Possible chromospheric response to the dynamics of photospheric G-band bright points

M. Bodnárová, D. Utz, J. Rybák

October 5, 2015

Coimbra Solar Physics Meeting "Ground-based Solar Observations in the Space Instrumentation Era", 5 – 9 October 2015, Coimbra, Portugal

Outline

Goals

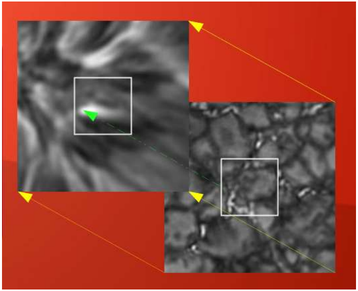
* to investigate the connection between structures observed in the chromosphere (Ca II H and Ha α) and the photosphere (G-band) with the help of co-spacial and co-temporal images

* to select an appropriate sub-field of the FOV and to investigate the effect of the size of this region of interest (ROI) on the area-averaged profile of the Hα spectral line

* to study four spectral characteristics of the Hα spectral line profile by employing auto-correlations and cross-correlations: the intensity in the line center I_c, the width of the profile w_p, the Doppler velocity v_c, and the Doppler velocity v_p

∗ to focus on a single structure (bright mottle) in the Hα images — to investigate how long in existed; its visibility in the Hα core and wings; effect on the temporal evolution of the studied spectral characteristics of the area-averaged profile

∗ to investigate the connection to the evolution of a long-living group of G-band bright points (GBPs)



Data

* **Instrument:** Dutch Open Telescope (DOT); La Palma, Canary Islands
* **Observation time:** 19th October 2005, 09:55 – 11:05 UT, 142 images with a cadence of 30 s (resp. 71 images with a cadence of 60 s)
* **Image properties:** FOV of 79 $\times$ 58 arcsec (1112 $\times$ 818 pixel); sampling of 0.071 arcsec/pixel

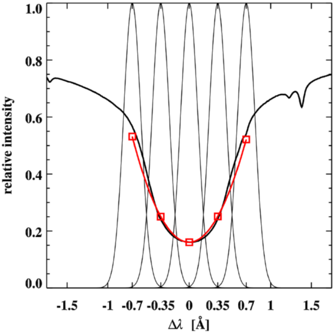
Data-sets

From all available data-sets of speckle reconstructed images we used three:
* **G-band** (430.5 nm)
* **Ca II H** (396.9 nm)
* **Hα** in the core of the line profile (λ_c = 656,3 nm) and in four points in the wings of the line profile ($\lambda = \lambda_c \pm$ 0.035 nm and $\lambda = \lambda_c \pm$ 0.07 nm, respectively)

Approximation of the Hα spectral line profile

$*$ **Input data:** simultaneous images in five points across the Hα line profile (core: $\lambda_c =$ 656,3 nm; and wings: $\lambda = \lambda_c \pm$ 0.035 nm and $\lambda = \lambda_c \pm$ 0.07 nm)

$*$ **Approximated profile:** deduction of the Hα line profile (re-sampled for 1400 points) based on the theoretical profile (spectral line atlas) and a 4^{th} order polynomial fit across five known points of the measured profile



$*$ the approximated profile can be computed for a single pixel within the FOV or averaged over a selected area – region of interest (ROI)

Spectral characteristics of the Hα line profile

* **Core intensity I_C:** intensity minimum

* **Width of the approximated profile w_p:** at the intensity level I_p

$$I_p = \frac{\langle I_{-0.7}, I_{+0.7}\rangle + I_c}{2}$$

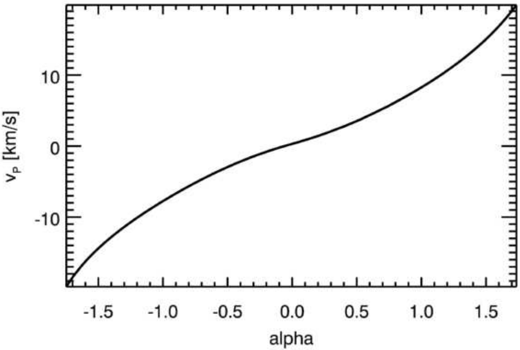
* **Doppler velocity v_C:** the Doppler-shift of the line core

