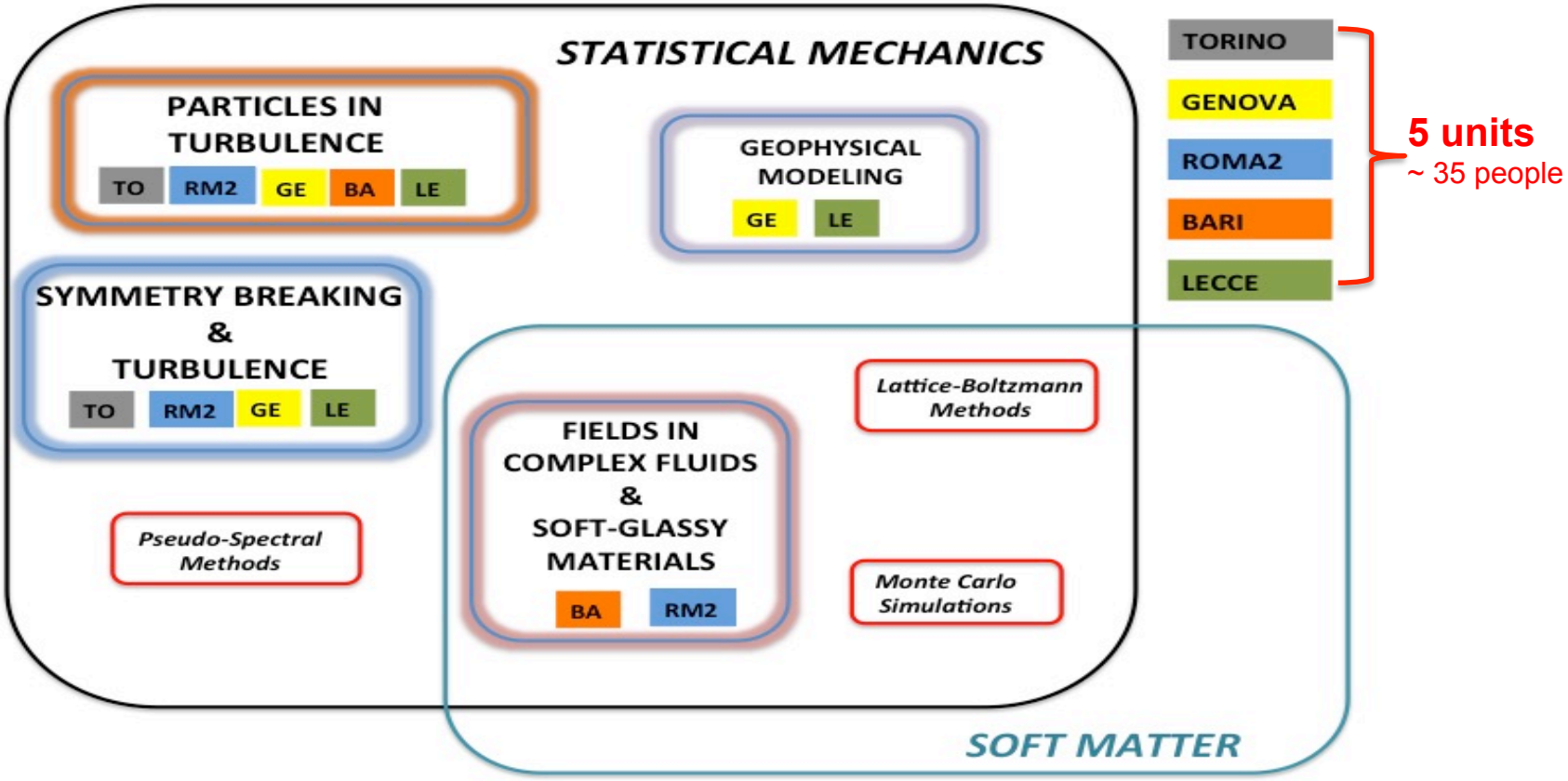
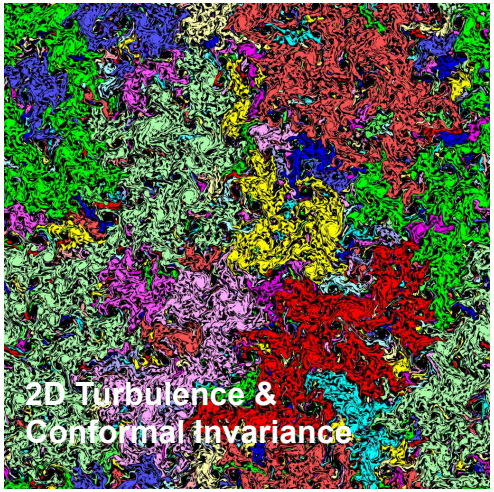
FIELDTURB: PARTICLES AND FIELDS IN TURBULENCE AND IN COMPLEX FLOWS



