In search of new observational tests for small-scale field-aligned coronal structures

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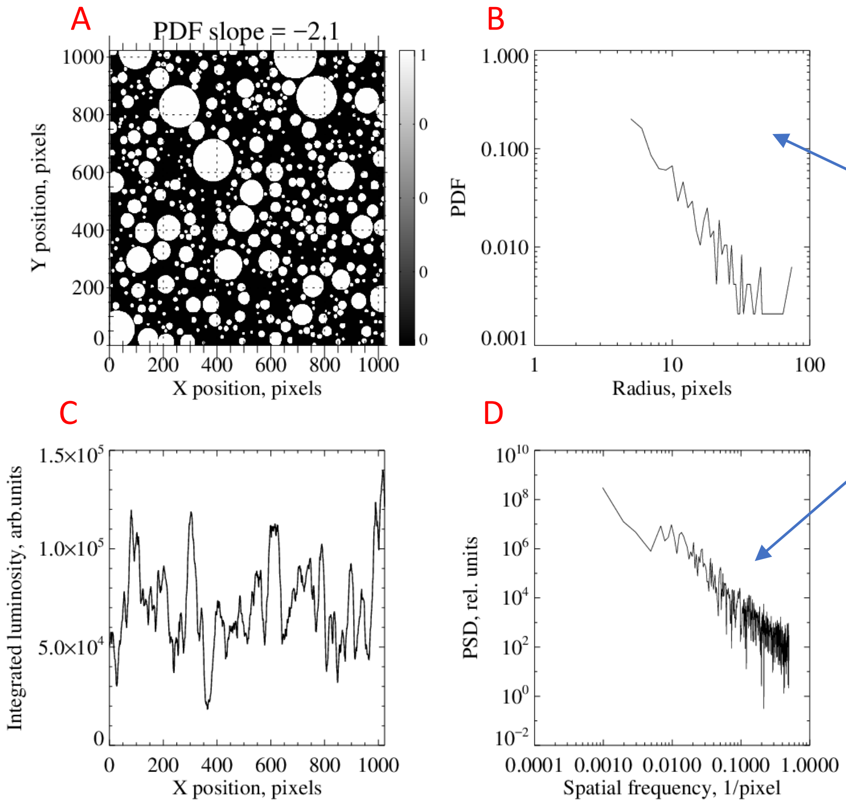
<u>**Main idea** (summer 2020): loop sizes from "diffuse corona"</u>

Allow numerous loops to overlap -> measure transverse spatial power spectra -> apply statistical model to deconvolve spectra -> recover underlying loop size distribution.

Main problem: image noise at most relevant scales

Possible solution: smart preprocessing + edge enhancement + regularized numerical inversion.

Modeling emission signal from unresolved overlapping loops



How are they related?

(Based on: Jensen at al., *Phys Rev B* 1989; Kertesz & Kiss, *J Phys A* 1990; Manna et al., *J Stat Phys* 1990)

Net emission impact from an individual strand of size D_s:

$$s = \int_{x}^{x+D_s} I_s(x_\perp)dx_\perp \tag{1}$$

Fourier transform of $I_s(x_\perp)$:

$$\tilde{I}_s(k_\perp) = \int \exp(ik_\perp x_\perp) I_s(x_\perp)dx_\perp \tag{2}$$

Mean energy density spectrum of strands of characteristic transverse linear size (diameter) D_s:

$$\langle E_s(k_\perp)\rangle = \left\langle |\tilde{I}_s(k_\perp)|^2 \right\rangle \tag{3}$$

Lorentzian energy density spectrum
(asymptotic solution for small $k_\perp$, normalization condition $\tilde{I}_s(k_\perp = 0) = s$):

$$\langle E_s(k_\perp)\rangle = \frac{s^2}{1 + k_\perp^2 D_s^2} \tag{4}$$

(W. Schottky, Phys. Rev. 28 (1926) 74)

Total power density spectrum is the weighted sum of individual contributions:

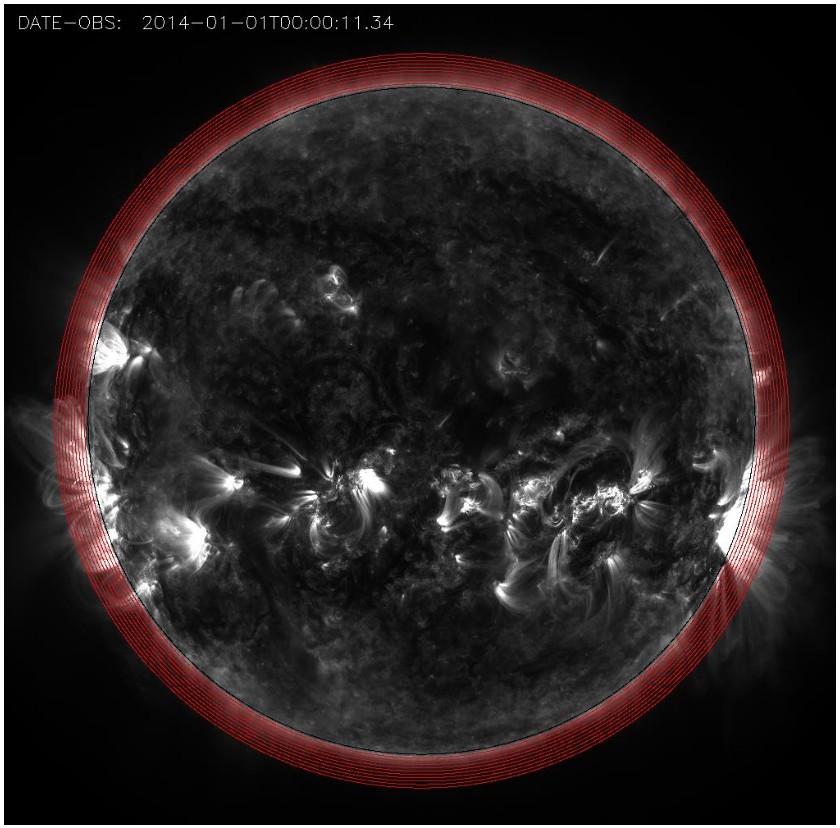
$$\langle S(k_\perp)\rangle \sim \int p(s)\frac{s^2 ds}{1 + k_\perp^2 D_s^2} \tag{5}$$

