Magnetic Topology at Venus: New Insights into the Venus Plasma Environment

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I: Abstract
This study provides the first characterization of magnetic topology (i.e., the magnetic connectivity to the collisional ionosphere) at Venus, which might give new insights into the Venustian space environment on topics such as the penetration of the interplanetary magnetic field (IMF) into the ionosphere, planetary ion outflow and inflow, and auroral emission. Magnetic topology is inferred from the electron and magnetic field measurements from Venus Express (VEX). We demonstrate through a few case studies that various types of magnetic topologies exist at Venus, including typical draped IMF, open magnetic fields connected to the nightside atmosphere or the dayside ionosphere, and unexpected cross-terminator closed field lines. We also provide a detailed characterization of an ionospheric hole event, where we find an open topology and a field-aligned potential of ~[−10, −20] V with respect to the collisional ionosphere, which has important implications for its formation mechanism. This study enhances our current understanding of Venus’ magnetic configuration and lays the groundwork for a new powerful tool to help understand various topics of the near-Venus space environment. (Geophysical Research Letters, 46, e2021GL095545)

II: Methodology and Motivation

- WHAT is magnetic topology
- WHY we study magnetic topology?
  - Why 1: To understand various important topics, most of which applicable for Venus
  - Why 2: Characterization of magnetic topology at Venus, new insights into the Venus space environment
- HOW to determine magnetic topology:
  - Electron pitch angle distribution (PAD): one-sided acoustic wave, open topology
  - Electron energy spectra for field-aligned directions: one direction, open topology
  - Solar wind electrons in both directions, no loss cone, draped topology

III: Magnetic Topology at Venus: Draped and Open-to-Night

- Draped: isotropic PAD, no loss cone
- Open-to-night: one-sided loss cone (nightside connectivity)

IV: Magnetic Topology at Venus: Open-to-Day and X-Term. Closed

- T1: Open-to-day (dayside connectivity)
- T2: Cross-terminator closed loop

V: Ionospheric Hole and Parallel E Field

- A hole structure identified by Collinson et al. (JGRA, 2014)
- Loss cone in anti/− (A4 & A5)
- Open magnetic topology (nightside connectivity)
- Energy-dependent loss cone size (B1 & B2)
- Loss cone fitting following Halekas et al. (JGRA, 2008)
- Best fit: Usc ~ 7 V & Uv ~ −5 V
- Usc = −10, Uv = −20, −10 V

VI: Discussion and Summary

- Key points
  - Various magnetic topologies inferred at Venus, including unexpected cross-terminator closed loops
  - Ionospheric hole formation: open topology and radial inward parallel E field
- Connectivity below the collisional atmosphere (e− exobase): 1. IMF penetrating deeply into the ionosphere
  2. Crustal magnetism (albeit weak)
  3. Or, even the conductive metallic core

VII: Broad Impact

- Magnetic topology can be a new powerful tool to help better understand the near-Venus space environment
- Raise interesting questions related to important Venus science questions
  - History and current nature of its magnetism
  - How possible coupling from the ionosphere to the interior as a whole might affect its interaction with the solar wind, and/or the history/evolution of its atmosphere
- Motivate future Venus orbiters coupled with sub-exobase magnetometer observations (on balloons or even on the surface)
- Enable Venus-Mars comparative study of their magnetic environments

VIII: Future Work

- Systematically catalog all types of magnetic topology at Venus with all VEX data
- Statistically analyze and map each type of topology and investigate its variation in response to solar drivers
- Search for more ionospheric hole events and field-aligned potential events and see if a robust relation exists

References:

*For more information, please refer to the original research. This summary is intended for educational purposes.*