National Coordinator: Guido Boffetta (University of Torino)

Keywords : Classical Non-linear Field Theory, Out-of-equilibrium Statistical Mechanics, Complex Systems

Strongly Non-Linear Dynamics in Complex Systems



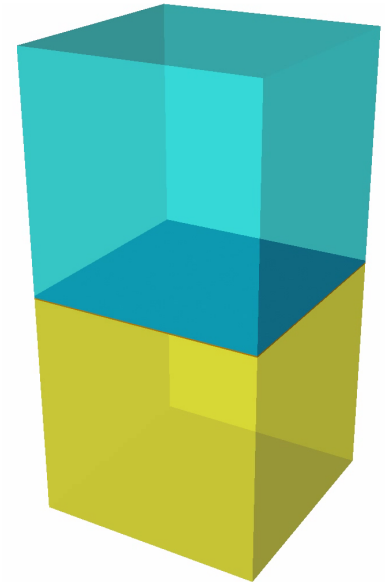
Complex systems far from equilibrium with many dof

Wide range of applications
(from astrophysics to biology)

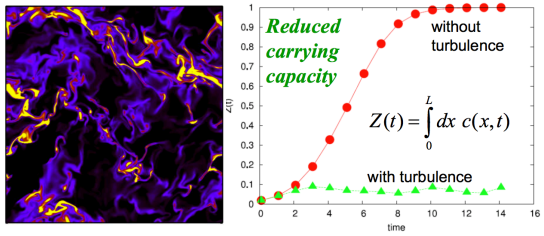
Theoretically challenging

Computationally and experimentally demanding

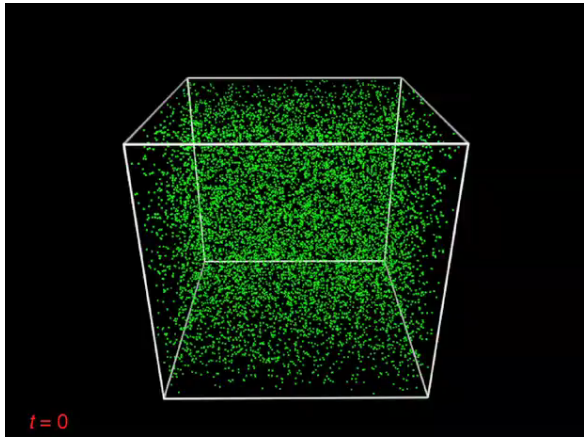
Of large impact



Turbulent convection



Population dynamics in flows



Recent relevant publications

Phys. Rev. Lett. **112**, 1 (2014); **112**, 18 (2014); **113**, 3 (2014); **113**, 11 (2014); **113**, 25 (2014); **115**, 26 (2015)

Phys. Rev. X **4**, 041006 (2014), **6** 041036 (2016)

Nat. Comm. **4**, 2148 (2013); **5** 5310 (2014)

