EXAMINATION OF THE PHOTOSPHERIC MAGNETIC FIELD UNDERLYING LONGITUDINALLY OSCILLATING CORONAL LOOPS

J. Ireland\textsuperscript{1}, R. W. Walsh\textsuperscript{2}, I. De Moortel\textsuperscript{3}, and P. F. Moretti\textsuperscript{4}

\textsuperscript{1}L3Com Analytics Corp., NASA-GSFC, Code 682.3, Bldg. 26, Greenbelt, MD 20771, USA.
\textsuperscript{2}Dept. Physics, Astronomy and Mathematics, UCLAN, Preston, PR1 2HE, UK.
\textsuperscript{3}School of Mathematics and Statistics, Univ. St. Andrews, St. Andrews, KY16 9SS, Scotland.
\textsuperscript{4}Osservatorio Astronomico di Capodimonte, Via Moiariello 16, 80131 Napoli, Italia.

ABSTRACT

Longitudinally oscillating coronal loops have been seen in TRACE 171 Å data in many different quiescent active regions. The oscillation is thought to be an example of an outwardly propagating slow magneto-acoustic wave. However, the source of these waves is as yet unknown. In the context of SOHO Joint Observing Program 144, we search for a possible photospheric driver to these waves. We examine the photospheric longitudinal magnetic flux underlying an oscillating loop observed between 1200-1300 UT on June 7th 2001. The field was imaged using the Kanzelhöhe Magneto-Optical Filter instrument and the SOHO Michelson Doppler Imager (MDI). The dynamics of the photospheric magnetic field underlying these loops is discussed in the context of possible mechanisms causing the observed coronal oscillations.

Key words: Sun; magnetic field; photosphere; corona.

1. INTRODUCTION

Recent observations have revealed the existence of longitudinally propagating intensity variations in apparently long coronal loops that are rooted in quiescent active regions. Given the relative paucity of coronal oscillations compared to other portions of the solar atmosphere, these have attracted a lot of attention as potentially interesting sources of information on the nature and efficacy of coronal heating as well as being a diagnostic tool of the corona. The source of these waves is as yet unknown, however. These waves are most easily seen in TRACE 171Å data, and appear as a small variation in the loop intensity. A review of the properties of these waves can be found in De Moortel et al. (2002a) (these proceedings) and will not be directly addressed here. It has recently been found (De Moortel et al 2002b) that these waves can be classified into two types, one set appearing to be rooted in sunspots having a period of approximately 3 minutes, and a second type not rooted in sunspots, having a period of approximately 3 minutes. A detailed discussion of the experimentally derived properties of both these types can be found in the companion papers De Moortel et al. (2002c,d) and the interested reader is referred to those articles. De Moortel et al. (2002c,d) note that these waves appear not to be flare generated as the coincidence between flare observations at the active region in question and the observation time of these waves is very poor (in contrast to transverse coronal loop oscillations of the type observed by Nakariakov et al. 1998, Schrijver et al. 2002, Aschwanden et al. 2002). The question of the generation mechanism of these waves remains open. However, the appearance of periodicities commonly found in the underlying photosphere in such a different portion of the Sun suggests the inviting idea that oscillations from lower down in the atmosphere are indeed propagating upwards along sunspot field lines. Support for this idea comes numerous papers (see Bogdan 2000 and references therein) detailing observations of oscillations in sunspots (Malmby et al. 1999, Byrneidsen et al. 2002) and sunspot plumes (Malmby et al. 2001). The existence of oscillatory power in the lower atmosphere is well documented. Oscillatory power has been detected in both Doppler shift and intensity in sunspots and has been well documented in the literature. Less sure is the observation of an oscillatory magnetic signal. Gurman and House (1981) reported on a 3 minute oscillation in magnetic field magnitude using the HAO Stokes Polarimeter. More recently, Horn, Staude and Landgraf (1997), using the Fabry-Perot instrument (FPI) VTT (Vacuum Tower Telescope) find evidence of magnetic oscillatory power in the 3 and 5 minute bands, with strongest power along the umbra/penumbra boundary. Lites et al. (1998), using the HAO/NSO Advanced Stokes Polarimetry also detect power over the 5 minute band and measure an oscillating field strength of about 4G. They also note that crosstalk between velocity fluctuations and any true magnetic signal is considerable and, via

