Chromospheric Response to the Dynamics of Photospheric G-band Bright Points

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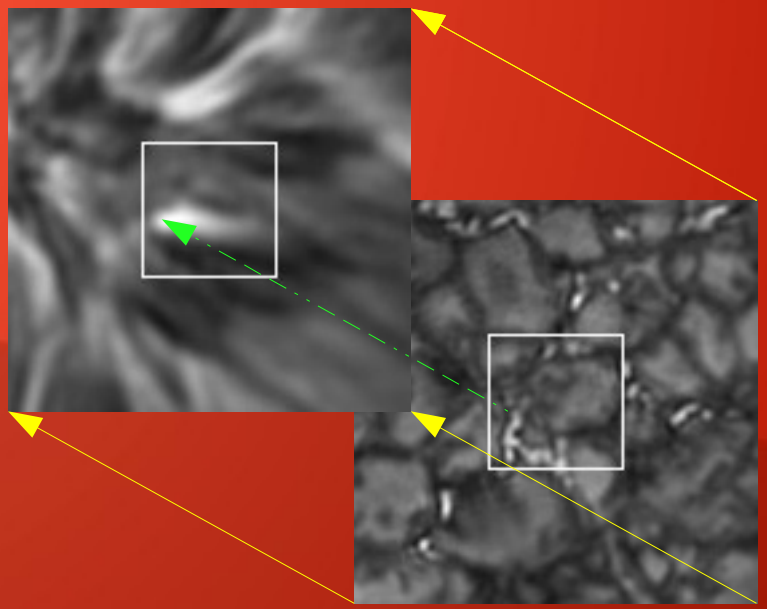
Goal & Outline

- **Goal:** → search for signatures of the heating of the outer solar atmosphere
  → investigation of a connection between the photosphere and the chromosphere
- **Outline:**
  → study of four spectral characteristics of the Hα line profile (auto- and cross-correlations)

→ focus on a single bright mottle observed in Hα
→ comparison with the simultaneous and co-spacial images in G-band
→ the numbers of GBPs and their velocities

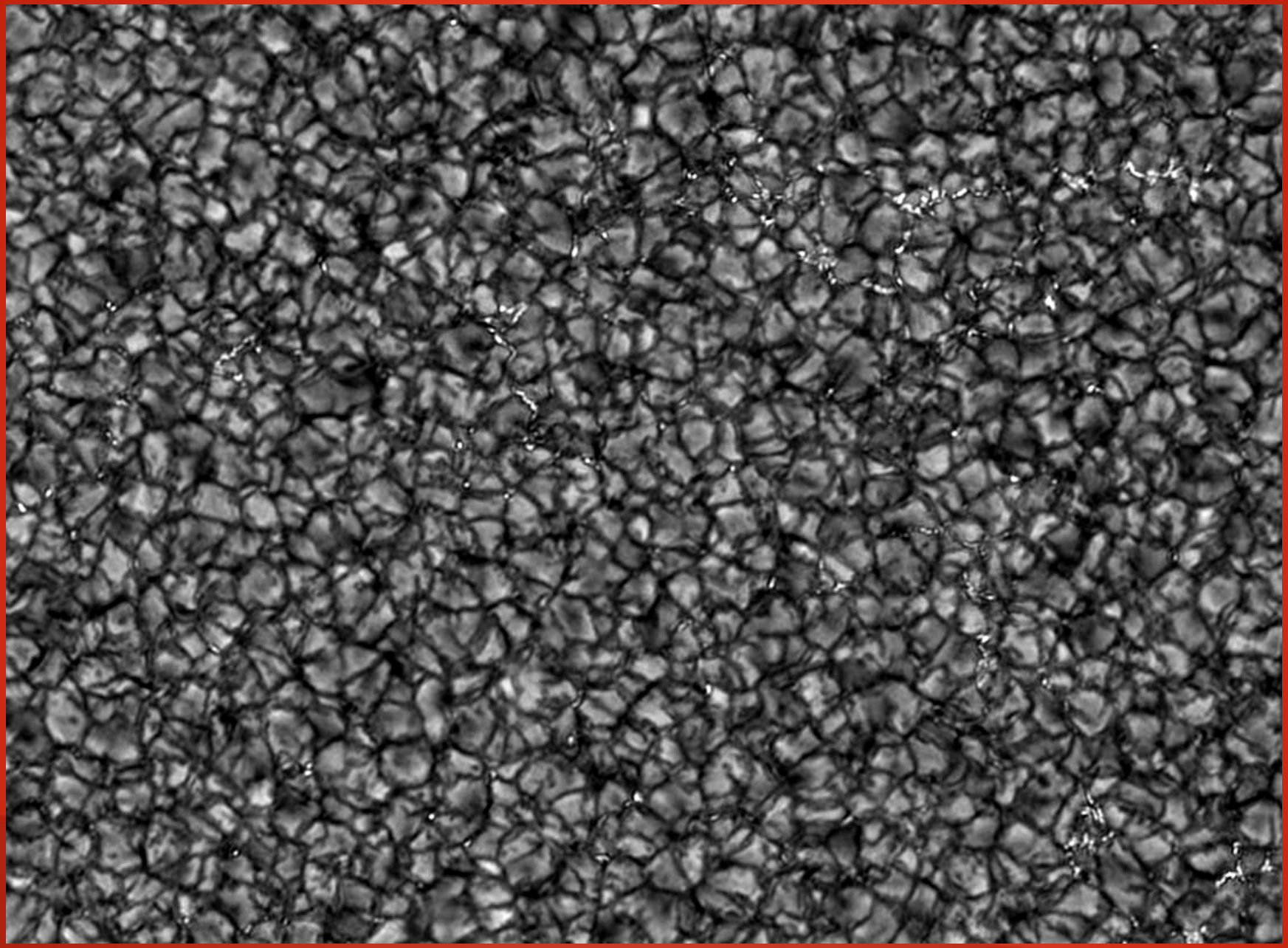


Data

- **Instrument:** Dutch Open Telescope (DOT)
- **Observation:** 19.10.2005, 09:55 - 11:05 UT, 142 (resp. 71) images, cadence 30 (resp. 60) s
- **Image properties:** size of 1112 pixel × 818 pixel
  FOV of 79 × 58 arcsec
  sampling of 0.071 arcsec/pixels

- **Photosphere:** speckle reconstructed images of the quiet Sun in the G-band (430 nm) near the disc center

- **Chromosphere:** speckle reconstructed images of the quiet Sun in the Hα spectral line (core: $\lambda c = 656.3$ nm; wings: $\lambda = \lambda c \pm 0.035$ nm and $\lambda = \lambda c \pm 0.07$ nm) strictly simultaneous spatially and temporally with G-band



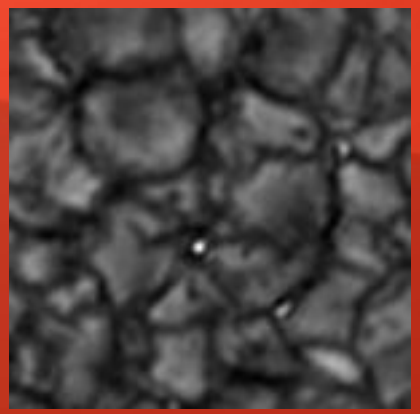
G-band: $\lambda = 430$ nm (79 × 58 arcesc)

