Before the seminar..

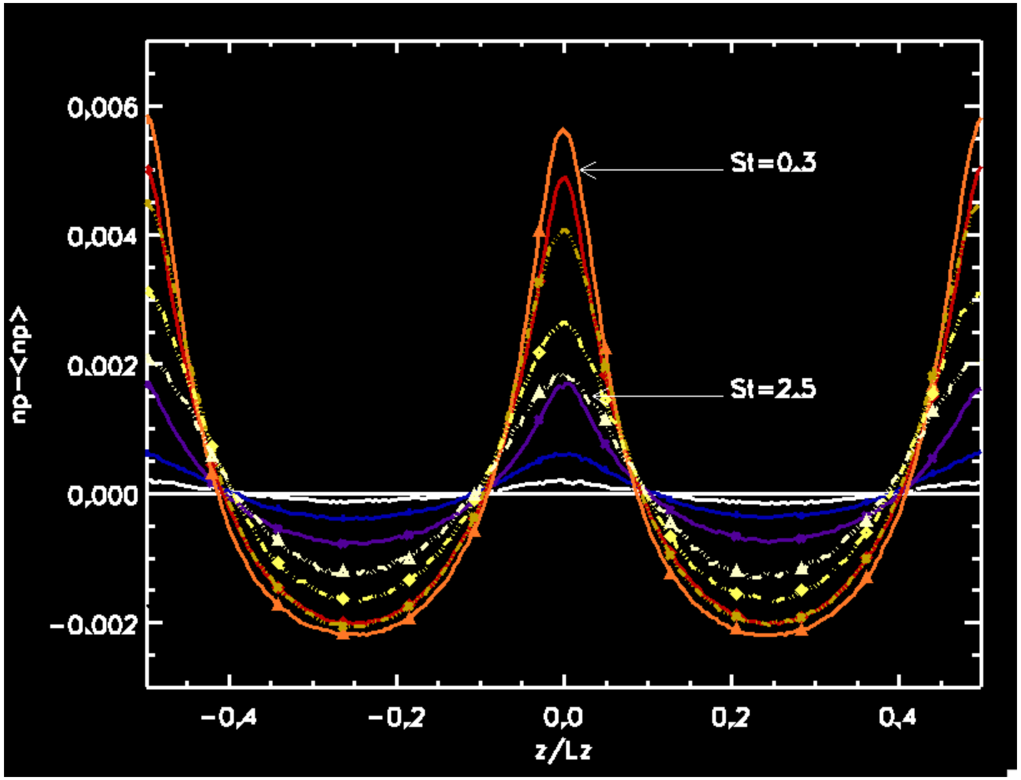
- @ Stockholm, hosted by KTH and SU
- Two postdoc positions available this fall ("particles in turbulence" and "flow-structures interactions").
- We run regular programs, like KITP, Isaac Newton Institute, etc

NORDITA

(Nordic Institute of Theoretical Physics)

Dynamos with multiplicative noise: Kazantsev-Kraichnan model

The Turbulence with (large and small) balls



Nils Haugen (NTNU), Dhrubaditya Mitra and Igor Rogachevskii

Few small balls

- Astrophysics (dusty disks), GFD (clouds, ..), Biological flows (blood) Industrial flows.
- Mutual reaction between solute and solvent can make the problem Non-Newtonian.

Passive particles in flows

- If the fraction of the additives are small, the back-reaction may be ignored.
- If the particles are small (than viscous scale) and spherical and heavy, they may be well approximated by a simple equation.

$$\dot{\mathbf{x}} = \mathbf{v}$$

$$\dot{\mathbf{v}} = \frac{1}{\tau}[\mathbf{u} - \mathbf{v}]$$

$$\tau = \frac{6\pi\mu r_p}{m_p}$$

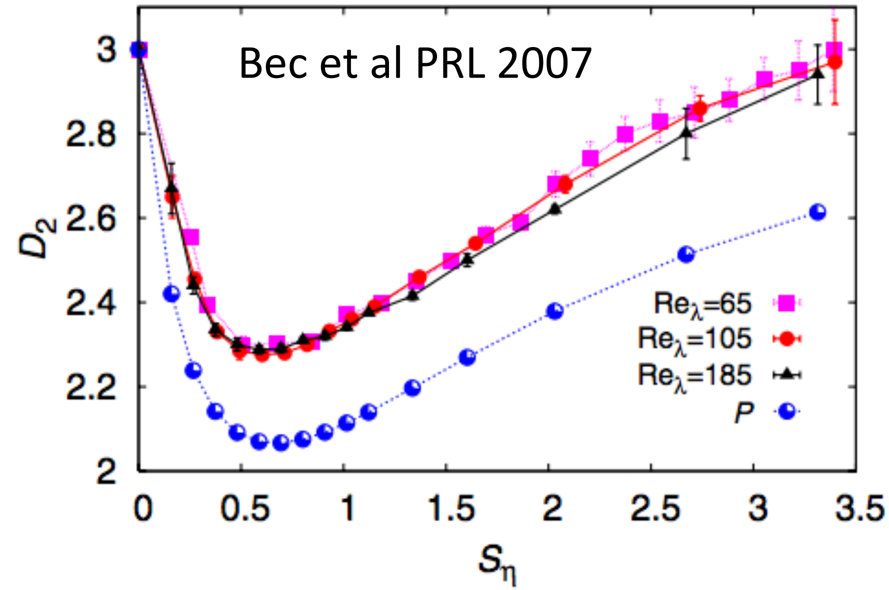
$$m_{\mathrm{p}}\dot{\mathbf{v}} = (\cdots) + m_{\mathrm{f}}\frac{D\mathbf{u}}{Dt} + \frac{1}{2}m_{\mathrm{f}}\frac{d}{dt}[\cdots] - 6\pi r_{\mathrm{p}}^2\mu\int_0^t d\tau\frac{\cdots}{\sqrt{\pi\nu(t-\tau)}}$$

