Power Spectrum, Cross Helicity and Residual Energy Analysis about Current Sheets' Effect on Solar Wind Turbulence

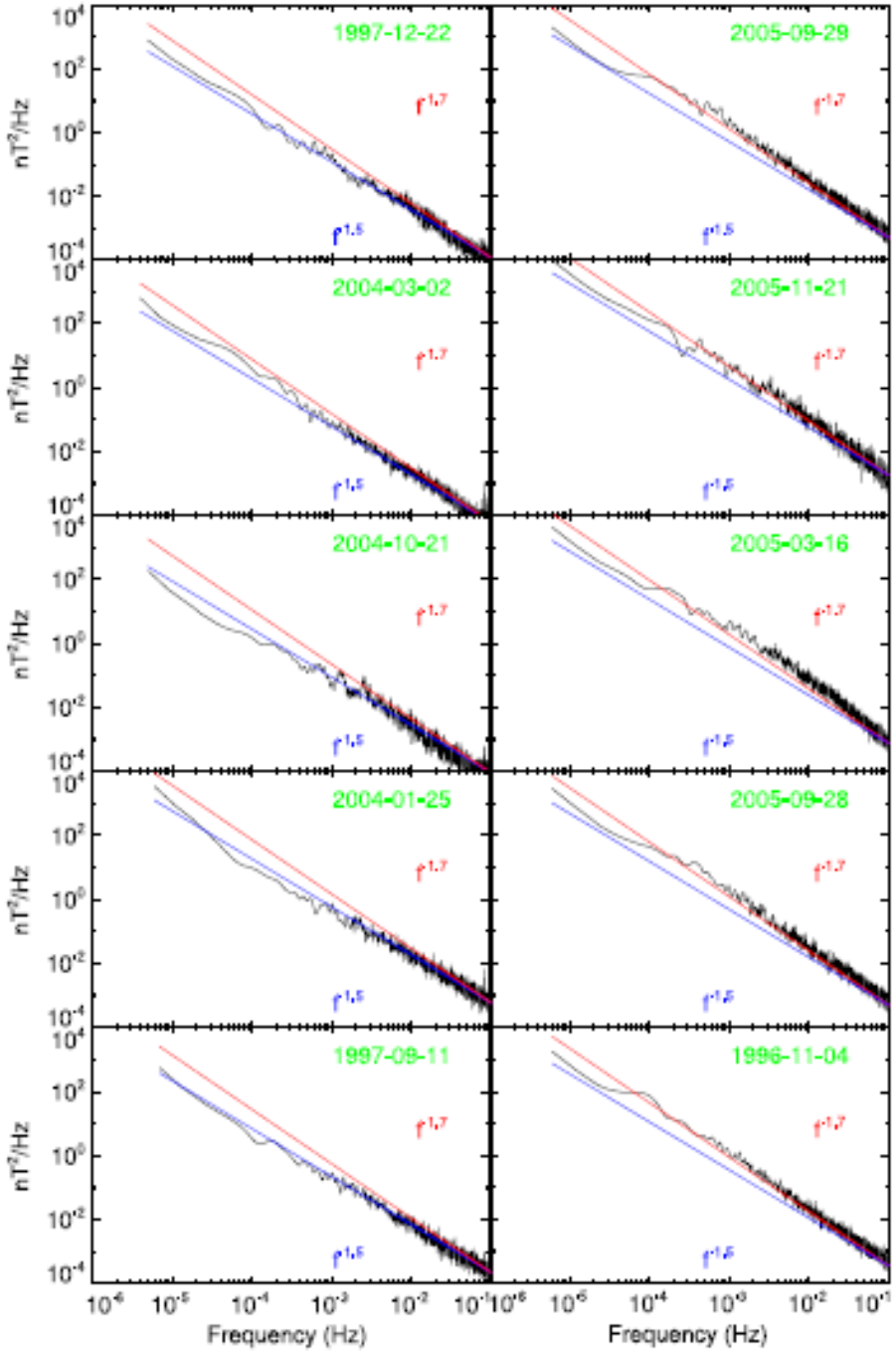
Junxiang Hu

1. Background

- Kolmogorov (K41 theory). He showed that the turbulence power law behavior in the inertial range has an index ~ -5/3.
- Iroshnikov-Kraichnan(Ik theory), the turbulence power has an exponent ~ -3/2.
- In most cases, turbulences act like K41.

1. Background

Gang Li et al. investigated the effect of the current-sheet structures on the power analysis of the solar wind magnetic field. They showed the magnetic field power spectrum of 5 longest current sheet free periods and another 5 current sheet abundant periods, found that current-sheet-free cases are all IK like with $E(f) \sim f^{-3/2}$ and current-sheet-abundant cases are K41 like with $E(f) \sim f^{-5/3}$.


1997-12-22
2005-09-29
2004-03-02
2005-11-21
2004-10-21
2005-03-16
2004-01-25
2005-09-28
1997-08-11
1996-11-04
f^-1.7
f^-1.5
nT²/Hz
Frequency (Hz)

