DETECTABILITY OF CRUSTAL REMANENT MAGNETISM ON VENUS FROM ORBITAL MAGNETOMETER MEASUREMENTS. J. G. O'Rourke[1] and C. Dong[2], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ (jgorourk@asu.edu), [2]Department of Astrophysical Sciences and Princeton Plasma Physics Laboratory, Princeton University, Princeton, NJ (dcfy@princeton.edu).

Introduction: Venus lacks a strong internally generated magnetic field today. Pioneer Venus Orbiter established ~10^{-5} times the total magnetic moment of Earth as the upper limit for Venus [1], which is consistent with magnetic measurements from Mariner 2 and 10, Venera 9–12, and Venus Express [2]. One lander (Venera 4) measured magnetic fields down to 25 km altitude above Eistla Regio but failed to detect any intrinsic field or crustal remanence [3]. However, whether a strong global field existed prior to the first flyby of Venus by Mariner 2 in 1962 is unknown. Any evidence for early intrinsic magnetism would provide vital constraints on the evolution of Venus.

Broadly speaking, there are two reasons why Venus may fail to sustain a long-lived dynamo like Earth. First, accretionary processes may naturally produce chemical gradients in planetary cores that inhibit convection and thus a dynamo. The giant, Moon-forming impact may have mechanically mixed Earth's core. If Venus did not suffer late energetic impacts during accretion, then its core may retain primordial stratification and never host a dynamo [4]. Second, Venus could have an "Earth-like" core (i.e., at least partially liquid and chemically homogeneous) that is cooling too slowly at present for vigorous convection. In most models, the mantle of Venus cools slowly in the absence of plate tectonics and thermally insulates the core. Cooling rates were probably faster in the past when the core was hotter. Critically, simulations suggest that Venus may have hosted a dynamo and a strong global magnetic field until recent times within the surface age [5].

Many studies have assumed that knowing whether Venus had a dynamo in the past is practically impossible [2]. Thermoremanent magnetization in rocks is less stable at higher temperatures, and the surface of Venus is famously hot. However, its average temperature now (~737 K) is still >100–200 K below the Curie points of common magnetic carriers such as magnetite and hematite. Plausible depths to the Curie temperature of magnetite are >5–10 km and perhaps >20 km at regions with low heat flow. As long as the surface was not much hotter in the past, Venusian rocks could retain remanent magnetism for billions of years if their magnetic mineralogy is similar to terrestrial basalts [6].

Exploration Objectives: This new step in an ongoing series of investigations has two objectives: (1) Determine the distribution and intensity of crustal magnetism that could have escaped detection by Pioneer Venus Orbiter and Venus Express, which reached periapsis within ±50º latitude of the equator and ±40º latitude of the North Pole, respectively, and (2) Derive realistic measurement requirements and detection thresholds for future orbiters that may perform aerobraking over the South Pole, which is unexplored.

Computational Methods: We use the BATS-R-US Venus multi-species magnetohydrodynamic (MS-MHD) model. The model solves a separate continuity equation for each ion species, whilst also solving one momentum and one energy equation for the four ion fluids: H^+, O^+, O_2^+, and CO_2^+. In contrast to most Earth global magnetosphere models that start from 2 to 3 Earth radii, the Venus MS-MHD model contains a self-consistent ionosphere. The MS-MHD model includes many of the detailed ionospheric chemical processes such as charge exchange, photoionization and electron impact ionization. In this study, we extend the model lower boundary into the planetary interior by including an electrically conductive core and a resistive mantle; therefore, the newly developed Conducting-Core-Surface-to-Interplanetary-Space MS-MHD (CCSIS-MS-MHD) model solves the planetary interior, planetary ionosphere, and solar wind-Venus interaction in a self-consistent way [7].

Possible Magnetization Distributions: Regions of magnetized crust are implemented as circular patches with a constant magnetization intensity down to a uniform depth. Python routines in SHTools are used to transform the crustal magnetization into a spherical harmonic (SH) basis [8]. Finally, the SH coefficients of the crustal magnetization are transformed into the SH coefficients for the lithospheric magnetic field [9], which is a boundary condition for the MS-MHD model. Given the wide range observed in terrestrial rocks, magnetization intensities on Venus are a priori uncertain within a few orders of magnitude [6]. Strong crustal fields may await detection near the South Pole, and weak magnetization could still exist at most locations.

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