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Evolution of primordial magnetic fields

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There was a time when primordial magnetic fields posed a serious contender to explaining the origin of magnetic fields in galaxies and on larger scales. This has changed drastically during the past three decades, and now the dynamo origin of galactic magnetic fields is unchallenged. Nevertheless, primordial magnetic fields might still be an attractive possibility to explaining magnetic fields between clusters of galaxies, which are difficult to get magnetized by astrophysical mechanisms such as outflows from active galactic nuclei. Primordial magnetic fields generated during the electroweak phase transition, for example would decay during much of their subsequent evolution, but helicity slows down the decay by inverse cascading the field to larger scales. Dynamo-generated magnetic fields, on the other hand, also tend to be helical, if the dynamo operates in the presence of rotation and stratification. In my talk, I will focus on the evolution of primordial magnetic fields using numerical simulations.
In the presence of magnetic helicity, inverse transfer from small to large scales is well known in magnetohydrodynamic (MHD) turbulence and has applications in astrophysics, cosmology, and fusion plasmas.
Using high resolution direct numerical simulations of magnetically dominated self-similarly decaying MHD turbulence, we report a similar inverse transfer even in the absence of magnetic helicity.
We compute for the first time spectral energy transfer rates to show that this inverse transfer is about half as strong as with helicity, but in both cases the magnetic gain at large scales results from velocity at similar scales interacting with smaller-scale magnetic fields.
This suggests that both inverse transfers are a consequence of a universal mechanisms for magnetically dominated turbulence.
Possible explanations include inverse cascading of the mean squared vector potential associated with local near two-dimensionality and the shallower kˆ2 subinertial range spectrum of kinetic energy forcing the magnetic field with a kˆ4 subinertial range to attain larger-scale coherence.
The inertial range shows a clear kˆ-2 spectrum and is the first example of fully isotropic magnetically dominated MHD turbulence exhibiting weak turbulence scaling.

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