**DEPTH OF MARTIAN MAGNETISM FROM LOCALIZED POWER SPECTRUM ANALYSIS.**

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**Introduction:** Mars today does not have a global magnetic field generated by a core dynamo. Orbital magnetic measurements do, however, show that portions of its crust are strongly magnetized, and the surface intensity of this crustal magnetic field is 1 or 2 orders of magnitude higher than that of other terrestrial bodies (including the Earth) [1]. Paleomagnetic analysis of Martian meteorite AL84001 also suggests that a dynamo might have operated on Mars at approximately 4 Ga [2].

The origin of the strong magnetic anomalies on Mars remains enigmatic. It is unclear whether these anomalies were formed at the same time as the primordial crust, or if they are a result of more recent geologic processes related to impact cratering or magmatic processes [3-5]. One key piece of information that would allow to discriminate between different formation mechanisms is the depth of the magnetic sources. The power spectrum of the magnetic field contains information about the geometry and depth of the sources, and here we will use a localized power spectrum analysis to investigate the origin of the magnetic sources.

**Theoretical magnetization model:** The power spectrum of a planet's crustal magnetic field depends on the geometry, magnetic moment, and the depth of the magnetic sources. This problem was studied previously for Mars and the Moon by confining the magnetization to either a series of randomly placed dipoles, prisms, or spherical caps [6-8].

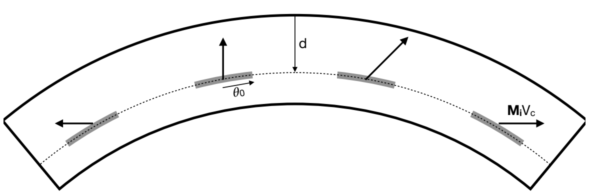


**Figure 1**. The stochastic model of crustal magnetization used in this study. The magnetization is confined to a series of thin spherical caps, and each possesses the same volume $V_c$, angular radius $\theta_0$, and depth d. The magnetization vectors $\mathbf{M_i}$ and the locations of the caps are both random.

In this study we use a simplified model where the magnetization is present as thin spherical caps at a single depth. This model improves upon the recent study of [7], who assumed that the magnetic sources were point dipoles. As shown in Figure 1, each spherical cap possesses the same volume $V_c$ and the same depth d below the surface. The magnetization vector of each cap is random, as is its position. The parameters of this model include the angular radius ($\theta_0$) and the depth of the caps (d), and a metric that quantifies the average magnetization ($\sqrt{n}MV$, where n is the total number of caps). We note that the power spectrum for unidirectionally magnetized caps is nearly the same as that for random magnetization directions [8].

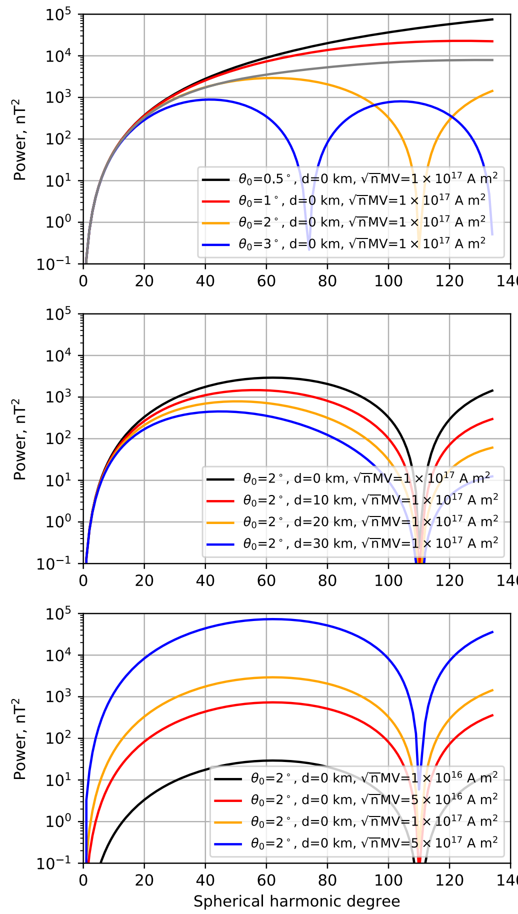


**Figure 2**. Example theoretical magnetic field power spectra. From top to bottom, the figures show the dependencies of the power spectrum on the angular radius of the caps, the depth of magnetization, and a parameter related to the total magnetic moment of the magnetized caps.

Figure 2 shows the dependency of the theoretical power spectra on the angular radius of the magnetized caps (upper), the depth of the magnetization (middle), and a metric that is related to the average magnetization (bottom). We note that the shape of the theoretical power spectra depends mainly on the angular radius of the spherical caps, and the amplitude of the spectra depends primarily on the parameter $\sqrt{n}MV$. When fixing the other two parameters, the depth of magnetization determines how quickly the spectrum decreases with increasing spherical harmonic degree.

