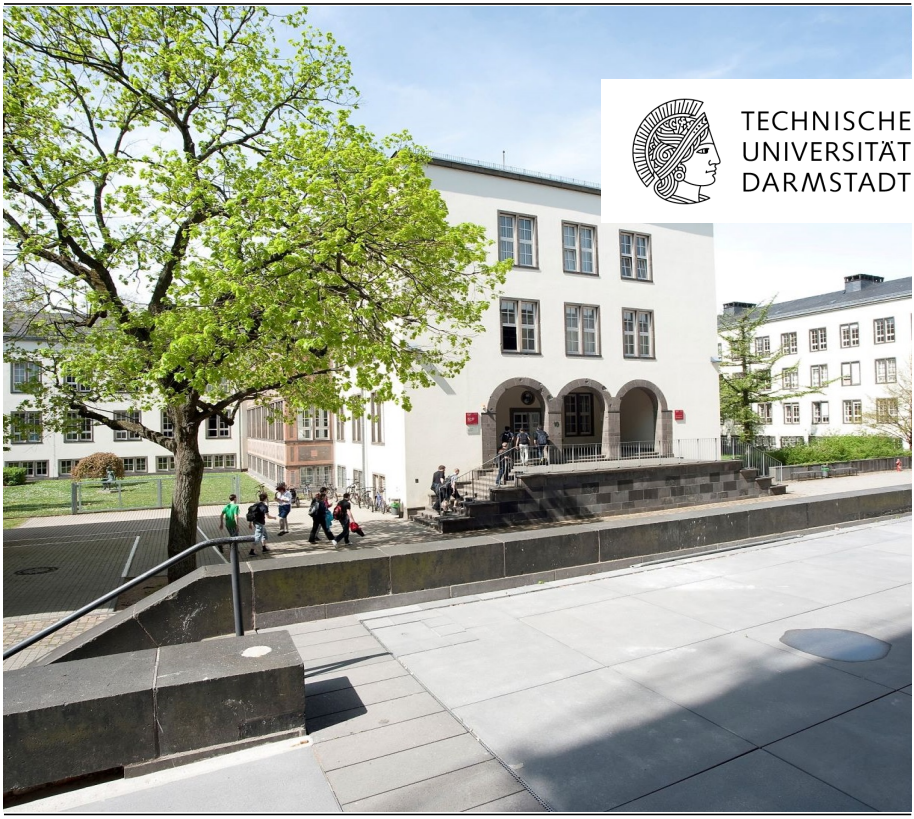
Extrema of logarithmically correlated random fields and applications

Spring school, March 24–28, 2025, TU Darmstadt

Mini Courses:
Marek Biskup
Oren Louidor

Invited Speakers:
Lisa Hartung
Pierre-François Rodriguez
Tianqi Wu

Organization:
Frank Aurzada
Volker Betz
Matthias Meiners



Contents

1 General Information

1.1 Registration

On Monday morning, starting from 8:00, registration is possible in the lobby of the lecture hall.

1.2 Lecture Hall

Location: Technische Universität Darmstadt. The registration and all lectures will take place in building S2|04, Hochschulstraße 8, 64289 Darmstadt in lecture hall S2|04 213. In the lecture hall, there are 2 large blackboards and 2 small blackboards and a projector.

1.3 Map & Points of Interest

The map can be found on the back cover.

1.4 Public Transportation

The closest bus and tram stops to the venue of the workshop are **Schloss** (trams: S2, S3, S9) and **Willy-Brandt-Platz** (trams: S4, S5, S6, S7, S8). Both stops are within 10 minutes walking distance to the lecture hall.

1.5 Food & Beverage

There are lots of good restaurants and bistros near TU Darmstadt. Please dial +49 6151 preceding the number given below.

