A PROSPECTIVE REMOTE SENSING BIOSIGNATURE FOR PEPTIDES IN ENCELADAN PLUME DEPOSITS

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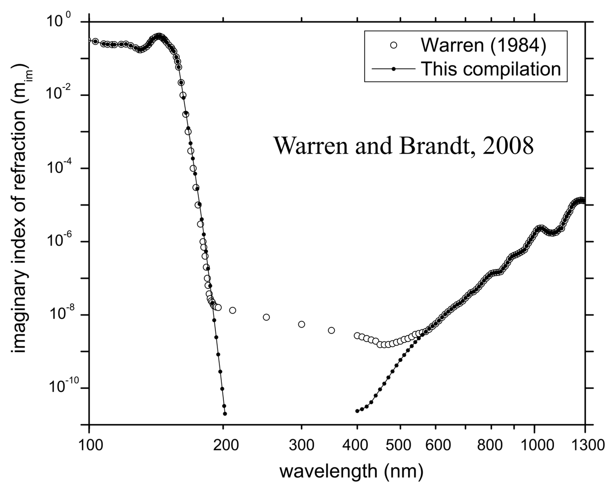
Synopsis

- Enceladan plume surface deposits are likely water-ice 'snow' with traces of organics [1-3]
- Remote sensing of surface organics informs landing-site selection and context, e.g., for Enceladus Orbilander [4], before and after landing, respectively
- Nearly all elements needed for carbon-based life present on Enceladus [5] -- but terrestrial amino acids? Nucleic acids?
- Many, varied proteins so essential on Earth [e.g., 6] argue for proteins in any alien carbon-based life in water (even if composed of different amino acids)
- Peptide bonds between amino acids define proteins –short peptides can occur abiotically [7-10] at low yields, but numerous peptide bonds indicate protein and thus life
- 'Gatekeeper' calculations support a solar-illumination, 200-350 nm (UV) imaging-spectroscopic signature of proteins (even alien ones) in porous water-ice surface deposits (i.e. 'snow') at concentrations of ppm by weight

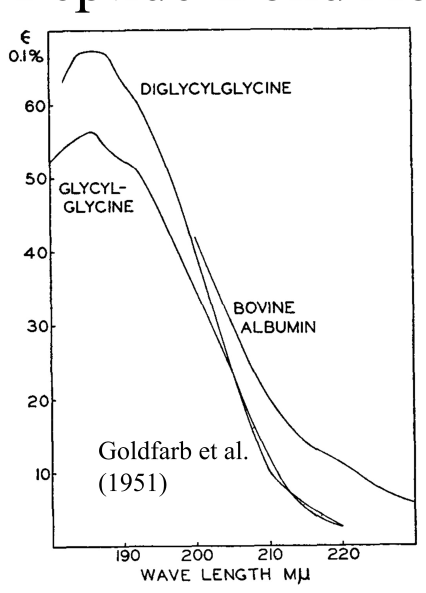
Background

Water-ice refractive index [11-13]



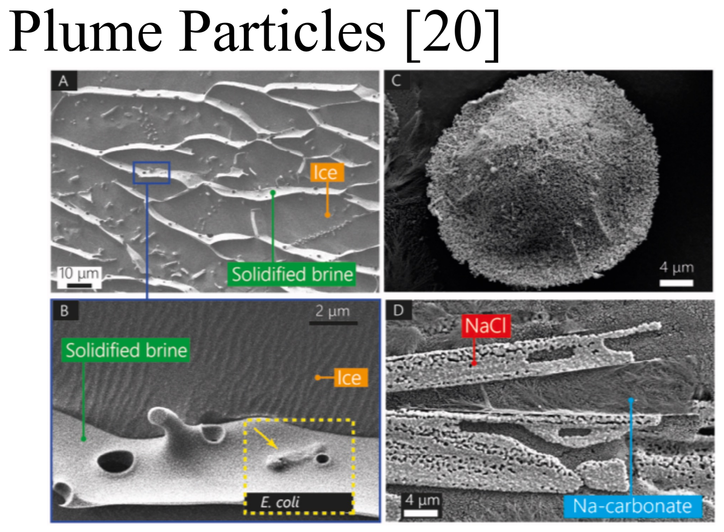
Water-ice is very transparent (imaginary part of refractive index $\sim 10^{-9}$) from 190-400 nm wavelength – ice particles scatter almost all and absorb almost no light in that band

Peptide-Bond Absorption [14-19]



Peptide bonds in aqueous solution (at ~ 300K) display a strong absorption feature centered at ~187 nm and extending to ~220 nm. Moreover, the strength of this absorption for proteins without aromatic side-chains on component amino acids scales linearly with the number of peptide bonds in the molecule. Even with aromatic side chains, peptide bonds are the dominant cause of 187-220 nm absorption.

