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Space Weathering On Mercury

Definition

- Space weathering describes a set of processes and their effects on the physical, chemical, and mineralogical properties of regoliths on airless bodies.
- Space weathering on Mercury is informed by lunar, asteroid, and laboratory studies, however:

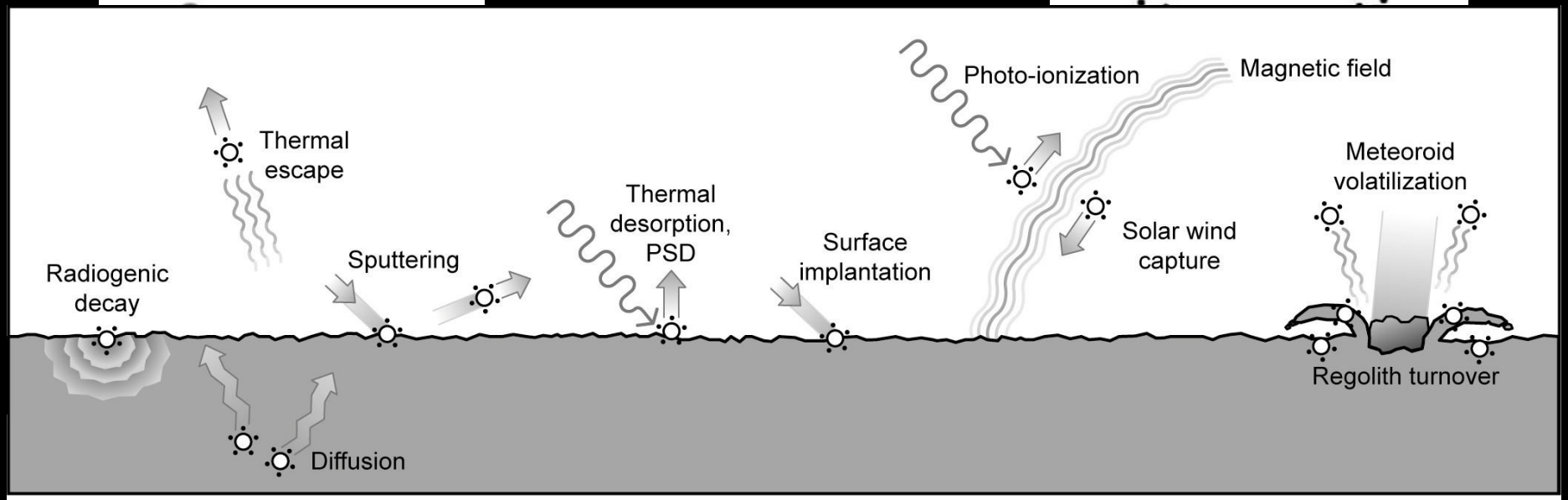
Space weathering on Mercury will be influenced by Mercury's unique environment and composition

Approach

- Examine each process and look at how each affects the surface of the Moon and asteroids
- Look at laboratory simulations of the space weathering process.
- Re-examine each process at Mercury, keeping in mind the unique conditions and environment of this planet

The Processes

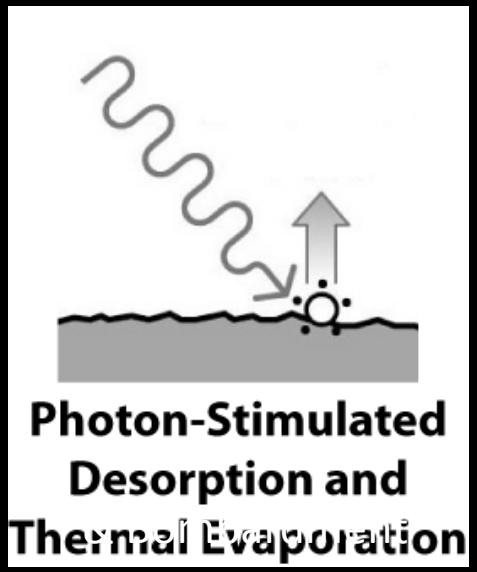
Same as those involved in the formation of Mercury's Exoshpere

