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Coronal Hole Oscillations as inferred from SDO/AIA data

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Abstract

With high temporal resolution (12 s) of about two hours duration, data of a coronal hole structure in 171 Å, 193 Å and 211 Å taken from SDO/AIA images is considered for examination of oscillations. After estimating the total DN counts of a whole coronal hole structure in three wavelength bands, the resulting time series are subjected to FFT and wavelet analysis. Significant periods in all the three wavelength bands are detected that are mainly concentrated around 500 s as a fundamental mode and its odd (167, 100, 71, 56, 46, 39, 33, 29, 26, 24 s) harmonics. Computed phases in all the three wavelengths band are estimated to be constant.

Keywords: SDO/AIA data; Coronal hole; Flux tube; Oscillations

1. Introduction

Apart from global oscillations of the Sun as a whole, other active regions of Sun also oscillate in different periods. Sunspots' oscillations have been investigated in several works (Kentischer and Mattig, 1995; Lites, 1986; Bogdan, 2000 and references there in). Fleck et al. (1994) studied the solar oscillations with height using He I 10830 Å in quiet solar atmosphere.

Since the launch of EUV telescopes in space, which have very good sensitivity and high spatial and temporal resolutions, coronal oscillations have been studied. As presented by Aschwanden (2003), Table 1 gives a flavor of coronal oscillations as observed in the EUV window.

Detection of oscillations in the chromosphere and corona can help us in understanding the magnetic structure of the solar atmosphere, and may provide valuable insight into the unresolved coronal heating problem (Tian and Xia, 2008).

Following is a brief history of previous studies on detection of short (∼ seconds to minutes) and long period (∼ days) coronal oscillations. The 3-min oscillations are detected above sunspot regions, especially in the transition region (Fludra, 1999; Brynildsen et al., 1999; De Moortel et al., 2002) and, 5-min oscillations are detected in "non-sunspot" loops. Quasi-periodic oscillations in polar plumes were studied by Deforest and Gurman (1998). O'Shea et al. (2006, 2007) studied oscillations in plumes, interplumes and coronal holes in the polar regions of the Sun. Periodic oscillations (7–64 min) in coronal bright points are also detected (Ugarte-Urra et al., 2004a,b; Tian et al., 2008). From the globally averaged radio fluxes (at 275, 405, 670, 810, 925, 1080, 1215, 1350, 1620 and 1755 MHz), Hiremath (2002) detected long period (∼ days) quiet coronal oscillations.

Coronal holes (CH) are large regions in the solar corona that have low density plasma (Krieger et al., 1973; Neupert and Pizzo, 1974; Nolte et al., 1976; Zirker, 1977; Cranmer, 2009 and references therein; Wang, 2009) with unipolar

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Table 1
Coronal oscillations observed in EUV. Table is taken from Aschwanden (2003).

Observer	Wavelength λ [Å]	Period P[s]	Instrument
Chapman et al. (1972)	304, 315, 368	300	OSO-7
Antonucci et al. (1984)	554, 625, 1335	141, 117	Skylab
Deforest and Gurman (1998)	171	600–900 (prop.)	SoHO/EIT
Aschwanden et al. (1999)	171, 195	276±25	TRACE
Nakariakov et al. (1999)	171	256	TRACE
Berghmans and Clette (1999)	195	(prop.)	SoHO/EIT
De Moortel et al. (2000)	171	180–420 (prop.)	TRACE
Nakariakov and Ofman (2001)	171, 195	256, 360	TRACE
Robbrecht et al. (2001)	171, 195	(prop. waves)	TRACE, EIT
Schrijver et al. (2002)	171, 195	–	TRACE
Aschwanden et al. (2002)	171, 195	120–1980	TRACE
De Moortel et al. (2002a,b)	171, 195	282±93 (prop.)	TRACE

magnetic structures (Harvey and Sheeley, 1979; Harvey et al., 1982) and are connected to interplanetary space. One of the main reasons that CH are important to study is that they are the primary sites of acceleration of high-speed solar wind that has a significant influence on the Earth's ionosphere, auroras, and on the telecommunication systems (Hiremath and Mandi, 2004 and references there in; Hiremath, 2009; Hiremath and Hegde, 2013 and references there in), etc.

