1 Curriculum-Vitae (brief CV)

Name: Satya Narayan Majumdar

Work Address:

Laboratoire de Physique Théorique et Modèles Statistiques (LPTMS),
Université Paris-Saclay, UMR 8626 du CNRS,
Bât. 530, 91405 Orsay cedex, France
Tel: 01-69-15-64-65
Email: satyanarayan.majumdar@cnrs.fr

Date of Birth: 01-01-1966

Education:

08/87 – 09/92	**Tata Institute of Fundamental Research** Ph.D. in Physics, September 1992. Thesis: Self-organized Criticality in Sandpiles and Driven Diffusive Lattice Gases. *Advisor:* Prof. Deepak Dhar, Tata Institute, Bombay, India.	**Bombay, India**
09/85 – 07/87	**University of Calcutta** M.Sc in Physics, 1987 (ranked 1st among approx. 200)	**Calcutta, India**
09/81 – 08/85	**Presidency College** B.Sc in Physics, University of Calcutta, 1985 (ranked 1st among approx. 2500)	**Calcutta, India**

Employment:

10/21 – present: Directeur de Recherche classe exceptionelle (DRCE) [highest acedemic rank in CNRS] at **Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris-Sud, Orsay, France**.

10/11 – present: Directeur de Recherche (DR1) at **Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris-Sud, Orsay, France**.

09/03 – 09/11: Directeur de Recherche (DR2) at **Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris-Sud, Orsay, France**.

01/00 – 09/03:	Chargé de Recherche (CR1) at **Laboratoire de Physique Théorique, IRSAMC, Université Paul Sabatier, Toulouse, France**.
11/96 – 12/99	Reader at **Tata Institute of Fundamental Research, Bombay, India**.
10/94 – 10/96	Post Doctoral Associate at **Yale University, USA**.
10/92 – 09/94	Post Doctoral fellow at **AT&T Bell Labs, USA**.
08/87 – 09/92	Thesis student and Research Assistant at **Tata Institute of Fundamental Research, Bombay, India.**

Honors and Awards:

1. **Gay-Lussac Humboldt** prize (awarded by Alexander von Humboldt foundation, 2019).

2. **EPS** prize for Statistical and Nonlinear Physics (2019) .

3. **CNRS** silver medal (medaille d'argent) (2019).

4. **VAJRA** fellowship (Visiting Adjoint Research Associate) awarded by the ministry of Science and Technology (Govt. of India) in 2018.

5. **Plenary** speaker at STATPHYS-25 (Seoul, South Korea, 2013).

6. **Plenary** speaker at 'Extreme Value Analysis' (EVA 2011) (Lyon, France, 2011).

7. **'Prime d'excellence Scientifique'** (PES) (2009-2012, 2013-2016, 2017-2020, 2021-2024, 2025–) awarded by CNRS.

8. **'Excellence Award'** (2009) for outstanding contributions to statistical physics, awarded by the Tata Institute Alumni Association.

9. **Paul Langevin Medal** for theoretical physics (2005) awarded by the French physical society.

10. **Young Scientist Medal** awarded by the Indian National Science Academy, 1998.

11. **Geeta Udgaonkar Award**, 1992 for outstanding Ph. D thesis in the school of Physics (Tata Institute, Bombay, India).

12. **Calcutta University Gold Medal** for securing first position in M.Sc (Calcutta University, India, 1987).

Editor of Journals:

• Divisional Associate Editor (DAE) of Phys. Rev. Lett. (Jan. 2011-Dec. 2013).

• Associate editor of the Journal of Statistical Physics (since 2011). Previously, member of the editorial board of Journal of Statistical Physics (2008-2010).

• Editor in Chief of J. Phys. A: Math. Theor. (since 2025). Previously, I was a member of the executive board of J. Phys. A: Math. Theor. (2020-2024), the chief Section editor (Statistical Physics) (2019-2020), member of the editorial board (2010-2018).

• Member of the editorial board of Journal of Statistical Mechanics: Theory and Experiment (since 2003).

• Editorial board member of "Lecture Notes in Physics" (Springer) (2023–).

Honorary Positions:

• Adjunct Professor at Tata Institute, Bombay (India) since 2005.

• Adjunct Weston Professor at the Weizmann Institute, Rehovot (Israel) since 2011.

• Adjunct Professor at the International Center for Theoretical Sciences (ICTS), Bangalore, (India) since 2011.

• Associate at the Higgs Center, the University of Edinburgh (UK) since 2012.

• Adjunct Professor at the Raman Research Institute (RRI), Bangalore, (India) since 2015. Also VAJRA fellow at RRI (2019-2025).

• Visiting Simon chair at the International Center for Theoretical Sciences (ICTS), Bangalore, (India) during September-October, 2017.

Publications and Invited Talks:

• **408** publications in reviewed journals (including **74** PRL's, 1 Science, 1 PNAS, 1 Adv. in Phys.), 4 conference proceedings and 9 invited reviews/book chapters. I have also wriiten a book: S.N. Majumdar and G. Schehr,*Statistics of extremes and records in random sequences* (Oxford University Press) (2024).

Total number of citations: 28200 (source: Google Scholar (GS) dated 15/08/2026) with an h-index: 86 *(GS).*

• **200** invited talks in international conferences/workshops/summer schools since (1996).

The full list of publications (along with their PDF's) and the list of invited talks can be found in my homepage:

https://www.lptms.universite-paris-saclay.fr/satya-majumdar/publications-and-invited-talks/

Named Lectures:

(i) M. L. Mehta memorial lecture (February, 2011) at the Tata Institute of Fundamental Research, Bombay, India.

(ii) Subhramanyam Chandrasekhar lectures (January, 2012) at the International Center for Theoretical Sciences (ICTS), Bangalore, India.

(iii) Higgs colloquium at the Higgs Center, the University of Edinburgh (UK) (May, 2013).

(iv) K. Lakshmanan memorial distinguished lecture at CMI (Chennai mathematical Insitute, Chennai) (India) (January, 2017).

(v) J. Mahanty memorial lecture at the Indian Institute of Technology (IIT) (Kanpur) (India) (October, 2017).

(vi) P. S. Narayanan memorial lecture at the Indian Institute of Science (IISC) (Bangalore) (India) (December, 2019).

(vii) Infosys-Chandrasekhar colloquiuum at the Tata Insititute of Fundamental Research (Bombay) (India) (March, 2021).

(viii) S. Pancharatnam memorial lecture at Raman Research Institute (Bangalore) (India) (April, 2024).