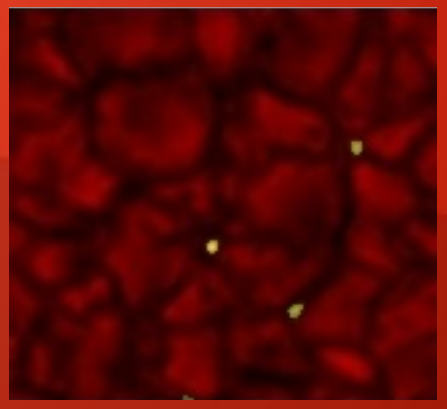
Identification and tracking of GBPs

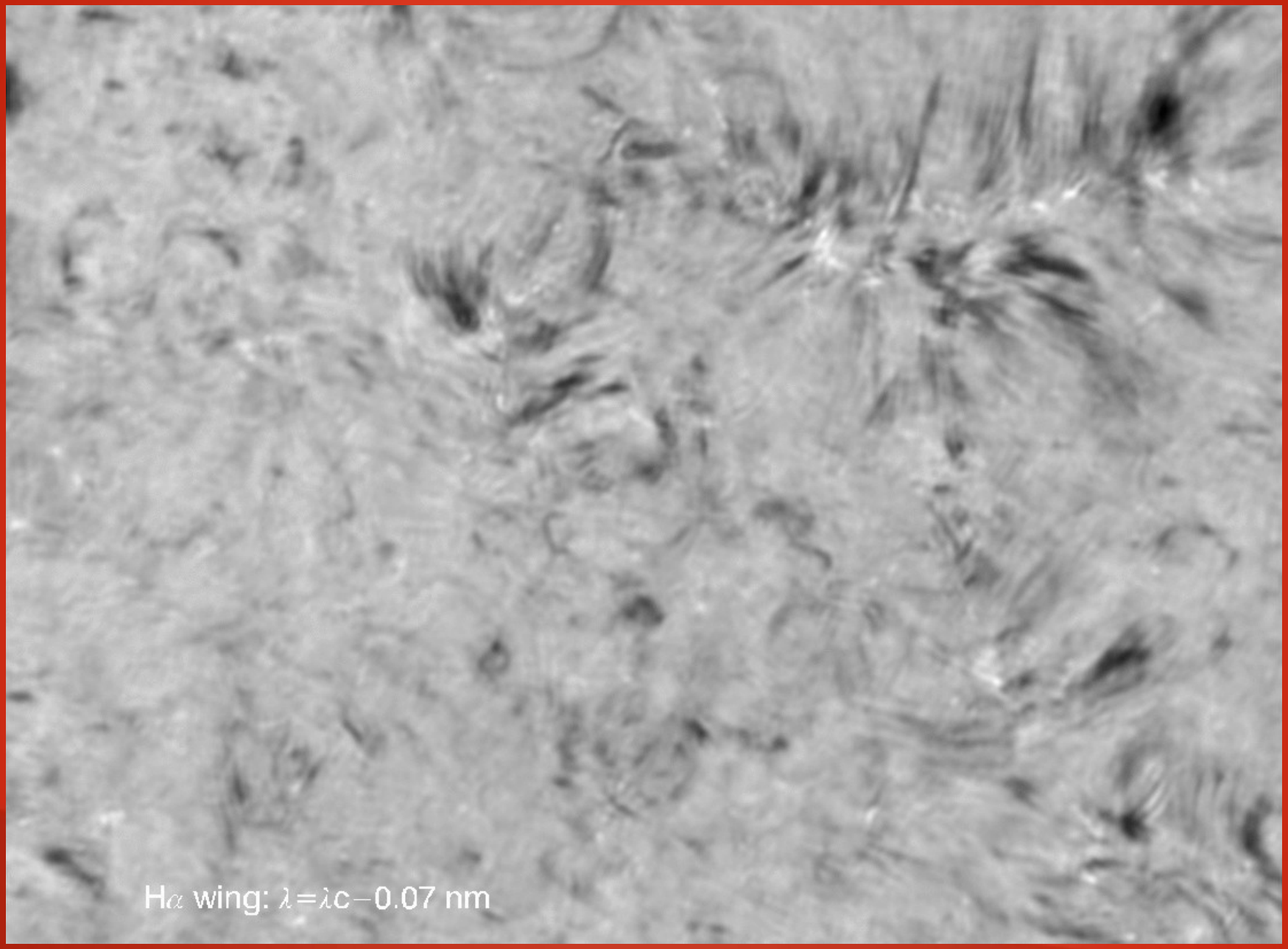
- GBPs were identified and tracked on G-band images using the algorithm developed by Utz et al. (A&A 498, 289293, 2009)
- 26238 GBP identifications of 4017 tracked GBPs on all 142 images of the data set

- <u>Statistical properties of the tracked GBPs:</u>
  average radius (244.9 ± 37.62 km)
  average lifetime (3.0 ± 2.72 min)
  median of velocity (1.3 km/s)

an example of the GBP identification using the Utz's algorithm







Hα wings to center [λc = 656.3 nm], FOV:79 × 58 arcesc

Spectral characteristics of the Hα line

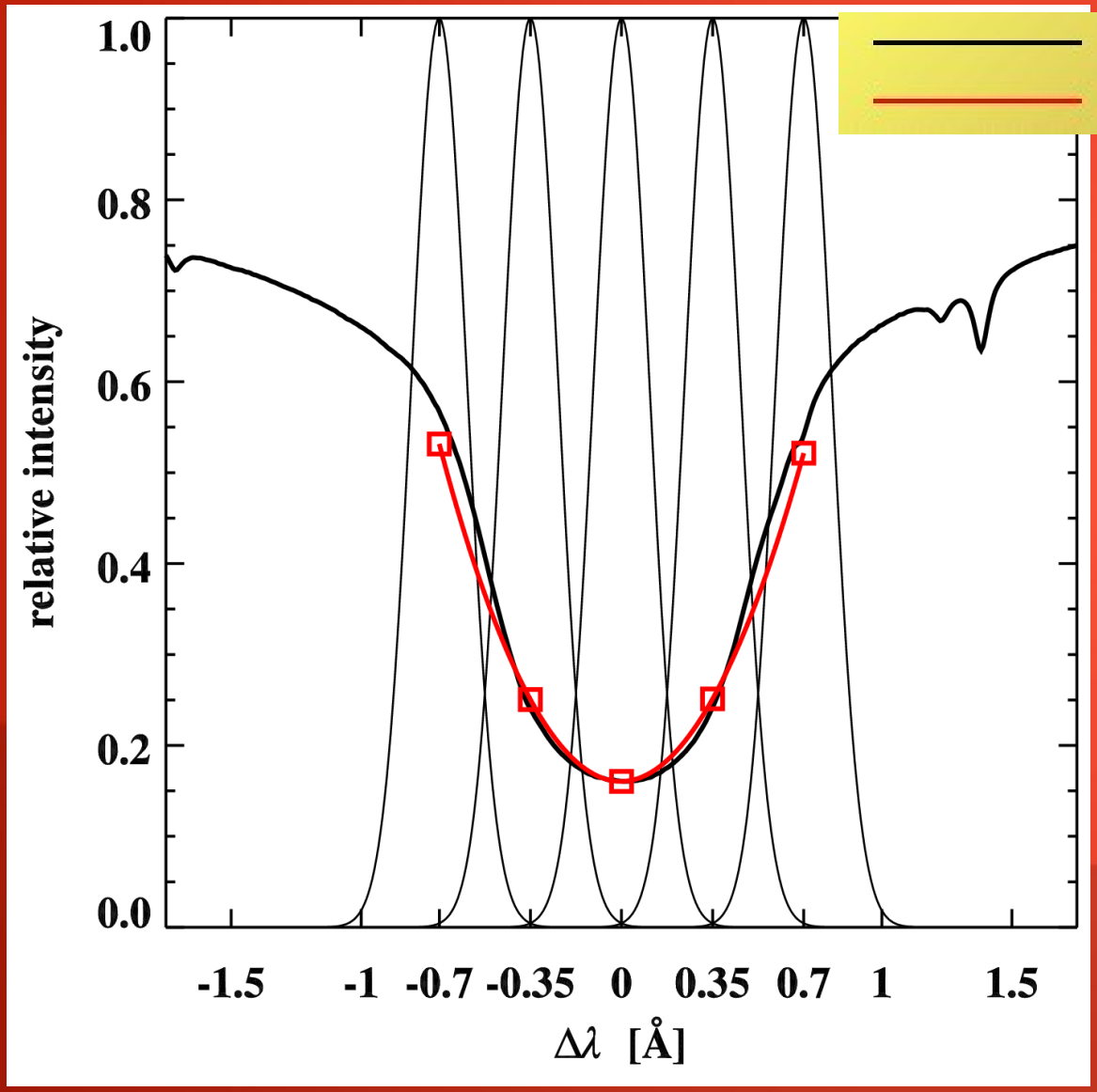
- **Input data:** simultanous images of the quiet Sun in 5 points of the Hα line profile (core: $\lambda c = 656.3$ nm; wings: $\lambda = \lambda c \pm 0.035$ nm and $\lambda = \lambda c \pm 0.07$ nm)

- **Hα line profile:** deduction of the shape of the Hα line profile (re-sampled for 1400 points) by employment of theoretical profile (spectral line atlas) and a polynomial fit through 5 known points of the measured profile

