

Revisiting the Retention Framework of Lunar Helium-3 through Space Weathering Processes and its Implications

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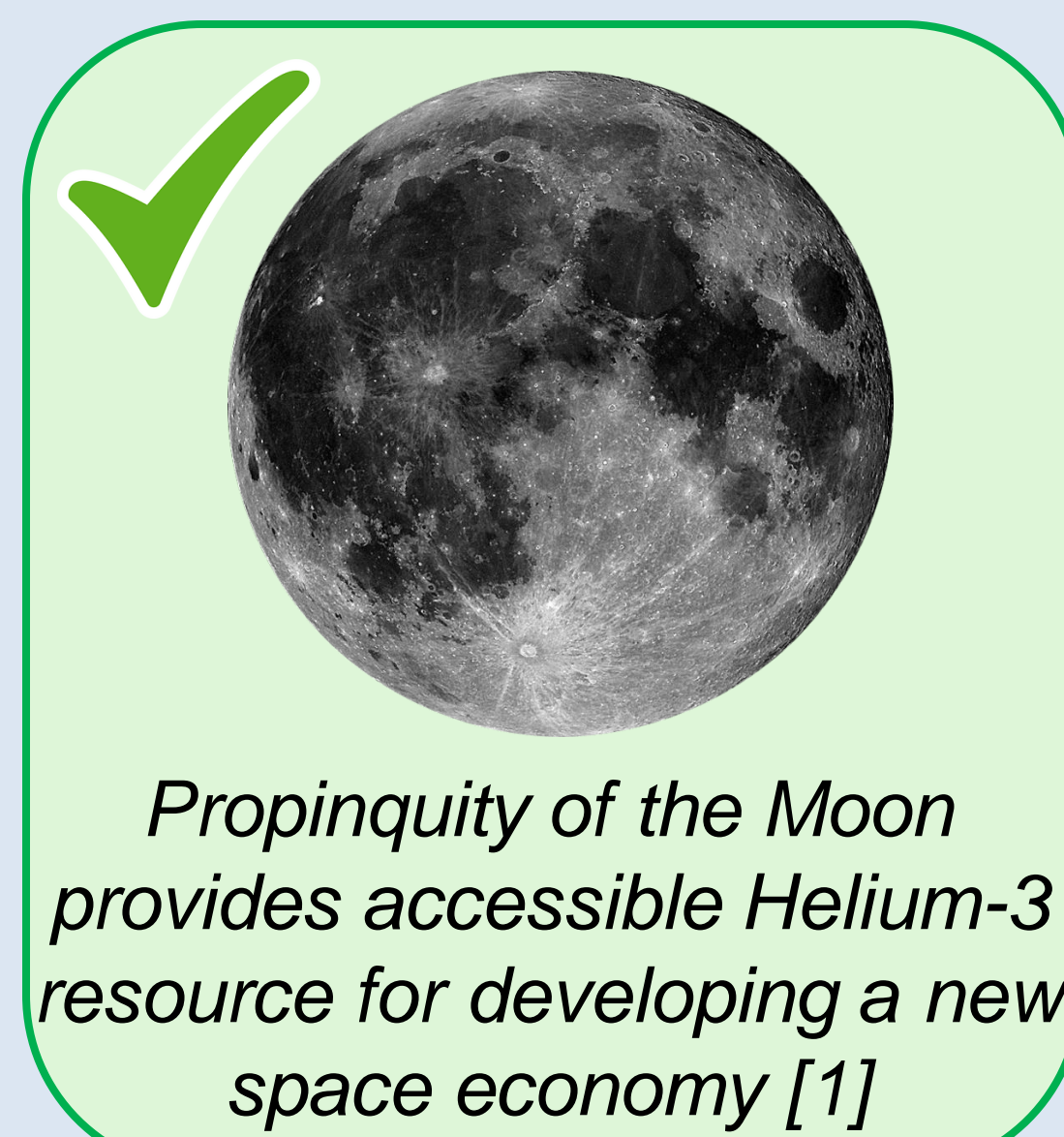
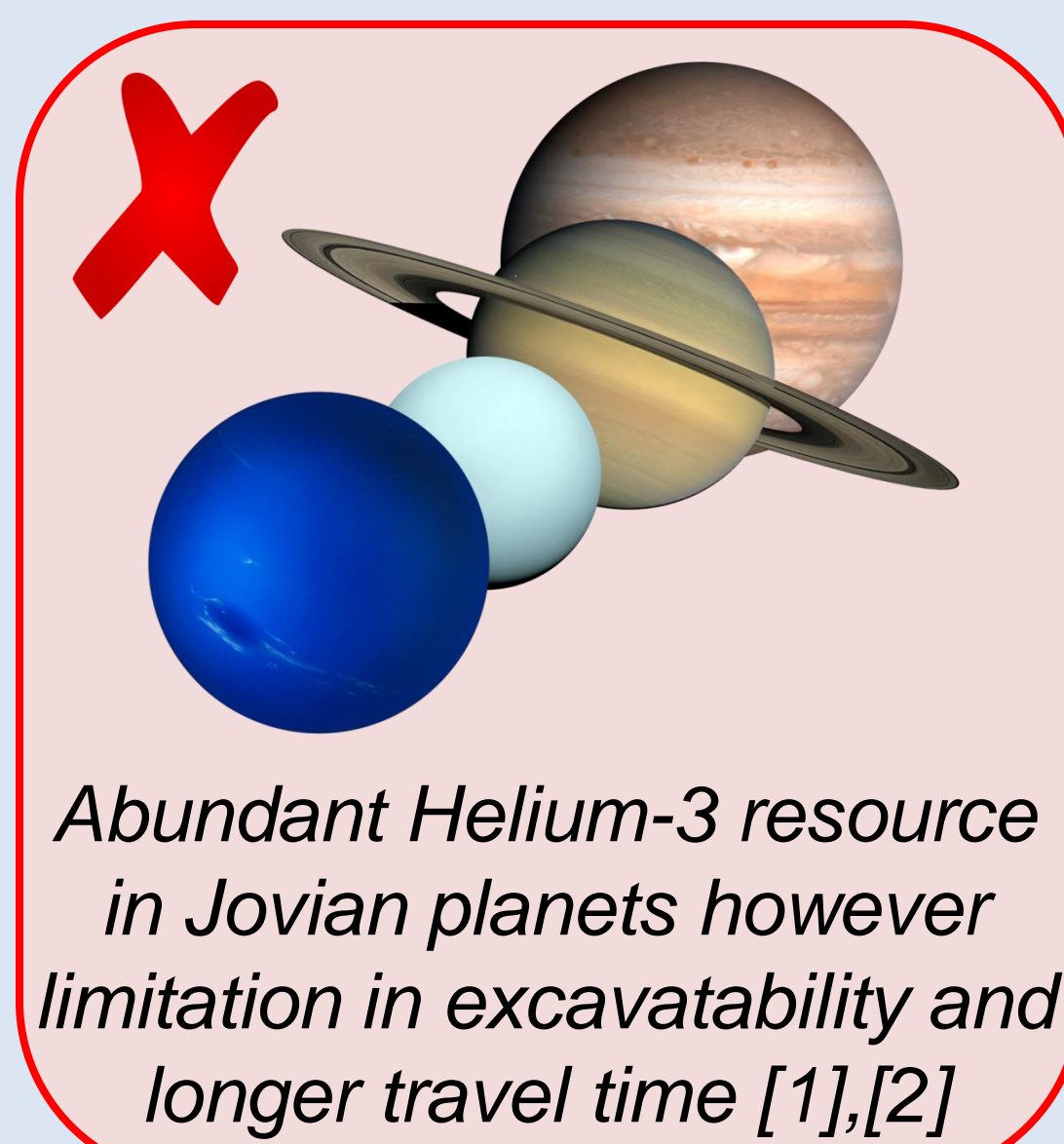


