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2019

The Undeniable Attraction of Lunar Swirls

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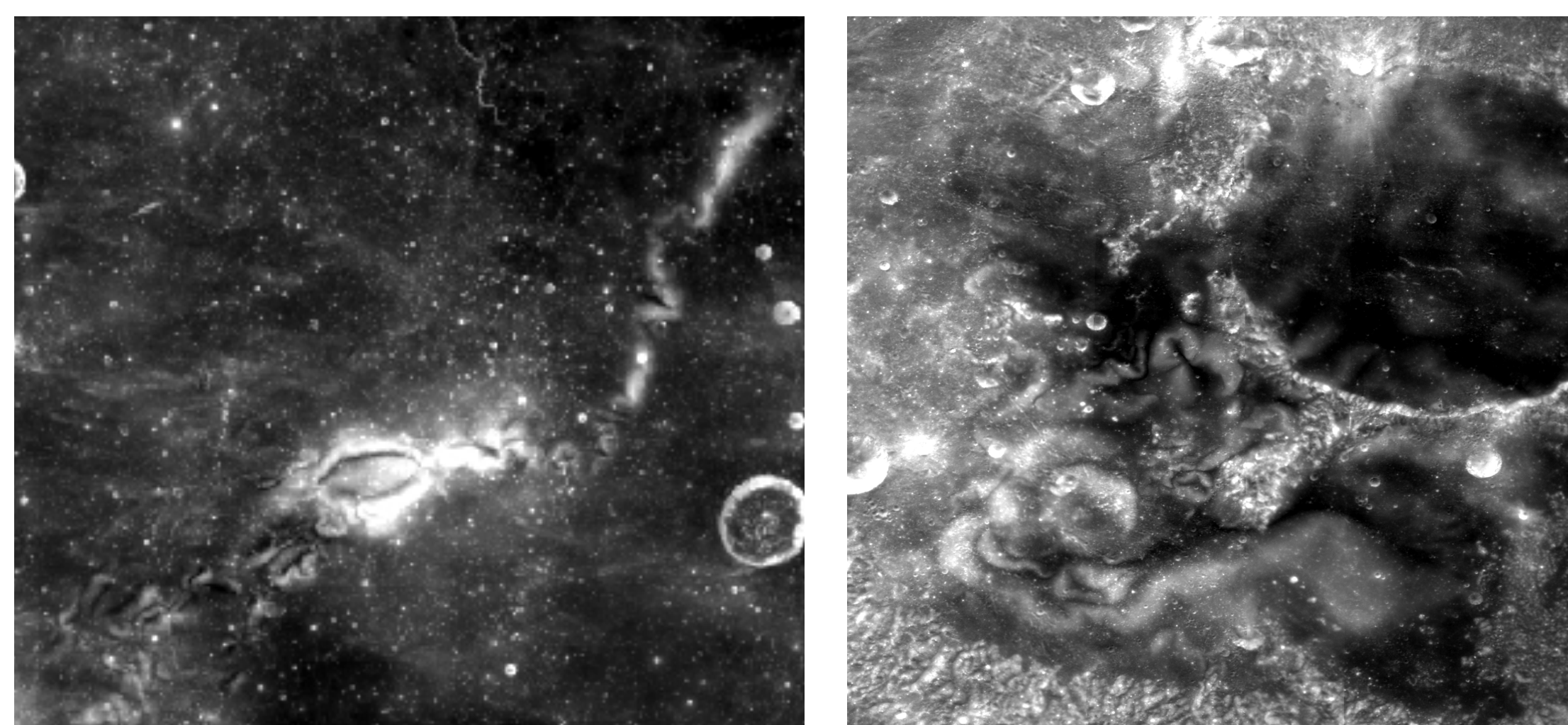
Recommended Citation

Waller, Dany, "The Undeniable Attraction of Lunar Swirls" (2019). *Posters-at-the-Capitol Presentations*. 11. https://uknowledge.uky.edu/capitol_present/11

