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Energy Transfer of Alfvénic Turbulence in the Heliosphere

Liping Yang[1,2], Jiansen He[2], Daniel Verscharen[3,4], Hui Li[5], Trevor A. Bowen[6], Stuart D. Bale[7,6,8,9], Ying Wang[2], Lei Zhang[10], Honghong Wu[2], Xueshang Feng[1]

[1]SIGMA Weather Group, State Key Laboratory for Space Weather, National Space Science Center, Chinese Academy of Sciences, Beijing 100190, People's Republic of China

[2]School of Earth and Space Sciences, Peking University, Beijing 100871, People's Republic of China

[3]Mullard Space Science Laboratory University College London Dorking, RH5 6NT United Kingdom

[4]Space Science Center, University of New Hampshire, Durham NH 03824, USA

[5]Theoretical Division, Los Alamos National Laboratory, Los Alamos NM 87545, USA

[6]Space Sciences Laboratory, University of California, Berkeley CA 94720-7450, USA

[7]Physics Department, University of California, Berkeley CA 94720-7300, USA

[8]School of Physics and Astronomy, Queen Mary University of London, London E1 4NS, UK

[9]The Blackett Laboratory, Imperial College London, London SW7 2AZ, UK

[10]Qian Xuesen Laboratory of Space Technology, Beijing 100190, People's Republic of China

e-mail (speaker):lpyang@swl.ac.cn

As a universal plasma process, Alfvénic turbulence plays a critical role in space, astronomy, and even laboratory. A fundamental issue about it is how the energy transfers, which remains a challenging mystery. By analyzing both the in-situ measurements from Parker Solar Probe and the advanced modeling results, we find that the energy transfer of Alfvénic turbulence is completed by nonlinear interactions between unidirectional Alfvén waves and mutualistic structures, rather than the interactions between counter-propagating Alfvén waves in the commonly invoked scenario. The major waves transfer their energy to smaller-scale waves chiefly through the interactions with the minor structures of similar scale, creating their Kolmogorov-like spectrum, while the structures cascade by the interactions with large-scale waves and get a power-law spectrum with the index being -1. Such findings unveil the essential energy transfer physics of Alfvénic turbulence, offering insights for MHD turbulence models while renewing our understanding of the turbulent plasma.