

# PLANETARY SCIENCE INSTITUTE

## NEWSLETTER

WINTER 2007 Vol. 8, No. 4



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## Dawn is launched! by Mark V. Sykes



Kennedy Space Center, FL — The rocket carrying NASA's Dawn spacecraft rises spectacularly from the launch pad to begin its 3-billion-mile journey through the inner solar system. Photo credit: NASA/Sandra Joseph & Rafael Hernandez.



The Delta II rocket carrying the Dawn spacecraft arcs through the sky at 7:34 am EDT from Cape Canaveral Air Force Station. Photo credit: Launch mosaic by Randy Pollock, stitching by Johan Kiviniemi, inset by NASA/Kim Shiflett.



Artist concept showing the Dawn spacecraft on its unique journey to two asteroids, Ceres and Vesta. Background painting by PSI scientist William K. Hartmann, montage by UCLA.

On September 27, the NASA Dawn Discovery mission successfully launched with the rising Sun. When communication was reestablished with the spacecraft — a critical milestone — there were no major problems.

The journey to the launch of the Dawn mission to Vesta and Ceres, however, was a rocky one. Originally scheduled for launch in June 2006, Dawn was caught up in bureaucratic red tape, a shut-down, and a temporary cancellation, which delayed its scheduled launch for a year to June 2007. Then, the temporary unavailabil-

(Continued page 5)

### Inside this issue:

HIRISE LOOKS AT MARTIAN SLOPE STREAKS	2
THE TALE TOLD BY MARTIAN ROCKS	3
AWARDS AND MENTIONS	4
DIRECTOR'S NOTE	5

## HiRISE Looks at Martian Slope Streaks

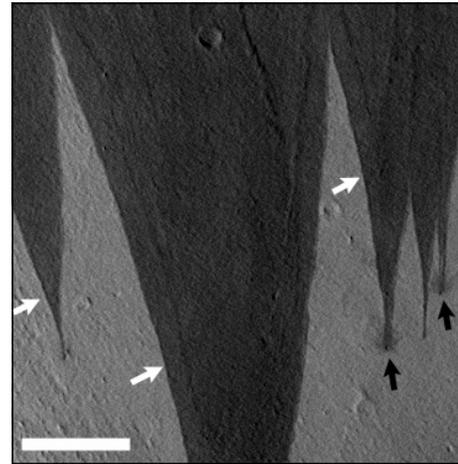
by Frank C. Chuang

This is a great time to be studying Mars. With so much new data, both orbital and surface robotic, there is no shortage of science that can be done. Most headlines these days involve the search for water, past or present, on the surface or in the shallow subsurface. But there are plenty of other things to study, and all this data can lead to new discoveries and the testing of old hypotheses. The recent mission to Mars, Mars Reconnaissance Orbiter (MRO), includes the most powerful camera ever sent to the Red Planet, HiRISE (High Resolution Imaging Science Experiment). As of this newsletter, HiRISE will have photographed the Martian surface for one full Earth year and returned thousands of spectacular images with spatial resolutions up to 25 centimeters/pixel (for more about HiRISE, see our Winter 2005 issue). This leap in resolution has allowed very detailed studies of small surface features, such as slope streaks, commonly seen in the equatorial regions of Mars.

Slope streaks, just as the name implies, are streaks that have formed on slopes, and are usually darker than their surroundings. First documented during the Viking missions to Mars in the 1970s, they have since been studied in greater detail beginning with images from the Mars Orbiter Camera (MOC). Typical characteristics of slope streaks are initiation at a point source, one streak splitting into two, deflection around or over obstacles such as small boulders or crater rims, widening below the source area up to a few hundred meters, and lengths of up to a few kilometers. Numerous explanatory models have been suggested, both dry- and wet-based, including briny liquid flows, groundwater piping, mixed water-dust flows, ground wetting and/or wicking from salty liquids, mass-wasting of dust, granular flows, and avalanching of heterogeneous dust accumulations along slopes. Although there is not one universally accepted model, one key observation has been that streaks do not have, or create, topographic relief; that is, until HiRISE came along.

