Dynamics of the DOT/LaPalma G-band bright points

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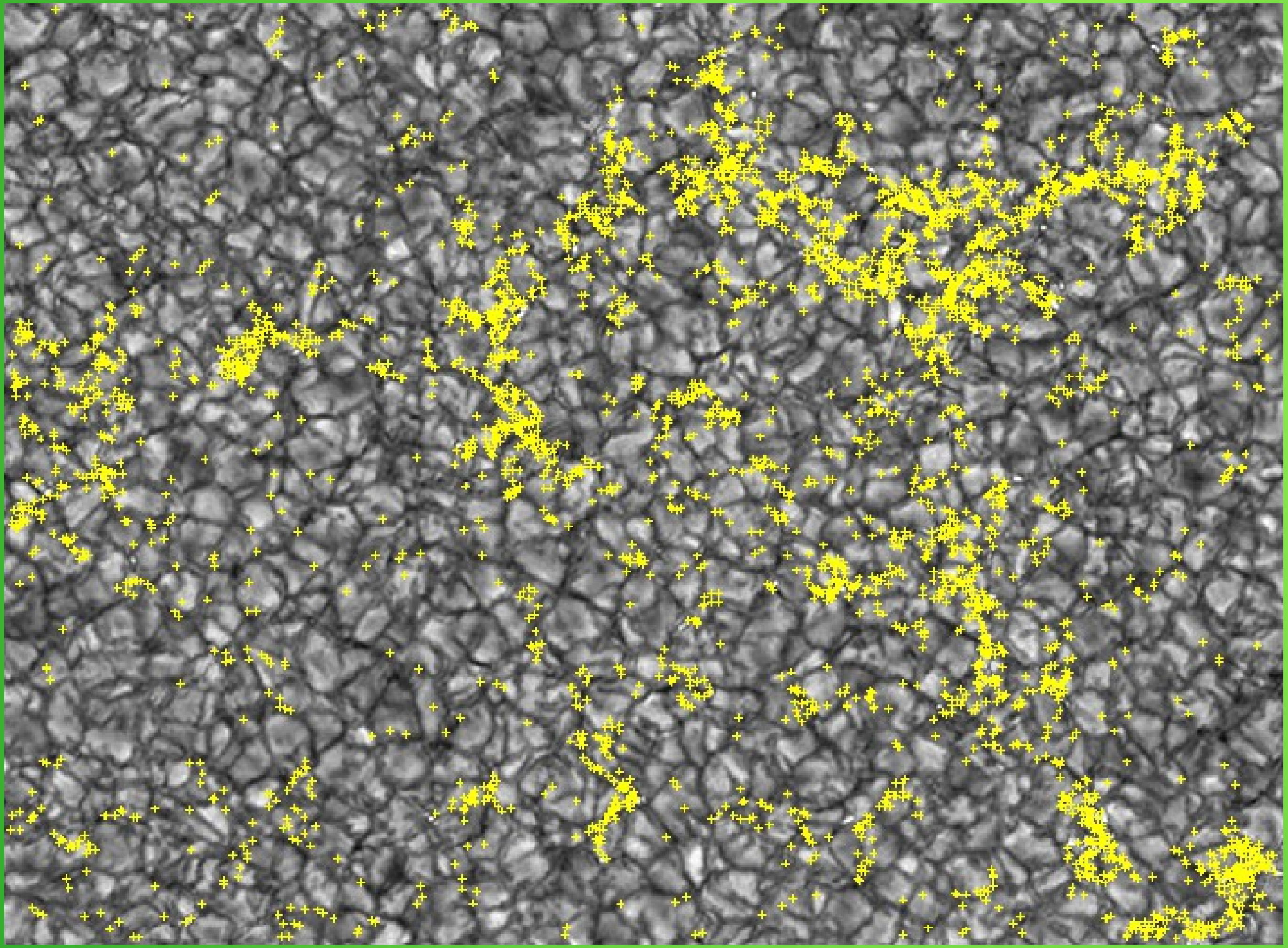
Introduction – What are G-band bright points?

