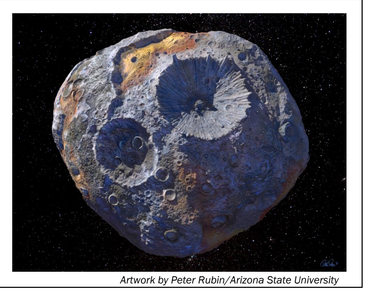
UV Spectroscopy of Metallic Asteroid (16) Psyche



Artwork by Peter Rubin/Arizona State University

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A. Introduction

Main-belt asteroid (16) Psyche is the largest M-type asteroid, and exhibits the relatively featureless, red-sloped visible/near-IR spectrum characteristic of this type. Its high radar albedo [1], high density [2], and high thermal inertia [3] suggest a mostly metallic composition.

What history could have produced this dense body without spectral signature of a rocky mantle?

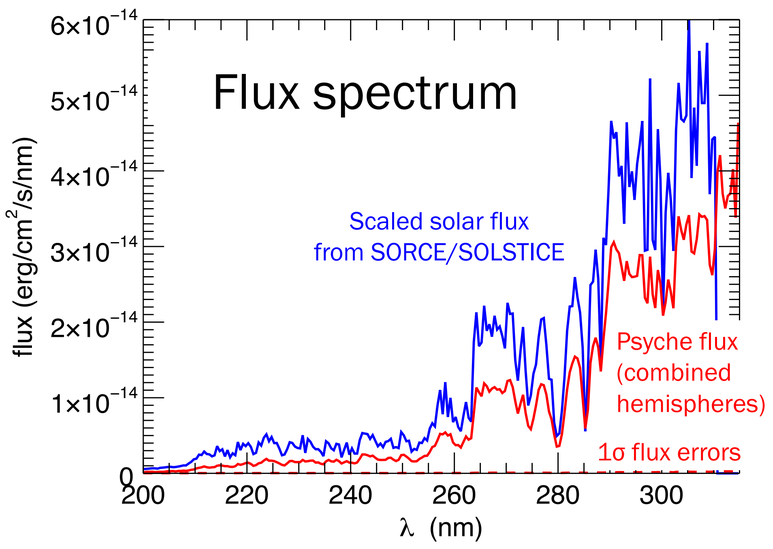
- *Leading theory:* Psyche is the exposed core of a differentiated asteroid, after collisional stripping of its mantle [4]. **Observing Psyche should provide insight into cores of terrestrial planets.**
- *Alternative #2:* Psyche accreted near the sun in a metal-rich, reducing environment, and never melted [5]. **Psyche could provide information about conditions in the early Solar System.**
- *Alternative #3:* Psyche is a differentiated body whose rocky mantle is spectrally disguised by space weathering. **This could point to a resolution of the "Great Dunite Shortage" (lack of olivine observed in asteroids)** [6].

Recent detection of a 3-μm absorption feature attributable to H_2O or OH complicates the picture [7]: suggests a small amount of hydrated silicate minerals in surface.

We employed ultraviolet (UV) spectroscopy with the Hubble Space Telescope (HST) as a novel way to study Psyche's surface and distinguish among the above scenarios. We looked for:

- Fe–O absorption bands near 220 and 260 nm. *Evidence against formation under strongly reducing conditions.*
- "Blueing" of spectral slope in the UV. *Signature of space weathering.*
- Matches to laboratory UV reflectance spectra.

