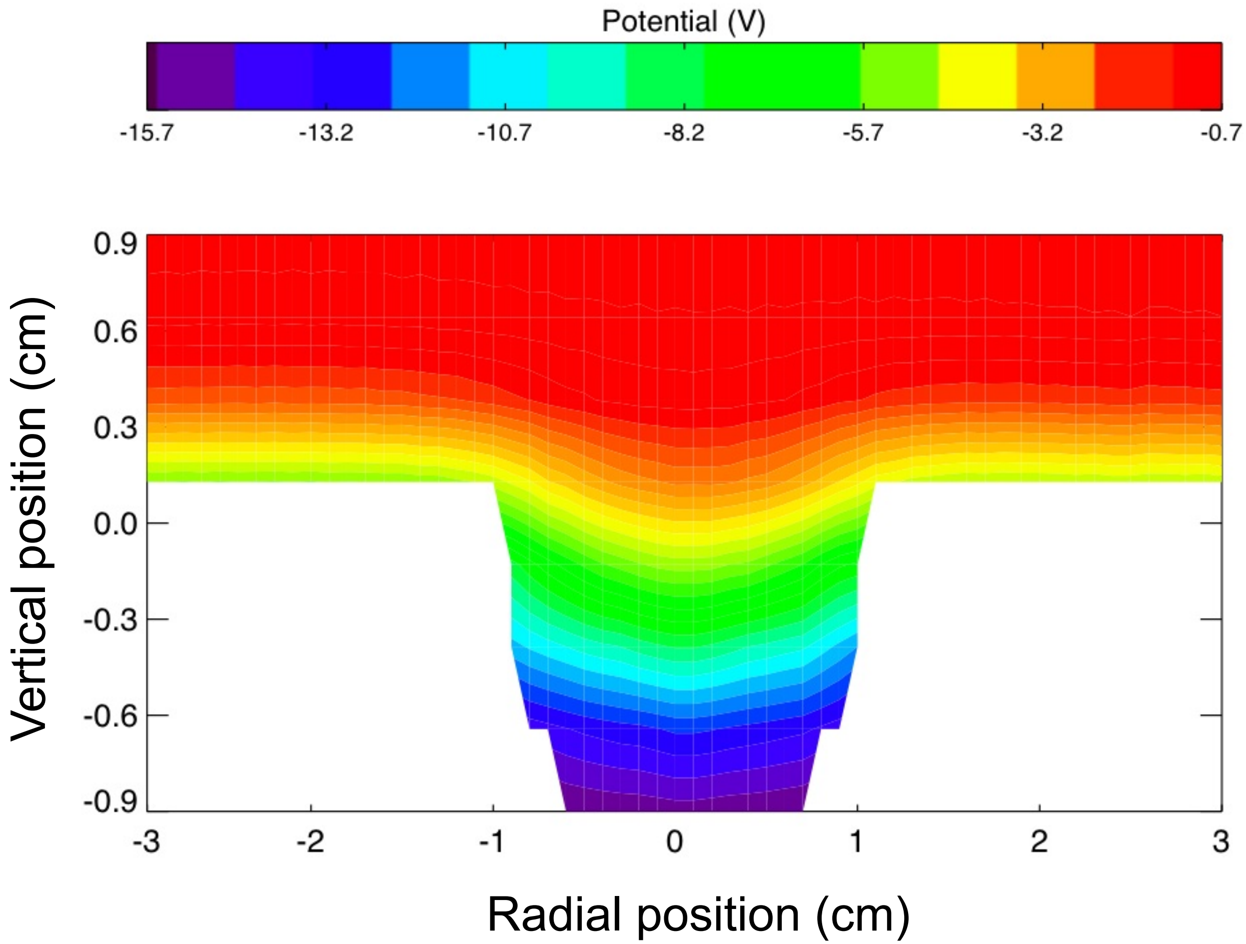


- Hot filament discharged plasma.

- Electron temperature T_e 1 ~ 2 eV (T_e^{cold}: 1 ~ 2 eV, T_e^{hot}: 4 ~ 5 eV).

- Total electron density n_e from 10^7 – 10^8 cm^{-3}.

