Great Debates

Life in our Solar System

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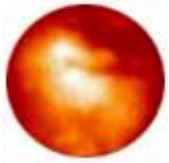
Does Titan Rain Methane?



Summary (Jan 25, 2005): As director of the Planetary Science Laboratory in the University of Michigan College of Engineering, Professor Sushil Atreya discusses the fate of carbon-based transformations on Titan. In this initial interview, Atreya describes why methane on Mars means different things to what might be happening on Titan.

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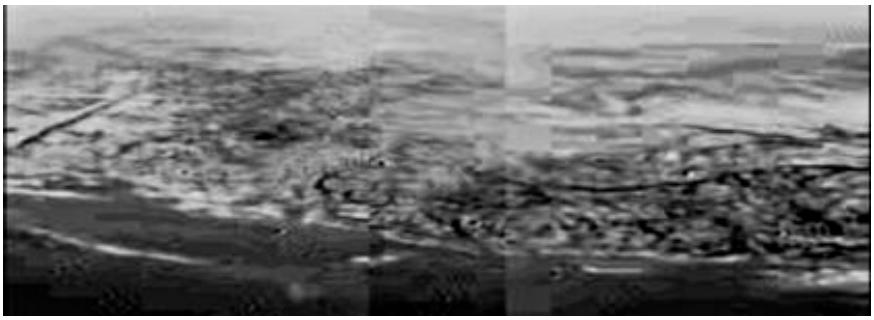

Does Titan Rain Methane?

The haze of an atmospheric layer on Saturn's moon, Titan. *Credit: Voyager Project, JPL, NASA*

Titan is unique as a moon because its atmosphere is even more dense than Earth's. Since the early Voyager flybys in the 1970's, this Saturnian moon's smog has intrigued planetary scientists, particularly since Titan's hydrocarbon chemistry may share common features with our own atmosphere or neighboring martian cases. For the first time, planetary scientists now can compare and contrast details of atmospheric chemistry with data and examples. What is the role of methane in explaining what drives geology and meteorology on this new and alien world?

As a member of the Cassini-Huygens Science and Experiment Teams [GCMS AND ACP], Sushil Atreya kindly shared his initial thoughts soon after the successful landing of the Huygens probe on Saturn's largest moon, Titan. Atreya is a professor and director of the Planetary Science Laboratory in the University of Michigan College of Engineering. He is the author of several books including *"Atmospheres and Ionospheres of the Outer Planets and their Satellites".*

Astrobiology Magazine (AM): If the half-life of Mars methane might be around 300 years, is there a different corresponding figure for Titan that might indicate how long methane survives in Titan's atmosphere?

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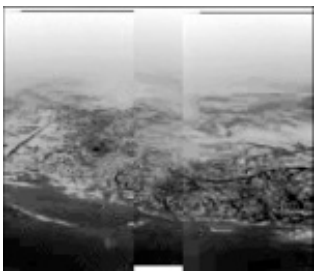
Ephemerids
On this day in...

1835
Charles Darwin & Mariano Gonzales meet at Portillo Pass
1851
Yosemite Valley discovered in California
1857
Earthquake hits Tokyo; about 107,000 die
1859
1st Zoological Society incorporates (Phila)

Sushil Atreya (SA): First, unlike nuclear physics where half-life is used, the jargon in atmospheric applications is "lifetime", which actually is "e-folding time". The e-folding time is the time over which the concentration drops by a factor of "e", roughly 3.



Shoreline horizon during descent to Titan. Click image for larger view. *Credit: ESA*

The lifetime of methane in Titan's atmosphere is approximately ten million years, compared to 300-600 years on Mars.

AM: Does the higher density of Titan's atmosphere change its ultraviolet degradation substantially, relative to the martian case?

SA: Indeed Titan's higher atmospheric density prevents the UV from penetrating to deep levels. As a consequence, most of the UV degradation occurs high in the atmosphere.

Three factors are involved in determining the lifetime: first, the density and composition of the atmosphere, second, concentration of methane, and finally, the solar ultraviolet flux.

Because of (1) and (2), methane is destroyed not just by the UV (above 60 km) but also by oxidation (below 60 km, mostly near the surface) on Mars, whereas the principal destruction of methane on Titan is by the UV well above 500 km.

Because of (3) alone the destruction rate at Titan, which is at ~10 AU from the Sun, is roughly a factor of 40 slower than at Mars, which is ~1.5 AU from the Sun. Considering the full photochemical loss and recycling mechanisms yields the ten million year lifetime for methane on Titan.

Surface orange pebbles from Titan. Click image for larger view. *Credit: ESA*

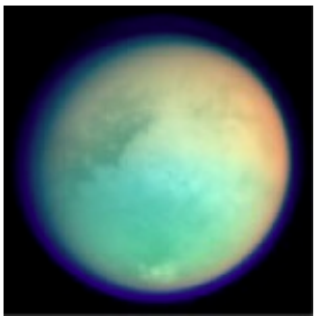
AM: The methane clouds are much different in frequency to, say, earth's water clouds--mainly Titan has fewer of these clouds that might be expected if the relative methane 'humidity' was greater than 30%. Is there a better picture now of whether methane rain is ever a possible working hypothesis that holds up?

