



Stony Brook **University**

# Diviner Lunar Radiometer Observations of Lunar Swirls

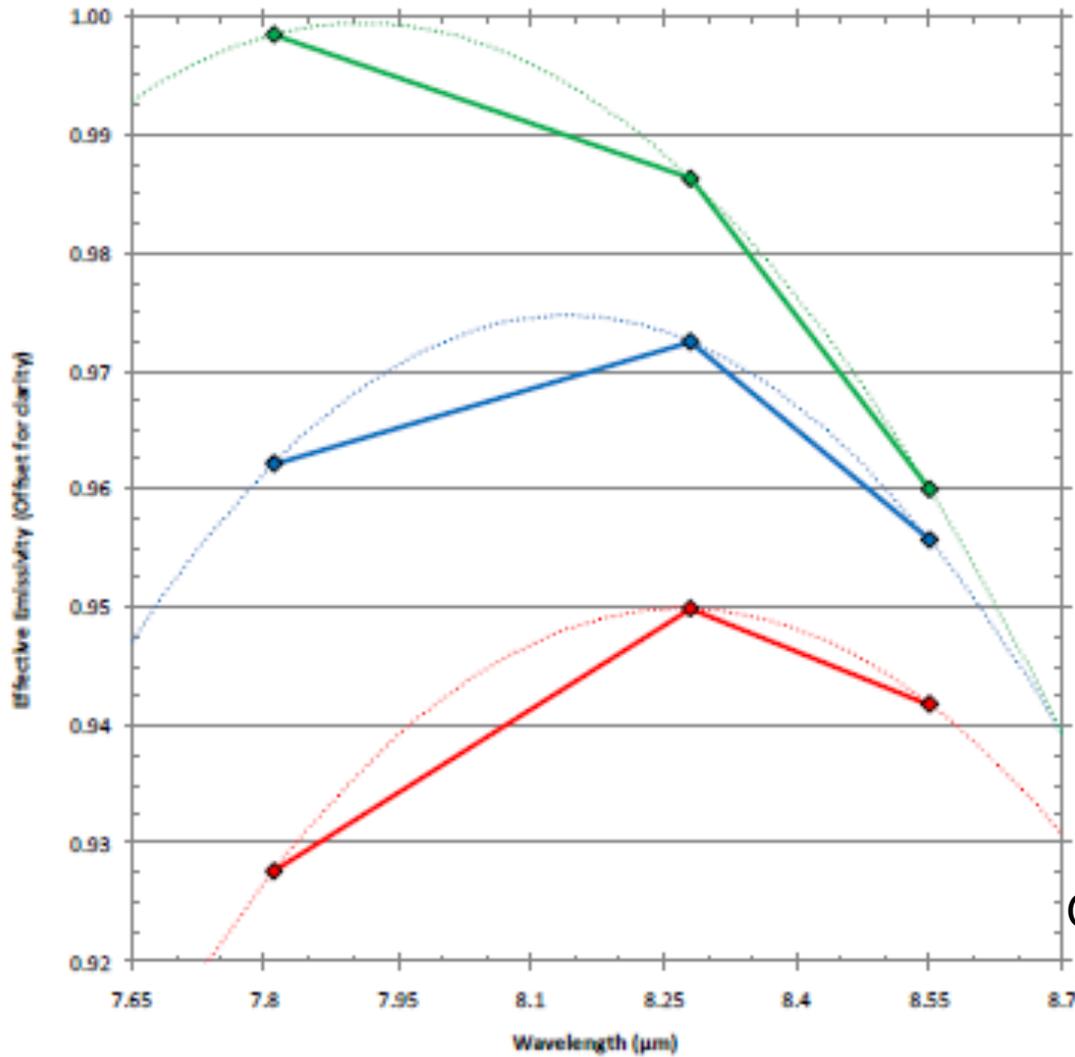
Tim Glotch, Paul Hayne, Paul Lucey, Katherine Shirley, Benjamin Greenhagen



NASA Exploration Science Forum, July 23, 2015



1. Abnormal Space Weathering
  - B- fields protect the surface from charged solar wind particles.
  
2. Impact by swarms of micro-comets or meteors
  - Swarms disturb regolith, revealing unweathered subsurface and transporting fines
  