Name	**Address**	**Phone**	**Cuisine**	**Opening**
Ratskeller	Marktplatz 8	26444	German	10:00 - 01:00
Pizzeria da Nino	Alexanderstr. 29	24220	Italian	18:00 - 23:00
Haroun's	Friedensplatz 6	23487	Oriental	11:00 - 22:30
Wellnitz	Lauteschlägerstr. 4	6699255	Bistro	12:00 - 24:00
Cafe Extrablatt	Marktplatz 11	5998820	Bistro	08:30 - 23:30
Ristorante Sardegna	Kahlertstraße 1	23029	Italian	11:30 - 14:45
Schwarz-Weiß-Cafe	Robert-Schneider-Str. 23	79417	Bistro	07:00 - 19:00
Schuhknecht	Schuhknechtstr. 1	4920255	Bistro	09:30 - 20:00

1.6 Conference Dinner

On Tuesday, March 25, 2025, there will be a conference dinner at the Restaurant *3-klang*, Riegerplatz 3, 64289 Darmstadt, Tel: +49-6151-6698843, kontakt@3klang-bar.de

1.7 Free Afternoon

On Wednesday, March 26, 2025, there will be a free afternoon.

Acknowledgements

Financial support by DFG Priority Programme SPP 2265: Random geometric systems and the Department of Mathematics at Technische Universität Darmstadt is acknowledged.

TECHNISCHE UNIVERSITÄT DARMSTADT

Fachbereich **Mathematik**

SPP2265 Random Geometric Systems

Time	Monday	Tuesday	Wednesday	Thursday	Friday
08:00	Registration				
09:00	Biskup	Louidor	Biskup	Louidor	Biskup
10:30	*Coffee break*	*Coffee break*	*Coffee break*	*Coffee break*	*Coffee break*
11:00	Louidor	Biskup	Louidor	Biskup	Louidor
12:30	*Lunch*	*Lunch*	*Lunch*	*Lunch*	*Lunch*
14:00	Invited talk: Wu	Invited talk: Hartung		Invited talk: Rodriguez	*End of* *Spring school*
15:00	*Coffee break*	*Coffee break*		*Coffee break*	
15:30	Exercise session Fels	Exercise session Fels		Exercise session Fels	
17:00	Short talks: Piesold Schickentanz Campailla Campos Schmidt Bäumler Kraft	Short talks: Günther Gros Schröder Wagner Klippel Alban	*Free* *Afternoon*	Short talks: Wachtel Stonner Schweiger Yujin Helmer Hanigk	
18:30	Reception	Dinner			

Monday, 24 March 2025

Time	Speaker	*Title of Talk*
09:00-09:05	Welcome	
09:05-10:35	Marek Biskup	*Mini course* *Extrema of logarithmically correlated random fields and applications*
10:35-11:00		–Coffee break–
11:00-12:30	Oren Louidor	*Mini course* *Extrema of logarithmically correlated random fields and applications*
12:30-14:00		–Lunch break–
14:00-15:00	Tianqi Wu	*Invited talk* *Growth of the extremal and cluster-level sets in branching Brownian motion*
15:00-15:30		–Coffee break–
15:30-17:00	Maximilian Fels	*Exercise session*
17:00-17:10	Janine Piesold	Short talk
17:10-17:20	Dominic T. Schickentanz	Short talk
17:20-17:30	Concetta Campailla	Short talk
17:30-17:40	Alberto M. Campos	Short talk
17:40-17:50	Tobias Schmidt	Short talk
17:50-18:00	Johannes Bäumler	Short talk
18:00-18:10	Mino N. Kraft	Short talk
18:30-23:00	Reception	–Cheese & Wine–

Tuesday, 25 March 2025

Time	Speaker	*Title of Talk*
09:00-10:30	Oren Loudior	*Mini course* *Extrema of logarithmically correlated random fields and applications*
10:30-11:00		–Coffee break–
11:00-12:30	Marek Biskup	*Mini course* *Extrema of logarithmically correlated random fields and applications*
12:30-14:00		–Lunch break–
14:00-15:00	Lisa Hartung	*Invited talk* *F-KPP equations, Feynman-Kac formulas, and branching Brownian motion*
15:00-15:30		–Coffee break–
15:30-17:00	Maximilian Fels	*Exercise session*
17:00-17:10	Boris Günther	Short talk
17:10-17:20	Annabell Gros	Short talk
17:20-17:30	Lars Schröder	Short talk
17:30-17:40	Maren Wagner	Short talk
17:40-17:50	Andreas Klippel	Short talk
17:50-18:00	Alexander Alban	Short talk
18:30-22:00	Conference Dinner	– 3klang, Riegerplatz 3 –

