Turbulence, heating and particle acceleration

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Personal interests

Disclaimer: (almost) no RHESSI and particle acceleration experience

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Some of my interests that may be related to RHESSI:

- Small-scale coronal heatings, and their statistics
- MHD turbulence in the corona

Small-scale heating of the corona

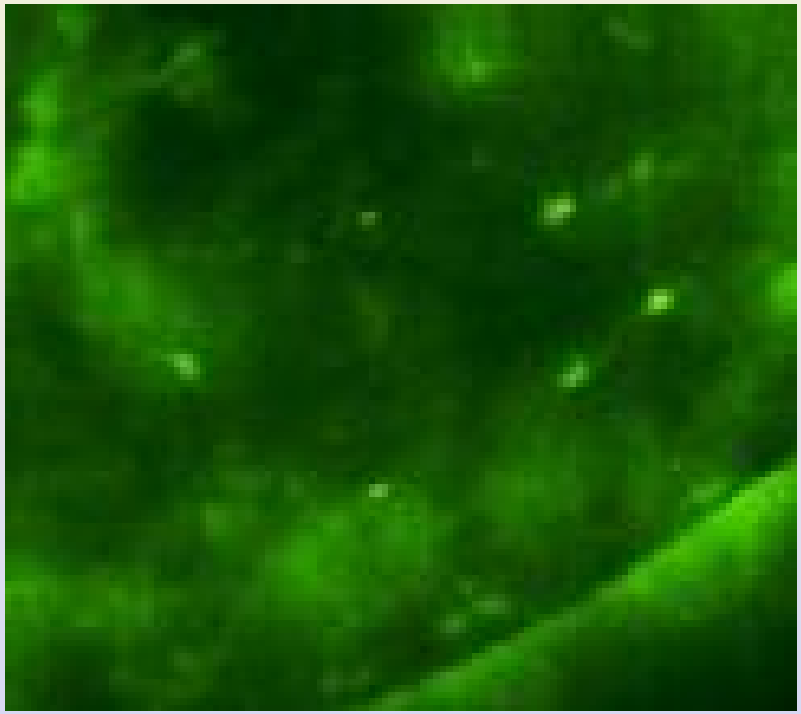
Need small scales for:

- theoretical reasons: dissipation is more efficient
- observational reasons: observed events (> 100 km) not sufficient

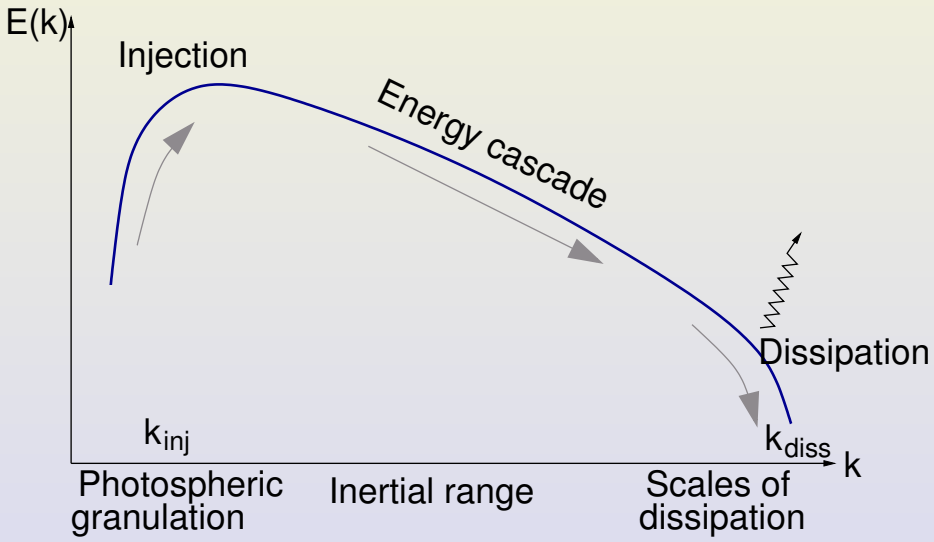
Small-scale structures are visible

X/UV bright points: small loops? Counterparts of RHESSI microflares

Even smaller structures can be expected



Possible origin of small scales



May be created by *turbulence*

In the corona:
$R_e = UL/\eta \approx 10^{13} \gg 1$
(for $U = 1$ Mm/s, $L = 10$ Mm, $\eta = 1\ \mathrm{m}^2/\mathrm{s}$)

Smallest scales (dissipative): 10–100 m!