PNAS **111**, 7558 (2014); **112**, 4208 (2015)

SOFT MATTER **10**, 4615 (2014); **11**, 1271 (2015); **12** 514 (2016)

Annu. Rev. Fluid Mech. **49**, 119 (2017)

Scientific projects

INFN by means of CIPE 2016
3 HPC – HTC grants **[TO RM2 LE]**

PRIN *Statistical Physics of Active Matter: Disentangling Complexity Patterns in Biological Systems* [**BA**]

PRIN *Studio delle interazioni fluido-struttura per l'estrazione di energia da fluidi in movimento* [**GE**]

PRIN *Meccanica Statistica e Complessita'* **[RM2]**

COST action MP1305 *Flowing Matter* **[TO RM2 LE GE]**

FP7 Research Infrastructure Initiative *EuHIT* : *European High-Performance Infrastructures in Turbulence* **[TO RM2]**

FP7 project *ICE-ARC* [**GE**]

ERC 2010 StG *DROEMU: Droplets & Emulsions: Dynamics and Rheology* **[RM2]**

ERC 2013 AdG *NewTURB*: *New eddy-simulation concepts and methodologies for frontier problems in TURBulence* **[RM2]**

HPC projects and related activities

EUROPEAN JOINT DOCTORATE

HPC-LEAP High Performance Computing in Life sciences, Engineering and Physics

SUPERCOMPUTING GRANTS

PRACE 2012 (22 Mh) No.04-806 *Eulerian and Lagrangian Turbulence over a reduced fractal skeleton*

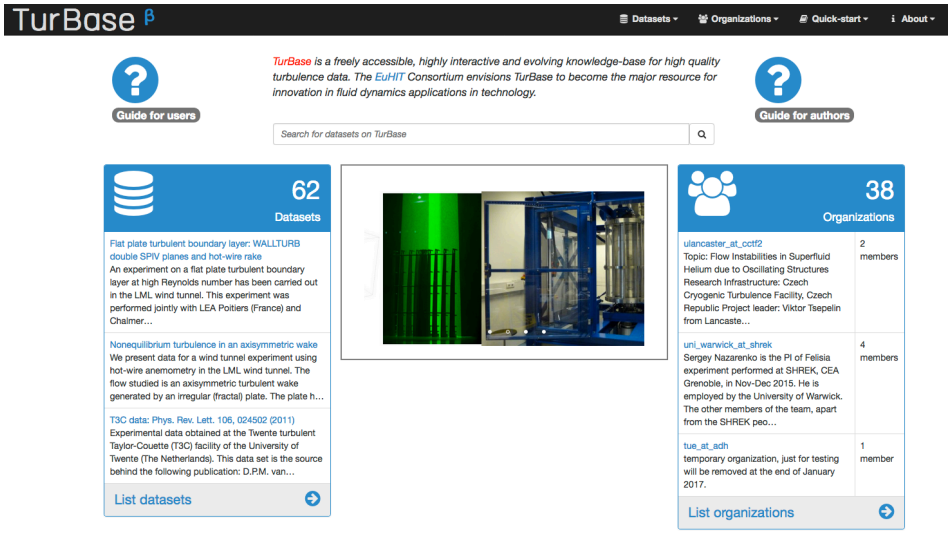
PRACE 2014 (55 Mh) No.09-2256 *Effect of Helicity and Rotation in Turbulent flows: Eulerian and Lagrangian statistics*

PRACE 2015 (22 Mh) *Anisotropic Homogeneous Turbulence*

PRACE 2016 (25 Mh) (under evaluation) *How stratification, rotation and confinement impact on the turbulent mixing of passive and active particulate matter*

ISCRA @ CINECA

ISCRA A : 2010, 2011, 2013
ISCRA B : 2011, 2013, 2016
ISCRA C : 2015



OPEN ACCESS DATABASE

TURBASE

62 different datasets produced by 38 organizations

Developed within the EuHIT project

COMMUNITY SERVICES

EUDAT

Collaborative Data Infrastructure for "*sharing data across borders and disciplines*"
funded by EU FP7 and H2020

