Photodegradation of meteoritics: alteration of solid organic carbon in the Murchison meteorite

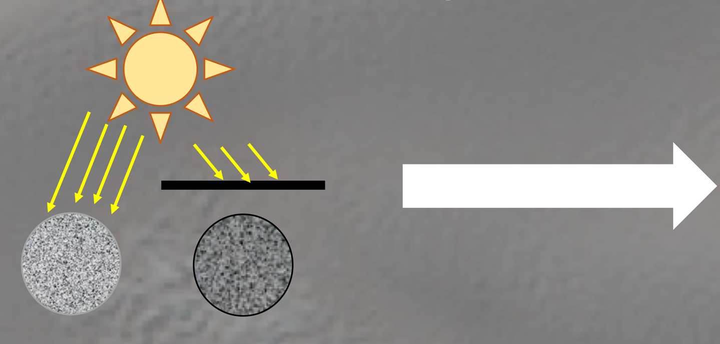
Arjen Boosman*[,1,2], Inge Loes ten Kate[2], Paul Mason[2], Lubos Polerecky[2], Dušan Materic[1], Rupert Holzinger[1], Thomas Roeckmann[1]

Introduction

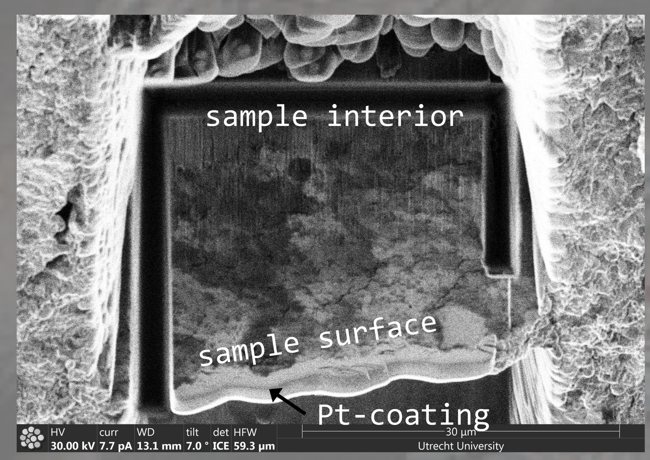
Many solar system environments are subject to ultra-violet (UV) irradiation. UV-irradiation has been shown to photodegrade organic matter in meteorites into several volatiles: CO2, methane, ethane propane, aldehydes, ketones and many more. Very little research has been done on the alteration of solid organic carbon and the residues after irradiation. However, understanding the preservation of organic matter when UV-irradiated, and the UV penetration into substrates (e.g. Carrier et al., 2017) is paramount to understanding the carbon budget and carbon cycling of meteoroids, asteroids, comets, and planetary surfaces. Furthermore, studying the preservation of organic carbon will help us understand the origin of organic carbon on e.g. the Martian surface (Eigenbrode et al., 2018)

Lab simulations

To test the preservation of meteoritic organic carbon when UV-irradiated, samples of the Murchison meteorite are placed in an N_2-flushed reaction chamber and irradiated. The sample surfaces are exposed using a focused ion beam, and analyzed using nanoSIMS and Electron microprobe analysis

