Coronal Heating from explosive events: A kinetic approach

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Building a new Active region

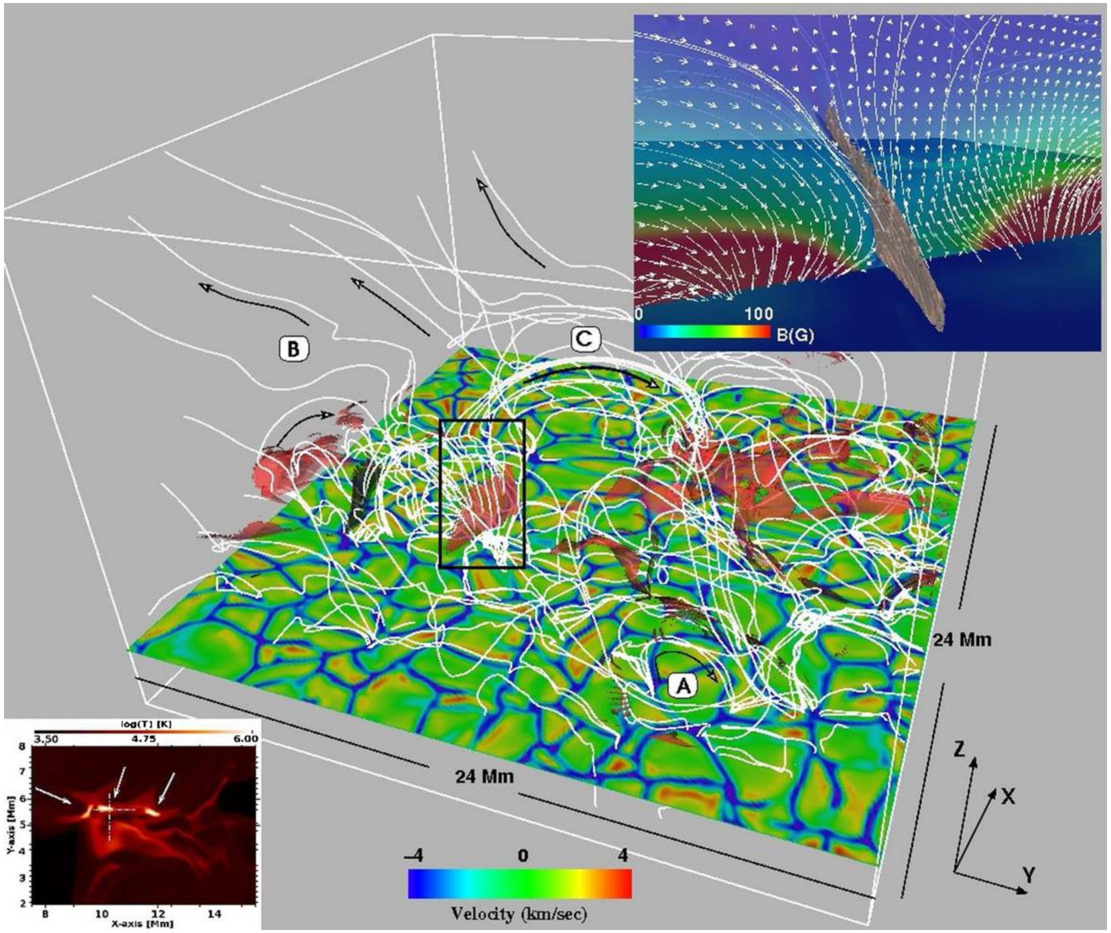
- The emergence of new flux tubes from the convection zone to the solar atmosphere is the simplest way for “building” an active region, using a 3D MHD.

- A fundamental research project can be the physics of flux emergence

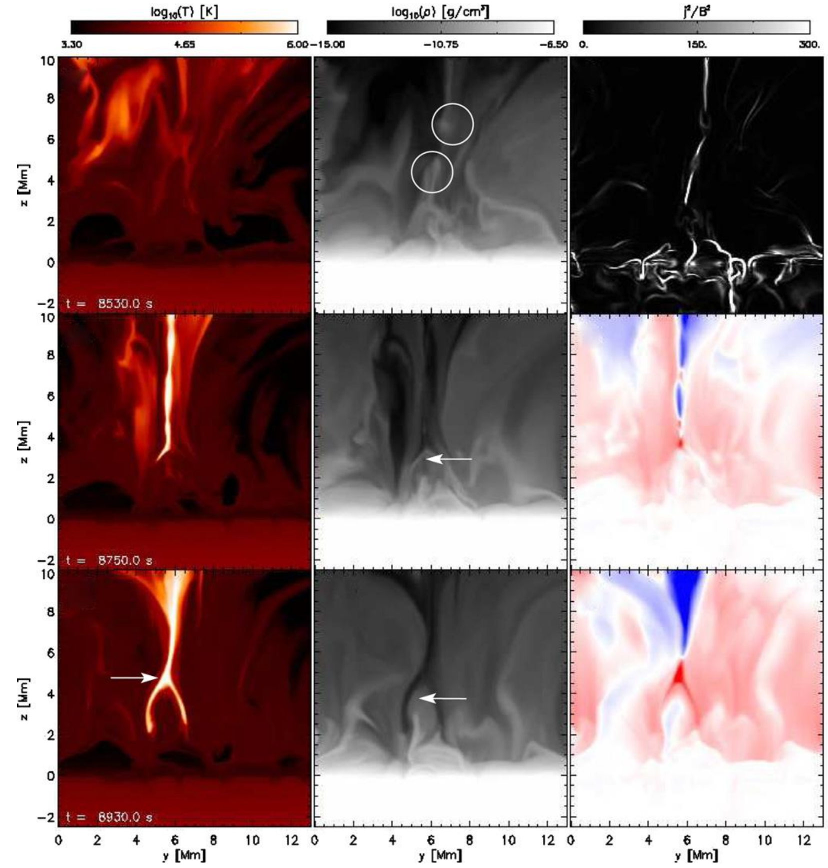
From a recent article of V. Archontis and V. Hansteen