(ix) Boltzmann lecture on "Stochastic Resetting" at SISSA (Trieste, Italy) (February, 2025).

Supervision of students and postdocs:

2 current Ph.D students, 17 (completed) Ph.D students (direction and co-direction), 16 M.Sc students and 8 postdocs.

Referee of Journals and Grants:

Since 1992, papers were regularly reviewed for several international journals including Physical Review Letters, Physical Reviews (A, B and E), Nature Physics, Europhysics Letters, Journal of Physics-A, Journal of Statistical Physics, Journal of Statistical Mechanics, Physica-A, IEEE transactions in Information Theory etc. The grant proposals for the Agence National de Research (ANR, France), National Science Foundation (NSF, USA) and the Israel Science Foundation (ISF, Israel) were also reviewed.

Recognized as a 'distinguished referee' by the EPL (Europhysics Letters) (2010).

Administrative Responsibilities:

I have been a member of various scientific commissions in and outside France. These include the following:

• Member of the commission de spécialistes (section 29) at the Université Paul Sabatier, Toulouse, France (2004-2009).

• Member of the 'Comité d'évaluation' of the Laboratoire de Physique Théorique (LPTENS) at Ecole Normale Superieure, January (2005).

• Member of the 'Conseil de laboratoire LPTMS' since November, 2005.

• Member of the 'Comité d'évaluation' (AERES) of the Laboratoire de Physique Théorique (LPTENS) at Ecole Normale Superieure, January (2009).

• Member of the 'Appointments Committee' and 'Management Board' of the International Center for Theoretical Studies (ICTS) at Bangalore, India, since 2011.

• Member of the comite de selection (section 29) (concours de recrutement MCF) at the Universite' Aix Marseille, April, 2012.

• Member of the comite de selection (section 29) (concours de recrutment Prof.) at the Universite' de Cergy-Pontoise, April, 2014.

• Member of the evaluation committee for IRMP (Institut de Recherche en Mathematique et Physique, Université catholique de Louvain, Belgium), March, 2018. I am also a member of the scientific advisory board of IRMP since 2018.

• Member of the advisory board of "Fundamental Problems in Statistical Physics" (FPSP) since 2015.

• Member of the International Advisory Board of Statphys 28 (Tokyo, 2023).

• Member of the International Advisory Board of Statphys 29 (Florence, 2025).

Research Topics :

My research interests cover various problems in equilibrium and nonequilibrium statistical physics with applications ranging from granular medium to computer science and biology. My basic interests and expertise are on stochastic processes with its diverse interdisciplinary applications. Some of my present and past research interests are listed below.

• *Extreme Value Statistics of Strongly Correlated Variables.*

• *Stochastic Resetting in Classical and Quantum Systems.*

• *Dynamics of Active Particles.*

• *Random Matrix Theory and its Diverse Applications.*

• *Large Deviation Techniques and Applications.*

• *Applications of Statistical Physics in Computer Science: Sorting and Search Algorithms.*

• *Persistence and first-passage properties in Nonequilibrium Systems:* Spin Models, Diffusion and Random Walks, Random Search problems, Non-Markov Processes etc.

• *Stress Propagation and Compaction in Granular Medium.*

• *Real-space Condensation in Nonequilibrium Steady-States:* Aggregation and fragmentation processes, Zero-range processes, Random Average processes etc.

• *Quantum Phase Transitions in Disordered Spin Chains.*

• *Coarsening and Phase Ordering Dynamics in Spin Systems.*

• *Transport Properties of Vortices in High-T_c Superconductors.*

• *Interacting Particle Systems:* Symmetric and Asymmetric Exclusion Processes, Vicious random walkers, Trapping problems etc.

• *Polymers and Self-Avoiding Walks.*

• *Self-organized Criticality in Sandpile Models* (Ph.D Thesis, 1992 under the supervision of Prof. D. Dhar at the Tata Institute of Fundamental Research (Mumbai, India)).

2 Evolution of research

This section partially summarizes how my research evolved in time with highlights on some of my principal scientific contributions.

I did my Ph.D thesis (1992) titled 'Self-organized Criticality in Sandpiles and Driven Diffusive Lattice Gases' under the supervision of Prof. Deepak Dhar at the Tata Institute of Fundamental Research, Bombay, India. When I started my thesis, self-organized criticality (SOC) was a relatively new field that started with the seminal paper by P. Bak, C. Tang and K. Wiesenfeld (BTW), published in 1987. The main idea behind the subject was that several interacting many-body systems evolve under their natural dynamics to a stationary state where measurable observables, such as two-point correlation functions, exhibit power-law decay. These power-law behaviors are considered as the signatures of 'criticality' and this critical state is reached without the fine tuning of any external parameter such as temperature (as is common in traditional liquid-gas or magnetic systems undergoing phase transitions). The latter fact justifies the name 'self-organized'. There are many examples of such SOC systems such as the granular systems including sandpiles and ricepiles and several reaction-diffusion systems amongst others. This area had been and is still an active area of research in statistical physics. Prior to my thesis, most of the existing work in this area were numerical in nature, except the seminal work by my advisor D. Dhar who discovered an abelian property of a particular class of sandpile models, now known as abelian sandpile models. In collaboration with my advisor D. Dhar, I used this abelian property in deriving analytically several properties of sandpile models for the first time and I believe that this work formed one of the cornerstones in understanding the mathematical mechanism behind SOC. Besides, we also established a connection between the abelian sandpile model (which is inherently non-equilibrium in nature) and the random spanning tree model in equilibrium statistical physics. This connection was particularly useful in 2-d where we could then use conformal field theory to understand the statistical properties of random spanning trees and hence those of the sandpile model. To my knowledge, this was the first time that conformal field theory was used to derive exact results for a nonequilibrium system.

Another offshoot of my Ph.D thesis was to prove, again using conformal field theory in 2-dimensions, that the fractal dimension of the loop-erased random walks (LERW) was exactly 5/4. This result was first conjectured by Gutmann and Bursill in the late 80's on the basis of numerical results. Loop-erased random walks became rather fashionable later as a concrete example belonging to the class of models evolving under the stochastic Loewner equation (SLE). To my knowledge, the result 5/4 was first proved in my paper [Phys. Rev. Lett., 68, 2329 (1992)], much before the later activities in SLE started.

