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Lunar and Planetary Science Conference 2017 Trip Report, 1/3

[Also posted at https://eugenebo.wordpress.com/2017/05/22/lpsc-2017-trip-report-44/]

Occasionally, I'd dive into an alternative life for a few days. Mix with people whom I don't know. Listen to conversatio unlike those of every day. Switch my thinking into a different mode.

Or just drop into a conference on a subject remote from my professional interests.

This year, I went to Lunar and Planetary Science Conference (LPSC) 2017 in Houston, Texas. This is one of the largest international meetings of astronomers, planetary scientists, and space agencies representatives where they share ne and plans.

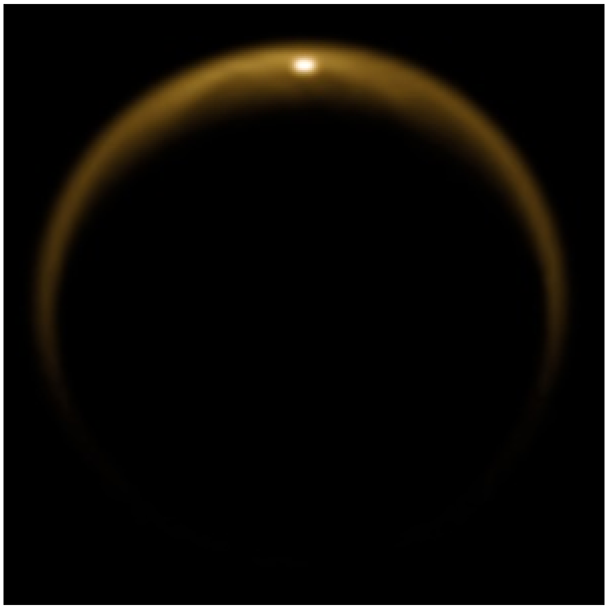
Some 3000 talks and posters were presented there – way more than any human could hope to attend in five days. Wi some planning and careful scheduling, I managed to see couple hundred of them. Most were interesting and worth m time. Here, I'm sharing summaries on twenty presentations that I personally found most inspiring or thought-provoki

That of course calls for a disclaimer. Being a physicist by education, I generally understand the language in use at LPSC I am **not** a planetary scientist. My selection of articles is almost certainly subjective and biased. My interpretations ma incorrect. If anything serious (such as your job, finances, or professional reputation) depends upon the accuracy of m narrative, I'd suggest verifying it with the authors. Their contact info is available within the referenced abstracts.

With that said, let's start.

TRANSIENT BROAD SPECULAR REFLECTIONS FROM TITAN'S NORTH POLE

Titan, Saturn's moon, features extensive set of lakes and seas (called lacus and mare) filled with liquid hydrocarbons. Sunlight reflecting off them has been photographed numerous times over the past ten years:



[Image Credit: NASA/JPL/University of Arizona/DLR]

However, sometimes similar bright spots are seen at locations with no lakes. Moreover, the effect is transient. On one Cassini flyby it glitters, but not on the next one with very similar geometry. What's going on?

As an explanation, a "wet asphalt" hypothesis is proposed.

Suppose a methane rain pours over a rough surface similar to asphalt in texture. "Asphalt" gets wet and starts reflect the sunlight, just like it happens on Earth after rain:

[Image Copyright: Eugene V. Bobukh]

By the next Cassini flyby, it all dries out -- and we see no bright spots anymore.

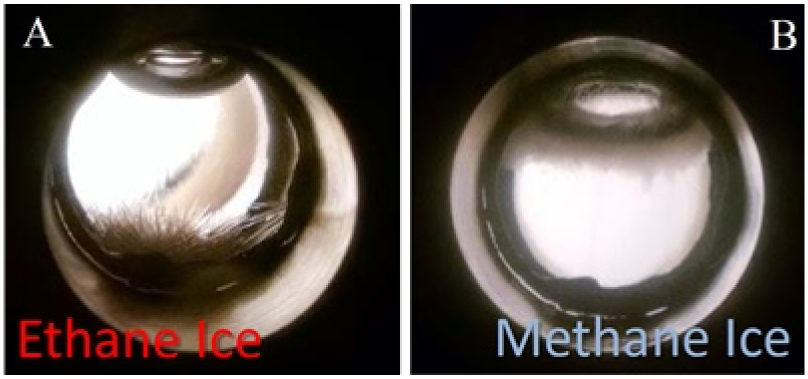
METHANE, ETHANE AND NITROGEN LIQUID STABILITY ON TITAN

This talk discusses Titan's hydrosphere, too. Except that the "hydro" part is not really appropriate, since there is no wa in Titan's lakes and seas. Instead, they are filled with liquid methane (CH_4), ethane (C_2H_6), and nitrogen (N_2). But we poorly know their proportions and don't know well how they interact under Titan's conditions.

After cooling those three gases to cryogenic (-300F…-350F) temperatures, the authors studied how they mix and free under various temperatures and pressures. What they found makes Titan's hydrosphere a far more complex system th Earth's oceans. Well, that is somewhat expected if three, not just one type of "water" and "ice" play together.

First, methane-ethane mixture freezes under lower temperatures than either of those gases. Thus, they act as mutua "antifreeze".

