TUBULENT AT HIGH AND LOW ROTATION RATES: EULERIAN AND LAGRANGIAN STATISTICS

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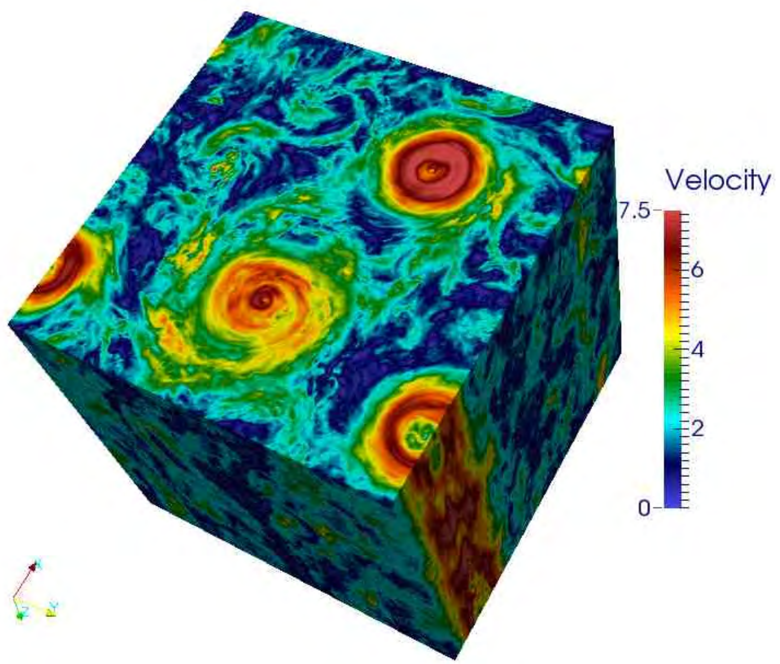
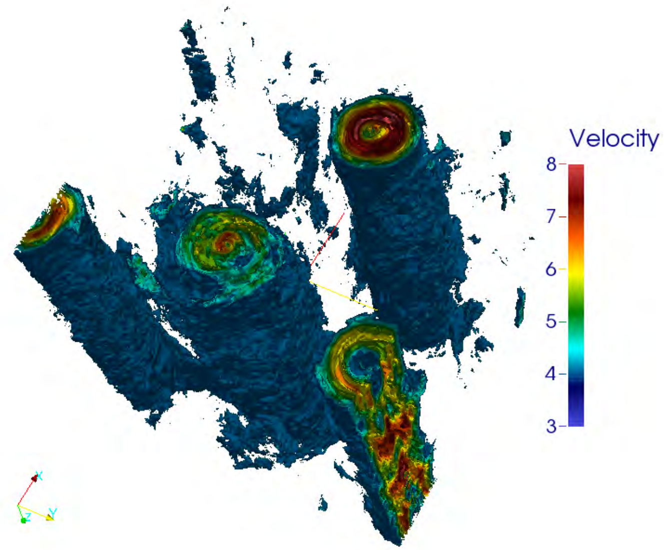




F.Bonaccorso, I.Mazzitelli (Rome, Italy)
M.Hinsberg, F. Toschi (Eindhoven, The Netherlands)
A.Lanotte (Lecce, Italy)
S. Musacchio (Nice, France)
P.Perlekar (Hiderabad, India)

Navier Stokes equation in a rotating frame

DNS: A. Pouquet, P. Mininni, A. Alexakis, C. Herbert, R. Marino, D. Rosenberg ...

$$\partial_t \mathbf{v} + \mathbf{v} \cdot \nabla \mathbf{v} + \boldsymbol{\Omega} \times \mathbf{v} = \nabla P + \nu \nabla^2 \mathbf{v} + \mathbf{F} - \alpha \mathbf{v}$$

NEW FEATURES:

1) IDEAL FORCING MECHANISM (AS NEUTRAL AS POSSIBLE: ISOTROPIC; NON HELICAL, TIME-COLORED) + LARGE SCALE FRICTION
2) UNPRECEDENTED NUMERICAL RESOLUTION/SCALE SEPARATION (**UP TO 4096^3**)
3) LAGRANGIAN STATISTICS (BOTH TRACERS AND INERTIAL PARTICLES)

