LUNAR SWIRLS: HOW DARK ARE "DARK LANES"? Ecaterina I. Coman[1,2], David T. Blewett[1], B. Ray Hawke[3], Jeffrey J. Gillis-Davis[3]. [1]Johns Hopkins Univ. Applied Physics Lab., 11100 Johns Hopkins Rd., Laurel, MD, 20723 USA, [2]Univ. of Maryland-Baltimore County, Baltimore, MD, 21250 USA (ecatcom1@umbc.edu), [3]Univ. of Hawaii, Honolulu, HI, 96822 USA.

Introduction: Image profiles across several prominent lunar swirls have been analyzed to determine the relation of dark lane reflectance to that of normal weathered regolith and ultimately the extent to which lunar crustal magnetization affects soil maturation.

Lunar swirls are sinuous markings exhibiting a high albedo and a low degree of optical maturity. The swirls lack a topographic expression, and may contain "dark lanes" within the bright undulating sections. All swirls correlate with the presence of a crustal magnetic anomaly, but not all magnetic anomalies exhibit unusual albedo markings [1]. Here we report on a study to determine if the dark lanes have truly low reflectance (i.e., are darker than the surrounding background), or instead just appear dark relative to the high-reflectance portions of the adjacent swirl.

Solar wind shielding by the magnetic anomalies is one hypothesis for lunar swirl formation [2]. Others include the impact of a comet coma and nucleus [3], comet fragments [4], or of meteor swarms [5] that scour the lunar surface and reveal fresh, high albedo material. A recently proposed hypothesis for lunar swirl formation involves electrostatic dust transport of fine, feldspathic dust caused by electric fields induced by solar wind interaction with a crustal magnetic anomaly [6].

According to the magnetic shielding hypothesis, crustal magnetic anomalies protect the lunar surface from solar wind bombardment, lessening the effect of space weathering and associated soil darkening [2, 7]. Micrometeoroids would be unaffected by the presence of a magnetic field. Hence it might be expected that micrometeoroid bombardment in a shielded area would still cause melting and vapor-phase reduction of ferrous iron in silicates to nanophase metallic iron [e.g., 8], darkening the surface. Therefore, the solar-wind shielding hypothesis requires that solar-wind ion bombardment be the primary agent of space weathering. By preventing this solar wind sputtering and implantation, the magnetic field preserves the high albedo evident as lunar swirls.

If a crustal magnetic anomaly blocks solar wind protons from striking the surface in areas where the field is strongest, it is possible that these deflected protons will collide with the surface around the perimeter of the anomaly where the field is weaker. The resulting enhancement of ion bombardment in these areas could cause "overmaturation," i.e., greater weathering than experienced by normal regolith. The comet-impact and dust-levitation models for swirl formation would predict that "dark lanes" consist of normal regolith and hence should be no darker than the background.

We have examined several dark lanes and compared their reflectance to the surrounding lunar surface as a way to test whether enhanced space weathering is taking place.

Data: Profiles were extracted from calibrated *Clementine* UVVIS reflectance image cubes (200 m/pixel) obtained from the U.S.G.S. Map-a-Planet website. Reflectance values in the 750-nm image were plotted against pixel location, and an average background reflectance value was estimated using sections of the profile away from swirls or fresh craters. Reflectance values for dark lanes and swirl perimeter were then compared to this background value.

Reiner Gamma: The most famous lunar swirl is found on the dark mare of Oceanus Procellarum at 7.5° N, 59° W. The complex albedo pattern is colocated with one of the strongest magnetic anomalies on the nearside, ~22 nT at 30-km altitude as determined from *Lunar Prospector* measurements [e.g., 1, 9, 10]. Two profiles were extracted across the main Reiner Gamma swirl (Fig. 1). The weathered background near the main Reiner Gamma swirl exhibits a reflectance of ~0.095 in the N-S and NW-SE profiles (Fig. 1). Neither profile shows a dark lane or perimeter reflectance value that is clearly less than that of the background; the N-S profile displays a minimum dark lane value of ~0.100, and the NW-SE traverse has minimum of ~0.096.

