TÉCNICO LISBOA

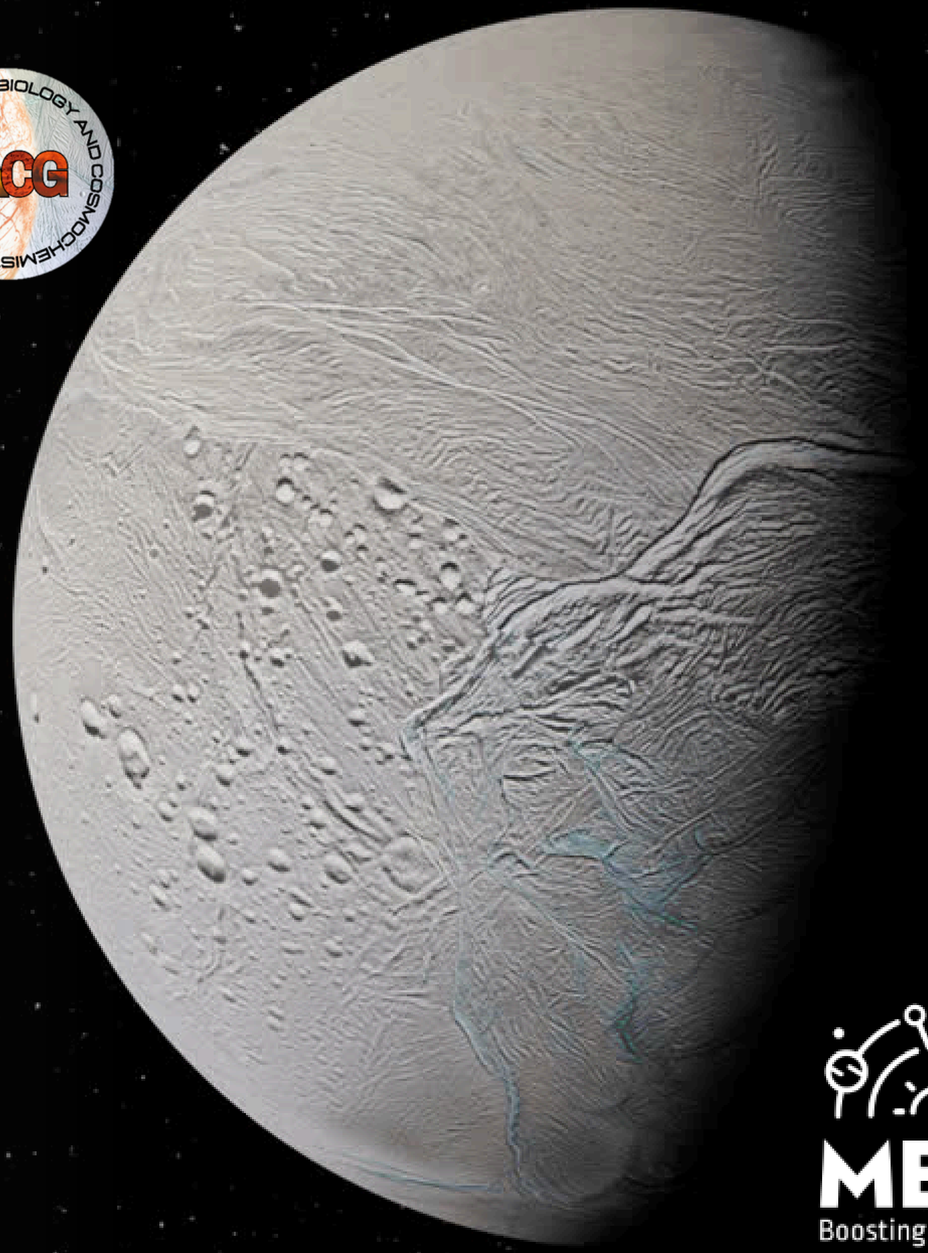
EXTREME ENVIRONMENTS

ia instituto de astrofísica e ciências do espaço

THE ASTROBIOLOGY AND COSMOCHEMISTRY GROUP TACG

2nd Cycle Integrated Project in Engineering Physics - 2025/2026

DETECTION OF BIOSIGNATURES AND ORGANIC COMPOUNDS IN ICY MOONS USING SPECTRAL FEATURES



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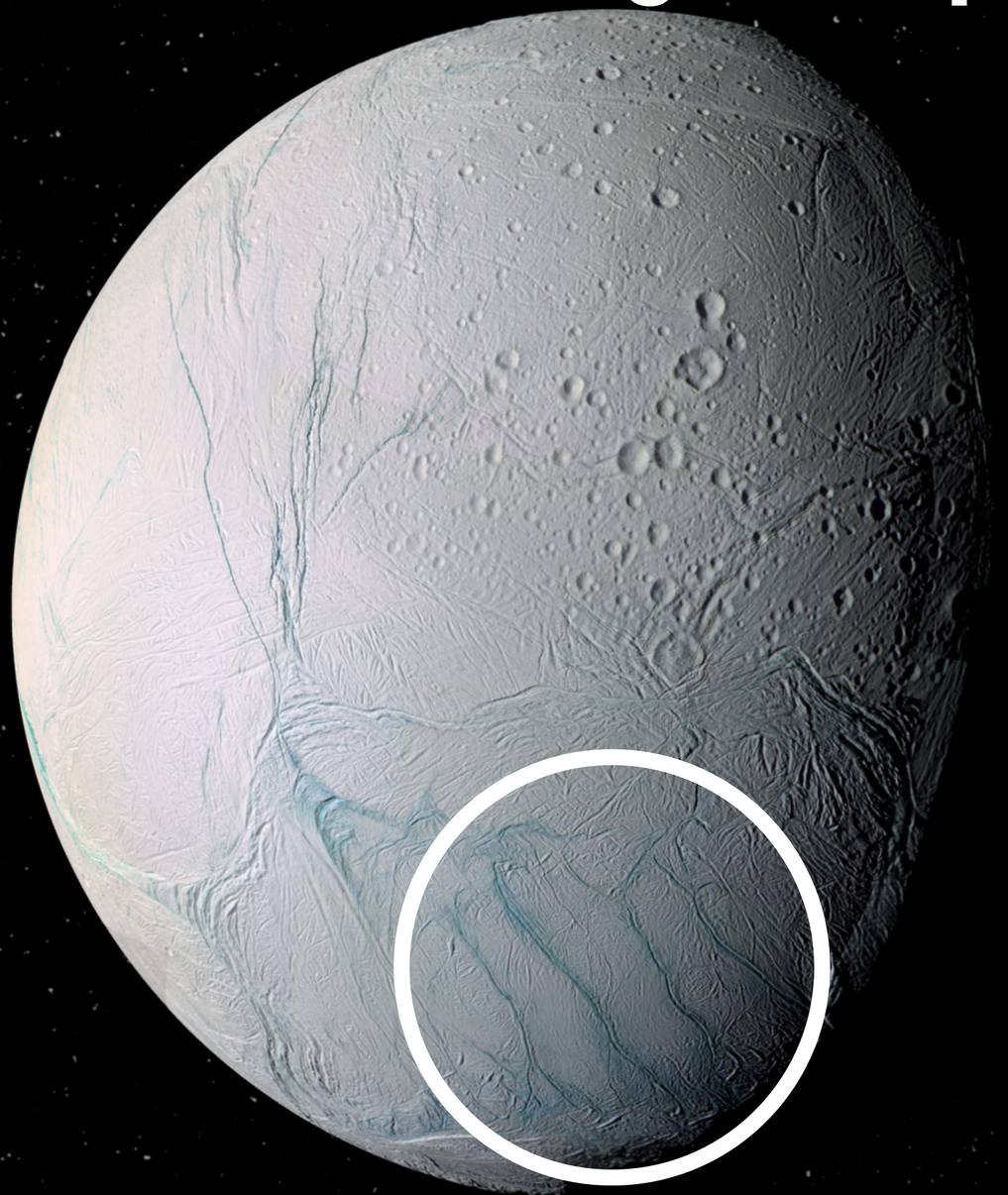
Supervisors: Prof. Zita Martins, Prof. Pedro Machado & Prof. Ana Noronha

MEFT
Boosting the Future

