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Slide of the Seminar

Waves and extreme events: from atmospheric to turbulent flows

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Waves and extreme events: from atmospheric to turbulent flows

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Roma, Italia
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- Can we "extract" the waves from the flow? Can we understand how they interact with other structures?
- Characterization of the effect of waves, and measurements of the amount of energy in wave modes has been done mostly indirectly.
- Space and time resolved spectra (e.g. [*Yarom and Sharom, Nature Phys (2014)*; *Cobelli et al, PRL (2009)*]) can study the effect of waves directly

Systems studied

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Rotating turbulence

Anisotropizatioin due to the effect of waves

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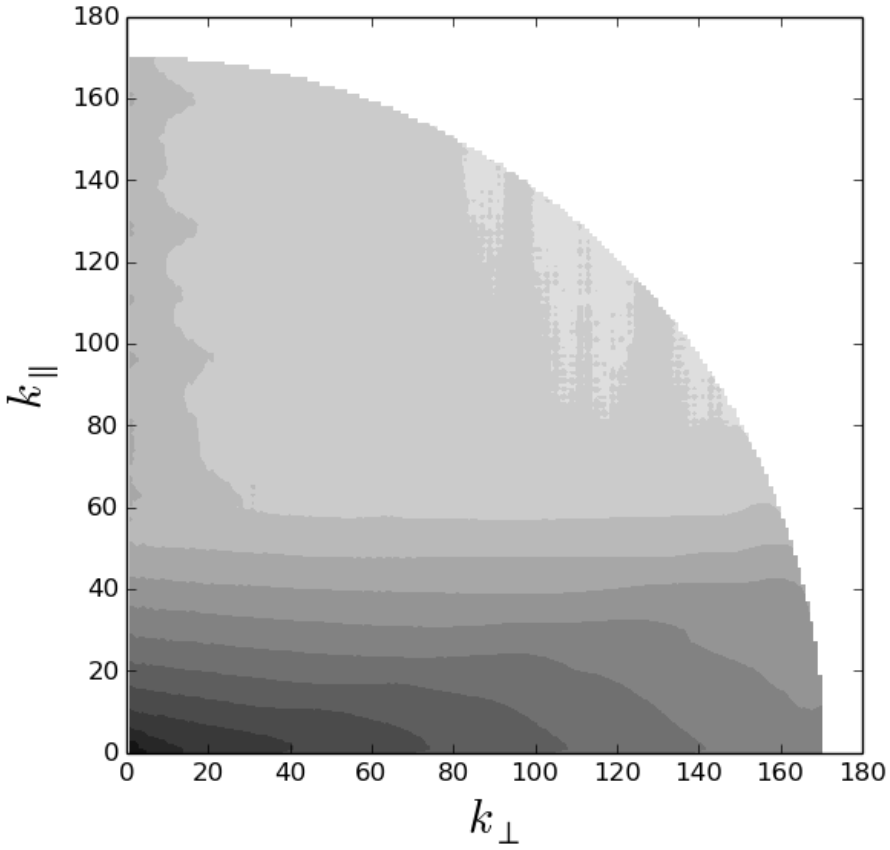
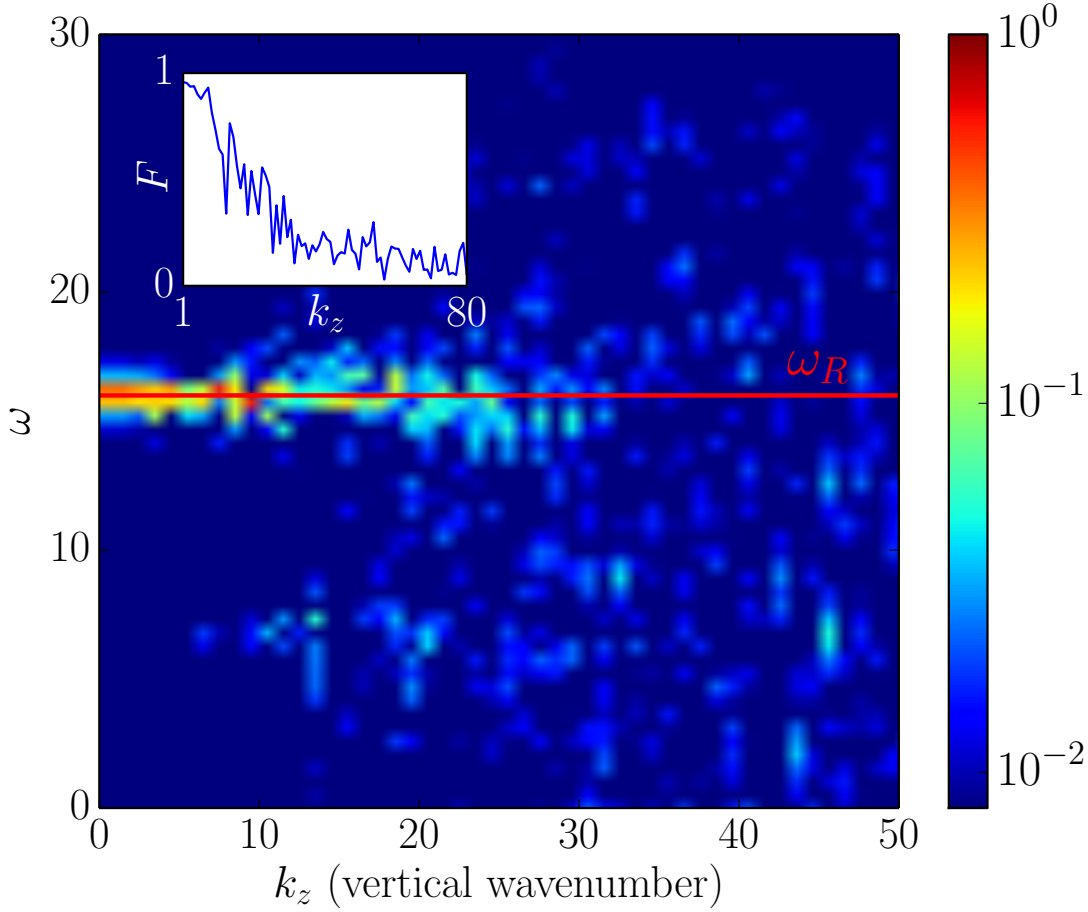


Preferential energy transfer towards modes with small $k_\parallel$ (Waleffe, PoF 93). But exactly where are the waves?
[*PC et al, PoF (2014)*]

Rotating turbulence

$E(k, \omega)$

Only in the larger scales energy accumulates along modes satisfying the dispersion relation of inertial waves!



$$\omega_R = \frac{2\Omega k_\parallel}{k} \Rightarrow \omega_R(0, 0, k_z) = 2\Omega$$

Stratified flows

Previous works

- Boussinesq model with no rotation. Buoyancy is now the restitutive force. Gravity acts in the vertical direction.

