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FILAMENTARY OSCILLATIONS IN THE PENUMBRA OF SUNSPOTS

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Abstract

We present the detection of dynamic phenomena along penumbral filaments observed in alpha-type sunspots. These perturbations show a broad distribution of periods of the order of several hours.

1. Data and Methodology

For this study, we have made use of the SHARP data products of the Helioseismic And Magnetic Imager (HMI, Scherrer et al. 2012, Schou et al. 2012) on board the Solar Dynamics Observatory (SDO, Pesnell et al. 2012). In particular, we used continuum intensity and the magnetic field vector (Figure 1). Although this study was carried out on 25 isolated sunspots, we chose the leading sunspot of AR11084 to illustrate the method and analysis procedure. This sunspot was followed for 12 days and 3 hours, with one frame every 12 minutes.

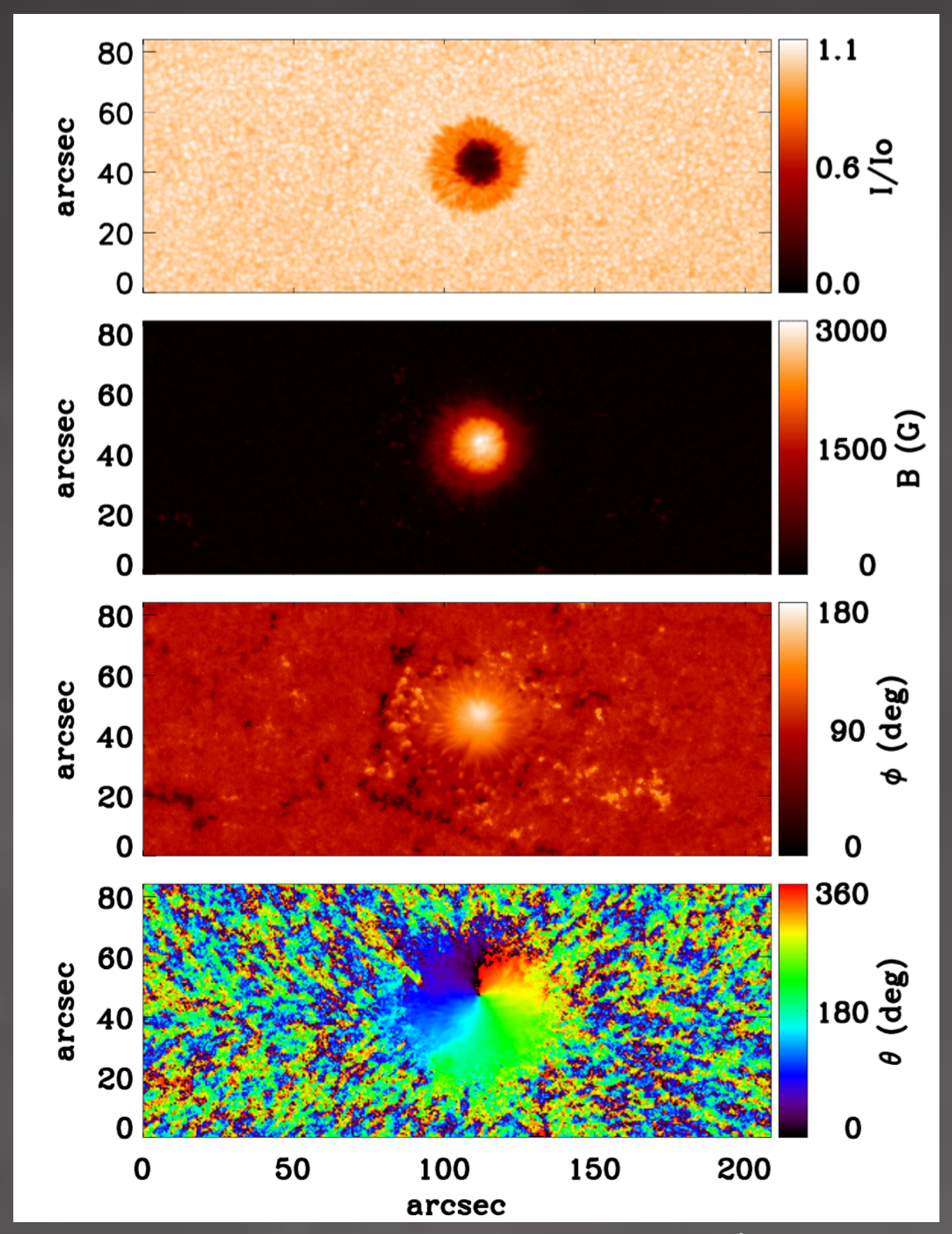

Figure 1. Parameters used for our analysis. From top to bottom: continuum intensity, magnetic field strength, inclination and azimuth for AR11084.

The SHARP data were further transformed for the purpose of this analysis by performing the following steps:

1. we changed from line-of-sight to local reference frame.
2. we deprojected the data to correct for perspective effects.
3. we aligned the images using correlation tracking techniques.
4. we calculated the time evolution of the magnetic field inclination (third row of the Figure 1) with respect to the local reference frame for each pixel in the image.