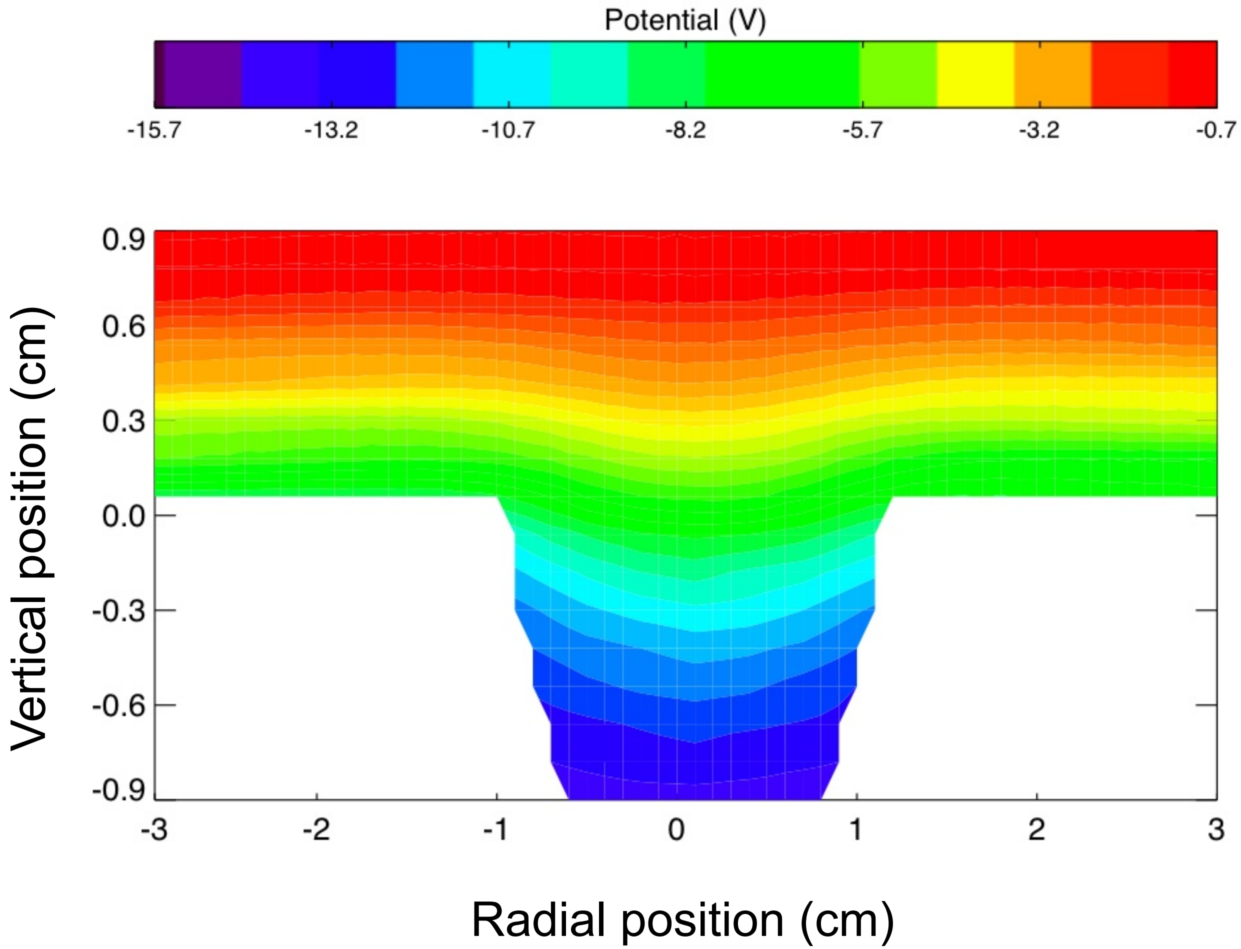
$S < R$



- Plasma expands into the crater.
- Potential gradients within the crater are large.
- However, potential gradient becomes smaller in the very bottom of the crater (Shielding effect).

