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Synoptic maps in three wavelengths of the Chromospheric Telescope

Andrea Diercke[1,2] **and Carsten Denker**[1]

[1]Leibniz-Institut für Astrophysik Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany
email: adiercke@aip.de

[2]Universität Potsdam, Institut für Physik und Astronomie, 14476 Potsdam, Germany

Abstract. The Chromospheric Telescope (ChroTel) observes the entire solar disk since 2011 in three different chromospheric wavelengths: Hα, Ca II K, and He I. The instrument records full-disk images of the Sun every three minutes in these different spectral ranges. The ChroTel observations cover the rising and decaying phase of solar cycle 24. We started analyzing the ChroTel time-series and created synoptic maps of the entire observational period in all three wavelength bands. The maps will be used to analyze the poleward migration of quiet-Sun filaments in solar cycle 24.

Keywords. Sun: chromosphere, Sun: filaments, methods: data analysis, techniques: image processing

1. Introduction

Synoptic maps allow us to see a more global view of the Sun and enable studying large-scale relations over a longer period of time. The first synoptic maps of the Sun were created for sunspot observations (Carrington 1858). Later physical relations were determined from such synoptic maps such as Spörer's Law (Cliver 2014). Nowadays, synoptic maps are available for many physical parameters. One prominent example are the hand-drawn McIntosh synoptic maps (Gibson *et al.* 2017), which facilitate determining a relation between open magnetic structures (coronal holes) and closed magnetic structures (filaments or active regions). Another example are long-term studies of filaments with full-disk images from the Kodaikanal Observatory from 1914–2007 (Chatterjee *et al.* 2017). In the following sections, we will present synoptic maps in three different chromospheric wavelengths, which will be used to study the polarward migration of high-latitude filaments during solar cycle 24.

2. Observations

The Chromospheric Telescope (ChroTel, Kentischer *et al.* 2008; Bethge *et al.* 2011) is a full-disk imager mounted on the telecope building of the Vaccum Tower Telescope (VTT, von der Lühe 1998) at the Observatorio del Teide in Tenerife, Spain. ChroTel is a robotic 10-cm aperture telescope observing the solar chromosphere in three different wavelengths since 2011. The telescope obtains full-disk images with 2048 × 2048 pixels in Hα λ6562.8 Å, Ca II K λ3933.7 Å, and He I λ10 830 Å using narrow-band Lyot filters. At the last spectral region, the instrument observes at seven filter positions, ±3 Å around the line core of the He I red component. In principle, ChroTel contributes to a variety of scientific topics (Kentischer *et al.* 2008), e.g, the dynamic response of the chromosphere to photospheric driving or the chromospheric source of the fast solar wind. For both topics, the calculation of Doppler velocities from the spectroscopic He I data is required.

