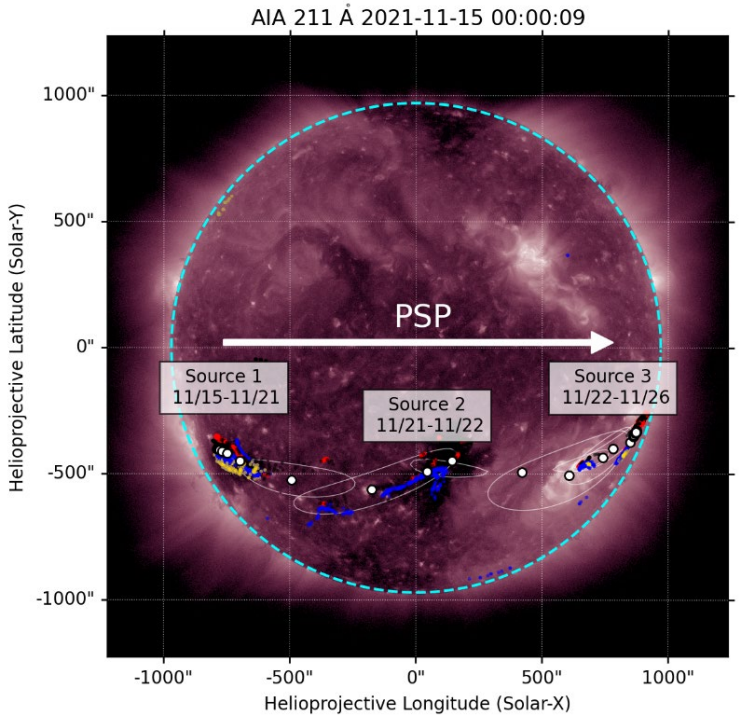
FIELDS/RPW meeting in Orléans, 26-29 February, Wed 14:00

Spicules, Network Bright Points, and Magnetic Switchbacks

Jeongwoo Lee
New Jersey Institute of Technology

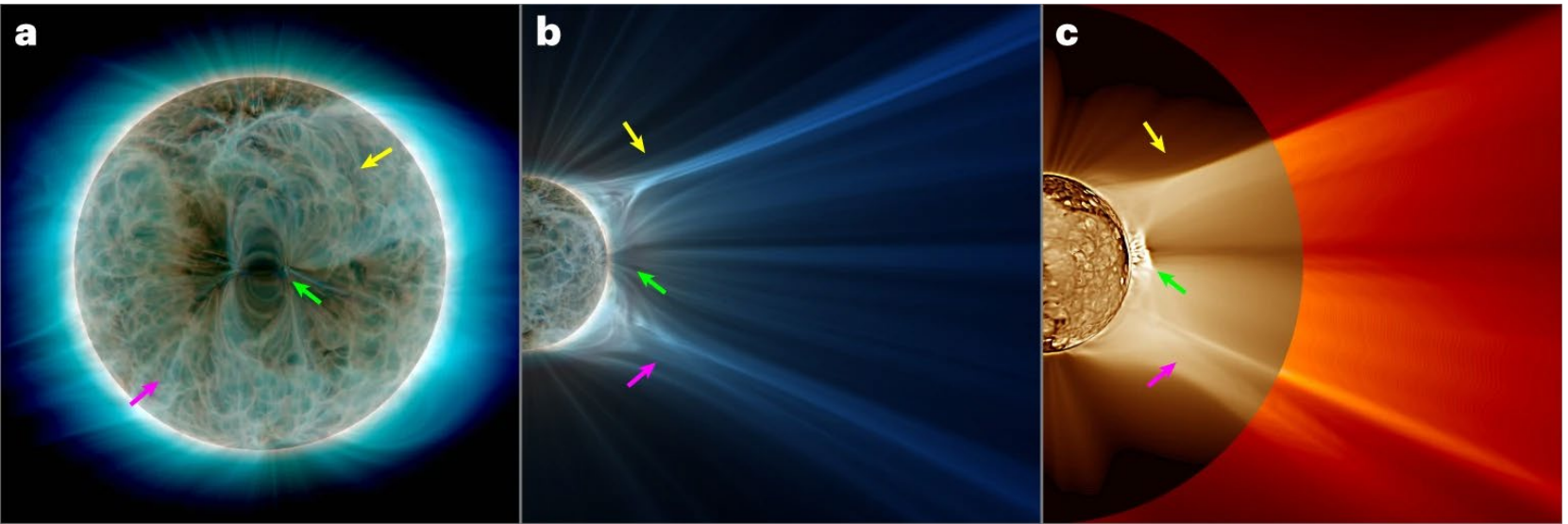
Four groups selected for HSO-C

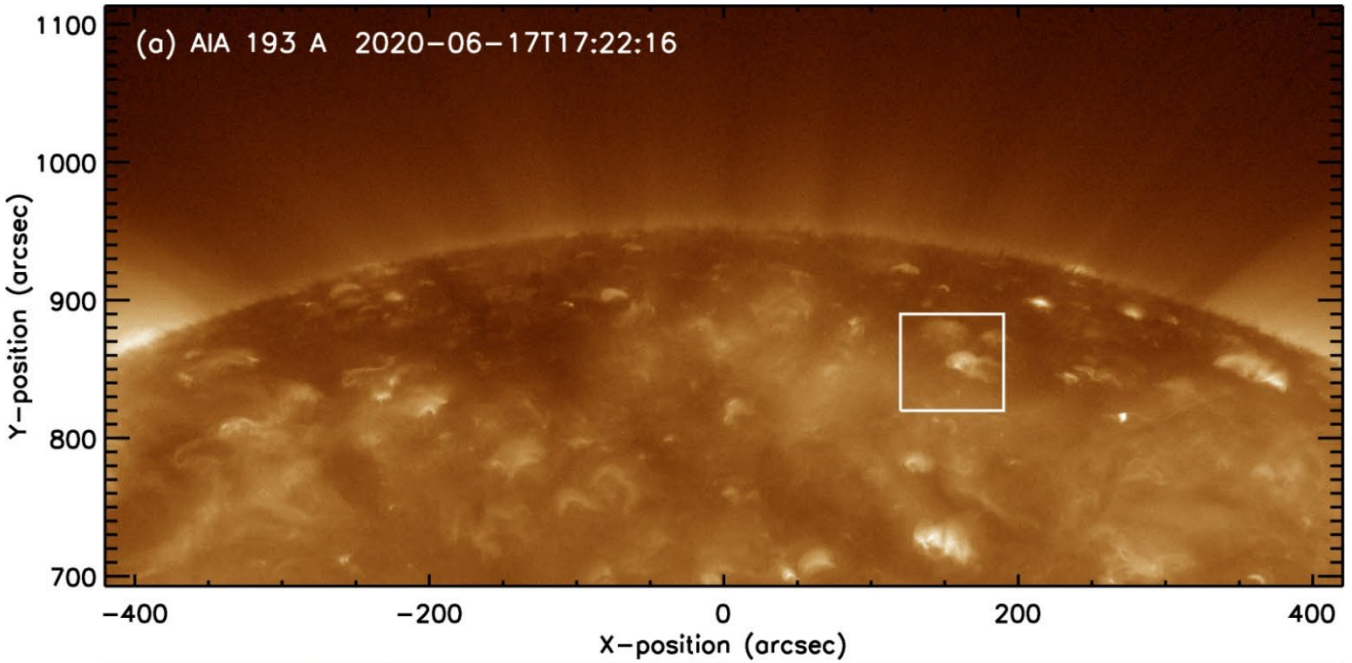
PI	Title
Eriksson (LASP)	Onset and suppression of magnetic reconnection at inner heliospherere
Riley (PredSCI)	Connecting HSO and models with PSP
Seaton (SwRI)	HSO-Connect: energetics of solar eruption

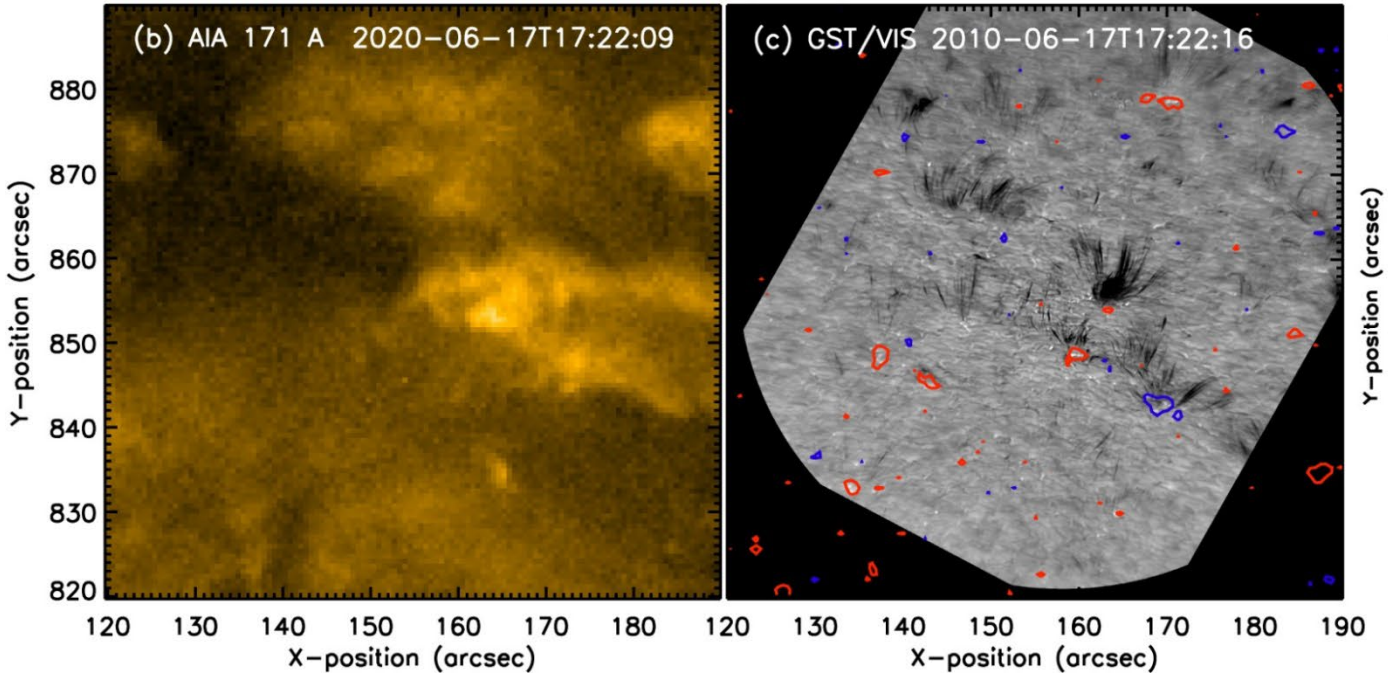


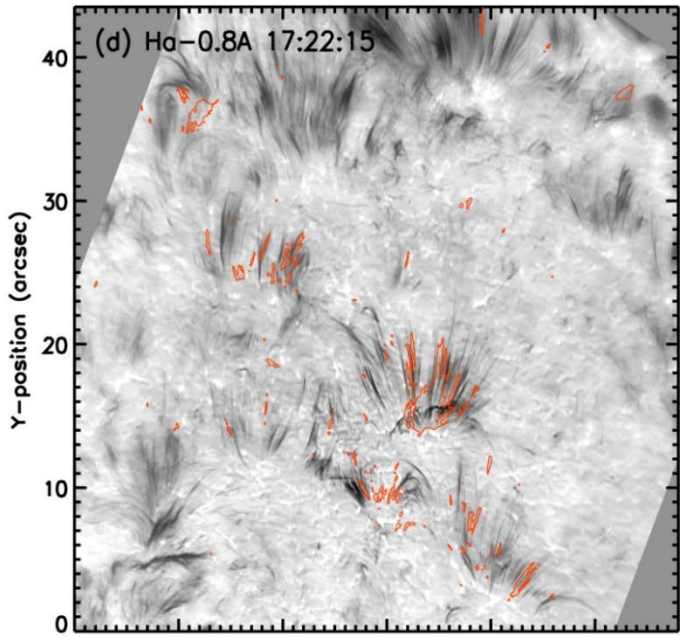
Wang (NJIT)
Small-scale magnetic reconnection, energy release in source regions of solar wind

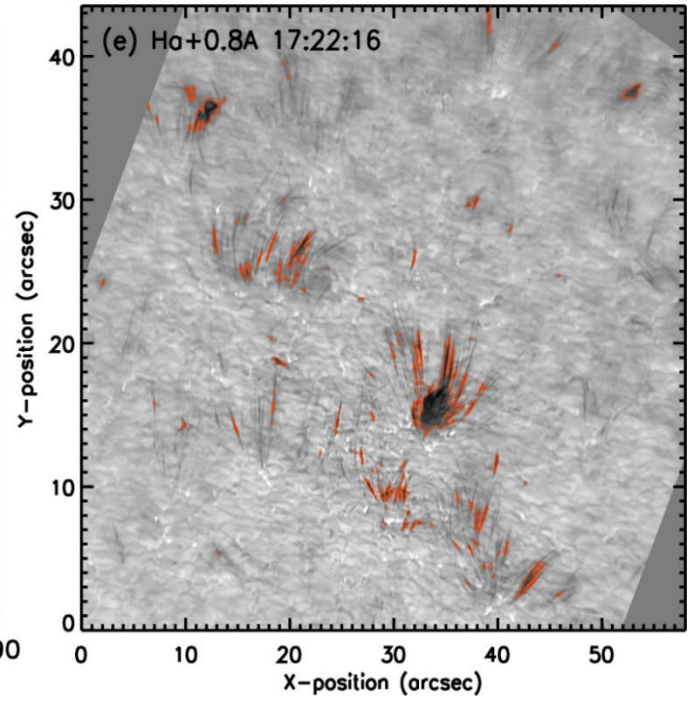












EUV images: SDO/AIA 193 Å image of the northern coronal hole on 2020 June 17 17:21:10 UT.