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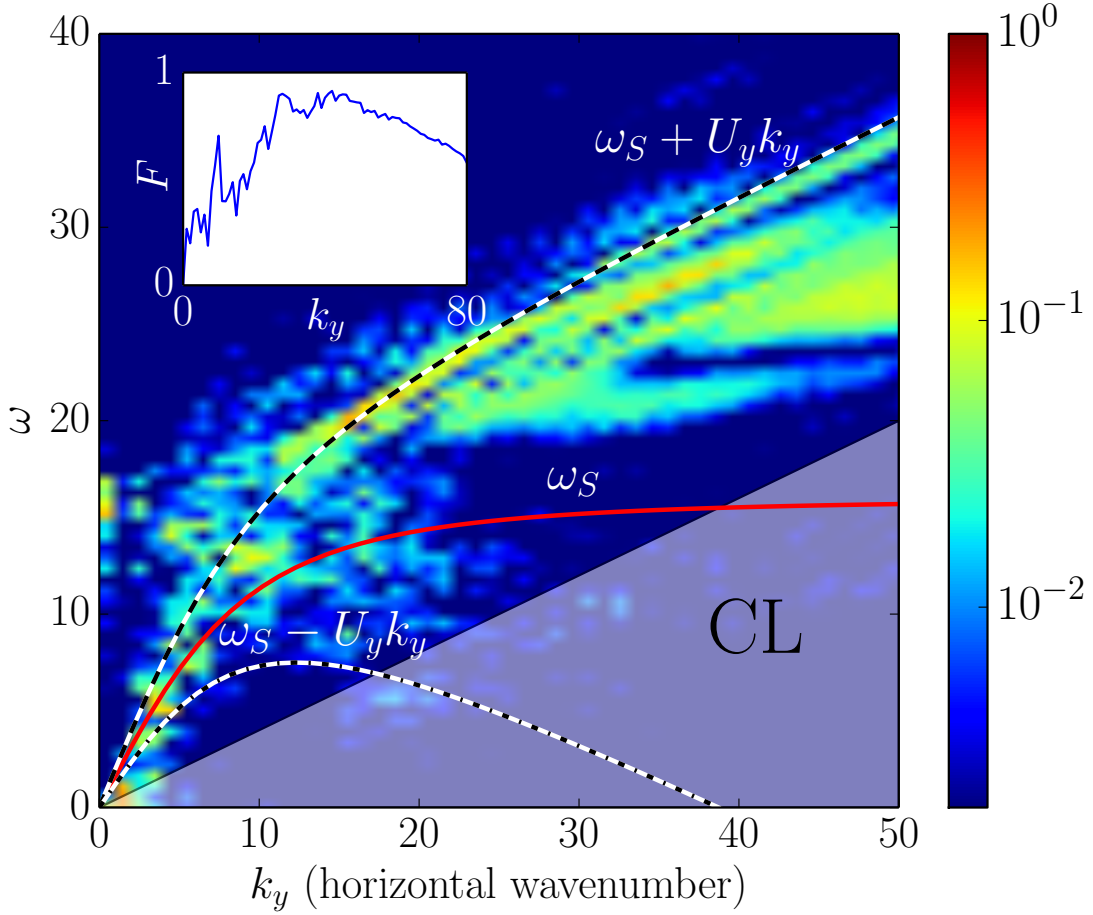
- Theories of stratified turbulence don't take this effects into account!

Stratified turbulence

$E(k, \omega)$



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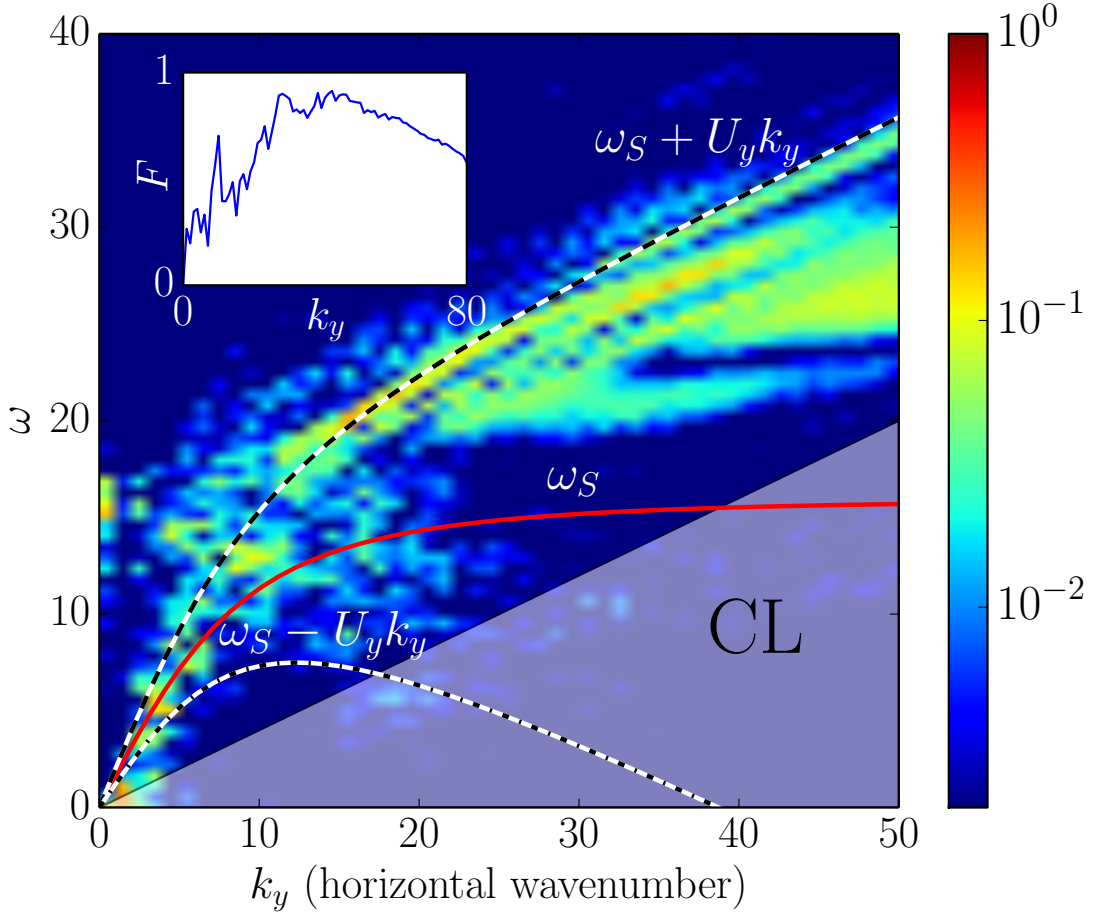

Doppler shifting and Critical Layer absorption appear! This indicates a nonlocal transfer of energy from the small to the large scales.
[*PC & P. Mininni, PRE (2015)*]

Free surface waves

Experiment of gravitocapillary waves in water:
$\omega(k) = \sqrt{\tanh(h_0 k)\left(gk + \frac{\gamma}{rho}k^3\right)}$

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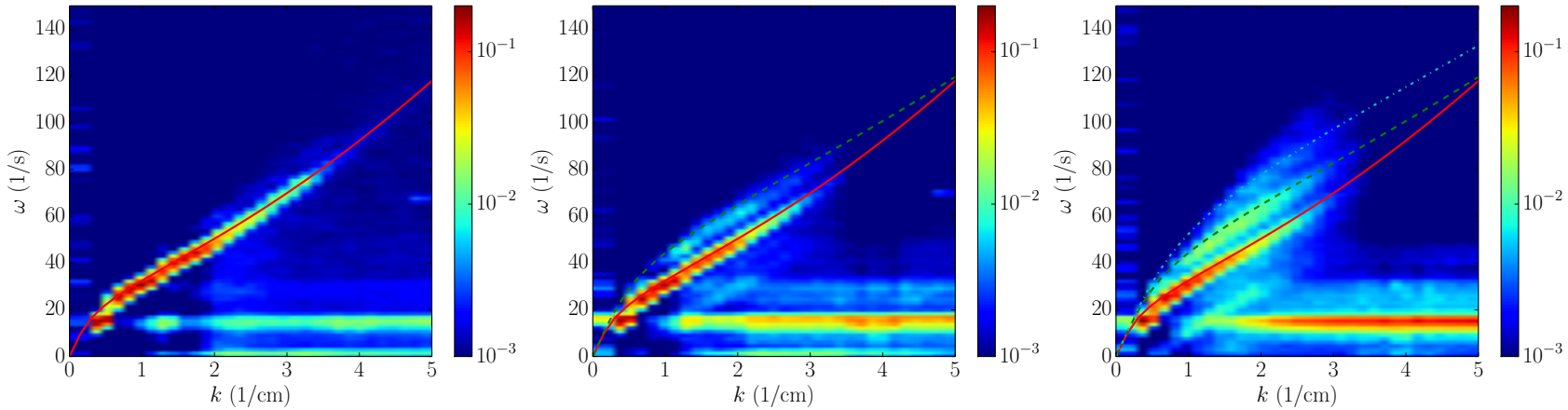
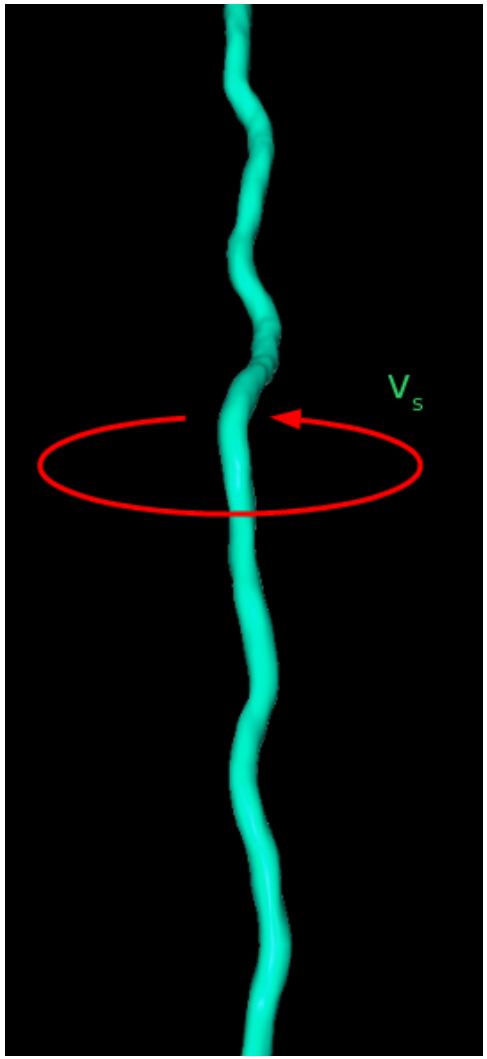


Injecting more energy creates bound waves and increases broadening!

