``The role of helicity* in 3D turbulence is, in our opinion, still somewhat mysterious …'' *Chen, Chen & Eyink, 2003*

* *(kinetic)*

Modeling of helical flows

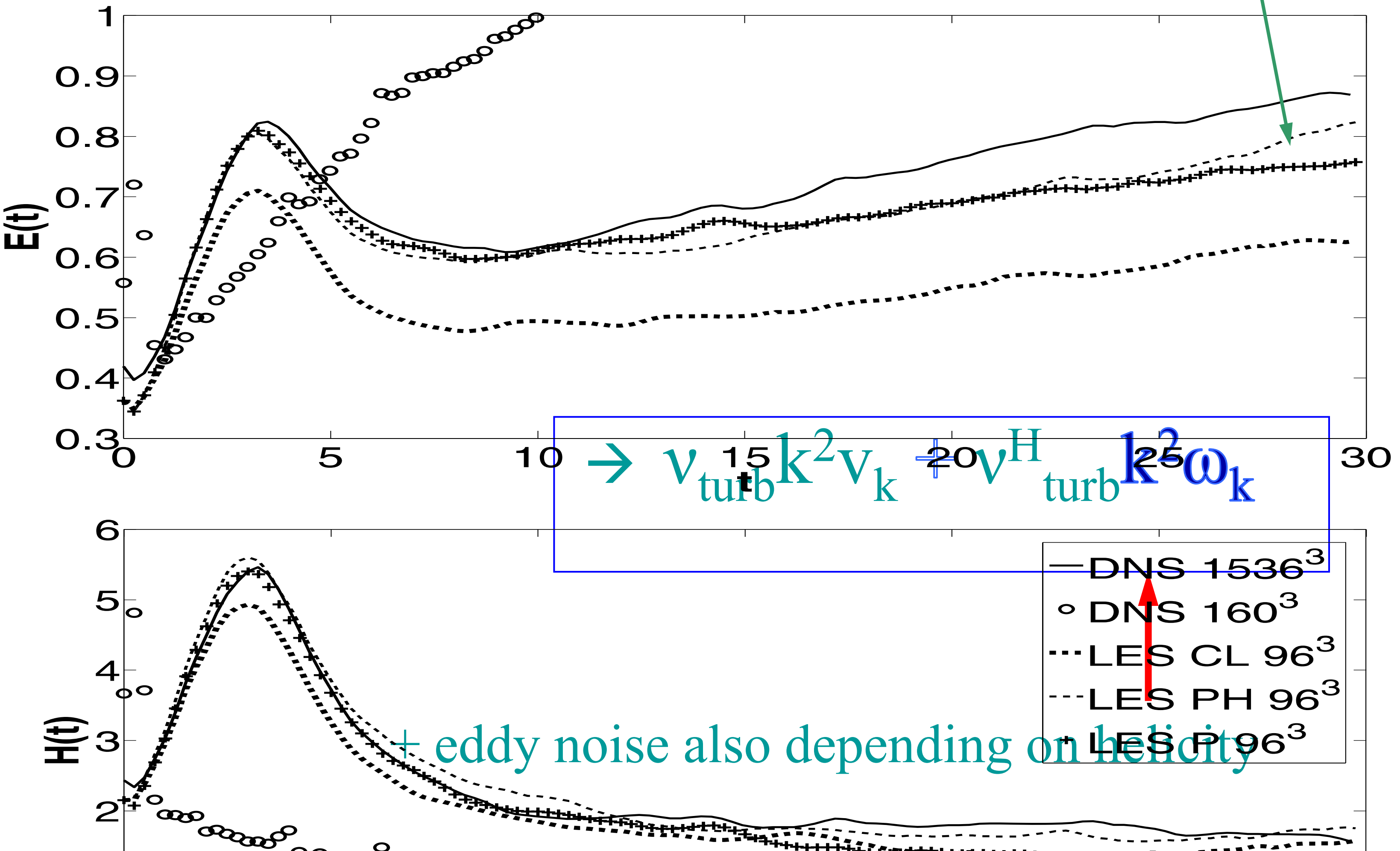
$$\tilde{\nu}^{>}(k|k_c,t) = \int\int_{\Delta^{>}} \frac{\theta_{kpq} S_{E_4}(k,p,q,t)}{2k^2 H(k,t)} dpdq$$

$$= \int\int_{\Delta^{>}} \theta_{kpq} \frac{1}{2k^2 q} z(1-y^2) H(q,t) dpdq.$$

$\rightarrow \nu_{turb} k^2 v_k + \nu^H{}_{turb} k^2 \omega_k$

+ eddy noise also depending on helicity

Modeling of helical flows



$\rightarrow \nu_{turb} k^2 v_k + \nu^H_{turb} k^2 \omega_k$

+ eddy noise also depending on helicity

Helicity

3D MHD, ν=η =0
Truncated system

Relaxation to
Gibbs ensemble
determined by the
3 invariants *(Frisch et al. JFM 1975)*

$E_T=E_V+E_M$
$H_C=<\mathbf{v.B}>$
$H_M=<\mathbf{A.B}>$

Relaxation to force-free
fields, including in the
presence of H_C

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Relaxation to force-free fields, including in the presence of H_C

$H_J(k) = k^2\, H_M(k)$

$H_C(k) \sim H_J(k) \sim H_V(k) \sim E_M(k)$

Relative energy and helicity
$E_R(k) = E_V(k) - E_M(k) < 0$
$H_R(k) = H_V(k) - k^2 H_M(k) < 0$

