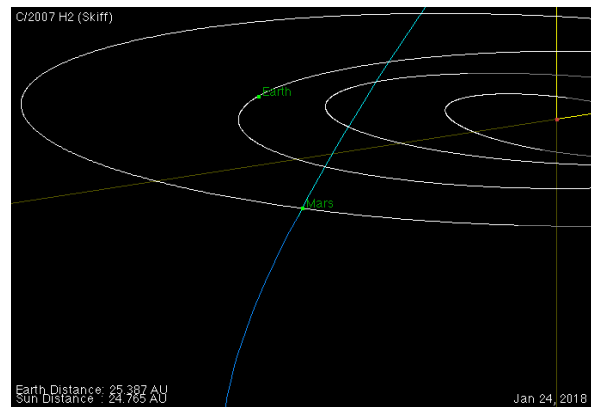


**TESTING THE MARTIAN METHANE FROM COMETARY DEBRIS HYPOTHESIS: THE UNUSUALLY CLOSE 24 JAN 2018 INTERACTION BETWEEN COMET C/2007 H2 (SKIFF) AND MARS.** M. Fries<sup>1</sup>, D. Archer<sup>2</sup>, T. Christou<sup>2</sup>, P. Conrad<sup>4</sup>, J. Eigenbrode<sup>5</sup>, I.L. ten Kate<sup>6</sup>, A. Steele<sup>4</sup>. <sup>1</sup>Astromaterials Research and Exploration Science (ARES), Johnson Space Center, Houston, TX 77058, <sup>2</sup>Jacobs, NASA Johnson Space Center, Houston, TX 77059, USA, <sup>3</sup>Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland, <sup>4</sup>Geophysical Laboratory, Carnegie Institute of Science, Washington DC 20015. <sup>5</sup>Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt MD 20771, <sup>6</sup>Dept. of Earth Sciences, Utrecht University, Netherlands. Email: marc.d.fries@nasa.gov

**Introduction and Background:** In previous work we proposed a hypothesis wherein debris moving along cometary orbits interacting with Mars (e.g. meteor showers) may be responsible for transient local increases of methane observed in the martian atmosphere (henceforth “the hypothesis”)[1]. An examination of the literature of methane detections dating back to 1997 showed that each detection was made, at most, 16 days after an interaction between Mars and one of seven small bodies (six comets and the unusual object 5335 Damocles)[*ibid*]. Two observations of high-altitude, transient visible plumes on Mars also correlate with cometary interactions, one occurring on the same day as the plume observation and the second observation occurring three days afterwards [2], and with two of the same seven small bodies. The proposed mechanism for methane production is dissemination of carbon-rich cometary material on infall into Mars’ atmosphere followed by methane production via UV photolysis, a process that has been observed in laboratory experiments [3,4]. Given this set of observations it is necessary and indeed conducive to the scientific process to explore and robustly test the hypothesis.

Researchers have challenged the hypothesis. One rebuttal [5] states that meteor showers should not generate sufficient infall mass to account for observed methane maxima, and that the Mumma et al. plume [6], which produced a reported 40,000 tons of methane, would generate observable thermal effects if it derived from meteoritic infall. A meteor shower of sufficient mass to generate 40,000 tons of methane would require a flux on the order of  $10^4$  times that of the background dust flux, which is an extraordinary amount [*ibid*]. However, the Mariner IV spacecraft recorded a meteor flux event in Mars’ vicinity in excess of  $10^4$  above the background which slewed and physically damaged the spacecraft [7]. While such an event is uncommon, the fact that it has been recorded indicates that it cannot be ruled out as a cause for large methane transients on Mars. Also, the release of 40,000 tons of methane is problematic regardless of the source, as eruption from an underground source should have generated surface features and large amounts of dust visible from orbiting spacecraft. To date, such features have not been reported even though the Mumma et al plume location is known. For further



*Figure 1:* Diagram showing the orbital interaction between comet C/2007 H2 (Skiff) and Mars on 24 Jan 2018. This unusually close interaction may allow a robust test of the hypothesis of martian methane via meteor shower influx. Image: JPL Small Bodies Database.

discussion see [5] and the follow-on reply. A second challenge to the hypothesis [8] showed on the basis of a statistical analysis that a significant number of comet orbit/Mars encounters have occurred without detectable increases in methane. This approach was investigated and discarded by the original hypothesis authors because, while orbital interactions can be predicted with great accuracy, the flux deposited by any given comet orbit/Mars encounter is unknown. Many such encounters should generate little infall, and since the lower limit of methane detection WRT infall flux is not known, it is currently unknown how many potential meteor shower events would produce sufficient methane to be detectable. This problem is confounded by a paucity of data on interplanetary dust particle (IDP) and meteor shower flux on Mars, and the lack of the sort of historical meteor flux data available for showers on Earth. Therefore, the statistical approach is likely to generate large numbers of false negatives in the data set, and was rejected by the hypothesis authors as insufficiently rigorous to serve as a standalone challenge to the hypothesis [9].