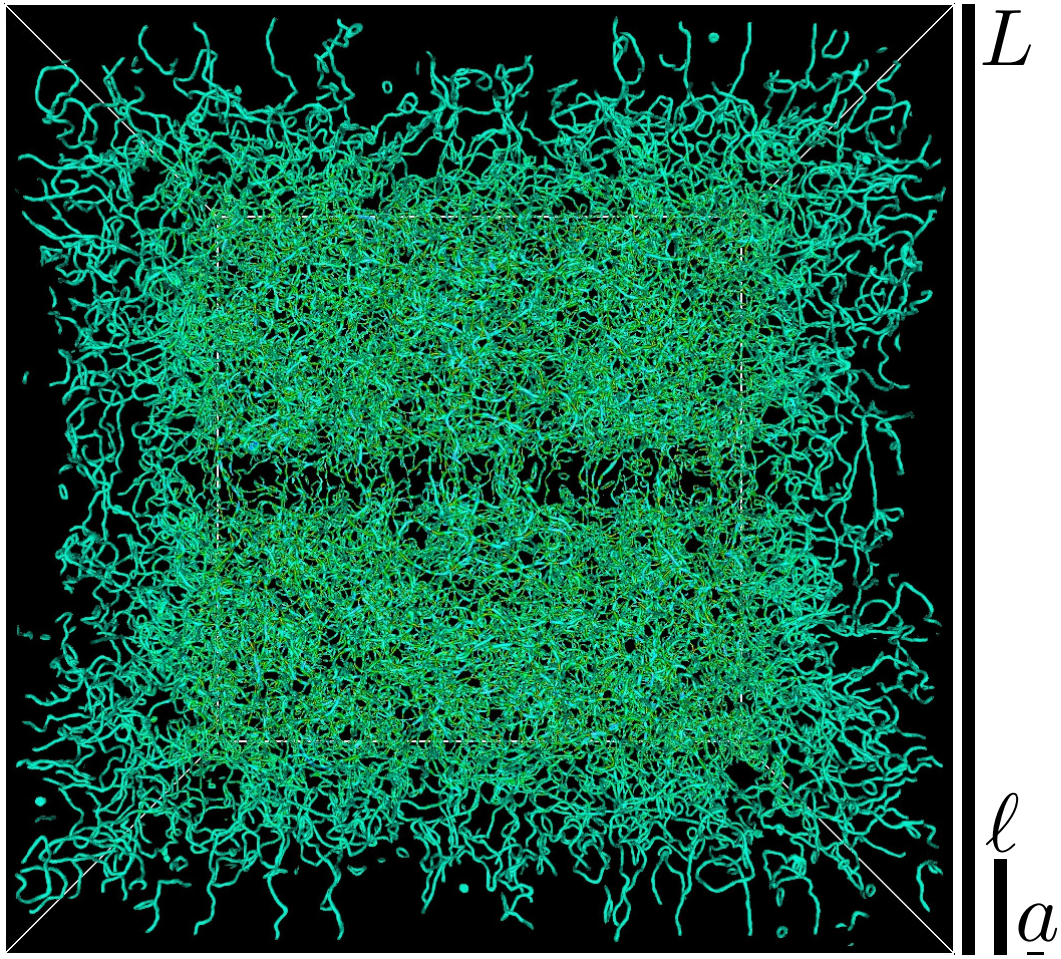
[*PC, P. Cobelli & P. Mininni, EPJE (2015)*]

Superfluid turbulence
Gross-Pitaevskii equation



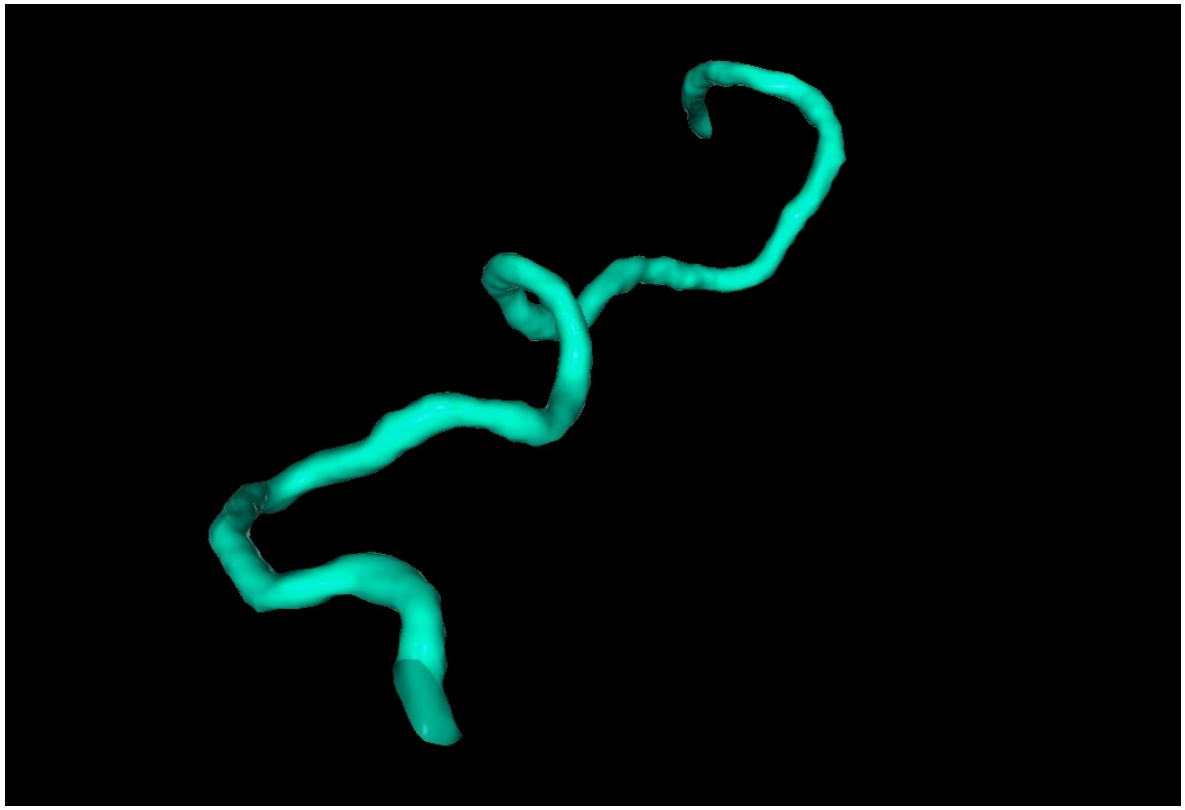
- Topological line defects
- Vorticity is quantized and concentrated along these lines
- Except along these lines, the equations can be transformed to that of an ideal fluid
- These are “decay” simulations, an initial condition is imposed and we don’t have forcing.