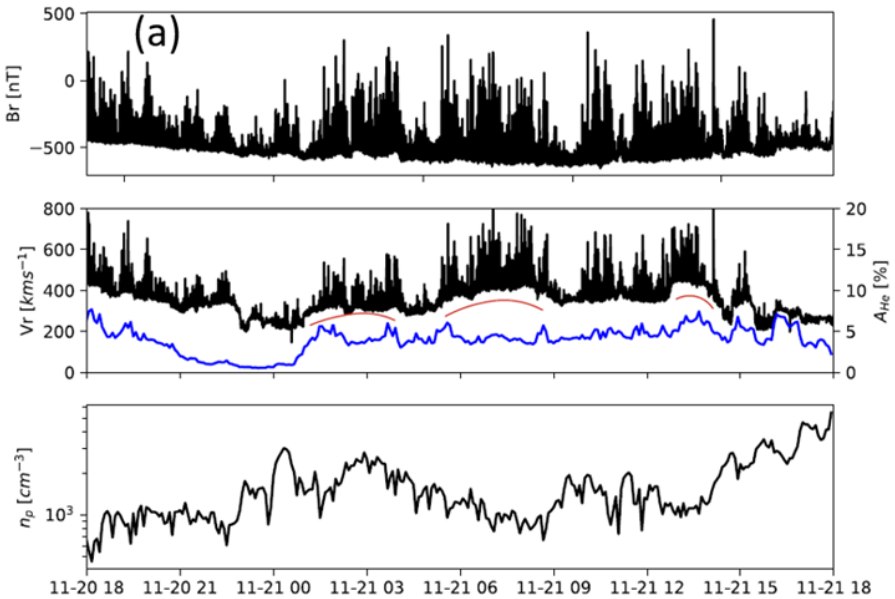
SDO/HMI magnetic field at ±30 G.

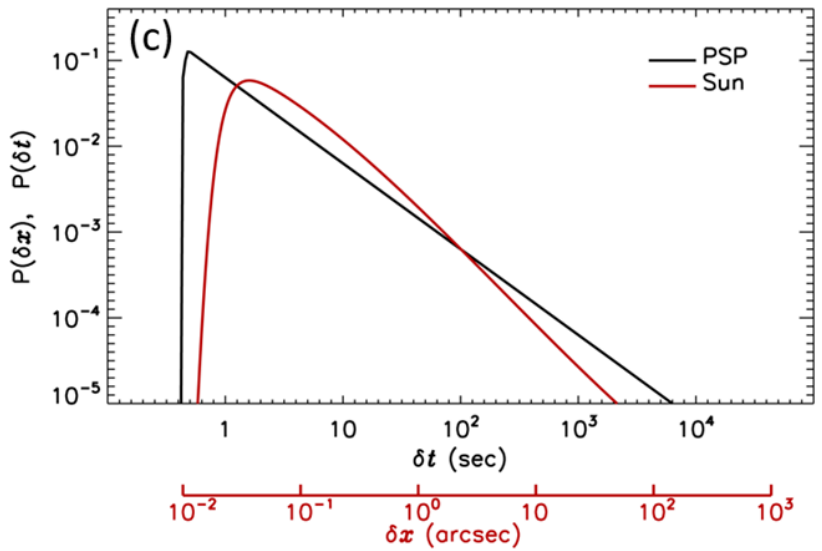
BBSO VIS Hα±0.8 Å

BBSO/GST:
VIS 0.029 arcsec
NIRIS 0.089 arcsec
Small FOV.

SDO:
AIA 0.6 arcsec
HMI 0.5 arcsec
Full disk

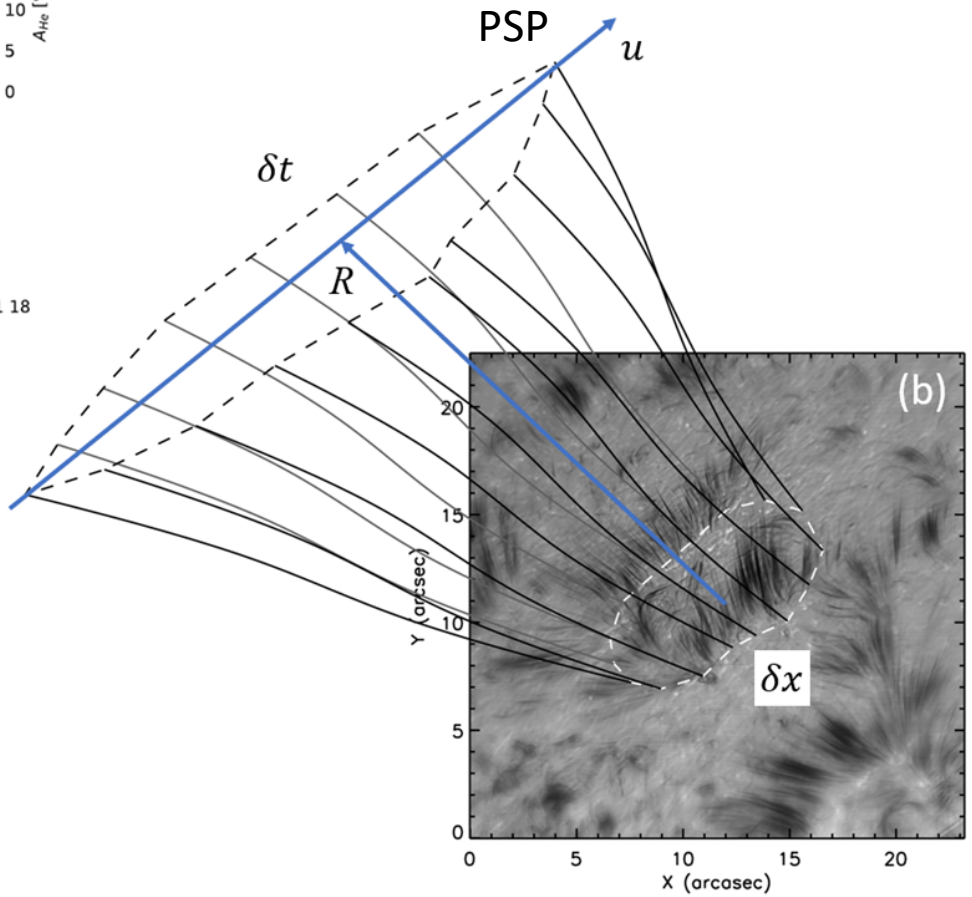
How to compare solar data with PSP data?

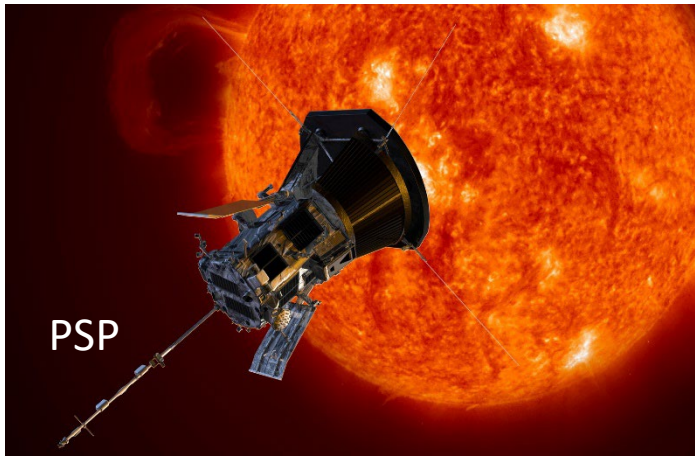




Time series ↔ Spatial image

$$\delta t = \frac{R\theta}{u} = \left(\frac{\delta x}{u}\right)\left(\frac{R}{R_s}\right)$$





SG	40”	30 min
Mini-filament	15”	10 min
Spicule	<0.2”	<10 sec

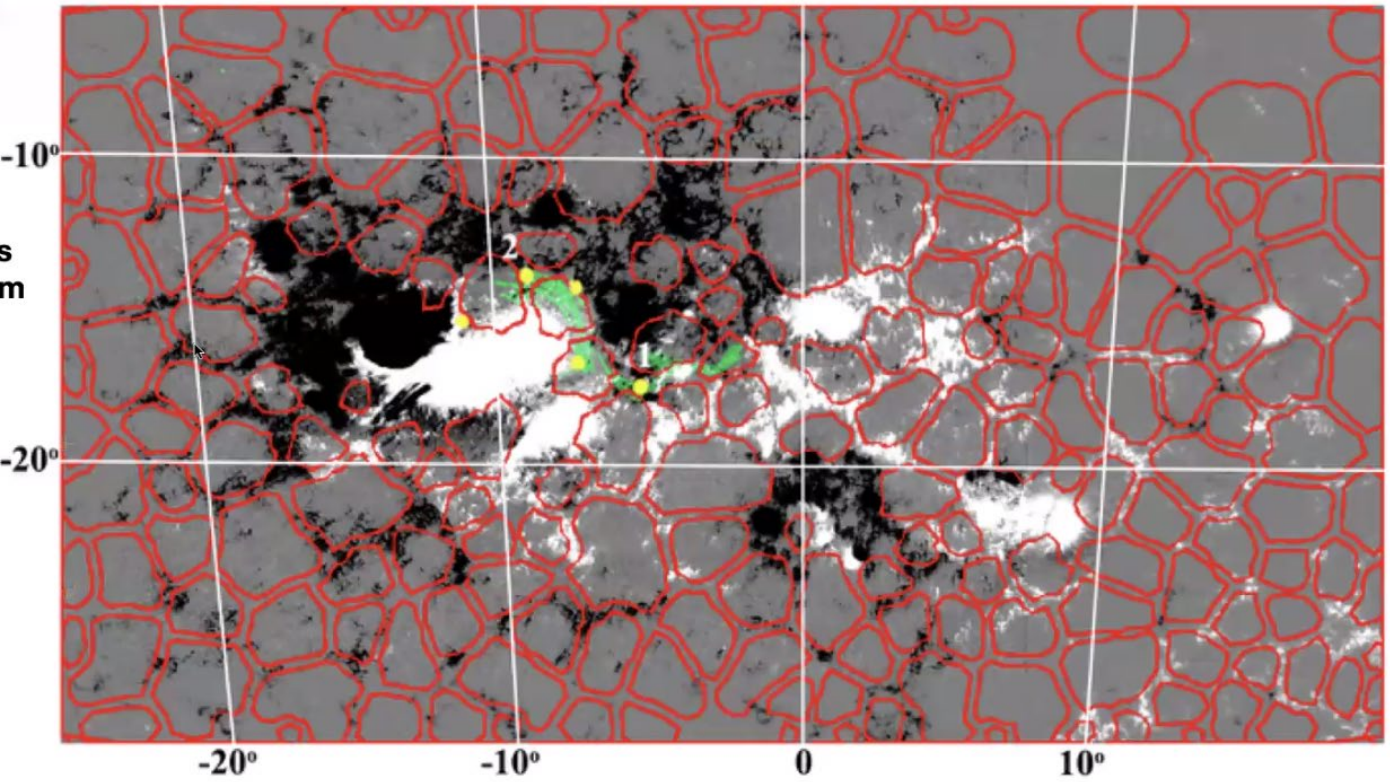


Cf. Time distribution of deflection (Dudok de Wit+ 2020)

What is the link between individual switchbacks and patches - if why?