2. Numerical model

- Morlet wavelet:

$$\psi(t) = \pi^{-1/4}\left[e^{i\omega_0 t} - e^{-\omega_0^2/2}\right]e^{-t^2/2},$$

$$F(s, k\Delta t) \simeq \sum_{n=0}^{N-1} s^{-1/2}\psi^*\left[\frac{(n-k)\Delta t}{s}\right] f(n\Delta t)\,\Delta t.$$

$$P(\nu_m) = \frac{4\pi\Delta t}{C\omega_0 T}\sum_{n=0}^{N-1} |F(s_m, t_n)|^2$$

$$\nu_m = \frac{\omega_0}{2\pi s}\left(1 + \frac{1}{2\omega_0^2}\right)$$

2. Numerical model

- Cross helicity and Residual Energy

$$\delta z^{\pm} = \delta v \pm \delta v_A$$

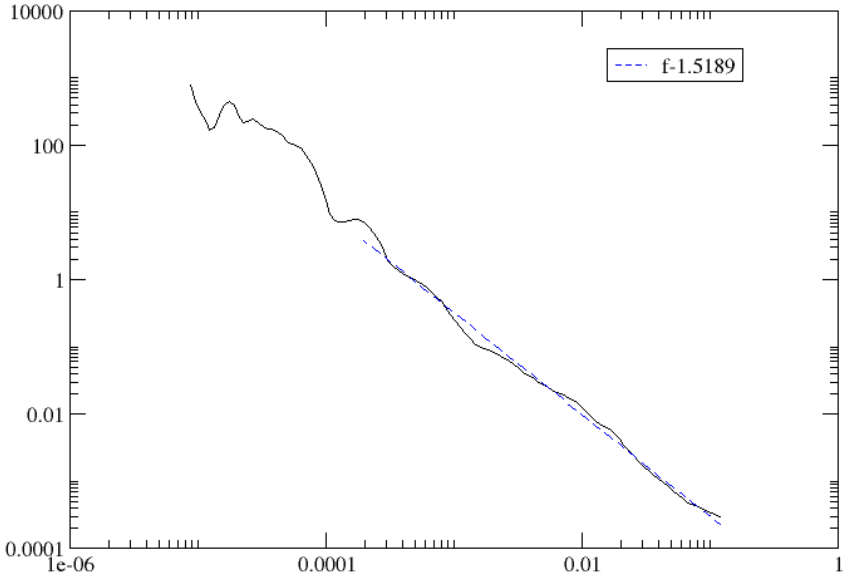
$$\sigma_C = \frac{< \delta z^{+2} > - < \delta z^{-2} >}{< \delta z^{+2} > + < \delta z^{-2} >}$$

$$\sigma_R = \frac{< \delta v^2 > - < \delta v_A^2 >}{< \delta v^2 > + < \delta v_A^2 >}$$

Results and Thoughts

Left column:
current sheet free

1997-12-22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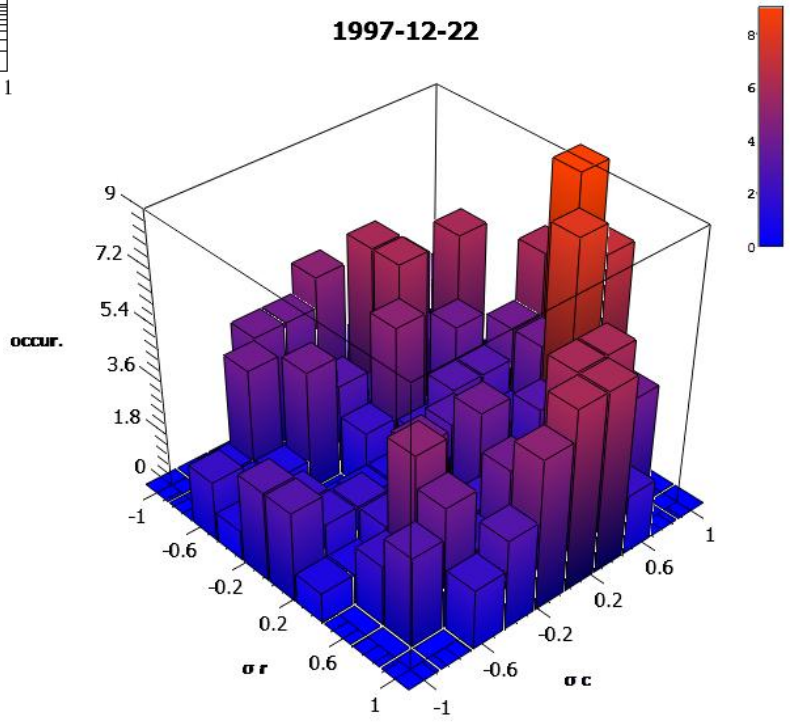
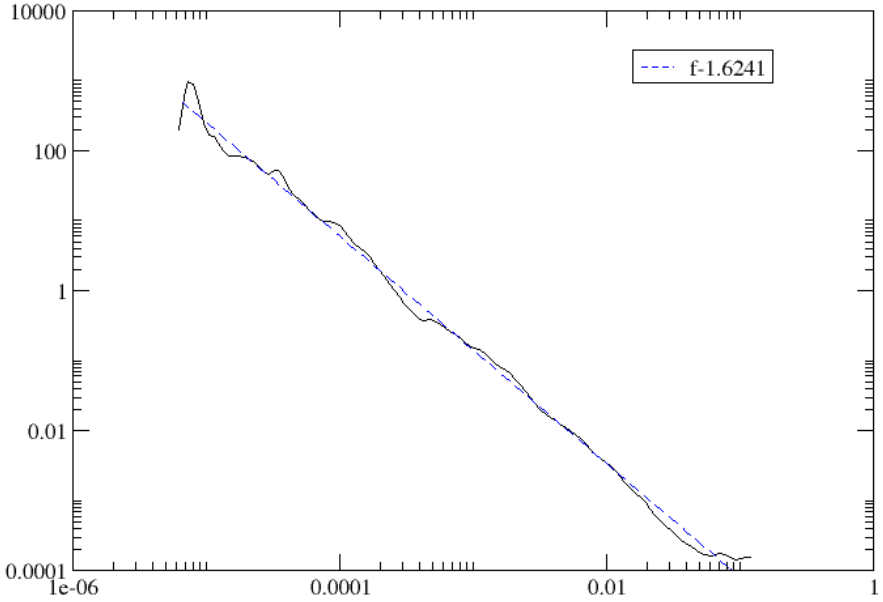