Enceladus model created by the author using NASA/JPL data (PIA18435)

Enceladus' Tiger Stripes



Mosaic image: NASA/JPL-Caltech/Space Science Institute (PIA06254) | Thermal map: Spencer et al. (2006). Cassini encounters Enceladus: Background and the discovery of a south polar hot spot. Science, 311(5766), 1401-1405. | Spencer et al. (2009). Enceladus: An active cryovolcanic satellite. Chapter 21 in Saturn from Cassini-Huygens. Springer.

VIMS Tiger Stripe Methodology

(Brown et al. 2006)

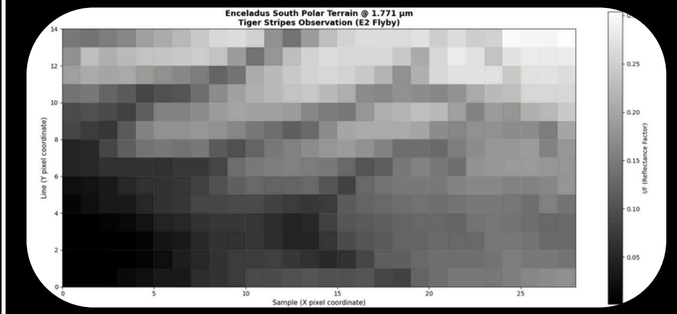
VIMS Cube Image
E2 flyby (14/07/2005)
Phase angle: 46°

