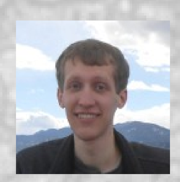
SHINE 2017

University of Colorado Boulder

Characterizing the Motion of Photospheric Magnetic Bright Points At High Resolution



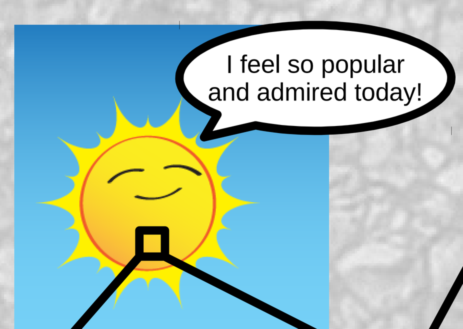
Sam Van Kooten[1], Steve Cranmer[1], Matthias Rempel[2]

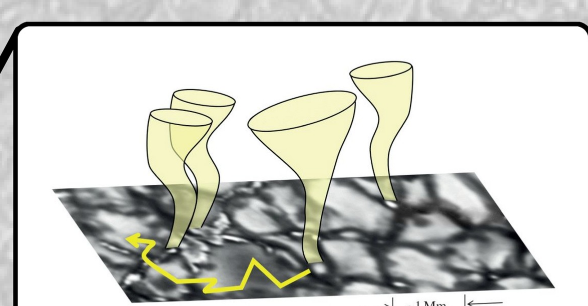
1: LASP, University of Colorado, Boulder, CO, USA. 2: High Altitude Observatory, NCAR, Boulder, CO, USA. Contact: samuel.vankooten@colorado.edu

Intro

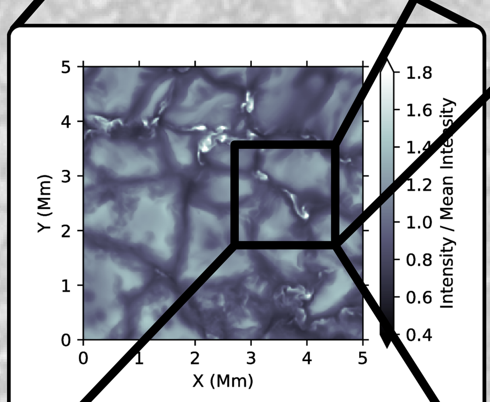
Photospheric bright points are small (~100 km) regions of concentrated (~1 kG), vertical magnetic flux. Bright points are the footpoints of flux tubes that reach into the corona. They appear in intergranular lanes and are shaken about by convective churning. This shaking excites MHD waves in the flux tubes which carry energy to the corona—**a model of coronal heating**. The power spectrum of this motion serves as input to models of Alfvén wave propagation through the corona and heliosphere [1].

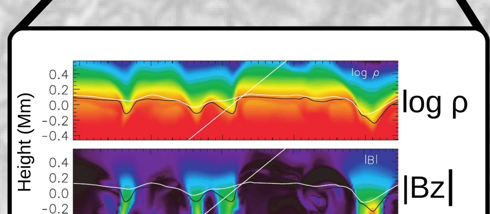
This project aims to investigate both **the motion of these bright points and how that motion is driven**. We use two different models, both achieving much higher spatial resolution than current observations (but comparable to DKIST's resolution).





Cranmer et al. (2015), RSPTA, 373, 20140148.





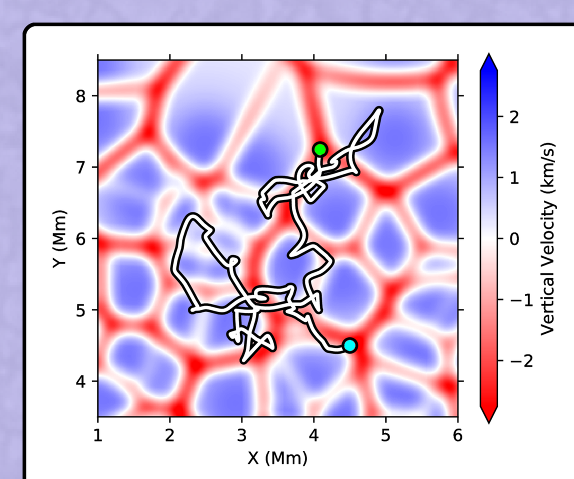
Carlsson et al. (2004), ApJ, 610, L137.

