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Coordinated observations between China and Europe to follow active region 12709

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Abstract. We present the first images of a coordinated campaign to follow active region NOAA 12709 on 2018 May 13 as part of a joint effort between three observatories (China-Europe). The active region was close to disk center and enclosed a small pore, a tight polarity inversion line and a filament in the chromosphere. The active region was observed with the 1.5-meter GREGOR solar telescope on Tenerife (Spain) with spectropolarimetry using GRIS in the He I 10830 Å spectral range and with HiFI using two broad-band filter channels. In addition, the Lomnicky Stit Observatory (LSO, Slovakia) recorded the same active region with the new Solar Chromospheric Detector (SCD) in spectroscopic mode at Hα 6562 Å. The third ground-based telescope was located at the Fuxian Solar Observatory (China), where the active region was observed with the 1-meter New Vacuum Solar Telescope (NVST), using the Multi-Channel High Resolution Imaging System at Hα 6562 Å. Overlapping images of the active region from all three telescopes will be shown as well as preliminary Doppler line-of-sight (LOS) velocities. The potential of such observations are discussed.

Keywords. Sun: activity, Sun: chromosphere, Sun: filaments, Sun: magnetic fields

1. Introduction

Solar phenomena extend over many layers of the atmosphere. Frequently magnetic fields are rooted in the photosphere and expand with height and twist, forming helical configurations such as filaments. In order to follow the field lines across the solar atmosphere, multiwavelength observations are crucial. However, current ground-based telescopes such as GREGOR only offer up to three simultaneous instruments which cover different wavelength ranges. To better understand the formation and evolution of solar phenomena we need more co-temporal observations with many wavelengths. This is also the main objective of future high-resolution telescopes such as DKIST (Tritschler *et al.* 2015) and EST (Collados *et al.* 2013). In the meantime, efforts are being done to coordinate high-resolution ground-based telescopes to study our Sun. This work shows the viability of coordinated observations between telescopes in Europe and China, as well as the potential when combining these observations.

2. Observations

Active region (AR) NOAA 12709 was observed on 2018 May 13 very close to disk center at heliographic coordinates (S6°, W3°). The AR was of interest because it enclosed several solar phenomena. In the center of the AR, a narrow polarity inversion line separated an

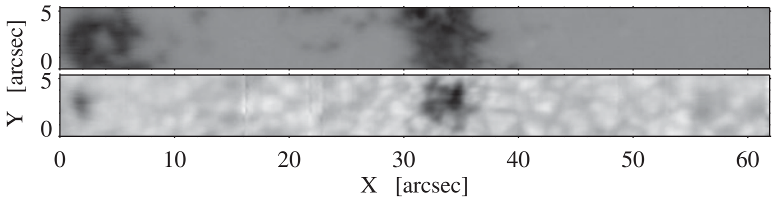

Figure 1. Continuum intensity (*bottom*) and Stokes V (*top*) slit-reconstructed image of AR NOAA 12709 recorded with GRIS between 08:53:13 UT and 08:57:02 UT on 2018 May 13.

extensive area of opposite polarities. Furthermore, a decaying pore was present at the border of the AR and an intermediate filament was seen in the chromosphere.

Four instruments, which were located at three different telescopes around the world, were recording simultaneously this active region: (1) The GREGOR Infrared Spectrograph (GRIS, Collados *et al.* 2012) and (2) the High-resolution Fast Imager (HiFI, Kuckein *et al.* 2017, Denker *et al.* 2018) attached to the 1.5-meter GREGOR solar telescope on Tenerife, Spain (Schmidt *et al.* 2012); (3) The new Solar Chromospheric Detector (SCD, Kucera *et al.* 2015) based on the Lomnicky Stit Observatory (LSO), Slovakia; and (4) the Multi-Channel High Resolution Imaging System (Xu *et al.* 2013) placed at the the 1-meter New Vacuum Solar Telescope, China (NVST, Liu *et al.* 2014).

We observed with HiFI anf GRIS around two hours and twenty minutes the same region (starting at 08:08 UT), mainly focusing on the main pore but also observing the polarity inversion line. The SCD science data were acquired in the time intervals 05:57 – 06:28, 06:43 – 07:19, 08:52 – 09:27, and 09:53 – 10:10 UT. We observed with a good afternoon seeing at the Fuxian lake around 1.5 hours with the Hα filter band on 08:48 – 10:22 UT while we only observed around 20 minutes with the TiO starting at 9:38 UT.

All data were dark and flat-field corrected, as well as polarimetrically calibrated following standard procedures. HiFI and NVST data were restored using the speckle code from Wöger & von der Lühe (2008) and Liu *et al.* (1998), respectively.