Following my thesis, I did my first postdoctoral research (1992-1994) at AT&T Bell Labs which at that time was arguably one of the best laboratories in the world in condensed matter physics. While my Ph.D thesis had lots of mathematical components including many exact results, at Bell Labs I took the opportunity to work on rather different areas of condensed matter physics in realistic systems. These include the phase ordering dynamics in systems such as magnets and liquid crystals, transport properties in high-T_c superconductors, and also on the stress propagation in granular systems. At Bell Labs, I interacted with many theorists (most notably D. Huse), as well as with many experimentalists. I collaborated with the experimental group of D. Bishop and P. Gammel and studied the transport properties in high-T_c superconductors in the vortex liquid regime. Based on a simple model that D. Huse and myself introduced (Phys. Rev. Lett., 71, 2473 (1993)), we predicted that the resistivity in the vortex liquid regime is essentially non-local in nature and one needs to generalize the simple Ohm's law to take into account this non-local behavior. The analytical results based on our simple model were in good agreement with later experimenal results (Phys. Rev. Lett., 72, 1272 (1994)). I also collaborated with the experimental group of B. Yurke on the persistence properties and the phase ordering dynamics in liquid crystals. At the same time, I collaborated extensively with C. Sire (Toulouse), who was also a post-doc at Bell Labs at that time, on the phase ordering dynamics in nonequilibrium systems and related topics.

Let me just mention here one work on phase ordering dynamics. When a magnetic system is quenched rapidly from the high temperature disordered phase to its critical point, the correlation length $\xi(t) \sim t^{1/z}$ grows with time t as a power law, where z is the dynamical critical exponent. Also the spin-spin auto correlation function (say at site i), $A(t) = \langle s_i(0)s_i(t)\rangle$, decays with time as $A(t) \sim \xi(t)^{-\lambda_c}$ with a nontrivial nonequilibrium critical exponent λ_c. It was known that the exponent depends on the conservation laws satisfied by the dynamics. However, prior to our work, there was a lot of controversies surrounding the value of the exponent λ_c for the case of the conserved order parameter dynamics. In collaboration with D. Huse and B. Lubachevsky (Phys. Rev. Lett., 73, 182 (1994)), we showed that for the conserved case, and provided some technical conditions are satisfied, $\lambda_c = d$ (where d is the spatial dimension) is a universal exponent. This settled the existing controversies and our result was verified experimentally later. In collaboration with C. Sire, we were the first to derive analytically the nonequilibrium exponents associated with the phase ordering dynamics in the Potts model (Phys. Rev. Lett., 74, 4321 (1995)).

At the end of my first post-doc at Bell Labs, I wanted to return to India and I had a permanent job offer from Tata Institute, Bombay (India). However, I took a leave of absence for 2 years to continue my post-doctoral research in the US, mainly because I wanted to broaden my scientific horizon a bit more. So, I did a second postdoc (1995-1996) at Yale university in the group of S. Sachdev. At Yale also, I worked on a variety of condensed matter subjects. I had the opportunity there to work with two highly talented Ph.D students of S. Sachdev, namely K. Damle (now a faculty at Tata Institute, India) and T. Senthil (now a faculty at MIT, USA). At that time, new experiments on trapped cold atoms were begining to be carried out which later led to a revival of the old subject of Bose-Einstein condensation in dilute gases. In collaboration with K. Damle and S. Sachdev, we addressed the following natural question: Consider a 3-dimensional dilute Bose gas initially in thermal equilibrium at a high temperature so that the condensate density in the gas is zero. Then the gas is rapidly quenched to a temperature below its critical point following which it evolves in time freely, starting from the initial high-temperature configuration. Eventually, the gas will reach thermal equilibrium corresponding to the final temperature which is below the critical temperature, i.e., eventually there will be a nonzero condensate density. How does the condensate density grow with time? A naive classical analysis based on the dissipative nonconserved dynamics of a 3-d X-Y model predicts that the condensate density would grow as $t^{3/2}$ at late times. However, contrary to this naive expectation, we found that the condensate density grows much faster as t^3 [Phys. Rev. A, 54, 5037 (1996)]. This is due to an additional sound wave mode in the dilute Bose gas. In $d = 2$, our corresponding result also provided a new and faster mechanism for the annihilation of topological defects such as vortices in this system. We also worked on the thermodynamics of the Bose gas in presence of a harmonic trap and demonstrated how its critical properties get modified in the presence of a trap [Europhys. Lett. 36, 7 (1996)]. At Yale, I also worked with T. Senthil on disordered quantum spin chains. We were able to obtain exact results on disordered quantum Potts chain using a real space renormalization group scheme (Phys. Rev. Lett., 76, 3001 (1996)).

During my stay at Yale, I also collaborated with S.N. Coppersmith (now at the University of Southern Australia at Sydney), T. Witten (University of Chicago) amongst other theorists and also the experimental group of S. Nagel (Chicago) on the stress propagation in granular medium. In the experiment a weight was put on top of a granular pile and then the stress at different points at the bottom layer of the pile was measured. The distribution of the stress at the bottom layer suggested that the stress from the top to the bottom layer propagates along rather irregular paths. We constructed a simple model of this stress propagation (now called the "q-model" of force fluctuations in the literature) which explained this anomalous stress propagation. This model also has beautiful exact solutions. Our work (published in **Science**, 269, 513 (1995) and Phys. Rev. E, 53, 4673 (1996)) in this area remains the two pioneering papers in this field (with a total of > 1000 citations (google scholar dated 23/03/2026). **Our work was reviewed in the popular press article: "Clues About How a Sand Pile Holds Itself Up: Scientists Get 3-D View of Force Chains in Granular Materials" by S. Koppes (University of Chicago)**, see http://www-news.uchicago.edu/releases/95/950820.granular.forces.shtml

At around the same time, I also started my work on the subject of persistence in nonequilibrium systems, in collaboration with C. Sire and A. Bray (Manchester,UK), following my visit to Toulouse (Sept.-Nov. 1995) for 3 months. The field of persistence essentially started in France and became rather popular shortly. Over the last 25 years, there have been a lot of work in this area, amongst which many major contributions came from France. I believe that my collective work on persistence spanning over more than 15 years and carried out in collaboration with many theorists and experimentalists, have been one of the major contributions of my scientific career (with > 40 papers including > 12 PRL's and an extensive review in Advances in Physics, carrying more than 2000 citations dated 23/03/2026). Let me highlight the main problem briefly here.