3. Dust Transport
  - Feldspathic dust lofted by electric fields generated as terminator passes over surface
  
4. Hybrid dust lofting + magnetic sorting + fairy castle destroying

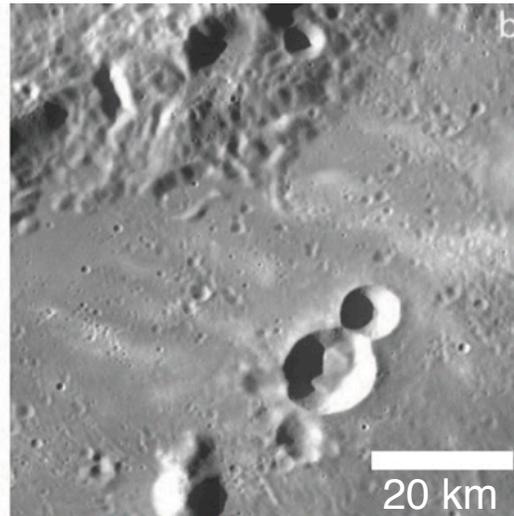
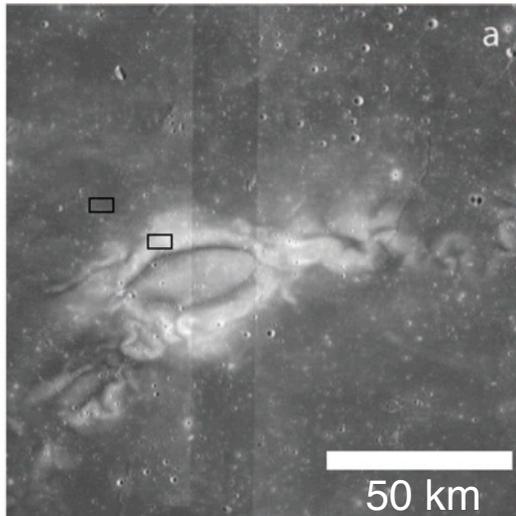


Greenhagen et al., 2010



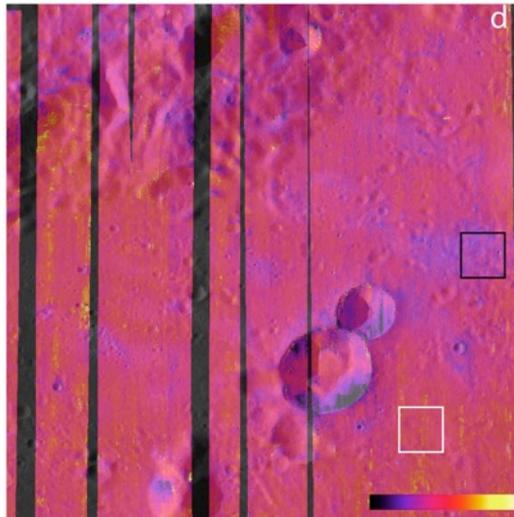
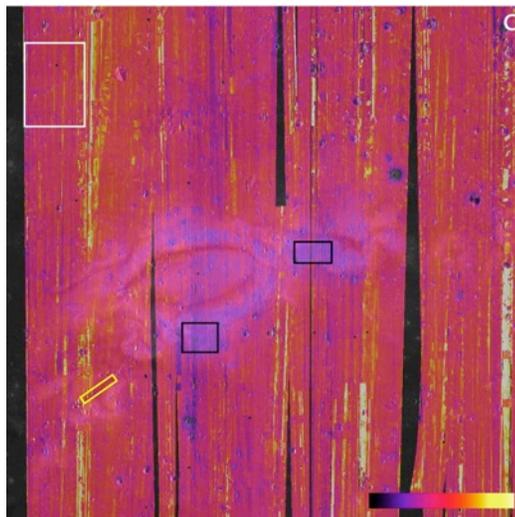
# CF ANOMALY AT SWIRLS

