HST Search for Irradiated NaCl on the Surface of Ceres

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Introduction

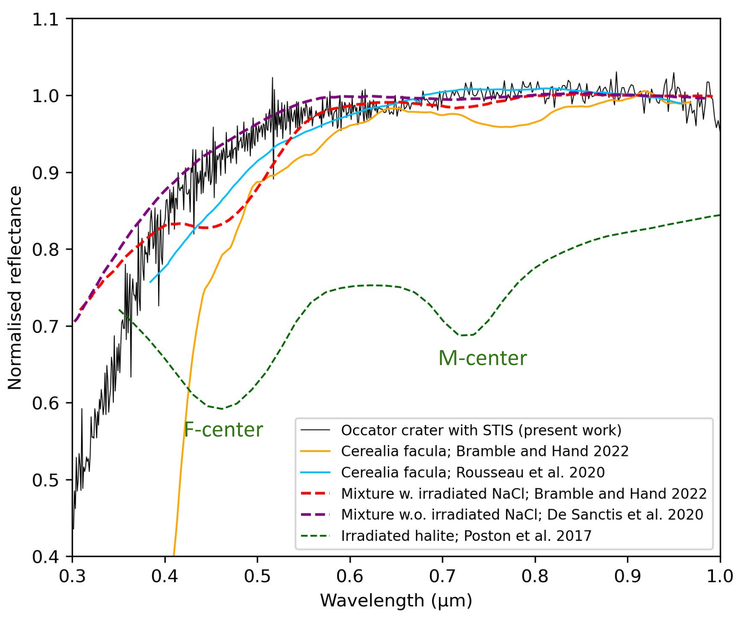
[1] reports evidence for irradiated halite (NaCl) at Occator crater, based on spectral characteristics in Dawn VIR data. While halite is featureless in the visible, when irradiated it develops colour centers, particularly near 0.46 µm (the F-center) and 0.72 µm (the M-center). The claimed detection is dependent on spectral behaviour in the blue, where VIR calibration is least certain. Spectral unmixing including irradiated halite has not been shown to uniquely explain the faculae spectra, and IR modelling of the composition does not require it. Other salts, carbonates, and phyllosilicates absorb across the same range. Furthermore, there is evidence that low radiation dosages, as well as photo-bleaching (both significant at Ceres) strongly suppress the presence of colour centers, and temperature is another influencing factor. Since HST is trustworthy at blue wavelengths, we use it as an independent test for the reported irradiated halite.

Methods

- HST/STIS long-slit spectroscopy targeting Occator
  - 52”x0.05” slit
  - gratings G430L and G750L, 0.27 to 1.07 µm
  - 35 exposures on-disk

We apply a ground-based correction, according to [5], to correct for slit losses and defringing artifacts at red wavelengths.

Results (I)