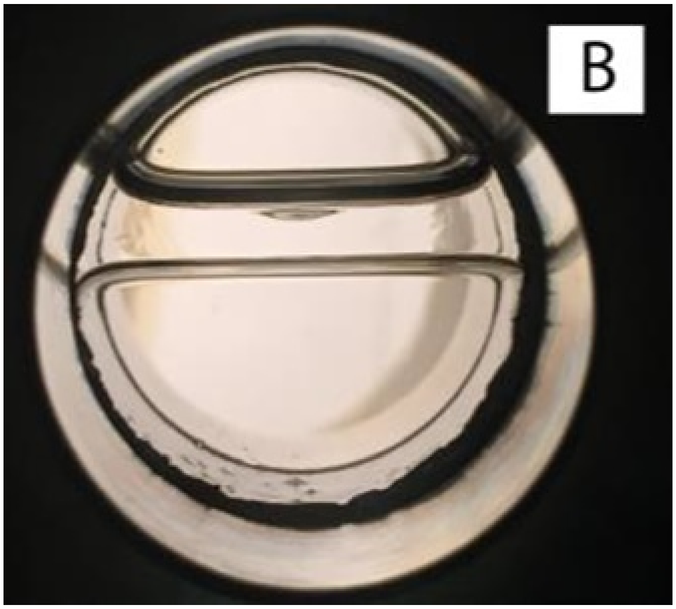
When they solidify, methane ice floats to the surface, while ethane's ice sinks to the bottom. The initial concentration defines which ice forms first. This is more complex than what we see on Earth, where ice always stays at the surface.



[An photo of the experimental camera from the abstract. On the left, ethane ice is on the bottom of the liquid mixture. On the right, methane i at the surface. Image Credit: J. Hanley, L. Pearce, G.Thompson, W. Grundy, H. Roe, G. Lindberg, S. Dustrud, D. Trilling, S. Tegler / Lowell Observat Flagstaff, AZ; Northern Arizona University, Flagstaff, AZ; University of Texas, Austin, TX.]

Addition of nitrogen (simply from the atmosphere) *increases* solidification temperature of the mixture and can cause sudden freezing of liquid. And another LPSC publication suggests that nitrogen dissolves very well in liquid methane – rather poorly in liquid ethane. As a result, evaporation of methane from the mixture could trigger bubbling nitrogen release from a lake. As if it was filled with sparkling wine, but at -300F and with nitrogen bubbles instead of carbon dioxide.

And here is the most interesting observation. At pressures exceeding 2.5 bars (corresponding to depths over ~300 fee Titan) methane-ethane-nitrogen mixture separates into two liquid phases. There was an amazing video in the presentation on that, but here we'll have to resort to a single picture:



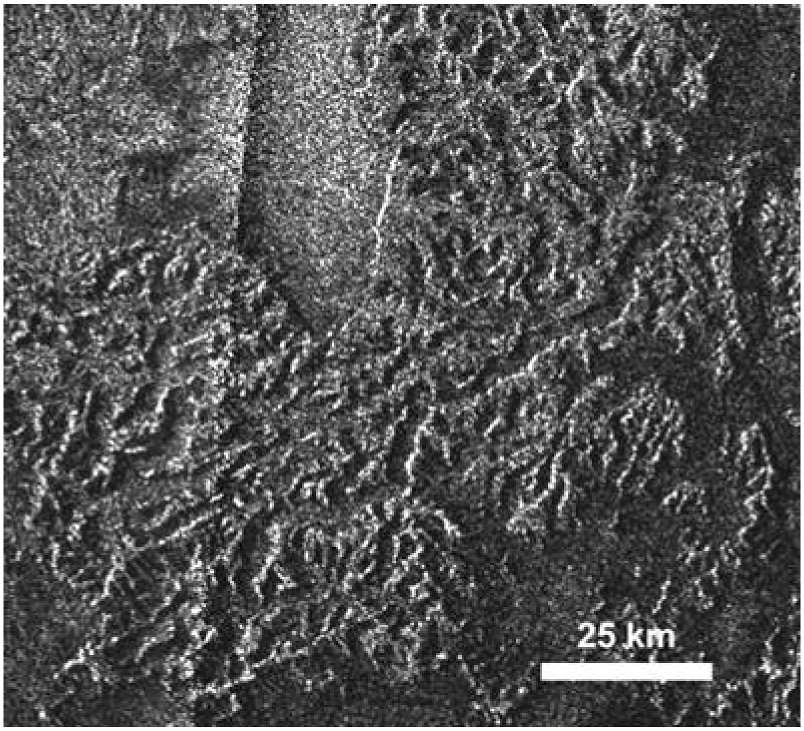
[Image Credit: J. Hanley, L. Pearce, G.Thompson, W. Grundy, H. Roe, G. Lindberg, S. Dustrud, D. Trilling, S. Tegler / Lowell Observatory, Flagstaff, Northern Arizona University, Flagstaff, AZ; University of Texas, Austin, TX.]

At the top of the experimental cell is gas. The first layer is ethane-rich liquid. Underneath it is the second liquid phase with nitrogen. And at the "ceiling" of the first phase you can see a tiny hint of a droplet. That is the 2nd phase conden Insoluble in the first phase, it flows and drops through it just like water through oil.

When I saw that, I immediately imagined two-layer seas on Titan. Did you?

