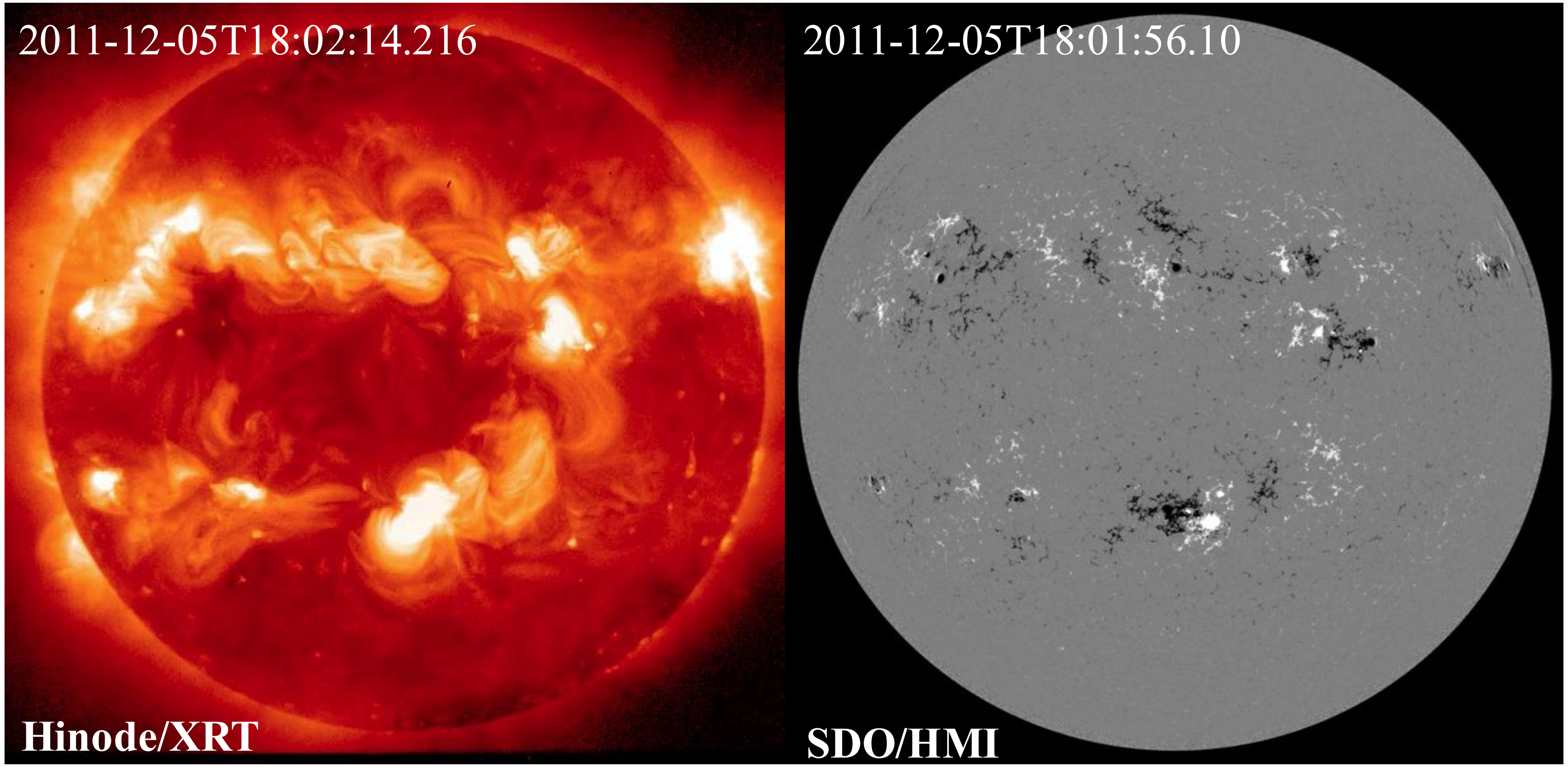
# Is Heating in Coronal Loops also governed by Field Advection Speeds?

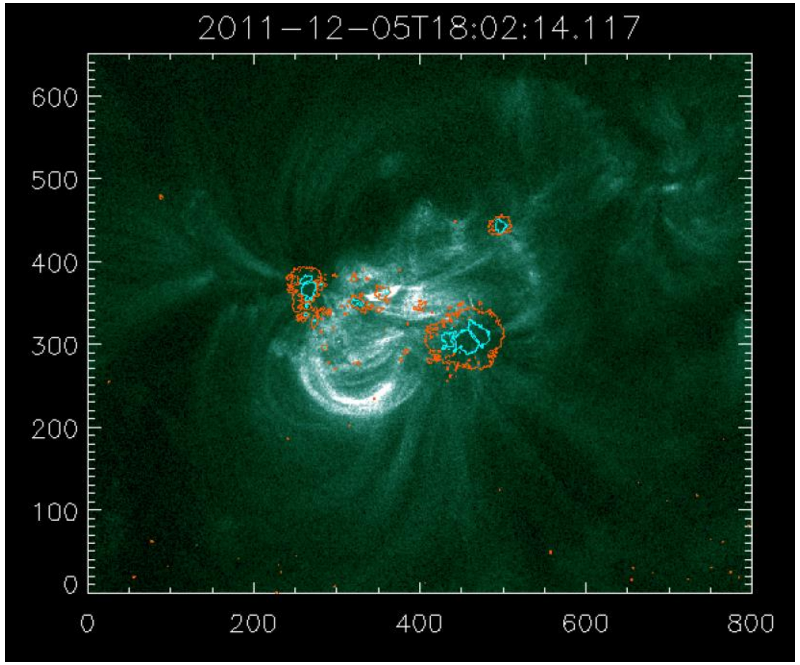
Aparna V.