$*$ **Doppler velocity v_p:** Doppler-shift of the line profile (based on four points in the wings of the Hα line profile — not computed from the approximated profile) based on the parameter α:

$$\alpha = (F_1 + F_2 - F_3 - F_4)/(F_1 - F_3)$$
$$if \qquad (F_1 + F_2 - F_3 - F_4) > 0 \qquad or$$
$$\alpha = (F_1 + F_2 - F_3 - F_4)/(F_4 - F_2)$$
$$if \qquad (F_1 + F_2 - F_3 - F_4) \leq 0$$

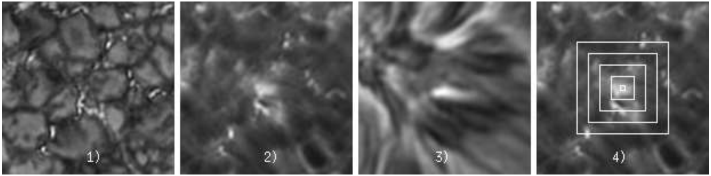
Scherrer et al., 1995; Sol. Phys. vol. 162,129 (algorithm for MDI on board SOHO)

parametric curve for α: computed from subsequent shifts of the atlas profile of the Hα spectral line in order to deduce the velocity v_p

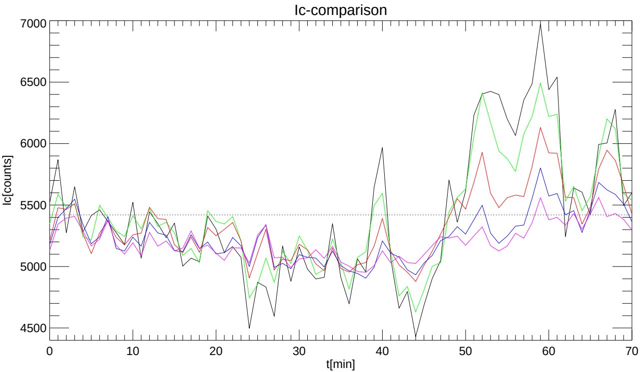


The effect of area averaging

* **Selected location:** a prominent network region
* **ROI of various sizes:** from 5 $\times$ 5 pixels to 81 $\times$ 81 pixels (0.071 arcsec/pixel)

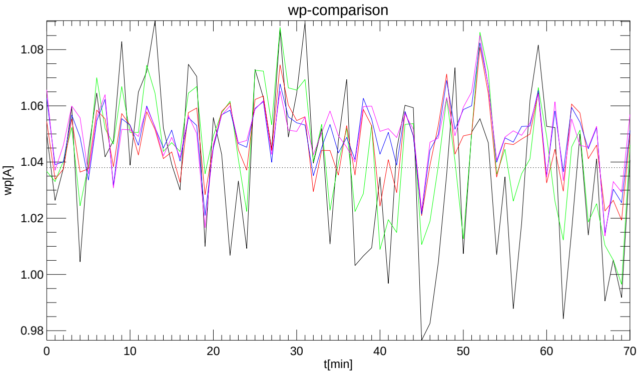


A sub-field of the FOV, centered at the selected ROI: 1) G-band; 2) Ca II H; 3) H$\alpha(\lambda_c)$; and 4) the sizes of the ROI.

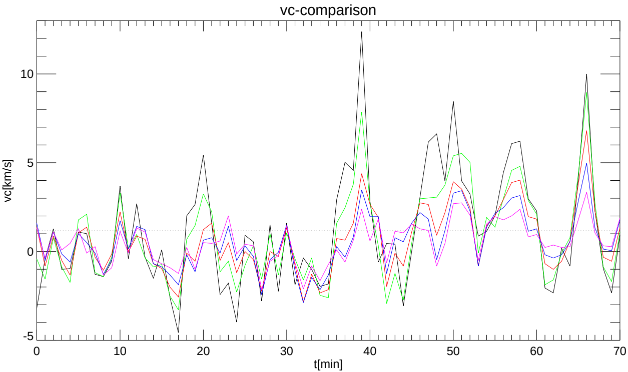


∗ I_C: *for areas of different size: 5× 5 (black), 21× 21 (green), 41× 41 (red), 61× 61 (blue) and 81× 81 (magenta) pixels. The horizontal line indicates the mean value for the smallest ROI.*