→

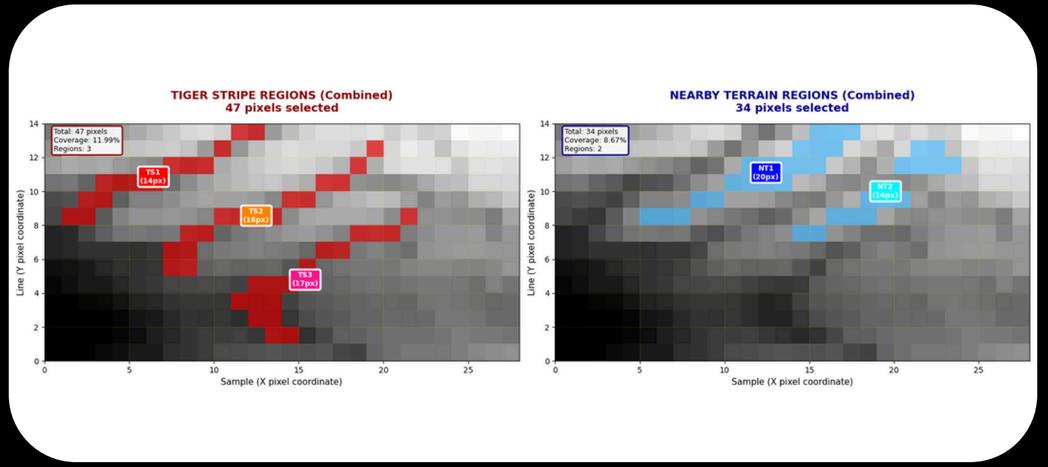
Area Selection

→

Spectra with pixel-to-pixel uncertainty

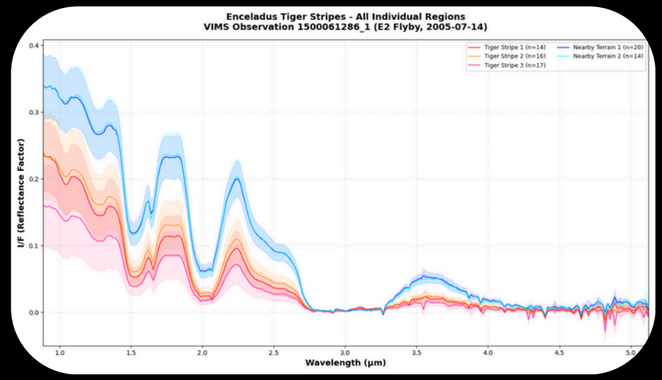


1.78 µm



Interactive polygon masking

Regions:
3 tiger stripes (47 pixels) + 2 nearby terrain (34 pixels)



Key features: H_2O ice (1.5, 2.0, 3.0 µm), CO_2 ice (4.26 µm), organics (3.45, 3.55 µm)

