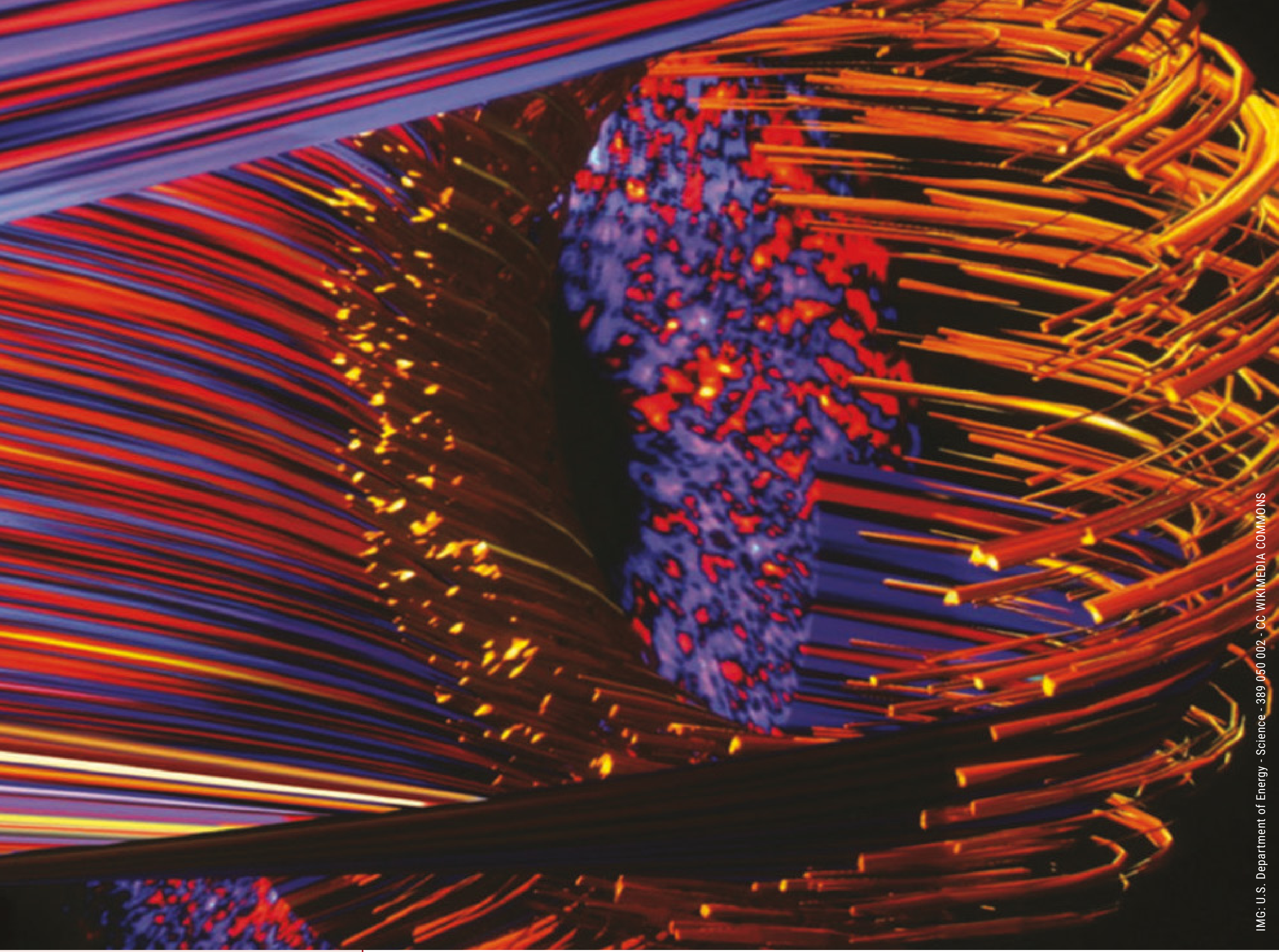

MAPsTu - Mathematical Aspects of Plasma Physics and Turbulence

4-8 MAY
2026

Aula Dini
Palazzo del Castelletto
Scuola Normale Superiore
Piazza del Castelletto
Pisa