After sifting through 1500 HiRISE images from the first seven months of data, my colleagues and I discovered that slope streaks do indeed have topographic relief (Chuang et al., 2007, published in the October issue of *Geophysical Research Letters*). Not every streak shows relief, because several conditions must be met in order to see it: low sun illumination (sun low in the sky), meters-thick dust coverage, slopes facing away from the sun, and sufficient spatial resolution (sub-meter). The image at top right shows an example of relief where the streak interior is lower than the surroundings, particularly along the streak margins. Another example of a streak in the lower image shows small pre-existing ripples, likely formed by aeolian (wind) processes, across both the area outside and inside the streaked surface, indicating a thin amount of material lost. Estimates of the depths along the margin of one streak using the shadows came out to a meter or less. Although many streaks do not show relief in HiRISE images, this does not necessarily mean they lack relief, but rather are below the capability of HiRISE to detect. Other interesting observations include triggering of slope streaks by an impact crater, blast from an impact explosion, or boulders rolling or bouncing downslope, and formation of long linear ridges within the streak that are parallel to its margins. Streaks initiate below localized features such as rock outcrops, crater rims, or boulders.

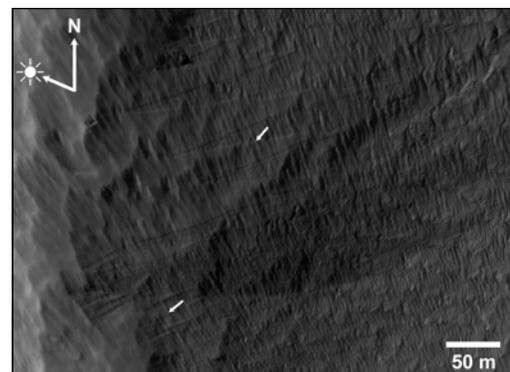
So, what does the discovery of topographic relief mean? The most important inference is that material had to be removed for the relief to be present. There are several processes, both wet and dry, that can remove material. A small stream of liquid water running over the surface could carve out the streaked area, but liquid water exposed at the surface is not stable under current



A HiRISE image showing dark slope streaks on the north-facing slope of an impact crater near Naktong Vallis. White arrows point to the margins of slope streaks that have topographic relief. Black arrows point to streaks triggered by impacts; note dark ejecta. Scale bar = 35 meters. Image resolution is 54 cm/pixel. (PSP\_003259\_1850)(5.0° N, 32.7° E)

Martian conditions. Water flowing below the surface, covered by an insulating layer of materials could be a possibility, but the surface would probably be wet if this occurred. HiRISE and other spectral cameras have yet to detect liquid water on the surface of Mars. Either of these processes would probably produce deposits at the termini of streaks, which has yet to be seen. Other evidence that would favor a wet process are detection of salts, alcoves or channels above the point source, or streaks beginning at the intersection of two different geologic layers (i.e., permeable and non-permeable layers). However, there are no documented cases where these are evident. Thus, a dry process appears more likely.

(Continued page 5)



Slope streaks on the east-facing slopes of a highland escarpment near Mangala Valles. Meter-scale ripples (arrows) can be traced across both streaked and un-streaked surfaces suggesting a thin layer of material was removed. Image resolution is 26.5 cm/pixel and downslope direction is to the east. Portion of HiRISE image PSP\_001472\_1745 (5.3° S, 213.7° E)

## Report from the 7<sup>th</sup> International Mars Conference – The Tale Told by Martian Rocks

by William K. Hartmann

July, 2007 — The seventh Mars Conference at JPL/Caltech was one of a series of conferences reviewing new Mars findings. One of the most interesting findings relates different Martian rock types to different periods of Martian history. This result comes from combining the two NASA rovers' discovery of sulfate sedimentary rocks on Mars at both rover landing sites, and detailed rock chemistry mapped spectroscopically from the European Mars Express orbiter.

The basic idea is that the three eras of Mars geology, defined in the 1970s from orbital mapping, had different conditions that produced three different dominant rock types, because of the evolution of the Martian environment. These eras are called Noachian (oldest), Hesperian, and Amazonian (youngest).

Most researchers have long agreed that early Noachian Mars had a thicker CO<sub>2</sub> atmosphere than modern Mars, and more liquid water on the surface. What Mars Express showed is that Martian clays and clay minerals called phyllosilicates are found mostly in the ancient Noachian highlands. In fact, according to the Mars Express spectrometer, these minerals dominate Noachian outcrops. Many of these minerals are hydrated, meaning that they have absorbed abundant water molecules into their crystal structure. They indicate that the maximum water abundance at the surface was during the earliest era, believed to have ended about 3.8 billion years ago. (The date is based on crater count studies developed partly at PSI.)