When $H \neq 0$

Cross correlation

3D MHD, ν=η =0

Truncated system

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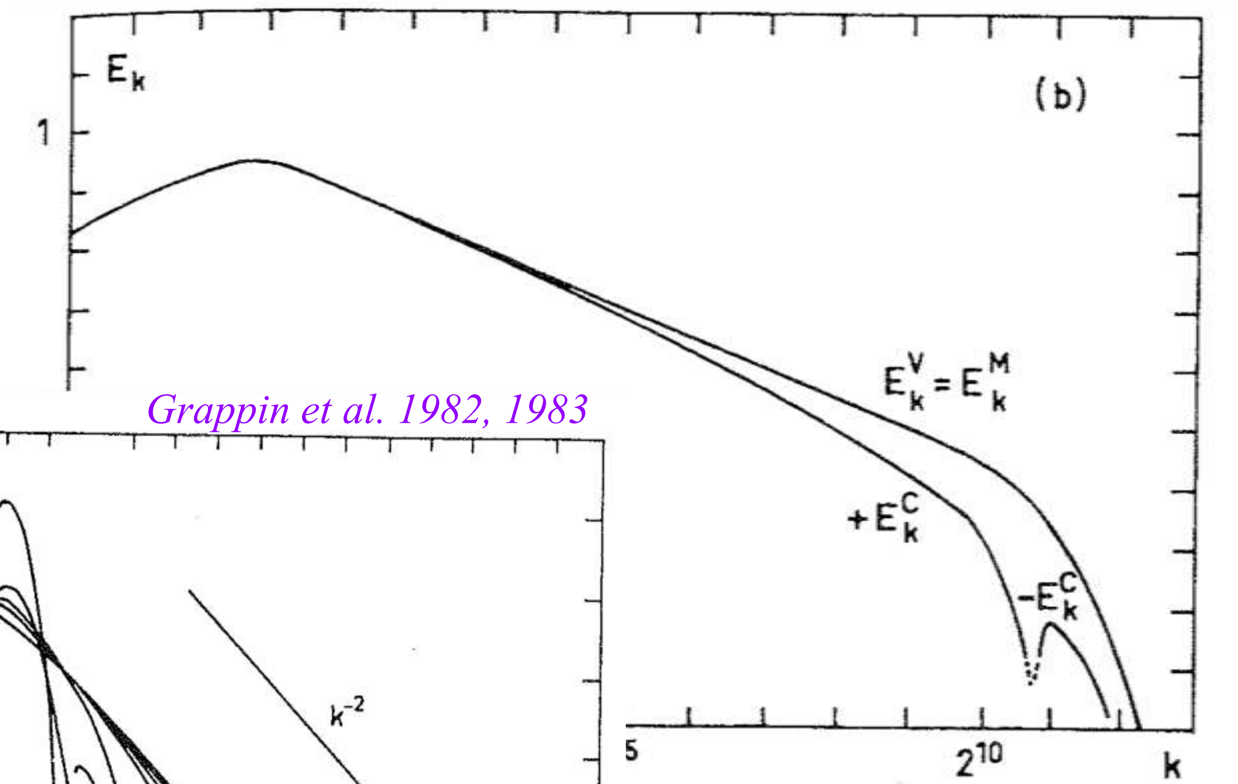
$E_T=E_V+E_M$