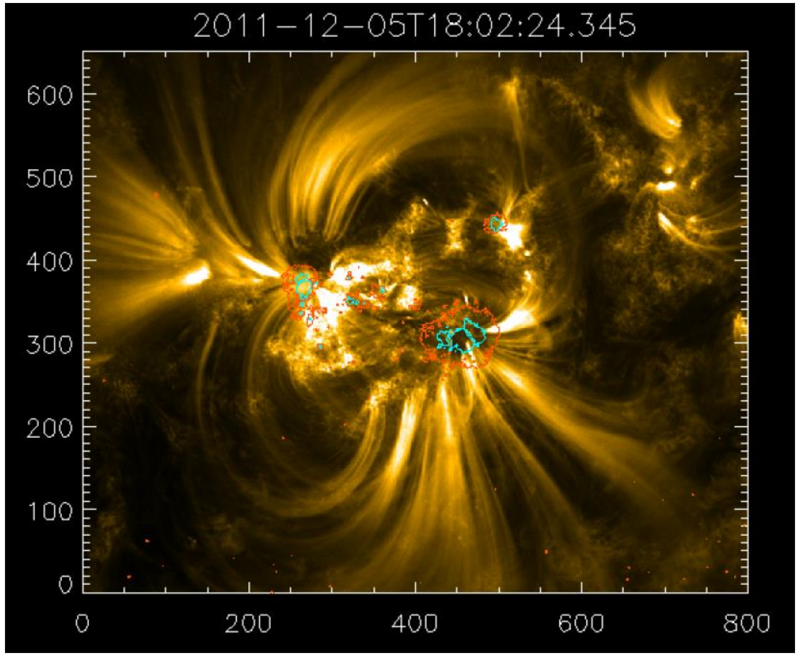
Mar 4, 2026

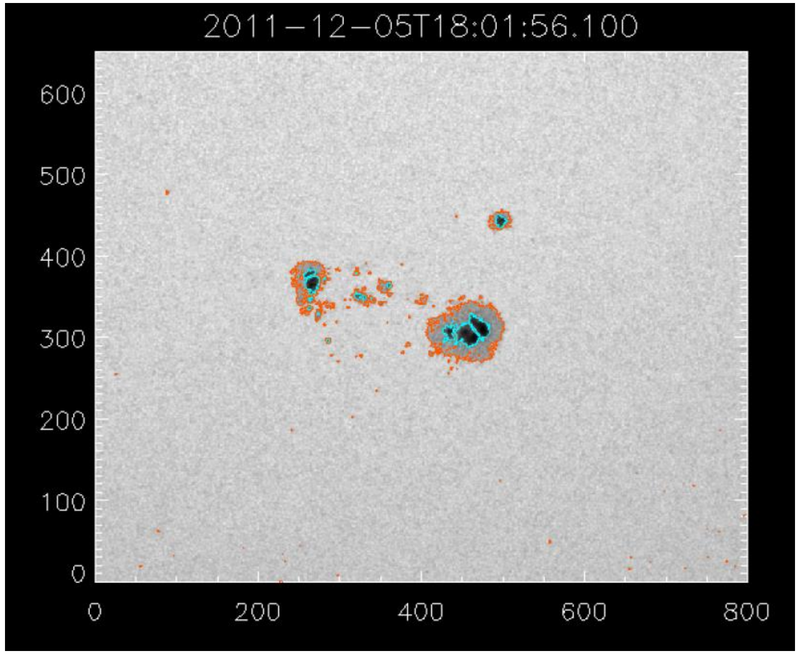
# Motivation


2011-12-05T18:02:14.216
Hinode/XRT
2011-12-05T18:01:56.10
SDO/HMI

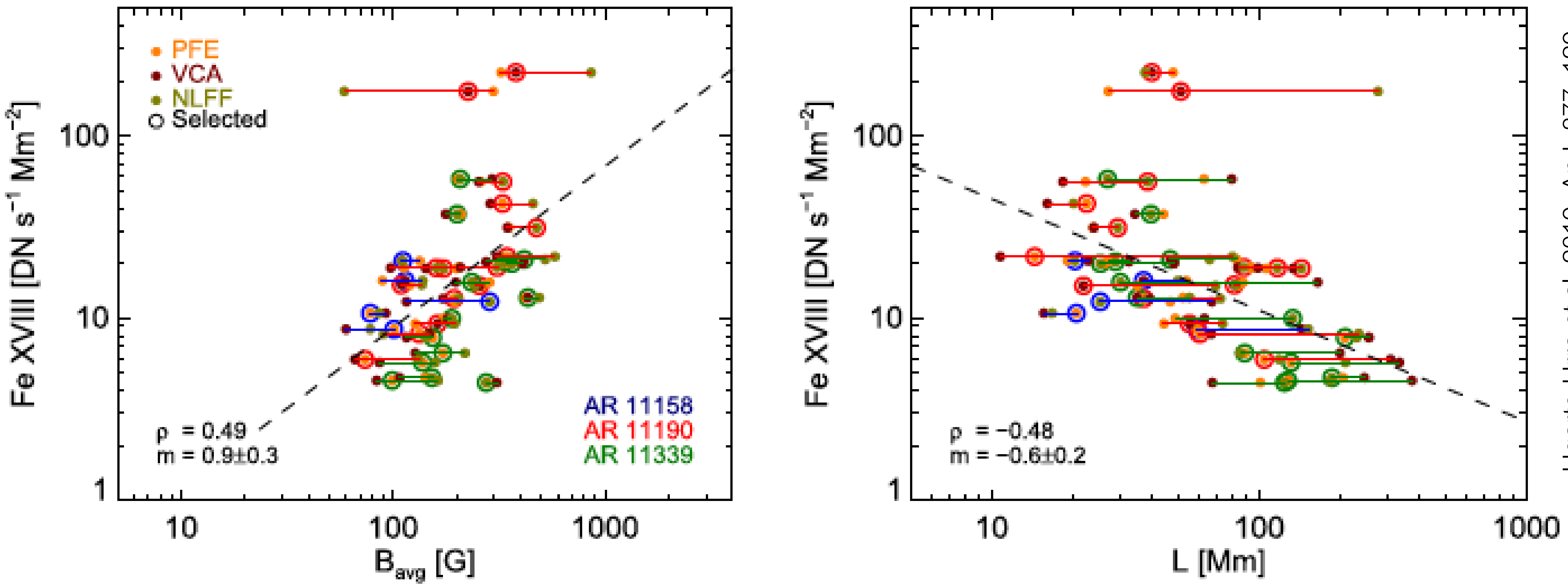
# Hi-Res & Close-up



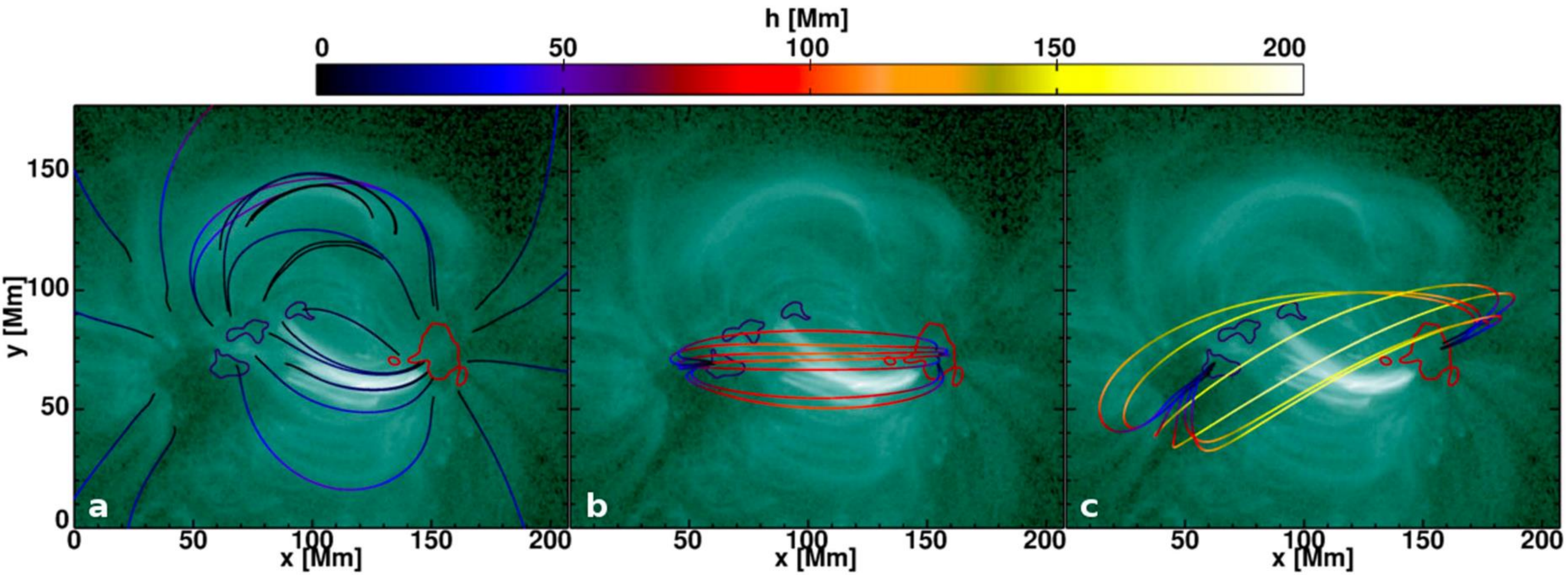
# Example

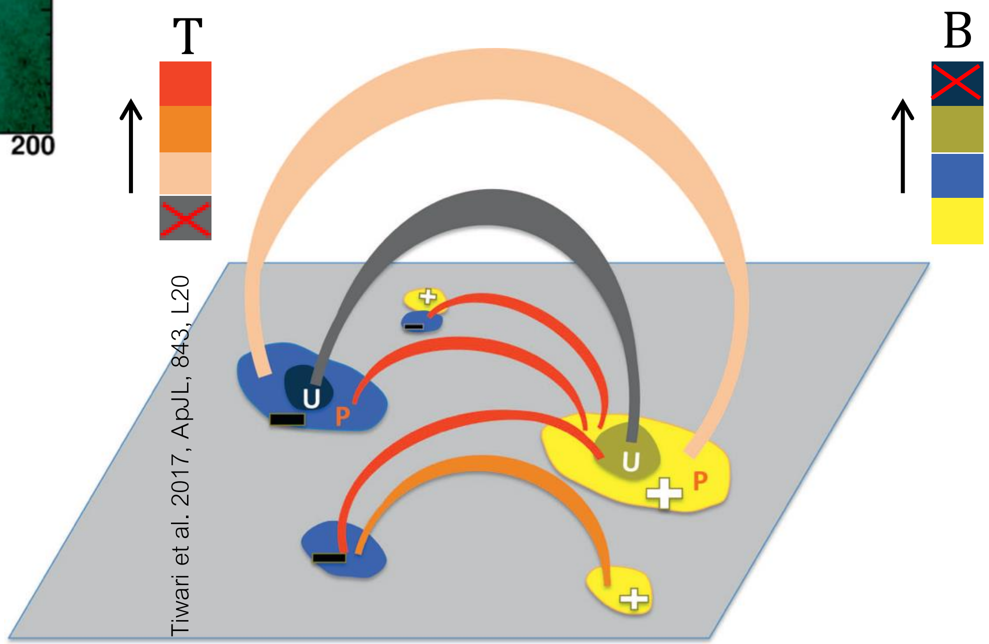



Ugarte-Urra et al. 2019, ApJ, 877, 129

$$I \propto \left(\frac{B_{avg}}{L}\right)^{0.52\pm0.13} \qquad H \propto \frac{B^{0.3\pm0.2}}{L^{0.2\pm0.1}}$$

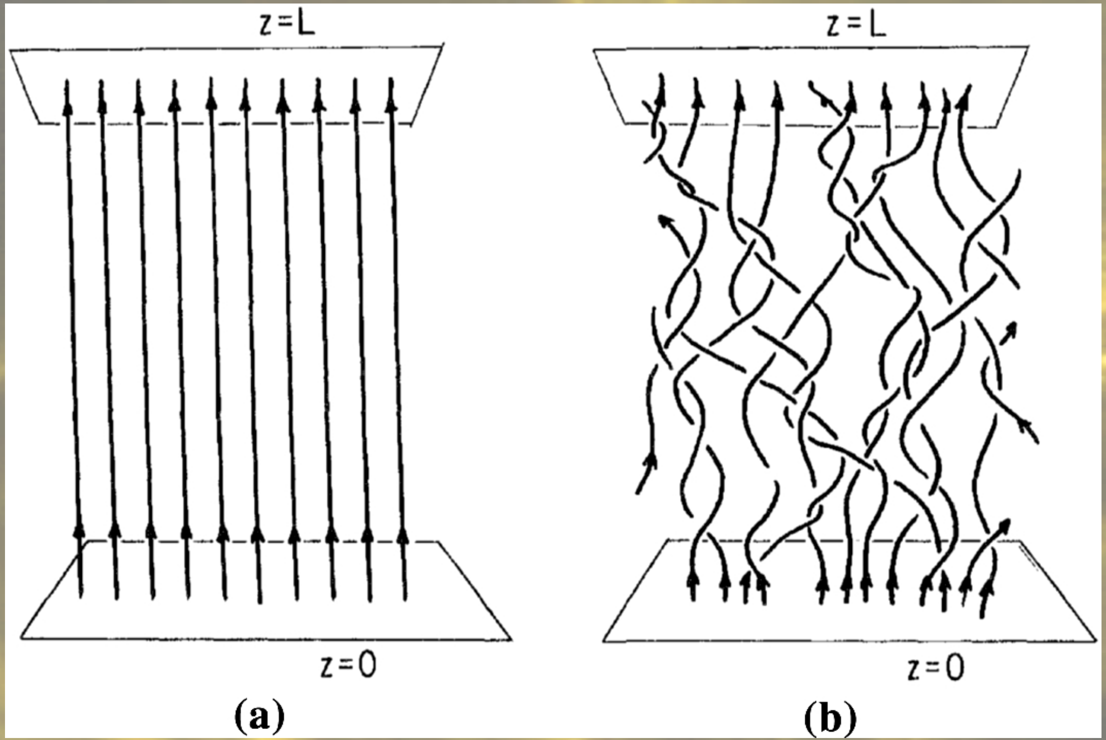
# Magnetoconvection drives Coronal Heating




- Loop-heating
  - Convective freedom
  - Magnetic field strength

# Loop Heating




Parker, 1994, *Intl. Ser. in A&A., vol 2., Oxford University Press*

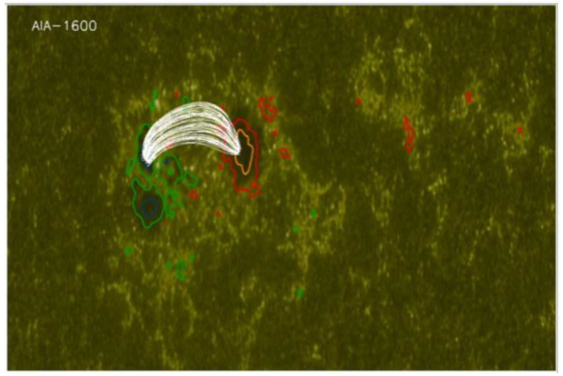
- Strong fields suppress convection
- Convection → braiding → Bright loops
  - Convection shuffles the field lines causing braiding
  - Braiding - 2 – 6 MK

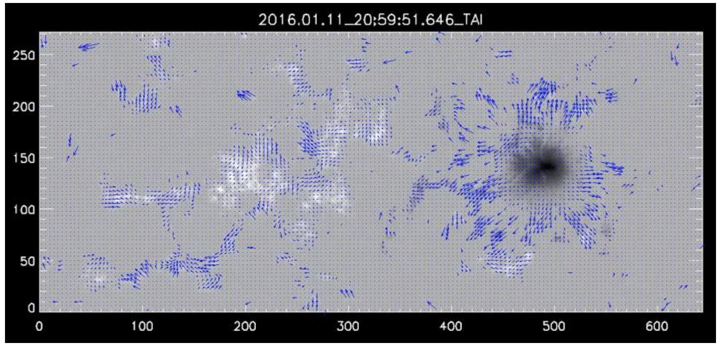
# Goals

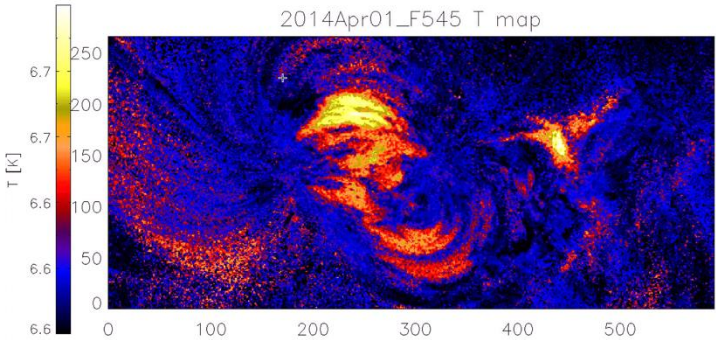
- New Scaling Law
  - Heating rate $\propto B^{\alpha} L^{-\beta}$
  - $v_h$
- Quantitative estimate of convective freedom
  - $v_h$ (B) – from FLCT
- Quantitative relation between B, T, L &. $v_h$
  - B & L – from NLFFF
  - T – from DEM

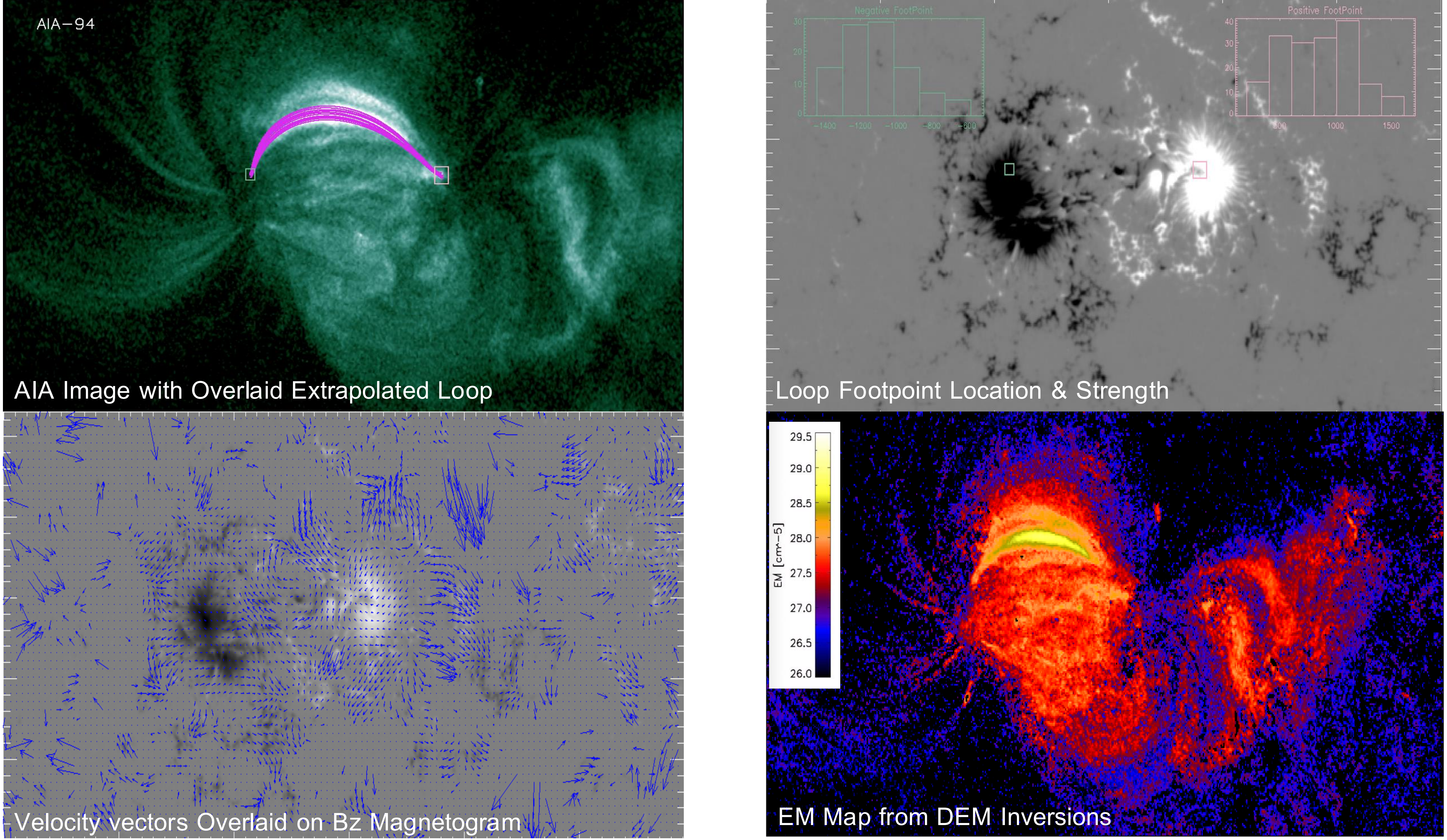
# Data & Methods

- Loop Length, Height, B along loop, Footpoint B
  - SHARP CEA Vector-magnetograms
  - NLFFF (Weigelmann et al. 2008)
- Field advection speed
  - SHARP CEA Bz magnetograms
  - FLCT (Fisher & Welsch 2008)
- Loop Temperature
  - AIA 6 EUV channels
  - DEM (Cheung et al. 2015)

