Dustgrain acceleration and MHD Turbulence

Study of magnetohydrodynamic turbulence and particle acceleration

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In Short

- We need to generate MHD turbulence data cubes and study their properties like power spectra, cascading rates etc. We want to focus on fast modes
- We want to study particle and grain acceleration due to turbulence and look for resonant mechanisms like gyroresonance and transit time damping.

The transport of cosmic rays and dust grains through interstellar space, their acceleration mechanisms etc are an ongoing subject of research in astrophysics. The study of transport of cosmic rays through magnetic turbulence could reveal understanding of fundamental physical processes like resonant mechanisms responsible for particle scattering and acceleration. Also it helps to understand the nature of MHD turbulence which is still under progress.

Most astrophysical fluids from stellar wind to interstellar medium is turbulent in nature and can be described by the MHD theory. They are key to processes like star formation, fragmentation of molecular clouds, heat and cosmic ray transport, magnetic reconnection etc. MHD turbulence comprises of the compressible fast and slow modes and the incompressible Alfven modes. The driving mechanism of turbulence determines the proportion of the component modes present in turbulence. The strength of turbulence is characterized by its Mach no. The important characteristics that helps determine the different properties of the MHD modes are their energy spectrum,cascading rate, structure function etc. Identification of these modes and their properties helps us study various astrophysical process, eg fast modes scatter CR more in comparison to Alfven mode [1] [2][3][4], in our galaxies and help in their confinement.

Particle acceleration has been studied analytically earlier where gyroresonance[5] and hydrodrag are identified in various phases of the ISM, like the warm ISM and cold neutral medium[6]. TTD was identified as another acceleration mechanism.[7]. A very few numerical simulations has tried to confront the analytical predictions of grain acceleration. Some work has been done to investigate the heating of particles [8]. Some follow up studies found these particle heating rates to be consistent and identified another type of acceleration mechanism Fermi B[9]. We aim to build up on previous numerical simulations by studying the interaction of test particles and turbulence especially acceleration of dust grains and particles.

Study of compressible MHD with different forcing mechanism has been studied in the past [10].While some of the properties of Alfvenic modes have been studied in details earlier for example their spectra, cascading rate etc, the study of the properties of fast modes through numerical simulations are still in demand. The energy spectrum and the cascading rates needs to be verified and calculated further which are import for understanding the nature of fast modes which is essential for high energy astrophysical processes

One investigation would be the nature of MHD modes generated in turbulence. We want to compare the properties of different modes for example their cascading rate. Another investigation would be the acceleration of particles in MHD turbulence. Due to the similarity of the dust and cosmic ray scenarios, the results of these studies are of interest to the present investigation. The aim of the proposed study is to build on previous numerical simulations by studying the interaction of test particles and turbulence driven with general compressible forcing. More specifically, the project will focus on investigating the acceleration of dust grains, to confirm the analytical predictions of [6]. The particle acceleration is also expected to behave differently in different decomposed modes in turbulence. The particle properties like initial charge to mass ratio and drag time is expected to influence particle acceleration in directions parallel and perpendicular to the magnetic field.

We intend to perform test particle simulations in order to obtain the trajectories of particle in MHD turbulence and evaluate the statistical properties of their transport. The particle tracer method follows the Bulrisch Stoer algorithm to solve the ODE and this method uses the adaptive time step where the total energy of the particle remains conserved to a high degree. The MHD turbulence can be generated with the fluid dynamics code PLUTO [11] which solves mixed hyperbolic/parabolic systems of partial differential equations (conservation laws) using a variety of finite-difference and finite-volume techniques based on Godunov schemes and is best suited for high Mach no flows in astrophysics. Using PLUTO the idea is to drive turbulence by the Ornstein-Uhlenbeck(OU) process. We also want to generate turbulence without using forcing mechanisms.

We present in Figure 1 the scattering of CR in MHD modes from our preliminary simulations where it is seen that fast modes scatter most.

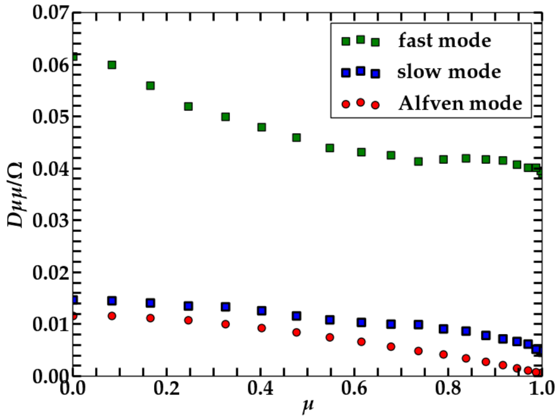

Figure 1: Pitch angle diffusion coefficients for CRs in different MHD modes with MA 0.9. The x axis represents the initial pitch angle cosine, μ. The y axis represents the pitch angle scattering coefficient normalised by the gyrofrequency, $D\mu\mu/\Omega$. Different symbols represent different MHD modes: Alfvén (red), slow (blue) and fast (green)

We present our study of the variation of diffusion index with mean free path(mfp) of CR in Fig2 and see that it reduces with the mfp,L being the simulation boxlength.

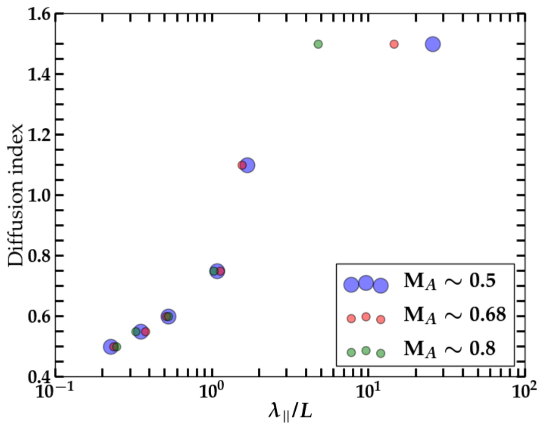

Figure 2: The diffusion index vs. λ || in the local reference frame.

To summarize, the purpose of the proposed simulations is to study the nature of MHD modes most importantly fast modes, their cascading rates, etc. Related to this we would also study the nature of particle and grain acceleration in different kinds of turbulence with different driving mechanisms and varying Mach Nos. We would like to primarily distinguish interactions of particle with different individual MHD modes. We would like to investigate the scattering properties and the acceleration mechanisms that influence particle transport. All these detailed studies has not been done earlier using numerical simulations. All these studies requires a considerable amount of parallel processing to run each simulation faster and a large amount of memory space to contain and process the large volume of data generated. As evident we have a variety of simulations to perform and each requires more computing time and resources. The proposed work can be accomplished with the requested computational resources

WWW

https://www-zeuthen.desy.de/ hyan/

More Information

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