CLASSIFICATION OF LABYRINTH TERRAINS ON TITAN

Titan's labyrinth terrains are highlands carved with complex system of ridges and valleys, visually resembling tree's ba



[Image Credit: NASA/JPL]

Their nature and origin and aren't completely clear. At the first glance, they look like riverbeds – and we know there a rivers on Titan. But if you examine them carefully, you might notice that some of those labyrinths are… closed. They d "flow" anywhere!

Does it mean at least some labyrinths are not riverbeds? The authors conducted morphological analysis of labyrinth terrains and concluded that at least some of them could be… karsts!

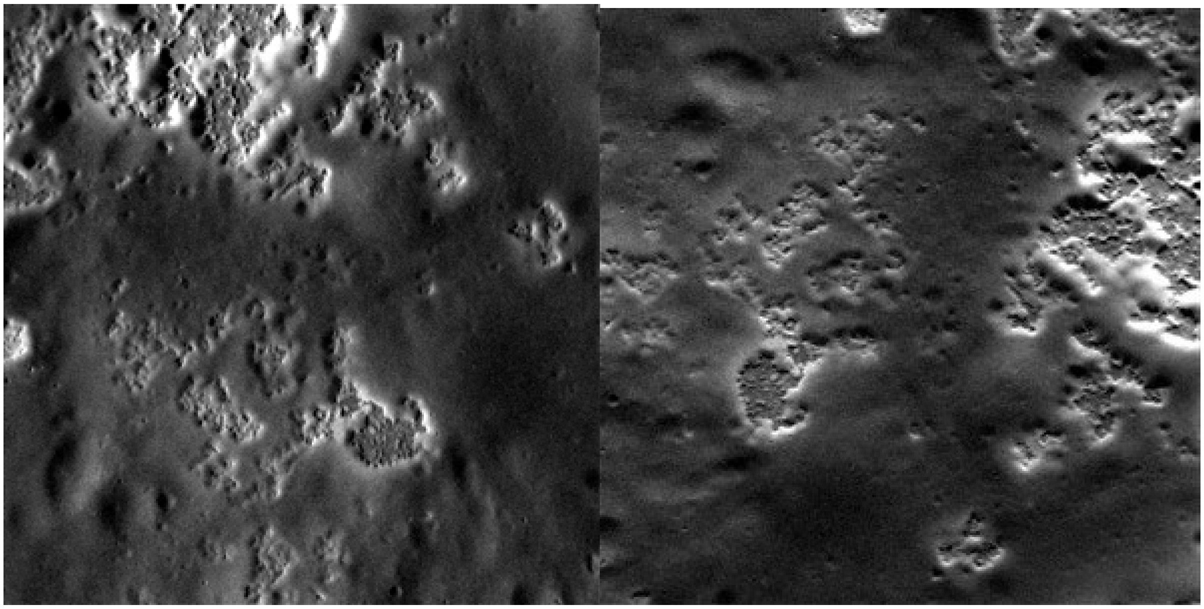
We still don't know whether they are produced via material evaporation, washing away, or dissolution. But maybe so of them are similar in appearance to this terrestrial karst washed through by ancient waterfall?

[Image Copyright: Eugene V. Bobukh]

TOPOGRAPHIC ASSESSMENT OF HOLLOWS ON MERCURY: DISTINGUISHING AMONG FORMATION HYPOTHESES

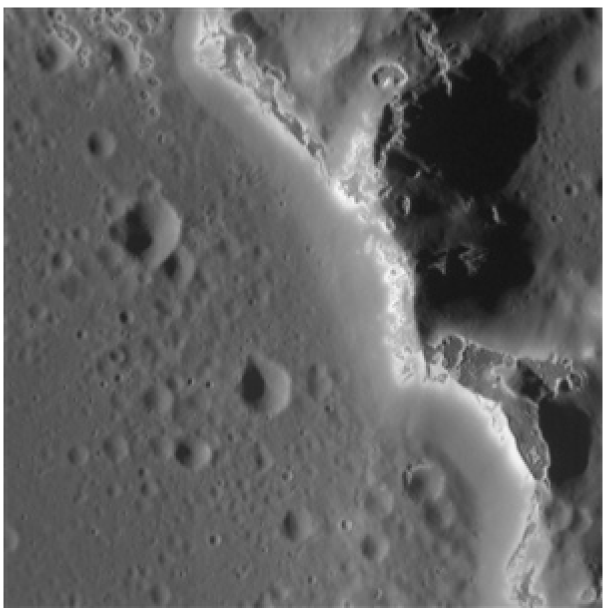
Now let's transition to Mercury, while staying on the same subject of karsts. Or hollows, actually.

Hollows are curious depression spots on the surface of Mercury. Their origin isn't fully clear yet. One of the explanati suggests that they are… karsts, too. But karsts formed through evaporation of some volatile material from beneath th dusty surface.



[Mercurian hollows. Yes, you should try to see depressions, not protrusions in these spots. And the “bumps” are craters. Sometimes rotating an image can help, so I added a rotated version. Another trick to assist with “flipping” the picture inside out is stepping back and temporarily defo one’s eyes. Image Credit: NASA]

We don’t know what that material is, although most likely it is not water. And I don’t know whether the hypothesis is correct. I just enjoyed some pictures of prominent hollows presented at the talk. I recorded their NASA numbers, I fou one of them in the Messenger catalog and posted here after some contrast enhancement. To my defense I shall ment that author’s photos were processed, too -- and some looked much better than my version:



[Image Credit: NASA/JPL]

OXYGEN DEPLETION ON THE SURFACE OF MERCURY: EVIDENCE OF SILICON SMELTING?