- they are revealed as isolated brightenings if the sun is imagined in the G-band (spectral range at 430 nm 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 coronal heating process and the variability of the solar irradiance

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
- with the indicated locations of the tracked G-band bright points (GBPs)

Identification and tracking of GBPs

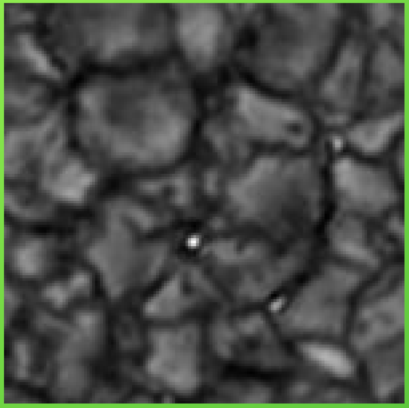
- **GBPs were identified and tracked on G-band images using the algorithm developed by Utz et al. (A&A 498, 289-293, 2009)**
- **26238 GBP identifications of 4017 tracked GBPs on all 142 images of the data set**
- **Statistical properties of the tracked GBPs:**

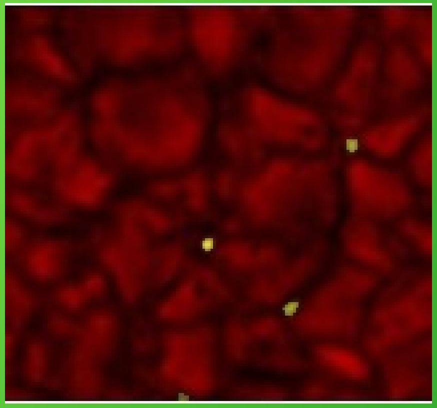
  average radius (244.9 ± 37.62 km)

  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 $v d\varphi/dt$

- new:

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

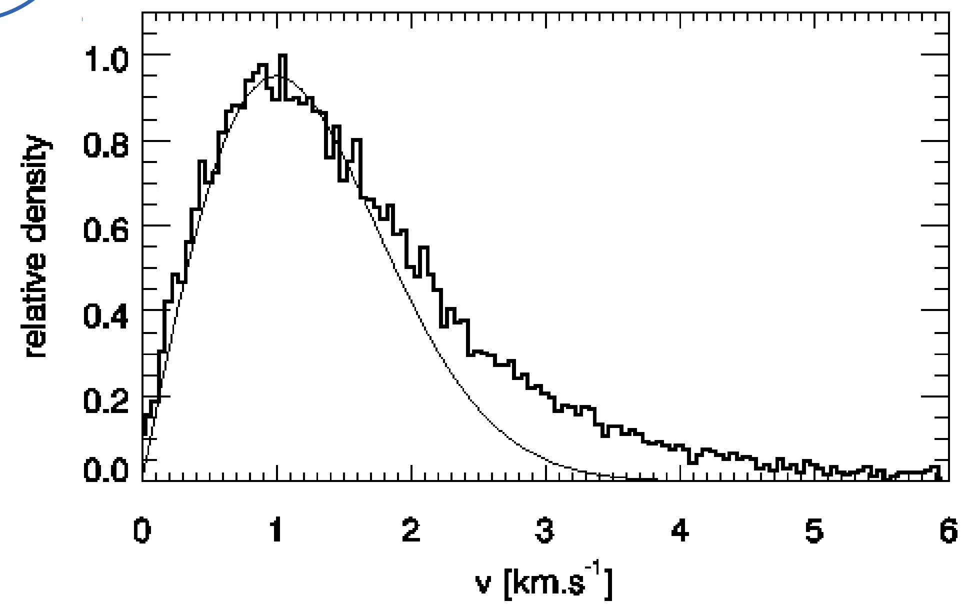
1) Effective velocity

- 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

- $v = \sqrt{v_x^2 + v_y^2}$
- Sample Rayleigh Distribution (σ=1)