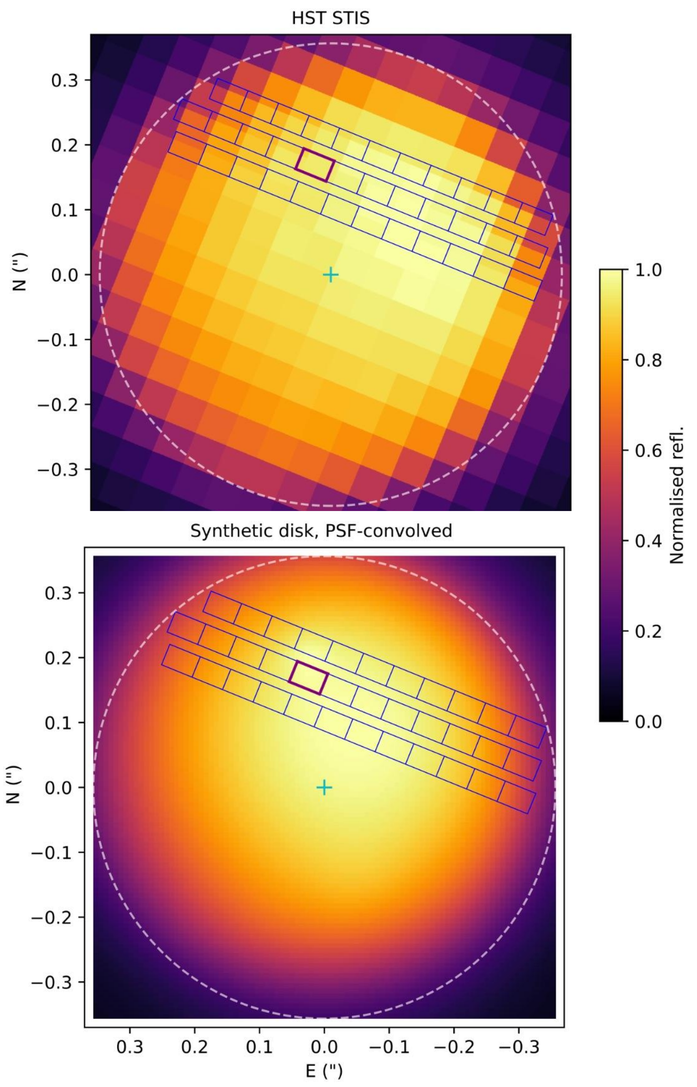
1. Occator spectra compared with laboratory and modelled endmembers. HST/STIS spectrum of Occator crater (this work) shown against Dawn VIR spectra of Cerealia facula from [1] and [8], the irradiated-NaCl endmember from [3], and the unmixing solutions with [1] and without [2] irradiated halite.

No spectral characteristics of irradiated halite are immediately evident. The Occator spectrum shows neither the ~0.46 µm F-center nor the ~0.72 µm M-center. Note that the two VIR reductions [1, 8] themselves diverge in the blue, illustrating the calibration uncertainty in this range.

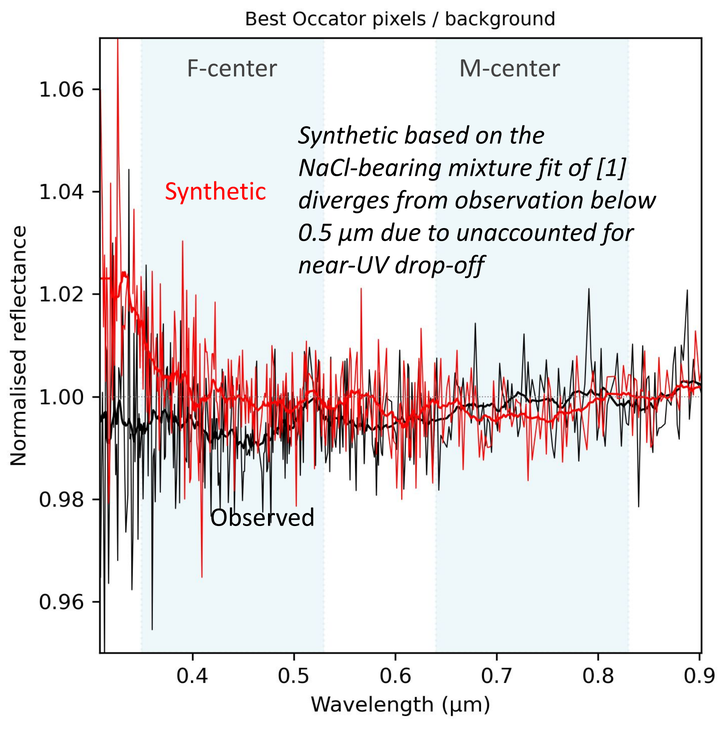
Results (II)

To test whether the mixture of [1] would be recoverable from our HST dataset, we model a synthetic Ceres disk, assuming the composition of [1] for the bright material of the faculae. Our modelling suggests that, were the mixture of [1] representative of the faculae, a slope change below 0.5 µm would be recoverable in the HST data via ratios to background pixels. We do not recover this behaviour, which suggests the mixture is not entirely representative of the compotision. We note that the faculae are unresolved at HST scales, so this test constrains the mixture only where its spectral behaviour survives PSF dilution (i.e. while we do not observe M-centers, we cannot exclude their presence and any influence of the F-center appears dwarfed by the disagreement in the near-UV).