Reiner Gamma



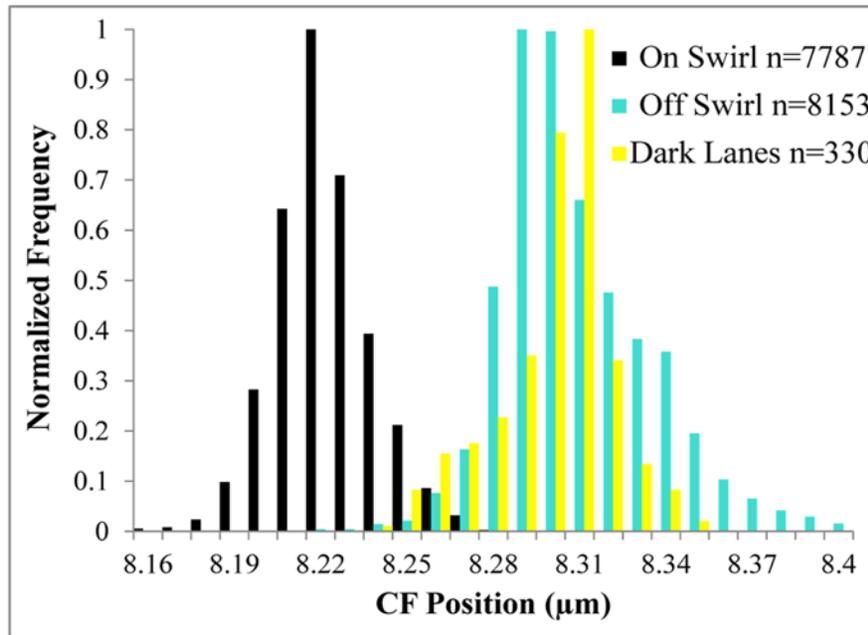
Van de Graaff Crater

CF, 815-8.45  
microns

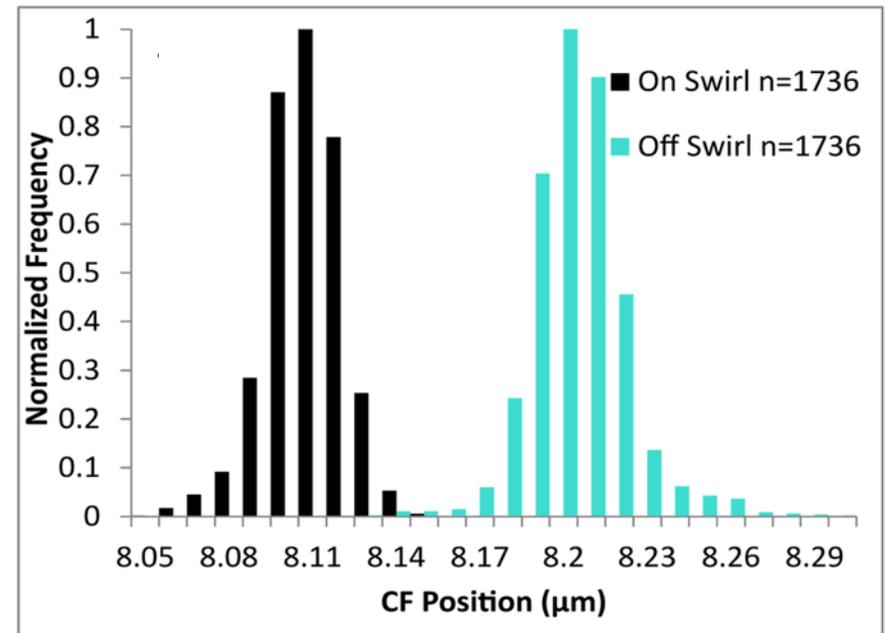


CF, 8.0-8.4  
microns

