Multifractals. Eulerian and Lagrangian Statistics

Vienna 2008

Luca Biferale
Dept. of Physics and INFN, University of Tor Vergata, Rome.
biferale@roma2.infn.it

ICTR Collaboration

Eulerian Turbulence

$$\partial_t \boldsymbol{v} + \boldsymbol{v} \cdot \nabla \boldsymbol{v} = -\nabla p + \nu \Delta \boldsymbol{v} + \boldsymbol{f}$$

8.5 Intermittency models based on the velocity 153

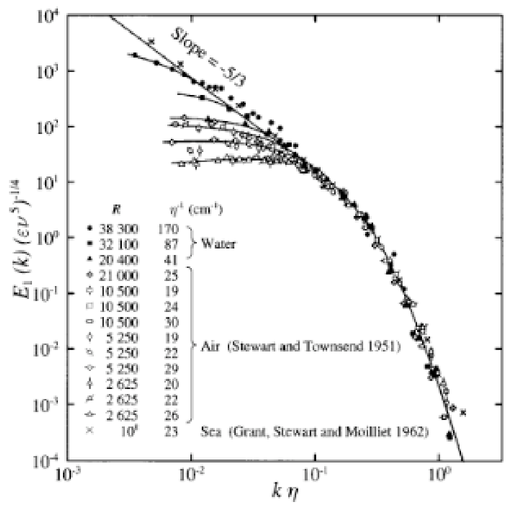


Fig. 8.14. Normalized longitudinal velocity spectrum in the time domain according to different authors (Gibson and Schwarz 1963).

$$\eta \ll r \ll L_0$$

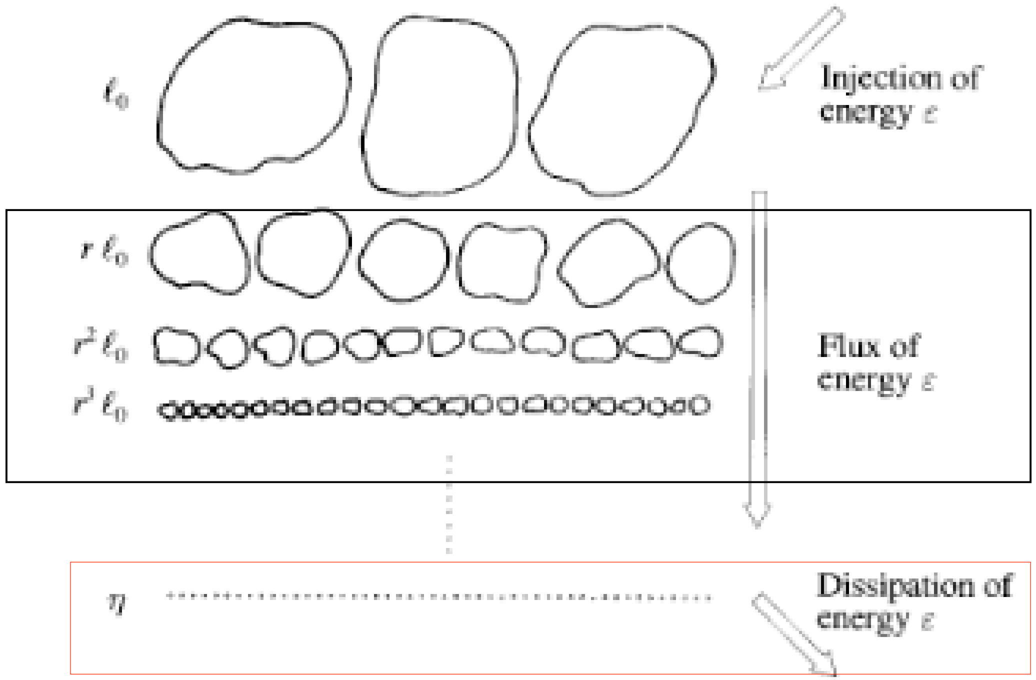
Inertial range

$$\eta = (\nu^3/\varepsilon)^{1/4}$$

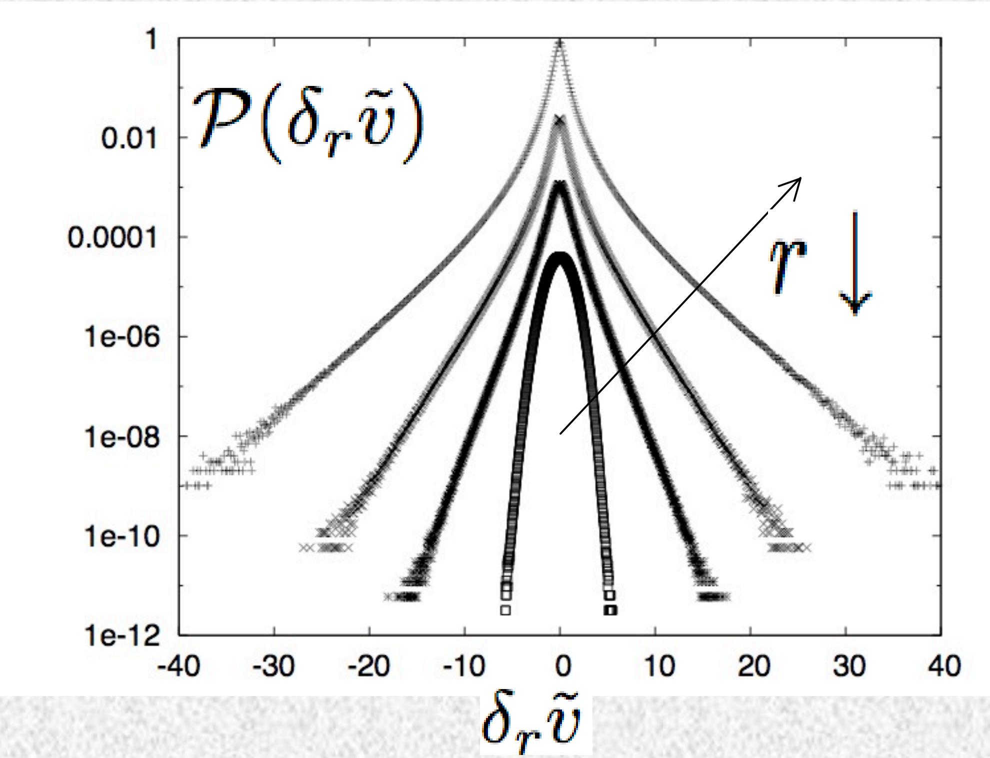
$$\tau_\eta = (\nu/\varepsilon)^{1/2}$$

Energy flux

104 *Phenomenology of turbulence in the sense of Kolmogorov 1941*



INTERMITTENCY



[DNS $Re_\lambda = 600$
2048^3 Benzi et al 2007,
PRL, submitted]

$$\delta_r \tilde{v} = \frac{\delta_r v}{\langle(\delta_r v)^2\rangle^{1/2}}$$

$$F_4(r) = \frac{\langle(\delta_r v)^4\rangle}{\langle(\delta_r v)^2\rangle^2}$$

$$F_4(r) \neq const.$$

The “Standard Model”

$$S_p(r) = \langle[\boldsymbol{v}(\boldsymbol{x}+\boldsymbol{r}) - \boldsymbol{v}(\boldsymbol{x})]^p\rangle \qquad \eta \ll r \ll L_0$$

$$\delta_r v \sim v_0 (\frac{r}{L_0})^{h(x)} \qquad \mathcal{P}_h(r) \sim (\frac{r}{L_0})^{3-D(h)}$$

$$S_p(r) = \langle(\delta_r v)^p\rangle \sim \langle v_0^p\rangle \int_I dh \left(\frac{r}{L_0}\right)^{hp+3-D(h)}$$

$$S_p(r) \sim \left(\frac{r}{L_0}\right)^{\zeta_p}$$

Parisi-Frisch 1983

Benzi, Paladin, Parisi & Vulpiani1984

$$\zeta_p = \inf_h (hp + 3 - D(h))$$

$$D(h)$$

$$F_4(r) \sim r^{\zeta(4)-2\zeta(2)}$$

CONNECTION CUMULANTS -- STRUCTURE FUNCTIONS

$$S_p(r) = \langle (\delta_r v)^p \rangle$$

$$\kappa_n(r) = \langle (log|\delta_r v|)^n \rangle$$

$$S_p(r) = \exp \sum C_n(r) \frac{p^n}{n!}$$

from Mordant et al NJP 04

$\zeta(p)$

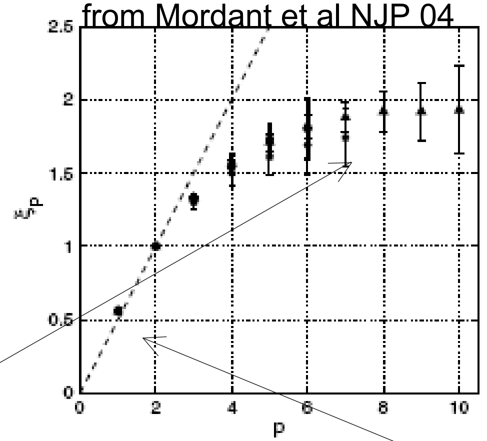


Figure 25. Structure function relative exponents ξ_p: (······) experiment; (▲) DNS $R_\lambda = 75$; (∗) DNS $R_\lambda = 140$. The dashed line is a K41 prediction for Lagrangian exponents.