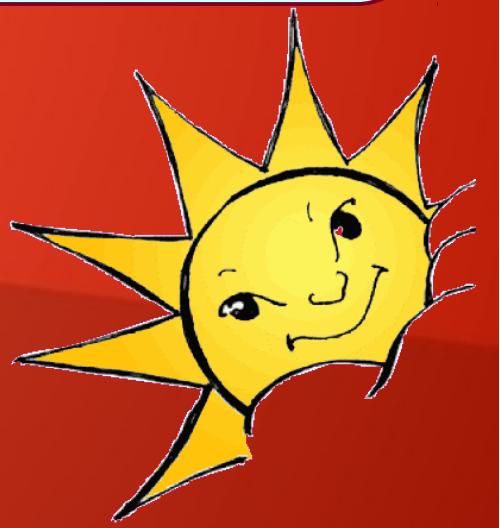
Koza, J. et al., 2013, Contributions of the Astronomical Observatory Skalnate Pleso, vol. 43, no. 1, p. 5-26

- **Studied parameters:** 4 computed spectral characteristics of the Hα line profile in each pixel of the studied FOV (Ic, wp, vc and vp)

Spectral characteristics of the Hα line



analytical profile → fitting of 5 intensity samples (separated by 0.035 nm) by a 4th order polynomial



Spectral characteristics of the Hα line

1) Core Intensity ***Ic*** – intensity minimum

2) Width of the profile of Hα line ***wp*** – at intensity Ip,

where $$I_p = \frac{\langle I_{-0,7}, I_{+0,7} \rangle + I_c}{2}$$

3) Velocity ***vc*** – from the doppler-shift of the line core

$$v_c = \frac{c \cdot (x_c - x_0) \cdot \Delta\lambda}{\lambda_c}$$

Spectral characteristics of the Hα line

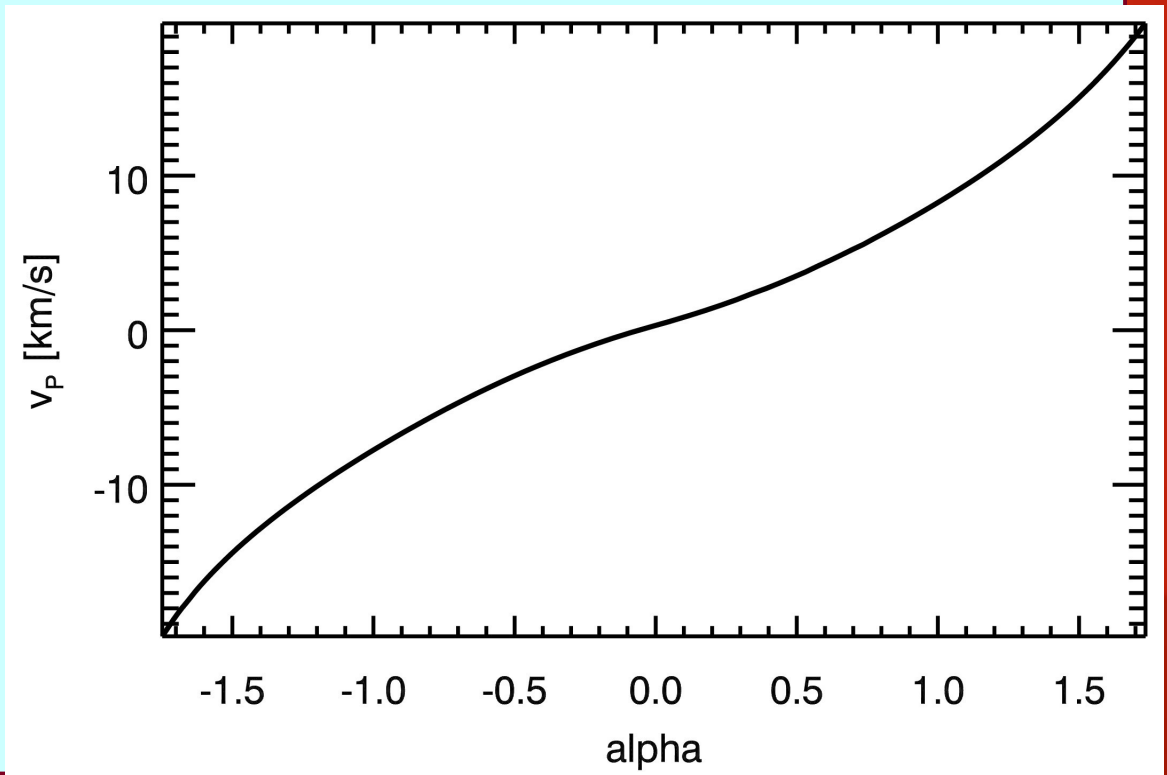
4) Velocity v_P – from the doppler-shift of the line profile (four positions in the profile except λc) via parameter α

$$\alpha = (F_1 + F_2 - F_3 - F_4)/(F_1 - F_3) \quad \text{if} \quad (F_1 + F_2 - F_3 - F_4) > 0$$

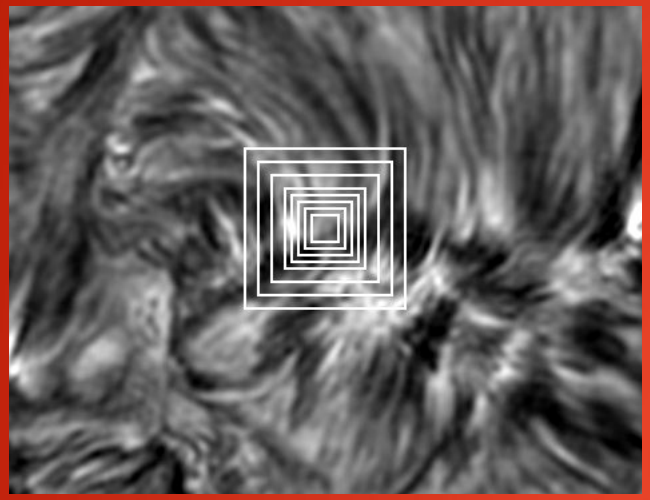
$$\alpha = (F_1 + F_2 - F_3 - F_4)/(F_4 - F_2) \quad \text{if} \quad (F_1 + F_2 - F_3 - F_4) \leqslant 0$$

Scherrer et al., 1995: SolPhys, vol. 162, 129

parametric curve for $\alpha \rightarrow$ calculated from subsequent shifts of the atlas profile of the Hα spectral line

