Magnetic and Dynamical Parameters of Active Region Filaments

Observing Time Proposal for the 1.5 m solar telescope GREGOR at the Observatorio del Teide, Tenerife, Spain

1 Applicants

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2 Justification

Scientific Objectives of Observing Time

(Please give a statement of the scientific objectives of the requested observing campaign and describe your observing plan in some detail (instrument, spectral line, other instrument specific details). Please make sure that all necessary information is provided.)

Filaments are elongated dark ribbons observed at the solar disk mainly in the chromospheric lines of hydrogen or helium. Filaments can be described as clouds of relatively cool plasma suspended by the magnetic field above the solar surface. They occur in the quiet Sun as well as in active regions. In

the quiet Sun, they are related to a weak magnetic field of the order of 10 G (e.g., Leroy et al., Solar Phys. 83, 135, 1983). But in active regions, the inferred magnetic field strength inside filaments can reach up to 600 - 700 G (Kuckein et al., A&A, 501, 1113, 2009; Kuckein et al., A&A, 539, A131, 2012). In fact, magnetic fields play a key role in all physical processes of the formation and evolution of filaments. Therefore, a better knowledge of the magnetic field in solar filaments is crucial for their complex physical understanding.

Filaments have been observed not only in hydrogen but also often in the neutral helium infrared triplet at 1083 nm. However, observations of filaments in another He spectral line, such as the He I 587.5 nm line (known as D_3 line), are highly desirable and especially valuable in combination with the He I infrared triplet (e.g., Leroy, Solar Phys. 71, 285, 1981). In such measurements, dark Hα structures appear also in He I D_3 in absorption, but not in all cases (Chapman, Solar Phys. 24, 288, 1972). This indicates that one probes different heights in the filament with the Hα, He I 1083, and He I D_3 spectral lines. In the meantime, telescopes with much higher spatial resolution and equipped with adaptive optics are available, as well as sophisticated tools to interpret such data (e.g. the HaZeL-code, Asensio Ramos et al., ApJ 683, 542, 2008). Therefore, simultaneous high-resolution observations taken in the He I 1083 nm and D_3 spectral lines combined with measurements in Hα can provide new insights of the structure and physical parameters of solar filaments. We plan to carry out the first simultaneous observations of He I 1083 nm with GRIS and He I D_3 with GFPI at GREGOR.

Our main goal is the observation of active region filaments acquired with high spatial and spectral resolution and the analysis of their fine structure. In active regions, there is a certain probability that a flare happens related to the rearrangement of the magnetic structure of the filament. So far, only very few observations were obtained where topological changes of the magnetic field within an active region related to a flare could be analyzed. Moreover, the existing studies show controversial results. Hudson et al. (ASP Conf. Ser. 383, 221, 2008) showed evidences that the magnetic vector in the photosphere changes into horizontal fields during the flare. This is supported by recent findings of Wang et al. (ApJL 745, 17, 2012) who found a significant increase of the photospheric magnetic field along the polarity inversion line related to a flare activity. In contrast, Kuckein et al. (ApJL 799, 25, 2015) with data acquired with the Tenerife Infrared Polarimeter at the VTT telescope in Tenerife reported a strong decrease of the magnetic field strength of both, horizontal and vertical components, during a flare.

We expect that observations of active region filaments with high spatial resolution obtained with the GREGOR telescope can significantly contribute to a better understanding of their magnetic field configuration and description of the physical processes related to topological changes of solar magnetic fields during eruptive events. Therefore, we propose here a coordinated observing campaign with other three observatories to investigate active region filaments and the topological changes of the magnetic field during flares. The other involved observatories are: (1) the Lomnicky Peak Observatory in Slovakia with the Coronal Multichannel Polarimeter for Slovakia (CoMP-S), (2) the Kanzelhöhe Observatory in Austria, and (3) the Bialkow Observatory of the University of Wroclaw in Poland.

The following setup will be used for each of the telescopes:

With GREGOR, we plan to acquire high-resolution IR spectro-polarimetric data recorded with the GRIS spectrograph in the 1 μm window to obtain all four Stokes profiles of the He I 1083 nm triplet together with the photospheric lines of Si I 1082.7 nm and Ca I 1083.9 nm. The observing strategy is as follows: we will scan a field of view (FOV) of $\sim 40'' \times 60''$, requiring a total time of about 30 minutes. Simultaneously, we would like to use the GFPI in spectroscopic mode. We plan to perform 2D spectroscopy in the He I 587.5 nm (D_3) spectral line. We are aware that the appropriate prefilter for the He I D_3 line is not available at the site. Therefore, we plan to bring our own prefilter with specifications which fit the requirements of the GFPI. We believe that the combination of simultaneous observations taken in the He I 1083 nm and He I D_3 lines will bring fundamentally new results and will be carried out for the first time at the GREGOR telescope. In addition, the observations will serve as a base for future polarimetric observations with the GFPI in the He I D_3 line.