Superfluid turbulence (Gross-Pitaevskii equation)



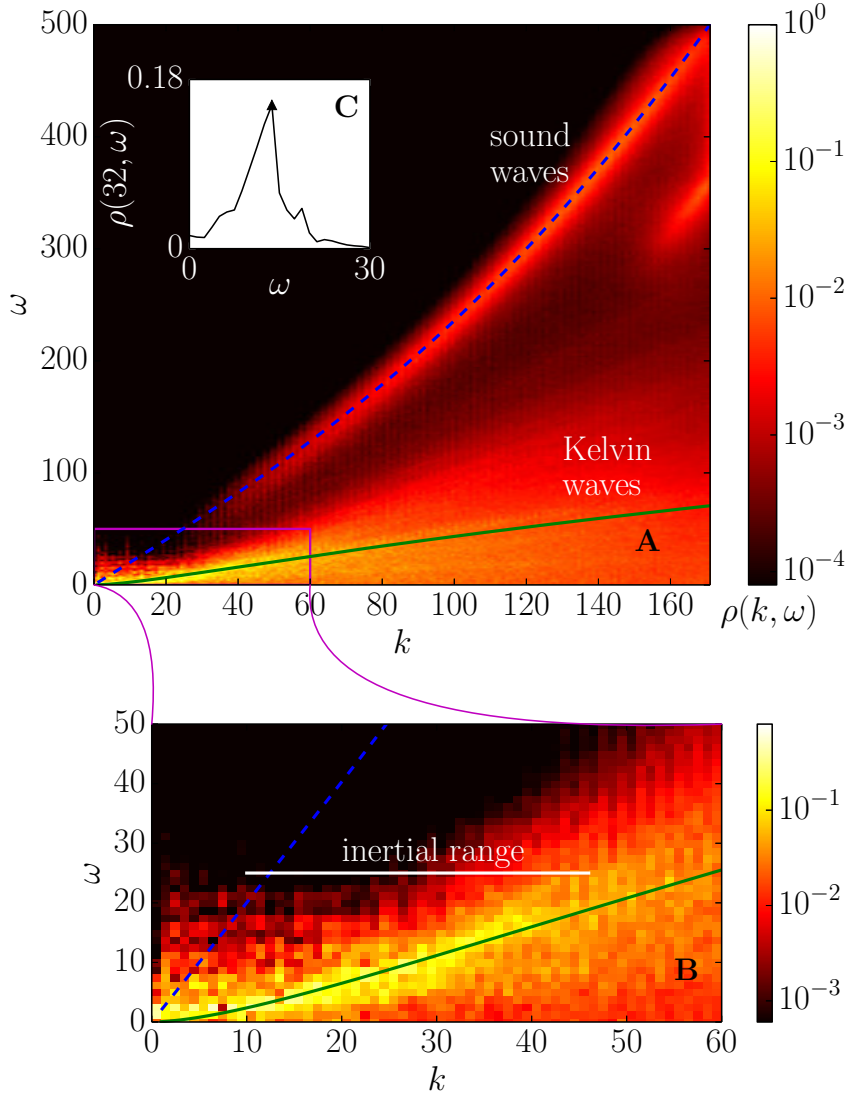
L: box size, ℓ: mean intervortex scale, a: vortex radius

Kelvin waves



Vortex lines have tension and Kelvin waves can travel through them.
Below the inervortex scale we can have Kelvin wave turbulence.
Kelvin waves are generated by reconnection events

Superfluid turbulence (Gross-Pitaevskii equation)



[*PC, P. Mininni & M. Brachet, PRA (2015)*]

Helicity in quantum flows

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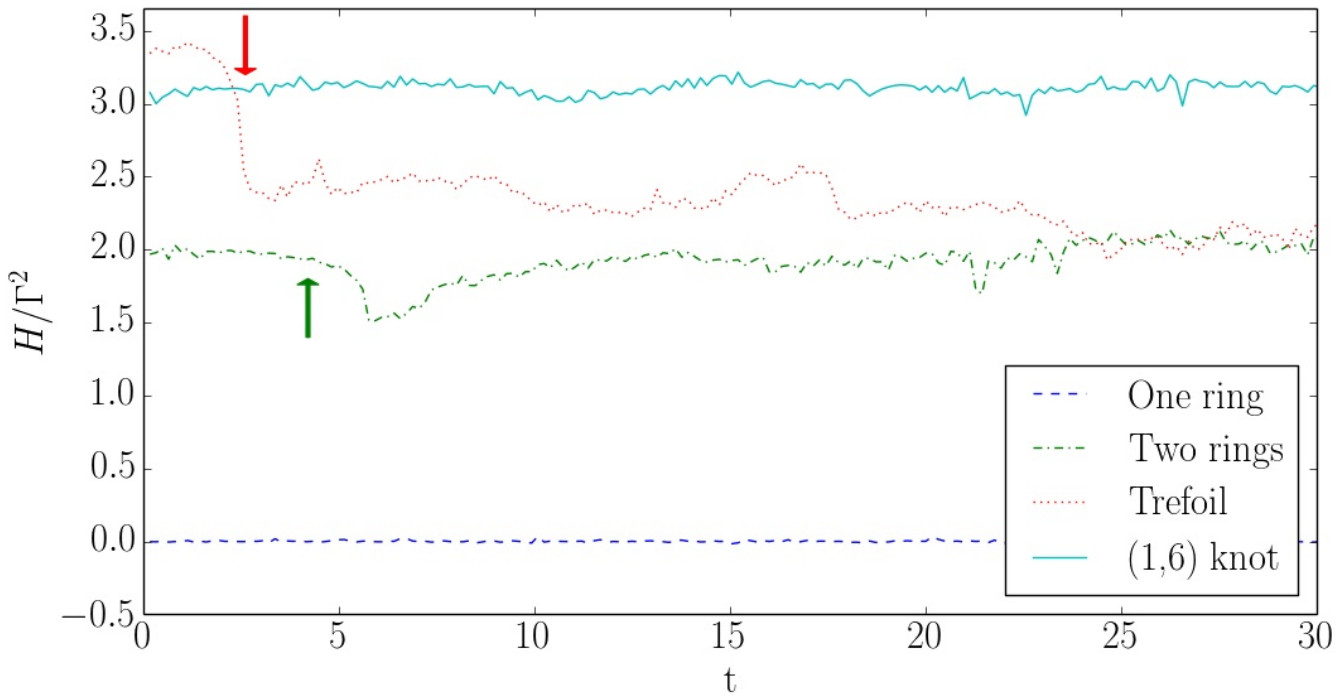
- Important in wide range of applications, from storm generation to DNA biology
- Calculating helicity is not trivial, as velocity and vorticity are both singular fields.
- Some authors have calculated helicity with topological tools, others have filtered the fields, we have regularized them!

