ASTEROID 16 PSYCHE: NASA'S 14th DISCOVERY MISSION

Linda T. Elkins-Tanton[1], Principal Investigator

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When our Solar System was just an infant, thousands of small early planets formed in just a few million years (Scherstén et al. 2006). Some grew to hundreds of kilometers in diameter as they swept up pebbles, dust, and gas within the swirling solar nebula. Heat from the decay of short-lived radioactive isotope ^{26}Al was trapped and, in some cases, melted the planetesimal interiors. The molten interiors quickly differentiated: denser material settled to their centers, leaving lighter silicates to cool into thick mantles that surrounded metal cores (e.g. Weiss and Elkins-Tanton 2013).

Over the next tens of millions of years, collisions between planetesimals created planetary embryos, and finally planets. While many collisions were accretionary, some were destructive "hit and run" impacts that stripped the silicate mantle from previously differentiated bodies (Asphaug and Reufer 2014). This is the leading hypothesis for asteroid 16 Psyche's formation: it is a bare planetesimal core.

16 Psyche is a large asteroid, containing about 1% of the asteroid belt's mass. Its shape is that of a triaxial ellipsoid, with an effective diameter of ~235 km (Shepard et al. 2017). 16 Psyche is thought to be made almost entirely of Fe–Ni metal (Shepard et al. 2010; Matter et al. 2013). Some evidence for its bulk composition comes from its density: estimates of density range widely, but include 6,980 ± 580 kg m^{-3} (Kuzmanoski and Kovačević 2002), 6,490 ± 2,940 kg m^{-3} (Lupishko 2006; Baer et al. 2011), and 7,600 ± 3,000 kg m^{-3} (Shepard et al. 2008). Any density higher than 3,500 kg m^{-3} likely indicates metal (M-type asteroid): other main belt asteroids have average densities of 1,380 kg m^{-3} for C-type (carbonaceous) asteroids and 2,710 kg m^{-3} for S-type (silicaceous) asteroids, roughly one-third to one-half their parent rock density (Krasinsky et al. 2002).

Stronger evidence for its metal composition comes from its largely metal bulk composition, which was confirmed by measurements of a radar albedo of 0.42 (Shepard et al. 2010) and a thermal inertia of ~120 J m^{-2} S$^{-0.5}$ K^{-1} (Matter et al. 2013) (the rocky asteroids Ceres, Pallas, Vesta, Lutetia all have thermal inertia between 5 and 30 J m^{-2} S$^{-0.5}$ K^{-1}). While 16 Psyche's bulk appears to be metal, its surface appears to have small areas that are rocky. A 0.9 µm absorption feature suggests a few percent of its surface is high-magnesian orthopyroxene (Hardersen et al. 2005). More recent results indicate hydrous features, likely hydrated silicates from chondritic impactors (Takir et al. 2016).

Asteroid 16 Psyche is, it would seem, the only candidate for a planetesimal core in our Solar System. Other asteroids suspected to be metallic are far smaller and have degenerate shapes. We will never directly observe our Earth's core, or the cores of Mercury, Venus, the Moon, or Mars, but with 16 Psyche we have the potential to visit outer space to investigate inner space. For the first time, humans might visit—albeit robotically—a body not made of rock, or ice, or gas, but of metal. And a visit is on the cards.

In January 2017, the 16 Psyche mission was selected as the fourteenth in NASA's Discovery program. The NASA mission is led by Arizona State University (USA), with the Jet Propulsion Laboratory (California, USA) being responsible for mission management, operations, and navigation. The mission will take advantage of the flexibility of solar-electric propulsion to travel most efficiently to 16 Psyche and deliver the spacecraft to the four science orbits. The solar-electric propulsion chassis will be built by Space Systems Loral in Palo Alto (California) (Oh et al. 2016), with some additional subsystems contributed by the Jet Propulsion Laboratory.

This mission will orbit asteroid 16 Psyche to fulfill the following objectives:

- Determine whether 16 Psyche is a core or if it is unmelted material.
- Determine the relative ages of regions of its surface.
- Determine whether small metal bodies incorporate the same light elements as are expected in Earth's high-pressure core.
- Determine whether 16 Psyche was formed under conditions more oxidizing or more reducing than Earth's core.
- Characterize 16 Psyche's topography and its impact crater morphology.

We will meet these objectives with three scientific instruments plus radio science:

1. Two block-redundant multispectral imagers with a clear filter and seven color filters will provide surface geology, composition, and topographic information.
2. A gamma-ray and neutron spectrometer will determine the elemental composition for key elements (Fe, Ni, Si, and K), as well as compositional heterogeneity across 16 Psyche's surface.
3. Dual fluxgate magnetometers in a gradiometer configuration will characterize the magnetic field.
4. Radio science will map 16 Psyche's gravity field using the X-band (microwave) system.

The mission is scheduled to launch in 2022, to rendezvous with 16 Psyche in 2026, and to orbit the body for 21 months. During the intervening years, the whole asteroid-research community has a new incentive to investigate topics we have largely overlooked: craters in metal, the likely topography of a metal asteroid, and the possibility of a metal asteroid having a magnetic field. There are also plans for years of student collaborations along the way, including art, writing, composing, primary and secondary education outreach (K-12 in the USA), and interdisciplinary capstone projects (a capstone project being a two-semester research project performed by a final-year school or university student).

Please visit the 16 Psyche website (https://sese.asu.edu/research/psyche) at Arizona State University for more information!

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1 Director, School of Earth and Space Exploration
Arizona State University
Tempe, AZ, USA
E-mail: ltelkins@asu.edu