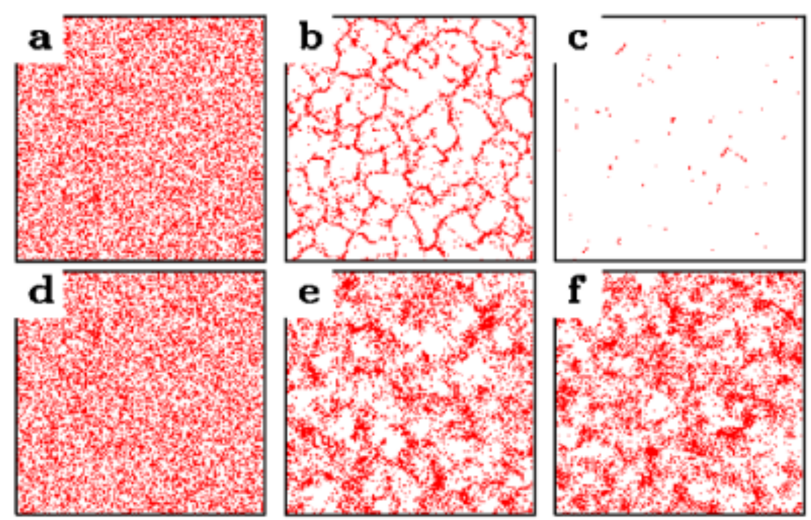
$$(\cdots) = 6\pi\mu r_{\mathrm{p}}[\mathbf{u} - \mathbf{v} + \frac{r_{\mathrm{p}}^2}{6}\nabla^2\mathbf{u}]$$

Maxey and Riley PoF 1982

Clustering and collision in HIT

- Maxey's argument suggests that inertial particles can cluster in incompressible flows.
- The grad v can develop finite-time singularities; i.e., formation of caustics. This may imply a significant increase in collision frequency.

