ACTIVE REGION OSCILLATIONS AS OBSERVED BY CDS, EIT AND TRACE

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ABSTRACT

We will present observational evidence of loop oscillations in an active region on the limb as seen by CDS on SOHO. The observations used in this work were obtained as part of the JOP 165 program run in September 2003. This JOP combined CDS, MDI, TRACE, SPIRIT/CORONAS-F and EIT to obtain spectral and spatial data at a range of temperatures, from the photosphere to the transition region/corona. For these observations EIT was operated in its shutterless mode in order to achieve high cadence. The results shown here in this short paper are preliminary results, mainly from the CDS instrument, showing a sample dataset from the large JOP 165 observing campaign. From the single location in the active region examined we find oscillation frequencies for intensity and velocity to be in the approximate range 2–3 mHz. We calculate phase velocities of the order of 28–42 km s⁻¹ for the waves producing the oscillations. Based on these rather low phase speeds we suggest that these waves are slow mode magnetoacoustic waves.

1. INTRODUCTION

Recent observations have revealed the existence of weak transient disturbances in extended coronal loop systems (Robbrecht et al, 2001). These propagating disturbances (PDs) originate from small scale brightenings at the footpoints of the loops and propagate upward along the loops. In all cases observed, the projected propagation speed is close to, but below, the expected sound speed in the loops. This suggests that the PDs can be interpreted as slow mode MHD waves. Such a conclusion is, however, hampered by the fact that the observed propagation speeds depend on the projection of the loops in the plane of the sky, that is, line-of-sight effects. Since we do not know the 3D configuration of the loops, it is generally not possible to confirm if the real speed (not projected) indeed matches the sound speed (or tube speed). Therefore, some doubts remain about whether the propagating disturbances should be interpreted as slow mode MHD waves or as bulk plasma flows. In the JOP 165 observations we followed a single active region as it rotated over the solar disk and as the line-of-sight perspective changed from day to day. We chose for these observations a relatively large, decaying bipolar active region (AR) with an extended loop system. For such an active region we can assume that the overall 3D configuration will remain fairly constant on a timescale of, say, 2 weeks. On a daily basis we we hope to determine the propagation speeds of PDs in the extended loop system. From the daily variation in the projected speeds we will be able to determine the 'actual' speed and check if this is indeed compatible with the slow mode MHD wave hypothesis.

Apart from studying the nature of the oscillations we would also like to address the origin of these oscillations. The origin of high-frequency oscillations is believed to be connected with magnetic footpoint motions. In decaying ARs the dominant type of footpoint motion is related to the so-called moving magnetic feature (MMF) activity, which has been related to sunspot decay. MMF activity is observed to be related to X-ray transient brightenings (Shimizu, 1994), and surge and X-ray jet activity (Canfield et al, 1996), and even hard X-ray emitting microflares (Nitta, 1997). Recently a relation to the Ellerman bomb phenomenon (H-alpha brightenings) has been proposed (see review by Martínez-Pillet, 2002). All these transient brightenings are due to some reconnection process taking place in different atmospheric layers. Furthermore, MMF activity has been shown to lead to the acceleration of electrons, which emit metric radio noise storms due to a large number of low-energy magnetic reconnection processes at the moat boundary (Bentley et al, 2000). We aim to investigate the possible wave-generating processes linked to the long-term sunspot decay, which would be best studied during the disc transit of a simple bipolar AR.

In this short contribution we will only present a brief outline of our observational campaign and provide a representative result from one of the datasets. The detailed results from JOP 165 will be presented in


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2. OBSERVATIONS AND DATA REDUCTION

In this campaign we used several instruments, CDS, MDI, TRACE, SPIRIT/CORONAS-F and EIT. For details please refer to the web-page: http://perswww.kuleuven.ac.be/~u0005791/werk/EITshutt/jop.html. For a description of the shuttless mode refer to the page: http://sol.oma.be/Highcadence/. The data discussed here were selected from the observations taken on the 17th September 2003. The observations were performed for active region, AR457. Details on the CDS reduction procedure, plus the wavelet analysis, may be found in O'Shea et al. (2001). The statistical significance of the observed oscillations was estimated using a Monte Carlo or randomisation method. The details can be found in O'Shea et al. (2001). The probability levels displayed in this paper are the values of \((1-p) \times 100\), i.e. the percentage probability that periodic components are present in the data. We choose a value of 95% as the lowest acceptable probability level.

3. RESULTS

In Figure 1 we show a TRACE 171 image, taken at 14:02:19UT on 17th September, showing the AR at the limb and overlaid with the slit from the s28636r00 CDS temporal series dataset, taken at roughly the same time (13:53 UT). As can be clearly seen from this image the CDS slit intersects with numerous thin fibrous loop structures. In Figure 2 we plot CDS intensity rasters of size \(240 \times 240\) arcsec\(^2\), in a number of different lines, which show the same active region at the limb. These raster were created from dataset 28535r00 which was obtained at 13:29 UT, some 30 minutes before the TRACE image. The thin rectangular boxes overlaid on these images show the location of the CDS slit not only for the s28536r00 dataset (the slit plotted on the far left) but also for the other temporal series datasets taken on this day, i.e. s28356r01, s28356r02, etc.

