

Matthieu BOUCHET

Cosmic ray transport, turbulence and nonlinearities

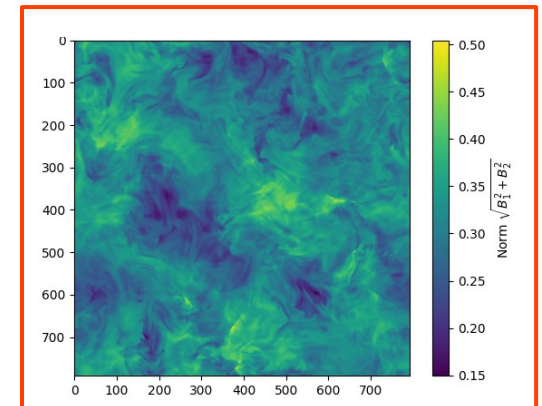
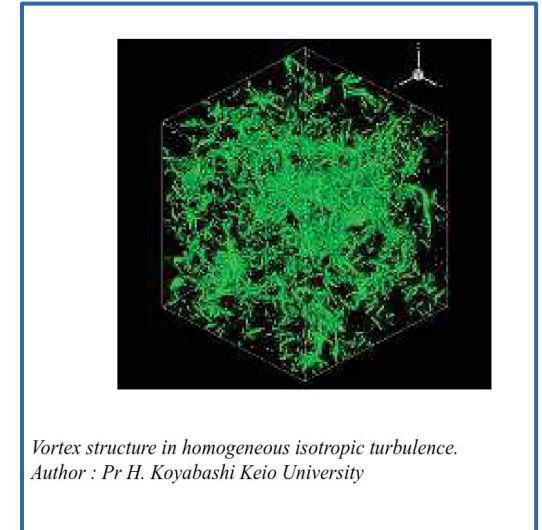
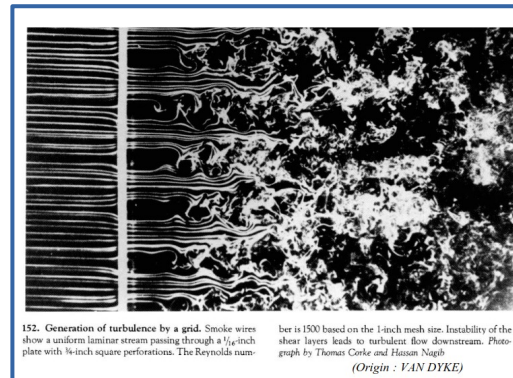
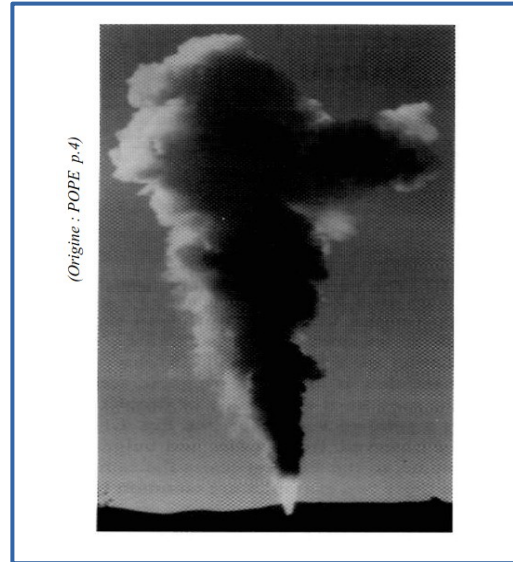
With Yoann GENOLINI at LAPTh



