Solar Polar Magnetic Field Observed by HMI Near Polarity Reversal

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North, Almost. South? Not Yet.

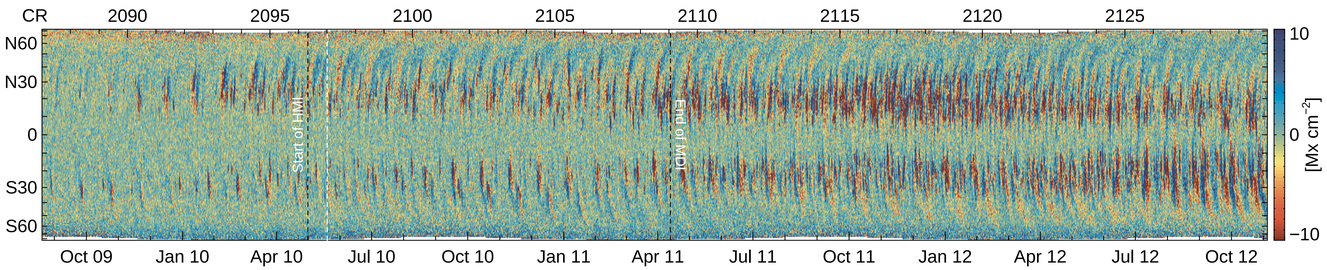


Fig 1 | "Super" synoptic map. Each column of data represents the radial field (converted from longitudinal field) measured near the central meridian passage by MDI and HMI. Active region belts and decaying flux moving towards the pole are clearly visible.

- Flux of new cycle started to move toward north pole from 2009, weakening the polar field (Fig. 1 and 2).
- Activities in the south lagged by over half a year, so did the "magnetic surges" to the pole (Fig. 2).
- Zonal average shows that for north the polarity has reversed up to ~70 degree by Oct 2012. For south its ~60 degree (Fig 3).

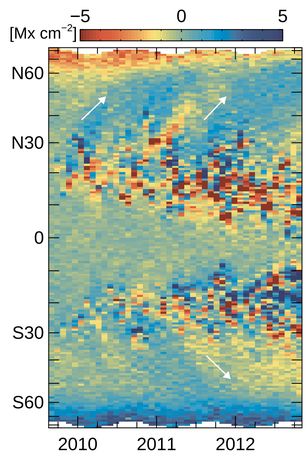
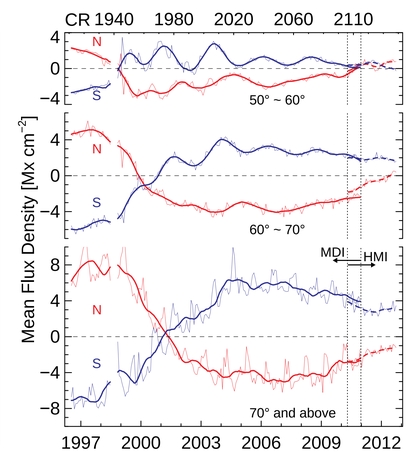


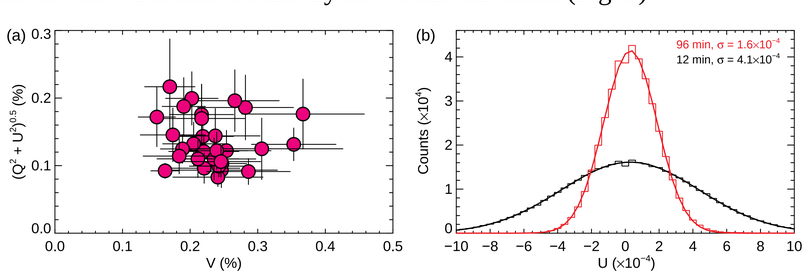
Fig 2 | Zonal flux density of the Sun. Each column of data represents the zonal flux density (averaged over one Carrington rotation.) The pattern is similar to the sunspot butterfly diagram. The north clearly leads by almost a year. Two apparent streams ("surge") of positive flux (white arrows) moved towards the north pole and canceled much of the old flux below N70. A new surge recently developed in the south, but the pole is not much affected yet.

Fig 3 | Mean flux density at different latitudes. From top to bottom: 50 – 60 deg, 60 – 70 deg, 70 deg and above, averaged over one Carrington rotation. Red is for north, blue for south. The thin lines are measured, the thick lines are smoothed with a low-pass filter (20 nHz, or 1.5 year) to remove the annual variation caused by the inclination angle. The north has switched sign below 70 degrees.



Polar Field Based on HMI Vector Measurement

- Strong polarization signals appear in patches in polar region. Many appear co-spatial with polar faculae (Fig. 4).
- Linear and circular polarizations appear to on the same order in many patches, about a few 10^{-3} (Fig. 5a).
- For 96-min averaged Stokes, 5-sigma noise for degree of polarization is about ~10^{-3}. Patches are mostly above this threshold (Fig. 5).