Need for statistics to describe coronal heating

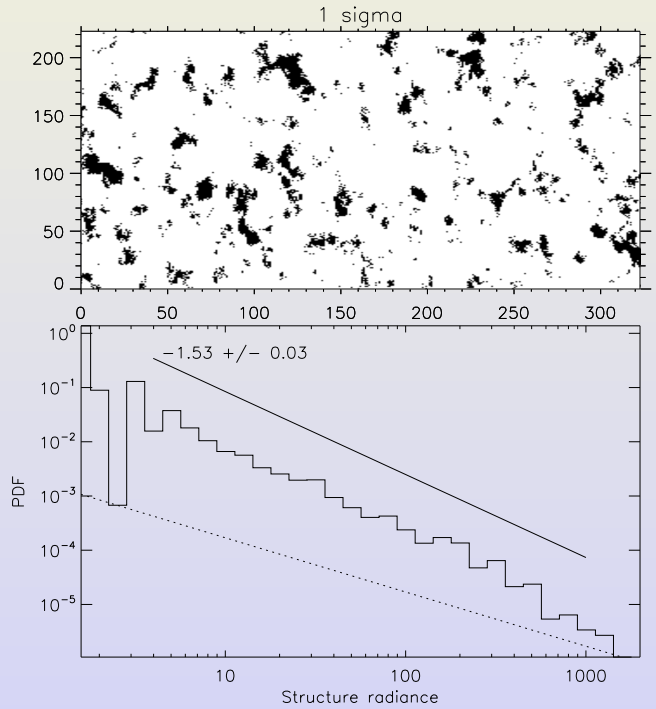
Why do we need statistics? (vs. morphology)

- Small structures/events/flares/scales:
  - Not seen directly, but the observable statistics may be preserved when going to smaller scales
  - Deductions based on statistics (Hudson 1991...)
- Statistical nature of description of turbulence: powerful means to tackle its *complexity*

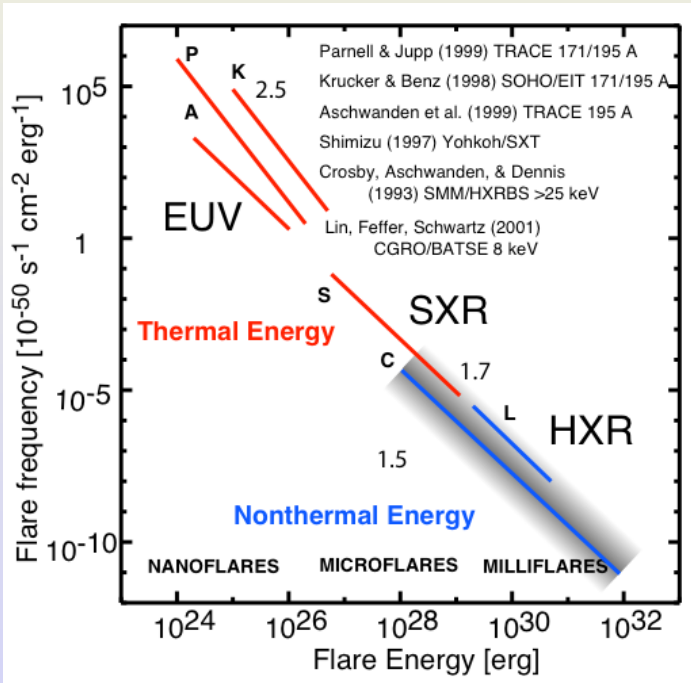
$\longrightarrow$ direct *comparison* between *observations* and *simulations* is possible

X/UV observational statistics (non-RHESSI)

- Energies, durations... of *events* (nanoflares) distributed as *power laws*
  Parnell & Jupp 2000 (TRACE), Aletti *et al.* 2000 (SOHO/EIT),
  Aschwanden *et al.* 2000, Buchlin, Vial and Lemaire, A&A 2006 (SOHO/SUMER)



