Searching for brightness variations in the solar corona during the total solar eclipse of August 21, 2017

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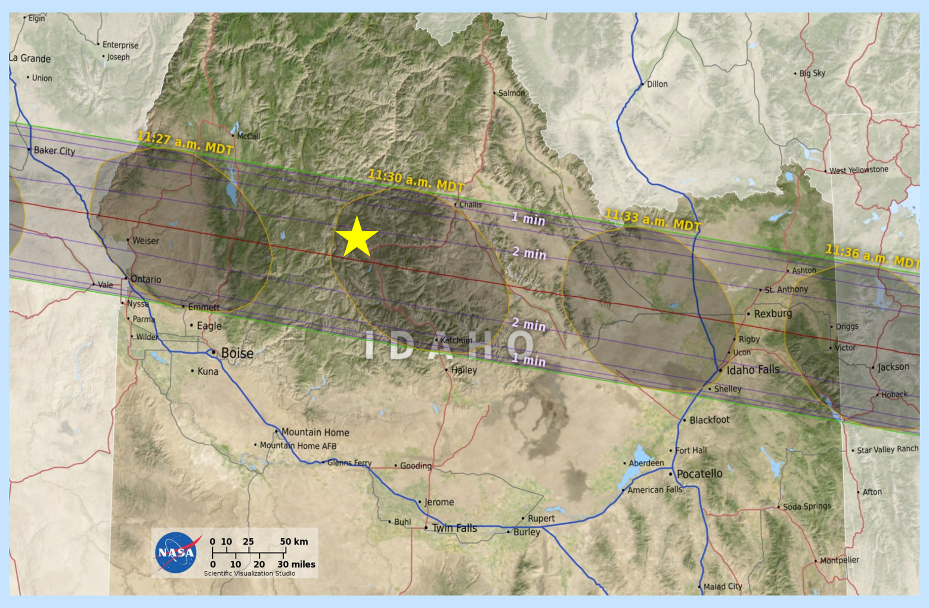
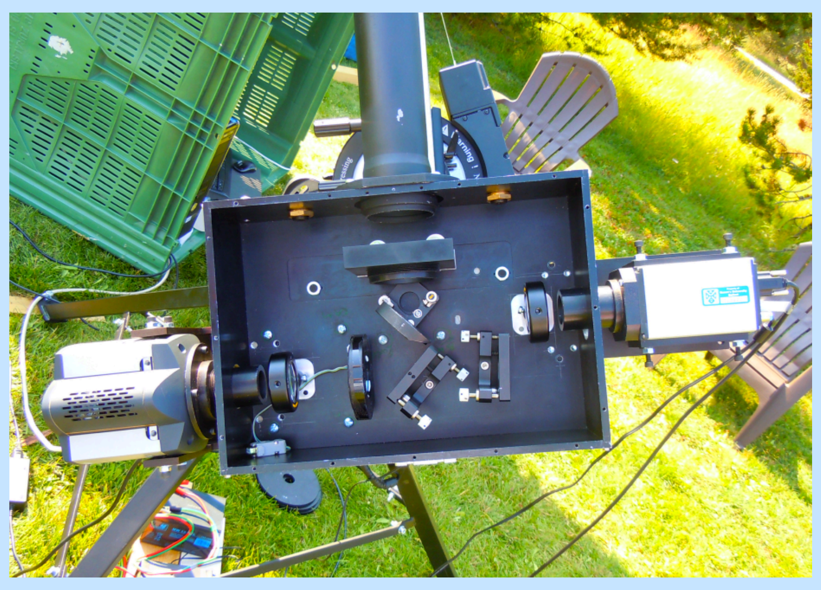
INTRODUCTION

We present the preliminary results of a search for short-period local brightness oscillations in the Fe XIV 530.3 nm solar coronal green line. Such oscillations are expected to be signatures of solar coronal heating by local dissipations of MHD/Alfvén waves. The data were collected by a joint UK-Polish team during the **August 21, 2017** total solar eclipse observed in USA. Over four hundred images of the solar corona above the eastern solar limb were recorded during eclipse totality, with spatial resolution of about of 2″ and with the time cadence of 3.5 images per second.

