SOLAR WIND PLASMA INTERACTION WITH ASTEROID 16 PSYCHE: PREDICTIONS FOR OBSERVATIONS BY THE *PSYCHE* MISSION. S. Fatemi[1] and A. R. Poppe[2], [1]Swedish Institute of Space Physics, Rymdcampus 1, 98128 Kiruna, Sweden, e-mail: shahab@irf.se, [2]Space Sciences Laboratory, University of California at Berkeley, Berkeley, CA, USA.

Introduction: Among the diverse populations of asteroids, 16 Psyche is a primitive metal-rich (M-type) asteroid that has not yet been visited by spacecraft. Its high albedo of 0.37-0.42 [e.g., 1,2], large density of 7600±3000 kg/m^3 [e.g., 1,2] and high thermal inertia of ~120 Jm^{-2}S$^{-0.5}$K^{-1} [e.g., 3] estimated by radio telescope observations have indicated that Psyche mainly consists of iron and nickel metal. Psyche may also have significant macro-porosity, with estimates ranging from ~30% to ~70% [e.g., 4]. However, the history of its formation and solidification is still unknown.

Generally, the two most probable scenarios for its formation and structure are (1) that Psyche is a remnant core of an ancient differentiated planetesimal exposed by hit-and-run collisions [e.g., 5, 6, 7], or (2) Psyche is not a planetary core, but is instead a re-accreted rubble pile of remnants from one or more of the collisions that impacted the parent planetesimal [e.g., 4, 8].

According to the former scenario, Psyche was initially molten or melted later by repeated impacts, and thus may possess remnant magnetic fields associated with a core dynamo [7]. On the contrary, the latter scenario suggests that Psyche has never melted, and thus, no dynamo formed [7]. Psyche's intrinsic magnetization properties, including the presence of any remanent fields, are currently unknown, yet will be explored in depth upon the arrival of NASA's Discovery mission, *Psyche* [6].

Similar to other terrestrial objects, the supersonic flow of the solar wind plasma and interplanetary magnetic fields (IMF) are continuously interacting with Psyche. However, this interaction with an object of Psyche's size (mean radius is ~120 km) that is highly conductive and perhaps magnetized defines a unique class of interaction, different from other previously studied terrestrial objects [9].

Psyche's electromagnetic environment provides distinctive information with respect to its magnetic properties, which in turn constrains various theories regarding its formation and evolution [9]. Therefore, studying the solar wind plasma interaction with Psyche to examine the possible magnetic signatures to be observed by NASA's *Psyche* mission will open new frontiers into Psyche's formation and solidification.

Model: We use the AMITIS simulation code, the first parallel GPU-based three-dimensional hybrid plasma (kinetic ions and fluid electrons) model that uses a single CPU-GPU (Graphical Processing Unit) pair [10]. We use typical solar wind parameters near the orbit of Psyche where plasma density is 2 cm^{-3}, solar wind speed is 400 km/s, solar wind temperature is ~8 eV, and the interplanetary magnetic field (IMF) is 2 nT and is perpendicular to the solar wind flow. For simplicity, we assume Psyche is a spherical object with R_Ψ=120 km in radius [9].

We examine the effects of the solar wind plasma interaction with Psyche for the two aforementioned scenarios for Psyche's formation. To assess the first scenario (i.e., remnant core), we assume Psyche is magnetized object with surface magnetic field of ~150 nT. For the second scenario (i.e. conductive rubble pile) we assume Psyche is not magnetized but instead is a highly conductive object with uniform electrical conductivity of 10 S/m [9].

Results: Figure 1 shows the hybrid simulation results for a magnetized Psyche. The solar wind proton gyroradius is nearly 15 times larger than the radius of Psyche, and is comparable to the size of Psyche's magnetosphere in this simulation run, indicating the necessity of using a kinetic plasma simulation to study the interaction for the spatial scales introduced in this run. In general, a magnetospheric-like structure forms around Psyche, where we see the magnetopause and extended magnetotail; however, we do not observe any clear evidence of a bow shock upstream. More details of this simulation, not shown here, including plasma density, signature of quasi-trapped particles, and a ring-like current on the equatorial plane of Psyche are observed in this simulation and shown in details by Fatemi and Poppe (2018) [9].