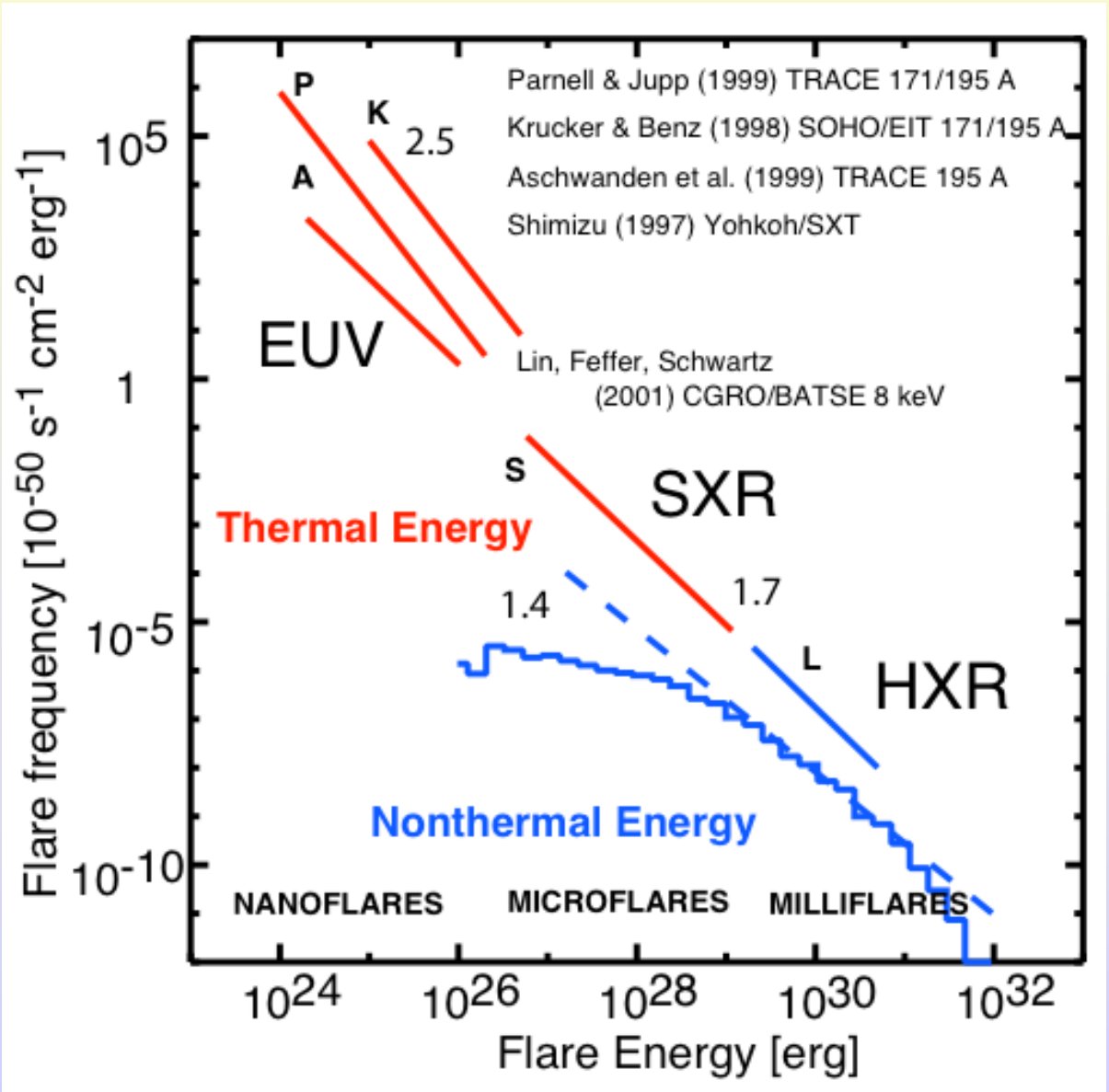
Buchlin *et al.* 2006



Aschwanden/Christe

- *Waiting times* between successive events distributed as power laws
  $\longrightarrow$ *Poisson process*, Lepreti, Carbone & Veltri 2001 (GOES)

RHESSI statistics: distributions of energies of microflares



Christe *et al.* SPD2005

Observational difficulties

In any case:

- Need to extract events from data (RHESSI time series, UV images or data cubes), and results may *depend on the definition of an event* that was used (Buchlin *et al.* A&A 2005)
- Need to get total event energy from observed variables, and results may *depend on the assumptions made* (Parnell SOHO15, 2004)
  - Would comparing observable variables (and forward-modelling) be preferable?
  - How to conclude on this "magical" -2 slope anyway?