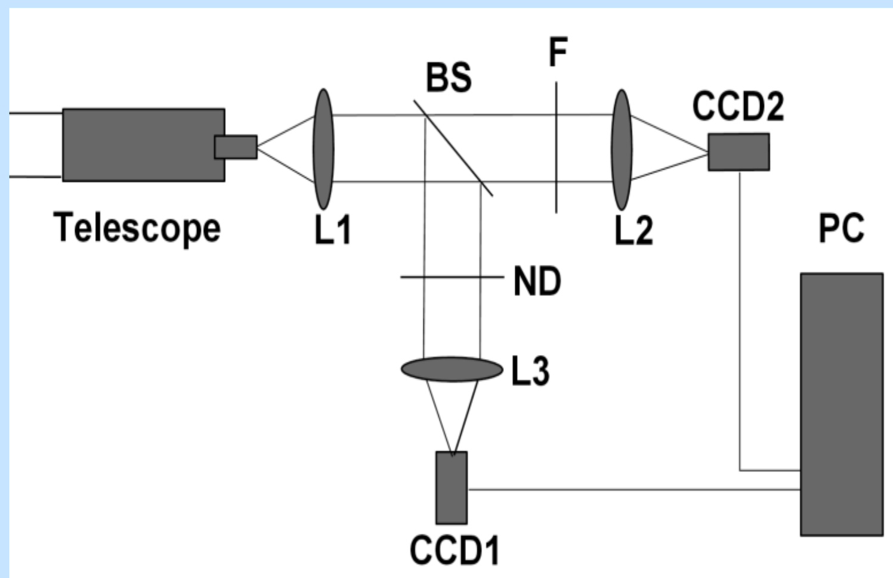


Our observing site was located in Park Creek Ranch, about 10 km to the north from Stanley city, Idaho, US

Observing setup: 20 cm telescope, SECIS II system with 2 cameras for the white light and 530.3 nm coronal line