- A three-dimensional (3D) magnetohydrodynamic (MHD) numerical experiment was performed, where a uniform magnetic flux sheet was injected into a fully developed convective layer. The gradual emergence of the field into the solar atmosphere results in a network of magnetic loops, which interact dynamically forming current layers at their interfaces.

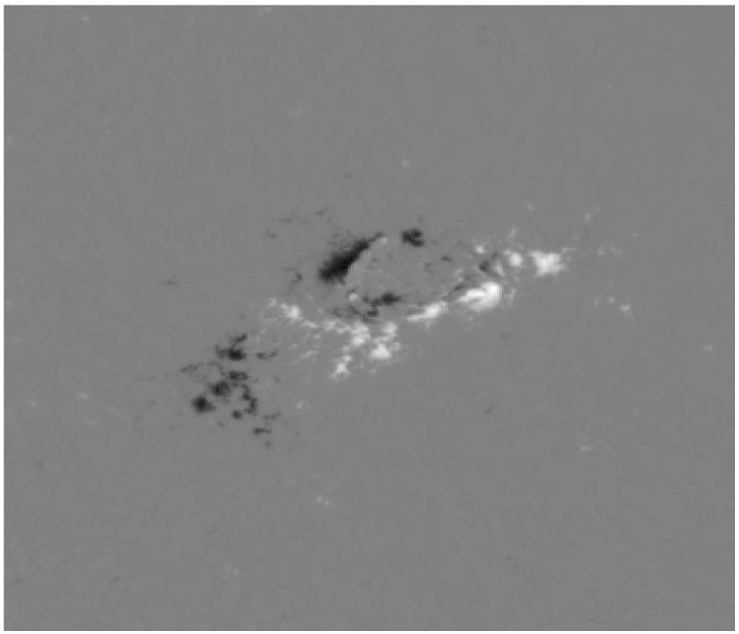
Emerging magnetic field

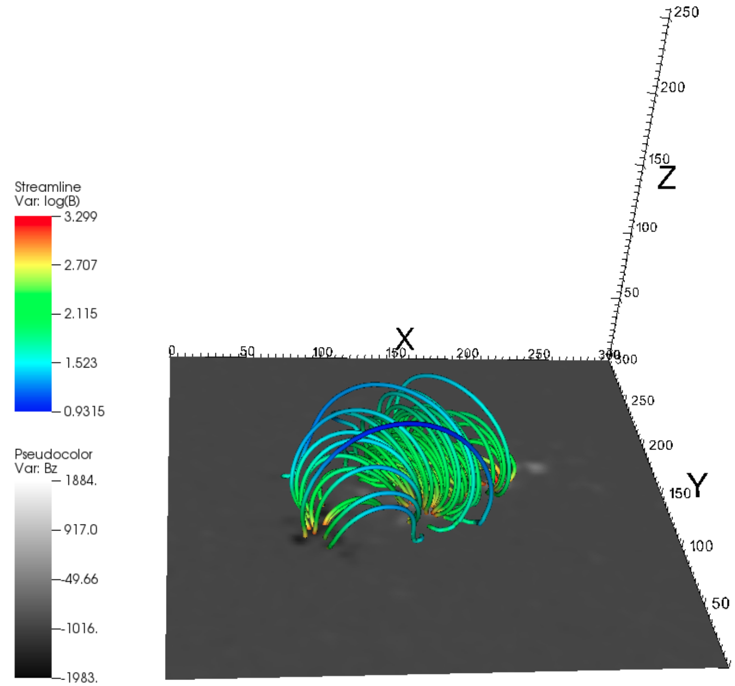


Explosive events



The real sun

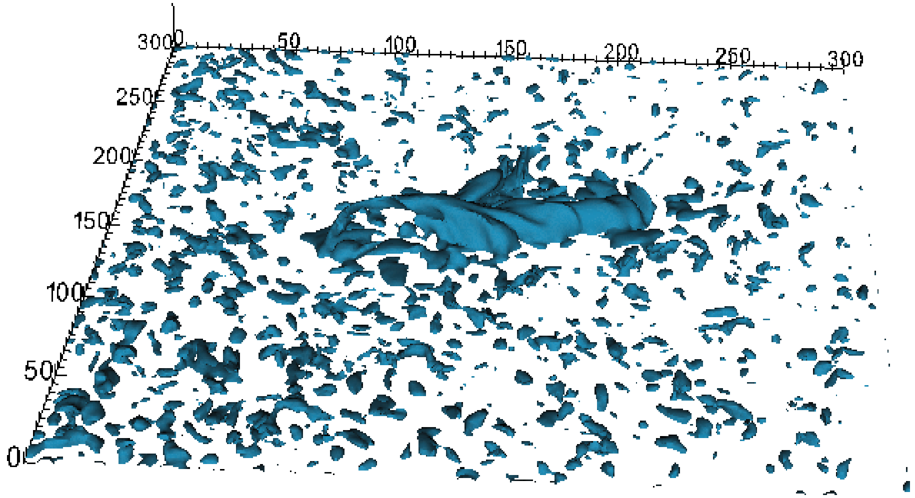




Original 300x300 SDO/HMI magnetogram
for Feb 13 2011, 04:00 UT snapshot

Corresponding 3D NLFF extrapolated field
(Wiegelmann 04 method)

