ASTEROID (16) PSYCHE: A FERROVOLCANIC WORLD? M. K. Shepard[1], K. de Kleer[2], S. Cambioni[2], P. Taylor[3], A. K. Virkki[4], E. G. Rivera-Valentín[3], C. Rodriguez Sanchez-Vahomonde[3], L. F. Zambrano-Marin[4], C. Magri[5], D. Dunham[6], J. Moore[6], M. Camarca[2]. [1]Bloomsburg University, Bloomsburg, PA, mshepard@bloomu.edu, [2]California Institute of Technology, Pasadena, CA, [3]Lunar and Planetary Institute, Houston, TX, [4]Arecibo Observatory University of Central Florida, Arecibo, PR, [5]University of Maine Farmington, Farmington, ME, [6]International Occultation Timing Association, Greenbelt, MD.

Introduction: As we countdown to the launch of the Psyche mission [1] to asteroid 16 Psyche, several studies have begun to refine its shape, identify potential surface features, and map variations in its surface albedo [2,3,4,5]. Here, we generate a new shape model for Psyche, overlay 30 continuous wave (CW) radar albedos acquired at Arecibo Observatory [2,6] on a previously published optical albedo map [4,5], and find a positive correlation between optical and radar albedos. The relevance of these findings for current models of Psyche are discussed.

Models for Psyche: Psyche is the largest M-class asteroid and numerous studies suggest it is a world dominated by iron [1]. There are presently three general models for the origin and structure of Psyche. (1) Psyche is the stripped remnant core of a planetesimal dominated by an iron composition [7]. (2) Psyche is a reaccumulated pile of rock and metal, a type of low-iron pallasite or mesosiderite parent body derived from repeated impacts [8]. (3) Psyche is either an iron [9] or a differentiated silicate-iron body [10] with surface eruptions of metallic iron, a.k.a. ferrovolcanism.

Psyche's overall bulk density is ~4000 kg/m3, roughly half that of Fe-Ni. If Psyche is a metallic relic core, it must be a rubble pile to explain its lower density [1]. Observational campaigns have found spectral signatures of silicates and hydroxyl [1] suggesting at least a veneer of silicate crust. Given its overall bulk density, it seems more likely that Psyche is a mixed silicate-metal world, better explained by models (2) [8] or (3) [10] above.

Psyche Shape Model: We derive a new shape model of 16 Psyche using the following datasets: Arecibo S-band (12.6 cm) delay-Doppler imaging [2], Atacama Large Millimeter Array (ALMA) plane-of-sky imaging [11], adaptive optics imaging from the Very Large Telescope (VLT) [4,5], Keck [2,3], and a 2019 occultation [12]. Our shape model is nominally 278 x 238 x 171 km in size and has a spin pole at J2000 ecliptic lon, lat (38, -6). It is consistent in shape, extent, and spin characteristics with recent published models [2,3,4,5]. Views of our model are shown in Fig. 1.

Psyche Optical Albedo and Radar Observations: Using a simultaneous optimization of AO imaging and lightcurves, two studies generated a shape model of Psyche with surface optical albedo variations [4,5]. Figure 2 shows a contour-filled interpolation of that albedo map. Our shape model is similar in shape, extent, and orientation of spin and major axes, so locations on this map are comparable to those on our model.

On Figure 2, we overlay the sub-radar points of 30 Arecibo calibrated radar echoes [2, and new work]. The symbol size is related to the radar albedo of our measurements – the ratio of echo power from our target to a metallic sphere of the same cross-sectional area.

Radar albedos for asteroids range from ~0.04 for primitive asteroids, e.g., P-class, to highs of ~0.6 for several M-class asteroids; the mean for common S-class asteroids is 0.14 ± 0.04 [13,14]. Our radar observations show the "background" radar albedo for much of Psyche to be ~twice as high as the typical S-class asteroid. This suggests the upper meter of the regolith has a significantly higher bulk density than other asteroids; the most likely reason is a higher metal (Fe-Ni) content. We find several regions with radar albedos ~3-4 times higher than the mean S-class, indicating a very high bulk density and metal content.

Radar albedo is a "whole-disk" measurement, but most of the echo power should originate from regions within 30-40 degrees of the sub-radar point. Given that, we find an apparent correlation between optical and radar albedos, *i.e.*, regions of higher optical albedos have higher radar albedos.

Is Psyche a Ferrovolcanic World?: The ferrovolcanic model neatly explains many of our observations. The relatively high background radar albedo is comparable to other M-asteroids like 21 Lutetia [14]. Spectral observations during the Rosetta flyby [15] indicate compositions analogous to enstatite chondrite (EH) or CH/CB chondrites. These meteorite classes all have elevated metal contents relative to ordinary chondrites. A similar regolith on Psyche readily explains its higher-than-S-class background radar albedo. The regions of very high radar albedo must be especially metal-rich and are consistent with regions of ferrovolcanism. The correlation of optical albedo with radar albedo is readily explained as a byproduct of the process; perhaps a blanket of silicate fines generated by eruptions, the flows themselves [16], materials entrained in the melt, or derivatives of them.

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Figure 1. Views of 16 Psyche Shape Model. Numbers below each figure are the longitude of the model facing the viewer. Numbers to the left are the longitudes of the model on that side.

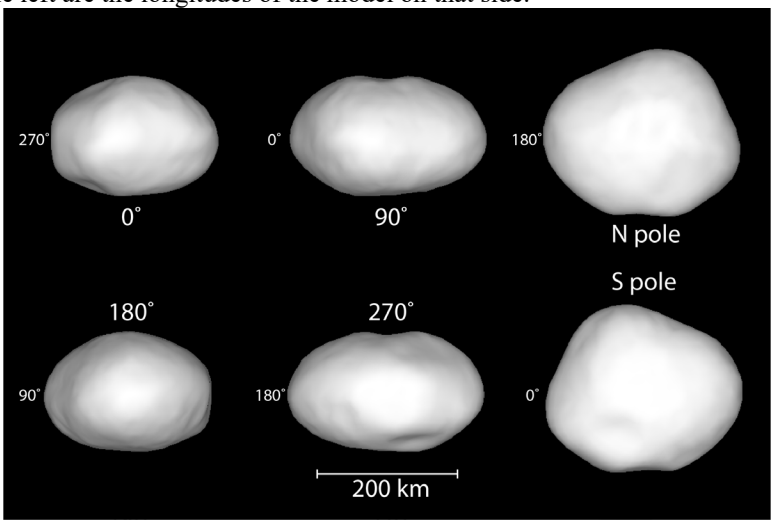

Figure 2. Global albedo map of Psyche [4,5] with Arecibo-derived radar albedos [2, new work]. Albedos are relative to the mean. Three flared white spots are areas of high optical albedo noted by [5] but not on the published map.