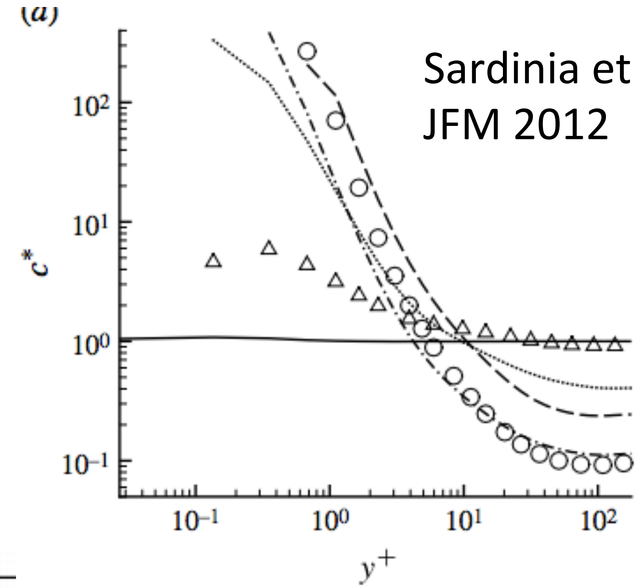




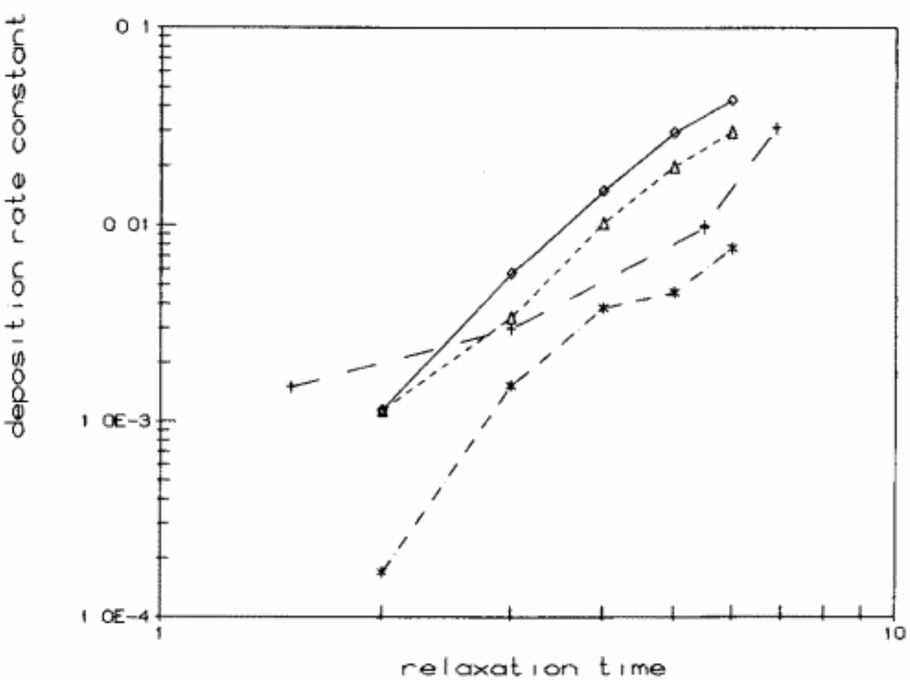
Wilkinson and Mehlig PRE 2003

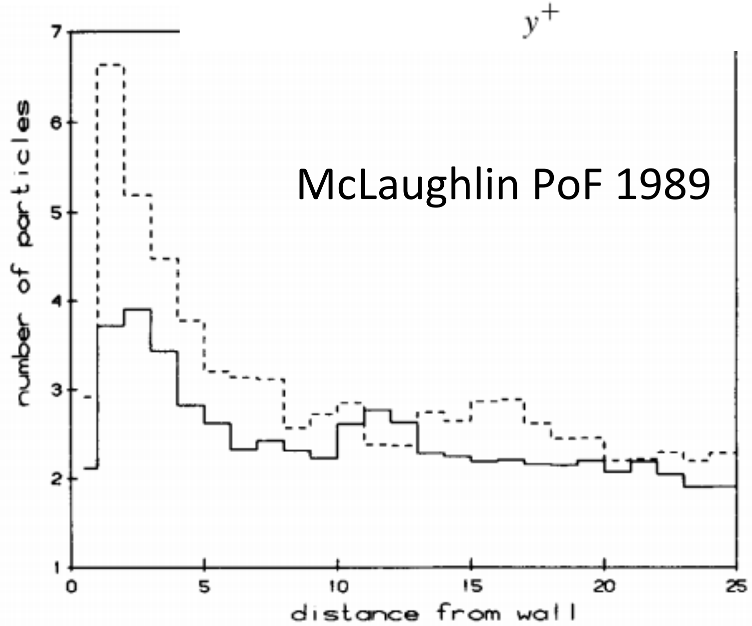
When the flow in inhomogeneous..

- Particles cluster near the wall in turbulent pipe flows.
- How many particles are deposited on the wall, what is the PDF of velocities of collisions ?



Sardinia et al JFM 2012





McLaughlin PoF 1989

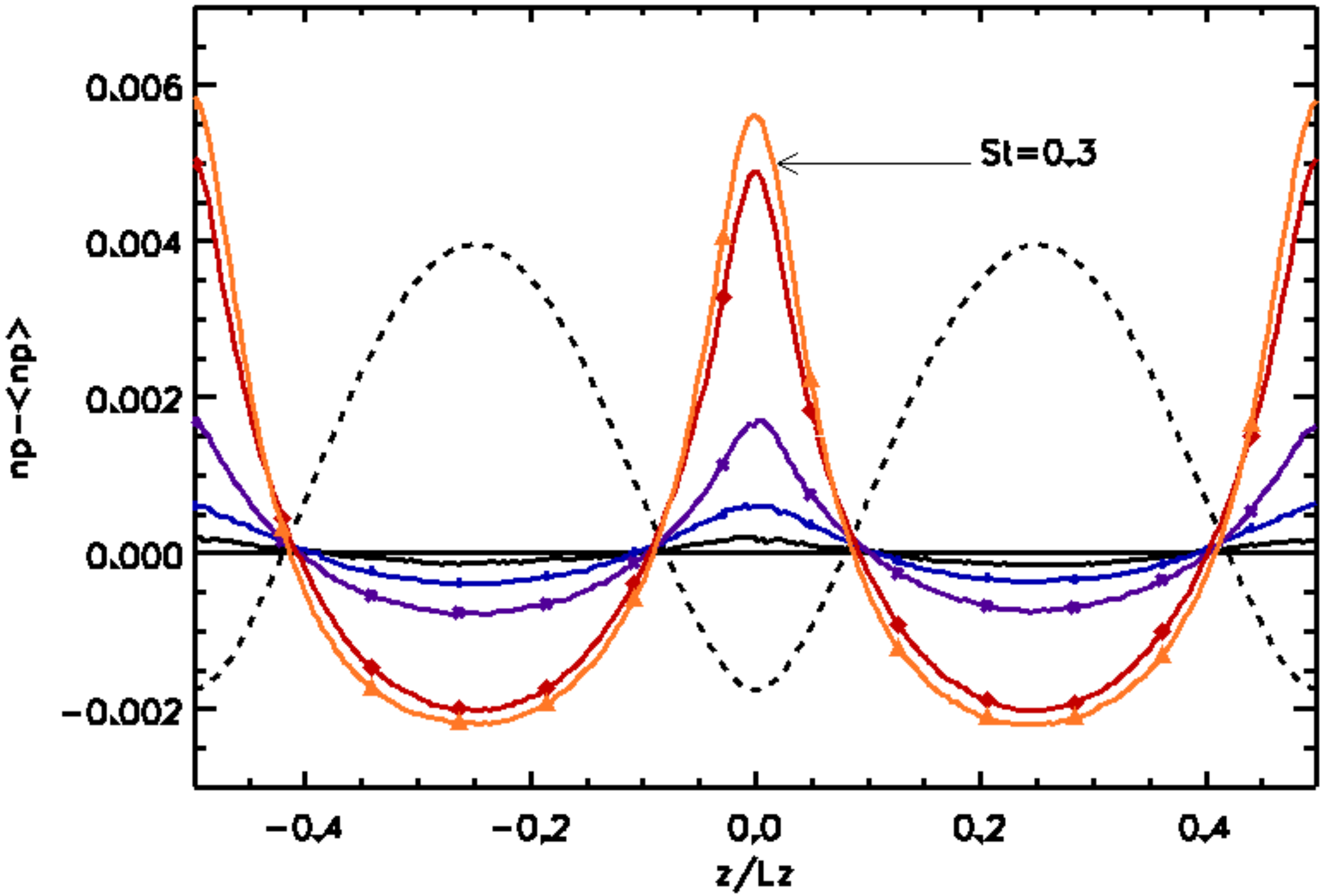
Simple but not too simple

- How do we understand this clustering ? Inhomogeneity of turbulent intensity is important. Is the boundary layer important ? Is shear important ?
- Simulations with no boundaries but inhomogeneous turbulent intensity.