International network

Dr. M. Baebler, KTH, Stokholm, Sweden
Prof. S. Bagheri, KTH, Stokholm, Sweden
Dr. J. Bec , Observatory of Nice, France
Prof. E. Bodenschatz, Max Plank Institute, Goettingen, Germany
Prof. L. Brandt, KTH Stockolm, Sweden
Dr. A. Celani, ICTP, Trieste
Dr. E. Calzavarini, University of Lille, France
Prof. L. Cugliandolo, Université Pierre et Marie Curie - Paris VI, France
Prof. R. Ecke, Los Alamos National Laboratory, USA
Prof. G. Falkovich, Weizmann Institute of Science, Israel
Prof. U. Frisch, Observatory of Nice, France
Prof. A. Liberzon, Tel Aviv University, Israel
Prof. D. Lohse, University of Twente, Enschede, The Netherlands
Prof. H. Kellay, University of Bordeaux 1, France
Prof. K. Jansen, DESY Germany
Prof. I.V. Kolokolov, Landau Institute for Theoretical Physics, Russia
Prof. V. Lebedev, Landau Institute for Theoretical Physics, Russia
Prof. Y. Lvov, Rensselaer Polytechnic Institute, New York, USA
Dr. D. Marenduzzo, Dept of Physics, University of Edinburgh, Gran Bretagna
Prof. C. Meneveau, Johns Hopkins University, USA
Prof. P. Muratore-Ginanneschi, University of Helsinki, Finland
Dr. S. Musacchio, University of Nice, France
Prof. S. Nazarenko, University of Warwick, UK
Prof. D. Nelson, Harvard University, Boston USA
Prof. I. Procaccia, Weizmann Institute of Science, Israel
Prof. A. Pouquet, Univ. Colorado, USA
Dr. D. Proment, University of East Anglia, UK
Prof. A. Prosperetti, Johns Hopkins University, Baltimore (MD) USA.
Prof. A. Pumir, Ecole Normale Superieure de Lyon, France
Prof. J.J. Riley, University of Washington, Seattle, USA
Prof. G. Saracco,INIFTA, Universita' di La Plata, Argentina
Prof. X. Shan, EXA corporation, Lexington (MA) USA
Prof. M. Shats, Australian National University of Camberra, Australia
Prof. V. Sofonea, Romanian Academy, Timisoara, Romania
Prof. R. Stocker, ETH Zurich, Switzerland
Prof. F. Toschi, Technical University of Eindhoven, The Netherlands
Dr. A. Wirth, LEGI, Grenoble France

