

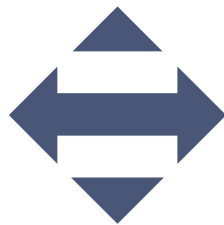
Dynamics of the DOT/LaPalma G-band bright points

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SLOVAK RESEARCH
AND DEVELOPMENT
AGENCY

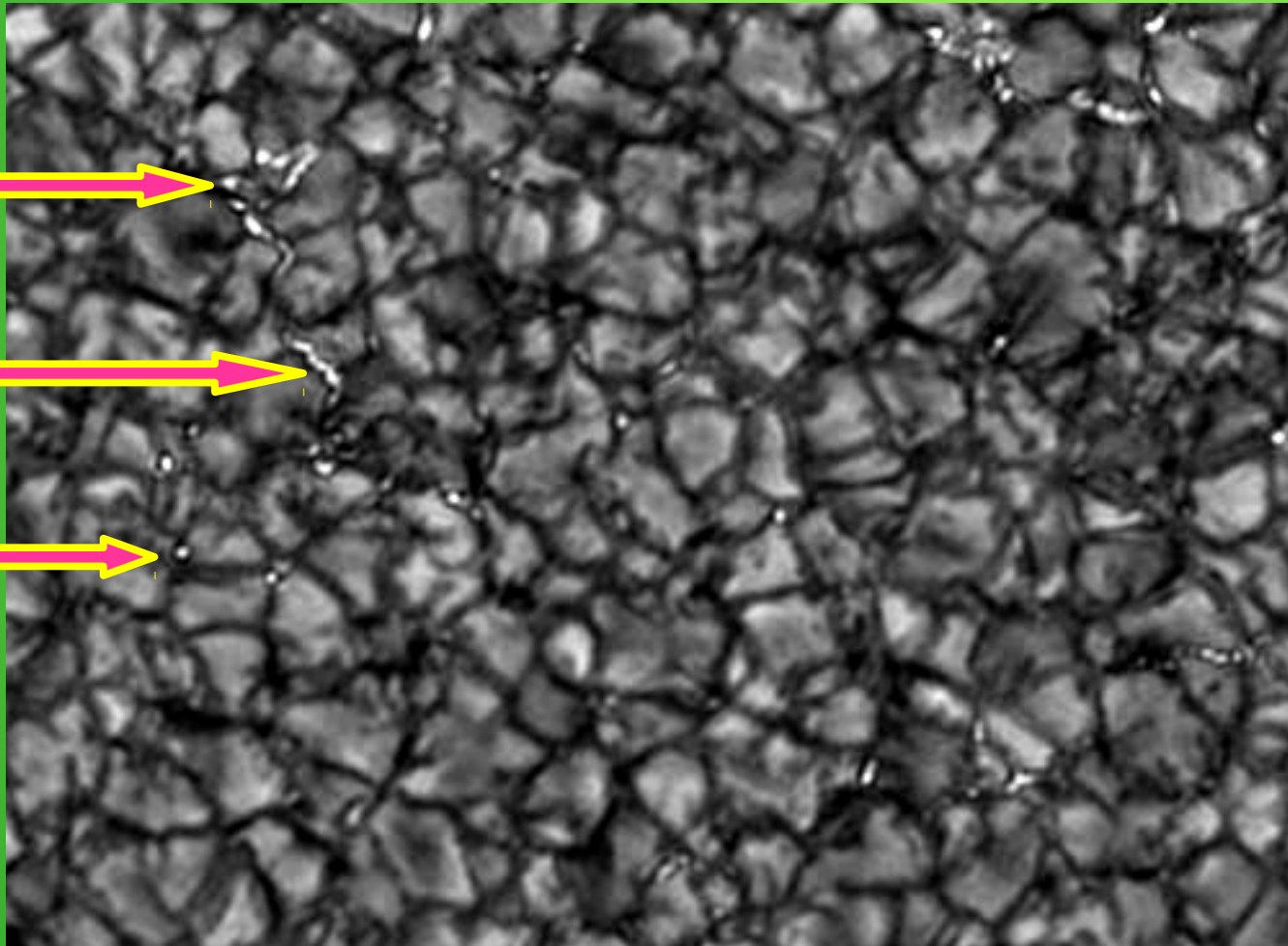


22nd National Solar Physics Meeting
March 24th – 26 - 30 May 2014,
Nižná nad Oravou, Slovakia

Introduction – What are G-band bright points?

