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Observed co-temporal oscillations by SOHO/CDS and TRACE and the implications for Solar-B instrumentation

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Atmospheric Seismology

ABSTRACT

This paper focuses upon a sunspot active region that was imaged with the CDS wide slit (with high time resolution in He I , O V, Mg IX) and also co-temporally in TRACE 171 Å. 3-min oscillations were observed above the sunspot umbra in He I and O V. These oscillations are then observed to propagate along the active region loops observed in TRACE with both displaying resonance-like multiple frequencies. It appears clear that these propagations are the same wave phenomena travelling through the chromosphere and transition region before dissipating in the corona. The implications of these results for the implemenation of Solar-B instruments to bettter refine and extend solar atmospheric seismology is discussed.

INTRODUCTION

3-minute oscillations have long been associated with sunspot umbrae from the days of SMM (Gurman et al, 1982) to the current SOHO and TRACE missions (for example Fludra, 2001; Brynildsen et al, 2003; O'Shea et al, 2002).

More recent are observations of intensity disturbances propagating along active region loops (for example, Berghmans & Clette, 1999; Nightingale et al, 1999; De Moortel et al, 2002).

In particular, Marsh et al (2003) present joint CDS and TRACE observations of a 5 minute oscillation at the base of a "non-sunspot" coronal loop. These are the first results that suggest that a propagating disturbance observed in TRACE at coronal temperatures is also present at chromospheric, transition region and coronal temperatures observed by CDS. They suggest that there is a coupling and propagation of slow magneto-acoustic waves at photospheric, chromospheric, transition region and coronal temperatures at the same location. However, it is found that the results obtained from narrow slit "sit and stare" studies may be severely limited by the pointing error of CDS combined with the short damping lengths of the propagations.

Thus in this work, for the first time we use the CDS wide slit as a chromospheric and transition region imager of active regions coupled with TRACE to directly observe the 3-minute chromospheric/transition region oscillations propagating into the emerging coronal loop system

OBSERVATIONS

Target Active Region

NOAA active region 10570 was observed on the 13th March 2004 near disk centre. While the active region consists of two clear sunspot regions, here we concentrate on the westerly sunspot region located at [315, -120] arcsec in solar coordinates. Fig. 1 shows the sunspot active region viewed with MDI (magnetogram and white light), CDS (He I, O V, and Mg IX) and TRACE (171 Å).

CDS Wide Slit

The non-rastering wide slit observations consist of 90" x 240" intensity images with a pixel size of 1.68" in He I 584, O V 629 and Mg IX 368 with an exposure of 20 s and cadence of 26 s.

DATA ANALYSIS

CDS Wide Slit

To investigate the spatial distribution of oscillations within the wide slit data, maps of Fourier power are formed with a randomisation method (Nemec & Nemec, 1985) employed to test for 95% significance. The time series at locations showing oscillating structures can then be investigated by Fourier analysis.

TRACE

A running difference method is used. A tube is defined overlying a coronal loop structure. Cross sections are formed along the tube of 2"width. A running difference is formed by using the integrated intensity profile of the tube along its length and subtracting the profile of the tube 90 s earlier. Any propagating oscillations should appear as diagonal light and dark bands in the difference image. The gradient of these bands can be used to calculate the propagation velocity of the oscillations.

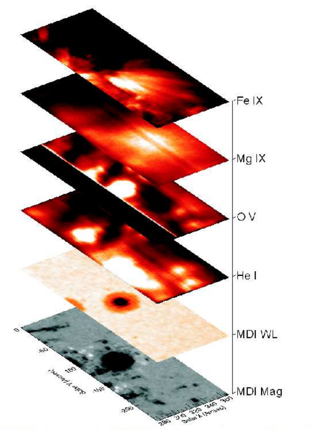

Figure 1. NOAA active region 10570 is observed near disk centre. The figure shows the sunspot atmosphere with increasing temperature as viewed by MDI (magnetogram and white light), CDS (He I Log T=4.5, O V Log T=5.4, and Mg IX Log T=6.0) and TRACE (171 Log T=6.0).

