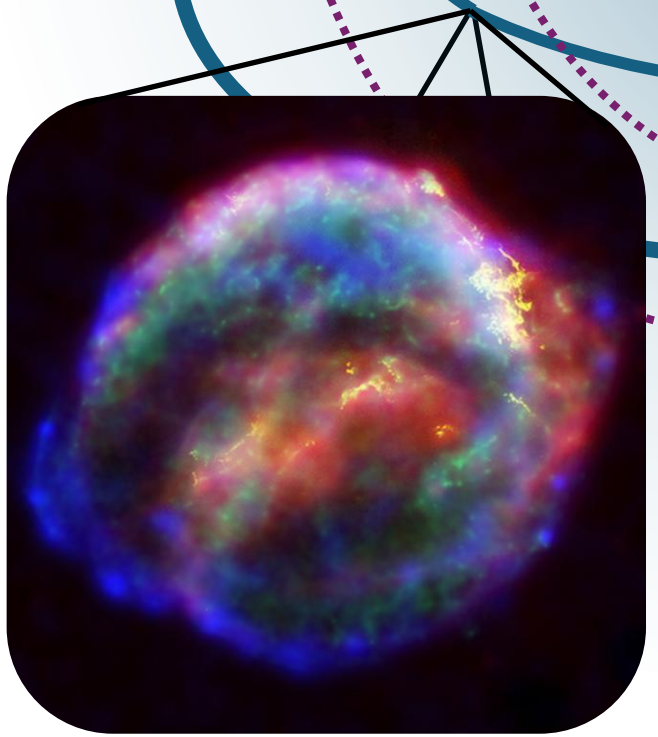
Cosmic ray diffusion in inhomogeneous magnetic turbulence

A presentation by Noa Peyrard

Tutored by Yoann Genolini, Pasquale Dario Serpico and Matthieu Bouchet

What are cosmic rays?

- They are produced by the expulsion of the outer shells of stars during supernovae
- They evolve in the galactic turbulent magnetic field at ultra-relativistic speeds
- Their diffusive behaviour is currently a topic of research