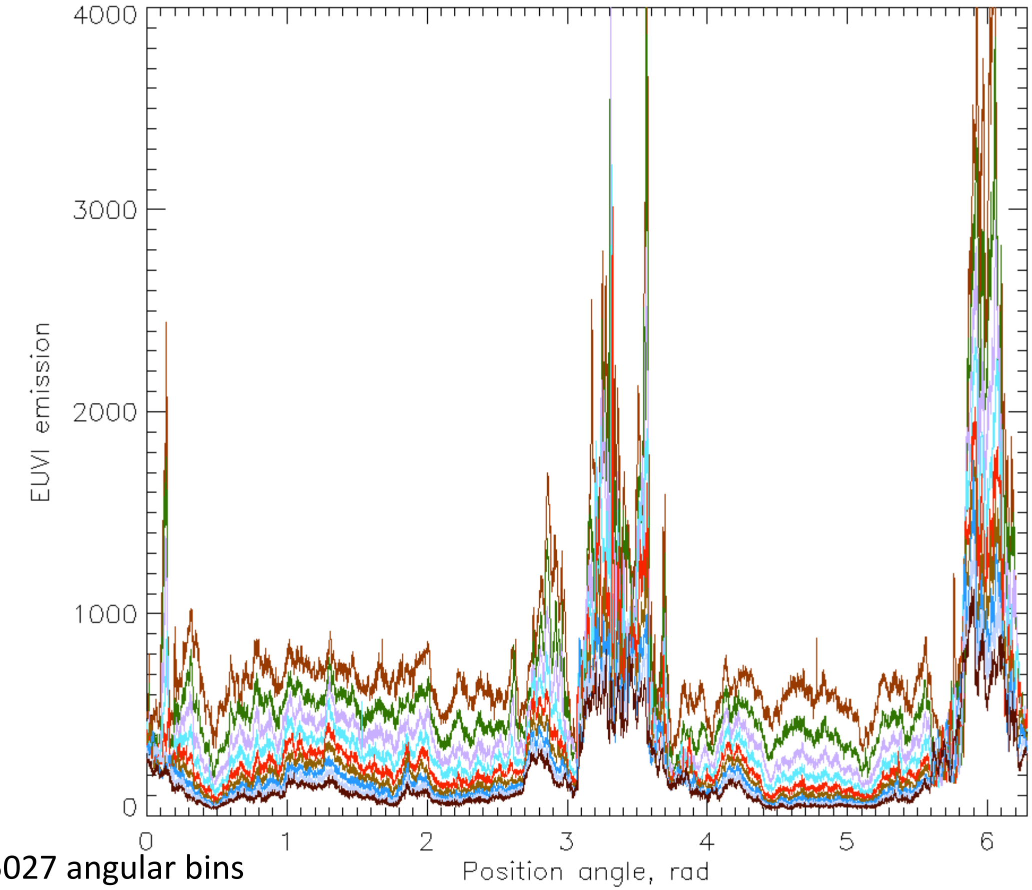
in which $p(s)$ is the density distribution of strands of net emission impact s.

$$\langle S(k_\perp)\rangle \sim \int_{S1}^{S2} p(s) \frac{s^2 ds}{1 + k_\perp^2 D_s^2}$$

	type	kind
$\int_a^x K(x,y)\varphi(y)\,dy = f(x)$	Volterra	1
$\varphi(x) - \int_a^x K(x,y)\varphi(y)\,dy = f(x)$	Volterra	2
$\int_a^b K(x,y)\varphi(y)\,dy = f(x)$	Fredholm	1
$\varphi(x) - \int_a^b K(x,y)\varphi(y)\,dy = f(x)$	Fredholm	2