- they are revealed as isolated brightenings if the sun is imagined in the **G-band** (spectral range at 430 nm [filter width ~1 nm] dominated by electronic transitions of the CH-molecule) at a sufficiently high resolution
- they are interpreted as **small-scale magnetic field concentrations** that are embedded in the convective flow field of the solar photosphere
- as manifestations of small-scale magnetic fields they become important for the understanding of the heating of the upper solar atmosphere

Introduction – What are G-band bright points?



G-band bright points:

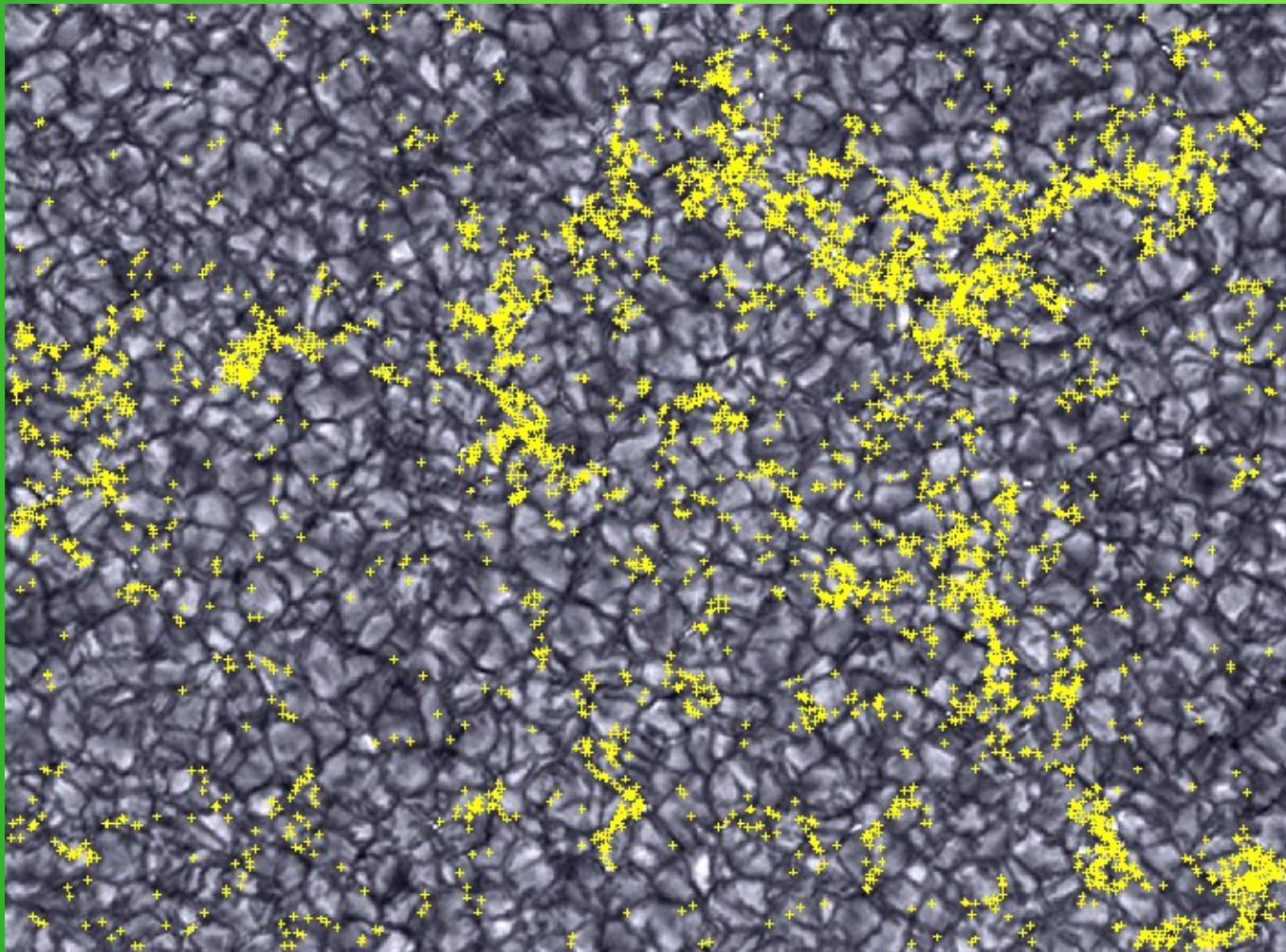
- **observed as conspicuously bright in dark intergranular lanes**
- **single points or groups of points - “filigree”**

