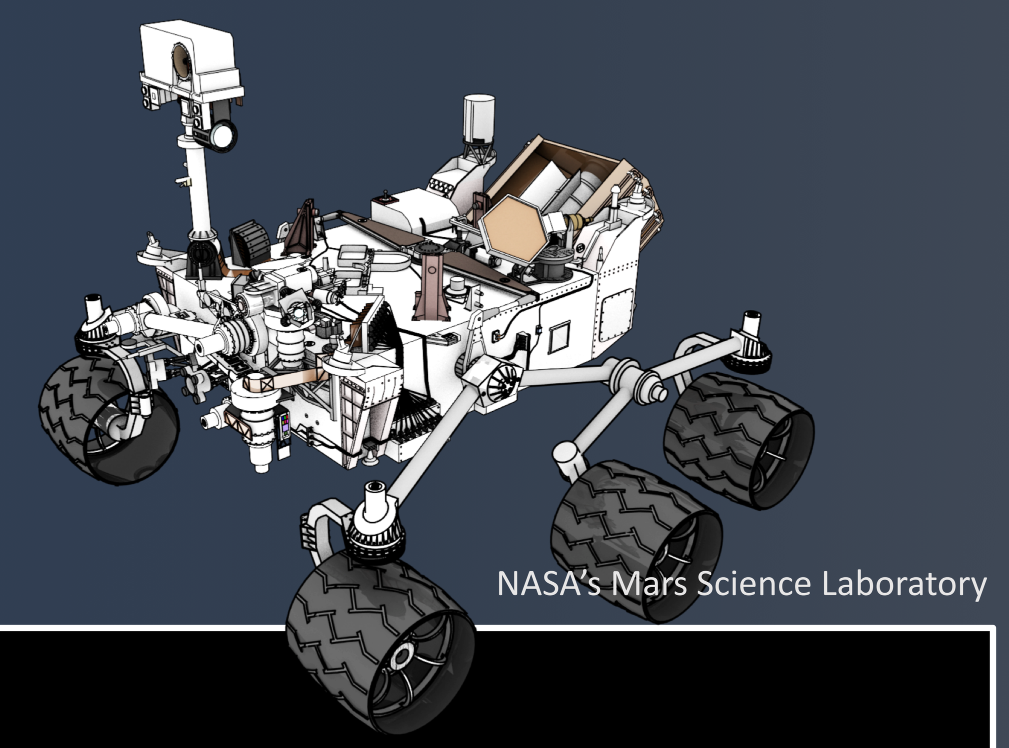
UV-induced volatile emissions form carbonaceous chondrites with a focus on the Martian surface

Arjen Boosman[1,2], dr. ir. Inge Loes ten Kate[2], Prof. dr. Thomas Röckmann[1]
Institute for Marine and Atmospheric Science Utrecht
Department of Earth Sciences, Utrecht University