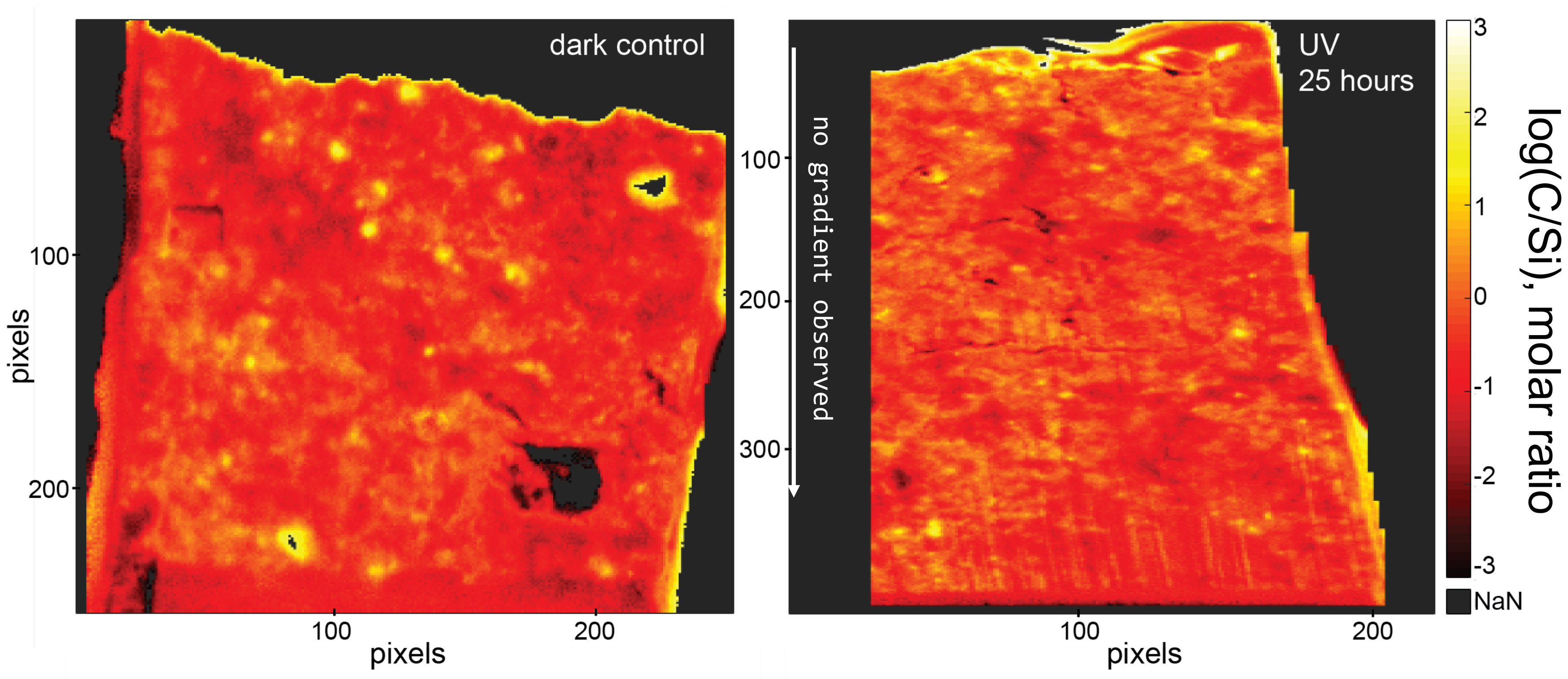


2 grains of the Murchison meteorite, 1 is irradiated with Martian-like UV radiation

