A NEW MAP OF THE INTERNAL MAGNETIC FIELD OF THE MOON AND ITS IMPLICATIONS.

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Introduction: An improved model of the internal magnetic field of the Moon is developed with an approach that coestimates internal and external fields, and also takes advantage of the orbit geometry of Lunar Prospector to extract the common signal from immediately adjacent passes. Internal and external magnetic fields characteristic of the longest wavelengths, corresponding to harmonic degres 1-3, are poorly separated and hence have been removed from the final model of the internal magnetic field. The new model, robust to at least spherical harmonic degree 170, is an improvement on our previous model [1] because of the replacement of a serial approach to signal extraction with a coestimation approach where we can properly assess the degree to which the internal and external signals can be separated.

Data: A global mapping of the lunar magnetic field was performed by the Lunar Prospector mission using both magnetometer and electron reflectometer instruments [2]. Data from the low-altitude phase of the mission (19 Dec 1998 to 29 Jul 1999) was used in the new map, and the altitude of the data ranges from 11 to 66 km, with a median altitude of 30 km. The magnetometer is a low-noise (6 pT RMS) boom-mounted fluxgate magnetometer. Calibrated, spin-averaged observations are available at 5 s intervals. The inherent accuracy of the resulting magnetic field measurements will be highest in the spin plane, and will be significantly better than can be achieved with three-axis stabilized spacecraft utilizing similar instrumentation.

Internal and external magnetic field model: The new model utilizes three adjacent passes covering a satellite half-orbit, and extending from pole to pole. These adjacent passes are separted by about 1 degree of longitude (30 km) at the equator. Because the distance between the adjacent orbits is approximately equal to the distance above the surface, the magnetic field measurements are sensitive to common internal sources. Because the adjacent orbits are separated in time by about 1.9 h, the resulting solution is characteristic of a particular lunar regime or regimes (wake, solar wind, magnetotail, or magnetosheath).

Using the radial and theta components of the vector magnetic field, the external field is modeled as a uniform field over each satellite half-orbit, whereas the internal field is modeled as a harmonic of degree 180. Although the external fields determined by this coestimation process are in good agreement with the T96 model of the Earth's magnetosphere [3], the first few degrees of the internal field are highly correlated with the external field. As a consequence we have removed internal harmonic degrees 1-3 from each of the solutions before proceeding to the integration of the models into a Moon-wide model.

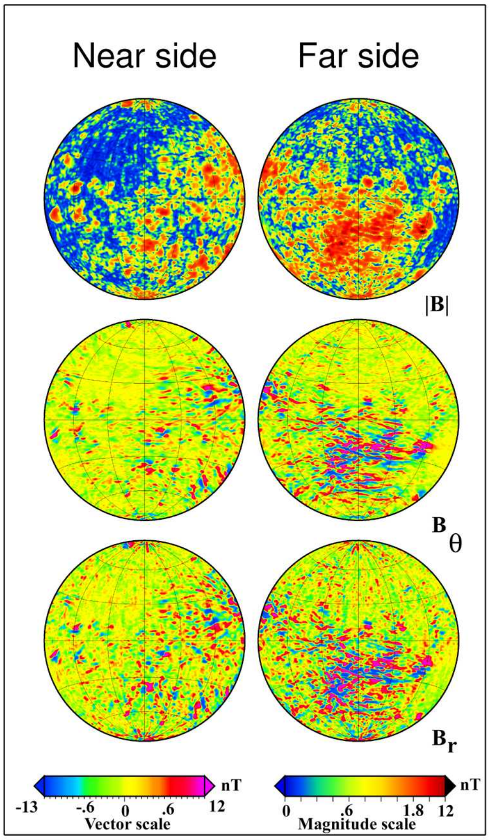

Figure 1: Global spherical harmonic model to degree 170 of the lunar magnetic field at an altitude of 30 km above the lunar mean radius. From top to bottom: Scalar magnitude, theta component, and radial component fields. Near side maps are shown on the left, far side on the right. Lambert equal area projections.