NASA's Mars Science Laboratory

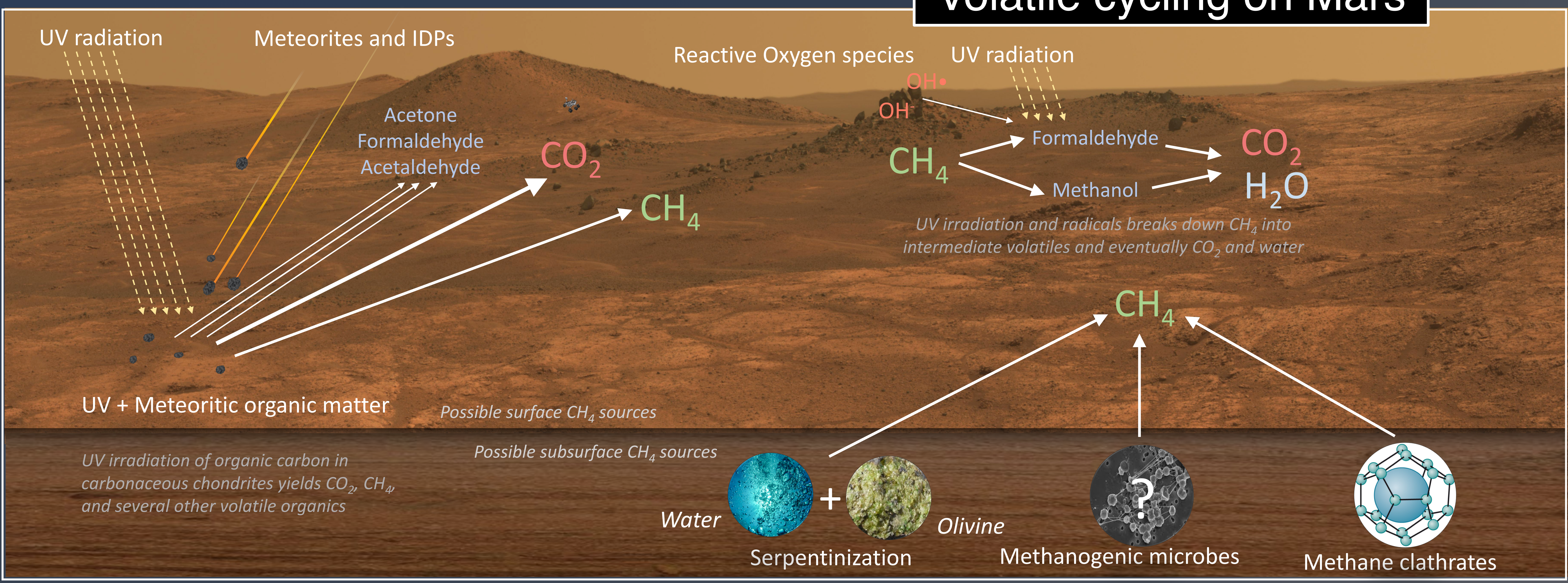
Introduction

Methane (CH_4) is a strong greenhouse gas that is abundant on Earth. ~90% of terrestrial CH_4 is produced by microorganisms. The discovery of CH_4 in the atmosphere of Mars (e.g. Mumma et al., 2003) has led to widespread speculation and several theories on its origin, including life (Krasnapolsky et al., 2004)! One of the other methods at which CH_4 can be produced is the irradiation of carbonaceous chondrites (a class of meteorites). An expected 3 to 60 million kg of meteorites and interplanetary dust particles (IDPs) reach the Martian surface each year (Flynn & McKay, 1990). These meteorites contain compounds such as amino acids, aromatic hydrocarbons, and macromolecular carbon. Irradiation of this carbon rich material has been proven to yield CH_4 in small amounts, (Keppler et al., 2012). Here, we conduct a study to find what organics, including CH_4, can be produced by photolysis of meteoritic organic carbon. In the near future, we will perform isotopic analysis of the produced organics to determine the process' isotopic fingerprint.

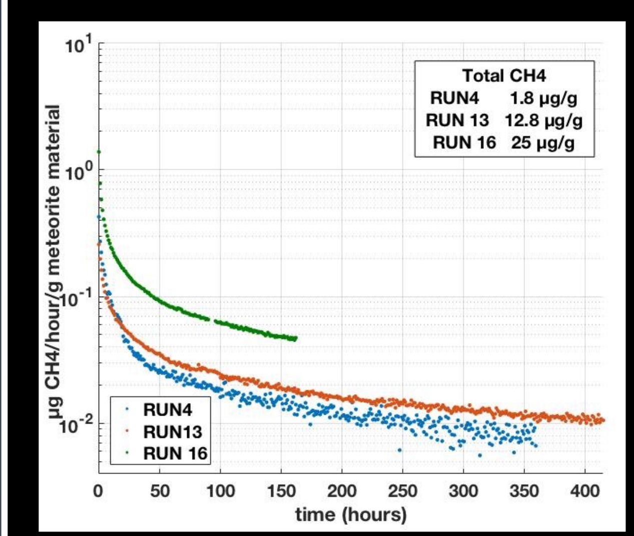
Methods

To test qualitatively and quantitatively what organics are emitted form carbonaceous chondrites, we built a setup consisting of a Xe-arc UV enhanced lamp (Osram), a reaction vessel through which a carrier gas is pumped, a Cavity Ring-Down Spectroscopy instrument (CRDS, Picarro), and a Proton Transfer Reaction Time Of Flight Mass Spectrometer (PTR-TOFMS, IONICON Analytik). A small piece (~100mg) of the Murchison meteorite (named after its fall in Murchison, Australia in 1969) is ground to a fine powder and irradiated in the sealed reaction vessel. A stream of N_2 gas flushes the headspace of the reaction vessel, carrying the emitted organics to the different analytical instruments. Every 30 minutes, the inlet to the instruments switches between the headspace gas and the pure carrier gas (as a background). Concentration data of the aforementioned volatiles are collected every 1 to 5 seconds and from these concentrations, emission rates can be calculated. Our experiments run up to 2 weeks, providing us with unique high resolution, long term experimental data.

