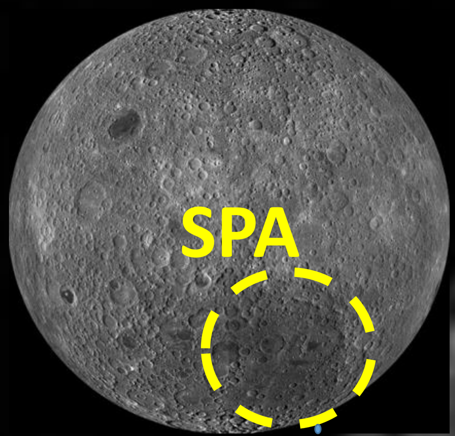
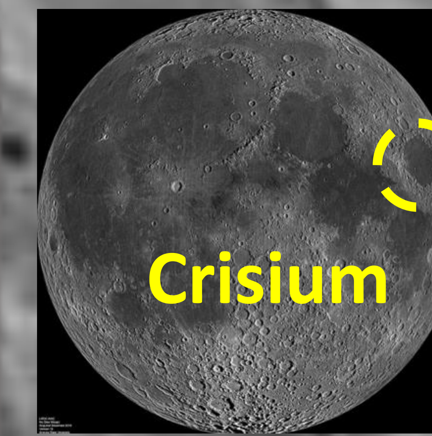


CORRELATING SWIRLS WITH PARTICLE TRACKING SIMULATIONS AT LUNAR MAGNETIC ANOMALIES IN SOUTH POLE-AITKEN BASIN AND MARE CRISIUM



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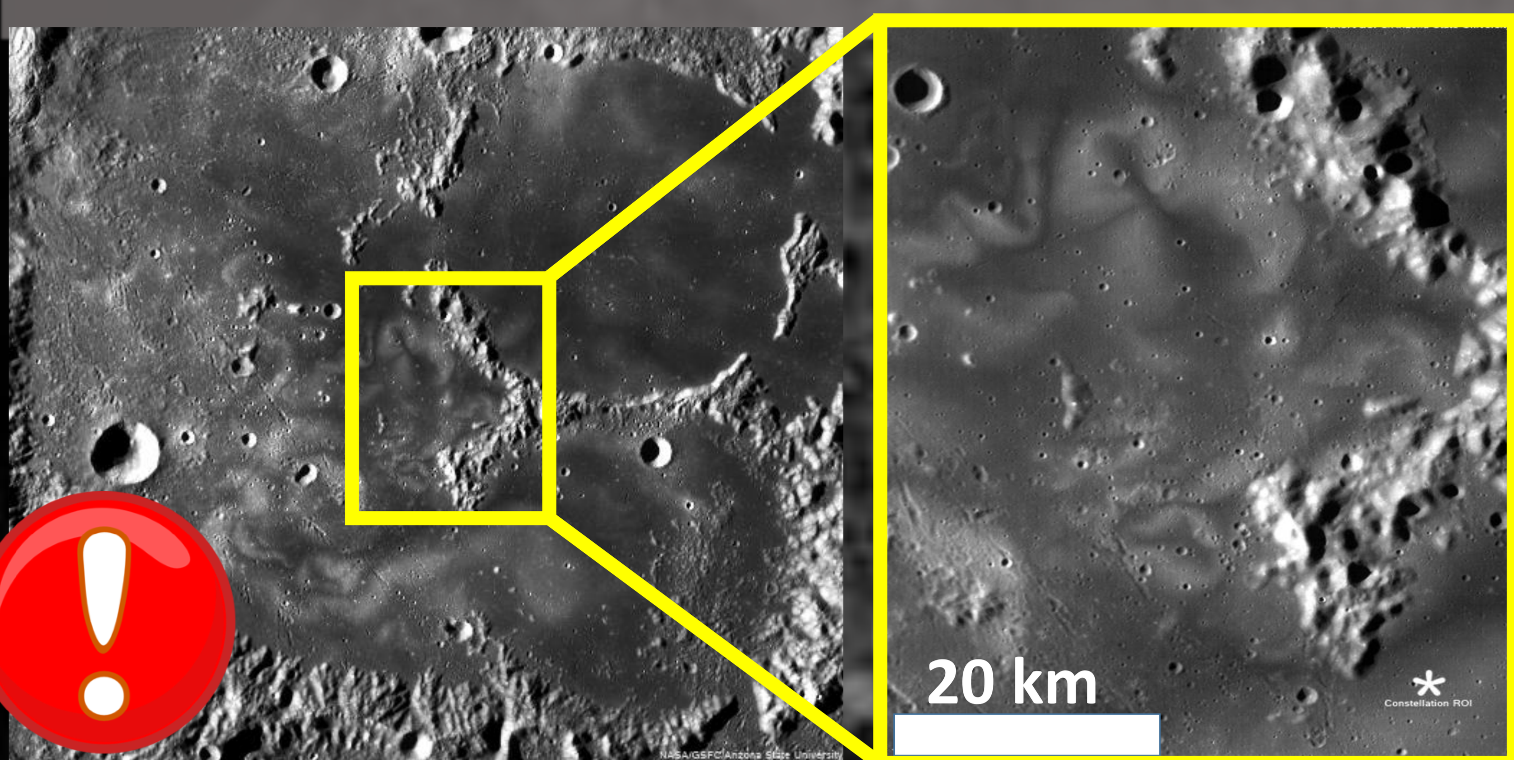