After spending four years in orbit around Mercury MESSENGER, the space probe, has measured the abundances of primary rock-building chemical elements (O, Si, Ti, Al, Cr, Fe, Mn, Mg, Ca, Na, K, S, Cl) in Mercury’s surface.

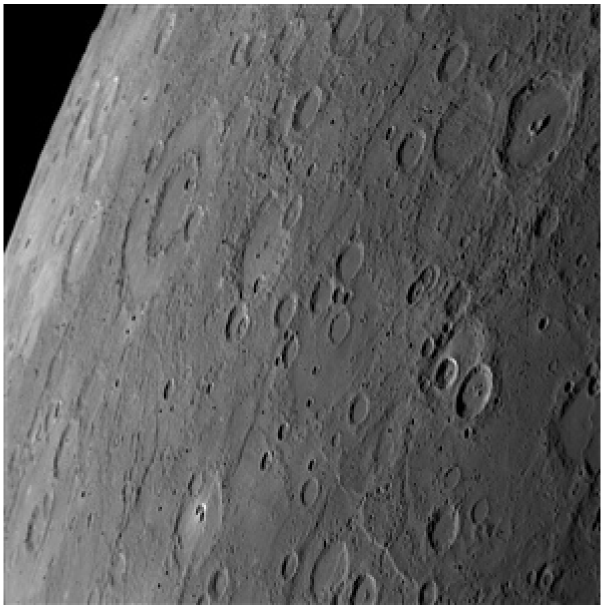
Yet MESSENGER’s instruments see only abundances of those atoms – not the chemical bonds between them or mineralogical composition. To obtain the latter, usually it is assumed that all metallic elements are fully oxidized. For instance, that Silicon is present as SiO_2, Titanium as TiO_2, Aluminium as Al_2O_3, and so on. Then, the minerals are “constructed” out of these oxides (e.g., Andalusite Al_2SiO_5 is represented as $Al_2O_3 + SiO_2$).

That usually works well – but not for Mercury. There seems to be not enough Oxygen to bind all metallic elements wh maintaining the measured Oxygen to Silicon ratio O/Si = 1.4 ± 0.03 (and even less, as the abstract suggests).

As an attempt to explain that discrepancy a hypothesis is proposed. It states that deep within Mercurian interiors sme
of metallic Silicon is possibly happening. The ingredients for it are Silicon dioxide (quartz, SiO_2) and graphite which, as
strongly suspect, is present in significant quantities within Mercury's crust.

If that is true then 12.6–17.9% (by weight) of Mercurian northern hemisphere could be made by pure Silicon or Silico
iron alloy.

Why is it interesting? First, you don't often meet metallic Silicon in nature. More importantly, on all other rocky bodie
(such as Moon, Earth, or Mars) oxygen is plentiful to have oxidized everything that could be oxidized. Why is it differe
a well-fried-through Mercury? That remains an open question.



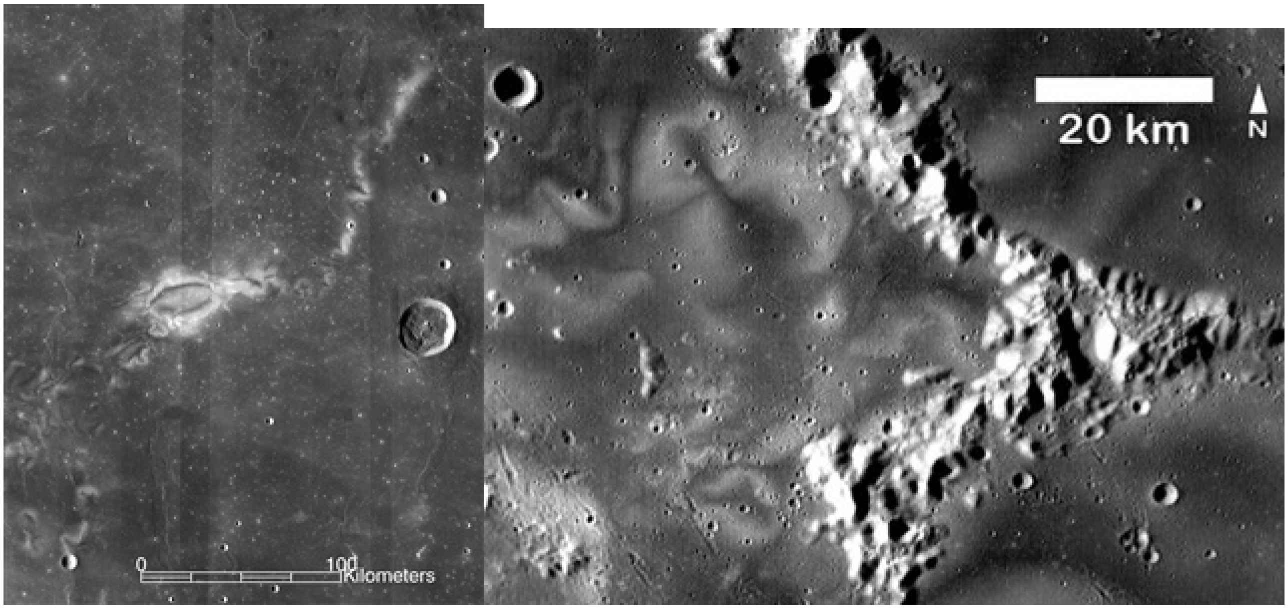
[Mercury and Silicon. Left Image Credit: NASA/JPL; Right Image Credit: Wikipedia]

LUNAR CRUSTAL MAGNETIZATION INFERRED FROM CHARACTERISTICS OF LUNAR SWIRLS

I thought that I knew quite a lot about the Moon. Yet I had no idea of so-called lunar swirls.