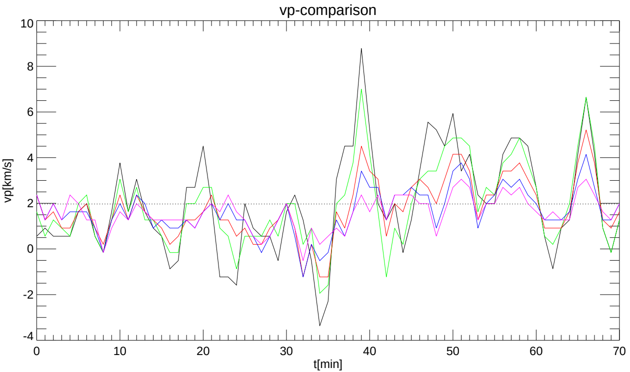
Chromospheric response to photospheric dynamics



* w_p: *for areas of different size: 5 × 5 (black), 21 × 21 (green), 41 × 41 (red), 61 × 61 (blue) and 81 × 81 (magenta) pixels. The horizontal line indicates the mean value for the smallest ROI.*



∗ v_c: *for areas of different size: 5× 5 (black), 21× 21 (green), 41× 41 (red), 61× 61 (blue) and 81× 81 (magenta) pixels. The horizontal line indicates the mean value for the smallest ROI.*



∗ v_p: *for areas of different size: 5× 5 (black), 21× 21 (green), 41× 41 (red), 61× 61 (blue) and 81× 81 (magenta) pixels. The horizontal line indicates the mean value for the smallest ROI.*

Small summary – 1

∗ with the increasing size of the averaged area the peaks of the temporal evolution are decreasing in value (their positions are maintained) $\Longrightarrow$ the source of the increase should be localized within the smallest area and larger areas are causing the highest/lowest values to be smoother over by numerous values in between

∗ w_p: shows minimal variations (within ∼0.011 nm)

∗ I_c,v_c and v_p: show prominent peaks during the second half (35–71 min) of the observation $\Longrightarrow$ possible indication of periodic behaviour

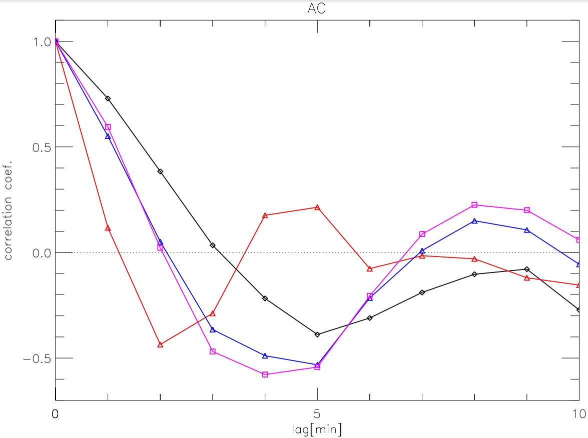
∗ for further studies we choose just one size of the ROI: 21×21 pixel $\Longrightarrow$ small enough to have a bigger percentage of network and big enough contain the interesting features for the duration of the observation

Auto-correlations and cross-correlations

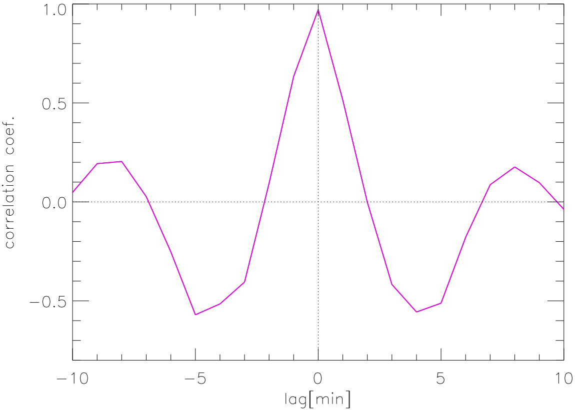
$*$ Auto-correlation is used in order to look for indication of periodicity of the spectral characteristics of the Hα line profile (I_c , w_p, v_c and v_p)

$*$ Cross-correlation is used in order to measure the similarity between the spectral characteristics of the Hα line profile (I_c , w_p, v_c and v_p)

