Mapping Thermal Emission from 16 Psyche with the Atacama Large Millimeter Array (ALMA). K. de Kleer[1], [1]Caltech (dekleer@caltech.edu)

Introduction: The accretion and evolution of planetesimals remains one of the fundamental outstanding questions in Solar System formation. Fragments of these bodies remain today in the form of asteroids, preserving a record of their thermal evolution and collisional histories. While the majority of asteroids are of primitive composition, M-type asteroids appear to be metal-rich and may be the core fragments of large planetesimals that had differentiated by the time they underwent cataclysmic collisions. As such, they present a rare opportunity to observe directly the fragments of differentiated objects, and provide constraints on the timescales for differentiation and major collisions in the early Solar System. Moreover, these objects are likely to have formed in the terrestrial region rather than the current asteroid belt, and thus represent the building blocks of the cores of our terrestrial planets [1].

M-type asteroids exhibit unusually high densities, thermal inertias, and radar albedos, indicative of dense surfaces and metallic, Fe-Ni compositions [2-4]. However, recent detections of spectral features indicative of silicates and even hydrated minerals are inconsistent with purely metallic surfaces, suggesting that these asteroids may also contain mantle material from their parent bodies, perhaps overlain by an exogenic veneer of primitive material [e.g. 5-6].

Observations: Observations at radio frequencies provide a complementary view to both radar and reflectance spectroscopy; radio telescopes are sensitive to thermal emission from the subsurface, sensing deeper at lower frequencies. The intensity of the emission provides the surface temperature, while the polarization of the emission constrains the dielectric constant of the surface, and is a strong function of surface roughness, porosity, and composition.

We observed the M-type asteroid 16 Psyche with the Atacama Large Millimeter Array (ALMA) in Chile on June 19, 2019 (UT). The observations were made at a frequency of 230 GHz (wavelength of 1.3 mm). For a target with icy or rocky regolith, data at this frequency would be sensitive to emission from the upper ~1-2 cm of the surface. The unusual properties of 16 Psyche suggest caution in applying standard rules of thumb, but regardless the depth probed is intermediate between the regions sensed by optical/infrared observations and active radar observations. Both the intensity and polarization of the emission were measured.

Individual observations were obtained every few minutes during a 2.6-hour interval, covering more than half of the target's 4.2-hour rotation period at this temporal sampling. At the time of observation, 16 Psyche was ~0.15" in angular size as viewed from Earth, and data were obtained at a spatial resolution of 0.02", corresponding to 30 km on the asteroid's surface.

The data were self-calibrated and imaged using the Common Astronomy Software Applications (CASA package).

Results: The final data product is a set of thermal emission (and polarization) images of the surface of 16 Psyche at 30 km resolution, obtained every few minutes over an interval of 2.6 hours, or more than half of the asteroid's rotation period. Figure 1 shows two examples from the full set of thermal images that will be shown in the presentation, and demonstrates the excellent spatial resolution that ALMA achieves.

The thermal emission from Psyche at 1.3 mm is found to be unpolarized, with upper limits below 1% even for the highest emission angle regions, indicating the absence of a sharp dielectric interface and/or obscuration of the polarization signature by surface texture or near-surface scattering. The implications of the surface temperature and polarization results will be discussed in the context of potential scenarios for the surface of this unusual object.

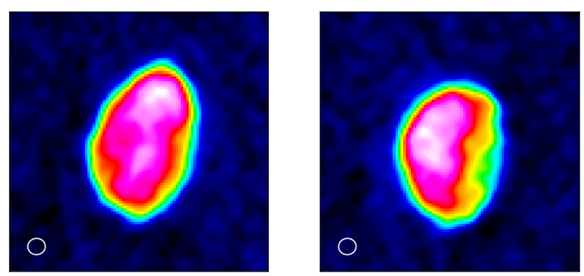

Figure 1: *Two example observations of thermal emission from 16 Psyche at 230 GHz on June 19, 2019 at different rotational phases. The circle in the lower left indicates the beam size (spatial resolution element).*

References: [1] Bottke et al. (2006). *Nature* 439, 821. [2] Shepard et al. (2015). *Icarus* 245, 38. [3] Descamps et al. (2008). *Icarus* 196, 578. [4] Matter et al. (2013). *Icarus* 226, 419. [5] Ockert-Bell (2010). *Icarus* 210, 674. [6] Rivkin et al. (2000). *Icarus* 145, 351.

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