Helicity dynamics for rings and knots

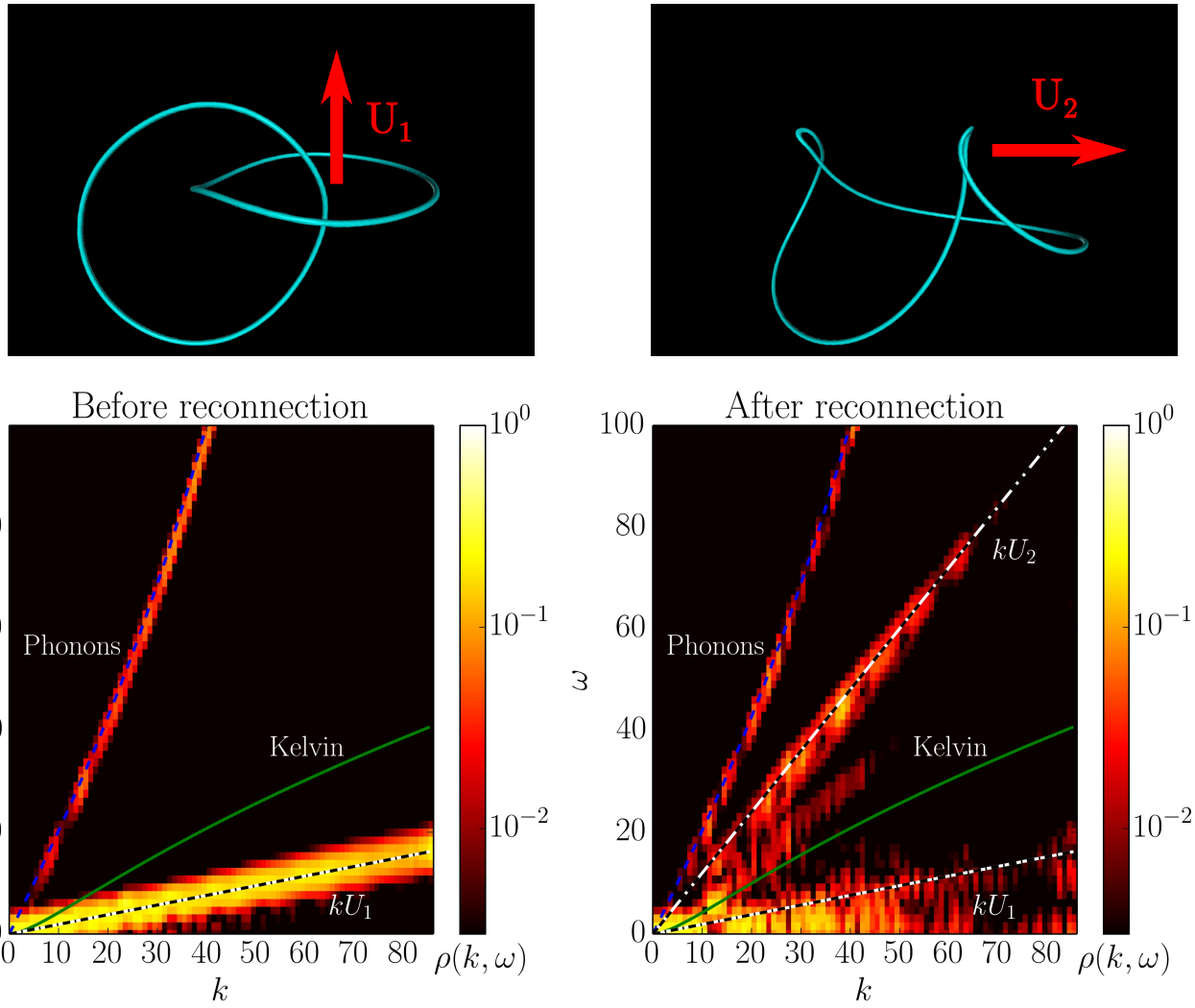


- Initial values of regularized helicity match other methods
- One ring and knot: No reconnection, helicity is conserved
- Two rings: reconnection but helicity also conserved
- Trefoil: reconnection, helicity is not conserved

[*PC, P. Mininni & M. Brachet, submitted to PRL (2016)*]