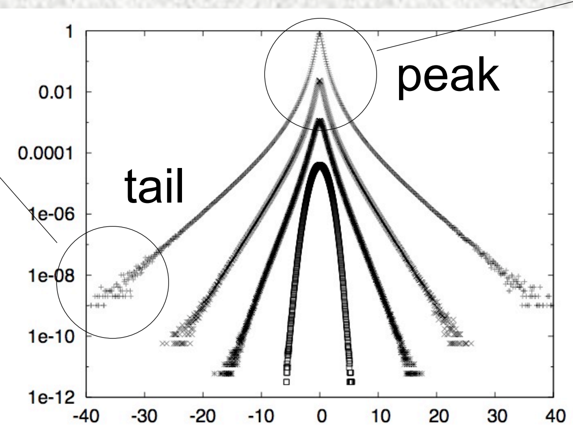
$$C_1(r) = \kappa_1(r)$$
$$C_2(r) = \kappa_2(r) - (\kappa_1(r))^2$$
$$C_n(r) = \kappa_n(r) + f(\kappa_{n-1} \ldots)$$

[Delour Muzy Arneodo EPJB 2001]

$$C_n(r) \sim c_n log(r)$$

$$S_p(r) \sim \left(\frac{r}{L_0}\right)^{\zeta_p}$$

$$c_n = \frac{d^n}{dp^n} \zeta(p)|_{p=0}$$



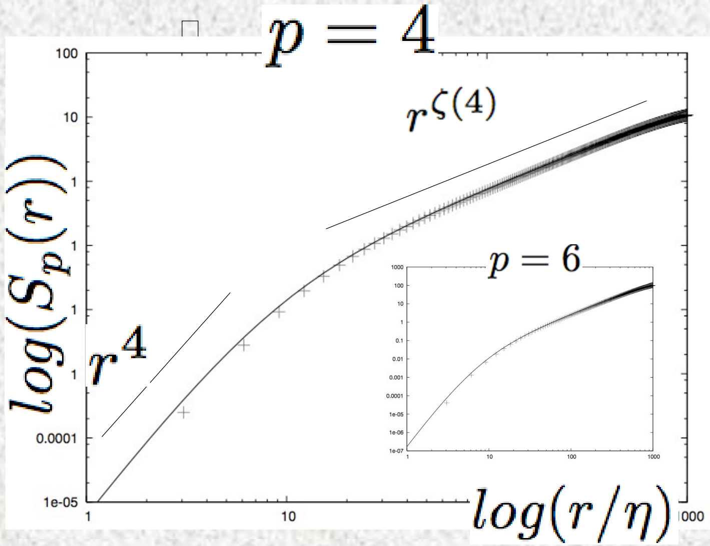
PHYSICS OF FLUIDS VOLUME 14, NUMBER 3 MARCH 2002

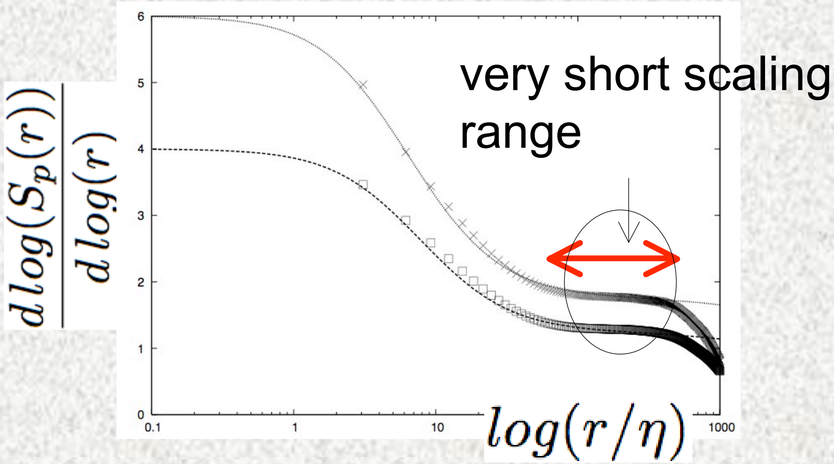
Velocity field statistics in homogeneous steady turbulence obtained using a high-resolution direct numerical simulation

Toshiyuki Gotoh[a]
Department of Systems Engineering, Nagoya Institute of Technology, Showa-ku, Nagoya 466-8555, Japan

Daigen Fukayama
Information and Mathematical Science Laboratory, Inc., 2-43-1, Ikebukuro, Toshima-ku, Tokyo 171-0014, Japan

Tohru Nakano
Department of Physics, Chuo University, Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan





$$S_p(r) \sim r^{\zeta(p)}$$

$$\frac{d\,log(S_p(r))}{d\,log(r)} \sim \zeta(p)$$

$$\zeta_p = \inf_h \left(hp + 3 - D(h)\right)$$

REMOVING FOCUS ON PURE POWER LAW:

TYPICALLY NEVER OBSERVED IN DNS OR CONTROLLED LABORATORY EXPERIMENTS (MODERATE REYNOLDS NUMBERS)

AT HIGH REYNOLDS NUMBERS (ABL, SOLAR WIND ETC..) CONTAMINATION FROM ANOSOTROPIES OR/AND NON-HOMOGENEITIES (DIFFICULT TO CONTROL)

IN PRESENCE OF FINITE INERTIAL RANGE EXTENSION: WHAT TO CONTROL? HOW TO TEST QUANTITATIVELY INFLUENCE/IMPORTANCE OF VISCOUS AND INTEGRAL SCALES?

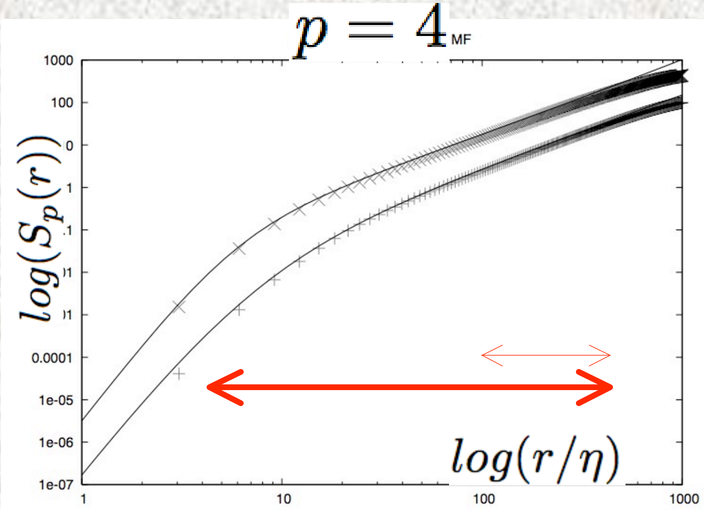
$$\eta \ll r \ll L_0$$

$$\eta \leq r \ll L_0$$

HOW TO CHECK D(h) QUANTITATIVELY CONSIDERING THE NATURAL LIMITATIONS IN THE INERTIAL RANGE EXTENSIONS?

LOOK FOR THE EFFECTS OF VISCOUS SCALES.
THE SO-CALLED: INTERMEDIATE DISSIPATIVE RANGE

AND TRY TO TEST MULTIFRACTAL PREDICTION ALSO ON THIS EXTENDED RANGE OF SCALES



RAPID COMMUNICATIONS

PHYSICAL REVIEW A VOLUME 35, NUMBER 4 FEBRUARY 15, 1987

Degrees of freedom of turbulence

Giovanni Paladin* and Angelo Vulpiani*

The dissipation scale η can be now determined by imposing that the Reynolds number related to an eddy of length scale l is of order 1,

$$Re(\eta)=\eta\delta_\eta v/\nu\sim\mathcal{O}(1) \quad (5)$$

This is equivalent to the requirement that the dissipative (linear) term of the Navier Stokes equations is able to compete with the nonlinear transfer term.

Inserting Eq. (3) in Eq. (5) we obtain

$$\eta(x)\sim Re^{-1/(1+h(x))} \quad (6)$$

$$Re(r)=\frac{r\,\delta_r v}{\nu}$$

$$\delta_r v\sim v_0\left(\frac{r}{L_0}\right)^{h(x)}$$

PHYSICAL REVIEW A VOLUME 42, NUMBER 12 15 DECEMBER 1990

Multifractal scaling of velocity derivatives in turbulence

Mark Nelkin*

VOLUME 67, NUMBER 17 PHYSICAL REVIEW LETTERS 21 OCTOBER 1991

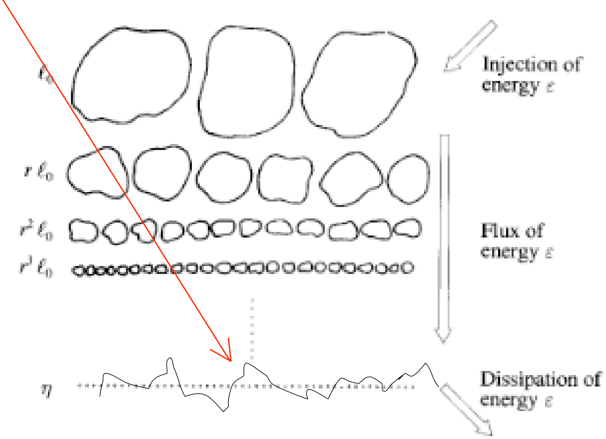
Multifractality in the Statistics of the Velocity Gradients in Turbulence

R. Benzi and L. Biferale
Dipartimento di Fisica, Università "Tor Vergata," via E. Carnevale, I-00173 Roma, Italy

G. Paladin and A. Vulpiani
Dipartimento di Fisica, Università dell'Aquila, I-67010 Coppito, L'Aquila, Italy

M. Vergassola

104 *Phenomenology of turbulence in the sense of Kolmogorov 1941*



EUROPHYSICS LETTERS 1 March 1991

Europhys. Lett., 14 (5), pp. 439-444 (1991)

A Prediction of the Multifractal Model: the Intermediate Dissipation Range.

U. FRISCH (*) and M. VERGASSOLA (*) (**)

$$S_2(l) = \langle v_l^2 \rangle \sim \int_{\eta(h) < l} \mathrm{d}\mu(h)\, l^{2h+3-D(h)}.$$

The prediction of universal scaling of multifractal type for the energy spectrum can be tested experimentally.

Recently, Gagne and Castaing [16] have analysed a wide sample of turbulence data with Reynolds numbers ranging from (roughly) 10^3 to 10^7. Remarkable agreement with scaling of multifractal type is obtained over the entire range of available scales. Traditional turbulence measurements involve probes with a length of one millimeter or more which can resolve only the beginning of the intermediate dissipation range. Multifractality predicts that there is considerable life in turbulence well below one-millimeter scales. Smaller probes or high-resolution nonintrusive techniques (^{5}) should be developed to meet the challenge.