$$f(v,\sigma) = \frac{v}{\sigma^2} \exp\left(\frac{-v^2}{2\sigma^2}\right)$$

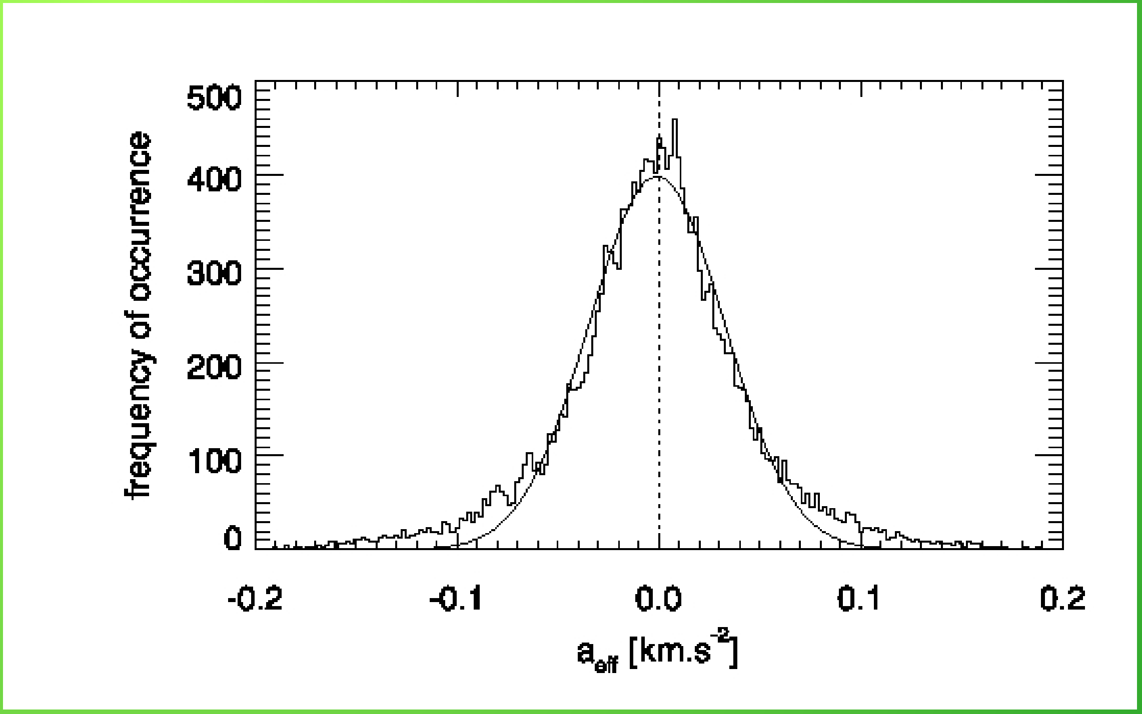
- good coincidence: 0.0 - 1.5 km/s
- discrepancy → increased numerosity of velocities: 2 - 4 km/s



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

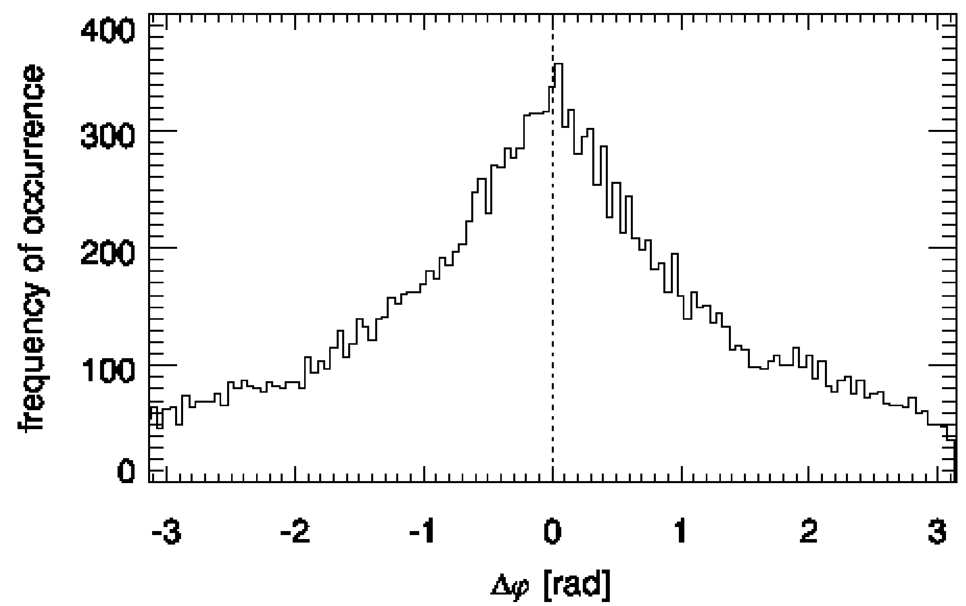
- +0.05 km/s² → increase of velocity by 1.5 km/s after 30 s
- Gaussian fit: FWHM = 0.08 km/s² shift of the center: –0.001 km/s²