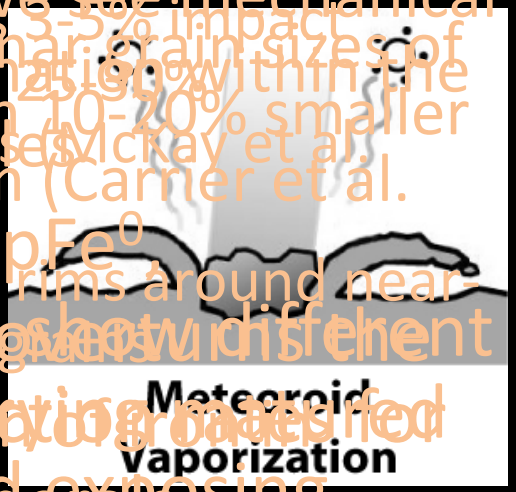


Low Energy **High Energy**

Mineralogical Changes

Same as those involved in the formation of Mercury's Exosphere



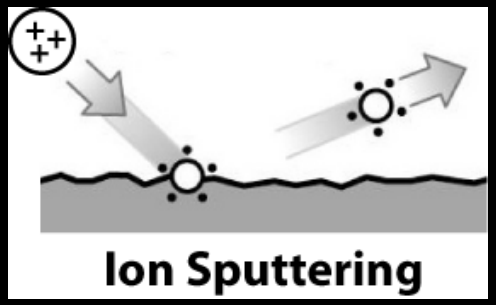


Low Energy

High Energy

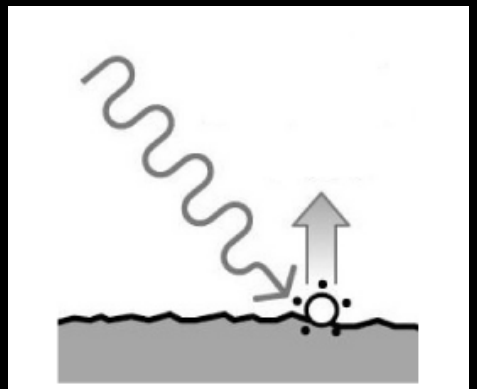
- Different minerals grind down at different rates and smaller pieces
  - On Moon we see mechanical sizes and 25-30% within the largest samples (Carrier et al. 1991)
  - Average lunar grain sizes of 20 µm with 10-20% smaller than 20 µm (Carrier et al. 1991)
- Rinds with $npFe^0$
  - Deposits as rims around near-spherical glass
- Experiments show different mineral and exposing fresher
  - Formation of sub-microscopic (nanometer scale) particles of iron, $npFe^0$
- Reduces volatile content

Physical Changes – Chemical/Mineralogical Changes



- Implantation of solar wind species (such as H and He) can produce a reducing environment
- Sputtering of material de-volatilizes surface materials
- Hydration of upper layers of surface grains
- Different minerals grind down at different rates
  - On Moon we see mechanical speciation with the lunar samples
- Rinds with $npFe^0$ experiments show different $npFe^0$ production rates for different minerals
- Reduces volatile content

Chemical/Mineralogical Changes



- Darkening of materials; lowers the intrinsic albedo
- Reduction of materials
- Oswald ripening of grains (esp. $npFe^0$)

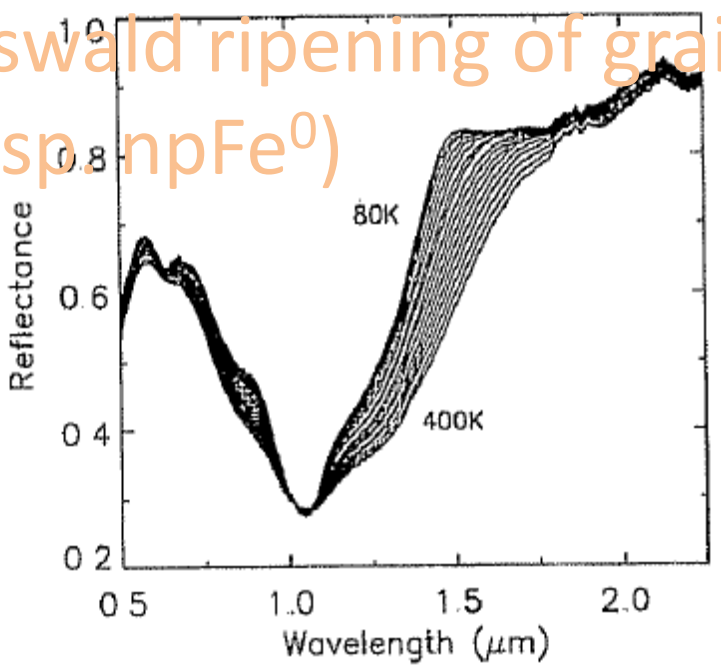


Figure 1 Reflectance vs. wavelength for forsteritic olivine (Fo_{88}) for cavity temperatures of 80 K to 400 K. Grain size 32-63 μm wet sieved. Sample courtesy of L. Moroz