Persistence is simply the fraction of points in space where a nonequilibrium field, fluctuating in space and time, has not changed sign upto some time t. In many nonequilibrium situations such as in systems undergoing coarsening after a rapid quench in temperature and even in the simple diffusion equation, the persistence decays with time t slowly as a power law $\sim t^{-\theta}$ for large t. This exponent θ is the simplest quantitative measure of the history dependence of the nonequilibrium process and is a new nonequilibrium exponent, not simply related to other dynamical exponents. Theoretical and experimental determination of θ has been the focus of intense research by a broad community of physicists in recent times. My collective contributions to the field of persistence have been considerable (more than 40 papers). To my knowledge, we were the first to make a connection between the persistence exponent and the late time decay of no barrier crossing probabilities in many stochastic Gaussian stationary processes. Thanks to this connection, it was realized that the reason this exponent θ is often nontrivial is due to the fact that the underlying Gaussian process in non-Markovian. Besides, this connection also led to many important new results in the field in addition to providing new analytical methods to calculate the persistence exponent [such as the independent interval approximation (Phys. Rev. Lett. , 77, 2867 (1996)), and a new perturbation theory around a Markov process (Phys. Rev. Lett., 77, 1420 (1996))]. Moreover, we showed that the persistence exponent associated with the no sign change of the global magnetization at the critical point is a new nonequilibrium critical exponent in the sense that it is not related to other critical exponents by a scaling relation (Phys. Rev. Lett., 77, 3704 (1996)).

Many of our results on persistence have been verified in diverse experiments. **Our work on persistence drew a lot of attention internationally and was reviewed in the research news section of Science [A. Watson, Science, 274, 919, (1996)]**. With A.J. Bray and G. Schehr, I have recently written an extensive review on the subject of persistence ["Persistence and first-passage properties in nonequilibrium systems", Adv. in Phys., 62, 225-361 (2013)]. As a theoretical physicist, I find this subject beautiful as it makes connections between the probability theory, statistical physics and realistic experimental systems. The subject of persistence remains one of my most favourite areas of research in which I continue to work. The subject of persistence has seen a recent revival among mathematicians.

Following my postdoc at Yale, I took up the permanent faculty position at Tata Institute (1997-1999) where I continued to work on persistence and related problems and also started my research in a different area, namely the aggregation and fragmentation phenomena and a class of mass transport models, in collaboration with M. Barma and the Ph.D students S. Krishnamurthy and R. Rajesh. To my knowledge, our paper (S.N. Majumdar, S. Krishnamurthy and M. Barma, Phys. Rev. Lett. 81, 3691 (1998)) was one of the first (along with a paper in the same year by O.J. O'loan, M.R. Evans and M.E. Cates, Phys. Rev. E 58, 1404 (1998)) to predict the existence of the phenomenon of **real-space** condensation. This phenomenon of real-space condensation is encountered in a variety of situations such as aggregation and fragmentation processes, granular clustering, phase separation, traffic and networks. Unlike traditional Bose-Einstein condensation in the **momentum space**, a condensate in these systems forms in **real space**, e.g., upon increasing the density beyond a critical value a macroscopically large mass/cluster may form at a single site on a lattice. This is a very popular subject currently and I have continued to work on this subject in collaboration with M.R. Evans (Edinburgh), R.K.P. Zia (Virginia Tech), M. Barma (Tata Institute) and others. We found the necessary and sufficient conditions for the occurrence of the real-space condensation in a class of generic mass transport models. Such models are generalizations of classical models such as Zero Range processes. In collaboration with E. Trizac (LPTMS), I. Pagonabarraga (University of Barcelona) and M.R. Evans, we have shown that this real-space condensation also happens in a fluid of polydisperse hard rods, a system that plays a central role in simulations of soft matters. In July 2008, I gave a set of lectures on this phenomenon of real-space condensation at Les Houches summer school "Exact Methods in Low-dimensional statistical physics and quantum computing". More recently, we have shown that this condensation phenomenon occurs in systems of active particles such as in the run-and-tumble models of bacteria, where in some parameter ranges, a single long run (condensate) dominates the trajectory of a bacteria.

In 2000, I joined CNRS at LPT (Toulouse). I chose to go to Toulouse since I had continued my collaborations with C. Sire there. In Toulouse, I played a role in forming the statistical physics group there which included, apart from myself, C. Sire, D.S. Dean, P-H. Chavanis and N. Destainville. We had extended visits by several people at Toulouse including A.J. Bray (Manchester) (with whom I had continued collaborations extending over more than 10 years) and P.L. Krapivsky (Boston).

While at Toulouse, in collaboration with Krapivsky and Dean, I started working in a new area namely the 'sorting and search' problems in computer science. This is a very active area of research in computer science, but physicists hardly worked in this area prior to us. To my knowledge, we were the first to realize that many problems in this area can be studied using the techniques of statistical physics. The basic problem in 'sorting and search' is simple and its solution has practical importance. When new data arrive in a computer, the computer sorts this data and arranges them using a suitable 'sorting' algorithm such that when one needs a particular data later, the computer spends minimum time in 'searching' it. The efficiency of a 'sorting and search' algorithm is quantified typically by its 'search time' t_{search}, i.e., the time needed to search a typical element from the already sorted data. Of course t_{search} depends on the data size N. If the data is organized in a linear fashion, i.e., they are put in an array in the same order as they arrive, then $t_{\text{search}} \sim O(N)$. This is clearly not very good. It turns out that one of the most efficient ways to organize the data is to arrange them on a binary tree. For these binary search trees, $t_{\text{search}} \sim c\log(N)$ for large N. It turns out that usually it is very difficult to find an algorithm whose search time will be faster than $\log(N)$. Hence, all one can hope for is to find algorithms which will minimize the coefficient c in front of the $\log(N)$. It is for this reason that the exact determination of the coefficient c for a given algorithm is rather important in computer science.

When the incoming data is completely random, the corresponding binary trees are generated randomly also, i.e., each tree has the same statistical weight. For such 'random binary search trees', the computer scientists have previously derived upper and lower bounds for the constant c. By mapping this problem onto a directed polymer problem, we have determined the constant c exactly as a root of a transcendental equation [Phys. Rev. Lett., 85, 5492 (2000)]. More importantly, we showed that the cumulative probability $P(t_{\text{search}} > x, N)$ for a given data size N has the form, $P(t_{\text{search}} > x, N) = f[x - c\log(N)]$ for large N. Thus if one interprets $\log(N)$ as a 'time' variable, this describes a 'traveling front' propagating with a velocity c. This observation has rather profound consequences. Physicists, over the years, had developed techniques for computing this velocity c of a traveling front in the context of various nonlinear reaction-diffusion systems (such as the Fisher-Kolmogorov-Petrovsky-Piskunov equation). We used some of these techniques from statistical physics in this computer science problem to determine the constant c exactly for random binary search trees. Moreover, this connection with 'traveling fronts' turns out to be more general and one can similarly study more generalized search trees and also for trees generated with unequal weights. This connection has thus enabled us to derive a host of exact analytical results for many computer science problems, some of which had remained unsolved for more than 20 years.