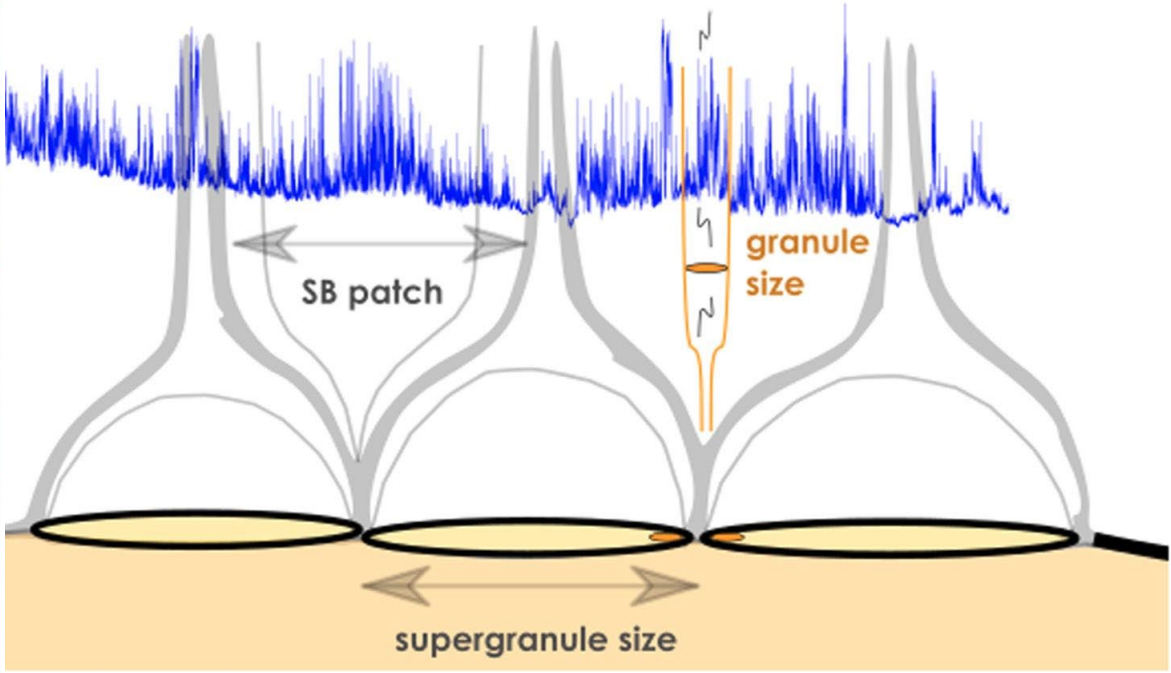
SB patches may be linked to supergranules working as magnetic funnel.

A midscale modulation exists, reminiscent of granules.



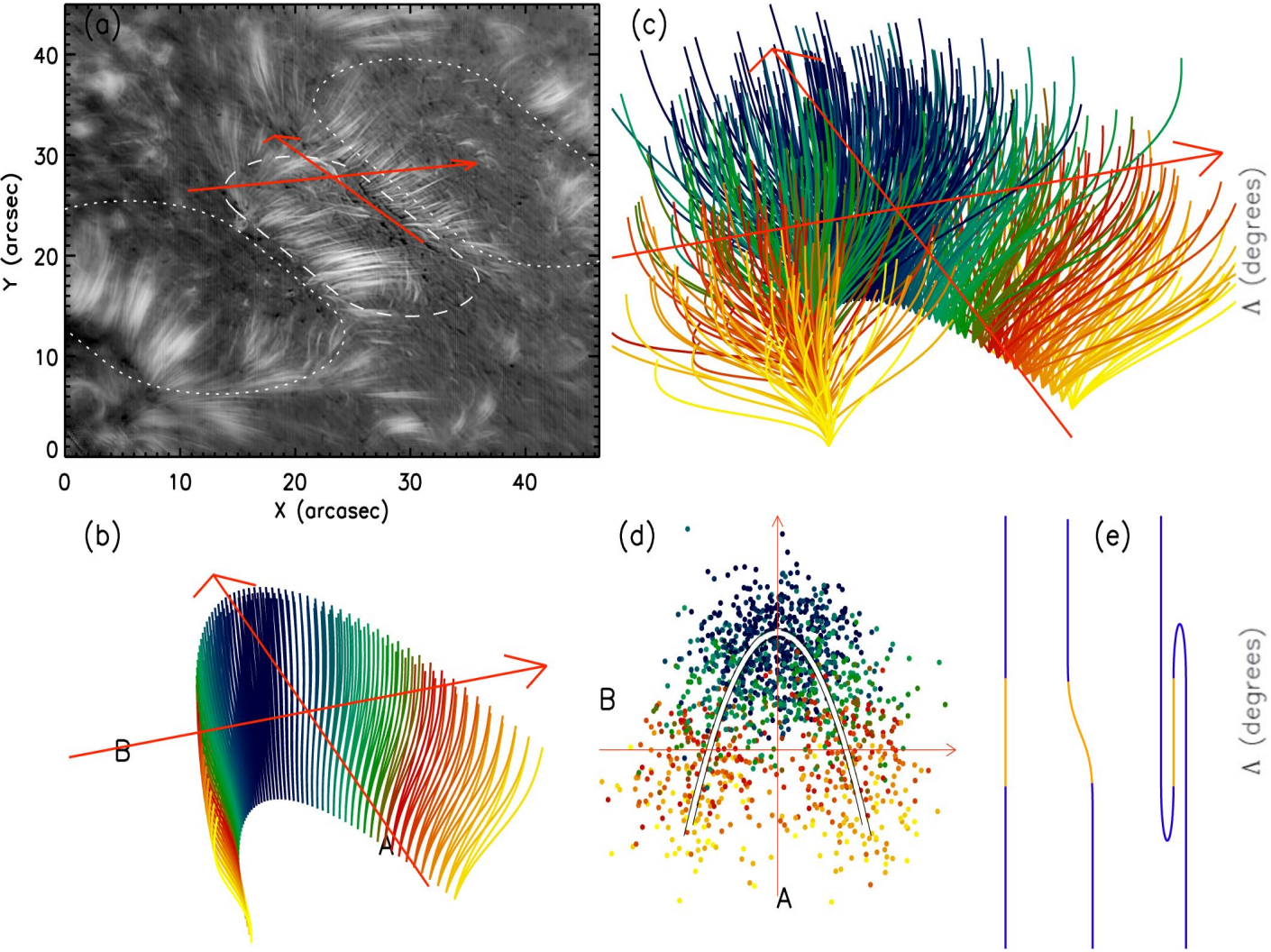
Red cells – supergranules.
AR 11520: HMI magnetogram with filament threads and barbs superposed. Yellow points are sites of the strong magnetic field cancellation = endpoints of barbs = intersections of supergranular cells.

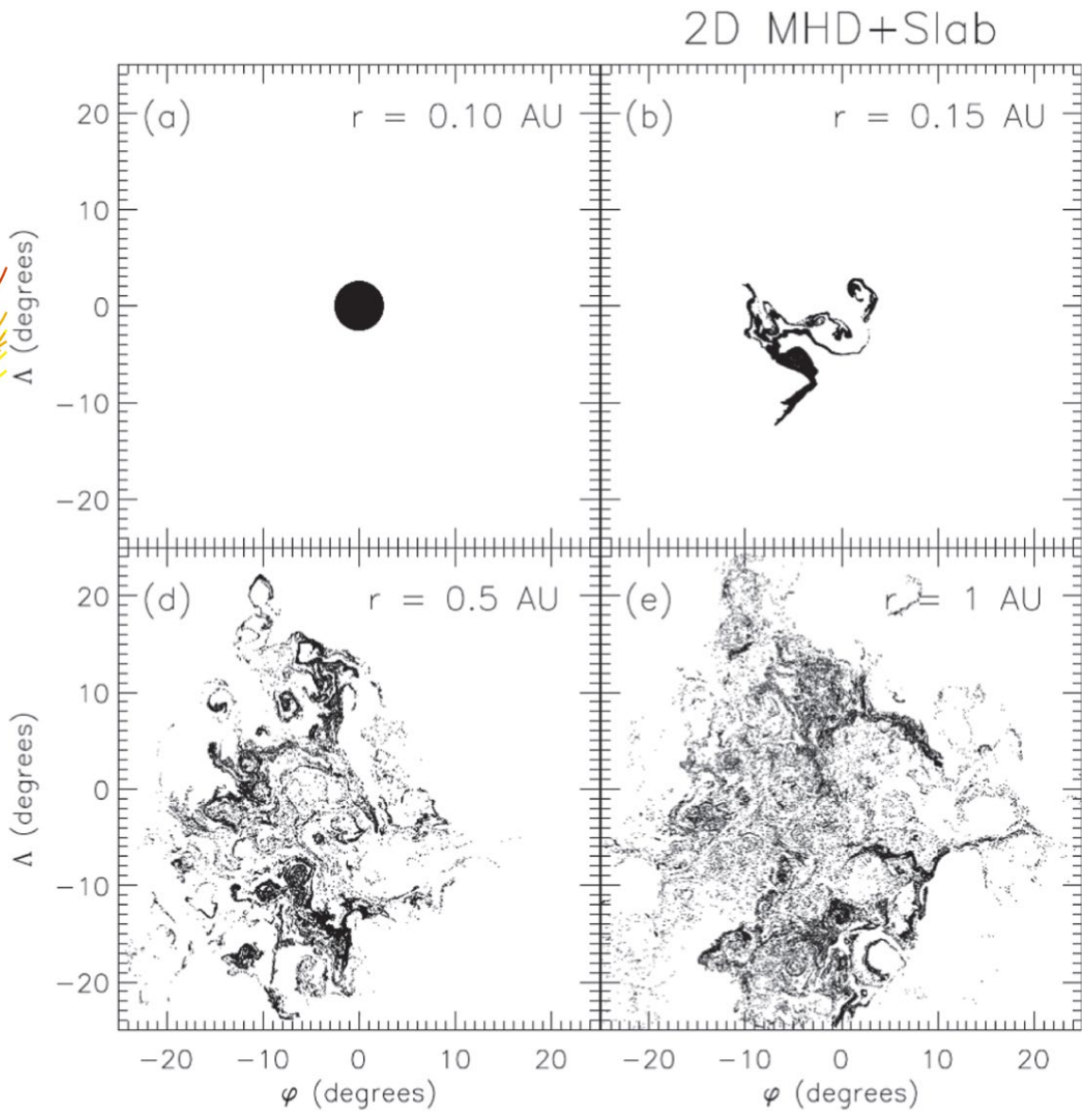
Supergranulation – Panasenco et al. 2021



Fargette+ 2021

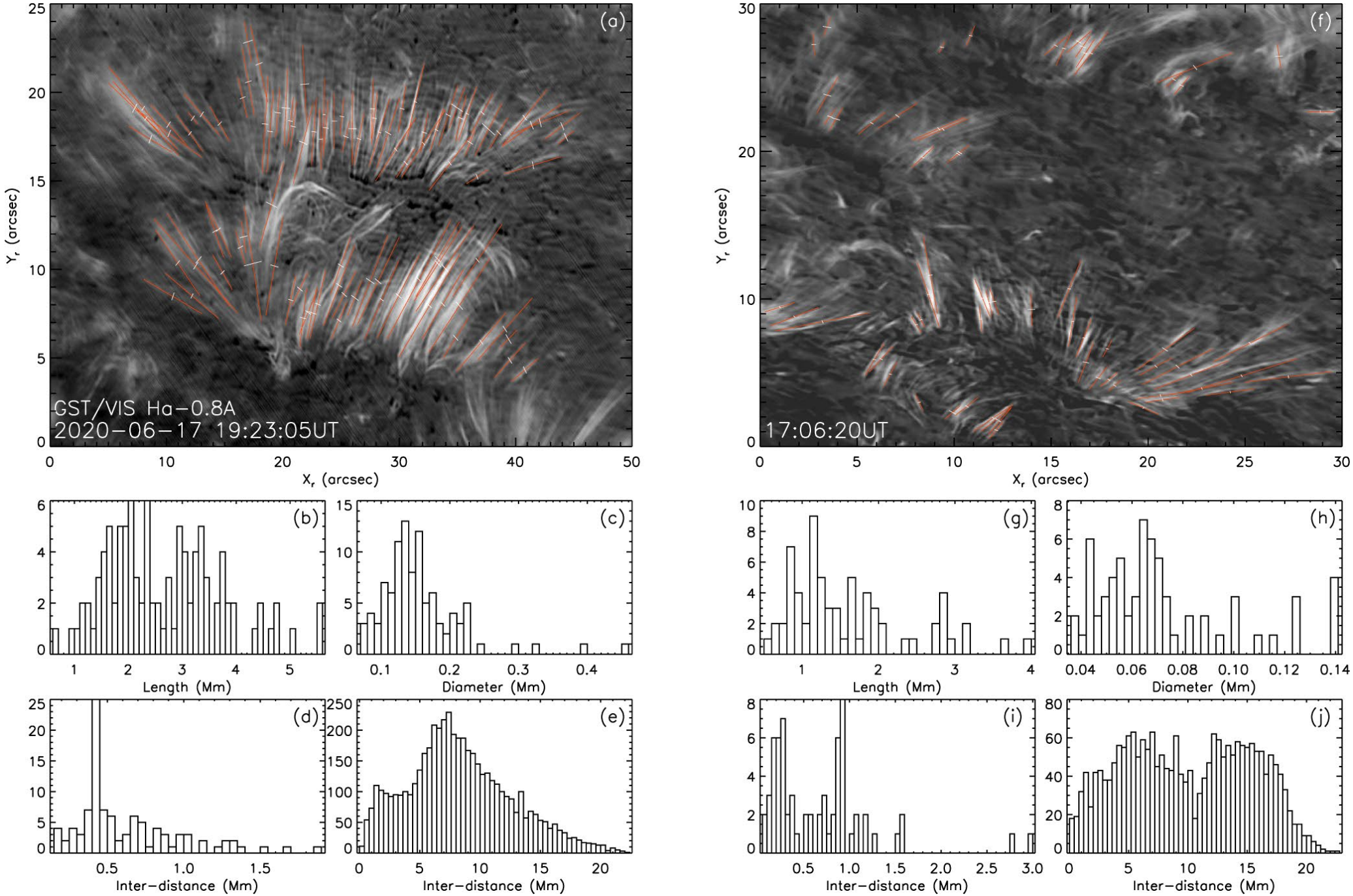
- A solar Source of SBs: In Situ Remnants of Magnetic Funnels on SG Scales (Bale+ 2021)
- Parker Solar Probe Enters the Magnetically Dominated Solar Corona (Kasper+ 2021)