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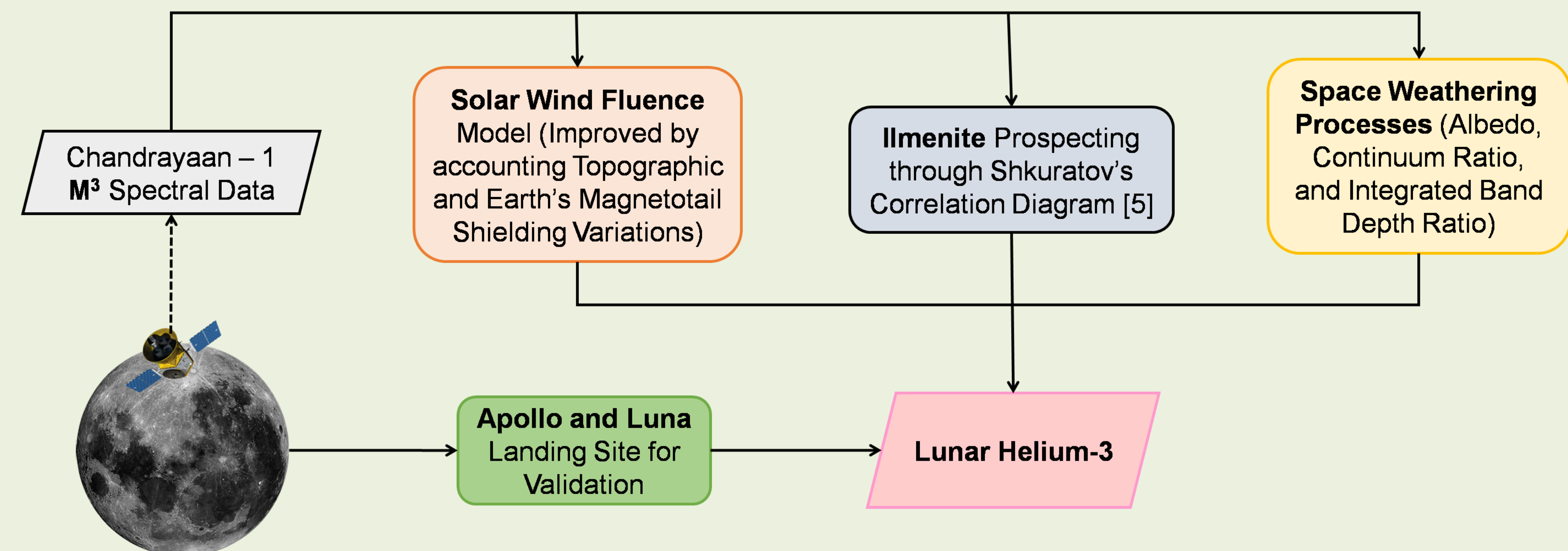
Rationale