3) Change in Direction Angle

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

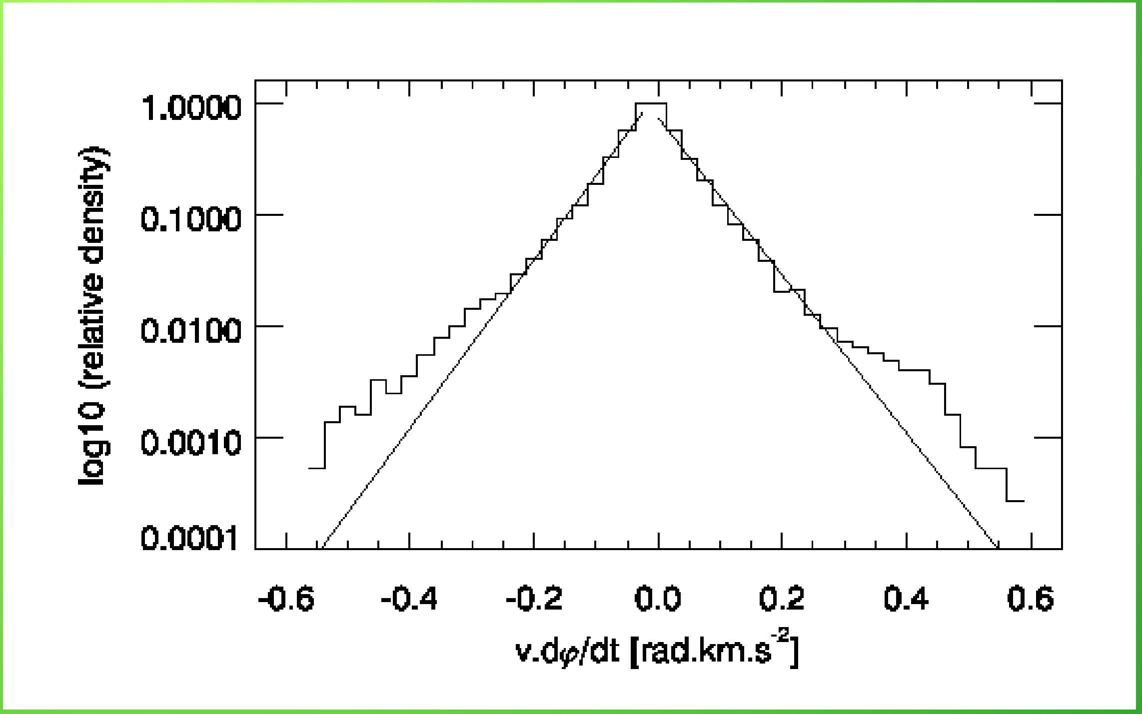
- **not Gaussian as a whole**
- **ratio of keeping ($-\pi/4 < \varphi < +\pi/4$) to reversing ($\varphi < -3\pi/4$ or $\varphi > 3\pi/4$): 4.07**