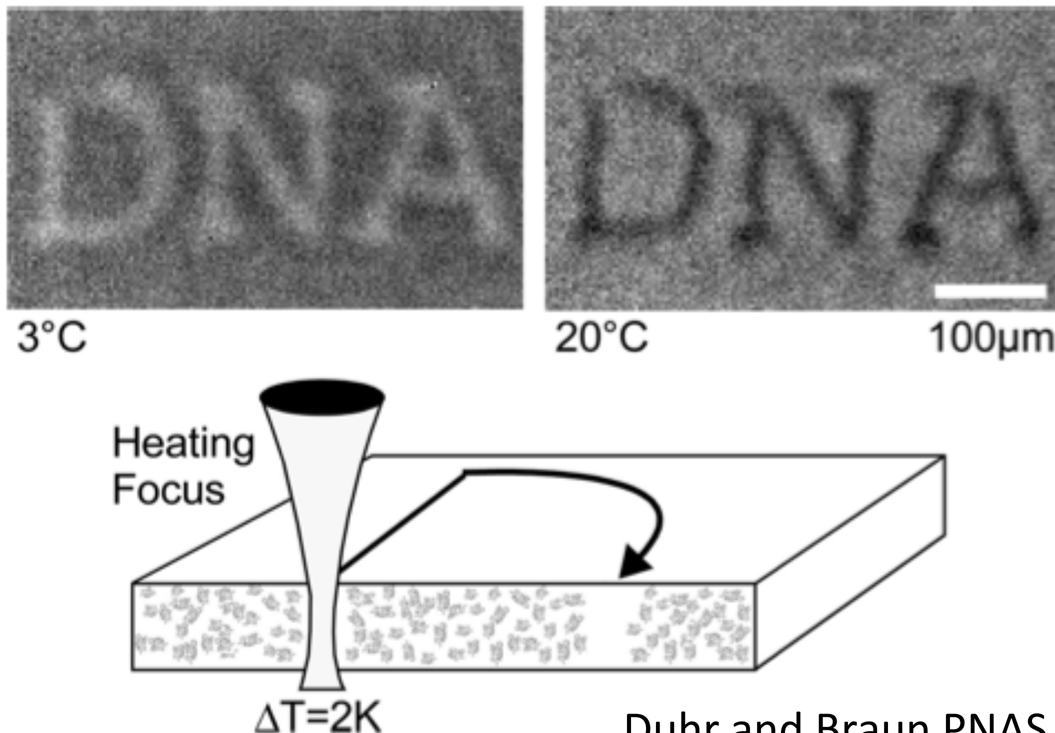
$$\frac{D\mathbf{u}}{Dt} = -\nabla p + \nu \nabla^2 \mathbf{u} + \mathbf{f}$$

$$\langle f_i f_j \rangle = f_0 \sin^2(z)$$

Clustering is observed



Soret effect



Duhr and Braun PNAS 2006

$$\mathbf{J} = -D\nabla c - D_T c \nabla T \qquad S = \frac{D_T}{D}$$

HIT and equilibrium ?

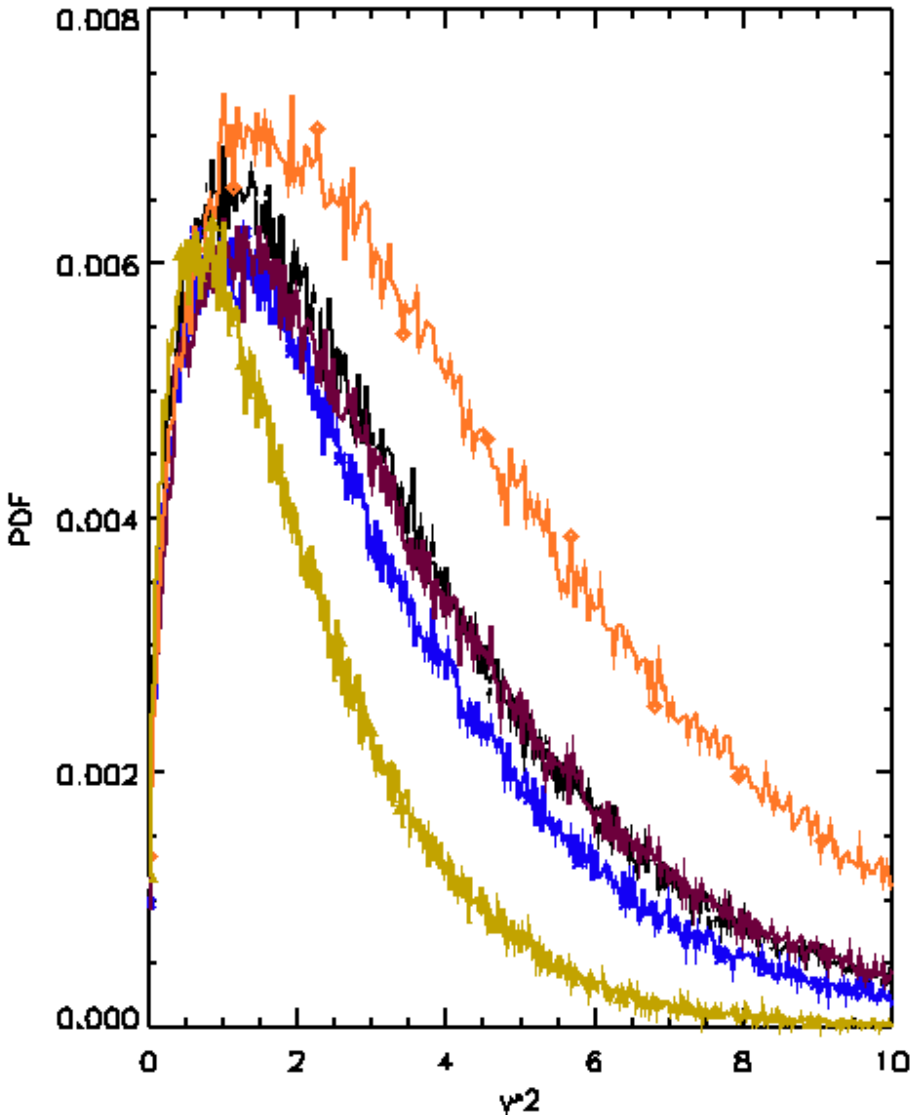
$$\dot{\mathbf{x}} = \mathbf{v} \qquad dX_t = V_t dt$$