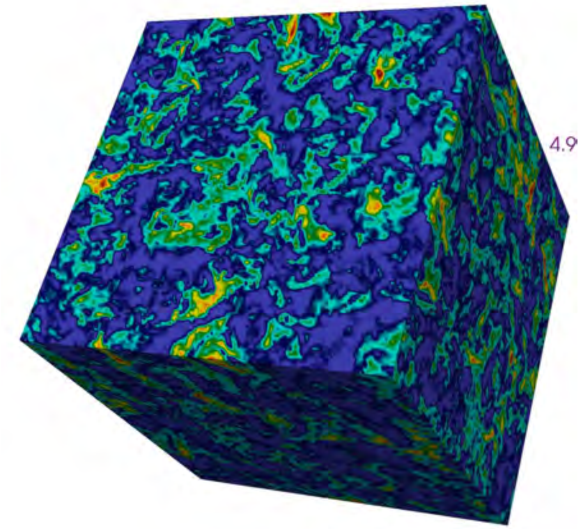
Rossby number

$$Ro = \frac{non\,linear\,term}{rotation} \sim \frac{U_0}{\Omega L_0}$$

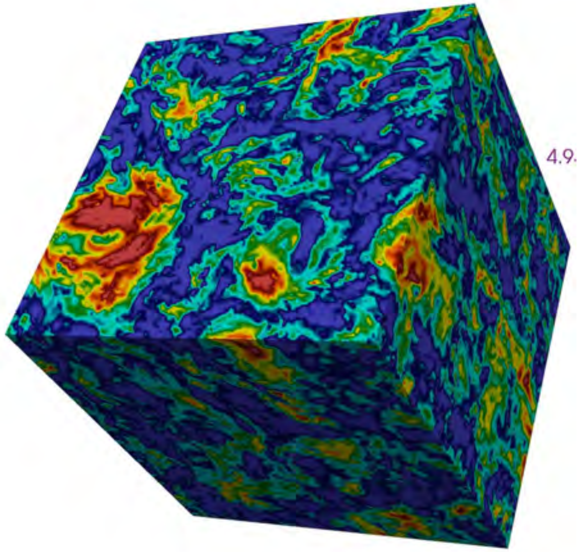
$Ro_c \,(\lesssim 1) \rightarrow$ direct energy cascade

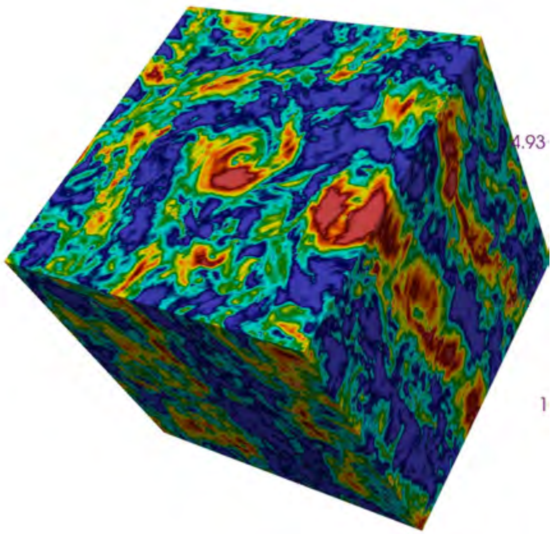
$Ro_c \rightarrow$ both direct and inverse cascade