Data

- speckle reconstructed images of the quiet solar photosphere in G-band (430 nm)
- Instrument:
Dutch Open Telescop (DOT)
19.10. 2005 (09:55 - 11:05 UT,
142 images, cadence 30s)
- Image size:
1112 pixel × 818 pixel
- FOV: 79 × 58 arcsec
- Sampling:
0.071 arcsec/pixels



Data – sample image

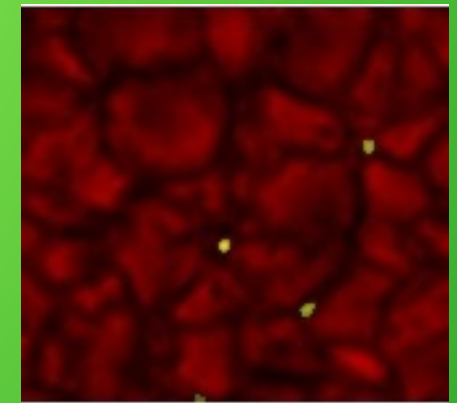
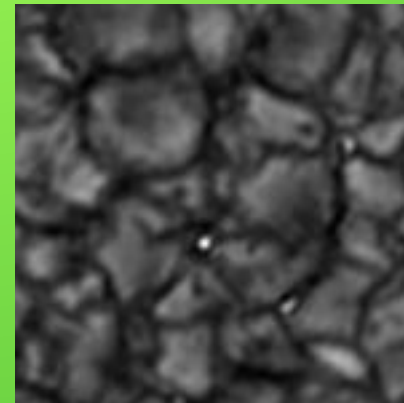


- a G-band image of the **quiet solar photosphere**
- **full FOV:**
78 × 59 arcsec
- **indicating the locations of tracked G-band bright points (GBPs)**
- **boundaries of supergranules**

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, 289-293, 2009)
- 26238 GBP identifications of 4017 tracked GBPs on all 142 images of the data set
- Statistical properties of the tracked GBPs:
 - 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



Dynamics of GBPs

Aim: to present a compact study of four traditional and two new parameters describing dynamics of tracked GBPs

Studied parameters - traditional:

- effective velocity v
- change in effective velocity dv/dt
- change in direction angle $\Delta\varphi$
- centrifugal acceleration $vd\varphi/dt$

- new:

- rate of motion d/r
- time lag between recurrence

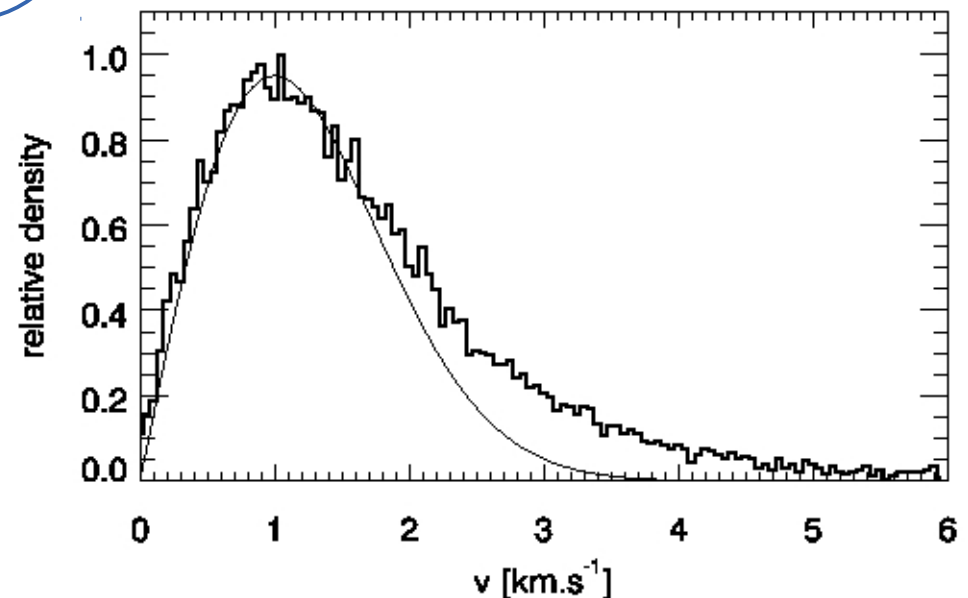


1) Effective velocity

- range of values: 0 - 6 km/s
- median value: 1.38 km/s
- mean value: 1.62 ± 1.06 km/s
- most probable value: 0.9 km/s
- numerous are low velocities:
~ 0.5 - 2.0 km/s
- only 10% higher than 3 km/s