Wednesday, 26 March 2025

Time	Speaker	*Title of Talk*
09:00-10:30	Marek Biskup	*Mini course* *Extrema of logarithmically correlated random fields and applications*
10:30-11:00		–Coffee break–
11:00-12:30	Oren Louidor	*Mini course* *Extrema of logarithmically correlated random fields and applications*
12:30-14:00		–Lunch break–
		–Free afternoon –

Thursday, 27 March 2025

Time	Speaker	*Title of Talk*
09:00-10:30	Oren Louidor	*Mini course* *Extrema of logarithmically correlated random fields and applications*
10:30-11:00		–Coffee break–
11:00-12:30	Marek Biskup	*Mini course* *Extrema of logarithmically correlated random fields and applications*
12:30-14:00		–Lunch break–
14:00-15:00	Pierre-François Rodriguez	*Invited talk* *Strongly correlated fields and universality*
15:00-15:30		–Coffee break–
15:30-17:00	Maximilian Fels	*Exercise session*
17:00-17:10	Arthur Wachtel	Short talk
17:10-17:20	Jakob Stonner	Short talk
17:20-17:30	Florian Schweiger	Short talk
17:30-17:40	Kim Yujin	Short talk
17:40-17:50	Max Helmer	Short talk
17:50-18:00	Pascal Hanigh	Short talk

Friday, 28 March 2025

Time	Speaker	*Title of Talk*
09:00-10:30	Marek Biskup	*Mini course* *Extrema of logarithmically correlated random fields and applications*
10:30-11:00		–Coffee break–
11:00-12:30	Oren Louidor	*Mini course* *Extrema of logarithmically correlated random fields and applications*
12:30-14:30		–Lunch, end of the Spring School–

2 List of Talks

2.1 Mini Courses

Marek Biskup
UCLA, USA
Mini course: Extrema of logarithmically correlated random fields and applications

The courses will survey recent developments in the theory of extreme values of logarithmically correlated fields, focusing on key examples such as branching random walks, the two-dimensional Gaussian Free Field, the local times of planar random motions and, time permitting, random interface models. The lectures will give a fairly self-contained introduction to the subject, including statements of the main results, and then proceed to develop the specific tools and techniques needed in the proofs. The two courses will be closely coordinated.

Oren Louidor
Technion Haifa, Israel
Mini course: Extrema of logarithmically correlated random fields and applications

We will survey recent developments in the theory of extreme values of logarithmically correlated fields, including key examples such as the 2D Gaussian Free Field, branching diffusions, and the local times of planar random motions. We will examine the key results, tools and techniques of the theory along with its applications to the analysis of extremal properties of random walks and random interfaces. Our lectures will be coordinated to provide a fairly self-contained introduction to the subject.

2.2 Invited Speakers

Lisa Hartung
F-KPP equations, Feynman-Kac formulas, and branching Brownian motion
JGU Mainz, Germany

In this talk, I will explain how Feynman-Kac formulas can be used to solve Fisher-Kolmogorov-Petrovsky-Pikunov equations (F-KPP). Maury Bramson first used this approach in his seminal paper on the F-KPP equation about 50 years ago. We will revisit his approach and then also apply this technique to systems of F-KPP equations. Moreover, I will explain the duality between (certain) F-KPP equations and spatial branching processes (such as branching Brownian motion).