Rossby = 2

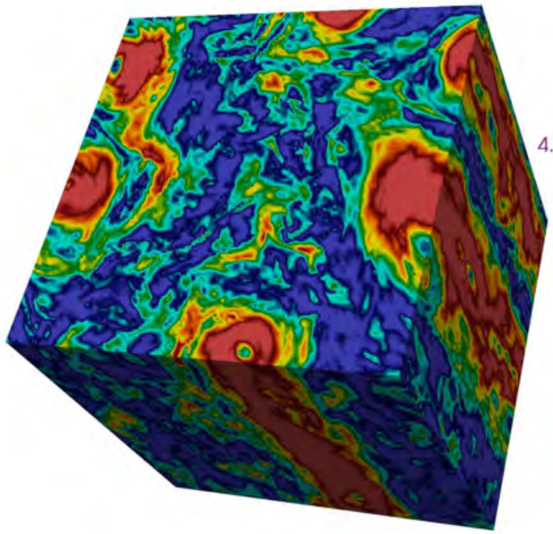


Rossby = 0.8





Rossby = 0.2

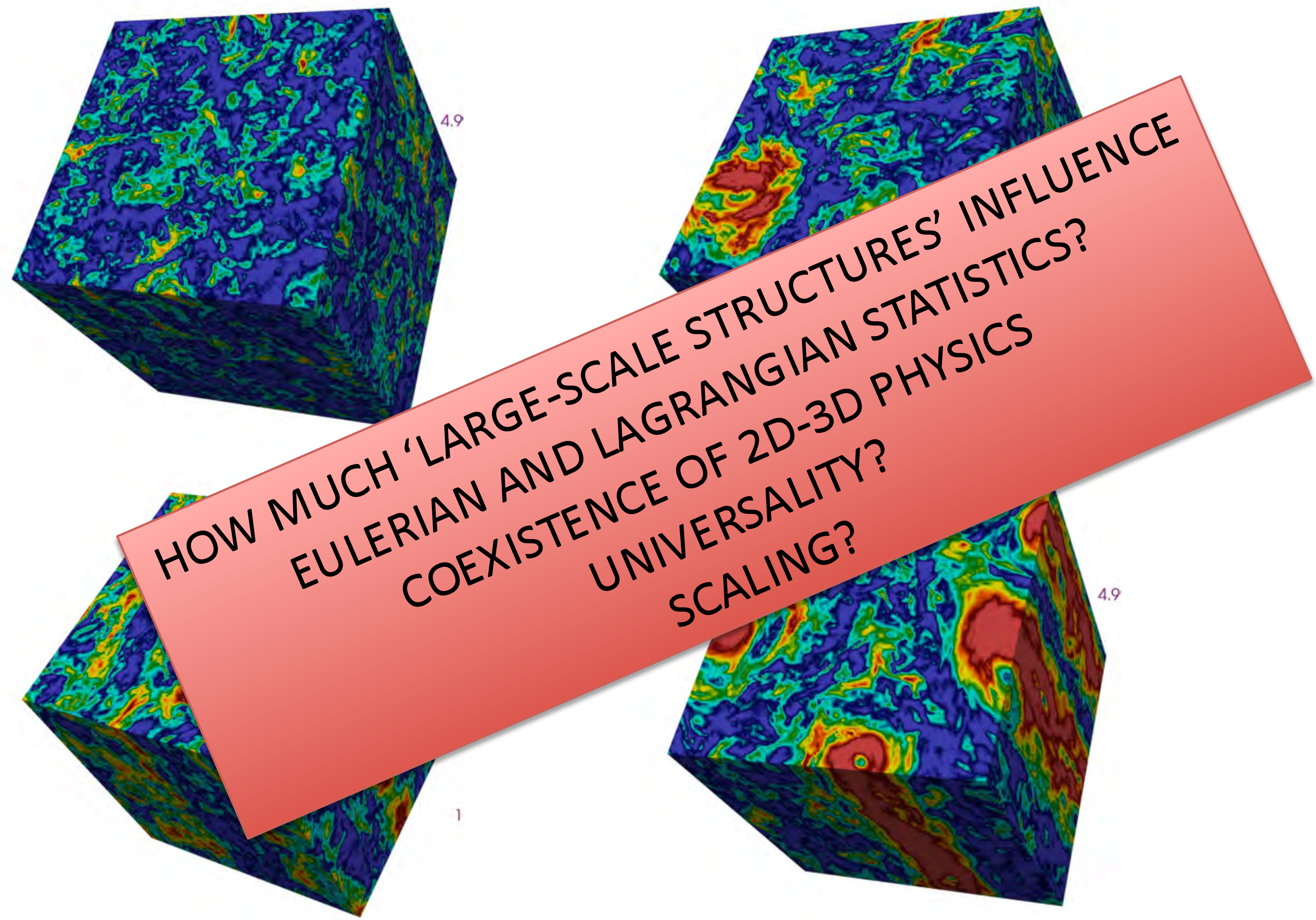


Rossby = 0.1

HOMOGENEOUS & ANISOTROPIC

Rossby = 2

Rossby = 0.8



Rossby = 0.2

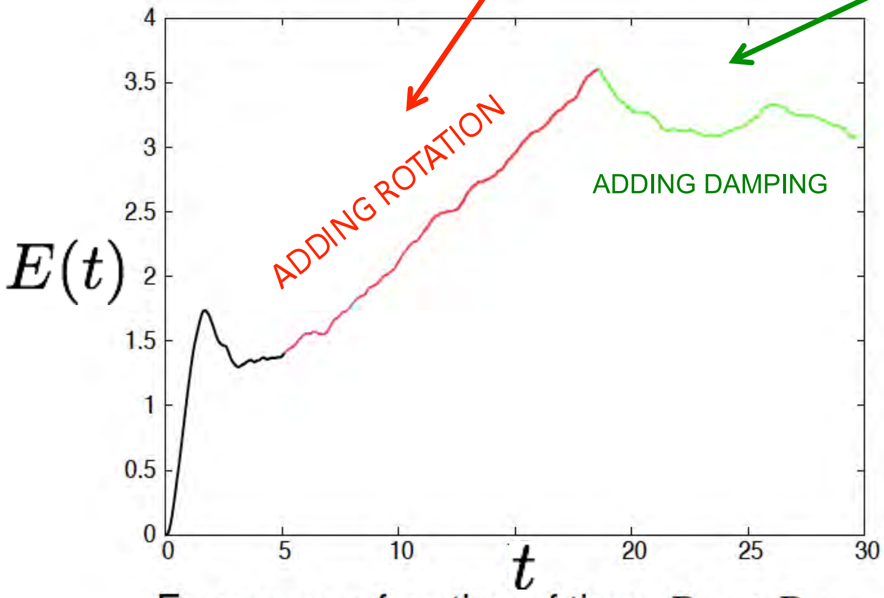
Rossby = 0.1

HOMOGENEOUS-ANISOTROPIC

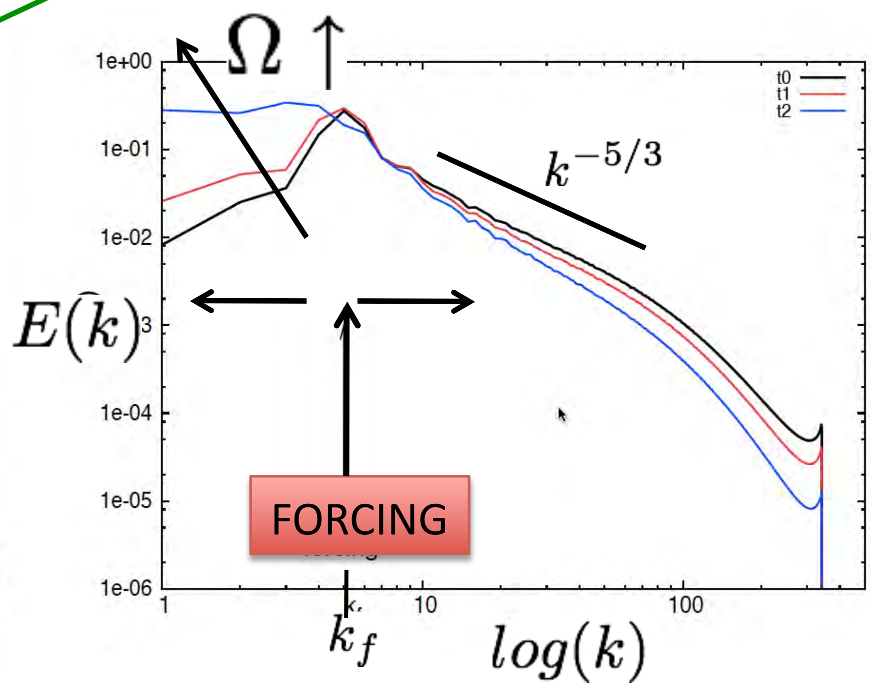
$$\partial_t \mathbf{u} + \mathbf{u}\cdot\nabla\mathbf{u} + \mathbf{\Omega}\times\mathbf{u} = \nabla P + \nu\nabla^2\mathbf{u} + \mathbf{F} - \alpha\mathbf{u}$$

ROTATION

DAMPING:
ECKMAN
FRICTION



Energy as a function of time, $Ro < Ro_c$



FORCING: 2°-order OU-PROCESSS: ISOTROPIC, HOMOGENEOUS **NOT** DELTA-CORRELATED

Particle equation of motion

NEW ! NEW !

$$\frac{d\mathbf{v}}{dt} = \beta \frac{D\mathbf{u}}{Dt} - \frac{1}{\tau_p}(\mathbf{v} - \mathbf{u}) + 2(\mathbf{v} - \beta \mathbf{u}) \times \mathbf{\Omega} - (1 - \beta)\mathbf{\Omega} \times (\mathbf{\Omega} \times \mathbf{r})$$

added mass + pressure — Stokes drag — Coriolis — Centrifugal force

$$\beta = \frac{3\rho_f}{\rho_f + 2\rho_p}, \qquad \tau_p = \frac{a^2}{3\nu\beta}$$