Firsov: Of the examples we have examined, the only dark lanes consistently exhibiting a lower reflectance than the surroundings were those of the swirls around Firsov crater, which is located in the farside highlands at 4.5° N, 11.2° E (Fig. 2). The magnetic anomaly at Firsov is of moderate strength, ~11 nT when continued to 30-km altitude [1, 9, 10]. Two diagonal profiles were taken of the main Firsov swirl (Fig. 2). Profile A shows a mature background value of ~0.204; the value in profile B is ~0.220. The dark lane reflectance in profile A is ~0.197. A possible perimeter weathering enhancement has an even lower reflectance, ~0.193. Profile B's dark lane has a minimum reflectance value of ~0.202.

Discussion: Two distinct swirl dark-lane locations, one mare and one highland, were examined in order to compare reflectance between dark lanes and normal weathered background. At Reiner Gamma, dark lanes do not appear to be appreciably lower in reflectance than the surrounding mature background. On the other hand, Firsov's dark lanes do exhibit lower reflectance values than the background. Therefore, enhanced space weathering by ions deflected by the magnetic anomaly could be taking place in the Firsov dark lanes. Profiles for other swirls (Airy, Hopmann, Ingenii, and Sirsalis) do not show definitive evidence for dark lanes with lower reflectance than the background. It is likely the structure of surface magnetic fields is complex [1, 11]. Therefore, "overmaturation" may not occur at all locations even if solar-wind shielding is the cause of the lunar swirls.

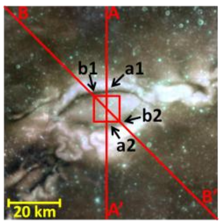
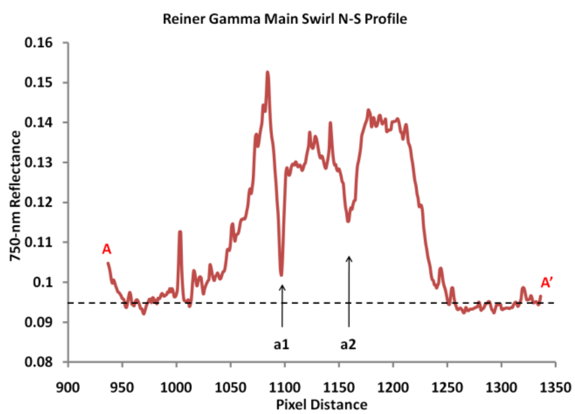
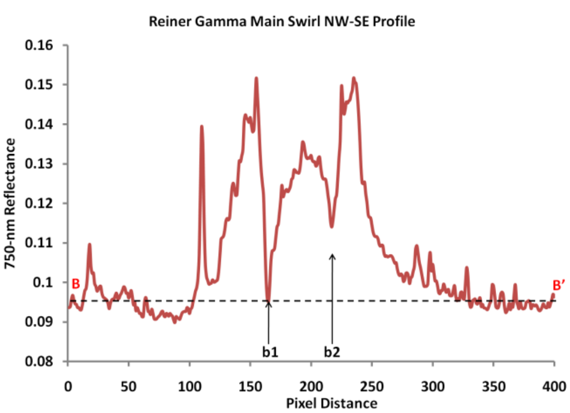


Fig. 1 Reiner Gamma. *Clementine* color composite image of 950-750-415 nm as R-G-B with profile locations overlain. Uppercase letters mark specific profiles, while lowercase letters represent dark lane locations. Dashed lines in the plots show the approximate reflectance of the mature background away from the swirl.





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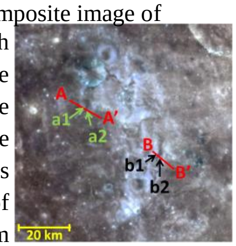

Fig. 2. Firsov. *Clementine* color composite image of 950-750-415 nm as R-G-B with profile locations overlain. Uppercase letters mark specific profiles, while lowercase letters represent dark lane locations. Dashed lines in the plots show the approximate reflectance of the mature background away from the swirl.