- good coincidence:
0.0 - 1.5 km/s
- discrepancy →
increased numerosity
of velocities: 2 - 4 km/s

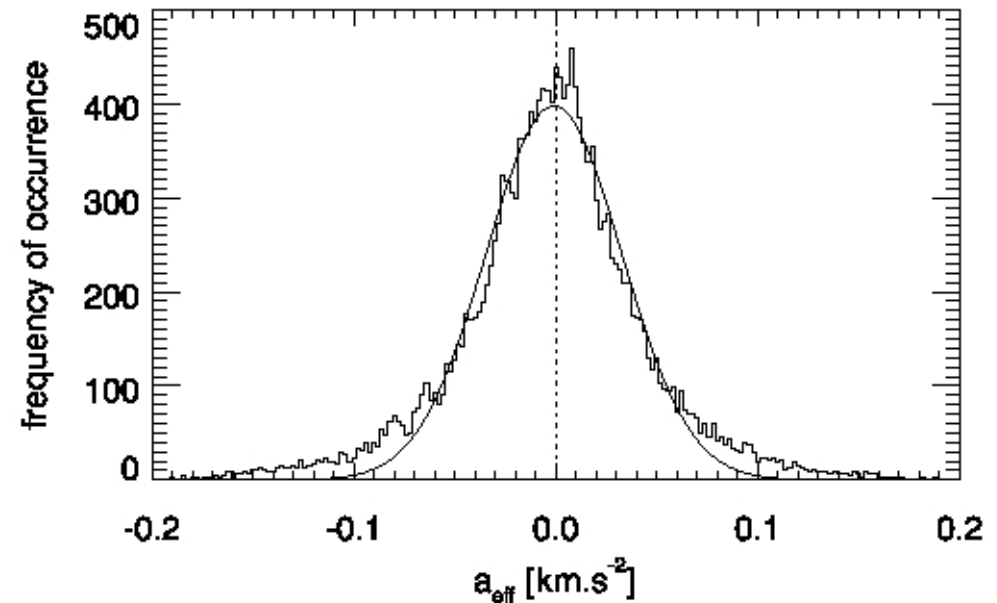
- $v = \sqrt{v_x^2 + v_y^2}$
- Sample Rayleigh
Distribution ($\sigma=1$)
$$f(v, \sigma) = \frac{v}{\sigma^2} \exp\left(\frac{-v^2}{2\sigma^2}\right)$$



2) Change in effective velocity

- $a_{eff} = dv/dt$
- positive (acceleration) and negative (deceleration)
- values in range: (-0.2) – (+0.2) km/s²
- 77.8% of values in range: (-0.05) – (+0.05) km/s²

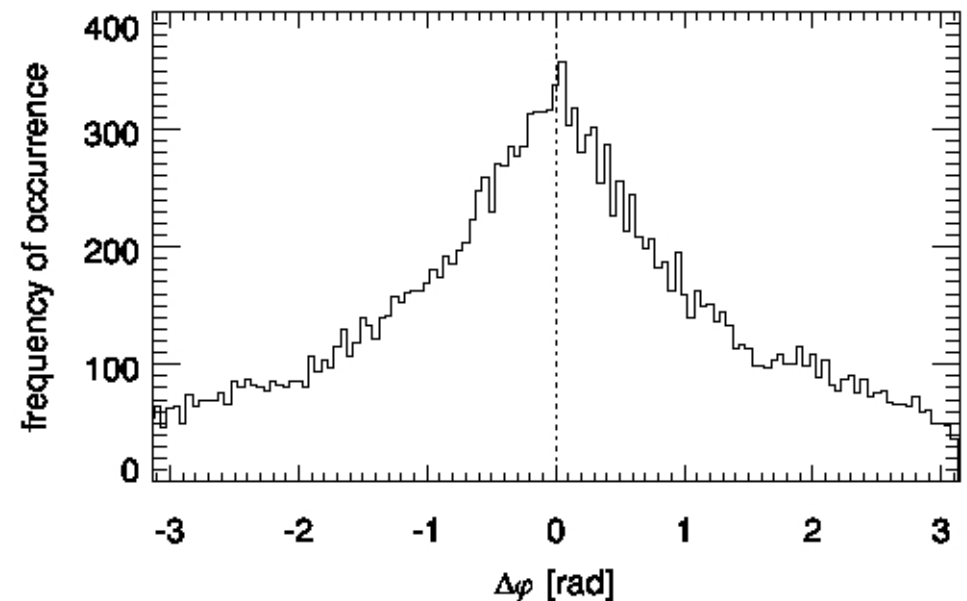
- +0.05 km/s² → increase of velocity by 1.5 km/s after 30 s
- Gaussian fit:
FWHM = 0.08 km/s²
shift of the center: -0.001 km/s²