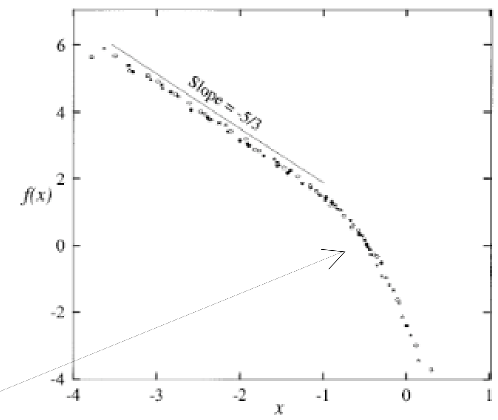


Fig. 8.15. Data in the time domain from nine different turbulent flows with R_λs ranging from 130 to 13000, plotted in log–log coordinates. The wavenumber (horizontal) and the energy spectrum (vertical) have been divided by $\ln(R_\lambda/R_*)$ with $R_* = 75$ and the resulting curves have been shifted to give the best possible superposition (Gagne and Castaing 1991).

$$\frac{\delta_\eta v\, \eta}{\nu} \sim \mathcal{O}(1) \qquad \eta(h) \sim Re^{-\frac{1}{1+h}}$$

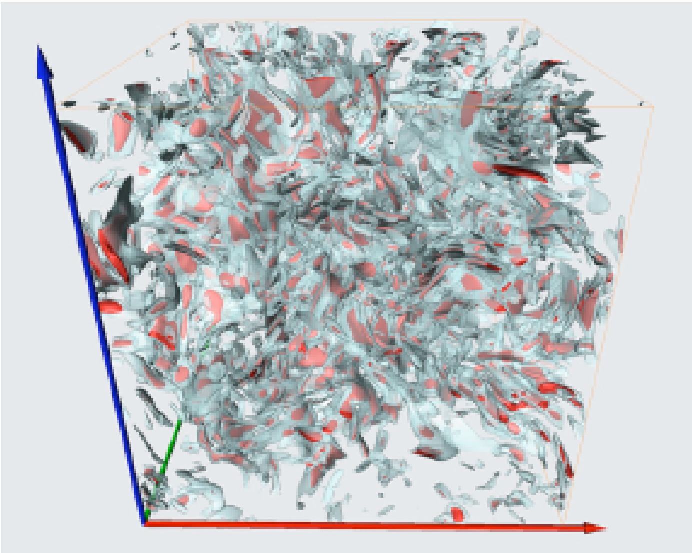
A Letters Journal Exploring the Frontiers of Physics

December 2007

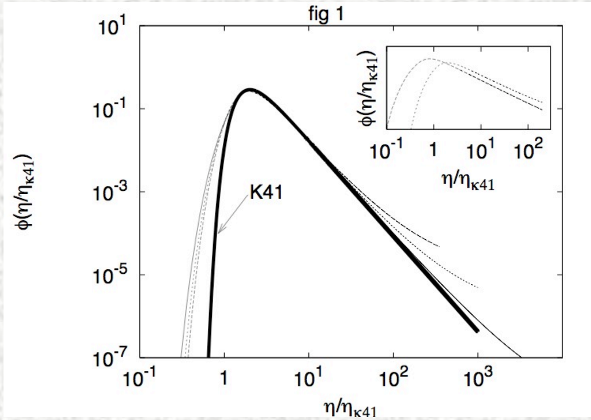
EPL, **80** (2007) 54001
doi: 10.1209/0295-5075/80/54001

www.epljournal.org

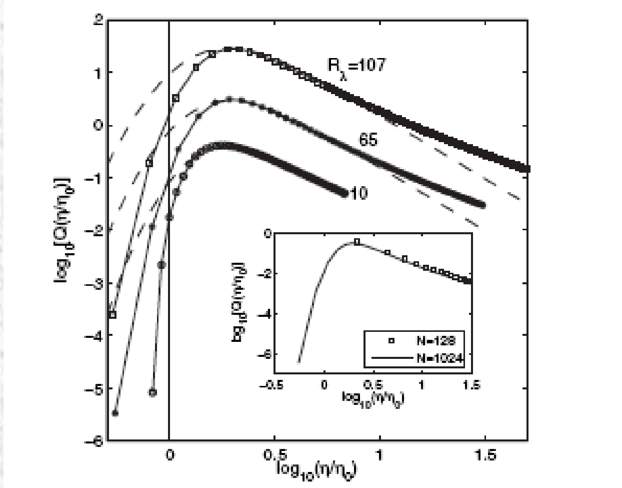
Sub-Kolmogorov-scale fluctuations in fluid turbulence



$$\frac{\delta_\eta v\, \eta}{\nu} \sim \mathcal{O}(1)$$



MF prediction
[Biferale PoF submitted]



PHYSICAL REVIEW E VOLUME 54, NUMBER 4 OCTOBER 1996

Transition between viscous and inertial-range scaling of turbulence structure functions

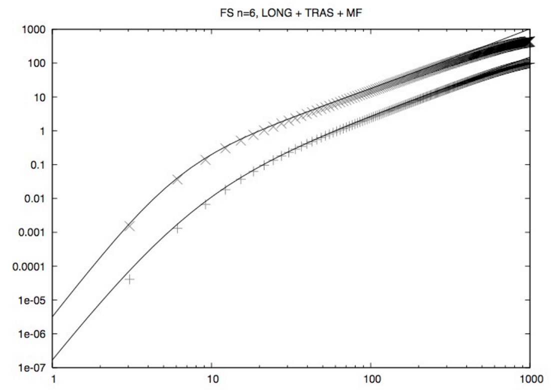
Charles Meneveau

[10] G. Stolovitzky, K. R. Sreenivasan, and A. Juneja, Phys. Rev. E **48**, R3217 (1993).
[11] L. Sirovich, V. Yakhot, and L. Smith, Phys. Rev. Lett. **72**, 344 (1994).
[12] D. Lohse, Phys. Rev. Lett. **73**, 3223 (1994).

BATCHELOR + MF PARAMETRISATION

$$\delta_r v \sim v_0 \frac{r}{[(\frac{\eta(h)}{L_0})^\alpha + (\frac{r}{L_0})^\alpha]^{(1-h/)\alpha}}$$

$$\begin{cases} \delta_r v \sim r^h & \eta \ll r \ll L_0 \\ \delta_r v \sim \dfrac{\delta_\eta v}{\eta} r & r \ll \eta \\ \eta(h) \sim Re^{-\frac{1}{1+h}} & \end{cases}$$



α Free parameter

See also Chevillard et al Physica D 2006

GOING LAGRANGIAN…..

WHY?

Frisch & Vergassola EPL 1991

The fact that exponents h significantly smaller than 1/3 have viscous cut-offs much smaller than the Kolmogorov dissipation scale, can be a severe constraint on experimental techniques where multifractality is measured from the statistics of the local dissipation. Such measurements can be spurious for those exponents which have cut-offs less than the probe size [12].

Chevillard et al Physica D 2006

$\langle(\partial_x u)^3\rangle$. Experimentally speaking, measuring gradients is still controversial mainly because hot wire probe sizes are in general of the order of the Kolmogorov scale [28,29,30,31]. We hope that further experimental studies will

[28] C. W. Van Atta and R. Antonia, Reynolds number dependence of skewness and flatness factors of turbulent velocity derivatives, Phys. Fluids **23**, 252 (1980).

[29] P. Tabeling, G. Zocchi, F. Belin, J. Maurer and H. Willaime, Probability density functions, skewness, and flatness in large Reynolds number turbulence, Phys. Rev. E **53**, 1613 (1996).

[30] K. R. Sreenivasan and R. A. Antonia, The phenomenology of small-scale turbulence, Annu. Rev. Fluid Mech. **29**, 435 (1997).

[31] H.S. Kang, S. Chester and C. Meneveau, Decaying turbulence in an active-grid-generated flow and comparisons with large-eddy simulation, J. Fluid Mech. **480**, 129 (2003).

Lagrangian turbulence?

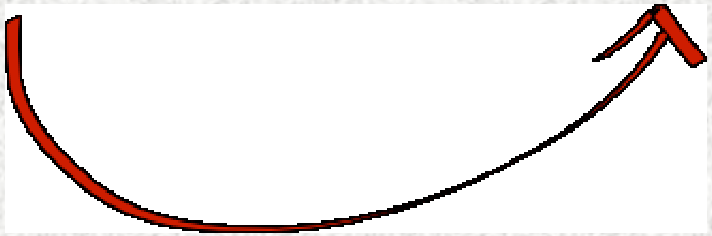
Is the multifractal formalism able to describe also the phenomenology of Lagrangian turbulence ?

"….Unfortunately, there are no significant lagrangian measurements of velocity, acceleration, etc., to test the multifractal predictions. …"

M.S. Borgas, "The Multifractal Lagrangian Nature of Turbulence", Phyl. Trans: Phys. Sciences and Eng. Vol. 342 (**1993**) 379.

Recently things are changing !

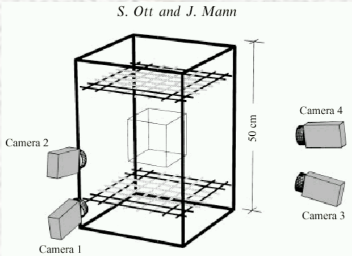
Eulerian MF Lagrangian MF



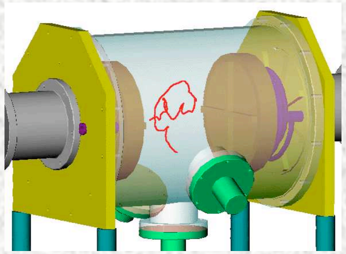
With some surprise…

Experiments

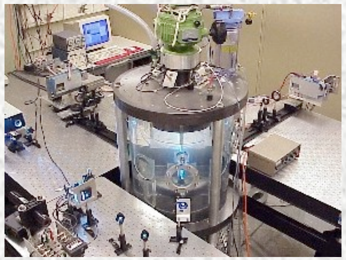
Experimental Lagrangian measurements are intrinsically difficult: one has to follow (many) Lagrangian trajectories for long time at high Reynolds (i.e. high sampling frequency)



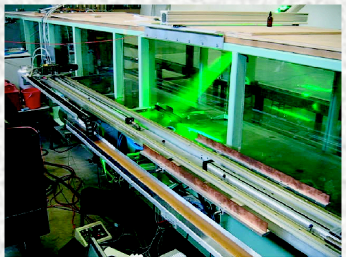
Ott and Mann experiment at Risø
conventional 3D PTV - Re_λ=100-300



Pinton et al ENSL
Acoustic/Laser Doppler tracking - Re_λ ~800 (single particle tracking)



Bodenschatz et al at Cornell-MPI
silicon strip detectors (now also CCD) $Re_\lambda \approx$ 1000-1500