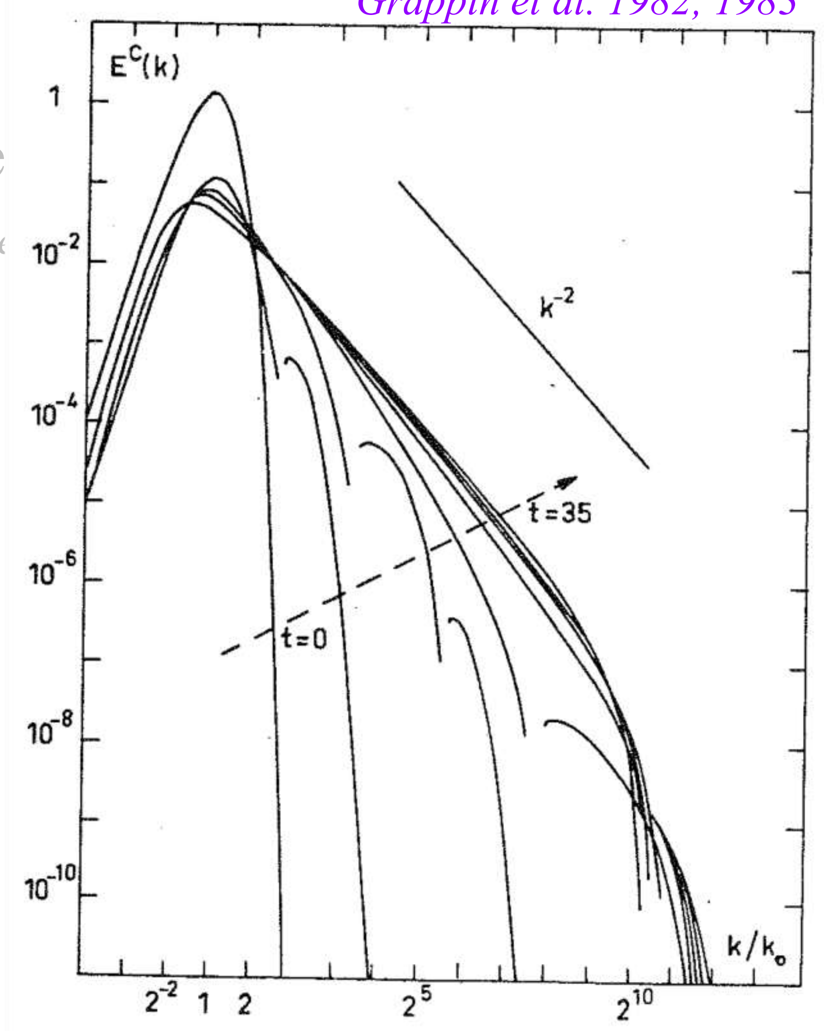
$H_C=<\mathbf{v.B}>$

$H_M=<\mathbf{A.B}>$

Relaxation to force-free fields, including in the presence of H_C



Grappin et al. 1982, 1983

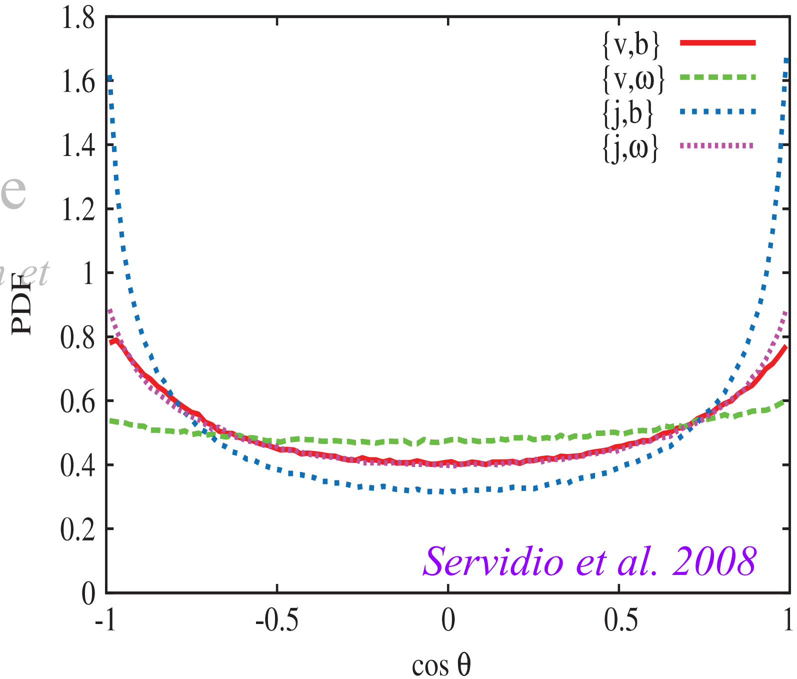


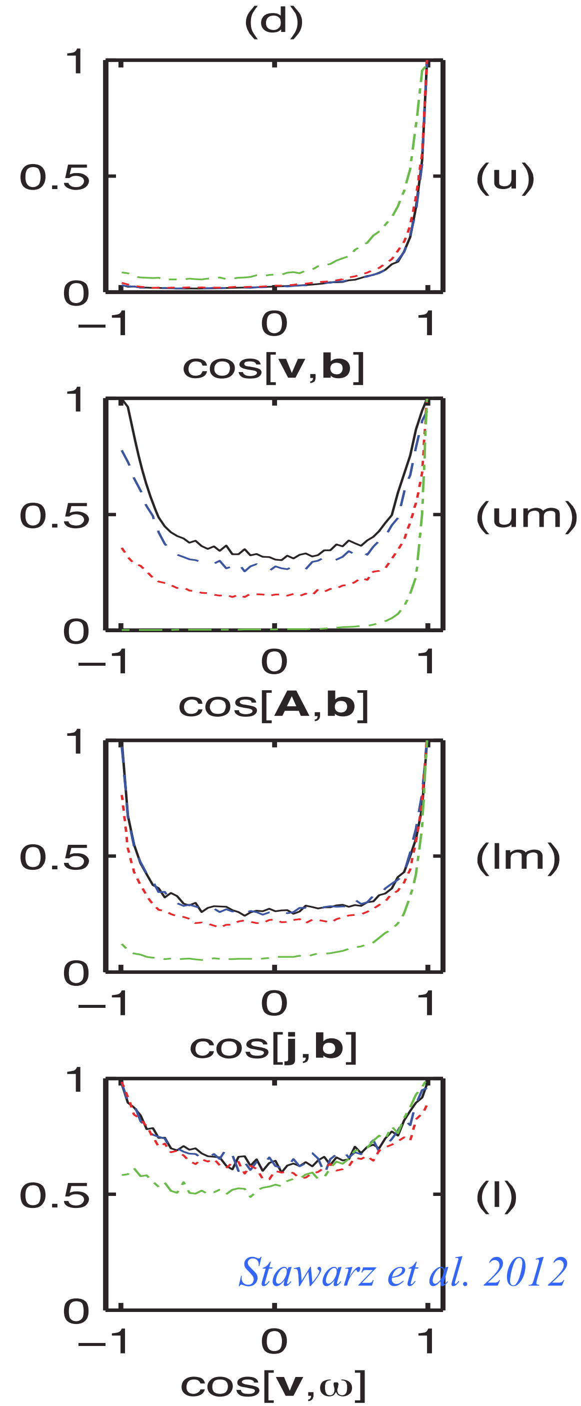
* Change of sign at the dissipation wvnb
- -2 law compatible with angle ~ $\theta^{1/4}$
- What happens at high correlation?

Alignments

3D MHD, ν=η =0
Truncated system

Relaxation to Gibbs ensemble determined by the 3 invariants *(Frisch et al. JFM 1975)*





$E_T=E_V+E_M$
$H_C=\langle \mathbf{v.B} \rangle$
$H_M=\langle \mathbf{A.B} \rangle$

Relaxation to force-free fields, including in the presence of H_C

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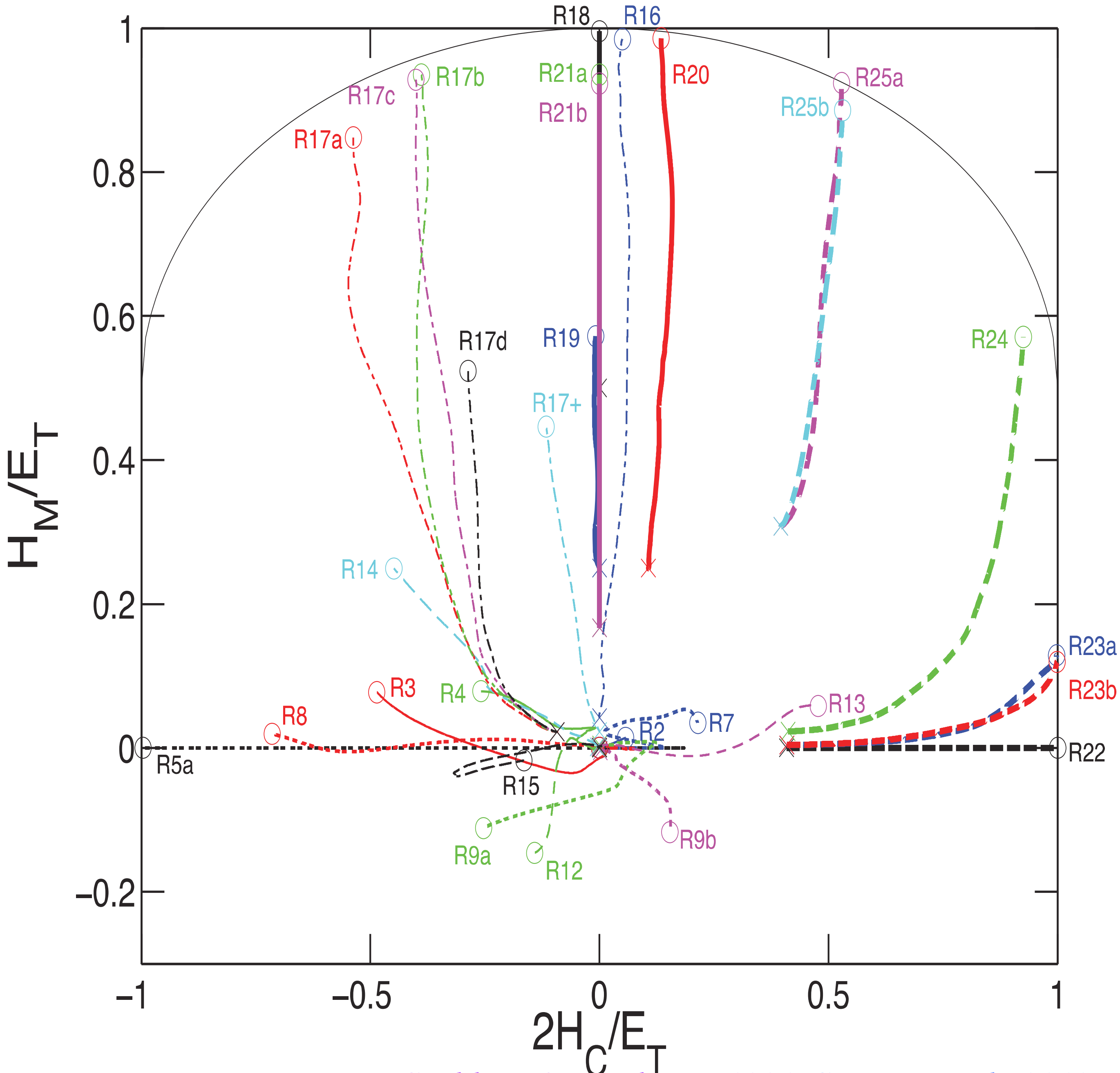