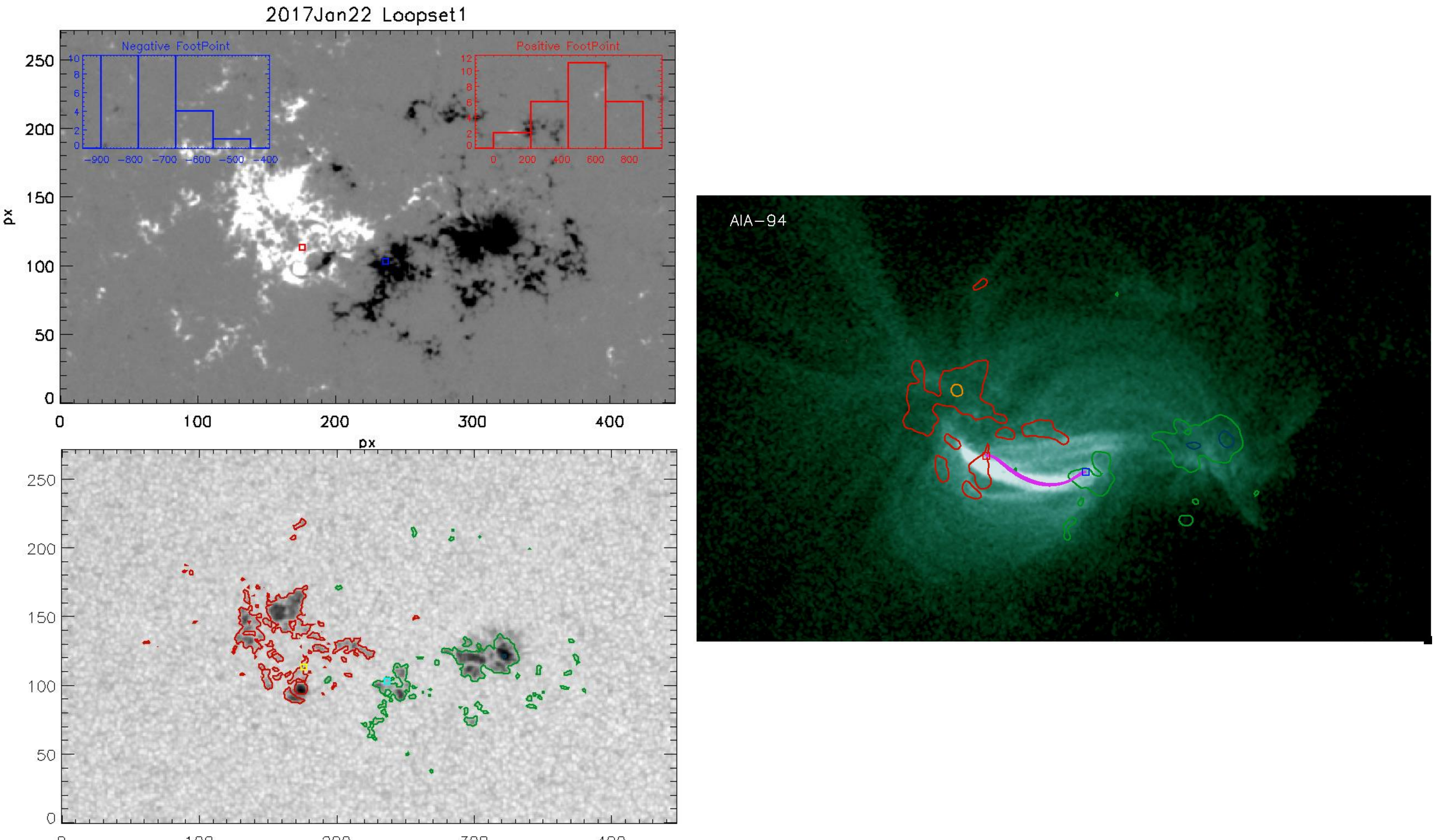


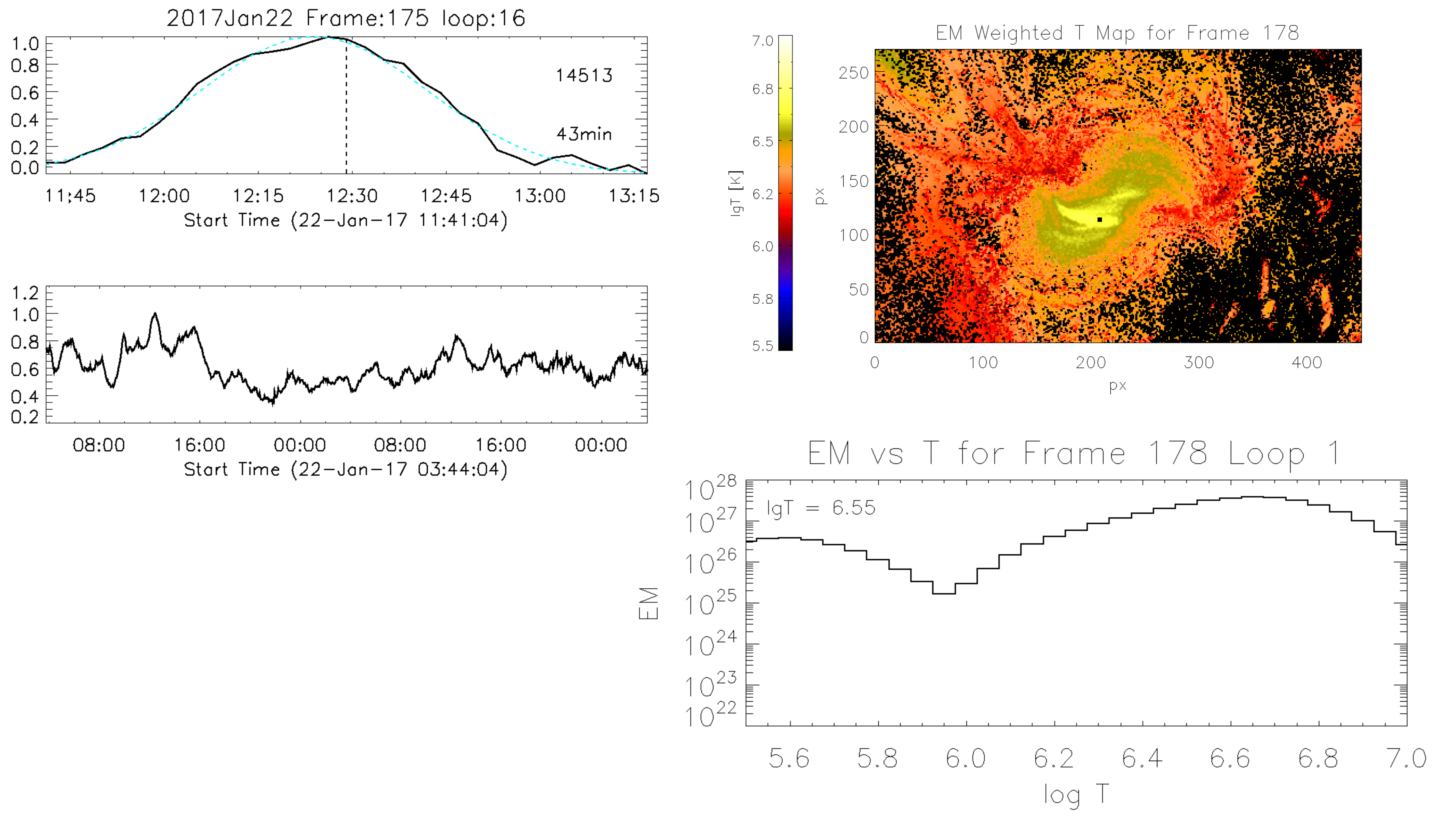





AIA−94
AIA Image with Overlaid Extrapolated Loop
Negative FootPoint
Positive FootPoint
Loop Footpoint Location & Strength
Velocity vectors Overlaid on Bz Magnetogram
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
EM [cm^-5]
EM Map from DEM Inversions

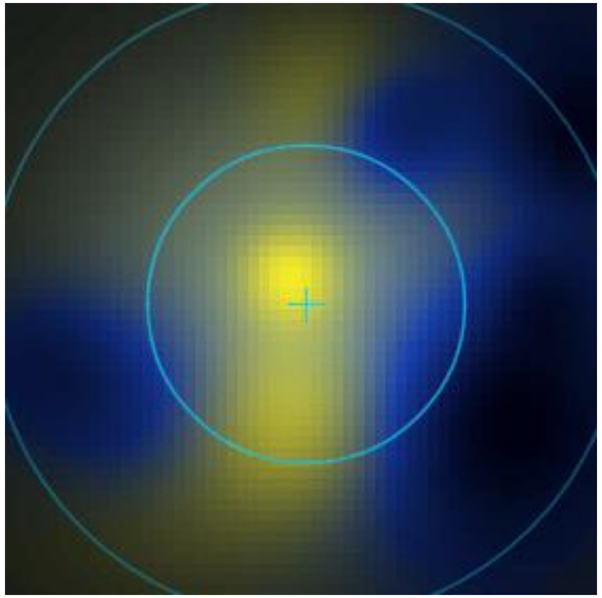

2017Jan22 Loopset1
Negative FootPoint
Positive FootPoint
px
px
AIA−94

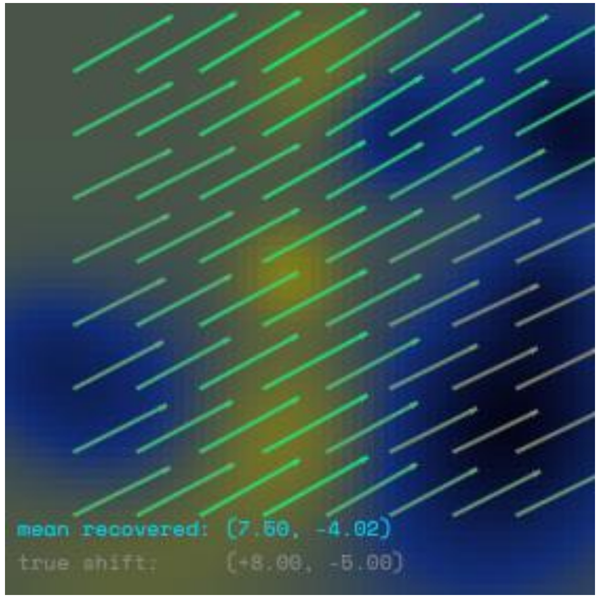


2017Jan22 Frame:175 loop:16
14513
43min
Start Time (22-Jan-17 11:41:04)
Start Time (22-Jan-17 03:44:04)
EM Weighted T Map for Frame 178
lgT [K]
px
EM vs T for Frame 178 Loop 1
lgT = 6.55
EM
log T

# FLCT to get a relation between $v_h$ & B

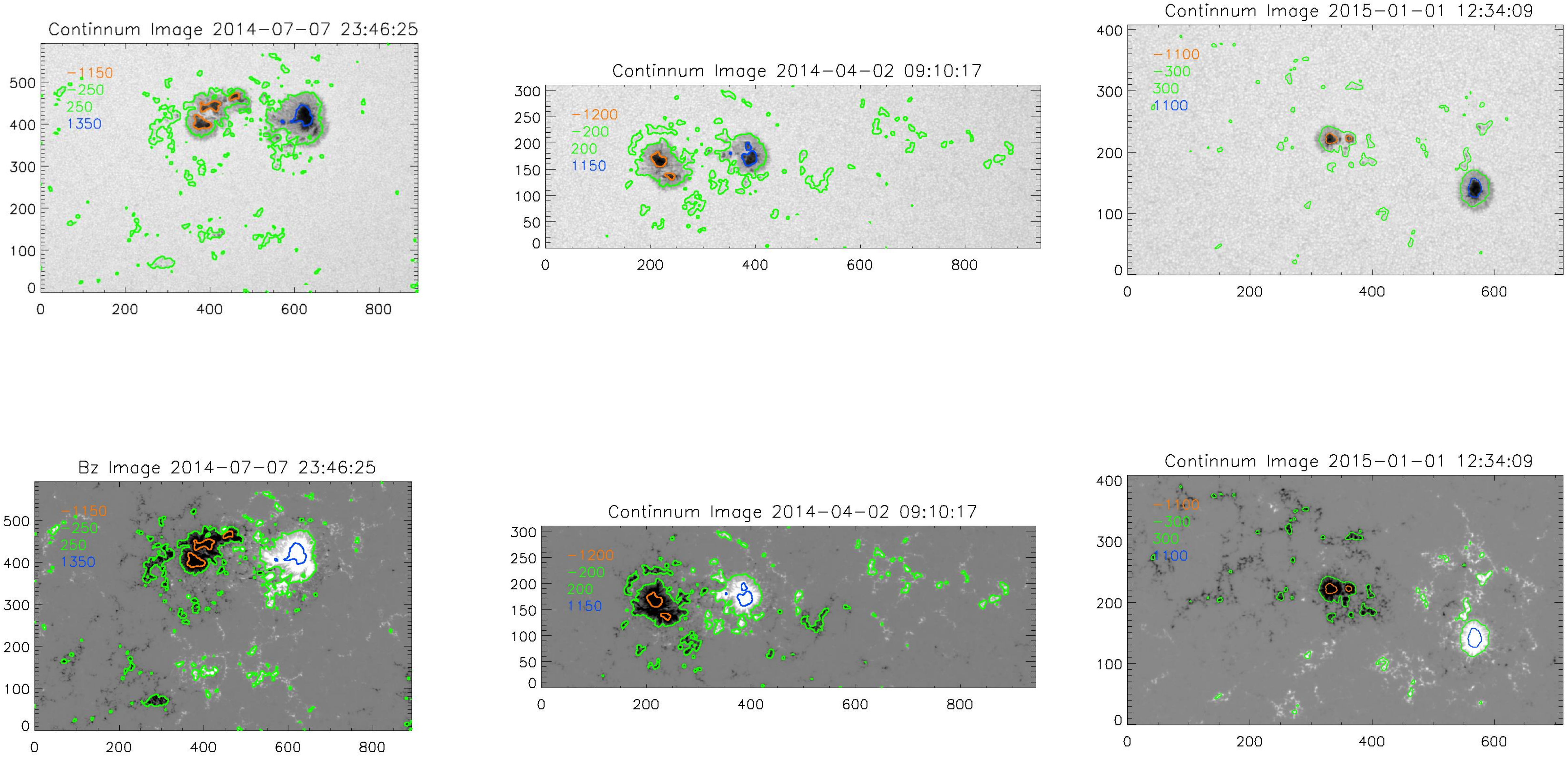
- Quantify Freedom of Convection
- Fisher & Welsch, 2008
- Two images separated by time *t*
- Windowing around each pixel
- Compute cross-correlation between two images
- Locate the peak of the cross-correlation function



