



Using Flux Measurements to Calculate Albedo and Characterize Solar System Objects

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INTRODUCTION

The albedo of an object is how much received light or radiation is reflected from the surface of its body^[1]. Albedo is measured on a scale from 0 to 1, akin to percentages. A measurement of 0 is a body that reflects no light and 1 is a body that reflects all the light that hits its surface. There are a variety of albedos that can be measured, for this investigation we use Geometric Albedo.

Geometric Albedo is a function of the phase function (ϕ), dependent on the phase angle (a) which is the angle between sunlight hitting an object and the light reflected to the observer. (R) - the radius of the object being observed, (r) - distance from Sun, (Δ) - distance from object to Earth, (F_{obj}) - measured flux of the target object, (F_{sun}) - flux from the sun at the target object.

$$A = \frac{F_{object}}{F_{sun}} * \frac{r^2 \Delta^2}{\pi R^2} * \frac{1}{\phi(a)}$$

Equation 1: Geometric Albedo Formula

HYPOTHESIS

For our project, we hypothesize that it is possible to use other solar system objects of known temperature, size, distance, and albedo to extrapolate the albedo and therefore composition of targets that have unknown characteristics. To attempt to prove this, we developed an astronomical model that uses measured flux to calculate albedo of unknown objects.

PROJECT MOTIVATION

Icy bodies are among the most important targets in modern planetary science. They are time capsules from our Solar System's formation, whose composition is essentially the same as its original state.

Many icy bodies, such as Europa and Enceladus, host sub-surface oceans underneath their icy crusts. This makes them prime targets for astrobiology research, as microbial life could be hidden underneath their surfaces, developing in that essential building block for life: water.

As astronomers search for more icy bodies, they use a variety of different measurements to determine composition. In our project we ask this: how can you characterize an object if you don't know any details about it?

METHODOLOGY

To take our observations, we used the Leto and Apollo telescopes at SBO. All images were taken in the UV-IR cut filter with 4x4 binning. We chose targets of varying composition to create our relationship between flux and albedo. First, the files with the training and unknown objects are calibrated with dark current, bias, and flat-field images. Next, aperture photometry is performed on all the objects to calculate the flux received from the targets. The flux is then divided by incident solar flux, as seen in Equation 1. The calculation for albedo also depends on the phase function. For this project, we used the Lambert phase function, assuming that target objects are perfectly reflecting spheres. After we had a library of geometric albedos for our training objects, we trained a linear regression model that calculated a geometric albedo for our unknown object from flux without the radius or observation geometry.