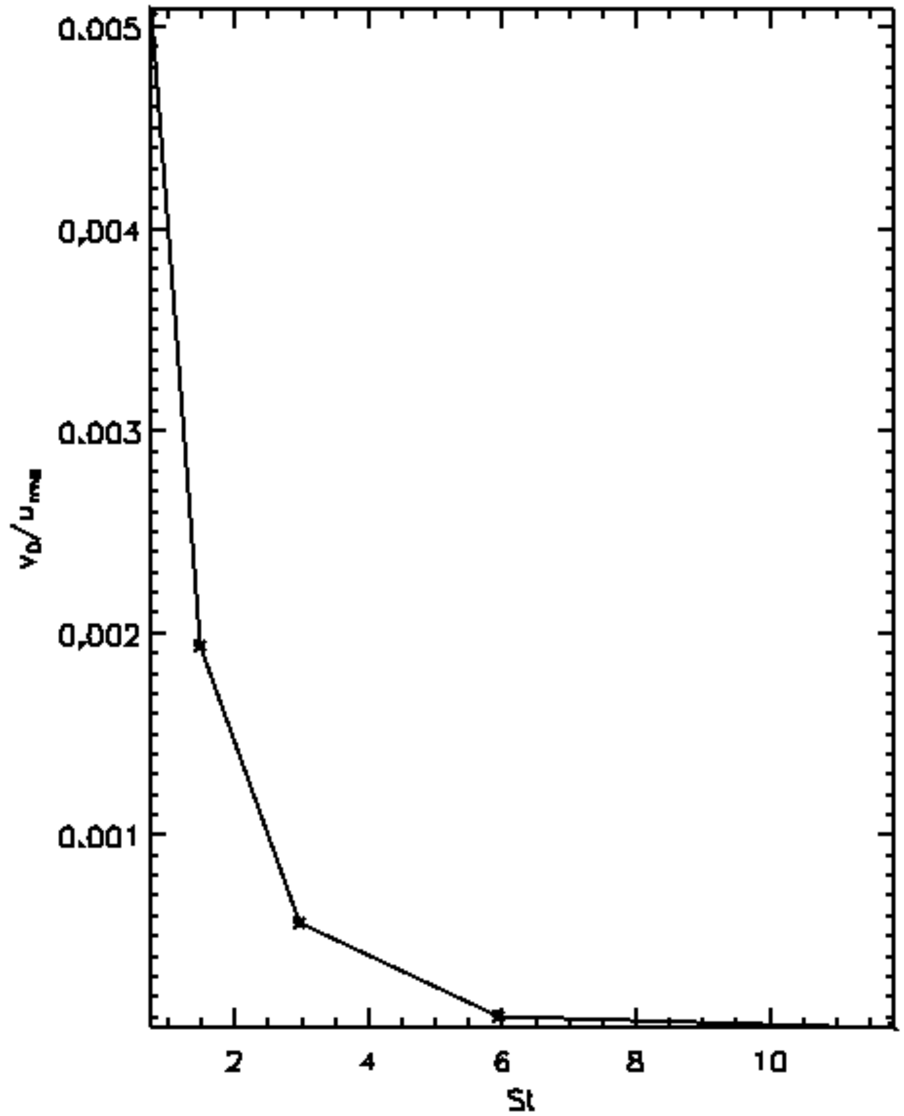
$$\dot{\mathbf{v}} = -\frac{1}{\tau}\mathbf{v} + \frac{1}{\tau}\mathbf{u} \qquad dV_t = -\frac{1}{\tau}V_t dt + \frac{\sigma}{\tau} dW_t$$

$$\partial_t \rho(x, v, t) = -\partial_x(v\rho) + \frac{1}{\tau}\partial_v(v\rho) + \frac{\sigma}{2\tau}\partial_v^2 \rho$$

$$\rho_{\mathrm{stat}}(v) \sim v^2 \exp[-\frac{v^2}{v_0^2}]$$

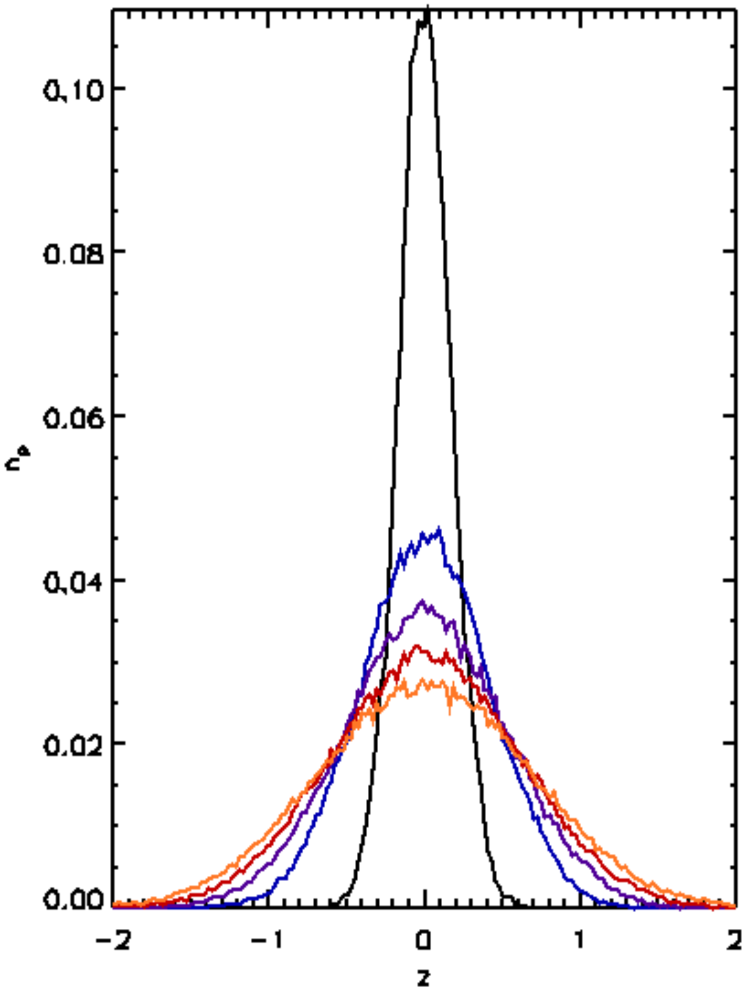
Maxwell-Boltzmann in turbulence ?

