Observations of upward propagating waves in the transition region and corona above sunspots

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Introduction

As one of the prominent phenomena observed in sunspots, sunspot oscillation has been intensively studied in the past (Khomenko & Collados 2015). Most observations have been reported with the variations of the brightness and the LOS velocities derived from the spectral observations. The 3-minute oscillations are the dominant mode of oscillations in the chromosphere, transition region and corona above sunspot umbrae (e.g., Gurman 1987; Brynildsen et al. 2002; Rouppe van der Voort et al. 2003; Centeno et al. 2006). Regarding their physical nature and their connections to in different solar atmospheric levels, the upward propagating wave scenario has been suggested by many studies (e.g., Brynildsen et al. 2002; Centeno et al. 2006; Reznikova et al. 2012). The upward propagating waves in sunspots may show nonlinear properties (e.g., Rouppe van der Voort et al. 2003; Centeno et al. 2006; Tian et al. 2014).

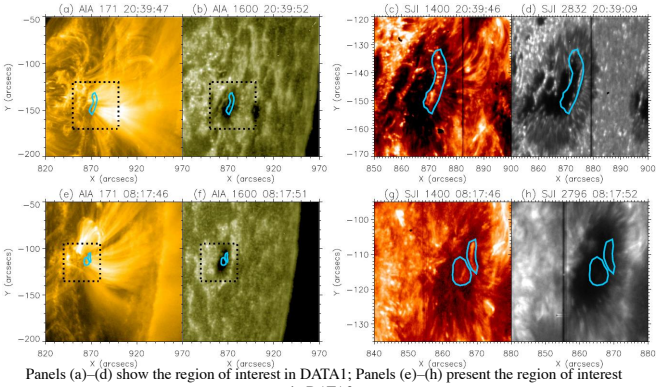
Using the imaging data taken by IRIS SJI and AIA, we report on the observations that show responses to upward propagating waves in the sunspots while they are propagating as intensity disturbances along coronal loops and while they are passing structures with enhanced emission in the transition region.

Observations

Two sets of data are analyzed, both close to the limb.

	DATA1 400-step raster mode	DATA2 2-step raster mode
SJIs 1400	**cadence**: 14 s	11 s
AIA 171	12 s	12 s
SJIs 2796	---	11 s
SJIs 2832	32 s	---
HMI vector magnetic field: 'hmi.B_720s'	---	---

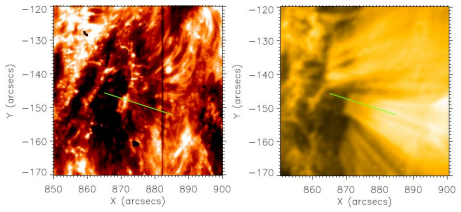
The FOVs of DATA1 and DATA2



Panels (a)–(d) show the region of interest in DATA1; Panels (e)–(h) present the region of interest in DATA2.

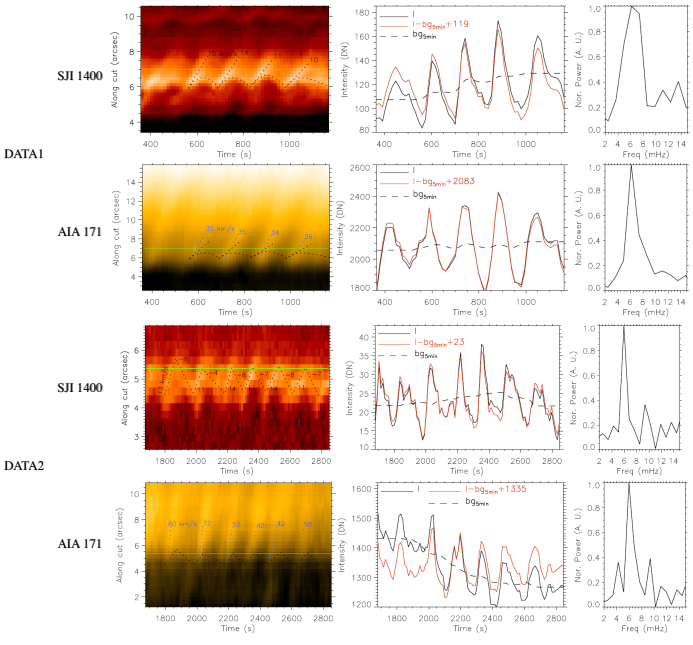
Mothed

For analyzing the oscillating behavior, we take a cut along the oscillating direction and along the coronal loop in each data-set. And then we choose a subsection of time series for analyzing the periodicities.