1997-12-22
occur.
9
7.2
5.4
3.6
1.8
0
σ r
σ c
-1
-0.6
-0.2
0.2
0.6
1
8
6
4
2
0

2004-03-02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0.01
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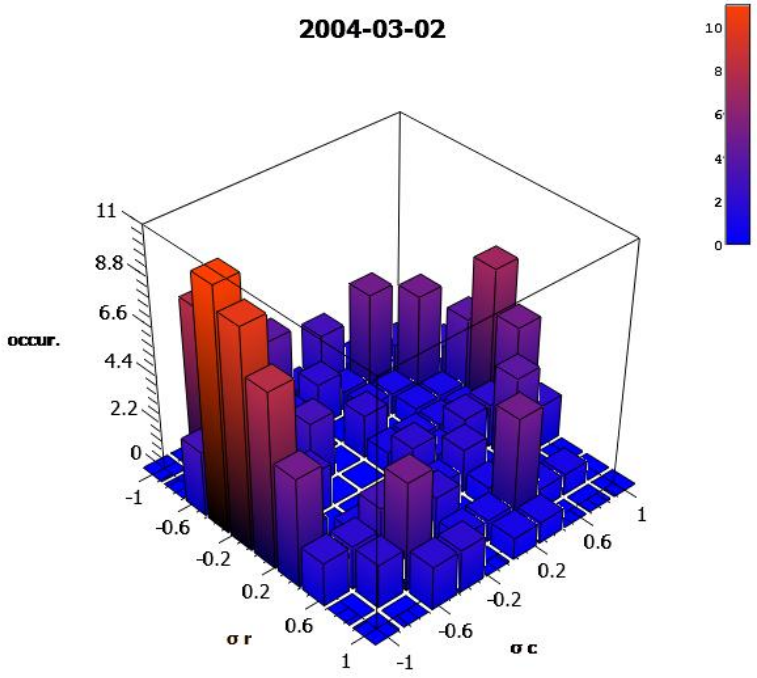
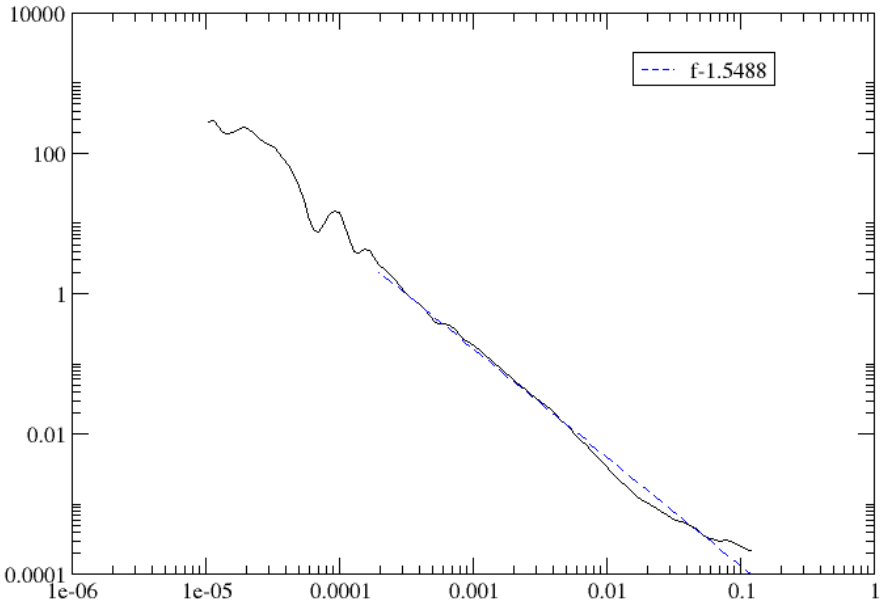

2004-03-02
occur.
11
8.8
6.6
4.4
2.2
0
σ r
σ c
-1
-0.6
-0.2
0.2
0.6
1
10
8
6
4
2
0