TARGETS: FROM ICE TO ROCK

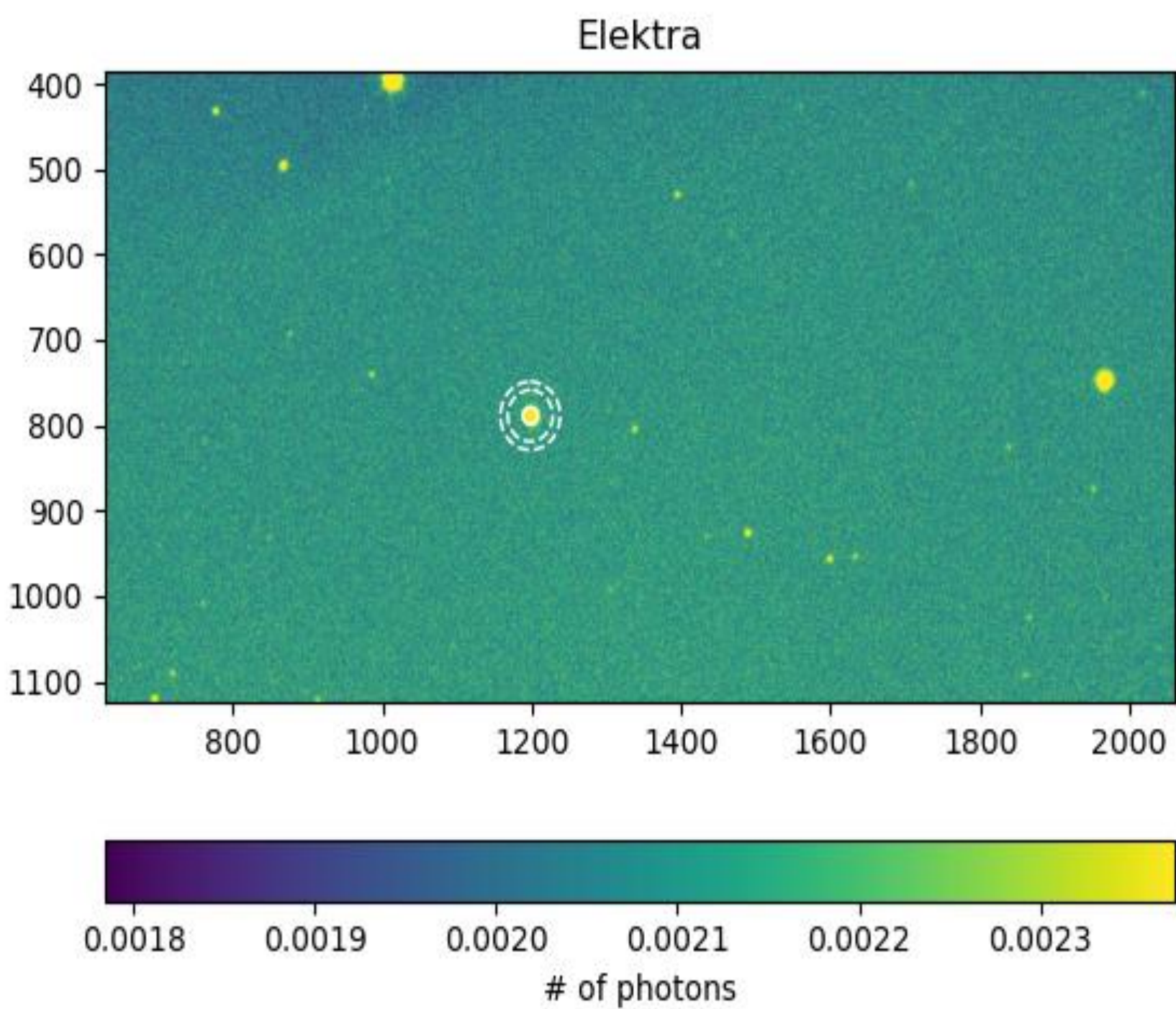


Figure 1: Training body 130 Elektra, a large asteroid in the Main Asteroid Belt

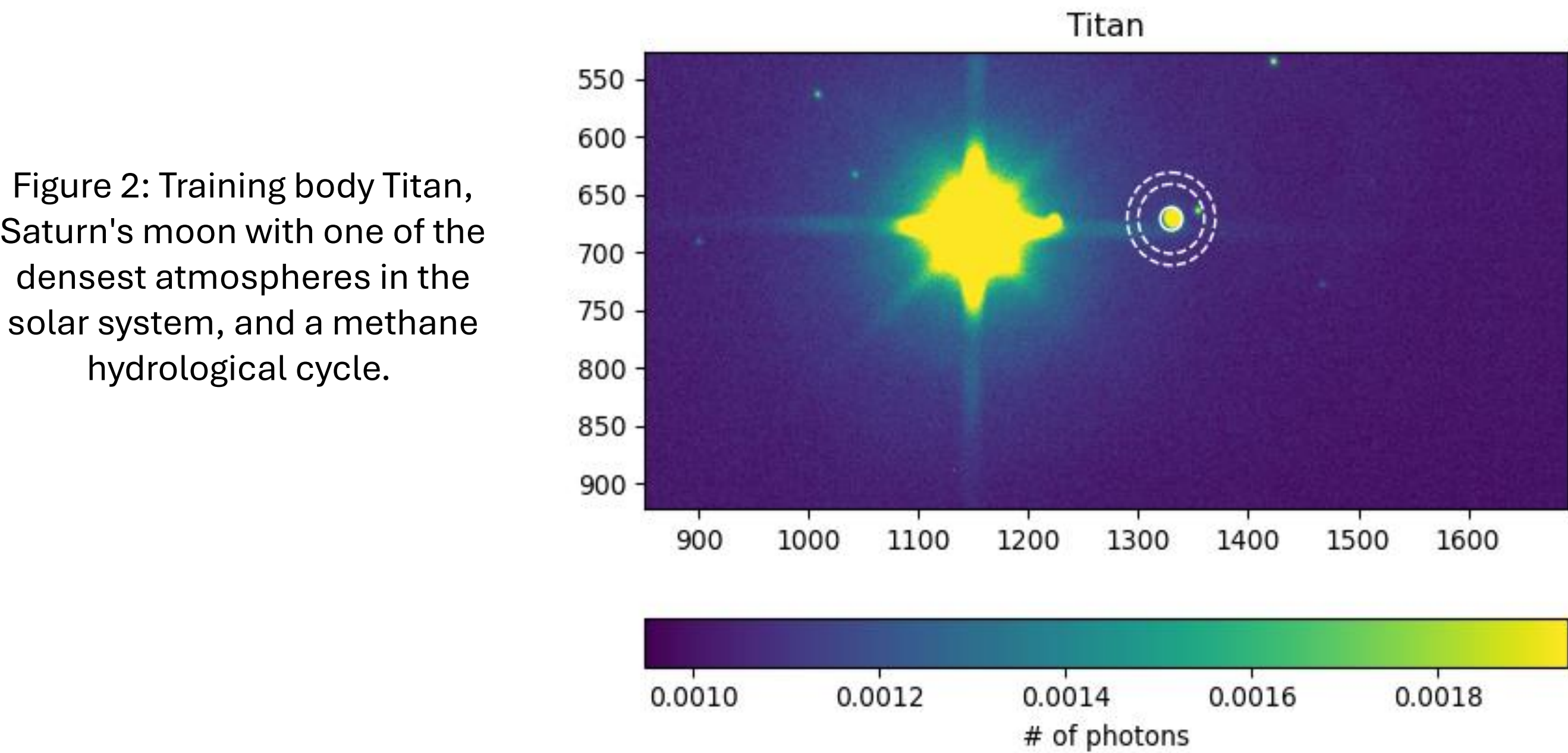


Figure 2: Training body Titan, Saturn's moon with one of the densest atmospheres in the solar system, and a methane hydrological cycle.

RESULTS

The calculated geometric albedos of our training objects fall close to literature values^[2]. However, after plotting the calculated geometric albedo of our training objects and unknown objects, there was not a strong correlation between measured flux and geometric albedo. Noticeably, the bodies clumped together within categories. When plotted against our training objects, the unknown object Psyche fell within the range of albedos for rocky objects. We therefore categorized Psyche as a rocky/asteroid body.