Proposed redistribution of solar fluxtubes in space, Lee+ 2022

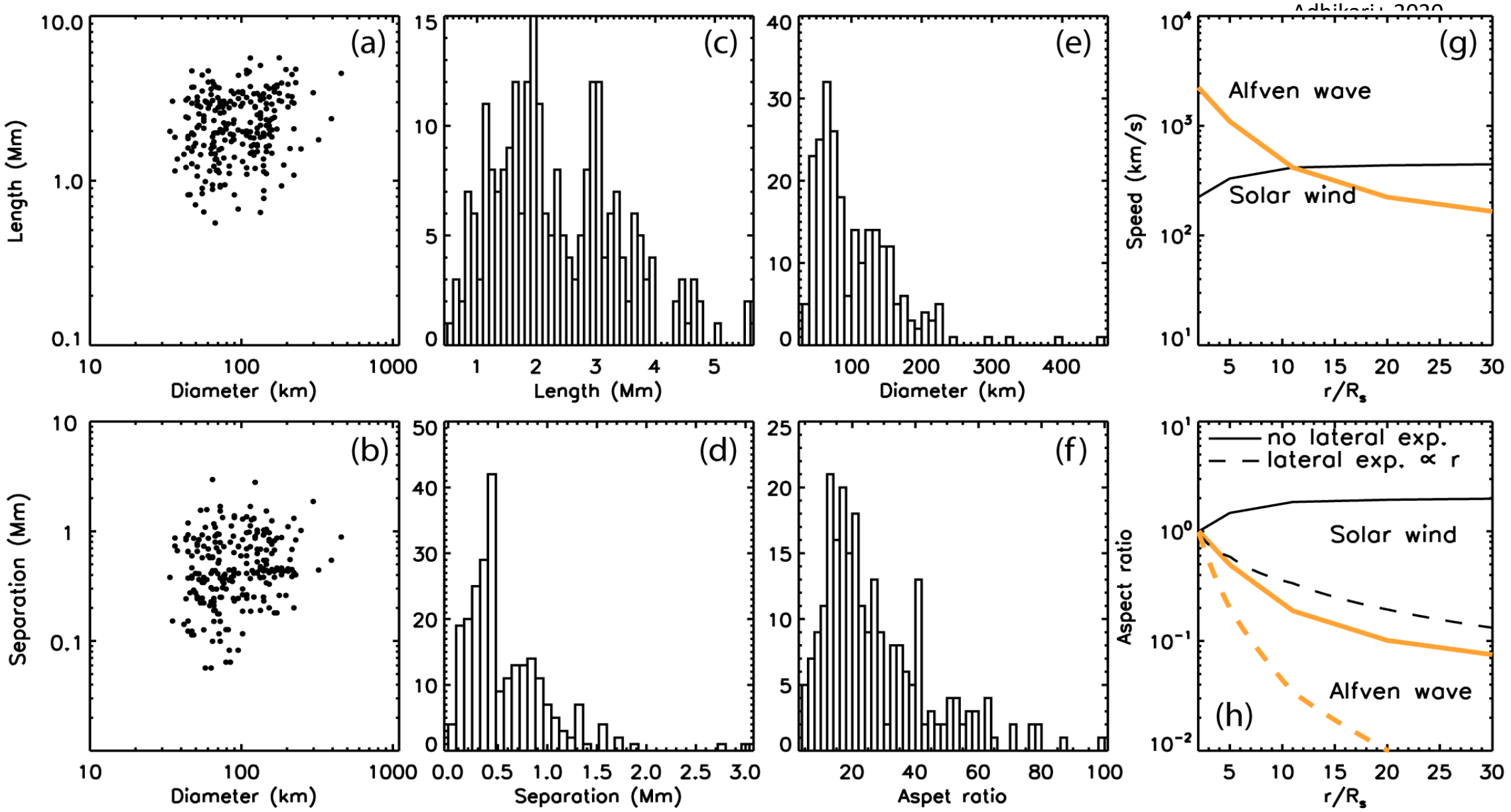
Random walk and trapping of IMFs. Field line trajectories in heliolon. and lat. Tooprakai+2016, Chhiber+ 2021.



Spicules (RBE, RRE) are an ideal candidate for SBs, in terms of size distribution.

Inverted Hα images with the lengths (widths) of flux tubes marked with red (white) bars.

Geometrical parameters of flux tubes on a SG boundary.



0.2 arcsec = 0.012°

1.0 arcsec = 0.06°

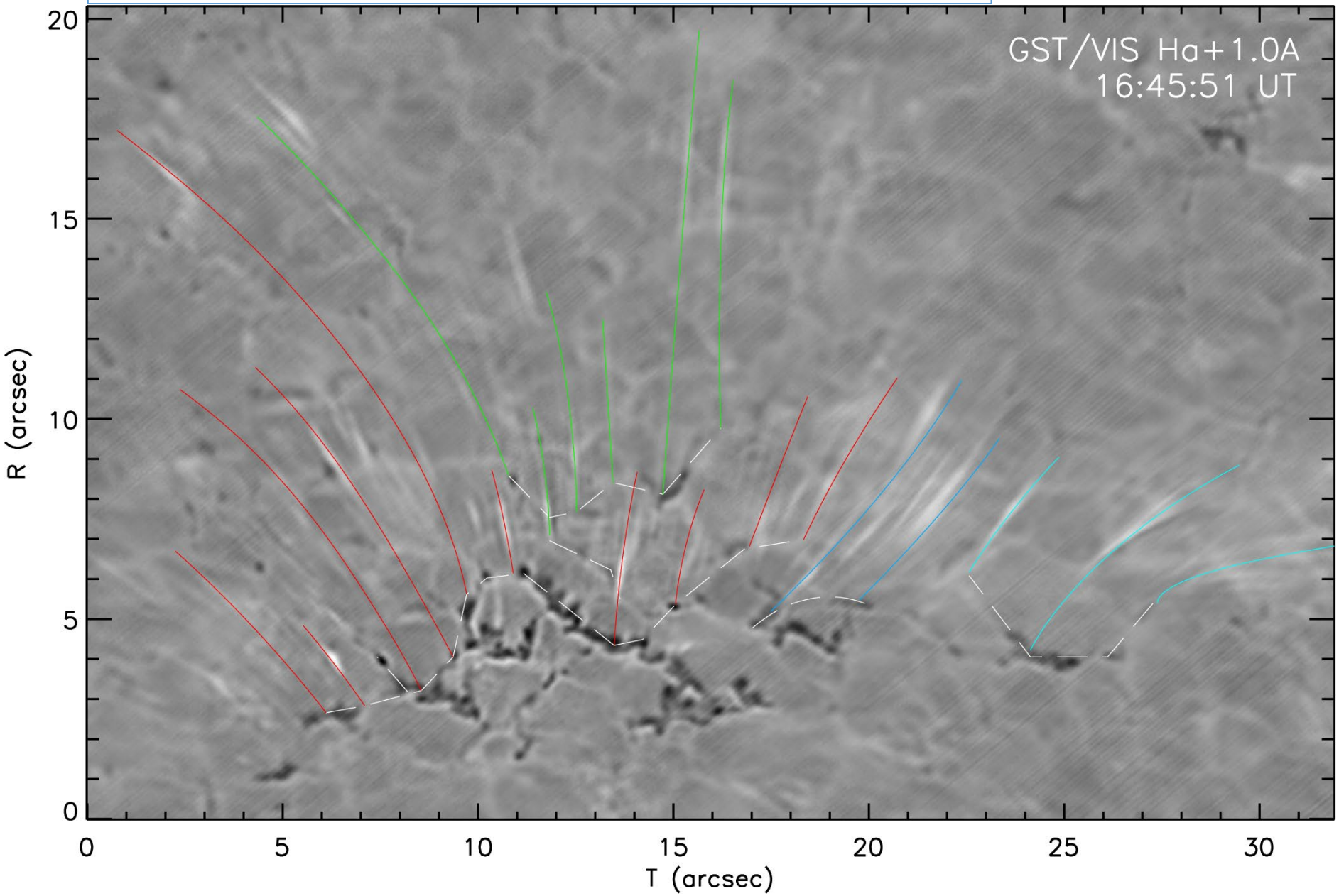
Computed aspect ratio using either Alfven or SW speeds.

Properties of SBs expected, detected, and inferred under various assumptions

Quantity	Medium	Large	Aspect ratio	Waiting/residence time distribution
Expected	0.08^{o} (Granulation)	1.6^{o} - 6.2^{o} (SG)	< 1	
Detected by PSP	0.12^{o} - 0.7^{o}	1.1^{o} - 4.4^{o}	>10	Broad w/o scales
Reference	(Fargette+ 2021, Bale+ 2021)		(Laker+ 2021)	(Dudok de Wit+ 2020)
Detected by GST	0.01^{o} - 0.12^{o}	0.6^{o} - 1.8^{o}	6 - 30	Narrow with scales

- Size of small solar feature match that of the medium size SBs. They tend to be more transient to appear as a spatial distribution when viewed in space.
- Larger-scale ejective solar features do not agree to the many SBs grouped in a patch. The large and medium sizes should come together.
- Some process must occur during transport to space, e.g., aggregation, and cascade by some instability or volume filling, expansion, etc.

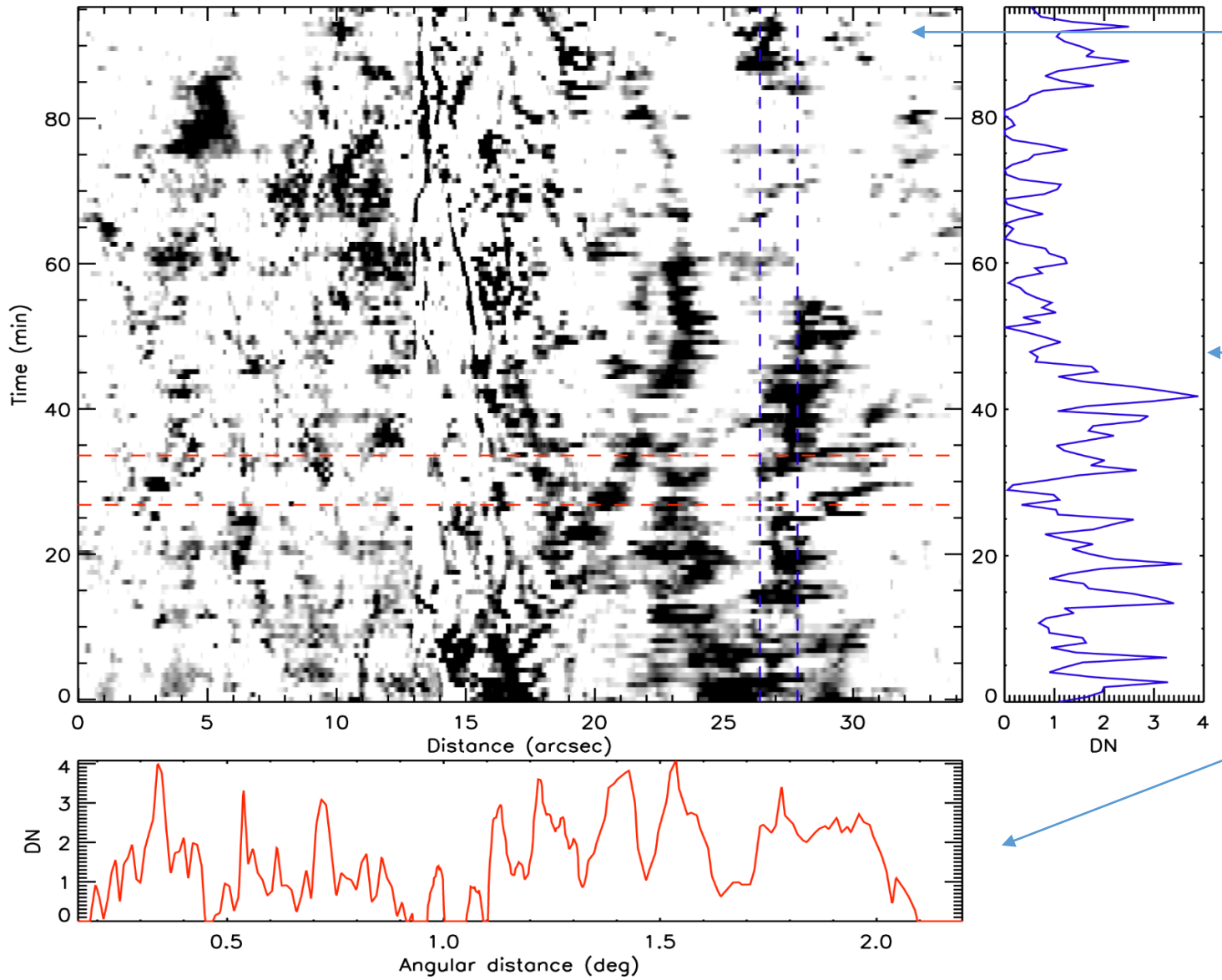
Spicules and filigrees (footpoints of open fields)



