Contrast of Magnetic Elements in the G−band and Across the Solar Spectrum

Poster in A4/PDF format available under
http://www.kis.uni−freiburg.de/~steiner

O. Steiner & J. Bruls, Kiepenheuer−Institut fuer Sonnenphysik, Freiburg
P.H. Hauschildt, Hamburger Sternwarte, Hamburg

1. Model and model atmospheres

In this study, the geometrical structure of the magnetic element is discarded: instead the internal and external atmosphere are taken *plane-parallel*. Correspondingly, synthetic results must be compared with contrast measurements that are corrected for the limited spatial resolution by means of instrumental and atmospheric modulation transfer functions, *i.e.*, with intrinsic contrast values.

We use the empirically derived *model atmospheres* for magnetic elements of network (`net`) and plage (`pla`) regions of Solanki & Brigljevic (1992) and compare the resulting spectra with that of the surrounding quiet Sun reference atmosphere (`FWFAK_C`) of Fontenla *et al.* (1999). We also compare to the plage model `FWFAK_P` of Fontenla *et al.*

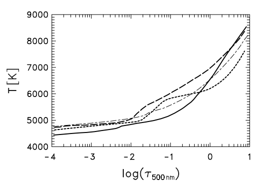

Fig. 1. Temperature as a function of continuum optical depth $\tau_{500\,\mathrm{nm}}$ of the modified quiet Sun model `FWFAK_C` (——) and the modified bright plage model `FWFAK_P` (−·−·−) of Fontenla *et al.* 1999, together with the magnetic flux tube atmospheres `net` (network elements, – – –) and `pla` (plage elements, ······) of Solanki & Brigljević (1992).

2. Synthetic G-band spectrum

We use the radiation transfer code PHOENIX (Hauschildt & *et al.* 1996, 97, 99) in order to compute synthetic spectra and the continuum radiation under the LTE assumption from each model atmosphere. The line lists include 47 million atomic and up to 350 million molecular lines. We use a height-independent microturbulence of 1 kms^{-1}. In the following, intensities correspond to disk-center position.

3. Synthetic G-band contrast

Figure 2 shows the synthetic G-band spectrum of the magnetic-element model (red), together with that of the quiet Sun model (blue) and with the continuum intensity attenuated by the transmission profile of the G-band pass filter (dashed). The magnetic element shows a higher intensity throughout because it is hotter than the quiet Sun model, but *the difference is more pronounced within ranges of CH-band lines* than in the continuum and many other spectral lines.

Table 1 gives contrasts for three model atmospheres against the quiet Sun reference, where

$$C_c = \frac{(I_{\mathrm{bp}\,c} - I_{0\,c})}{I_{0\,c}}\,, \quad \text{and} \quad C_G = \frac{\int T_G (I_{\mathrm{bp}} - I_0)\,\mathrm{d}\lambda}{\int T_G I_0\,\mathrm{d}\lambda}\,.$$

Index c refers to the theoretical continuum at 430 nm, bp to the flux-tube atmosphere, and 0 to the quiet Sun model. T_G is the G-band filter transmission. $C_{G'}$ is the "G-band" contrast when discarding the molecule CH in the radiation transfer.

	net	pla	FWFAK_P
C_G	1.34	0.28	0.39
C_c	0.33	-0.22	-0.03
$C_{G'}$	0.66	-0.05	0.12

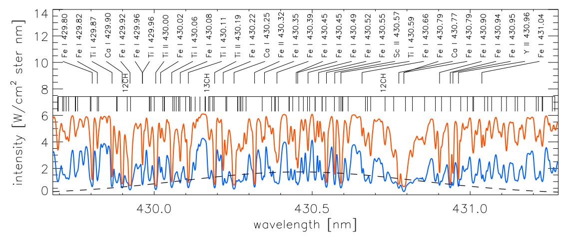

Fig. 2. Synthetic G-band spectrum of the quiet Sun model `FWFAK_C` (blue curve) together with that of the magnetic-element atmosphere `net` (Solanki & Brigljević 1992) (red curve) and the continuum intensity attenuated with the transmission profile of the G-band pass filter (dashed curve).