2004-10-21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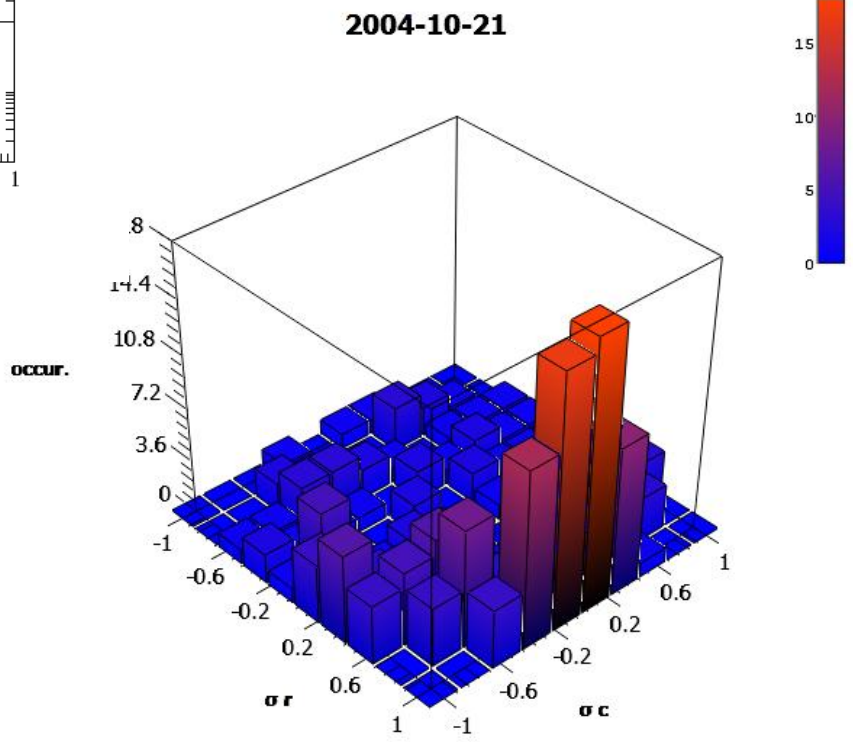
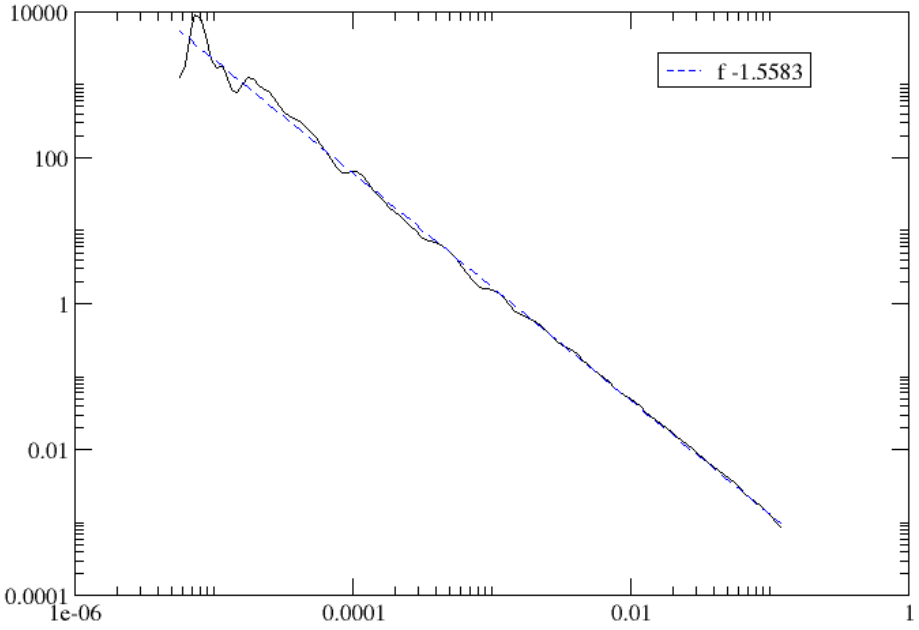
0.001
0.01
0.1
1


2004-10-21
occur.
14.4
10.8
7.2
3.6
0
-1
-0.6
-0.2
0.2
0.6
1
σ r
σ c
15
10
5
0

2004-01-25


f -1.5583
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0.0001
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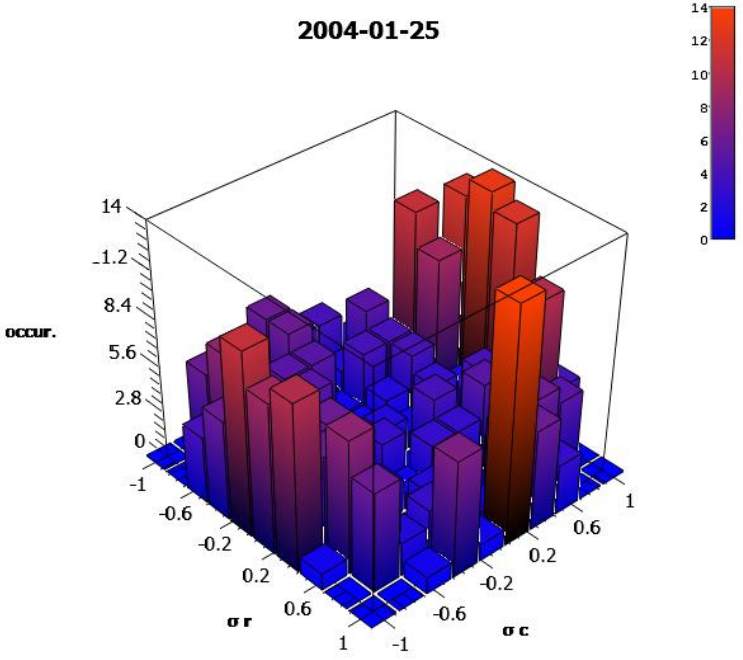
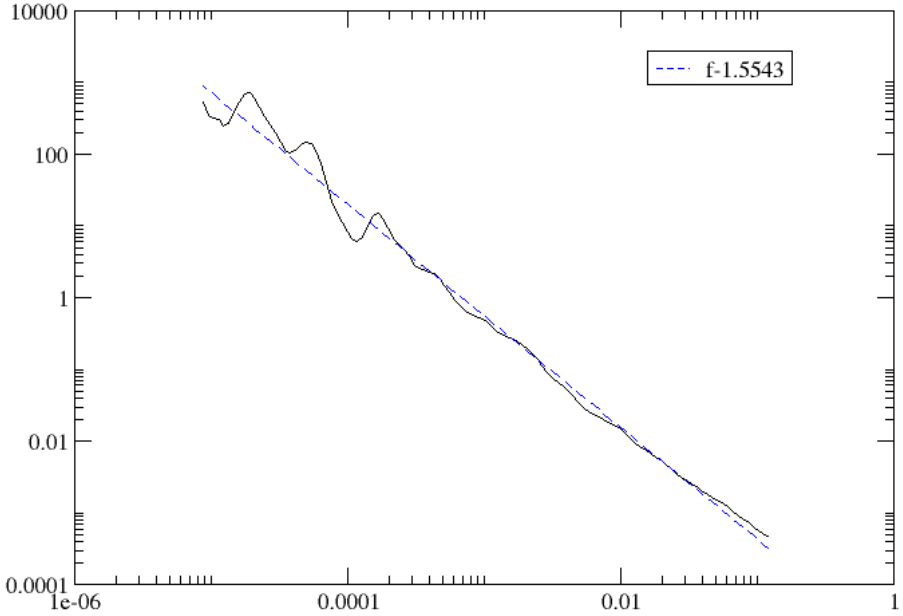
0.0001
0.01
1