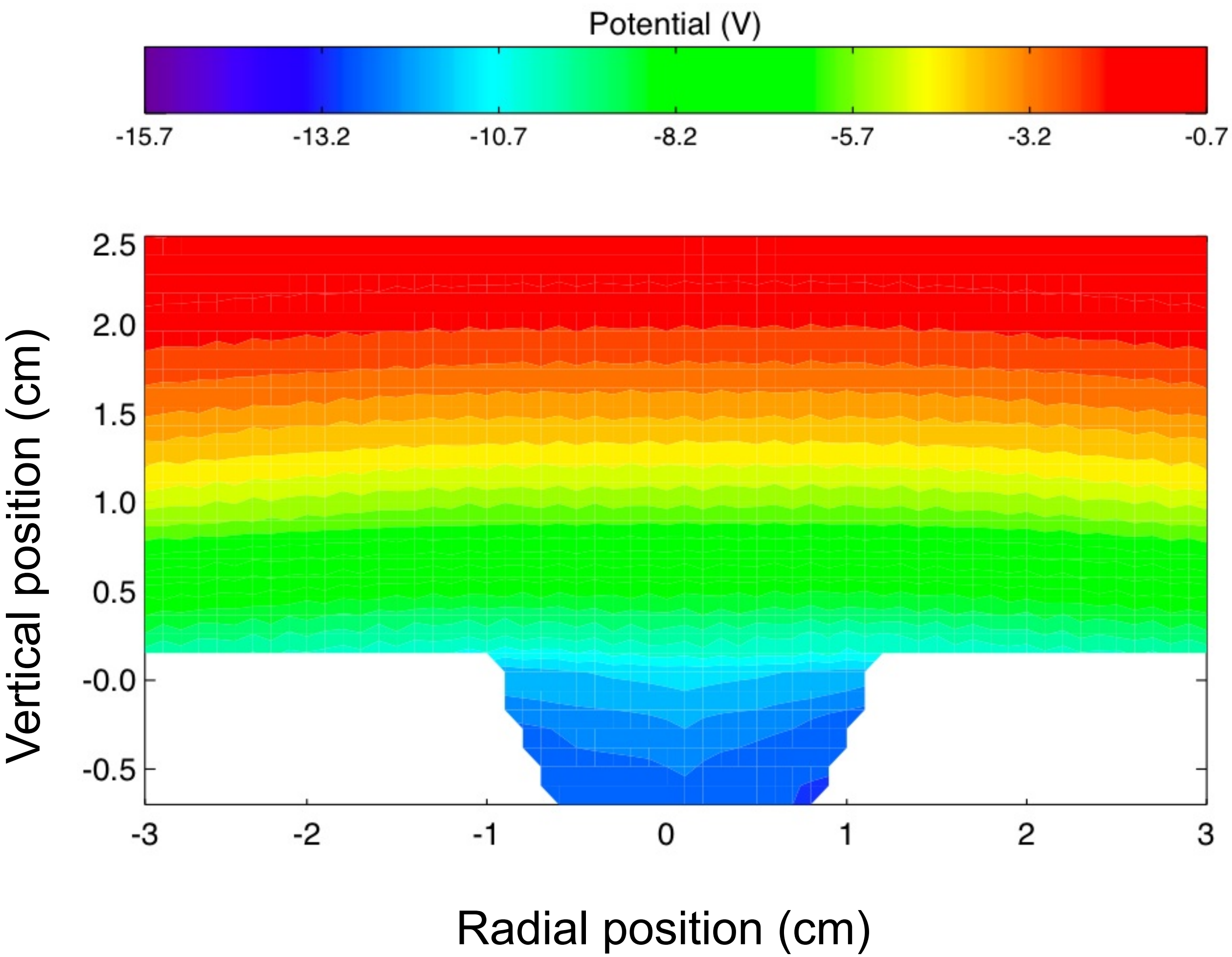
This plot is data not simulation!