A new space weathering perspective enables precise identification and characterization of lunar Helium-3, as a potential resource for providing clean and sustainable energy.



Retention Chemistry of Lunar Helium-3: An Improved Approach

Interaction of solar wind with lunar regolith retains Helium-3 depending upon the ilmenite abundance and degree to which regional soils are weathered [2]-[4].



Higher Retentivity of Aristarchus Pyroclasts

- ✓ From comparing spectral indicators, modelled solar wind fluence, and in-situ Helium-3 data for 61 Apollo and Luna samples, a *high correlation* is observed in Figure 1 (c).
- ✓ Luna samples receive ~47.77% solar wind flux more than that of the Apollo samples, possibly attributing to *higher Helium-3 saturation*.
- ✓ Most abundant regoliths emerge out to be *regional pyroclasts* (red color) with >7.3 ppb, as shown in Figure 1 (a), and reduced Fe²⁺ band depths.
- ✓ Further traces of *hydrated* spectra, depicted by 2800 nm absorption dip in Figure 1 (b), incline such regions to be of *ISRU potential*.
- ✓ Other promising sites include Herodotus crater floor, Agricola mountaintop, and hotspots near primary rille.

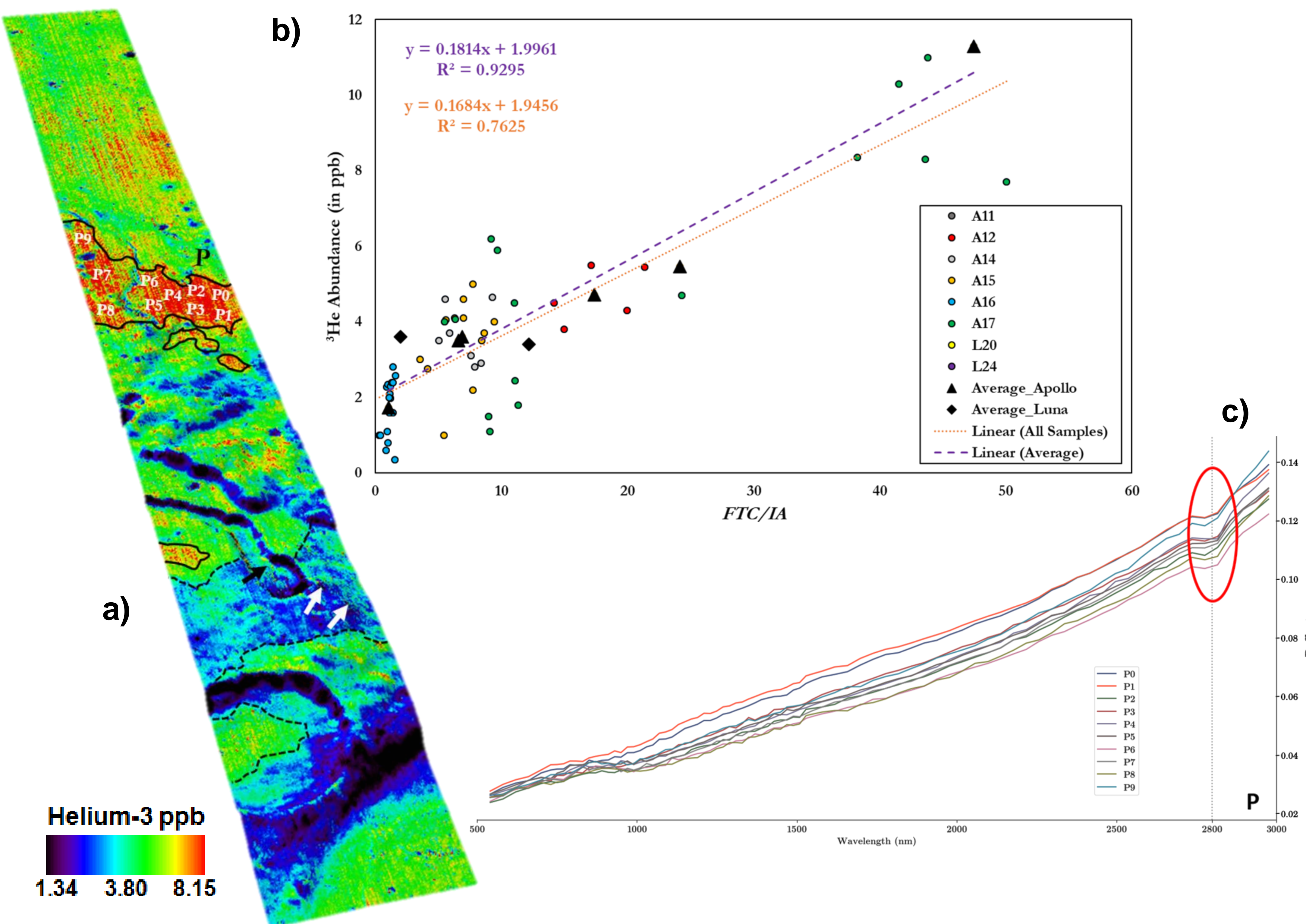


Figure 1. a) Retained Helium-3 abundance of the Vallis Schroteri region. Solid black line delineates the most retentive regoliths (>6 ppb) whereas dotted black line separates the medium to high abundant regions. Black arrow shows an increased Helium-3 concentration near the inner rille and floor of primary rille whereas white arrows depict lower abundant regolith near the Cobra head feature. b) Statistical (regression) analysis of proposed spectral hybrid indicator and in-situ Helium-3 data of 61 samples. Measurement bias is observed due to the irregular spatial distribution of samples. It is avoided by considering site-specific averaging. c) Extracted spectra from higher abundant pyroclastic deposits, showing prominent dips at 2800 nm in red circle.

Novel Contributions to the Lunar ISRU Community

- ✓ Effects of individual space weathering process towards Helium-3 retention capture *subtle variations in maturity*, thereby delineating precise deposits for subsequent excavation.
- ✓ Compared to previous studies, error is reduced to about <1 ppb, thereby improving drilling uncertainty for *prospective Helium-3 exploration* through the use of well calibrated M³ data.
- ✓ The study further proposes the prospectivity of the pyroclastic regoliths to be aimed as *landing site* for the upcoming *ISRU missions*.
- ✓ The lower abundant regions, along with uncertainty, could be used for designing *optimal routing* to the prospective Helium-3 resources.
- ✓ The developed framework, along with high quality maps, provides new insights into *mining site identification for initiating the establishment of lunar energy sector*.