Pierre-François Rodriguez
Strongly correlated fields and universality
Imperial College London, United Kingdom

The talk will survey recent developments in the mathematical study of critical phenomena. The focus will be on the critical and near-critical behaviour of certain percolation models in dimensions larger than 2. These models are built using very natural probabilistic objects, such as random walks and the Gaussian free field. One specific model exhibits a degree of integrability and allows the rigorous derivation of various associated critical exponents, for instance in dimension 3. Their values are functions of the underlying dimension and the exponent governing the polynomial decay of correlations alone. They rigorously confirm heuristics from scaling theory below the upper-critical dimension.

Tianqi Wu
Growth of the extremal and cluster-level sets in branching Brownian motion
Technion Haifa, Israel

Branching Brownian motion (BBM) is a classical probabilistic model that has "log-correlated" behavior. Its limiting extremal process has been derived to be that of a randomly shifted clustered Poisson point process with an exponential intensity (Aidekon-Berestycki-Brunet-Shi; Arguin-Bovier-Kistler). In this talk, I will discuss some recent results on the asymptotic growth of upper-level sets $[-v, \infty)$ for the limiting extremal process and the cluster process. For the extremal process E, we show that $E([-v, \infty))$ grows like $C * Z v e^{\sqrt{2}v}$ almost surely, with random fluctuations of order $e^{\sqrt{2}v}$ coming from from clusters in an $o(v)$ window around $-\log(v)\sqrt{2}$ and governed by a 1-stable law in the limit. For the cluster process C, we show that the logarithm of $C([-v, \infty))$ grows like $\sqrt{2}v$ minus

random fluctuations of order $v^{\frac{2}{3}}$ governed by an explicit law in the limit. The first result improves the work of Cortines et al. in which asymptotics are shown in probability, and makes probabilistic sense of the work of Mytnik et al. in which the asymptotics and 1-stable law are derived by PDE methods, while the second result makes rigorous the derivation in the physics literature by Mueller et al. and Le et al. and resolves a conjecture thereof. Based on joint work with Lisa Hartung and Oren Louidor.

2.3 Contributed talks

Alexander Alban
The Hamilton-Jacobi approach for the free energy of the CREM
JGU Mainz, Germany

The Hamilton-Jacobi approach compares the limiting free energy of mean field spin glass models to the viscosity solution of a Hamilton-Jacobi equation (HJE). This talk deals with the case of the continuous random energy model (CREM) with a convex speed function, which describes the time-inhomogeneous variance. We establish a HJE on an infinite-dimensional space and prove that a unique viscosity solution exists, which is characterised by a variational formula. Also, we give an explicit description of the so-called initial condition of that HJE, which allows to simplify the variational formula of the viscosity solution. The limiting free energy of the CREM with a convex speed function is equal to the aforementioned viscosity solution. This is based on joint work-in-progress with Fu-Hsuan Ho and Justin Ko.

Johannes Bäumler
The truncation problem for long-range percolation
Deparment of Mathematics UCLA, USA

In long-range percolation on the integer lattice, for each pair of points $\{x, y\}$, there is an open edge between these points with probability depending on the Euclidean distance between the points, independent of all other edges. When are the long edges necessary for the existence of an infinite cluster? The truncation problem asks whether one can remove all long enough edges while still retaining an infinite open cluster. I will present the truncation-problem with non-summable regime in dimension $d = 2$.

Concetta Campailla
The critical density of the Stochastic Sandpile model
La Sapienza University, Italy

The Stochastic Sandpile model is an interacting particle system introduced in the physics literature in the '90s to study the phenomenon of self-organized criticality. This model undergoes a phase transition when the initial particle density exceeds a critical threshold, raising important questions about this critical density. In this talk, I will present this model and the results I have obtained in answering some of these questions.