SA: The sudden change in the methane mixing ratio at 17-19 km altitude detected by the Huygens Gas Chromatograph Mass Spectrometer (GCMS) is a strong indicator of a thick cloud or haze layer of methane. The methane mixing ratio steadily rose below this altitude. Upon impact the GCMS inlet was heated, and a surge in the methane mixing ratio was recorded, indicating a reservoir of liquid methane on the surface.

The above behavior of methane, together with the images reminiscent of river channels, as well as the "wet clay" like surface concluded by the Surface Science Package, all argue for methane rain on Titan.

Titan's methane cycle is somewhat like the water cycle of the earth involving evaporation (from oceans/lakes), clouds, and precipitation.

AM: Was there anything specific that you were looking for in pictures to help understand if the methane source might be surface volcanism or actual pooling of hydrocarbons?



Titan in different wavelengths and atmospheric depths. *Image Credit: NASA/JPL*

SA: Unlike Mars, existence of methane on Titan is not surprising. But, how does the methane get replenished on Titan is the big question. For this, a source is required.

We were on the lookout for any telltale signs like fumaroles [vents], etc. but it was a long shot, and we didn't see any in the landing site.

On the other hand, we did detect radiogenic argon (40Ar) with the GCMS. It arises from the decay of potassium (40K) that is in the rocks deep in the interior of Titan. This detection indicates that there must be out-gassing going on.

AM: Are there scenarios where methane production on Titan is only geological venting or volcanism? In other words, is there really tectonics that make sense on Titan or is that not understood well enough yet?

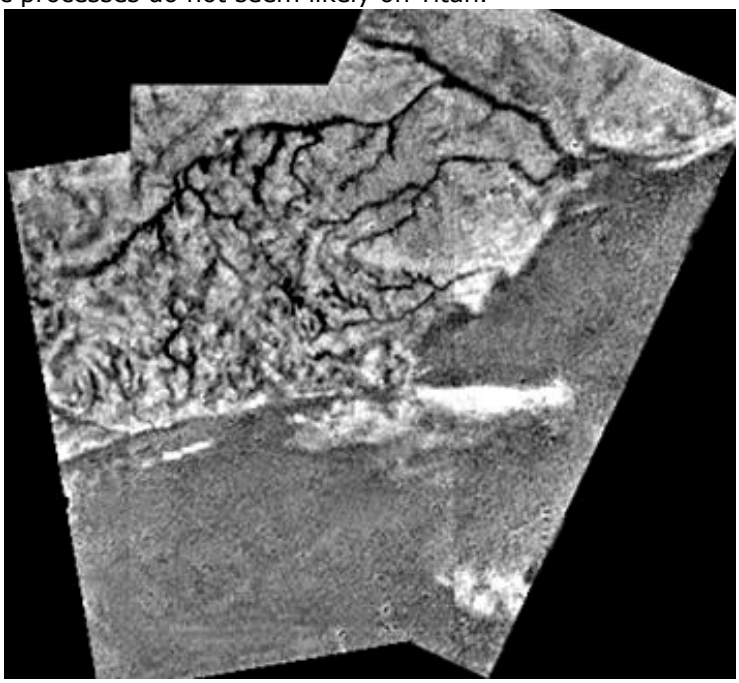
SA: Venting may not be an issue. The detection of argon-40 (40Ar) is good news for methane, provided that it can be manufactured in Titan's interior. Could the process be hydro-geological, a possibility I have discussed in the context of Mars? We don't know at this moment, but are in the process of developing a scenario by integrating all available evidence from Huygens.

Large scale magmatic or tectonic processes do not seem likely on Titan.

AM: On Mars, the methane was almost a trace gas in parts per billion, while almost half of Titan's thick atmosphere is methane. What does this tell about what makes all the methane on Titan? For example, is the UV so low there that the rate of decay is slower and thus methane accumulates in different ways in the outer solar system?

SA: First, a small correction--methane on Titan is roughly 3-4% by volume of the atmosphere, not 50%. But, yes, a much bigger fraction than on Mars.

The reservoir of carbon on Mars, Earth and Venus is carbon dioxide (CO_2), whereas carbon resides predominantly in methane (CH_4) in the outer solar system. This is due to the difference in the way the outer solar system bodies formed compared to the inner planets. In the hydrogen-rich environment of the outer solar system, carbon (which was originally in the form of organics or CO) is converted to



"We had great difficulty obtaining these pictures. We had only one percent of the illumination from the sun, we're going into a very thick atmosphere with lots of haze that blocks light from penetrating to low levels, and we're taking pictures of an asphalt parking lot in dusk situations, and trying to stretch the contrast. So to a human eye, those dark regions would be very black. But there are bright regions as well, the hills, for example - those are significantly brighter. I think that's because the dark material has washed off the top of those hills, and has now been concentrated into the river channels and into the low lying regions where the liquid finally dries out and leaves the dark organic material concentrated." - Martin

CH4. Tomasko Click image for larger view. *Credit: ESA*

The destruction by UV comes into play only after methane has been incorporated into the planet or satellite like Titan. The slower destruction rate in the outer solar system would simply drag out the destruction process, but in the end a mechanism would still need to be found to replenish the methane so destroyed.

And, that's still a mystery, but Huygens data are expected to reveal the secret, in time.

Listen to sounds from the microphone onboard the Huygens during its descent (wav file format, approx. 600 kB each):

+ *Track One*
+ *Track Two*
+ *Track Three*
+ *Flash animation of Landing*
+ *Surface GIF animation, rock shadow*

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Tuesday, January 25, 2005

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