3) Change in Direction Angle

- $\Delta \varphi = \varphi_2(t_2) - \varphi_1(t_1)$ $t_1, t_2 (t_2 = t_1 + 30s)$
- change in direction of motion of GBPs between two successive time steps (30s)
- each possible value has nonzero probability \rightarrow no preferred direction of motion common for all tracked GBPs

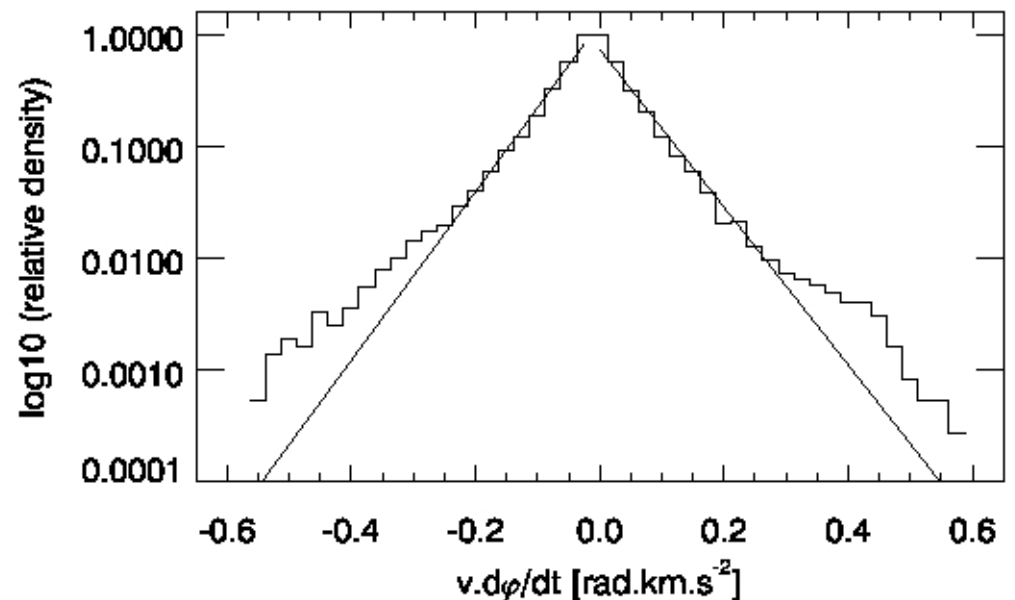
- not Gaussian as a whole
- ratio of keeping ($-\pi/4 < \varphi < +\pi/4$) to reversing ($\varphi < -3\pi/4$ or $\varphi > 3\pi/4$): 4.07



4) Centrifugal acceleration

- $v \cdot d\varphi/dt$
- a relevant quantity when considering the generation of waves in magnetic flux tubes
- exponential distribution \rightarrow logarithmic scale
- Gaussian shape

- **two linear fits:**
- in the range from -0.25 to 0.0 rad km/s² (slope $+5.54$) \rightarrow **0.87 %**
- in the range from 0.0 to 0.3 rad km/s² (slope -5.48) \rightarrow **0.42 %**

