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Predicting, testing, and measuring the effects of the space environment on space missions (3)

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MAGNETIC TRACES OF PLASMA JETS OF SPACE ENGINES

Abstract

Modern space missions require constant and accurate adjustment of satellite trajectories. For the past 65 years, these adjustments have mainly been made using chemical engines. However, in modern astronautics, the development of ion thrusters is gradually leading to the displacement of chemical engines for changing satellite trajectories. There are three general types of ion engines: the first one is engine with a grid, in which plasma is created by applying voltage to the cathode and anode, where the cathode is an electron emitter, and the resulting ions are accelerated by the grids. Another one is plasma engines that work on the Hall effect, in which plasma is formed between coaxial cylinders with the supply of high voltage to the anodes. And the last one is helicon double-layer thruster, in which electromagnetic wave emitted by the antenna causes the gas to break down and form a plasma jet. But it is important for us that a common feature of all types of ion engines is the plasma trail left behind.

Plasma medium, characterized by collective interactions of charged particles, are highly susceptible to various instabilities. Laminar plasma jets in ion engines fast enough acquire a turbulent nature, but these turbulent plasma flows can generate very strong magnetic fields. Direct numerical simulation of such magnetic generation is extremely difficult due to the need to take into account completely different scales of vortices. Therefore, a statistical method is the only way to model strong magnetic fields in turbulent plasma jets.

Theory of magnetic generation in turbulent plasma give us a powerful tool for such statistical studies: first of all, we use the Steinbeck-Krause-Rädler approach to model the generation of mean magnetic fields and Kazantsev approach to model the generation of mean magnetic energy. These models allow us to investigate the formation of mean magnetic field in plasma engine jets, its amplification and transformation of the mechanical energy into the magnetic one. By modeling mean magnetic field generation in various types of engines, we compare magnetic traces of engines and their characteristic markers. Analyzing the behavior of markers and their dissipation in time, we try to answer the question if it is possible to determine the type of plasma engine, its mode of operation, and the time of flight of a space mission from the magnetic trace.