$S \approx R$



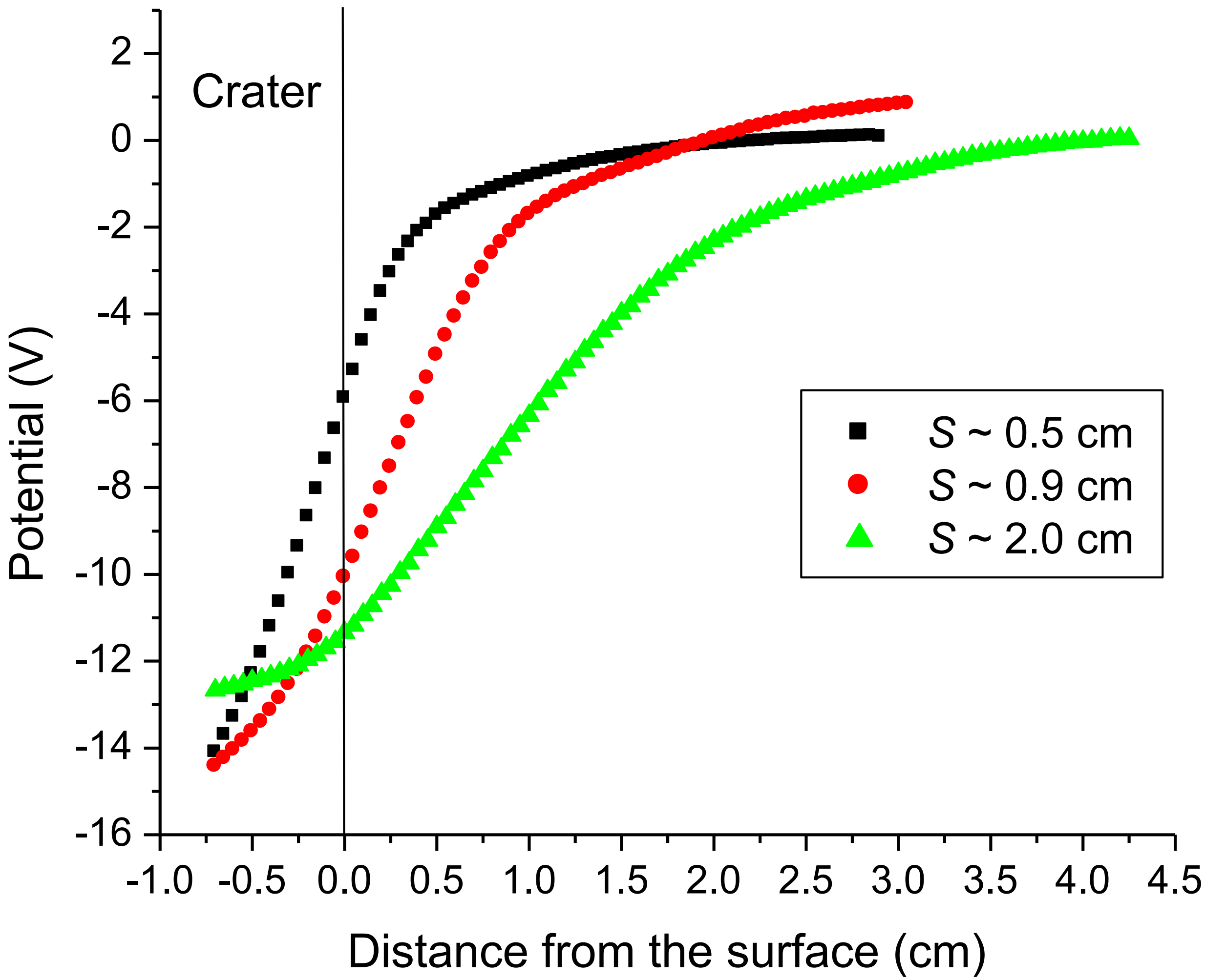
- Plasma expands less into the crater.
- Potential gradients within the crater are less large.
- A shielding effect is stronger within the crater.

$S > R$



- Plasma is shielded out from the crater.
- Electron and ion fluxes should be balanced at the top of the crater.
- Potential gradients (i.e. Electric fields) significantly decrease within the crater.

