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SOLAR CA II K PLAGE REGIONS AS PROXIES FOR MAGNETIC FIELDS OF SOLAR LIKE STARS

S. GUTTENBRUNNER[1], A. HANSLMEIER[1], D. UTZ[1,2], B. LEMMERER[1], I. PIANTSCHITSCH[1] and S. THONHOFER[1,2]

[1] *IGAM/Institute of Physics, Karl Franzens University of Graz, Universitätsplatz 5, AT–8010 Graz, Austria*
[2] *Instituto de Astrofísica de Andalucía (CSIC), Granada, Glorieta de Astronomía s/n, ES–18008 Granada, Spain*

Abstract. Solar plage regions can be observed directly, whereas plage regions as well as star-spots on solar like stars, can only be detected via their contribution to spectral irradiances of these stars. Such a spectral irradiance can be modelled by fractions belonging to the quiet star, the plage regions, and the star-spots. The idea is, to measure these fractions as well as the intensity enhancement due to plage regions on our Sun and then use this information to be able to model solar like stars. We verify the close connection between the size of the plage regions and the luminosity of the Sun, given by a correlation coefficient of 0.822. The size of the plage regions varies from 0%, when the Sun is very quiet, up to 2.7% for a more active Sun (a complete solar cycle is not yet analysed and hence our study does not contain an activity maximum). The used data sets are full-disc images taken by the RISE/PSPT instrument during the period from 2005 to 2012, at the MLSO.

Key words: Ca II K plage region - chromosphere - RISE/PSPT - MLT

1. Introduction

Solar Ca II K plages are regions of enhanced brightness, which can be seen directly in the chromosphere of the Sun in the Ca II K line. They represent medium-sized magnetic fields of the Sun and are strongly correlated to the variation of the activity of the Sun. By measuring the fractions of the quiet Sun, the plage regions, and the sunspots as well as their intensity enhancements compared to the mean quiet Sun, we will also be able to derive more information about the variation of magnetic activity on solar like stars. A similar approach was previously outlined by Lean *et al.* (1998).

2. Data

The used data set consists of 96 images observed in the spectral line of Ca II K during eight consecutive years of observations. The images are obtained via the PSPT website `http://lasp.colorado.edu/pspt_access`. We selected one representative image per month, starting from January 1st, 2005 and lasting till December 31st, 2012. These images are obtained fully processed (dark current and flat field corrected) and taken by an instrument delivering exposures with a diffraction limited resolution of about 2 arcsec/pixel. Hence the designers of the instrument implemented a CCD with a spatial sampling of 1 arcsec/pixel.

The PSPT *(Precision Solar Photometric Telescope)* is the scientific instrument of the RISE *(Radiative Inputs from Sun to Earth)* project and operates with three interference filters (Ca II K, blue and red). The main purpose of this project is to measure the contribution of the brightness structure of magnetic active regions to the total solar irradiance, i.e. the contribution of plages and sunspots. Further information about the RISE/PSPT project is given in Coulter and Kuhn (1994) and Ermolli *et al.* (1998).

3. Analysis

Our first approach consists of choosing a threshold for segmenting the images in regards of plage regions visually, allowing us to estimate the coverage of the plage regions and the variation in brightness of the Sun. Therefore, we choose an initial threshold value visually by comparing the bright regions from the original image with the binary mask of the thresholded and hence segmented image of it. This chosen threshold value is fixed for all images, but does not fit for all images, because of their different intensity distributions (caused by, e.g., different exposure time). Thus, the visual selection is only a rough tool for estimating the size of the plage areas. For precise estimation of the size of plage regions, we applied an automatic Multi-level threshold algorithm *(MLT)*.

This algorithm was originally developed by Bovelet and Wiehr (2001) and later run time improved by Lemmerer *et al.* (2012). For its successful and consistent identification of plage regions we have to modified the data by setting negative pixel values (coming from a non perfect calibration) to zero, normalizing the data to values within an interval between 0 to 1, and applying a correction for different exposure times by co-aligning the frequency maxima of individual intensity distributions (see Fig. 1). Afterwards, we set an initial threshold value of 0.77, for identifying the initial seeds of the bright regions lying above this threshold. Then we decrease the threshold by a step size of 0.04 and adding up newly found adjacent regions to the already previously identified bright regions. In Fig. 2, we show two examples of identified plage regions based on the MLT algorithm.