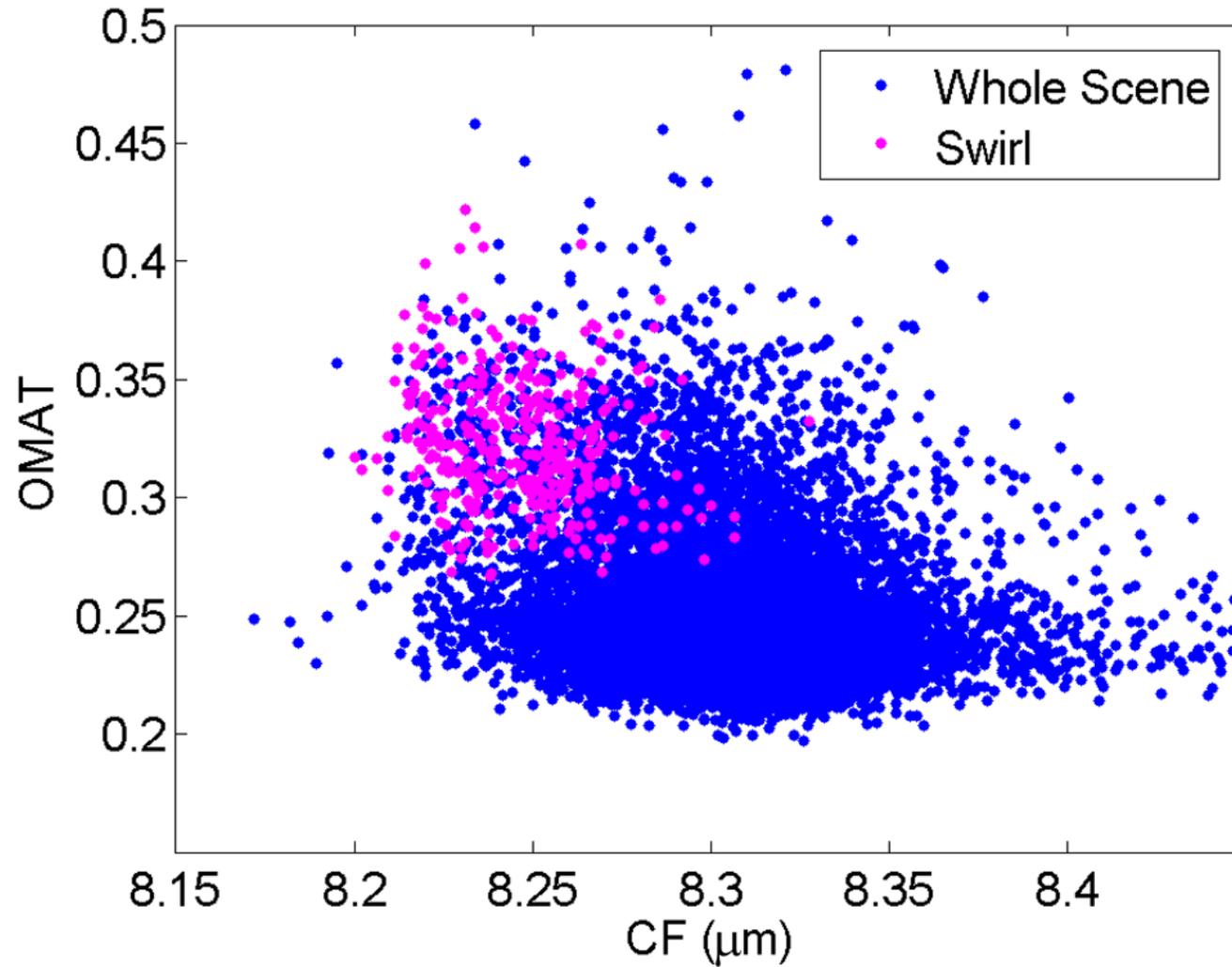
Glotch et al., 2015  
*Nature Comms.*

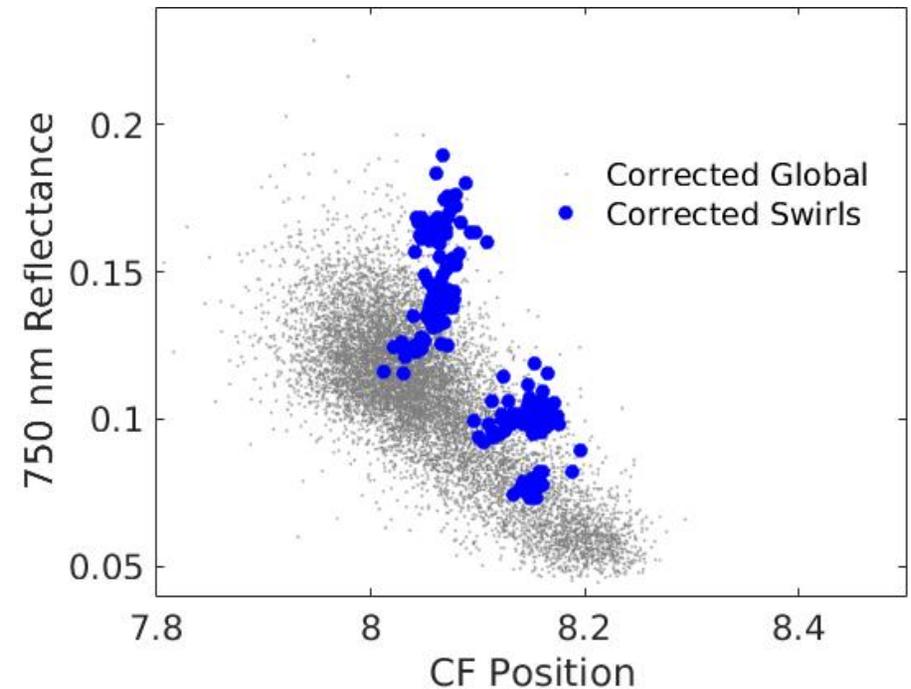
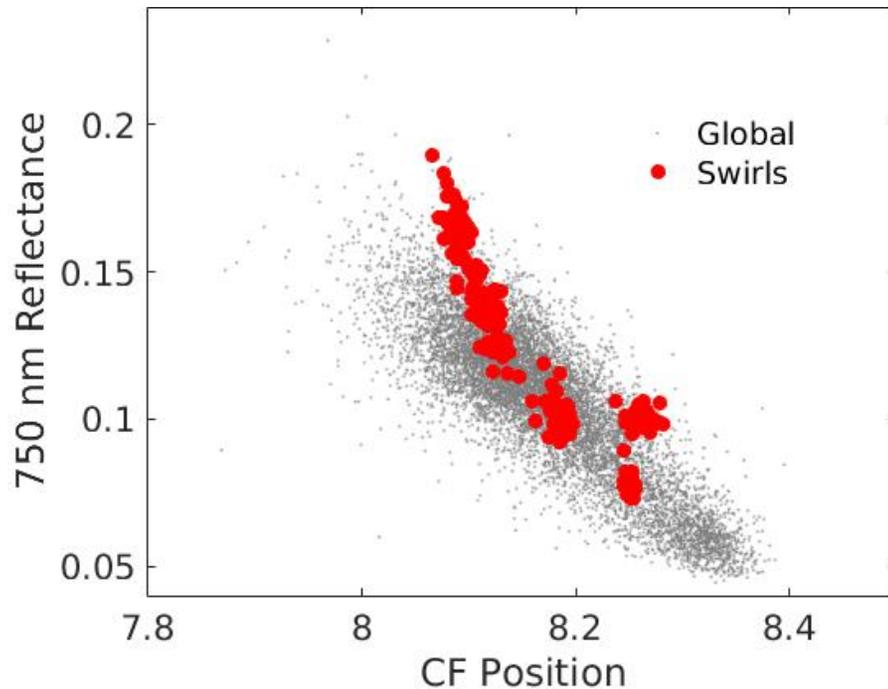