Solar maximum example: 2014/01/01

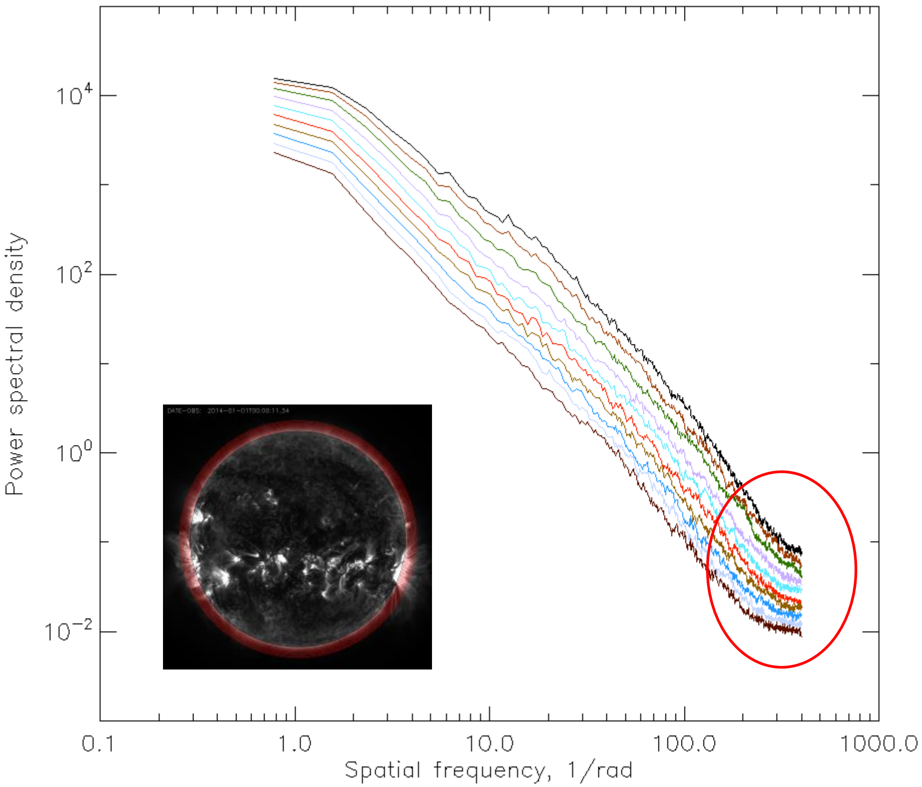




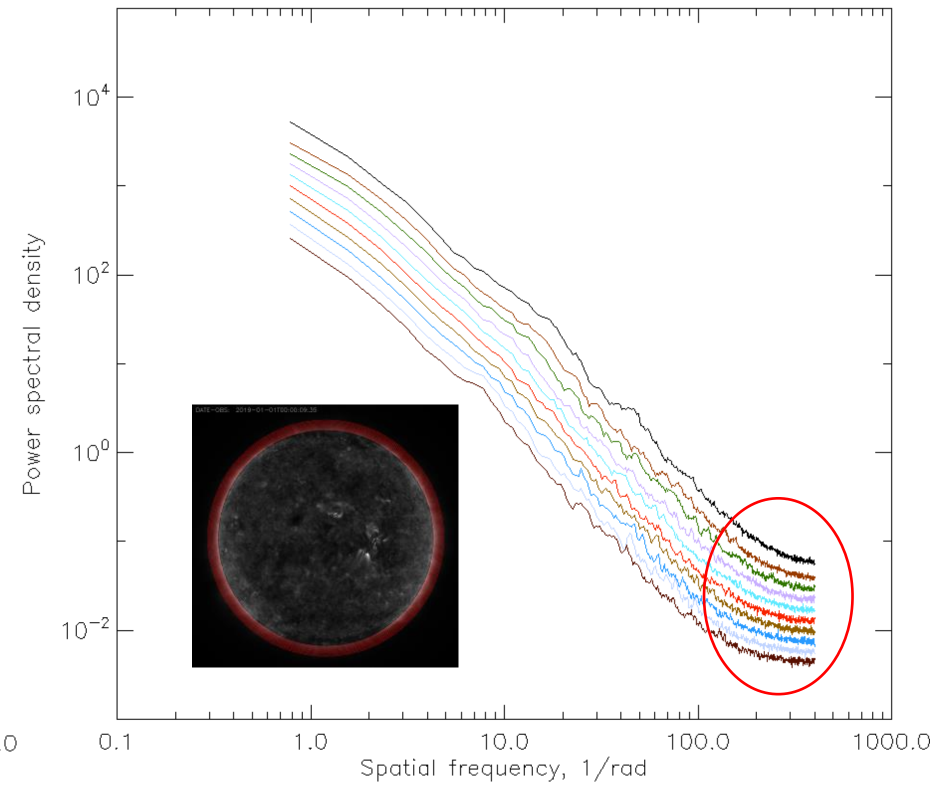
R_{min} = 1.01 R_S, R_{max} = 1.11 R_S, 100 azimuthal profiles, 5027 angular bins

Yearly-averaged azimuthal profiles around solar limb (SDO AIA 171A)