Figure 1. LRO WAC image of swirls in Mare Ingenii.

Begin here and follow white swirl path

What are lunar swirls?

- High albedo, curvilinear surface features, unrelated to topography (Fig. 1).
- Associated with magnetic anomalies. **But not every anomaly has an identified swirl!**
- Optically immature.

Study goals

- Map swirls in South Pole-Aitken (SPA) basin.
- Run particle tracking simulations (see explanation in box at bottom right of poster).
- Correlate particle tracking results with SPA map.
- Use particle tracking to find swirls at Mare Crisium.

Study sites

South Pole-Aitken is the largest lunar basin located on the far side of the Moon. It has a complex magnetic anomaly with variable intensities across its extent. Prominent swirls have been mapped in this area before [1][3][6]. We extend the swirl mapping to cover the entire basin and map previously unmapped swirls.

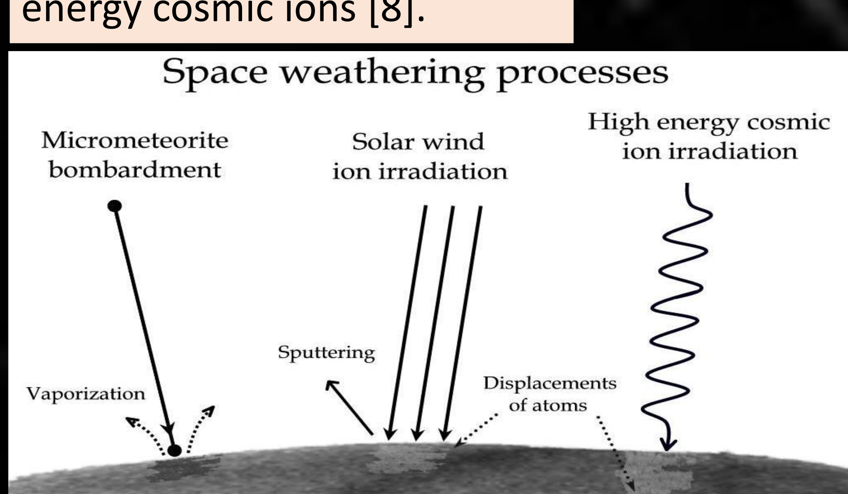
Mare Crisium coincides with one of the moderate magnetic anomalies (~5nT at 40km elevation) [2][7], and is notable for the lack of swirls – which is why we chose to investigate this region.

Solar wind shielding model

Leading theory for swirl formation. It suggests that:

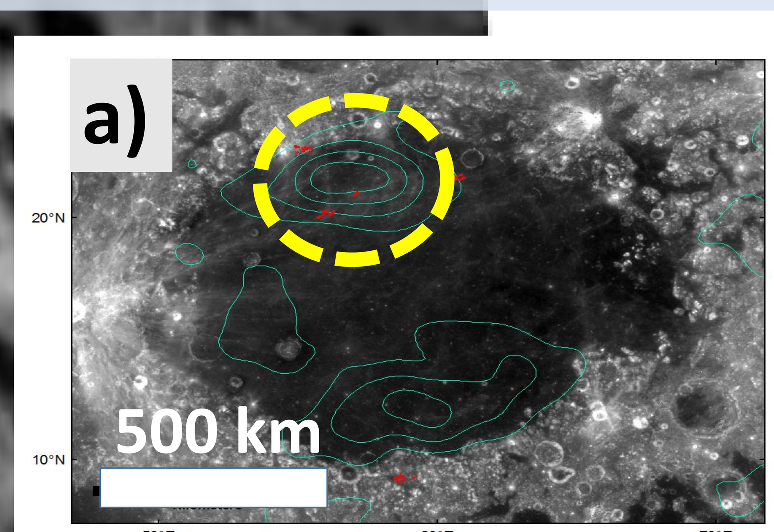
- Magnetic anomalies protects the surface regolith by deflecting solar wind ions [1].
- Swirl surfaces appear immature by inhibiting formation of nanophase iron ($npFe^0$) by solar wind ions (see "Space Weathering" at right).

Figure 2. Schematic showing the causes of space weathering and the resulting processes: Vaporization due to micrometeorite bombardment; sputtering and displacement of atoms due to solar wind ions and high energy cosmic ions [8].



Mare Crisium results