Reiner Gamma



Van de Graaff Crater

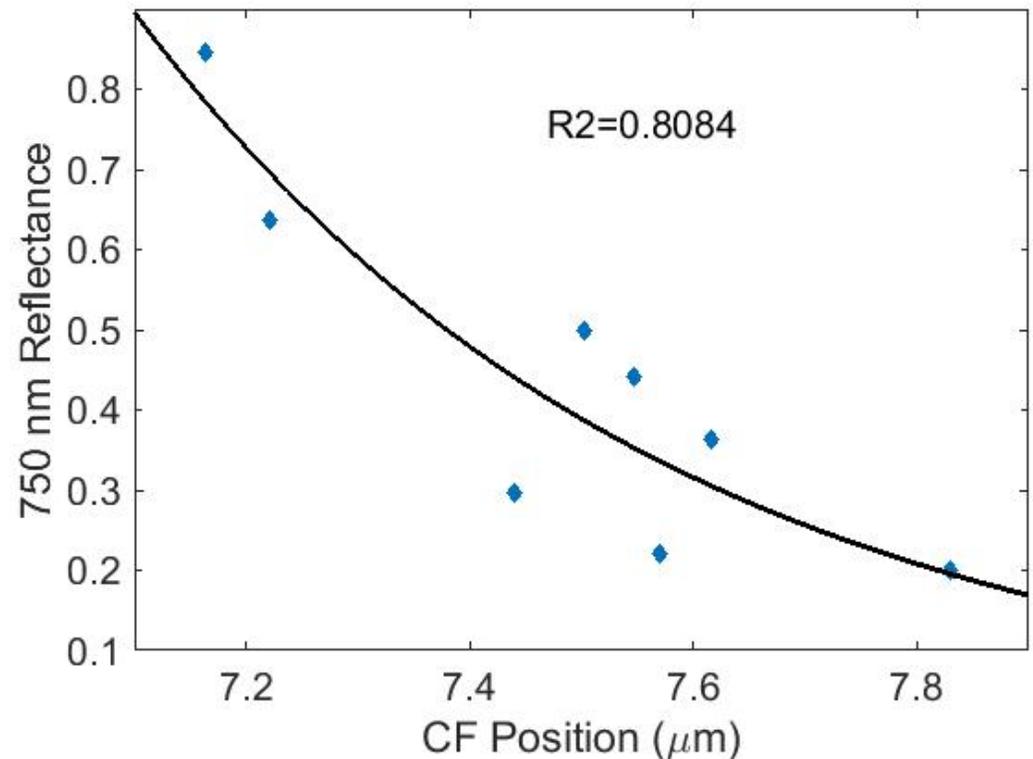




- OMAT-based CF correction (Lucey et al. 2015) provides some separation of swirls from global trend.
- Hypothesis: Diviner's sensitivity to space weathering is due to albedo.



- Test: Simulated lunar environment MIR-measurements of quartz + amorphous carbon (h/t Katherine Shirley).
- Result: Strong correlation between albedo and CF independent of composition (but main driver of CF position is still composition).





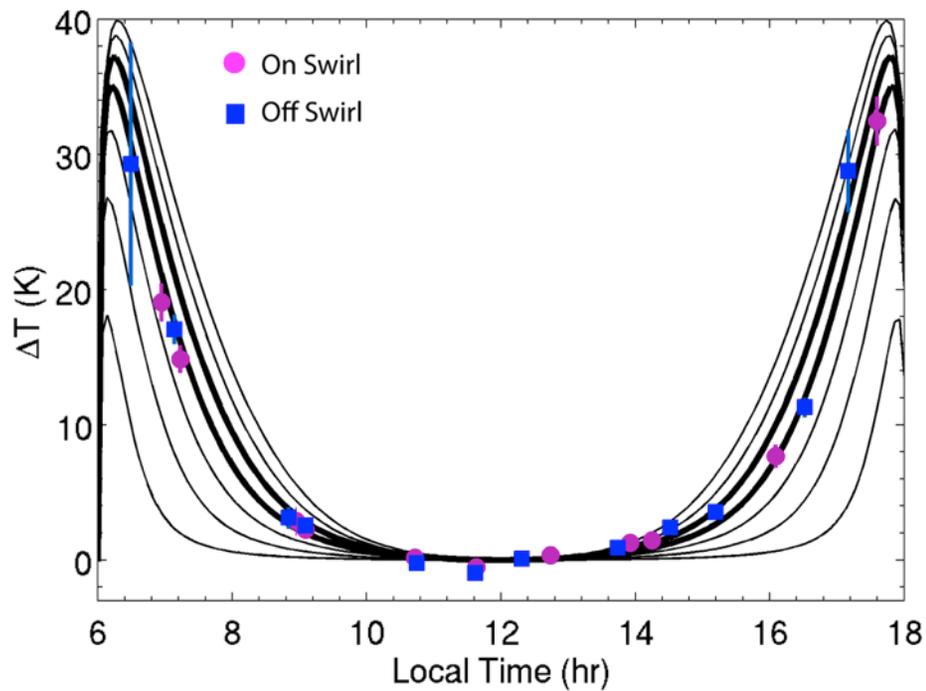
- Diviner observations show CF shift at both highlands and mare swirl sites
- CF sensitivity due to albedo variations
- Consistent with atypical space weathering related to solar wind deflection + continued impact bombardment
  - Implication: Solar wind sputtering and/or implantation “more important” than micrometeorite bombardment?
  - Implication: Micrometeorite bombardment necessary but not sufficient for optical maturation?



