RevMexAA (Serie de Conferencias), **40**, 159–162 (2011)

INTERSTELLAR TURBULENCE

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RESUMEN

O meio interestelar (ISM) é um sistema complexo, em várias fases, onde a história das estrelas ocorre. Os processos de formação e morte das estrelas estão fortemente acoplados à dinâmica do meio. Os movimentos caóticos e difusivos observados no meio interestelar caracterizam a turbulência local. A compreensão da turbulência é crucial para o entendimento dos processos de formação estelar e o feedback de massa e energia ao meio a partir das estrelas evoluidas. Campos magnéticos também permeiam o meio interestelar fazendo dessa tarefa ainda mais complicada. Neste trabalho, eu reviso brevemente as principais observações e a caracterização da turbulência no meio interestelar. Também, mostro os principais resultados teóricos e de simulações numéricas que podem ser usados para construir observáveis, e comparo essas previsões a algumas observações.

ABSTRACT

The Interstellar Medium (ISM) is a complex, multi-phase system, where the history of the stars occurs. The processes of birth and death of stars are strongly coupled to the dynamics of the ISM. The observed chaotic and diffusive motions of the gas characterize its turbulent nature. Understanding turbulence is crucial for understanding the star-formation process and the energy-mass feedback from evolved stars. Magnetic fields, threading the ISM, are also observed, making this effort even more difficult. In this work, I briefly review the main observations and the characterization of turbulence from these observable quantities. Following on, I provide a review of the physics of magnetized turbulence. Finally, I will show the main results from theoretical and numerical simulations, which can be used to reconstruct observable quantities, and compare these predictions to the observations.

Key Words: ISM: clouds — ISM: kinematics and dynamics — methods: numerical — MHD — stars: formation

1. INTRODUCTION

Turbulence is ubiquitous in the Universe, from scales of few centimeters in the water running in the sink of our homes, to kiloparsecs at the flowing plasmas in the intergalactic medium (Falceta-Gonçalves et al. 2010). The classical work of Kolmogorov in the 40's have provided a fundamental theoretical basis for the study of the dynamics of turbulence. In a very simplistic picture, the turbulence is characterized by chaotic motions in a fluid, resulting in diffusion of matter and decay of the kinetic energy from large to smaller scales, which end up killed by the fluid viscosity with the release of heat. But few questions remain: how does the energy cascades from the large to the smaller scales? or does this picture changes when the fluid is a plasma threaded by magnetic fields?

In order to answer the first question, Kolmogorov assumed that the turbulence in incompressible fluids should obey the principles of *(i) homogeneity, (ii) isotropy, (iii) scale invariance* and *(iv) locality.* By "locality" one should understand wave-wave interaction at a local wavenumber at Fourier space. In this sense, the large scale eddy (k_1) decays into smaller eddies k_2, being $k_2 = 2k_1$. The energy transfer rate at a given scale l is given by $\dot{\epsilon} \sim \delta v_l^2/\tau_l$, being $\tau_l \sim l/\delta v_l$. Therefore, $\delta v_l \sim (\dot{\epsilon} l)^{1/3}$. Regarding the power spectrum, if the density is a passive scalar we can write $\delta v_l^2 \sim \int_k^\infty E(k')dk'$, with $k = 2\pi/l$, resulting in the well-known Kolmogorov's spectrum $E(k) \sim \dot{\epsilon}^{2/3} k^{-5/3}$.

In the presence of magnetic fields the turbulence cascades quite differently. The main issue is that the eddies are compressed by the field lines in the perpedicular direction only. In the model presented by Goldreich & Sridhar (1995) the timescales for alfvenic and sonic motions are assumed to be similar, i.e. $\tau_A \sim \tau_s$, which corresponds to $l_\parallel/l_\perp \sim c_A/\delta v_l$. Using the scaling relation of δv_l one obtains $l_\parallel \propto l_\perp^{2/3}$. This result shows that the turbulence in magnetized plasmas is *anisotropic*, and that this anisotropy is larger at smaller scales.

Kolmogorov's scalings also fail for compressible turbulence. In the case of supersonic flows the shocks are responsible for energy exchanges that results also

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