They were discovered in 1960s, but their nature remains elusive. They are strange white markings on the surface of t
Moon. Often bended, often curved, they frequently display somewhat periodic patterns, resembling those inflicted b
magnet to a CRT monitor. That lends credibility to interpreting lunar swirls as areas protected from the solar wind by
natural magnets buried underneath the surface. Whether those magnets are solidified ancient lava tubes, or remains
iron meteorites, we don't know. In fact, we still don't know whether this explanation is correct -- although swirls are
associated with magnetic anomalies detected from the orbit.

The rest of the work was concerned with estimating the parameters of those putative magnets. And I enjoyed a very thought of a natural invisible shield protecting lunar surface from solar radiation…



[Lunar swirls. Left Image Credit: Wikipedia; Right Image Credit: NASA]

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HOW DIELECTRIC BREAKDOWN MAY WEATHER THE LUNAR REGOLITH

Not only meteorite impacts reshuffle lunar surface. Solar wind, especially during long lunar nights, probably makes a comparable contribution to that process. How? Via a flow of energetic electrons. Which can reach the night side of th Moon and hit and charge regolith particles up to electric field strengths of ~10^6 V/m. Which would cause electric breakdowns within particles, resulting in their destruction or partial re-melting. Which amounts to slow mixing and resurfacing of the lunar soil. The darker and the colder it is, the better this process presumably works (in “warmer” locations, electric charges dissipate via normal conductivity).

We don’t know for sure whether this actually happens as described. But it would be worth figuring that out. Who kno maybe in countless millions of years the astronaut’s footprints would disappear not under the dust of nearby meteor impacts, but via trillions of microscopic discharges?

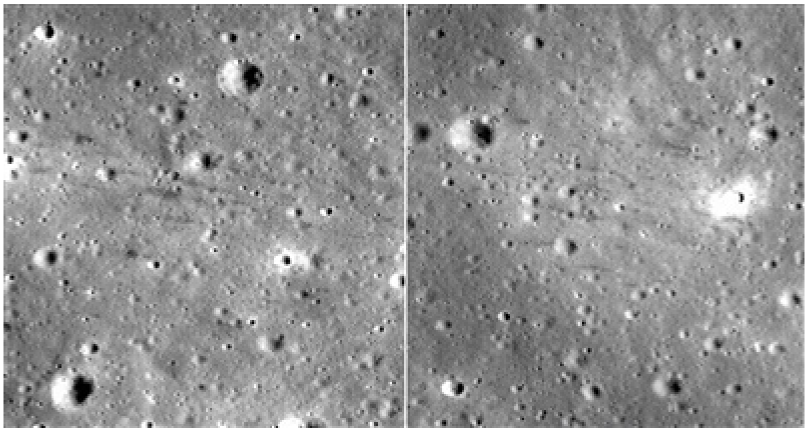
[This is an electric discharge, too. Just a larger one. Image Copyright: Eugene V. Bobukh]

SPACECRAFT IMPACTS ON THE MOON: CHANG’E 1, APOLLO LM ASCENT STAGES

[Electronic poster]

Over the past 60 years, Solar System exploration has gotten its own history… and archaeology. Yes, people search for landers of 1970s in contemporary satellite imagery from other planets, and sometimes find them, as that wonderfully happened with the mysteriously silenced Mars-3 Soviet probe.

The author of this presentation specializes on lunar impacts and has built a whole collection of them. This year, four r were added to it: ascent stages of Apollo-12 and -14, Chinese Chang'E 1 and (very recently) European SMART-1.



[Impact traces from ascent stages of Apollo-12. Image Credit: NASA / Philip J. Stooke]

I found it surprising that many impacts leave behind not craters, but streaks. Apparently, grazing collisions at velocitie ~1 km/s just result in violent rotation and breakup of the impactor, scattering the debris over long distances along the orbital path.

SIZE AND SOLAR INCIDENCE DISTRIBUTION OF SHADOWS ON THE MOON

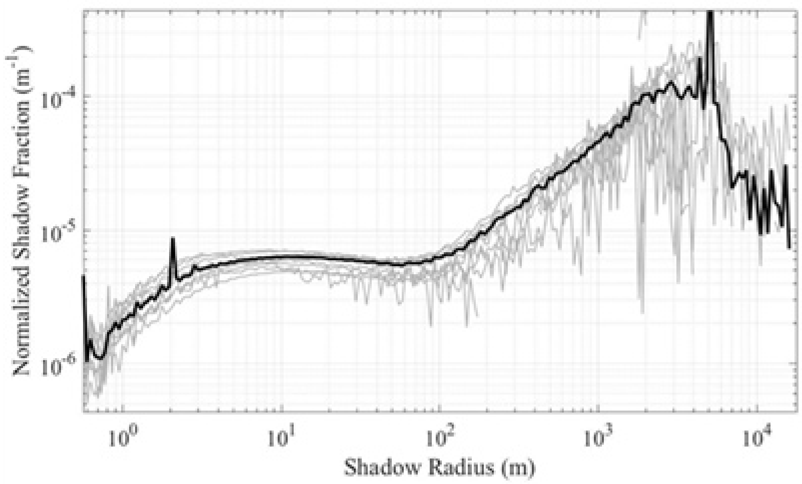
It may be hard to accept that after studying the Moon for hundreds years, walking on it, making 12-inch resolution ph of it, and dumping 180 tons of trash on its surface we can still have something unclear about it. Especially about such seemingly trivial thing as shadows.