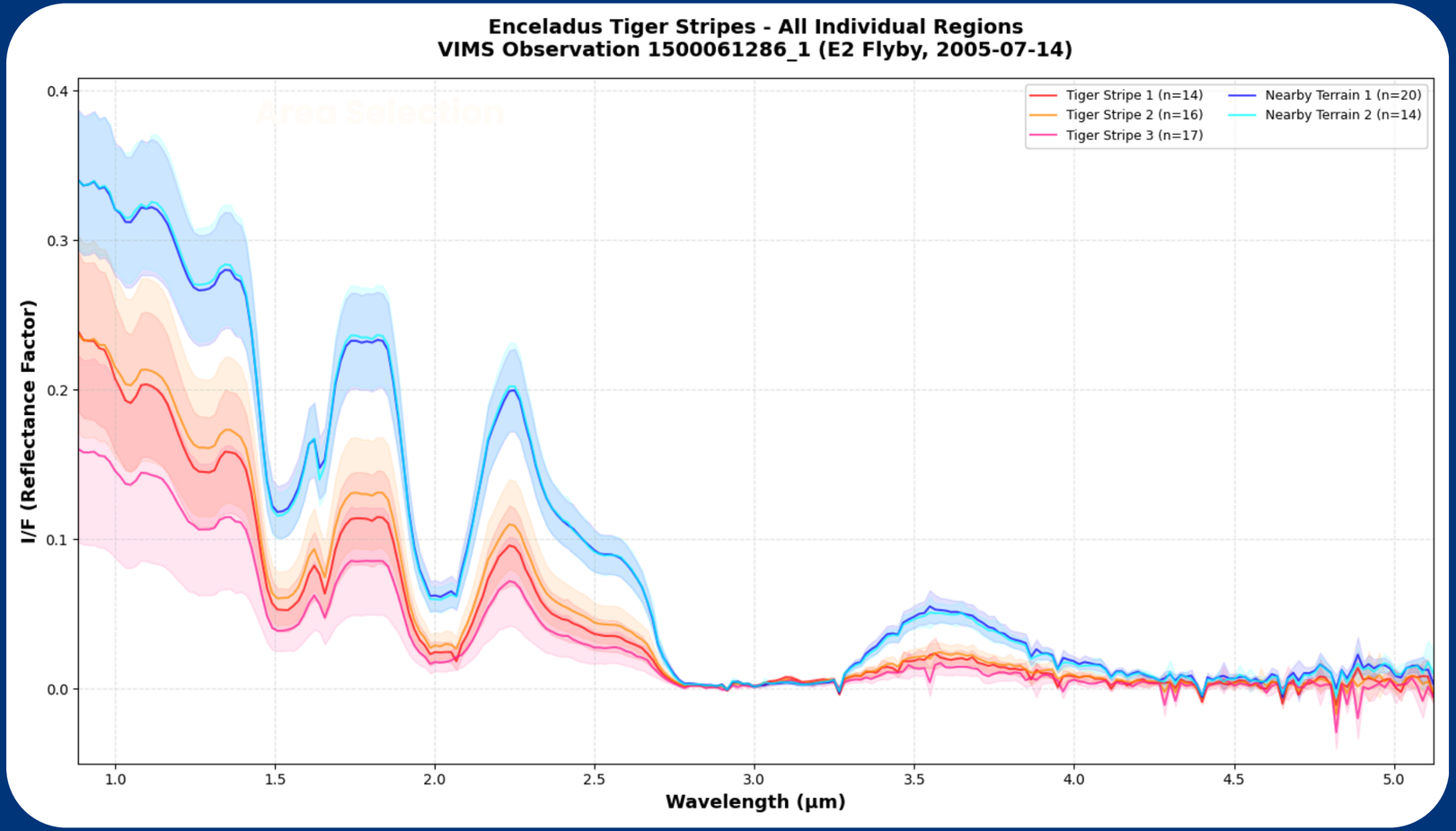
VIMS Tiger Stripe Methodology

(Brown et al. 2006)

Tiger Stripe vs Nearby Terrain (47 vs 34 pixels)

Systematic throughout NIR: 57% (1.5 μm), 61% (2.0 μm), 63% (3.6 μm)

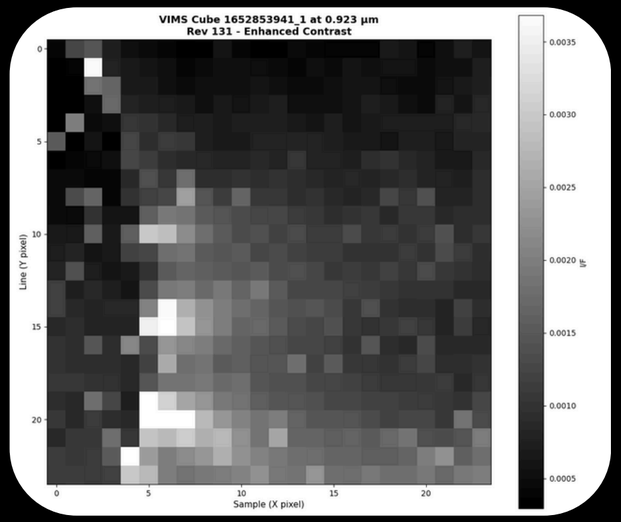
Grain size interpretation: Coarser ice at tiger stripes (>500 μm vs 70-300 μm)



VIMS Plume Methodology

(Dhingra et al. 2017)

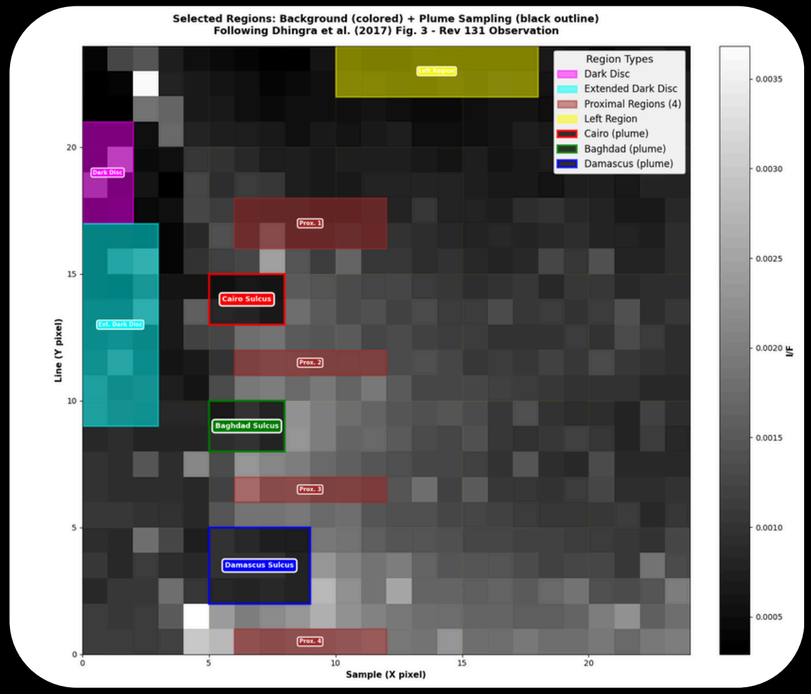
VIMS Cube Image
High Phase Angle (156°)