2004-01-25
occur.
14
11.2
8.4
5.6
2.8
0
-1
-0.6
-0.2
0.2
0.6
1
σ r
σ c
14
12
10
8
6
4
2
0

1997-09-11



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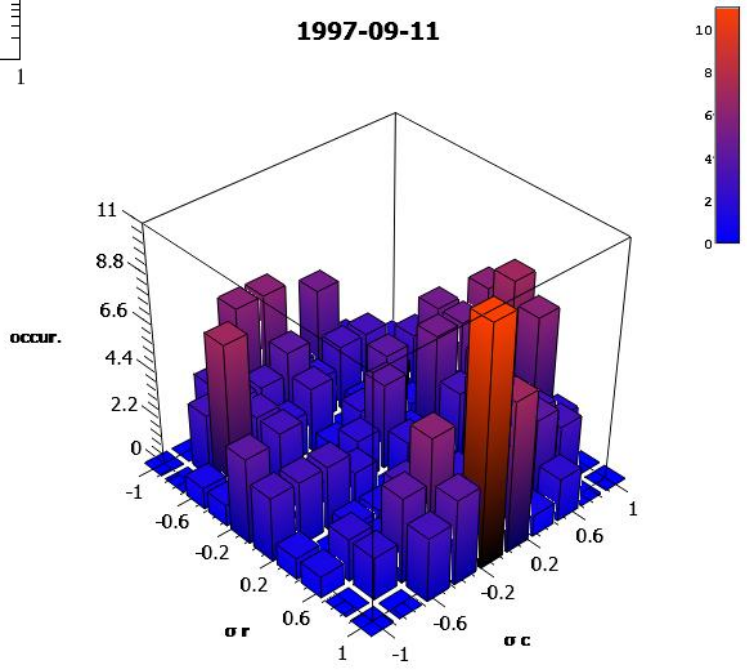
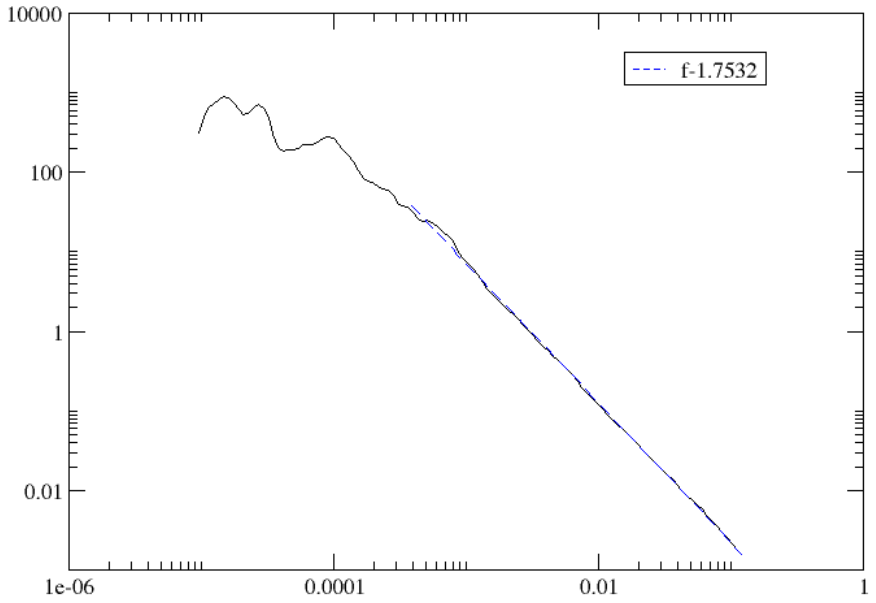


Right column:
current sheet abundant

2005-09-29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0.01
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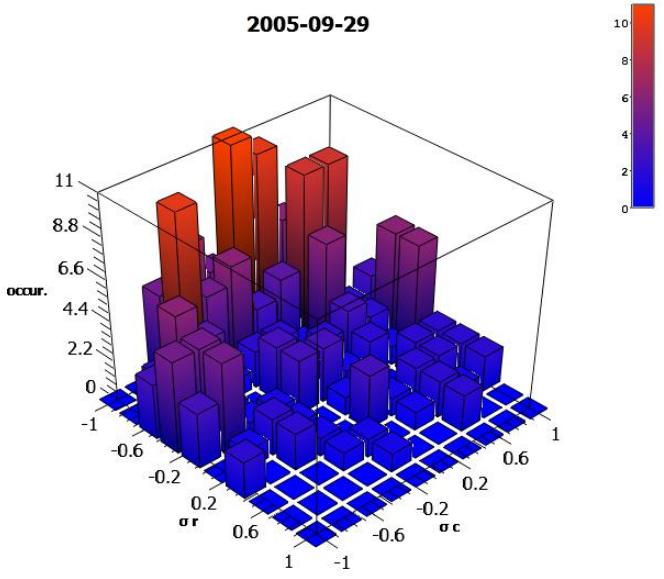
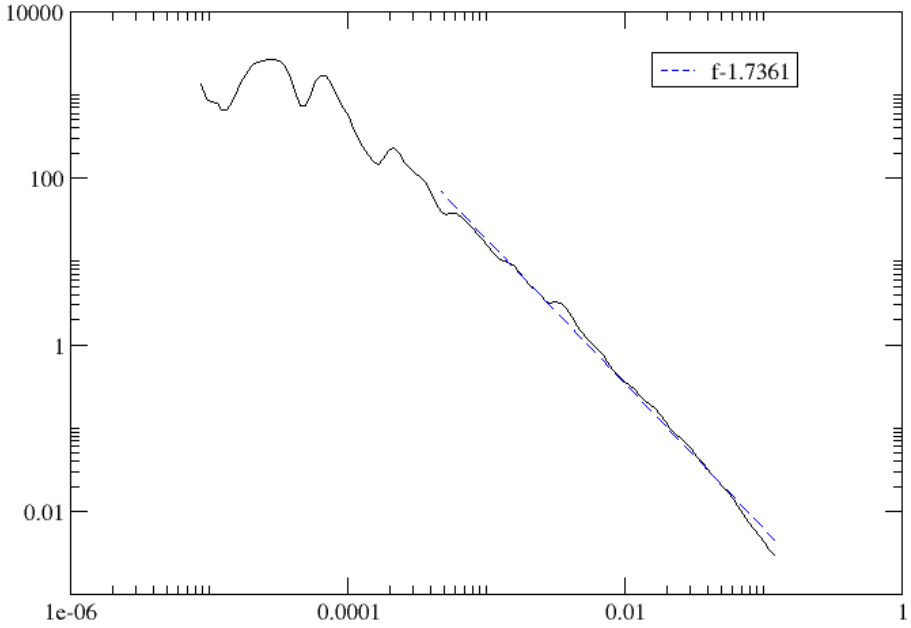
0.0001
0.01
1