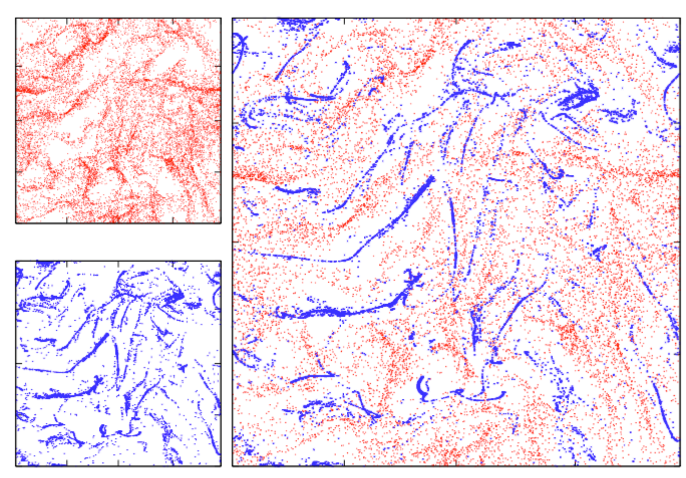
Warhaft et al experiment at Cornell
Fast moving camera
$Re_\lambda \approx 300$

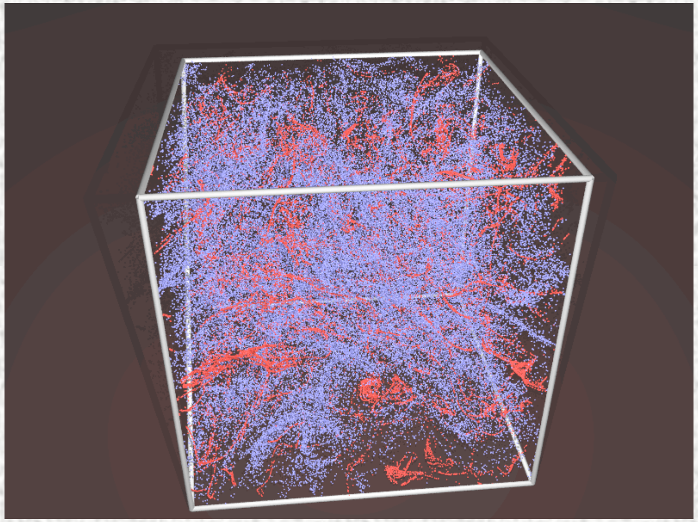
Luthi, Tsinober et al
3D PTV and 3D scanning PTV for velocity gradients

non intrusive tracking down to

$$\tau \sim \tau_\eta$$

DNS





+s and -s

- low to moderate Reynolds numbers, Re
- computationally expensive (Cpu time $\propto Re_{\lambda}^{6}$)
- memory demanding (ram $\propto Re_{\lambda}^{9/2}$)

+ high time resolution and
  long tracking

$$\tau \ll \tau_{\eta}$$

+ large Lagrangian statistics
+ multiparticle tracking
+ simultaneous
  Eulerian-Lagrangian statistics

N	Re_λ	η	L	T_L	τ_η	T	δx	N_p
512	183	0.01	3.14	2.1	0.048	5	0.012	$0.96\ 10^6$
1024	284	0.005	3.14	1.8	0.033	4.4	0.006	$1.92\ 10^6$
2048	400	0.0025	3.14	1.8	0.02	5.9	0.003	$2\ 10^9$

Pseudo spectral code - dealiased 2/3 rule - normal viscosity -

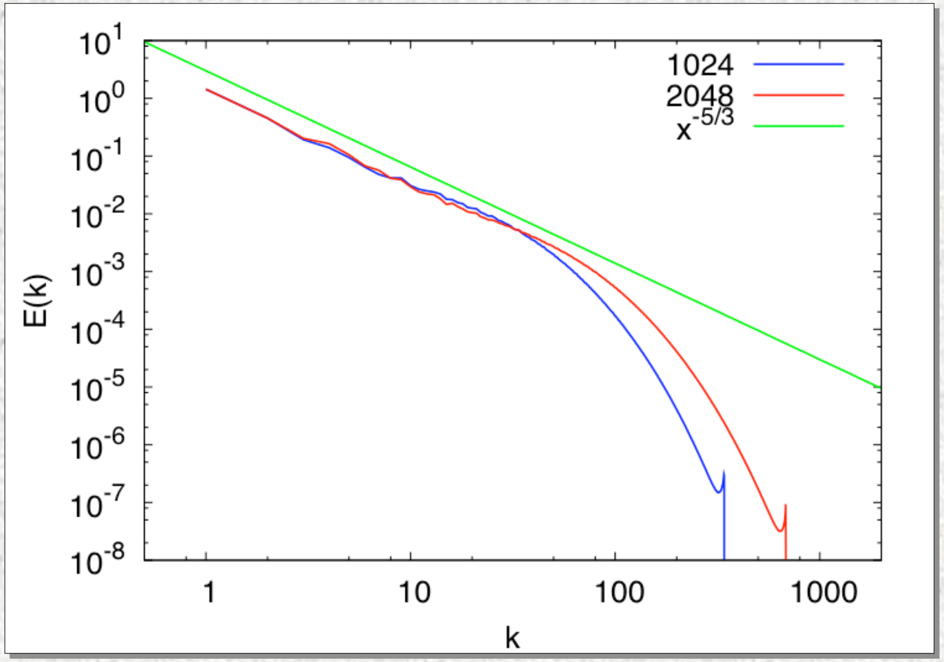
2 millions of passive tracers- code fully parallelized with

MPI+FFTW - Platform IBM SP4 (sust. Performance

150Mflops/proc) - 50000 cpu hours -

duration of the run: 40 days

Energy spectrum



PHYSICS OF FLUIDS 17, 021701 (2005)

Particle trapping in three-dimensional fully developed turbulence

PHYSICS OF FLUIDS 17, 115101 (2005)

Lagrangian statistics of particle pairs in homogeneous isotropic turbulence

PHYSICS OF FLUIDS 17, 111701 (2005)

Multiparticle dispersion in fully developed turbulence

PHYSICS OF FLUIDS 18, 091702 (2006)

Lyapunov exponents of heavy particles in turbulence

[L.B. G. Boffetta, A. Celani, B. Devenish, A.S. Lanotte, F. Toschi]

Lagrangian velocity statistics

$$S_p(r) = \langle (u(x+r) - u(x))^p \rangle \sim r^{\zeta_E(p)}$$

$$S_p(\tau) = \langle (v(t+\tau) - v(t))^p \rangle \sim \tau^{\zeta_L(p)}$$

$$\tau_\eta \ll \tau \ll T_L$$

Does it exist and how to estimate $\zeta_L(p)$?

In Eulerian turbulence we have $\zeta_E(p) = \inf_h (hp + 3 - D(h))$

Let's try to make a **predictions**

$$\delta_\tau v \sim \delta_r u$$

We assume that r and τ are linked by the typical eddy turn over time at the given spatial scale

$$\tau_r \sim r/\delta_r u$$

Bridge between Eulerian and Lagrangian description:

$$\tau \sim \frac{L_0^h}{v_0} r^{1-h}$$

[Borgas (1993); Boffetta et al (2002)]

$$S_p(r) = \langle (\delta_r v)^p \rangle \sim \langle v_0^p \rangle \int_I dh \left(\frac{r}{L_0}\right)^{hp+3-D(h)}$$

EULERIAN

Multifractal prediction for the Lagrangian structure functions

$$S_p(\tau) \sim \langle v_0^p \rangle \int_{h \in I} \mathrm{d}h \left(\frac{\tau}{T_L}\right)^{\frac{hp+3-D(h)}{1-h}}$$

where

$$\zeta_L(p) = \inf_h \left(\frac{hp+3-D(h)}{1-h}\right)$$

Same D(h) of the Eulerian field !!

WARNING: NO EXACT RESULTS SUPPORTING THE EXISTENCE OF SCALING LAWS IN LAGRANGIAN FRAMEWORK

BATCHELOR-MENEVEAU -> LAGRANGIAN

[CHEVILLARD ET AL PRL 2003]

$$\delta_\tau v = v_0 \frac{\tau / T_L}{[(\frac{\tau}{T_L})^\beta + (\frac{\tau_\eta}{T_L})^\beta]^{\frac{1-2h}{\beta(1-h)}}}$$

$$\delta_\tau v \sim \left(\frac{\tau}{T_L}\right)^{\frac{h}{1-h}}$$

$\tau \gg \tau_\eta$

$$\delta_\tau v \sim \tau \frac{\delta_{\tau_\eta} v}{\tau_\eta} \sim a\tau$$

$\tau \ll \tau_\eta$

β free parameter

$$\mathcal{P}_h(\tau, \tau_\eta) \sim \left[(\frac{\tau_\eta}{T_L})^\beta + (\frac{\tau}{T_L})^\beta\right]^{\frac{3-D(h)}{\beta(1-h)}}$$

Start from Eulerian $D(h)$

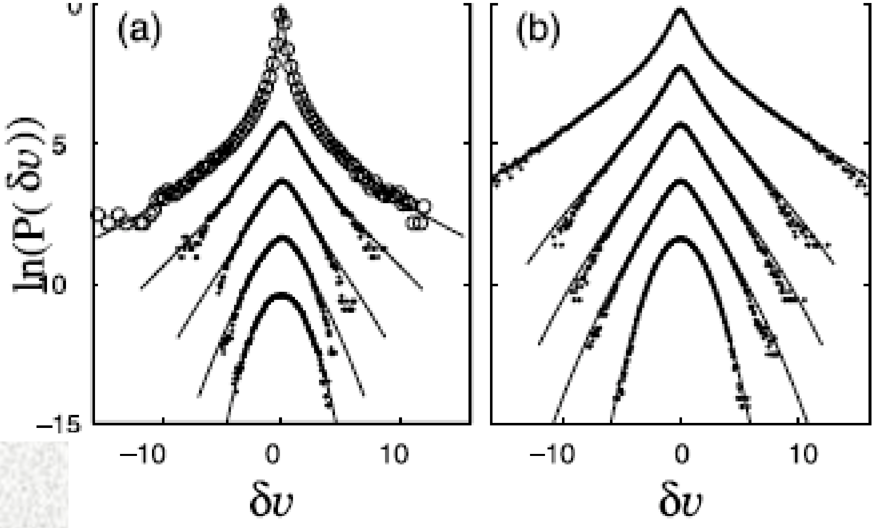
but: dissipative time fluctuates (as the dissipative scale)