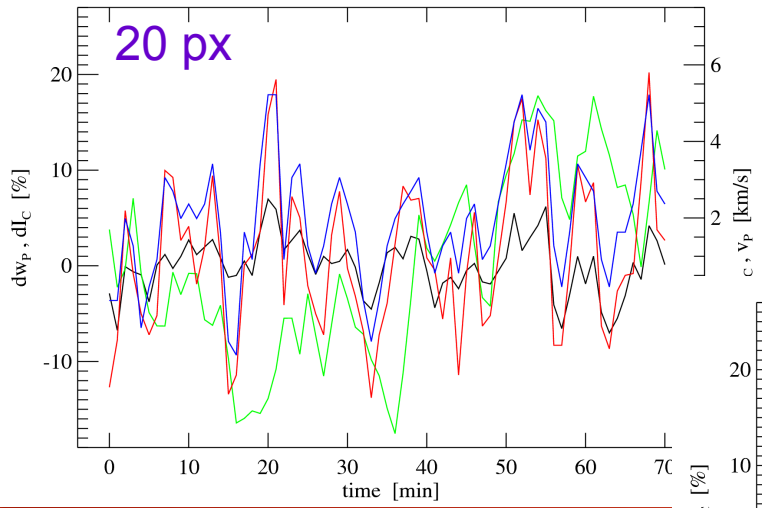


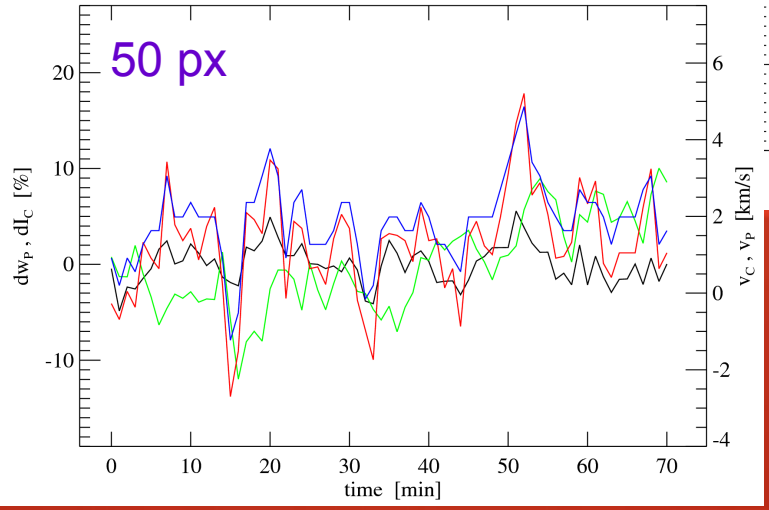
Area selection - size

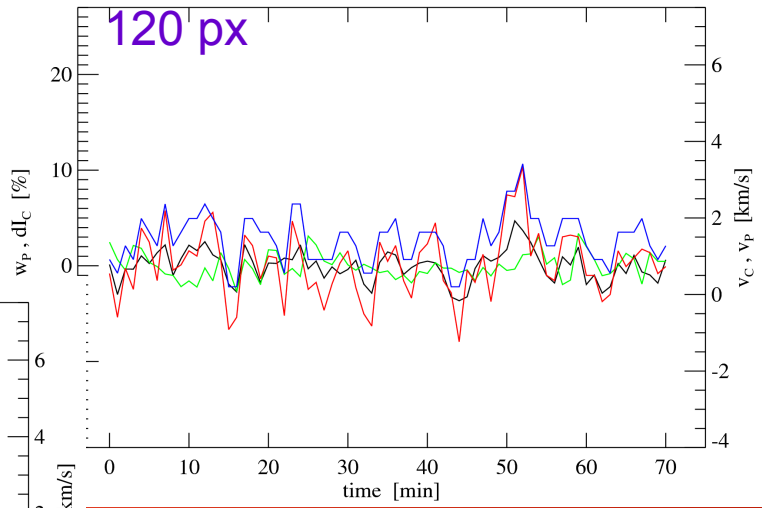


- **Area:** = sub-field of FOV → mean values of the spectral characteristics
- **Widths of Areas:** 20, 30, 40, **50**, 60, 80, 100 and 120 pixel (1 pixel = 0.071 arcsec)

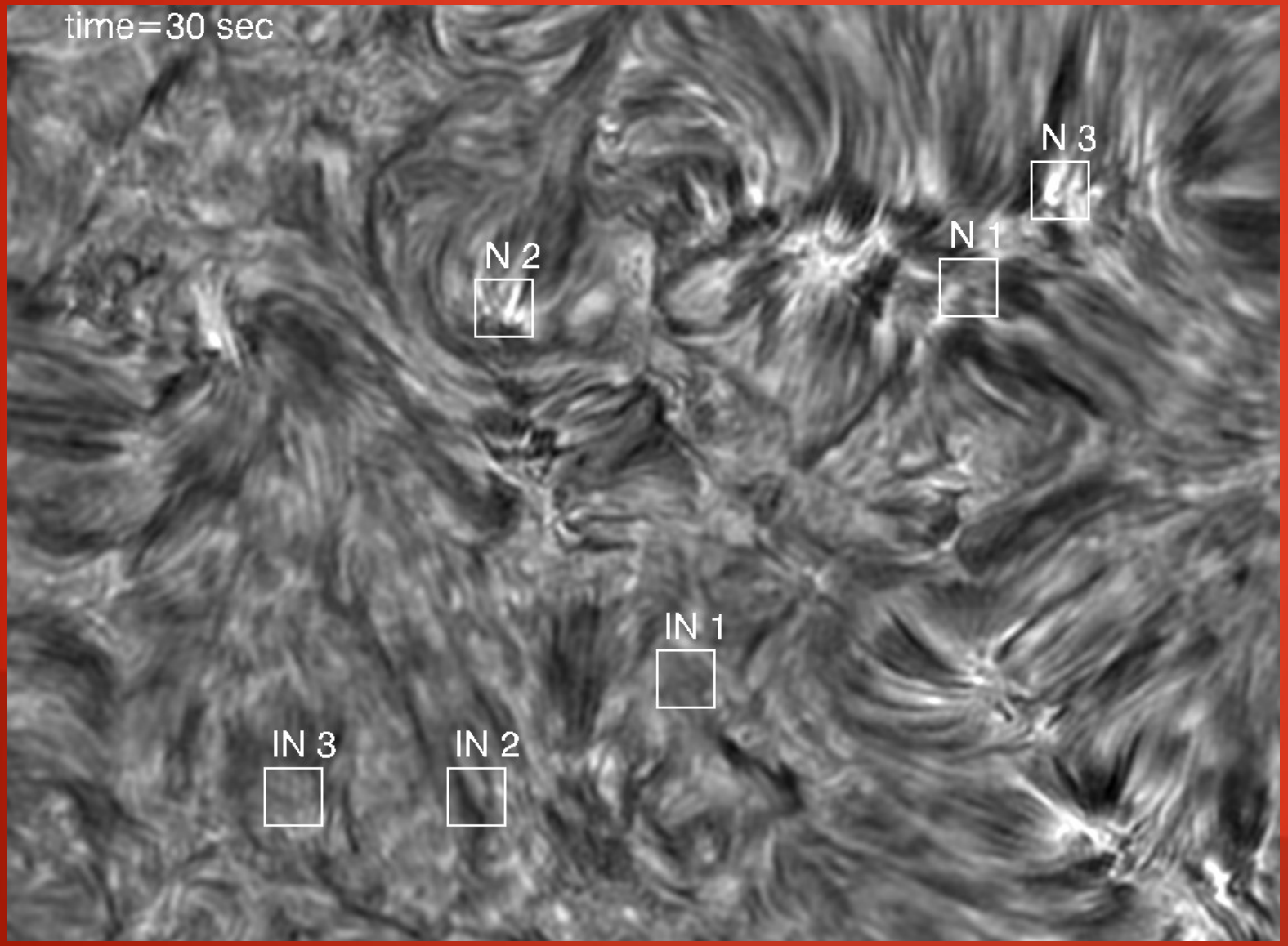
Black - wp
Green - Ic
Blue - vp
Red - vc