Yet it appears to be the case.

The authors conducted a research that may look like a simple and boring activity. They studied the distribution of luna shadows by size. This is pure statistics – but with a twist. Shadows sizes and shapes could be rather complex and depe on lunarscape characteristics in non-obvious ways. That is particularly pronounced at lunar "mornings" or "evenings", when the sunlight is parallel to the surface and minute roughness variations cause great impact on the projected shadows.

They found that the number of shadows with sizes between 3 and 100 meters (10 to 300 feet) does not depend on th size. More importantly, they saw no clear good explanation for that. So perhaps there is something in the distribution lunar bumps and ditches that we don't understand well? This conclusion caused some serious discussion at the conference, with people was trying to interpret it via crater size statistics, but I did not quite capture all the details so convey them here.

So yes, this is a seemingly trivial statistic of black and white patches. But done right, it reveals something enigmatic ab our well-studies Moon – something hidden within its shadows…



[Shadows area distribution from the discussed work. Image Credit: Oded Aharonson, Paul O. Hayne, Norbert Schorghofer]

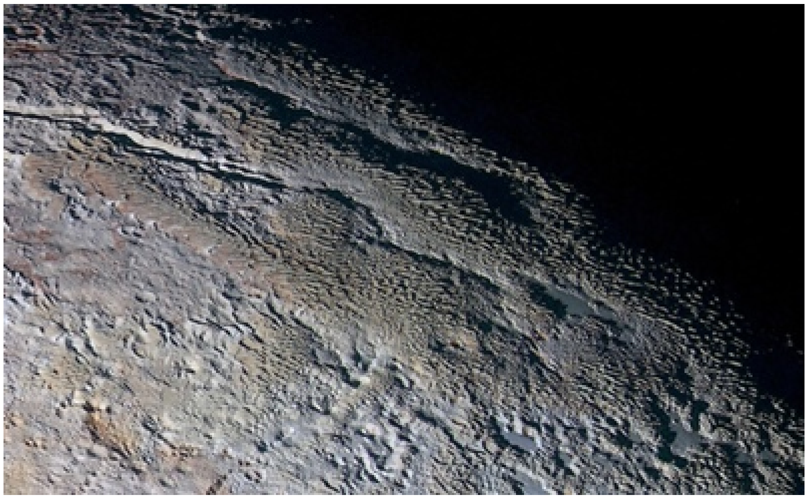
PENITENTES AT TARTARUS DORSA, PLUTO

Penitentes are bizarre needle-like snow formations known so far only on Earth:

[Image Credit: Wikipedia]

[Image Credit: Wikipedia]

But, according to the presentation, they may also exist on… Pluto! While we haven't seen them close enough to be 10 confident, these longs stripes "are well described by the theoretical penitente models of [4] with spacing, orientation growth rates matching well with observations for the methane ices observed by New Horizons (NH) [5] on Pluto". And they most likely are made of methane (CH_4) ice.



[Tartarus Dorsa are on Pluto. Image Credit: NASA/JHUAPL/SWRI]

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BISMUTH TELLURIDES AND SULFIDE MIXTURES AND THEIR RELATION TO METAL FROST ON VENUS

In some radar images of Venusian highlands, there is something that looks almost like a snow. Of course, at 500 degre Centigrade, that must be something else. Something with high reflectivity and high dielectric constant. Probably of ar almost metallic nature. What could that be?

[“Snow” in Maxwell Montes on Venus. Image Credit: NASA/Magellan]

The authors hypothesized that this could be tellurides or sulfides-tellurides of Bismuth (Bi_2Te_3, Bi_2Te_2S). They recreat Venusian conditions in the lab to test how these compounds sublimate and interact with CO2-rich Venusian atmosph and whether they would, like our snow, make “frost” in Venusian mountains at 300-degree “coldness” out there.

Their conclusions did not look very solid to me, and I’m not sure why only these two compounds were tested with qu many alternatives potentially imaginable. But the notion of “semiconductor snow” has certainly resonated within my mind, so I’ll keep that publication in the list.

[Sulfide-telluride of Bismuth Bi_2Te_2S, also known as telluric bismuth. Image Credit: Wikipedia]

THE BIOPAUSE PROJECT: BALLOON EXPERIMENTS FOR SAMPLING STRATOSPHERIC BIOAEROSOL

Whoever have read Michael Chriton's *The Andromeda Strain* would immediately appreciate this work. The idea is the same: go as close to the outer space as possible, scoop life samples from out there and bring them back to study. Wh see how far the Earth's live continues into space, and what it is like there.

Of course, many countries and organizations have conducted these studies over the past 70 years. USSR, for example, have brought microorganisms from altitudes of 48-77 kilometers back in 1976. But Japan Aerospace Exploration Ager (JAXA) is notable for coming up with new interesting projects for rather modest money.

