

**Martian slope streak brightening mechanisms** Ross A. Beyer<sup>1,2</sup>, Frank C. Chuang<sup>3</sup>, Bradley J. Thomson<sup>4</sup>, Moses P. Milazzo<sup>5</sup>, James J. Wray<sup>6</sup> and the HiRISE Team; <sup>1</sup>Carl Sagan Center at the SETI Institute; <sup>2</sup>NASA Ames Research Center (Ross.A.Beyer@nasa.gov), <sup>3</sup>Planetary Science Institute; <sup>4</sup>Jet Propulsion Lab, Caltech; <sup>5</sup>The University of Arizona; and <sup>6</sup>Cornell University

Slope streaks have been observed on Mars since the era of the Viking Orbiters [e.g. 1], and continue to be of interest through to the present day [e.g. 2, 3].

Three decades of slope streak observations show that while most streaks are darker-toned than their surrounding surfaces, multiple streaks along the same slope can also have varying albedo, or even change albedo within a single streak (dark to bright). Schorghofer et al. [4] demonstrate that new streaks are dark and that they appear to fade with time. Their observations indicate that new streaks have formed since the Viking era, and that all new streaks are dark, with no new bright streaks having formed since that time. This and one observation of a dark streak becoming bright lead Schorghofer et al. [4] to speculate that streaks start dark and then become bright, but no hypothesis for a mechanism is given.

HiRISE observations support the hypotheses of slope streak formation by down-slope mass movement [5, 6], although do not exclude wet or fluid-lubricated formation hypotheses for all streaks [e.g. 7], and have allowed more detailed examination of streak texture and morphology. These observations show that streaks excavate a layer of material (presumably dust) at their apexes and throughout the body of the streak, as well as depositing material both within the streak as longitudinal ridges and mounds upstream of topographic obstacles, as well as at the streak's terminus.

#### Additional evidence that dark streaks fade

HiRISE shows that on almost every slope where previous studies have identified dark slope streaks, there are also streaks which show no albedo difference with the surrounding surface [5]. These streaks are identifiable only by their morphological pattern of excavation and longitudinal flow deposits. These streaks show no albedo difference with the surrounding surface and thus were largely unresolved by pre-HiRISE imagers.

These observations, along with the evidence that new streaks are darker than pre-existing streaks on the same slope [2, 4], provide additional evidence that dark streaks fade over time because they are covered by an optically thick layer of particles (presumably airfall dust).

#### Brightening of slope streaks

Bright slope streaks, although rarer than dark streaks, are not well explained. Sullivan et al. [2] hypothesized that perhaps the failure plane along the path of bright streaks

does not penetrate through the entire layer of dust, and that the exposed bright surface is simply an indurated dust surface. This hypothesis is unsatisfactory, and does not account for observations that bright streaks appear to be relatively old, and that one dark streak appears to have transitioned to a bright one [4].

Here we present two alternative hypotheses for the formation of bright streaks based on differences of surface (dust) morphology between the streak and the surrounding surface. Other hypotheses for bright streak formation mostly assume that material of inherently different albedo is exposed in these streaks. The hypotheses below do not require this. They assume that average albedo dust has settled onto the streak surface, but that these surfaces appear bright due to photometric effects based on the difference of morphology between the surfaces inside and outside of the streak.

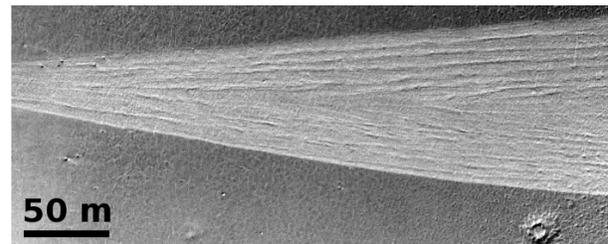


Figure 1: Longitudinal ridges in a bright streak in this portion of HiRISE image PSP\_002586\_1880. A change in texture between the smooth surfaced streak and the surroundings is also evident here. North is to the right of frame, and the Sun is from the top of the frame.

#### Longitudinal ridge orientation

One hypothesis arises from longitudinal flow structures observed by HiRISE in some streaks (figure 1). These ridges have a roughly convex-up shape in cross-section and can run from streak apex to terminus. They are covered with the same albedo material as their surroundings. If the solar azimuth is perpendicular to the ridges they will provide a long surface tilted towards the sun, increasing their observed brightness. Multiple longitudinal ridges within a streak will enhance this effect. Even if the illumination geometry is not perpendicular to the ridge trend, there will still be an effect as long as the streak is not oriented in the down-sun direction. The brighten-

ing effect of the ridges is small compared to the contrast provided by a fresh dark streak surface. However, over time dust would be deposited within the streak, eliminating the initially dark contrast, and allowing the ridges to reflect slightly more light than the surrounding surface. This type of streak should remain bright unless enough dust were deposited to bury the longitudinal ridges.