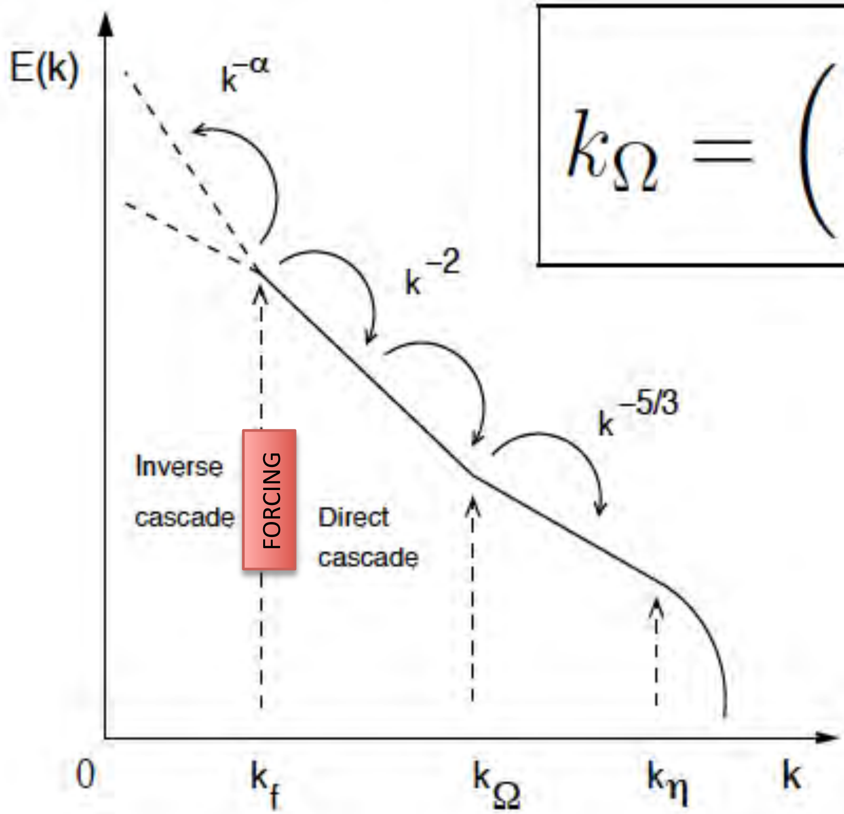
$\beta < 1 \rightarrow$ heavy particles $\rho_p > \rho_f$

$\beta > 1 \rightarrow$ light particles $\rho_p < \rho_f$

Stokes number: $St = \frac{\tau_p}{\tau_\eta}$

Energy spectrum scaling

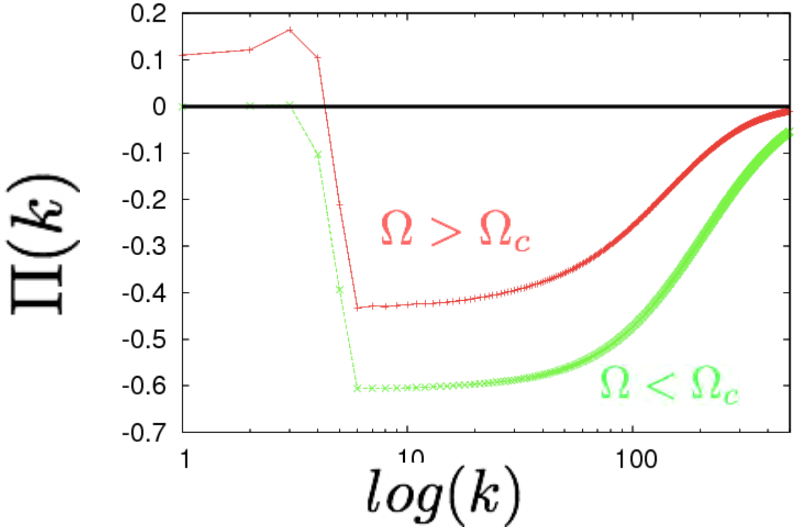
- $k > k_\Omega \longrightarrow E(k) \sim \varepsilon^{2/3} k^{-5/3}$
- $k_f < k < k_\Omega \longrightarrow E(k) \sim (\varepsilon\Omega)^{1/2} k^{-2}$
- $k < k_f \longrightarrow E(k) \sim \Omega^2 k^{-3}$ - - - $E(k) \sim k^{-5/3}$ (?)