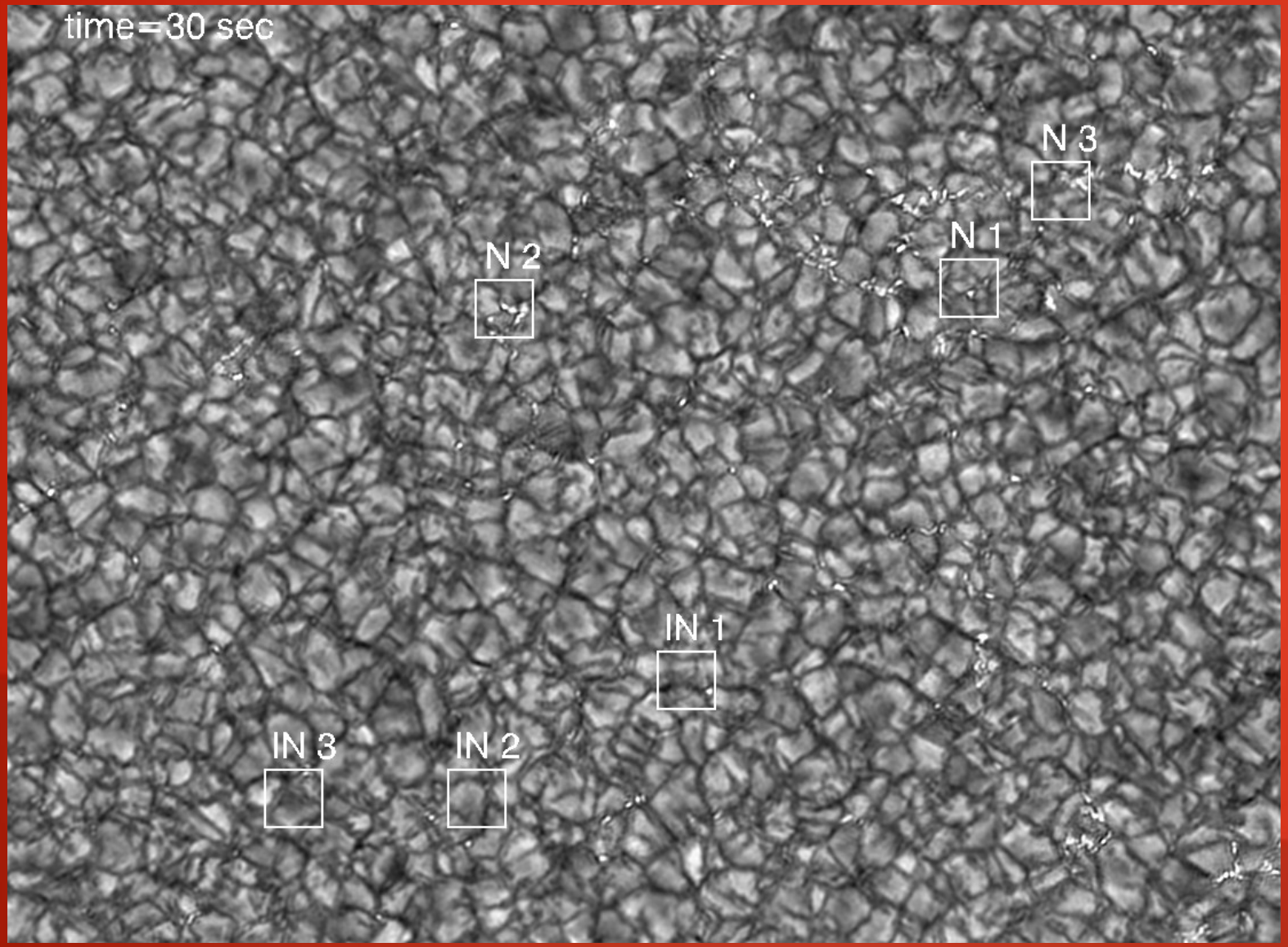
Area selection - location



6 Areas

- **network: N1, N2, N3**
- **internet-work: IN1, IN2, IN3**

Area selection - location



6 Areas

- **network:**

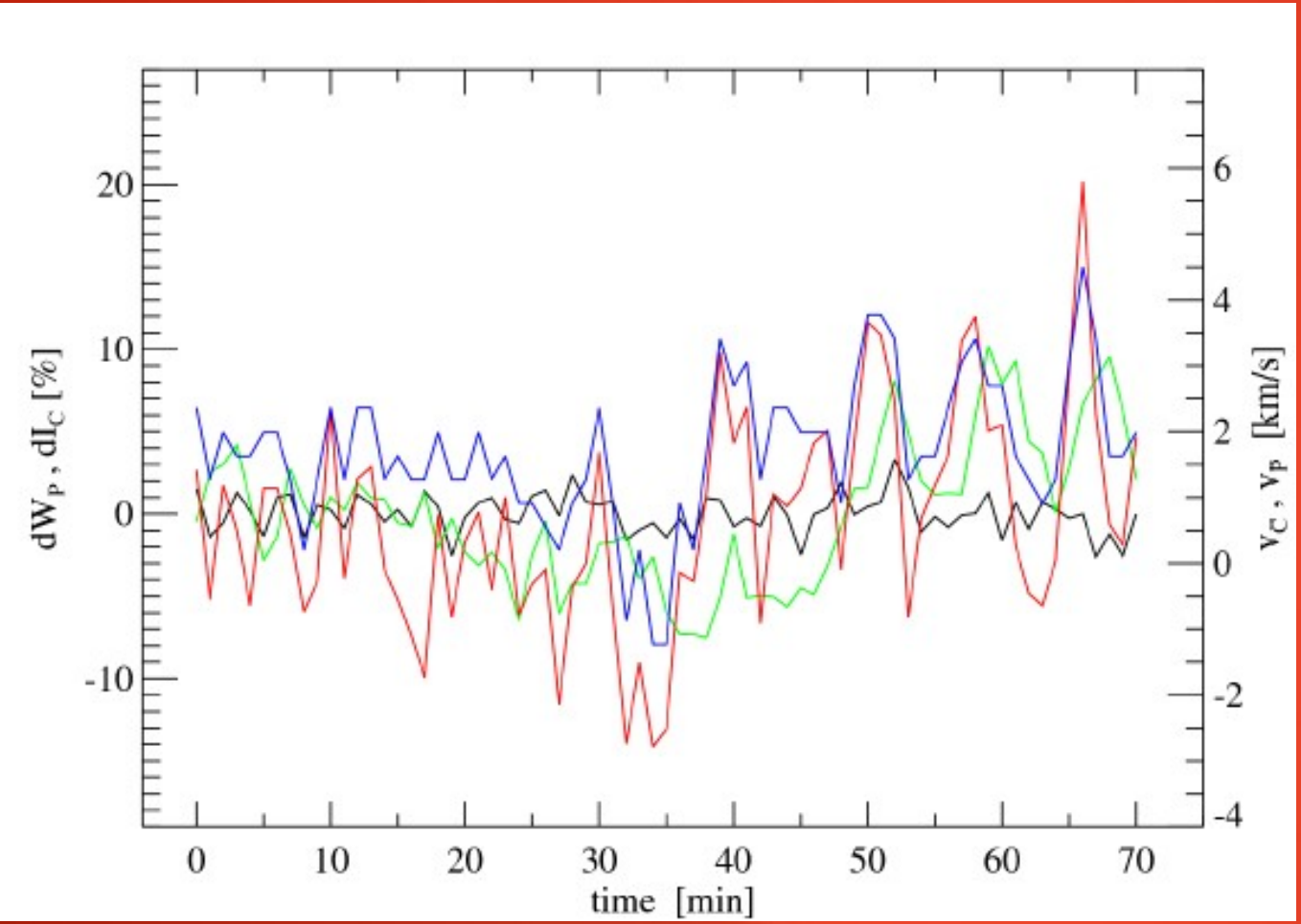
N1: 626 GBP
N2: 472 GBP
N3: 467 GBP

- **internet-work:**

IN1: 117 GBP
IN2: 149 GBP
IN3: 99 GBP

number of identifications on all 142 images

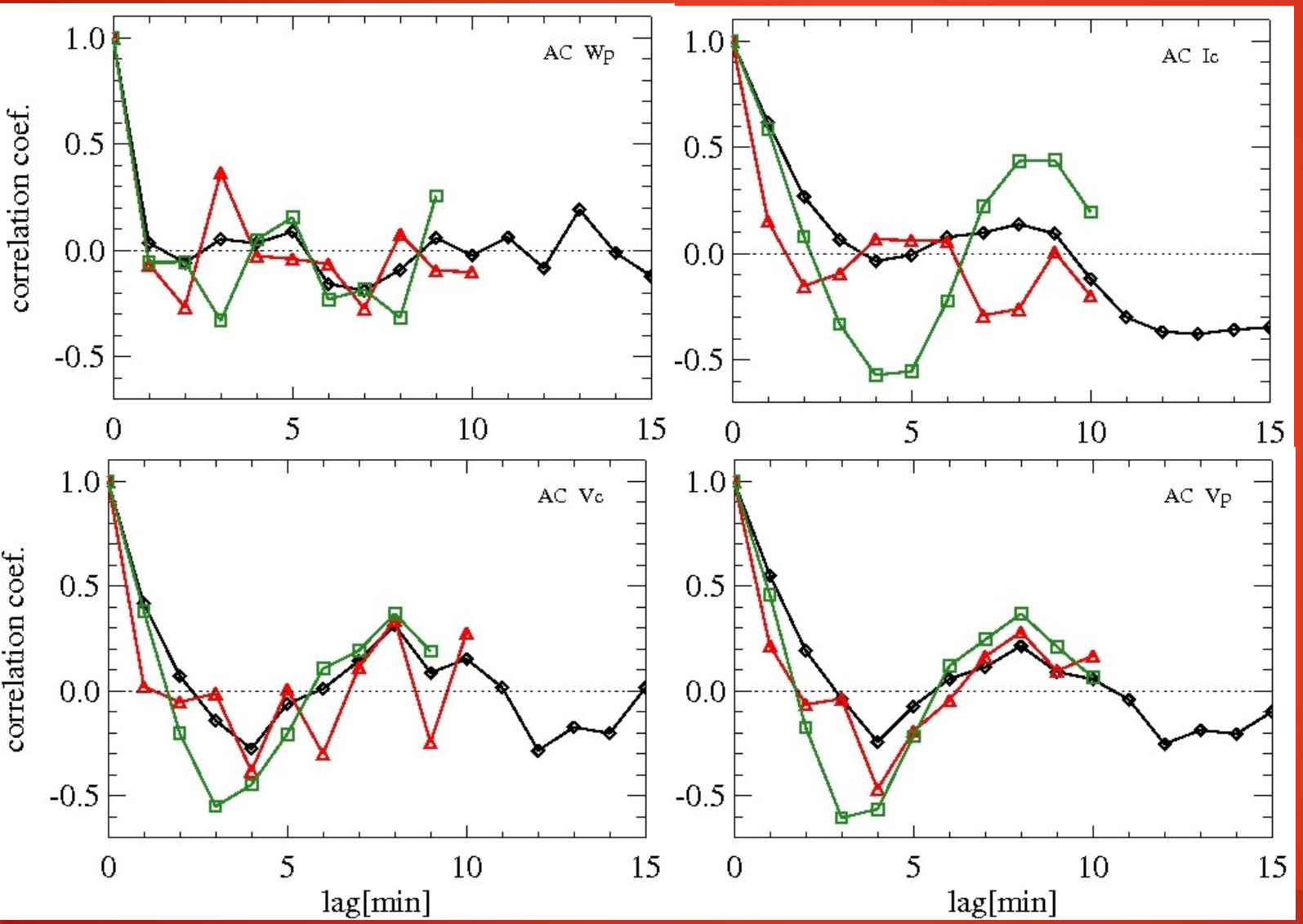