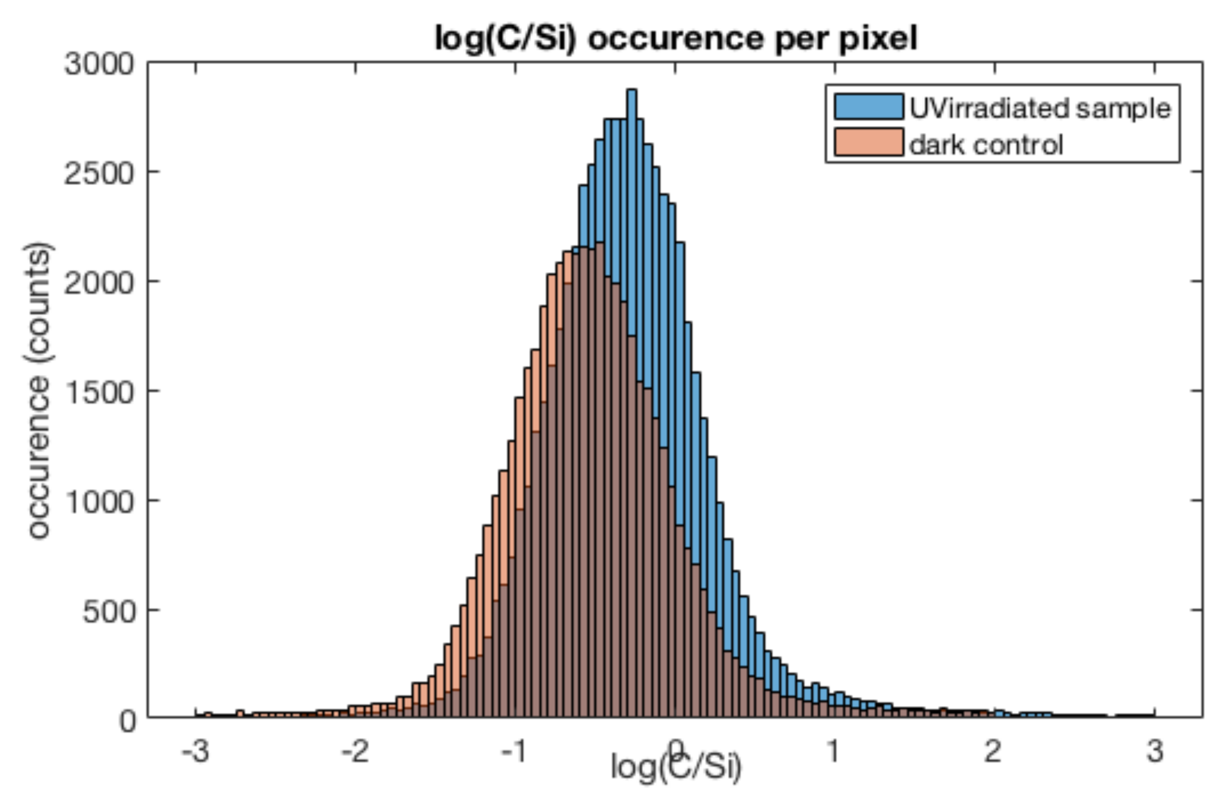


A focused ion beam makes 20x20 µm thin sections, perpendicular to the sample surface

Carbon in irradiated surfaces



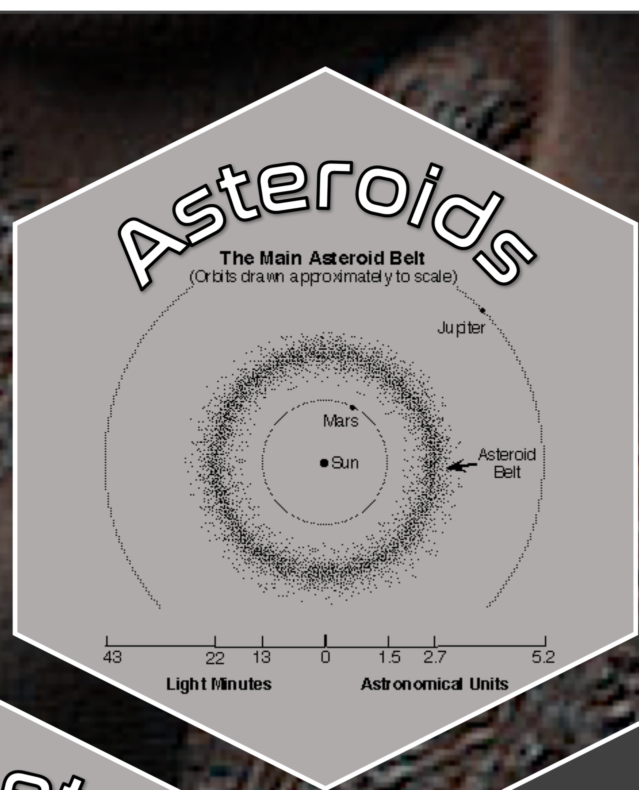
This image shows a cross section of meteorite surface after UV irradiation, and without UV irradiation. The heterogeneous distribution of carbon can be seen. Also, carbon occurs throughout both samples. Radiation would be expected to remove carbon from the top layer of the irradiated sample, but this is not the case. This implies that a large part of organic carbon is not accessible to photodegradation under Martian radiation conditions.



Comparing the dark control sample to the irradiated sample shows that there is no apparent decrease in C:Si ratio. Removal of carbon, and a subsequent decreasing C:Si ratio would result in a shift of the histograms peak to the left after irradiation, which can not be seen.