In this final integration, the radial magnetic field solutions from wake and tail times were assembled into one degree in longitude by one-half degree in latitude bins, and a median value was determined for each bin. These median values cover more than 99% of the Moon, and the only holes are in the vicinity of the poles. These holes were filled by interpolation, using an adjustable tension spline (t=0.25). This set of radial field values was then utilized to construct a spherical harmonic potential to degree and order 178 via the Driscoll and Healy sampling theorem [4]. The radial, theta and scalar components calculated from this model are shown in Figure 1. From the spherical harmonic model, the Lowes-Mauersberger power spectra [5] is calculated and shown (Figure 2), and compared with recent determinations of the power spectra of the Earth [6,7].

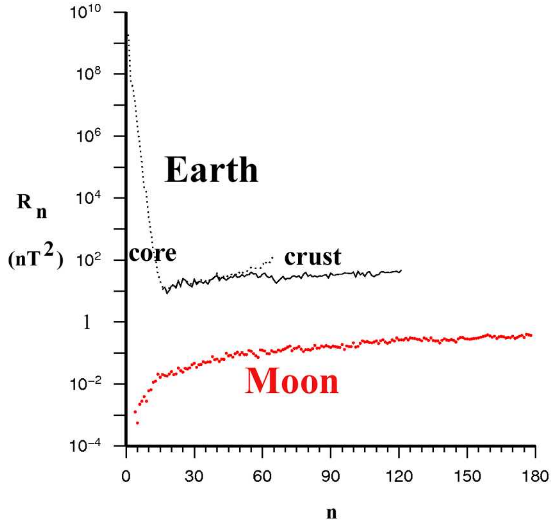

Figure 2: Lowes-Mauersberger power spectra at the Moon's surface, compared with recent determinations of the power spectra of the magnetic field of the Earth [6,7]. Rn is the mean square amplitude of the magnetic field produced by harmonics of degree n

Comparison with previous models*:* Recent maps of the crustal magnetic field of the Moon are available from both the electron reflectometer [8] and the magnetometer [1]. The new map exhibits a correlation coefficient in excess of 0.9 with our previous map [1], and a correlation of 0.6 with the electron reflectometer (ER) map [8]. We do not expect the ER and magnetic field maps to correspond exactly, since the ER map should have more sensitivity to localized incoherent magnetization at the surface, while the magnetometer map should have more sensitivity to more coherent and/or deep-seated magnetizations.

Error Analysis: The new power spectra does not exhibit any marked increase in power at a particular degree. An example of such an increase can be seen in one of the terrestrial power spectra [6] at about degree 60 in Fig. 2. Such an increase usually marks the onset of siginificant noise in the solution. The previous solution [1] was truncated to spherical harmonic degree 150 on the basis of a gradual increase in power beginning at that degree. On the basis of the lack of such an increase we think that the new solution is good to at least spherical harmonic degree 170, and Figure 1 shows the solution to that degree.

Conclusions: The power spectrum of the new model contains a change in slope at about spherical harmonic degree 13-16. The power spectrum of the earth's magnetic field contains a change in slope at the same degree [6], associated with the change from crust to core magnetic field domination. This slope change can be seen in Figure 2. If the moon once had a core field, and it was removed, some signature of it may still be retained in the low-degree magnetic power spectrum. This presentation will explore some of the ways in which this signature may be manifest, and compare those predicted signatures with the observed change in slope of the new lunar power spectrum.

References: [1] Purucker M. E.(2008) *Icarus, 197,* 19-23. [2] Binder A.B. (1998) *Science,* 281, 1475-1476. [3] Tsyganenko, N.A. (1996) *ESA Spec Pub.* 181-185. [4] Driscoll J. R. and Healy D. M. (1994) *Adv Appl. Math.* 15 202-250. [5] Lowes F.J. (1966) J. *Geophys Res*. 71, 2179. [6] Sabaka T.J. et al. (2004) G*eophys. J. Int., 159,* 521-574. [7] Maus, S.J. et al. (2007) *Geochem.Geophys.Geosyst.*, 10, Q08005 . [8] Mitchell D.L. Et al., (2008) *Icarus*, 194, 401-409.

Additional Information: The spherical harmonic coefficients and grids of the model reported here are available at http://core2.gsfc.nasa.gov/research/purucker/moon09