Noachian Martian conditions, including the CO<sub>2</sub> dominated atmosphere, were probably similar to early Earth conditions, but the next part of the story shows the different evolutionary paths taken by Mars and Earth. The two rovers discovered sulfate-based sedimentary rocks on Mars. Rover photos show textures indicating that at least some of these rocks were precipitated in flowing water — the first proof of water-based sediments on the red planet. Mars Express, from orbit, showed that sulfate-based sedimentary rocks are concentrated in Hesperian strata. So, Hesperian Mars was a period of sulfate-rich sediments, yet sulfate sediments are rare on Earth. We have more carbonate sediments, like limestones. What caused the difference?

The new interpretation is that Mars' atmosphere thinned and surface waters evaporated, so that Hesperian Mars had less liquid water on the surface. Volcanism continued, however, and a single volcanic outburst could increase the relative proportion of

sulfurous gases in the now-thinner Martian atmosphere; these gases dissolve in water. With large amounts of sulfur-rich gas dissolving in less and less water, the *concentration* of sulfur in the water got greater and greater. The Hesperian waters became weakly acidic with sulfuric acid, and therefore precipitated sulfate sediments as they evaporated. This did not happen on Earth

because the partial pressure of CO<sub>2</sub> in the air, and the water volume in the oceans, were so great that the sulfur content never got high enough to dominate the chemistry. Instead, Earth's waters tend to precipitate carbonate rocks, like limestones.

In Amazonian times, Martian waters eventually evaporated and the surface became the global desert we see today. Vestigial moisture oxidized, or rusted, the iron minerals and rusty red compounds coated most of the eroded rocks and soils. Ever since, Mars has

been a relatively dry, cold, red planet. Only sporadic periods of high axial tilt produce transient snow, ice deposits, and perhaps small amounts liquid water on the surface. Yet these Martian "ice ages" with their water mobility have their own fascination, as discussed in the articles on Martian climate change in our Summer and Fall 2007 newsletters. □



*Photo taken on Mars, May 6, 2006, shows layered sedimentary rocks in the wall of Victoria crater in Meridiani Planum. Some of the layers were deposited by winds, but others are sulfate sediments apparently deposited in sulfur-rich acidic water. (Image credit: NASA's Opportunity rover)*

## Bleamaster Reaches Antarctica



*PSI Research Scientist Les Bleamaster arrived at McMurdo Station, Antarctica, in late November for a six-week ice-camping, meteorite-gathering excursion. Stay tuned to future newsletters for a full report on his excellent adventure.*

## Awards and Mentions

PSI is very pleased to acknowledge three recent donations to the California Science Education Field Trip Program from organizations that share our goals for the community.

The **Dwight Stuart Youth Foundation**, Beverly Hills, awarded \$7,000 for the Journey through the Solar System program. The mission of the Dwight Stuart Youth Foundation is to support organizations that provide direct services and experiences to underserved children and youth so they may gain the skills, values, and confidence to achieve their potential.

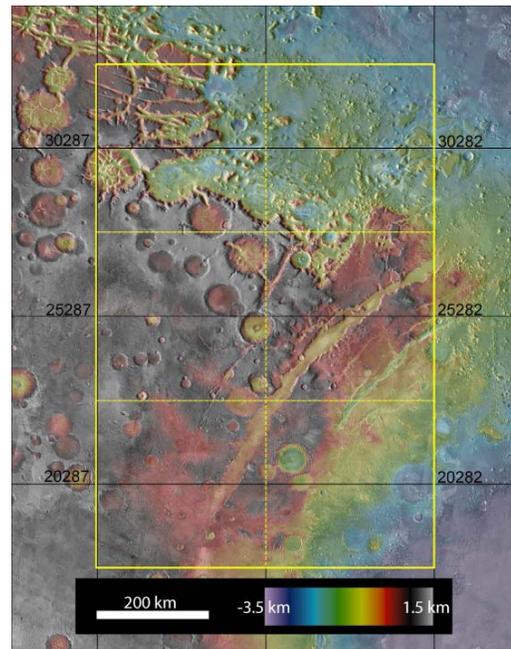
**Wal-Mart**, Laguna Niguel, donated \$500 to PSI in support of our Journey through the Solar System program. The Wal-Mart Foundation is dedicated to addressing environmental issues and promoting education through their corporate giving program.

