Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Inertial Transfer in Saturated Magnetohydrodynamic Dynamos

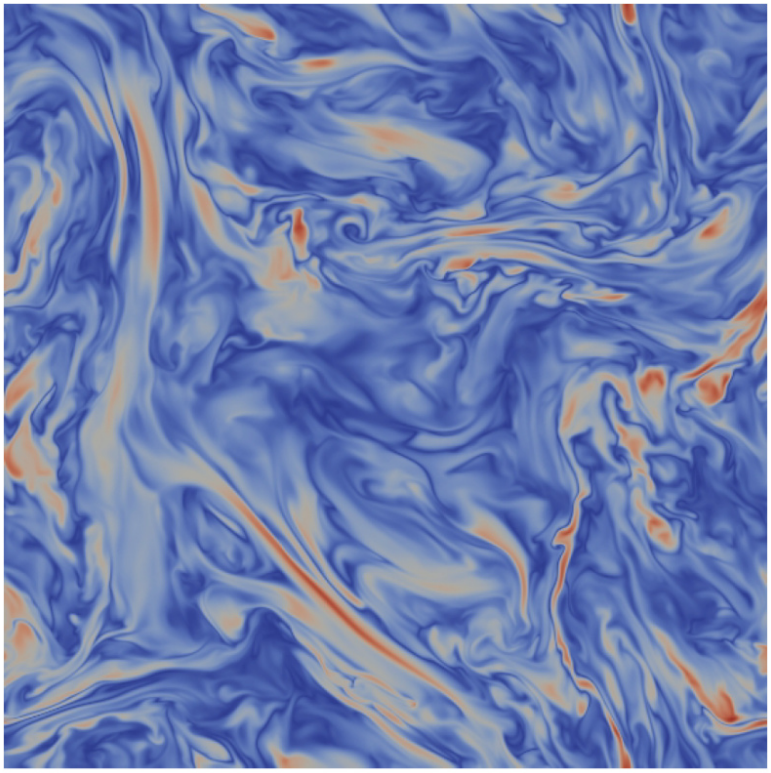


Figure 1: Instantaneous magnetic field fluctuations. The colour coding represents the magnitude of the magnetic field.

Introduction

The ratio of viscous to Joule dissipation in turbulent conducting fluids is of importance in solar- and astrophysical applications. In solar physics it is connected to a long-standing problem concerning the temperature of the solar corona, which is much higher than in the Sun's interior. Conversion of turbulent kinetic energy into magnetic energy and its subsequent dissipation through Joule heating in the solar corona could provide of the necessary additional heat sources. Concerning the fundamental physics, different ratios of viscous to Joule dissipation originate from differences between magnetic and kinetic energy transfers in turbulent magnetohydrodynamic (MHD) dynamos. In this project we investigate the influence of a fluctuating magnetic field on the inertial transfer in highly turbulent conducting flows through high-resolution computer simulations. The need for a computational approach is borne out of the difficulties that are inherent in laboratory experiments with hot plasmas and liquid metals and observational studies of the solar wind.

Project Manager
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Project Term
2018 - 2019

Project Areas
Statistical Physics, Soft Matter, Biological Physics, Nonlinear Dynamics

Clusters
Lichtenberg Cluster Darmstadt

Additional Software
mDNS – a pseudospectral solver for the Navier-Stokes equations and the equations of magnetohydrodynamics

Institute
AG Komplexe Systeme

University
University of Marburg

Methods

Inspired by studies of homogeneous isotropic turbulence, we study MHD turbulence numerically by emulating free space through periodic boundary conditions and maintain it with external body forces. This allows the use of pseudospectral algorithms to solve the equations of motion, and thus to generate time series of magnetic and velocity fields at different Reynolds numbers. This data was subsequently compared with a theoretical prediction derived by functional analytic methods.

Results

In body-forced non-conducting turbulent flows, the inertial flux becomes independent of the Reynolds number provided the latter is high enough. Conducting flows behave similarly with respect to the total energy flux, however, however it is unclear how inertial and magnetic fluxes saturate. Magnetic and inertial transfer and the corresponding dissipation rates were measured in a wide range of magnetic Reynolds numbers. Unlike in non-conducting fluids, the inertial flux does not saturate monotoneously, instead there is a range of Reynolds numbers where the suppression of inertial transfer in favour of its magnetic counterpart is maximal. In this range of Reynolds numbers fluid turbulence is suppressed by magnetic field fluctuations.

Discussion

The Reynolds numbers that were achieved in this project were not large enough to reach an asymptotic regime. As the present results suggest that the inertial transfer increases again after reaching its minimum, open questions concern its asymptotic value relative to the magnetic transfer, and in comparison with inertial transfer in non-conducting fluids.

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