Not all slope streaks have pronounced longitudinal ridges and therefore not all bright streaks are expected to be caused by this mechanism, it is simply one possibility. This hypothesis explains bright streaks only for a particular set of conditions in which longitudinal ridges provide a distinct surface texture to the surrounding surface.

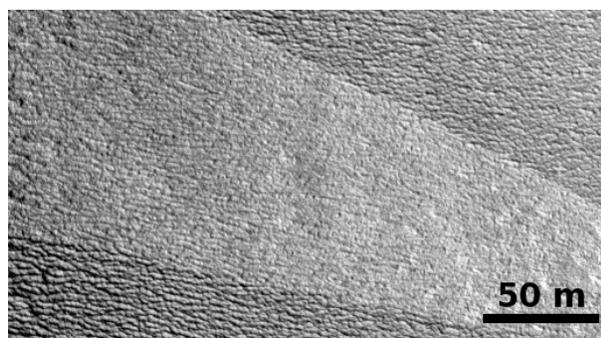


Figure 2: This bright streak shows a difference in texture between the streak and its surroundings in this portion of HiRISE image PSP\_002586\_1880. North is to the top of frame, and the Sun is from the left of the frame.

### Removal of surface roughness effects

Another hypothesis arises from differences in surface roughness. HiRISE observations of exceptionally dusty areas (which are also those areas with the greatest number of observed slope streaks) show that there is a very fine sub-meter-scale network of ridges forming a reticulate pattern [8]. These ridges are presumably aeolian in origin and are pervasive on dusty surfaces where observed. When a streak occurs on a surface with these reticulate ridges, the streak surface is initially smoother than the surrounding dust surface due to the mass movement that formed the streak. As dust particles settle onto the streak, over time an optically thick layer of dust will form whose surface is smooth like the streak surface which it conforms to, and has not yet developed these fine reticulate ridges.

In this scenario, the dust particles both within the streak and outside the streak have the same albedo. However, there are reticulate ridges on the surface outside

the streak that create macroscopic roughness which is often below the resolving limit of imagers. This isotropic macroscopic roughness will cause a decrease in the observed brightness [9] relative to a smooth surface of the same albedo. As such, the streak interior will appear brighter than the surrounding ridged surface (figure 2).

Over time, the dust within the streak boundaries will develop these reticulate ridges, and the apparent bright streak will lose its contrast difference.

### Summary

These two hypotheses of bright slope streak formation are consistent with the current and past observations of slope streaks, and the various hypotheses for their formation. Both of these mechanisms could be causing bright streaks. The statistics of occurrence of these morphologies are not yet quantified, but if they are not common features to slope streaks, then this could explain why there are fewer observed bright streaks than dark ones. In this case, the cycle of an initial dark streak whose contrast fades away would be the norm, but these hypotheses indicate that there are some streaks that start dark, transition to bright, and then ultimately fade to a neutral tone.

### References

- [1] E. C. Morris. Aureole deposits of the Martian volcano Olympus Mons. *Journal of Geophysical Research*, 87:1164–1178, February 1982.
- [2] R. Sullivan, P. Thomas, J. Veverka, M. Malin, and K. S. Edgett. Mass movement slope streaks imaged by the Mars Orbiter Camera. *Journal of Geophysical Research*, 106(E10):23607–23634, October 2001.
- [3] N. Schorghofer, O. Aharonson, and S. Khatiwala. Slope streaks on Mars: Correlations with surface properties and the potential role of water. *Geophysical Research Letters*, 29(23):41–1, December 2002. doi: 10.1029/2002GL015889.
- [4] N. Schorghofer, O. Aharonson, M. F. Gerstell, and L. Tatsumi. Three decades of slope streak activity on Mars. *Icarus*, 191:132–140, November 2007. doi: 10.1016/j.icarus.2007.04.026.
- [5] F. C. Chuang, R. A. Beyer, A. S. McEwen, and B. J. Thomson. Hirise observations of slope streaks on mars. *Geophys. Res. Lett.*, 34(L20204), October 2007. doi: 10.1029/2007GL031111.
- [6] C. B. Phillips, D. M. Burr, and R. A. Beyer. Mass movement within a slope streak on Mars. *Geophysical Research Letters*, 34(L21202), November 2007. doi: 10.1029/2007GL031577.
- [7] J. W. Head. Slope streaks in the Antarctic Dry Valleys: Characteristics, candidate formation mechanisms, and implications for slope streak formation on Mars. *AGU Fall Meeting Abstracts*, (#P22A-08), December 2007.
- [8] N. T. Bridges, P. E. Geissler, A. S. McEwen, B. J. Thomson, F. C. Chuang, K. E. Herkenhoff, L. P. Keszthelyi, and S. Martínez-Alonso. Windy Mars: A dynamic planet as seen by the HiRISE camera. *Geophysical Research Letters*, 34:L23205, December 2007. doi: 10.1029/2007GL031445.
- [9] B. Hapke. Bidirectional reflectance spectroscopy. III - Correction for macroscopic roughness. *Icarus*, 59:41–59, July 1984. doi: 10.1016/0019-1035(84)90054-X.