**Allergan Foundation**, Irvine, donated \$2,500 to the Journey through the Solar System program. Allergan, Inc. is a premier, global specialty pharmaceutical and medical device company. The Allergan Foundation is committed to providing a lasting and positive impact on the community and is focusing their support in four philanthropic areas: the arts, civic programs, education, and health and human services.

We offer our sincerest thanks to the Dwight Stuart Youth Foundation, Wal-Mart, and the Allergan Foundation for their generous financial assistance to this community program for Orange and Los Angeles County elementary school students.

### Bleamaster Receives PG&G Award

Congratulations to PSI Research Scientist **Les Bleamaster** on receiving a NASA Early Career Fellowship for his Planetary Geology and Geophysics (PG&G) proposal, "Geologic Mapping along the Arabia Terra Dichotomy Boundary: Mawrth Vallis and Nili Fossae, Mars" (see image below). This award qualifies him for up to \$100,000 in additional start-up funds. Les will be looking at spectrally interesting outcrops in both regions (specifically phyllosilicates/clays) and placing them into a broad geologic context. The abundance, distribution, and age of these materials may help us to better understand the role of water through Mars' history. Les joins David O'Brien and Becky Williams as PSI recipients of this award.



*This is a topographic view of Nili Fossae, one of the two areas on Mars that will be studied by Les Bleamaster with an Early Career Fellowship award from NASA. The yellow outline marks the cartographic boundaries of the geologic map to be published by the U.S. Geological Survey.*

### NASA Award for Sykes

The American Astronomical Society Division of Planetary Sciences' (DPS) 39th annual meeting, held in Orlando, FL, in October, featured a surprise commendation for PSI's Director **Mark Sykes**. He was honored by James Green, Director of the Planetary Science Division at NASA Headquarters, with the first "Planetary Science Division's Distinguished Service Award." Mark received this award for his tireless support of the planetary science community through efforts such as organizing source material for the development of the Solar System Exploration Decadal report and starting the Planetary Exploration Newsletter, a weekly electronic update of happenings in the planetary community. Dr. Green wanted a way to communicate with the entire planetary science community, not just the DPS membership, and Mark stepped up to make that happen.

Bravo, Mark!

### PSI in Nature Article

The October 15 issue of *Nature* featured an article about science career issues and alternative jobs for scientists entitled "Freedom of the skies" by Genevive Bjorn in which **Planetary Science Institute** was highlighted. The article explained that PSI was the trendsetter in the early 1970s in creating a non-profit institution—outside of a university—that allows scientists to do their work independently while the Institute handles the complicated grant management work demanded by NASA or the National Science Foundation.

### Aviation Week Covers Dawn Mission

NASA's Dawn mission was the cover story for a "science fiction becomes fact" six-page article in *Aviation Week & Space Technology*, July 2, 2007 (pp. 56-61), and the **Planetary Science Institute** was identified as a Science Team Partner.

Among many interesting facts: Dawn is so named because its mission is to study how different bodies formed out of the planetary nebula orbiting the Sun at the "dawn" of the Solar System.

Dawn is the first U.S. science mission to use ion propulsion and is the first mission *ever* to rendezvous with two different bodies in space.

## Dawn is Launched! *(continued from front page)*

ity of engineers resulted in a delay from early June to late June. Then a crane on the launch pad broke delaying the launch to early July. An engine explosion on a tracking boat resulted in a loss of critical coverage for ascent, delaying the launch until late September! And, if it had not launched this fall, the next launch window to allow Dawn to reach Vesta and Ceres would have been in another 15 years!

Currently, Dawn is operating smoothly and responding properly to all commands. Since launch, the instruments have been checked out and found to be in excellent health with the Framing Camera returning its first images of stars.

The big question was how the ion engines would perform. These engines were based on the single ion thruster used by the technology demonstration mission Deep Space 1 (DS1) in 1998. The DS1 engines had some initial problems with shorting out due to local contamination on the grids. Would the Dawn engines have similar problems? Dawn has three thrusters, it needs two to complete its mission (based on estimates of the thruster lifetime); the third is extra or "margin." Each of Dawn's thrusters was tested in sequence; all three performed perfectly and without interruption. In fact, there is indication that they are performing with greater efficiency than planned, meaning more flexibility when it comes to mission operations.