E10 flyby
(18/05/2010)

→

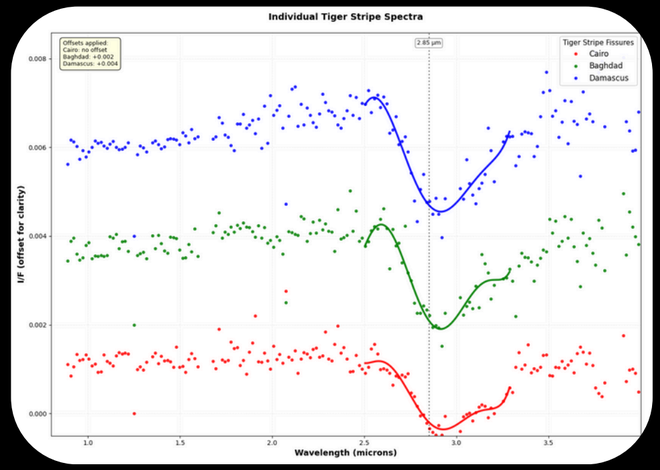
Background + Plume Selection



7 background regions
+
3 plume regions

Background Subtraction →

Spectra
Crystallinity



λ_min > 2.8 µm
T > 130 K

VIMS Plume Methodology

(Dhingra et al. 2017)

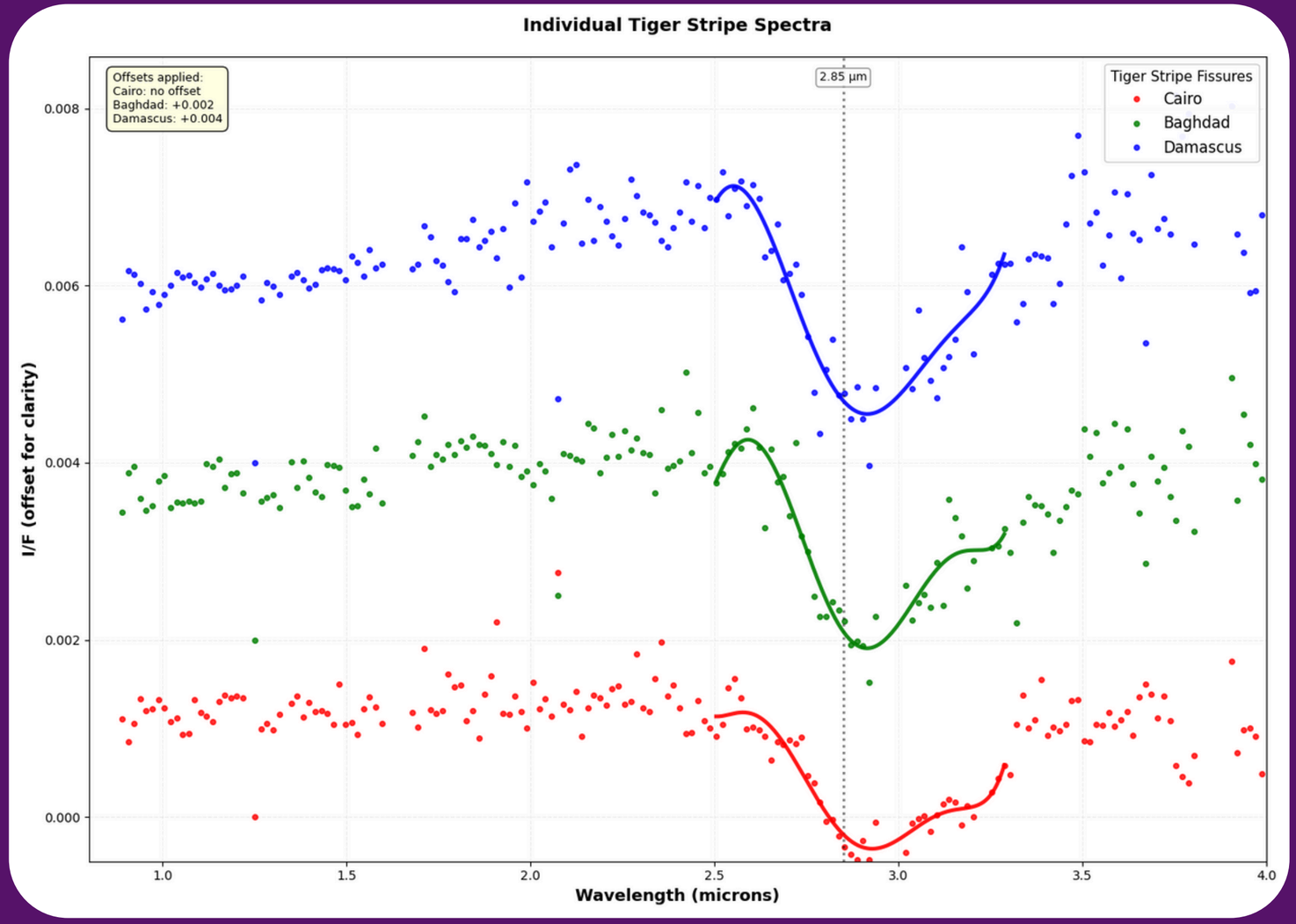
Band minimum positions:
Cairo: 2.930 μm
Baghdad: 2.914 μm
Damascus: 2.914 μm