A brief talk about turbulence

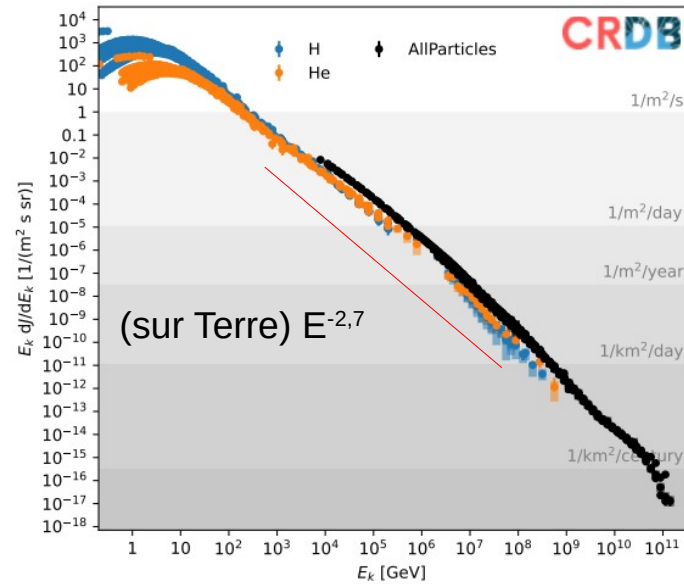
- In **Hydrodynamics** :
 - Chaotic movement of particles in a fluid
 - Characterized by vortices, strong instabilities

- In **Magnetohydrodynamics**
 - Turbulent stream of plasma
 - Consequences on electromagnetic field and transport of particles in the interstellar medium

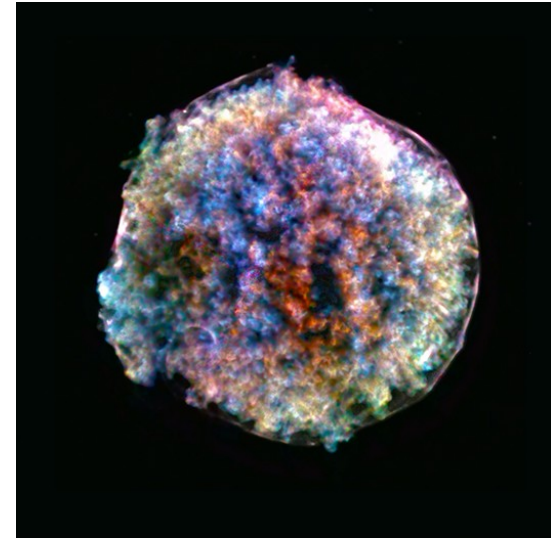


Introduction to cosmic rays

- Relativistic particles
 - Power law of the energy spectra
- Galactic and extra-galactic origins
 - Supernovae remnants
 - ultra-high-energy : not very well known



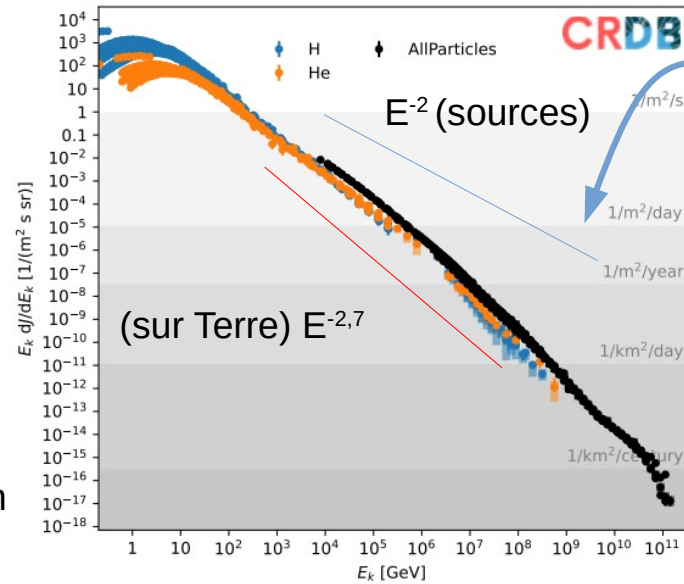
Spectra Flux VS Energy of cosmic rays, observed from Earth