B. Observations

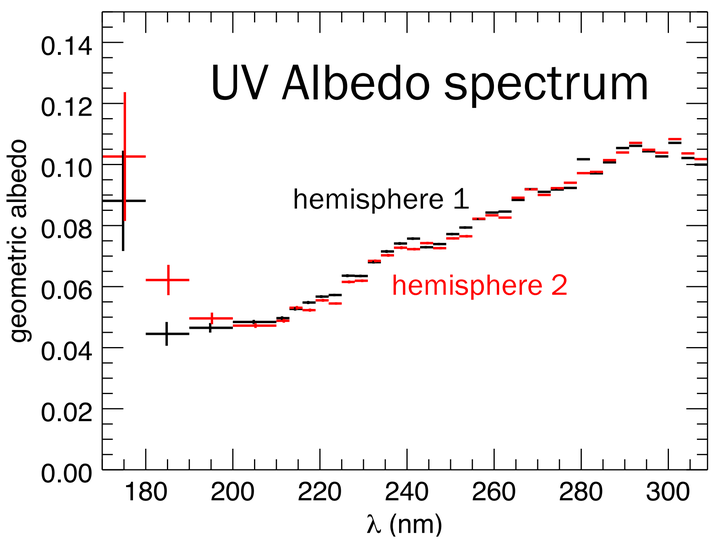


- HST/STIS spectra, grating G230L
- 2 observations: 4 Apr and 6 Apr 2017, **cover opposite hemispheres** (12.5 Psyche rotation periods apart)
- Exposure time: 2288s each
- Solar phase angle: 10.7°–11.3°
- *HST/COS 120 – 200 nm observations also made, but Psyche too faint for detection*

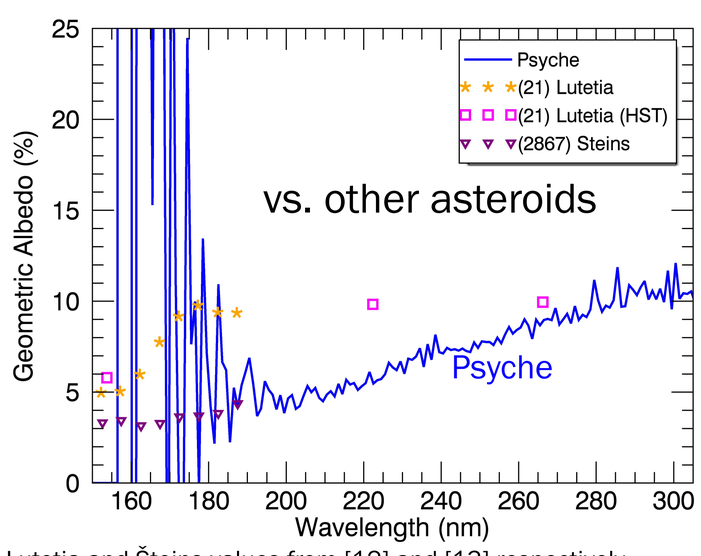
C. Spectral features

Geometric albedo computed from flux spectrum, using

- Solar spectrum of observation days from SORCE/SOLSTICE [8]
- Psyche effective diameter 226 km from recent radar-based shape model [9]
- Multiplication by 1.8 to correct to zero solar phase angle, consistent with UV and visible phase curves for Psyche from [10] and [11]