Two rings evolution

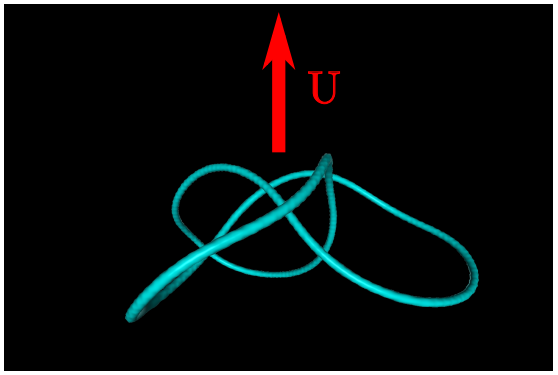
Before and after reconnection

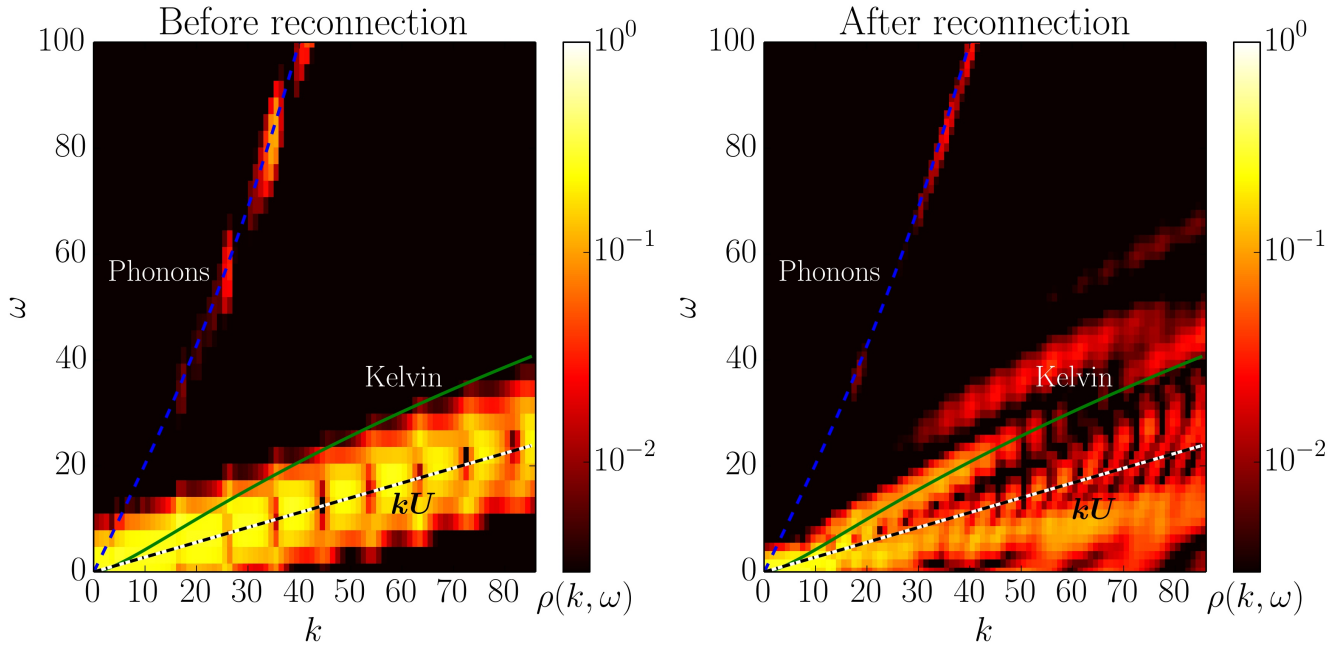


Lines get to align before reconnection so helicity is conserved

Trefoil evolution

Before and after reconnection



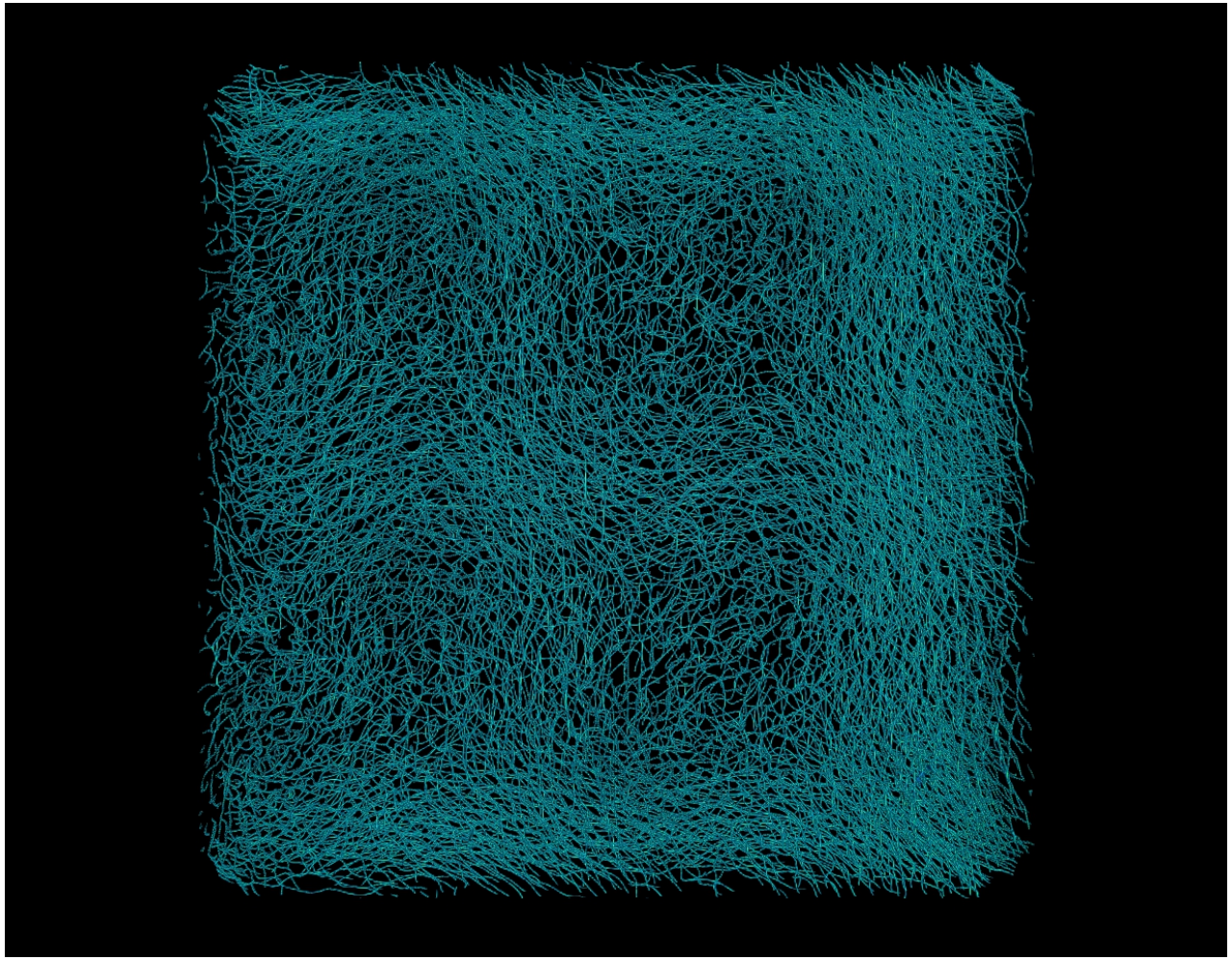


Lines don't align perfectly, helicity is not conserved and Kelvin waves are generated

