

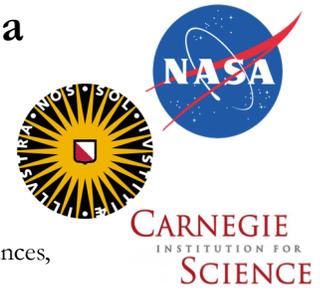
The Mars Methane Plume of 2003 Was Caused by a Meteor Outburst from Comet C/2007 H2 Skiff

A Hypothesis

Marc Fries¹, Pan Conrad², Inge los ten Kate³

¹NASA JSC Astromaterials Research and Exploration Science (ARES), Houston TX 77058

²Geophysical Laboratory, Carnegie Institution for Science, Washington DC ³Department of Earth Sciences, Utrecht University, Netherlands



A Meteor Shower Origin?

On 11 Jan 2003 a regional “plume” of methane was observed on Mars via Earth-based telescopic observation [1]. An accumulation of lines of evidence has led to the hypothesis that this methane plume arose from an intense meteor outburst (or “meteor storm”) in the same latitude, a few days previously [2], arising from Mars-crossing comet C/2007 H2 Skiff. The lines of evidence for this hypothesis are presented here for further discussion.



Fig. 1: A meteor outburst

In the larger picture, understanding the origin of this methane plume is very important for the search for potential life on Mars because it is reasonable to expect multiple sources for methane on Mars, and characterizing abiogenic methane sources is a critical step in the search for potential biological signatures.



To View a Short Accompanying Video Scan this QR code or go to: <https://youtu.be/6qAsq5yFVFQ>

Methane Generation Mechanism

The fundamental question behind the origin of the 2003 methane plume (M03 hereafter) is what mechanism delivered sufficient reduced carbon to Mars’ atmosphere to account for the plume. Several possibilities have been discussed elsewhere [e.g. 1] but we will focus on the meteor origin hypothesis here. The proposed mechanism is: meteor showers deliver reduced carbon to Mars’ atmosphere and surface [3], meteoritic material is disaggregated by infall, and methane is produced readily by UV photolysis of meteoritic carbon [4,5]. See [2] and the abstract for detail and discussion.

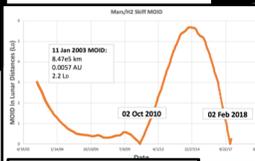


Fig. 2: MOID between H2 Skiff and Mars

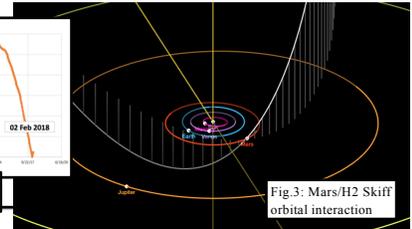


Fig. 3: Mars/H2 Skiff orbital interaction

C/2007 H2 Skiff Orbital Dynamics and Geometry

Christou and Vaubaillon (2011) identified comet C/2007 H2 Skiff (hereafter H2 Skiff) as likely to produce meteor outbursts, and as the source of the strongest meteor showers predicted for Mars among the Mars-crossing comets they examined [9]. Meteor outburst duration data from [6,9] and the sub-radiant latitude from [9] indicate that the expected spatial extent of an H2 Skiff meteor storm show reasonable coincidence with the observed location of the Mumma et al methane plume, provided the outburst timing coincides. H2 Skiff’s orbit interacted with Mars with a MOID of only 8.47e⁵ km (2.2 lunar distances) on 11 Jan 2003 (Fig. 3), with closest interaction calculated on 06 Jan 2003 by [9]. H2 Skiff’s orbit crossed Mars’ orbit twice in the past nine years (Fig.2), showing that Mars interacts with the densest central concentration of H2 Skiff debris. Also, [8] found that H2 Skiff is likely to produce strong outbursts late in its interaction with Mars (Fig. 3). H2 Skiff’s calculated debris stream features heavier debris concentration late in the encounter with Mars (Fig.4). These factors combine to indicate that H2 Skiff may generate meteor outbursts within ~3 sols prior to the M03 methane detection.

Mischna et al [10] found that methane abundance in [1] cannot be reconciled with a ground or underground source, and must derive from “a near-instantaneous release” over “a large source region (80° in latitude...)”, “no more than 1-2 sols earlier” than the M03 detection. This description closely matches the methane production expected from a meteor outburst. Outbursts typically last ~1 hour [15] and therefore deliver their infall mass over an area approximately hemispherical in extent (Fig. 5). Taken together, H2 Skiff features significant potential for generating strong meteor showers and outbursts, and that infall would occur at a location coincident with that of M03.

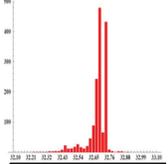


Fig. 4: H2 Skiff outburst activity – see [8]

The Mass Question

The most significant difficulty with the meteor outburst impact hypothesis may be the amount of mass needed [7] for a meteor outburst to generate the amount of methane calculated by [1]. Mumma et al (2009) found that 1.86e⁷ kg (19,000 tons) of methane is required to explain their observations in the March 2003 event. We calculate ~8e8 kg of infall material is needed [2], which is dramatically greater mass than that observed in historical meteor outbursts [14]. Several mitigating factors exist, however:

- 1) The M03 event has been challenged on grounds that it cannot be reconciled with currently understood martian atmospheric chemistry, to include the measured concentrations of other atmospheric species [11].
- 2) It was also challenged on spectroscopy grounds, with [14] demonstrating that the Doppler-shifted martian methane absorption feature used in [1] is overprinted by a much stronger ¹³CH₄ feature that was not accommodated in the M03 calculations. Other methane absorption features in the same spectra did not support the amount of methane observed in [1], and [12] finds that the maximum methane concentration observed was less than 3 ppbv.
- 3) The orbit of H2 Skiff may indicate a potential for significant debris mass. The orbit has small MOID values for Mars and Saturn. This is an unstable orbit on long time periods, thus H2 Skiff must not have populated this orbit for long. Similarly, H2 Skiff may have been perturbed into its present orbit by a past encounter with either planet, and this perturbation may have fragmented the comet to generate a significant debris component. Further observations are needed to constrain this possibility.
- 4) Crismani et al [7] calculate that a meteor outburst origin for M03 methane would require four orders of magnitude increase over background, a dramatic increase. Mariner IV encountered a debris stream on 15 Sep 1967 which appears to have met this criterion, indicating that such a flux, while extreme, is possible. Mariner IV was struck by a meteoroid flux “10,000-fold” greater than background which physically slewed the spacecraft and damaged its thermal protection system [6].

The mass required for the M03 event features significant uncertainty, and the range of potential infall flux from H2 Skiff may accommodate the amount needed to explain the methane flux. Without additional data this aspect of the hypothesis may be difficult to resolve.

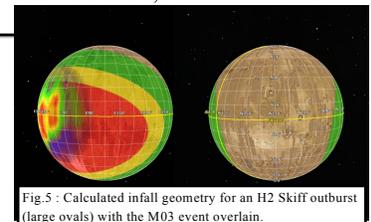


Fig.5 : Calculated infall geometry for an H2 Skiff outburst (large ovals) with the M03 event overlain.

Summary – A Meteor Outburst May Explain the M03 Event

The above confluence of factors indicates that a meteor outburst from H2 Skiff may explain the M03 methane event, although the mass question requires resolution.