There are two locations where the field strengths reach local maximums - in the north and south of the mare (see contours in Fig. 5a). Particle tracking showed a weak deflection of particles only on the stronger northeastern part (Fig. 5b). Possible swirls (outline in red in Fig. 5a) were found on the northeastern edge of the mare, coincident with the low particle density region (Fig. 5b). However, the signals are very faint and inconclusive.



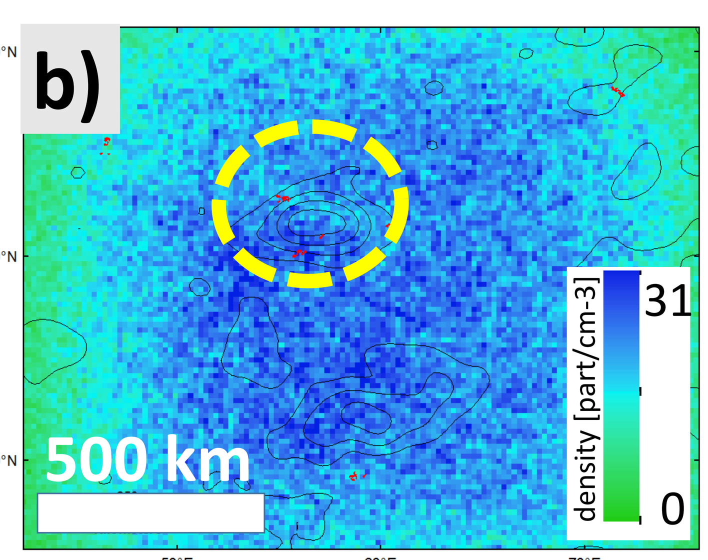
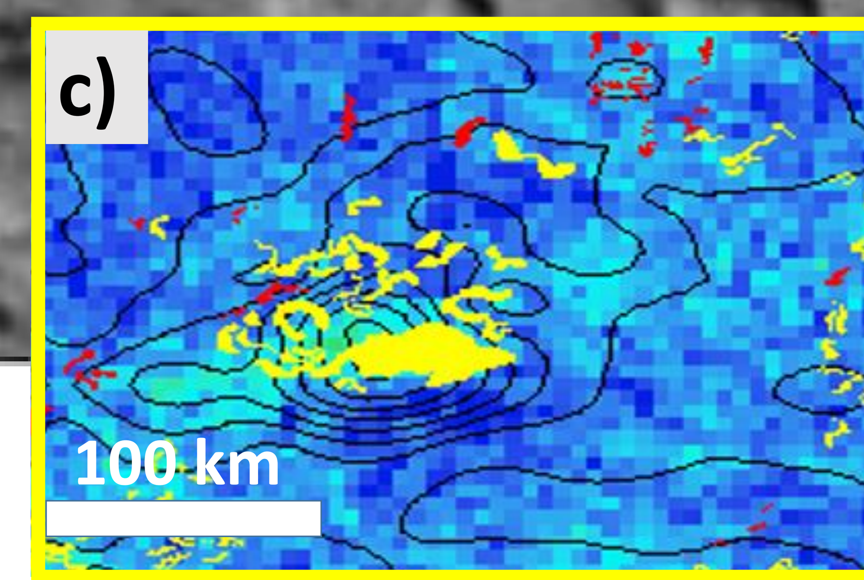
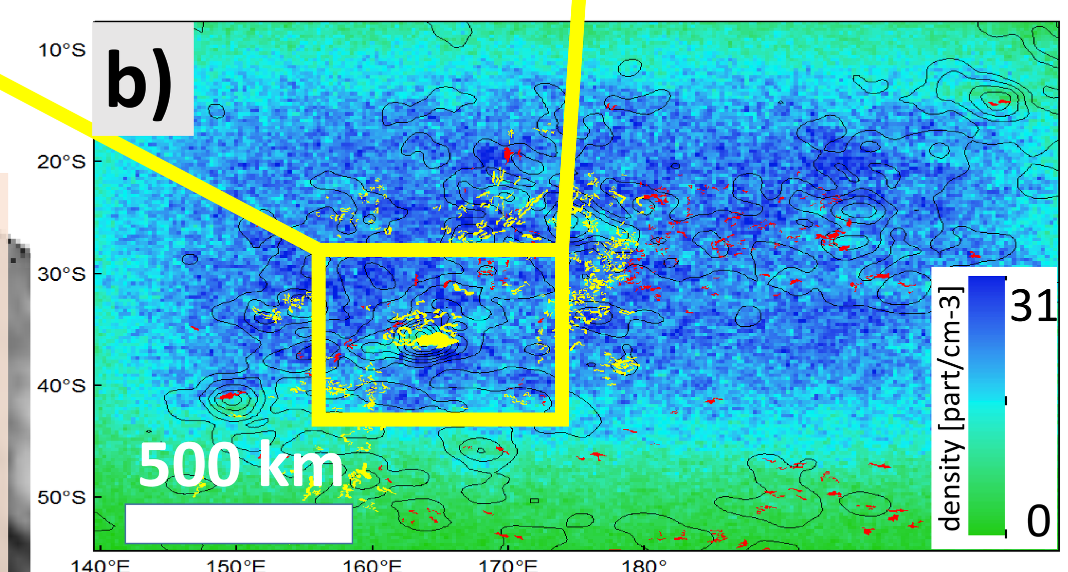