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Introduction

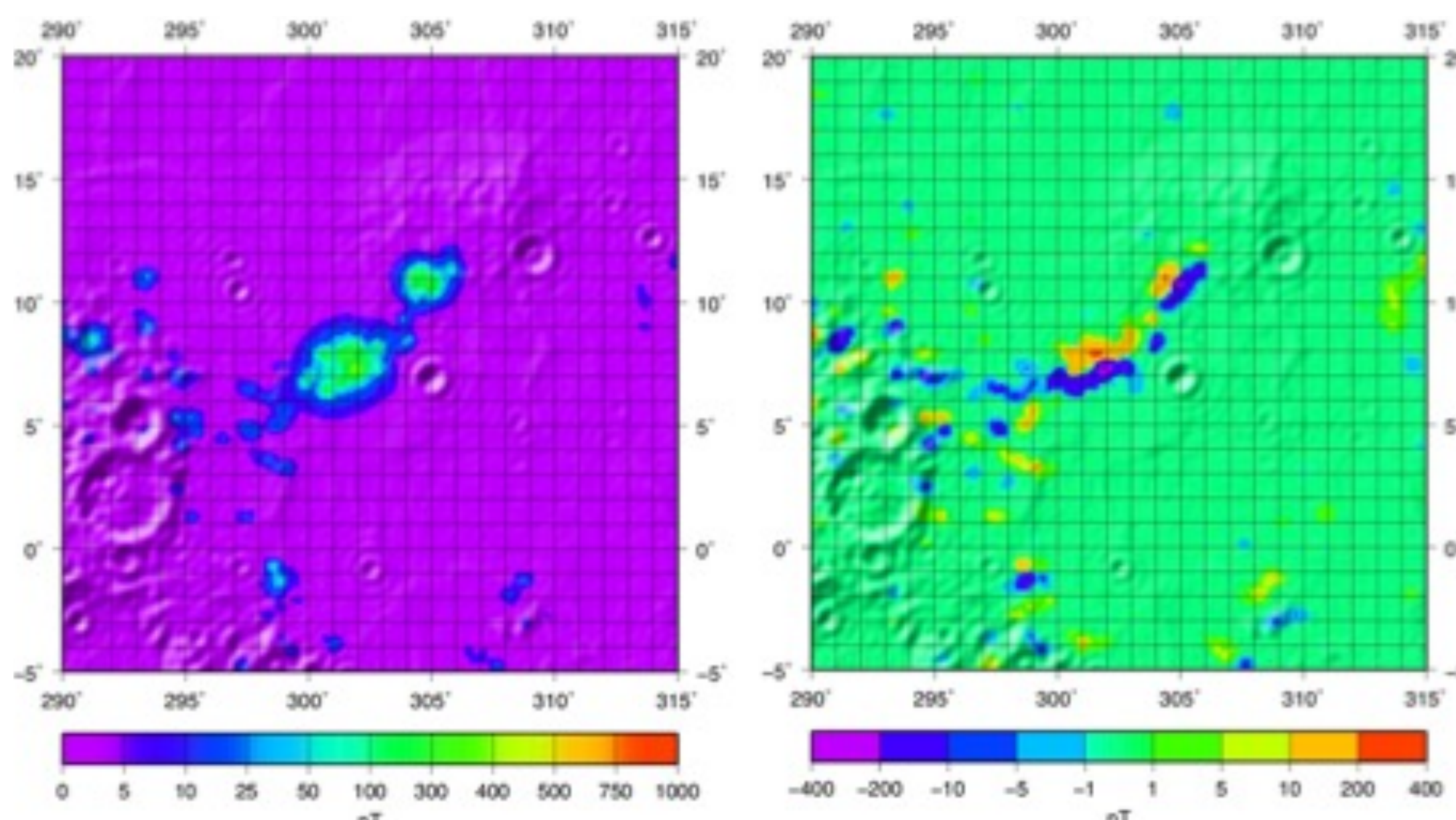
Lunar swirls are complex optical structures that occur across the entire surface of the moon. They are associated with magnetic anomalies, which may dictate the formation pattern and affect the optical brightness of these anomalies. Swirls are thought to be a product of delayed solar weathering, due to the differences in soil composition and reflectance ratios between the swirl and its surrounding regolith.



Left, the swirl known as “Reiner Gamma” displays a more complex structure than its neighboring craters. Right, the swirl overlaying Mare Ingenii is more diffuse and less symmetric than Reiner Gamma (images from Clementine, 750nm wavelength).

The magnetic anomalies associated with lunar swirls are measurable from satellite altitude, and vary in the presence of solar wind. Over the past two years, this project has focused on refining satellite data to produce high resolution magnetic maps of the moon.

Lunar Prospector data was refined by selecting for data least exposed to solar wind, removing artefacts by visual selection, and final data selection from along-track gradient processing.



This is a map of the magnetic anomaly at Reiner Gamma using select Lunar Prospector data, modeled at 1km above the surface. (B_{total} right, B_{θ} left; downward continuation produced by D. Ravat).