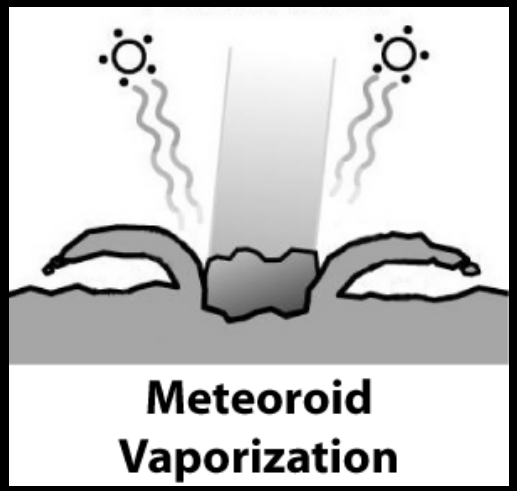
Laboratory Experiments

- Micrometeorite bombardment has been simulated in laser oblation experiments (Moroz et al. 1996, Yamada et al. 1999, Sasaki et al. 2001, 2002, Sasaki and Hiroi 2003, Brunetto et al. 2006)
- Ion bombardment has been simulated in ion radiation experiments (Brunetto and Strazzulla 2005, Marchi et al. 2005, Strazzulla et al. 2005, Brunetto et al. 2006)
- $npFe^0$ has been produced in these laboratory simulations, supporting the role of these particles in producing the effects attributed to space weathering.

Laser and Ion Irradiation

- Mostly targeted to explain/understand the weathering process on asteroids
  - Lower micrometeorite impact velocity than experience on Moon
  - Relative roles of ion versus micrometeorite bombardment
- All minerals do not weather the same:
  - Sasaki et al. (2002) irradiated low-iron olivine and pyroxene with nanopulse laser: olivine showed larger spectral changes
  - Marchi et al. (2005) ion irradiated low-iron olivine and pyroxene: olivine showed larger spectral changes
- The rate and magnitude of weathering is mineral dependent

Mercury



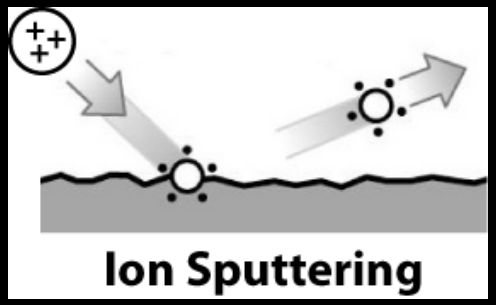
& Bombardment

- Fluxes:
  - Cintala (1992) predicted 5.5 times more flux at Mercury than the Moon
  - Borin et al. (2009) predict 76 times greater flux than Cintala's prediction
  - Mouawad et al. (2010) show mismatch w/Borin predict & exospheric sodium ion abundance from impact vaporization. They predict ~6 times that calcuated by Cintala
- Impact velocities
  - Moon: 12.75 km/s (Cintala 1992)
  - Mercury: 20.5 km/s (Cintala 1992) 16.81 km/s (Borin et al. 2009)
- Glass, agglutinate, & vapor production
  - 14 times more melt, 20 times more vapor produced at Mercury compared to Moon (Cintala 1992)
  - 0.06 to 5 time more than Cintala's calculation (Morgan et al. 1988, Mouawad et al. 2010)

Predictions

- Higher glass and agglutinate production
  - 3-5% impact glass on Moon, 25-30% agglutinates on Moon
  - Cintala (conservative prediction) suggests 14 times more melt….glass and agglutinates could comprise more than 50% of the regolith
- Increased vapor rim production
  - Thicker coatings?
  - What type of nano-scale particles will there be?

