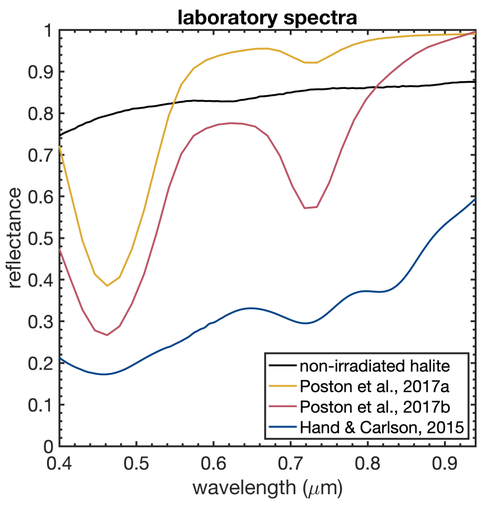
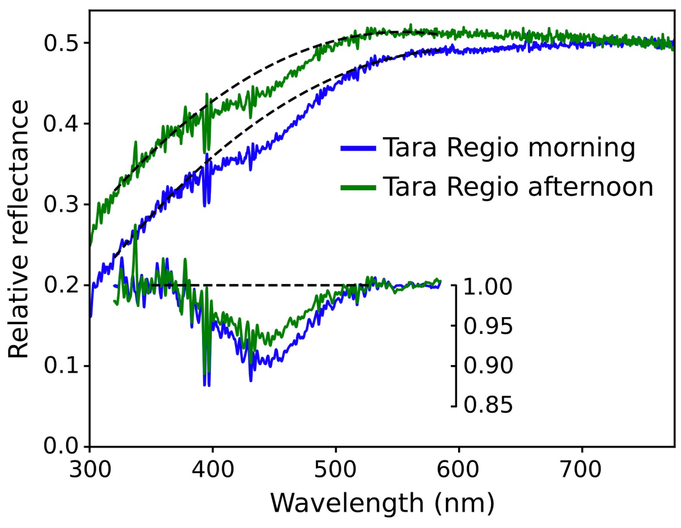
National Aeronautics and Space Administration

Radiation-Formed Color Centers of Sodium Chloride on Inner Solar System Bodies

Michael Bramble (3224), JPL Postdoctoral Fellow and
Kevin Hand (3204), Jet Propulsion Laboratory

Radiation-Formed Color Centers





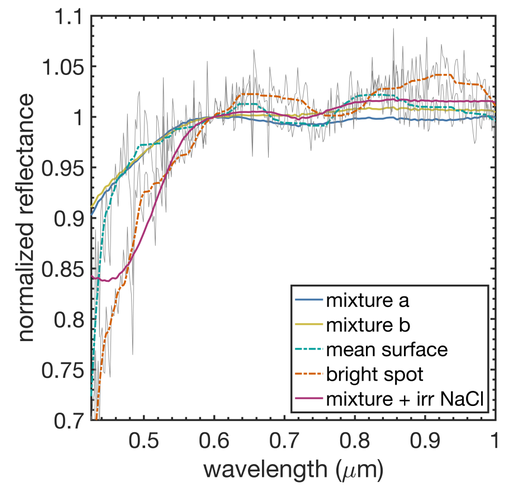
Alkali halides (such as halite (NaCl) or sylvite (KCl) are generally featureless at visible to near-infrared wavelengths.

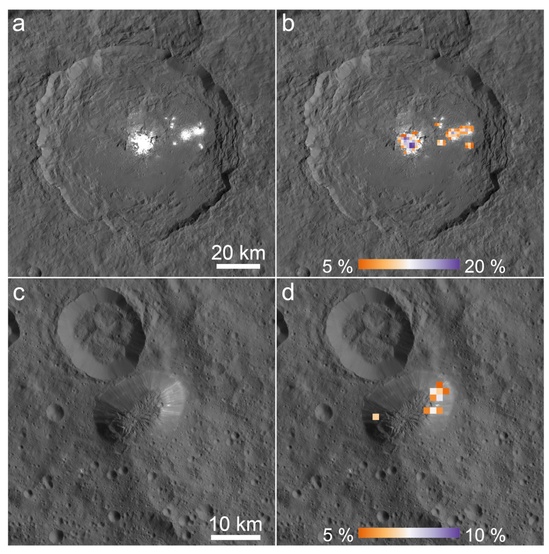
When irradiated by high-energy electrons, ions, and photons, they develop readily-identifiable spectral features in the form of color centers.