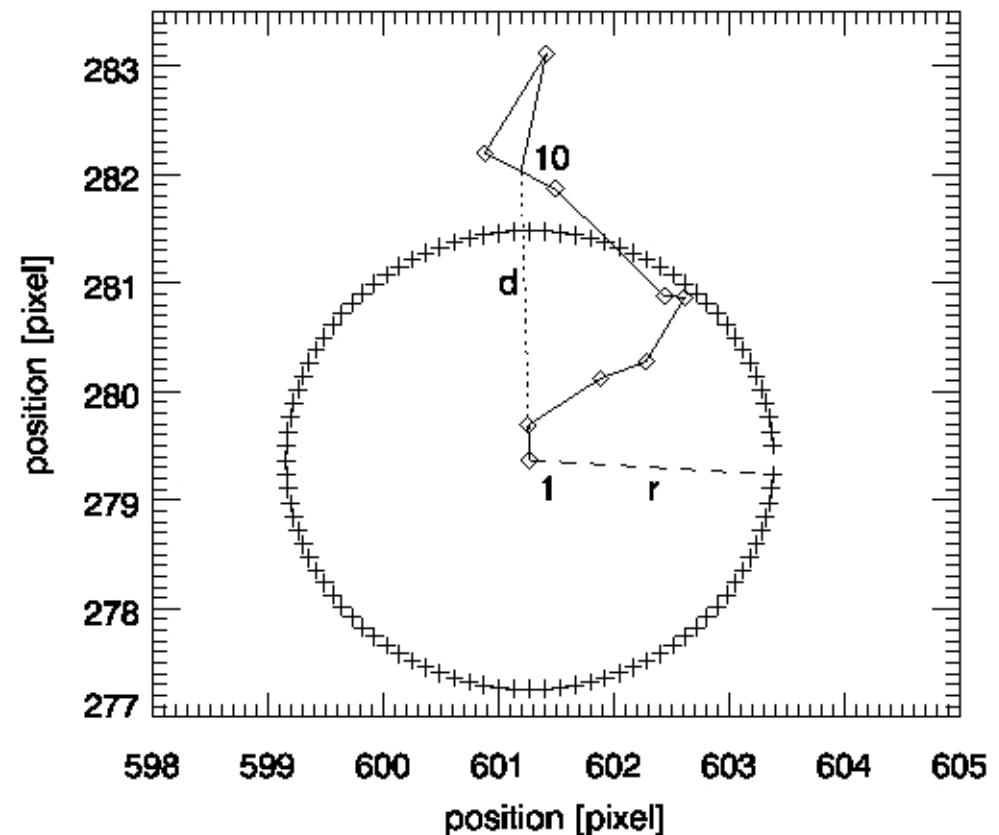


5) Rate of motion

- location of a **GBP** = location of barycenter of brightness
- the observed motion of GBPs is minimal – distances made during existence are mostly up to ~1 arcsec
- mean area of a **GBP**: ~ 20 px², i. e. ~ 0.1 arcsec²

$$m = d / r$$

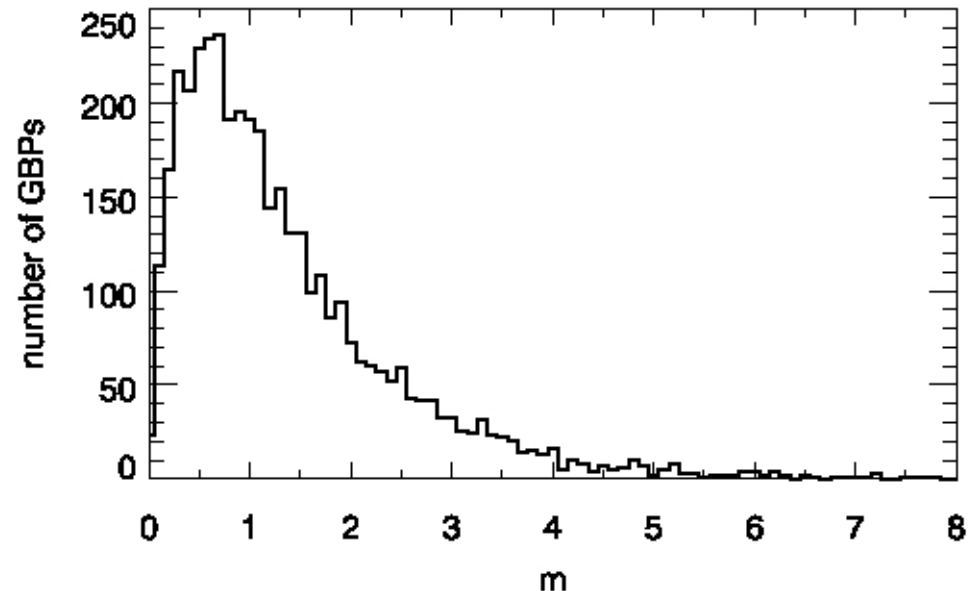
- **m** - tells if the **GBP** at the end of its existence left the circle defined by the size of the **GBP**
- **d** - the distance between the first and the last location of the **GBP**
- **r** - the radius of the circle