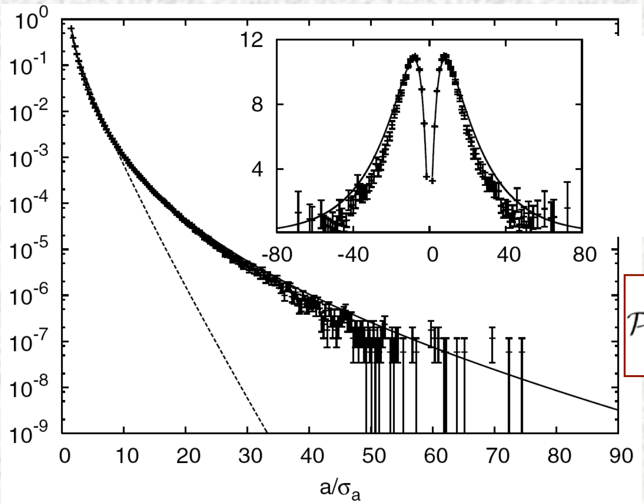
$$\tau_\eta(h) \sim Re_\lambda^{\frac{2(h-1)}{1+h}}$$

VOLUME 91, NUMBER 21 PHYSICAL REVIEW LETTERS week ending 21 NOVEMBER 2003

Lagrangian Velocity Statistics in Turbulent Flows: Effects of Dissipation

L. Chevillard, S. G. Roux, E. Levêque, N. Mordant,* J.-F. Pinton, and A. Arneodo
Laboratoire de Physique, École Normale Supérieure de Lyon, 46 allée d'Italie, F-69007 Lyon, France





VOLUME 93, NUMBER 6 PHYSICAL REVIEW LETTERS week ending 6 AUGUST 2004

Multifractal Statistics of Lagrangian Velocity and Acceleration in Turbulence

L. Biferale,[1] G. Boffetta,[2,6] A. Celani,[3] B. J. Devenish,[1,7] A. Lanotte,[4] and F. Toschi[5]

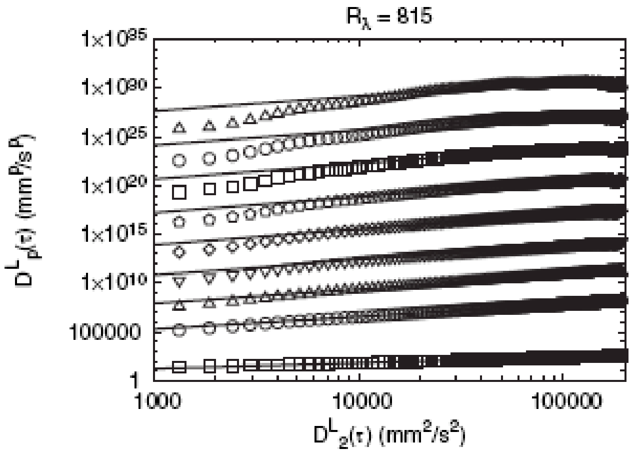
$$\mathcal{P}(a) \sim \int_{h\in I} \mathrm{d}h\, a^{\frac{h-5+D(h)}{3}} \nu^{\frac{7-2h-2D(h)}{3}} L_0^{D(h)+h-3} \sigma_v^{-1} \times \quad \exp\left(- \frac{a^{\frac{2(1+h)}{3}} \nu^{\frac{2(1-2h)}{3}} L_0^{2h}}{2\sigma_v^2} \right)$$

$$\delta_\tau v \sim \tau \frac{\delta_{\tau_\eta} v}{\tau_\eta} \sim a\tau$$

PRL 96, 024503 (2006) PHYSICAL REVIEW LETTERS week ending 20 JANUARY 2006

High Order Lagrangian Velocity Statistics in Turbulence

Haitao Xu,[1,2] Mickaël Bourgoin,[3] Nicholas T. Ouellette,[1] and Eberhard Bodenschatz[1,2,*]



GLOBAL FIT? -> POWER LAW?

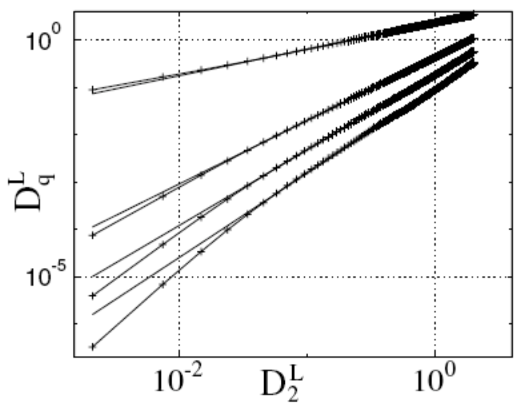


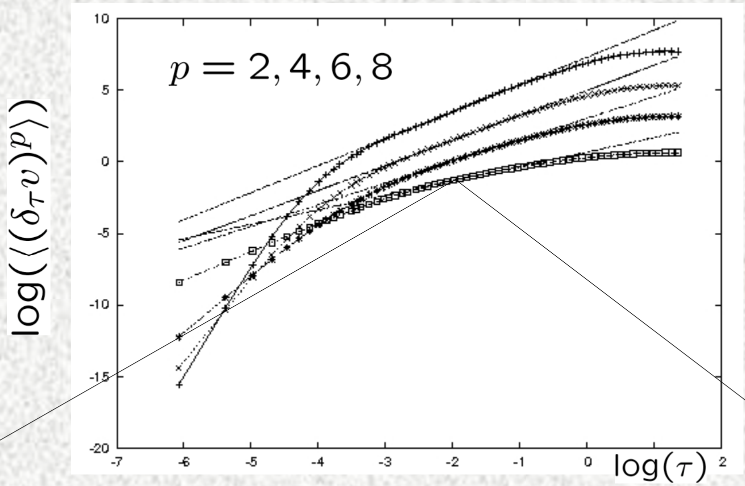
FIG. 5. ESS plots of the structure function variation (in double log coordinates). The solid curves are best linear fits with slopes equal to $\xi_q^L = 0.56 \pm 0.01$, 1.34 ± 0.02, 1.56 ± 0.06, and 1.8 ± 0.2 for $p = 1, 3, 4$, and 5 from top to bottom. Coordinates in arbitrary units.

$$S_p(\tau) \sim \langle v_0^p \rangle \int_{h \in I} \mathrm{d}h \left(\frac{\tau}{T_L} \right)^{\frac{hp+3-D(h)}{1-h}}$$

$$S_p(\tau) \sim \tau^{\zeta_L(p)}$$

Measurement of Lagrangian Velocity in Fully Developed Turbulence

N. Mordant,[1] P. Metz,[1] O. Michel,[2] and J.-F. Pinton[1]
[1]*CNRS & Laboratoire de Physique, École Normale Supérieure, 46 allée d'Italie, F-69007 Lyon, France*
[2]*Laboratoire d'Astrophysique, Université de Nice, Parc Valrose, F-06108, Nice, France*
(Received 26 March 2001; published 2 November 2001)



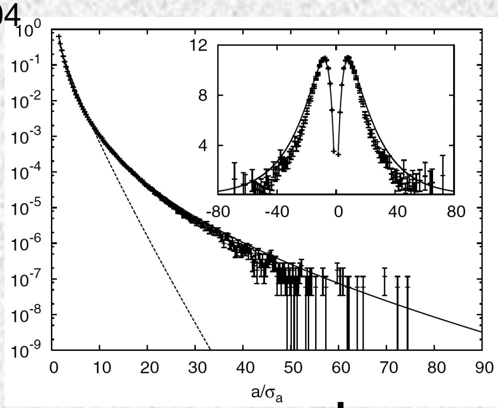
$$\zeta_p(\tau) = \frac{\mathrm{d}\log\left(S_p(\tau)\right)}{\mathrm{d}\log\left(S_2(\tau)\right)}$$

The local exponents $\zeta_p(\tau)$ act as **magnifying glass**, probing locally the value of the scaling exponents.

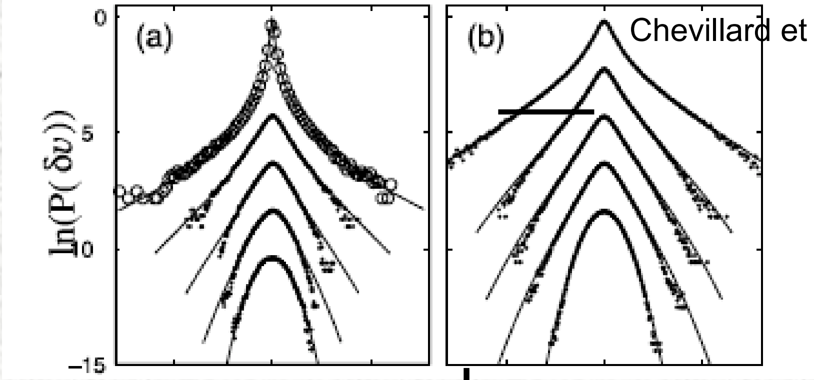
-) Power law scaling -> plateaux for **local scaling exponents**

-) Comparing results from different components: estimate of anisotropy

Biferale et al prl 2004

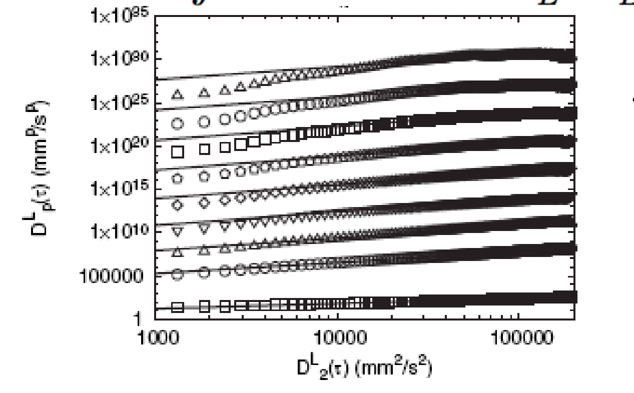


Chevillard et al PRL 2003



$$\langle (\delta_\tau v)^p \rangle \sim \int dh \; (\delta_\tau v)^p \; \mathcal{P}_h\left(\frac{\tau}{T_L}, \frac{\tau_\eta}{T_L}\right)$$