Stribling & Matthaeus 1991, Stawarz et al., 2012

Helicity

3D MHD, ν=η =0
Truncated system

Relaxation to Gibbs ensemble determined by the 3 invariants *(Frisch et al. JFM 1975)*

$E_T = E_V + E_M$
$H_C = \langle v.B \rangle$
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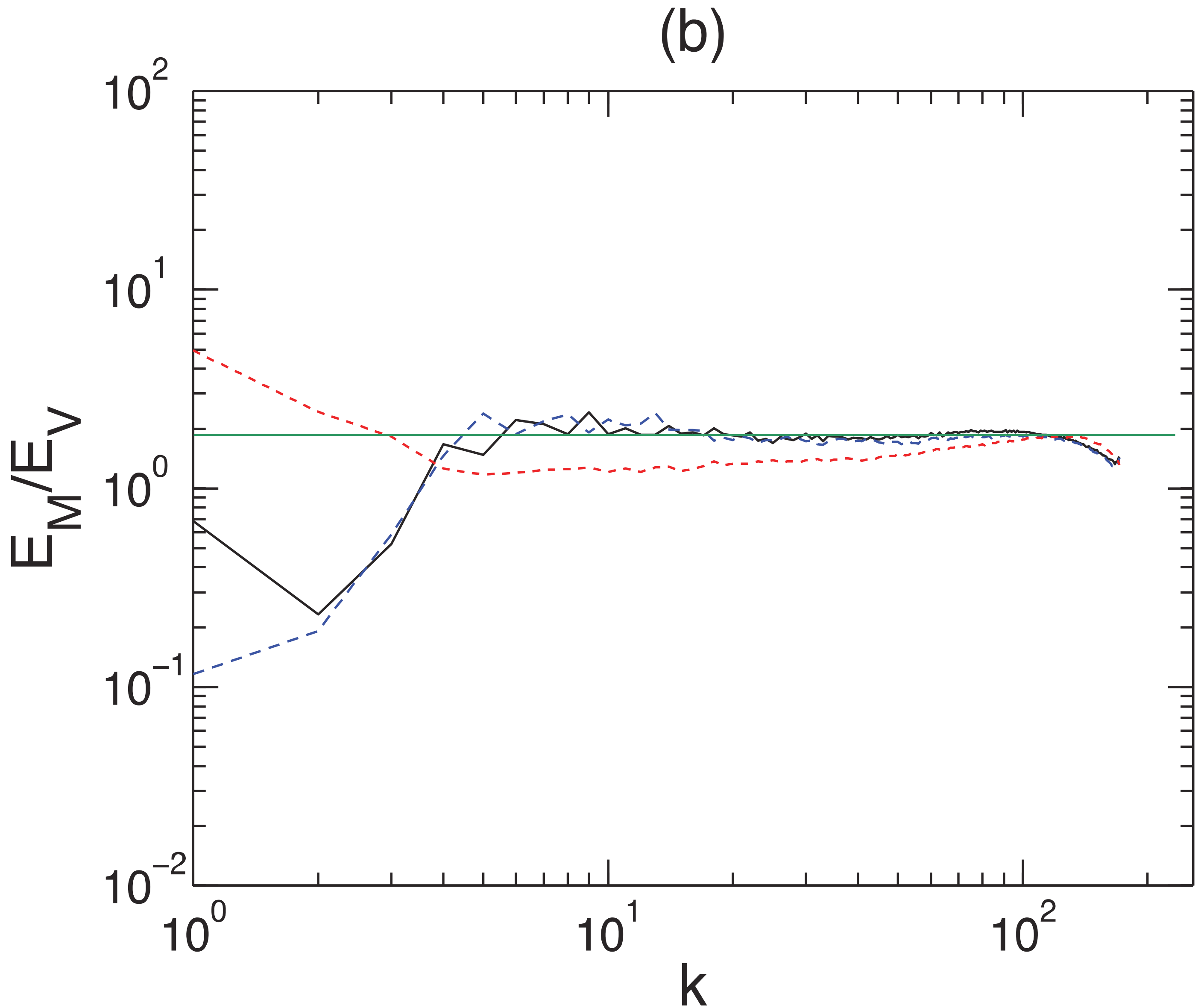
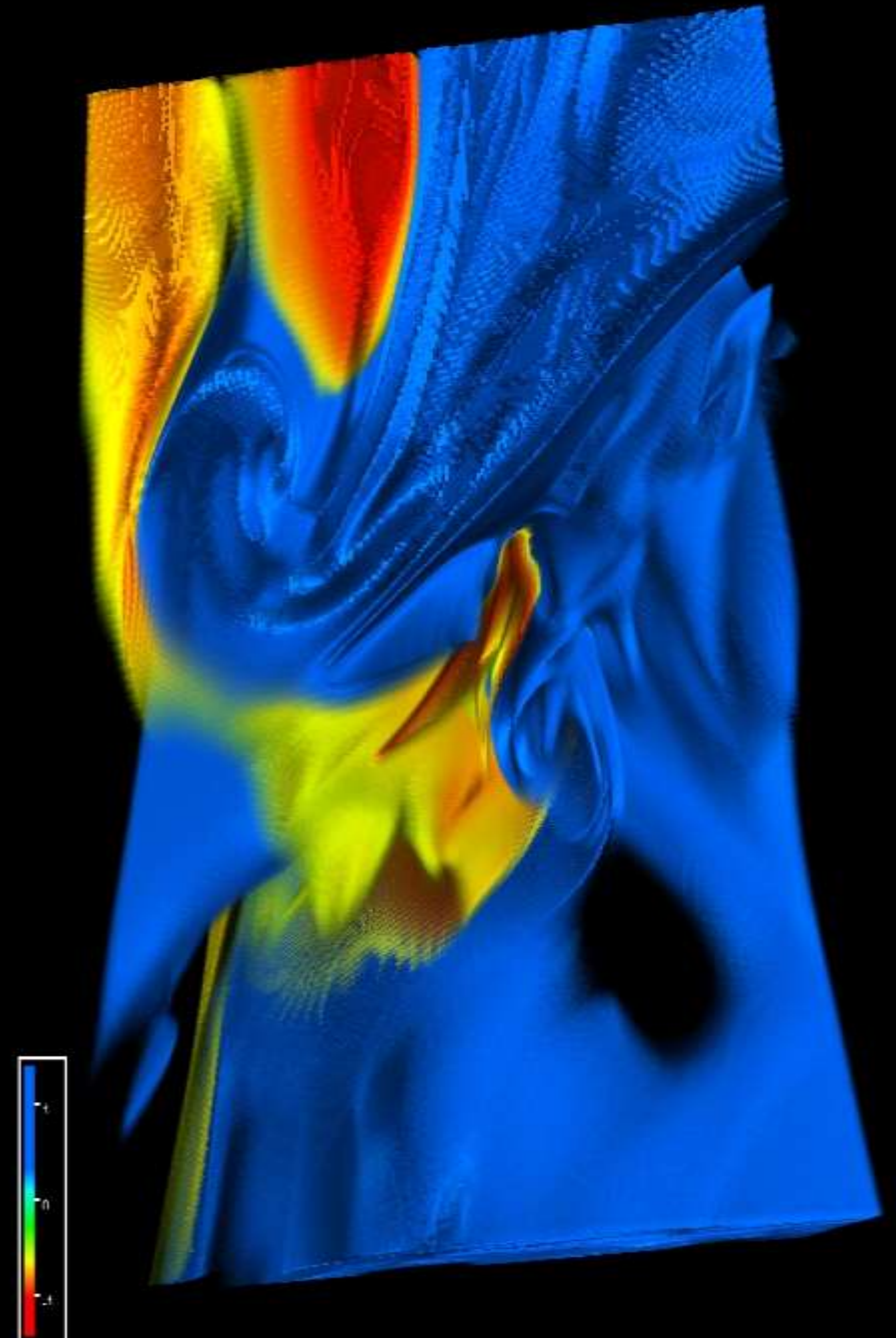
Relaxation to force-free fields, including in the presence of H_C