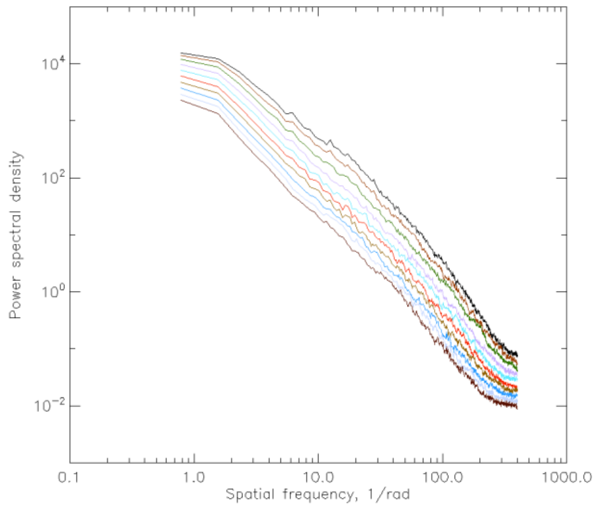
2014, averaged over 1024-point profiles



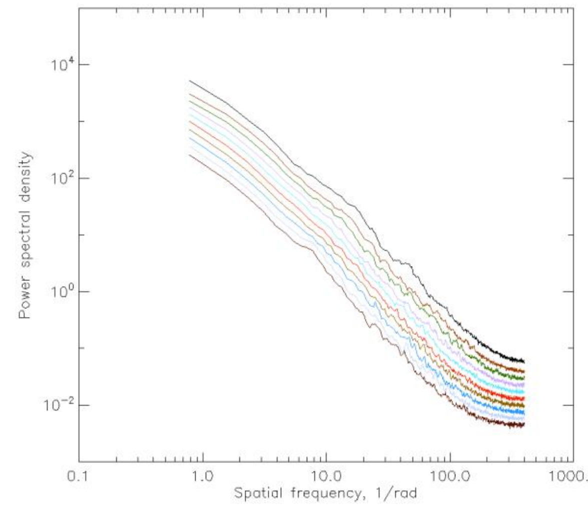
2019, averaged over 1024-point profiles



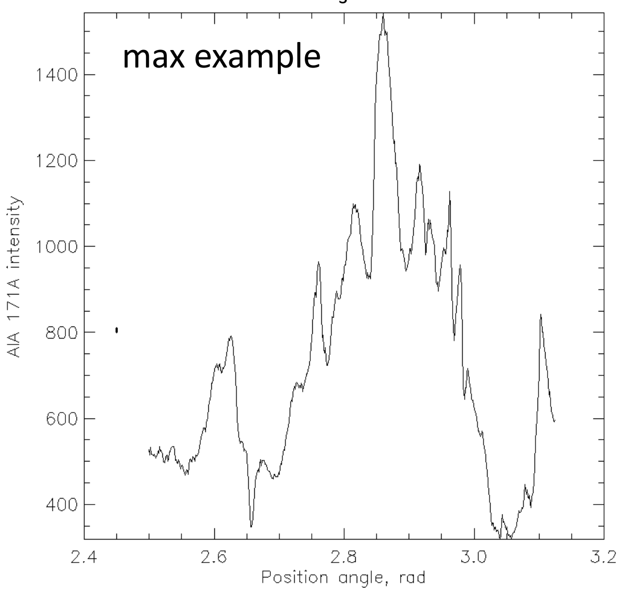
2014



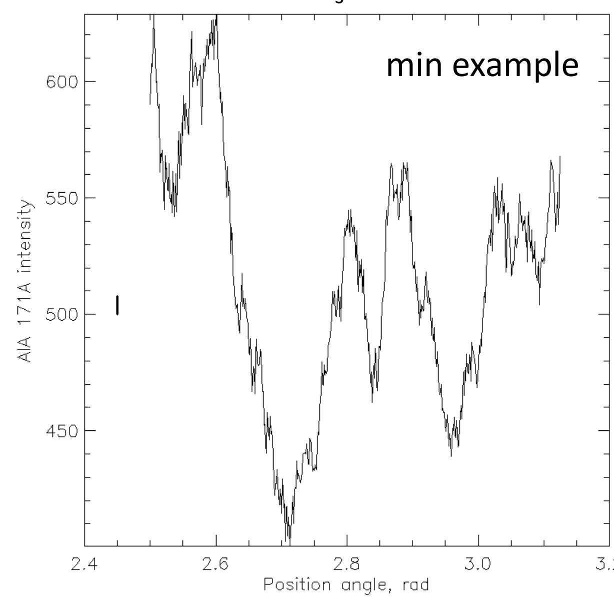
2019



R = 1.02 – 1.03 R_s



R = 1.02 – 1.03 R_s



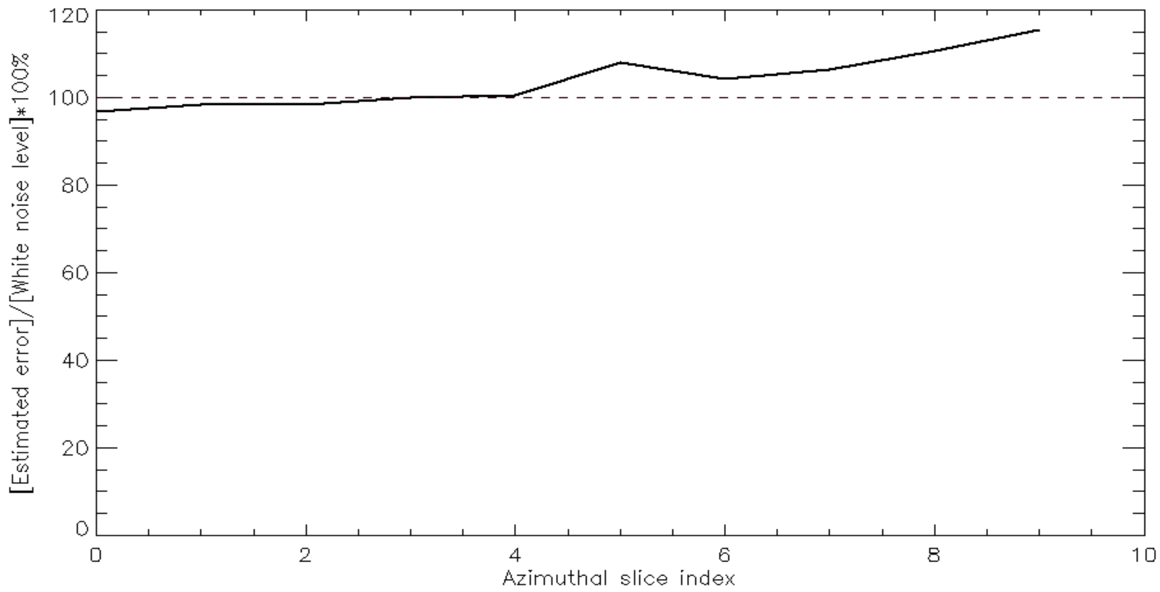
Q = **AIA_BP_ESTIMATE_ERROR**(mean(res_2014.cut_arr[0,1].intensity[2000:2500]), 171, /loud)

Counts [DN]	Compress	RMS Error	Chianti	Calibrat	SNR	Shot	Dark	Read	Quant
724.87		28.61	25.33		28.52	0.18	1.15	0.29	1.98
	0.00	0.00							

q = **AIA_BP_ESTIMATE_ERROR**(mean(res_2019.cut_arr[0,1].intensity[2000:2500]), 171, /loud)

Counts [DN]	RMS Error	SNR	Shot	Dark	Read	Quant	Compress	Chianti	Calibrat
514.13	24.11	21.33	24.02	0.18	1.15	0.29	1.67	0.00	0.00

2014



Instrumental noise prevents (1) accurate PSD measurements and (2) stable numerical inversion at relevant scales. Efficient "SNR boost" and image enhancement steps <u>preserving loop scales</u> are required.

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Plumelets: Dynamic Filamentary Structures in Solar Coronal Plumes