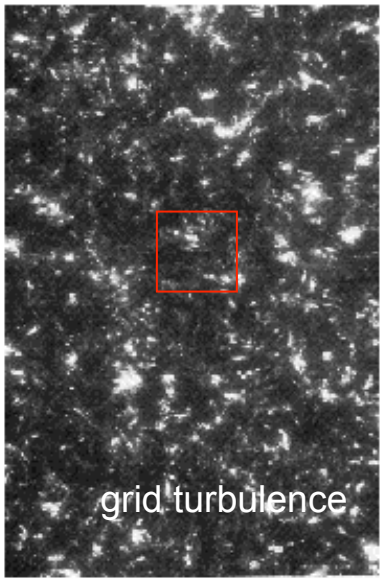
Italy

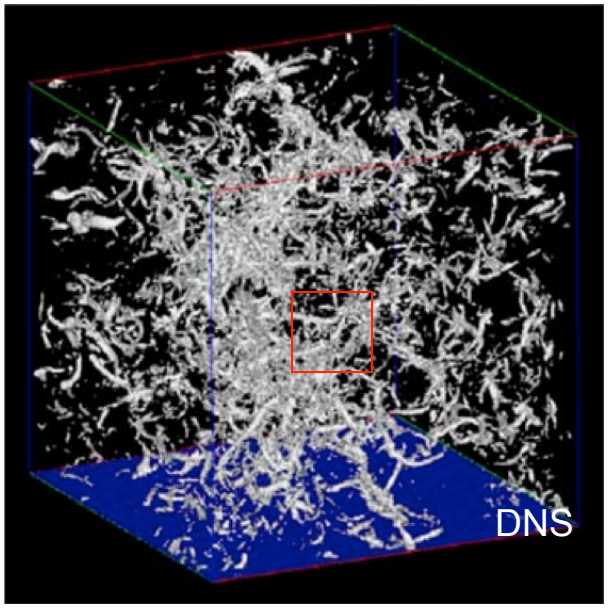
Dip. Fisica, Sapienza
Dip. Fisica, Padova
Dip. Fisica, Genova
Politecnico Milano
Politecnico Torino
CNR
SISSA

Example 2015 : 49 papers with 29% authors from 17 foreign Institutes

Why turbulence ?

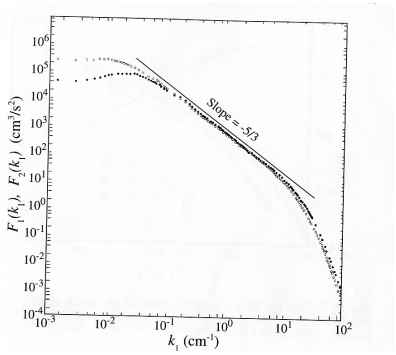
Classical non-linear field theory, out of equilibrium, non-perturbative with non Gaussian, anomalous fluctuations



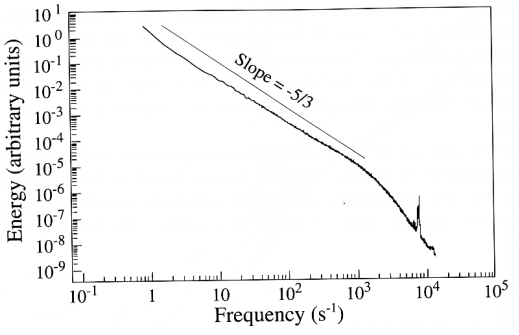


Universality of small scale statistical properties:

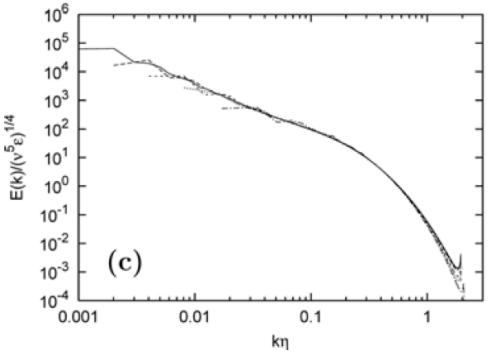
Kolmogorov spectrum $E(k) \approx k^{-5/3}$



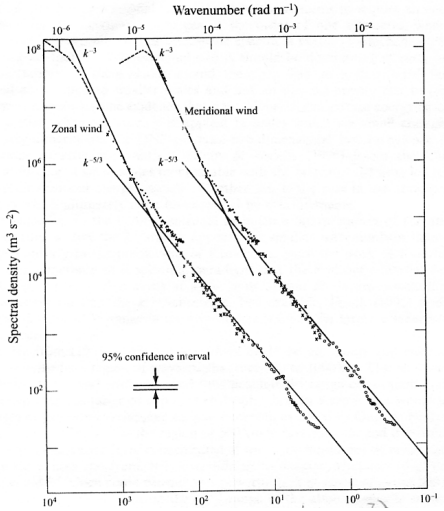
L=10 cm



L=10 m (Onera)