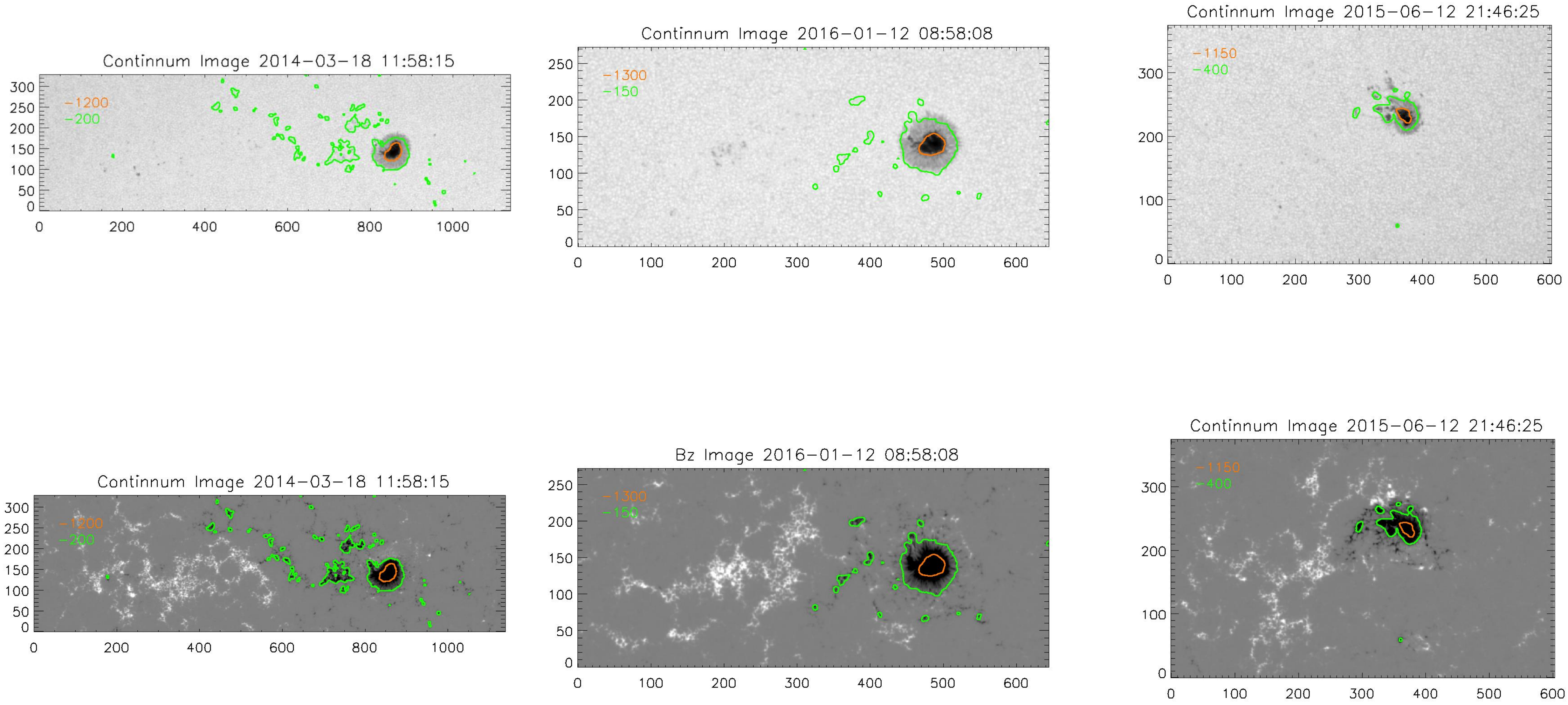



| **Sunspot-Sunspot** | | **Sunspot-Plage** | |
|---|---|---|---|
| Date | NOAA AR | Date | NOAA AR |
| 2014Apr01 | 12021 | 2016Jan29 | 12489 |
| 2014Jul07 | 12108 | 2015Jan12 | 12365 |
| 2015Jan01 | 12254 | 2016Jan12 | 12480 |