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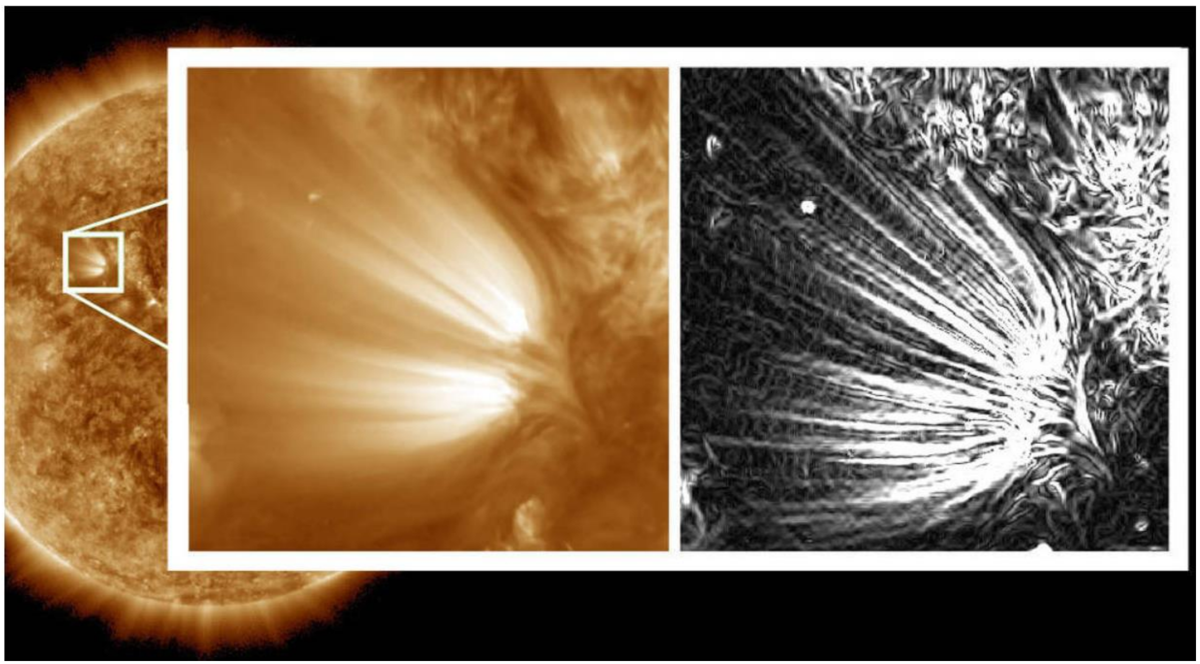


Cause of switchbacks?

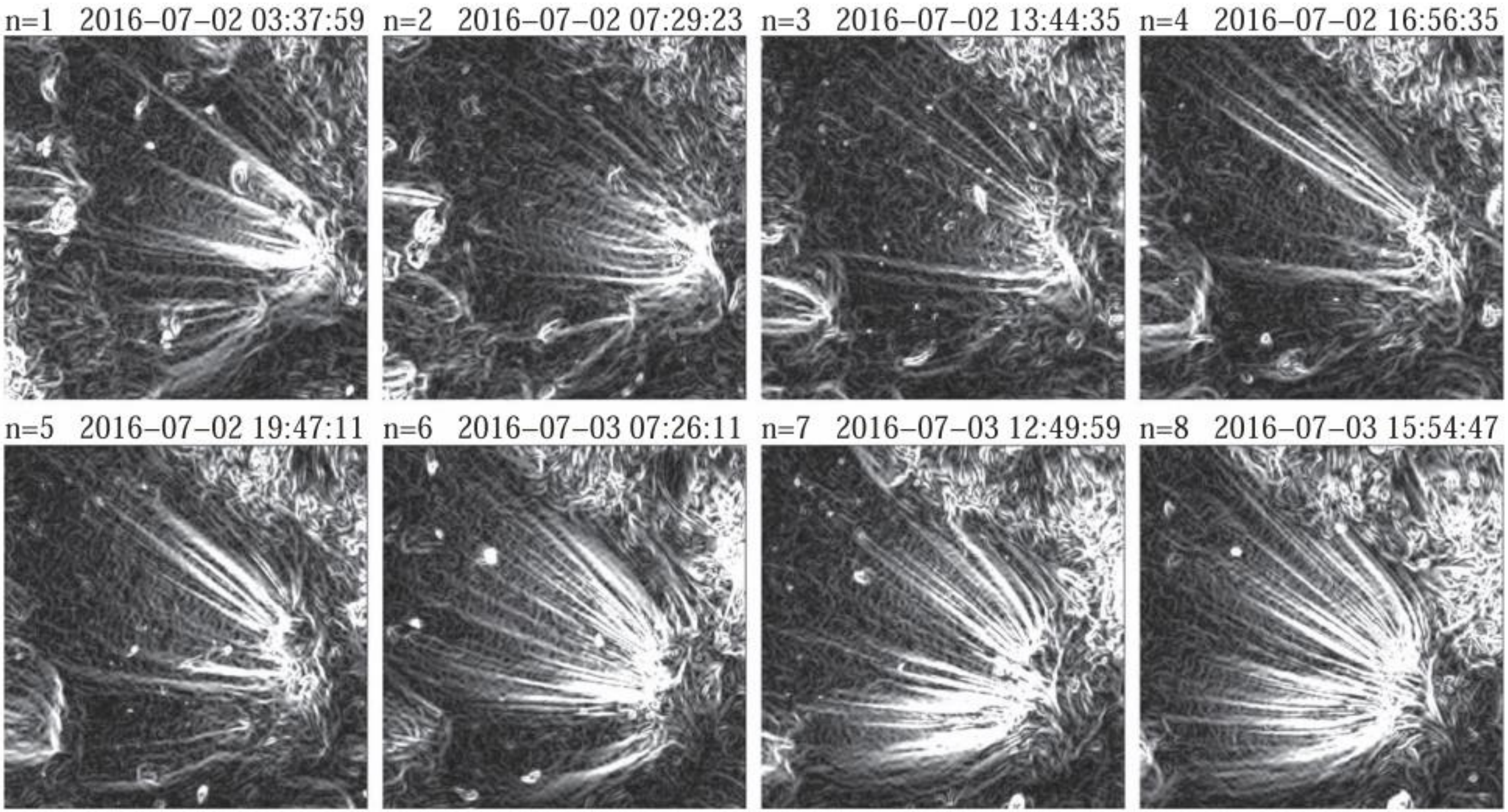
C. DeForest's magic +

Roberts cross edge-detection operator (Roberts 1963):

$$R_{m,n} = |L_{m,n} - L_{m+1,n+1}| + |L_{m,n+1} - L_{m+1,n}|, \quad (1)$$

where m and n are the discrete coordinates of image pixels and R is the Roberts transform of the original image L. The first and the second terms on the right-hand side are obtained from the image convolution using the masks

$$\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}, \quad \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}. \quad (2)$$