Bright points have flux tubes extending from the photosphere to the corona. The above panel illustrates the flux tubes, widening at the lower gas pressures above the surface and with kinks propagating upward from past shaking of the footpoints. At the photosphere, the tubes' magnetic pressure offsets gas pressure. This reduces the gas density and allows lines of sight to reach deeper, hotter, brighter depths. This is shown in the bottom-left panel's simulated data by the black line marking the average formation height for vertical rays.

(Random, Observationally-motivated, Unphysical, Granule-based Heliophysics)

ROUGH

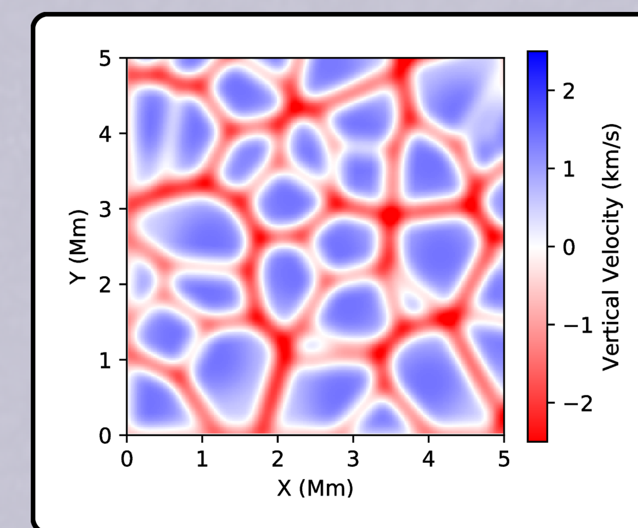
- 2D, simplified, home-brewed model of granulation
- Arbitrary resolution
- Produces reasonable, strictly laminar granulation
- Bright points emulated as passive tracers ("corks")
- We track one cork in each of ~3000 independent model runs
- Offers direct control of granulation properties



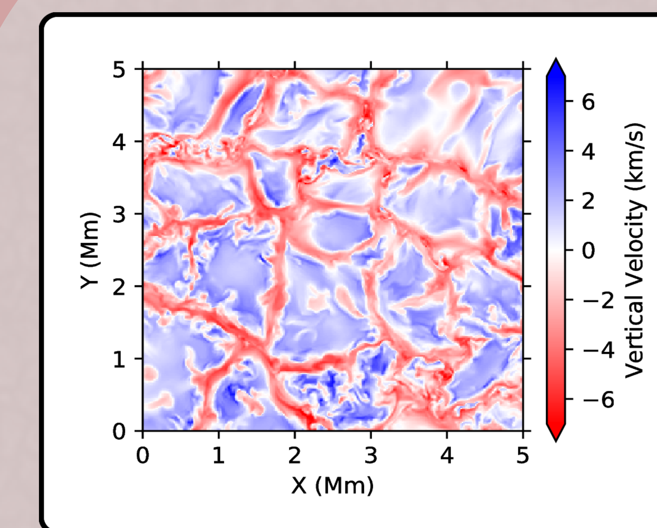
Above is the motion path for a single cork tracked over 166 minutes. Note the presence of both long-term, steady motion and short-term, rapidly-changing motion.

MURaM

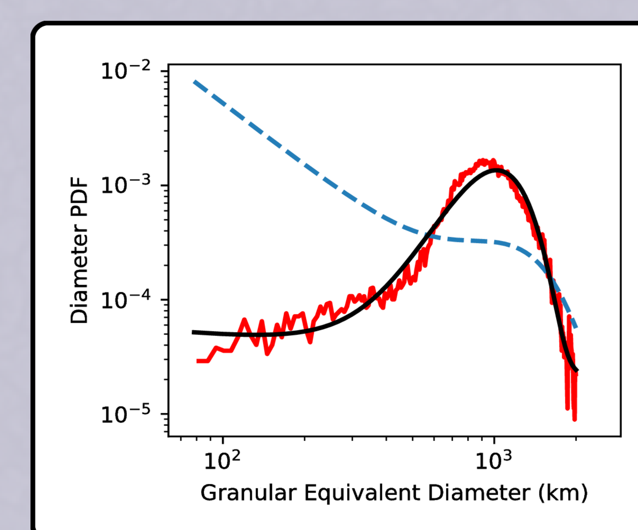
- 3D RMHD simulation of photosphere
- 16 ✕ 16 km resolution
- Produces realistic granulation with turbulence
- Bright points emerge from simulation physics
- We automatically track thousands of bright points over 2.3 hours