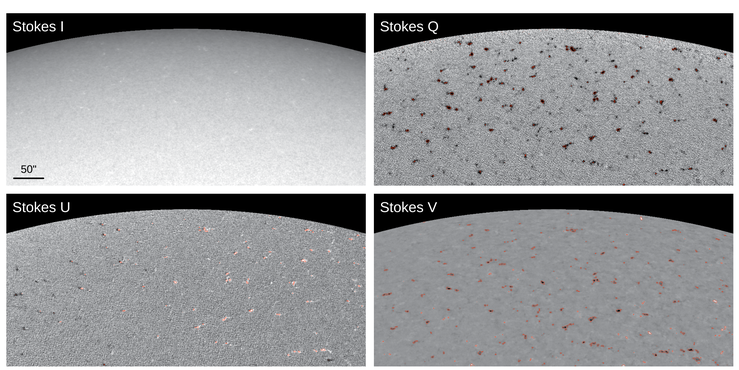


Fig 4 | (up) Degree of polarization in the northern polar region. A 96-min average is taken for the Stokes centered at 2010-10-06 12:48 UT. Degree of polarization in calculated by averaging Q and U across the spectral line and differencing two lobes in V. They are then normalized by the continuum. Red contours denote 5-sigma value. Degree of polarization is a few 10^{-3} in the patches.

Fig 5 | (left) Statistics of the degree of polarization. (a) Scatter plot for linear vs. circular polarization for 30 patches (above 3-sigma). The error bars are 3 times the standard error. (b) Histogram of U for 96-min (red) and 12-min average (black). The noise level scales as expected.

- HMI pipeline ME inversion (with filling factor 1) infers a few hundred Mx cm^{-2} flux density in strong field patches (Fig. 6 and 7b).
- During reversal, patches of both polarity coexist. However, the flux density in the patches appears to be smaller compared to minimum (Fig. 7b).
- LOS field and radial assumption yield a weaker polar flux density compared to the vector measurement in the patches (Fig. 7c).

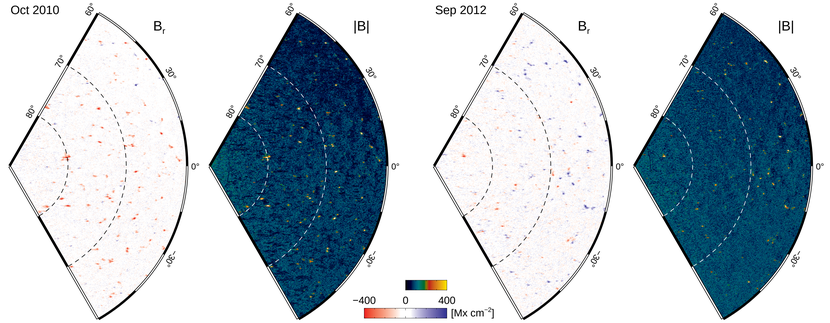


Fig 6 | Map of the north pole magnetic field in 2010 and 2012. North polar view (stereographically remapped) of the inferred HMI radial and total magnetic flux density from E60 to W60, N60 and above. The two frames on the left are taken at 2010-10-06 12:48 UT; the right 2012-09-02 12:48 UT. Negative patches pervade the north pole in 2010, while positive ones invade N60-N70 in 2012, consistent with the LOS data. The maximum is ~730 Mx cm^{-2}.

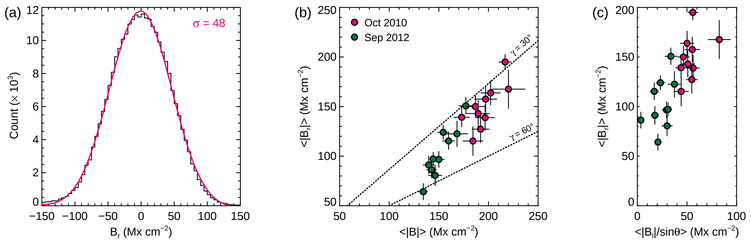


Fig 7 | Statistics of the polar magnetic field. (a) Histogram of the radial field; all pixels included. The 1-sigma noise is about 50 Mx cm^{-2}. (b) Comparison between mean total field and radial field in 10 arbitrarily selected strong negative patches. Pink is for 2010, green for 2012. The error bars are 3 times the standard error. Dotted lines indicate inclination angle of 30 and 60 degrees. An apparent decrease in flux density is observed. (c) Comparison between radial field derived from LOS data and the vector data. LOS underestimate the flux density.

Summary & Future Work

- HMI LOS field show the polarity in the north has reversed below 70 deg. The south lags over half a year, but has almost reversed below 60 deg.
- Strong magnetic patches pervade the polar region. 96-minute averaged HMI data has polarization signal in the patches mostly above 5-sigma.
- ME inversion infers a few hundred Mx cm^{-2} flux density in the patches. During reversal, patches of both polarity coexist. The flux density in each patch appears smaller.
- LOS field and radial field assumption seem to underestimate the flux density.
- More work is needed: 1) estimation of the effect of noise, filling factor, and disambiguation scheme; 2) characterization of the evolution of the patches.