These color centers have been identified in remotely sensed spectra of Europa, confirming the presence of NaCl in some locations of the uppermost surface.

Top-left: Colorless NaCl crystals turn reddish orange when irradiated by 10 keV electrons [1]. **Top-right:** Spectra of irradiated NaCl [1,2] develop distinct spectral features when irradiated. **Left:** Color centers of NaCl identified on at Tara Regio on Europa via telescopic observations [3].

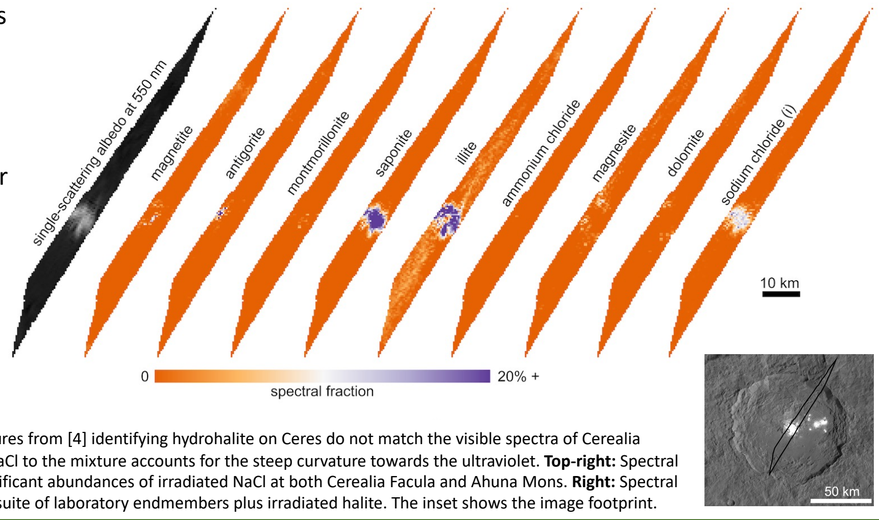
Irradiated NaCl on Ceres





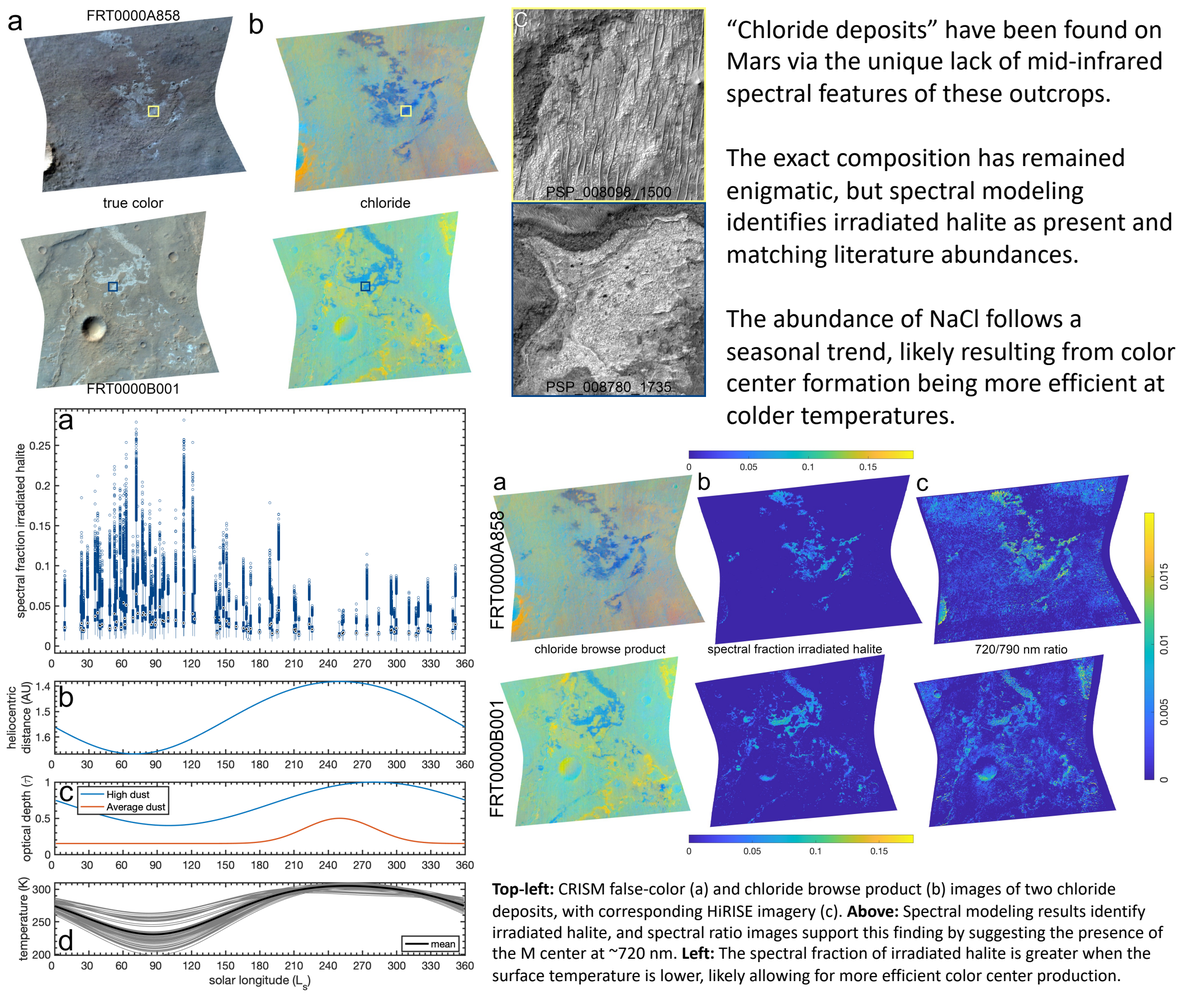
Previous modeled mixtures of the bright spots on Ceres identified hydrated NaCl in the near-infrared. The visible spectra corresponding to these mixtures do not account for the spectral curvature.

Spectral modeling of the visible data from the Dawn VIR instrument identified the presence of irradiated NaCl in the bright spots of Ceres.



Top-left: Endmember mixtures from [4] identifying hydrohalite on Ceres do not match the visible spectra of Cerealia Facula. Adding irradiated NaCl to the mixture accounts for the steep curvature towards the ultraviolet. **Top-right:** Spectral model results suggests significant abundances of irradiated NaCl at both Cerealia Facula and Ahuna Mons. **Right:** Spectral modeling was done with a suite of laboratory endmembers plus irradiated halite. The inset shows the image footprint.

Irradiated NaCl on Mars



“Chloride deposits” have been found on Mars via the unique lack of mid-infrared spectral features of these outcrops.

The exact composition has remained enigmatic, but spectral modeling identifies irradiated halite as present and matching literature abundances.

The abundance of NaCl follows a seasonal trend, likely resulting from color center formation being more efficient at colder temperatures.

Top-left: CRISM false-color (a) and chloride browse product (b) images of two chloride deposits, with corresponding HiRISE imagery (c). **Above:** Spectral modeling results identify irradiated halite, and spectral ratio images support this finding by suggesting the presence of the M center at ~720 nm. **Left:** The spectral fraction of irradiated halite is greater when the surface temperature is lower, likely allowing for more efficient color center production.