Figure 2 shows the hybrid simulation results assuming Psyche has no intrinsic magnetic dipole, but is instead a conductive obstacle to the solar wind plasma. In this simulation, we kept all the solar wind parameters and the IMF orientation and strength constant in time at the upstream inflow boundary of our simulation box. The convective electric field of the solar wind, $\mathbf{E}=-\mathbf{v}\times\mathbf{B}$, generates an electric current inside Psyche. This electric current, which is known as the toroidal current, acts as a unipolar generator (i.e., a Faraday disc) and induces a toroidal magnetic field in the conductive body of Psyche [e.g., 9, 11]. Since the direction of this current inside Psyche is parallel to the electric field (along the -y axis in this simulation), the induced magnetic field is parallel (anti-parallel) to the direction of the IMF upstream (downstream) of Psyche and increases (decreases) magnetic field intensity there, as shown in Figure 2.

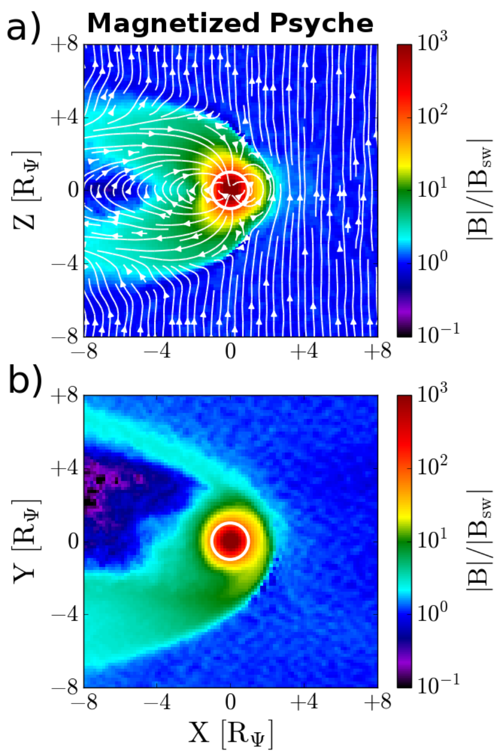

Figure 1. Hybrid simulation results for a magnetized Psyche taken from [9] showing the magnitude of the magnetic field normalized to the undisturbed upstream magnetic field Bsw=2 nT. (a) a cut in the xz plane at y=0, and (b) a cut in the xy plane at z=0. The solar wind flows along the -x axis, the IMF is along the +z axis, and the dipole moment of Psyche is along the -z axis. Streamlines in panel a show the magnetic field line tracing in the xz plane. Psyche is the white circle at the center of the coordinate system.

Discussion: Primitive bodies such as asteroids witness the various processes that have occurred during the solar system formation era. The interior properties of these bodies reflect their formation and subsequent evolution, yet much is still poorly understood, mainly due to the paucity of direct (in-situ) observations of these objects. Using a GPU-based hybrid model of plasma, the AMITIS code, we have examined the solar wind plasma interaction of the M-type (metallic) asteroid 16 Psyche assuming two different magnetization scenarios, both of which are associated with distinct hypotheses for Psyche's formation [9].

Conclusion: These results have important implications for the interpretation of magnetometer observations to be taken by the upcoming *Psyche* mission and any other future missions to metallic asteroids. If the magnetometer on-board the *Psyche* mission observes a large coherent dipolar magnetic field around Psyche, the structure of Psyche's magnetosphere may be similar to that presented in Figure 1. In contrast, if the magnetometer does not observe a dipolar magnetic field structure, the metallic and conductive body of Psyche should generate induced magnetic fields that perturb the magnetic field and plasma around Psyche, similar to the simulations presented in Figure 2 [9].

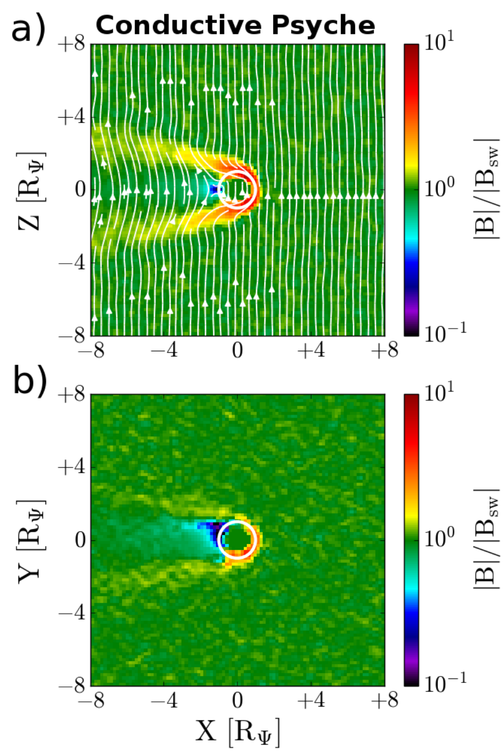

Figure 2. Hybrid simulation results for a non-magnetized but conductive Psyche taken from [9]. The description of each panel and geometry of the cuts are the same as those in Figure 1.

References:

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