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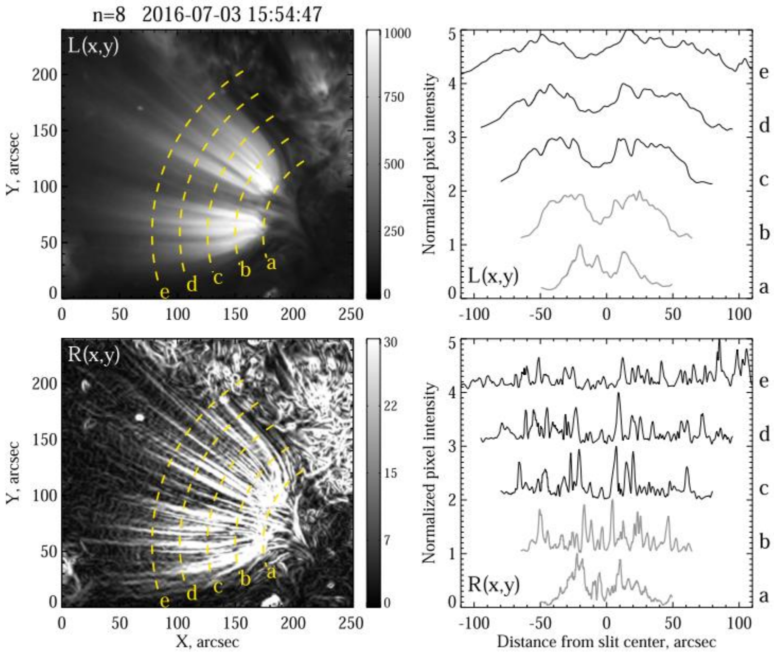