A supernova remnant, principal source of CR

Kepler supernova, Hubble telescope

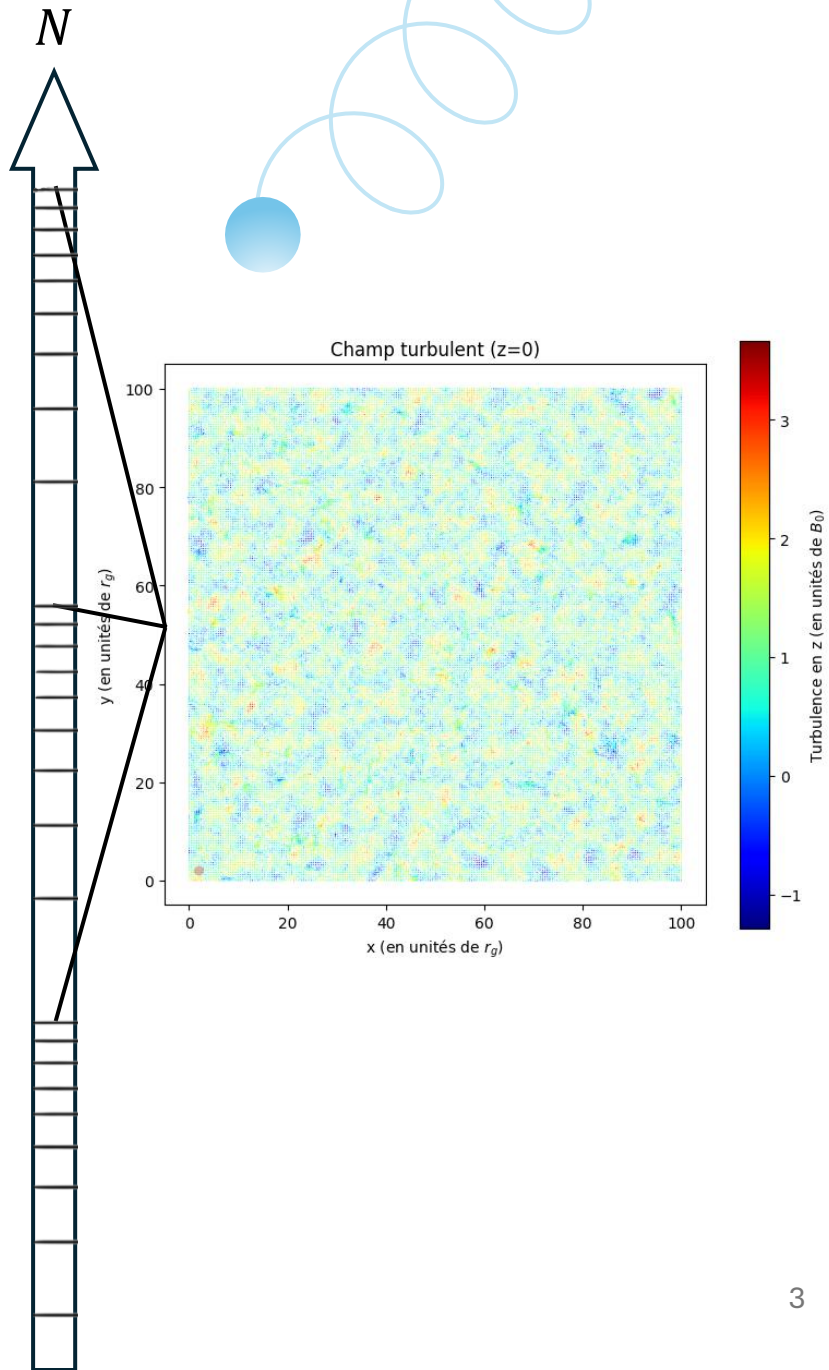
Generation of a harmonic turbulence

- We can simulate a fixed turbulent magnetic field by creating a sum of harmonics, weighted by the power spectrum of a Kolmogorov turbulence

Turbulent field — Random polarisations — Random phase

$$\delta \boldsymbol{B}(x,y,z) = \sum_{i=1}^{N} A_n \, \hat{\boldsymbol{\xi}}_n \cos\left(k_n \, \boldsymbol{k}_n \cdot \boldsymbol{r} + \beta_n\right)$$