Since then, we have worked extensively in this area over the past few years (see section 7.8 for more details). Our work in this area have been recognized by the computer science community. In France, many computer scientists have worked in this area including P. Flajolet (INRIA), B. Chauvin and D. Gardy (Université de Versailles) amongst others. I have active interactions with B. Chauvin and D. Gardy. Over the past years, I have been invited to many of their conferences (for example, in 'Arbres Aléatoires et Algorithmes', Versailles, 2003, 'Analysis of Algorithms 2006' Alden Biesen (Belgium), 'Random Shapes' at UCLA, 2007 etc.). I have also given a set of invited lectures at two summer schools on the interface between physics and computer science, one in Beijing (2006) and one in Bremen (2007). The computer science community have followed up our work and have proved some of our exact 'physics' results via more rigorous mathematical methods.

Thus, in my opinion, I (along with my collaborators) have played an original role in establishing this new area of exciting research, bringing in a section of the physics and the computer science community together.

In 2004 February, I moved to LPTMS (Orsay). While I was at Toulouse, I already had started my collaborations at LPTMS with A. Comtet on a number of problems in disordered systems. So, it was rather easy for me to integrate into this new laboratory.

After moving to LPTMS I started a new area of research in which I am currently most active, namely the 'extreme value statistics of correlated variables'. This is a very general problem that appears in a number of areas ranging from disordered systems and random matrices to mesoscopic transport and computer science problems. Since these subjects cover the research interests of many people in LPTMS, it naturally led to several collaborations inside LPTMS (see later).

Let me briefly mention here the main interests in this extreme value problems. The statistics of the minimum or the maximum of a set of random variables is interesting in many systems and have many applications ranging from weather records, finance, earthquakes and oceanography. When the random variables are uncorrelated, it was known for a long time that the distribution of the maximum (say) (properly centered and scaled) follows one of the three universal laws, namely (i) the Gumbel (ii) the Frèchet and (iii) the Weibull. The question is what happens when the variables are strongly correlated? This is indeed the generic situation in many systems. For example, the height fluctuations in a random interface are strongly correlated. Similarly, the eigenvalues of a random matrix are also strongly correlated. For such strongly correlated systems, one can no longer apply the theory of uncorrelated variables and one needs new methods. There are very few exact results available for strongly correlated systems. In collaboration with A. Comtet (Phys. Rev. Lett., 92, 225501 (2004)), we computed exactly the distribution of maximal height fluctuations in a general class of one dimensional interfaces. Curiously, we found that the distribution function of the maximum height fluctuations in this class is universal and is the same as that of the area under a Brownian excursion and it is called the Airy-distribution function. It turns out that exactly the same function also appears in many problems in graph theory and computer science. To my knowledge, this is one of the first exact results for the extreme statistics in a strongly correlated system. Besides, our result showed for the first time that the Airy-distribution function, which so far appeared only in graph theory and computer science as a purely mathematical object, could possibly be measured in a real experimental system such as the fluctuating step edges in Si-Al surfaces.

Another correlated extreme value problem that I studied with D.S. Dean deals with the distribution of the largest eigenvalue of a random matrix. The problem is very simple to state and it arises in many areas of physics. 'Random landscapes' appear in many systems such as in glasses, spin glasses and even in string theory. Understanding the geometrical properties of such random landscapes have direct consequences in the macroscopic collective behavior in such systems. One such natural question is: Given a random landscape, what fractions of its stationary points are local maxima, local minima or saddles? To analyse the nature of a stationary point of a random surface $V(\{x_i\})$ in N dimensions, one needs to know the eigenvalues of the $(N \times N)$ Hessian matrix: $H_{i,j} = \partial^2 V/\partial x_i \partial x_j$. For example, if all the eigenvalues are positive (negative), one has a local minimum (maximum). If some of are positive and some are negative, one has a saddle. In a simple 'random Hessian model' where one assumes that the elements of the Hessian matrix are uncorrelated Gaussian variables, one is then led to the question: Given a random $(N \times N)$ Gaussian matrix, what is the probability P_N that all its eigenvalues are positive (or equivalently negative)? Thus P_N is the fraction of local minima (or maxima). This problem had been open for quite some time (more than 10 years) and most of the previous results were numerical. In a joint work with D.S. Dean (Phys. Rev. Lett., 97, 160201 (2006)) we proved that $P_N \approx \exp[-\theta\beta N^2]$ for large N where $\beta = 1$, 2 or 4 is the Dyson index characterizing the orthogonal (GOE), the unitary (GUE) or the symplectic (GSE) nature of the Gaussian matrix and the exponent $\theta = (\ln 3)/4 = 0.274653...$ is universal. Our exact result shows that P_N is very small indicating that in this simple random Hessian model, there are very few local minima or maxima, most of them are saddles.

This work essentially started my interest in random matrix theory, in particular the study of the statistics of the largest eigenvalue in random matrix theory. This subject has become very fashionable these days, following the celebrated work of C. Tracy and H. Widom, who computed the limiting distribution of the largest eigenvalue for Gaussian random matrices. Since then, the Tracy-Widom distribution has surfaced in numerous other areas of statistical physics. In the context of the largest eigenvalue of a random matrix, Tracy-Widom describes the distribution of 'typical' small fluctuations of $\lambda_{\max}$ around its mean value. However, it does not describe the probability of 'atypical' large fluctuations, which is often of interest as mentioned before. Using Coulomb gas method, myself and collaborators, were able to compute exactly the large deviation functions of $\lambda_{\max}$. Our results were thus complementary to Tracy-Widom distribution. Moreover, we showed that the large deviation tails of $\lambda_{\max}$ are 'asymmetric': left is not similar to the 'right'. Indeed, our subsequent work revealed that the there is actually a 3-*rd order phase transition* separating the 'left' and the 'right' and the Tracy-Widom is just crossover function connecting the left (pushed Coulomb gas) and the right (pulled Coulomb gas) phases. Moreover, we have demonstrated that this 3-rd order phase transition in the distribution of $\lambda_{\max}$ is quite generic and occurs in many other systems, notably in Yang-Mills gauge theory, distribution of conductance in mesoscopic systems, vicious walker problem amongst others. *On this subject, I gave a* **Plenary** *talk at STATPHYS-25 (Seoul, South Korea, 2013) and with G. Schehr (LPTMS), we wrote a recent review on this very exciting and rapidly evolving field.*