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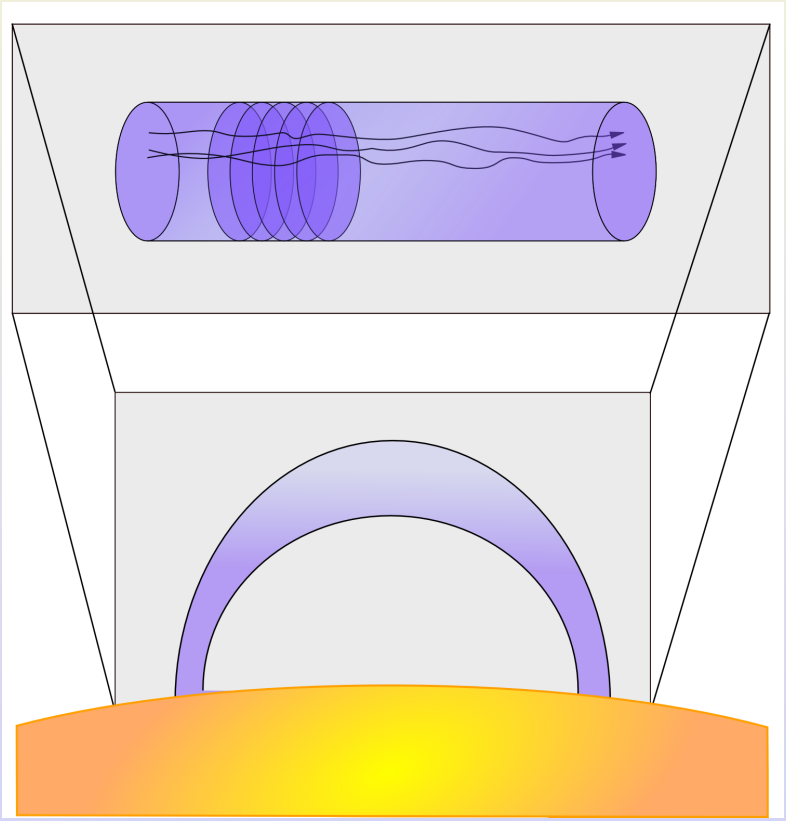
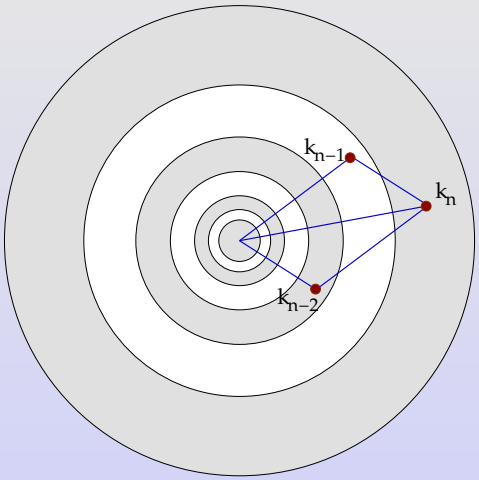
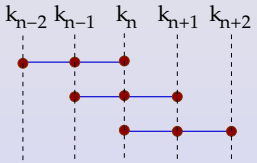
Numerical simulations: shell-models

Need of long time series for statistics: direct numerical simulations are not suitable $\longrightarrow$ we use MHD shell-models to simulate a loop