**Localized Power Spectrum Analysis:** Given that the depth and the strength of magnetization of the sources within the crust will vary laterally, we employ the localized power spectrum analysis technique as developed by [9]. For each location, we first computed the localized power spectrum of the observed magnetic field. Next, we calculated the expectation of the localized theoretical model, and then calculated the misfit between the model and observations. The best-fitting parameters were determined by using a grid search in the parameter space along with a Monte Carlo technique to compute the uncertainties of each parameter.

**Results:** We use the magnetic field model of [10] that is derived from both MGS and MAVEN observations and expressed in spherical harmonics up to degree and order 134. We performed the localized spectral analysis and inversion for the model parameters on an equally spaced grid that covered the surface with a grid spacing of ~1200 km (20° at the equator).

Windows were used that were localized within an angular radius of 20° with a spectral bandwidth of 23. For these parameters, there are eight orthogonal windows that are well-localized. Given the bandwidth of the window and maximum degree of the magnetic field model, we interpret the localized spectrum from degree 23 to 111.

Preliminary results of our inversions are plotted in Figure 3 (centered over 180° E). As shown in the upper panel, the best-fitting angular radius of the magnetized caps for most of the regions is nearly 2° (~120 km), and smaller sizes were obtained only near the south pole. The middle panel shows the best-fitting depth of magnetization, which is referenced to the actual surface of Mars. In general, the magnetic sources are mostly located close to the surface, with depths less than 20 km. Some best-fitting depths lie above the surface (plotted as negative values), but these are all consistent with being located at the surface given the inversion uncertainties. Portions of the area in the southern hemisphere are found to possess depths of magnetization that are ~50 km, including regions near the south pole and northeast of Hellas Planitia. Regardless, these depths are all consistent with residing within the crust of Mars based on the crustal thickness model of [11].

**Conclusion:** A localized spectral analysis was used to constrain the depth of magnetization on Mars. Our preliminary results show that the northern hemisphere possesses magnetization depths that are close to the surface and that the magnetization depths in the southern hemisphere are deeper, with an average value of 7 km. All of the magnetization depths are located within the crust. The deepest magnetization depth is 76 km (northeast of Hellas Planitia), which might provide a constraint on the maximum depth of the crust in this region.

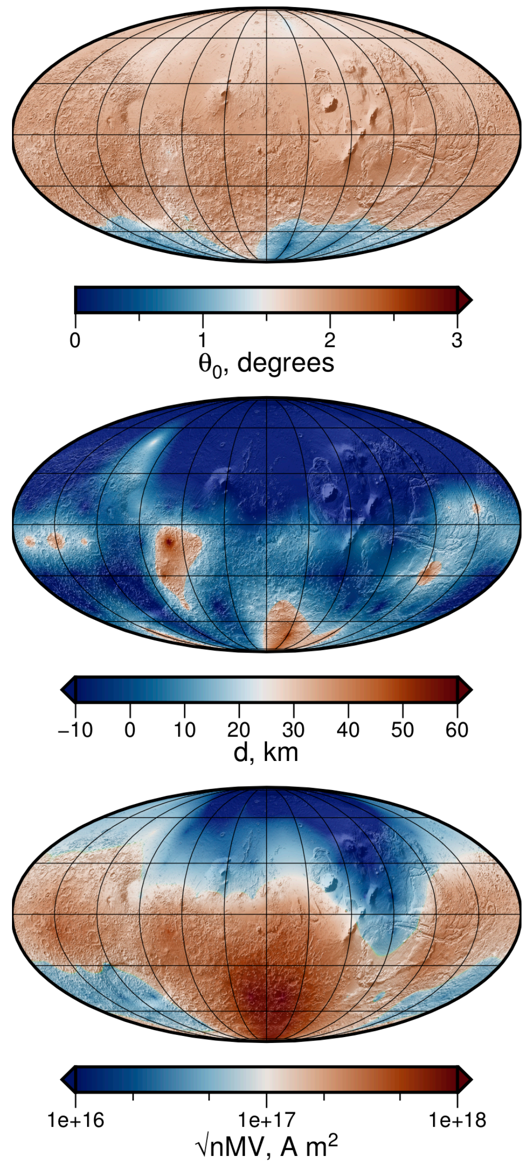


**Figure 3.** Inversion results. From top to bottom are the angular radius of the caps, the depth of magnetization, and a parameter that quantifies the average magnetization. Data are presented in Mollweide projections centered on the 180° meridian. Grid lines are spaced every 30° in both latitude and longitude.

**References:**

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