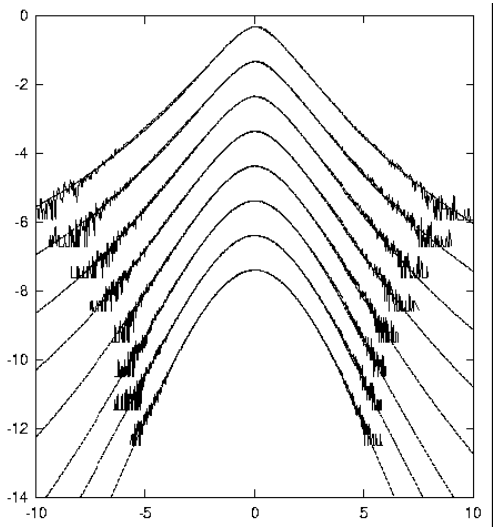


DNS



L=100 km

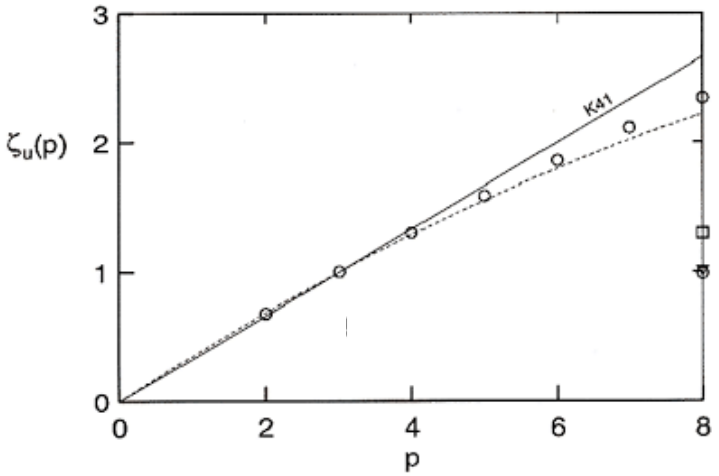
Open problems



Intermittency

violation of self-similarity in the turbulent cascade

anomalous scaling exponents
of higher order statistics $\zeta_p \neq p/3$



Methods

Laboratory experiments (higher Re)
Numerical simulations (all observables)

