LUNAR ION TRANSPORT NEAR MAGNETIC ANOMALIES: POSSIBLE IMPLICATIONS FOR SWIRL FORMATION. J. W. Keller[1,4] , R. M. Killen[1,4], T. J. Stubbs[1,2,4], W. M. Farrell[1,4], and J. S. Halekas[3,4], [1]Goddard Space Flight Center, Greenbelt MD 20771, CA, [2]Goddard Earth Science and Technology Center, University of Maryland, Baltimore County, Baltimore, MD, [3]Space Science Laboratory, University of California, Berkeley, California, [4]NASA Lunar Science Institute, Moffett Field.

Introduction: The bright swirling features on the lunar surface in areas around the Moon but most prominently at Reiner Gamma, have intrigued scientists for many years. After Apollo and later Lunar Prospector (LP) mapped the Lunar magnetic fields from orbit, it was observed that these features are generally associated with crustal magnetic anomalies. This led researchers to propose a number of explanations for the swirls that invoke these fields[1]. Prominent among these include magnetic shielding in the form of a mini-magnetosphere which impedes space weathering by the solar wind[2], magnetically controlled dust transport[3], and cometary or asteroidal impacts that would result in shock magnetization with concomitant formation of the swirls[4]. In this presentation, we will consider another possibility, that the ambient magnetic and electric fields can transport and channel secondary ions produced by micrometeorite or solar wind ion impacts. In this scenario, ions that are created in these impacts are under the influence of these fields and can drift for significant distances before encountering the magnetic anomalies when their trajectories are disrupted and concentrated onto nearby areas. These ions may then be responsible for chemical alteration of the surface leading either to a brightening effect or a disruption of space weathering processes. To test this hypothesis we have run ion trajectory simulations that show ions from regions about the magnetic anomalies can be channeled into much small areas near the anomalies and although questions remain as to nature of the mechanisms that could lead to brightening of the surface it appears that the channeling effect is consistent with the existence of the swirls.

Concept: Ions created on the surface of the Moon through impact processes or photoionization are subjected to the Lorentz force by local electromagnetic fields that arise from surface charging and the ambipolar electric field [4,5], the interplanetary magnetic field and its associated motional electric field, electric fields arising from the interaction of the solar wind with the moon, and to local magnetic fields such as the aforementioned magnetic anomalies. To test our hypothesis we use a simplified model of the fields which incorporates the two-dipole magnetic field model for Reiner Gamma developed by Kurata[6], and typical solar wind conditions with the Reiner Gamma located on the lunar night side. The two dipole model for the magnetic anomalies at Reiner Gamma reproduce the field observed from orbit by LP however the details of the field at or close to the surface remain unknown since high order multipole moments of the field may operate close to the surface but that fall off rapidly with distance and would not have been observed by LP. Thus the model cannot be expected to reproduce the detailed shape of the lunar swirls but only to verify that the results are consistent with them. The mechanism which we are describing could operate on the day side as well but the fields around the anomalies are more complex due to the solar wind plasma and the establishment of mini-magnetospheres [6,7]. The night side charges negative due to a "filling in" of solar wind electrons which leads to a repulsive force (away from the Moon) on negative oxygen ions, which on the night side may be the most important species for chemically "bleaching" the swirls. We expect a significant yield of negative oxygen ions from micrometeorite impacts on the Lunar surface where the highly electronegative oxygen atom can combine with free electrons in the microplasma initiated by the high speed impacts.

We will present preliminarily results suggesting that ions created over significant areas of the lunar surface can be transported under the influence of local and interplanetary electromagnetic fields to narrow areas near areas of high crustal magnetic field strength. The flux of these focused ions may be of sufficient intensity to chemically process or otherwise bleach the surface leading to the formation of the lunar swirls. The theory is attractive since through focusing, it is possible that this flux is sufficient to overcome other space weathering processes which would otherwise tend to erase the effect. Also, with relatively low energy ions, and consistent with the observed focusing, the ion gyro radii in the local magnetic fields is small enough to resolve the swirls.

References: [1] Blewett D. L., et al., (2010) *Icarus* 209 239–246 and references therein. [2] Hood, L. L. (1980), *Proc. Lunar Planet. Sci. Conf.*, 11th, 1879–1896. [3] Garrick-Bethell, I., Head, J.W., Pieters, C.M., Icarus (2010), doi: 10.1016/j.icarus.2010.11.036. [4] Schultz, P. and Srnka,L.J., Nature, 284, 22-26, 1980[5] Farrell et al., (2007) *Geophys. Res. Let.*, 34, L14201 [6] Kimura S. and T. Nakagawa, (2008) *Earth Planets Space*, 60, 591–599. [6] Kurata M., et al. (2005), *Geophys. Res. Let.*, 32, L24205. [7] Dyal, P., C. W. Parkin, C. W. Snyder, and D. R. Clay (1972), *Nature,* 236, 381–385.