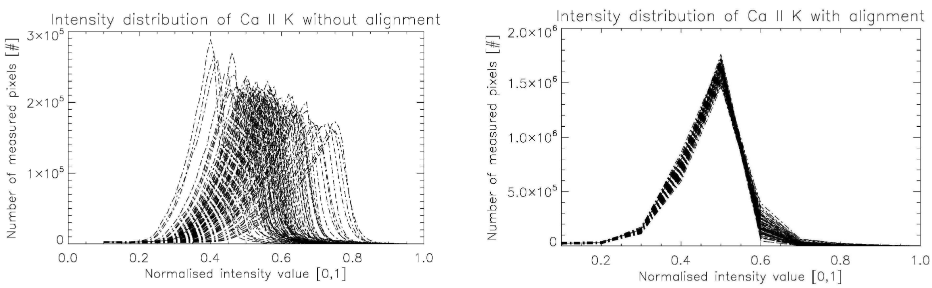

Figure 1: Left side: Original intensity distribution of 96 images of the Sun in the spectral line of Ca II K. Right side: The intensity distribution after the intensity co-alignment.

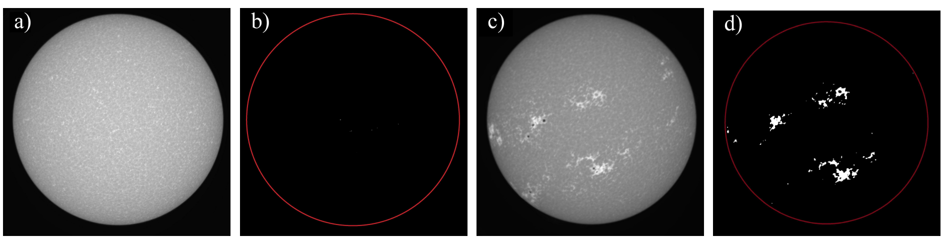

Figure 2: An example of a quiet (a) and active (c) image of the Sun with their segmentation masks (b and d, respectively).

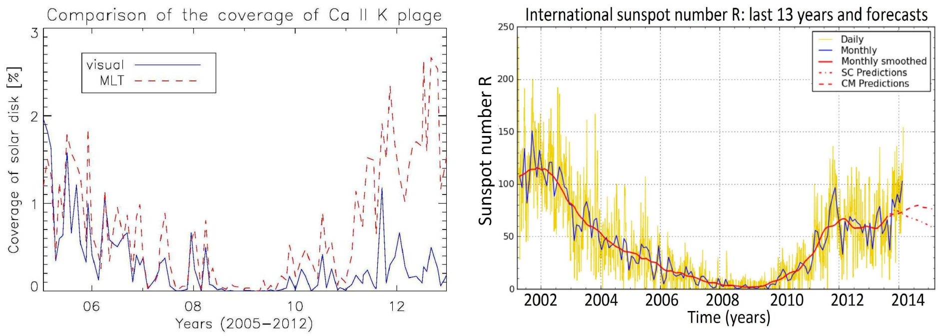

Figure 3: Left side: Results for the Ca II K plage coverage between the years 2005 and 2012 as proxy for the activity of the Sun. Right side: The sunspot numbers taken from the website of the Royal Observatory of Belgium (2014), for comparison reasons.

4. Results

Figure 3 shows the coverage of the plage regions (left), which represents the activity of the Sun in a similar fashion as the sunspot number obtained by the Royal Observatory of Belgium (right). The total area of plage regions determined by the two applied algorithms is comparable from 2005 until 2011 (left plot in Fig. 3). However, significant differences can be seen in 2012 due to different exposure times of the analysed images leading to unrealistically small plage regions for the visual method. Therefore, we will focus in the following on the more accurate results of the MLT algorithm.

Figure 4 outlines the close connection between the size of the plage areas (top) and the resulting change in brightness of the Sun (middle), which is also shown by the high correlation coefficient of 0.822 between these two parameters (bottom). When the Sun is very active, the value of the coverage for the solar surface with plage regions increases up to 2.7% and the Sun irradiates stronger by -0.15^m compared to the average quiet Sun.

