The possibility of dielectric breakdown weathering on airless bodies in the Solar System

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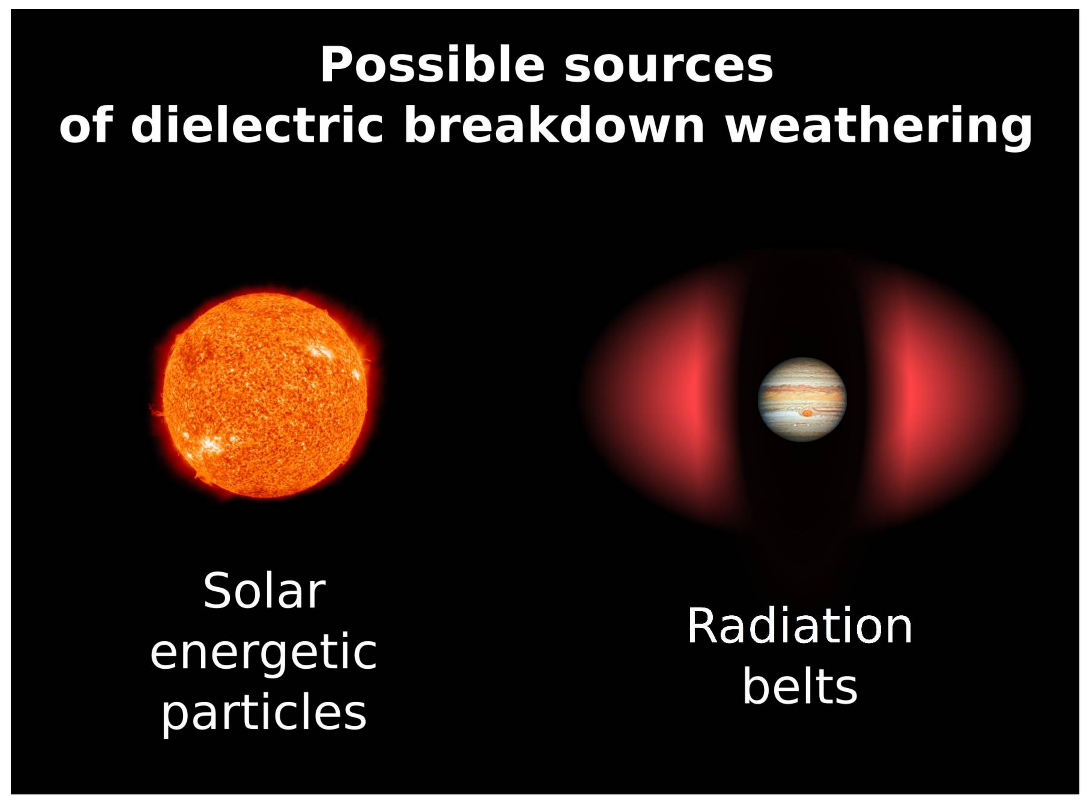
Dielectric breakdown, or "sparking", can occur in electrically insulating materials (dielectrics) exposed to high fluxes of energetic charged particles.

It is a well-known phenomenon in spacecraft dielectrics, but few studies have investigated whether it occurs on airless bodies exposed to high fluxes.