ORGANIZING COMMITTEE:
Federico Butori
Ciro Campolina
Franco Flandoli
Yassine Tahraoui
Scuola Normale Superiore
Theresa Lange
MPI Leipzig

PHILIP MORRISON (University of Texas at Austin)
Who will provide a comprehensive overview of mathematical models for plasma dynamics

NICOLAS BESSE (Observatoire de la Côte d'Azur, Nice)
Who will cover diffusion limit theorems related to the Vlasov–Poisson system in weak turbulence regimes, as well as reduced magnetohydrodynamics models

DANIEL HAN-KWAN (Nantes Université)
Who will present rigorous justifications of quasi-neutral limits for the Vlasov–Poisson system

Registration open until **26 April**

Web Site
Registration

INFO
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erc European Research Council

This event is funded by the European Union under ERC grant NoisyFluid no. 101053472

MAPsTU

Mathematical Aspects of Plasma Physics and Turbulence

May 4-8, 2026
Scuola Normale Superiore, Pisa, Italy

Venue

Aula Dini
Palazzo del Castelletto
Via del Castelletto 11
56126 Pisa, Italy

Program

Time	Mon 04/05	Tue 05/05	Wed 06/05	Thu 07/05	Fri 08/05
8:30	*Registration*				
9:00	P. Morrison (1/3)	D. Han-Kwan (1/2)	N. Besse (2/3)	P. Morrison (3/3)	
9:45					M. Maurelli
10:30	*Coffee break*	*Coffee break*	*Coffee break*	*Coffee break*	*Coffee break*
11:00	D. Manzini	M. Griffin-Pickering	D. Han-Kwan (2/2)	E. Tassi	P. Mantica
11:45	T. Seetohul				Discussion
12:00		D. Fedeli		G. Zirilli	
12:30	*Lunch*	*Lunch*	*Lunch*	*Lunch*	*Lunch*
14:00	N. Besse (1/3)	P. Morrison (2/3)	*Free afternoon*	N. Besse (3/3)	
14:45					
15:30	*Coffee break*	*Coffee break*		*Coffee break*	
16:00	H. Xiang	M. P. Basile		E. Breton	
16:45	C. Mindrilla	F. Ferrarese		D. Dechicha	
17:30	*End of session*	*End of session*	*End of session*	*End of session*	
20:00			*Conference dinner*		

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Coffee Breaks and Lunches

Coffee breaks will be served in the morning and afternoon in the lecture room. Lunches will be provided at the canteen of the Scuola Normale Superiore, at Palazzo d'Ancona, located at Via Consoli del Mare 1.

Conference Dinner

The conference dinner will take place on May 6 at 20:00, at the restaurant *Quore*, located at Via del Cuore 1.

Moderated discussion on Friday

On Friday morning, the event will close with a moderated discussion chaired by the organizers, focusing on *future perspectives and challenges in the mathematics of plasma dynamics*.

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Abstracts of talks

Michael Pio BASILE *(ONERA/Institut Polytechnique de Paris)*
Non Interpolating Semi Lagrangian Methods for Plasma Physics
Tuesday, 5 May, 16:00–16:45
Abstract: In this work, we present a novel formulation of non-interpolating semi-Lagrangian (NISL) methods for plasma physics models. We introduce a NISL formulation integrated with a Runge–Kutta (RK) time-stepping approach and incorporate Weighted Essentially Non-Oscillatory (WENO) reconstruction within this NISL–RK framework. The stability and convergence of the proposed method are rigorously analyzed both theoretically and through standard advection test cases. We demonstrate the effectiveness of our approach in plasma physics simulations, specifically for the Vlasov–Poisson system. By reformulating semi-Lagrangian schemes to avoid interpolation and by using RK integrators, we achieve a structure closer to traditional Eulerian schemes, facilitating the straightforward integration of established numerical techniques such as WENO. Additionally, removing interpolation steps enhances computational efficiency, offering a more robust alternative to traditional interpolating semi-Lagrangian schemes. Finally, we apply the proposed method to the simulation of plasma turbulence using the Hasegawa–Mima model, illustrating its effectiveness for more complex nonlinear plasma dynamics.