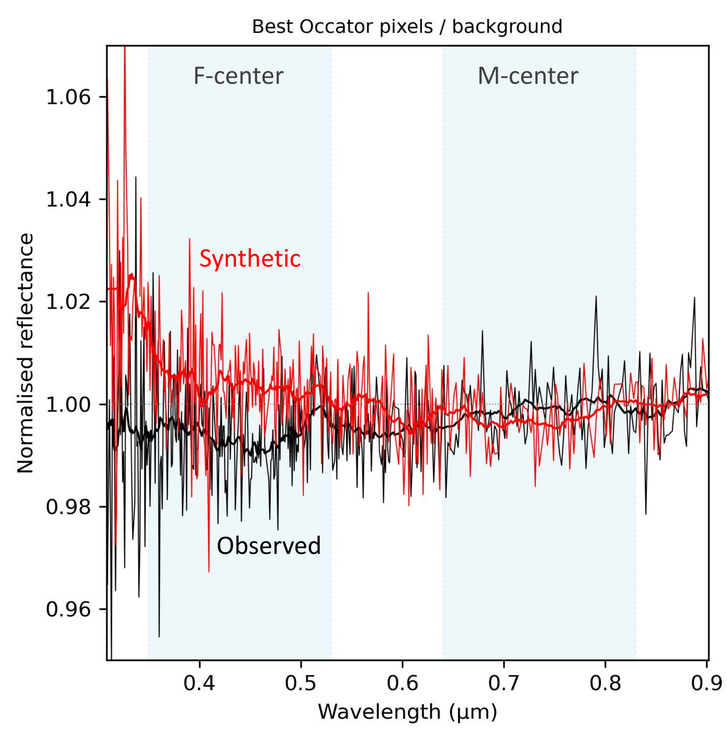
Our observations similarly diverge from the halite-free mixtures of [2]. Therefore, we suggest there may be a near-UV absorber missing from the mixtures, which could potentially reproduce the Dawn spectra without irradiated NaCl. However, our data do not exclude its presence.



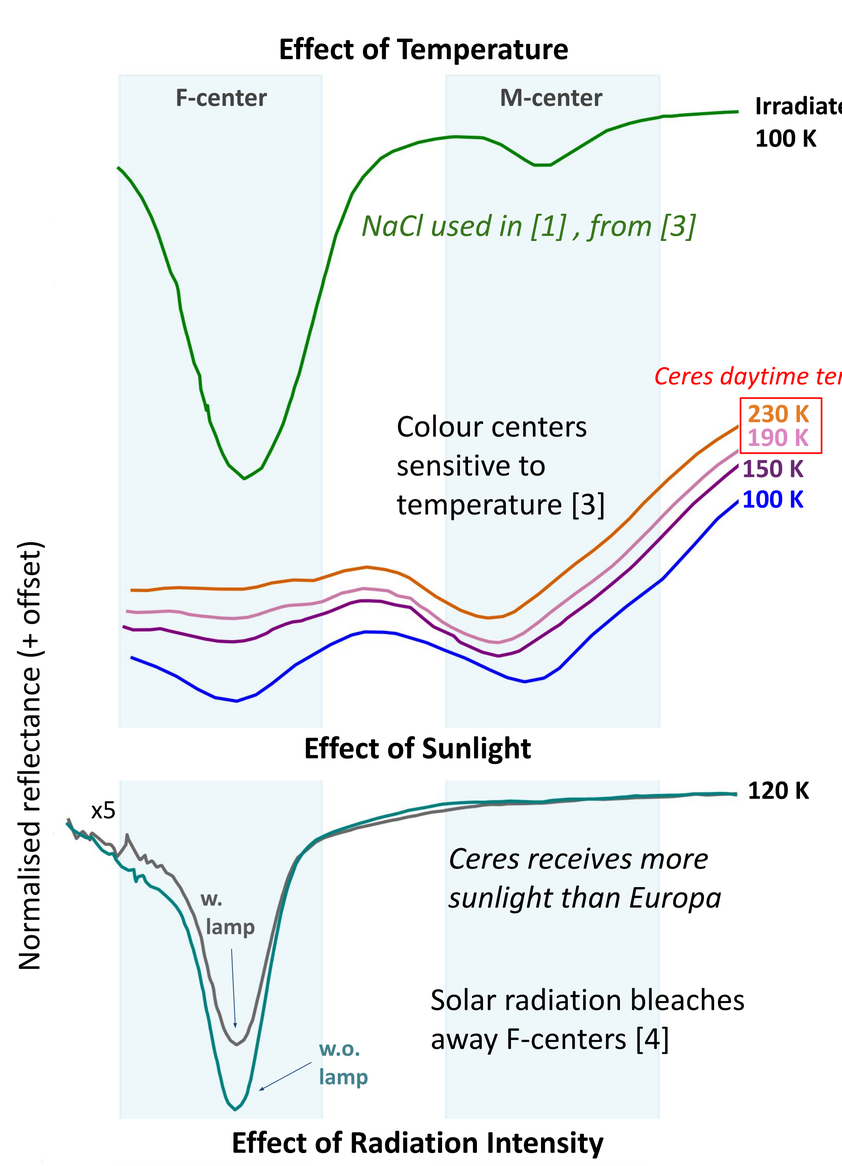
2. Ceres disk (top: real; bottom: modelled). We use Tiny Tim to model the HST PSF. Multiple pixels therefore contain some contribution from the halite mixture in the faculae. Here we use isotropic limb darkening, but applying Minnaert or Lommel-Seeliger darkening does not change our results.