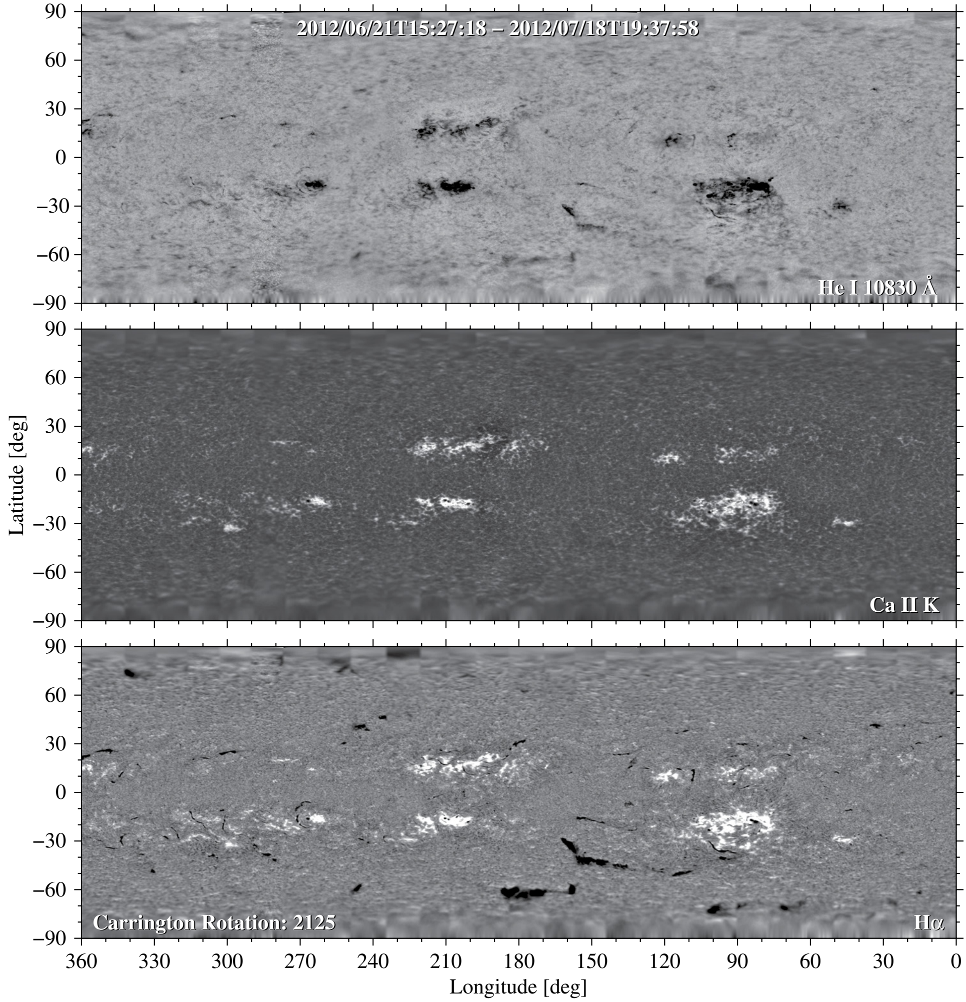

Figure 1. Synoptic map for Carrington rotation 2125 in different wavelengths: He I λ10 830 Å (line core), Ca II K, and Hα. The full-disk images were corrected for limb darkening and intensity variations, derotated to the corresponding time in the Carrington grid, and merged together to create a Carrington map with a sampling of 0.1°.

In addition, ChroTel full-disk images assist in finding large-scale structures and track the chromospheric plasma during and after eruptive events. The cadence between the images of the same filter is three minutes in the standard observing mode. Higher cadences of up to 10 s are possible, for example, during periods with enhanced flare activity.

The synoptic maps from ChroTel contain, among others, information about the number, location, area, and orientation of the filaments. The location of filaments follows the solar activity cycle. We focus in our study on large-scale filaments, polar crown filaments, and high-latitude filaments and their propagation towards the pole, which is known as "dash-to-the-pole" (Cliver 2014). Furthermore, other properties of filaments can be determined from these data such as length, width, and lifetime, which can be statistically analyzed throughout the cycle.

3. Methods

Between 2012 and October 2018, ChroTel observed the Sun in Hα on 950 days. For each day we downloaded all images in Hα and selected the best image of the day by calculating the Median Filter-Gradient Similarity (MFGS, Deng *et al.* 2015; Denker *et al.* 2018). In addition, we downloaded the closest images in time for Ca II K and He I. In the pre-processing, we rotated and rescaled the images, so that the radius corresponds to $r = 1000$ pixels, which yields an image scale of about $0.96''$ pixel^{-1}. Furthermore, all images are corrected for limb-darkening as described in Diercke *et al.* (2018). Due to intensity variation introduced by filter transmission, we had to correct all the images with a newly developed method using Zernike polynomials to compute an even background (Shen *et al.* 2018, submitted). To create the Carrington maps, one image a day was derotated to the corresponding longitudinal positions on a Carrington grid. These image slices were merged together to create a Carrington map for each rotation with a sampling of 0.1°. The process is repeated for all three wavelength bands (Fig. 1). In the Hα data we clearly recognize the filaments as elongated black structures, whereby the active regions appear bright. The map of Carrington Rotation 2125 also contains polar crown filaments (PCFs). In the He I data, the active regions and filament regions appear dark. The Ca II K line is sensitive to magnetic fields and appears bright at these locations. The filaments are not recognizable at this wavelength.

4. Future Plans

The final goal is to create a super-synoptic map with the location of the filaments to study the “dash-to-the-pole” of the PCFs in cycle 24, not only in Hα, but also in the He I triplet, as well as with full-disk Doppler maps. To extract the filament information, we will compare two methods: morphological image processing and neural networks. In addition, the statistical properties of the filaments will be scrutinized. Xu *et al.* (2018) describe solar cycle 24 as “abnormal” because of a faster poleward migration of the southern PCFs compared to other cycles. This poleward movement will be validated with the ChroTel data set.

References

Bethge, C., Peter, H., Kentischer, T. J., *et al.* 2011, Astron. Astrophys., 534, A105

Carrington, R. C. 1858, Mon. Not. R. Astron. Soc., 19, 1

Chatterjee, S., Hegde, M., Banerjee, D., & Ravindra, B. 2017, Astrophys. J., 849, 44

Cliver, E. W. 2014, Space Sci. Rev., 186, 169

Deng, H., Zhang, D., Wang, T., et al. 2015, Sol. Phys., 290, 1479

Denker, C., Dineva, E., Balthasar, H., et al. 2018, Sol. Phys., 293, 44

Diercke, A., Kuckein, C., Verma, M., & Denker, C. 2018, Astron. Astrophys., 611, A64

Gibson, S. E., Webb, D., Hewins, I. M., et al. 2017, in IAU Symposium, Vol. 328, Living Around Active Stars, ed. D. Nandy, A. Valio, & P. Petit, 93–100

Kentischer, T. J., Bethge, C., Elmore, D. F., et al. 2008, in Proc. SPIE, Vol. 7014, Ground-Based and Airborne Instrumentation for Astronomy II, ed. C. M. M. McLean, I. S., 701413

Shen, Z., Diercke, A., & Denker, C. 2018, Astron. Astrophys., submitted

von der Lühe, O. 1998, New Astron. Rev., 42, 493

Xu, Y., Pötzi, W., Zhang, H., et al. 2018, Astrophys. J., 862, L23