Émile BRETON *(IRMAR)*
The Vlasov-Maxwell system: modified scattering and absence of linear scattering
Thursday, 7 May, 16:00–16:45
Abstract: We consider the solutions to the Vlasov-Maxwell system exhibited by Glassey and Strauss, arising from small and compactly supported data. We prove that the particle densities exhibit a modified scattering dynamic in the multi-species case. Moreover, in this setting, we show the absence of linear scattering, i.e., there exists at least one particle density that does not converge when composed with the linear flow.

Dahmane DECHICHA *(New York University Abu Dhabi)*
Fractional diffusion limit for Fokker–Planck with(-out) drift and for a general heavy tail equilibrium
Thursday, 7 May, 16:45–17:30
Abstract: We study a kinetic Fokker–Planck equation with a general heavy-tailed equilibrium that may be non-symmetric and does not admit an explicit formula. Assuming that the equilibrium behaves like $\langle v\rangle^{-\beta}$ at infinity with $\beta > d$, we analyze the spectral problem associated with the Fokker–Planck operator in the presence of the transport term and prove the existence and uniqueness of an eigenpair. This spectral analysis allows us to derive the fractional diffusion limit of the kinetic equation. The approach applies both to Fokker–Planck equations with or without drift in the kinetic model and extends previous results on fractional diffusion limits to a broad class of heavy-tailed equilibria.

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Daniele FEDELI *(Scuola Normale Superiore)*
Asymptotic reduction of the gyrokinetic equation: a two-field model for ITG turbulence
Tuesday, 5 May, 12:00–12:30
Abstract: Understanding turbulent transport in magnetically confined plasmas requires tractable reduced models that retain the essential physics of the underlying kinetic description. In this talk I present a two-dimensional, two-field fluid model for ion-temperature-gradient (ITG) driven turbulence in a Z-pinch geometry, recently introduced by Ivanov et al. (2020). Starting from the electrostatic ion gyrokinetic equation, I show how a careful asymptotic ordering yields a closed system of evolution equations for the perturbed electrostatic potential and ion temperature. I then discuss the structure of the resulting equations, their conservation laws, and the linear curvature-driven ITG instability they support. Despite its simplicity, the model is rich enough to exhibit a sharp Dimits-like transition between a low-transport saturated state and a strongly turbulent regime.

Federica FERRARESE *(University of Ferrara)*
Robust control strategies for magnetically confined fusion plasma
Tuesday, 5 May, 16:45–17:30
Abstract: The study of the problem of plasma confinement in huge devices, such as for example Tokamaks and Stellarators, has attracted a lot of attention in recent years. Strong magnetic fields in these systems can lead to instabilities, resulting in vortex formation. Due to the extremely high temperatures in plasma fusion, physical materials cannot be used for confinement, necessitating the use of external magnetic fields to control plasma density. This approach involves studying the evolution of plasma, made up of numerous particles, using the Vlasov-Poisson equations. In the first part of the talk, the case without uncertainty is explored. Particle dynamics are simulated using the Particle-in-Cell (PIC) method, known for its ability to capture kinetic effects and self-consistent interactions. The goal is to derive an instantaneous feedback control that forces the plasma density to achieve a desired distribution. Various numerical experiments are presented to validate the results. In the second part, uncertainty and collisions are introduced into the system, leading to the development of a different control strategy. This method is designed to steer the plasma towards a desired configuration even in the presence of uncertainty. The presentation concludes by outlining a future perspective focused on developing a robust control strategy based on neural networks.