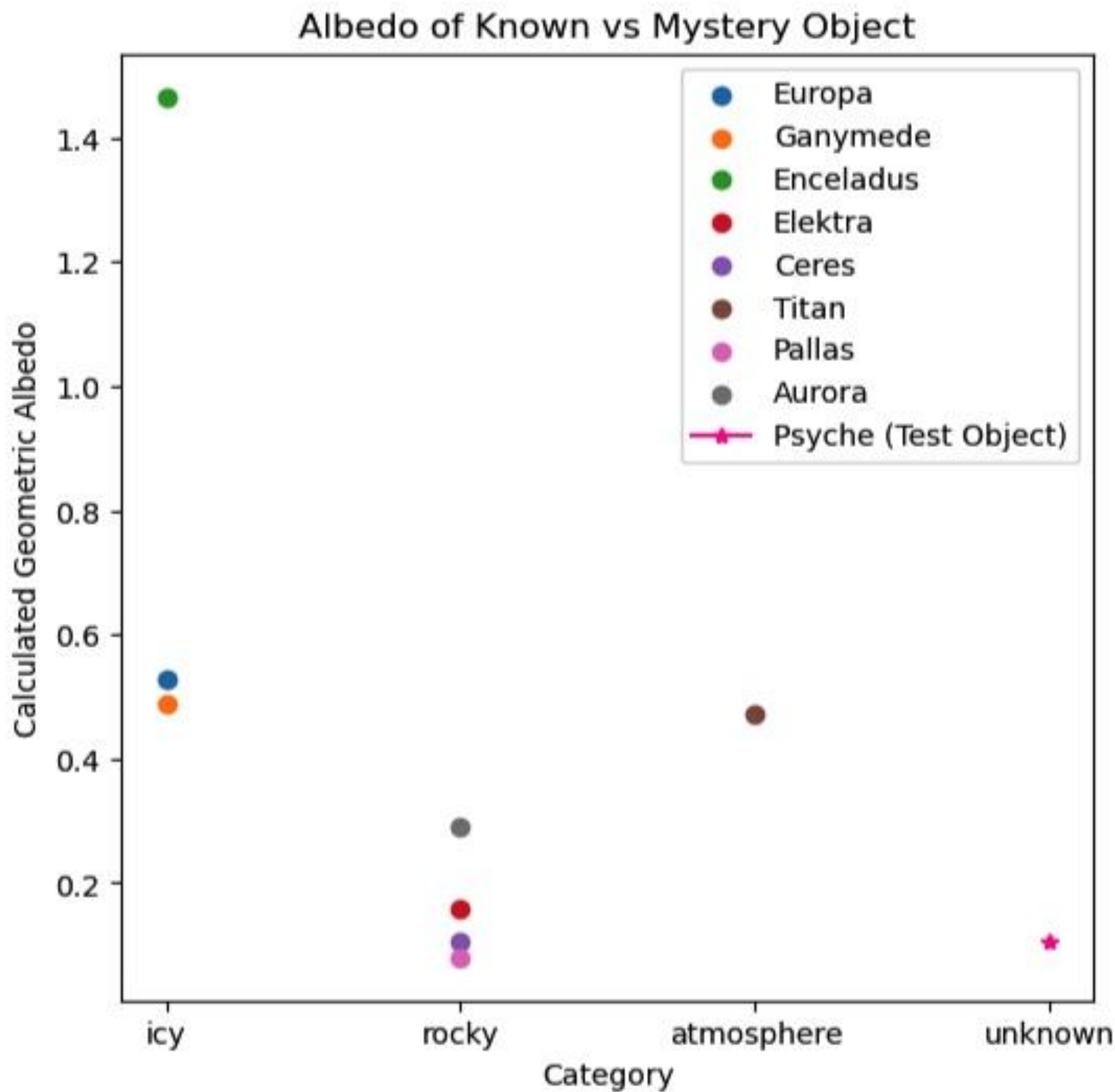


Figure 3: Plot of calculated geometric albedo versus category

CONCLUSIONS

In conclusion, we were able to qualitatively characterize our mystery object. We estimate our unknown object Psyche to be in the rocky asteroid family. Based on real observations of Psyche, it is more metallic than rocky in composition, with an albedo around 0.15^[3]. This discrepancy highlights the fallbacks of a model with only three categories, and a limited training dataset.

REFERENCES

[1] Glossary. (n.d.). Albedo definition <https://cneos.jpl.nasa.gov/glossary/albedo.html>

[2] Madden, J. H., & Kaltenegger, L. (2018). A Catalog of Spectra, Albedos, and Colors of Solar System Bodies for Exoplanet Comparison. *Astrobiology*, 18(12), 1559-1573. <https://doi.org/10.1089/ast.2017.1763>

[3] Shepard, M. K., Richardson, J., Taylor, P. A., Rodriguez-Ford, L. A., Conrad, A., de Pater, I., Adamkovics, M., de Kleer, K., Males, J. R., Morzinski, K. M., Close, L. M., Kaasalainen, M., Viikinkoski, M., Timerson, B., Reddy, V., Magri, C., Nolan, M. C., Howell, E. S., Benner, L. A. M., ... Harris, A. W. (2017). Radar observations and shape model of asteroid 16 Psyche. *Icarus*, 281, 388-403. <https://doi.org/10.1016/j.icarus.2016.08.011>