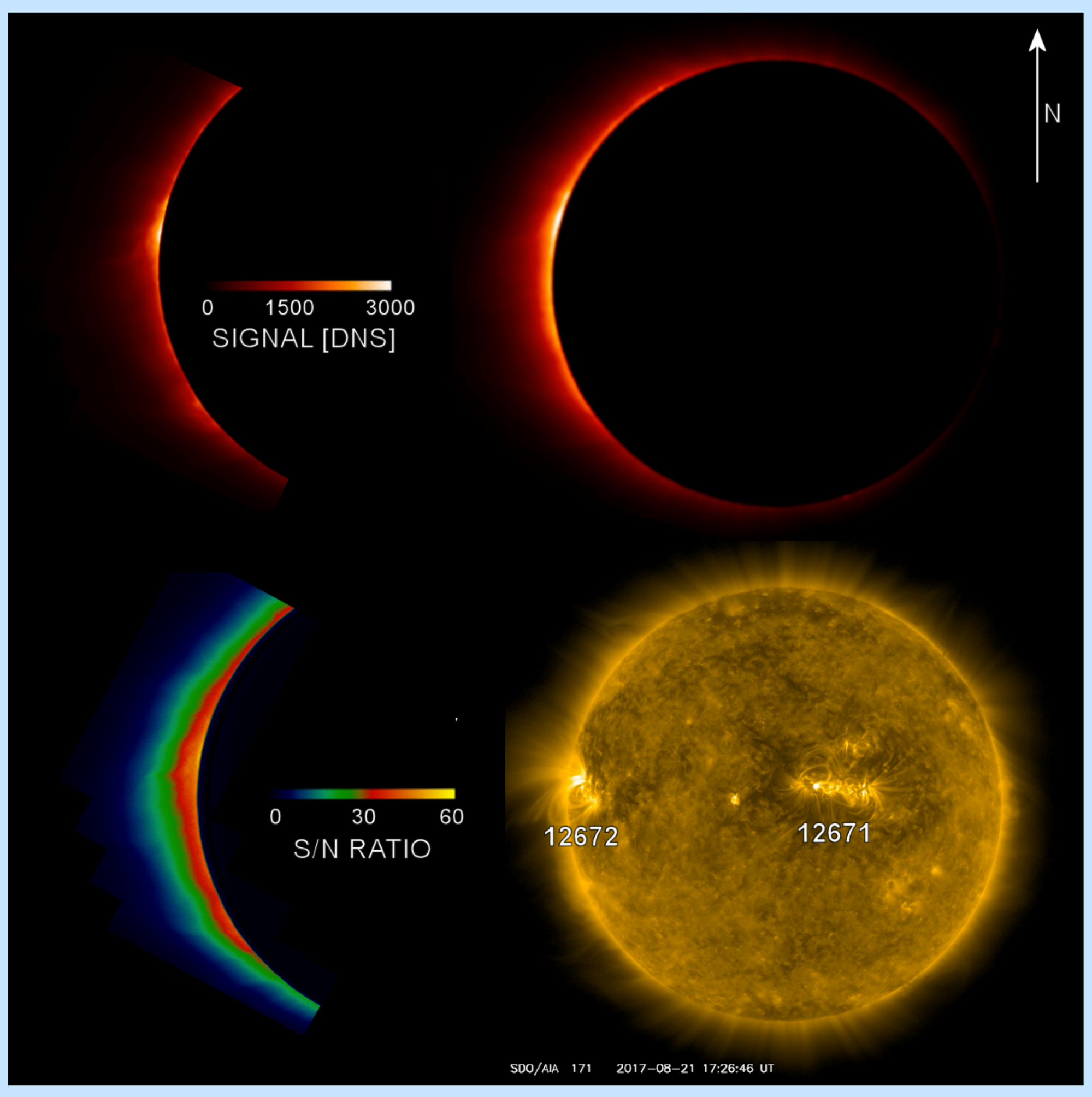
View of the SECIS II system with beam splitter, filters, lenses and 2 CCD cameras.



Schematic layout of the SECIS II optical system

OBSERVATIONS

An image of the solar corona, formed by the telescope, was projected into the SECIS II optical box which consisted of a collimating lens, a pellicle beam splitter, green-line and neutral density filters, and two output lenses forming recorded images. The beam splitter has a 90% transmission in the straight path and 10% in the reflected path, with the former passing through a narrow-band filter centered on the Fe XIV 530.3 nm line. Subsequently, the beam was re-focused on a sensor of the Andor iXon3 885 CCD 16-bit monochrome camera, comprising 1004 X 1002 square pixels of dimensions 8x8 μm^2, with a quantum efficiency of about 55% at 530 nm. Transmission in the white-light beam was through a neutral-density filter at a level of 6.3%, and images recorded with an Andor Zyla 5.5 sCMOS16-bit monochrome camera, consisting of 2560x2160 square pixels with dimensions 6.5x6.5 μm^2.



SELECTION OF THE OBSERVED REGION OF THE SOLAR LIMB

Solar magnetic activity before and during the eclipse was low. Two active regions were seen during the eclipse day: NOAA 12671 near the central part of the solar disk and NOAA 12672 near the east limb.

The selected FOV included a bright system of loops emerging from the active region AR12672.