Results & Discussion

Our analysis of the surfaces of irradiated and non-irradiated grains of the Murchison meteorite indicate that there is no fully depleted zone at the top of an irradiated meteorite surface. This is in contrast with earlier reports suggesting that the grain-surfaces are fully carbon-depleted at the upper 20-130 nm (Keppler et al, 2012). These findings furthermore emphasize that a large part of meteoritic carbon can **not** be photodegraded, dramatically limiting the total production of volatiles, such as methane, CO_2, and many others, which could be emitted at the surface of planets such as Mars (Keppler et al., 2012, Schuerger et al., 2012). Volatile carbon emission experiments (Boosman et al., in prep.) indicate kerogen, the most abundant type of organic matter in meteorites is mostly chemically inert in a Martian like UV-irradiation environment. Also, the preservation of carbon in meteorite grains, even when irradiated, implies there is a potential extra-Martian origin for organics found on Mars nowadays.

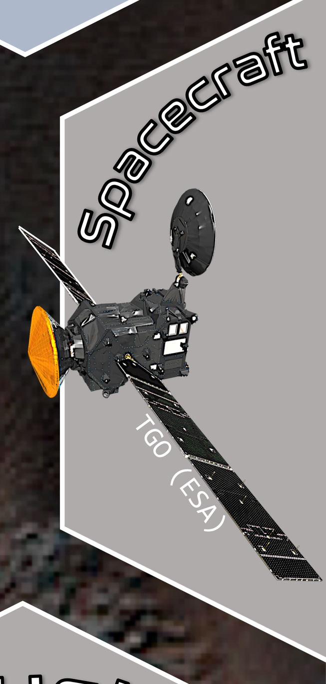


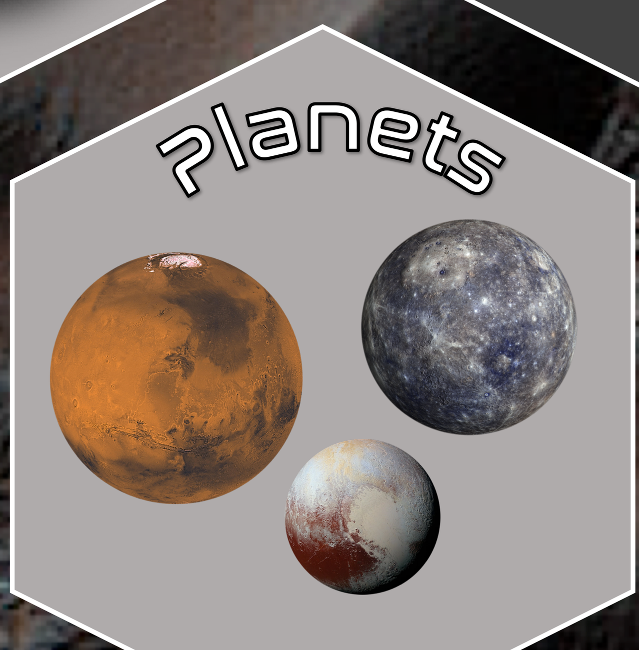
Not only meteorites undergo UV degradation. Many organic-rich surfaces in the solar system experience strong UV irradiation. These include spacecraft, asteroids, dust, comets, and planets!

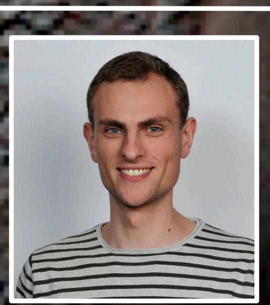
Photodegradation

throughout

space







*Corresponding author: **Arjen Boosman**, a.j.boosman@uu.nl
1. Institute for Marine and Atmospheric Research Utrecht, The Netherlands
2. Department of Earth Sciences, Utrecht University, The Netherlands

Picture references: nasa.gov (planets, comets), solarviews.com (asteroid belt)

References:
1. J. L. Eigenbrode *et al.*, Organic matter preserved in 3-billion-year-old mudstones at Gale crater, Mars. *Science (80-.)*. **360**, 1096–1101 (2018)
2. F. Keppler *et al.*, Ultraviolet-radiation-induced methane emissions from meteorites and the Martian atmosphere. *Nature*. **486** (2012)
3. A. C. Schuerger, J. E. Moores, C. A. Clausen, N. G. Barlow, D. T. Britt, *J. Geophys. Res. Planets*, in press (2012)

Utrecht University

IMAU Institute for Marine and Atmospheric research Utrecht

PALLAS