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this effect, set an rms amplitude of about 0.5 G, considerably lower than the Horn, Staude and Landgraf (1997) values (reaching a peak of 100 G, rms around 20-30 Gauss), and at or within the error expected via inversion and instrumental error. In contrast, Rüedi et al. (1998) and Norton et al. (1998) both use MDI and find power in the 5 minute band but in small highly localised positions. This may explain why the earlier, single slit study of Lites et al. (1998) may not have observed any significant power - they simply were not looking in the right place. MDI and ASP comparisons of the same sunspot reported by Norton and Ulrich (2000) show coincidental magnetic variations, although periodicities and powers are not quoted. Finally, Settele et al. (2002) shows that the nature of most Fabry-Perot interferometer observations introduce systematic crosstalk from Doppler velocities into the magnetic variable. MDI is also affected by this crosstalk, but to a lesser extent than FPI instruments. This raises the possibility that contamination via crosstalk may be responsible for at least some of the signal seen in the data. Given this, we seek the presence of magnetic oscillations in sunspots to establish the possibility of magneto-acoustic wave propagation in sunspot rooted loops.

2. JOP144 AND SUNSPOT OBSERVATIONS

The analysis in this paper uses data taken in the context of SoHO Joint Observing Program (JOP) 144. Its first run took place from 5 - 13 June, 2001. Below we describe the JOP itself and the role of the constituent experiments. JOP 144 is designed to look for the magnetic sources of coronal oscillations using as high a cadence as possible in all the participating instruments. TRACE, observing in its 171 Å passband, is used to identify the presence of oscillations in the corona. Typically, 512 x 512 pixel images at 0.5" pixel size are taken, at cadences of around 30 seconds. The Coronal Diagnostic Spectrometer (CDS) searches for the presence oscillations at different temperatures, at hence approximately at different heights in the solar atmosphere, ranging from the chromosphere at 20,000K (He I 584.33 Å), the lower transition region at 200,000K (O V 629.73 Å), the upper transition region / lower corona at 400,000 and 500,000 K (Ne VI 558.59 Å and Ca X 557.77 Å) and the corona itself (Fe XVI 369.09 Å). A single slit is placed on a loop footprint, a location where previous experience has shown (De Moortel et al., 2000) TRACE sometimes sees coronal, longitudinally propagating slow magneto-acoustic waves. The remaining two instruments look at the magnetic field of the target active region and have complementary abilities. The Michelson Doppler Imager (MDI) has a pixel size of 1" in full disk mode and 0.625" in the high resolution field of view. Image cadence is one minute. The Kanzelhöhe MOF (Magneto-Optical Filter) takes full disk intensity, Doppler and magnetograms (measuring sodium-D lines) with a pixel size of 4.3" (Cacciani et al. 1999, Moretti et al., 2001) but has a variable cadence. Typically, good images

Figure 1. Kanzelhöhe intensity data detailing location of the sunspot studied in this presentation.

can be reliably obtained with a cadence of 20 seconds. This cadence can be pushed down to 5 seconds on occasion, however. The two instruments are complementary: Kanzelhöhe allows this JOP to examine the time dependence of the photospheric field, whilst MDI permits the finer length scales than those available to Kanzelhöhe to be successfully resolved.