By measuring the intensity versus time in these slits it is possible to produce X-T slices, that is the variation of the intensity at each position along the slit versus time. In Figure 3 we show examples of this for the s28536r00 dataset. To bring out the details of the original intensity map we have filtered the long period components in the image. In this contrast enhanced image (Fig. 3), the solar north-south (SOLAR_Y) direction is on the vertical axis, the horizontal axis is time. The total number of counts in a pixel (summed counts) during the observation is shown in the right columns of Fig. 3. The brightening seen at approx. pixel location 25–35 in He i, O iii, O v and Mg x is probably an explosive event. It is not seen in the higher temperature Si xii and Fe xvi lines. By using this contrast enhanced X-T slices it is possible to pick out regions along the slit where oscillations are occurring.

In Figure 4 we show a representative example of intensity and velocity oscillations and the corresponding power spectra analysis for pixel location 45 in dataset s28536r00. In the wavelet spectrum, the dark contour regions show the locations of the highest powers. Only locations that have a probability greater than 95% are regarded as being real, i.e. not due to noise. Cross-hatched regions, on either side of the wavelet spectrum, indicate the ‘cone of influence’ (COI), where edge effects become important (see Torrence & Compo, 1998). The dashed horizontal line in the global wavelet spectrum indicates the lower frequency cut-off, in this instance 1.6 mHz. The results from the intensity phase plots indicates significant power in the 2-3 mHz range for each of the lines except O iii, lasting for most part of the observing sequence. The global wavelet spectrum, which is the average of the wavelet power spectrum over the entire observing period, provides an estimate of the ‘average’ frequency of the oscillations and the value of this together with the probability estimate is printed out above the global wavelet power spectrum. We note that the results for O iii are not significant by our definition, having a probability level of 77%. In the lowest panels we show the variation of the probability level as estimated from the randomization test. Note that the statistical significance is calculated only for the maximum powers in the wavelet spectrum marked by the dotted white line in the dark patches.

For the velocity results these same 2-3 mHz oscillations are present in the O v and Fe xvi plots but are absent in the Mg x and Si xvi plots, where the significant oscillations are present at higher frequencies of 10.6 and 4.8 mHz respectively. We do not know the reason for this difference with respect to the inten-
Figure 2. CDS raster images for the s28535r00 dataset, in different temperature lines (as labeled)

Figure 3. Space-time behaviour of the intensity in the different temperature lines for dataset s28536r00. The right panels show the counts summed over all time against the slit locations
Figure 4. Intensity and velocity wavelet results corresponding to the s28536r00 dataset at pixel 45
sity results. However it should be pointed out that the velocity resolution of CDS is poor, at best, 5 km s\(^{-1}\), and so, even by using a reliable significance test as is the case here, it is generally difficult to detect velocity oscillation from noisy data. He I and O III do not show significant oscillations in velocity.

In Figure 5 we show the results of the phase delay analysis carried out between each of the lines and the Mg X line, using the intensity oscillations show in Figure 4. The measured phases have been converted to seconds to produce time difference values. It should be pointed out that we do not use the He I line in these measurements due to its uncertain formation height. If we look at, e.g. the Si XII values, plotted as box symbols in this plot, it is clear that the measured time differences are clustered around zero. In this plot negative values indicate time lags and positive values the opposite. These values for Si XII do not seem credible, if we consider that the distance between the height of Mg X and Si XII is of the order of 8500 km. These very small time differences for Si XII would then indicate implausibly large phase velocities for the presumed waves. We note that a limitation of using Fourier phase delay techniques is that it is not possible to measure time differences greater than half of the period of the measured oscillations. Thus for time differences greater than half of the period it is liable to give erroneous values. For example, it can make it appear as if one line is leading another when the opposite is, in fact, the case. In the case of the Si XII results shown in the plot it is likely that the 'real' time difference are different to the ones initially returned by the phase analysis and plotted as the (heavier line) square symbols in Figure 5. By subtracting one whole period off these initial values it is possible to obtain an estimate of the 'real' time difference, that is, values of \(~200 - 300\) seconds, shown as the lighter grey symbols. These corrected time differences would suggest phase velocities of 28-42 km s\(^{-1}\), indicating that the waves producing the oscillations are slow magnetoacoustic waves.

In this short paper we have shown some preliminary CDS results from the JOP 165 program run in September 2003. We have shown intensity and velocity oscillations and their measured periods for one sample position in an active region (AR457) at the limb. We find oscillation frequencies for intensity and velocity to be in the approximate range 2–3 mHz. We also show an example of the phase delay analysis we hope to carry out on the CDS data obtained in JOP165. From an initial study and making a correction for the limitations of the Fourier method, we calculate phase velocities of the order of 28–42 km s\(^{-1}\) for the waves producing the oscillations. Based on these rather low phase speeds we suggest that these waves are slow mode magnetoacoustic waves.

REFERENCES