# SS: Contours from CEA Bz



# SP: Contours from CEA Bz

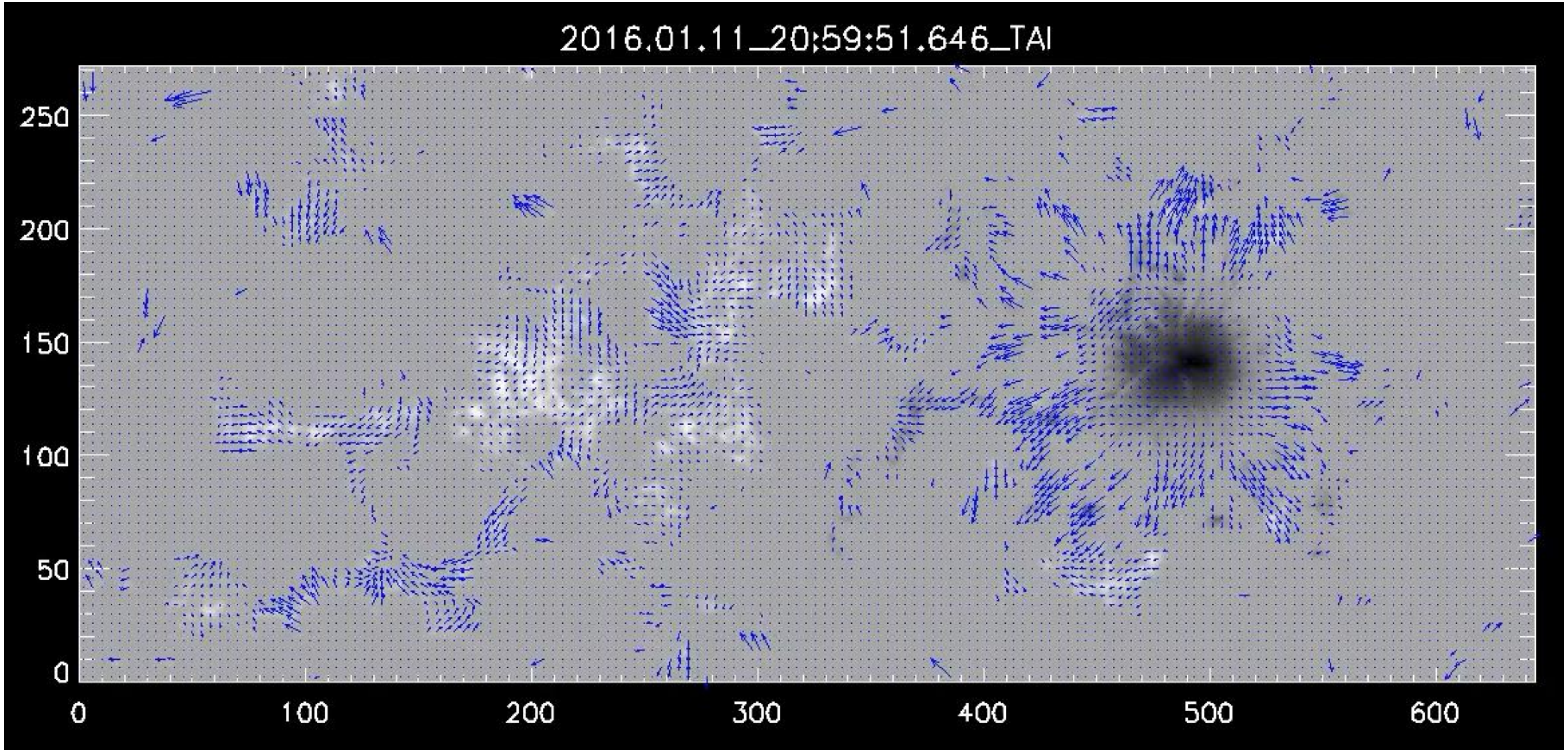


# Measuring Convective Freedom

Noise level = 150G

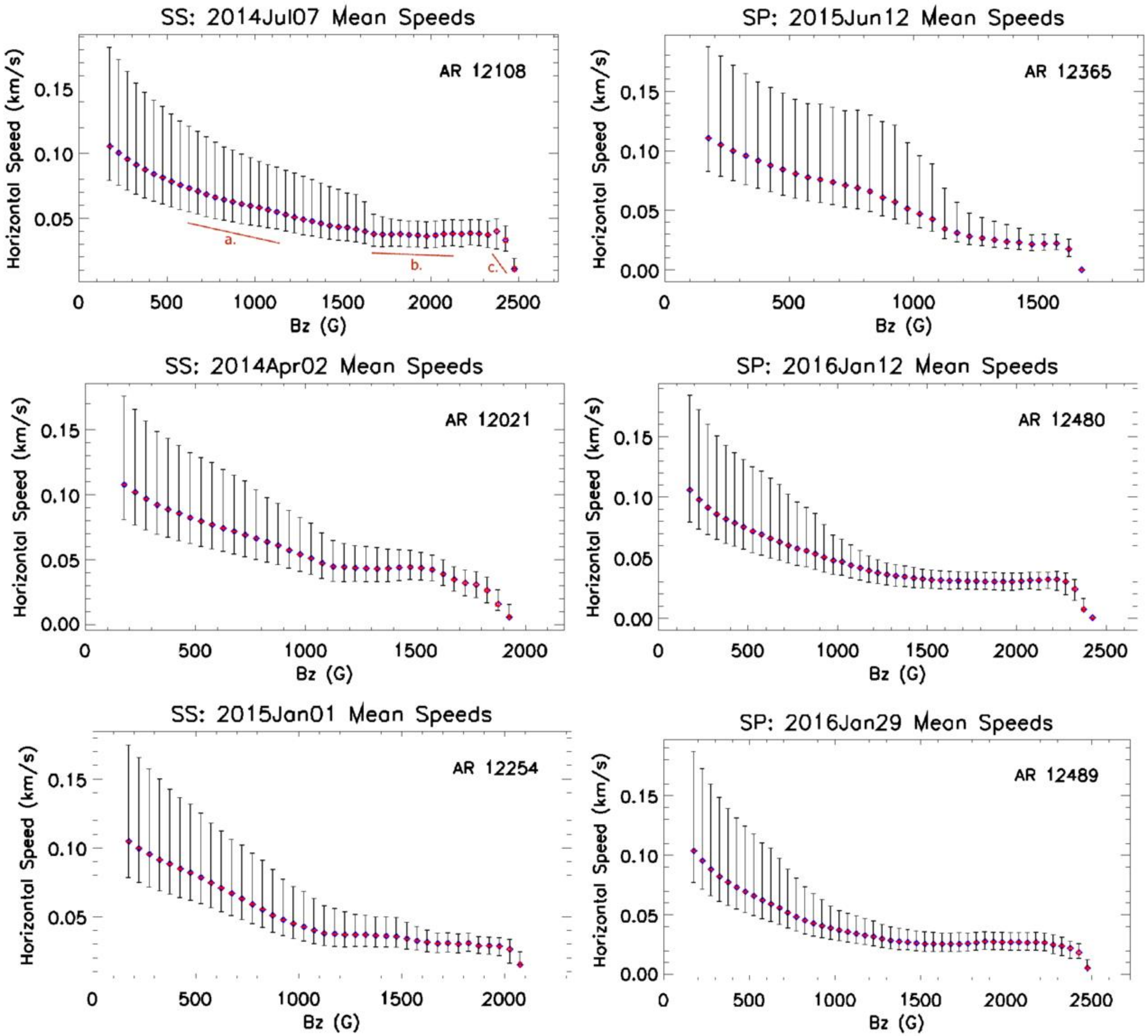
data length = 24 hours

Sig = 15

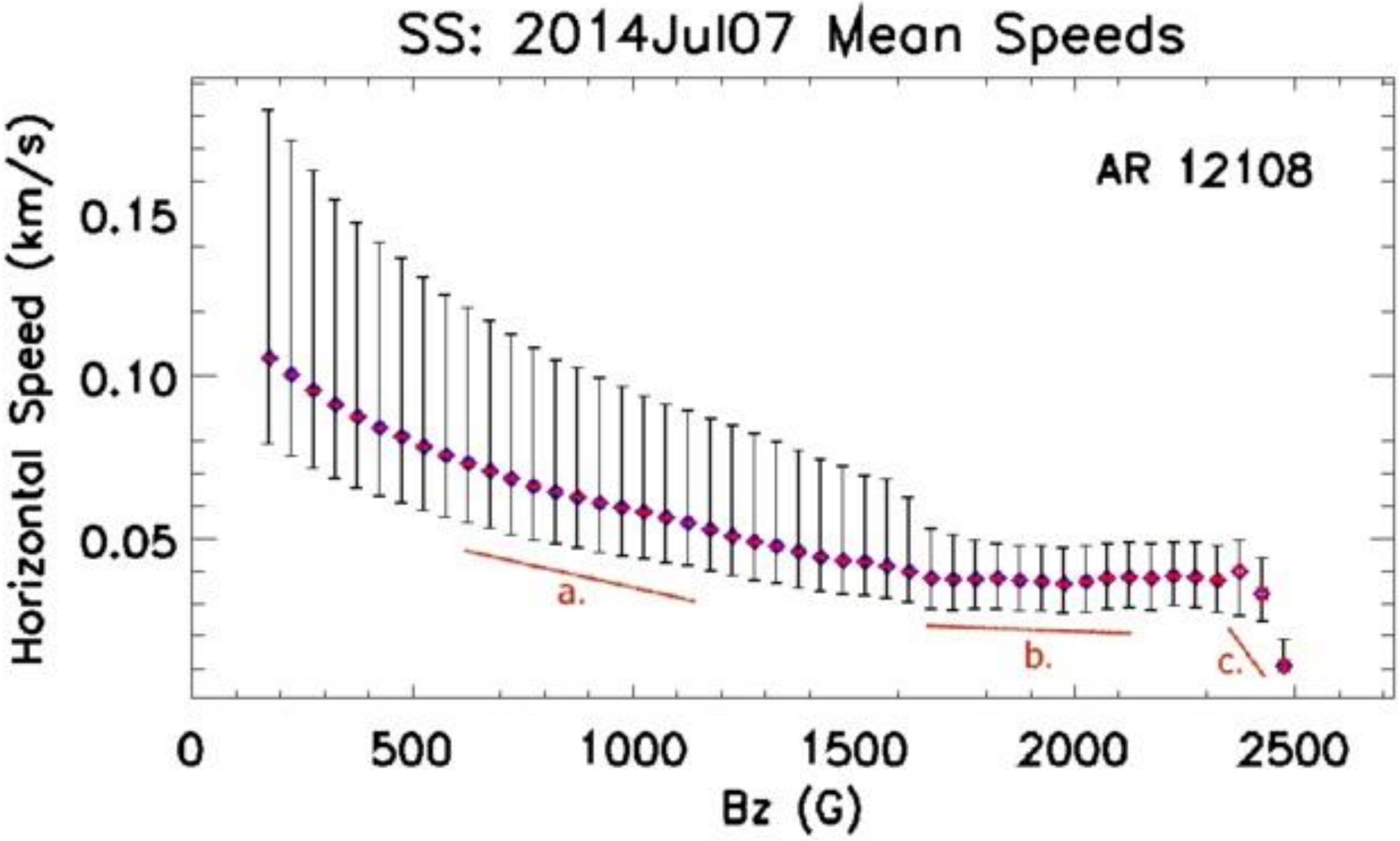


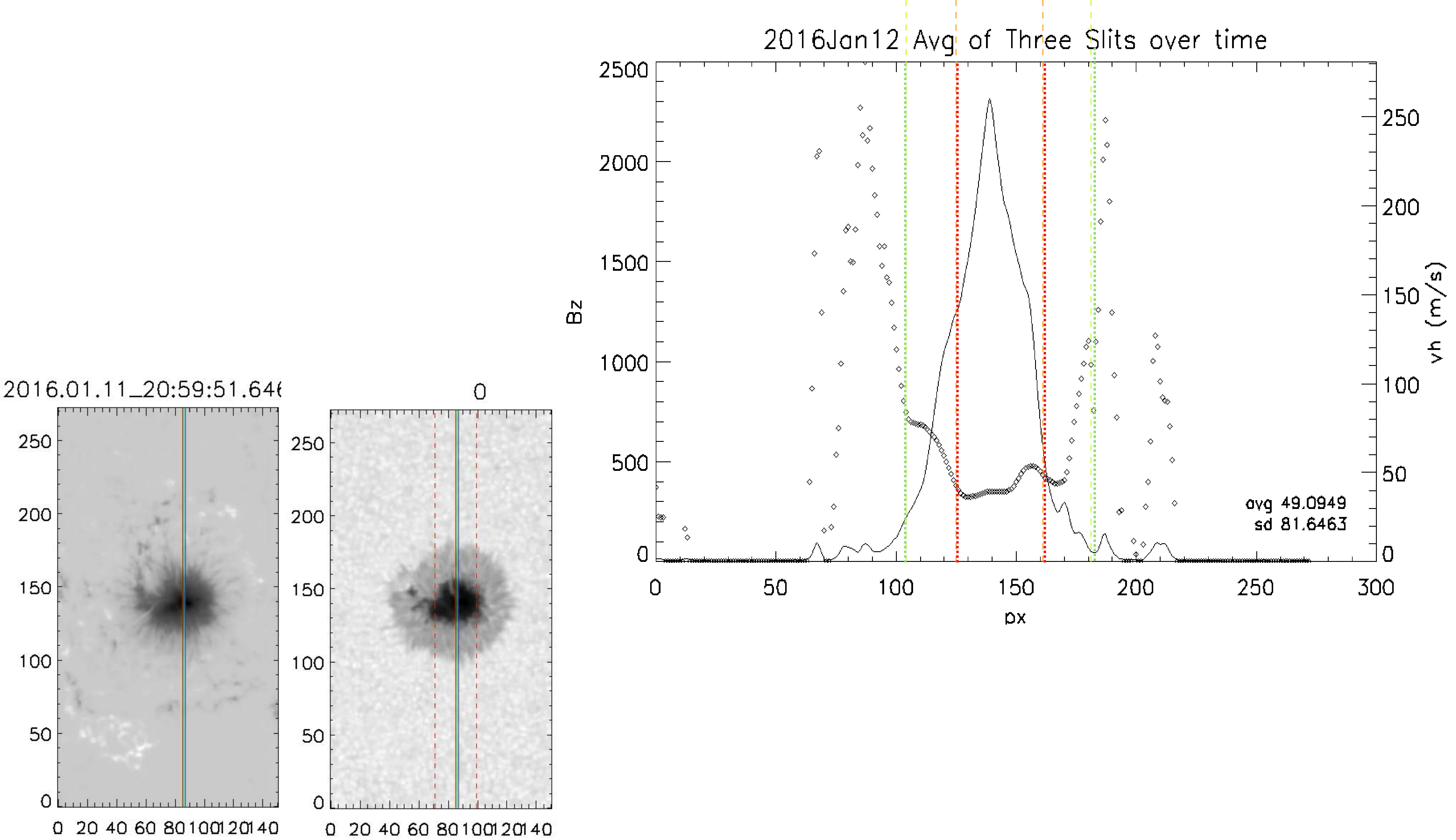
# Mean Advection Speeds using SHARP Bz Magnetograms for six ARs

- 12min cadence
- stderr = $\frac{\sigma}{\sqrt{n}}$ (red)
- stddev (black)

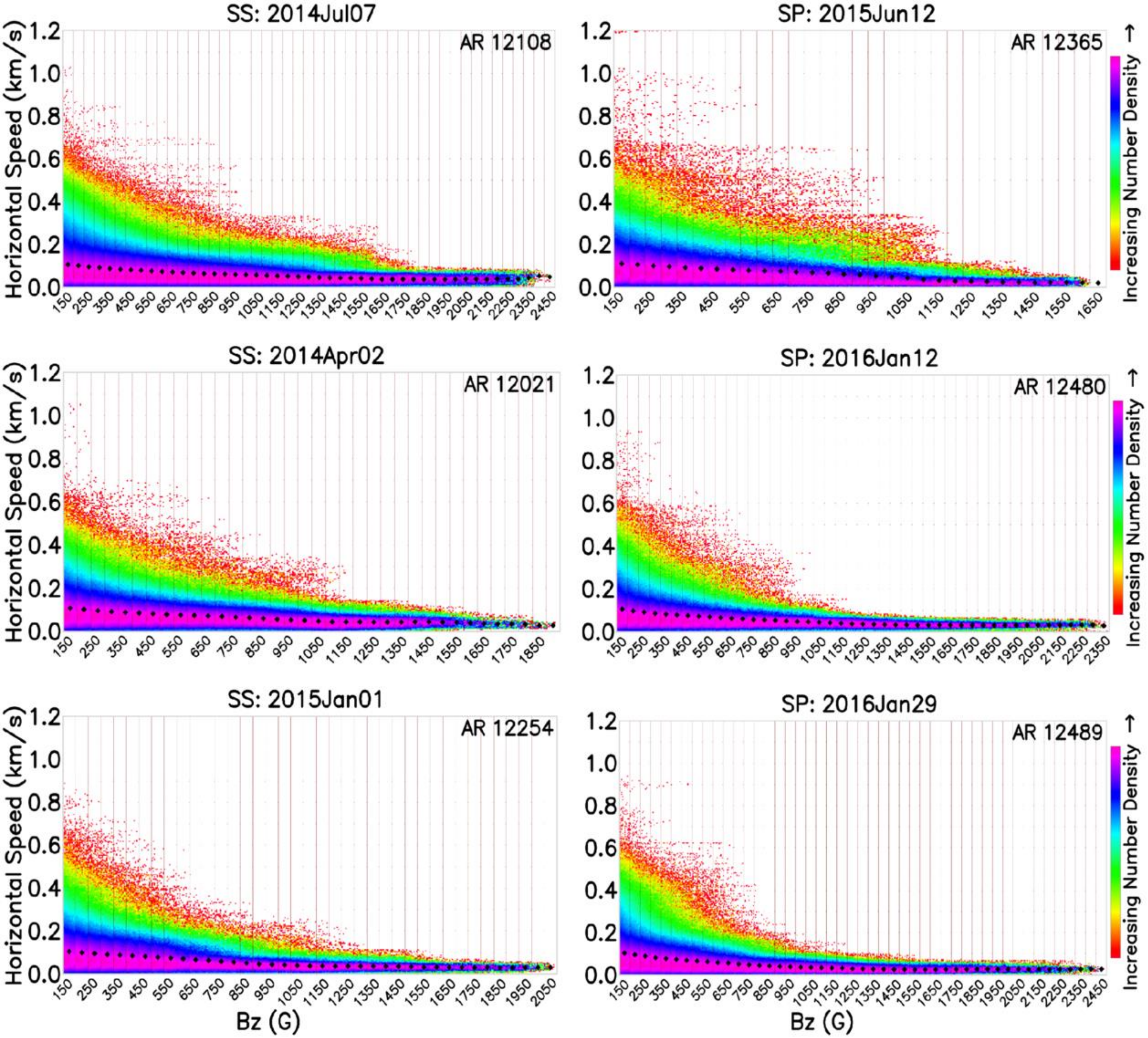


- Steady decrease from 200-1200 G (a)
- Plateau – 1200-2300 (b)
- Knee – Bz > 2300 (c)

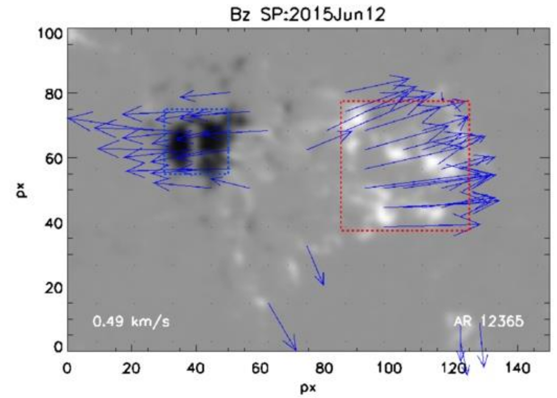


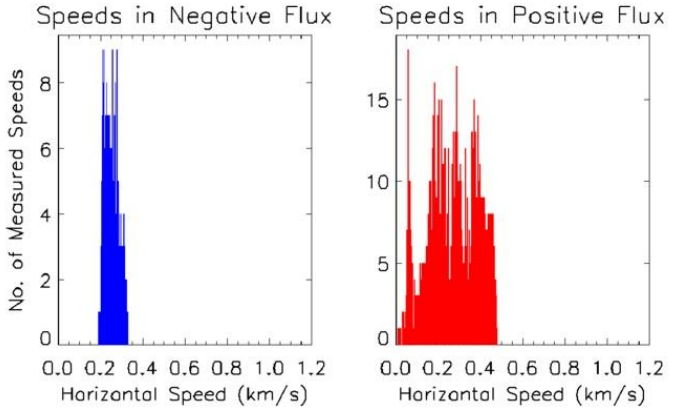


2016.01.11_20:59:51.646
0
2016Jan12 Avg of Three Slits over time
Bz
vh (m/s)
px
avg 49.0949
sd 81.6463

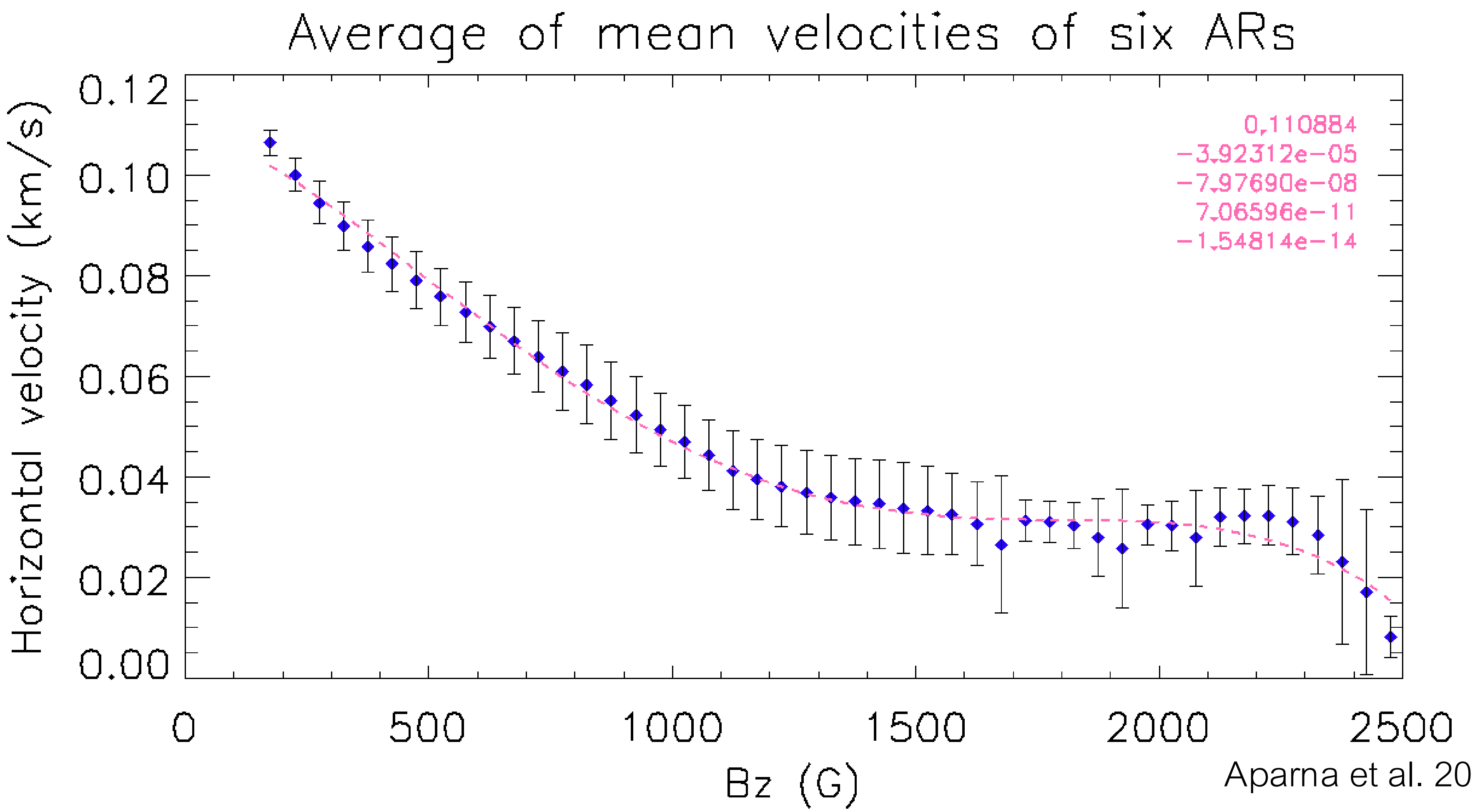



# Advection Speeds Histogram of SHARP Bz Magnetograms



# Horizontal Advection Speeds with Magnetic Field




Aparna et al. 2025, ApJ, 987, 98

$$v_h = -1.55 \times 10^{-14} x^4 + 7.06 \times 10^{-11} x^3 - 7.97 \times 10^{-8} x^2 - 3.92 \times 10^{-5} x + 0.11$$