Typically, such research relies upon cultivation of specimens for analysis. Obtain, seed, grow, study what has germinat But, according to the author, "more than 99% of the microbes in nature are thought to be uncultivated species" (++another link). So cultivation-based analysis is bound to miss 99% of the catch's biological diversity – including perh the most bizarre and unusual microbes.

To work around that problem, JAXA decided to not cultivate. Instead, they simply studied **all** collected samples with a fluorescence microscope and a scanning electron microscope. And even though their balloon brought the microbes fr a relatively "modest" altitudes of 13-27 kilometers, they (according to the abstract) "estimated the number density of stratospheric microbes including those that cannot be cultivated for the first time in the world."

Unfortunately, during the mission return they've lost the negative test chamber. So the next flight, tentatively schedu for June 2017, should help with verifying the results.

SURVIVABILITY OF RNA AND PROTEIN MONOMERS AGAINST EFFECTS OF SHOCK PRESSURES

Suppose a meteorite contaminated with terrestrial DNA hits another planet. Explosion, pressure spike, instantaneous heating -- would organic matter survive such an ordeal?

Sometimes there the best way to find out is to run an experiment. That's what the authors did. They shot artificial "meteorites" with proteins and RNA fragments added against solid targets and measured how much of the organic m survived impacts. It turns out, rather little:

Shock stress – (approximate impact velocity) -- % of organics survived

10.5 GPa -- (~2.2 km/c) -- 4.3%

28 GPa -- (~4 km/c) -- 0.7%

40 GPa -- (~6 km/c) -- 0%

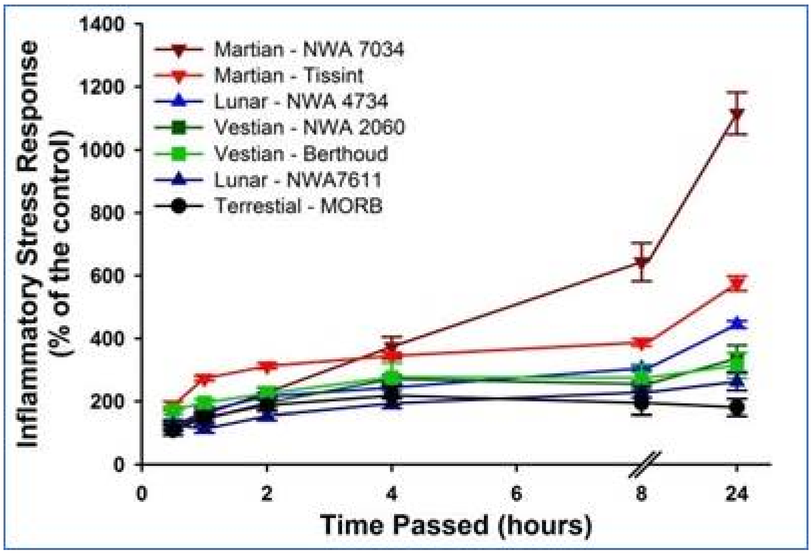
Does that mean that panspermia does not work? Not at all. It's possible to imagine numerous less stressful ways of organics delivery by meteorites. However, a direct impact against a body the size of Mars without significant slowdow atmosphere is apparently fatal even for relatively simple organic molecules.

[PULMONARY INFLAMMATORY RESPONSES TO ACUTE METEORITE DUST EXPOSURES - IMPLICATIONS FOR HUMAN SPACE EXPLORATION]

Again, this area of research isn't new. I vaguely remember some papers from 1990s concluding that lunar dust is harn for lungs and causes strong silicosis in rats.

In this work, inflammatory stress response of human lung tissue to lunar, Martian, Vestian and terrestrial dust was measured. The first three were obtained from corresponding meteorites. The last one was made from terrestrial basa

The observations are rather gloomy. All dust caused significant negative effect on lungs. But the worst of four types studied was the dust from Mars. Its effect is comparable to that of terrestrial mine tailings, notable for causing severe health problems in mine workers. Lunar dust is the next, followed by least harmful terrestrial basalts (although they weren't completely benign, to be clear).



[Inflammatory Stress Response to various types of dust. Image Credit: A.D. Harrington, F.M. McCubbin, J. Kaur, A.Smirnov, K. Galdanes, M.A.A. Schoonen, L.C. Chen, S.E. Tsirka, T. Gordon / NASA Johnson Space Center; Dept. of Environmental Medicine, New York University School of Med Dept. of Geosciences, Stony Brook University; Geology Dept., Lone Star College; Environmental Sciences Dept., Brookhaven National Laborator Pharmacological Sciences, Stony Brook University]

I can see several implications here. First, if humans would ever walk on Mars, they would have to invest considerably protecting against dust there. Second, my pile of paper sheets with imprecisions noted in "The Martian" just grew on item larger :) Third, we often underestimate seriousness of dust effects on other planets. For example, Lunar dust is s strongly abrasive that it destroys moving parts and surfaces exposed to it an order of magnitude faster than what's expected on Earth. If interested, take a look at the last passage on the 5th page of this document.

LPSC 2017 Trip Report, 4/4

[CLIMATE OPTIMUM ON MARS INITIATED BY ATMOSPHERIC COLLAPSE]

Cold, dry and sterilized are three words that best describe today's Mars. Yet we know that there were better times th Warmer times with denser atmosphere and liquid water that left riverbeds clearly visible even today. How long ago w that? How long did that period last, what have started and stopped it? That's where the certainty steps away to be replaced with various hypotheses.