Megan GRIFFIN-PICKERING *(University of Zurich)*
The Vlasov-Poisson system for ions: Wasserstein stability and the quasineutral limit
Tuesday, 5 May, 11:00–12:00
Abstract: Vlasov-Poisson systems are well-known kinetic models for dilute plasma. The precise structure of the model differs according to which species of charged particle (electrons or ions) it describes. I will discuss a Vlasov-Poisson model for ions interacting with thermalized electrons. In comparison to the model for electrons, the ionic equation features an additional exponential nonlinearity in the Poisson coupling for the electrostatic potential that creates new mathematical difficulties.
Quantitative stability estimates in Wasserstein distances have played a crucial role in the theoretical understanding of equations of Vlasov type. I will discuss recent developments in Wasserstein estimates for the ionic Vlasov-Poisson system, including applications to the

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quasineutral limit in which the Debye length tends to zero. Based on joint works with Mikaela Iacobelli (ETH Zürich).

Paola MANTICA *(Istituto per la scienza e tecnologia dei plasmi, CNR, Milano)*
Progress and challenges in understanding core transport in tokamaks in support to ITER operations
Friday, 8 May, 11:00–11:45
Abstract: Fusion performance in tokamaks depends on the core and edge regions as well as on their nonlinear feedbacks. The achievable degree of edge confinement under the constraints of power handling in presence of a metallic wall is still an open question. Therefore, any improvement in the core temperature and density peaking is crucial for achieving target performance. This has motivated further progress in understanding core turbulent transport mechanisms, to help scenario development in present devices and improve predictive tools for ITER operations. In the last two decades, detailed experiments and their interpretation via the gyrokinetic theory of turbulent transport have led to a satisfactory level of understanding of the heat, particle, and momentum transport channels and of their mutual interactions. This talk presents some highlights of the progress, which stems from joint work of several devices and theory groups, in Europe and worldwide within the International Tokamak Physics Activities framework. On the other hand, the achievement of predictive capabilities of plasma profiles via integrated modeling, which also accounts for the nonlinear interactions inherent to the multi-channel nature of transport, is a priority in view of ITER. This requires using faster, reduced models, and the extent to which they capture the complex physics described by nonlinear gyrokinetics must be carefully evaluated. Present quasi-linear models match well experiments in baseline scenarios, and thus offer reliable predictions for the ITER reference scenario, but have issues in advanced scenarios. Some of these challenges are examined and discussed. In the longer term, advances in high performance computing will continue to drive physics discovery through increasingly complex gyrokinetic simulations, allowing also further development of reduced models. The development of neural network surrogate models is another recent advance that bridges the gap towards physics-based fast models for optimization and control applications.

Davide MANZINI *(Queen Mary University of London)*
Phase Space Turbulence in Weakly Collisional Magnetized Plasmas
Monday, 4 May, 11:00–11:45
Abstract: A central problem in turbulence theory is to understand how energy, injected at large scales, is transferred to scales at which it can be dissipated. In neutral fluids, this process is generally described as a cascade toward small spatial scales, where large spatial gradients compensate for the smallness of viscosity. In weakly collisional, magnetized plasmas, the situation is more intricate. Efficient dissipation requires the development of filamentation in the velocity distribution function (i.e., the generation of fine-scale structure in velocity space), a process with no fluid analog. As a consequence, plasma turbulence is fundamentally kinetic and requires tracking the evolution of fluctuations in the full phase space. After reviewing theoretical approaches to phase-space turbulence within gyrokinetic theory, we present results from Eulerian Vlasov–Maxwell simulations that reveal strikingly distinct dissipation pathways for ions and electrons. Electrons predominantly dissipate energy via linear phase mixing (Landau damping), while ions undergo nonlinear phase mixing, a process known as entropy cascade, in which the distribution function develops progressively finer

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scales in both physical and velocity space. These simulations provide new evidence on how irreversible thermalization is achieved in weakly collisional systems.