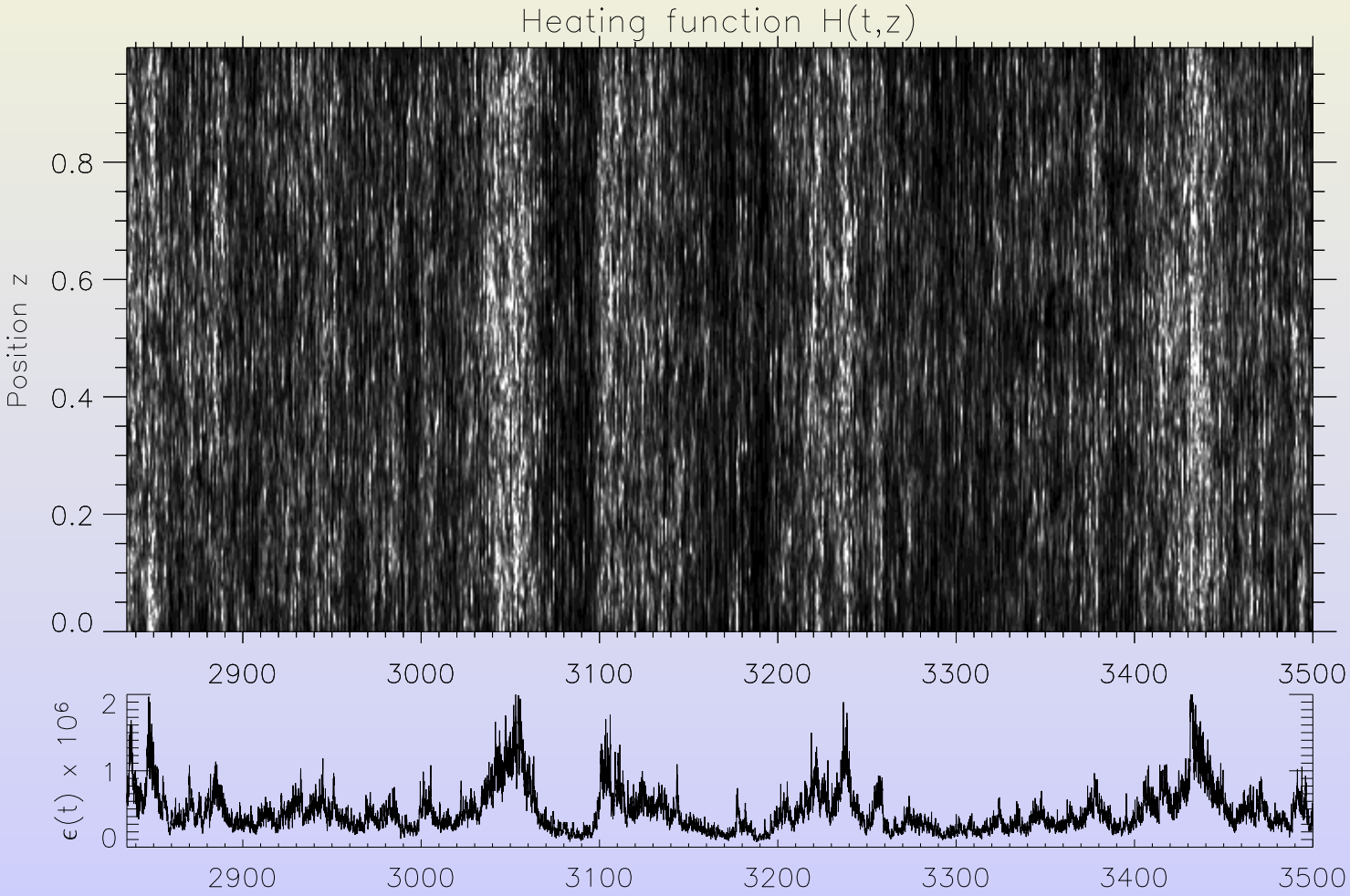




Numerical simulations: dissipation in shell-models

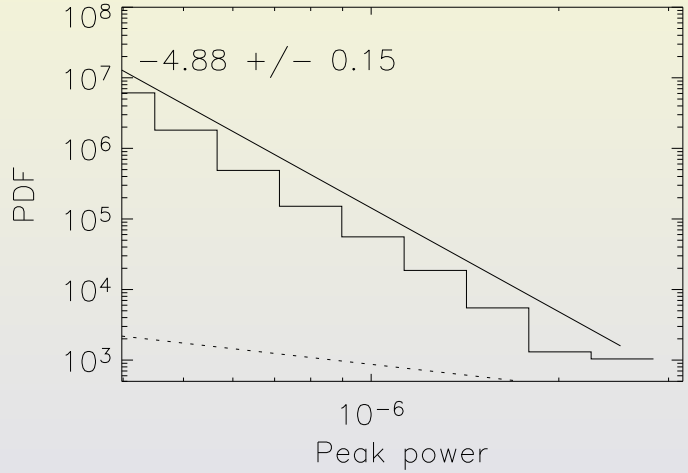
MHD turbulence at very large Reynolds numbers (10^4–10^6) $\longrightarrow$ smaller scales than in DNS

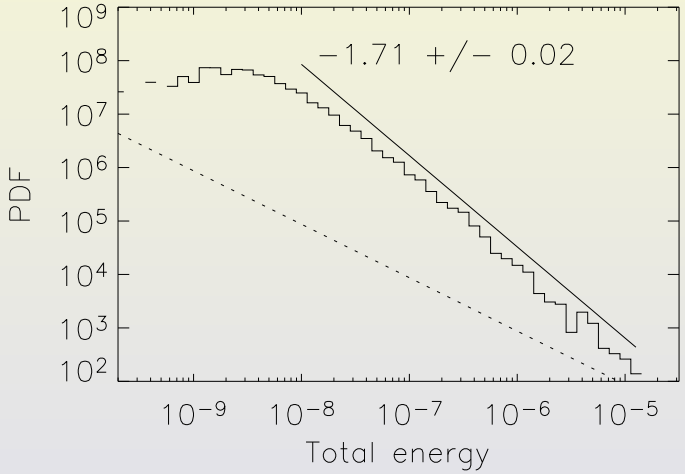
A heating function is obtained, and a time series of energy dissipation.