Helicity beyond simple knots

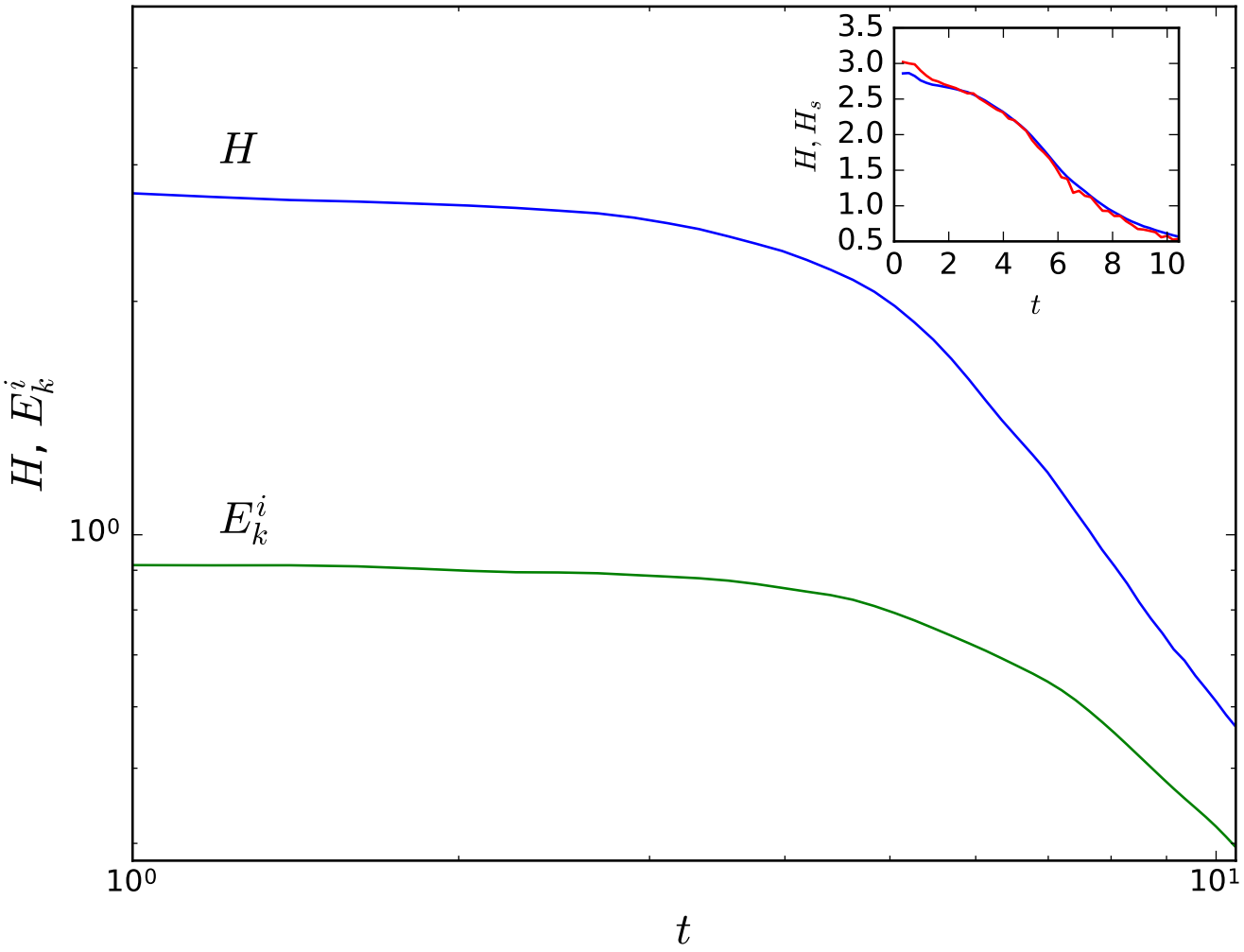
ABC flow

With the regularized helicity we can study complex flows

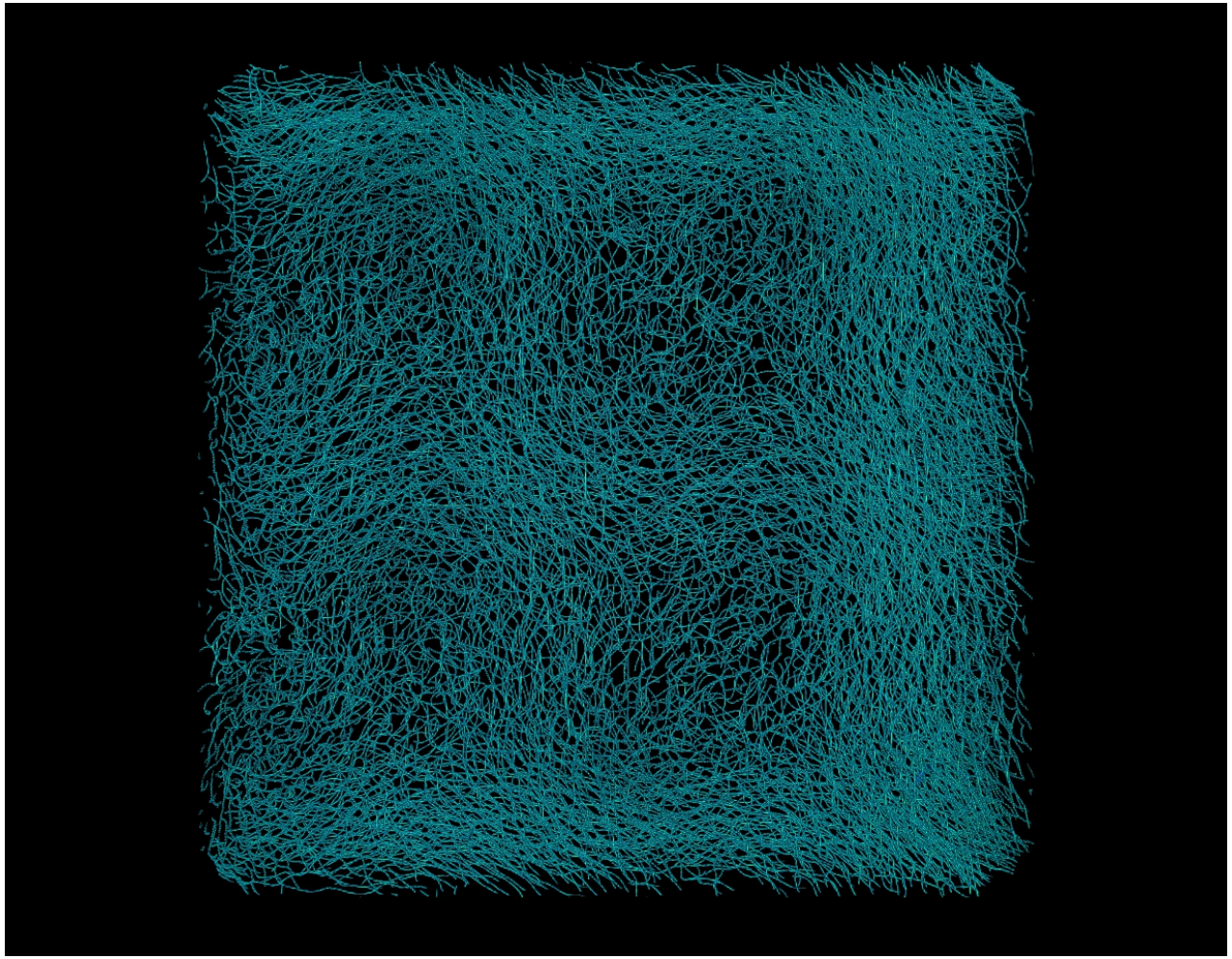


2048^3 simulation, $H \approx 480000\Gamma^2$

Evolution of helicity in ABC flow



Effects of helicity in the flow



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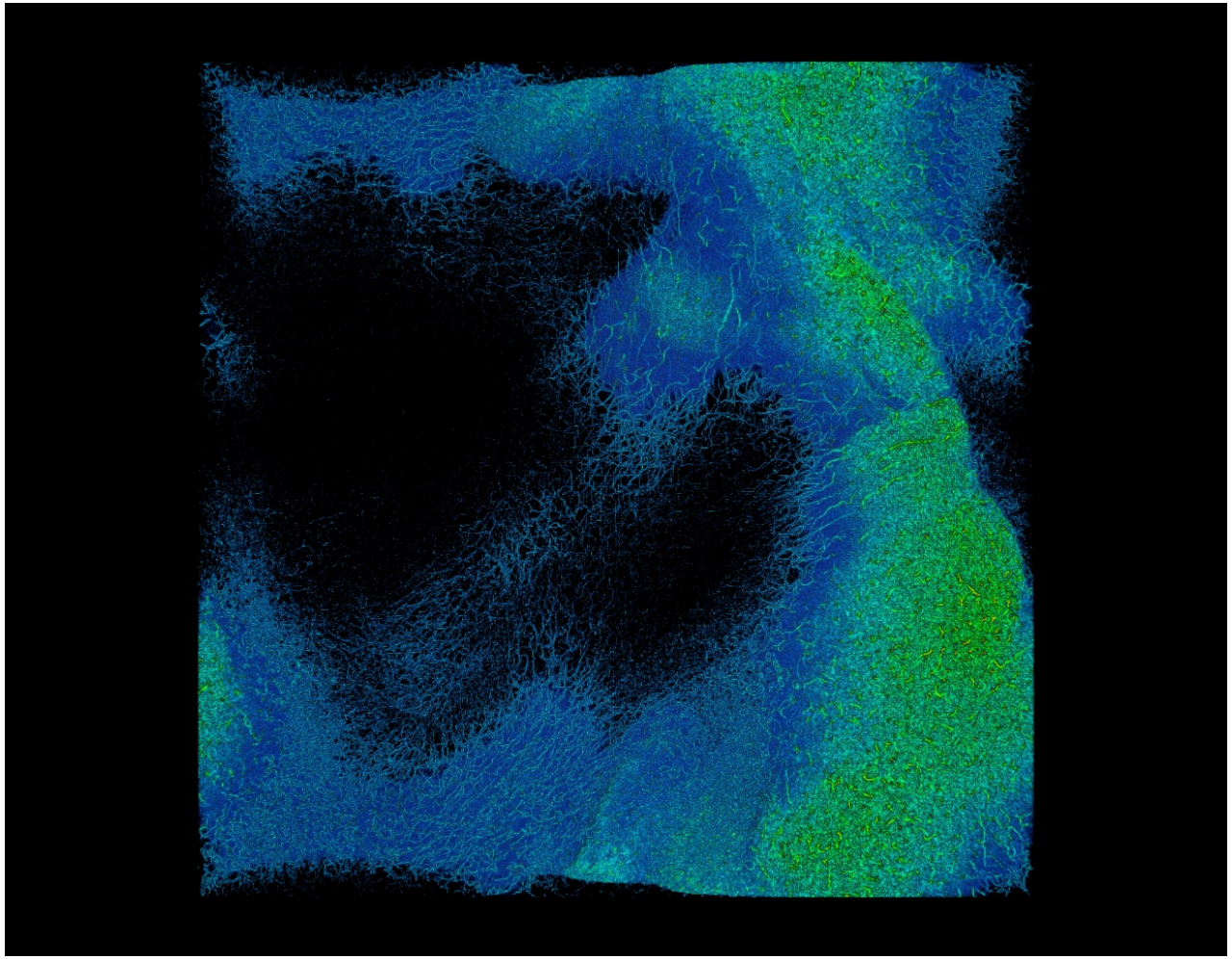

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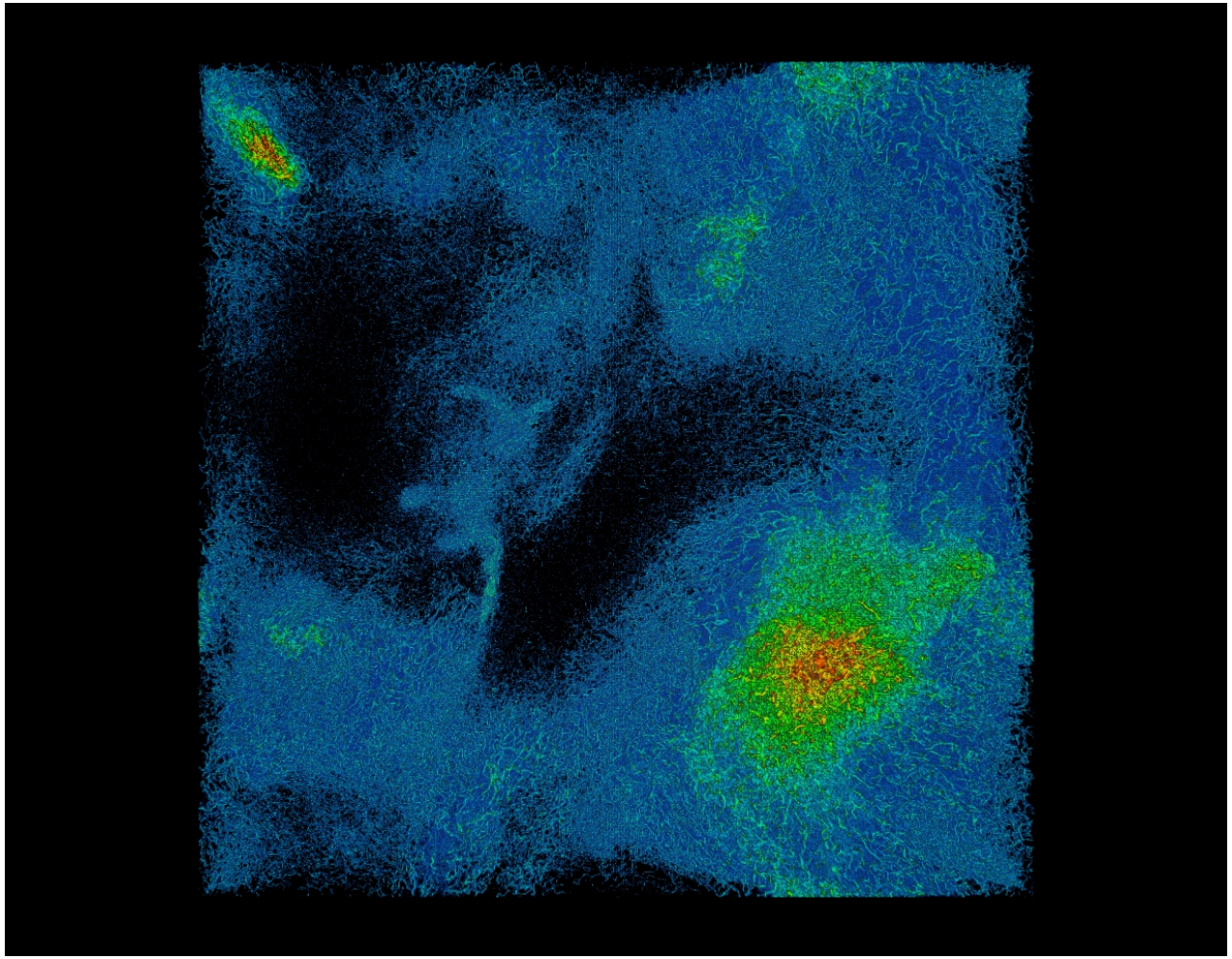