J fragmentation

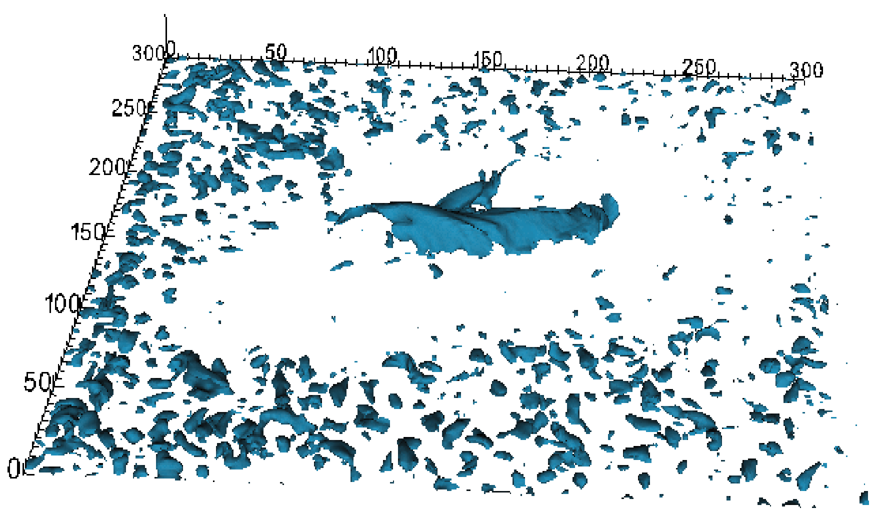


We calculate current

$$\mathbf{J} = \frac{c}{4\pi} \nabla \times \mathbf{B}$$

and then its magnitude (isosurface shown)

J fragmentation, r<0.3



We calculate potential field B_p, free energies *Er1*, *Er2*(that should be equal) and their fractional difference *r*

$$E_{f1} = \frac{1}{8\pi}\int dV\, \boldsymbol{B}^2 - \frac{1}{8\pi}\int dV\, \boldsymbol{B}_p^2$$

$$E_{f2} = \frac{1}{8\pi}\int dV\, (\boldsymbol{B} - \boldsymbol{B}_p)^2$$

$$r = \frac{|E_{f1} - E_{f2}|}{|E_{f1}| + |E_{f2}|}$$

And keep points with *r<0.3*,
i.e. of higher quality

Dataset
Fundamental Processing

initially
NLFFF extrapolations of NOAA AR 11158
(Sun et al. 2012)
resolution: 300x300x256
pixel size: 720 km (~1")

rebin to ½ and extrapolate
resolution: 150x150x128, pixel size: 1440 km

rebin to 2 and extrapolate
resolution: 500x400x255, pixel size: 360 km

finally
NLFFF extrapolations of NOAA AR 11158 @
3 resolutions: '150', '300', '600'
2 snapshots: 13 Feb 2011, 04:00 UT *or* 't1'
14 Feb 2011, 20:00 UT *or* 't2'

Data Analysis: Procedure I → Results for t1: Comparing quality of 3D fields

For each 3D magnetic field **B**:

I. Calculate current from Amp $\mathbf{J} = \frac{c}{4\pi}\nabla \times \mathbf{B}$

II. Take the magnitude of the current J

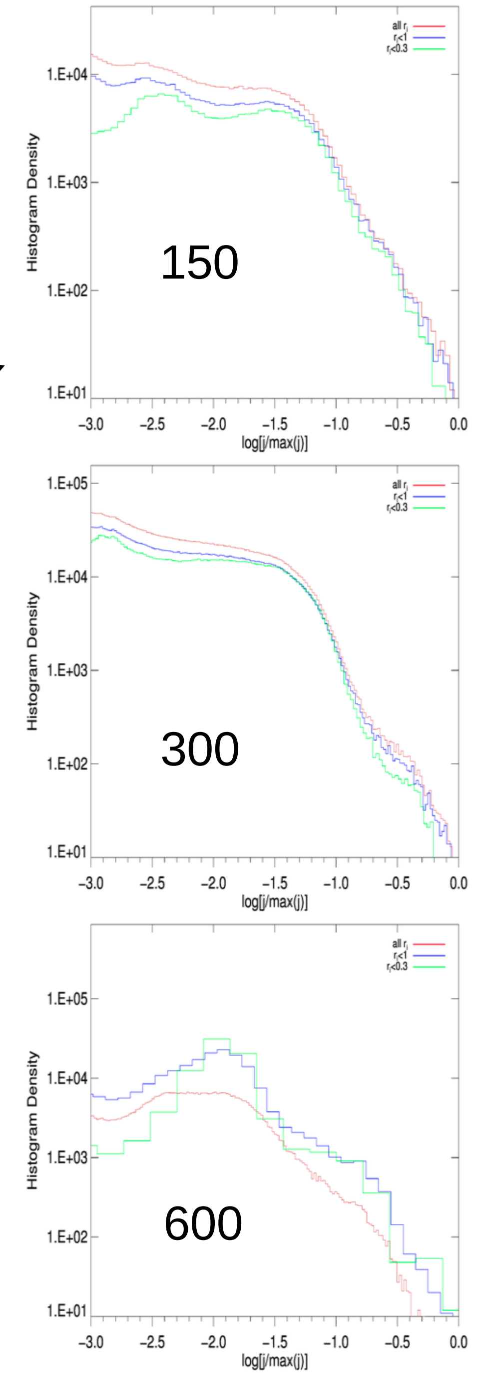
III. Calculate free energy fraction (3D field's quality indicator)

