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Radiative emission of solar features in Ca II K

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Abstract. We investigated the radiative emission of different types of solar features in the spectral range of the Ca II K line. We analyzed full-disk $2k\times 2k$ observations from the Precision Solar Photometric Telescope (PSPT). The data were obtained by using three narrow-band interference filters that sample the Ca II K line with different pass bands. Two filters are centered in the line core, the other in the red wing of the line. We measured the intensity and contrast of various solar features, specifically quiet Sun (inter-network), network, enhanced network, plage, and bright plage (facula) regions. Moreover, we compared the results obtained with those derived from the numerical synthesis performed for the three PSPT filters with a widely used radiative code on a set of reference semi-empirical atmosphere models.

Key words. Techniques: photometric – Sun: atmosphere – Sun: photosphere – Sun: magnetic fields

1. Introduction

The intensity of the Ca II K resonance line observed with spectrographs and Lyot-type filters has long served as a diagnostic of the solar chromosphere and as an indicator of magnetic activity. However, the literature is lacking in long term analysis of the radiative properties of solar features in this spectral range. Measurements of large-scale phenomena on Ca II K images provide us with observational constraints for modeling the solar atmosphere, the differential rotation and meridional circulation, and the behavior of the solar dynamo. Moreover, they give input for improving the calibration and analysis of historical Ca II K observations, which were made at several observatories for many years.

We investigated the radiative emission of different types of solar features in the spectral range of the Ca II K line. We analyzed full-disk $2k\times 2k$ observations from the Precision Solar Photometric Telescope (PSPT, Coulter & Kuhn 1994; Ermolli et al. 1998; Rast et al. 2008). The data were obtained by using three narrow-band interference filters that sample the Ca II K line with different pass

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bands. Two filters are centered in the line core, specifically PK-027 and PK-010. The other filter, PKR-011, is centered in the red wing of the line. We measured the intensity and contrast of various solar features, specifically quiet-Sun (inter-network), network, enhanced network, plage, and bright plage (facula) regions. Moreover, we compared the results obtained with those derived from the numerical synthesis performed for the three PSPT filters with the RH code Uitenbroek (2001, 2002) on a set of reference atmosphere models Fontenla et al. (2007, 2009).

2. Observations

We analyzed 157 sets of full-disk observations available on the MLSO PSPT archive for the period June 7th to July 31st, 2007.

All the images were pre-processed to apply the standard instrumental calibration (Rast et al. 2008). Then, each image was resized and aligned, by using linear interpolation, to a common reference grid in which the solar disk size is constant.

Figure 1 shows central disk details extracted from the PSPT images obtained with the three filters sampling the Ca II K line with different pass bands, specifically PK-027 (top), PK-010 (middle), and PKR-011 (bottom). Visual inspection reveals that the same set of disk features is present in all the images, although their contrast and area look different.

The transmission profiles measured for the three PSPT filters are larger than the ones measured for a typical Lyot-type birefringent filter and do not allow the separation of the features of the Ca II K line.

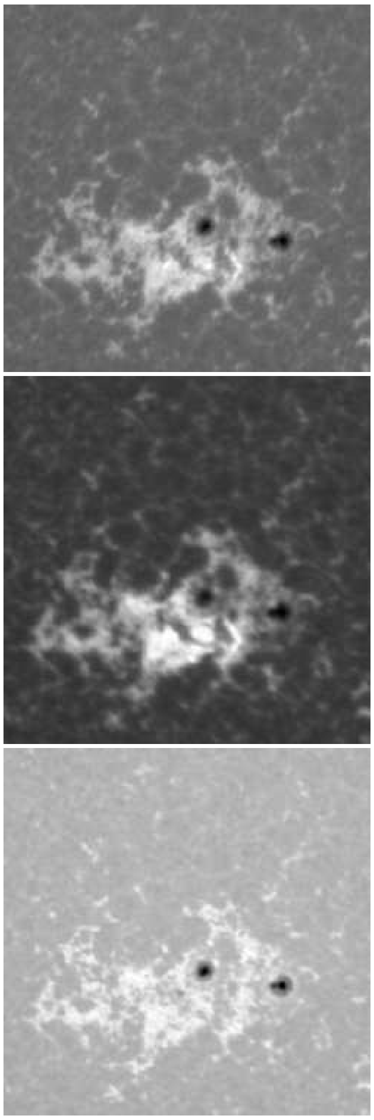

Fig. 1. Central disk details extracted from the PSPT images obtained with the three filters sampling the Ca II K line with different pass bands, specifically PK-027 (top), PK-010 (middle), and PKR-011 (bottom).

3. Method

We computed synthetic spectra in the range of Ca II K with the RH code developed by Uitenbroek (2001, 2002). Our calculations were performed assuming non-LTE and PRD through the set of atmosphere models presented by Fontenla et al. (2007) and Fontenla et al. (2009). These models describe the temperature and density vertical stratification of various solar features: quiet Sun (model B), network (model D), enhanced network (model F), plage (model H), and bright plage (model P).

We used the SRPM image decomposition method (Fontenla et al. 2009) to separate the various solar features.