The comet implicated in the Mumma et al. methane plume is long-period comet C/2007 H2 (Skiff) (hereafter “Skiff”). In Mumma et al’s 2003 methane observation, the comet was in one of its closest approaches to

Mars in its 351-year orbit, and its orbit passed only  $\sim 1/3$ rd of an Earth-Moon distance from Mars. Calculations of methane dispersion show that Mumma's plume are most likely to have occurred only a few sols before Mumma's observation, and from a short-lived event [10]. The Skiff orbit/Mars encounter occurred over a period centered 3-4 sols prior to Mumma's methane observation, and dust evolution calculations by Vaubaillon [11] predict a clumpy particle distribution conducive to strong, brief meteor outbursts. This is generally in agreement with methane generation consistent with Mumma's 2003 observations, if the hypothesis is valid.

A recent paper revealed observations of Mars during the period of comet Skiff's 2016 orbit interactions, around 08 Mar 2016 [12]. This paper reports non-detection of methane during the period of the Skiff orbit/Mars interaction. However, the MAVEN orbiter observations at the same time did not conclusively indicate evidence for a meteor shower [M. Crismani, pers comm], and so this interaction may not have generated significant cometary infall.

In short, a correlation has been observed between martian methane "plumes" and interactions between Mars and a small number of cometary orbits, and a mechanism with supporting experimental evidence has been proposed to explain the production of methane. All evidence thus far, both in favor of the hypothesis and in opposition to it, is hampered by significant uncertainties. The most robust test of the hypothesis will be two-fold: 1) conclusive evidence that a meteor shower of significant magnitude accompanied a given comet orbit/Mars interaction, and 2) sensitive observations for methane before, during, and after the time of the event to test for methane evolution from the meteor shower.

**The 24 Jan 2018 Interaction:** An upcoming interaction between Skiff and Mars may facilitate a robust test of the hypothesis (Figure 1). The comet's orbit interacts with Mars every martian year, and the upcoming 24 Jan 2018 encounter has characteristics favorable for producing a significant infall flux. The comet orbit/Mars interaction distance is predicted to be only 0.08 lunar distances at closest approach [P. Jenniskens, pers comm]. Vaubaillon predicted in [10] that this encounter may be significant, with predicted dust encounters at 0000 and 2100-2300 UTC on 24 Jan 2018. Testing the hypothesis could be accomplished with assets capable of observations of infall flux and methane production. The MAVEN orbiter is capable of measuring meteoritic infall through detection of  $Mg^+$  [13], but is insensitive to methane. Several terrestrial observatories are capable of methane detection (such as in [6]) and at least one will be dedicated to this task [14]. If the 24 Jan 2018 interaction generates a significant meteor shower, the

paired MAVEN/ground observations may allow a robust test of the hypothesis.

**Implications:** Regardless of the outcome, testing the hypothesis amounts to a triumph of basic, hypothesis-driven science. A suite of ground-based and orbital assets will be utilized in a coordinated analysis that will reveal fundamental processes on Mars. If the hypothesis is proven, part of the mystery of martian methane plumes will be clarified. If the hypothesis is disproven, then the search for the cause of the plumes will focus towards its eventual resolution, and a greater understanding of meteor flux on other worlds will result. Even if the hypothesis is proven, it will not preclude input from other methane sources such as underground aqueous activity, or even extant or extinct life, and will actually assist in distinguishing signals from these inputs against a meteoritic background.

**References:** [1] Fries, M., Christou, A., Archer, D., Conrad, P., Cooke, W., Eigenbrode, J., ten Kate, I.L., Matney, M., Niles, P., Sykes, M. and Steele, A., 2016. *Geochim. Perspect. Lett.*, 2, pp.10-23. [2] Sánchez-Lavega, A., et al., 2015. *Nature*, 518(7540), pp.525-528. [3] Keppler, F., et al (2012) *Nature* 486, 93-96. [4] Schuerger, A.C., et al (2012) *JGR: Planets* (1991–2012), 117(E8). [5] Crismani et al., 2017. *Geochim. Perspect. Lett.*, 3, p.1716. [6] Mumma, M.J., et al 2009. *Science*, 323(5917), pp.1041-1045. [7] NAS Mariner-Venus1967 Final Project Report, NASA Spec.Pub, SP-190, 1971. [8] Roos-Serote, M., Atreya, S.K., Webster, C.R. and Mahaffy, P.R., 2016. *JGR: Planets*, 121(10), pp.2108-2119. [9] Fries, M., 2017. *JGR: Planets*, 122(4), pp.784-786. [10] Mischna, M.A., et al, 2011. *Planetary and Space Science*, 59(2), pp.227-237. [11] Moser, D.E., Hardin, B.F. and Janches, D., 2011. Meteoroids: The Smallest Solar System Bodies. [12] Aoki, S., et al., 2017. *Astronomy & Astrophysics*. [13] Crismani, M., et al 2016, April. In *EGU General Assembly Conference Abstracts* (Vol. 18, p. 11110). [14] Hand, E. *Science* 359, 6371 (2018) pp. 16-17.