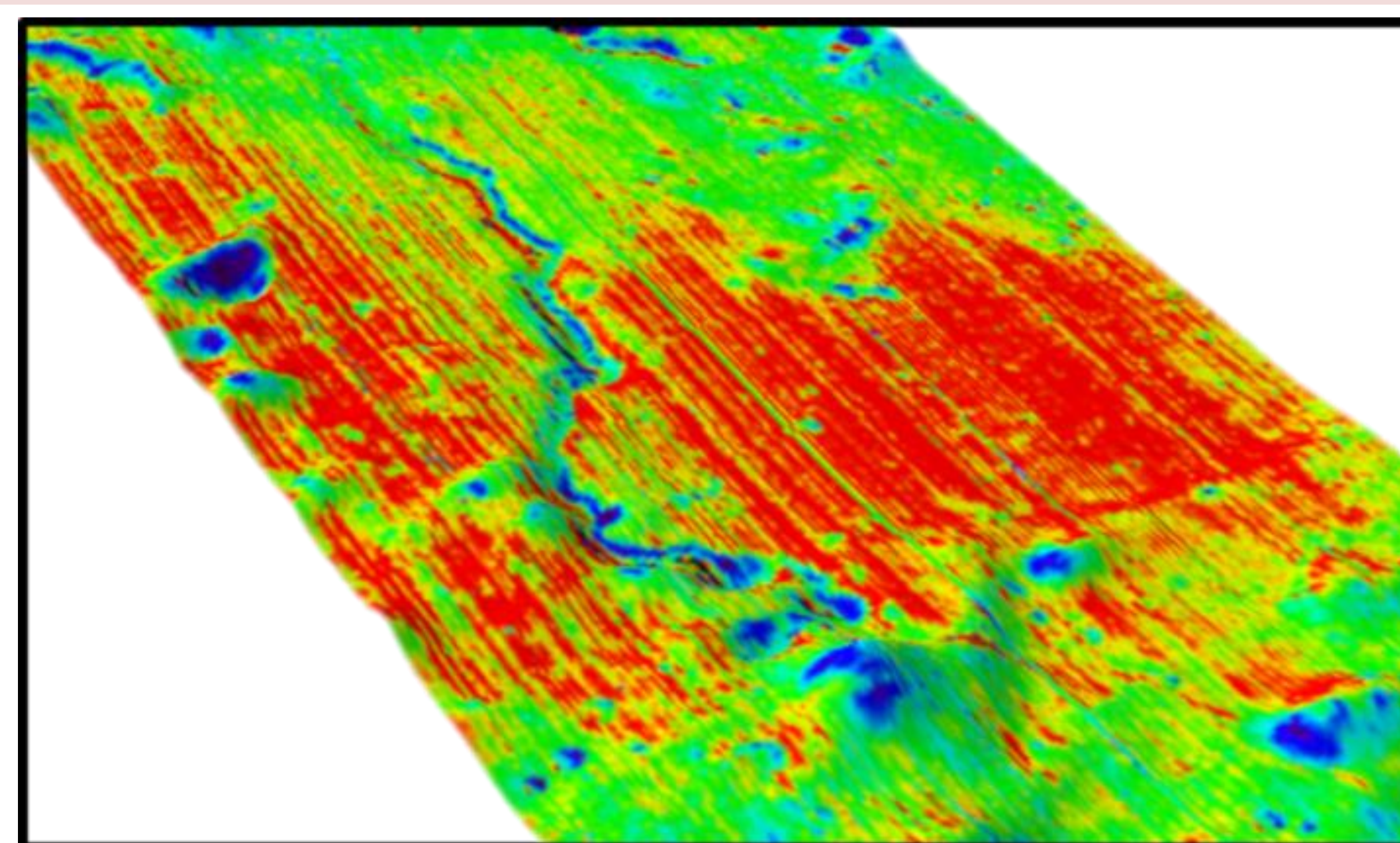


Figure 2. Localized lower abundant deposits emplaced over pyroclastic regoliths are indicative of high albedo and continuum ratio compared to attenuated band depths (regions in blue to purple color). This may suggest freshly gardened regolith which is less exposed to the incident plasma flux. Utilizing such immature tracks with low abundance of Helium-3, ISRU excavator trajectory could be mapped, thereby avoiding mining losses.

Discussion

- ✓ Most dominating process responsible for Helium-3 retention is *reduced spectral contrast*, due to the attenuation of mafic absorption band depths, followed by *increased reddening* of the regolith.
- ✓ The attenuation is mainly controlled by both *maturity and pyroclastic glass content* towards the retention.
- ✓ The abundant regolith is more likely to be *highly crystalline gardened with ilmenite-rich glass beads*, encapsulating water within the grains. Particularly, in this vicinity, there may be possible reduction of the *npFe⁰ particles* in the accreted rims.

Acknowledgements & References

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References: [1] Wittenberg L. J. et al. (1987) *Fusion Technology*, 10, 167-178. [2] Swindle T. D. et al. (1990) *UA/NSERC*. [3] Johnson J. R. et al. (1999), *GRL*, 26, 385-388. [4] Fa W. and Jin Y. Q. (2007), *Icarus*, 190, 15-23. [5] Shkuratov Y. G. et al. (1999), *Icarus*, 137, 222-234.