2005-09-29
occur.
11
8.8
6.6
4.4
2.2
0
σr
σc
-1
-0.6
-0.2
0.2
0.6
1
10
8
6
4
2
0

2005-11-21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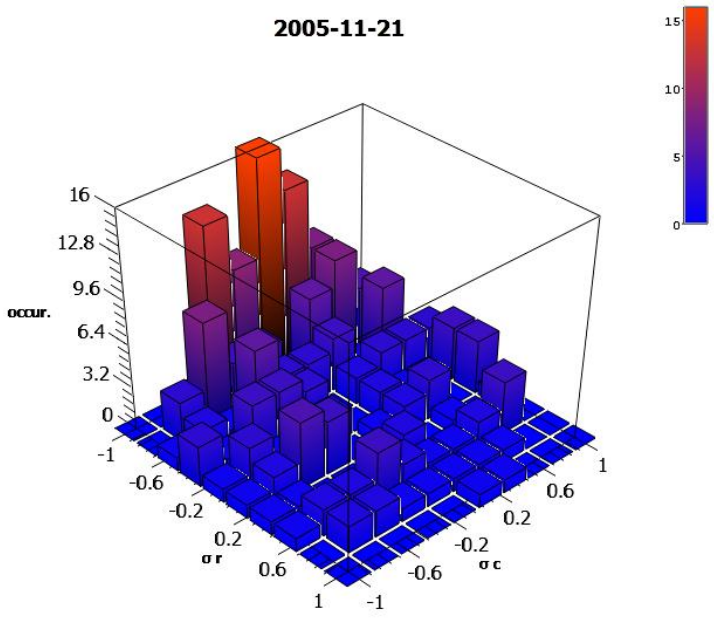
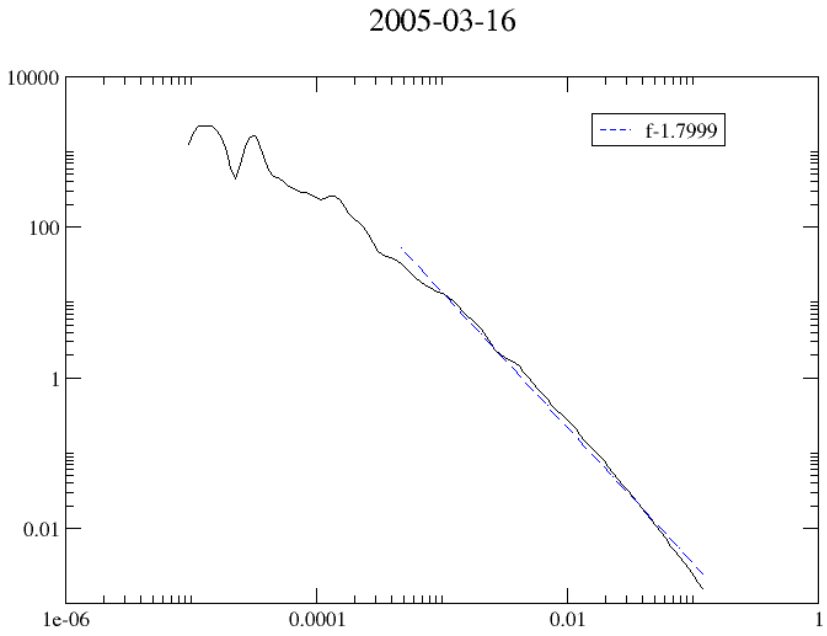
1
f-1.7361