Alberto M. Campos
Covering Distributions
Universität Augsburg, Germany

An introduction to the covering process of the discrete one-dimensional torus using connected arcs of random sizes. Given a distribution μ on $\mathbb{N}$, the torus $\mathbb{Z}/n\mathbb{Z}$ is covered as follows: at each time step, an arc with a length distributed according to μ is placed at a uniformly chosen starting point. Over time, the entire space becomes covered by these arcs. Variations in the arc length distribution μ can influence the limiting behavior of the covering time. Four distinct phases for the fluctuations of the covering time in the limit are identified, referred to as the Gumbel phase, the compactly supported phase, the pre-exponential phase, and the exponential phase. Additionally, a continuous-time covering process is introduced, which acts as a limiting distribution within the compactly supported phase.

Annabell Gros
Microscopic analysis of branching Brownian motion with decreasing velocities
Universität Bonn, Germany

The extremes of variable speed branching Brownian motion (BBM) exhibit a phase transition when the "speed function", which describes the time-inhomogeneous variance, is the identity function. In this talk we study this transition more closely by choosing piecewise linear, concave speed functions converging to the identity function from above. We show that the logarithmic correction of the order of the maximum interpolates smoothly between the correction of standard BBM, $\frac{3}{2\sqrt{2}}\log(t)$, and the correction for BBM with piecewise linear speed functions. Based on joint work with Alexander Alban (JGU Mainz), Anton Bovier (University Bonn) and Lisa Hartung (JGU Mainz).

Boris Günther
Fourier-Laplace Functional of Affine Non-Markovian Processes
JLU Gießen, Germany

Affine processes provide a powerful framework in stochastic modeling and finance because their conditional Fourier-Laplace functional admits an exponential-affine form that reflects the underlying Markovian SDE structure. However, recent evidence suggests that volatility is rough, giving rise to models that are neither semimartingales nor Markov processes. In this talk, we will take a look at recent results, showing that an exponential-affine form can still emerge in these rough settings, and outline how these insights can be used for path-dependent affine processes.

Pascal Hanigk
Branching Brownian Motion with space-heterogeneous branching rates
JGU Mainz, Germany

In this talk we consider Branching Brownian Motion with increased branching rate to the right of zero and discuss its impact on the minimal particle position.

Max Helmer
Persistence probabilities of spherical fractional Brownian motion
TU Darmstadt, Germany

We consider spherical fractional Brownian motion $(S_H(\eta))_{\eta\in\mathbb{S}_{d-1}}$, which is obtained by taking fractional Brownian motion indexed by the (multi-dimensional) sphere $\mathbb{S}_{d-1}$, and calculate its persistence exponent. Persistence in this context is the study of the decay of the probability

$$\mathbb{P}\left(\sup_{\eta\in\mathbb{S}_{d-1}} S_H(\eta) \le \varepsilon\right)$$

when the barrier $\varepsilon \searrow 0$ becomes more and more restrictive. Our main result shows that the persistence probability of spherical fractional Brownian motion has the same order of polynomial decay as its Euclidean counterpart.

Andreas Klippel
Strict Inequalities: Loops vs. Percolation
TU Darmstadt, Germany

In recent years, many models in mathematical physics have been encoded into graphical models, which are more accessible through the lens of probability theory. These graphical models often exhibit a natural percolation structure. One such model is the Random Loop Model introduced by Daniel Ueltschi. Peter Mühlbacher showed that the loop threshold for the Random Loop Model with $\theta = 1$ is larger than the percolation threshold. This is due to so-called blocking events in graphs with uniformly bounded degree. The proof primarily relies on a coupling method. In my talk, I will introduce the model and the basic proof techniques. Furthermore, I will discuss a recent result where we generalize the method to obtain new results for trees. I will explain why the tree case differs from the case of a general graph. If time permits, I will use the Galton-Watson case to illustrate how the coupling in the proof works. This talk is based on joint work with B. Lees and C. Mönch.

Mino Nicola Kraft
Phase transitions in the continuum long range Ising model
TU Darmstadt, Germany

In this talk, I will introduce a continuum version of the long-range Ising model, motivated by its application to the Spin-Boson model, where it implies a phase transition for the existence of ground states. The long-range Ising model has been extensively studied in the discrete setting its own right and already has shown its use to derive results for the Spin-Boson model in a related framework. I will provide a brief introduction to the model and an overview of key related results. Finally, I will outline how we extended these results to our continuum setting. If time permits, I will also discuss potential directions for future work.