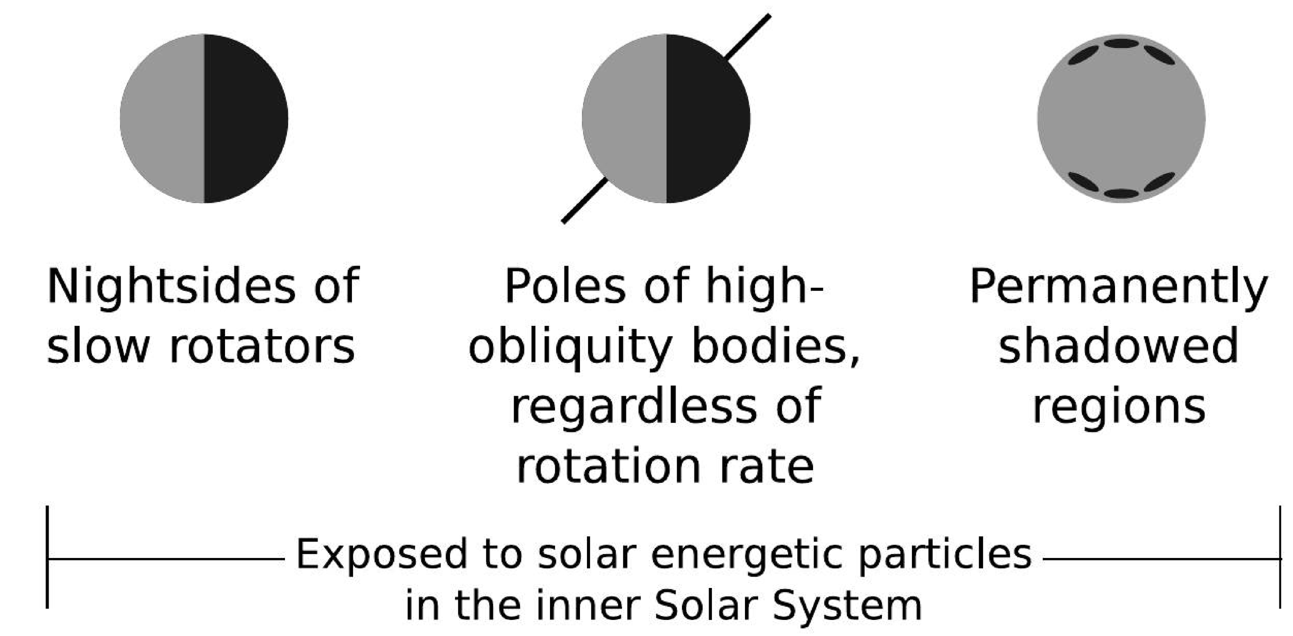
We review work that has been done and open questions.



Large solar energetic particle (SEP) events and planetary radiation belts (see left) have caused breakdown in spacecraft dielectrics (e.g., Fieseler et al., 2002) and may do the same in electrically insulating material on airless bodies.

Two things are needed for breakdown: a sufficiently long discharging timescale (which is longest in cold regoliths) and sufficiently high fluxes of energetic charged particles (see right).

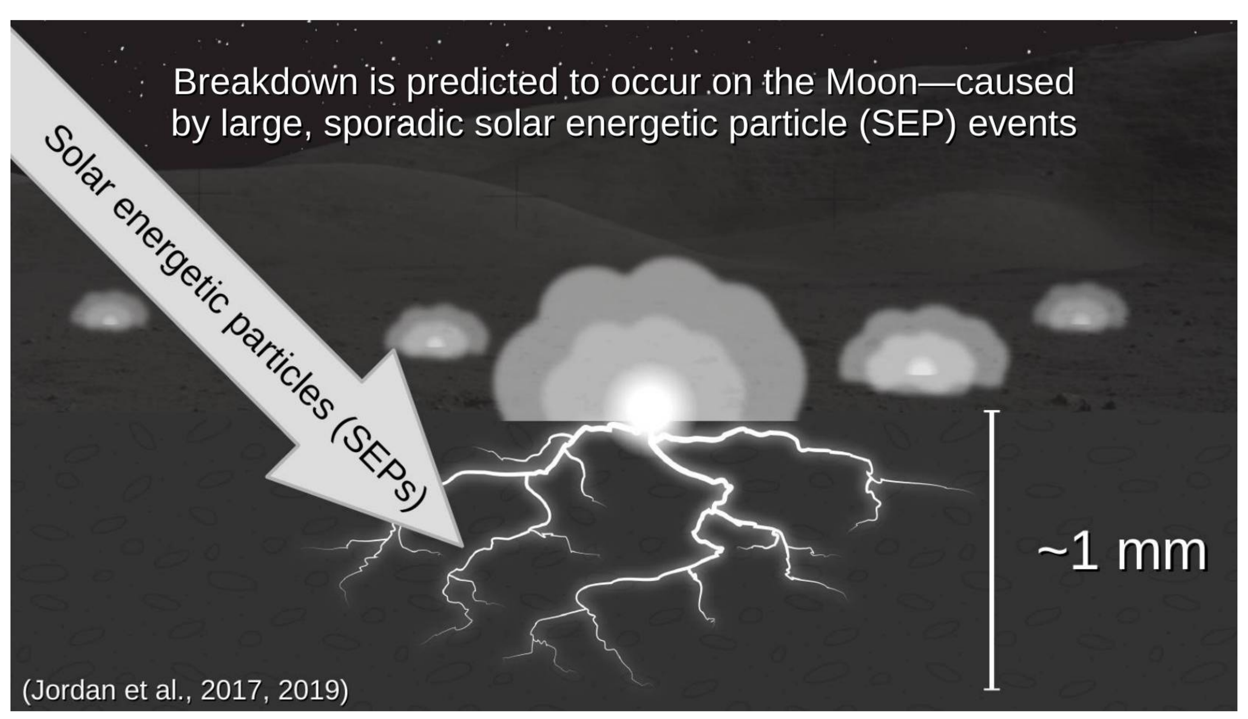
Locations where dielectric breakdown may be important



(Jordan, 2022)

Dielectric breakdown has been predicted to occur on the Moon in permanently shadowed regions (PSRs) and across much of its nightside during large SEP events (see right).