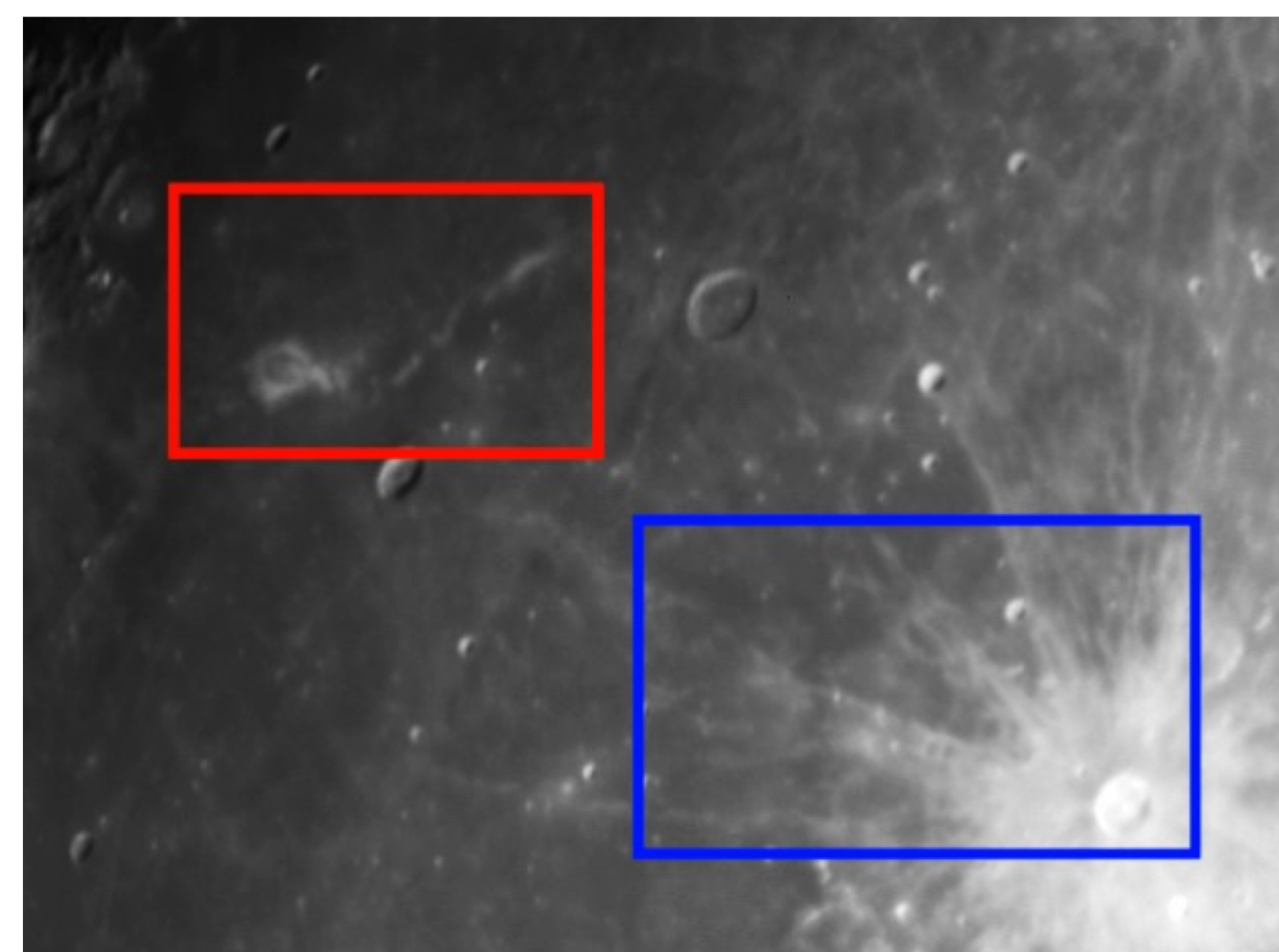
Solar Weathering and Standoff

Lunar swirls possess a unique difference in albedo, or reflectance, from the surrounding soil. This bright pattern is often associated with new impact craters, as it is indicative of freshly exposed silicate materials on the surface of the moon. When exposed to solar wind, this brightness is reduced as a function of time; the process is known as solar wind weathering.

Swirls are not as young as their appearance would indicate, however, as the local magnetic fields are interfering with solar wind weathering.

Magnetic fields have been shown to slow and turn away solar wind, creating nearly plasma-free bubbles around a planet. This “standoff” is what protects Earth’s atmosphere and surface from being weathered, or bombarded by ions from our Sun.

Although the Moon does not have a large-scale magnetic field like Earth, local remanent magnetization can influence incoming solar wind. Small magnetic anomalies can impede solar wind through electric field interactions, slowing weathering on the lunar surface.



Reiner Gamma (red) and the crater rays of Kepler (blue) look very similar, however, Reiner Gamma is shielded by its magnetic anomaly where Kepler experiences ion bombardment that darkens the appearance. (image from MacAdam Observatory, 450nm wavelength).