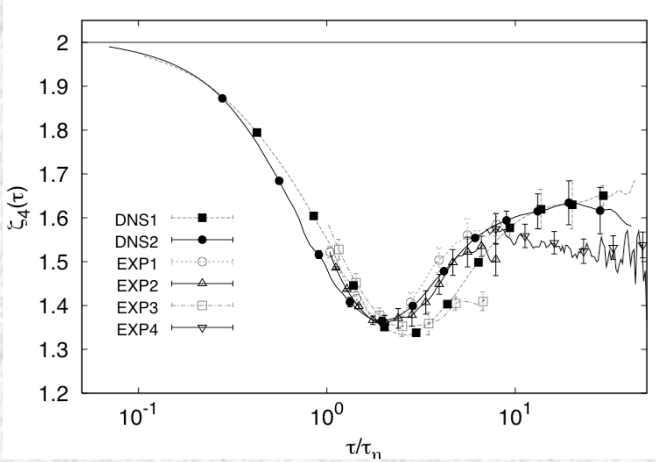
Xu et al PRL 2006

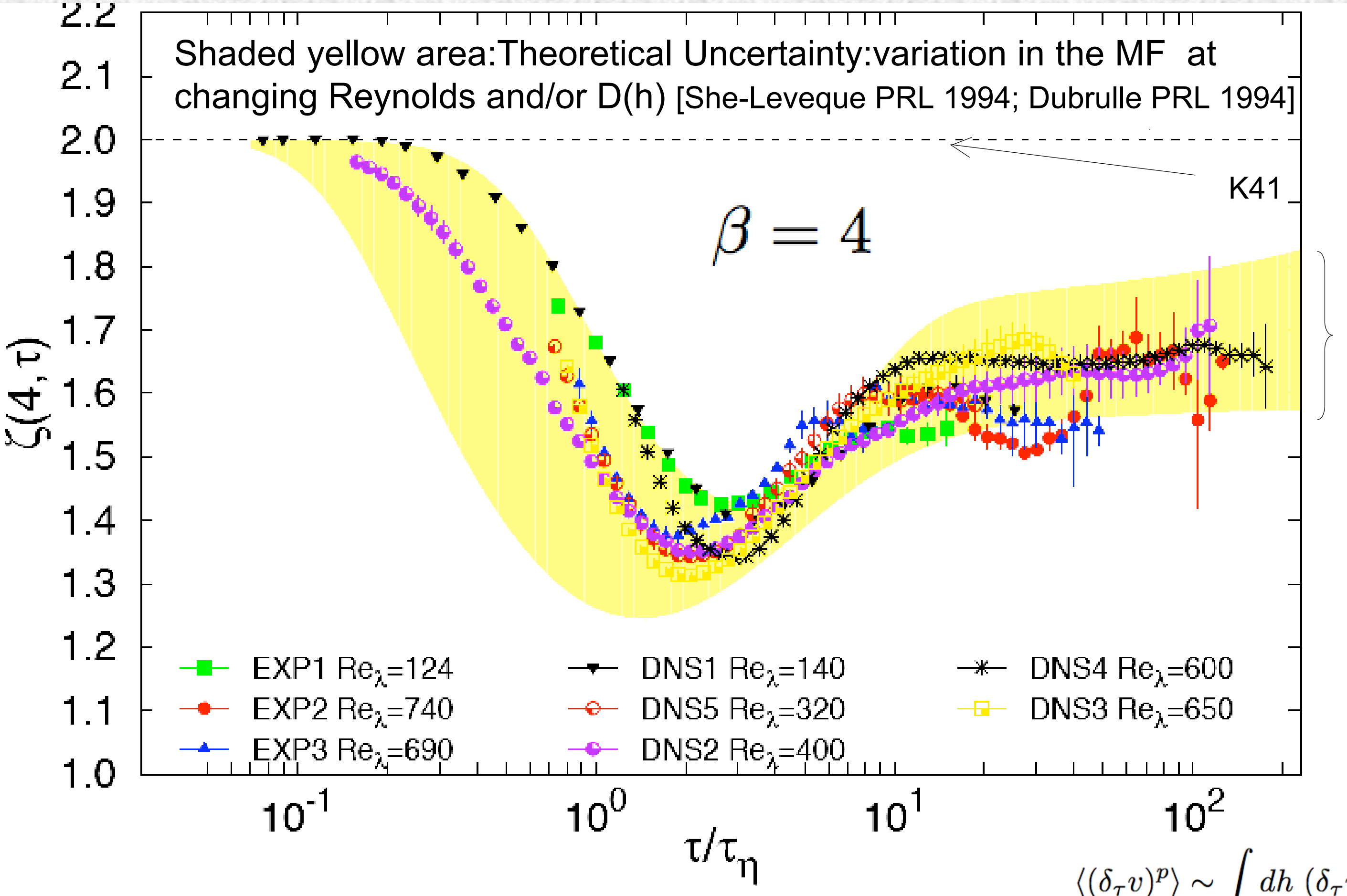


$$\zeta_p(\tau) = \frac{\mathrm{d}\log\left(S_p(\tau)\right)}{\mathrm{d}\log\left(S_2(\tau)\right)}$$

Biferale, Bodenschatz, Cencini

et al, PoF 2007 submitted





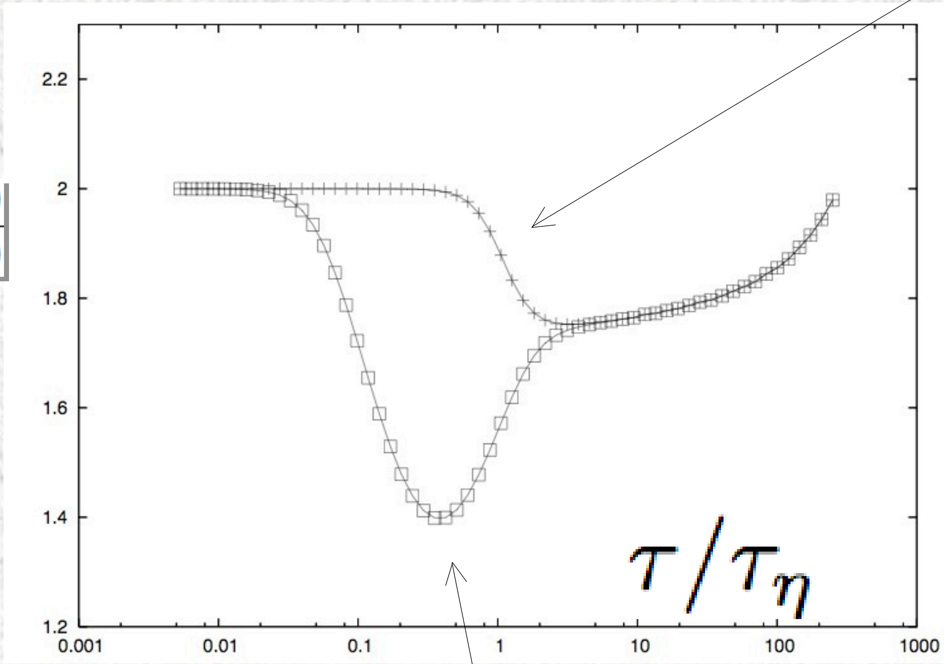
$$\langle(\delta_\tau v)^p\rangle \sim \int dh\ (\delta_\tau v)^p\ \mathcal{P}_h(\frac{\tau}{T_L}, \frac{\tau_\eta}{T_L})$$

International Collaboration for Turbulence Research, A. Arneodo,[1] J. Berg,[2] R. Benzi,[3] L. Biferale,[3] E. Bodenschatz,[4] A. Busse,[5] E. Calzavarini,[6] B. Castaing,[1] M. Cencini,[7] L. Chevillard,[1] R. Fisher,[8] R. Grauer,[9] H. Homann,[9] D. Lamb,[8] A.S. Lanotte,[10] E. Leveque,[1] B. Lüthi,[11] J. Mann,[2] N. Mordant,[12] W.-C. Müller,[5] S. Ott,[2] N. Oullette,[13] J.-F. Pinton,[1] S.B. Pope,[14] S.G. Roux,[1] F. Toschi,[15,16] H. Xu,[4] and P.K. Yeung[17]

WE LEARN ABOUT:
(i) INTERMITTENCY; (ii) UNIVERSALITY; (iii) ANISOTROPY

MultiFractal WITHOUT DISSIPATIVE FLUCTUATING $\tau_\eta(h)$

$$\zeta_p(\tau) = \frac{\mathrm{d}\log\left(S_p(\tau)\right)}{\mathrm{d}\log\left(S_2(\tau)\right)}$$



MultiFractal WITH DISSIPATIVE FLUCTUATING $\tau_\eta(h)$

WHAT HAPPENS AROUND DISSIPATIVE TIME?