Janine Piesold
On a Branching Annihilating Random Walk
JGU Mainz, Germany

We consider a discrete-time branching annihilating random walk (BARW) on $\mathbb{Z}^d$. Within a time step, each particle, before dying, produces a random number of offspring which are then randomly and independently displaced in space. If, after the displacement, a site is occupied by several particles, all particles at that site are annihilated. This can be thought of as a very strong form of local competition and entails that the system is not monotone. We are now interested in the long-term behaviour of this system. For a Poissonian number of offspring and a uniform displacement within a ball of finite radius around the parent's position, it was shown by Birkner et al. (2024) that the process survives for certain ranges of the parameters of the model and possesses, for an even more restricted parameter range, a non-trivial ergodic equilibrium to which, conditioned on survival, the process started in any non-trivial initial condition converges. We discuss extending these results to other offspring and offspring displacement distributions and possibly examine mixing properties of the non-trivial equilibrium distribution.

Dominic T. Schickentanz

Brownian Motion with Occupation Time Restrictions Outside a Compact Interval (Vol. II)

Universität Paderborn, Germany

We condition a Brownian motion on spending atypically little time outside a compact interval and characterize the resulting process in terms of an SDE. In particular, we encounter situations where the process almost surely does not leave the interval at all, discovering a very rare extreme example of entropic repulsion. Moreover, we explicitly determine the exact asymptotic behavior of associated conditioning probabilities on $[0, T]$, as $T \to \infty$. This is joint work with Martin Kolb (Paderborn), extending our project with Frank Aurzada (Darmstadt) presented last year.

Tobias Schmidt

Enhanced binding of a quantum particle coupled to a scalar quantized field

TU Darmstadt, Germany

A quantum particle coupled to a quantised field behaves as if it were effectively heavier than its actual mass. Enhanced binding refers to the phenomenon that due to this effective mass of the particle, the system admits a ground state, unlike the uncoupled system. Feynman-Kac formulas allow for a probabilistic interpretation of the problem: one studies a pinned Brownian motion with a Gibbs-type reweighting. The reweighting incorporates two factors: a reward for paths that stay close to the origin and a reward for paths that look locally the same. The strength of the second reward is determined by a system parameter called the coupling strength. We are interested in the behaviour of the path at $t = 0$ (taking the pinning at $-T$ and T) for T large. Our main contribution is that for large enough coupling, these distributions do not vanish in a neighbourhood around 0. This can be interpreted as the particle localising, which implies the existence of a ground state in the quantum system. Joint work with Volker Betz and Mark Sellke.

Lars Schröder

Stationary distribution of node2vec random walks on household models

University of Twente, Netherlands

Node2vec random walks are tuneable random walks that come from the popular computer science algorithm node2vec which is used for feature learning on networks. The transition probabilities of the random walks depend on the previous visited node and on the triangles that contain the current and the previous node. Even though the algorithm is very popular in the field of computer science, mathematical properties of the random walks almost have not been explored. We will present results on the stationary distribution of these random walks on household models.

Florian Schweiger
Extrema of two-dimensional Ginzburg-Landau fields
Université de Genève, Switzerland

Ginzburg-Landau fields are a class of models from statistical mechanics that describe the behavior of interfaces. They are a generalization of the Gaussian free field, and in two dimensions they form natural examples of random fields that are logarithmically correlated, but not Gaussian. I will explain how one can nonetheless find the asymptotics of the maximum of these fields.

Jakob Stonner
Explosion of Crump-Mode-Jagers processes with critical immediate offspring
JLU Gießen, Germany

We study the phenomenon of explosion in general (Crump-Mode-Jagers) branching processes, which refers to the event where an infinite number of individuals are born in finite time. In a critical setting where the expected number of immediate offspring per individual is exactly 1, whether or not explosion occurs depends on the fine properties of the reproduction point process. We provide sufficient criteria for explosion in these CMJ processes and give an equivalent characterization of explosion in the case where the reproduction point process is Poissonian.