A wavelet analysis was performed on the time series for each pixel in the penumbra in order to study the oscillatory nature of the dynamic phenomena. The wavelet analysis shows the oscillatory power as a function of frequency and time. We labeled dynamic events that fulfilled the following requirements: 1- the power at a given frequency, location and time corresponds to an oscillation of >20.5 in the magnetic field inclination, and 2- the enhancement in power lasts at least 2 full periods at the considered frequency.

This procedure gives us pixel by pixel events. However, in order to avoid spurious events, we imposed yet another requirement: the spatial coherency of the oscillation. We removed all of those events that didn't show power in, at least, three adjacent pixels at the same time. In this way, we constructed a database of events that showed a dynamic behavior that is spatially and temporally coherent. Figure 2 depicts some of these structures.

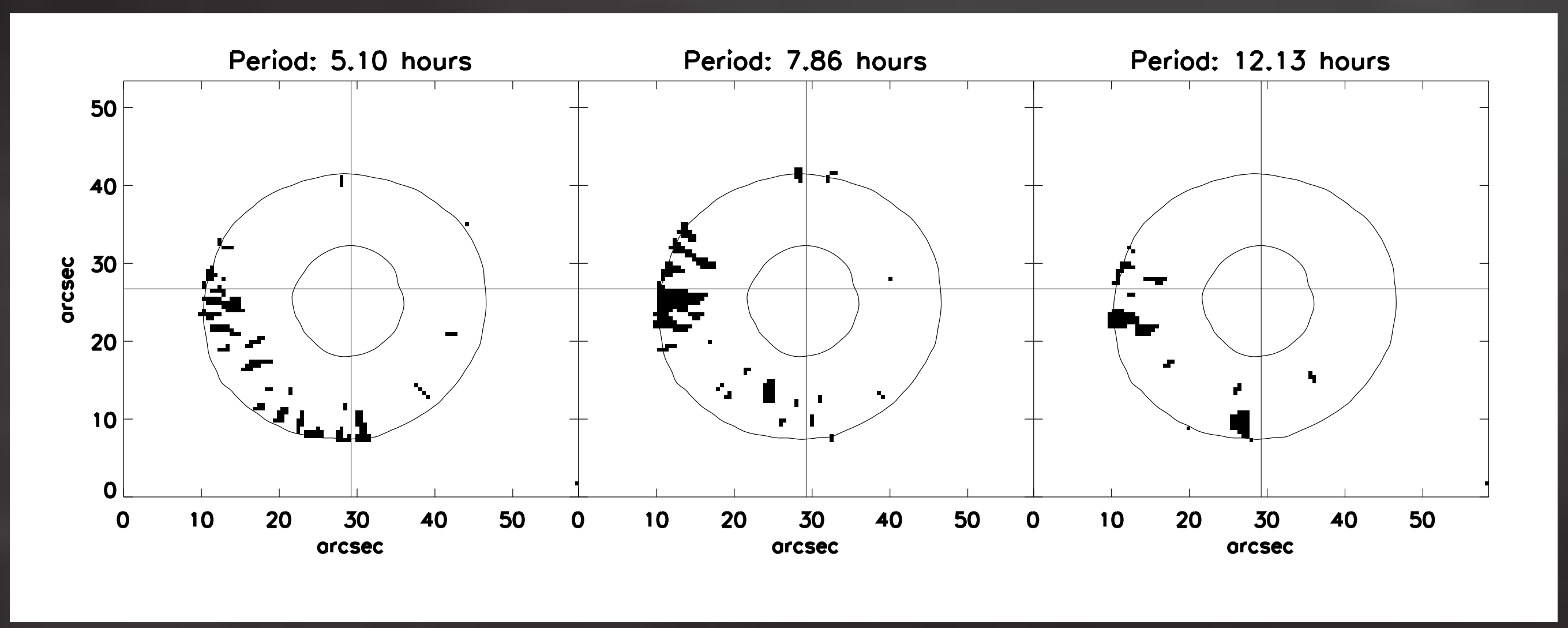

Figure 2. Spatial distribution of the detected events for 3 frequencies of the wavelet analysis.

2. Results

An interesting property of these events is that they do not appear homogeneously all around the penumbra but they seem to be concentrated at particular locations. These structures seemed to appear predominantly on the Eastern side of the penumbra. Because the 25 sunspots that we analyzed correspond to the leading polarity of their active regions, the dynamical events always seem to appear on the side of the penumbra that connects the two main polarities of the active region.

In order to characterize the dominant period of each one of the events, we averaged the time sequences of all the pixels in some structure. Then, we fitted a sinusoidal function with period, phase and amplitude as free parameters. An example of this Fitting Procedure is Shown In Figure 3.