IV. Make the log-log histogram of J

I. Determine threshold above which power-law forms

II. Make power-law fit to the tail of the distribution

III. **Resolution comparison** (r_i < 0.3) each curve with its own J_{max}



Data Analysis: Procedure I → Results for t2: Comparing quality of 3D fields

For each 3D magnetic field **B**:

I. Calculate current from Amp $\mathbf{J} = \frac{c}{4\pi}\nabla \times \mathbf{B}$

II. Take the magnitude of the current J

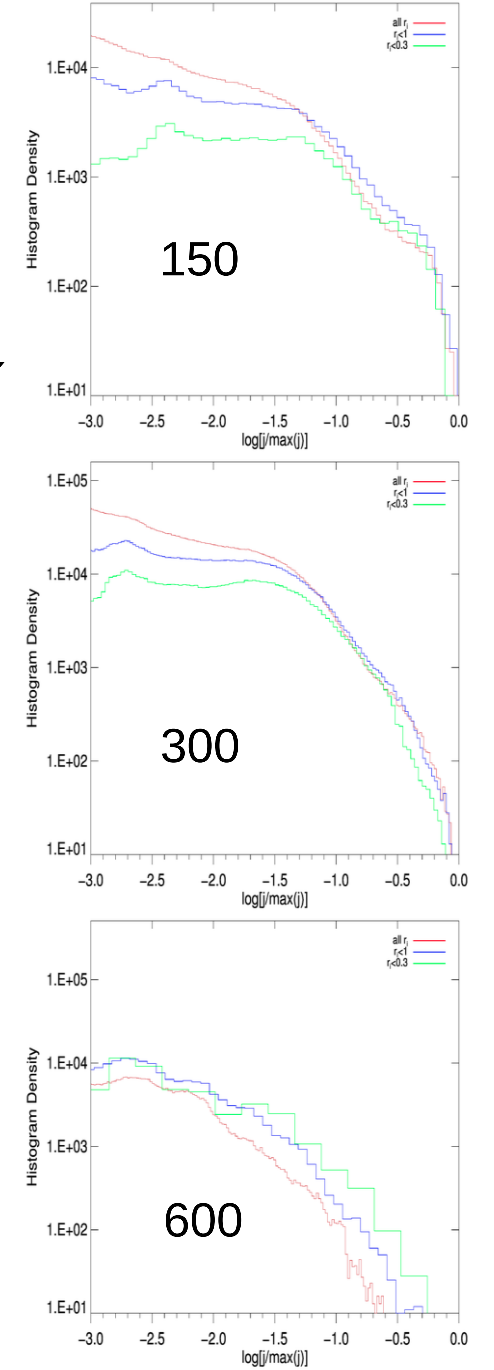
III. Calculate free energy fraction (3D field's quality indicator)

IV. Make the log-log histogram of J

V. Determine threshold above which power-law forms

VI. Make power-law fit to the tail of the distribution

VII. **Resolution comparison** ($r_i < 0.3$) each curve with its own J_{max}



Data Analysis: Procedure II → Results for t1: Comparing Resolutions

For each 3D magnetic field **B**:

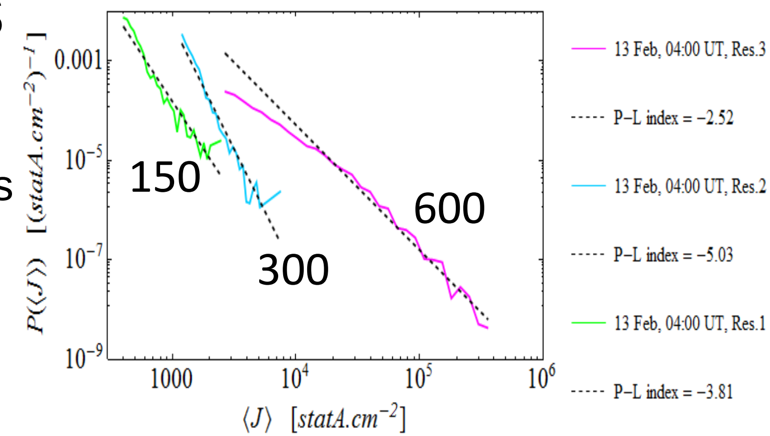
I. Perform a spatial clustering to identify localized regions