3. Viability check for detecting halite. Using the representative mixture given by [1] for the faculae. Modelling HST observations at Occator suggests that, were the mixture representative of the faculae, we would recover slope behaviour via ratios to background pixels.



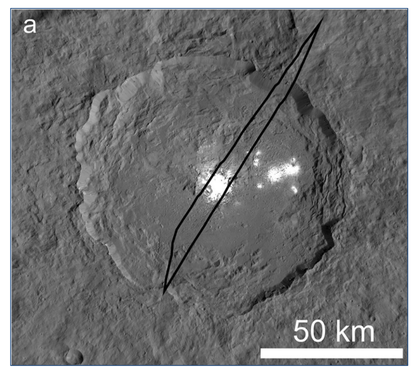
4. Mixture for the faculae proposed by Dawn VIR IR analyses [2]. We agree with [1] that this composition also does not fully account for the spectral behaviour seen at Occator. The mixture of [2] reproduces our HST spectrum equally as poorly as the mixture of [1]. The poor match in the near-UV suggests an additional, unidentified absorber, which may also affect the blue slope that [1] matched using irradiated NaCl.



Since Ceres is warmer, receives more bleaching sunlight, and receives less colour-center-forming radiation, we expect irradiated NaCl to look very different spectrally on Ceres compared to Europa.

Further work

We return to the Dawn VIR Visible dataset used by [1]. We will re-analyse the data following the improved artifacts reduction methods of [6, 7, 8] in parallel with [1]’s reduction and look for features uniquely attributable to NaCl. We will consider other irradiated salts and near-UV-darkening compounds, which may provide alternative explanations for the UV-VIS spectral behavior of the faculae .



5. Dawn footprint overlaid on Occator crater, from [1]

Conclusion

We do not detect halite colour center absorptions in HST spectra of Occator. Our synthetic disk modelling shows that irradiated halite as proposed by [1] would have produced a recoverable slope change in these data, which we do not observe. We therefore do not support irradiated halite as a unique explanation for the reported spectral behaviour; alternative absorbers remain viable. We return to Dawn, using HST as a calibration reference in the blue.

References

[1] Bramble & Hand, GRL 49, e2021GL096973 (2022); [2] De Sanctis et al., Nat. Astron. 4, 786 (2020); [3] Poston et al., JGR Planets 122, 2644 (2017); [4] Denman et al., PSJ 3, 26 (2022); [5] Trumbo et al., PSJ 3, 272 (2022); [6] Carrozzo et al., Rev. Sci. Instrum. 87, 124501 (2016); [7] Rousseau et al., Rev. Sci. Instrum. 90, 123110 (2019); [8] Rousseau et al., A&A 642, A74 (2020)