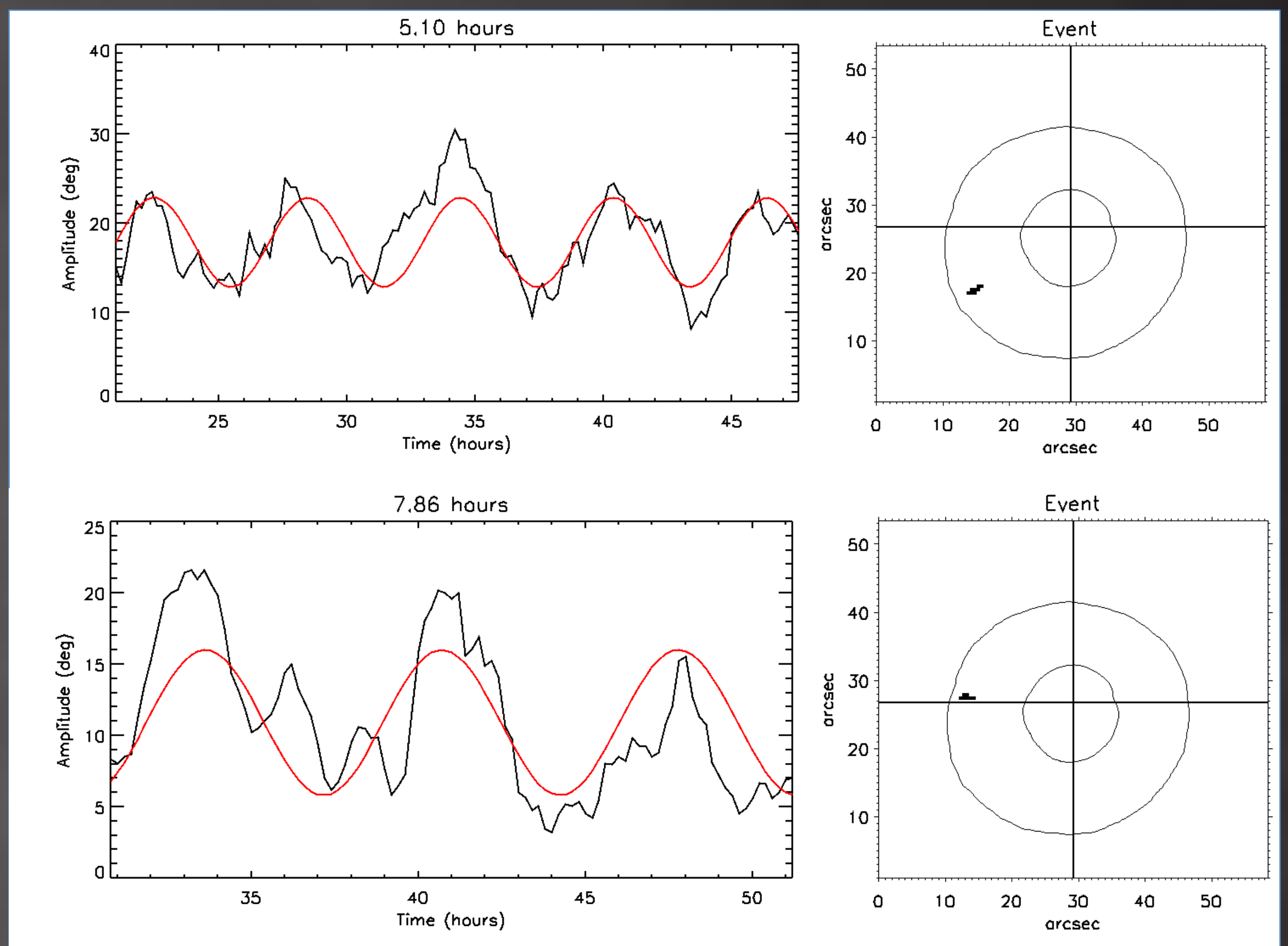

Figure 3. Two examples of the filamentary-shaped oscillations. The time sequence on the left (black solid line) is the mean average of the temporal evolution of the pixels that belong to the events shown on the right pannels. The red solid line is the best fit to a sinusoidal function. The contours of the right pannels mark the limits between umbra-penumbra and penumbra-quiet sun.

We applied this procedure some events to obtain the dominant oscillation period in each one. Although each individual event has a rather characteristic dominant oscillation, this periodicity is different for all of the events investigated.

3. Conclusions and Future Work

1. We see filamentary-like oscillations in the inclination of the magnetic field of penumbral filaments of sunspots.
2. Although individual events show dominant oscillation modes, there appears to be no clear periodicity in general. Instead a broad distribution is retrieved.
3. The spatial distribution of the events in the penumbra is not homogeneous but they appear, predominantly, along the line that connects the main polarities of the active region. The physical reason for this distribution is yet unclear.

Conjecture: The fact that the dynamical events always seem to appear on the side of the penumbra that connects both polarities of the active region is interesting and striking. The coronal loops that connect the two polarities of the AR share this same orientation. It is tempting to speculate that the dynamical patterns reported in this work might be related to these arch filament systems. And maybe, dynamical perturbations in the upper layers could propagate down the arches, causing the phenomena that we see in the penumbra.

References

Pesnell et al. 2012
Scherrer et al. 2012
Schou et al. 2012

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