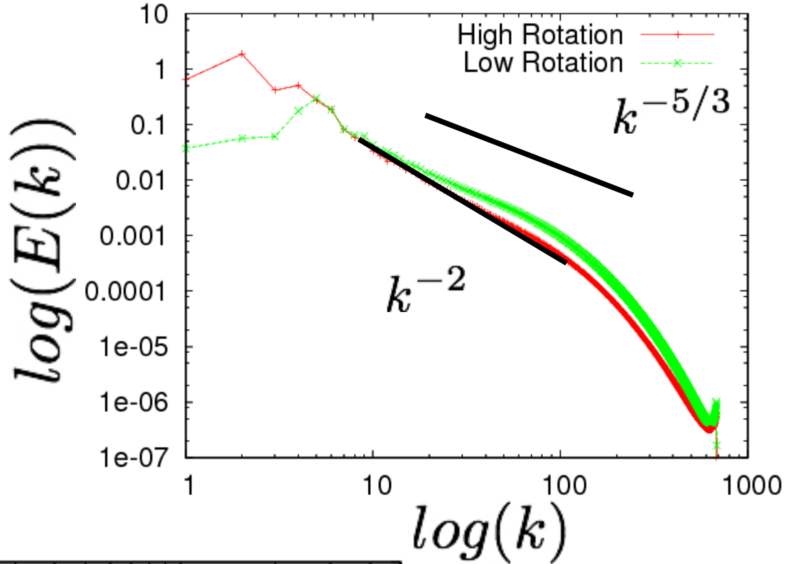


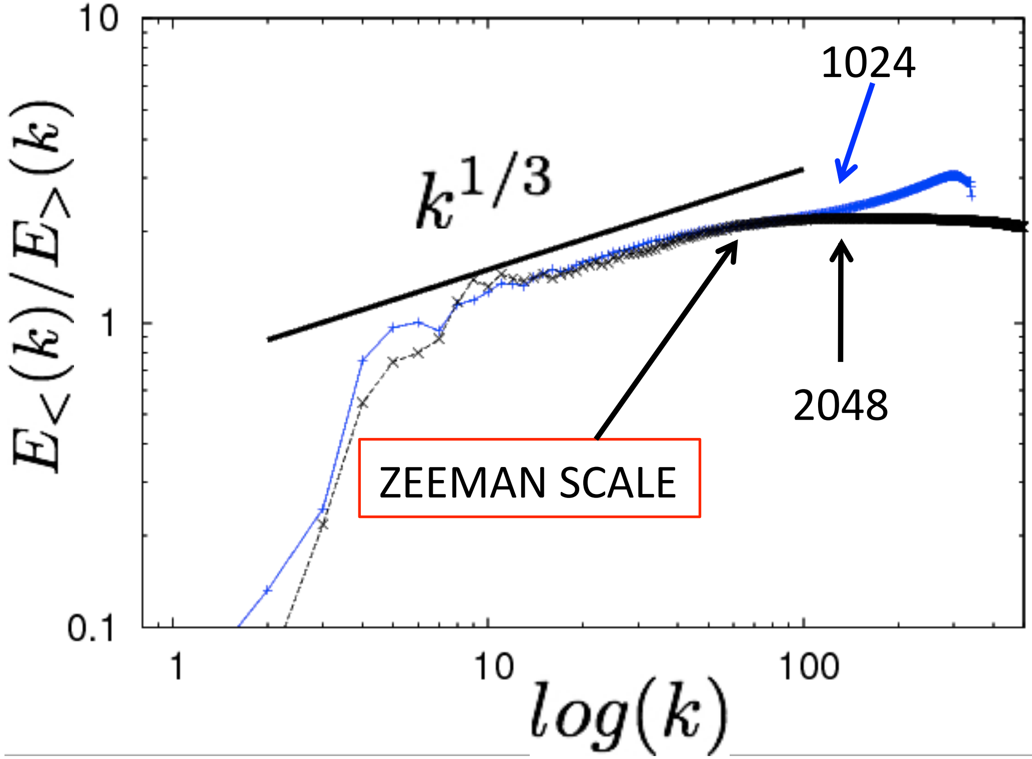
$$k_\Omega = \left(\frac{\Omega^3}{\varepsilon}\right)^{1/2}$$