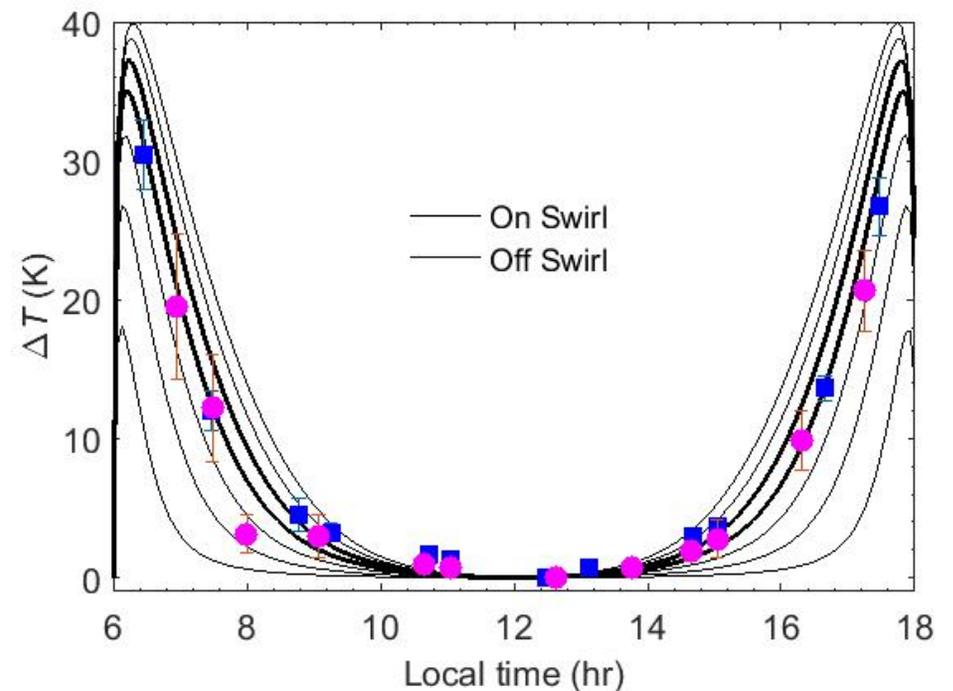
- Dust lofting and micro-comet/meteoroid swarm hypotheses would be expected to alter surface regolith structure at cm to mm scales.
  - Regolith disturbance via bombardment would make surface rougher
  - Dust lofting would make surface smoother
- What do Diviner daytime measurements and Hayne roughness model have to say about this?