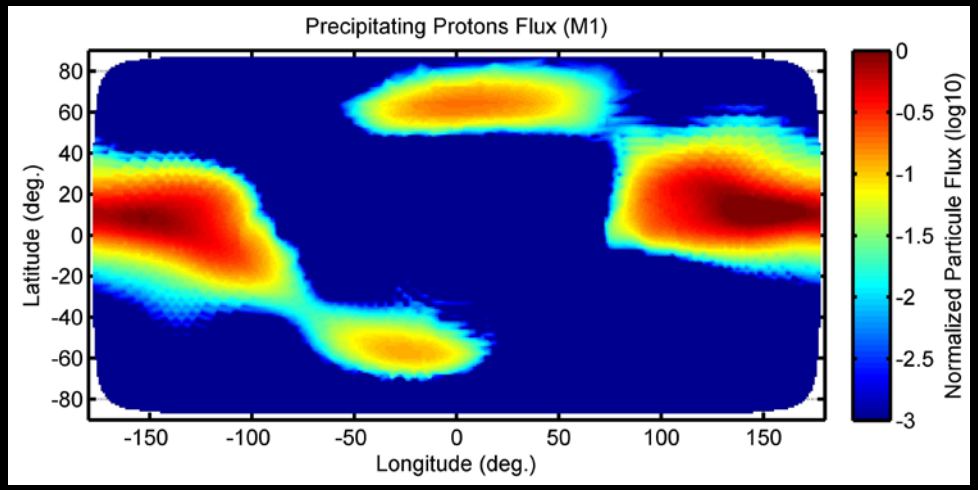
Mercury

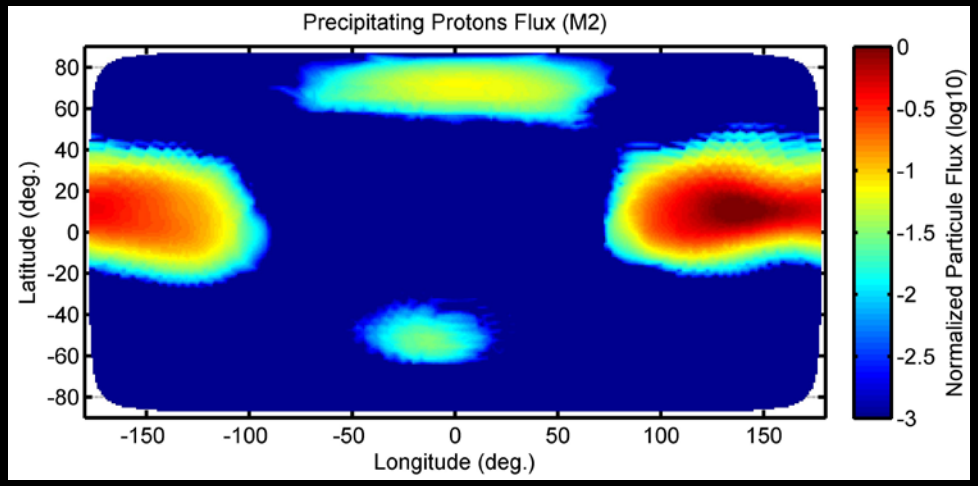


& Implantation

- Ions need to reach the surface, with some flux and velocity, to sputter and implant materials…
- Mercury has an intrinsic magnetic field so…
- What can make it to the surface?

Environment



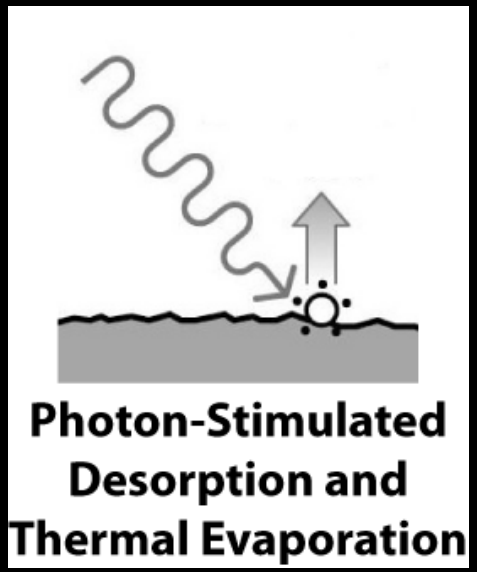


- Particles can make it to the surface
- Not just during re-connection events
- Most of the action is happening on the night side from the tail region
- No obvious latitudinal dependence to the ion bombardment flux

Predictions

- Closer to the Sun, thus higher density of solar wind species interacting with the Mercury system
- Need to quantify the rates of implantation and sputtering compared to the Moon in terms of:
  - Ion species present
  - Flux and velocity
- More reducing environment?

Mercury



- Burger et al. (2010) found that the primary source of sodium during the M1 flyby was PSD by solar UV radiation
- Higher flux of UV solar radiation at Mercury than at the Moon
- Higher temperatures are experienced at Mercury than the Moon

Predictions

- Higher UV radiation will increase the rate and role of PSD in modifying the regolith (release of volatiles)
- Higher thermal temperatures will lower the albedo of minerals compared to the Moon
- Oswald ripening will coarsen or enhance grain growth

Composition

- These processes are all composition dependent
  - Mechanical fractionation
  - Production of $npFe^0$, native Fe & Ti
  - Glass & agglutinate properties
- Mercury and the Moon are not compositionally the same
  - low abundance of Fe-bearing silicates
  - Fe and Ti are present
    - NS observations (Lawrence et al. 2010) indicate 8-22 Fe-equivalent wt%,or 3-8 T-equivalent wt%, or 14 & 5 Fe-Ti-combined wt% (respectively).
    - MDIS color observations indicate presence of Fe-Ti opaque oxides (such as illmenite or ulvospinel) of 15 to 40 vol%
  - Abundances of glass and agglutinates
    - What is the composition of these compared to the Moon?
    - Are they more ‘reduced’?

NOTES

- Role of composition
  - Nano-scale materials
  - Form of iron (silicate, opaques, glasses)
  - Process effects
- Time
  - Magnetic field characteristics
  - Solar wind characteristics
  - Regolith formation/processing