Stawarz et al., 2012

J^2 , *early times*



Magnetic helicity H_M , *normalized*

Dimensional analysis: $H_M(k) \sim k^{-2}$

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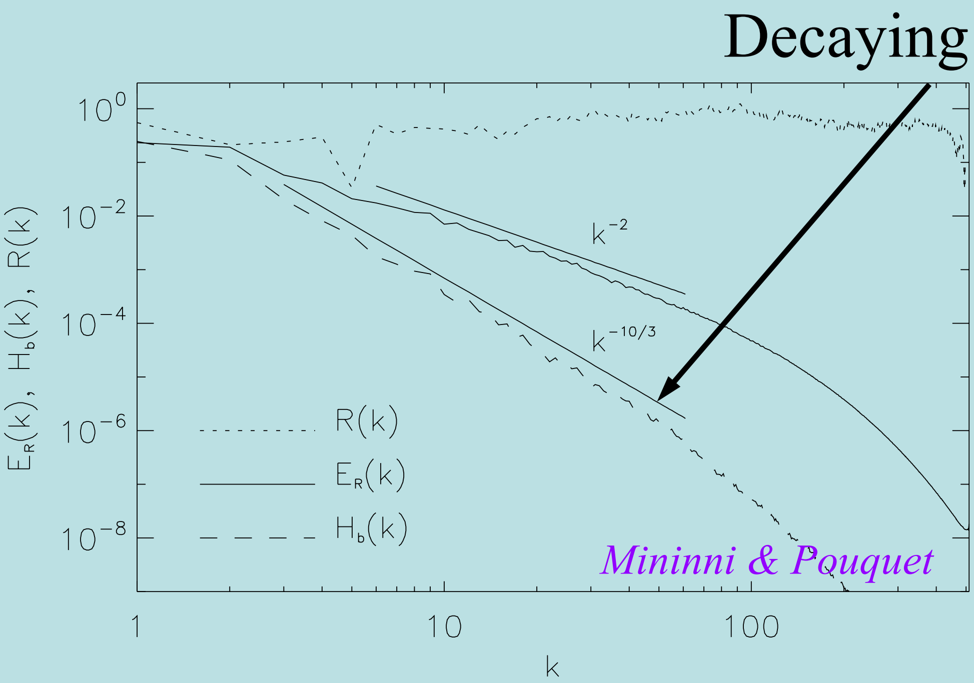
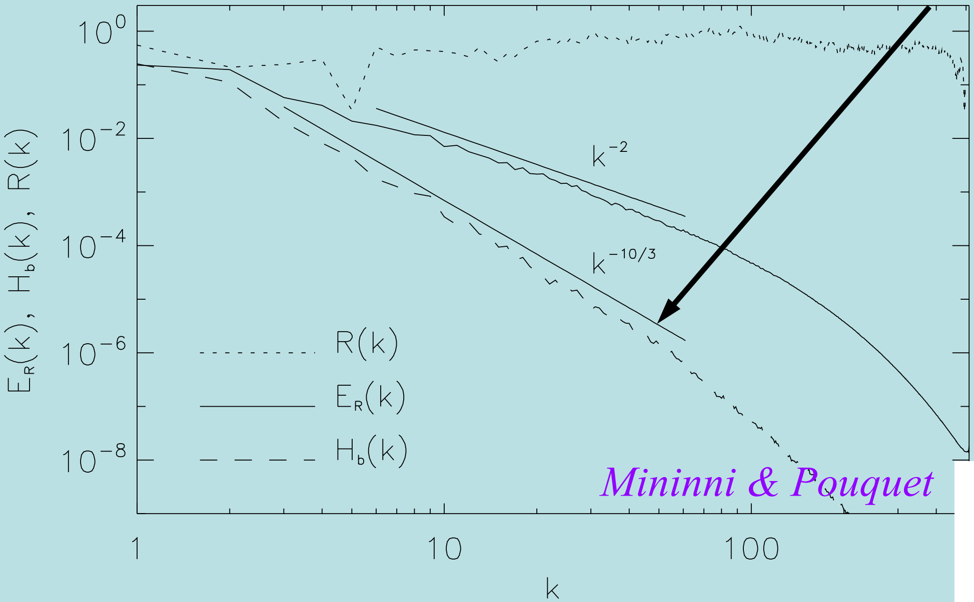
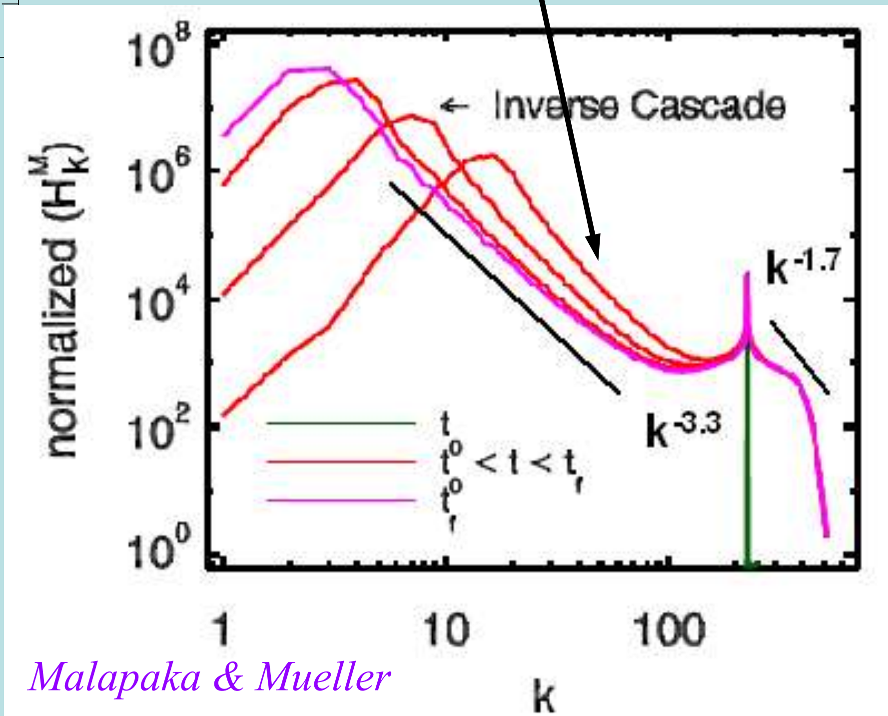