In addition, we would like to acquire high resolution context images in the blue imaging channel (BIC) of Ca II H and G-band using, if available, the new HIgh resolution Fast Imager (HiFI). We also plan to use the slit-jaw system of the telescope. For a context purposes, we would be grateful also for the ChroTel full disk images. Especially data taken in the Helium channel are of high interest for us.

The CoMP-S is a 2D multi-channel spectro-polarimeter operated at the Lomnicky Peak Observatory. It is attached to a 200/3000 ZEISS coronagraph, but with a neutral filter, measurements on the solar disk are also possible. The observations performed with CoMP-S will cover areas large enough to enclose the whole filament. We plan to take data in two spectral lines (Hα 656.3 nm and Ca II 854.2 nm) that probe different temperature regimes in the filament.

Kanzelhöhe Observatory for Solar and Environmental Research (KSO) regularly performs high-cadence full-disk observations of the Sun in the Hα spectral line, the Ca II K spectral line, and in white-light. The KSO Hα telescope is a refractor with an aperture ratio number of d/f = 100/2000 and a Lyot band-pass filter centered at the Hα spectral line (λ = 656.3 nm) with a Full-Width-at-Half-Maximum (FWHM) of 0.07 nm. The Hα observations are regularly carried out with a cadence of 10 s but could be enhanced up to 2 s in campaign mode (Pötzi et al., SoPh 290, 951, 2015).

Observations will be also supported by two solar telescopes of the Bialkow Observatory of the University of Wroclaw: (1) Large Coronagraph (LC) and (2) Horizontal Telescope (HT). Both instruments can be coupled with the Multichannel Subtractive Double Pass (MSDP) spectrograph and we plan to acquire observations in the Hα spectral line with them. The rectangular entrance window of the MSDP spectrograph covers the area of around 325×41 arcsec^2 on the sky plane. The spectrograph has a nine-channel prism-box creating $\delta\lambda = 0.04$ nm steps in wavelengths between consecutive nine channels at the MSDP spectral images. The effective time step between consecutive scans varied between 10 and 30 s, depending on the scan size.

3 Observing Request

Observing Schedule: 19th - 26th June, 07:30 UT - 13:30 UT

4. Role of Hinode, IRIS and the Ground-based Instruments

Details given above show that the involved instruments will provide 2D data (imaging, imaging-spectroscopy, scanning) which leads to limited time cadence. Thus, 1D (sit-and-stare) spectroscopy with high temporal cadence is missing. But such data are very important for precise description of Active Region dynamic events like flares.

Therefore, we think that running HOP-180 will provide very important data which will complement the other instruments. In addition to the high temporal cadence, Hinode/EIS data cover temperature regimes which are not observed by other instruments. Moreover, the spectral lines selected for HOP-180 allow us to calculate electron densities which is additional physical quantity not provided by the other instruments. So EIS data will significantly contribute to clarifying the complexity of the overall observations.

In addition to Hinode/EIS, observations with IRIS have been agreed by the IRIS Team. The IRIS observations will be as follows:

- observing mode: sparse rasters (with 1" step size) with FoV of 31"x120" (i.e., scans with 32 steps).
- exposure time: 4s
- slit-jaw: cycle of all four slit-jaw channels (cadence = 20.7 s)
- binning: on-board binning (2x spatial, 2x spectral)
- spectral lines: flare line list
- raster cadence: 165.53 s

The ground-based instruments will provide the following data:
GREGOR/GRIS: Slit spectrograph, spectropolarimetry with He I 10830. FOV: 40" x 60", ~ 30 min cadence

GREGOR/GFPI: Fabry Perot, imaging spectroscopy with He I D3 5875. FOV: 55" x 41" cadence: 2-3 min

GREGOR/HiFI: imaging in the blue continuum; e.g., blue continuum (450 nm) + Ca II H (396 nm)). FOV: 73" x 56", fast cadence: 1 image below 1 second BUT ONLY IMAGING
CoMP-s: spectro-polarimeter with Halpha and Ca II 854 cadence: 2-3 minutes

Kanzelhoehe: full-disk filtergrams Halpha.

5. Previous HOP 180 Publications

- Gömöry, P.; Veronig, A. M.; Su, Y.; Temmer, M.; Thalmann, J. K.: Chromospheric evaporation flows and density changes deduced from Hinode/EIS during an M1.6 flare. Astronomy & Astrophysics, Volume 588, id.A6, 12 pp.
- Veronig, A. M.; Gömöry, P.; Kienreich, I. W.; Muhr, N.; Vršnak, B.; Temmer, M.; Warren, H. P.: Plasma Diagnostics of an EIT Wave Observed by Hinode/EIS and SDO/AIA. The Astrophysical Journal Letters, Volume 743, Issue 1, article id. L10, 7 pp.
- Harra, L. K.; Sterling, A.C.; Gömöry, P.; Veronig, A.: Spectroscopic Observations of a Coronal Moreton Wave. The Astrophysical Journal Letters, Volume 737, Issue 1, article id. L4, 6 pp.