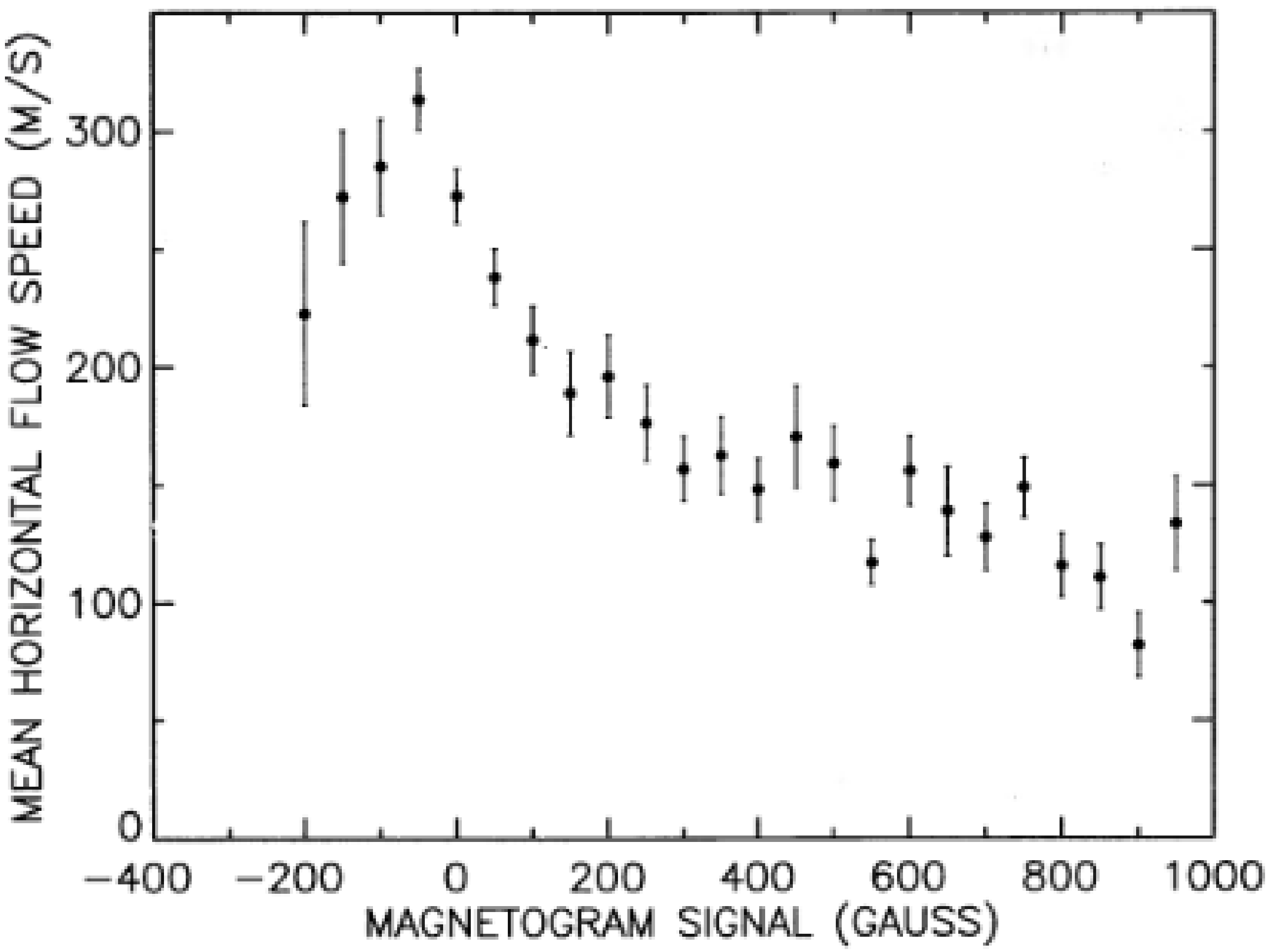
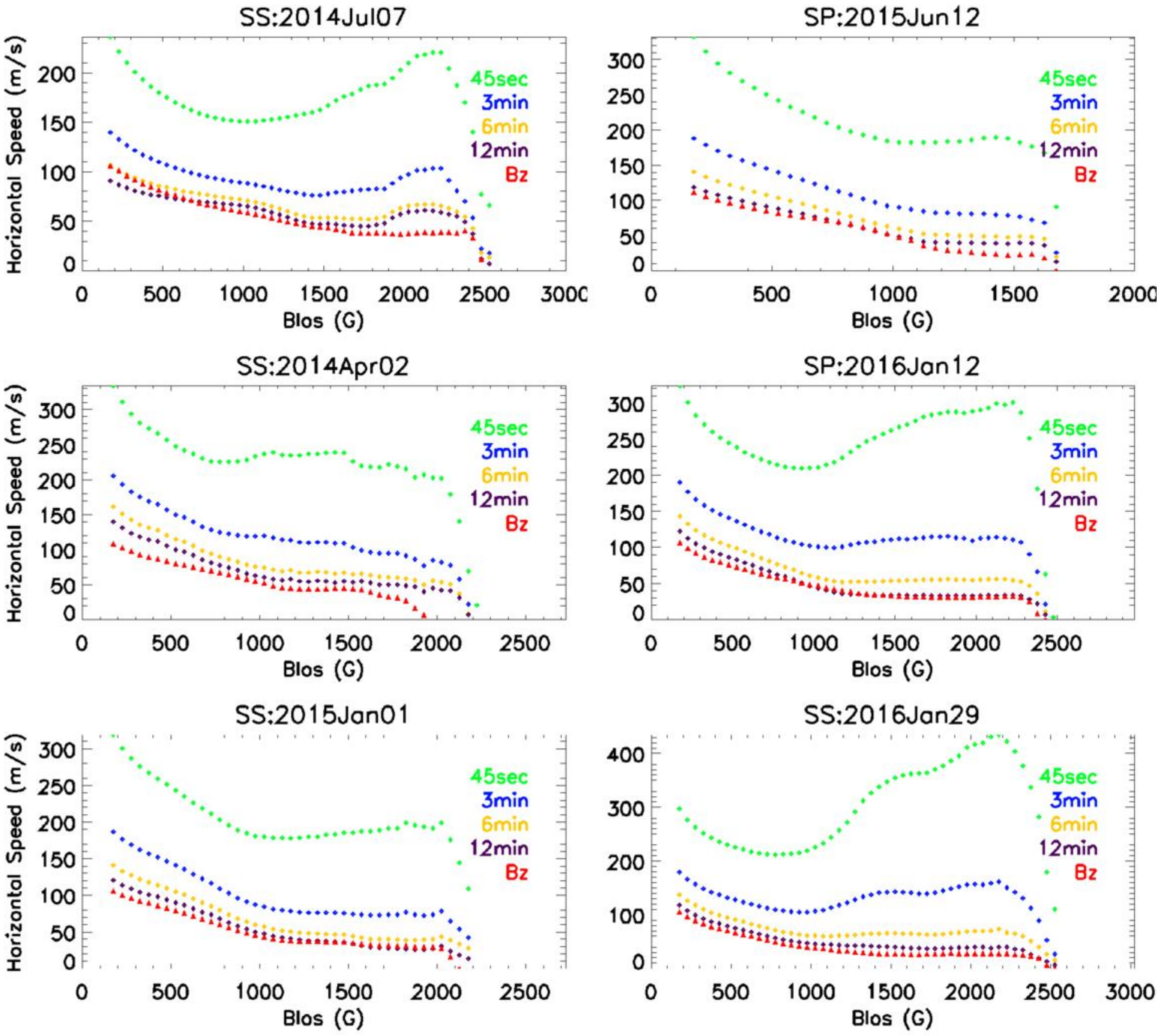


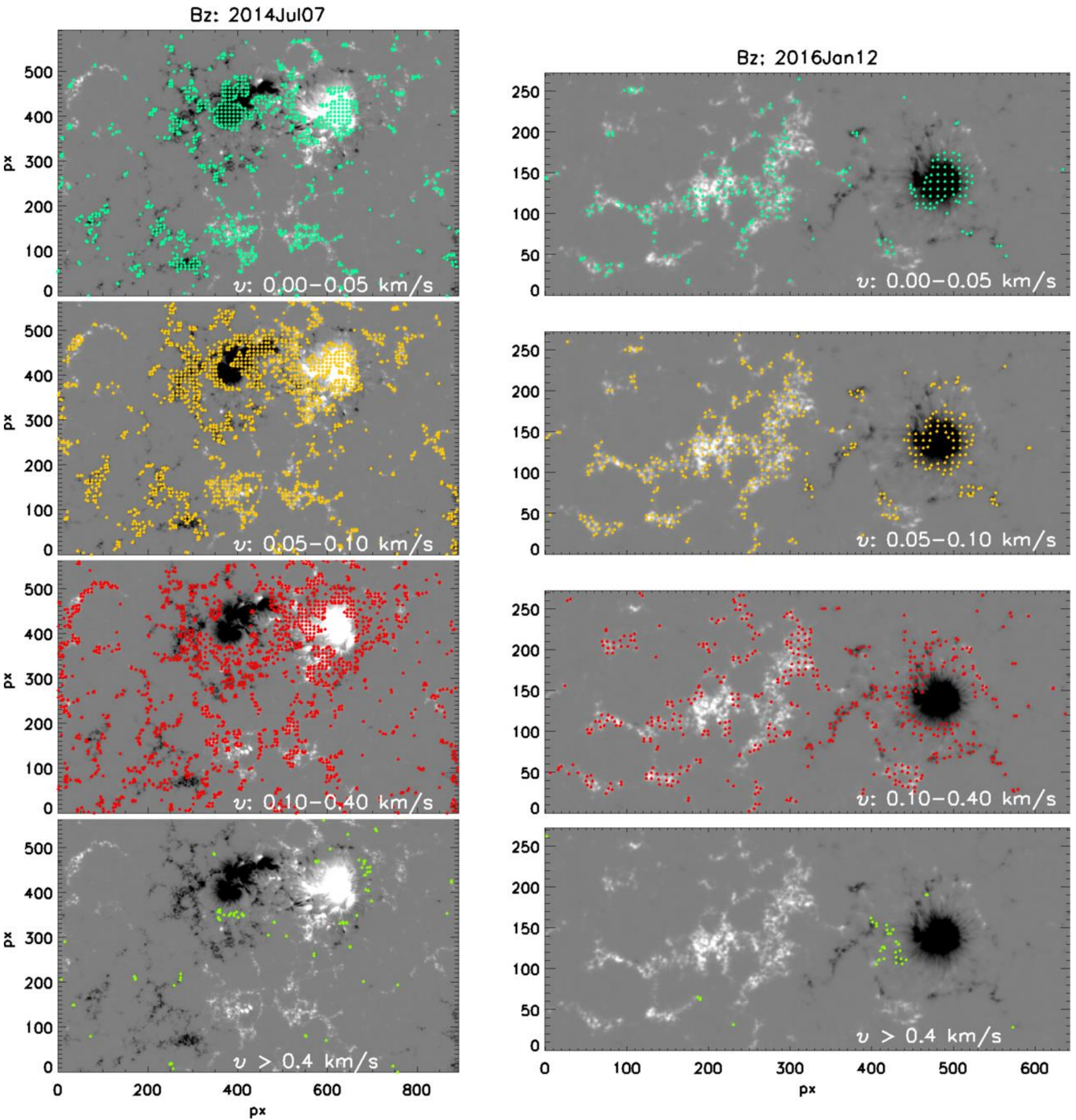

FIG. 27.—Mean horizontal flow speed vs. magnetogram signal. The error bars indicate the error of the mean.

- Title, Topka & Tarbell, 1992
  - 60s cadence
  - 370 – 125 m/s weak to strong
  - 800 – 1000 G strongest field
- BLOS magnetograms
  - 45s cadence
  - Comparable speeds

# Advection Speeds using BLOS Magnetograms

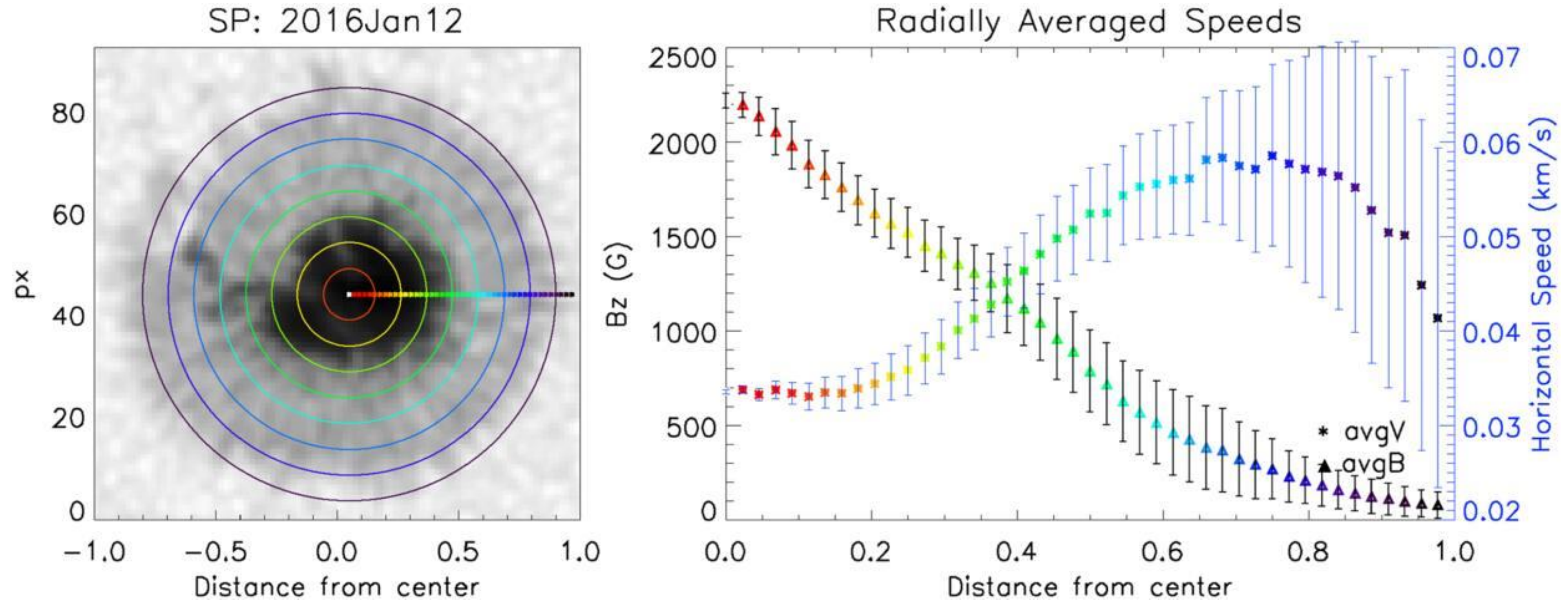
- 45sec, 3, 6, 12 min cadence
- Bz for comparison
- Threshold 20G
- Similar trends as in Bz
  - Except near high Blos
- Higher cadence – tracks shorter flows






