I. Products

Journal publications

1. Francesco Pecora 2024 Plasma Phys. Control. Fusion 66 125008 (DOI 10.1088/1361-6587/ad8a8b) https://iopscience.iop.org/article/10.1088/1361-6587/ad8a8b
   – Open access version https://arxiv.org/abs/2410.16099

Presentations

1. 50th European Physical Society Conference on Plasma Physics, 2024 July 8–12, Salamanca, Spain, **invited presentation**.
2. Cross-Scale Energy Transfer in Space Plasmas, International Space Science Institute, 2024 October 21-25, Bern, Switzerland, **invited presentation** as external expert.
3. Arcetri Workshop on Plasma Astrophysics, 2024 October 28–31, Firenze, Italy, **oral presentation**.
4. First Plasma Observatory Community Workshop, 2024 November 12-14, Agenzia Spaziale Italiana (Italian Space Agency), Rome, Italy, **oral presentation.**

II. Participants & Other Collaborating Organizations

University Research Team Member

Name ..... Francesco Pecora
Project Role ..... PI
Nearest person month worked 1
Contribution to Project ..... The PI has applied the novel LPDE technique to an extensive database of datasets in the terrestrial magnetosheath and presented this work in several conferences and workshops. He also published a paper in which this technique is used. He is also supervising a graduate student teaching her fundamental theoretical background, how to use multispacecraft data, and performing some analyses that require advanced numerical expertise.
Funding Support ..... This grant and NASA MMS.

Name ..... Jiaming (Victoria) Wang
Project Role ..... Graduate student
Nearest person month worked 1

Contribution to Project ..... The student has been learning fundamental theoretical frameworks in the realm of energy transfer in turbulent plasma and performing analyses on multispacecraft data comparing historical approaches that used strong approximations, with the novel LPDE technique promoted by this grant.
Funding Support ..... This grant and NASA MMS.

III. Changes/Problems

The work plan is going as expected, with no changes or problems to report.

IV. Impact

We have developed a new method to track energy in space using multiple satellites, offering a clearer picture of how the energy in the solar wind, the stream of magnetic field and energetic particles flowing from the sun, is transferred from large-scale swirling motion down to the smallest of the effects.

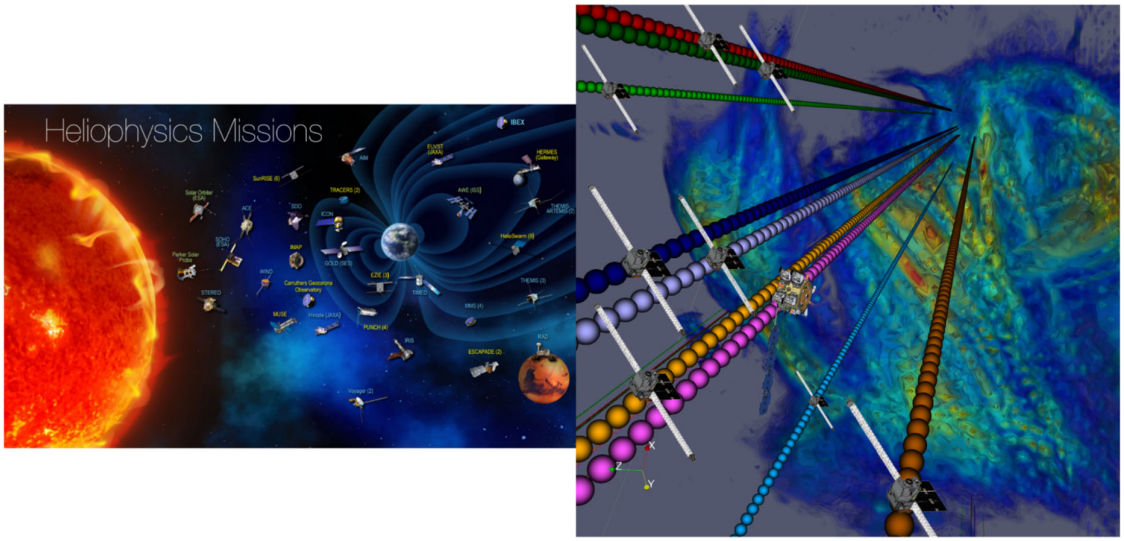
NASA's upcoming HelioSwarm mission, which will deploy nine satellites in the solar wind, will benefit from this technique. For the first time, researchers can precisely measure how much energy from solar events might affect our planet's magnetosphere—the magnetic region that shields us from solar radiation.

This approach takes advantage of the unique configurations created by multiple spacecraft. By carefully analyzing data from satellites flying in formation, scientists can now detect and measure energy transfer in ways that were previously impossible.

The research has already gained international recognition. It has been featured in a Science Highlight for the Magnetospheric Multiscale (MMS) mission quarterly Report to NASA HQ, and presented at the European Physical Society meeting. Potential European Space Agency missions such as Plasma Observatory are also exploiting this technique to support their science questions.

Understanding these energy dynamics is more than an academic exercise. It could help us better predict and prepare for space weather events that might disrupt communication systems, power grids, and satellite operations.

By improving our ability to observe and interpret these interplanetary interactions, this research provides valuable insights into the complex relationship between our planet and the solar environment, as well as for understanding the outer universe currently inaccessible to our satellites.



(Left) NASA heliophysics missions – from science.nasa.gov. (Right) A numerical simulation of the solar wind, where we included virtual spacecraft in a multipoint configuration obtained from HelioSwarm. Adapted from Pecora et al 2023 ApJL 945 L20.