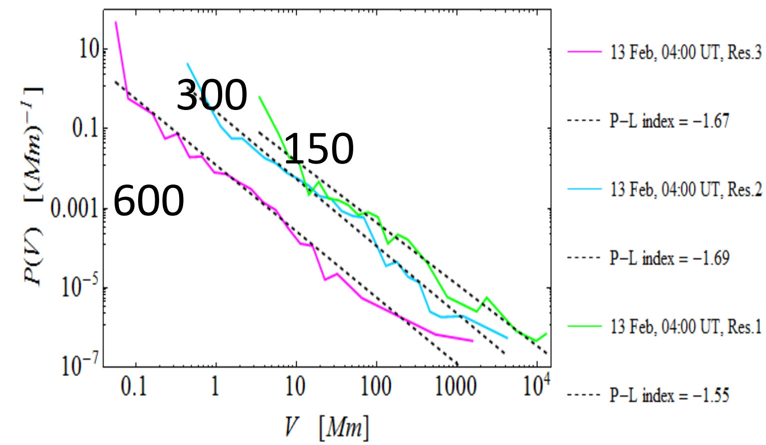
II. Calculate the free magnetic energy content of the clusters and their PDF

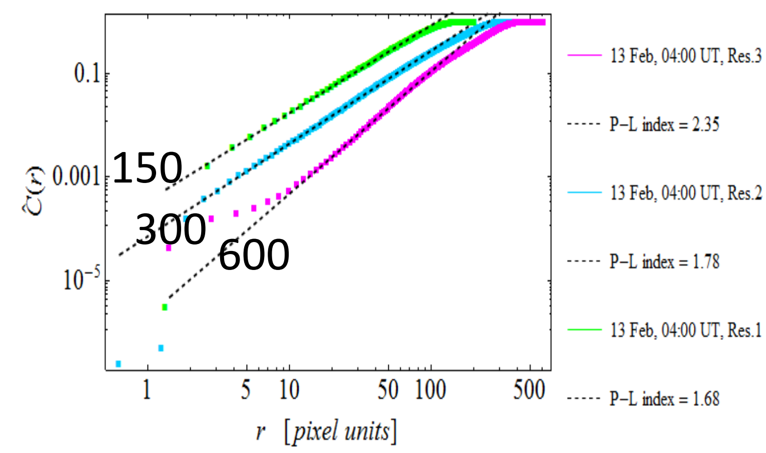
I. Average the current density of the identified regions and their PDF

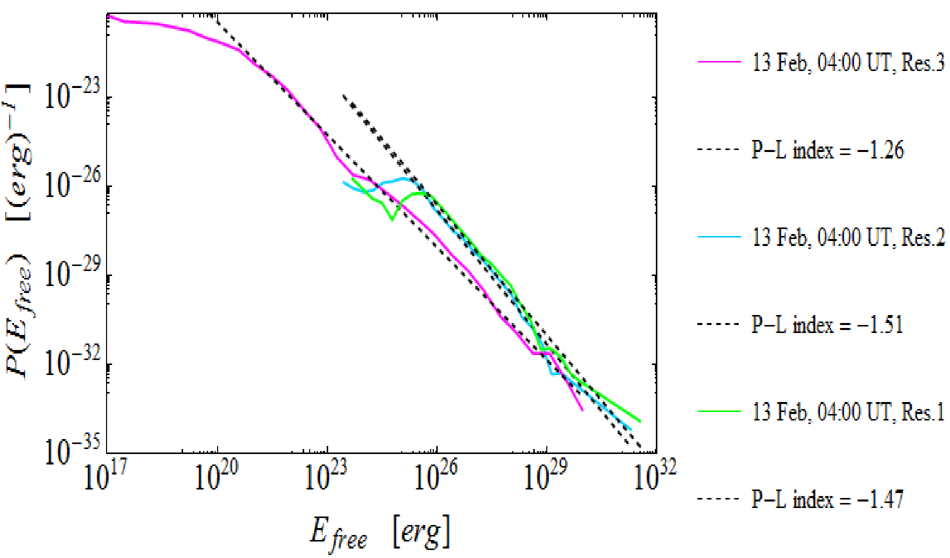
I. Calculate their volumes and their PDF

II. Use the cluster' centroids to compute the
III. fractal dimension of this magnetic configuration









Data Analysis: Procedure II → Results for t2: Comparing Resolutions

For each 3D magnetic field **B**:

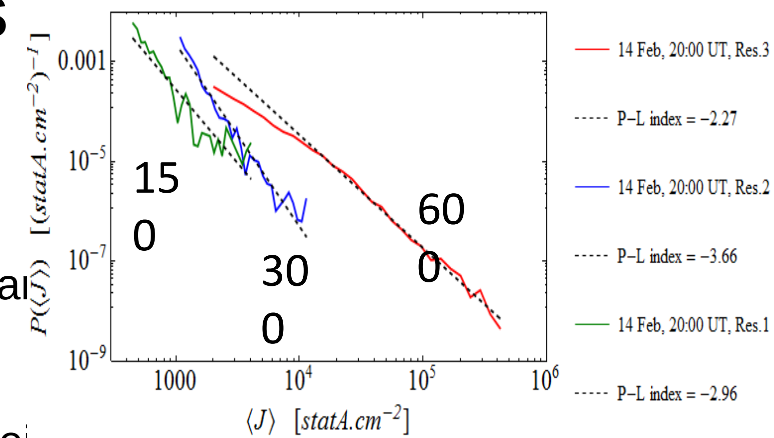
Perform a spatial clustering to identify localized regions