4. What causes the high G-band contrast?

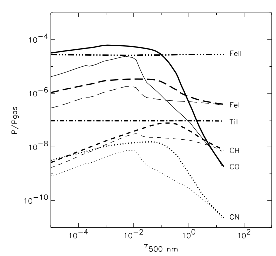

Fig. 3. Partial gas pressure for the molecules CO, CH, and CN as a function of optical depth $\tau_{500\,\mathrm{nm}}$. Thick curves refer to the quiet Sun model, thin curves to the magnetic-element atmosphere. The partial pressures of Fe II and Ti II are practically identical and constant for both atmospheres.

From Fig. 3 we see:

- CH increases with height less steeply than CO does because CO curtails the formation of CH with height. → *Deep formation of the G-band.* The CH line-cores form around $\tau_{500\,\mathrm{nm}} = 0.1$.
- The CH partial pressure of the flux-tube atmosphere is markedly reduced w.r.t. the reference atmosphere in the deep layers. This reduction is due to the elevated temperature of up to 800 K within the flux tube, causing CH to dissociate. This weakens the CH lines in the G-band of magnetic elements, allowing more of the continuum to "shine through the thinned forest" of CH-lines. → *The high contrast* of G-band bright-points *is due to the depletion of CH*, induced by the enhanced temperature of magnetic elements.
- Fe I behaves similar to CH. → The multitude of Fe I lines within the G-band also contributes to the contrast enhancement. This is the reason for $C_{G'} > C_c$.

5. The contrast across the spectrum

Figure 4 shows the synthetic spectrum of the quiet Sun atmosphere `FWFAK_C` from 350 to 800 nm together with the contrast of the magnetic element atmosphere `net` relative to `FWFAK_C` (bottom panel). Continuum, C_c, and total contrast, C, are given, computed for a Gaußian filter of 10 Å full width at (1/e)·max. Here, C_c and C are defined as:

$$C_c(\lambda) = \frac{\int T_{\lambda-\lambda'}(I_{\mathrm{bp}\,c}(\lambda') - I_{0\,c}(\lambda'))\mathrm{d}\lambda'}{\int T_{\lambda-\lambda'} I_{0\,c}(\lambda')\mathrm{d}\lambda'}\,,$$

$$C(\lambda) = \frac{\int T_{\lambda-\lambda'}(I_{\mathrm{bp}}(\lambda') - I_0(\lambda'))\mathrm{d}\lambda'}{\int T_{\lambda-\lambda'} I_0(\lambda')\mathrm{d}\lambda'}\,.$$

$T_{\lambda-\lambda'}$ is the transmission of the Gaußian filter. While C_c remains practically constant, the total *contrast increases towards the blue* due to the increasing density (per wavelength interval) of spectral lines, which generally have a higher temperature sensitivity than the continuum (see, *e.g.*, Fe I of Fig. 3). Clearly, the G-band is the most conspicuous contrast enhancement longward of 4000 Å . Ca H and K and the iron complexes shortward of 4000 Å are mostly of chromospheric origin for which case our model and the LTE-assumption breaks down. The *CN-bandhead at 3883 Å* gives a slightly higher contrast than the G-band does.

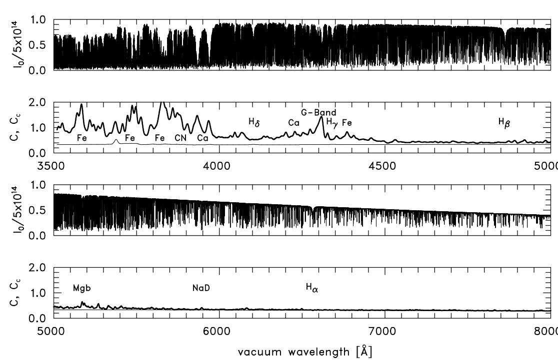

Fig. 4. Synthetic spectrum of the quiet Sun atmosphere `FWFAK_C` from 350 to 800 nm (1st and 3rd panel) together with the total and continuum contrast of the magnetic element atmosphere `net` relative to `FWFAK_C` (2nd and 4th panel) computed for a Gaußian filter of 10 Å band width.