(Upper left): the eastern part of the solar corona seen in the Fe XIV 530.3 nm green coronal line; **(Upper right):** the white-light corona as viewed after the second contact at 17:28:23 UT. Images are rotated so that the orientation matches the SDO/AIA image, **(Lower left):** signal-to-noise ratio corresponding to the green-line image in the panel above; **(Lower right):** SDO/AIA image taken at 17:26:46 UT. NOAA active region numbers are shown in the SDO/AIA image

HEATING MECHANISMS AND PREVIOUS OBSERVATIONS

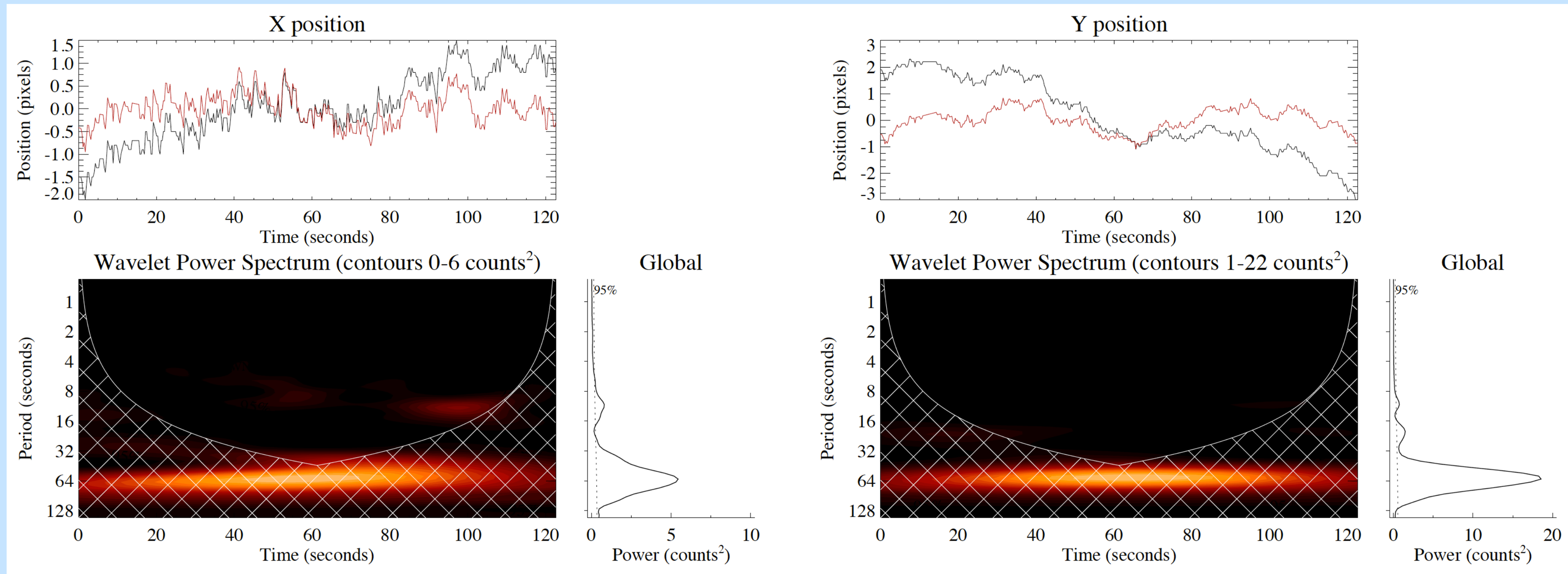
Two possible heating mechanisms acting in the solar corona:
- DC heating mechanism via uncountable tiny local reconnections (nanoflares)
- AC heating mechanism via local dissipation of the MHD or Alfven waves spreading along the magnetic structures

Direct observations of the Alfven waves in the solar corona:
- Alfven waves detected in data of Coronal Multi-Channel Polarimeter (CoMP) Tomczyk et al. 2007
- Alfven waves detected in Hinode/SOT data (De Pontieu et al. 2007)