4) Centrifugal acceleration

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

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

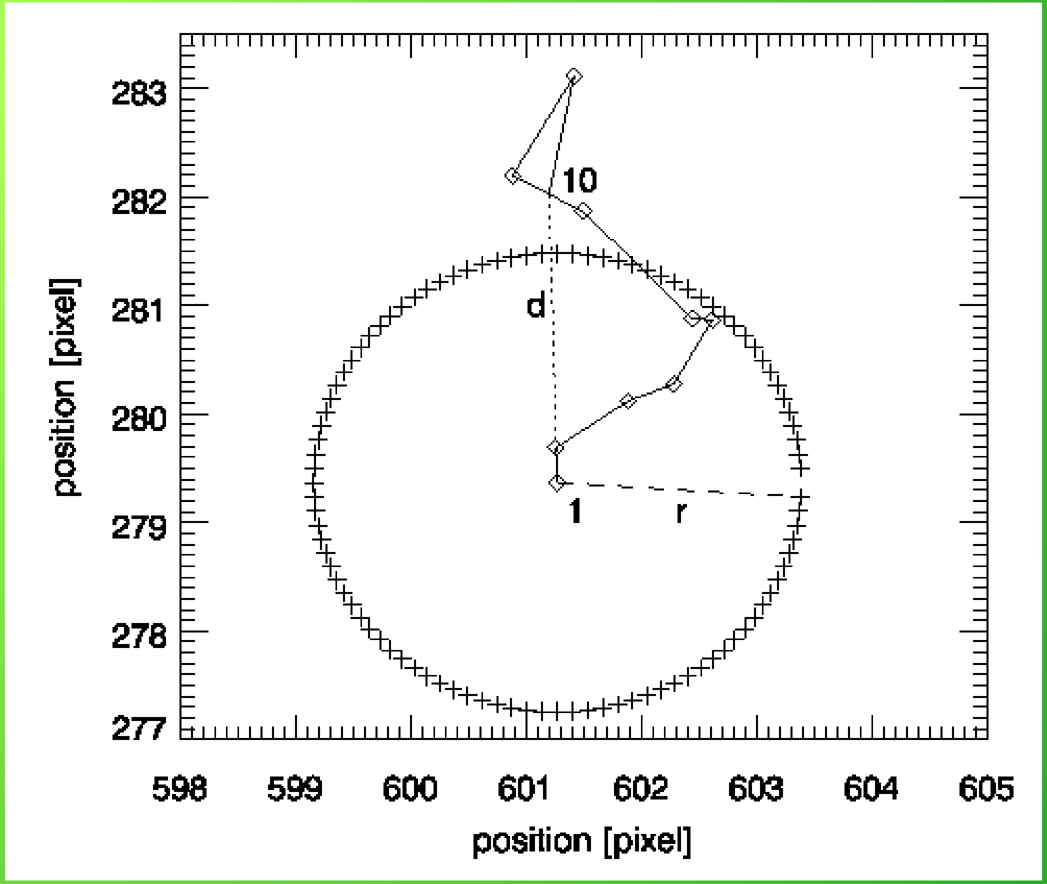


5) Rate of motion

- **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**

$$m = d / r$$

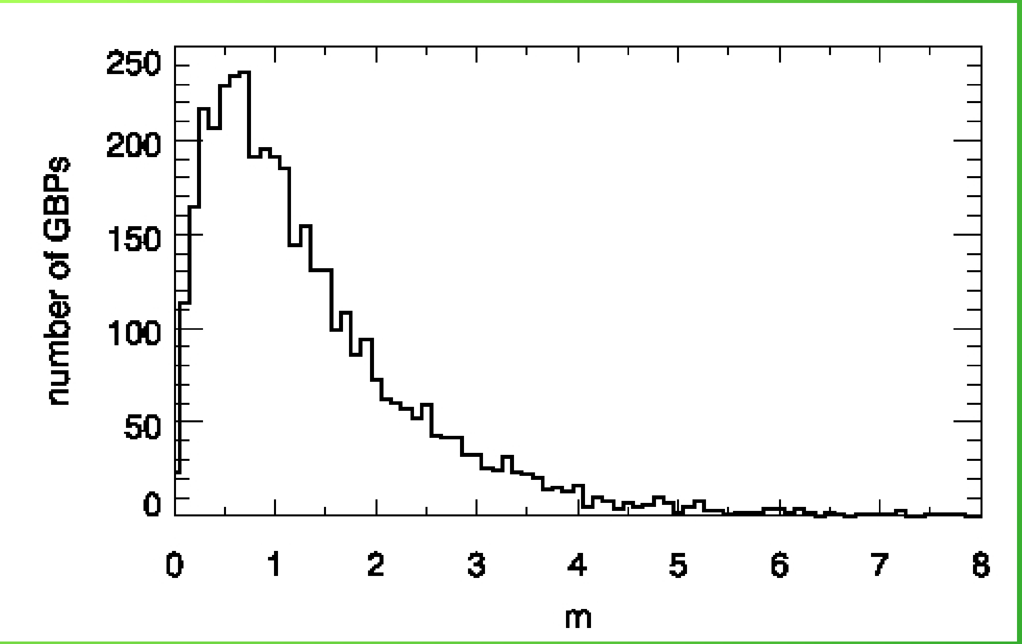