Molecular/Microbial Entrainment in Plume Particles [20]

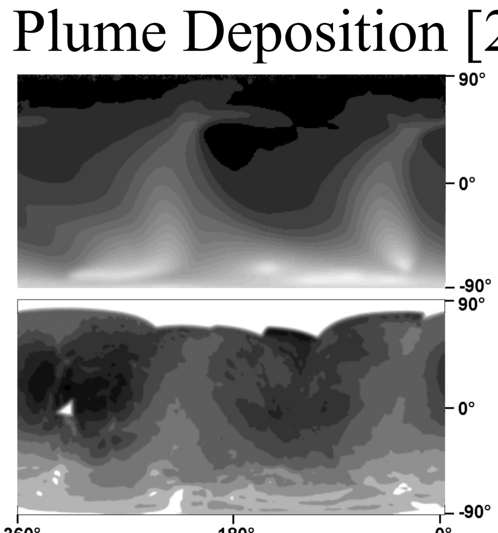


10^5 – 10^7 cells/ml [3]

'typical' cell 1 micron size,

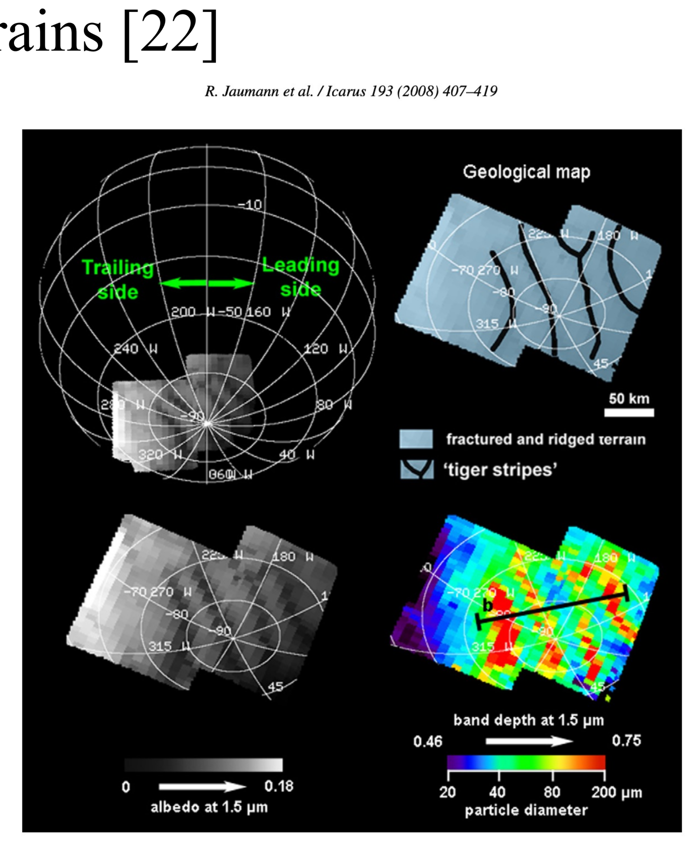
7×10^{-13} g, 70% water by mass, half of solid mass is protein

Plume Deposition [21]