Based on my talk on this subject at the international conference "Viewpoints on Emergent Phenomena in Non-equilibrium Systems", held at the Higgs Centre for Theoretical Physics, University of Edinburgh (UK, June, 2014), Mark Buchanan (a science writer with Nature Physics and Science) wrote an essay "Equivalence Principle" in Nature Physics (vol-10, 543, (2014)). This is available at: http://www.nature.com/nphys/journal/v10/n8/pdf/nphys3064.pdf

Also, a related popular science article by Natalie Wolchover appeared in the Quanta magazine (published by Simon's foundation) in the October 15 (2014) issue, with the title "At the Far Ends of a New Universal Law". This can be found online at: https://www.quantamagazine.org/20141015-at-the-far-ends-of-a-new-universal-law/

My work with Gregory Schehr on the large deviations of the top eigenvalue of a random matrix and the ubiquity of third order phase transitions was recently highlighted by the CNRS-Institut National de Physique (INP) with the title "L'universalité de la distribution de Tracy-Widom proviendrait d'une transition de phase"

see online at: http://www.cnrs.fr/inp/spip.php?article3403

Even though random matrix theory is rather a classical area of research in physics, I believe that our work in random matrix theory brought new tools and methods to the existing traditional tools in this area and also posed new kinds of questions. In collaboration with P. Vivo (now at King's College, London), O. Bohigas (LPTMS) and M. Vergassola (Institut Pasteur, now at ENS, Paris) (J. Phys-A, 40, 4317 (2007) and Phys. Rev. Lett., 102, 060601 (2009)), we applied the Coulomb gas method to understand the large deviation properties of the extreme eigenvalues in other classes of random matrices (beyond the Gaussian ensemble), such as Wishart matrices which are random covariance matrices used routinely in statistical data analysis. Our work brought out interesting applications of these large deviation probabilities in the so called Principal Component Analysis (PCA) that is used in practical methods such as in image processing. *Our large deviation results on Wishart matrices have subsequently been verified experimentally in coupled fiber laser systems by the group of N. Davidson at the Weizmann Institute (Israel) (see e.g., arXiv: 1012:1282).* With my former Ph. D student C. Nadal, we showed how Wishart matrices also appear in physics problems such as nonintersecting fluctuating interfaces that are used as models of fluctuating step edges on a crystalline surface (Phys. Rev. E., 79, 061117 (2009)).

Another system where our techniques were very useful is in the problem of estimating the entanglement entropy in a coupled random quantum bipartite system. In collaboration with O. Bohigas and A. Lakshminarayan (I.I.T Madras, India) we computed the exact probability distribution of the minimum eigenvalue of the reduced density matrix in this entanglement problem (J. Stat. Phys. 131, 33 (2008)). With my former Ph.D student C. Nadal and in collaboration with M. Vergassola, we have succeeded [Phys. Rev. Lett., 104, 110501 (2010)] in computing the exact probability distribution of the entanglement entropy in such bipartite systems (the previous results were known only for the mean and the variance of the entropy). In collaboration with O. Bohigas and P. Vivo at LPTMS, we applied similar techniques to compute the distribution of conductance and current fluctuations in an open mesoscopic system such as a quantum dot (Phys. Rev. Lett., 101, 216809 (2008)). In the latter problem, we have discovered new singularities in the conductance distribution which are the direct consequence of two new phase transitions in an associated Coulomb gas problem (Phys. Rev. B, 81, 104202 (2010)). Subsequently, we have used random matrix theory in other related problems in mesoscopic transport, such as in computing the distribution of Andreev conductance across the normal-superconductor junctions [Ref. 162] and also in computing the distribution of Wigner-time delay [Ref. 181].

Another interesting extreme value problem with connections to random matrix theory appears in the so called 'vicious walker' problem introduced by P.G. de. Gennes and later studied by M.E. Fisher. This problem has many applications most notably in characterizing the topological excitations (the so called 'watermelons') that appear in systems with a commensurate-incommensurate phase transitions. 'Watermelon' simply refers to the configuration of N non-crossing Brownian motions that start at the origin (in one dimension) at time 0 and regroup again at the origin at a fixed time t. One of the questions that concerned mathematicians and computer scientists alike and that remained open for many years: what is the distribution of the maximal height of the watermelon, i.e., the distribution of the maximal distance travelled in time t by the rightmost walker. With my former Ph.D student J. Randon-Furling, and in collaboration with A. Comtet (LPTMS) and G. Schehr (LPT), we computed this distribution exactly (Phys. Rev. Lett., 101, 150601 (2008)). Moreover, we also showed that at any fixed intermediate time $0 \leq \tau \leq t$, the joint distribution of the positions of the non-intersecting walkers in the watermelon geometry is given exactly by the joint distribution of the eigenvalues of the Wigner-Dyson Gaussain matrices. In addition, if there is a hard wall at the origin so that the walkers move only in the positive semi-axis (the half-watermelon geometry), the joint distribution of the positions is isomorphic to the joint distribution of the eigenvalues of the Wishart matrix mentioned before, thus providing yet another physical application of the Wishart matrix. **Our work was reviewed in the 'research highlights' section of Nature Physics (vol-4, page 829, November 2008 issue).**

In collaboration with P.J. Forrester (Melbourne), G. Schehr (LPTMS), and A. Comtet, we have established an exact mapping between the vicious walker problem and the Yang-Mills gauge theory in two dimensions [Refs. 154, 175]. This mapping helped us understand why Tracy-Widom distribution appears as the limiting distribution of the maximal height in the vicious walker problem.

On this subject, we obtained the ANR grant (2011) "Marcheurs browniens répulsifs et matrices aléatoires" acronymed 'WALKMAT' (projet blanc) [Principal investigators: S.N. Majumdar (LPTMS, Orsay) and G. Schehr (formerly at LPT (Orsay), now at LPTMS (Orsay)). We recruited A. Kundu in 2012 as a postodoc under this ANR grant. Kundu has since successfully worked on a number of problems related to this project and has now obtained (since 2015) a faculty position at ICTS (Bangalore, India).