Dimensional analysis: $H_M(k) \sim k^{-2}$

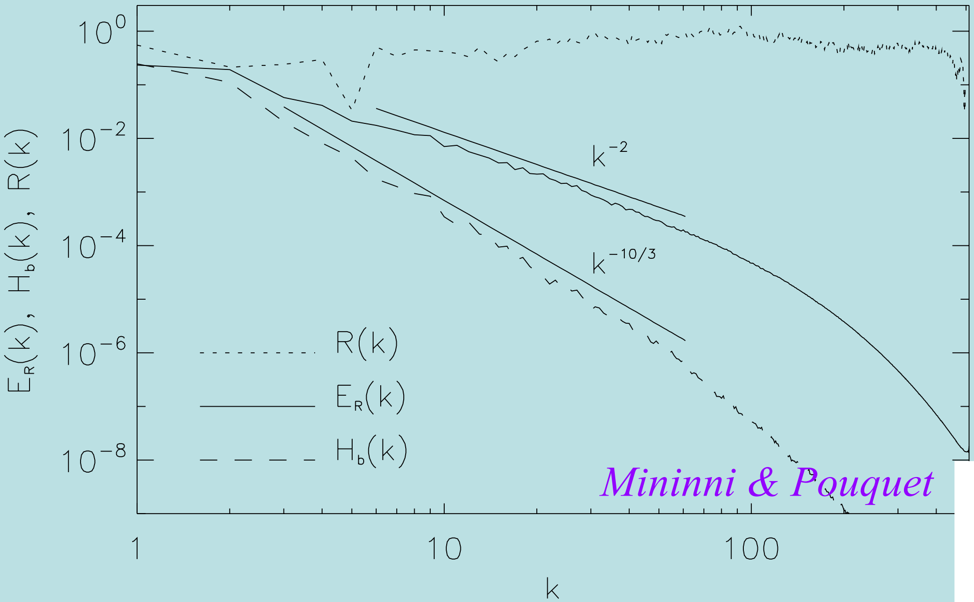
Decaying and forced runs: $H_M(k) \sim k^{-3.3}$





$$H^K_k \sim \left(\frac{E^K_k}{E^M_k}\right)^\gamma k^2 H^M_k, \quad \gamma = 1$$

Dimensional analysis: $H_M(k) \sim k^{-2}$



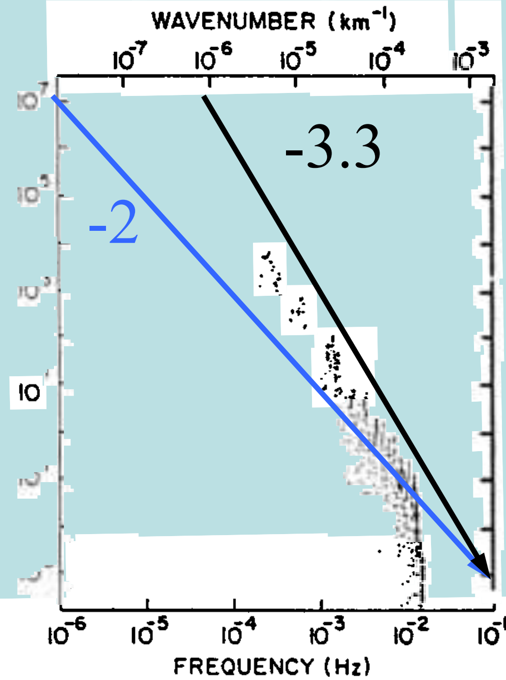
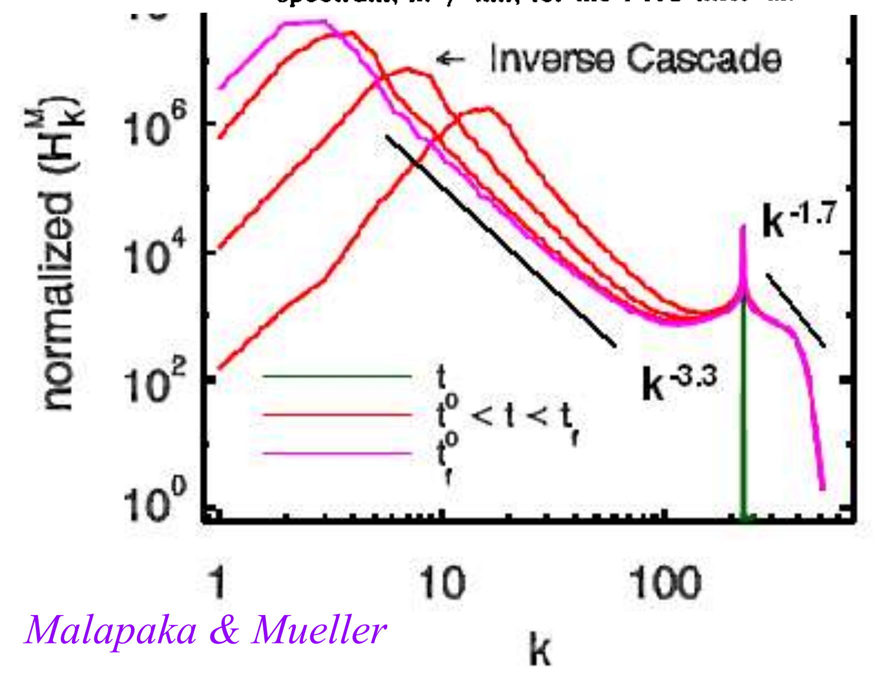
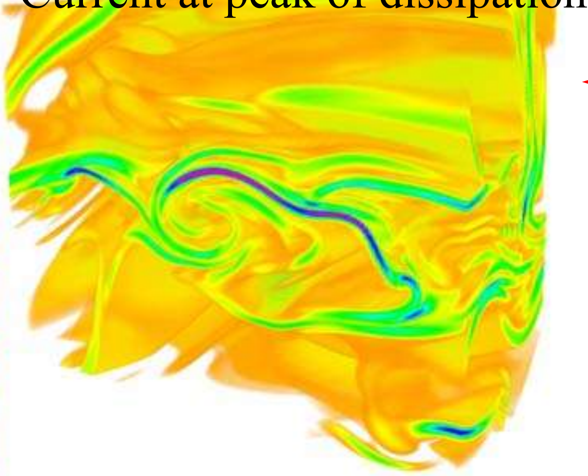


Fig. 4*a*. Scatter plot of the positive values of the magnetic helicity spectrum, in γ^2 km, for the 1 AU interval.