Mario MAURELLI *(Università di Pisa)*

The nonsmooth Kraichnan model

Abstract: The nonsmooth Kraichnan model is a linear stochastic transport model in which the velocity field is Gaussian, white in time, isotropic, and spatially rough. Introduced as a toy model for turbulent transport, it allows explicit computations and has become a benchmark for predictions such as Richardson pair dispersion and intermittency. In mathematics, it stands out as one of the few transport models exhibiting both well-posedness and, depending on the compressibility degree, spontaneous stochasticity or particle coalescence. More recently, renewed interest has followed rigorous results on anomalous dissipation and anomalous regularization, as well as related regularization-by-noise results. In this talk, we will review these mathematical developments.

Claudiu MINDRILA *("Gheorghe Mihoc – Caius Iacob" Institute of Mathematical Statistics and Applied Mathematics of the Romanian Academy)*

Existence of weak solutions for fluid –Koiter shell interactions with Navier slip boundary conditions

Monday, 4 May, 16:45–17:30

Abstract: We study a three-dimensional fluid--structure interaction problem describing the motion of an incompressible, viscous fluid coupled with a deformable elastic shell of Koiter type that forms part of the fluid boundary. The fluid motion is governed by the incompressible Navier--Stokes equations posed on a time-dependent domain, while the shell evolution is described by a nonlinear elastic model. At the fluid--structure interface, we impose Navier slip boundary conditions, allowing for tangential slip penalized by friction. Our main result establishes the global-in-time existence of weak solutions up to the first possible self-intersection of the shell, for arbitrarily large initial data with finite energy. The analysis is carried out in a fully three-dimensional setting and addresses the major mathematical challenges arising from the moving domain, the geometric nonlinearity of the shell, and the reduced regularization induced by the slip boundary condition. Joint with Arnab Roy (BCAM, Bilbao).

Tooryanand SEETOHUL *(Université de Rennes - INRIA)*

Landau damping around inhomogenenous equilibria for the Vlasov-HMF model

Monday, 4 May, 11:45–12:30

Abstract: Plasma dynamics are often modeled by Vlasov equations, with interactions encoded by potential kernels. A striking phenomenon in such systems is Landau damping, where particles relax back to a natural equilibrium state when slightly perturbed. In this talk, we investigate this phenomenon around inhomogeneous (spatially-dependent) steady states. We focus on the Vlasov-HMF (Hamiltonian Mean-Field) model, a simplification of the interaction kernel of the more central Vlasov-Poisson system that retains its essential nonlinear features. I will first present the linearized analysis, demonstrating how Landau damping emerges in this inhomogeneous setting. The core of the talk will then address how to ascend from this linear picture to a nonlinear result for initial data of weak (Sobolev) regularity, guaranteeing that Landau damping holds for long and finite time.

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Emanuele TASSI *(CNRS Laboratoire Lagrange)*

Hamiltonian fluid models for plasmas in the presence of a strong guide field

Thursday, 7 May, 11:00–12:00

Abstract: In many space and laboratory plasmas, as for instance in tokamak devices for thermonuclear fusion, plasma dynamics occurs in the presence of a strongly anisotropic magnetic field. In this situation, the dynamics of the plasma and of the electromagnetic field, can be locally described by means of fluid models within the so-called strong guide field assumption. In this talk I will present an infinite family of such models, derived from a parent model of the so-called drift-kinetic type. By means of an orthogonal transformation, the model equations can be cast in a form which, in the two-dimensional (2D) limit, reduces to that of a system of advection equations for Lagrangian invariants. This helps to reveal the presence of a noncanonical Hamiltonian structure in the family of models. In particular, in the 2D limit, the corresponding Poisson bracket corresponds to the direct sum of Lie-Poisson brackets analogous to those of the 2D Euler equation for an incompressible fluid. Casimir invariants for the models can then be easily obtained [1,2]. The above mentioned formulation of the models in terms of Lagrangian invariants also helps to prove global existence and uniqueness of weak solutions in the 2D limit. Part of the work was carried out in collaboration with Nicolas Besse. 1 E. Tassi, Poisson brackets and truncations in nonlinear reduced fluid models for plasmas, Physica D, 437, (2022), 133338. 2 E. Tassi, Generalized Hamiltonian drift-fluid and gyrofluid reductions, J. Phys. A: Math. Theor. , 56 (2023), 335701.