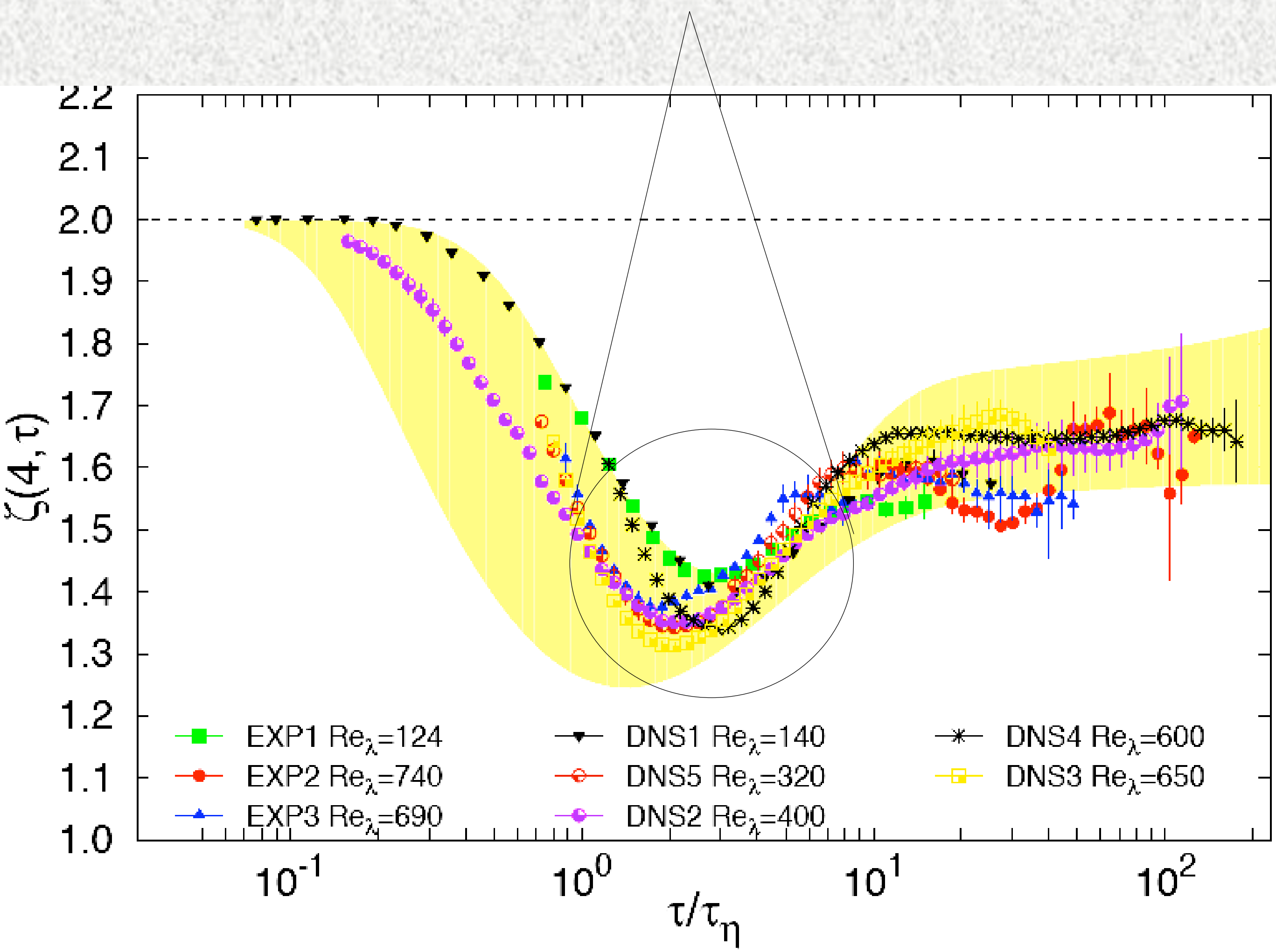
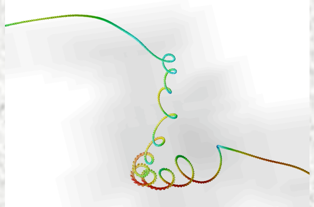
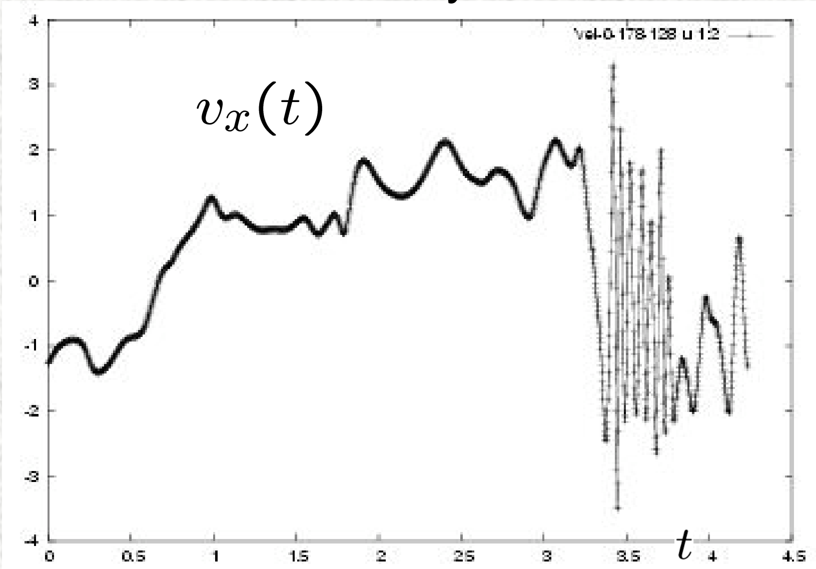


FIG. 1: Log-Lin plot of the local exponent for the fourth moment, $\zeta(4,\tau)$, averaged over the three velocity components, as a function of the normalised time lag τ/τ_η. Data sets come from three experiments (EXP) (see table 1) and five direct numerical simulations (DNS) (see table 2). Error bars are estimated out of the spread between the three components, but for EXP1 and EXP3 where only two components have been considered because of large systematic anisotropic effects in the third one. Each data set is plotted only in the time range where the known experimental/numerical limitations are certainly not affecting the

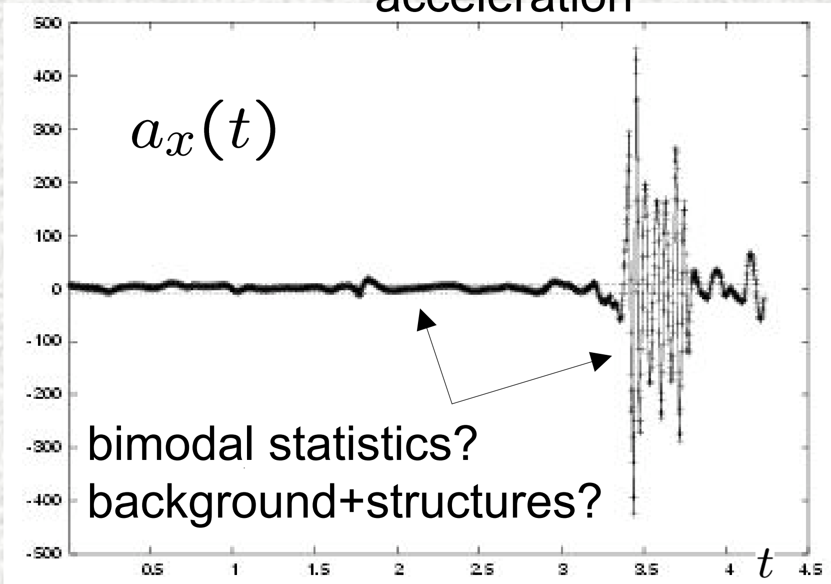
TRAPPING INTO VORTEX FILAMENTS



velocity



acceleration



Particle trapping in three-dimensional fully developed turbulence

L. Biferale
Dipartimento di Fisica and INFN, Università degli Studi di Roma "Tor Vergata," Via della Ricerca Scientifica 1, 00133 Roma, Italy

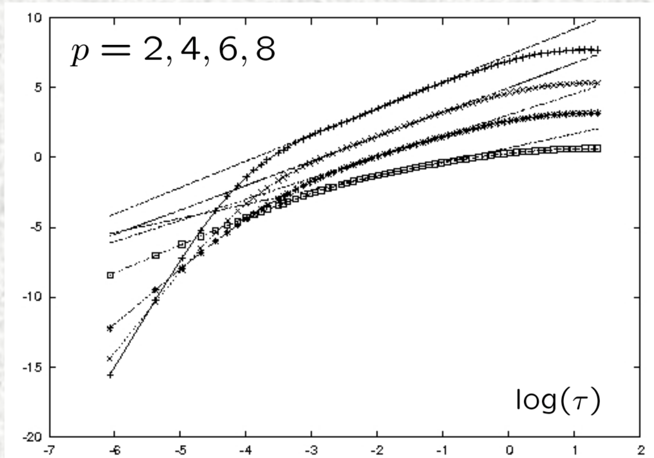
G. Boffetta
Dipartimento di Fisica Generale and INFN, Università degli Studi di Torino, Via Pietro Giuria 1, 10125 Torino, Italy

A. Celani
CNRS, INLN, 1361 Route des Lucioles, 06560 Valbonne, France

A. Lanotte
CNR-ISAC, Str. Prov. Lecce-Monteroni km. 1200, 73100 Lecce, Italy

F. Toschi
Istituto per le Applicazioni del Calcolo, CNR, Viale del Policlinico 137, 00161 Roma, Italy

[see also La Porta et al Nature 2001)]

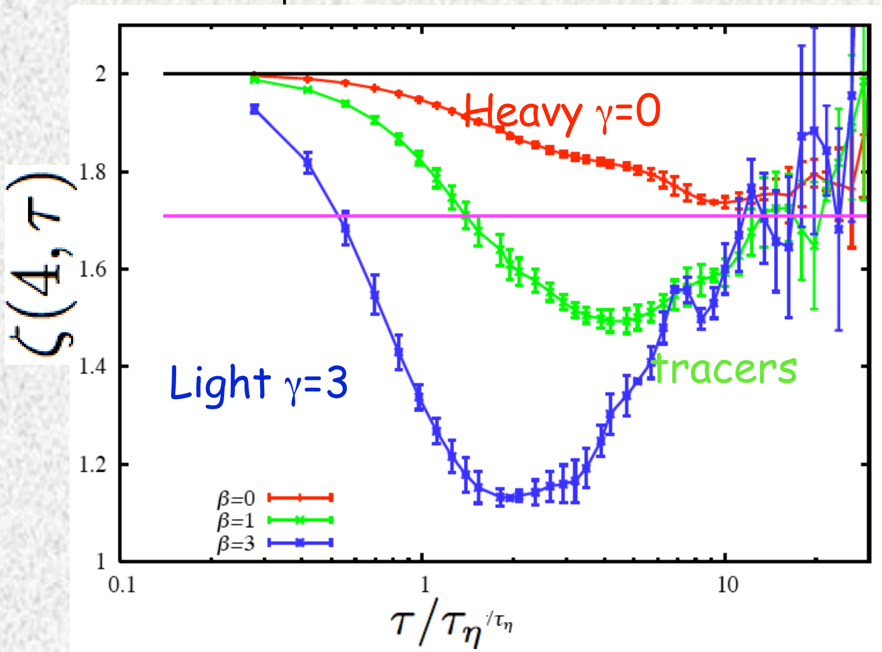


$$\boldsymbol{v}_L(t) = \dot{\boldsymbol{x}}_L(t) = \boldsymbol{v}_E(\boldsymbol{x}_L(t), t)$$

$$\frac{d\boldsymbol{v}(t)}{dt} = \gamma \frac{D\boldsymbol{u}(\boldsymbol{x},t)}{Dt} - \frac{1}{\tau}\left[\boldsymbol{v}(t) - \boldsymbol{u}(\boldsymbol{x}(t),t)\right]$$