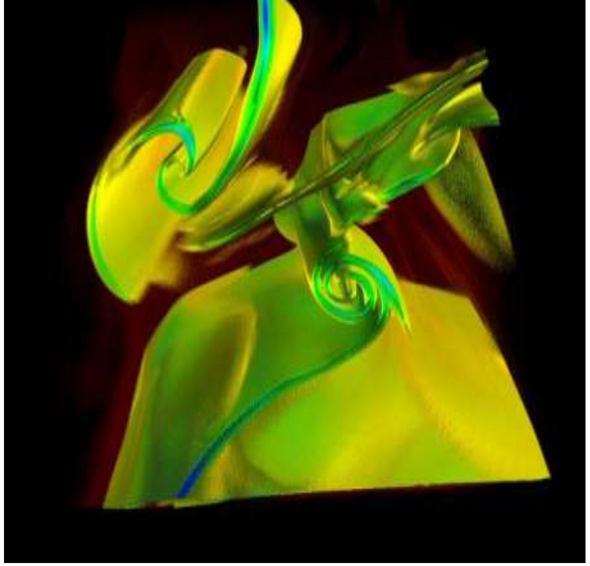


$$H_k^K \sim \left(\frac{E_k^K}{E_k^M}\right)^{\gamma} k^2 H_k^M, \quad \gamma = 1$$