Figure 5. a) 643 nm normalized WAC image of Mare Crisium overlain with mapped swirls (red) and isoTeslas at 5 nT (green). b) Particle density map. Yellow circled areas show the only significant low particle flux in the mare.

SPA results

Figure 4 shows swirls mapped in this study (red) with swirls mapped by [6] (yellow). The SPA magnetic anomaly (black contours in Figs. 4b,c) consists of multiple mini-anomalies, where particle tracking results showed significant proton deflection. Swirl locations coincide with these sites of low particle fluxes and densities very well (Fig. 4b,c).





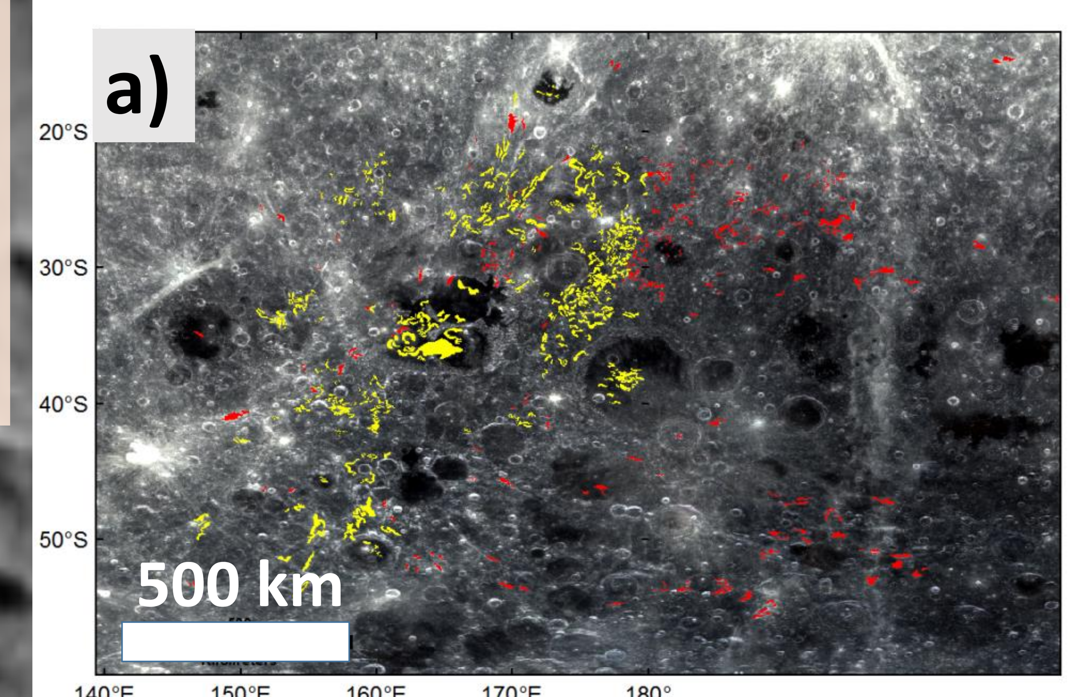


Figure 4. a) 643 nm normalized WAC image of SPA and mapped swirls. In red: swirls mapped in this study; in yellow: swirls mapped by [6]. b) Particle tracking results showing particle density map overlain with mapped swirls and isoTeslas in black (contours are 5 nT). c) Close up view of (b) shows a prominent swirl coincident with a significant particle density cavity as well as a high magnetic field strength area.

Summary and conclusions

South Pole-Aitken:

Strong proton deflection -> many large swirls

Swirls match low particle density areas -> support solar wind shielding hypothesis

Crisium:

Weak deflection -> no distinct swirls found

Radial magnetic field and/or weak coherence -> no strong proton deflection

Weaker magnetic field than at SPA & field structure can explain the lack of swirls

Space weathering

The Moon is constantly bombarded by micrometeorites and solar wind particles due to the lack of an atmosphere and a global magnetic field. The process that causes physical and chemical changes in the regolith due to these influences is termed space weathering (Fig. 2). Formation of nanophase iron ($npFe^0$) - by reduction of ferrous iron - is one of these changes. $NpFe^0$ is responsible for the changes in the optical properties of the regolith that has been exposed to space weathering, which includes a decrease in overall reflectance, increase in spectral slope, and reduced absorption band depths [4] (Fig. 3).

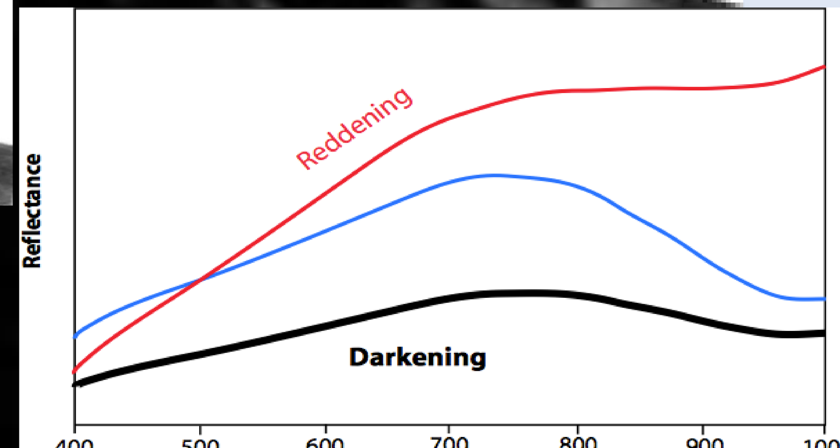


Figure 3. The spectral effects of space weathering.

Particle tracking simulation

The simulation used models of the magnetic field obtained from http://www.planetary-mag.net [5]. 400,000 non-interacting protons were launched on the magnetic anomaly of Mare Crisium, and 800,000 for SPA due to the larger extent of the area. Protons were chosen for the simulations because they are considered the primary reducing agents for the formation of npFe0 [3] [5]. They were tracked until they impacted on the surface or left the simulation area due to deflection by the field. Density and flux maps generated from the simulation results were normalized to nominal solar wind densities at 1 AU of 5 particles/cm^3.

References: [1] Hood & Williams (1989) PLPSC 19. [2] Blewett et al., (2011) JGR 116.E2. [3] Kramer et al., (2011) JGR 116.E4. [4] Pieters & Noble (2016) JGR 121, 1865–1884. [5] Harnett et al., (2016) arXiv preprint arXiv:1605.05778. [6] Denevi et al., (2016) Icarus 273: 53-67. [7] Purucker & Nicholas (2010) JGR 115.E12. [8] image taken from http://l3.dmf.unisalento.it