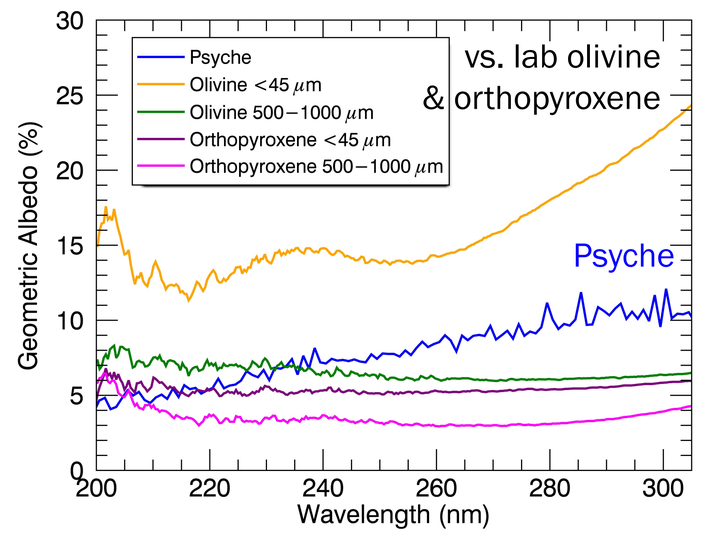


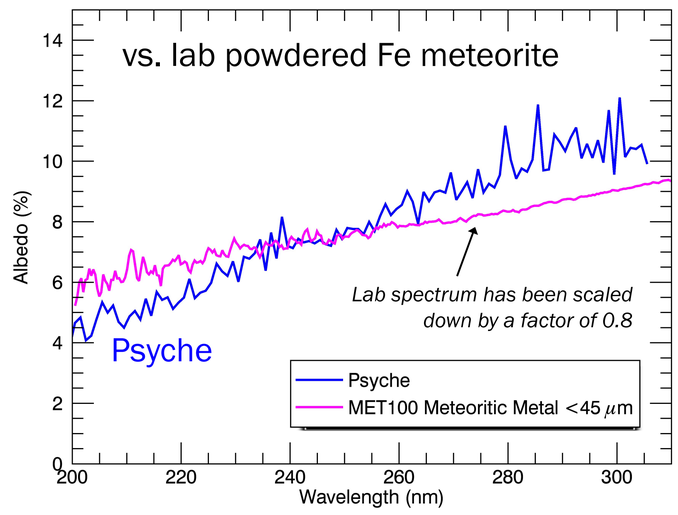
Transition to blue slope at short wavelengths may indicate presence of nanophase Fe; location of turnover depends on amount of this nanophase Fe.



Lutetia and Šteins values from [12] and [13] respectively. *Psyche's UV spectrum is markedly different from that of Lutetia, another M-type asteroid.*

The following two figures compare Psyche's spectrum against reflectance of lab materials reported in [14]:





D. Results

- **Spatial homogeneity:** Two observed hemispheres exhibit nearly identical spectra at λ > 190nm *despite* ***visible*** *reflectance variations of ± 20% from mean*
- **Spectral slope:** (6.50 ± 0.03)% per 100 nm, from 220 – 290 nm, same for both hemisph.
- **Spectral blueing:** On 2nd hemisphere, transition from red to blue slope occurs between 190 – 210 nm. 1st hemisphere may have ~ 10 nm shorter turnover wavelength.
- **Fe–O absorption bands:** No significant Fe^{2+}–O or Fe^{3+}–O absorptions.
- **Comparison to laboratory spectra:** best match is powdered metallic meteorite, though Psyche is redder and less bright.

E. Conclusions

Psyche's spectrum continues to be red-sloped and relatively featureless in the UV, until it becomes blue-sloped at our shortest wavelengths. We initially interpret the difference in this spectral "blueing" between hemispheres as evidence for enhanced space weathering on hemisphere 2, with relatively more nanophase iron there than hemisphere 1; surface 2 may be more mature or have a higher iron abundance than 1.

Absence of Fe-O absorption bands in either hemisphere suggests either:

- formation under highly reducing conditions;
- top layer of the surface probed by UV photons obscures a stronger Fe-O composition; or
- Psyche may be less iron-rich than initially considered.

Additional effort to match Psyche's spectrum against a composite built from lab spectra is warranted.

Acknowledgements

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References

[1] **Ostro**, S.J., Campbell, D.B. & Shapiro, I.I., Science, vol. 229, pp. 442–446, **1985**.
[2] **Kuzmanoski**, M. & Kovačević, A., Astronomy & Astrophysics, vol. 395, pp. L17–L19, **2002**.
[3] **Matter**, A. et al., Icarus, vol. 226, pp. 419–427, **2013**.
[4] **Asphaug**, E., Agnor, C.B., & Williams, Q., Nature, vol. 439, pp. 155–160, **2006**.
[5] **Elkins-Tanton**, L.T. et al., 47th LPSC, 1631, 21-25 March **2016**, The Woodlands, Texas, USA.
[6] **Britt**, D., et al., DPS Meeting #46, 506.01, 9-14 November **2014**, Tucson, Arizona, USA.
[7] **Takir**, D. et al., Astronomical Journal, vol. 153, 31, **2017**.
[8] **McClintock**, W.E., Rottman, G.J., & Woods, T.N., Solar Physics, vol. 230, pp. 225–258, **2005**.
[9] **Shepard** et al., Icarus, vol. 281, pp. 388–403, **2017**.
[10] **Roettger**, E.E., & Buratti, B.J., Icarus, vol. 112, pp. 496–512, **1994**.
[11] **Lupishko**, D. F. et al., Soviet Astronomy Letters, vol. 6, pp. 102–104, **1980**.
[12] **Weaver**, H.A. et al., Astronomy & Astrophysics, vol. 518, A4, **2010**.
[13] **A'Hearn**, M.A. et al., Planetary & Space Science, vol 58, pp. 1088-1096, **2010**.
[13] **Cloutis**, E. A. et al., Icarus, vol. 197, pp. 321–347, **2008**.

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