- **All exceed threshold at 2.8 μm**
  ➜ Crystalline ice

Uniform thermal conditions across eruptions (Δλ = 0.016 μm)

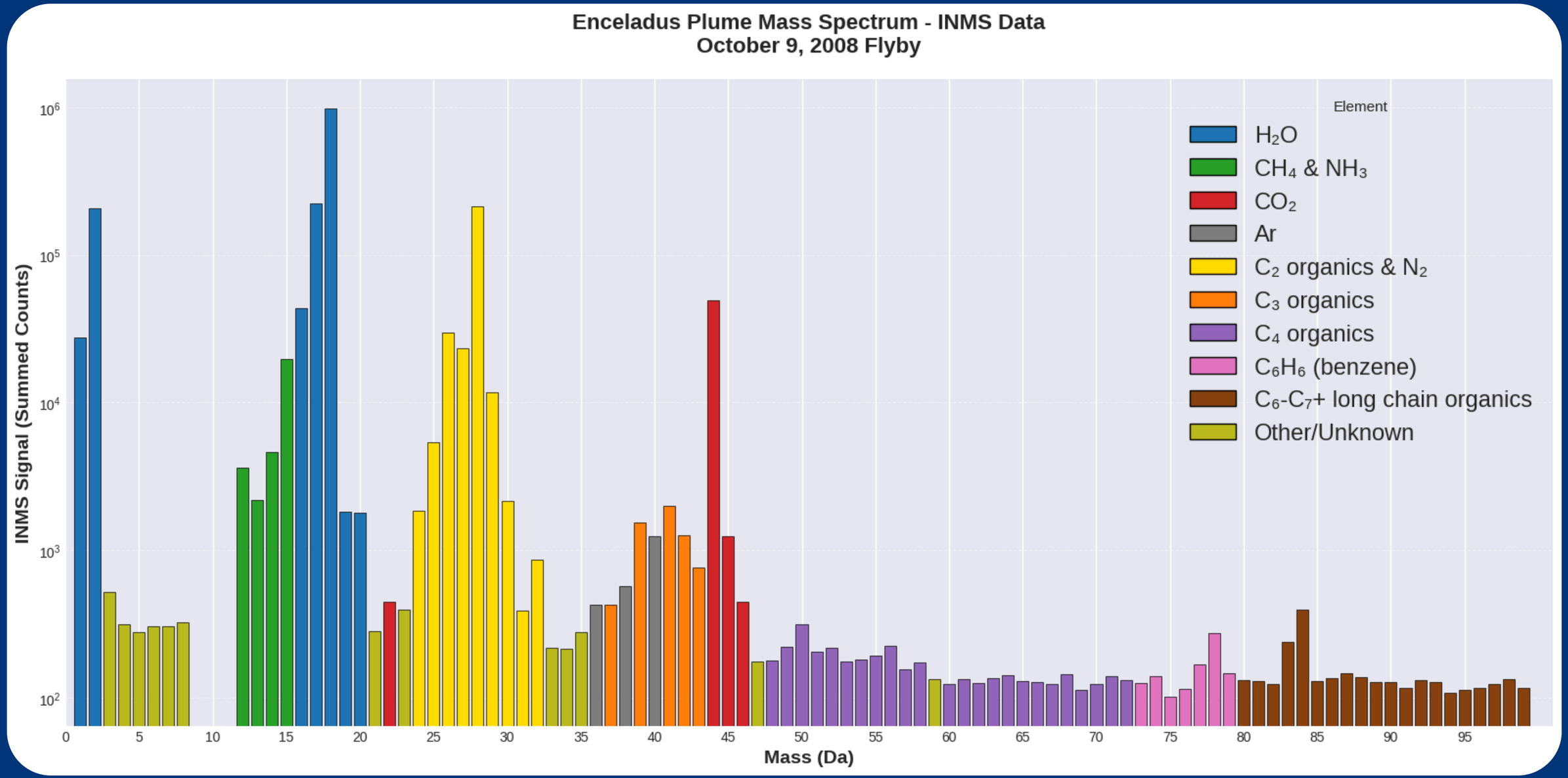
Temperature constraint: T > 130 K during condensation

Implication: Warm hydrothermal source (active subsurface ocean)