Arthur Wachtel
Fluctuations in the optimal matching problem
Universität Münster, Germany

The optimal matching problem is one of the classical random optimization problems and has received a lot of attention in the literature. In recent years, by reformulation the point clouds as point measures, the application of techniques from optimal transport have lead to new insights. In this talk we will present a fluctuation result for the displacement of the optimal coupling, namely the convergence to a curl-free Gaussian Free Field. We conclude with directions for future invesigation into quantitative results for this convergence and connections to the KMT coupling

Maren Wagner

Convergence of Nearly Unstable Hawkes Processes

JLU Gießen, Germany

Hawkes processes are self-exciting point processes, which are widely studied for their ability to model self-exciting phenomena. It is known that nearly unstable Hawkes processes with heavy-tailed kernels converge with suitable rescaling to the rough Heston model, a framework used to model stochastic volatility in financial markets. In this talk, I will give a brief introduction to Hawkes processes and their connection to rough volatility models.

H. Kim Yujin

Absolute continuity of non-Gaussian and Gaussian multiplicative chaos measures

New York University, USA

Gaussian multiplicative chaos (GMC) is a well-studied random measure appearing as a universal object in the study of Gaussian or approximately Gaussian log-correlated fields. On the other hand, no general framework exists for the study of multiplicative chaos associated to non-Gaussian log-correlated fields. In this talk, we examine a canonical model: the log-correlated random Fourier series, or random wave model, with i.i.d. random coefficients taken from a general class of distributions. The associated multiplicative chaos measure was shown to be non-degenerate when the inverse temperature is subcritical ($\gamma < \sqrt{2d}$) by Junnila. The resulting chaos is easily seen to not be a GMC in general, leaving open the question of what properties are shared between this non-Gaussian chaos and GMC. We answer this question through the lens of absolute continuity, showing that for inverse temperature outside the L^2-regime, there exists a coupling between this chaos and a GMC such that the two are almost surely mutually absolutely continuous. Notably, our coupling does not hold in the L^2-regime, where historically the situation has been nicer to handle.