- **m - tells if the GBP at the end of its existence left the circle defined by the size of the GBP**
- **d - the distance between the first and the last location of the GBP**
- **r - the radius of the circle**



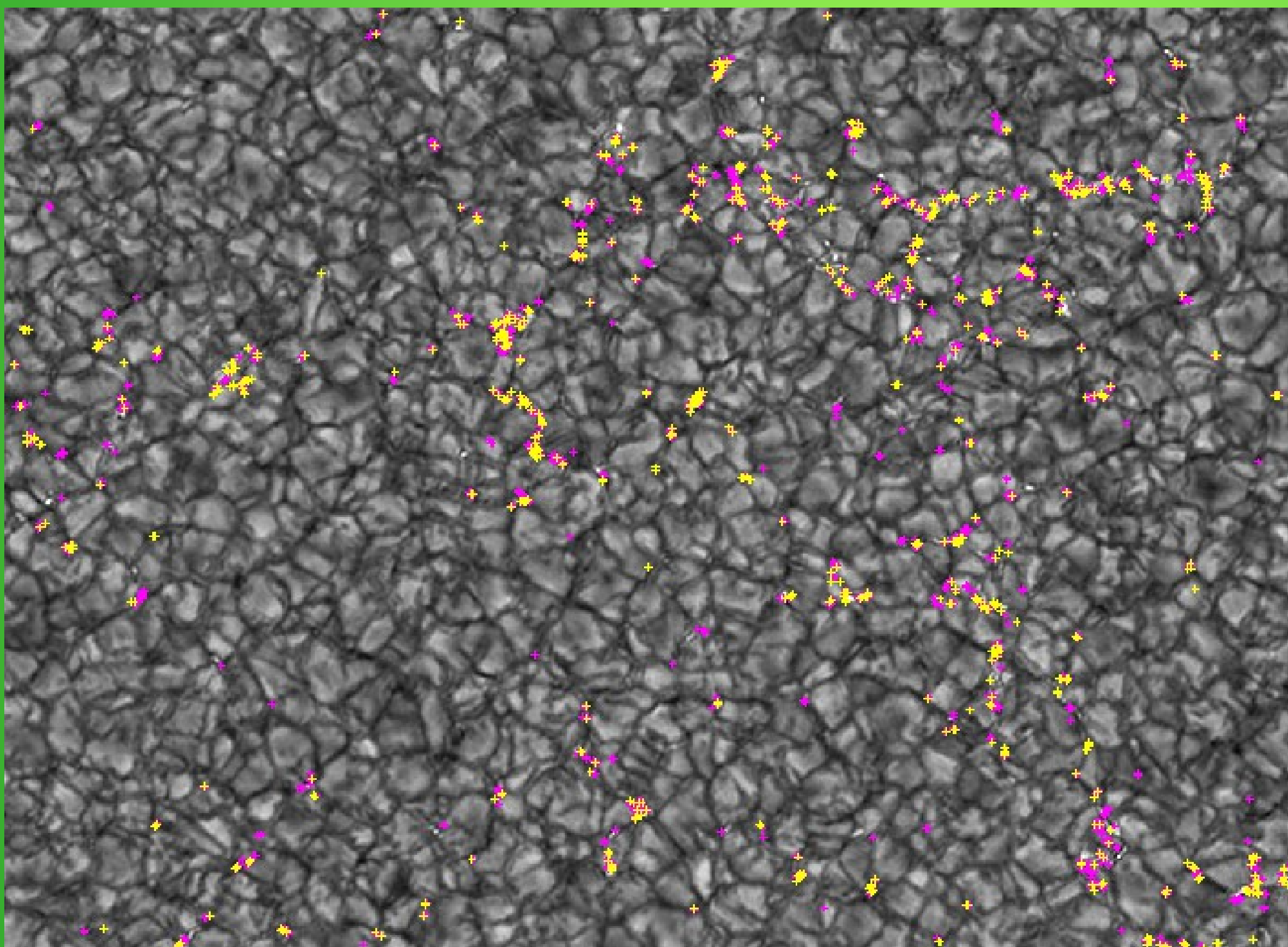
5) Rate of motion - cont.