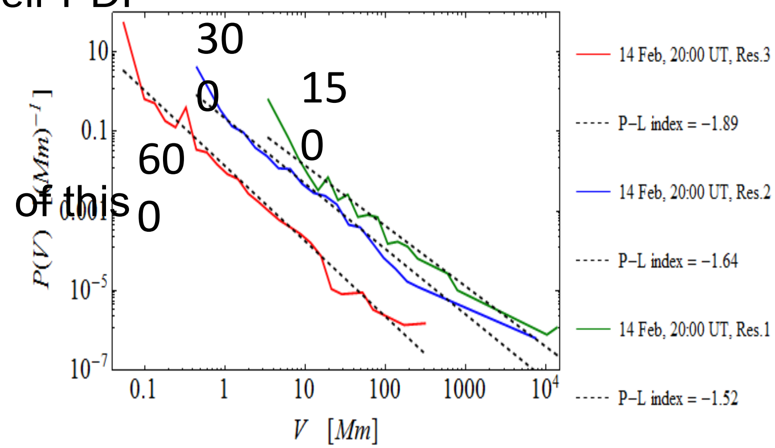
Calculate the free magnetic energy content of the clusters a
PDF

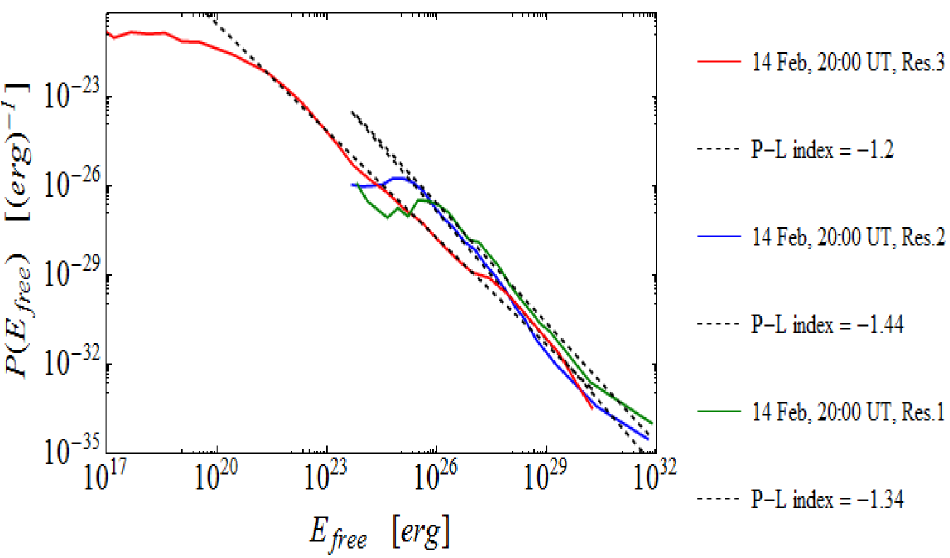
Average the current density of the identified regions and thei

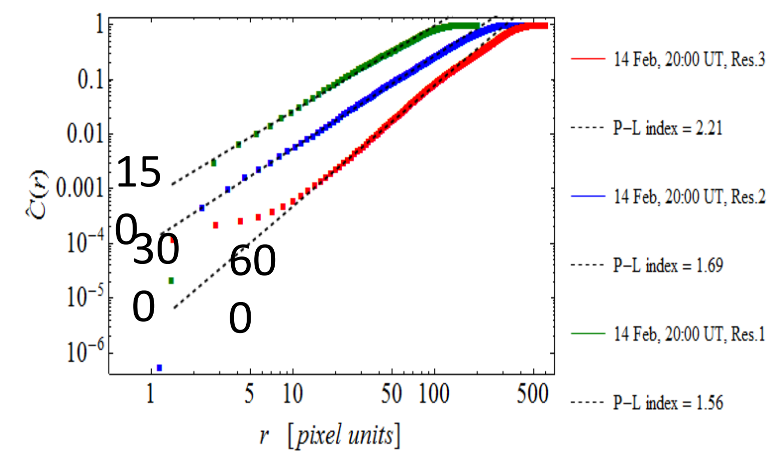
Calculate their volumes and their PDF

Use the cluster' centroids to compute the fractal dimension of this magnetic configuration Fit the distributions