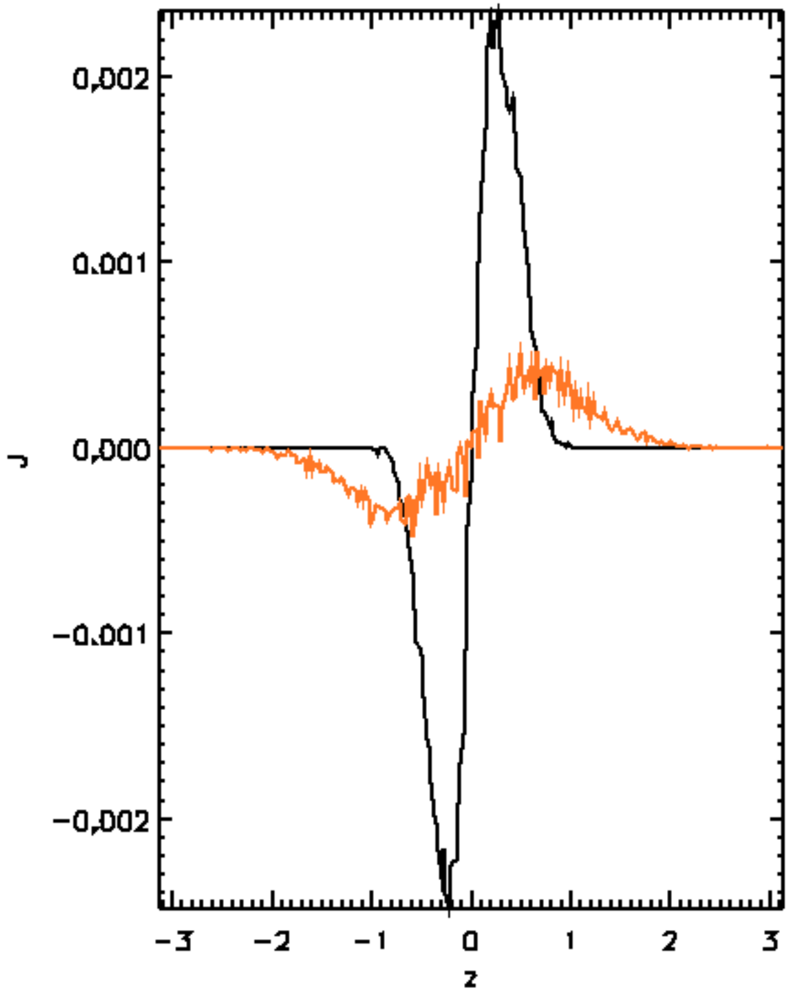




Linear response in NESS

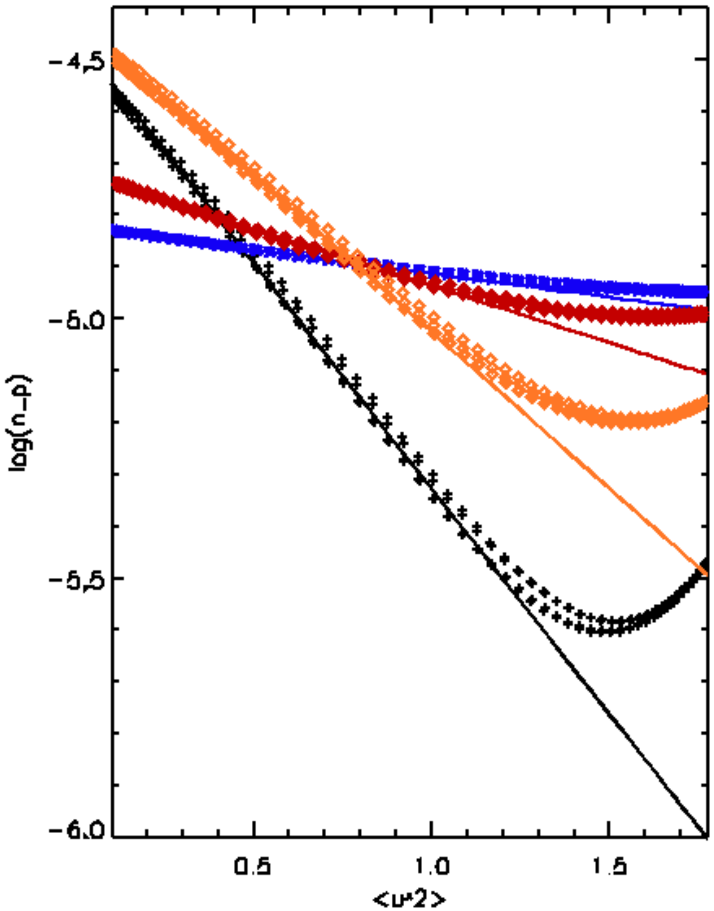
$$J_z = -\kappa \frac{d}{dz} n_{\rm p} \qquad \kappa \approx \frac{u_{\rm rms}}{k_{\rm f}}$$