2005-11-21
occur.
16
12.8
9.6
6.4
3.2
0
-1
-0.6
-0.2
0.2
0.6
1
σ r
σ c
15
10
5
0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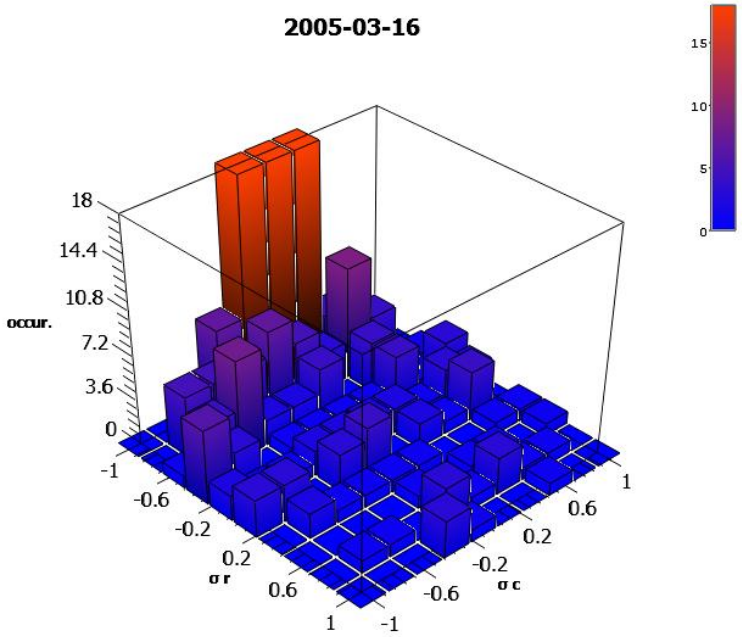
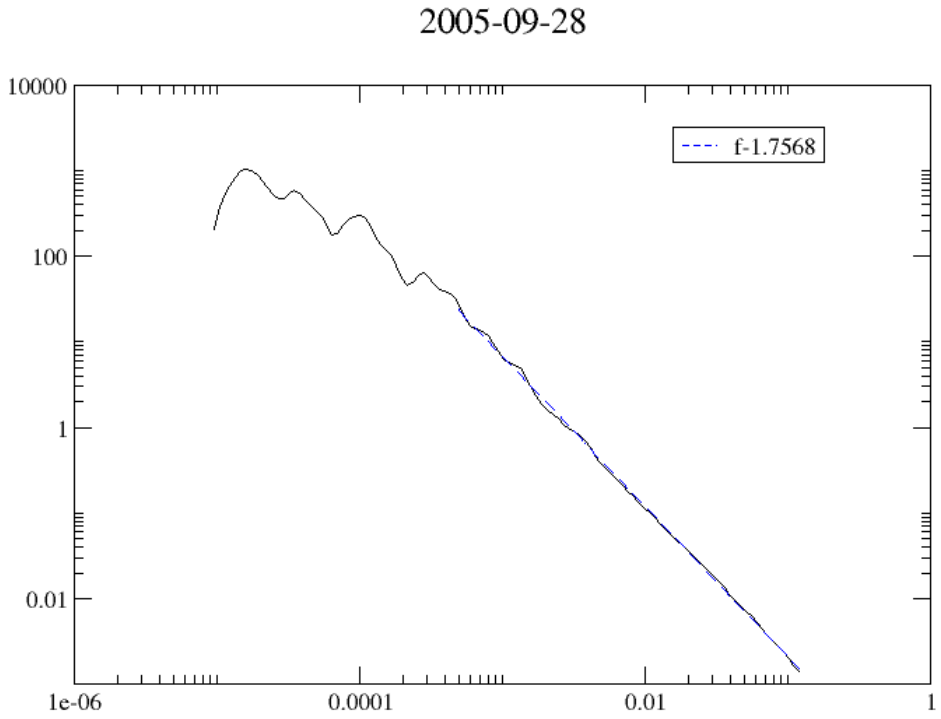
0.01
1


2005-03-16
occur.
18
14.4
10.8
7.2
3.6
0
σ r
σ c
-1
-0.6
-0.2
0.2
0.6
1
15
10
5
0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1
0.01
1e-06
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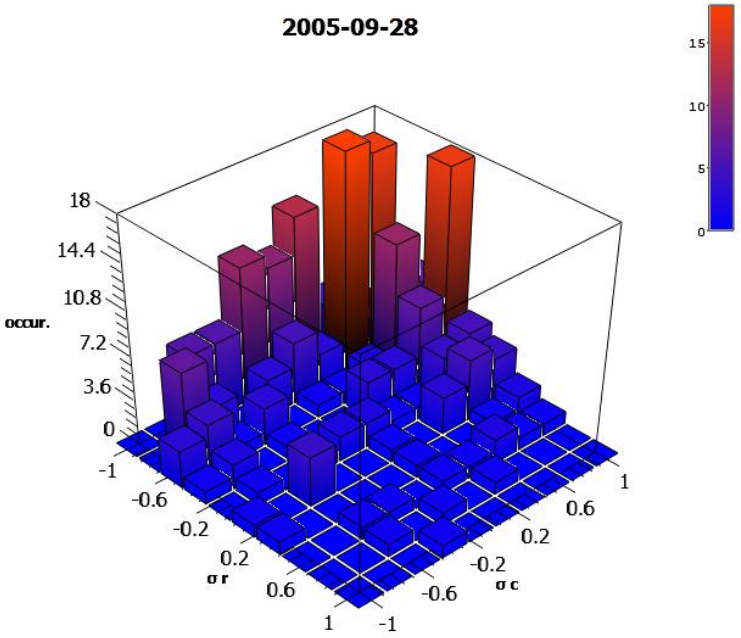
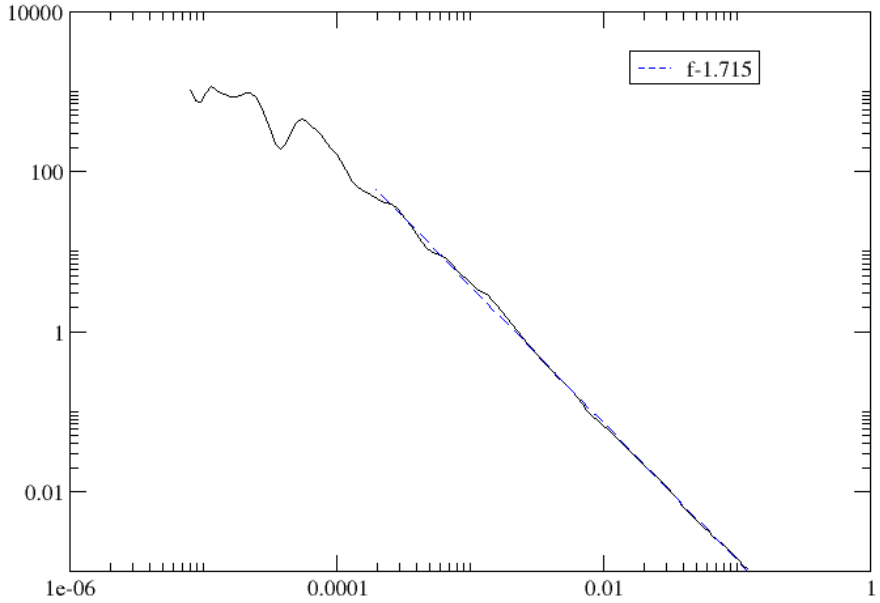
1