Purpose of this study is to investigate whether a large-scale structure like coronal hole oscillates or not. Idea of this study is to examine if large-scale oscillations (rather than small spatial scales) of the coronal hole exist or not. This is equivalent to examining the global oscillations of the sun with small l (degree) modes, such as $l = 1$ or $l = 2$. As oscillations are in three dimensions, summing of intensity of all the pixels of the coronal hole on the surface is equivalent to examining the oscillations of the entire flux tube along the direction of axis of the coronal hole flux tube. Although small spatial scale oscillations and hence phases of the coronal hole observed at corona cancel along the direction parallel to the photosphere, oscillations of large length scale ($\sim$ of dimension of visible diameter of the coronal hole) that have same phase at different heights in the corona may exist. Aim of the present study is to probe such oscillations of the coronal hole if exist.

In the present study, using SDO/AIA data, total intensity (DN counts) of the coronal hole structure in three wavelength bands is examined for the oscillations. Structure of this manuscript is as follows. Section 2 introduces data and analysis technique. In Section 3 we present results. In Section 4, with a brief discussion on the nature of detected oscillations, concluding remarks are presented in Section 5.

2. Data and analysis

Data is taken from *Atmospheric Imaging Assembly (AIA) instrument* (Lemen et al., 2012) on board the Solar Dynamics Observatory (SDO). The instrument provides continuous data of the full Sun with four 4096 X 4096 detectors with a resolution of 0.6 arcsec/pixel. AIA observes at ten different wavelength channels in which three are UV–visible channels and seven are EUV channels (94 Å(Fe XVIII), 131 Å(Fe VIII, XX, XXIII), 171 Å(Fe IX), 193 Å(Fe XII, XXIV), 211 Å(Fe XIV), 304 Å(He II) & 335 Å(Fe XVI)) respectively. This observational spectral range covers coronal temperature structure from $\sim$ 0.6 million °K to $\sim$ 16 million °K. AIA records near-simultaneous images in each temperature filter with a sustained cadence of currently 12 s. Other details about the instrument can be found in Boerner et al. (2012).

With the help of "Spaceweather.com" website, presence of coronal hole (CH) is confirmed and, from AIA web (http://www.lmsal.com/get_aia_data/) cut-out service, CH image is separated for further analysis. This data set contains images observed from 05:00 to 07:00 h UTC on February 08, 2011, in 171 Å, 193 Å and 211 Å pass bands. Cadence of this data set is 12 s. Further, images with embedded coronal hole data is calibrated using aia_prep.-pro. Fig. 1(a) illustrates a typical full disk image of sun taken on February 08, 2011, 05:11:50 UT. Following the method of Hiremath and Hegde (2013), for images of CH, in each wavelength region, threshold intensity (DN counts) for detecting CH boundary is estimated as follows.

In order to extract physical parameters of CH from the cut-out images, we use FV interactive FITS file editor (http://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/). Depending upon shape of the CH, from the FV editor, a circle or an ellipse is drawn covering the whole region of CH and, average DN counts (intensity) (that is set as a threshold for detecting the boundary) of CH is computed for detecting the boundary (private communications with Prof. Aschwanden). Similar to Karachik and Pevtsov (2011), for some of the CH images, threshold is modified to match the visually estimated boundary. This method yields results consistent with the previous intensity histogram methods (Krista and Gallagher, 2009; Krista, 2011; de Toma, 2011 and references there in). In this way, for each wavelengths, typical intensity threshold values for detecting the coronal hole boundary are: (i) for 171 Å-113 DN counts; (ii) for 193 Å-76 DN counts and, (iii) for 211 Å- 30 DN counts respectively. Thus, coronal hole pixels are considered if the pixel values have ranges in between

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