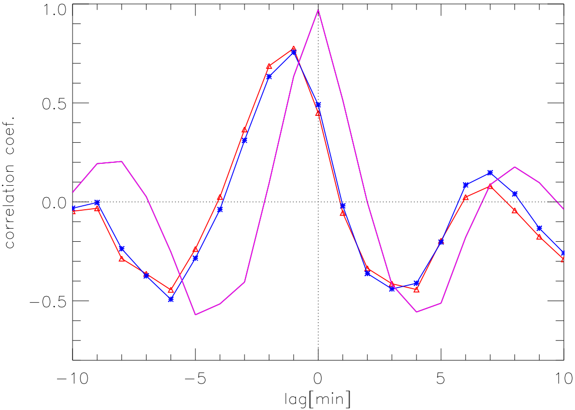
$*$ these were done for ROI of 21×21 pixel (0.071 arcsec/pixel) and only for the second half (35–71 min) of the observation $\Longrightarrow$ events of interest



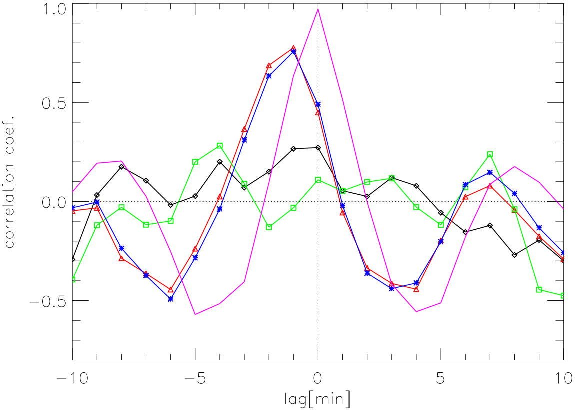
Auto-correlations of the spectral characteristics of the Hα line profile for ROI of 21 × 21 pixels: I_c *(black),* w_p *(red),* v_c *(blue) and* v_p *(magenta).*



Cross-correlations of the spectral characteristics of the Hα line profile for ROI of 21 × 21 pixels: v_c and v_p (magenta)



Cross-correlations of the spectral characteristics of the Hα line profile for ROI of 21 × 21 pixels: I_c and v_c (red); I_c and v_p (blue); v_c and v_p (magenta).



Cross-correlations of the spectral characteristics of the Hα line profile for ROI of 21 × 21 pixels: I_c and w_p (black); I_c and v_c (red); I_c and v_p (blue); v_c and v_p (magenta); w_p and v_p (green).

Small summary – 2

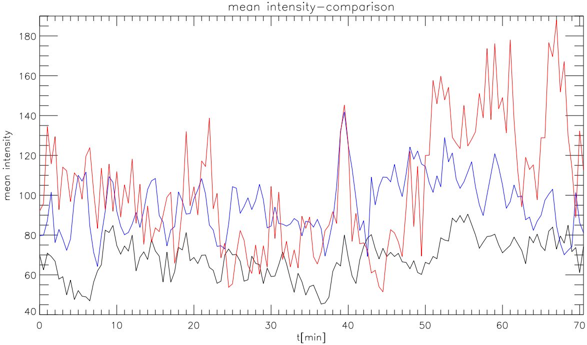
* Auto-correlations of I_c , v_c and v_p indicate the existence of a period ~8 min, where this indication is stronger for the velocities than for the intensity

* Cross-correlations of I_c with both v_c and v_p show high values for I_c lagging behind v_c and v_p by ~1.5 min

* Cross-correlation of v_c with v_p show that both parameters obtained with different methods and from different input data represent the same physical quantity

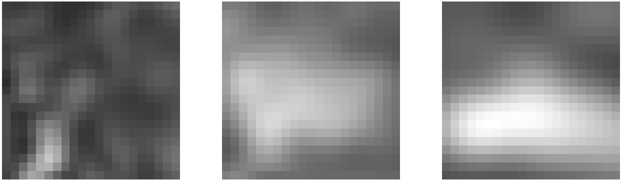
* Cross-correlations of w_p with both I_c and v_p show no statistically significant similarity between the studied parameters

