Extreme Limb Polarization Measurement From HMI: A Progress Report

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Abstract. We have obtained the first direct measurement of the continuum polarization near the extreme limb using the Helioseismic Imager (HMI) on board the Solar Dynamics Observatory (SDO). The polarization is small (much less than 1%) but easily distinguished from statistical and systematic noise sources. These measurements differ from previous attempts to measure small continuum polarization that depended on a model of line polarization to infer the continuum (cf. Stenflo 2005) polarization.

1. Introduction

The solar limb polarization is expected to be a declining function with increasing wavelength which increases toward the limb (Stenflo 2005). This polarization is due primarily to scattering from neutral Hydrogen and Thomson scattering from free electrons. Thus a careful measurement of this scattering polarization is sensitive to the radiation anisotropy in the photosphere and a test of solar atmosphere models. Previous attempts to measure this (cf. Wiehr 1975, 1978) have depended largely on model extrapolations from measurement of the differential line polarization. With HMI it is possible to directly measure the continuum limb polarization from full disk Stokes I+Q, I-Q, I+U, and I-U photometry at the continuum near 6173Å. We obtain the polarization from an analysis originated to obtain the solar limb shape (cf. Emilio et al. 2007) from full-disk solar imagery at various spacecraft roll-angles. This paper reports our preliminary direct measurement of the continuum scattering polarization near the limb. We are in the process of deriving the $\mu$ dependent scattering polarization and the complete continuum and line scattering polarization.

2. Spacecraft Operations and Instrument Configuration

Roll Campaigns. Every 6 months SDO will be rolled in order to calibrate instruments. The first roll was executed April 9 2010 with 16 steps of 22.5° to make a complete roll of the spacecraft in 6 hours, with 10 minutes slew followed by 15 minutes of observing time.
The Image Stabilization System (ISS) loop is open during maneuvers and closed in between.

**Observing Program.** With the side camera, a framelist of filtergrams is taken at the continuum tuned wavelength centered at 6173Å. Polarization states are stepped through a set of linear and circular polarization settings. Around 35 images are then available at each roll-step and polarization state.

### 3. Data Processing and Analysis

Each image is calibrated with a preliminary flat-field that yields relative photometric accuracy of about 1%. Using a Limb Darkening Function (LDF) (Bush et al. 2010), the local limb brightness ($\alpha$) and displacement ($\beta$) (cf. Kuhn et al. 1998) are computed as in Emilio et al. (2007) (see Figure 1). Data used for this analysis were obtained from the first HMI/SDO roll campaign described above.

**Data preparation.** Data from each roll-angle of the spacecraft was prepared following a prescription that required:

- Closed Image Stabilization System loop
- No missing pixels
Figure 2. The mean image brightness at each filter position. This shows the effective line profile at each HMI filter stop wavelength. The data for these observations was obtained at the reddest continuum wavelength

- Eliminate outlier observations (from the first harmonics)

Data analysis. Data were then analyzed in a generalized procedure built upon the Michelson Doppler Imager/Solar Heliospheric Imager algorithms (Emilio et al. 2007).

- Average $\beta$ of selected observations per roll-angle
- Remove disk harmonic component
- Rebuild limb
- Subtract noise and co-align averaged $\beta$ according to the roll-angle
- Extract oblateness
- Correct $\beta$ for active regions contamination (from $\alpha$ and $\beta$ cross-correlation)

4. Results

The output from the analysis was a "limb-brightness" vector for each polarization I+Q, I-Q, etc. We obtain the mean polarization at a given position angle around the limb from the difference in the derived $\alpha$ coefficients. Thus the 'Q' polarization is obtained from the difference in $\alpha$ coefficients from the I+Q and I-Q images. Figure 3 shows the Q and U limb polarization averaged over the outer 6 arcsec of the limb. Note that Q
and U represent polarizer states with fixed orientation in the frame of the spacecraft. We have also plotted the expected cosine and sine variations in polarization given the instrumental Q, U reference phase. Our results are consistent with an average limb polarization of 0.01% in the outer 6 arcseconds near the limb.

Figure 3. left: $\alpha_Q$ polarization, right: $\alpha_U$ polarization.

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References