Kinetic Instabilities and Turbulence in the Solar Wind

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Abstract

The solar wind is a continuous outflow of plasma from the Sun, which expands into the space between the planets in our solar system and forms the heliosphere. The solar wind is inherently turbulent and characterised by kinetic micro-instabilities on a range of scales. The Sun also intermittently ejects mass (coronal mass ejections; CMEs) or solar energetic particles (SEPs) which change their trajectory or energy due to their interactions with the solar wind. When these violent particle events hit the Earth's magnetosphere, they can cause "space weather" with both long- and short-term impacts on our natural and technological environment. This presentation investigates the behaviour and the effects of kinetic instabilities in a turbulent plasma with particular emphasis on energy transfer processes. We utilise the unprecedented observations from ESA's Solar Orbiter spacecraft, launched in February 2020, to advance our understanding of the Sun, the solar wind, and space weather. Large-scale compressions (ubiquitous in solar-wind turbulence) create conditions for proton, alpha-particle and electron microinstabilities, which then transfer energy to small-scale fluctuations. These instability-driven small-scale fluctuations, including those driven by turbulence and other sources of free energy (e.g. particle beams, differential flows, heat fluxes, temperature anisotropies), make a significant contribution to the fluctuation spectrum at kinetic scales, where energy dissipation occurs. We consider instabilities driven by turbulence in the plasma by using statistical methods to analyse the Solar Orbiter data and characterise the turbulence at the relevant scales and amplitude. Specifically, we evaluate the processes by which turbulence combined with temperature anisotropy causes instability, comparing theoretical calculations with the high resolution data available from the Solar Orbiter MAG and SWA instruments.

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Kinetic Instabilities and Turbulence in the Solar Wind

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INTRODUCTION

Can instabilities exist in a turbulent plasma and if so, what conditions are needed for instabilities to arc?

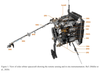


Figure 1. Time series when spacecraft encountering the solar wind in the ecliptic plane at 1AU. Adapted from Bruno & Carbone, 2005.

The work utilizes early data from the Solar Orbiter mission (orbit phase 1) to study the kinetic properties of the solar wind turbulence in the Earth's surface and the outer corona and to arc conditions to measure the kinetic properties of the solar wind turbulence.

The various instruments are shown in Figure 2 and for the purposes of this project the instruments of interest are the Solar Wind Analyser (SWA) and the Magnetometer (MAG). The Solar Wind Analyser (SWA) is a suite of three sensors that measure the electron, proton and alpha components of the fundamental in the range energy range from 0.5 eV/q to 5 keV/q. The Electron Analyser System (EAS) is a set of two sensors (EPS), for solar or cosmic ray-dominated, field fluctuations measurements, and the Proton and Alpha Sensor (PAS) measures the proton and alpha density, speed and temperature, which are a small component of the solar wind.

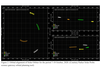
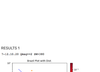


Figure 2. Solar Orbiter Spacecraft and its instruments.
Credit: ESA, Medialab, Science Office, Science Operations Department.

Driving in radio calibration noise (RTS) data with FIR noise(s) – the region from Solar Orbiter(s) that produce out of RTS data and the in quality. Fig. 3 is below. According to the publishing of the ESTEC/ESA (Science Operations, Science Office, Medialab, ESA) and the Solar Orbiter Science Team (Science Operations). The orbital position of the spacecraft at the time of the data is shown.

Figure 3. Solar Orbiter Spacecraft and its instruments.
Credit: ESA, Medialab, Science Office, Science Operations Department.

RESULTS 1


T-12.10.20 (pap=2 DH:DD)
Small PAA with Dist
Spectral Index
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Speed
Temperature
Alpha Density
Alpha Speed
Alpha Temperature
Alpha Flow Speed
Alpha Flow Angle
Alpha Flow Angle Variance
Alpha Flow Speed Variance
Alpha Flow Temperature
Alpha Flow Density
Alpha Flow Density Variance
Alpha Flow Temperature Variance
Alpha Flow Speed Variance
Alpha Flow Angle Variance

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