Inverted Ha blue wing

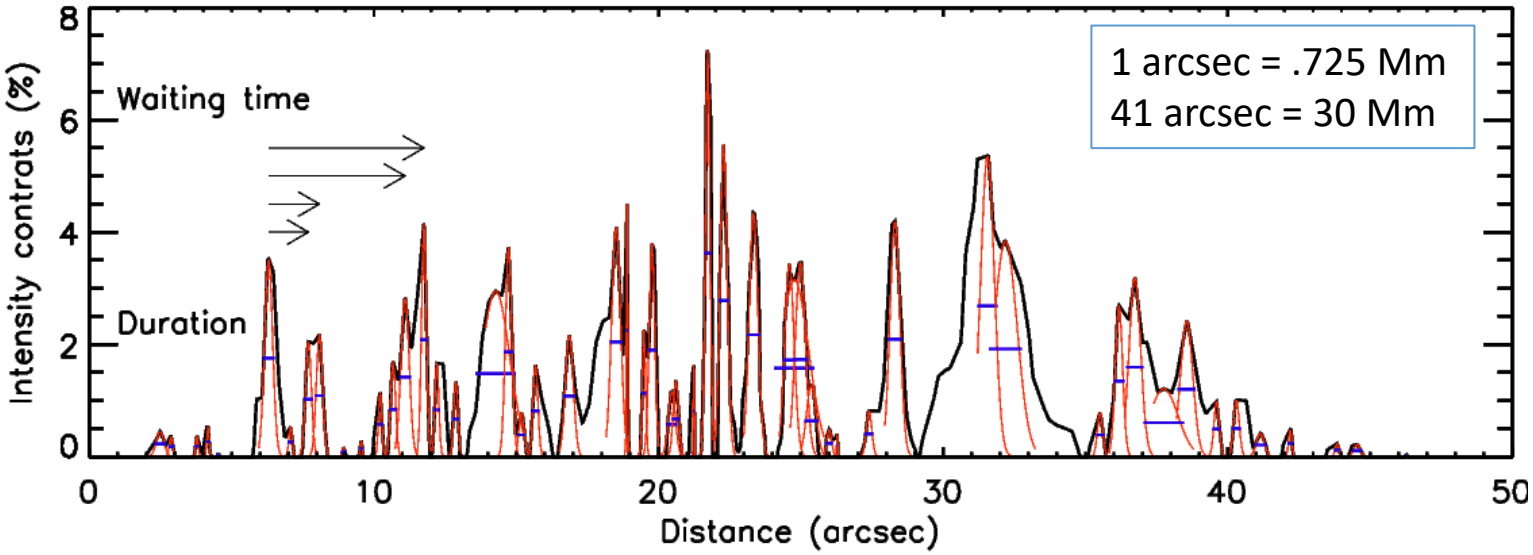
- Spicules (white)
- Filigrees(black dots)
- Normal convection (white)

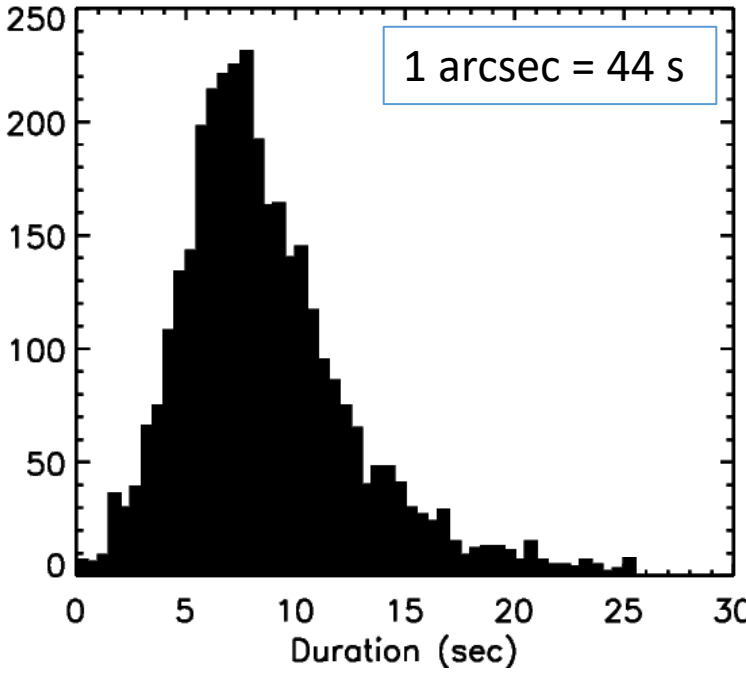
Time-distance map of spicules exhibits scales of solar fluctuation and switchbacks

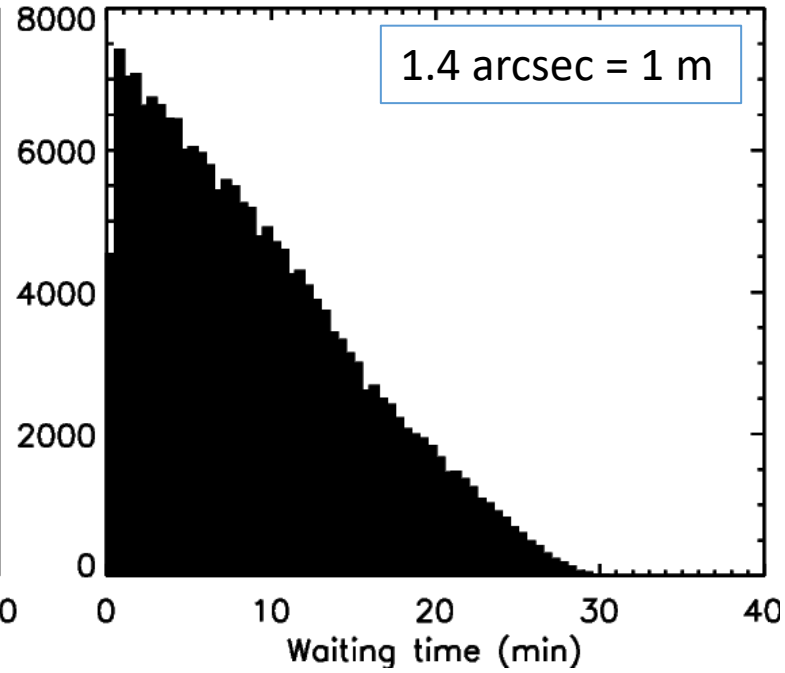


- Time-distance map of spicules does not clearly exhibit progressive motions but rather discontinuous appearance of spicules.
- Time profiles of sign-reversed intensity contrast mimics the quasi-periodic EUV fluctuations claimed to be solar sources of micro-streams (Kumar et al. 2023) but not locally periodic.
- Spatial distribution shows scales comparable to the time scales of switchbacks measured by PSP (Dudok de Wit+ 2021)

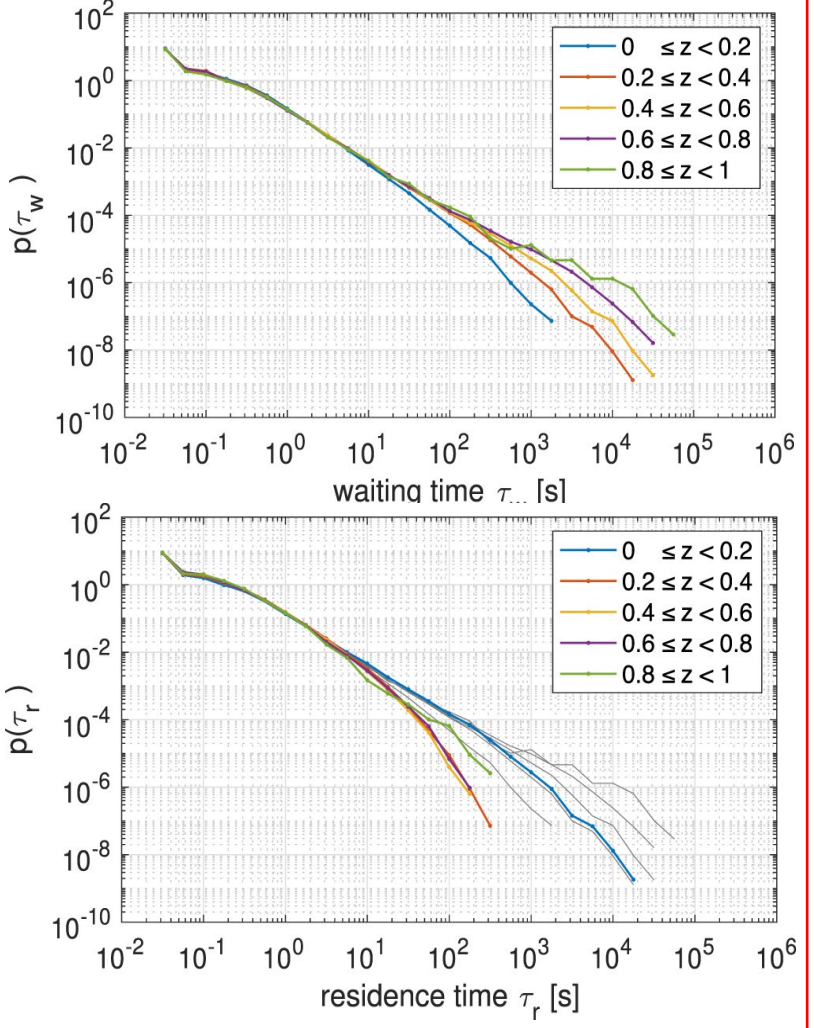
Spicule distribution vs. switchback distribution







Time distribution of deflection
(Dudok de Wit+ 2020)

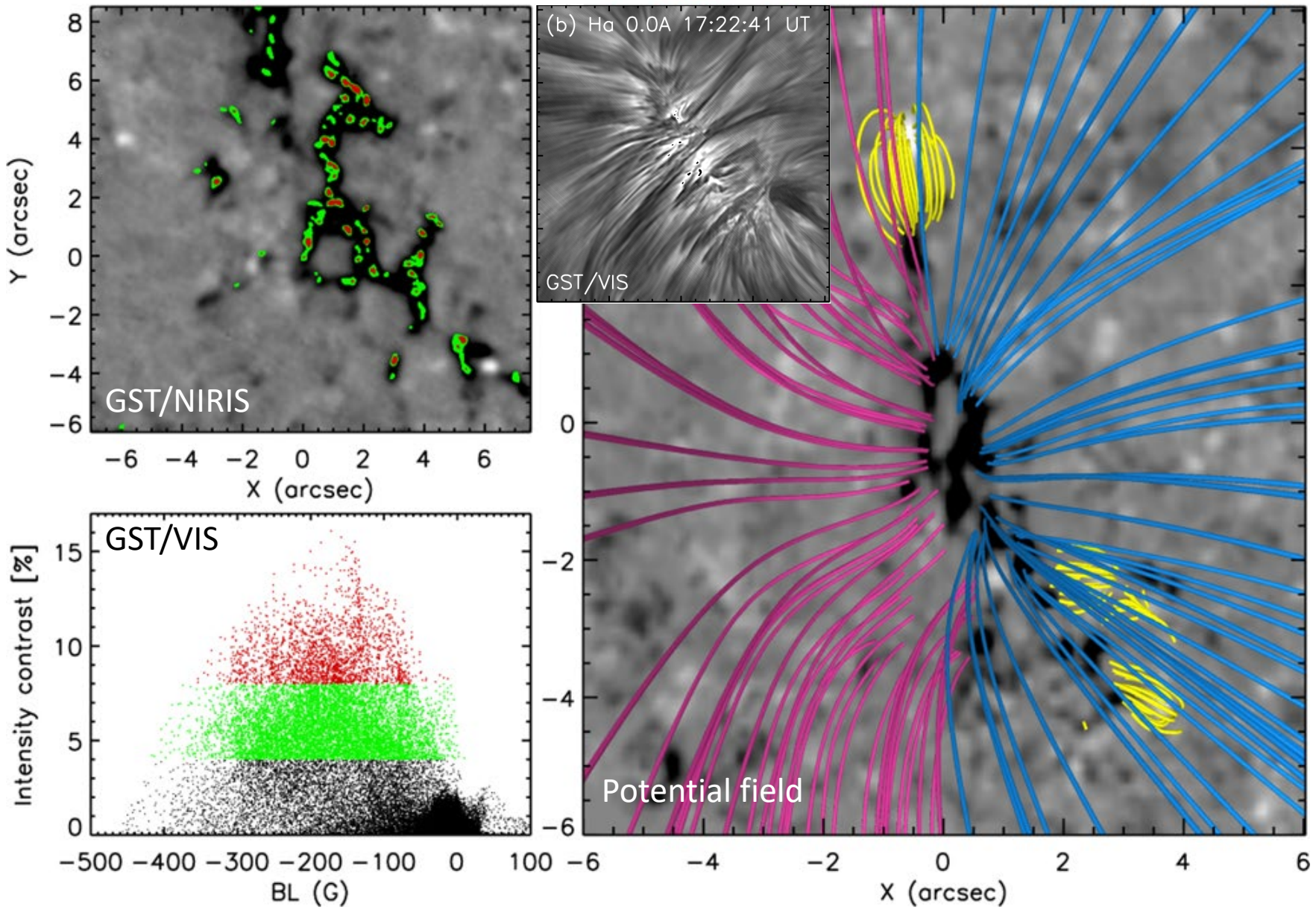


Estimated from spicule t-d map assuming $30R_s$, 500 km/s.