# Locations of the Speeds

- Plage (yellow/ red)
- Intermediate – Network/ Plage (yellow/ red)
- Slow speeds – umbra (mint)
- Fast speeds – MMFs (lime green)

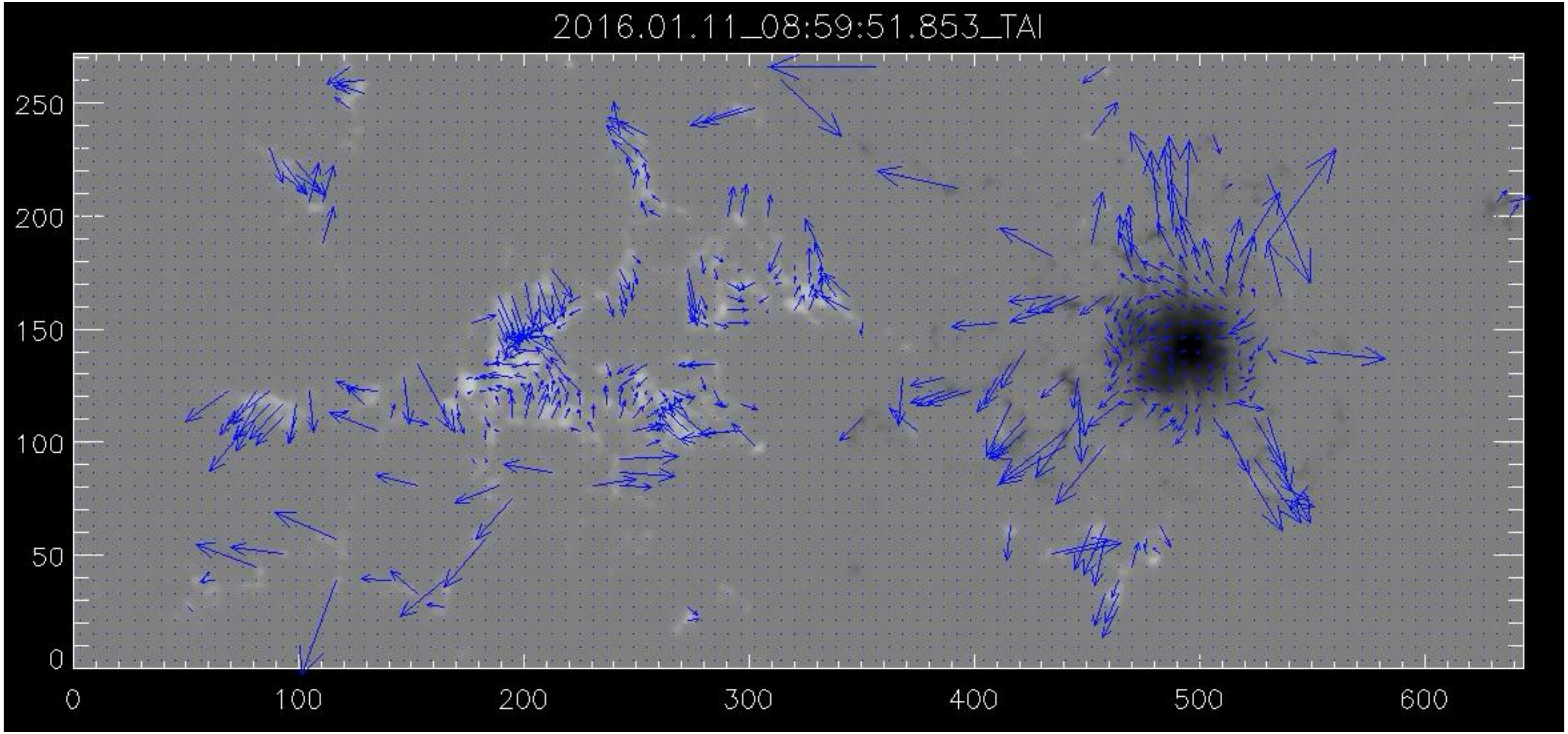


SP: 2016Jan12
px
Distance from center
Radially Averaged Speeds
Bz (G)
Horizontal Speed (km/s)
Distance from center
avgV
avgB

Noise level = 150G

data length = 24 hours

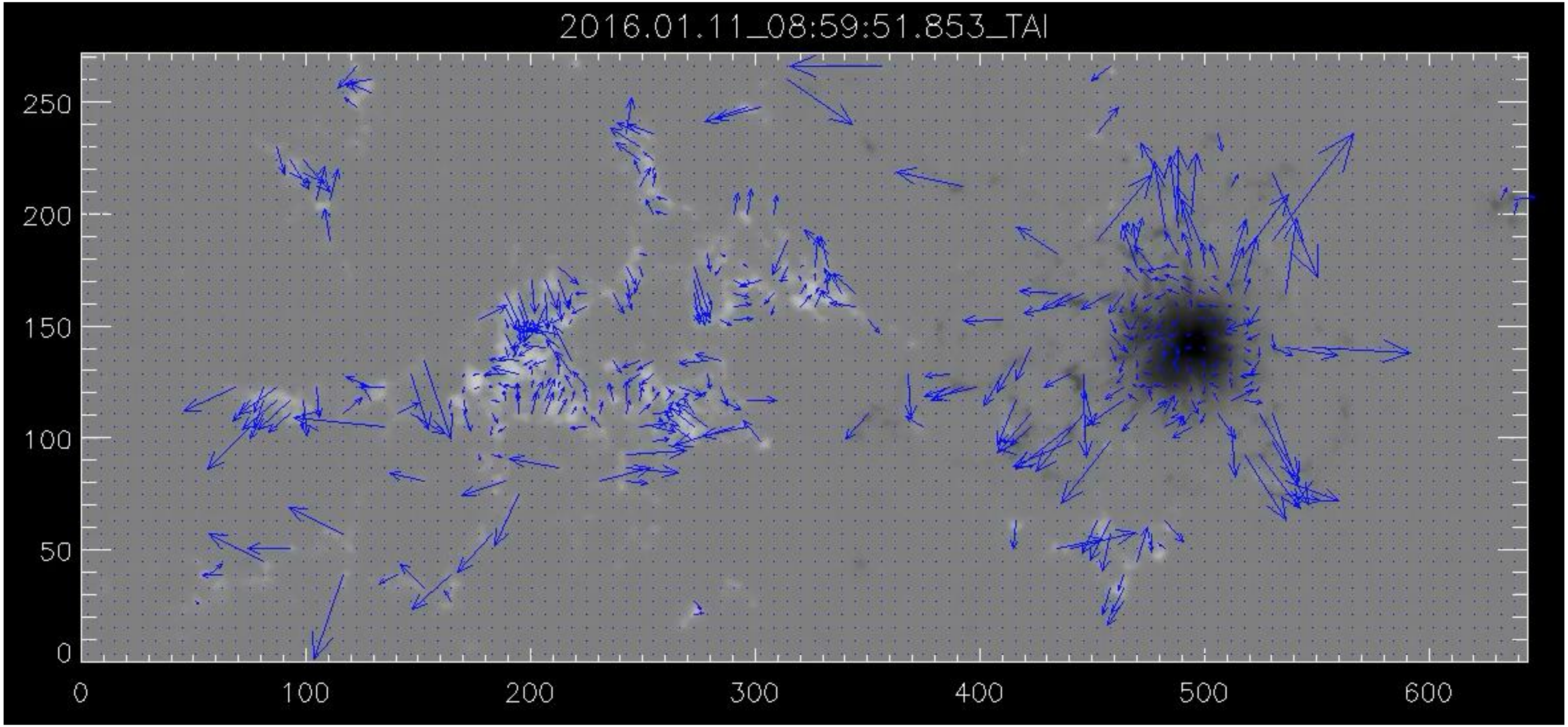
Sig = 12



Noise level = 150G

data length = 24 hours

Sig = 9

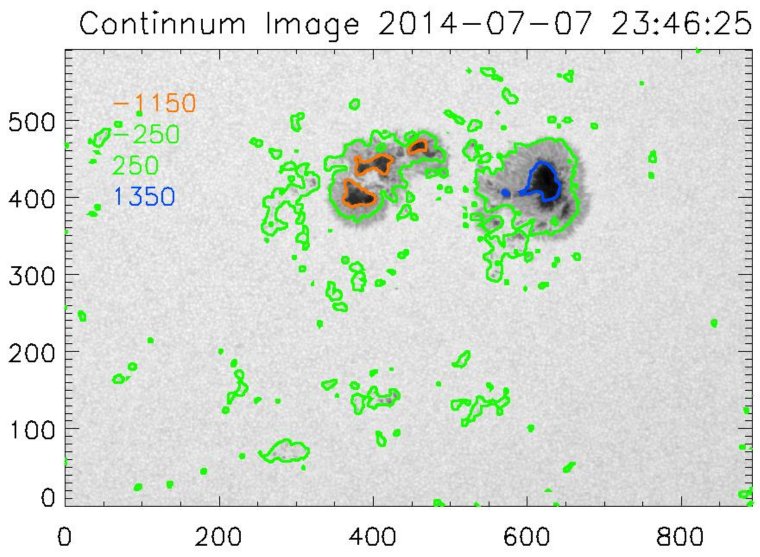


# 98 Loops

| Bt avg (G) | B LoopAvg | Bz[0] | Bz[n] | Bz_stronger | Bz_weaker | Bz_avg | EM Weighted T | Vh_strong * 10^5 (cm/s) | vh_weak * 10^5 (cm/s) | Loop Length (cm) | Loop Height (cm) | vh_avg (cm/s) | Bt_Strong | Bt_Weak | Bt_Avg | Vh @ BtStrong | Vh @ BtWeak | VhAvg @ BtAvg | Avg Vh @ Bt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 509.271 | 373.37 | 255.472 | -262.243 | 262.243 | 255.472 | 258.8575 | 6375436.141 | 9631.118086 | 9676.753403 | 11331700000 | 3669480 | 9653.935744 | 976.415 | 716.958 | 846.6865 | 4823.27201 | 6370.34141 | 5541.504368 | 5596.80671 |
| 504.609 | 305.957 | 119.651 | -734.052 | 734.052 | 119.651 | 426.8515 | 6376349.301 | 6255.732733 | 10516.58103 | 13608300000 | 7170740 | 8386.156884 | 1299.07 | 689.494 | 994.282 | 3611.930463 | 6557.436227 | 4734.184207 | 5084.68335 |
| 572.023 | 309.687 | 1586.57 | -1305.68 | 1586.57 | 1305.68 | 1446.125 | 6869246.482 | 3194.573279 | 3595.899334 | 17144900000 | 17616800 | 3395.236306 | 1870.71 | 1637.16 | 1753.935 | 3132.266937 | 3169.320483 | 3142.522609 | 3150.79371 |
| 540.156 | 380.796 | 691.155 | -1633.84 | 1633.84 | 691.155 | 1162.4975 | 6176698.459 | 3170.665096 | 6546.022176 | 10810500000 | 10297000 | 4858.343636 | 1714.72 | 948.816 | 1331.768 | 3147.905063 | 4965.721661 | 3535.907903 | 4056.81336 |
| 319.679 | 120.085 | 511.861 | -601.05 | 601.05 | 511.861 | 556.4555 | 5187084.226 | 7180.892117 | 7831.679657 | 27250400000 | 28658400 | 7506.285887 | 1197.23 | 916.933 | 1057.0815 | 3902.691554 | 5137.427142 | 4441.079854 | 4520.05935 |
| 62.7914 | 34.3016 | 412.761 | -652.379 | 652.379 | 412.761 | 532.57 | 5792682.163 | 6815.536522 | 8562.012303 | 20690800000 | 16933100 | 7688.774413 | 657.272 | 535.241 | 596.2565 | 6781.191229 | 7659.755986 | 7215.431603 | 7220.47361 |
| 619.874 | 314.59 | 1480.79 | -1151.98 | 1480.79 | 1151.98 | 1316.385 | 5989715.573 | 3287.277759 | 4058.878537 | 19932600000 | 16531200 | 3673.078148 | 2154.18 | 1500.95 | 1827.565 | 2917.204299 | 3264.848327 | 3136.493932 | 3091.02631 |