Area N1



Black - w_p
Green - I_c
Blue - v_p
Red - v_c

Temporal variations → three of the studied parameters (I_c, v_c and v_p) noticeably changed after the first ~35 min of the observation → split into two independent halves (0-35 min and 36-70 min)

Area N1: auto-correlations



First half:

Ic, wp: no detectable periods!

vp, vc: indication of periodicity

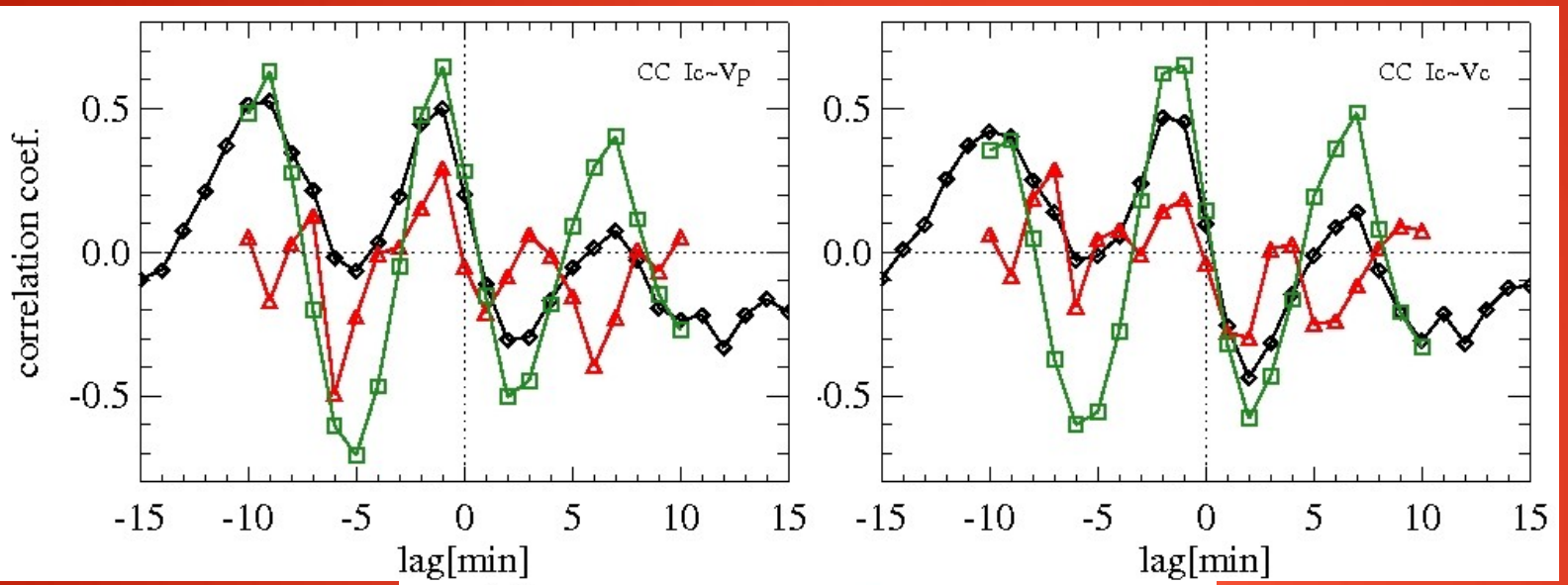
Full & second half:

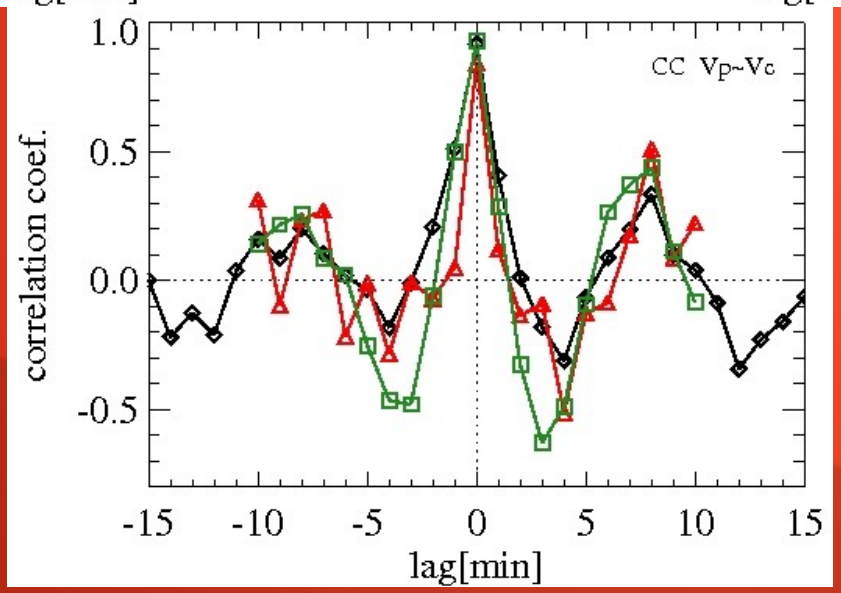
Ic, vp, vc: ~ 8 min period

wp: no periods

Red – first; Green – second; Black – full

Area N1: cross-correlations



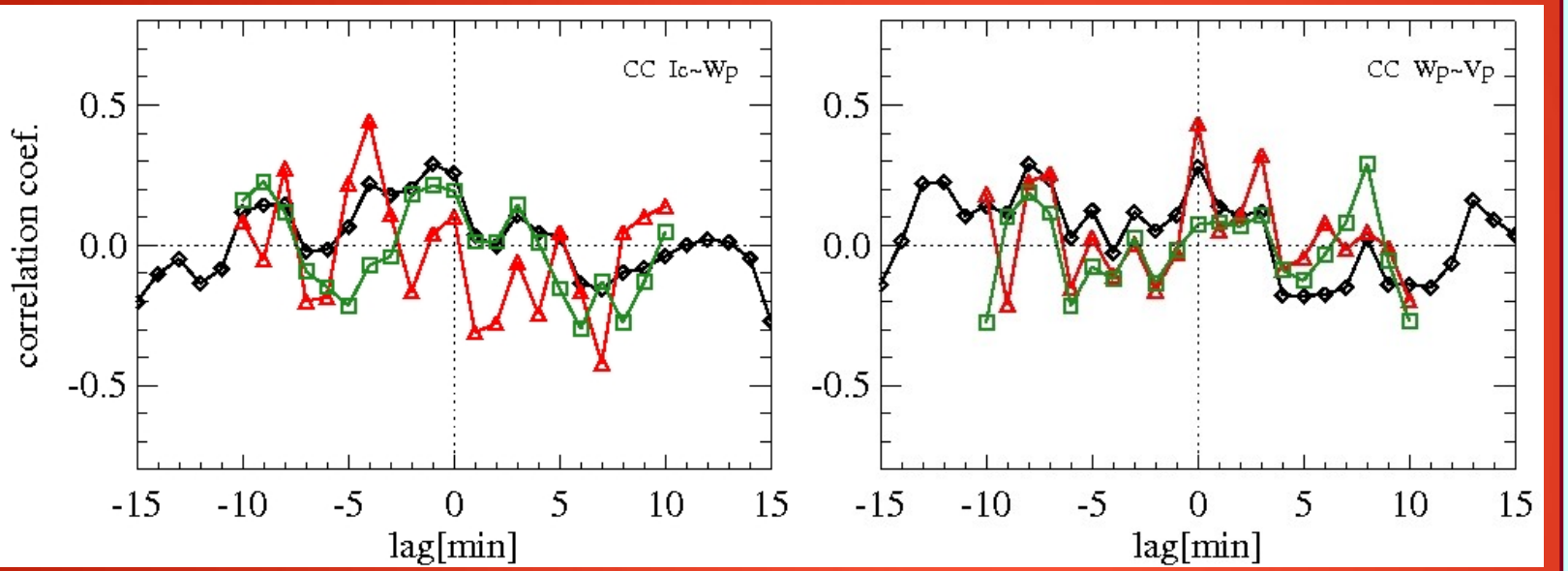


First half:
no significant correlations

Full & second half:
Ic with vp & vc: significant correlation
~ 8 min period
Ic behind vp & vc
~ 1.5 min
vp corr. with vc

Red – first; Green – second; Black – full

Area N1: cross-correlations



First half:
no significant correlations

Full & second half:
w_p no significant correlation with Ic or v_p

Red – first; Green – second; Black – full

Area N1 – Summary

- **we found statistically significant variations in the intensity I_c and both studied velocities v_c and v_p→**

… Magneto-acoustic waves can cause both intensity variations and Doppler shifts ... (Mathioudakis M. et al.: 2013, Space Sci. Rev., Vol. 175, Iss. 1-4, pp. 1-27)

- **we found a period of ~8 min → frequency of ~2 mHz →**

… The solar magnetic network ... shows evidence for MHD waves with frequencies in the range of 1-4 mHz ... (Mathioudakis M. et al.: 2013, Space Sci. Rev., Vol. 175, Iss. 1-4, pp. 1-27)

- **=> we found <u>evidence of propagation of MHD waves</u>**

Network areas N2 and N3

N2

Ic, vp, vc: ~ 12-14 min period
vp~vc: corr.
wp~vp and Ic~ wp: no corr.
Ic~ vp: Ic behind vp
~ 1.5 min

N3

Ic, vp, vc: ~ 16-17 min period
vp~vc: corr.
wp~vp and Ic~ wp: no corr.
Ic~ vp: Ic behind vp
~ 2 min

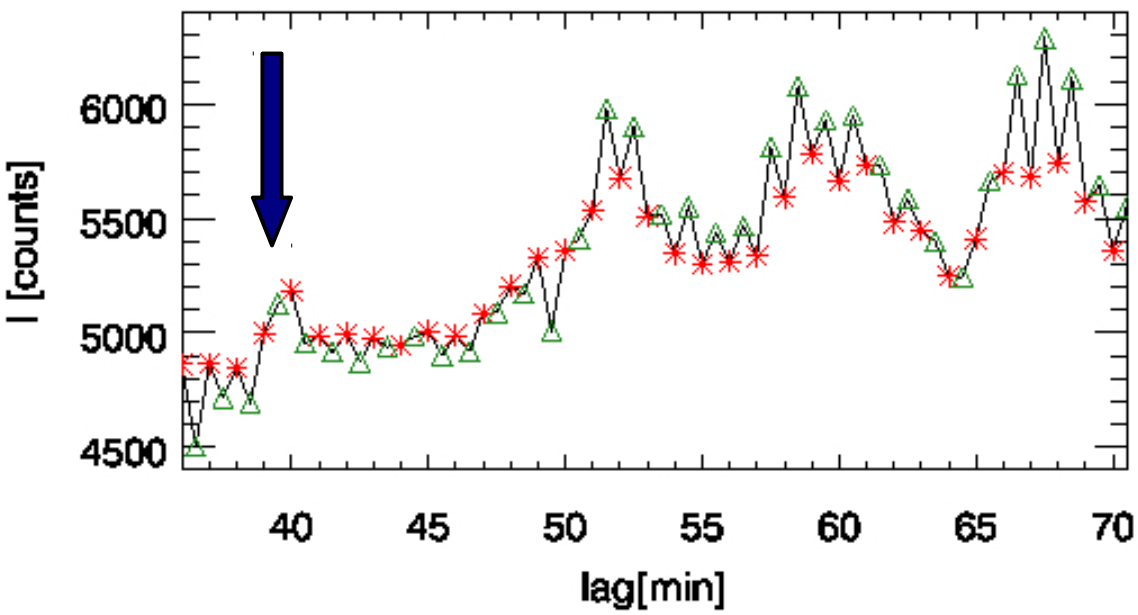
the observed periods are less significant than in case of area N1