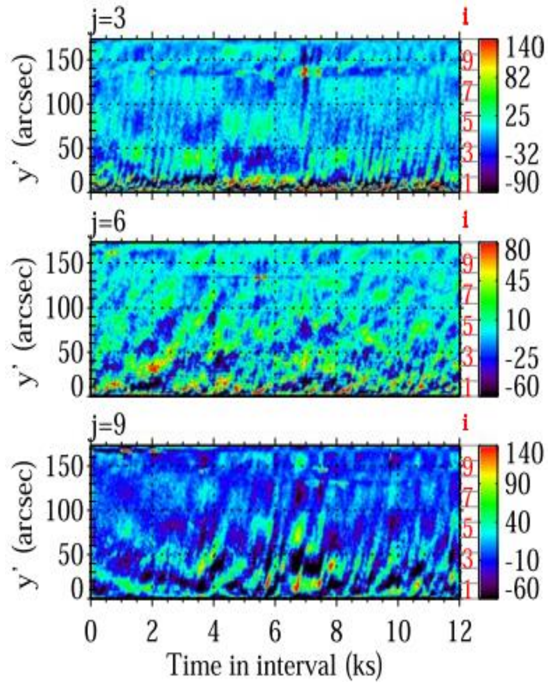

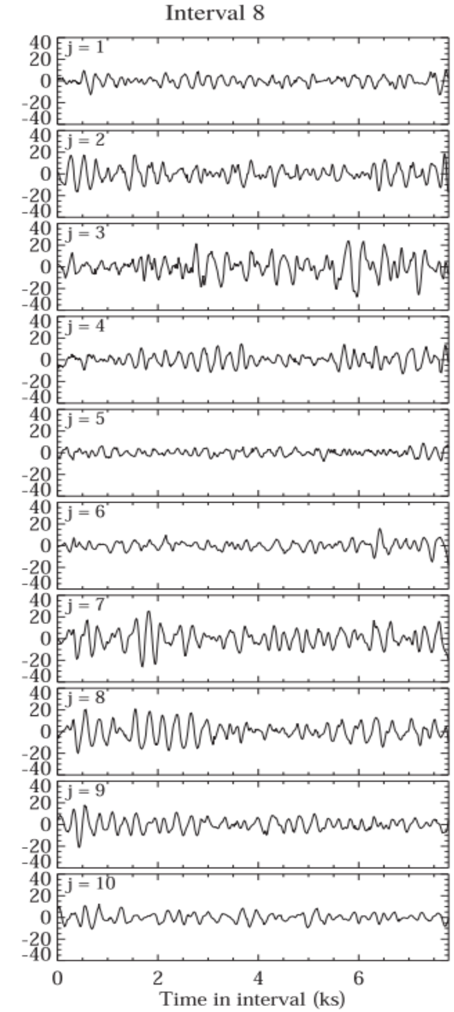

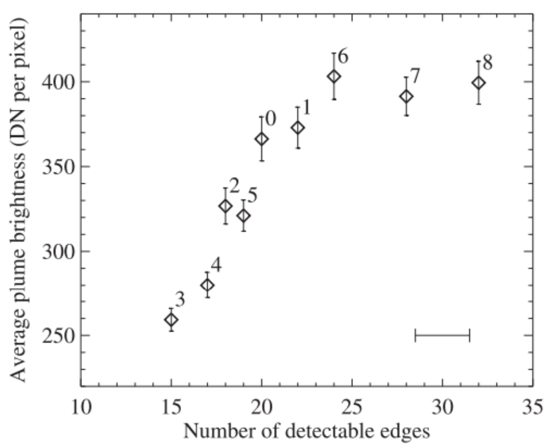

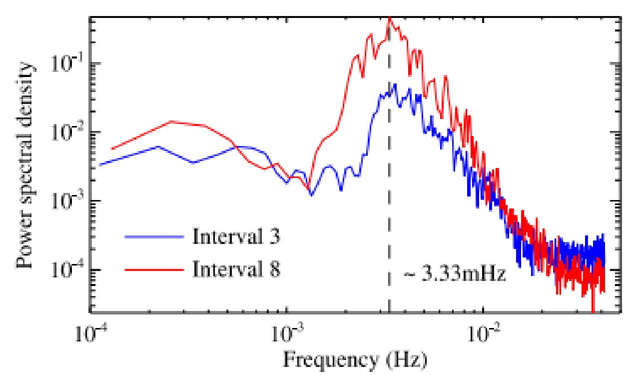

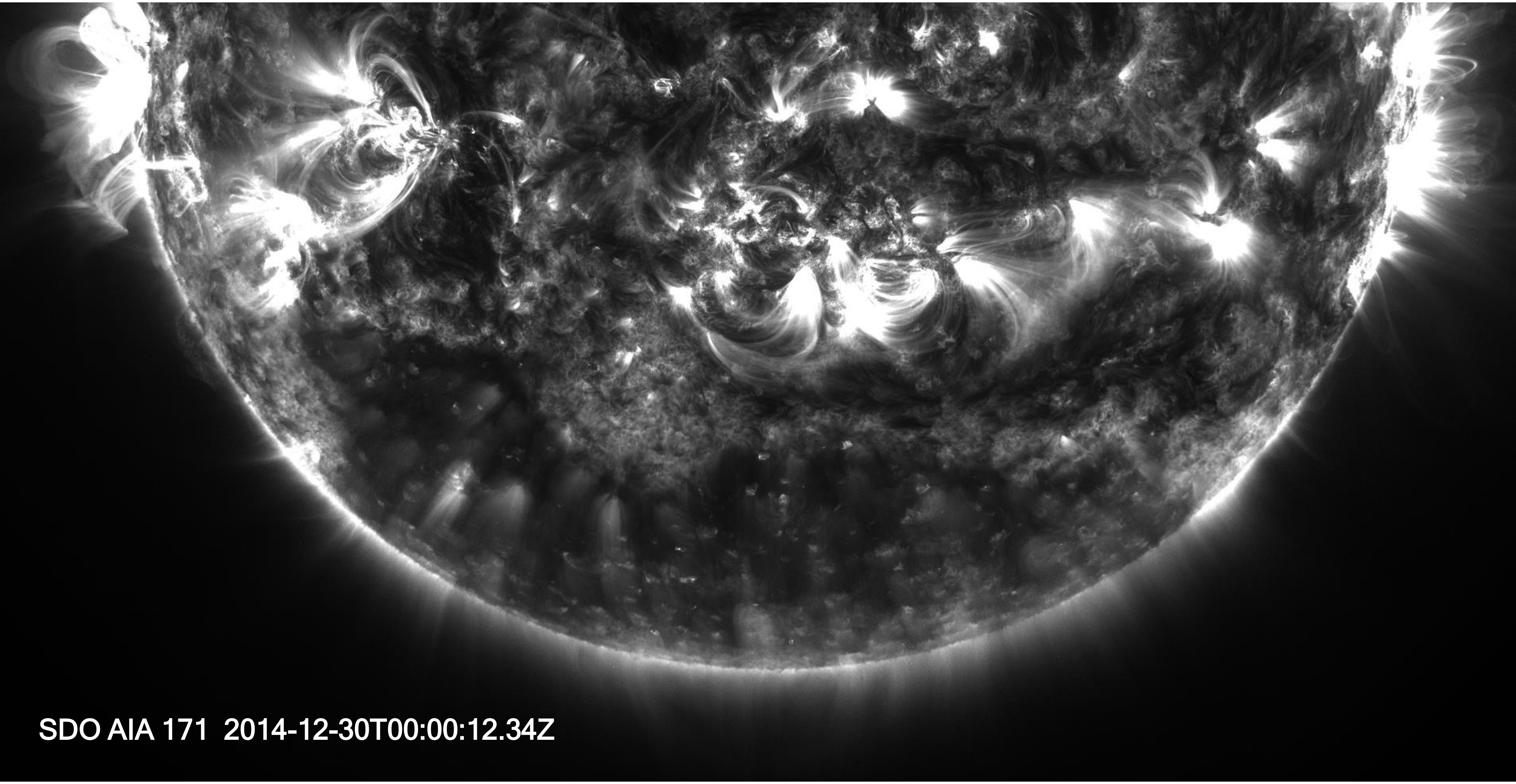
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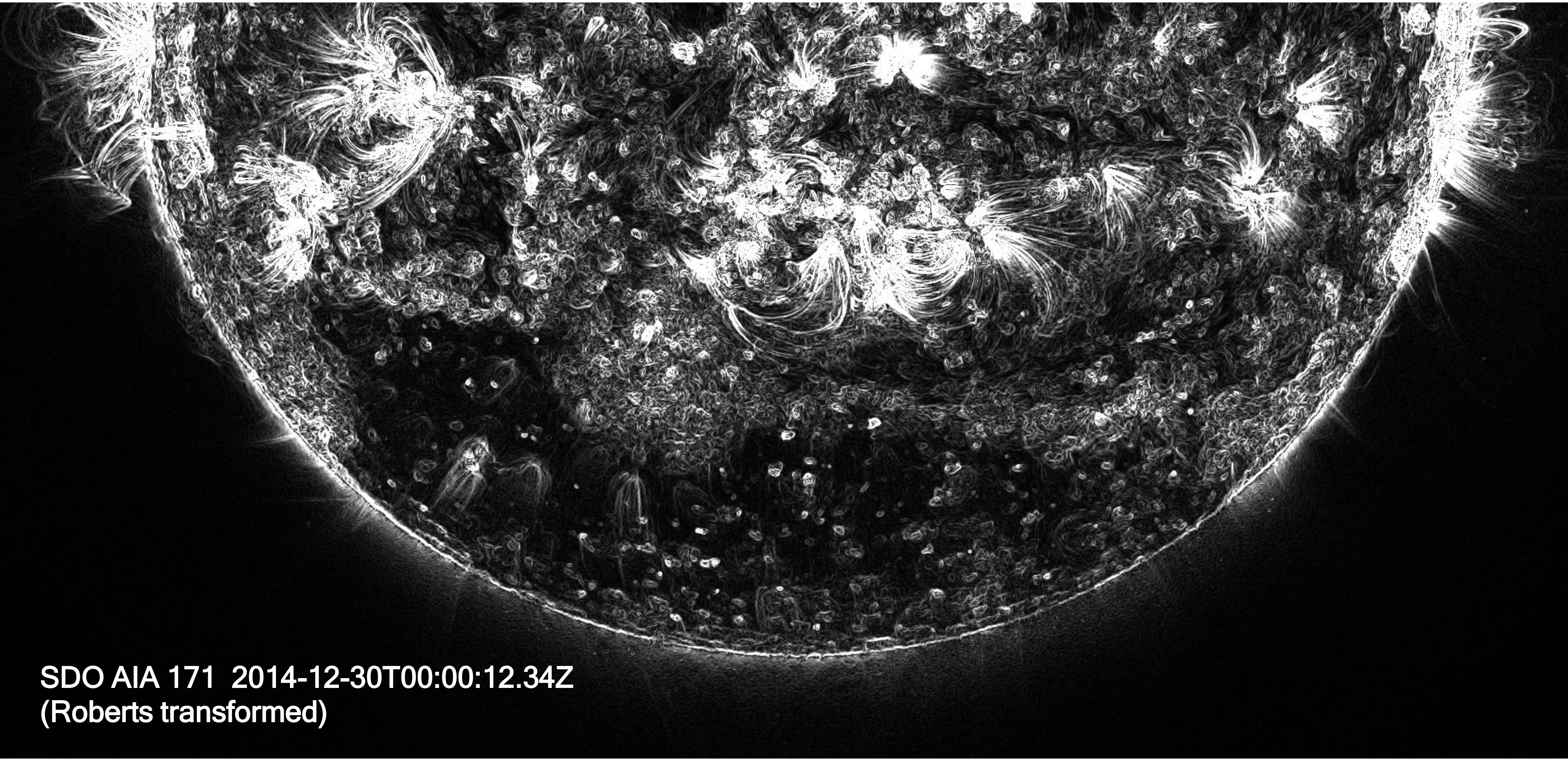
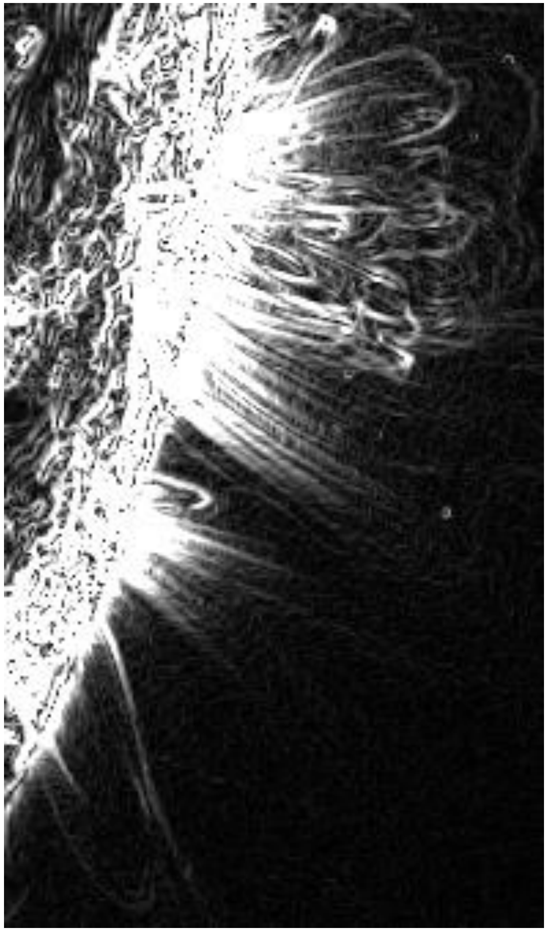