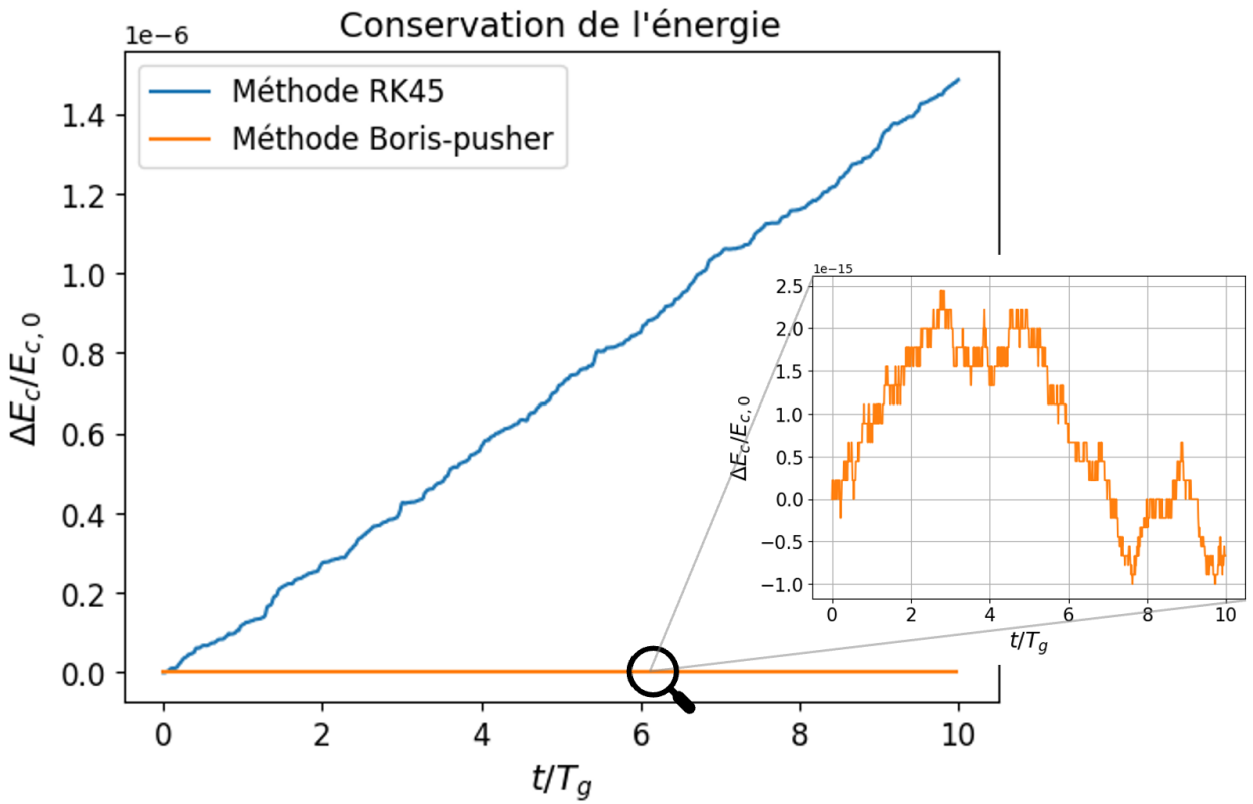
Normalised amplitudes in $k_n^{-5/3}$ — Random wavevector

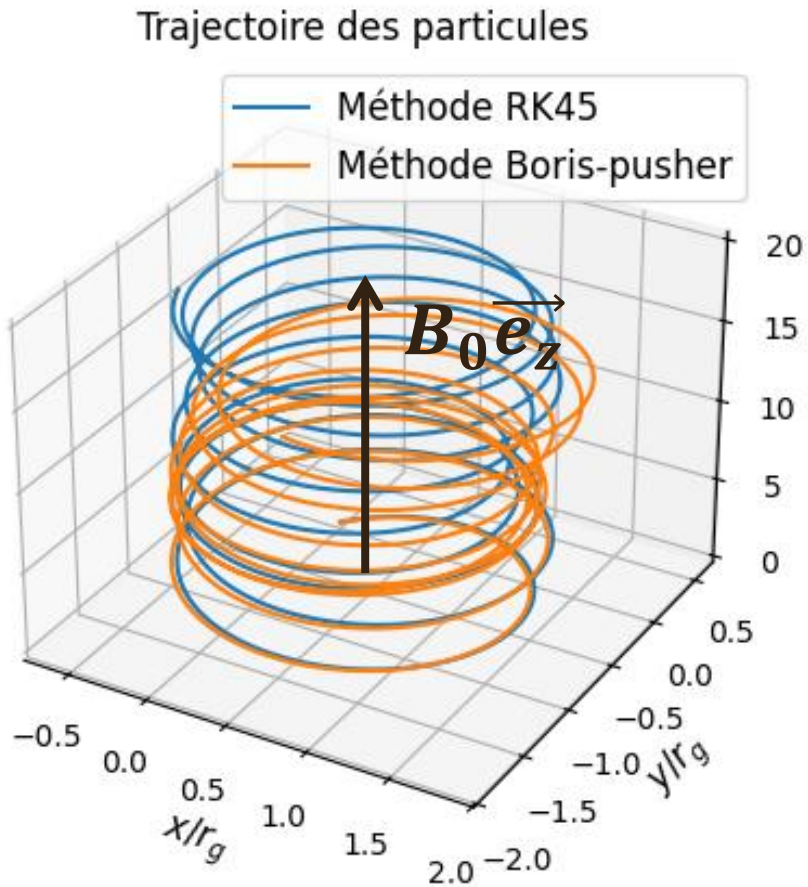


Particle trajectories – integration methods

$$r_g = \frac{\gamma m c}{qB}$$

- In an electromagnetic field, the Boris-pusher method is more accurate, because it conserves energy (simplectic scheme)