ZEEMAN SCALE

2048^3 resolution

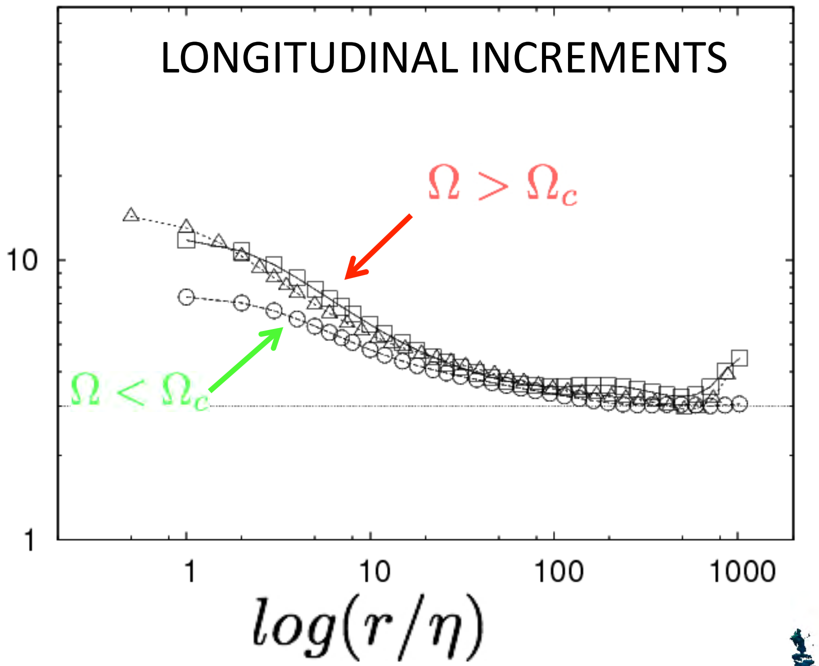


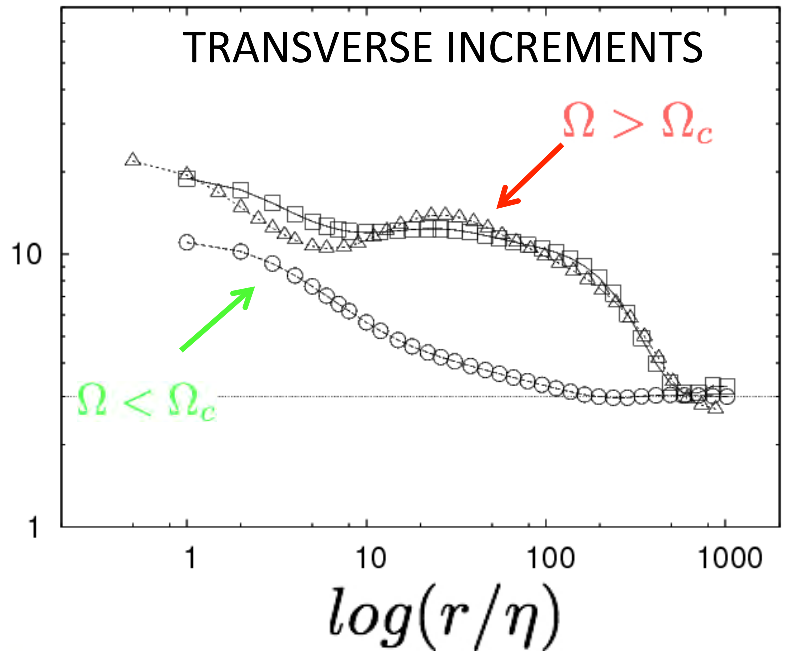


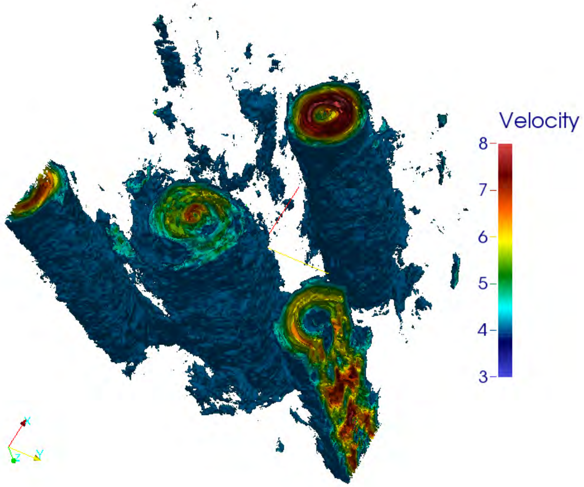


FLATNESS

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

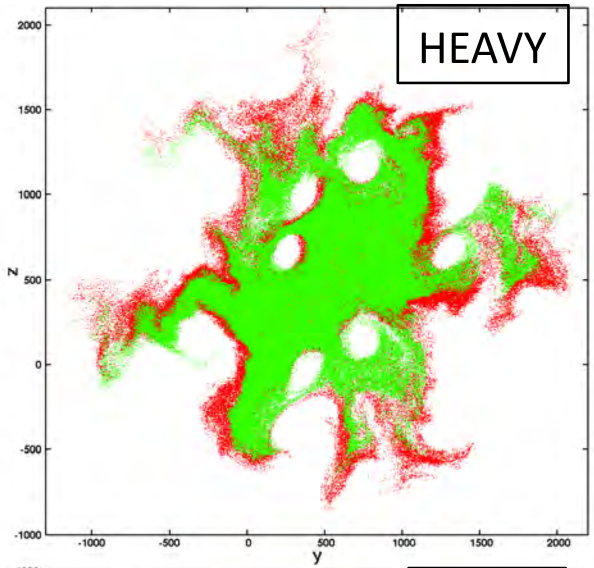


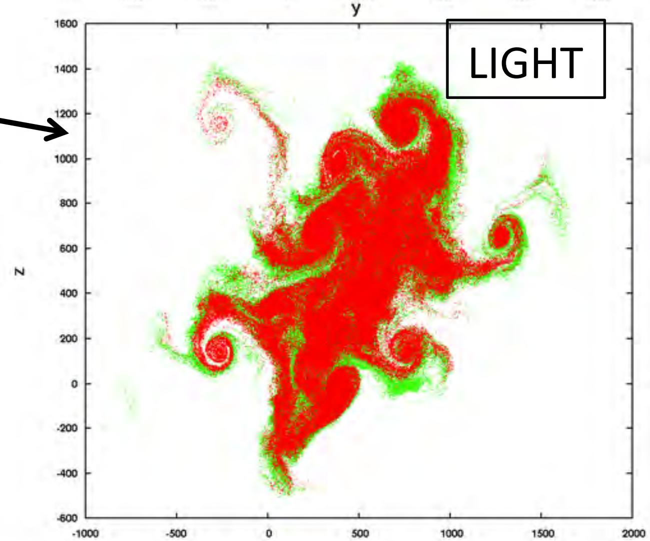




PREFERENTIAL SAMPLING-> WHERE DO PARTICLES GO?

family	β	St	type
1	0.4	0.3	Heavy
2	0.4	0.7	
3	0.8	0.3	
4	0.8	0.7	
5	1.2	0.3	Light
6	1.2	0.7	
7	1.6	0.3	
8	1.6	0.7	
9	1.6	1	
10	1.6	5	





$$\frac{d\mathbf{v}}{dt} = \beta\frac{D\mathbf{u}}{Dt} - \frac{1}{\tau_p}(\mathbf{v}-\mathbf{u}) + 2(\mathbf{v}-\beta\mathbf{u})\times\mathbf{\Omega} - (1-\beta)\mathbf{\Omega}\times(\mathbf{\Omega}\times\mathbf{r})$$

CONCLUSIONS:

-HIGH RESOLUTION ROTATING TURBULENCE: FIRST ATTEMPT TO CONTROL SIMULTANEOUSLY EULERIAN & LAGRANGIAN STATISTICS

-IDEAL SET-UP (1): HOMOGENEOUS AND ISOTROPIC TIME-CORRELATED FORCING

-IDEAL SET-UP (2): SCALE-SEPARATION

-STRONG INFLUENCE OF LARGE-SCALE (NON-UNIVERSAL?) VORTICAL STRUCTURES

-DEPARTURE FROM GAUSSIANITY (BUT NO/LITTLE INTERMITTENCY)

-EFFECTS OF CORIOLIS AND CENTRIFUGAL ON LAGRANGIAN PREFERENTIAL SAMPLING (NOT SHOWN TODAY)