Mean intensities in Hα, Ca II H and G–band



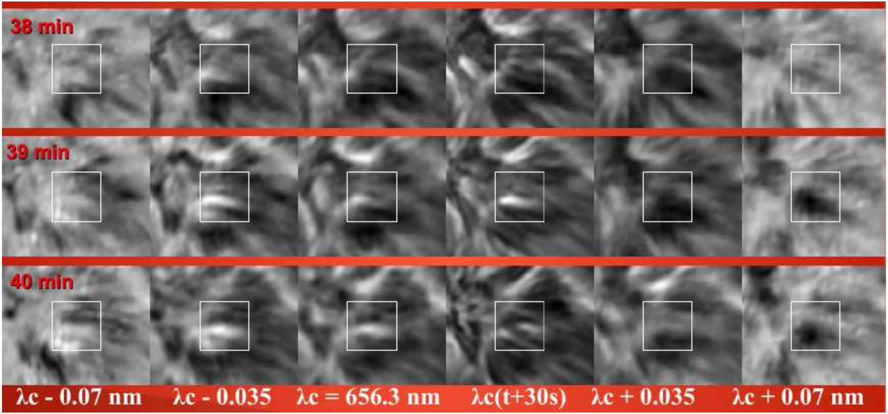
$*$ ROI of 21 $\times$ 21 pixels: *The temporal evolution of the mean intensities for the selected ROI: in G-band (black), in Ca II H (blue), and in Hα (red) at λ_c.*

$*$ t = 39.5 min: a prominent peak of the mean intensity in Ca II H and Hα $\Longrightarrow$ corresponds to answerable peaks for the spectral characteristics of the Hα line profile (I_c, v_c and v_p)



The zoomed ROI: 1) G-band; 2) Ca II H; and 3) H$\alpha(\lambda_c)$ $\Longrightarrow$ *co-spacial location of GBPs and bright features in Ca II H and H*α

Bright "mottle" – temporal evolution in Hα

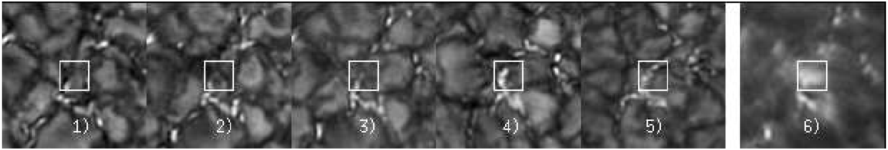


Small summary – 3

$*$ bright "mottle": a short-lived ($\sim$2 min) feature observed in Hα (λ_c) as a bright feature; also in one wing at shorther wavelengths, but observed in absorption at longer wavelengths $\Longrightarrow$ may suggest physical movement of the plasma towards the surface of the Sun

$*$ at 38 – 40 min: v_c and v_p have positive values (peak positive values in plots of temporal evolution of v_c and v_p) $\Longrightarrow$ suggest down-flow

Temporal evolution of the group of GBPs



Evolution of locations of the GBPs - from left to right: 1) G-band at 35 min; 2) G-band at 37 min; 3) G-band at 39.5 min; 4) G-band at 45 min; 5) G-band at 54.5 min and 6) Ca II H at 39.5 min.

Small summary – 4

∗ a "long-lasting" conglomeration of GBPs starts to form 30 min after the beginning of the observation $\Longrightarrow$ it exist during the remainder of the observation

∗ it undergoes some development $\Longrightarrow$ after ∼39 min a meandering vertical "filigree" (buffeted by granulation)

∗ numerous occurences of bright "mottles" during the existence of the group of GBPs (not observed before the formation of the conglomeration)

Conclusion

∗ auto-correlations: statistically significant variations in the intensity and Doppler velocity $\Longrightarrow$ ∼8 min periods $\Longrightarrow$ could be an indication of magneto-acoustic wave propagation (Mathioudakis M. et al., 2013; Space Sci. Rev. vol. 175, Iss. 1-4, pp. 1-27)

∗ cross-corelations:I_c lagging behind v_c and v_p by ∼1.5 min $\Longrightarrow$ may indicate upward propagating waves and transport of energy (Kneer F. et al., 1981; Astron. Astrophys. vol. 102, pp. 147-155)

∗ repetitive occurences of bright "mottles" in Hα co–temporal and co–spacial with a conglomeration of GBPs $\Longrightarrow$ representations of the same magnetic features (magnetic flux tubes buffeted by the granulation)

Questions?