St=0.6

plot from E. Calzavarini



CAN WE PREDICT IT USING A SUITABLE MF?

$$\delta_\tau v = v_0 \frac{\tau/T_L}{\left[(\frac{\tau}{T_L})^\beta + (\frac{\tau_\eta}{T_L})^\beta\right]^{\frac{1-2h}{\beta(1-h)}}}$$

$$\beta(St)?$$

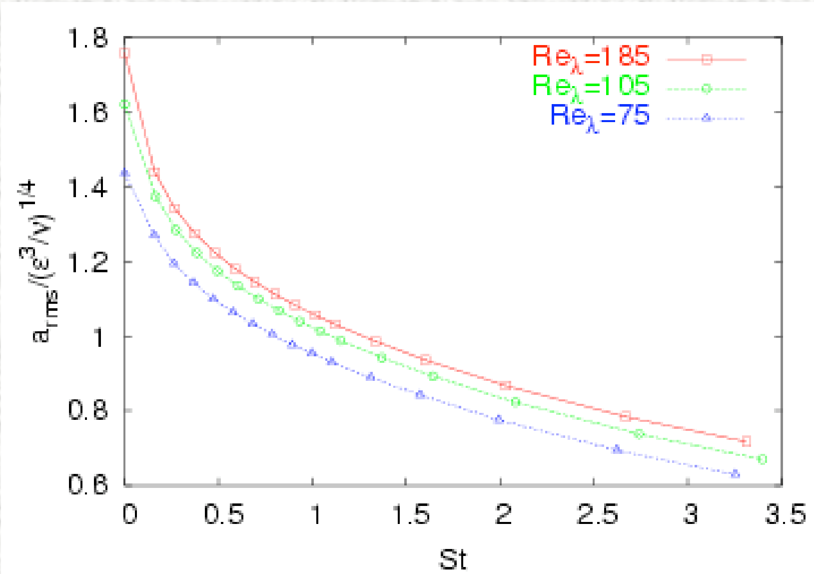
Not so simple, where is preferential concentration?

Acceleration statistics

J. Fluid Mech. (2006), vol. 550, pp. 349–358. © 2006 Cambridge University Press 349
doi:10.1017/S002211200500844X Printed in the United Kingdom

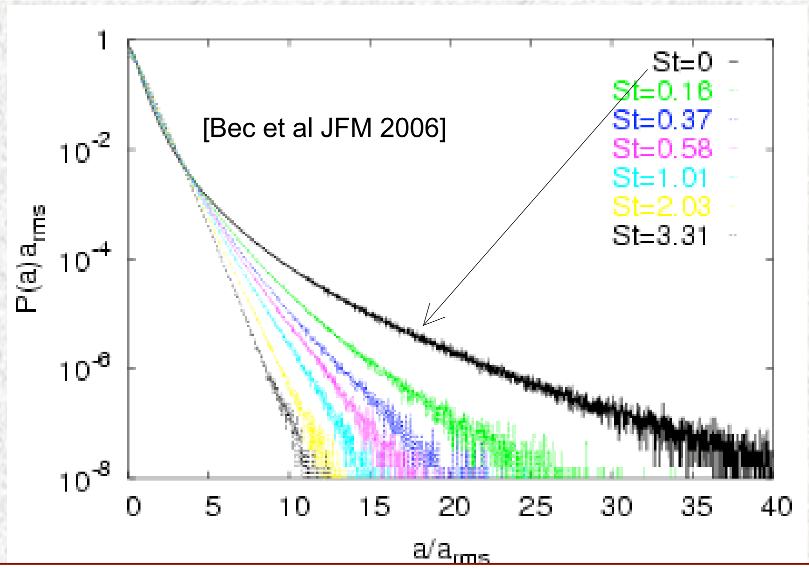
Acceleration statistics of heavy particles in turbulence

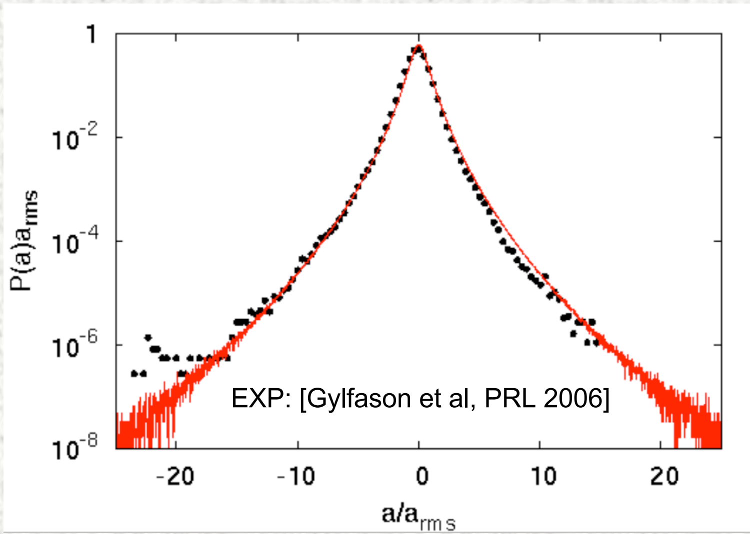
By J. BEC[1], L. BIFERALE[2], G. BOFFETTA[3], A. CELANI[4], M. CENCINI[5], A. LANOTTE[6], S. MUSACCHIO[7] AND F. TOSCHI[8]



- At increasing St: strong depletion of both rms acc. and pdf tails.
- Residual dependence on Re very similar to that observed for tracers. [Sawford et al (2003); Borgas (1993)]

CAN WE PREDICT USING A SUITABLE MF? $\beta(St)$?





$$P(a) \sim \int_{h\in I} \mathrm{d}h\, a^{\frac{h-5+D(h)}{3}} \nu^{\frac{7-2h-2D(h)}{3}} L_0^{D(h)+h-3}\sigma_v^{-1}\times \quad \exp\left(-\frac{a^{\frac{2(1+h)}{3}}\nu^{\frac{2(1-2h)}{3}}L_0^{2h}}{2\sigma_v^2}\right)$$

OPEN PROBLEMS

HOW TO EXTEND THE MF PREDICTION TO INCLUDE PREFERENTIAL CONCENTRANTION.

PROBE EULERIAN <-> LAGRANGIAN MF CONNECTION TO HIGHER ORDER STATISTICS. IS LAGRANGIAN REALLY FULLY INCLUDED IN EULERIAN? (AND VICEVERSA)

OBSERVED MISMATCH BETWEEN LONGITUDINAL-TRANSVERSE SCALING IN EULERIAN SF, AND BETWEEN ENSTROPHY AND ENERGY DISSIPATION. FINITE REYNOLDS EFFECT?

PROBE REFINED KOLMOGOROV HYPOTHESIS IN LAGRANGIAN DOMAIN -> IMPORTANT FOR MODELISATION [preliminary results -> OK]

PROBE MULTISCALE-MULTITIME CORRELATION FUNCTIONS $\langle |\delta_r v(t)|^p |\delta_R v(t+\tau)|^q \rangle$

INCLUDE IN MF DESCRIPTION KNOWN EXACT RESULTS (KARMAN-HOWART EQ)

ANISOTROPIC FLUCTUATIONS: IS THERE A CASCADE, IS THERE INTERMITTENCY? IS IT UNIVERSAL?

BUILD UP SEQUENTIAL MF SURROGATES $v_i(\mathbf{x}(t),t); \partial_j v_i(\mathbf{x}(t),t)$ TO FEED STOCHASTIC MODELS FOR PARTICLE ADVECTION IN TURBULENCE.

Anisotropy in turbulent flows and in turbulent transport
L. Biferale and I. Procaccia Phys. Rep. 2005

Fusion Rules in Turbulent Systems with Flux Equilibrium
V. S. L'vov and I. Procaccia Phys. Rev. Lett 1996

Multiscale velocity correlations in turbulence
R. Benzi and L. Biferale and F. Toschi Physical Review Letters 1998

Multiscale Model of Gradient Evolution in Turbulent Flows
L. Biferale and L. Chevillard and C. Meneveau and F. Toschi Physical Review Letters 2007

A conditionally cubic-Gaussian stochastic Lagrangian model for acceleration in isotropic turbulence
A.G. LAMORGESE and S. B. POPE and P. K. YEUNG and B. L. SAWFORD J. Fluid Mech. 2007

Refined similarity hypothesis for transverse structure functions in fluid turbulence
S. Chen and K. R. Sreenivasan and M. Nelkin and N. Z. Cao Phys. Rev. Lett. 1997

G. Stolovitzky and K. R. Sreenivasan Rev. Mod. Phys. 1994

Transition between viscous and inertial-range scaling of turbulence structure functions
C. Meneveau Physical Review E 1996

Mimicking a turbulent signal: sequential multiaffine processes
L. Biferale, G. Boffetta, A. Celani, A. Crisanti and A. Vulpiani
Phys. Rev. E 1998.

Unified multifractal description of velocity increments statistics in turbulence: Intermittency and skewness
L. Chevillard and B. Castaing and E. Leveque and A. Arneodo Physica D2006

Thanks to:

J. Bec, E. Bodenschatz, G. Boffetta, A. Celani, M. Cencini, A.S. Lanotte,
F. Toschi, H. Xu.

and many others:

R. Benzi, E. Calzavarini, L. Chevillard, B. Devenish, R. Fisher, T. Gotoh, L. Kadanoff,
D. Lamb, S. Musacchio, N. Ouellette.

small text normal text large text

Search

iCFDdatabase

home | news | members

you are not logged in | log in

you are here: home

navigation

- Community members
- CFD raw data repository (1015Gbyte)
- CFD preprocessed data repository
- User area

log in

Name

Password

Log in

Forgot your password?

CFD database

Computational Fluid Dynamics database

This is the web site of the **free CFD database**, kindly hosted by Cineca supercomputing center (Bologna, Italy).

The administrator of the site, in charge of registering new users on the site is: Federico Toschi. Please refer to him any question or comment regarding this web site.

If you wish to contribute to this DNS database of fluid-dynamics data by sharing your raw data or computer codes you [illegible] r[illegible]; please contact the admini[illegible]ator of the site.

Thank you

http://cfd.cineca.it

upcoming events

Computational Physics and New Perspectives in Turbulence
Nagoya - Japan, 2006-09-11

«			March 2006			»
Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	