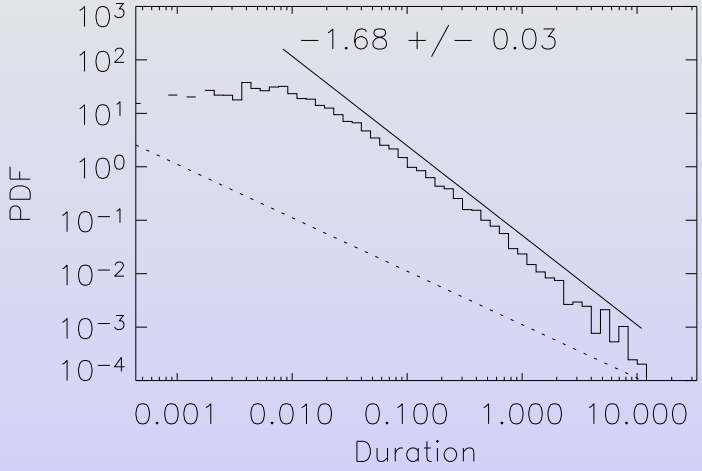


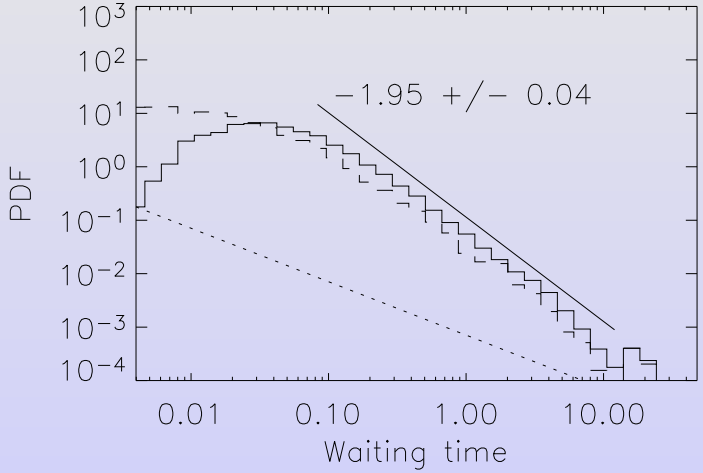
Statistics from shell-model numerical simulations

Distributions of events energies, durations, waiting times:









How to relate this to acceleration of particles?

Energy release at small scales $\longrightarrow$ MHD not valid anymore, super-Dreicer fields... (gray zone for the heating model! difficulties of cross-scale physics)

With some assumptions it would be possible to deduce distributions of accelerated particles and RHESSI spectra (Cyril?)

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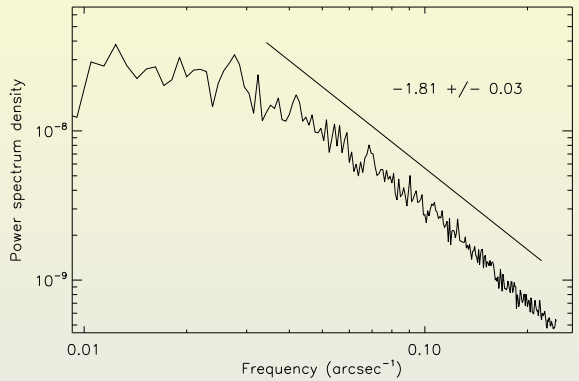
Coronal turbulence: observations and simulations

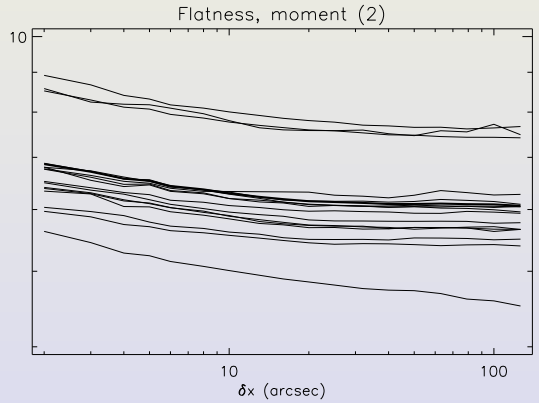
- Power-law spectra, *turbulence*
  Martens & Gomez 1992,
  Benz *et al.* 1997 (Yohkoh/SXT),
  Berghmans *et al.* 1998 (SOHO/EIT),
  Espagnet *et al.* 1993 (ground),
  BVL06 (SUMER)

- *Intermittency* of this turbulence
  Patsourakos & Vial 2002 (SOHO/SUMER),
  Abramenko *et al.* 2002–2005 (MDI),
  BVL06 (SUMER)

also in time series of the shell-model:



Buchlin 2006



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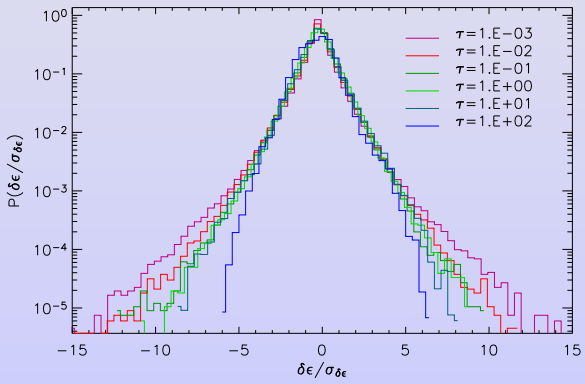