SDO AIA 171 2014-12-30T00:00:12.34Z
(Roberts transformed)

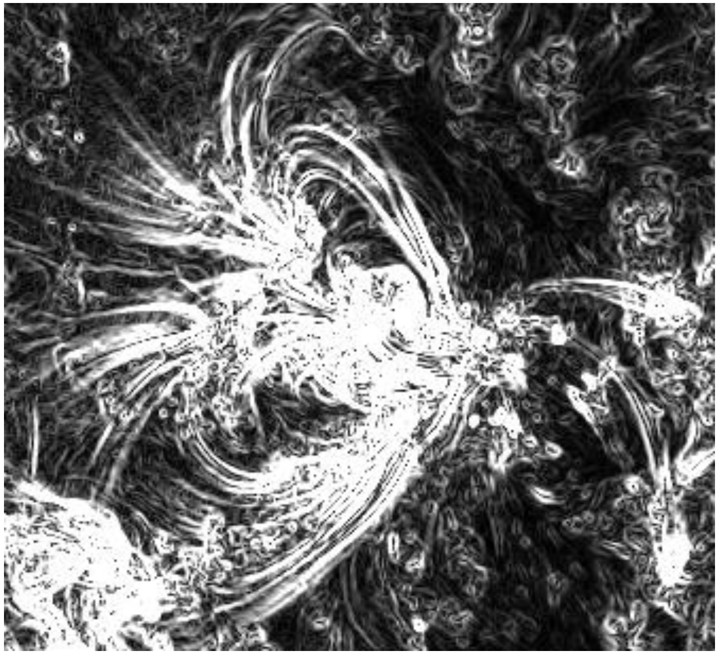
Roberts transform applied to EUV images:
an uncalibrated proxy for the magnitude of the image-plane gradient of the squared column plasma density.

$$R_{m,n} = |L_{m,n} - L_{m+1,n+1}| + |L_{m,n+1} - L_{m+1,n}|, \quad (1)$$

$$\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}, \quad \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad (2)$$

$$R(x, y) \propto \left| \nabla \int n_e^2 \, dl \right|. \quad (3)$$





Some questions:

1. How is the **filamented structure** of edge-enhanced coronal EUV images related to **coronal loops sizes**?

2. What are the **characteristic spatial scales** of the individual filaments and of their spatial arrangement?

3. How does the **amount of the filaments** within a given loop system correlate with its **brightenss** and **heating/cooling dynamics**?

4. Are **field-aligned motions** of adjacent filaments dynamically coupled or independent of each other? Are these motions related to **oscillations in the photosphere**?

5. *Question to modelists*: do the observed filament edges trace **current sheets between flux tubes**, or something else? What defines their scale **kinetically**?