# MHD modes in turbulent star formation

## Magnetohydrodynamic mode decomposition in turbulent star formation

***H. Yan, K. D. Makwana**, Institut für Physik & Astronomie, Universität Potsdam & Deutsches Elektronen-Synchrotron (DESY), Zeuthen*

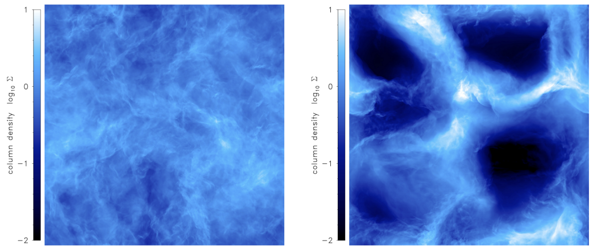

*Figure 1: An example of density fluctuations taken from Ref. [3]. The left profile is for solenoidal forcing while the right profile is for compressive forcing. We can see clearly that compressive forcing creates more extreme density structures.*

### In Short

- Turbulence is well-known to play an important role in star formation
- Compressive motions are found to be much more important in star formation compared to solenoidal motions
- However, the separate roles of the different MHD eigenmodes have not been studied
- We intend to study decomposition of MHD eigenmodes in simulations relevant for star formation
- This also has implications for cosmic ray transport in star forming regions

It is well-known that turbulence plays an important role in star formation processes in the universe. Turbulence creates regions of overdensity to initiate gravitational contraction of collapse, and it also counters the effect of gravity in these overdense regions [1]. Therefore the star formation is intimately linked with the properties of turbulence in the star forming molecular clouds. Numerical simulations have played a major role in understanding this star formation process. Since the formation of overdense structures and the feedback of turbulent pressure on star formation are highly nonlinear processes, numerical simulations are indispensible. The problems studied in this range from the driving mechanism of this turbulence, its dissipation mechanism, the effect of self-gravity, the statistical properties of density fluctuations, etc.

It has been realized that the nature of driving plays an important role in the properties of turbulence. Recently techniques have been developed to separate solenoidal motions from compressive motions in observations of molecular clouds [2]. It is found that regions with dominant compressive motions are also regions of higher star formation rate, while dominant solenoidal motions correlate with regions of low star formation. On the other hand, the compressive versus solenoidal nature of turbulence can be easily controlled in numerical simulations. Magnetohydrodynamic simulation studies have shown that compressive driving gives rise to more extreme density fluctuations [3]. An example of this is shown in Fig. 1

An unexplored aspect of this turbulence is the presence of different MHD modes which have significantly different properties. The MHD eigenmodes are well known, the incompressible Alfvén mode, and the compressible fast and slow modes. These modes have different power spectra, differen correlation functions. As a result their roles can be expected to be quite different in the scheme of star formation. We propose to study this unexplored aspect of MHD turbulence that is relevant for star formation. We already have diagnostics for separating MHD simulation data into the three MHD eigenmodes [4]. These diagnostics have been applied to earlier MHD simulations to reveal that the fast mode spectrum is isotropic whereas the Alfvenic and slow mode spectrum is anisotropic. An example is shown in Fig. 2.

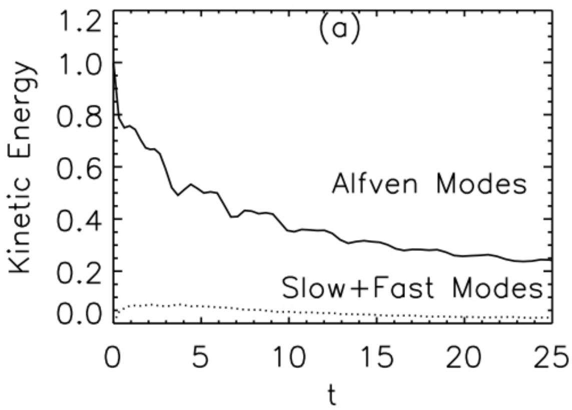


*Figure 2: Decomposition of the kinetic energy into the three eigenmodes in Ref. [4]. Since the forcing was solenoidal the component of slow and fast modes is small. We can expect this contribution to increase in simulations with more compressive forcing.*

Some of the drawbacks of these earlier simulations have been that the level of compressibility was not controlled. Also the resolution was quite limited in resolving the inertial range. We can overcome these problems by a recent model of forcing which can carefully control the fraction of compressive to solenoidal forcing [3]. This is called as an Ornstein-Uhlenbeck (OU) process of randomly forcing the plasma at large scales where the force at each time step is changed by a random small fraction which is Gaussian distributed. Also the forcing is projected onto the compressive and solenoidal modes whose relative fractions can be accurately controlled. Also we can achieve a significant improvement in the resolution with state-of-the-art computing resources of HLRN. This would help us achieve a larger inertial range with better correlation functions, helping us probe the scale dependent anisotropy. The other advantage of such a study is that we can study the density statistics of the three MHD modes separately. Another useful result would be to find out the cosmic ray transport through star-forming regions. This is because earlier studies have showed fast-mode turbulence to be especially effective in cosmic ray scattering compared to Alfven and slow modes [5].

In this project we propose simulations with two goals

- Study decomposition of MHD turbulence into the three MHD eigenmodes for simulations with a varying level of compressibility
- Study the density statistics as a function of the compressibility for the three separate eigenmodes

We propose MHD simulations of the turbulence in star-forming regions by using the PLUTO code [6]. This code has been widely used for astrophysical applications. It has a ready module for forcing turbulence with an OU process. We intend to modify it in order to induce an anisotropy in the forcing wavenumbers. This makes it easier to study scale dependent anisotropy. The simulations can be done with a resolution of $800^3$ cells, which is significantly larger than the previous resolution studies of MHD mode decomposition. The diagnostics for mode decomposition and correlation functions are already ready. Diagnostics to study density statistics will need to be developed. This project will tell us about which MHD modes are conducive for star formation. This also ties in with our recent efforts to link MHD modes with observations of star formation [7].

## WWW

http://www.uni-potsdam.de/astroparticle/plasmaastrophysik.html

## More Information


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