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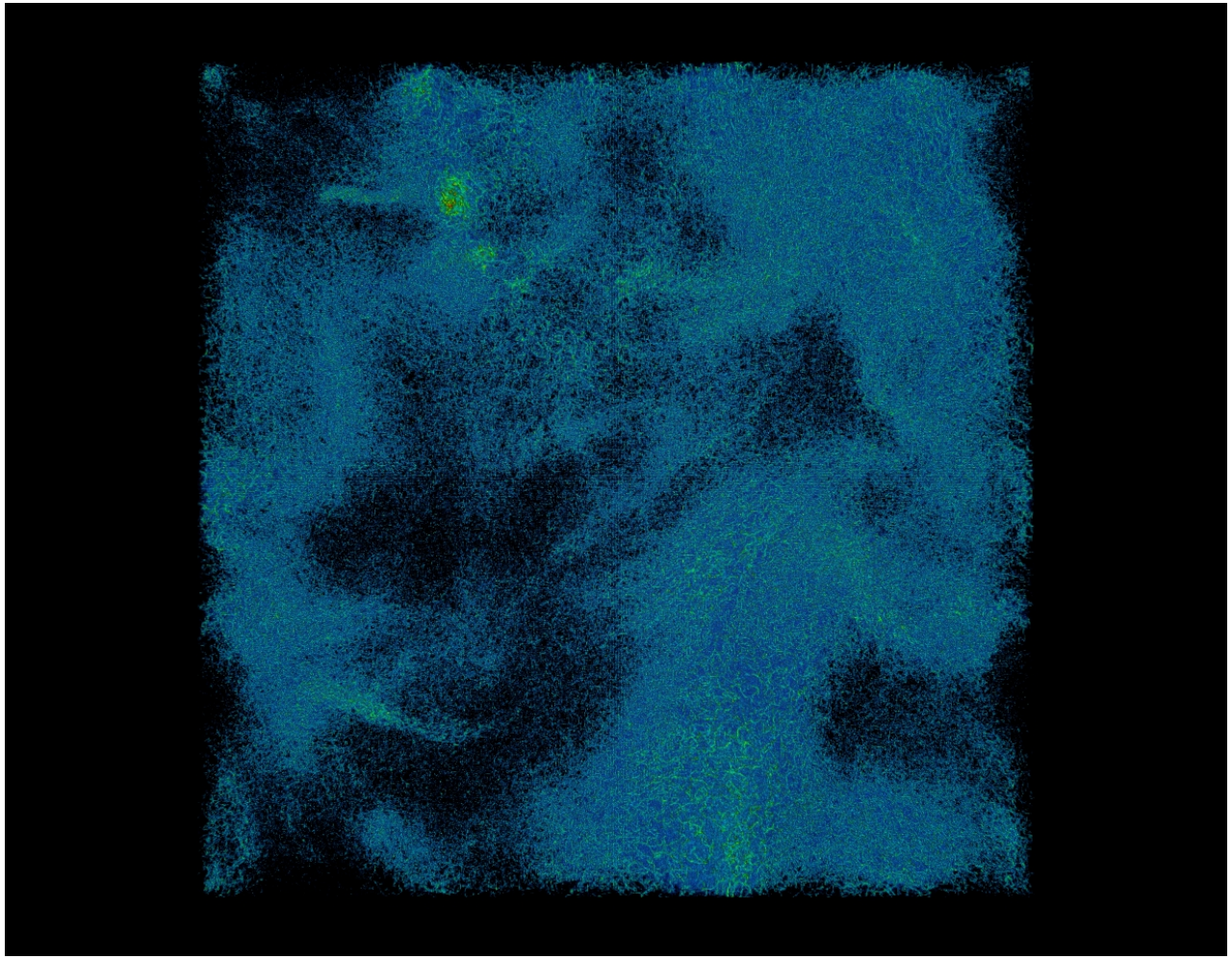
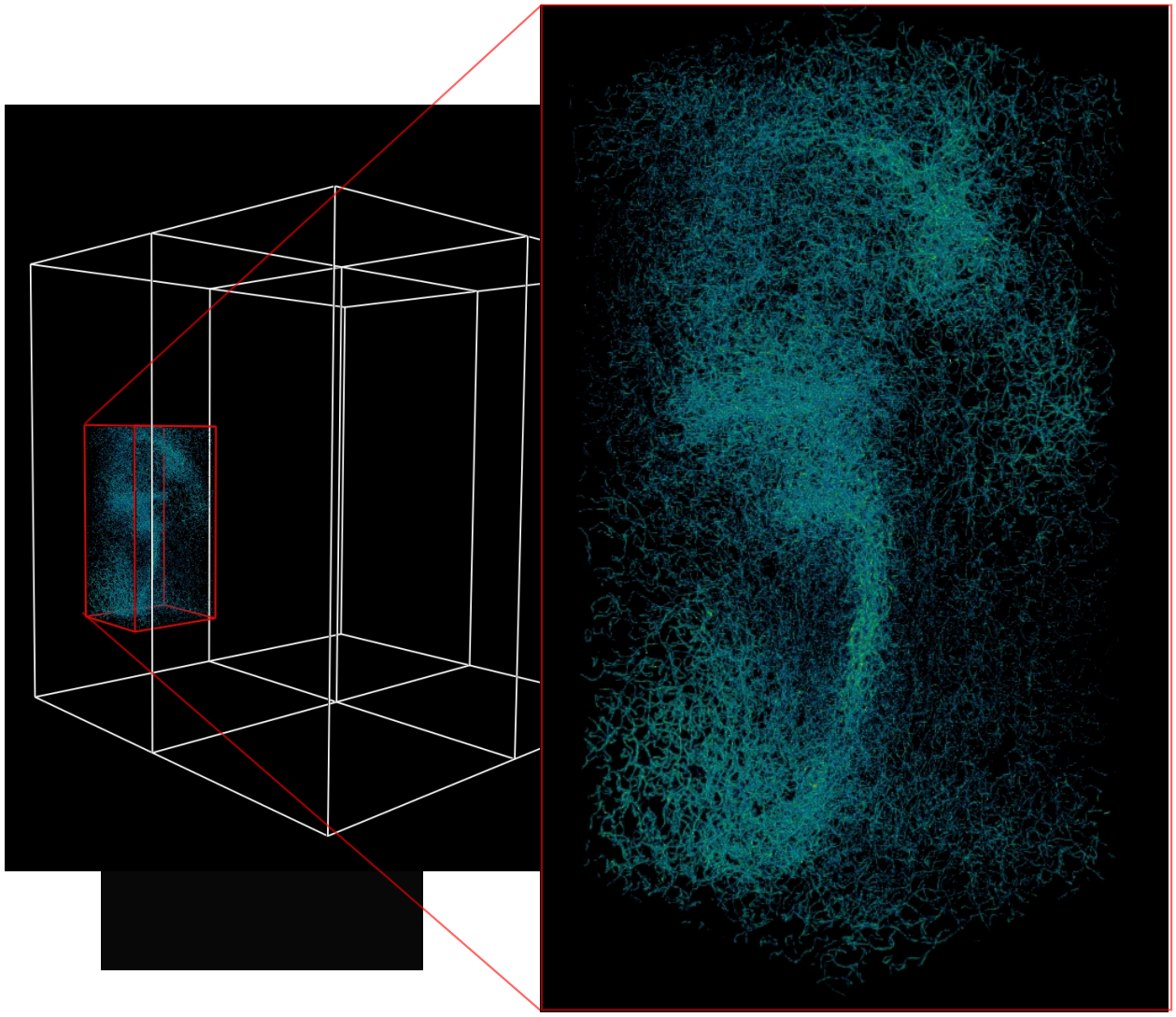


Quantum tornadoes



Work in progress!

Thanks!