- ~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.

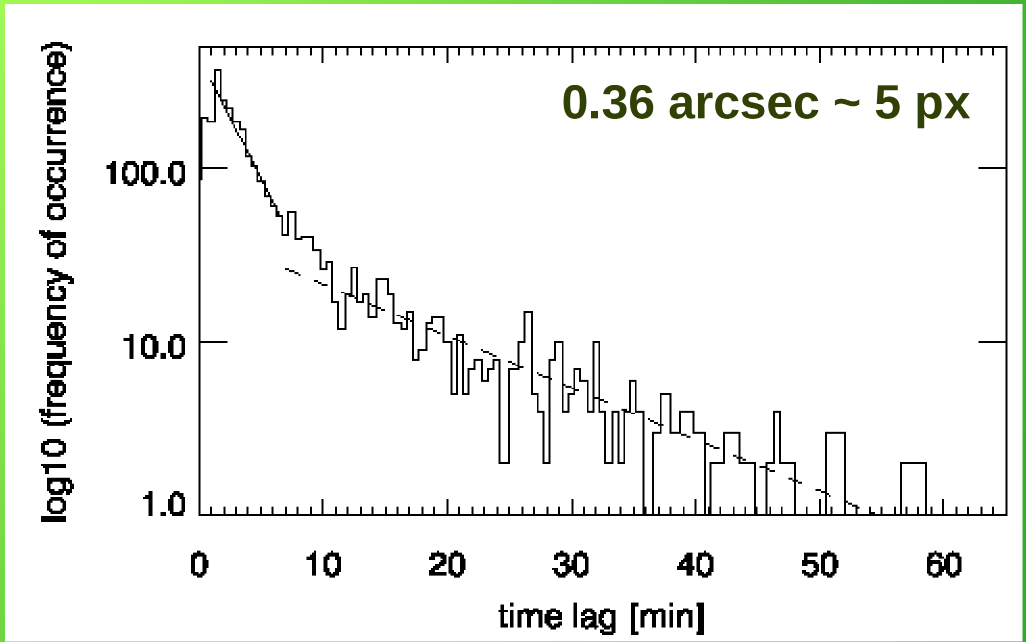


- sample G-band image of the quiet solar photosphere
- FOV: 78 × 59 arcsec
- indicated locations of the tracked GBPs with m<1 and with m>2

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 (σ = 1.0) in the range ~2-4 km/s
- **change in effective velocity:** Gaussian (FWHM = 0.087 km/s^2)
- **change in direction angle:** non-Gaussian, symetric
- **centrifugal acceleration:** highly exponential
- **rate of motion:** ~45% of tracked GBPs → 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 ~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