3. Combining different telescopes

One big challenge is the combination of data acquired with different instruments. While SCD, NVST, and HiFI are imaging instruments, GRIS is a slit spectrograph. Hence, GRIS only provides slit-reconstructed 2D images (Fig. 1). Furthermore, all instruments have a different image scale. While HiFI provides very high spatial resolution images in the blue wavelength range (about $0.025''\text{pixel}^{-1}$), a lower spatial sampling of $0.136''\text{pixel}^{-1}$ or $0.340''\text{pixel}^{-1}$ is recorded by NVST and SCD in Hα, respectively. Yet, having different image scales can be beneficial because they produce different sizes of the FOV. SCD provides the largest FOV with about $410''\times335''$ (Fig. 2) and therefore it is an excellent instrument to cover context information surrounding the largely spread AR. The images from the 1-meter NVST provide high resolution images of the chromosphere and still cover a large FOV of about $126''\times126''$ (left panel of Fig. 3).

4. Potential of coordinated multiwavelength observations

For the analysis of the central pore in Fig. 3, the combination of the present instruments, together with space telescopes, have the potential to provide: (1) the vector magnetic field and LOS velocities in the photosphere and chromosphere by applying spectral line inversion tools to the four Stokes parameters (GRIS data set); (2) tracking of horizontal flows using the high-resolution data of HiFI and NVST; (3) Doppler velocities of the chromosphere in the whole AR using SCD, to study the connectivity of the pore to the entire AR; (4) context data from the Solar Dynamics Observatory

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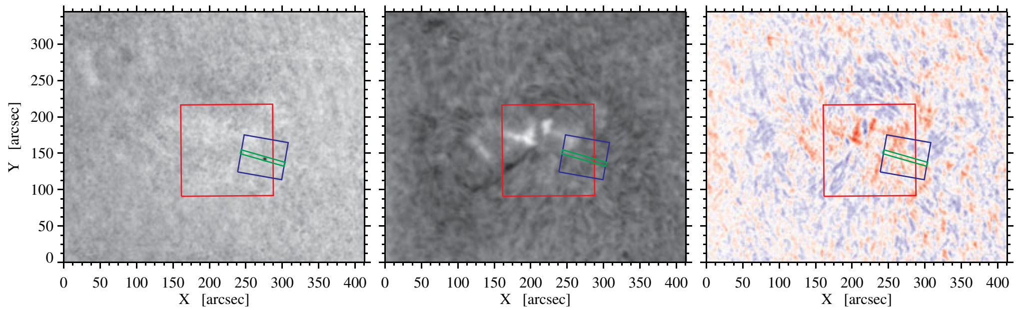

Figure 2. Overview of AR NOAA 12709 obtained with the SCD at 08:53:09 UT on 2018 May 13. Quasi-continuum intensity in the far Hα blue line wing (*left*), Hα line core intensity (*middle*), and Doppler shifts clipped between ± 2 km s^{-1} (*right*). The red and blue rectangles represent FOVs of NVST and HiFI instrument at GREGOR, respectively. The green rectangle represents the FOV covered by GRIS.

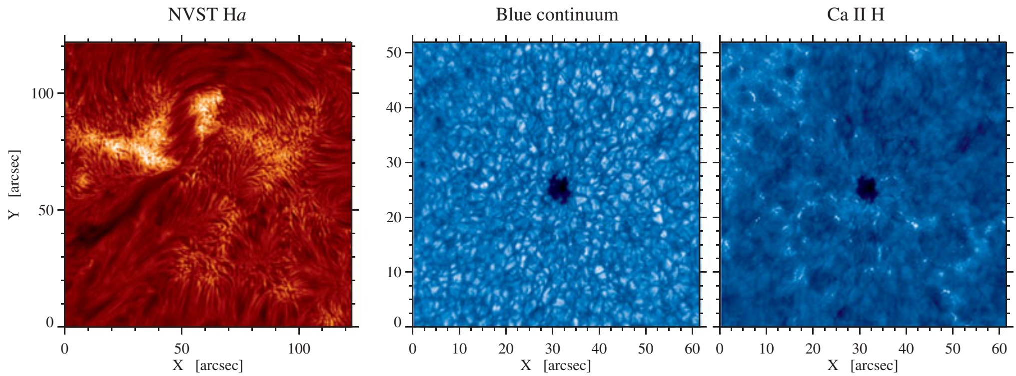

Figure 3. Overview of the active region NOAA 12709 obtained on 2018 May 13. Restored Hα 6562.8 Å image recorded (08:53:05 UT) with the Multi-Channel High Resolution Imaging System placed on the NVST (*left*), and HiFI Speckle-reconstructed (08:53:08 UT) blue continuum 4505 Å (*middle*) and Ca II H 3968 Å (*right*). NVST and HiFI are not showing the same FOV.

(SDO, Pesnell *et al.* 2012) will be used to follow the dynamics of the AR at different coronal layers of the atmosphere. Additionaly, the Helioseismic and Magnetic Imager (HMI, Scherrer *et al.* 2012; Schou *et al.* 2012) provides the possibility to investigate the evolution of the vector magnetic field of the whole AR by carrying out magnetic field extrapolations.

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