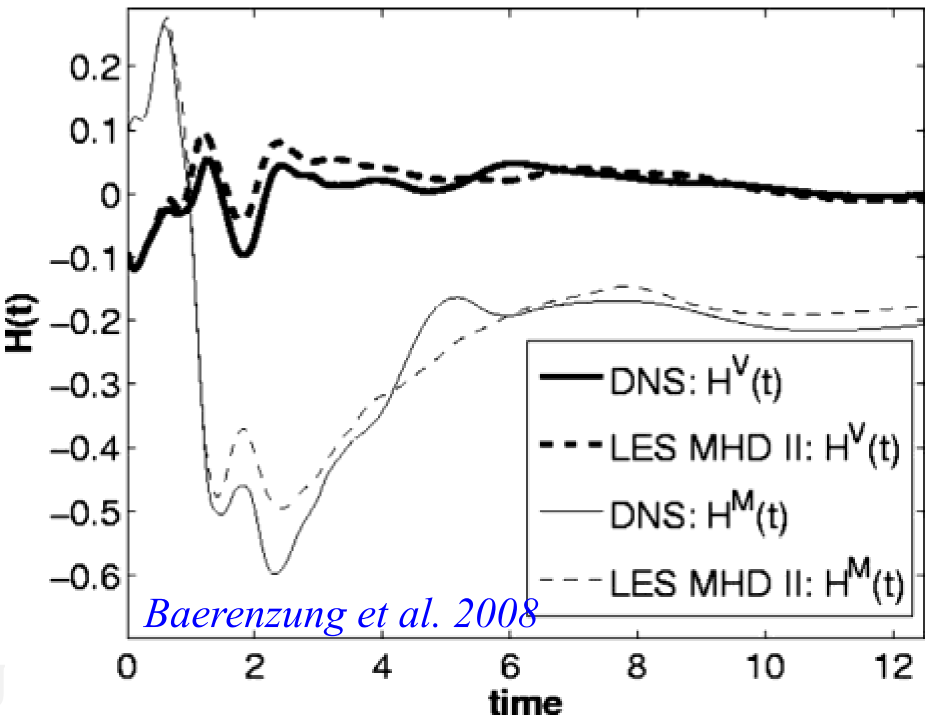
Current at peak of dissipation



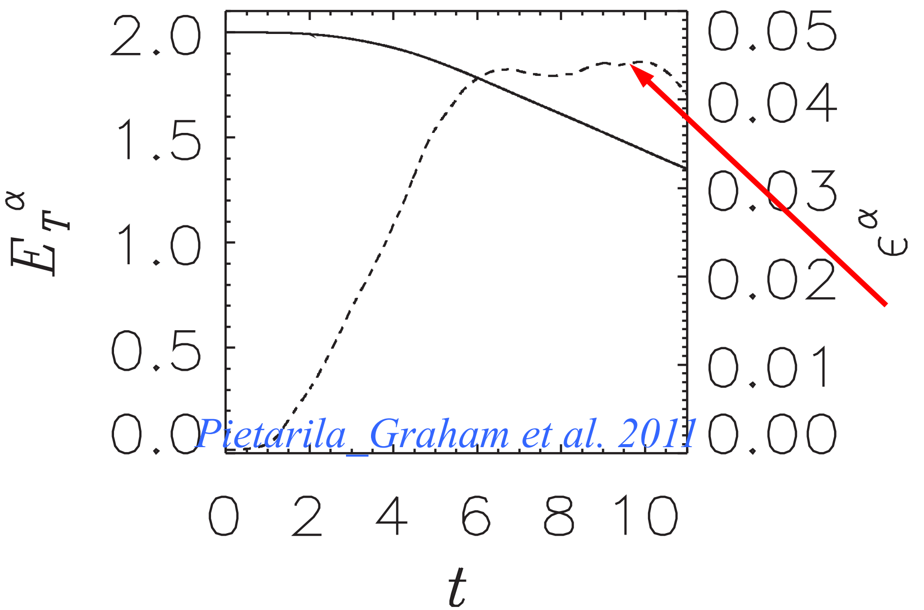
Modeling



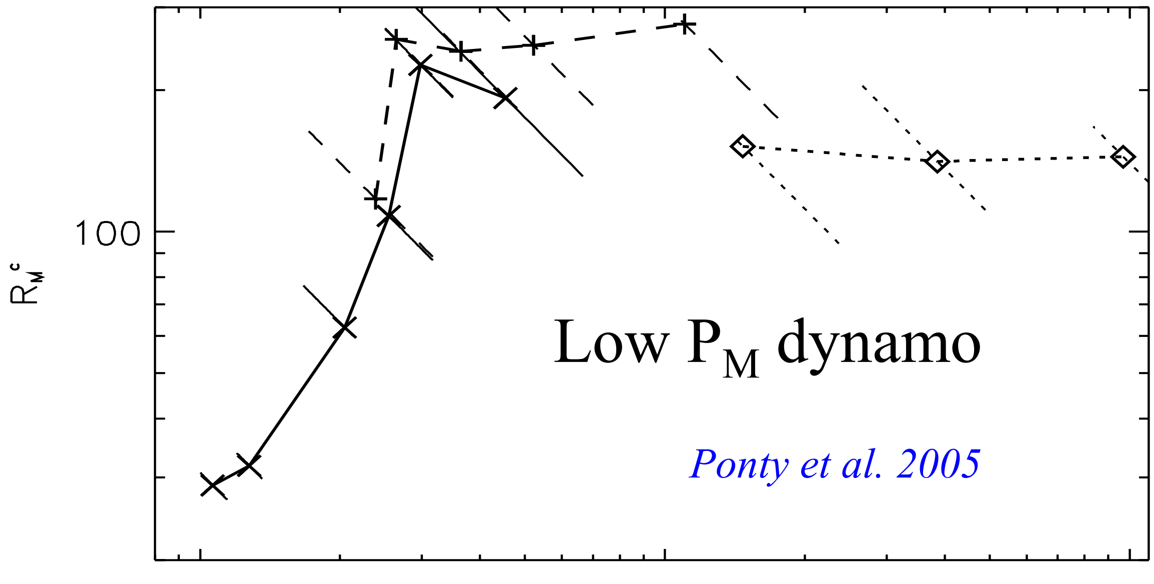
Helical EDQNM+ model



Lagrangian model *(filter)*

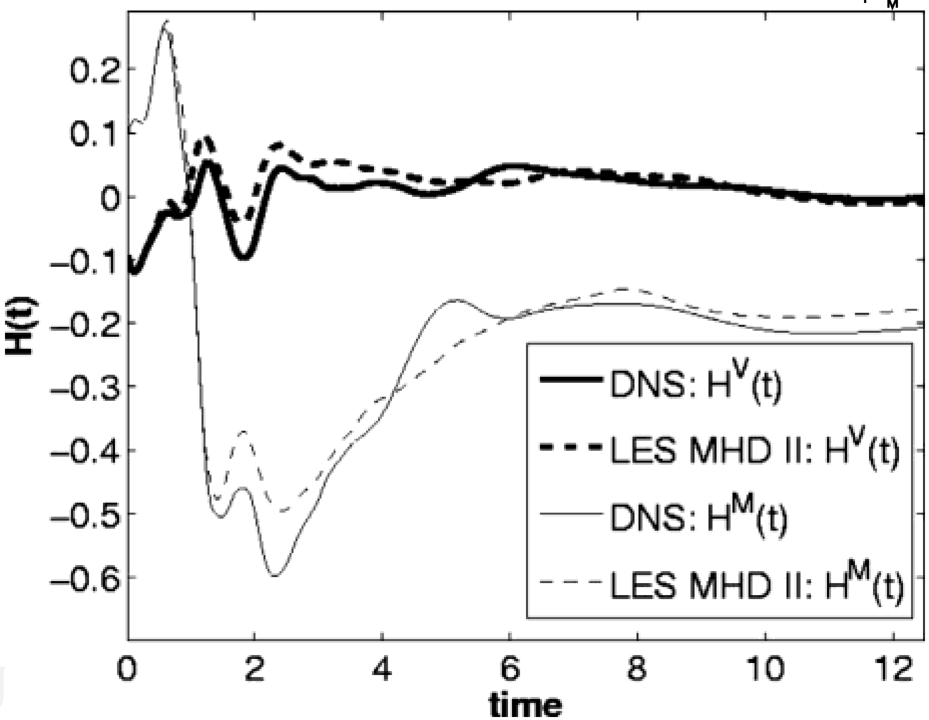


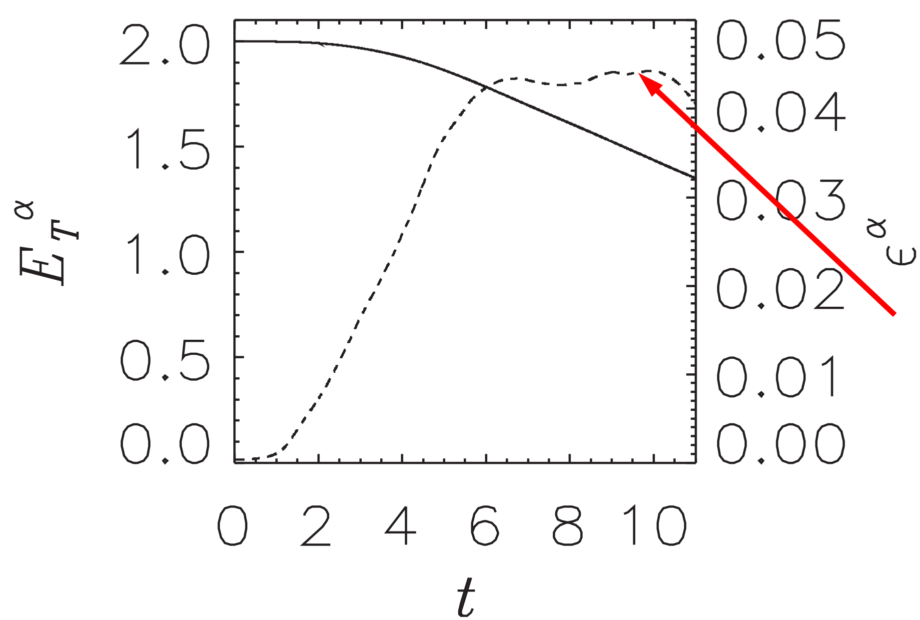
Lagrangian model, 6000^3 equiv.



Helical EDQNM model+

Lagrangian model *(filter)*





Lagrangian model, 6000^3 equiv.

Magnetic helicity $H_M = < A.B >$

* Invariant of the ideal MHD equations
* Not definite positive
* Relaxation to force-free fields

What is the large-scale dynamics of H_M?
How does H_M behave at small-scale?
Is there a connection between small-scale and large scales?

Where/how does it play a role *(e.g., equipartition, or nonlinear dynamo)*?
Does it play a role in reconnection?
What is the relationship between cross and magnetic helicity?
What about kinetic helicity?

What happens when plasma effects are added (e.g., Hall MHD)?

How can it be modeled?

What would be a ``big" run to progress and to test LES?