Previous search for the local periodic brightness variations in the solar corona:
- Weak (<1%) periodic oscillations in FeXIV brightness during the 1980 eclipse (Pasachoff & Ladd 1987)
- Periodic oscillations with periods between 1 and 1.3 sec during the 1999 eclipse (Pasachoff et al. 2002
- Oscillations with periods between 20 and 27 sec during the 2009 eclipse (Singh et al. 2009)
- No significant oscillations detected during the 1999 eclipse (Rudawy et al. 2004)
- No significant oscillations detected during the 2001 eclipse (Rudawy et al. 2010)

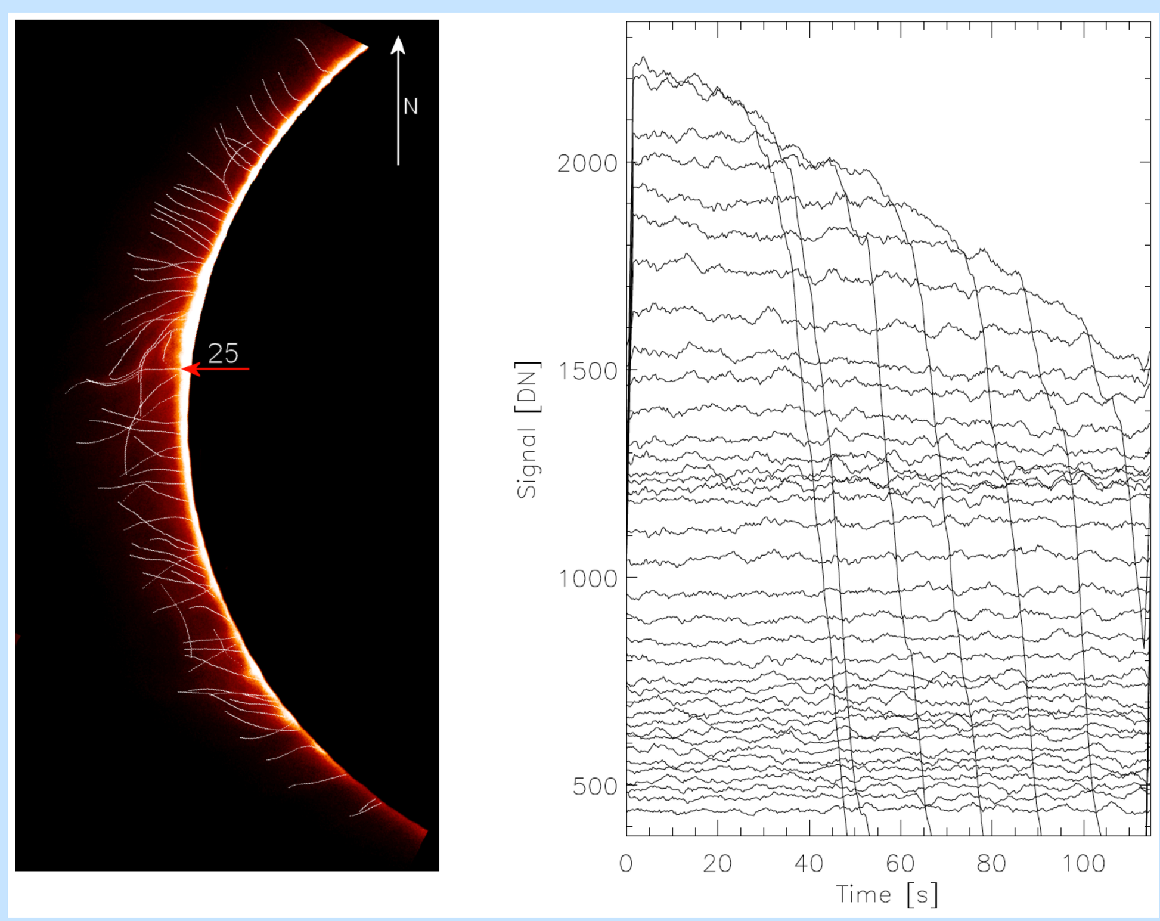
DATA ANALYSIS

FOV STABILITY AND IMAGE COALIGNMENT: The pointing of the telescope was not perfectly stable against the solar corona. Slow drift caused by errors in an adjustment of the drive axes - sub-pixel quasi-stochastic variances of the pointing in both axes. 2D correlations of the bright coronal structures were used to coalign all images.