3. ANALYSIS AND RESULTS

The target sunspot was chosen from the list provided by De Moortel et al. (2002b) (examples 14e,f on that list). There are many loops associated with this active region (AR9484) that support longitudinal intensity oscillations. At two positions a period in the 180 second range is measured, with these loops apparently anchored in the sunspot. Coronal intensity oscillations are noted at 1314UT on 7 June 2001. The Kanzelhöhe data at this time is unfortunately afflicted by cloud, and so the possibility of a co-temporal observation of a corresponding photospheric oscillation (of any type) is not open. Instead, we used Kanzelhöhe data as close as possible to the required time that was free of cloud, from 1237-1257 UT. The observation cadence was 20 seconds (see Ireland et al. 2002 for comments on the performance of the Kanzelhöhe Magneto-Optical Filter system at this cadence). Images from the MOF are shown in Figures 1 and 2. Figure 1 shows an intensity im-
Figure 2. A Kanzelhöhe longitudinal magnetogram of the magnetic field underlying the sunspot boxed in Figure 1. The outer black box delineates the area over which a Fast Fourier transform of timeseries arising from single Kanzelhöhe pixels is performed. The box in the bottom left hand corner of this region is used as a comparison with the properties of the longitudinal magnetic field in the remaining box, located over the sunspot. The colour bar denotes the magnetic field in Gauss.

Figure 3. Fast Fourier transform of Kanzelhöhe magnetic time series. The x-axis is spatial extent. The y-axis repeats the spatial y-extent of the data through binning of the Fourier power. The Fourier power bins are centred at 1 (bottom), 3, 5, 7, 9 an 11 (top) mHz and are all 2mHz wide. The quantity $\sigma$ denotes the average standard deviation of the time series over the entire image (measured in Gauss). The colour bar indicates multiples of this $\sigma$ as a measure of signal strength.

Figure 4. A MDI longitudinal magnetogram of the magnetic field underlying the sunspot boxed in Figure 1. The boxes in this image have the same meaning as those described in Figure 2.

Figure 5. Fast Fourier transform of MDI magnetic time series. The x-axis is spatial extent and the y-axis repeats the spatial y-extent of the data through binning of the Fourier power as in Figure 3. The Fourier power bins are centred at 1 (bottom), 3, 5, 7, 9 an 11 (top) mHz and are all 1mHz wide.
age and the region of the Sun under consideration. The longitudinal magnetic field at this small region is shown in Figure 2.

In an effort to get co-temporal magnetogram information, therefore, the seeing at Kanzelhöhe determines the time range used in MDI. MDI full disk magnetogram data from 1200-1251 UT was also analysed for the presence of magnetic oscillations. An example image is shown in Figure 4.

These two datasets are analysed for the presence of oscillatory power. A subset of the data is chosen, indicated by the larger black boxes in Figures 2 and 4. Time series are formed from fluctuations in single pixels in each dataset. The time series then have a 10 point running mean subtracted from them, and a fast Fourier transform is then used to isolate the periods. Maps of Fourier power over the region for both MOF (Figure 3) and MDI (Figure 5) are formed as multiples of the average timeseries variance.

4. DISCUSSION

Power at around 2 - 2.5 times the average variance is found in the 3.0 ± 1.0 mHz frequency bins in the Kanzelhöhe data over the sunspot. Using Groth (1975) it is found that the probability that this signal has arisen randomly in the highest power pixel is about 20%. Hence an unequivocal detection of a magnetic oscillation has not been made in this case. In addition, the overlapping MDI time series reveals no significant power in this frequency band at this location.

Although the time series have the cadence to be able to resolve any oscillations present in the magnetic field, it is clear that evidence for an unequivocal detection of an oscillation in the magnetic field of this sunspot is tentative to say the least. The statistics imply that this sunspot at least does not support a Kanzelhöhe detectable magnetic oscillation. The MDI data also suggest that an oscillation is not present at the level suggested by Horn, Staude and Landgraf (1997).

Much more work remains to be done however. Rebinning the data to improve statistics may improve the signal to noise ratio. A better estimate of the true noise in the signal is also important. In addition, there are many more sunspots within the JOP144 dataset that require attention. It may be that not all sunspots support magnetic oscillations - this hypothesis will be tested in future work. Further to the question of wave propagation from lower levels, the relative strength of Doppler and intensity oscillations in the photosphere compared to the type and appearance of waves in the corona (De Moortel et al 2002b) will also be investigated. The fact that not all coronal loops support longitudinal oscillations with photospheric periods may suggest that the power available, in whichever physical quantity, from the photosphere is a significant factor.

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