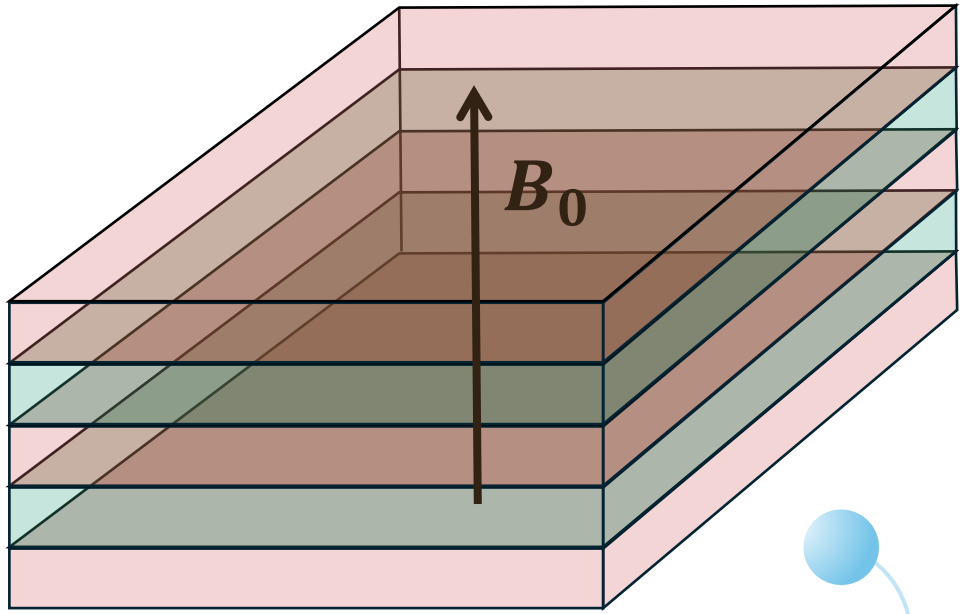




Inhomogeneous diffusion – Lasagna configuration

$$\eta = \frac{B_{rms}^2}{B_0^2 + B_{rms}^2}$$

- An intense field is imposed in the z-direction
- The turbulence is more or less intense according to the layer: $\eta_{weak} = 0.09$, $\eta_{strong} = 0.5$
- The theory suggests that the mean diffusion coefficient are obtained by applying the following formulas:

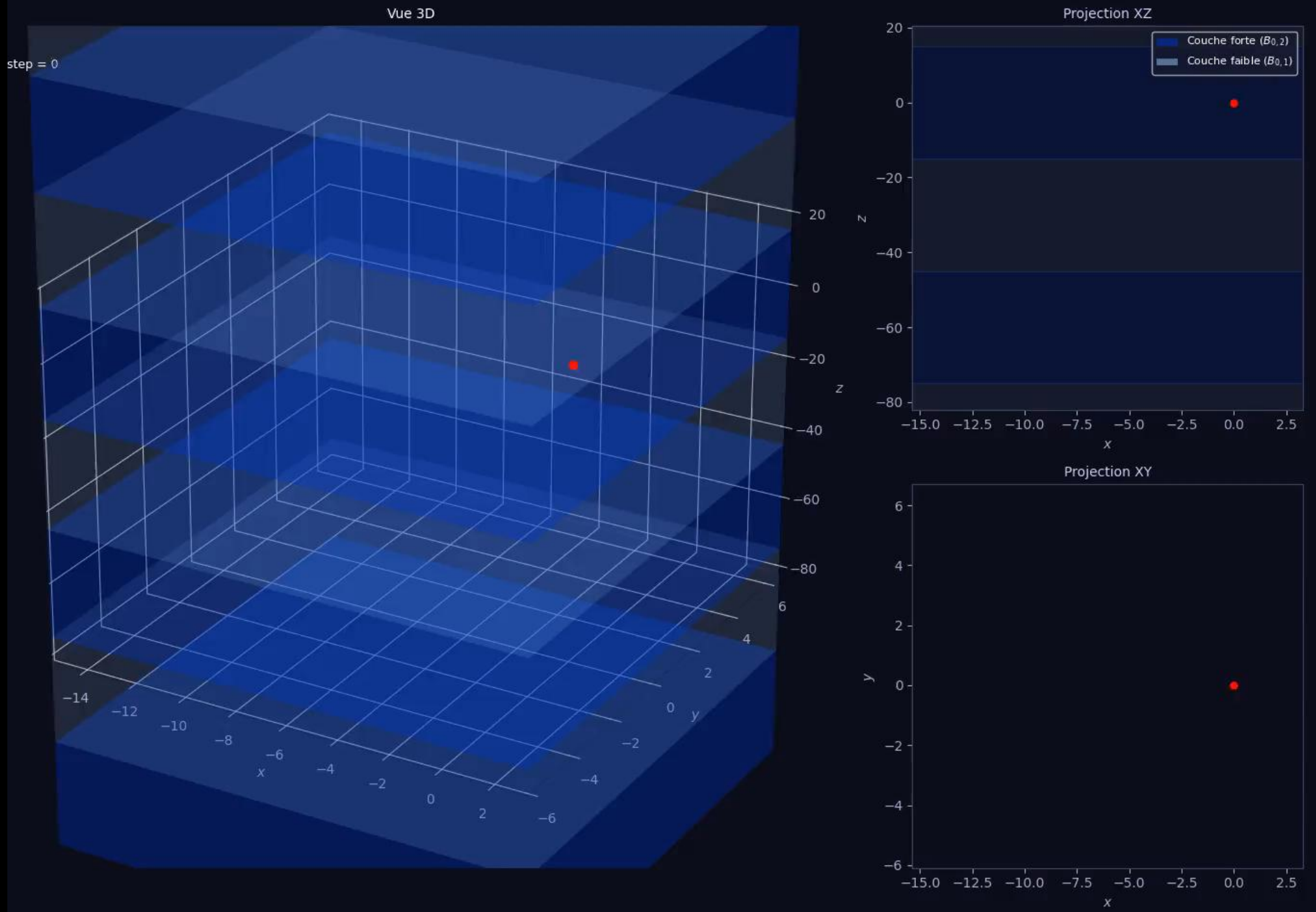


$$K_{\parallel,\mathrm{moy}} = \frac{1}{\dfrac{f}{K_{\parallel,1}} + \dfrac{1-f}{K_{\parallel,2}}}$$