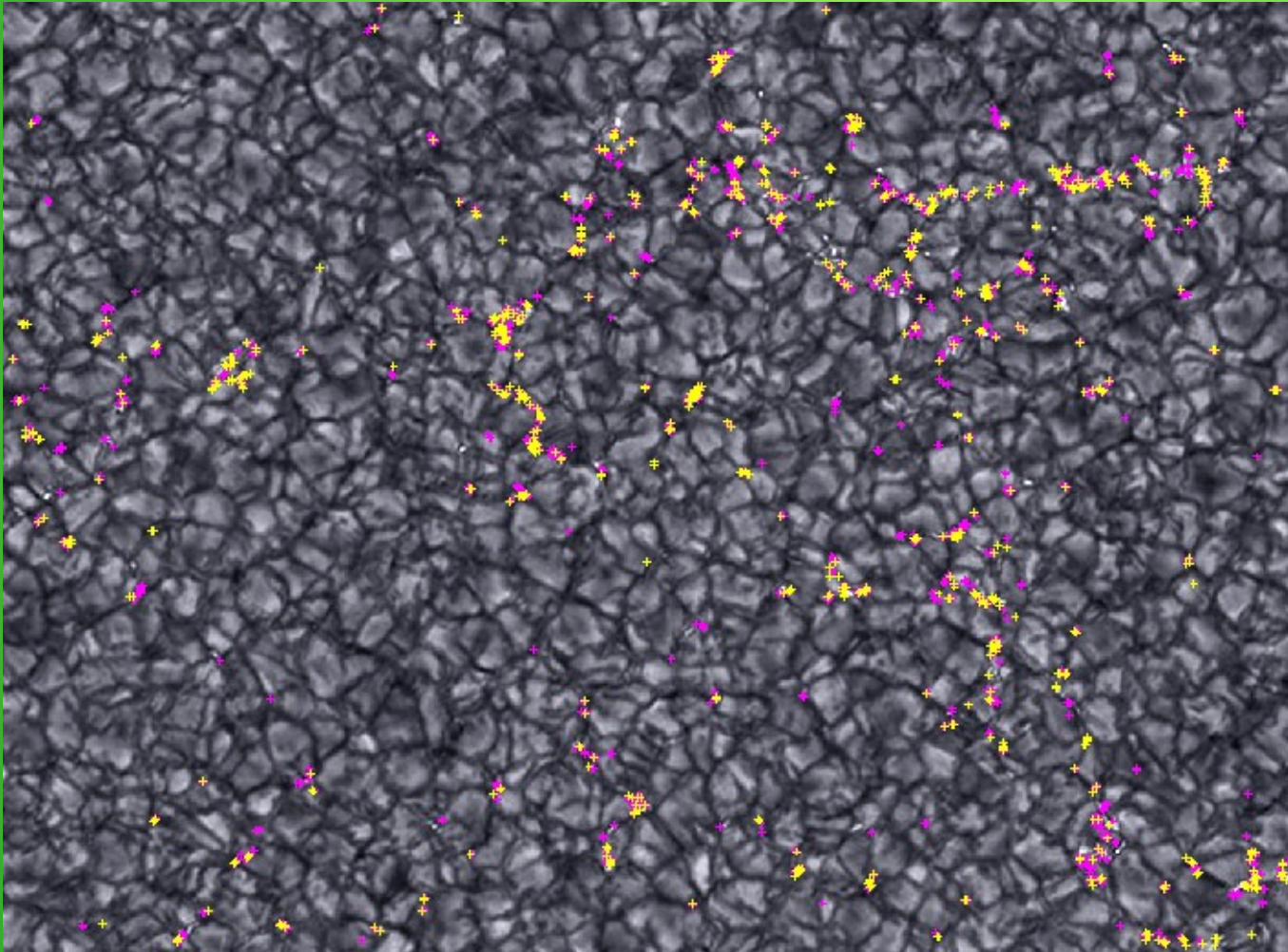
5) Rate of motion - cont.