## 5° contours from 10° to 40° RMS roughness



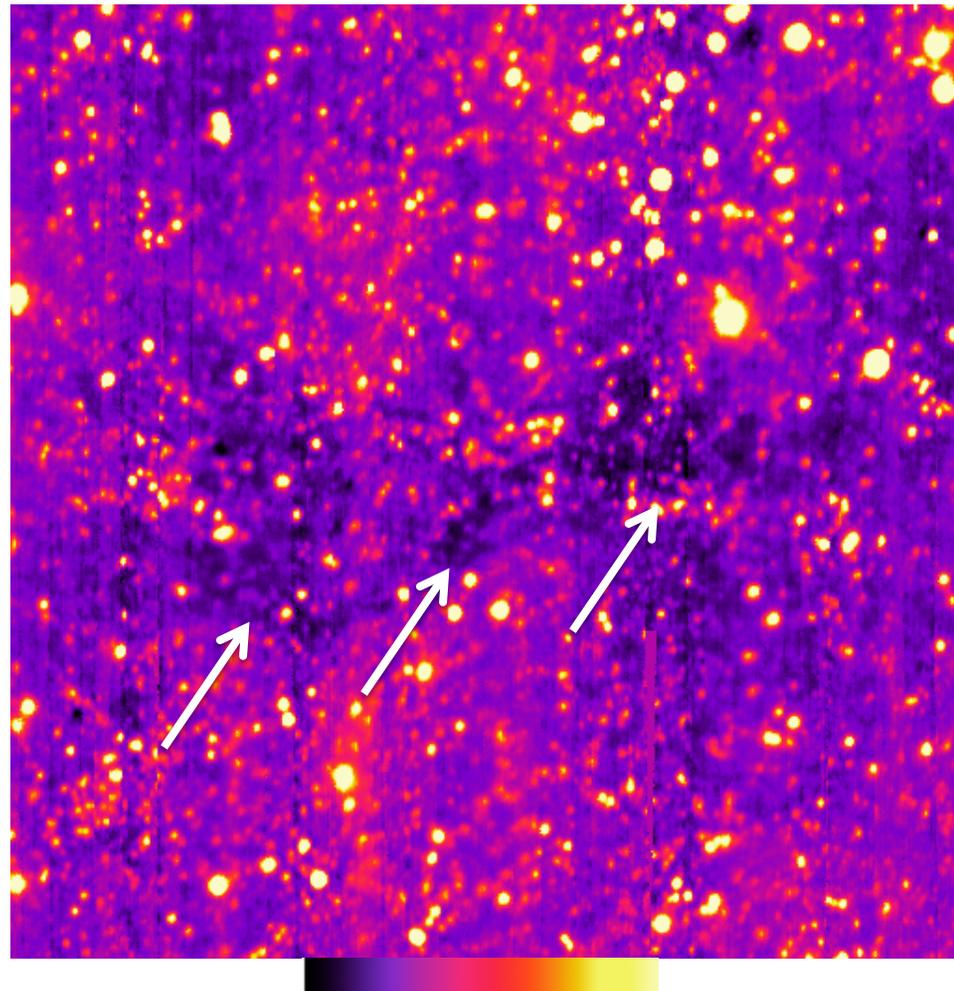
Reiner Gamma



Airy



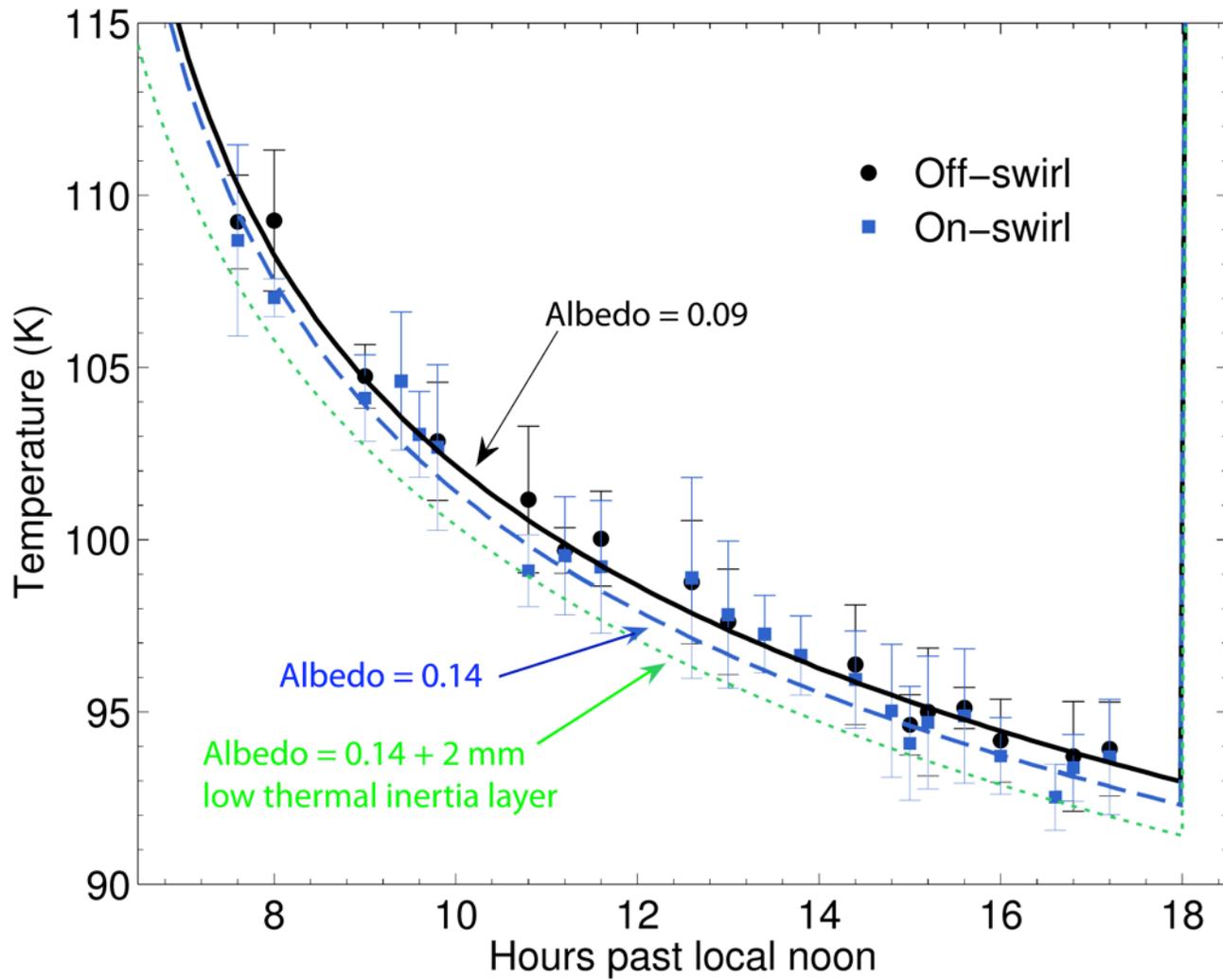
- Dust lofting, magnetic sorting, and micro-comet/meteoroid swarm hypotheses would be expected to alter surface regolith structure at cm to mm scales.
  - Regolith disturbance via bombardment would make surface rougher
  - Dust lofting would make surface smoother
- Both swirl and off-swirl sites have RMS roughness values between  $25-30^\circ$ , typical of lunar regolith.