Temporal variations in the positions of the images collected in the Fe XIV green coronal line during the totality in the reference system of the CCD sensor. The variations of the positions were calculated using two-dimensional correlations of the observed coronal structures. Upper panels: relative translations with (black lines) and without (red curves) general linear trend. The slightly non-linear drift across the field-of-view was caused by the imperfect adjustment of the rotation axes of the equatorial drive. The X- and Y-directions are along the rows and columns of the sensor, respectively. Lower panels: wavelet power spectra of the relative translations without general linear trend. No high-frequency periodic translations were detected.

Observations provided 429 well exposed images of the solar corona in the green coronal line recorded during a 122.9 s portion of the totality (approx. 3.5 images/s), starting from the seventh second of the phenomenon. According to the eclipse circumstances calculated with the Solar Eclipse Computer provided by the Astronomical Applications Department of the U.S. Naval Observatory, totality for the observing site was predicted to last 2m 14.3s , so our images covered nearly 92% of the available time. The unprocessed images show rather diffuse green-line corona over the eastern limb. However, the same images with enhanced contrast revealed many bright loop-like and pillar-like structures, between other numerous loops of various inclinations, some of them associated with the AR 12672, visible near the east limb in SDO/ AIA images.



Using the wavelet spectral analysis technique, temporal variations in 404000 pixels of the images were analyzed and searched for oscillation at frequencies lower than 1.6 Hz. To detect fast-mode magneto-acoustic waves travelling along the magnetic loops observed in our coronal images, we analyzed variations of the local brightness measured at numerous points selected **along the bright structures**. Paths were selected manually, trying to follow visible coronal structures.

Left panel: locations of the 65 paths selected to search for fast-mode magneto-acoustic waves in the loop-like and pillar-like magnetic structures observed over the eastern limb of the Sun during eclipse totality. Selected paths are indicated as chains of white dots in the enhanced contrast image of the solar corona recorded in the green coronal line. The red arrow indicates path number 25.