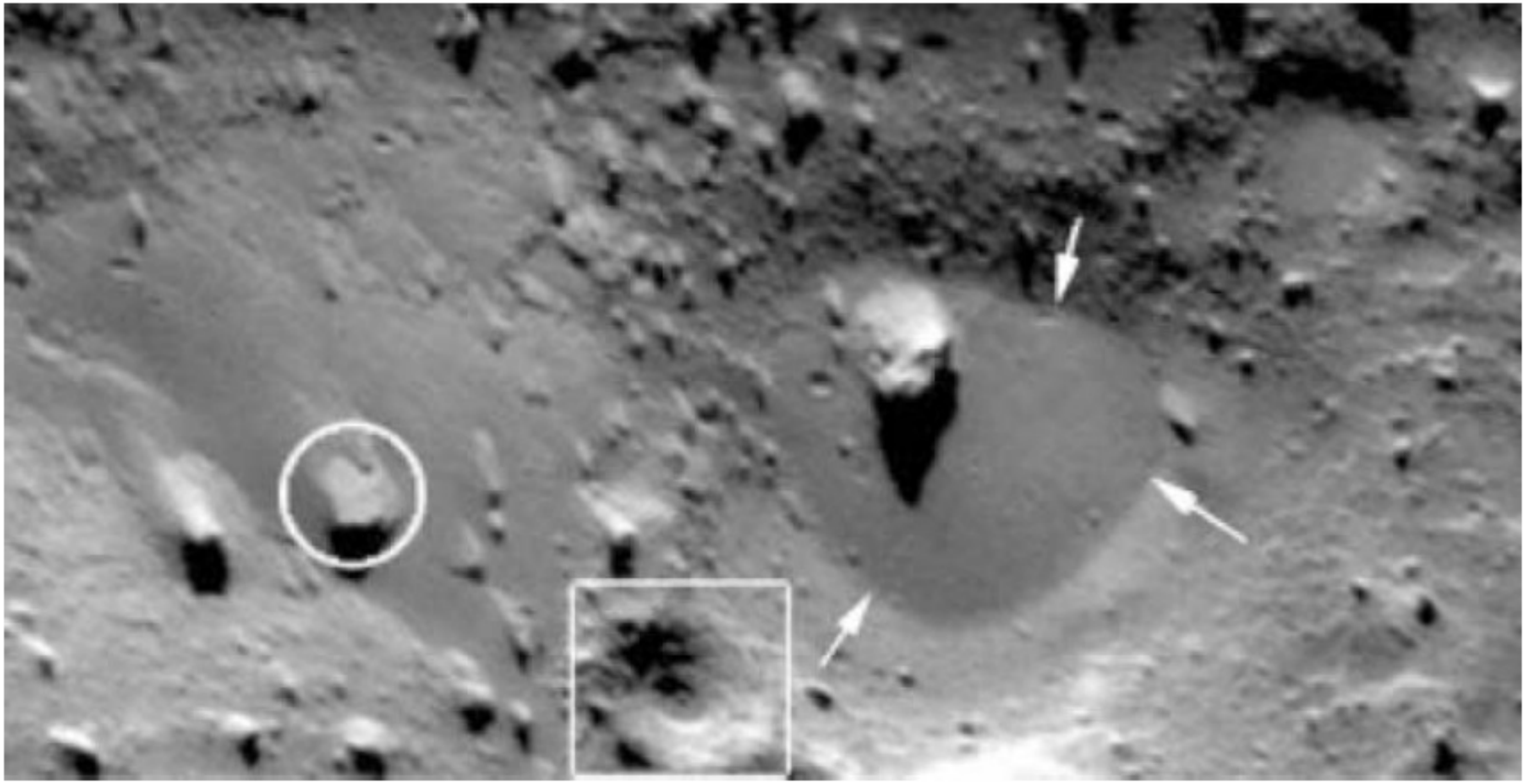
Vertical potential profiles in the central axis of the crater



- Electric field (i.e. potential gradient) approaches 0 in the bottom of the crater when $S > R$.
- Particles that transport from outside are likely to get trapped in smaller craters, possibly forming a dust pond.

Dust transport at craters

Image of a dust pond on asteroid Eros



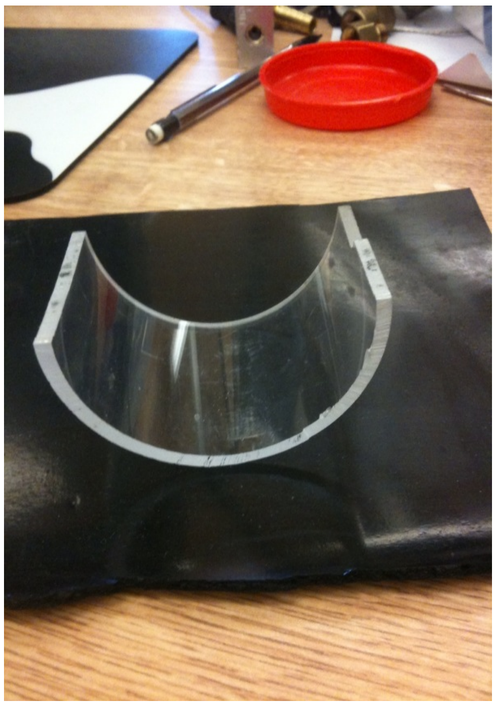
Renno and Kok, Space Sci. Rev. (2008)