Haoling XIANG *(Imperial College London)*

From the FPU Paradox to Kinetic Theory: Extended Lifespan for the Inhomogeneous Kinetic FPU Equation

Monday, 4 May, 16:00–16:45

Abstract: The Fermi–Pasta–Ulam (FPU) experiment revealed an unexpected lack of thermalization in weakly nonlinear oscillator chains, giving rise to the well-known FPU paradox. Kinetic theory provides a natural framework to describe this phenomenon through effective equations governing phonon interactions. In this talk, I will briefly review the kinetic description of the β-FPU chain and recall the formal derivation framework for kinetic equations developed by Germain et al. as background and motivation. I will then discuss recent progress on the rigorous derivation of wave kinetic equations, including the long-time breakthrough of Deng–Hani, as well as derivation results by Wu and by Hani from suitably reduced versions of the FPU dynamics. I will highlight the remaining challenges, in particular the passage from the full FPU system and the extension of short-time derivations to the kinetic time scale. The main focus is the inhomogeneous kinetic FPU equation, which couples free transport in physical space with a degenerate collision operator in momentum space. Using dispersive estimates for the linear transport semigroup, we show that small solutions near the vacuum admit an extended lifespan, improving the classical quadratic time scale to a quartic one.

Giovanni ZIRILLI *(Scuola Normale Superiore)*

A dynamical model for turbulence on a dyadic tree

Thursday, 7 May, 12:00–12:30

Abstract: Turbulence remains a paradigmatic example of a strongly non-equilibrium system, where energy is injected, transferred across scales, and dissipated in a statistically stationary

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yet intrinsically irreversible regime. Capturing such scale-to-scale dynamics within a tractable statistical framework remains a central challenge of non-equilibrium statistical physics.

We introduce a stochastic cascade model defined on a dyadic grid, in which coarse-grained energy variables evolve according to a continuous-time Markov process with self-similar transition rates. The construction is directly rooted in the Kármán–Howarth–Monin–Hill equation, which expresses the conservation of velocity-increment energy across space and scale. Its discretization yields a minimal yet dynamically consistent representation of the turbulent energy cascade, amenable to efficient simulation via the Gillespie algorithm.

Despite its simplicity, the model reproduces three hallmark features of fully developed turbulence: anomalous dissipation, spatial intermittency, and spontaneous stochasticity. In contrast to classical multiplicative cascade models, intermittency emerges here from the intrinsic stochastic dynamics rather than being imposed a priori. Under steady forcing, the system reaches a non-equilibrium stationary state characterized by non-Gaussian statistics and anomalous scaling of energy moments, reflecting a constant flux of conserved quantities across scales.

At the analytical level, the master equation enables explicit predictions for the statistics of energy fluxes, in good agreement with numerical simulations. The stationary measure is well described by a log-divisible process, highlighting deep connections with multiplicative cascades while extending them to a dynamical, time-resolved setting. Furthermore, the fluctuating direction of energy transfers gives rise to backward propagation of uncertainties from small to large scales, providing a minimal framework to investigate spontaneous stochasticity as an emergent non-equilibrium phenomenon.

This approach opens a route toward identifying universality classes of turbulent cascades within the broader context of non-equilibrium statistical mechanics. Perspectives include extensions to incorporate additional conserved quantities, coupling with particle dynamics, and connections with large-deviation theory and stochastic thermodynamics, with the aim of characterizing irreversibility and flux fluctuations in multiscale systems.

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