Reiner Gamma, -3.6 to 7.0  $\Delta K$



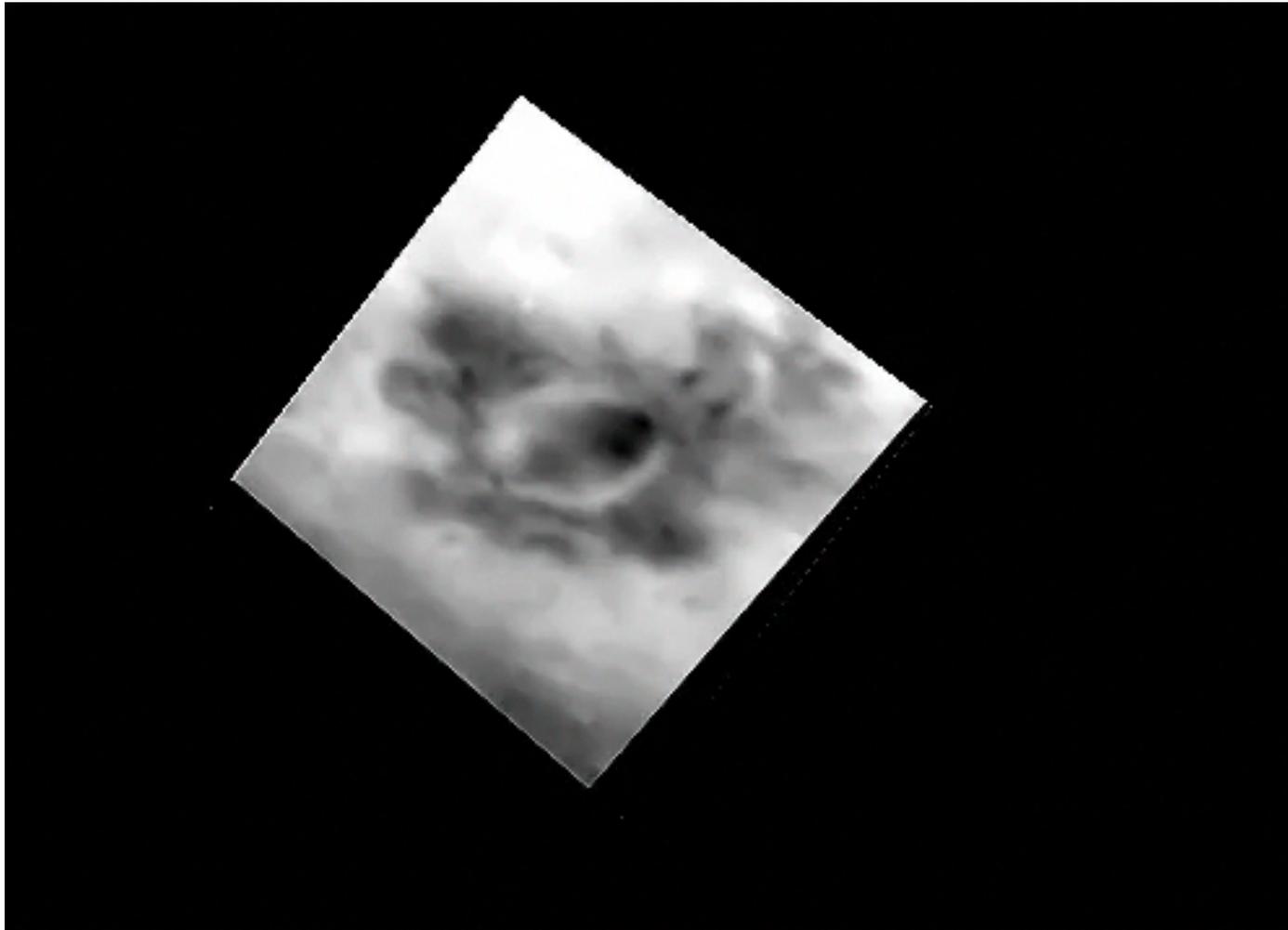
- Reiner Gamma swirl is, on average, only 0.5 K cooler than surrounding terrain at night time.
- Night-time cooling model can shed light on swirl formation mechanism.
  - Can lofted dust pile account for temperature difference at swirl sites?





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# SWIRL THERMOPHYSICS



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- Reiner Gamma swirl is, on average, only 0.5 K cooler than surrounding terrain at night time.
- Night-time cooling model can shed light on swirl formation mechanism.
  - Adding even a 2 mm “fluffy” layer results in swirl temperatures that are much too cold to explain Diviner observations
- Eclipse cooling observations constrain swirl “layer” to  $< 1\text{mm}$



- CF sensitivity to space weathering correlated to visible albedo variation.
- Diviner data and related lab measurements and models support “solar wind standoff” model of swirl formation.
- Dust lofting, micrometeoroid/comet bombardment, and “hybrid” models must account for Diviner CF measurements, roughness properties, and thermophysical properties.