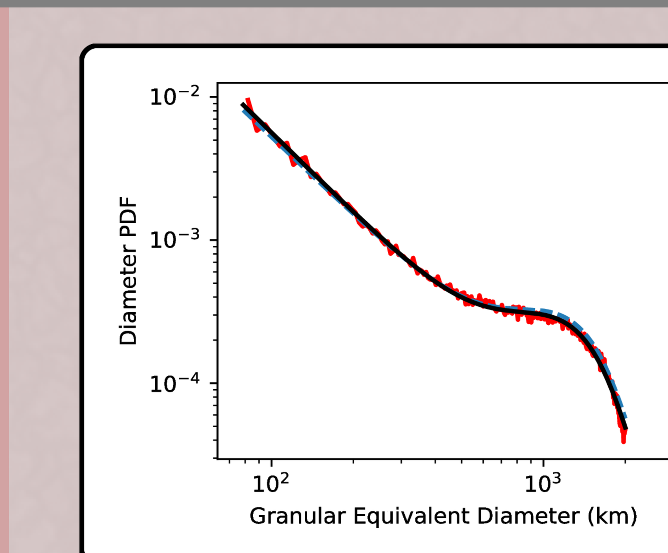


By design, ROUGH lacks the wispy, turbulent edges in MURaM.



Otherwise, the granulation patterns look similar between the two models.





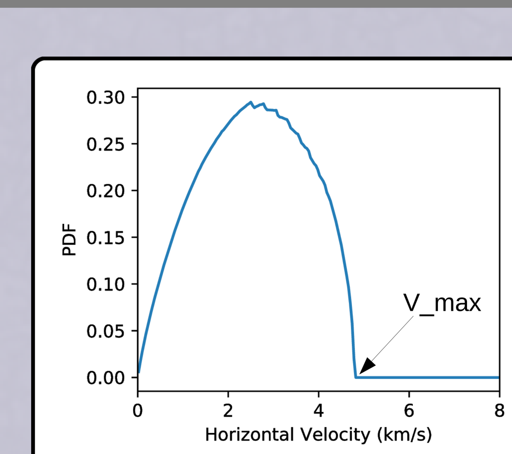
MURaM's granules fall along the same size distribution as observed granules [3]. This distribution is the sum of a Gaussian and a power-law component. ROUGH granules are fit by only the Gaussian component.

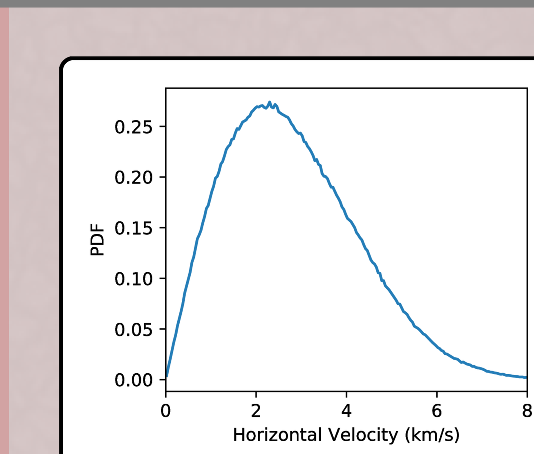
Red line: Data

Black line: Two-component model fit

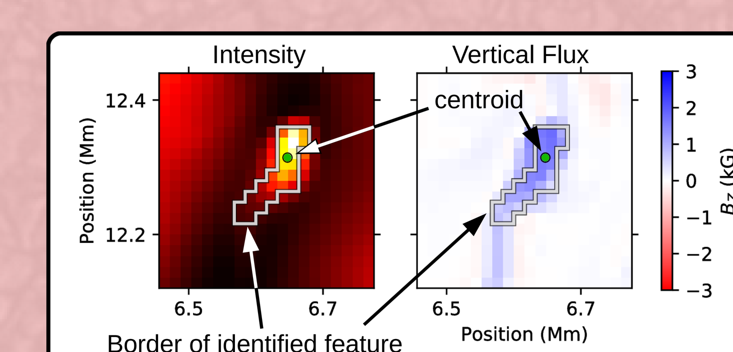
Dashed line: Model fit to observations [3]