3 List of Participants

Alban, Alexander JGU Mainz, Germany

Aurzada, Frank TU Darmstadt, Germany

Bäumler, Johannes UCLA, USA

Betz, Volker TU Darmstadt, Germany

Biskup, Marek UCLA, USA

Campailla, Concetta La Sapienza University, Italy

Campos, Alberto M. Universität Augsburg, Germany

Dalessi, Flavio University of Basel, Switzerland

Danković, Irina University of Cambridge, United Kingdom

Dremaux, Arthur University of Cambridge, United Kingdom

Fels, Maximilian Technion Haifa, Israel

Franck, Sascha Universität zu Lübeck, Germany

Gros, Annabell Universität Bonn, Germany

Günther, Boris JLU Gießen, Germany

Hammami, Mohamed Ali Faculty of Sciences of Sfax, Tunisia

Hartung, Lisa JGU Mainz, Germany

Hanigk, Pascal JGU Mainz, Germany

Helmer, Max TU Darmstadt, Germany

Klippel, Andreas TU Darmstadt, Germany

Kolodziejska, Alicja JLU Gießen, Germany

Kraft, Mino Nicola TU Darmstadt, Germany

Kriechbaum, Xaver Weizmann Institute of Science, Rehovot, Israel

Louidor, Oren Technion Haifa, Israel

Meiners, Matthias JLU Gießen, Germany

Müller, Sabine TU Darmstadt, Germany

Mönch, Christian JGU Mainz, Germany

Ott, Tobin JGU Mainz, Germany

Piesold, Janine JGU Mainz, Germany

Rodriguez, Pierre–François Imperial College London, United Kingdom

Schickentanz, Dominic T. Universität Paderborn, Germany

Schmidt, Tobias TU Darmstadt, Germany

Schröder, Lars University of Twente, Netherlands

Schweiger, Florian Université de Genève, Switzerland

Stonner, Jakob JLU Gießen, Germany

Wachtel, Arthur Universität Münster, Germany

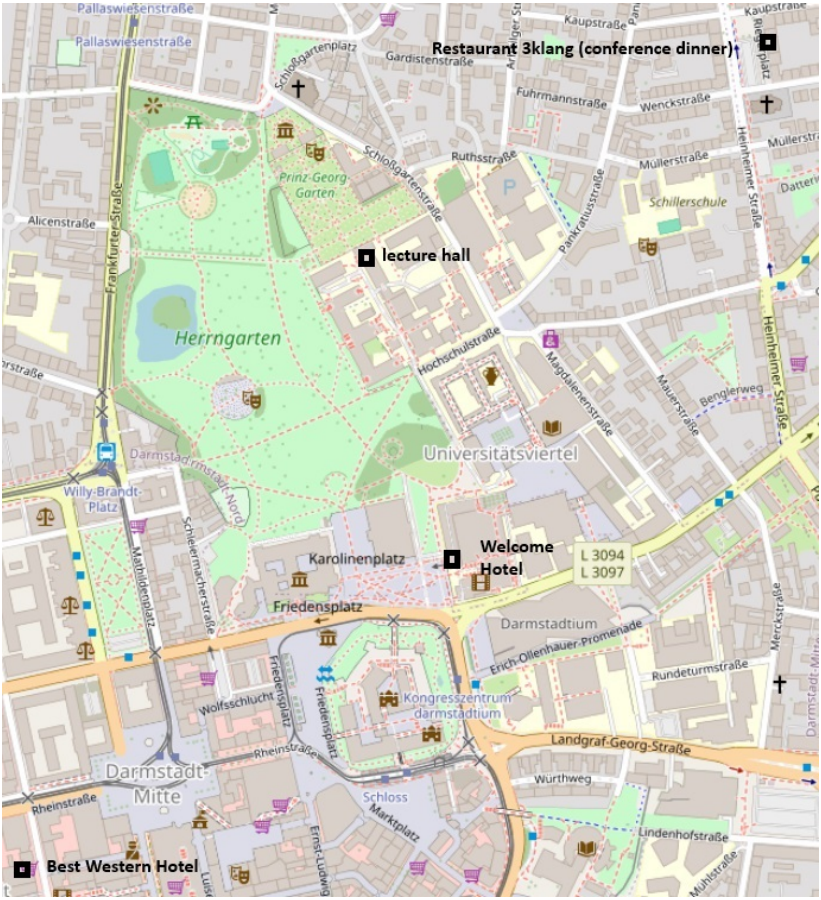
Wagner, Maren JLU Gießen, Germany

Worf, Virginia TU Darmstadt, Germany

Wu, Tianqi Technion Haifa, Israel

Yujin, H. Kim New York University, USA

Zouboulоglou, Pavlos Universität Münster, Germany


Restaurant 3klang (conference dinner)
lecture hall
Welcome Hotel
Best Western Hotel
Herrngarten
Prinz-Georg-Garten
Universitätsviertel
Darmstadtium
Kongresszentrum darmstadtium
Darmstadt-Mitte
Schloss
Pallaswiesenstraße
Schloßgartenplatz
Gardistenstraße
Kaupstraße
Fuhrmannstraße
Wenckstraße
Ruthsstraße
Müllerstraße
Schillerschule
Heinheimer Straße
Alicenstraße
Frankfurter Straße
Schloßgartenstraße
Pankratiusstraße
Hochschulstraße
Magdalenenstraße
Mauerstraße
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Karolinenplatz
Friedensplatz
Schleiermacherstraße
Mathildenplatz
Erich-Ollenhauer-Promenade
Rundeturmstraße
Wolfsschlucht
Friedensplatz
Rheinstraße
Landgraf-Georg-Straße
Würthweg
Lindenhofstraße
Marktplatz
Ernst-Ludwig
L 3094
L 3097