We have also applied the ideas on extremes from the random matrix theory to the physical system of trapped fermions in a confining potential. This has led to exciting new developments (see later for details). On this subject, we have obtained an ANR grant (2017) ""Random matrices and trapped fermions" (RAMATRAF) jointly with D. Dean (Bordeaux), P. Le Doussal (ENS, Paris) and G. Schehr (LPTMS, Orsay, coordinator). We recruited N. Smith as a postdoc under this grant. Naftali has recently obtained a faculty position at the Ben-Gurion University (Israel).

Another extreme value problem that I studied in collaboration with S. Nechaev (LPTMS) is worth mentioning. This problem appears in the context of biological sequence matching (for details see section 6.2), where one tries to optimize the number of matches between two random DNA sequences. For two random sequences, it is important to understand the statistics of the number of maximal matches. A particularly useful and well studied model is the so called Bernoulli matching model. While the average maximal match length in this model was well known from the early 90's, the variance was unknown prior to our work. We computed the variance exactly (Phys. Rev. E, 72, 020901(R), (2005)). Moreover, it was believed for a long time that the distribution of the number of maximal matches was Gaussian around its mean. We computed this distribution exactly and showed that the limiting distribution is precisely the same as the Tracy-Widom distribution that describes the probability distribution of the largest eigenvalue of a random matrix (as described earlier) and hence is non-Gaussian. This work made a link between two apriori unrelated fields of research namely the sequence matching problems and the random matrices.

Amongst other extreme value problems that we studied, let me briefly mention some of our exact results concerning Brownian motions with 'constraints' and their various applications. With my former Ph.D student J. Randon-Furling we have used path-integral methods to study analytically the distribution of the time at which a Brownian motion achieves its maximum within a fixed time interval. While for a simple unconstrained Brownian motion the result was known since P. Lévy (1941), it was not easy to extend the available mathematical methods in probability theory to study this distribution to more generalized Brownian motions such as Brownian bridge, Brownian excursion and Brownian meander. We succeeded in computing exactly this distribution for a variety of constrained Brownian motions. Use of the path integral method in this problem led to the discovery of new mathematical identities in number theory. This is a very successful project and led to our joint collaboration with M. Yor (Laboratoire de Probabilités et Modèles Aléatoires, Jussieu) (J. Phys. A. Math. Theor. 41, 365005 (2008)). These results also have important applications in finance where it gives a precise prediction about the time at which one should sell one's stock. The application of these path-integral methods in finance led me to start a new collaboration with J-P. Bouchuad (Capital Fund Management) (Quantitative Finance, 8, 753 (2008)). In collaboration with A. Comtet and J. Randon-Furling, we have applied some of these results to compute exactly the mean and the perimeter of the convex hull of N independent Brownian motions (Phys. Rev. Lett., 103, 140602 (2009)) with important applications in the estimation of the home range of foraging animals in the context of ecolgical conservation. In collaboration with A. Rosso (LPTMS) and A. Zoia and E. Dumonteil (CEA, Saclay), we have extended our method to compute the mean perimter and the mean area of a two-dimensional stochastic branching Brownian motion, which has interesting applications in estimating the range of epidemic spread in animal polpulations. Our results appeared in **PNAS**, 110, 4239 (2013).

We have since studied the extreme statistics and its different aspects in many other systems. This is a very active area of research worldwide where I believe that I have made very significant and important contributions (a total of ~ 70 papers including > 25 PRL's). On my research in this area, I gave a set of invited lectures at Les Houches summer school on 'Complex Systems' (2006), organized by M. Mèzard and J-P. Bouchaud, a set of 8 lectures on "extreme statistics of correlated random variables" at the Beg-Rohu summer school (June, 2008) organized by G. Biroli and A. Lefèvre, a set of 4 lectures on this subject at the summer school "Fundamental problems in statistical physics XII" at La Foresta, Belgium (2009). In May 2011, I have given a set of 5 lectures on this subject at the Les Houches summer school "Vicious Walkers and Random Matrices". In June 2011, I have given a plenary lecture at the international conference 'Extreme Value Analysis" held at the University of Lyon (This is one of the biggest conferences in Statistics in the area of extremes). I also gave a set of 9 lectures at the Beg-Rohu school in 2013 on this subject. As mentioned earlier, I gave a plenary talk at STATPHYS-25 (Korea, 2013) on this subject. Recently, I gave a set of lectures on this subject at the Galileo Galilei Institute (Florence, Italy, May 2014) and a set of 10 lectures at the Spring College at GGI (Florence, February 2018). Also, with C. Godreche (CEA, Saclay) and G. Schehr (LPT, Orsay), I organized the 16-th Claude Itzykson meeting "Extremes and Records" at Saclay in 2011 on this subject. We wrote a review aerticle on this subject: S. N. Majumdar, A. Pal, G. Schehr, "Extreme value statistics of correlated random variables: A pedagogical review", Phys. Rep. v-840, 1 (2020). Ny collective work on extreme value statistics also led to the publication of a recent book:

S.N. Majumdar and G. Schehr, *Statistics of Extremes and Records in Random Sequences* (Oxford University Press, (2024)).

I have had many fruitful collaborations with several people at LPTMS on a variety of subjects. They include faculty members, students and postdocs listed below.

• O. Bohigas (on extreme value problems in random matrices, applications to mesoscopic transport and also to entanglement problems in quantum bipartite systems)

• A. Comtet (on a variety of extreme value problems in disordered systems and in fluctuating interfaces, on various statistical aspects of Brownian functionals and their applications, on reaction-diffusion problems, on integer partition problem and its applications etc.)

• J. Desbois (on the occupation time problems on graphs)

• P. Leboeuf (on integer partition problem and its connection to level density of Bose and Fermi gases)

• O. C. Martin (on the statistics of maxima and minima in random landscapes in glassy systems)

• S. Nechaev (on growth models, biological sequence-matching problems and the Tracy-Widom distribution in random matrices)

• S. Ouvry (on integer partition and exclusion statistics problems)

• A. Rosso (on the translocation dynamics of a polymer chain (DNA) through a pore and the associated first-passage properties of non-Markovian processes, 2-d spread of epidemics in animal populations etc.)