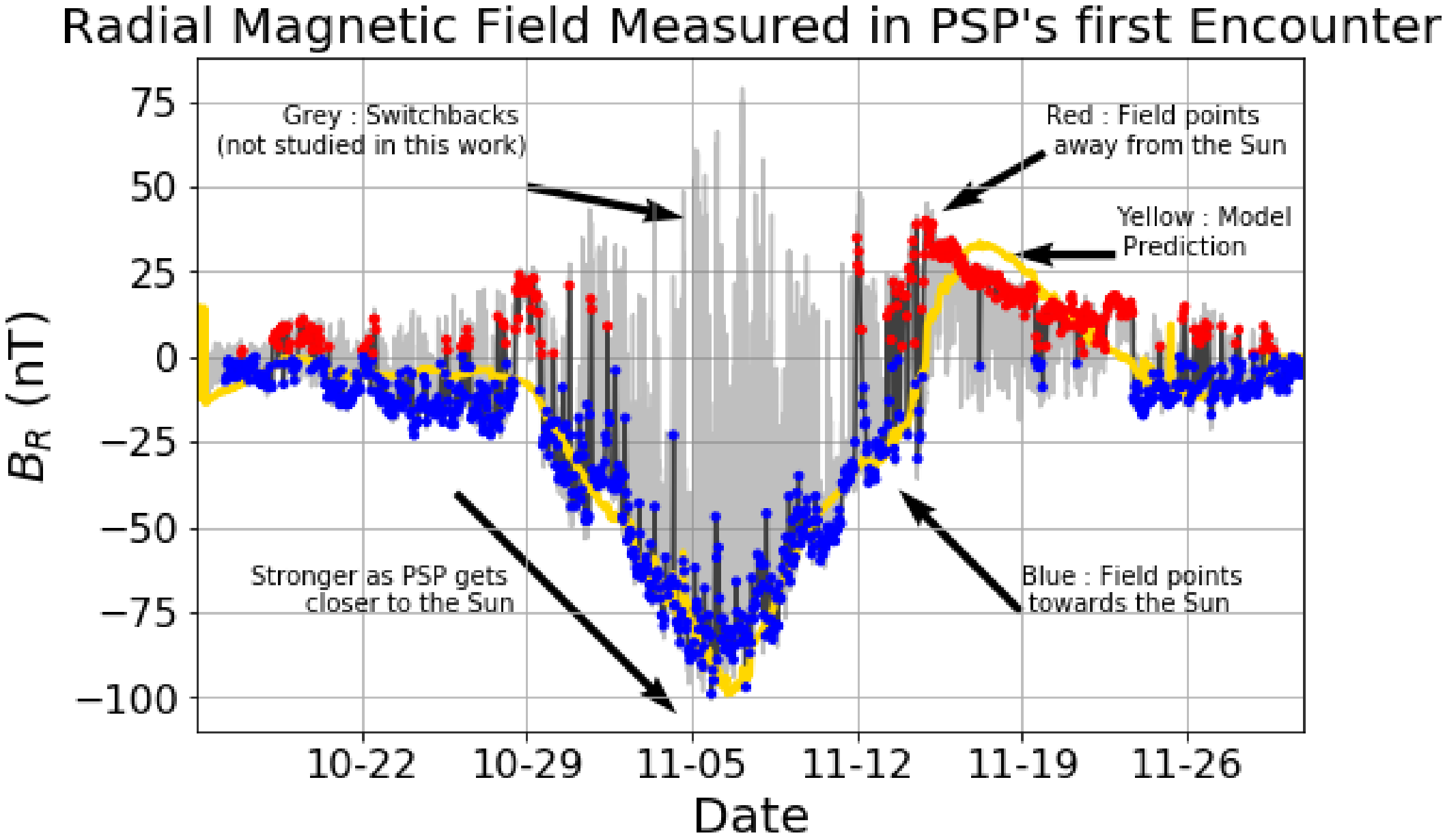
- Size-wise, spicules are a good SB candidate in that they come in the two-scale combination.

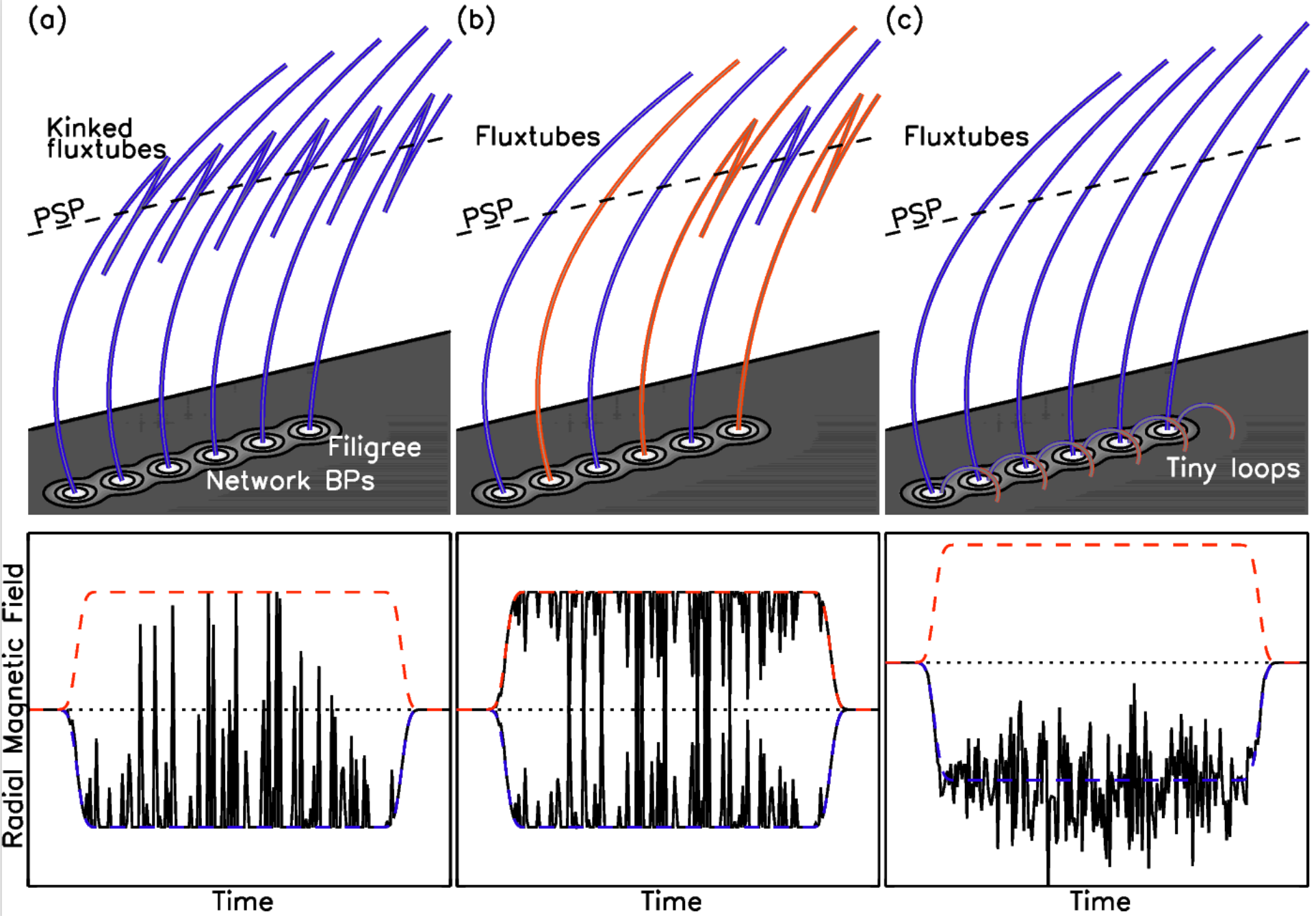
- How about spicules' magnetic field and dynamic behaviors? Are they consistent with SBs?

Magnetic property of filigrees or that of spicule-guiding field lines



- Spicules have not only magnetic field bases (Samanta+ 2019) but filigree bases.
- Filigrees work as placeholders for spicules.
- Tracing filigrees polarity, they are found all in one polarity, the negative in this case.
- Not all negative polarity but some of them do.
- The spicule-guiding field lines are only in a single polarity.


Radial Magnetic Field Measured in PSP's first Encounter
Grey : Switchbacks
(not studied in this work)
Red : Field points
away from the Sun
Yellow : Model
Prediction
Stronger as PSP gets
closer to the Sun
Blue : Field points
towards the Sun
B_R (nT)
75
50
25
0
−25
−50
−75
−100
10-22
10-29
11-05
11-12
11-19
11-26
Date

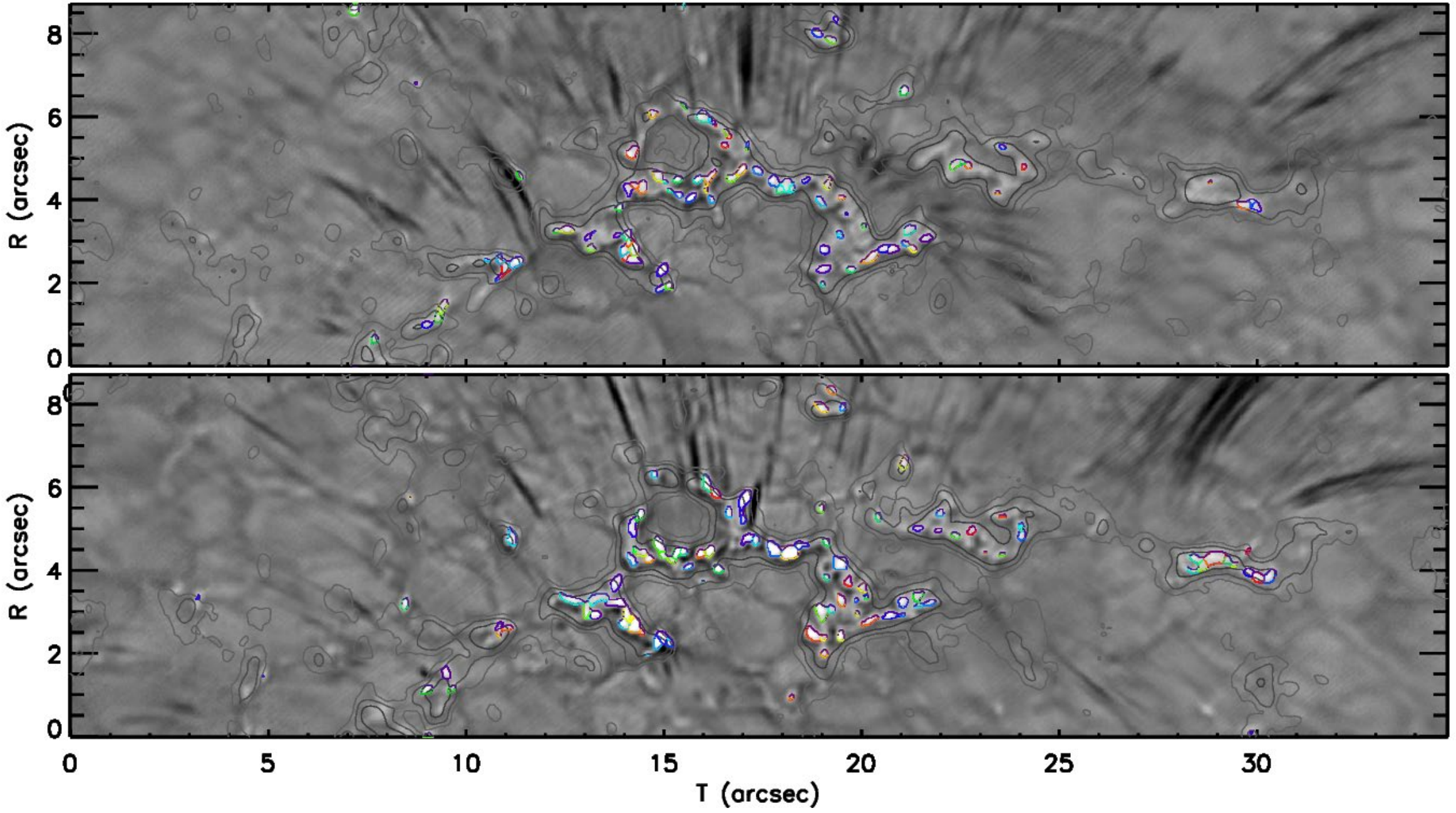


A new constraint on the magnetic polarity of footpoints:

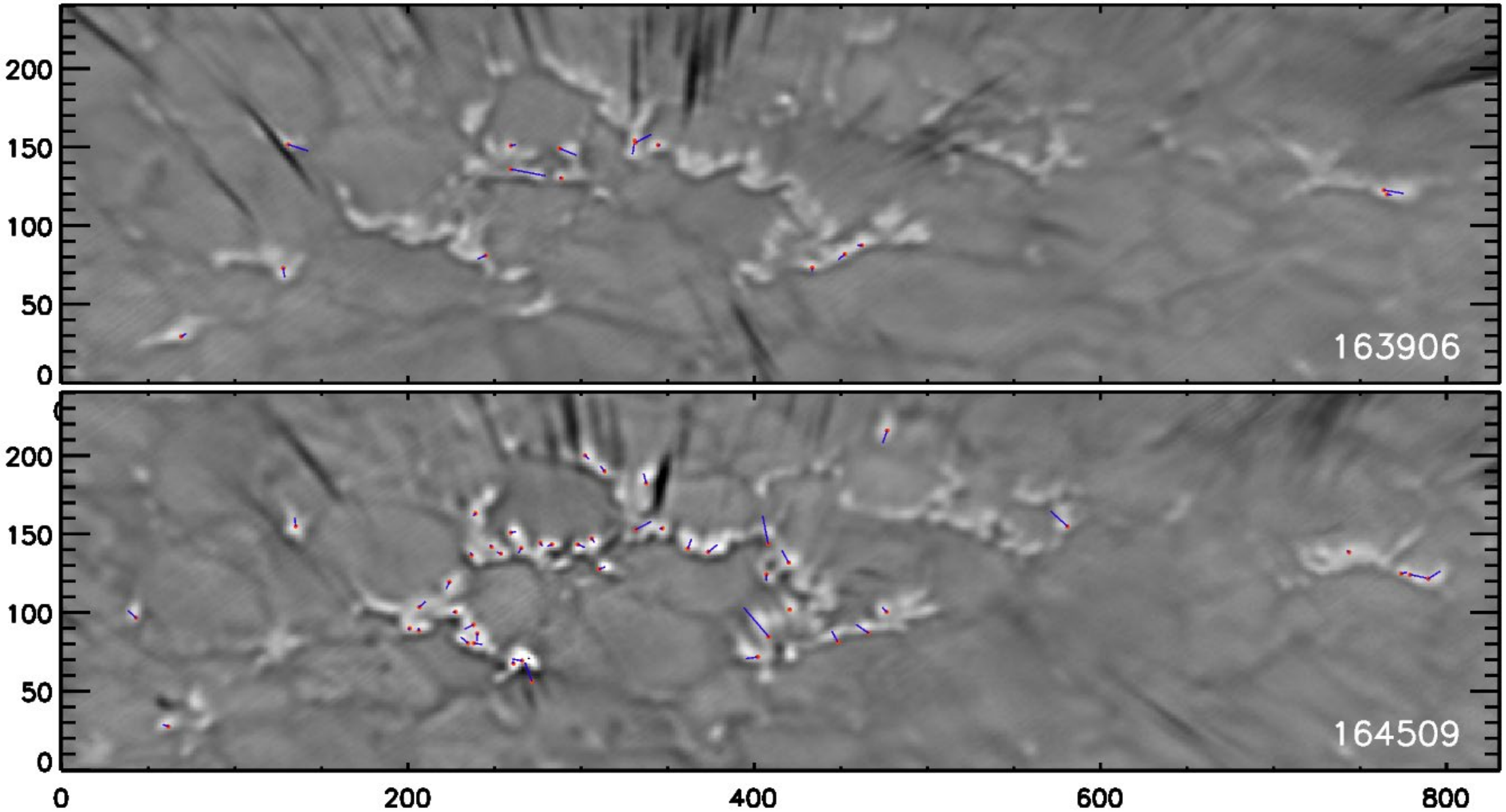
- A cluster of solar ejections should be in a single polarity to become SBs.
- Not attended before, but important.
- Difficult to trace spicules but easy for NBPs
- Satisfied under a circumstantial condition

- Size-wise, spicules are a good SB candidate.
- Magnetic property of spicules is consistent with those of SBs (if kink occurs afterward)
- Generation of Alfven waves in a CH boundary?

Magnetic field strength *B* and area *A* of the NBPs are recorded with SWAMIS



Motions V and lifetimes τ are also recorded.



Propagation speed, density

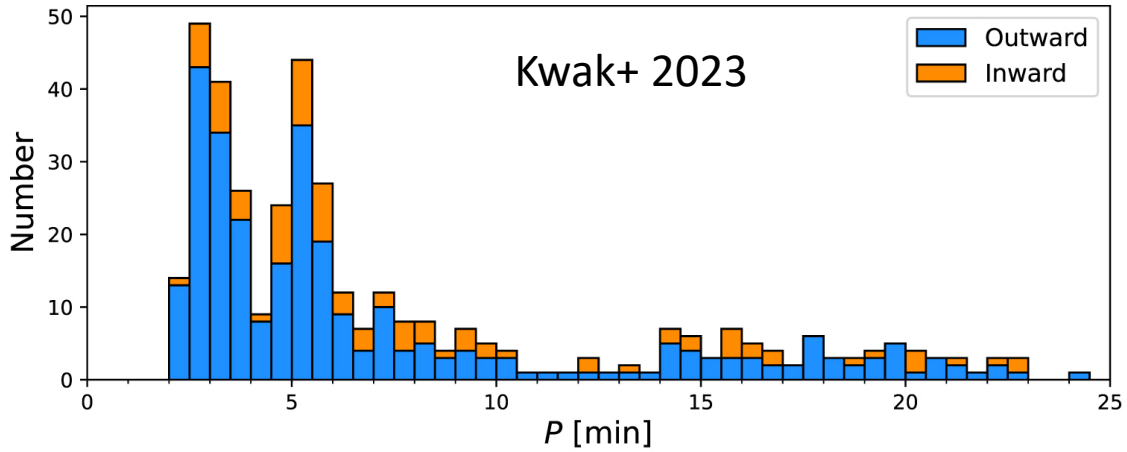
$$V_A = \frac{B}{\sqrt{4\pi\rho}}, \qquad \frac{1}{2}\rho u^2 = \alpha\frac{B^2}{8\pi}$$

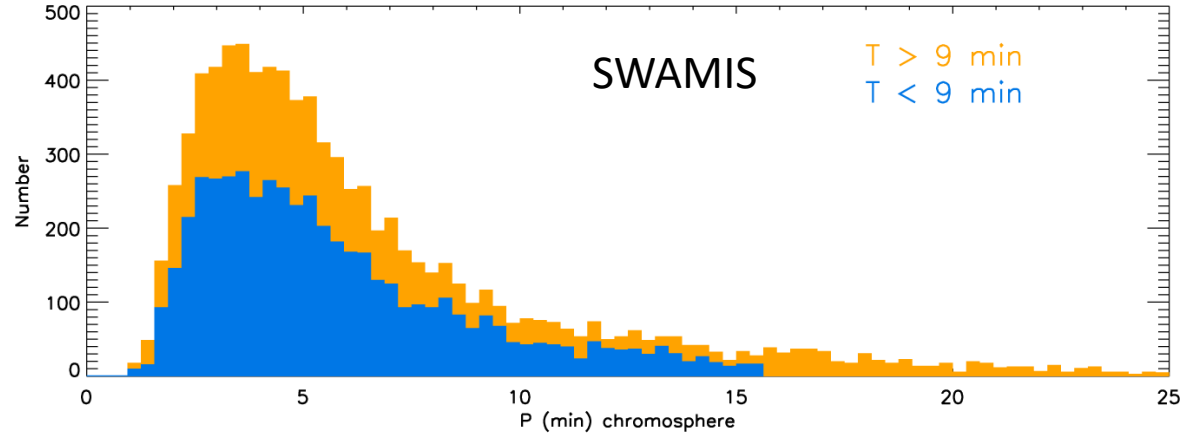
Individual wave flux and energy

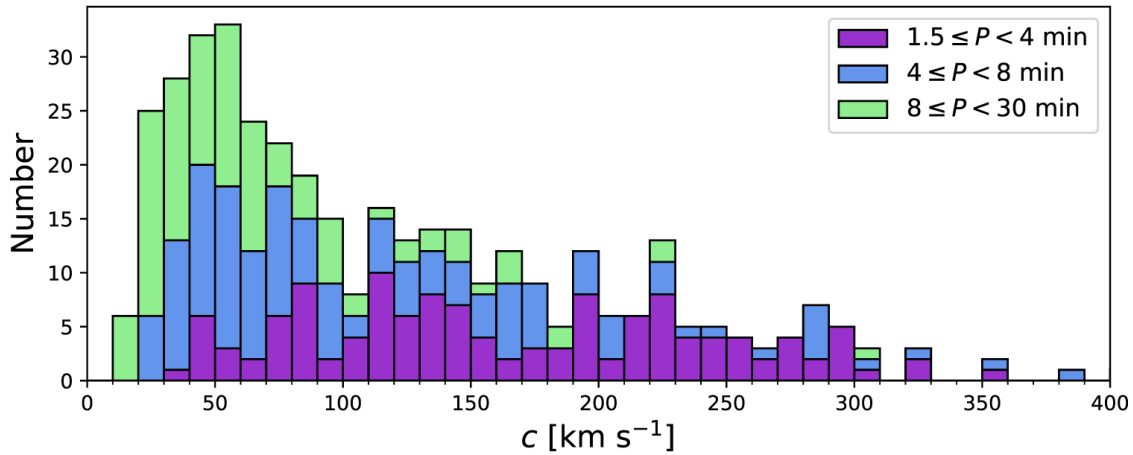
$$F = \frac{1}{2}\rho u^2 V_A, \qquad E = \int_0^\tau \int_0^A F \; da \; dt$$

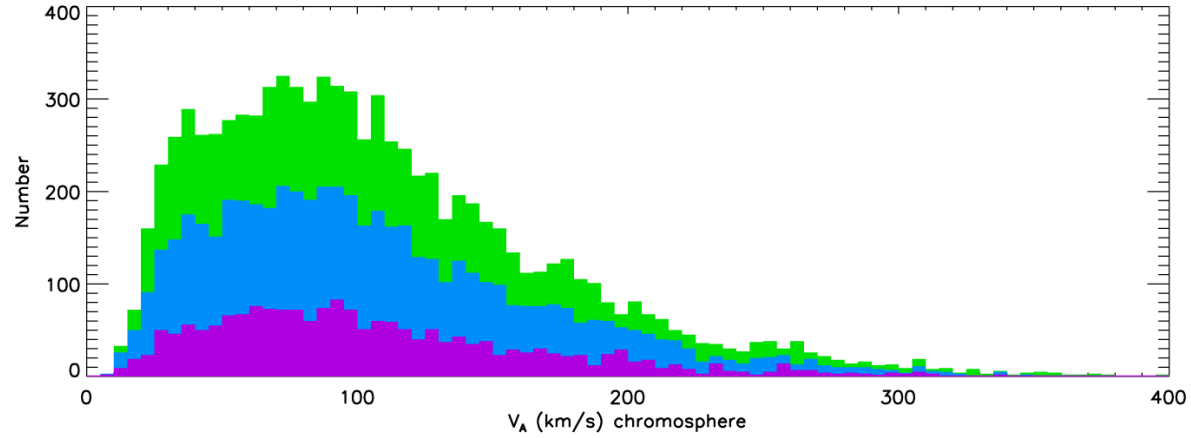
Total energy ejection rate, wave spectral energy density

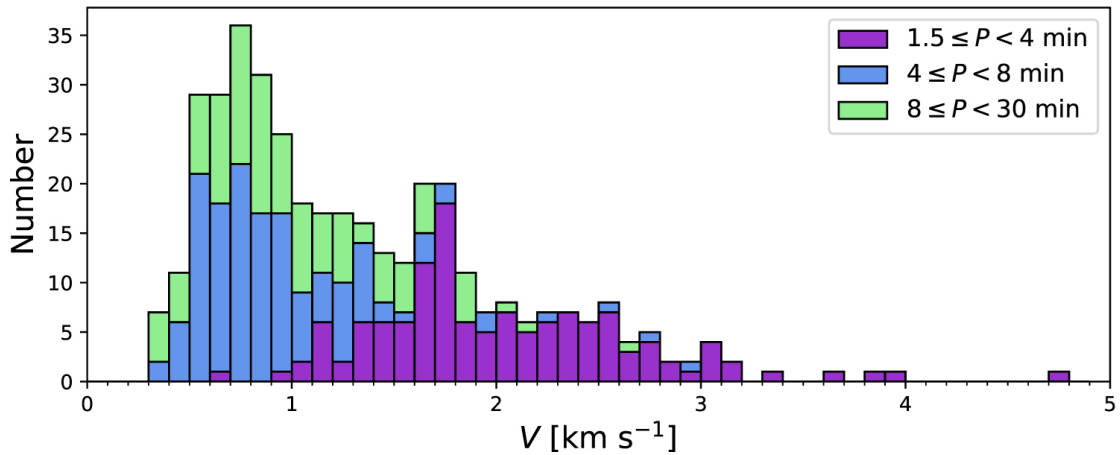
$$\dot{\mathcal{E}} = \frac{\sum_A \sum_i E_i}{T}, \qquad \mathcal{E}_k = \frac{\sum_k^{k+\delta k} E(k)}{\delta k}$$