Internetwork areas IN1, IN2 and IN3

IN1, IN2 and IN3

Ic, vp, vc, wp:
→ no corr. and no measurable shifts
→ noise ~ no period

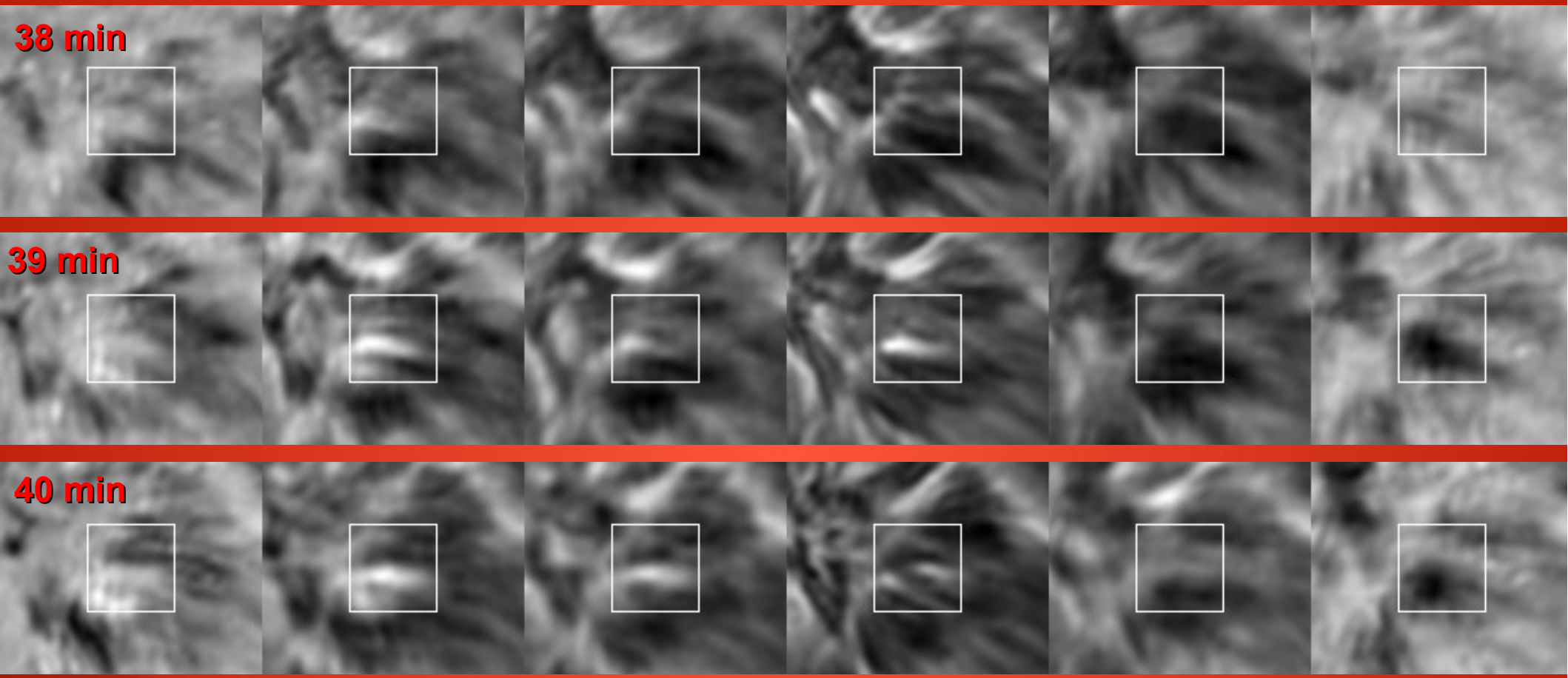
Case study – bright structure in Hα



Area N1:
mean intensity in Hα at λc:
→ four "bumps" ~ local peaks in brightness

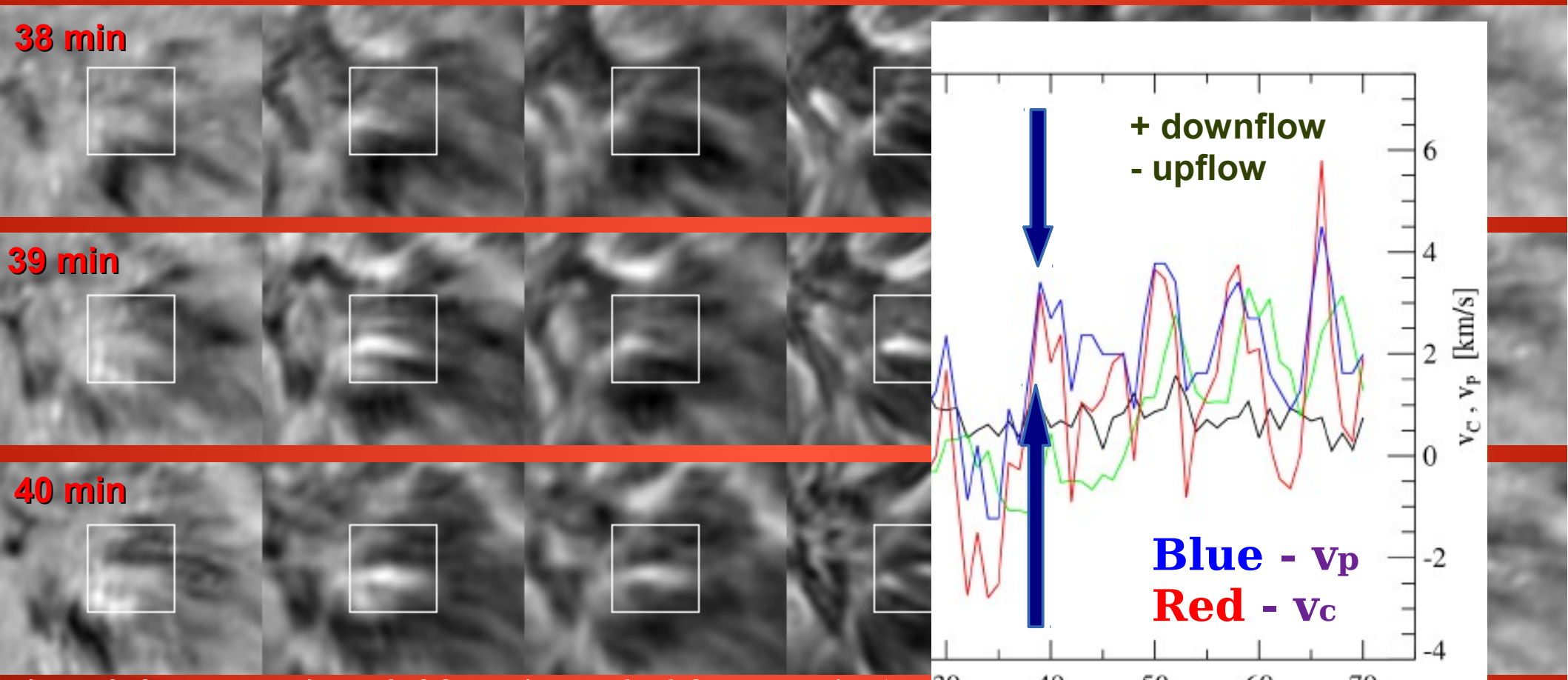
→ at ~39.5 min, ~52 min, ~60 min and at ~ 67 min
→ can single short-living bright structures be responsible?
→ lag ~10 min, ~8 min and ~7 min → coincidence?

Case study – bright structure in Hα



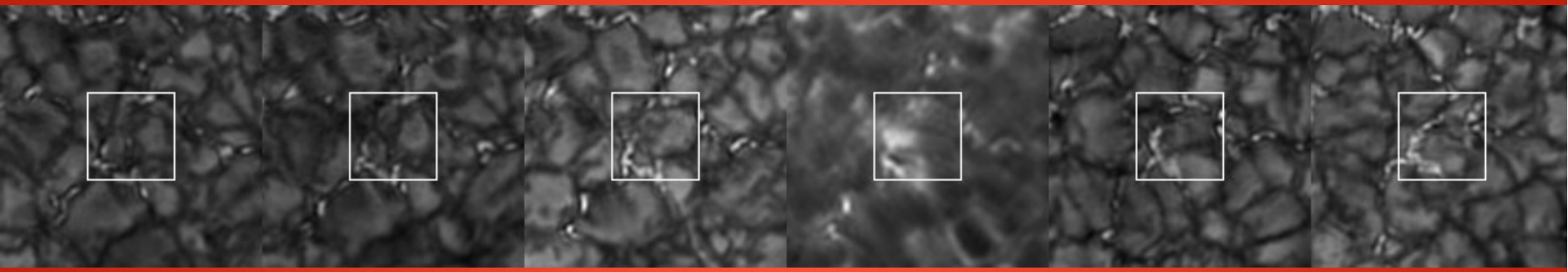
bright mottle in the Hα (λ_c): 39.0 - 40.5 min and at shorter wavelengths (blueshift) but not at longer wavelengths (redshift) → physical movement of the matter towards the solar surface (downflow)?

Case study – bright structure in Hα



bright mottle in the Hα (λ_c): 39.0 - 40.5 min and at shorter wavelengths (blueshift) but not at longer wavelengths (redshift) → physical movement of the matter towards the solar surface (downflow)?

Case study – G-band and Ca II H



- previously well-separated, single GBPs form a group in the left bottom part of N1
- ~ 39.5 min → a vertical filigree structure
- co-spacial bright point observed simultaneously in Ca II H
- the group of GBPs remain distinct and continues to evolve until the end of the observations
- → strong and stable underlying small-scale magnetic field concentration?

Case study – GBP numbers & velocities

N1 - numbers of GBPs:

- 626 GBPs identifications on all 141 images ~4.4 GBPs/image
- first 38 images (19 min): 93 GBPs ~ 2.4 GBPs/image
- next 122 images (51.5 min): 533 GBPs ~ 5.2 GBPs/image

for N2: 472 GBPs → 3.3 GBPs/image

for N3: 467 GBPs → 3.3 GBPs/image

N1 - velocities of GBPs:

- full FOV: most probable velocity ~ 0.9 km/s
- in N1 mean velocities of the tracked GBPs in range: from ~0.39 to ~2.40 km/s

Case study – Summary

we studied a bright mottle (lifetime ~ 1.5 min) in Hα-center within area N1

- causes significant increase of the mean intensity of N1 in Hα-center (first of the four observed)
- visible at ~39.5 min (beginning of the second half of the observation)
- a downflow of plasma
- co-spacial with the location of a conglomeration of GBPs (lifetime ~ tens of min) observed in G-band → evolved into a filigree during the observation (was a less concentrated group in the first half)
- greater number of identified GBPs after the first 19 min

Conclusions

- we studied the evolution of the mean values of four spectral characteristics (wp, Ic, vc and vp) of the Hα spectral line in the area (3.6 × 3.6 arcsec) designated N1
- we found statistically significant variations in the intensity Ic and both studied velocities vc and vp with a period of ~8 min→ indication of magneto-acoustic waves
- repetitive increases of the mean intensity of N1 in Hα-center → bright mottles
- co-spacial with the location of a conglomeration of GBPs observed in G-band → formed before the first distinct increase in brightness in Hα and evolved into a filigree during the observation → coincidence? or causal relation?

Thank You For Your Attention!!!