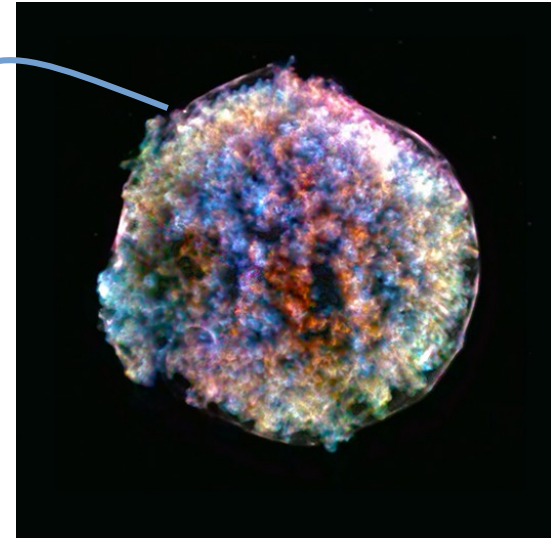
Tycho (Tycho Brahé, 1572), observed in X rays by Chandra telescope

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- Principal problem : what phenomenon influence their propagation?
 - Spectra observed at sources different from the one observed on Earth



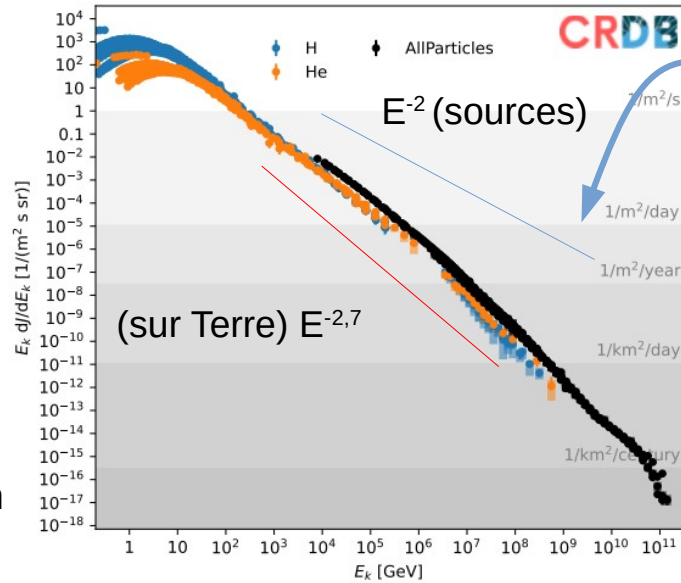
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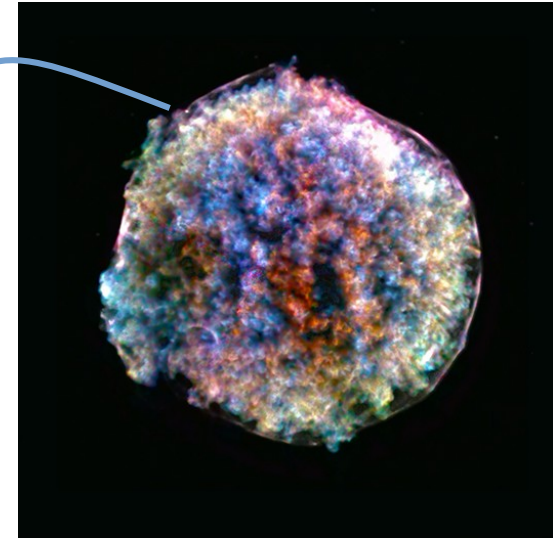
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- Charged particles
 - Influenced by magnetic fields
 - Complexe trajectories
 - **diffusion** of cosmic rays