One of them is proposed in this paper. At the first glance, it looks awkward. The concept behind it is akin to a fire bein accidentally started by a firefighter machine arriving on a false call.

It states that warmer climate was a response to the very first atmosphere collapse on Mars. That collapse triggered release of large quantities of methane clathrates that have accumulated under martian soil earlier. Photolysis and oxidation products of that methane increased greenhouse warming to the point of climate change, enabling liquid wa flows on the surface.

But did it really happen exactly like that? I guess, nobody knows for sure yet.

CAN MARS BE TERRAFORMED?

The short answer is No.

Of course, there are details. In theory, many approaches to that problem are imaginable. But at least the most straightforward of them isn't likely to work. It suggests that if enough CO_2 from the Martian polar cups is artificially evaporated, the greenhouse effect on Mars could be boosted to the point where the planet's climate would become warm and self-sustaining.

However, after accounting for CO_2 supply based on the most recent data, the authors concluded that there is not enc of that gas there for this project to work. And even complete evaporation of the Martian polar cups would warm the planet by ~10 C (~20 F) only. That would not be enough to shift the atmosphere into a self-sustaining warm mode.

EFFICIENCY OF ATMOSPHERIC EROSION BY IMPACTS: ENERGY CONSIDERATIONS AND APPLICATIONS

Let's start with Shuvalov parameters. They are formulas that relate efficiency of planetary atmosphere erosion by impacting asteroids to parameters of those asteroids, mainly mass and velocity:

$$\xi = (d_i^3 \rho_i / H^3 \rho_0)[\rho_i/(\rho_i + \rho_t)][(v_i^2 - v_{esc}^2)/v_{esc}^2],$$

$\chi_a = (m_{esc}/m_i)[v_{esc}^2/(v_i^2 - v_{esc})^2]$ The impactor diameter is d_i, velocity v_i, density ρ_i and mass is m_i; the atmosphere is characterized by surface density ρ_0 and scale height H; the planet escape velocity is v_{esc} and ground ("target") density ρ_t.

That efficiency has a maximum. A meteorite (or an asteroid) that is too large or too fast is less efficient in "splashing c an atmosphere than a smaller or a slower one:

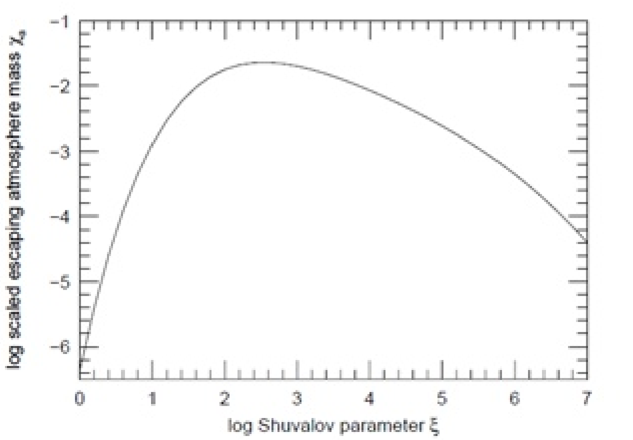


Figure 1: Empirical fit of χ_a vs. ξ by Shuvalov[3] to impact erosion simulation results.

[Efficiency of atmosphere erosion by an asteroid as a function of its Shuvalov parameter ξ. Image Credit: Shuvalov, V., 2009. Meteorit. Planet. Sc 1095-1105.]

By choosing asteroids of the maximum efficiency, one can calculate how many of them would be required to complet strip off the atmosphere of Venus. The answer is "a lot". Unrealistically many. We are talking about (0.5-9)% of the ma the Moon. The upper limit of that estimate exceeds Solar System asteroids' mass combined. Using that figure, I can crudely estimate that the energy needed to deflect that enormous fleet of asteroids is no less than ~10^{27} Joules. That million times more than the current yearly energy "budget" of the whole human race.

Alas, the plan of terraforming Venus by removing its atmosphere with asteroid impacts remains a sci fi – at best.

A GEOPHYSICAL PLANET DEFINITION

From the standpoint of geophysics, Pluto and all sufficiently large bodies like Titan, Ganymede or Europa are genuine planets irrespective of their orbits.

Their descriptions usually mention most features absent in small bodies but common in "real" planets, such as spheri equilibrium shape, differentiation, tectonic activity (current or past), atmosphere, certain resurfacing processes, form and thermal history. In planetary science textbooks Pluto or Ganymede are more naturally presented in the same cha with Mars or Venus rather than with small asteroids or comets. Language used when writing about Pluto is closer to t of Mars rather than of comets. Finally, the authors mention over 40 peer-reviewed publications referring to Titan and Europa as planets, "both pre- & post-IAU planet decision".

And none of that depends on the body's orbital parameters.

Therefore, the proposal is to stop messing around with "dwarf planets" and, without waiting for IAC approval (which needed anyways), just start calling all these bodies planets.

Planetary Topography from Laser Altimetry

A great lecture on laser altimeters in service around other worlds. The video opens with honors and awards. If you ar eager to see the technical part, jump to the 16th minute.

NASA Headquarters Briefing

In this video, NASA reports on past progress, budget and plans. Q&A start at the 51st minute and is worth attention in own.

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This is it. Thank you!

Eugene V. Bobukh

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