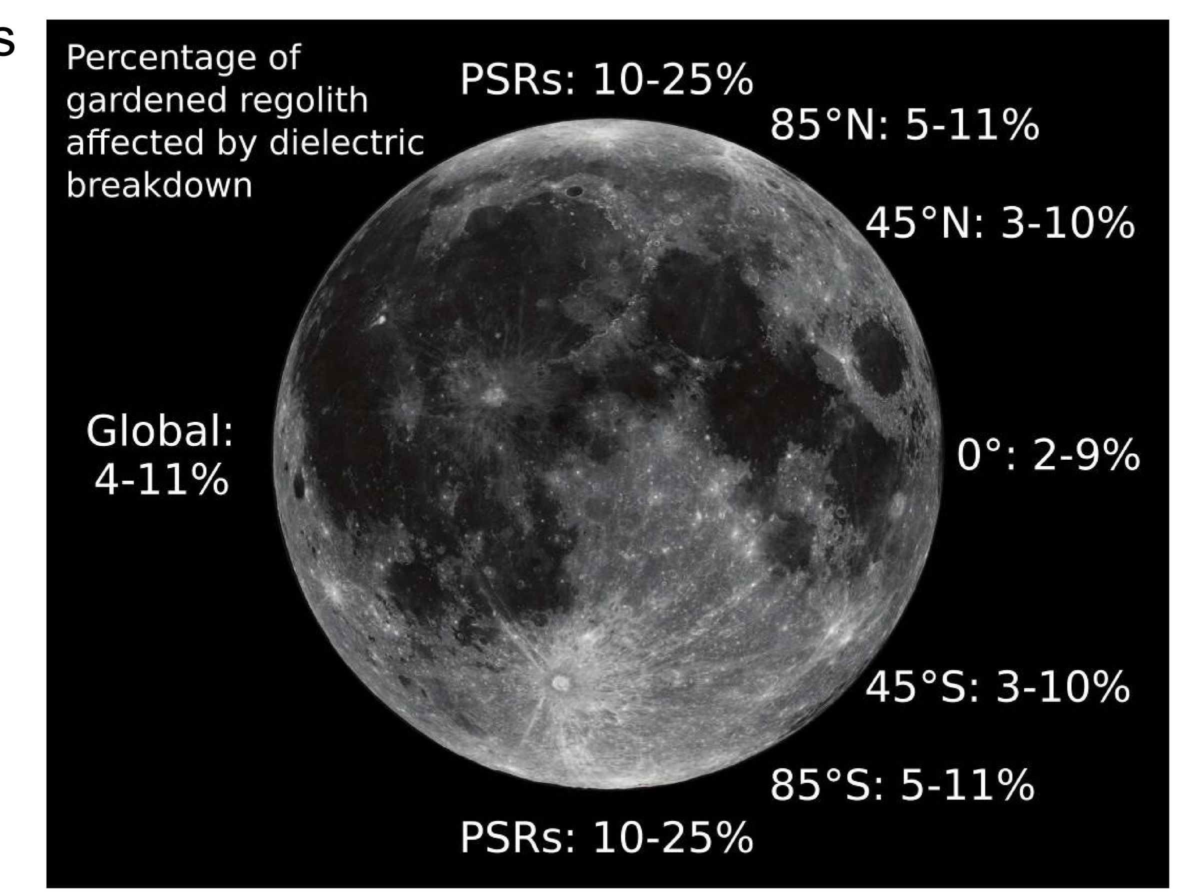
SEPs are isotropic at the Moon, as shown by observations by the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) onboard the Lunar Reconnaissance Orbiter (LRO).



Dielectric breakdown may occur in the top ~1 mm of lunar soil at temperatures <120 K (Jordan et al., 2014).

If so, then melting/vaporizing caused by breakdown (see left) may cause comminution and would drive optical maturation of the soil by creating submicroscopic iron; impact gardening would work these products deeper into the soil.