Volatile cycling on Mars

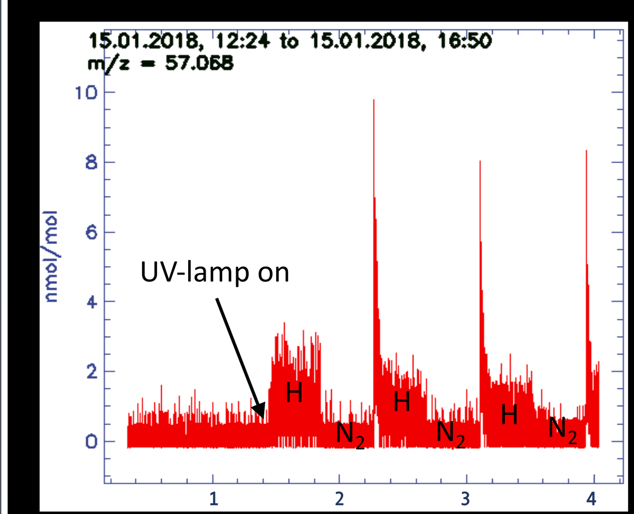


Results



Concentration of CH_4 form freshly ground meteorite material when UV-irradiated. CH_4 emissions are normalized to mass of the meteorite material.

Methane emissions follow a three-term exponential function. The three terms contribute to ~5%, ~25%, and ~70% of the total emitted methane in every experiment. It is not yet understood why the emission follows these curves or whether there are 3 different processes involved in CH_4 emission. At most, a total of ~0.1% of organic carbon can be converted to methane, probably due to the limited penetration depth of UV in solid materials, which is usually less than 1 µm.



Concentration of an unidentified organic volatile emitted form freshly ground meteorite material when UV-irradiated. X-axis shows time in hours Measurement alternate between headspace gas (H) and a pure background (N_2).

Several volatiles are emitted besides CH_4 and CO_2. PTR-TOFMS measurements show several tens of compounds emitted when meteorite material is irradiated. Although not every mass detected can be immediately linked to a molecular structure, experiments suggest meteorite material emits methanol, formaldehyde, acetaldehyde, acetone, and many other compounds when irradiated. The image on the left shows the concentration of an **unknown volatile organic compound** in the sampled head space (H) and in the pure carrier gas (N_2). Clearly visible is the increase in concentration of this compound in the headspace gas when the lamp is turned on.

Implications for the Martian atmosphere

Understanding the emission of volatile organic compounds from meteorite material is important when trying to model the composition of the Martian atmosphere. It can predict what volatile organics could potentially be found in the Martian atmosphere and what compounds they can derive from. Future modelling of the CH_4 cycle on Mars should take into account that photodegradation products of CH_4 can also be a degradation products derived from the photodegradation of meteoritic carbon. In the future, higher sensitivity organic measurements and CH_4 isotope data (e.g. by ESA's Trace Gas Orbiter) can provide new data on the presence of methane and other volatiles, and the origins and pathways through which they form. Apart from the impacts meteoritic carbon can have on a planetary atmosphere, this research sheds light on the behavior of organic compounds - the building blocks of life – and could eventually improve our understanding of the origin of life.

ESA's Exomars Trace Gas Orbiter

References
Krasnapolsy, V. A., Maillard, J. P. & Owen, T. C. Detection of methane in the martian atmosphere: evidence for life? *Icarus* **172,** 537–547 (2004).
Flynn, G. J. & Mckay, D. S. An Assessment of the Meteoritic Contribution to the Martian Soil. *J. Geophys. Res.* **95509,** 497–14 (1990).
Keppler, F. *et al.* Ultraviolet-radiation-induced methane emissions from meteorites and the Martian atmosphere. *Nature* **486,** (2012).
Mumma, M. J. *et al.* Strong Release of Methane on Mars in Northern Summer 2003. *Science (80-.).* **323,** 1041–1045 (2009).

Author information
Arjen Boosman MSc
a.j.boosman@uu.nl

Aardwetenschappen
Princetonlaan 8A
3584 CB Utrecht

Universiteit Utrecht

IMAU Institute for Marine and Atmospheric research Utrecht