Buchlin 2006b

Acceleration in a turbulent field

Take a 3D snapshot of fields of MHD turbulence

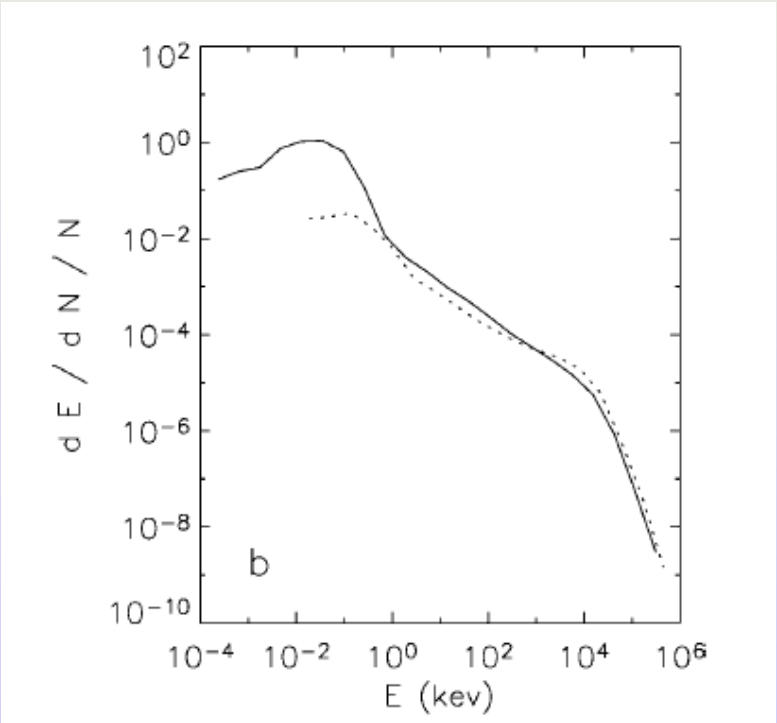
PARTICLE ACCELERATION IN STRESSED CORONAL MAGNETIC FIELDS

R. TURKMANI,[1] L. VLAHOS,[2] K. GALSGAARD,[3] P. J. CARGILL,[1] AND H. ISLIKER[2]

(ApJL 2005)

(see also M. Onofri,
or reconstruct the fields from a shell-model: see Lepreti *et al.* 2005),
and accelerate *test particles* in it.

- Fast and efficient acceleration
- Distributions of particle energies



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What can we tell from the comparison with observed distribution?

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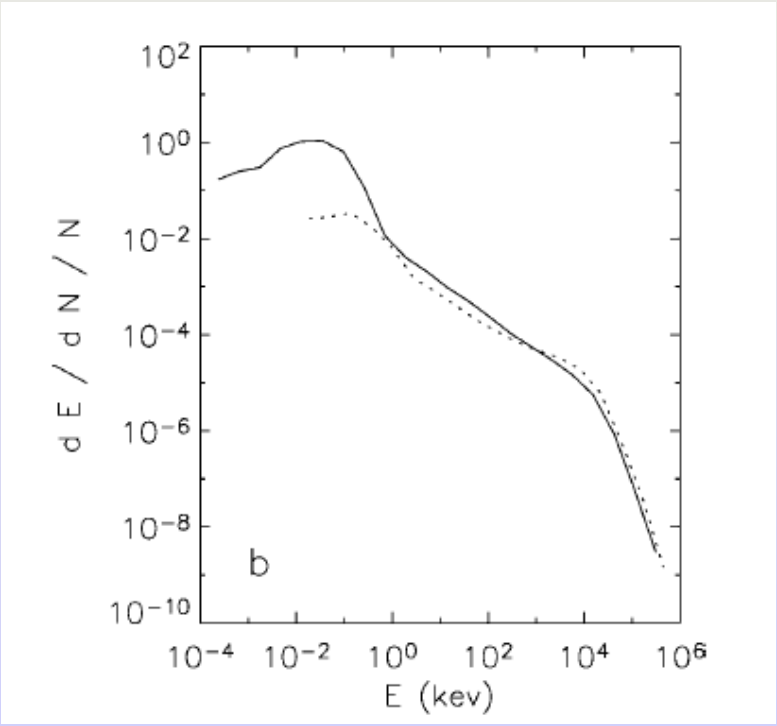