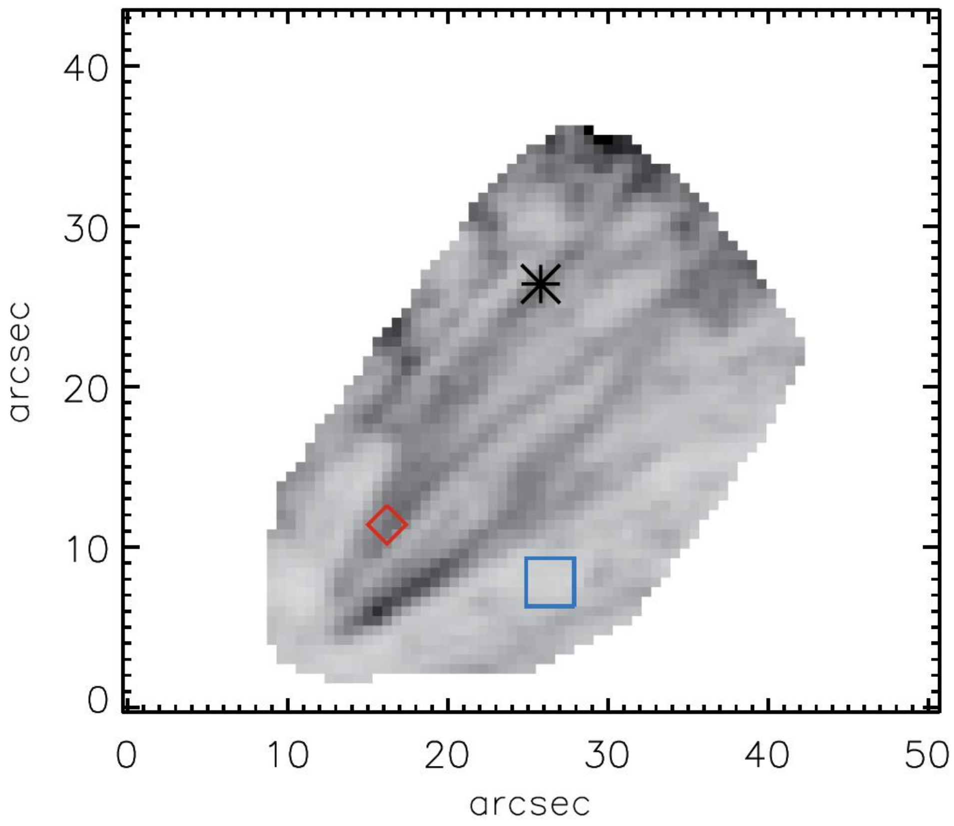
## Loop Types

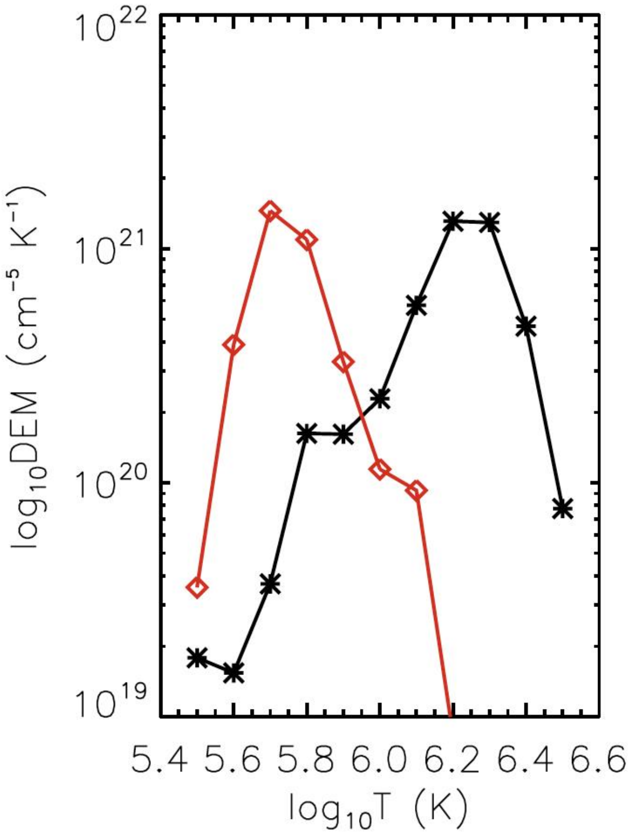
- Umbra-Umbra
- Umbra-Penumbra
- Umbra-Plage
- Penumbra-Plage
- Penumbra-Penumbra
- Plage-Plage



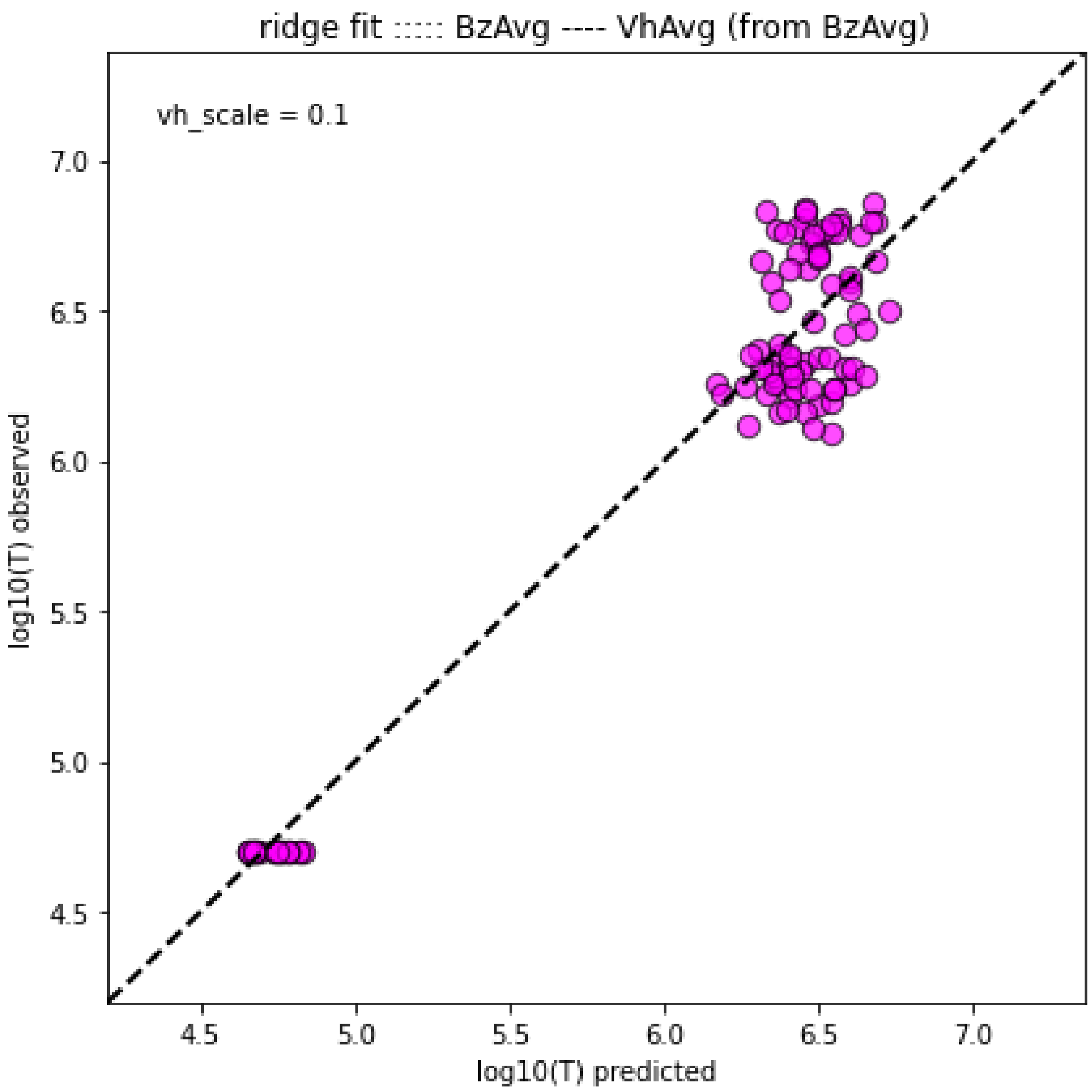

# Temperature of Umbral Loop (Light Bridge)

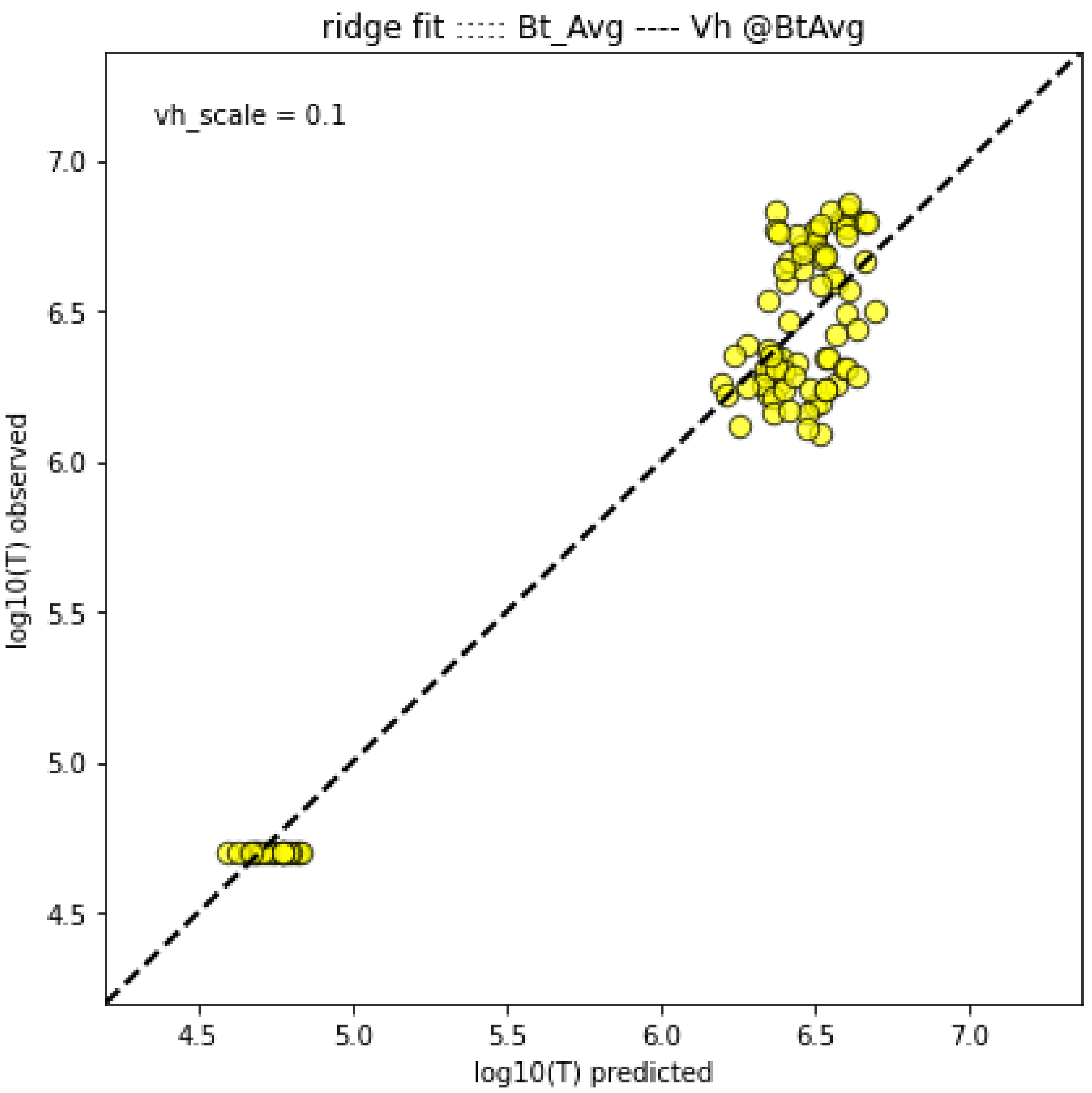
Chitta et al. 2016, A&A 587, A20




- AR 12108 (2014Jul09)
- Umbral loop ending in Light Bridge
- Red – closer to loop footpoint
- Black – away from footpoint
- Blue – background
- 0.5 MK

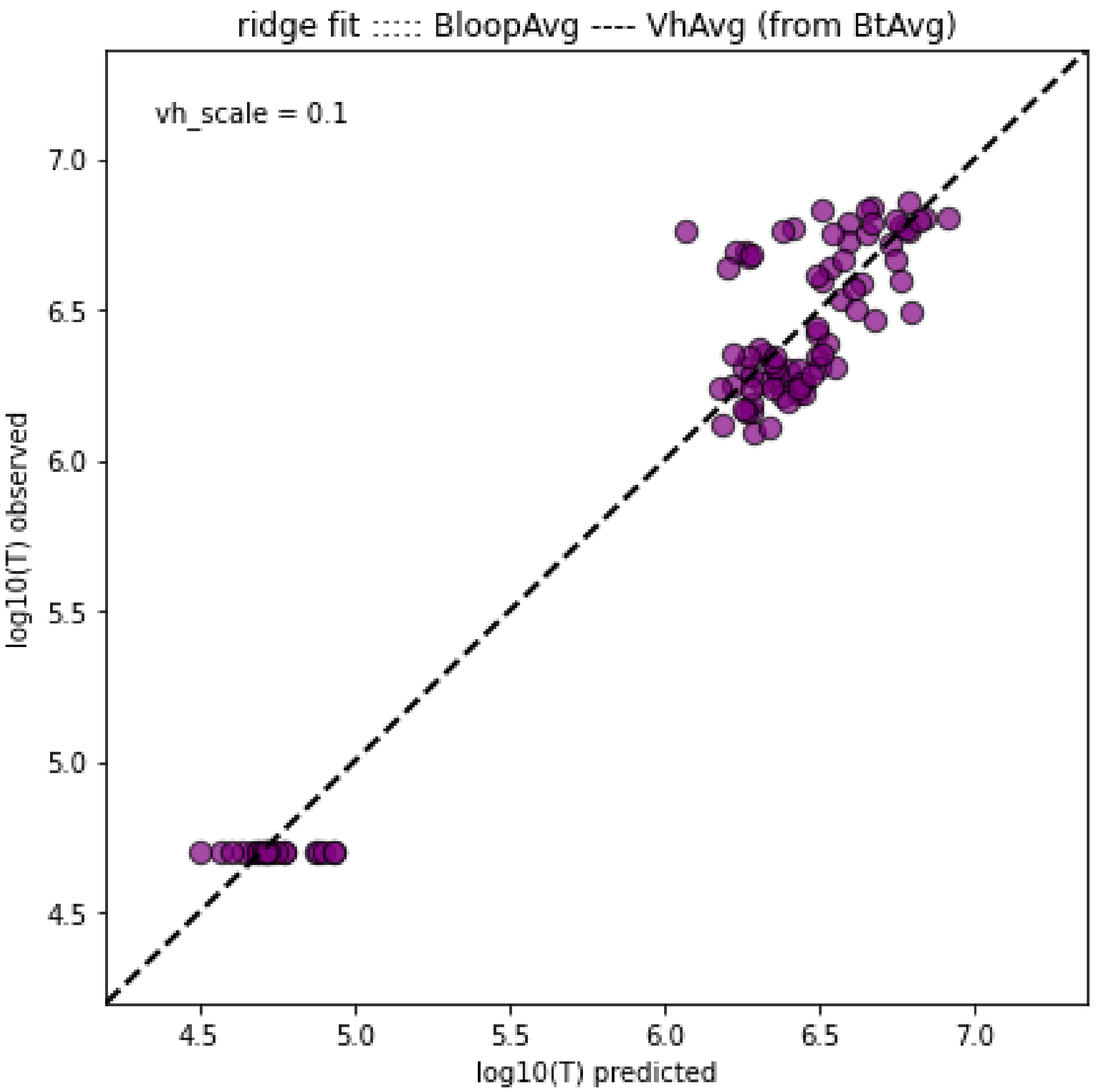



$$T \propto \frac{B^{1.1} {v_h}^{1.6}}{L^{0.4}}$$

Preliminary Results

$$T \propto \frac{B^{1.5} {v_h}^{1.8}}{L^{0.4}}$$




Preliminary Results

$$T \propto B^{1.3} {v_h}^{1.7} L^{0.6}$$

Thank You