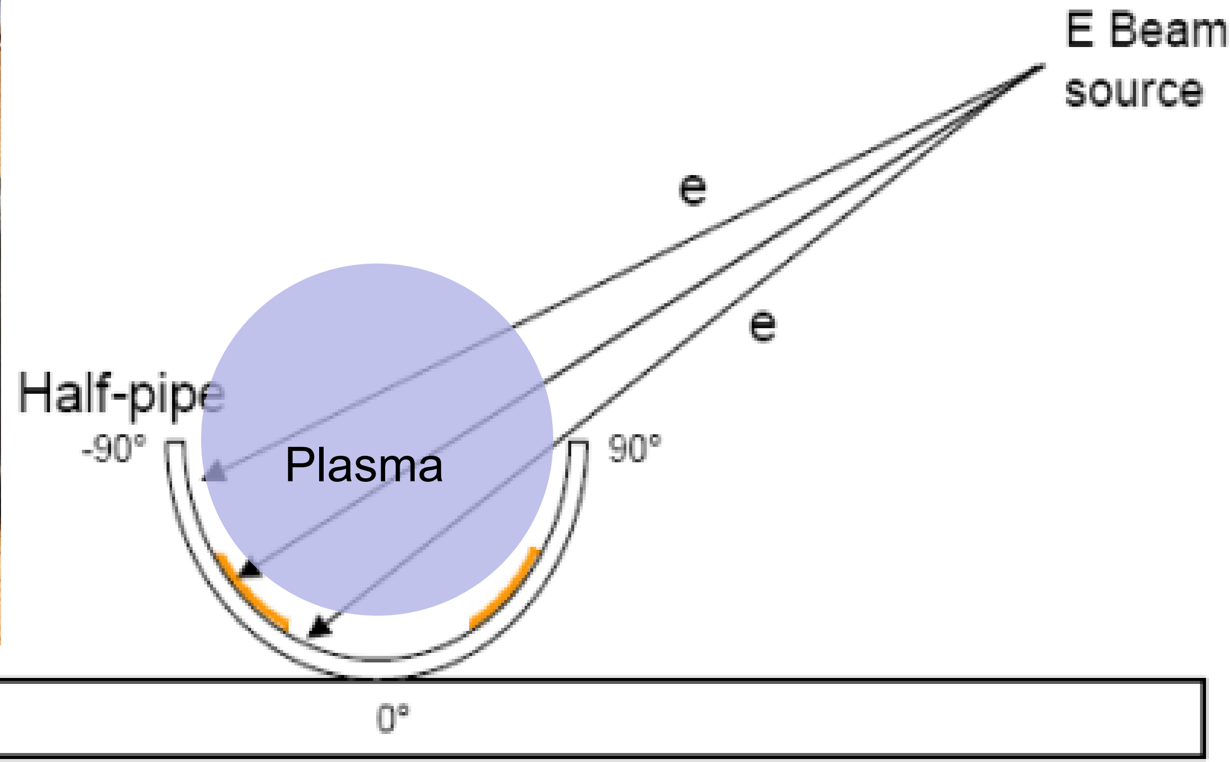
Two possible electrostatic mechanisms for the formation of dust ponds:

1. Dust transports from outside of the crater and stays in the bottom.
2. Dust transports from the upper slope to the bottom.

Dust transport due to obliquely incident e-beam

- When the moon or asteroids enter the earth's plasma sheet, high-energy electron flux can be incident on the craters obliquely.
- We expect a large potential difference between the electron impact/shadow boundary on the crater surface, leading to dust transport.





Wang et al., Planet. Space Sci. (2011)

Potential profiles along the surface of the half-pipe

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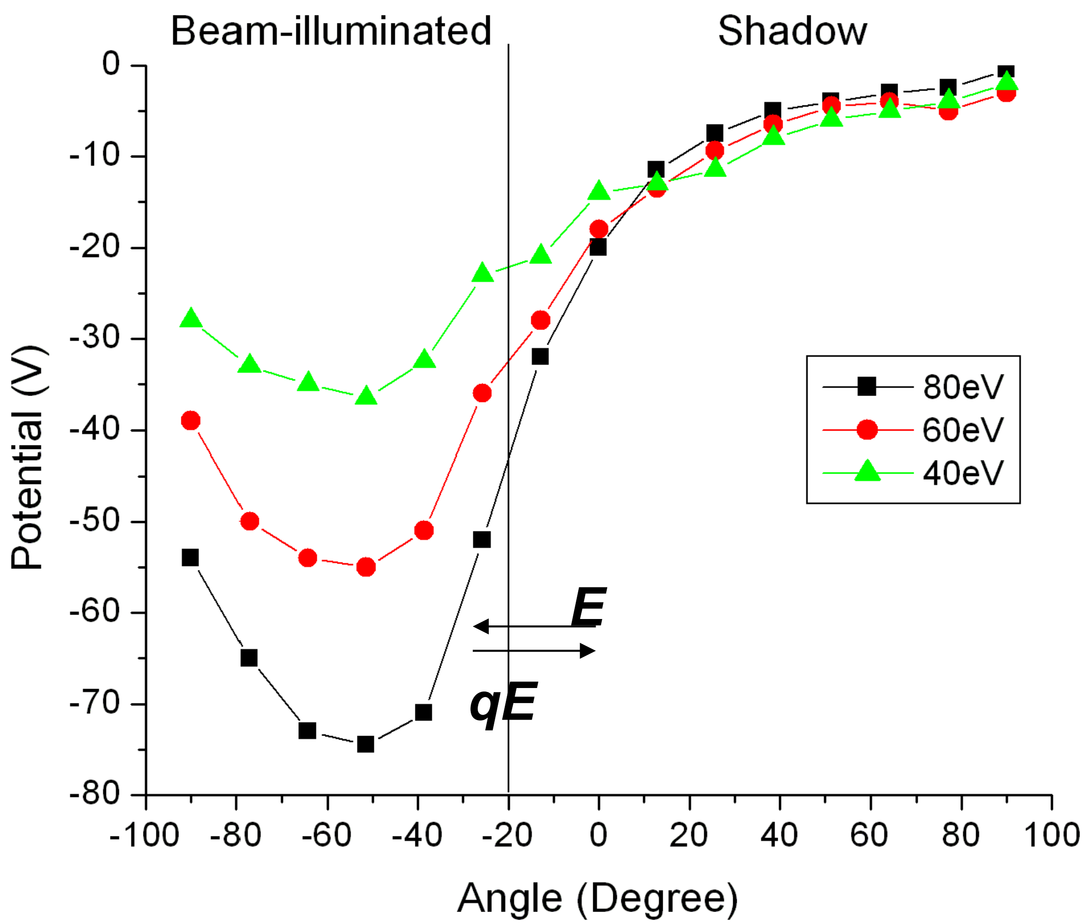