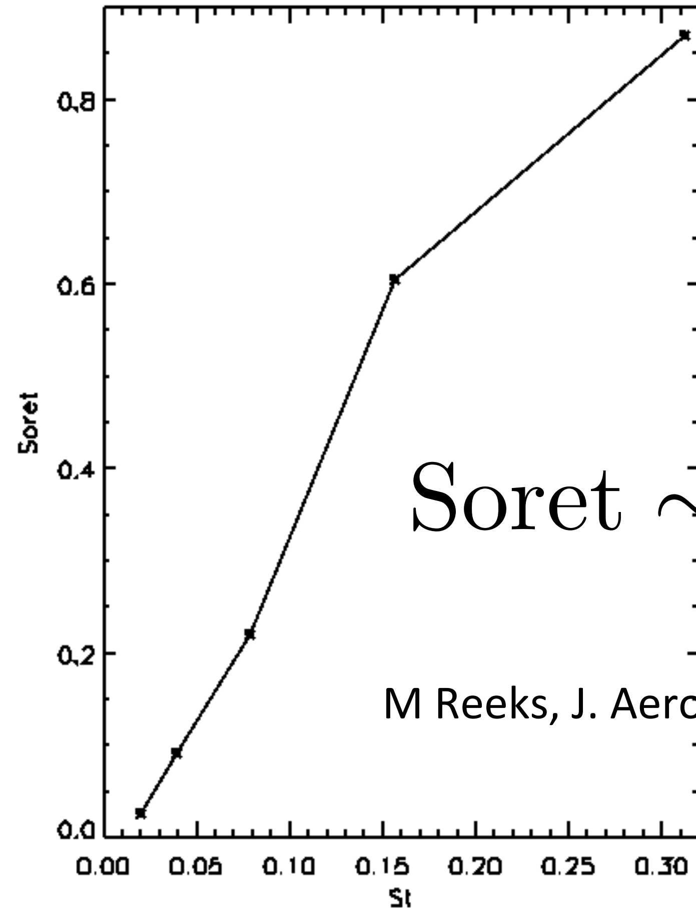




Fluxes in turbulent state

$$J_z^{\rm stat} = -\kappa \frac{d}{dz}\langle n_{\rm p}^{\rm stat}\rangle_{xy} - \langle n_{\rm p}^{\rm stat}\rangle \kappa_T \frac{d}{dz}\langle u^2\rangle_{xy} = 0$$