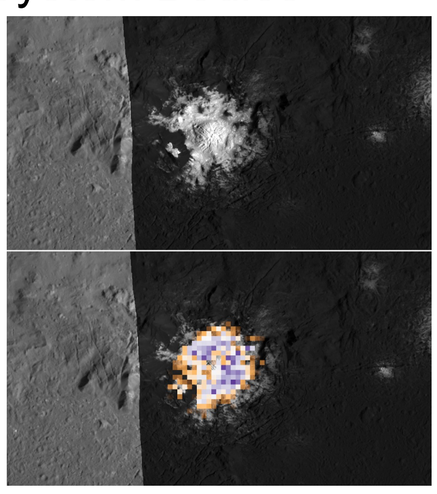
Implications for Inner Solar System Bodies

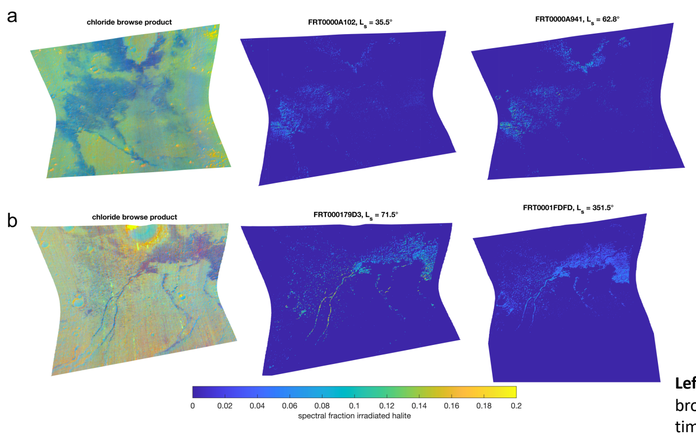
The lack of a latitude trend at Ceres suggests that Galactic cosmic rays are the radiation source producing color centers.

Active lag deposit formation may be currently observed as hydrohalite has been identified at the center of CF [4], and anhydrous irradiated halite is modeled as more distal.

Radiation-damaged halite crystals have been observed in regolith breccia meteorites [5]. The cratering, recycling, and excavation of halite-bearing terrain on Ceres may have led to the distribution of this material across Ceres and the asteroid belt.

Right: Framing Camera observations of Cerealia Facula with spectral modeling results overlain.





The seasonal cycle of irradiated halite abundance at Mars, and the inverse of this signal with ultraviolet irradiation of the surface may also favor Galactic cosmic rays as the radiation source.

The identification of large deposits of sodium chloride on Mars implies sustained water-rock interactions consistent with large aqueous bodies, such as salty seas with geologically active seafloors.

Left: CRISM observations of chloride deposits (blue in chloride browse product) and corresponding spectral modeling results at two timepoints. The colder winter temperatures (low Ls) have higher spectral fractions of irradiated halite than in the summer (higher Ls).

References: [1] Hand, K., & Carlson, R. (2015). Geophysical Research Letters, 42(9), 3174–3178. [2] Poston, M. J., Carlson, R. W., & Hand, K. P. (2017). Journal of Geophysical Research: Planets, 122(12), 2644–2654. [3] Denman, W. T., Trumbo, S. K., & Brown, M. E. (2022). The Planetary Science Journal, 3(2), 26. [4] De Sanctis, M., et al. (2020). Nature Astronomy, 4(8), 786–793. [5] Zolensky, M. E., et al. (2017). Philosophical Transactions of the Royal Society A, 375(2094), 20150386.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Poster Number: PRD-P#019

Copyright 2022. All rights reserved.

Publications:

- M. S. Bramble and K. P. Hand. 2022. Spectral evidence for irradiated sodium chloride on the surface of 1 Ceres. *Geophysical Research Letters,* 49, e2021GL096973.
- M. S. Bramble and K. P. Hand. 2022. Spectral evidence for irradiated halite on Mars. *In Review*.

Author Contact Information:

- ***michael.s.bramble@jpl.nasa.gov – 626-298-2075***