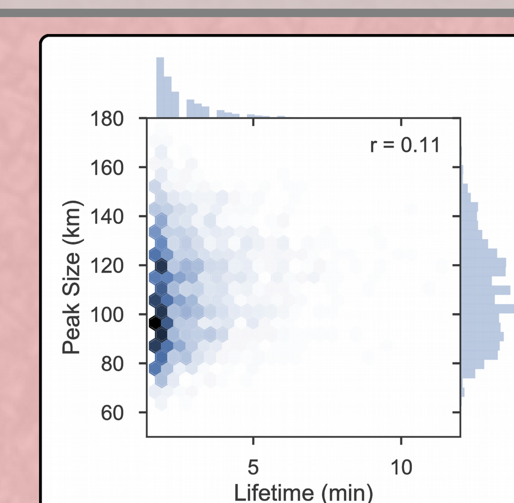
ROUGH is able to match MURaM well in terms of the pixel-by-pixel distribution of horizontal velocities. Since these are the velocities moving the corks, that's good. ROUGH is missing the high-velocity tail since it lacks turbulence. Our V_max scaling factor is set so ROUGH matches the value of its integrated power spectrum (see below) with MURaM.



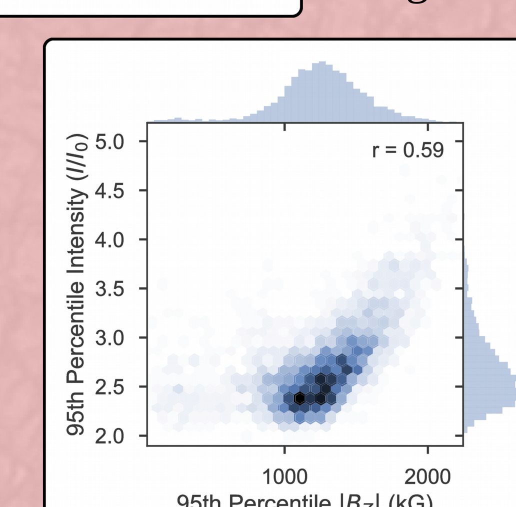


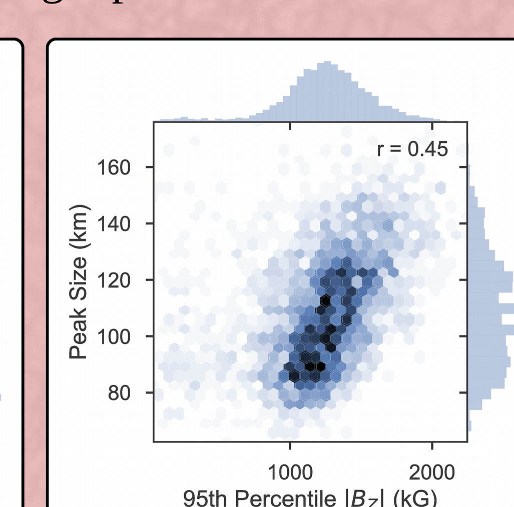
Below-right is a sample bright point found in the MURaM data, featuring both enhanced intensity and concentrated vertical flux. Our automated tracking uses only intensity data for an apples-to-apples comparison with observations, but the match to vertical flux is usually good. We let the motion of the intensity-weighted centroid (the green dots) represent the motion of the bright point.