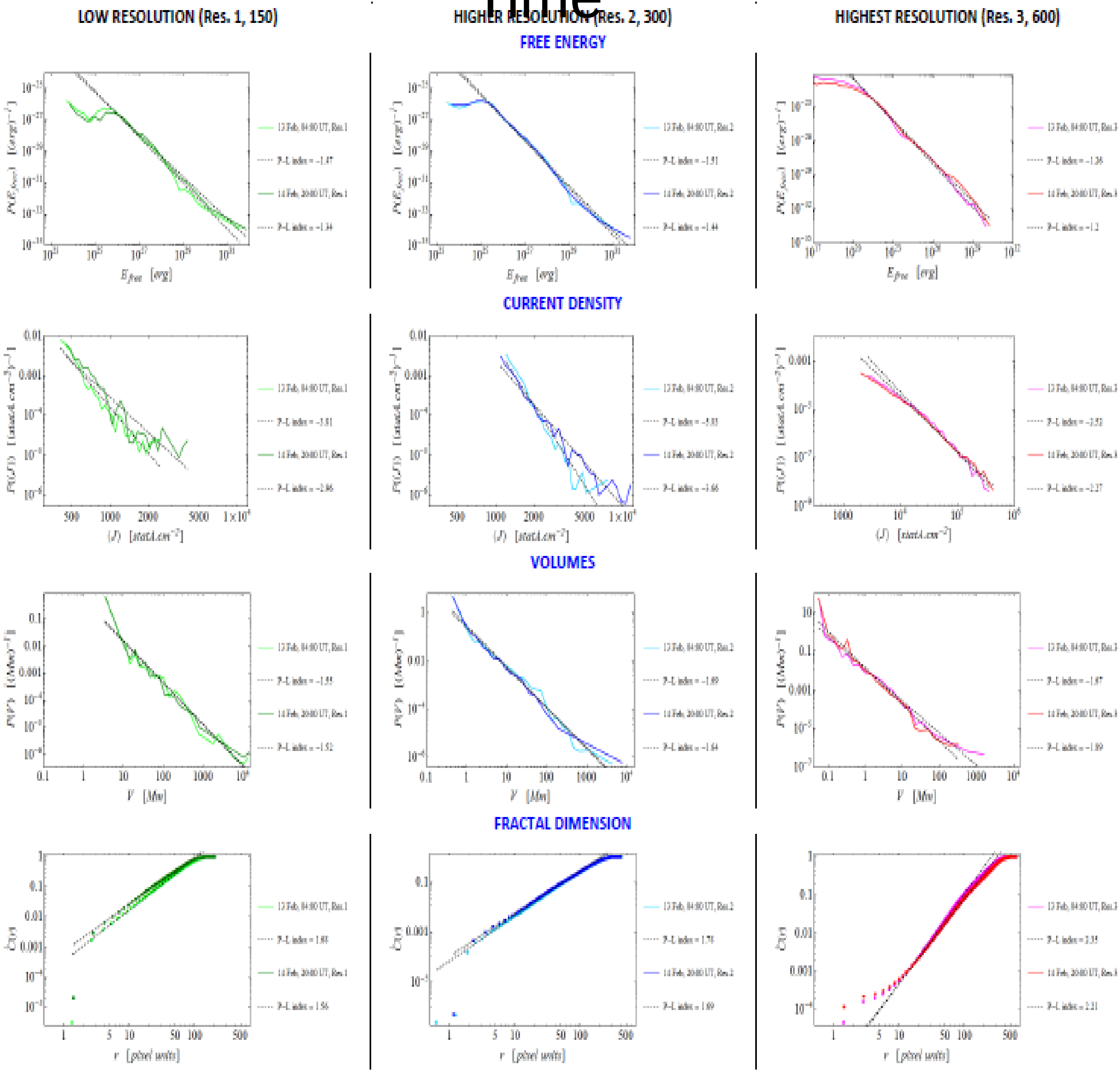








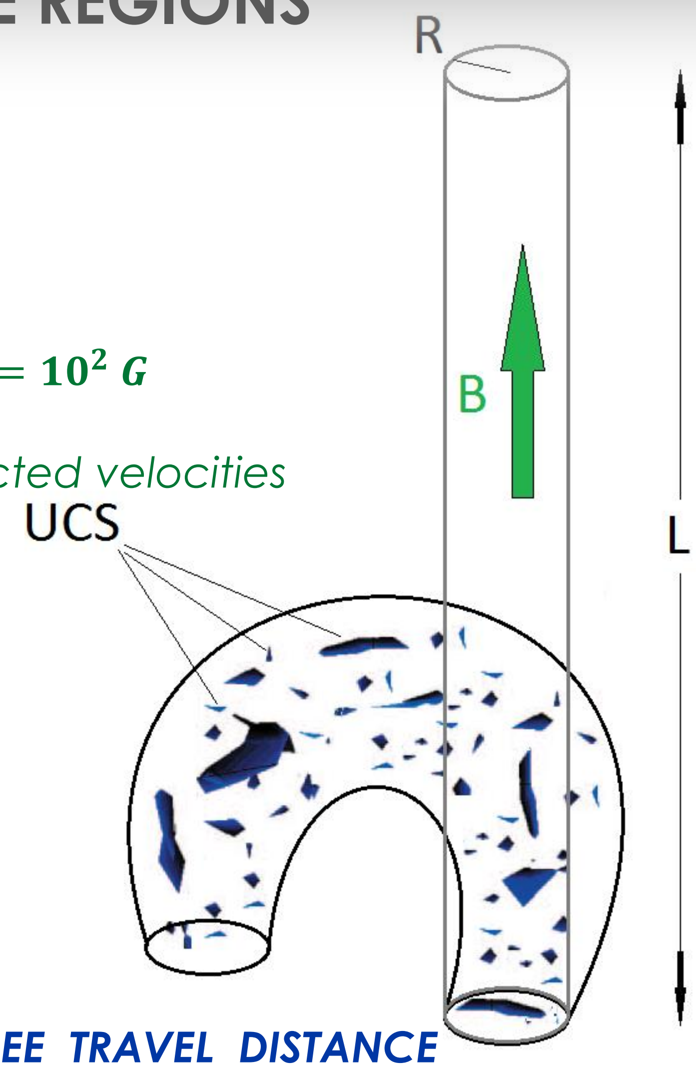
Data Analysis: Procedure II → Comparing Instants in Time