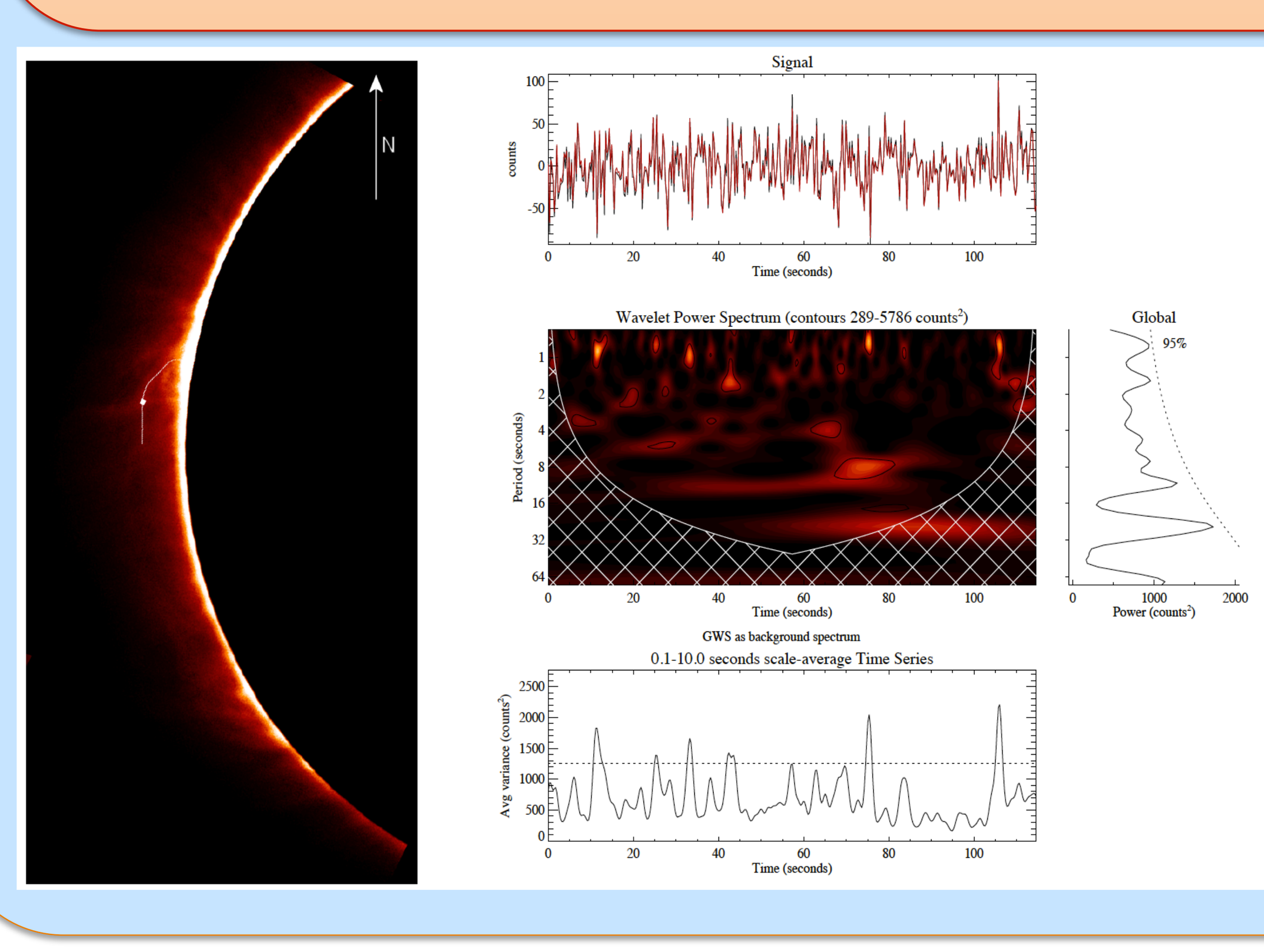
Right panel: light curves measured for consecutive points located along the indicated path. For clarity, only every third light curve is presented, and data are smoothed using 10-point box car for better clarity. The white arrow indicates the north direction.

RESULTS

Although the quality of recorded data was significantly better than observations collected during the previous total solar eclipses, similar to the previous results, no statistically significant evidence for local periodic variations in Fe XIV coronal green line emission was detected. This result suggests that Alfvén-type wave phenomena, even if present in the solar corona, do not lead to periodic intensity fluctuations in coronal emission.

It is also possible that the spatial resolution of the ground-based instruments, limited by their apertures and the atmospheric seeing, is too small to resolve any local variations in the brightness of the solar corona (Porter et al. 1994; Rudawy et al. 2010). This may be due not only to very small diameters of the magnetic structures forming the larger ones observed in the solar corona.

Another reason of no presence of periodic intensity variation can be the fact that in given pixel of the image there is an emission coming from a long volume of the optically thin coronal plasma, then encompassing emissions from numerous individual plasma structures located along LOS. Different phases and amplitudes of variations can be just averaged and thus is possibly below the detection limit.



Wavelet analysis of the local brightness variations in the solar corona recorded in the Fe XIV green coronal line during the total solar eclipse on 21 August 2017. **Left panel:** an enhanced image of the corona with an over-plotted path no. 3, and the analyzed pixel no. 51 marked with a white dot. **Right panels: (upper)** variations of the measured signal in the analyzed point; **(middle left):** the wavelet power spectrum with an over-plotted cone of influence; **(middle right)** global power vs. period; **(lower):** global power vs. time. The applied significance limit is 95%. The white arrow indicates the north direction.