Example: the cut used for analyzing is marked by green lines in IRIS SJI 1400 Å and AIA 171 Å images.

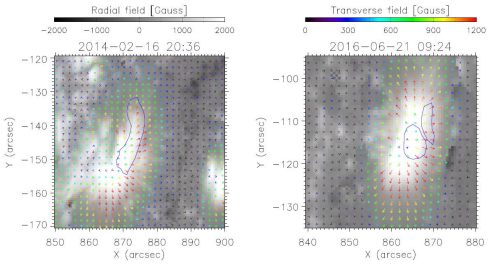
Result1



From left to right: subsections of time-distance images, light curves and power spectra.

Result2

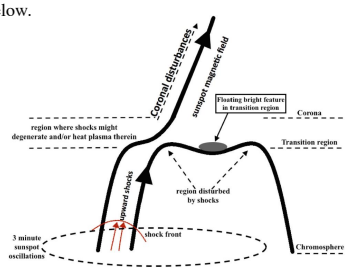
The photospheric vector magnetic fields of the sunspots for DATA1 and DATA2 are given below. Around the regions surrounding the features, beside the single polarity radial components, the strong transverse components also appear clearly, which might provide necessary magnetic tensions to support the features floating above the sunspot umbrae.



Phtospheric vector magnetic fields of the regions taken with HMI.

A cartoon scenario

Based on this observations and the magnetic configurations of the sunspots, a cartoon model is given below.



Properties for oscillating features:

1, Oscillations of the transition region bright features are observed above the sunspot umbrae with periods of ~3 minutes.
3, The spatial displacement of the oscillation of the feature is about 1″.
4, The apparent velocities of the oscillating motions are about 10 km s^{-1}.
5, The amplitudes of the intensity fluctuations take more than 24% of the background emissions, indicating some nonlinear effects.

Properties for coronal disturbances:

1, Upward propagating disturbances with the same period of ~3 minutes are observed along the loops rooted in the same regions as the oscillating features.
3, The intensity variations take only 10-15% of the background emissions.
4, The apparent upward propagating velocities are about 30 km s^{-1} in DATA1 and in the range of 40-80 km s^{-1} in DATA2.
5, The upward motions of the oscillating features appear earlier than the coronal disturbances, but moving slower.

Conclusions

Unlike the signatures of oscillations revealed in the light curves of a particular location in the previous studies, the transition region structures here present persistent oscillations with clear spatial displacements in the high resolution IRIS data. And the oscillating features were located in the foot-point regions, where recurring bright disturbances are observed while they are propagating along the loops in a manner of quasi-periodicity.

The oscillations of the transition region structures are powered continuously by upward propagating shocks.

The upward propagating quasi-periodic coronal disturbances could be recurrent plasma flows driven by the shocks. Or alternatively, when the shocks become slow magnetic-acoustic waves after heating the plasma in the coronal loops at their transition-region bases, the coronal disturbances could be responses of these degenerated shocks.

A full story could be found in a published paper: Hou, Huang, Xia, Li & Fu 2018, ApJ, 855, 65

IRIS-9, Göttingen, 25-29 June 2018

Poster

2. Chromospheric heating and dynamics

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We present observations of persistent oscillations in the transition-region above sunspots taken by IRIS SJ 1400 Å and upward propagating disturbances along coronal loops rooted in the same region taken by AIA 171 Å passband. The oscillations of the features are cyclic oscillatory motions without any obvious damping. The amplitudes of the spatial displacements of the oscillations are about $1''$. The apparent velocities of the oscillations are comparable to the sound speed in the chromosphere. The intensity variations can take 24–53% of the background. The FFT power spectra of the oscillations show dominant peak at a period of about 3 minutes, in consistent with the omnipresent 3 minute oscillations in sunspots. The amplitudes of the intensity variations of the upward propagating coronal disturbances are 10–15% of the background. The coronal disturbances have a period of about 3 minutes, and propagate upward along the coronal loops with apparent velocities in a range of $30\sim80\,\mathrm{km\,s^{-1}}$. We propose a scenario that the observed transition region oscillations are powered continuously by upward propagating shocks, and the upward propagating coronal disturbances can be the recurrent plasma flows driven by shocks or responses of degenerated shocks that become slow magnetic-acoustic waves after heating the plasma in the coronal loops at their transition-region bases.