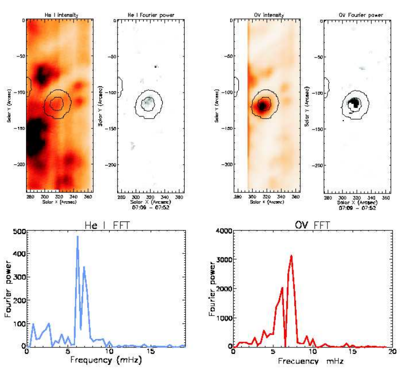

Figure 2. *Upper images*: He I and O V maps of intensity and Fourier power within the 3 minute band. *Lower graphs*: FFTs of the same lines formed from pixels above the umbra with significant 3-minute power. Closely spaced, resonance-like frequencies are observed.

RESULTS

CDS Wide Slit

As can be seen in Fig 2., the region above the sunspot appears quite uniform in He I intensity. The power map for He I, however, shows significant 3-min power confined above the sunspot umbral region. This suggests the region above the sunspot umbra is not quiescent and supports a dynamic oscillating structure at the temperature of He I. The FFT reveals two dominant frequencies within the 3-minute band (164 and 141s).

Similiarly, the O V power map shows significant power above the umbra in the intense emission of a plume. The FFT once again shows that the oscillation is composed of multiple frquencies centred around 169 and 137s. Fig 3. Displays the time series for both He I and O V- the oscillation amplitude for O V is greater with a relative amplitude of about 4%.

TRACE

The TRACE data displays propagating oscillations present in many of the loop structures emerging from the sunspot. Fig. 4 shows the TRACE 171 Å context image of the CDS wide slit field of view. Over-plotted are the MDI white light contours of the sunspot umbra and penumbra along with the tube outlining the loop structure that forms the running difference image.

Fig. 4 shows light and dark diagonal bands that indicate intensity propagations along the loop structure. The regular spacing of the bands suggests that the propagations have a periodic nature over the duration of the observations with a period of about 3 minutes.

The positive gradient of the bands indicates that the propagations originate at the base of the loops and propagate outwards along their length. The gradient of the dashed yellow lines in the running difference image gives an estimate of the propagation velocity perpendicular to the line of sight of 80km/s.

Pixels at the base of the defined tube are summed to form a time series- Fig. 4 displays this time series with a relative amplitude of about 3%. As in He I and O V the FFT shows that in the 3-min band the TRACE propagating oscillations consist of two dominant frequencies. These frequencies are centred around 169 and 137 s. Also power is observed at 330 s coincident with the 5-min p-mode oscillation.

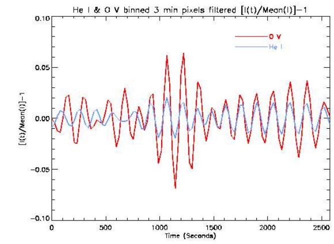

Figure 3. He I and O V time series, Fourier filtered within the 3-min band. O V has a greater oscillation amplitude and the beat frequencies can be seen clearly.

IMPLICATIONS FOR SOLAR-B

As a consequence of this work, the characteristics of these propagations will be much better defined when observed with Solar-B. Part of the difficulty with pining down this phenomena has been coordinating the precise pointing required for the spectrometer slit coupled to the fact that these oscillations dissipate very rapidly from the loop base. Given that Solar-B will be a "true" observatory with coordinated spacecraft pointing, it is our belief that many more examples of these propagations will be observed (hence providing a statistical sample of their properties).

For example, observations using the EIS slots in different temperature lines simultaneously with high time resolution XRT images will provide a complementary but better resolution (in space and time) data set to build upon the CDS/TRACE observations outlined here. Similiarly, keeping the EIS slit at a fixed position at a loop base will build upon the results obtained in Marsh et al (2003) but with a superior cadence (possibly <10s)- leading to the possibility of detecting higher frequency oscillations than we can currently. .At the same time, direct observations of the source of these waves would be undertaken using SOT (as attempted in for example, Ireland et al, 2002).

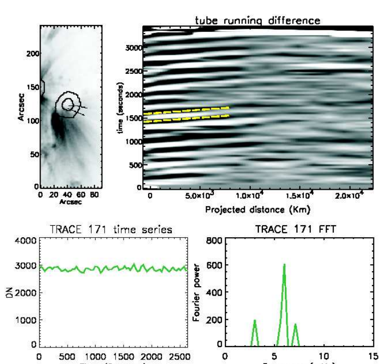

Figure 4. *Upper left*: TRACE 171 Å image with MDI contours and the tube used to form the running difference. *Upper right*: running difference image. *Lower left:* time series formed from pixels at loop base. *Lower right*: resulting FFT of time series.

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