PROBING MARS' CRUSTAL MAGNETIC FIELD AND IONOSPHERE WITH THE MGS ELECTRON REFLECTOMETER.

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Introduction: Mars lacks a global magnetic field. Consequently, the solar wind, a plasma flowing away from the Sun at ~400 km/s, is able to impinge directly on Mars' atmosphere/ionosphere. The Electron Reflectometer (ER) onboard Mars Global Surveyor (MGS) detected a boundary between the ionosphere and the solar wind as the latter is diverted around and past the planet [1]. Above this boundary the electron population from 10 eV to 1 keV is dominated by solar wind electrons, while below the boundary it is dominated by ionospheric photoelectrons. Here, we refer to this as the "photoelectron boundary", or PEB.

During aerobraking, periapsis was low enough that the spacecraft crossed the PEB on every orbit, at altitudes ranging from 180 km to over 800 km, with a median of 380 km [2]. The 400-km-altitude polar mapping orbit is close to the median PEB altitude measured during aerobraking. Consequently, the spacecraft makes numerous PEB crossings as the boundary moves up and down in response to changes in the solar wind and solar EUV flux.

The Electron Reflectometer has obtained more than 3 million electron energy spectra during the first Martian year of the mapping phase. We have classified all spectra as either ionospheric photoelectrons or solar wind electrons and calculated a multi-dimensional function that describes the probability that the PEB is above the spacecraft for a given combination of longitude, latitude, altitude, solar zenith angle, EUV flux, and solar wind dynamic pressure. This function is used to conduct a statistical analysis of the ionospheric morphology and its response to crustal magnetic fields and solar activity.

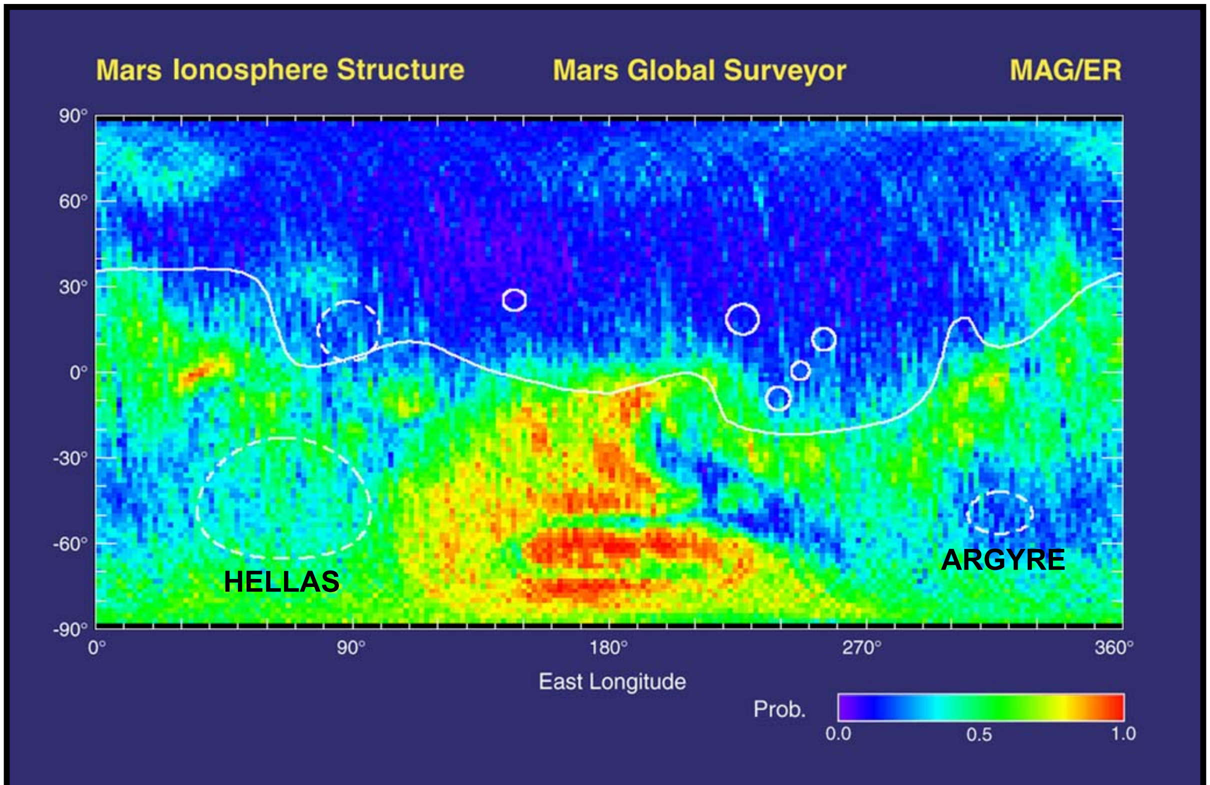

Figure 1: Probability that the photoelectron boundary extends to an altitude of 400 km or higher at a local solar time of 2 pm. The long snaking curve is the dichotomy boundary. Solid and dashed circles mark the locations of selected volcanoes and impact basins, respectively.