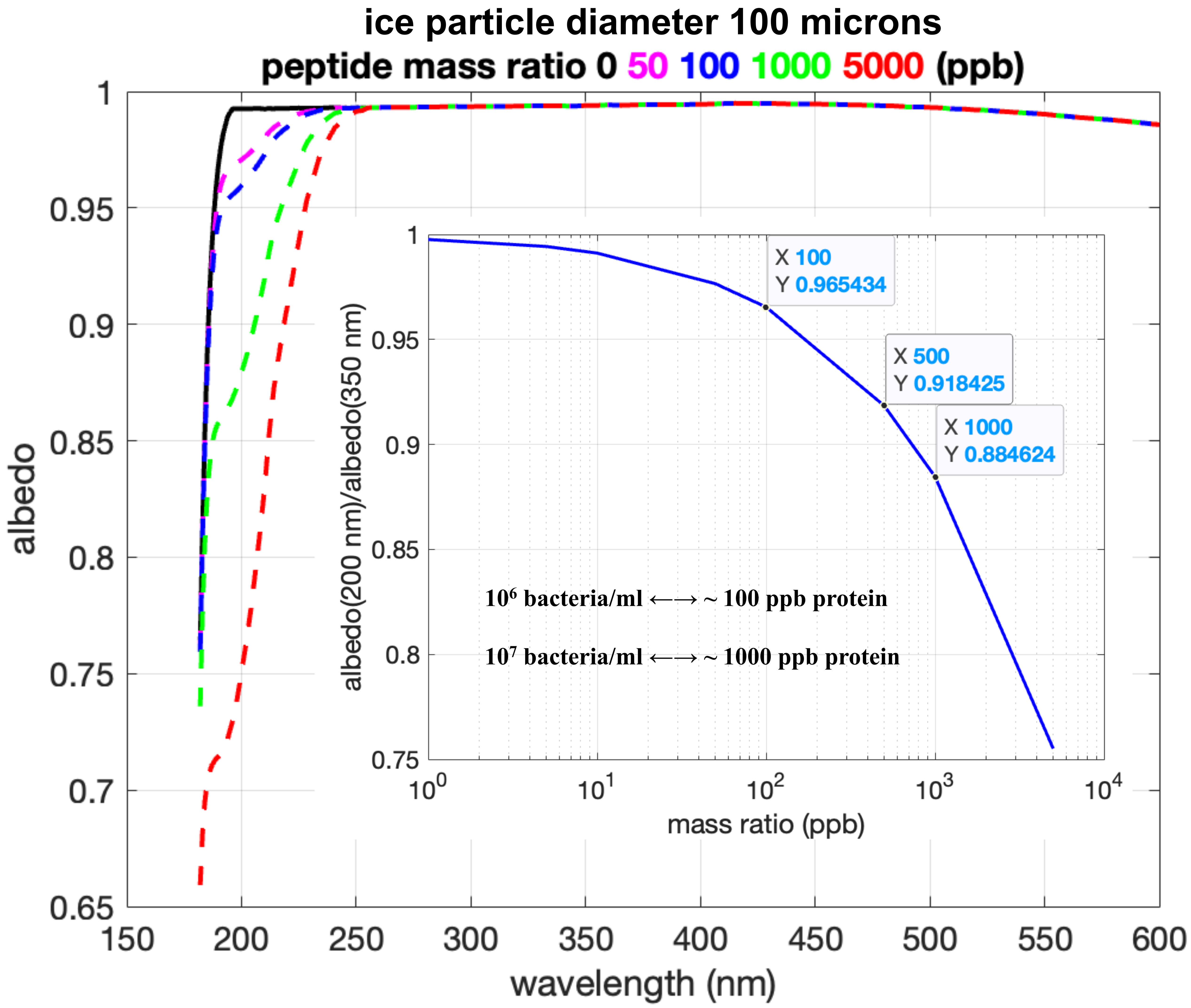


Global predicted plume fallout deposition map (top) and UV(338 nm)/ IR(930nm)/ color ratio map (bottom) of Enceladus. Brightness in top map indicates highest deposition rates. Brightness in bottom map primarily indicates low IR brightness.

Focus on Tiger-Stripes, 'large' ice grains [22]



Brightness Ratio of Enceladan 'Snow' in Scattered Sunlight at 200 nm vs 350 nm Depends on Protein/Peptide-Bond Concentration at ppm Level



Methods

- We initially take peptide bond absorption as measured in aqueous solution [14-19] as representative of absorption at ~70-140K in ice on Enceladus. The spectral width of the absorption at low temperature is critical and should be the first target of further investigation.
- For initial work, assume homogeneous distribution of peptides/proteins in spherical ice particles comprising Enceladan 'snow' (and add contributions of ice and protein to the imaginary part of the refractive index).
- Use Mie-scattering code of Wiscombe and Warren [23, 24] to compute single-particle scattering parameters, and the 2-stream model of Petty [25] to compute albedo of a semi-infinite snowpack.

Interferences by Other Molecules?

- solid NaCl: High, featureless reflectivity (i.e., low absorption) of unirradiated solid salt from 500 nm to 200 nm [26], electron irradiation induces a broad, shallow absorption at~230 nm [27]. Hydrated salt data apparently unavailable.
- solid ammonia: Very low absorption at visible and long UV wavelengths, sharp, strong absorption edge for wavelengths <190 or perhaps 200 nm [28,29]. Hydrated solid ammonia data unavailable
- amino acid aromatic side chains: Add to peptide absorption at 190-220 nm [17].
- adenosine in DNA and ATP: Adenosine also shows a broad absorption peak at ~190 nm, but weaker and with lower abundance in cells than protein [30-32].

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