The solar wind: a paradigm for complex system dynamics

Simone Benella

INAF – Istituto di Astrofisica e Planetologia Spaziali, Roma

simone.benella@inaf.it

IAPS ISTITUTO DI ASTROFISICA E PLANETOLOGIA SPAZIALI

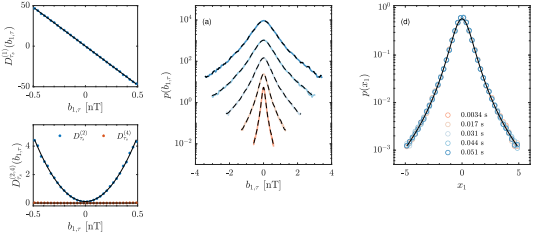
Primary objectives of the project

- Provide a phenomenological framework for solar wind turbulence at kinetic scales based on Langevin equation
- Use the model for making predictions on typical statistical quantities investigated in the field of turbulence, e.g., scaling exponents of structure functions and test them on independent spacecraft observations
- Investigate the stochastic entropy production associated with the Langevin process and make a link between stochastic thermodynamics and scaling properties of turbulence (e.g., intermittency)

The Astrophysical Journal Letters, 928:L21 (7pp), 2022 April 1 https://doi.org/10.3847/2041-8213/ac6107
© 2022. The Author(s). Published by the American Astronomical Society.
OPEN ACCESS

Markovian Features of the Solar Wind at Subproton Scales

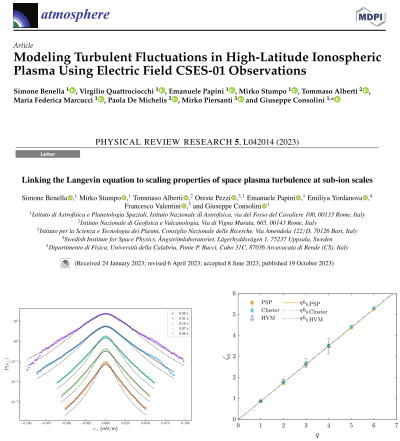
Simone Benella[1], Mirko Stumpo[2,1], Giuseppe Consolini[1], Tommaso Alberti[1], Vincenzo Carbone[3], and Monica Laurenza[1]
[1] INAF-Istituto di Astrofisica e Planetologia Spaziali, I-00133 Roma, Italy; simone.benella@inaf.it
[2] Dip. Fisica, Università degli Studi di Roma Tor Vergata, I-00133 Roma, Italy
[3] Dipartimento di Fisica, Università della Calabria, Rende (CS), I-87036, Italy
Received 2022 January 21; revised 2022 March 3; accepted 2022 March 11; published 2022 April 5



[SBenella+2022ApJL]

Milestones

- The selection of suited high-resolution data intervals for the developing of the project as been completed
- The Python code for modeling plasma turbulence through Langevin equation has been finalized and it has been used in a recent work https://doi.org/10.3390/atmos14091466
- The first test of the Langevin modeling of kinetic scales on indpendent data samples from both spacecraft observations and numerical simulations has been published https://doi.org/10.1103/PhysRevResearch.5.L042014
- The exploration of the stochastic thermodynamics application to solar wind, constituting the second part of this project, has begun, and first results have been submitted for publication to Astrophys J Lett



atmosphere MDPI

Article

Modeling Turbulent Fluctuations in High-Latitude Ionospheric Plasma Using Electric Field CSES-01 Observations

Simone Benella [1], Virgilio Quattrociocchi [1], Emanuele Papini [1,2], Mirko Stumpo [1], Tommaso Alberti [3], Maria Federica Marcucci [4], Paola De Michelis [5], Mirko Piersanti [4] and Giuseppe Consolini [1,*]

PHYSICAL REVIEW RESEARCH 5, L042014 (2023)

Letter

Linking the Langevin equation to scaling properties of space plasma turbulence at sub-ion scales

Simone Benella [1], Mirko Stumpo [1], Tommaso Alberti [2], Oreste Pezzi [2,3], Emanuele Papini [1], Ermiliya Yordanova [4], Francesco Valentini [5], and Giuseppe Consolini [1]

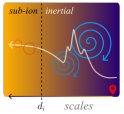
[1] *Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale di Astrofisica, via del Fosso del Cavaliere 100, 00133 Rome, Italy*
[2] *Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata, 605, 00143 Rome, Italy*
[3] *Istituto per la Scienza e Tecnologia dei Plasmi, Consiglio Nazionale delle Ricerche, Via Amendola 122/D, 70126 Bari, Italy*
[4] *Swedish Institute for Space Physics, Ångströmlaboratoriet, Lägerhyddsvägen 1, 75237 Uppsala, Sweden*
[5] *Dipartimento di Fisica, Università della Calabria, Ponte P. Bucci, Cubo 31C, 87036 Arcavacata di Rende (CS), Italy*

(Received 24 January 2023; revised 6 April 2023; accepted 8 June 2023; published 19 October 2023)

Deliverables and future activities

Invited Talks

- XVIII Encuentro de Fìsica, Oct 15 – 20 2023, Quito, Ecuador
- CMD30 - FisMat, Sep 4 – 8 2023, Milan, Italy
- IUGG, Jul 11 – 20 2023, Berlin, Germany
- Isradynamics, March 7 – 14 2023, Dead Sea, Israel



Conferences

- AGU 2023, San Francisco, *abstract ID 1404723*
- Società Italiana di Fisica Statistica, Jun 21 – 23 Jun 2023, Parma, Italy
- EGU General Assembly, 23 – 28 April 2023, Wien, Austria
- Workshop on Plasma Astrophysics, Nov 14 – 18 2022, Arcetri, Italy

Publications

- S Benella, M Stumpo, G Consolini, *et al.*, (2022). Rend. Lincei-Sci. Fis., 33(4), 721-728. `https://doi.org/10.1007/s12210-022-01108-2`
- S Benella, V Quattrociocchi, E Papini, *et al.*, (2023). Atmosphere, 14(9), 1466 `https://doi.org/10.3390/atmos14091466`
- S Benella, M Stumpo, T Alberti, *et al.*, (2023). Phys. Rev. Research 5, L042014 `https://doi.org/10.1103/PhysRevResearch.5.L042014`
- M Stumpo, S Benella, T Alberti, *et al.*, submitted to Astrophys. J. Lett.

Potential Issues

- Lack of reliable high-frequency measurements of plasma parameters (e.g., velocity and density) in solar wind

Future Activities

- Test and generalization of the Python codes developed for Langevin modeling and stochastic entropy analysis
- Publication of final results obtained in the context of the project
- Presentation of results to international conferences to disseminate results and forster possible international collaborations