$$K_{\perp,\mathrm{moy}} = f K_{\perp,1} + (1-f) K_{\perp,2}$$

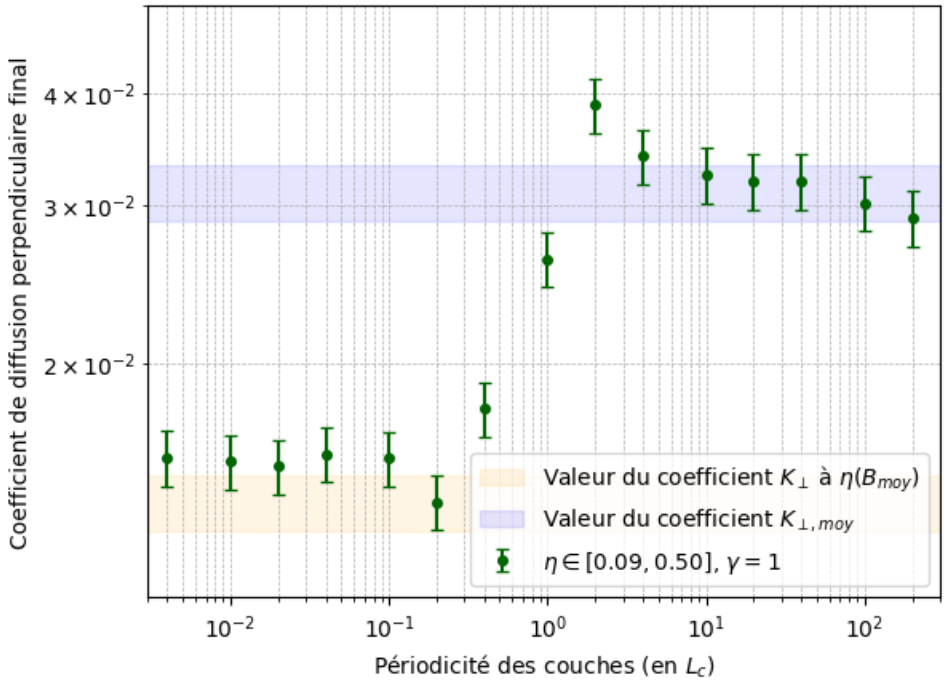
At the condition that $B_z \gg B_x, B_y$

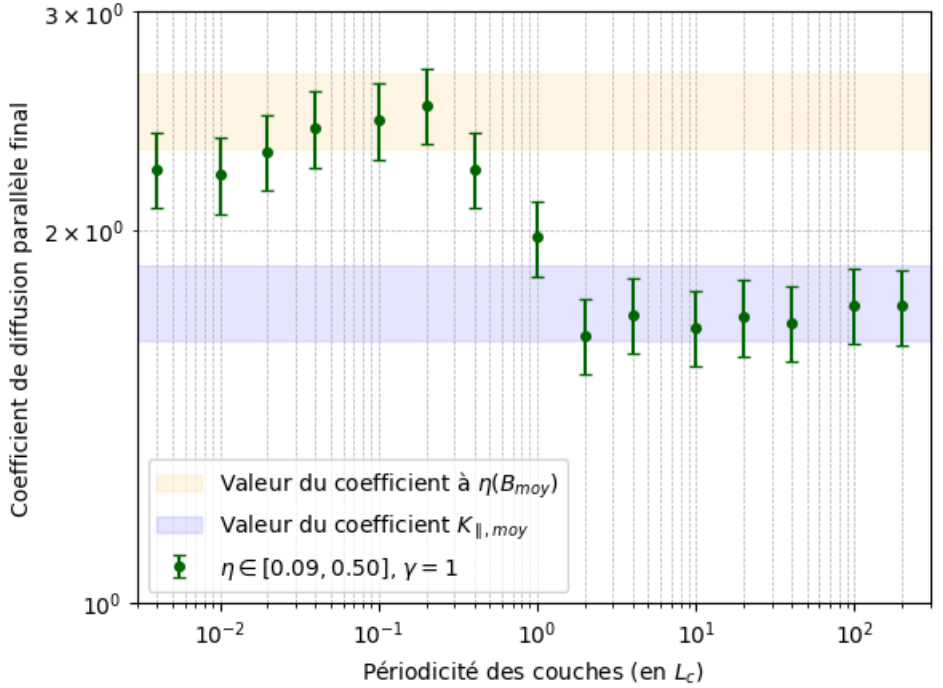
Propagation d'une particule dans une turbulence lasagne



Inhomogeneous diffusion – Lasagna configuration

- ☛ When we decrease the periodicity of the layers, an unexpected jump appears
- ☛ At very low λ, the inhomogeneous turbulence behaves like a homogeneous one, with a guiding field equal to the average of the two individual ones!





Thanks for your attention!