Breakdown weathering has been predicted to create an effect almost as significant as micrometeoroid impact weathering (see right).



(Jordan et al., 2019)

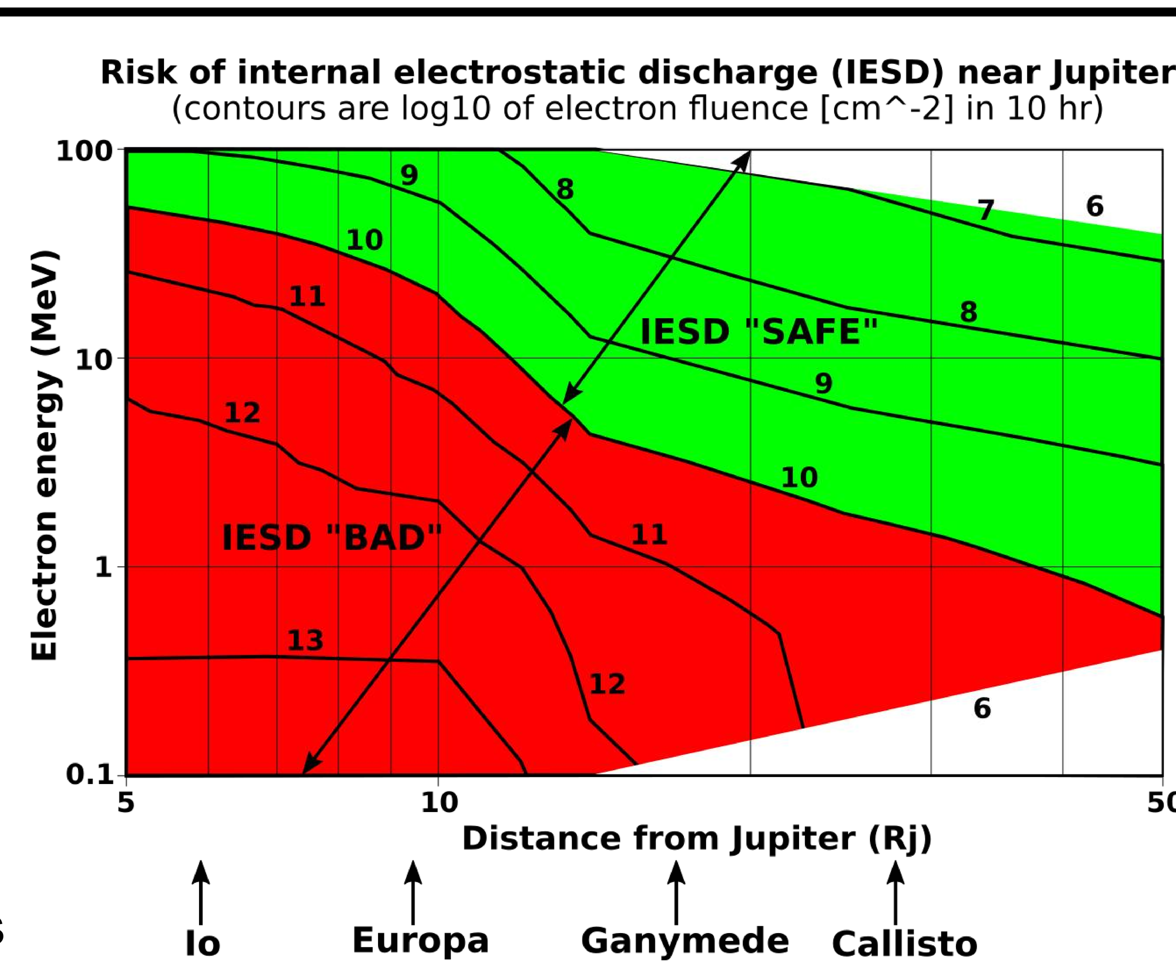
Possible evidence includes latitudinal and longitudinal variations in optical maturity (Jordan, 2021; Jordan et al., 2022) and the increased porosity observed in PSRs (Jordan et al., 2015; Byron et al., 2019).

We are in the process of investigating the causes and effects of breakdown in the lab (e.g., MacLeod et al., in prep.). Stay tuned!

Jupiter's innermost moons are exposed to a more intense and continuous radiation environment than any other airless bodies in the Solar System.

Jupiter's radiation belts have caused repeated dielectric breakdown in components of the Voyager 1 and Galileo spacecraft (Leung et al., 1986; Garrett and Evans, 2001; Fieseler et al., 2002).