Potential on the beam-impacted slope follows the beam energy to be largely negative with respect to the potential on the shadowed slope.

Sheath potential profile across the half-pipe at 2 mm deep

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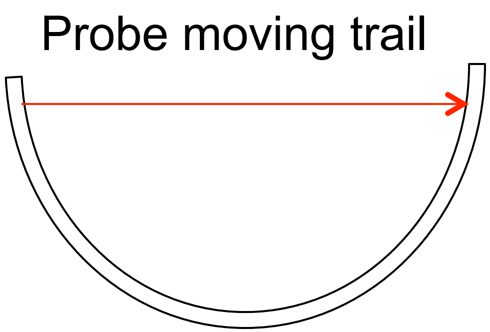

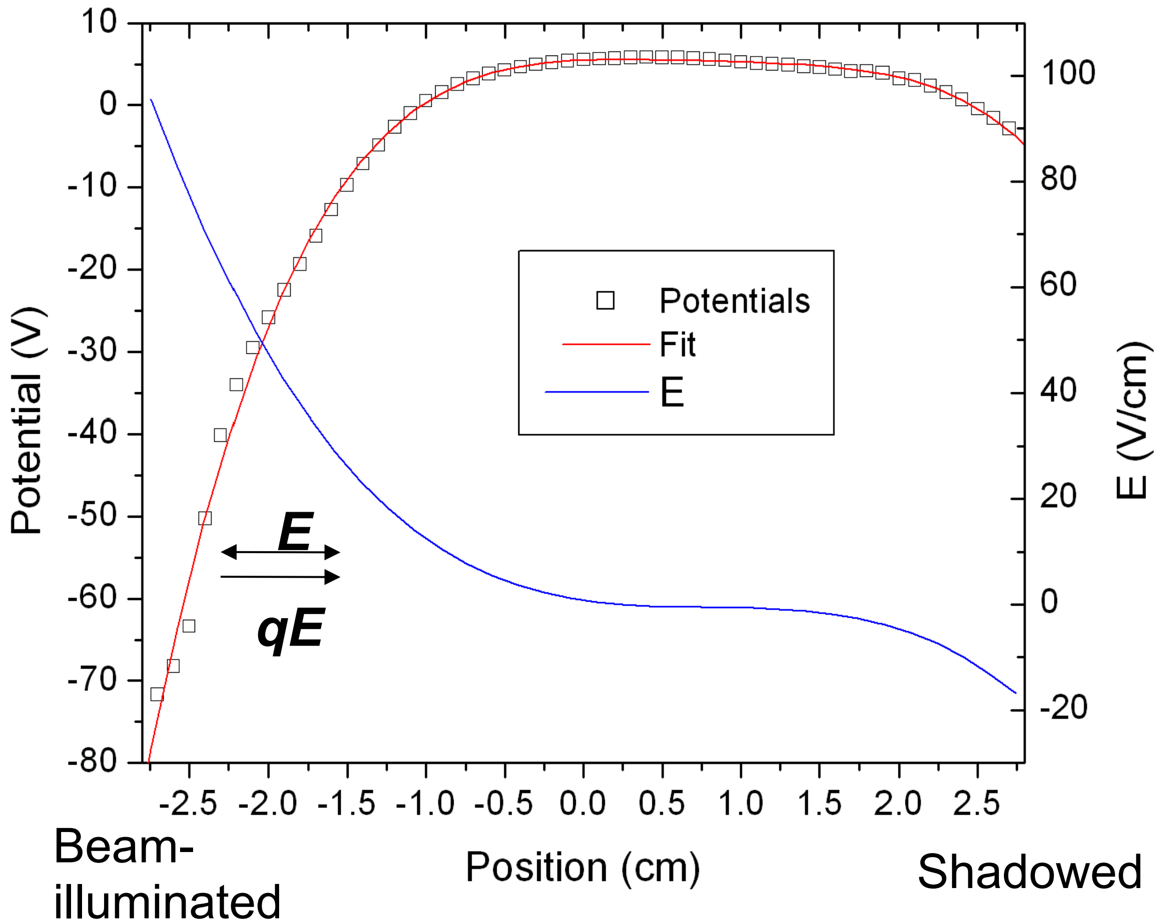

Electric field at the beam-impact surface is 5 times larger than that at the surface in shadow, leading to a higher possibility to lift dust off.

Still-images of dust transport

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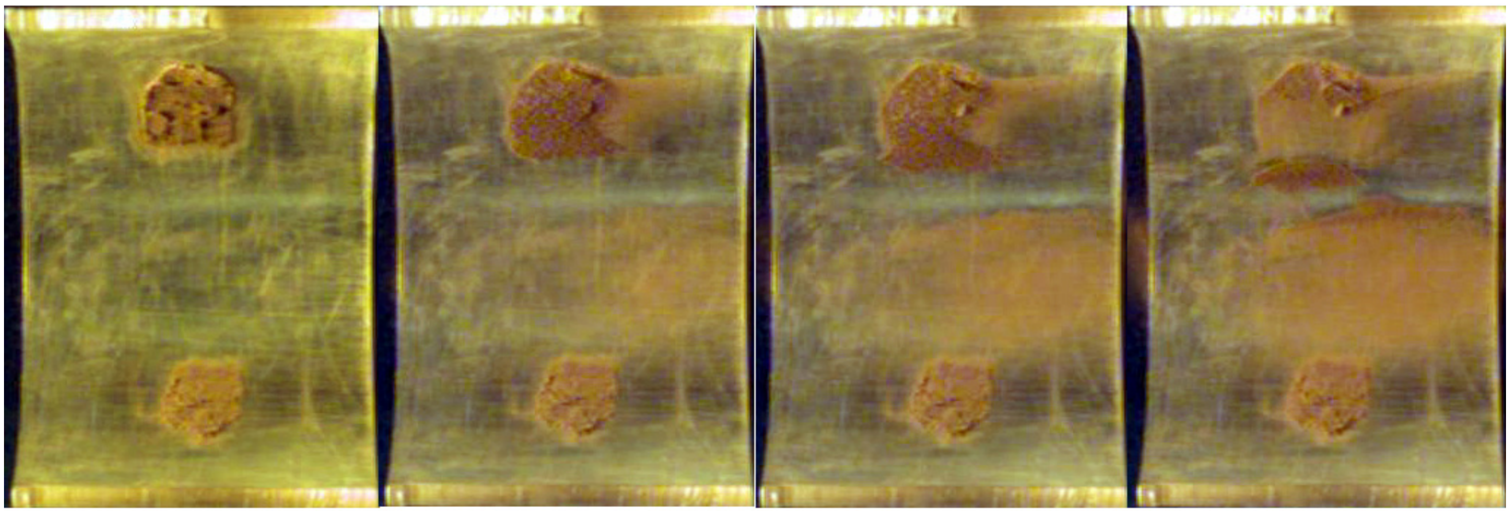

Beam-illuminated

Shadow

0 min   75 min   140 min   230 min

Dust particles on the beam-impacted slope move downhill and hop to the bottom but remain unmoved on the surface in shadow.

Summary

• We have shown that the electric potential distribution within a crater is very different depending on the crater radius relative to the ambient plasma shielding distance.

• The plasma shielding effect is larger for smaller craters, suggesting that smaller craters are more easily to trap dust particles transported from outside to form dust ponds.

• The high-energy electron flux obliquely incident upon an insulating cratered-surface caused dust particles on the beam-illuminated slope to move downhill to the bottom, suggesting another possible mechanism for formation of dust ponds.

Thank You