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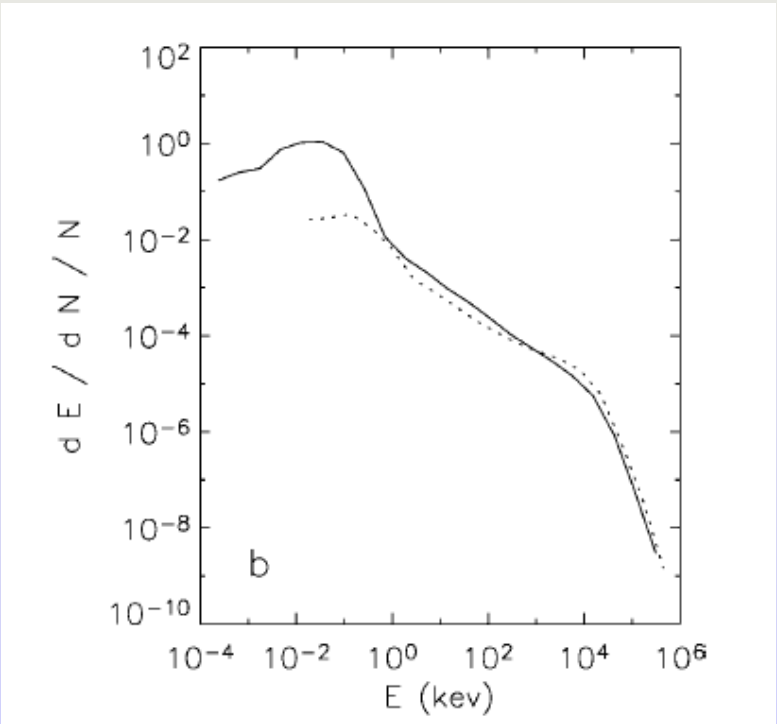

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Intermittency considered as being non-uniform scattering time (?)
$\longrightarrow$ fine structures and non-stationarity of particle distribution in space

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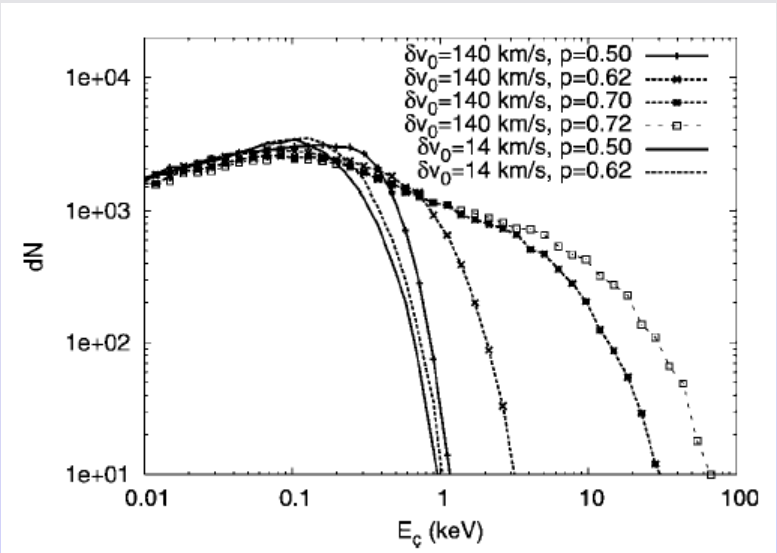
Simple *p*-model to have only intermittency as a parameter
$\longrightarrow$ Intermittency makes acceleration more effient



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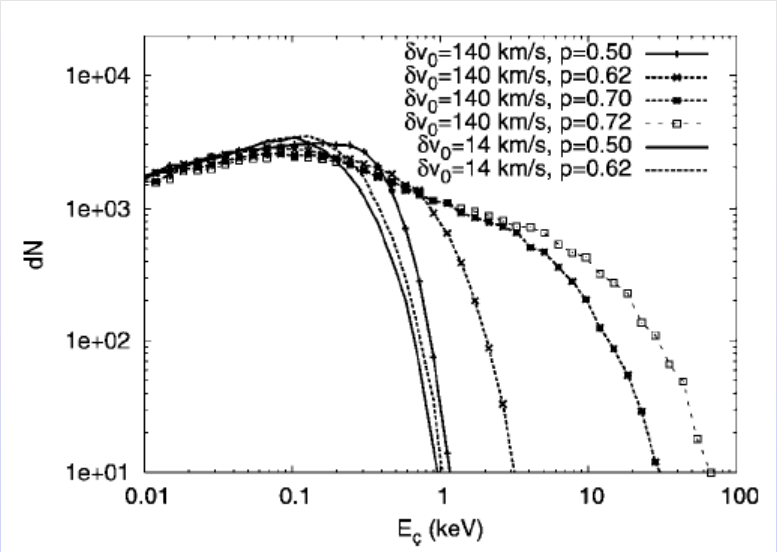

Décamp & Malara 2006

Discussion

Let's discuss some possible links and possible mechanisms between heating and acceleration.

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