History of DNS of turbulence

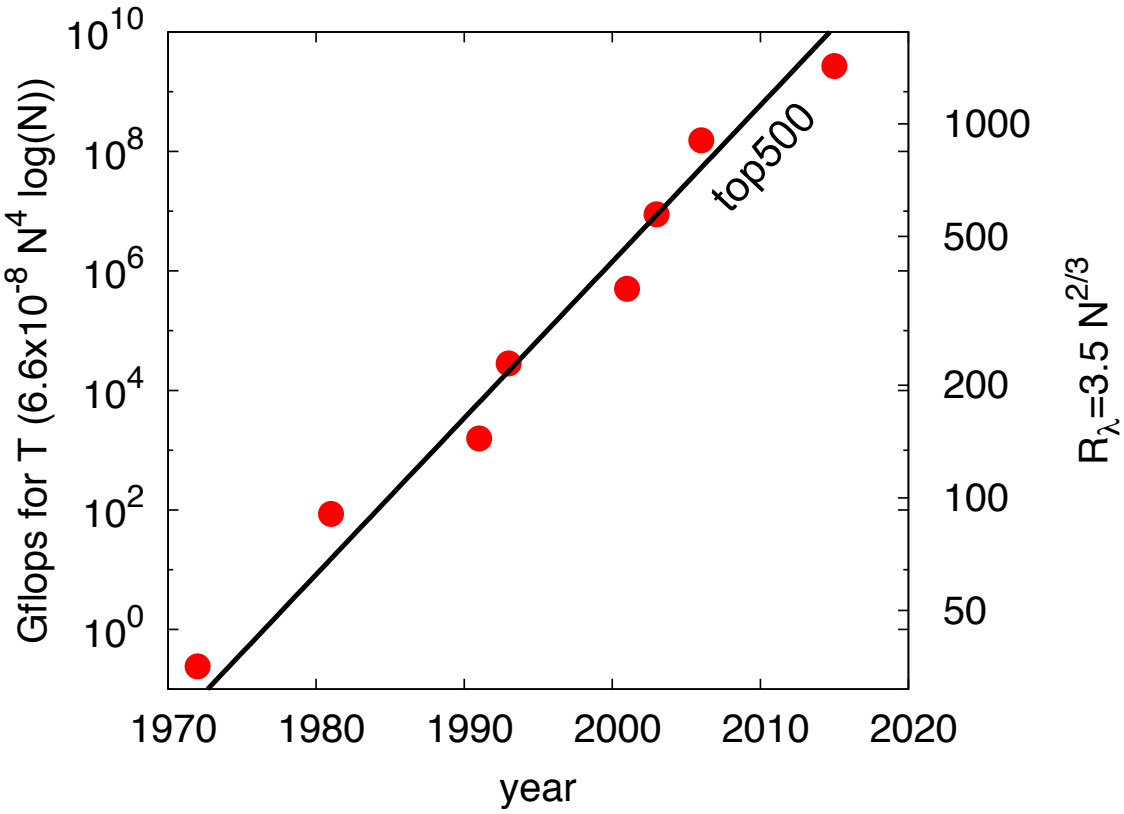
K41: $R_\lambda \approx N^{2/3}$

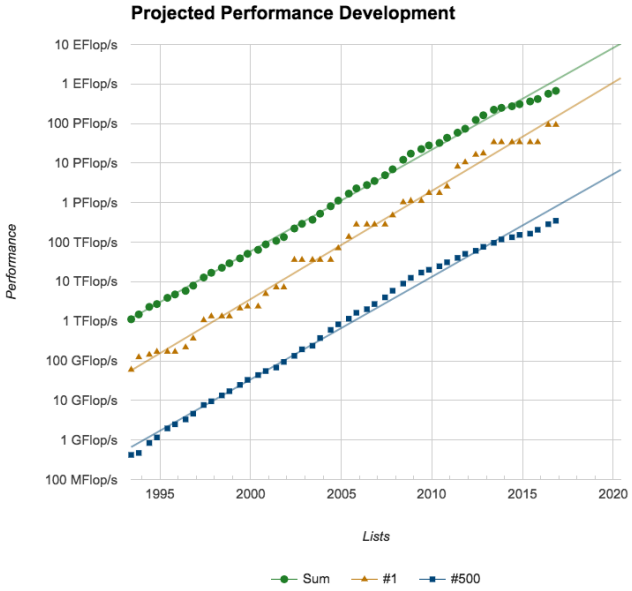
Year	N	R_λ	Computer	Ref
1972	32	35	IBM 360-95	Orszag, Patterson, PRL **28** 76
1981	128	84	Cray 1	Rogallo, NASA Rep PRL **58** 547 (1987)
1991	256	150		Vincent, Meneguzzi, JFM **25** 1 Sanada, PRA **44** 6480
1993	512	200	Caltech Delta machine	She et al., PRL **70** 3251
2001	1024	460	VPP5000/56	Gotoh, Fukuyama, PRL **86** 3775
2003	2048	429	Earth Simulator	Kaneda et al. Phys.Fluids **15** L21
2006	4096	675	Earth Simulator	Kaneda, Ishihara, J. Turb. **7** N20
2015	8192	1300	Cray XE Blue Waters	Yeung et al. PNAS **112** 12633

Resource requirements:
floating Point Operation for eddy turnover time: flop ≈ $N^3 \log(N) \times N$
(at high N flop=660 $N^3 \log(N)$ for time step)

Method: pseudo-spectral code

Evolution of turbulence DNS follows supercomputer performance





top500.org: $P \approx 2^{t/1.15}$

DNS resolution doubles on the basis of:
performance every 4.6 (=4x1.15) years
memory every 5.4 (=3x1.8) years (main limitation)