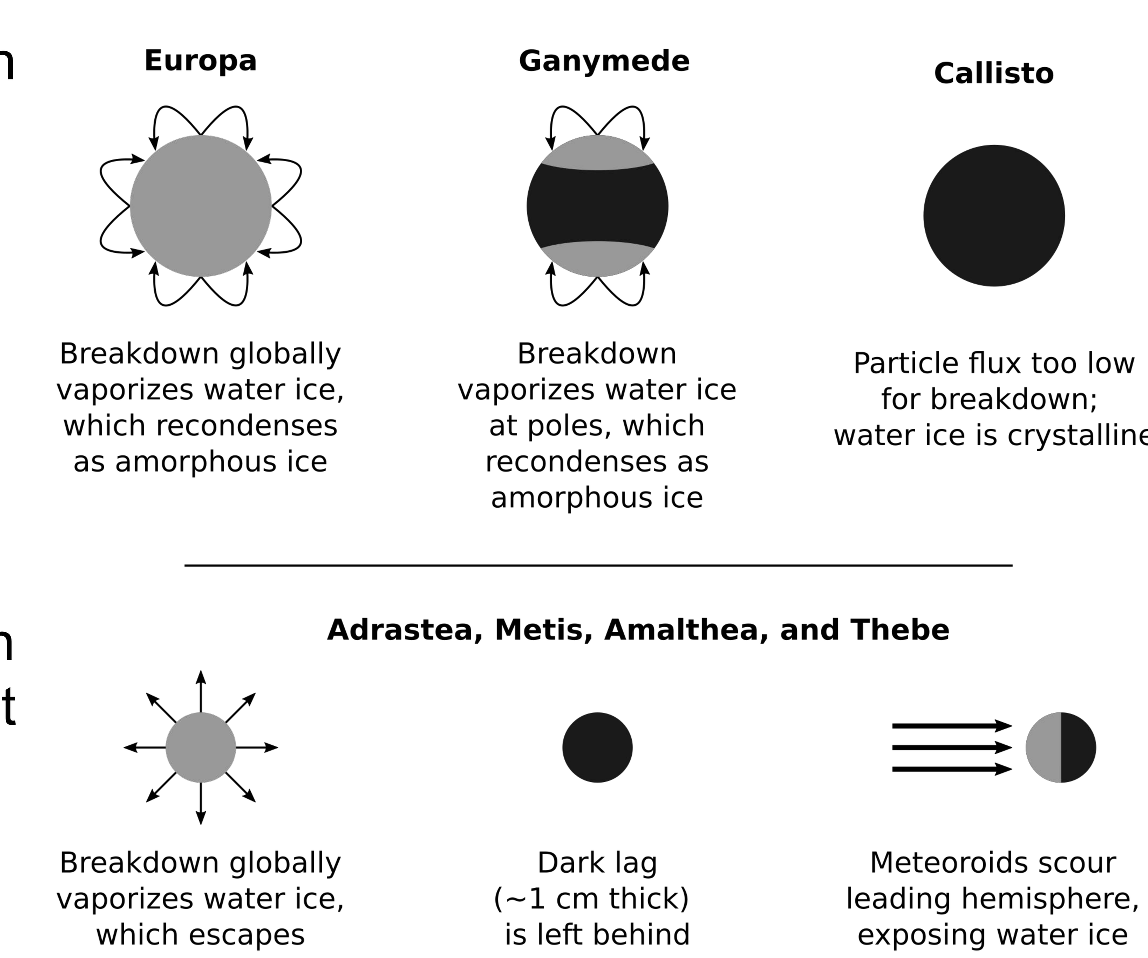
Breakdown in spacecraft dielectrics is a hazard throughout Jupiter's belts (see right).



(adapted from Garret et al., 2012)

Experiments show that breakdown may occur on Io (Campins and Krider, 1989), and the process may help explain where water ice is amorphous on the Galilean moons (see right).

Closer to Jupiter, fluxes are sufficient to cause breakdown in ~100 s, possibly helping to explain why at least three of the innermost moons (Thebe, Amalthea, and Metis) have leading hemispheres that are 30% brighter than the trailing (Jordan, 2022; see right).



Conclusions

Dielectric breakdown may be an important space weathering process on airless bodies exposed to high fluxes of solar energetic particles or to radiation belts.

Experiments are critical to understand how breakdown weathering alters the materials found on these airless bodies.