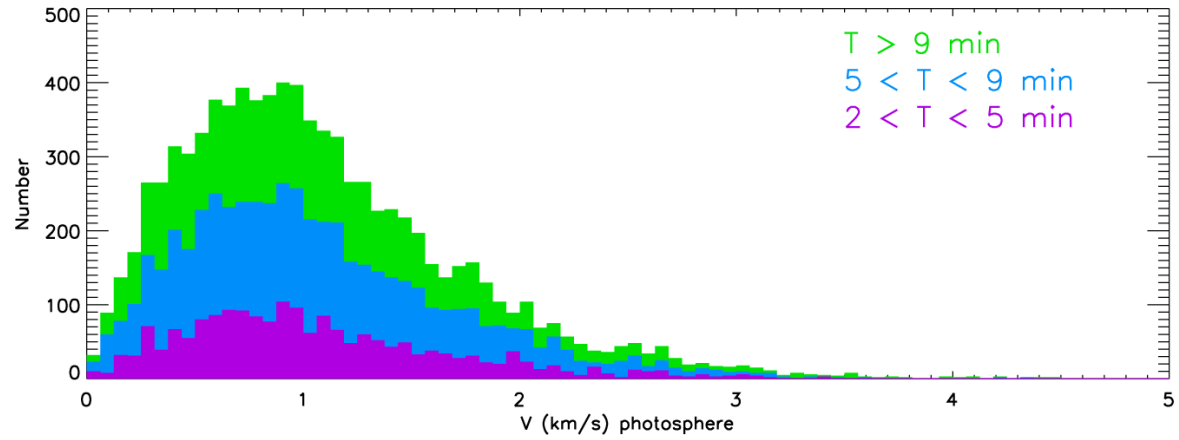

Kwak+ 2023
Outward
Inward
Number
P [min]

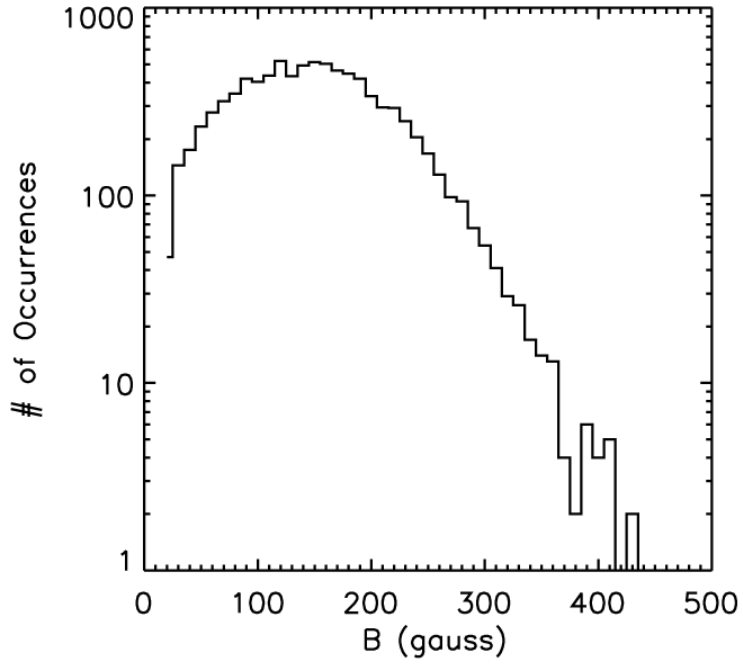

SWAMIS
T > 9 min
T < 9 min
Number
P (min) chromosphere

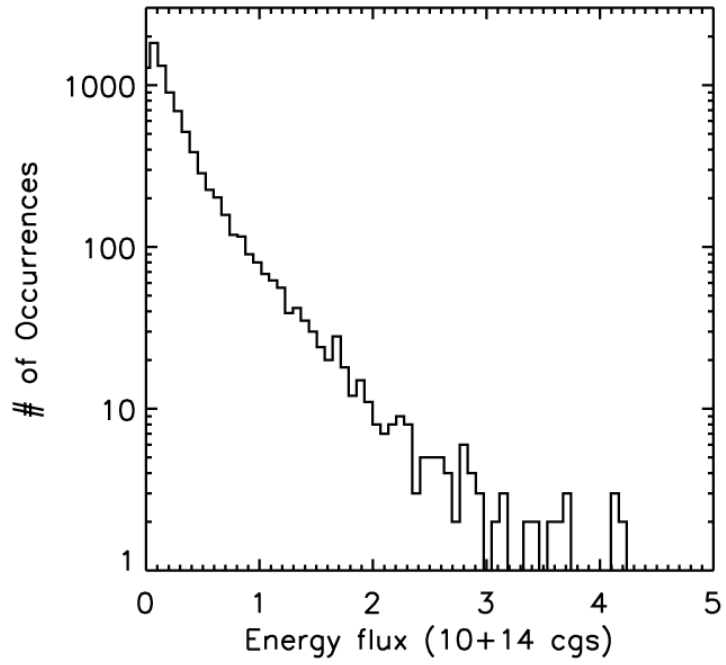

1.5 ≤ P < 4 min
4 ≤ P < 8 min
8 ≤ P < 30 min
Number
c [km s−1]

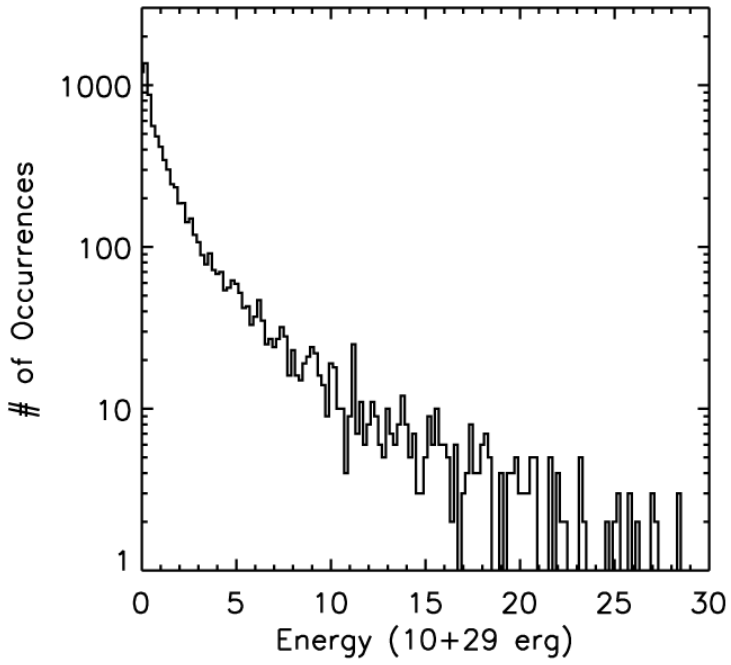

Number
VA (km/s) chromosphere

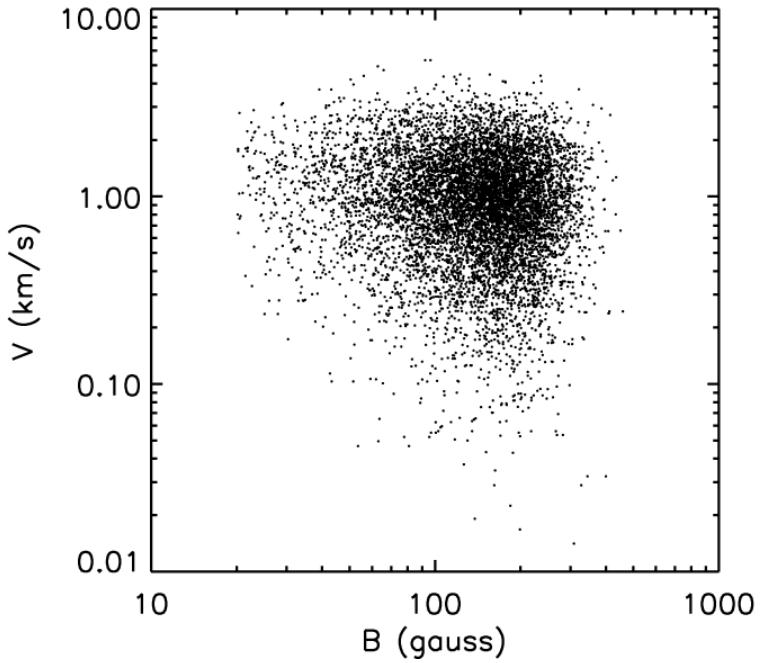

1.5 ≤ P < 4 min
4 ≤ P < 8 min
8 ≤ P < 30 min
Number
V [km s−1]

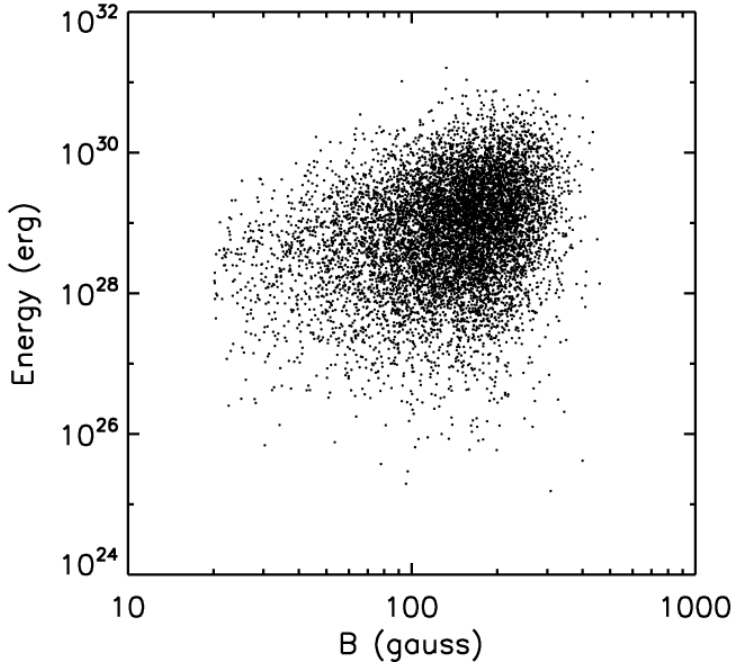

T > 9 min
5 < T < 9 min
2 < T < 5 min
Number
V (km/s) photosphere

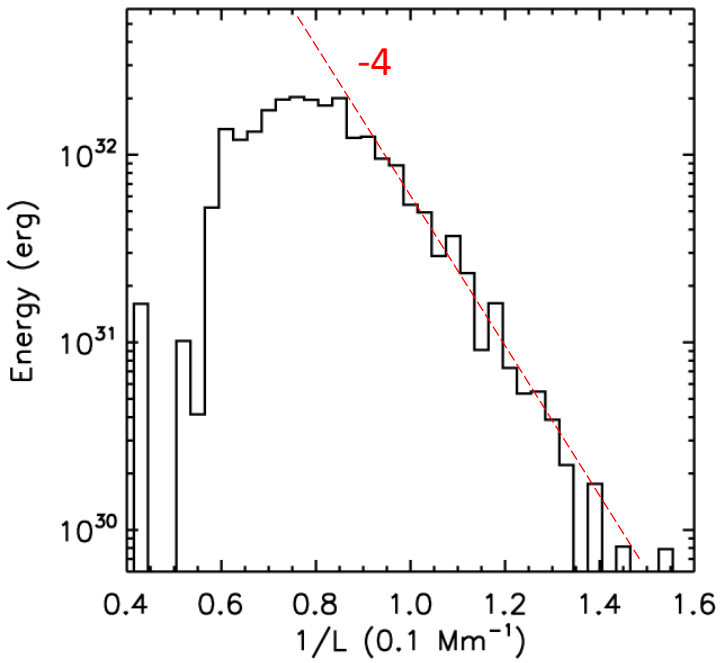

# of Occurrences
B (gauss)


# of Occurrences
Energy flux (10+14 cgs)


# of Occurrences
Energy (10+29 erg)


V (km/s)
B (gauss)


Energy (erg)
B (gauss)


-4
Energy (erg)
1/L (0.1 Mm^{-1})

Spicules, NBPs, and SBs

- Spicules are a good solar candidate for SBs for their size combination, magnetic property, and occurrence rate.

- NBPs can generate Alfven waves propagating along open unipolar fields, which may also develop into SBs.