2005-09-28
occur.
18
14.4
10.8
7.2
3.6
0
σ r
σ c
-1
-0.6
-0.2
0.2
0.6
1
15
10
5
0

1996-11-04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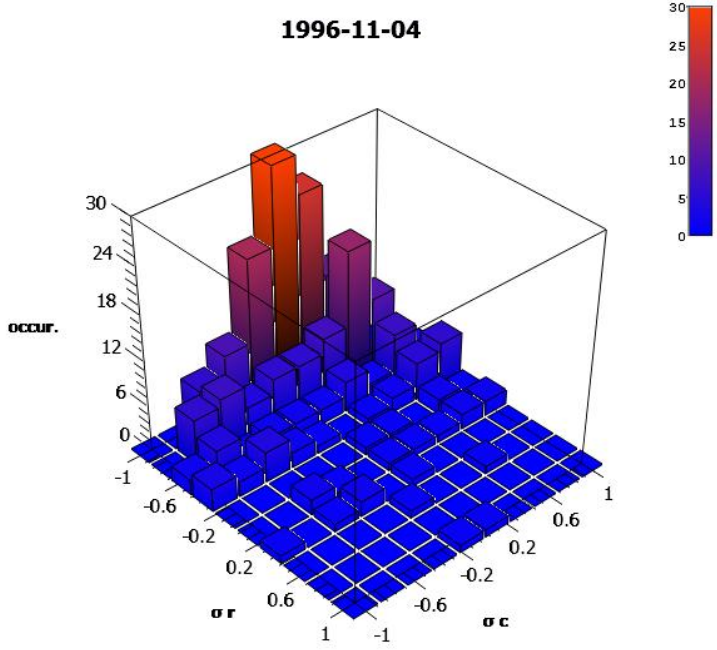
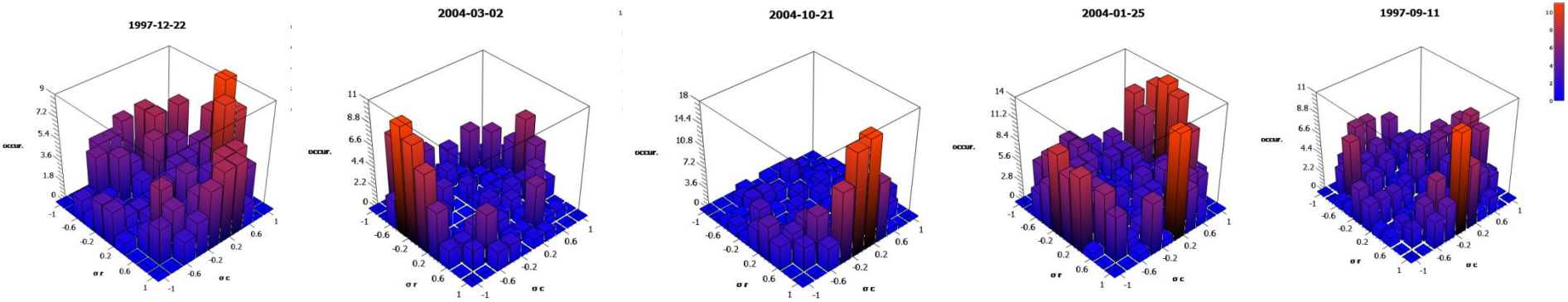
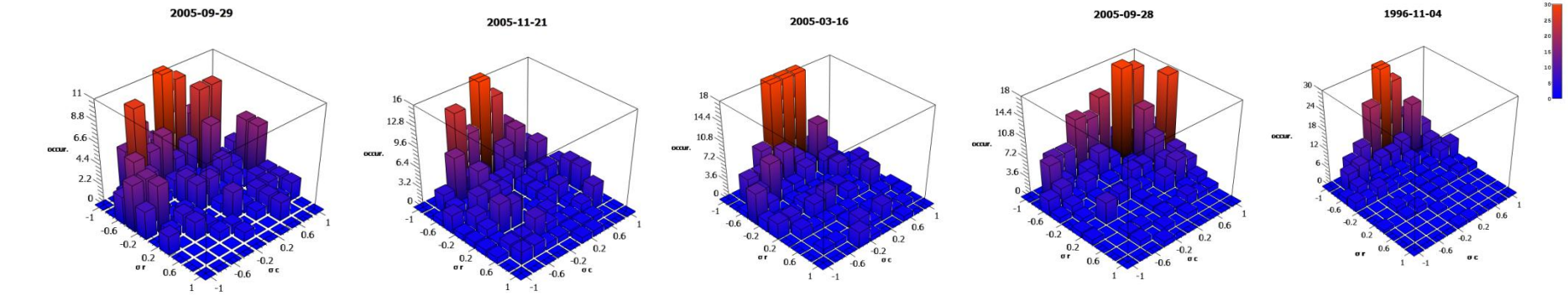
0.01
1e-06
0.0001
0.01
1
f-1.715


1996-11-04
occur.
30
24
18
12
6
0
-1
-0.6
-0.2
0.2
0.6
1
σ r
σ c
30
25
20
15
10
5
0

Current sheet free



Current sheet abundant



4. Summary

- Power spectrum can be linearly fit well with a index very close to 1.5(for current-sheet-free) and 1.7(for current-sheet-abundant).
- In the current sheet abundant periods, $\sigma_R \sim -1$ and $\sigma_C \sim 0$.
- In the current-sheet-free periods, most of them appear to be alfvenic.
- Maybe the possibility density distribution on cross helicity and residual energy can be a criterion of current sheet abundance or absence.