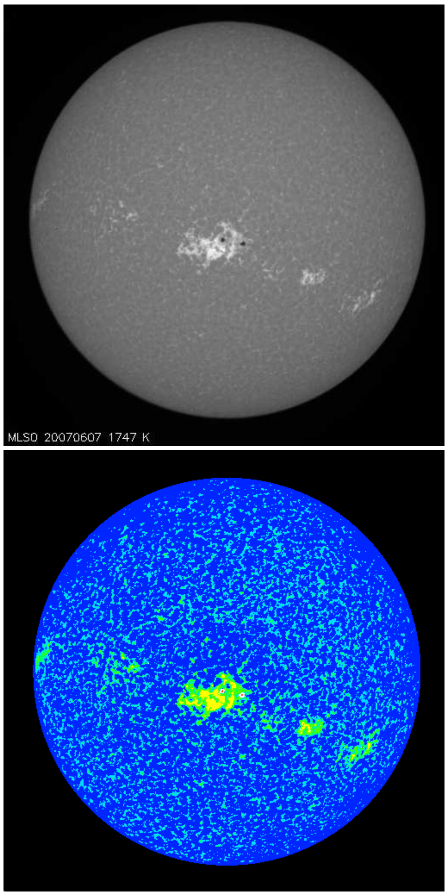

Fig. 2. Example of PK-027 (top panel) observation analyzed in this study and of the corresponding mask image (bottom panel). This observation was taken on June 7th 2007. The disk features identified on the images are shown with different colors; blue, light blue, green, and yellow show quiet Sun, network, enhanced network and plage regions; white and red show penumbra and umbra regions (visible only by blowing up the figure). Black shows off-disk regions. A color version of this figure is available in the online version of this paper.

Figure 2 shows an example of the PK-027 observation and corresponding mask (bottom) obtained with the image decomposition. The various disk features are shown in different colors; blue, light blue, green, and yellow show quiet Sun, network, enhanced network and plage regions.

4. Results

For each atmosphere model, we calculated with RH the Response Functions (RFs) at the disk center for the various PSPT filters and atmosphere models. These RFs indicate that the filters sample quite wide ranges of atmospheric heights, but the radiative signals are dominated by the wings of the Ca II K line, that form at heights lower than 500 km. These RFs also confirm that the narrower filters sample higher layers than broader ones; the filters in the line core also sample higher layers.

Next, for each filter and disk feature, we analyzed the median and the standard deviation of intensity values measured in 50 equal-area annuli around the solar disk center. Figure 3 shows the comparison between the center-to-limb variation (CLV) of intensity values measured on PSPT images (symbols) for the various disk features and those derived from the spectral synthesis (lines) performed for the same filters on the reference atmosphere models. All the values are normalized to the intensity obtained at the disk center. The results for the various filters are shown with different symbols and line-styles; green diamond and solid line, violet square and dotted line, and red asterisk and dashed line show the results obtained for PK-027, PK-010, and PKR-011, respectively.

We also analyzed the contrast CLV measured on PSPT images for the various disk features. For each disk position and feature, the contrast was defined as the ratio between the intensity value derived for the feature and the value obtained for the quiet Sun. Finally, we compared the results of our measurements with those derived from the spectral synthesis.

5. Conclusions

We studied the radiative emission of solar features at the Ca II K spectral range. We analyzed moderate resolution PSPT observations taken with interference filters that sample the Ca II K range with different pass bands. We compared the results of our CLV measurements for various disk features with the output of the spectral synthesis performed on the most recent set of

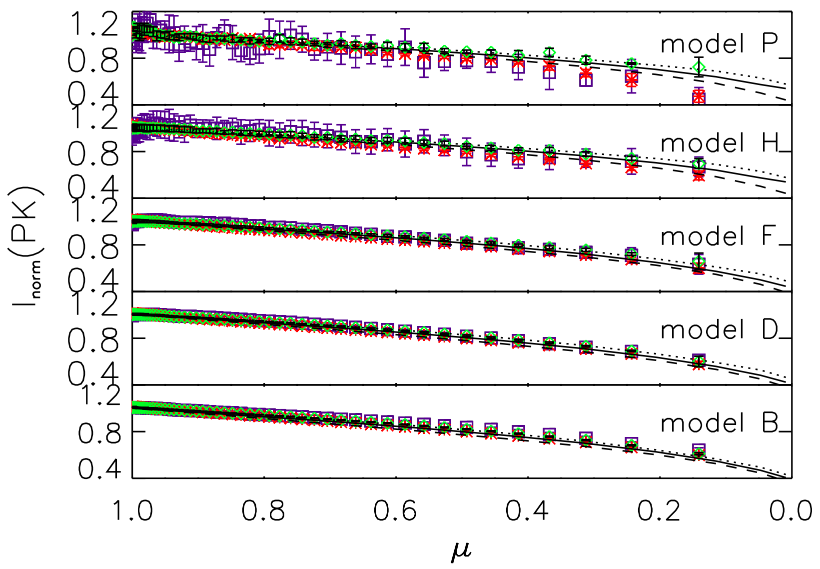

Fig. 3. Comparison between the CLV of intensity values measured on PSPT images (symbols) for the various disk features and those derived from the spectral synthesis (lines) performed for the same filters on the reference atmosphere models. All the values are normalized to the intensity obtained at the disk center. The results for the various filters are shown with different colors and line-styles as described in the text. A color version of this figure is available in the online version

semi-empirical atmosphere models presented in the literature by Fontenla et al. (2007, 2009).

We found that the Response Functions derived for the three PSPT filters depend only slightly on the filter band pass and reference atmosphere; the most sensitive are the ones derived for the filters with the narrowerband and for the reference atmosphere of bright plage (model P). We also found that the CLV of contrast values measured for the various features observed at the line core with the PK-010 filter are in good agreement with the outcome of the spectral synthesis. However, the CLV of the contrast obtained for the plage regions (model H) identified in our observations has a larger decrease toward the limb than the one derived from the corresponding atmosphere model used in this study.

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