Spectra Flux VS Energy of cosmic rays, observed from Earth



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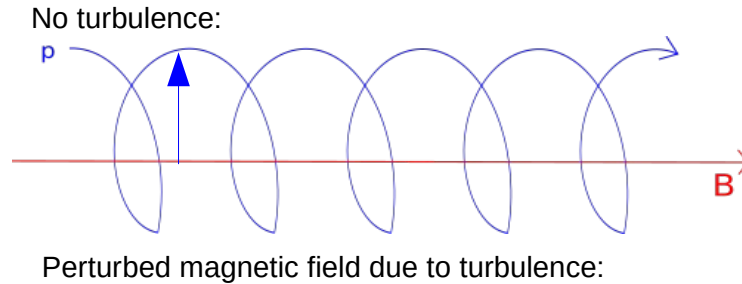
Diffusive behaviour of milk in the coffee

$$\langle x^2 \rangle \propto Dt$$



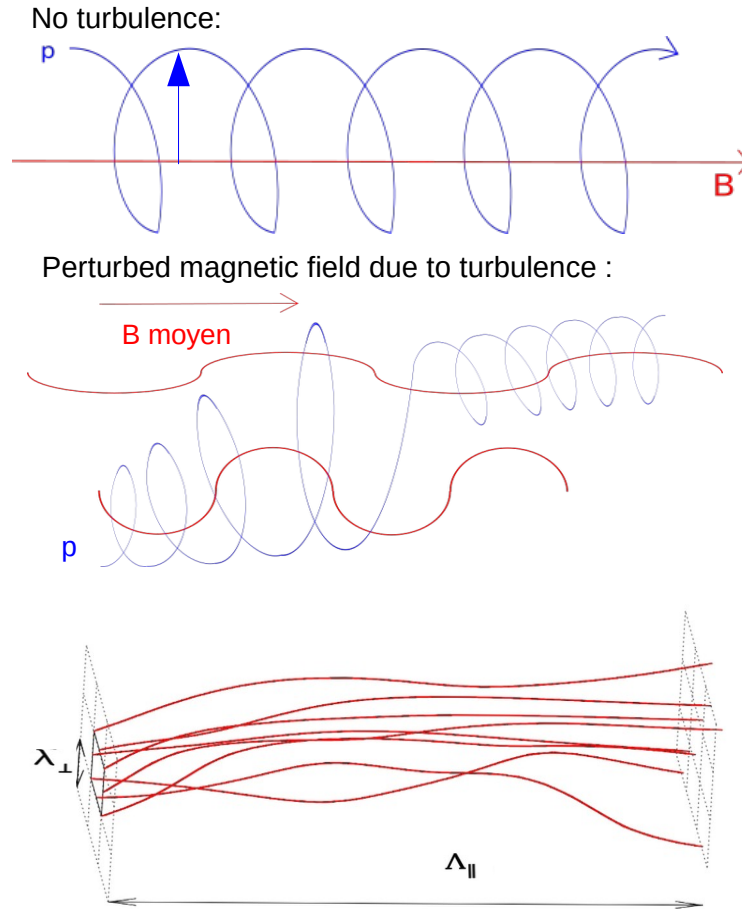
Problematics

- Turbulent interstellar medium plasma
 - The magnetic field serves as a guide (or rails) for cosmic rays
 - Turbulence induces magnetic perturbations



$$R_L = \frac{\gamma m v}{q B}$$

- Turbulent interstellar medium plasma
 - The magnetic field serves as a guide (or rails) for cosmic rays
 - Turbulence induces magnetic perturbations
- Cosmic ray trajectories are perturbed
 - Interactions between particles and magnetic field fluctuations
 - Field line random walk (FLRW)




$$R_L = \frac{\gamma m v}{q B}$$

Gyro-resonance: the particle jumps from one field line to another

Field line random walk

Conclusion

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non-linearities

A composite image of Earth from space, showing the curvature of the planet and the atmosphere. Several bright blue laser beams or particle tracks are shown entering the atmosphere from the top left and spreading out across the globe. The background is a dark starry sky.

Goal: develop a theoretical framework for cosmic ray transport to learn more about present and futur observables

Thank you for your attention !