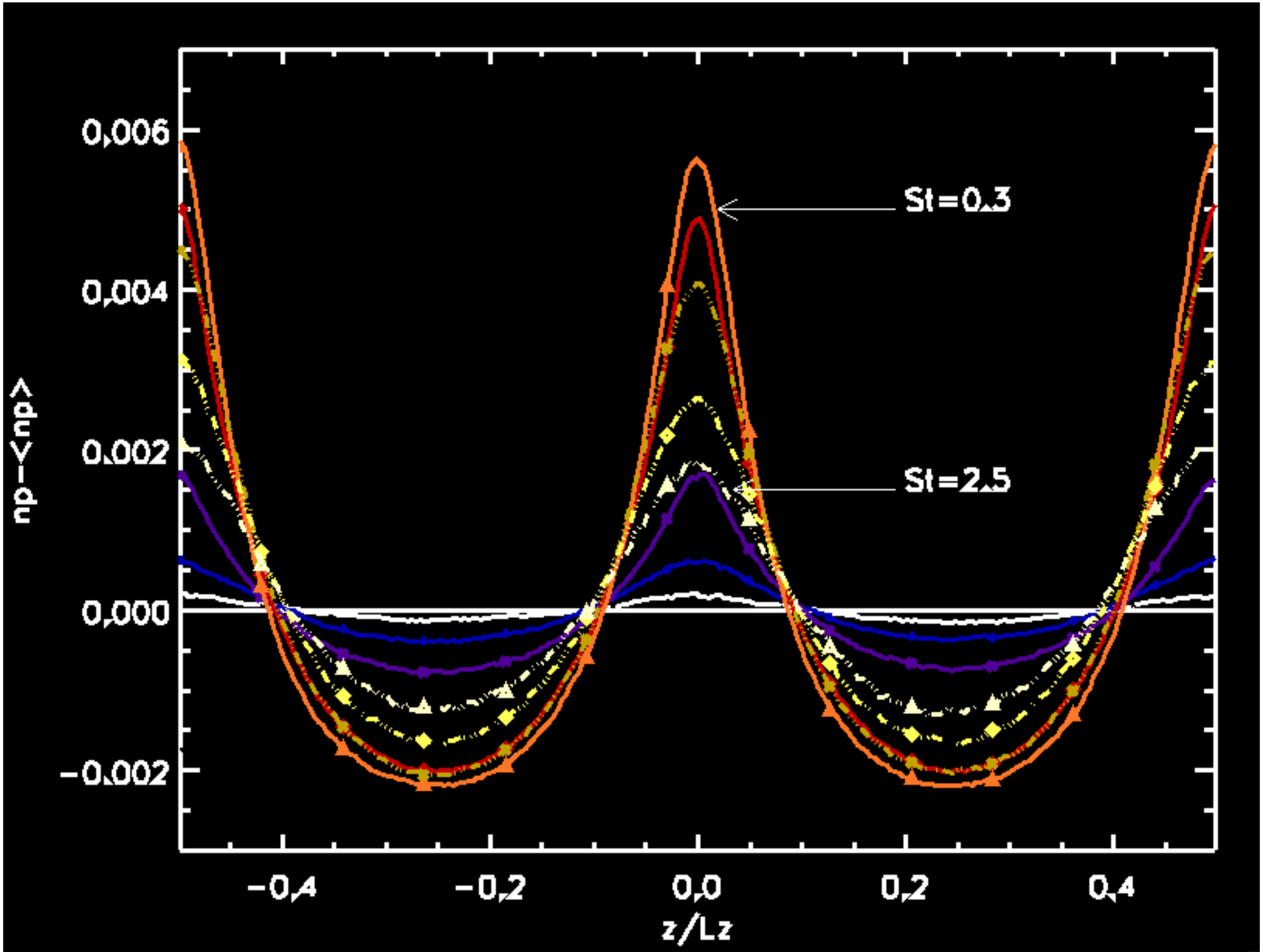
$$\mathrm{Soret} \sim \mathrm{St}$$

M Reeks, J. Aerosol. Sci. 1983

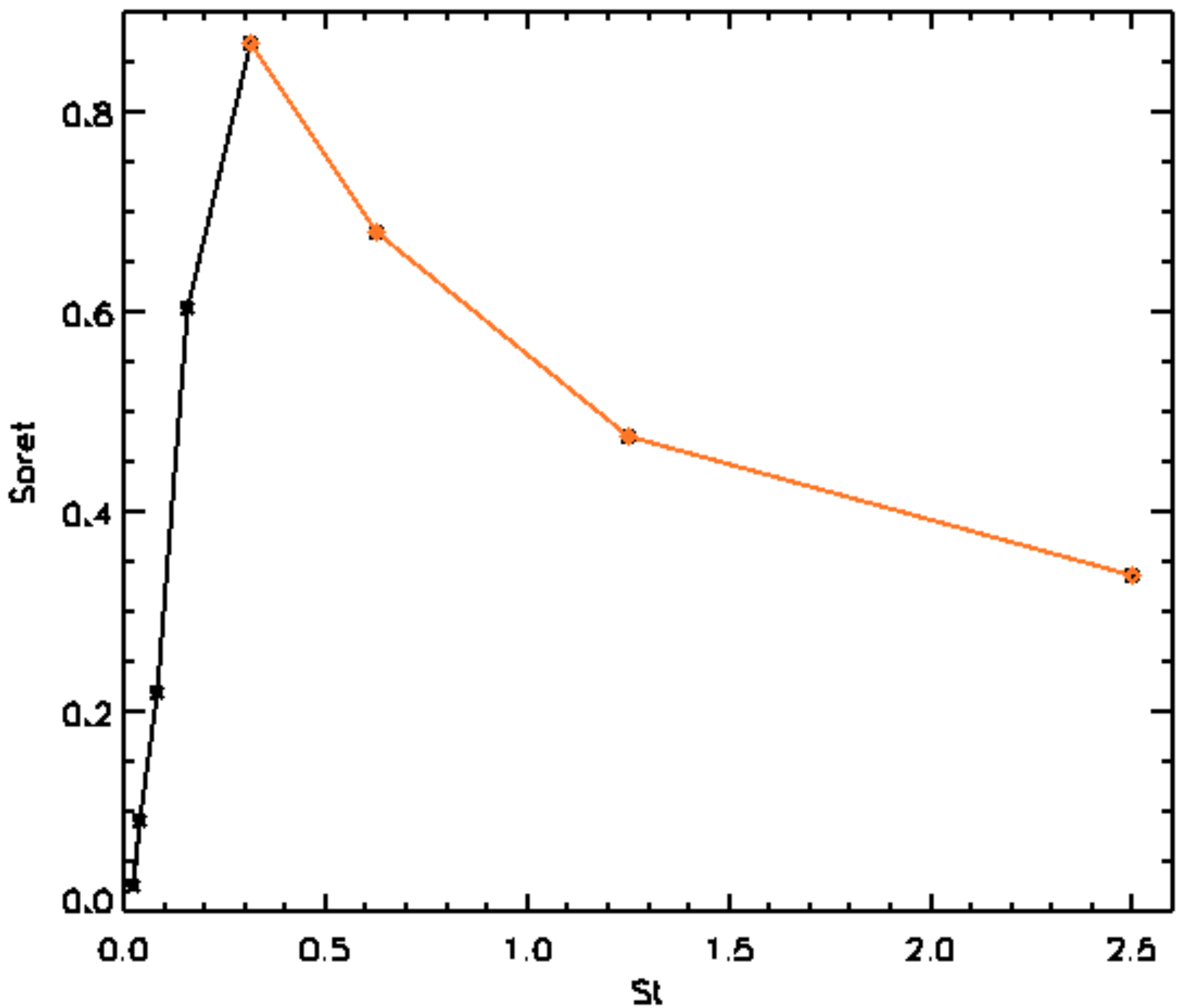
Understanding clustering..

- In INT (Inhomogeneous Turbulence) difference in intensity of turbulence can generate a flux of inertial particles.
- The flux can be described by assuming local “equilibrium” in a way similar to what is done in Soret efffect.
- LHDIA closure gives turbophoretic coefficient proportional to Stokes number.
- At larger St number there is minor departure from this prediction.

But not quite



Non-monotonic Soret coefficient



An attempt at understanding

$$\partial_t \rho(z,v,t) = -\partial_z(v\rho) + \frac{1}{\tau}\partial_v(v\rho) + \frac{\sigma(z)}{2\tau}\partial_v^2\rho$$

$$\sigma(z) = \mu z^2 \quad \partial_t P(\xi) = \partial_\xi[U'P] + \mu\gamma^2\partial_\xi^2 P$$

$$U(\xi) = \frac{\gamma}{2}\xi^2 + \frac{1}{3}\xi^3$$

- A localization-delocalization transition is predicted, but we do not see that, we see a gradual change.