PARTICLE ACCELERATION
IN TURBULENT SOLAR ACTIVE REGIONS

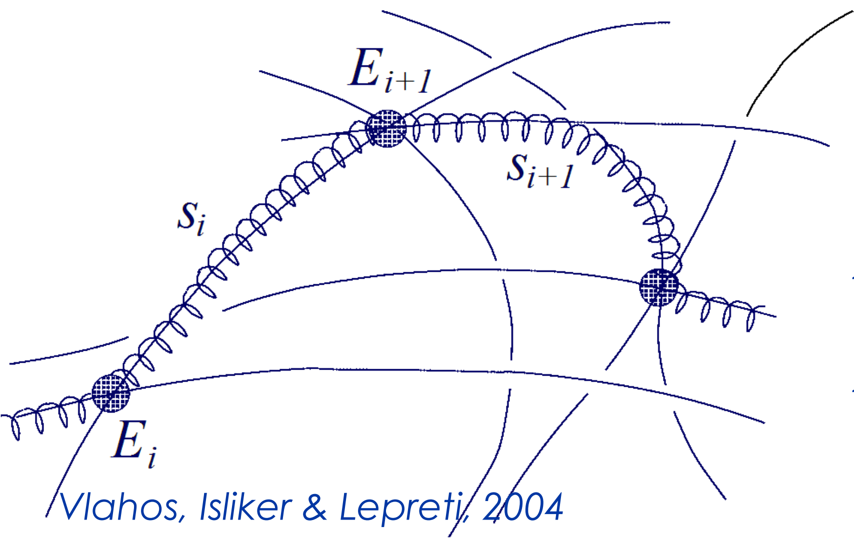
SETTING A.

- *Cylindrical volume simulating a **flux tube***
- *Initially occupied by **maxwellian plasma***
- *Of **uniform density** and temperature $T = 10^6\ K$*
- ***Uniform and stationary** magnetic field of magnitude $B = 10^2\ G$ directed upwards along the axis*
- ***Test-electrons** randomly distributed with randomly directed velocities*
- *A **particle code** traces their **guiding center** trajectories*



SETTING B.

*Statistical description of the **electric field**'s fractal structure*



Vlahos, Isliker & Lepreti, 2004

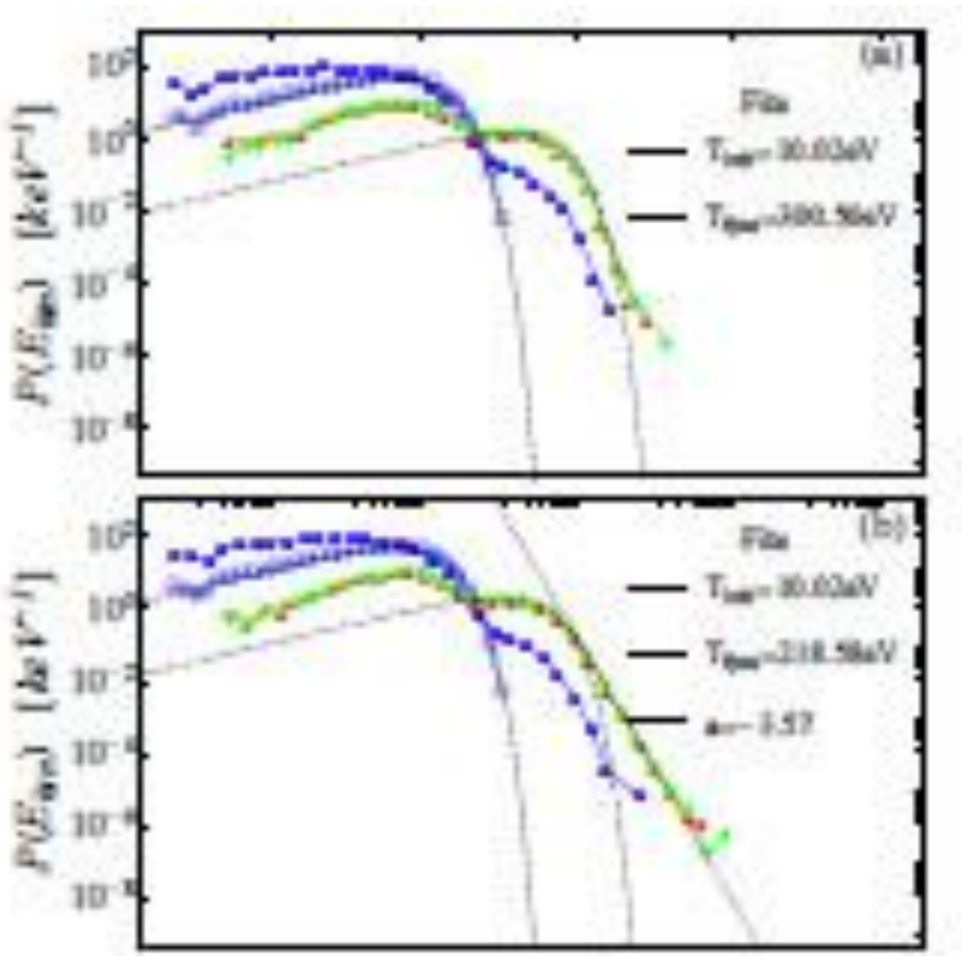
3 PDFs

$P_1 = P_1(s)$ ***FREE TRAVEL DISTANCE***

$P_2 = P_2(E)$ ***ELECTRIC FIELD STRENGTH***

$P_3 = P_3(d)$ ***ACCELERATION LENGTH***

Kinetic evolution of particles in distributed electric fields



Conclusions

- Heating and acceleration of particles is related with the emergence and evolution of active regions
- Fragmentation of Currents serve as a distributed accelerator in a resistive plasma ($E=\eta j$) inside the active region
- In summary emergence and evolution of active regions lead to nano-micro-flares/CME all this creates a fragmented current distribution which heats and accelerates the coronal plasma.