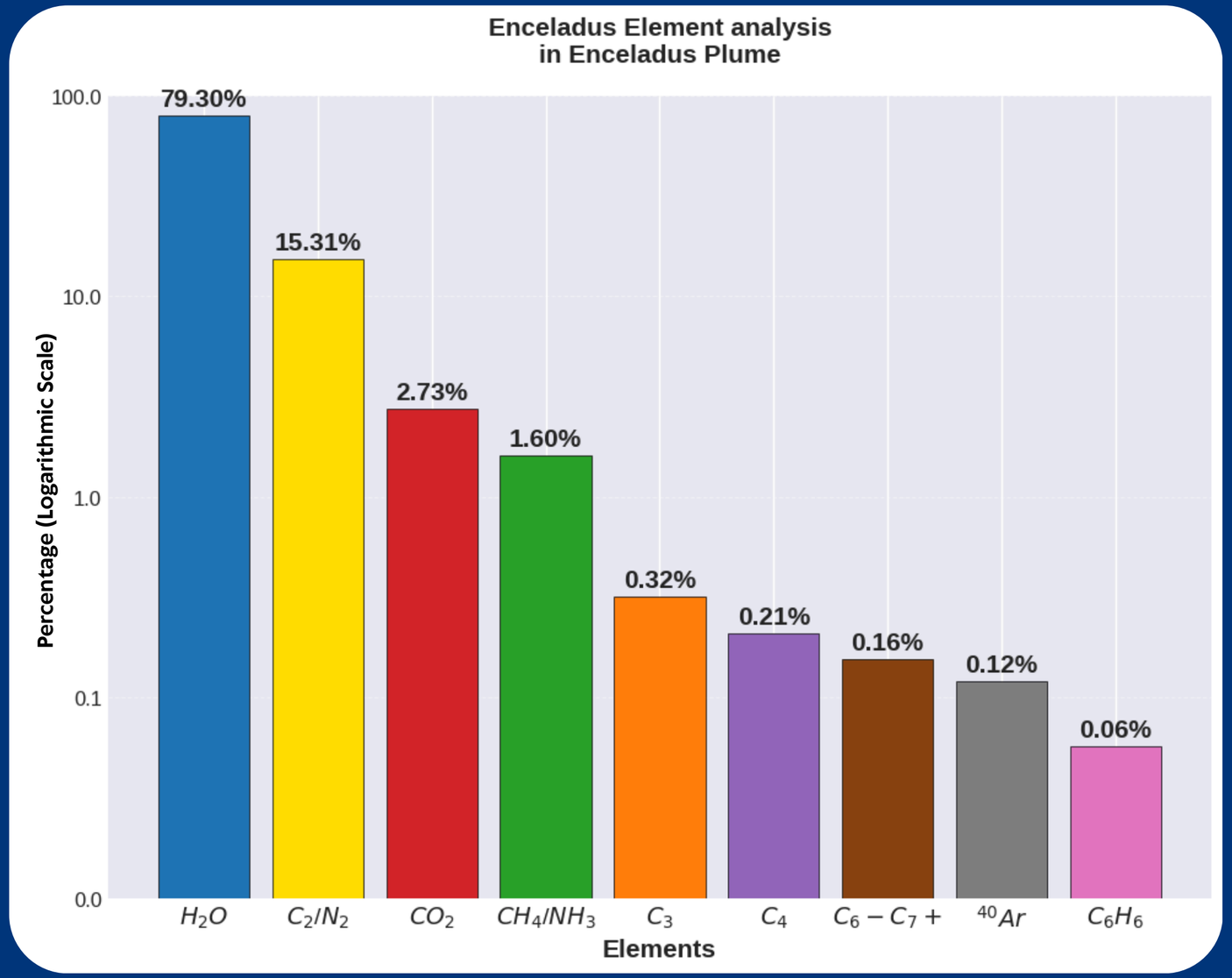


λ_min > 2.8 μm
T > 130 K

RESULTS: INMS Composition



RESULTS: INMS Composition



E5 Flyby Plume Composition (1.88×10^6 total counts)

H_2O: 79.30% (dominant) → Ocean-derived plume

C_2/N_2 organics: 15.31% (mass 28 ambiguity: $N_2/CO/C_2H_4$)

CO_2: 2.73%

CH_4/NH_3: 1.60% (NH_3 ~0.8% - antifreeze effect)

Complex organics:
C_3: 0.32%
C_4: 0.21%
Long chain organics (C_6-C_7+): 0.16%
Benzene (C_6H_6): 0.06%

^{40}Ar: 0.12% (3 orders of magnitude enrichment!)