Dawn will fly by Mars in early 2009 and reach the asteroid Vesta in 2011. After nine months studying and mapping Vesta, Dawn will leave orbit and arrive at Ceres in 2015.

In the meantime, PSI scientists are busy with the mission. PSI Senior Scientist Bill Feldman is one of the designers of the Gamma Ray Neutron Spectrometer. He and I, both Co-Investigators on the Dawn mission, are participating in general mission planning. PSI Associate Research Scientist Pasquale Tricarico is determining unplanned flyby opportunities and whether hazards lay ahead as Dawn approaches the orbits of comets and asteroids. I am participating in planning for data processing and archiving. PSI Postdoctoral Research Scientist Matt Chamberlain is measuring thermal radiation from our target objects with various telescopes to learn more about the properties of their surface materials. PSI Senior Scientist Bob Gaskell will be determining object shape and surface topography.

There is a lot to do in the early phases of this mission, and it is exciting to see it finally flying seven years after it was proposed.

*For more information about the NASA Dawn mission go to <http://dawn.jpl.nasa.gov> and the PSI Summer 2007 Newsletter.*

## HiRISE Looks at Martian Slope Streaks

*(Continued from page 2)*

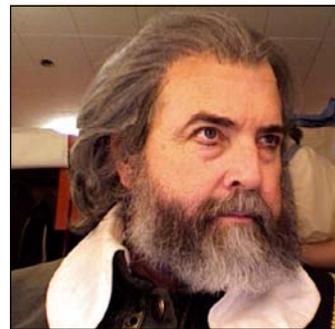
In the *Geophysical Research Letters* article we proposed that the morphologic and topographic characteristics of Martian slope streaks seem to best fit models that involve dry dust avalanches, a process discussed in 2001 by Sullivan et al. (*Journal of Geophysical Research*, **106**). The avalanche is somewhat like a snow avalanche where a layer of powdery material breaks loose and cascades downslope as a dense mass of particles. Most of the dust is probably scattered into the atmosphere and settles elsewhere,

## Director's Note

I am often struck by the contrast between the geeky pocket-protector-wearing stereotype of scientists and real scientists at PSI (I'll let other institutions speak for themselves). They tend to be leaders: gregarious, imaginative and enthusiastic, and can also be serious and thoughtful. They like to have fun, and frankly are fun to be around. Many are serious athletes. We have marathon runners, a competitive swimmer, soccer players, hikers — basically, you name it, people do it. Then we have people like Matt Chamberlain and David O'Brien, who recently competed in a 252-mile bike race, in Cochise County, AZ, lasting more than 15 hours. Matt also likes to compete in 100-mile ultra marathons.

PSI scientists are also artists, authors and professional musicians. Most notable is our own Bill Hartmann, one of PSI's founders and internationally noted not only for his science, but for his paintings and books. We reported in the Spring 2007 newsletter on *Science* magazine's spread on Bill as a modern Renaissance man. Bill is not alone, however. Our walls have been graced by the art of some of our younger scientists as well, and our shelves display their latest books. There is something fundamentally creative as well as rigorous about science, but combined with the need to support oneself and families through the highly competitive process of writing successful grant proposals, I think we end up with a pool of broadly creative and highly motivated individuals whose energy and talents spill over into many other areas such as the arts, athletics, community activism, educational initiatives, and other sciences and professions.

So, the next time you see an apparently mild-mannered PSI scientist, consider that his or her true identity might be more than meets the eye.



Happy Holidays!

Mark V. Sykes  
December, 2007

*In costume for the Arizona Opera Company's Lucia di Lammamore performance in October.*

which may explain why there are no terminal deposits associated with slope streaks.

There are still many unknowns about slope streaks. Why are they dark? If not because the ground is wet, is it some kind of dark material that is now exposed with the dust gone? There are also streaks that are brighter than their surroundings and even a case where a streak transitions from dark to bright along its length. There is speculation among HiRISE science team members that the tone may be related to small-scale surface roughness, but more work, including field analogs, is needed to better understand these issues. In any case, one thing is clear — slope streaks highlight the current ongoing surface modification of Mars by mass-wasting and aeolian processes. □

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