Theoretical Impact

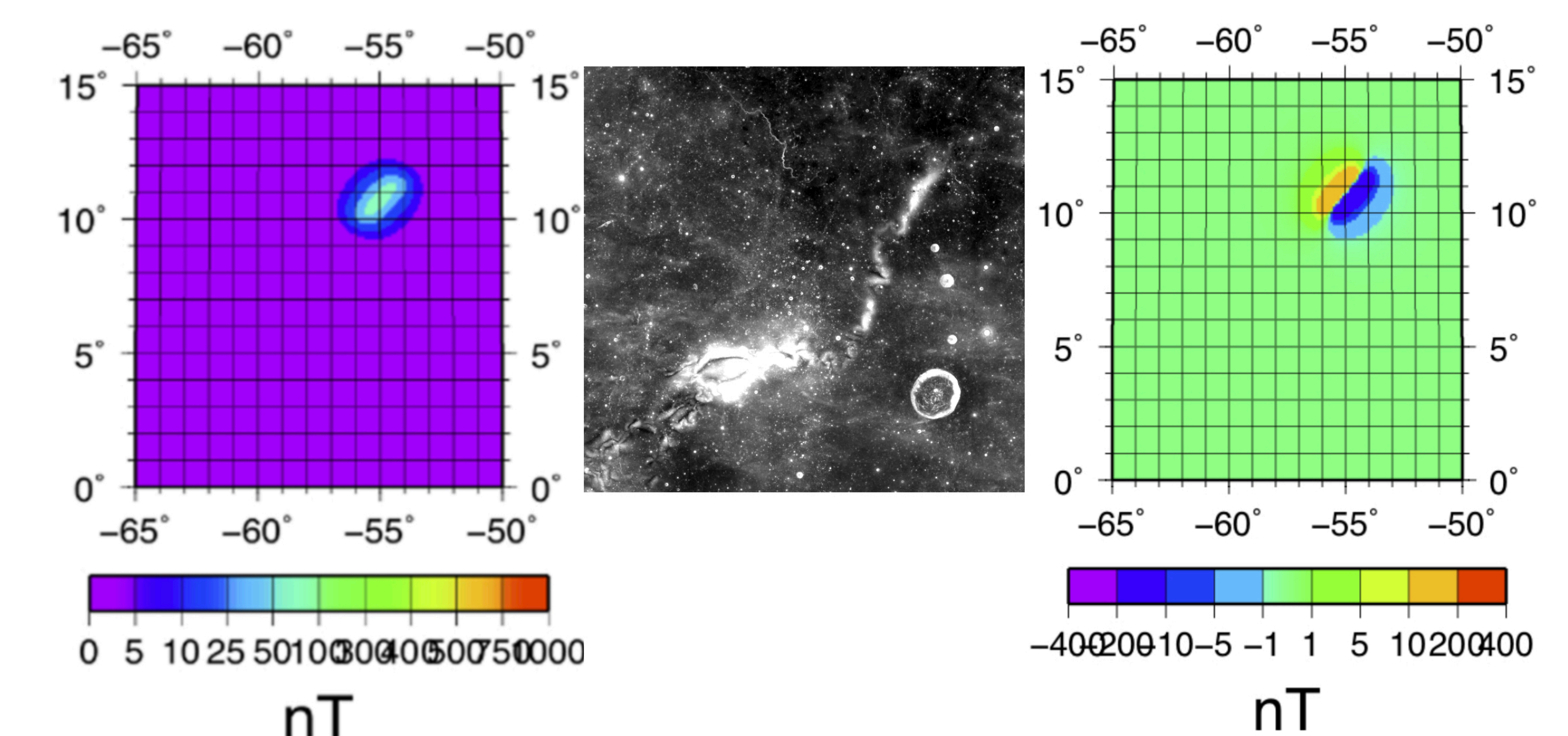
The formation, lifespan, and loss of planetary scale magnetic fields, or magnetosphere, is still the subject of rigorous study. Anomalies such as lunar swirls offer an opportunity to examine local magnetic fields that exist without a current magnetosphere, and may contain insight into a period of magnetic activity on the Moon. These anomalies provide a chance to study the effect of solar wind on planetary bodies as well.

Lunar swirls also appear to be unique to our Moon, such structures have not yet been observed on the surface of Mars.

Continued Work

Our first step was to refine satellite data from Lunar Prospector, then produce high resolution local maps. We began our work with Reiner Gamma because of the strength of its associated anomaly. Now we are working on creating a model at the surface that matches satellite observations to constrain the geometry of the source.

Modeling each swirl at the lunar surface will provide data about the direction of magnetization and depth of magnetic anomalies, which will tighten the constraints on the age of each swirl and possible methods of magnetization. This will give more information on the time frame of solar wind weathering and magnetic activity on the Moon.



Reiner Gamma and associated magnetic anomaly (B_{total} right, B_{θ} left from model produced with D. Ravat; middle image from Clementine, 750nm wavelength).

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