Conclusion

Key Findings:

- Multi-instrument methodology successfully developed and validated
- Tiger stripes: 51% reduced reflectance, coarser grains, enhanced organics + CO_2
- Plume: Crystalline ice (T > 130 K) confirms warm ocean confirmed
- INMS: 79.30% H_2O + high molecular diversity
- Radiogenic ^{40}Ar (1000× enrichment): Suggests water-rock interactions

Enceladus as Astrobiology Target:

Liquid water ✓ | Organics ✓ | Chemical energy ✓

Enceladus represents an exceptional candidate for a dedicated astrobiology mission with life-detection instrumentation

Acknowledgements

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Prof. Pedro Machado (Faculdade de Ciências)
Prof. Ana Noronha (Instituto Superior Técnico)

Data Sources:
VIMS: Laboratoire de Planétologie et Géosciences, Université de Nantes
INMS: NASA Planetary Data System

This work builds upon the legacy of the Cassini mission team.


Thank you

Appendix

Enceladus Internal Structure

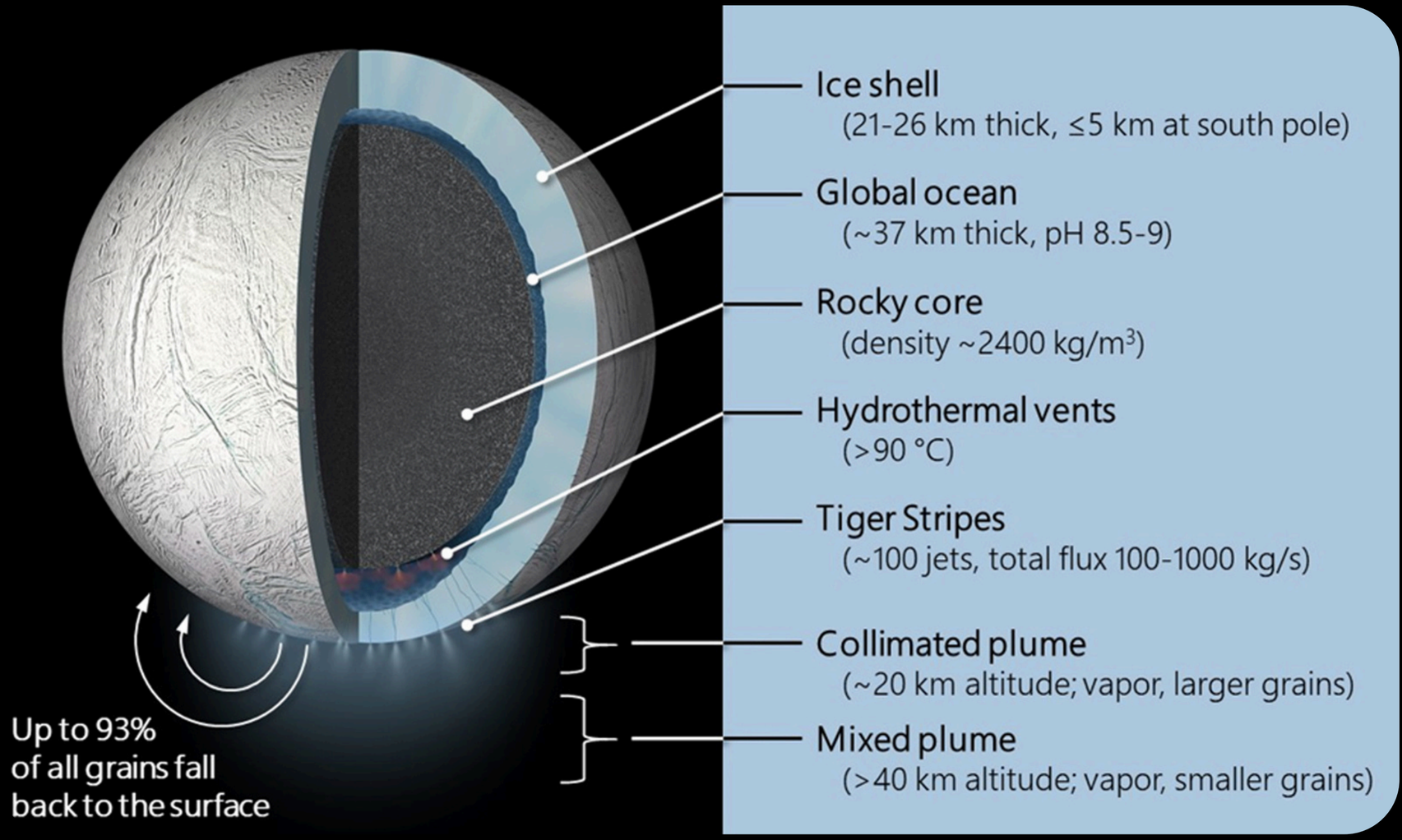

Diagram: Cable et al. (2021). The science case for a return to Enceladus. The Planetary Science Journal, 2(4), 132. | Iess et al. (2014). The gravity field and interior structure of Enceladus. Science, 344(6179), 78-80. | Thomas et al. (2016). Enceladus's measured physical libration requires a global subsurface ocean. Icarus, 264, 37-47.