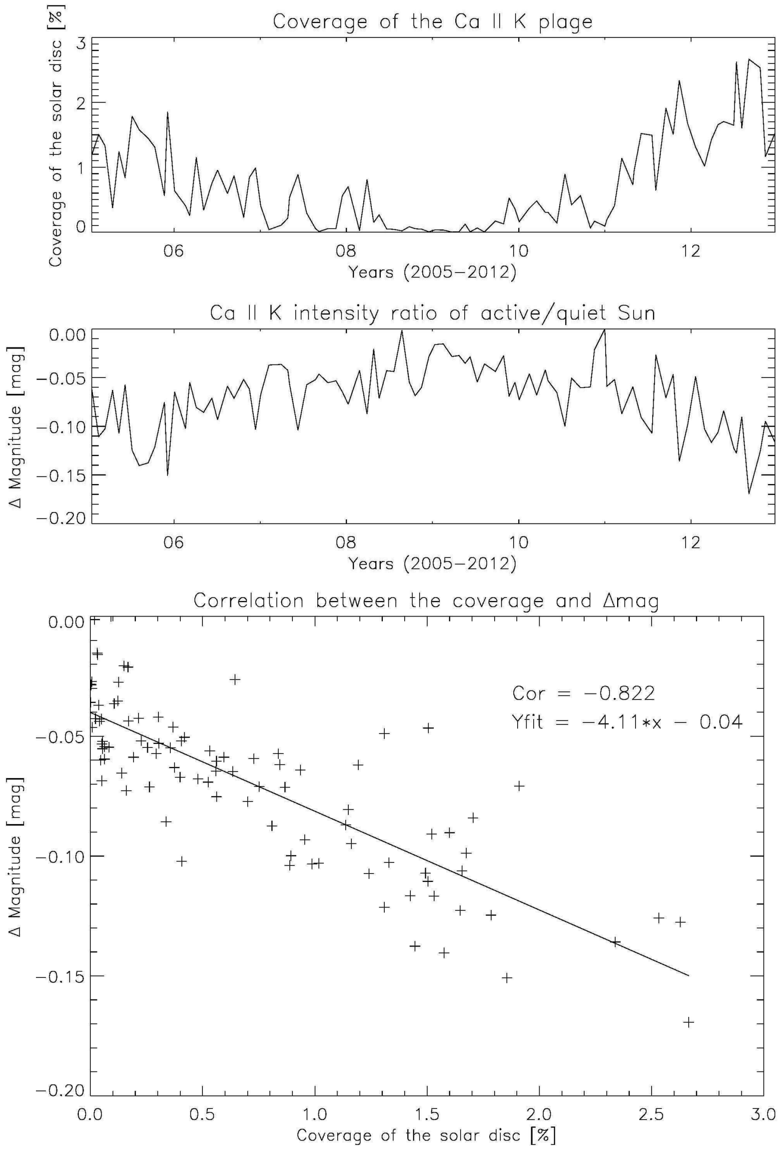

Figure 4: The upper panel shows the coverage of the plage regions compared to the full disc of the Sun. The Ca II K intensity ratio of active/quiet Sun is given in the middle panel and the lower panel shows the correlation between these two parameters.

5. Outlook

The next step will be, to observe images of the Sun in the Ca II K spectral line containing only sunspots (without plage regions) and afterwards, to observe only images containing plage regions. By doing so, we will be able to disentangle the effects of sunspots and plage regions on the total spectral irradiance and hence estimate the corresponding enhancement factors. These results can then be applied to solar like stars in order to gain information about the magnetic fields of these stars. Moreover, this approach can be executed for other spectral lines as well (e.g, Mg II k and/or Hα) leading probably to the possibility of modeling the stars magnetic fields and its components (spots, plage regions).

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References

Bovelet, B. and Wiehr, E.: 2001, *Solar Phys.* **201**, 13.

Coulter, R. L. and Kuhn, J. R.: 1994, *in* K. S. Balasubramaniam and G. W. Simon (eds.), *Solar Active Region Evolution: Comparing Models with Observations*, Vol. 68 of *Astronomical Society of the Pacific Conference Series*, p. 37.

Ermolli, I., Fofi, M., Torelli, M., and Reardon, K.: 1998, *Mem. Soc. Astron. Ital.* **69**, 631.

Lean, J. L., Cook, J., Marquette, W., and Johannesson, A.: 1998, *Astrophys. J.* **492**, 390.

Lemmerer, B., Utz, D., Hanslmeier, A., Kühner, O., Grimm-Strele, H., Pauritsch, J., Thonhofer, S., and Muthsam, H.: 2012, *Cent. Eur. Astrophys. Bull.* **36**, 29.

Royal Observatory of Belgium: 2014, Daily and monthly sunspot number (last 13 years).
URL: *http://sidc.oma.be/sunspot-index-graphics/wolfjmms.php*