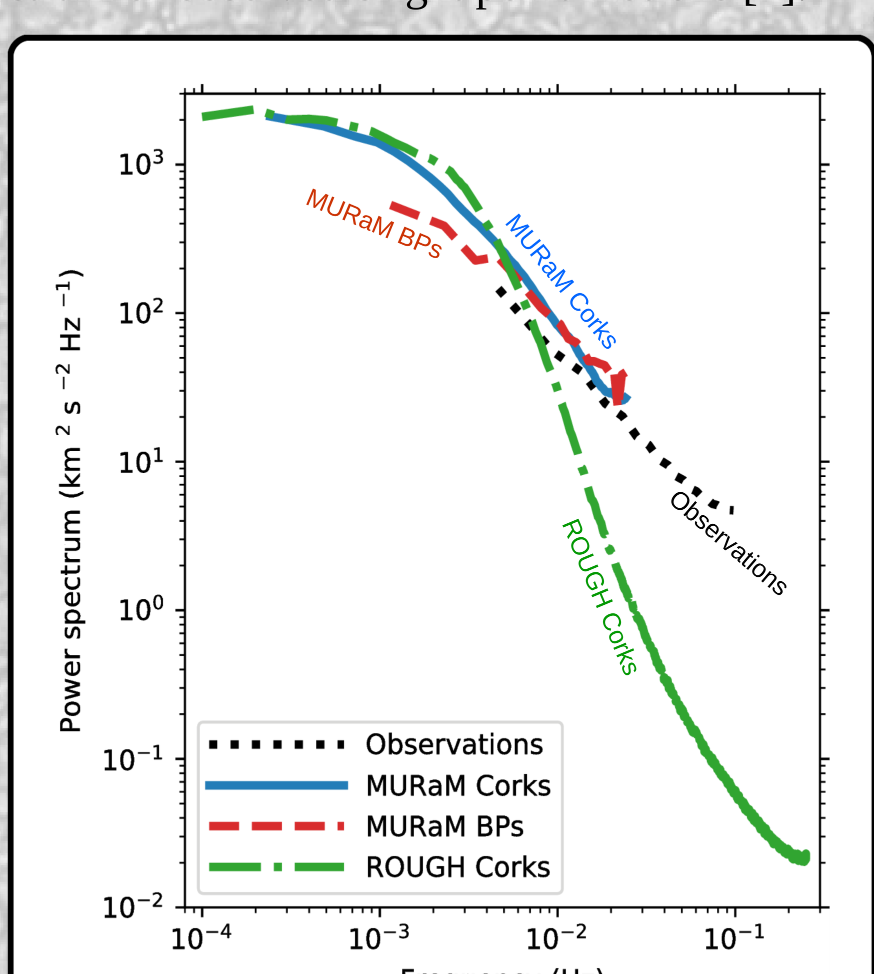
Here are statistics on ~3,000 identified MURaM bright points. Size and lifetime show little correlation. However, size, magnetic field strength and intensity all show good correlations. A stronger flux concentration tends to yield a bigger and brighter bright point.





Conclusions

We computed power spectra for bright points tracked in MURaM and for passive tracers ("corks") in both MURaM and ROUGH, all to be compared with the spectrum of observed bright point motions [2].



Observations from [2]

- The ROUGH and MURaM cork spectra are very similar at low frequencies, suggesting low-frequency cork motion is driven by the **long-term granule evolution** present in both simulations.
- The ROUGH and MURaM cork spectra are very different at high frequencies, suggesting high-frequency cork motion is driven by the **turbulence** present only in MURaM.
- MURaM bright points show **increased power** at all frequencies of overlap with observed bright points. This may mean that the alignment process for observations tends to mute bright point motion, or that higher resolution and more precise centroid locations measure a real increase in power. DKIST's VBI will match MURaM's 16 km resolution and test this idea.
- The MURaM cork and bright point spectra are very similar at high frequencies but diverge at low frequencies. Since bright points involve flux tubes with some vertical extent into the plasma, whereas corks exist as point particles at a fixed height, bright points will respond according to the sum of depth-dependent forces. The spectrum comparison may indicate that long-term motion is more varied at different depths, causing bright point motion to be reduced compared to corks, whereas short-term, turbulent motion is due to either depth-coherent flows or a strong and dominant flow at the surface moving bright points and corks the same.

Poster PDF at samvankooten.net

Read more in Van Kooten et al. (nearly submitted) later this year

References: [1] Cranmer & van Ballegooijen (2005), ApJ, 156, 265. [2] Chitta et al. (2012), ApJ, 752, 48. [3] Abramenko et al. (2012), ApJ, 756, L27.