Ionosphere Morphology Near Strong Fields: Crustal magnetic fields strongly influence the probability that the PEB will occur at altitudes of 400 km or higher (**Fig. 1**). This probability is about 10% in weak-field regions of the northern hemisphere, but it is over 90% in strong-field regions of the southern hemisphere. The probability map bears a striking resemblance to a map of the crustal magnetic fields [3], which are strong enough to locally stand off the solar wind to altitudes well above the spacecraft. The region of highest probability (> 0.75) is shaped like a flattened letter "G". Local minima inside the "G" are aligned with regions of strong vertically oriented field suggesting the presence of cusp-like magnetic regions that are connected to the solar wind, providing a conduit for solar wind plasma to reach low altitudes. Taken together, maps of the probability and crustal magnetic field constrain the topology of the crustal field lines.

A region of moderate probability (30–50%) occurs over the relatively weak north polar anomalies (20° W to 45° E, and >60° N), which have strengths of only a few nT at 400 km altitude [3, 4]. Evidently, even weak crustal fields such as these are able to positively bias the PEB altitude directly above them. Several regions of moderate probability hint at the presence of weak crustal fields at other locations. Not all of these regions have corresponding features in maps of the radial magnetic field component [3, 4], most notably over the Hellas basin (66° E, 44° S), which is thought to have been demagnetized by the Hellas impact [3]. The probability enhancement over Hellas cannot result from sampling bias, since ER measurements were obtained over Hellas and Argyre at similar altitudes, solar zenith angles, and ranges of solar activity, yet the probability is significantly different over these two basins. Magnetic fields as weak as a few nT at 400 km could account for the PEB signature over Hellas, which is just below the detection threshold of the MGS Magnetometer.

Ionosphere Morphology Near Weak Fields: If we consider only regions where the crustal field is likely to be very weak (purples and blues in **Fig. 1**), then we can use the probability function in those regions to investigate the shape the PEB away from the influence of crustal magnetism. In such regions, the probability increases from 5 to 35% as the solar zenith angle (SZA) increases from 30 to 90°, indicating an overall flaring of the PEB. Such a flaring was observed by Pioneer Venus Orbiter at Venus during solar maximum conditions. Beyond 90° SZA the probability drops sharply, but with a finite value (<3%) beyond 116° SZA, where the spacecraft is in the planet's optical shadow. This indicates transport of ionospheric plasma from day to night and/or an ionization source other than solar EUV, such as micrometeorites or energetic particles.

Response of the Ionosphere to Solar Activity: The probability in weak-field regions also responds to variations in the solar EUV flux, increasing from 2 to 38% as the F10.7 flux increases from 35 to 95 solar flux units (**Fig. 2**). This implies an overall expansion and contraction of the ionosphere in response to solar activity. There is no such EUV response in strong-field regions, where the probability remains nearly constant (~70%) for F10.7 fluxes from 40 to 95 solar flux units.

Since we cannot measure the solar wind dynamic pressure (ρv^2, where ρ and v are the mass density and velocity of the solar wind), we use the magnetic pressure ($B^2/8\pi$) associated with the solar wind magnetic field (away from crustal sources) under the assumption that the dynamic pressure well upstream of Mars is converted predominantly into magnetic pressure very close to the planet. In weak-field regions, the probability function decreases from 45 to 5% as the magnetic pressure increases from 0.1 to 1 nPa, suggesting that an increasing solar wind dynamic pressure pushes the PEB to lower altitudes. There is a similar but much weaker trend in strong-field regions, suggesting a compressibility of the crustal magnetic fields.

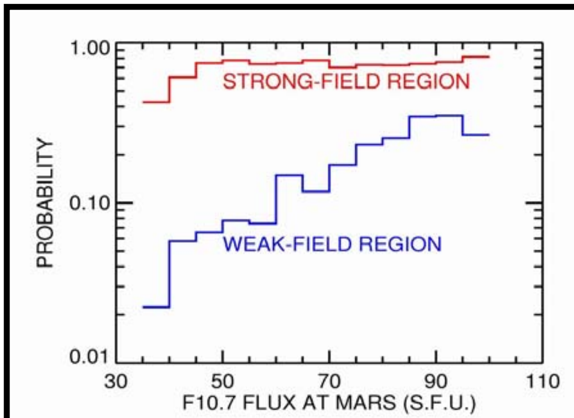

Figure 2: Probability that the ionosphere extends to an altitude of 400 km or higher as a function of the F10.7 radio flux at Mars.

References: [1] Mitchell D. L. et al. (2000), *GRL, 27*, 1871. [2] Mitchell D. L. et al. (2001), *JGR, 106*, 23419. [3] Acuña M. H. et al. (1999) *Science, 284*, 790. [4] Acuña M. H. et al. (2001), *JGR, 106*.