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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 x 2k observations from the PSPT Precision Solar Photometric Telescope. 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. Sun: full-disk observations – Sun: atmosphere – 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 at 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,

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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 x 2k observations from the PSPT Precision Solar Photometric Telescope (Coulter et al. 1994; Ermolli et al. 1998; Rast, Ortiz & Meisner 2008). 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, specif-

ically PK-027 and PK-010. The other fil-
ter, PKR-011, is centered in the red wing
of the line. We measured the intensity and
contrast of various solar features, specifi-
cally 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 ref-
erence atmosphere models (Fontenla et al.
2007, 2009).

2. Observations

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

   All the images were pre-processed to ap-
ply the standard instrumental calibration
(Rast, Ortiz & Meisner 2008). Then, each
image was re-sized 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 ex-
tracted 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 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 bire-
fringent filter and do not allow to separate
the features of the Ca II K line.

3. Method

We computed synthetic spectra in the
range of CaII K with the RH code de-
veloped by Uitenbroek (2001, 2002).
Our calculations were performed as-
suming nLTE and PRD through the
set of atmosphere models presented by
Fontenla, Balasubramaniam & Harder
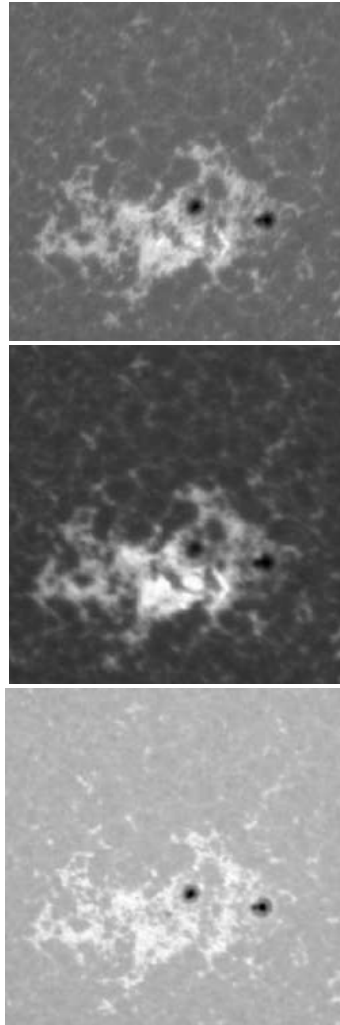(2007) and Fontenla et al. (2009). These

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

models describe the temperature and den-
sity vertical stratification of various solar
features: quiet Sun (model B), network
(model D), enhanced network (model F),
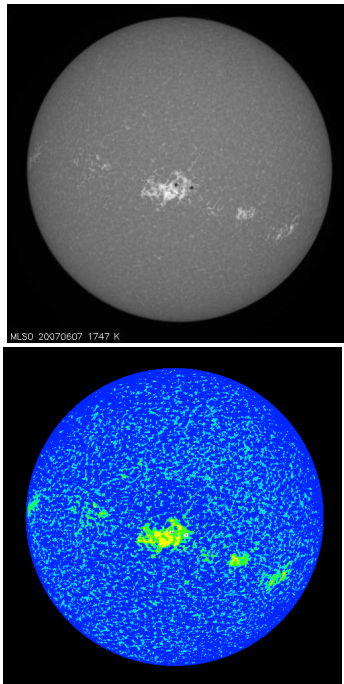plage (model H), and bright plage (model
P).

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 show 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 blowing up the figure). Black shows off-disk regions.

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

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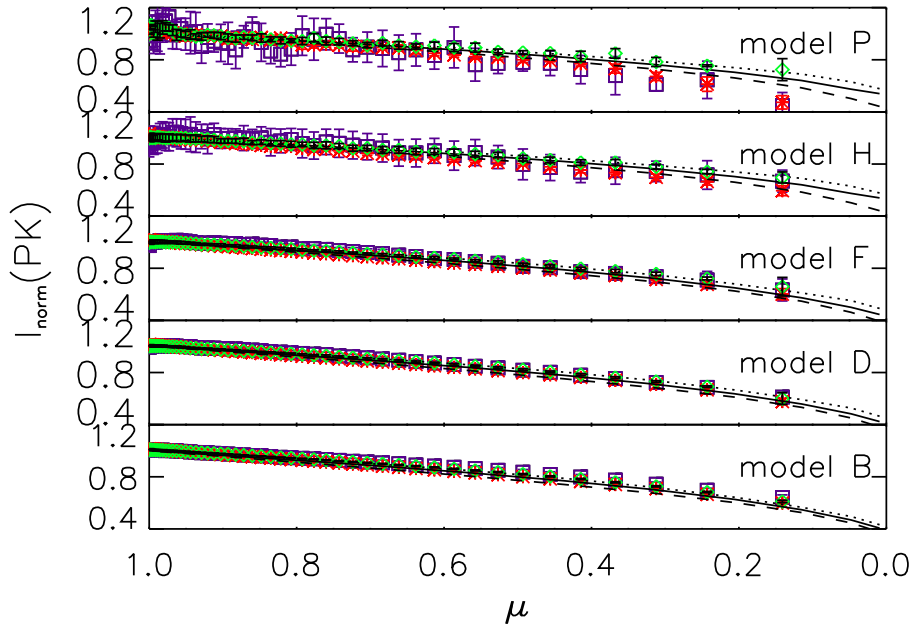
Fig. 3. Comparison between the CLV of intensity values measured on PSPT images (symbols) for the various disk features and those derived from the spectral synthesis (lines) performed for the same filters on the reference atmosphere models. All the values are normalized to the intensity obtained at the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

sented 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 narrower-band and 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 outcomes of the spectral synthesis. However, the CLV of the contrast obtained for the plage regions (model H) identified on our observations have larger decrease toward the limb than the one derived from the corresponding atmosphere model used in this study.

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