- ~45% GBPs: $m < 1$ → stay within the circle of the first identification
- ~55% GBPs: $m > 1$ → get outside of the circle of the first identification

- ~18.5% have $2 < m < 4$ → significant movement → cannot be accounted for by the momentary location of the barycenter of brightness within the area of the GBP



Rate of motion – cont.

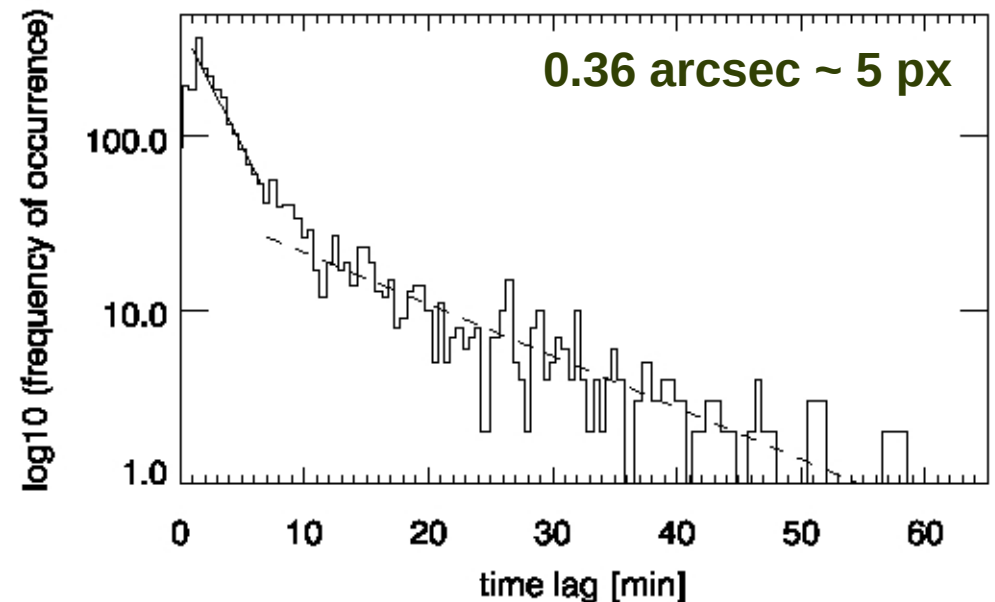


- sample G-band image of the quiet solar photosphere
- FOV: 78×59 arcsec
- indicated locations of the tracked GBPs with $m < 1$ and with $m > 2$

6) Time-Lag Between Recurrence of GBPs

- the frequency of recurrence of different GBPs on the same locations - areas of a given size
- studied areas: **0.36, 0.50, 0.64, 0.78 and 0.92 arcsec**
- small time lags (up to ~4 min) → **most frequent**
- most numerous time lags: **~2-3 min**
- time lags longer than ~10 min → **less frequent**

- **two trend lines:**
- values lower than ~7 min (solid, slope of **-0.14**)
- values higher than ~7 min (dashed, slope of **-0.03**)



Summary

- **effective velocity:** most probable value is ~ 0.9 km/s; deviation from the Rayleigh function ($\sigma = 1.0$) in the range $\sim 2-4$ km/s
- **change in effective velocity:** Gaussian (FWHM = 0.087 km/s²)
- **change in direction angle:** non-Gaussian, symmetric
- **centrifugal acceleration:** Gaussian, highly exponential
- **rate of motion:** $\sim 45\%$ of tracked GBPs \rightarrow displacement is smaller than their initial size; same locations of GBPs with $m < 1$ and $m > 2$
- **time lag of recurrence of GBPs:** most numerous are lasting $\sim 2-3$ min and lags up to ~ 4 min are more numerous than longer lags; two different trends for time lags smaller and greater than ~ 7 min

Conclusion

- our results for effective velocities, change in direction angle and centrifugal acceleration acknowledge the results of previous authors
- we defined two new parameters: to help to estimate the real displacement of GBPs during their existence (rate of motion) and the frequency of their recurrence on the same locations (time lag between recurrence of GBPs)
- the observed movement of GBPs is within a small area along the intergranular lanes
- there is no difference in locations of stable and more vigorously moving GBPs
- numerous relatively short time lags indicate that GBPs tend to vanish and reoccur on their locations → manifestations of underlying longer-living magnetic fields

Thank you for your attention!



For more details on the topic check out:

Bodnárová, M., Utz, D. and Rybák, J., On Dynamics of G-Band Bright Points, Solar Phys (2014) 289:1543–1556