• G. Schehr (on a variety of extreme value problems from Brownian motion to random matrix theory)

• C. Texier (on the distribution of Wigner time-delay in chaotic cavities and constrained Coulomb gases)

• E. Trizac (on the real-space condensation in polydisperse hard rod systems, intriguing integrals, Monte Carlo dynamics)

Apart from the permanent members at LPTMS, I also worked with several Ph.D students and postdocs at LPTMS. My Ph. D students include

- J. Randon-Furling (graduated in 2009) (who worked on random convex hulls and extreme value statistics and his Ph.D had the title “Statisques d’extremes du mouvement brownien et applications”). Julien is currently a mathematics faculty at the Universite Paris-Saclay.
- C. Nadal (graduated in 2011) (who worked on “Matrices aléatoires et leurs applications à la physique statistiques et physique quantique”). Celine is currently a curator and founder CEO of MuseoScience (Rouen, France).
- R. Marino (graduated in 2015) worked on “Number Statistics in random matrices and applications to qunatum systems”). He is currently working at Google, Paris.
- C. De Bacco (graduated in 2015) (jointly with S. Franz) (who did her Ph.D on “Decentralized network control, optimization and random walks on networks”). Caterina has been awarded the EPS-SNPD early carrer prize in 2021. She is currently a faculty at TU Delft (The Netherlands).
- J. Bun (graduated in 2016) (jointly with M. Potters from CFM) (who worked on “Application de la théorie des matrices aléatoires pour les statistiques en grande dimension”).
- A. Grabsch (graduated in 2018) (jointly with C. Texier) (who worked on “Random matrices in statistical physics: quantum scattering and disordered systems”). He is now a CNRS faculty at LPTMC (Sorbonne University).
- B. Lacroix-A-Chez-Toine (gradauted in 2019) (officially the Ph.D student of my colleague G. Schehr), who has collaborated with me extensively during his Ph.D work on “Extreme value statistics of strongly correlated systems : fermions, random matrices and random walks”. He is currently a faculty at King’s College (London).
- F. Mori defended his thesis in June, 2022. After doing postdocs at Oxford and Harvard, he just accepted permanent faculty offer from Imperial College (London, UK). Francesco was awarded the EPS-SNPD junior prize in 2025.
- B. De Bruyn (1st year) (joint Ph. D student with G. Schehr) defended in 2023 (he worked on constrained Brownian motions and random walks) and is now working for the finance company QRT (Paris, France).
- P. Mergny defended his Ph. D thesis in 2023 (jointly with M. Potters at CFM) on “Applications of random matrix theory”. He is currently a postdoc at EPFL (Lausanne, Switzerland).
- T. Gautie defended his Ph. D thesis (jointly with P. Le Doussal and J.-P. Bouchaud) in 2023 on “Nonintersecting Brownian motions”. He is working currently in a data science company in Paris.
- A. Flack defended her Ph. D thesis (jointly with G. Schehr and S. Nechaev) on “Truncated linear statistics in one dimensional 1-component plasma” in 2024. Currently she is woeking for a data science company in Lyon.
- M. Biroli defended his Ph.D thesis in 2025 on ‘dynamically emergent correlations’ and is currently doing his postdoc at the University of Chicago (USA).
- I. Burenev is finishing his Ph.D on ‘random walks and large deviations’ (in 2026) and is moving to a finance company QRT (Paris).

- G. de Mauro is in the second year of his Ph.D. He is working on various aspects of stochastic resetting.

In addition, several Ph.D students have worked with me during their Ph.D thesis. They include

- H. Kallabis (former Ph.D student of J. Krug from the University of Cologne, 1997)
- G.C.M.A Ehrhardt (former Ph.D student of A.J. Bray from the University of Manchester, 2001)
- M. Constantin (former Ph.D student of S. Das Sarma from the University of Maryland, 2003)
- P. Vivo (former Ph.D student of G. Akemann, Brunel University, UK, 2007)
- R. Allez (former mathematics Ph.D student of M. Gubinelli and V. Vargas from Universite' Paris-Dauphin, 2009)
- G. Borot (former Ph.D student of B. Eynard from IPhT, Saclay, 2010)
- J. Franke (former Ph.D student of J. Krug from the University of Cologne, 2012)
- A. Gabel (former Ph.D student of S. Redner from Boston University, 2012)
- G. Wergen (former Ph.D student of J. Krug from the University of Cologne, 2012)
- A. Perret (former Ph.D student of G. Schehr from LPTMS, Univerite' Paris-Sud, 2013)
- J. Whitehouse (former Ph.D student of M. R. Evans from the University of Edinburgh, 2013)
- Y. Edery (former Ph.D student of B. Berkowitz from the Weizmann Institute, 2013)
- M. Chupeau (former Ph.D student of O. Benichou from LPTMC, UPMC, 2015)
- G. Claussen (former Ph.D student of A.K. Hartmann from the University of Oldenburg, 2015)
- A. Bar (former Ph.D student of D. Mukamel from the Weizmann Institute, 2016)
- H. Schawe (ex Ph. D student of A.K. Hartmann from the University of Oldenburg, since 2017 and is currently a postdoc at Univ. of Cergy Pontoise, France).

My postdocs at LPTMS include

- S. Sabhapandit (2006-2008, currently a Professor at Raman Research Institute, Bangalore, India) who worked on disordered systems, extreme value statistics, integer partition problems.
- D. Villamaina (2011-2013, currently at CFM) who worked with me on extreme eigenvalues of Cauchy random matrices.
- A. Kundu (2012-2014, currently a faculty member at ICTS, Bangalore, India) who has worked on vicious walker problem as well as on the number of distinct and common sites visited by random walkers.

- S. Gupta (2012-2014, currently a faculty member at Tata Institite, Mumabi, India) who worked on nonequlibrium steady states induced by 'resetting' dynamics in fluctuating interfaces.
- K. Ramola (2012-2014, currently a faculty member at Tata Institute, Hyderabad, India), who has worked on the order and gap statistics in one dimensional branching Brownian motion.
- J. Grela (2016-2018), currently a faculty at Jagiellonian University (Cracow, Poland) who worked with me on linear statistics of trapped fermions at finite temperature.
- U. Basu (2017-2018), currently a faculty member at S. N. Bose Center for Basic Sciences (Kolkata, India) who worked with me on "active Brownian motion".
- T. Banerjee (2018-2019) (currently a faculty at Niser (Bhubaneswar, India) worked with me on transport properties of active particles.
- N. Smith (2019-2020), currently a faculty at the Hebrew University of Jerusalem (Israel) worked with me on fermions, active particles and resetting Brownian motions.
- G. del Vecchio del Vecchio (2025-2026) is currently doing his postdoc jointly at LPTMS and LPENS, under our ANR grant 'EDIPS'.

The research environment at LPTMS is exciting and I hope to have brought new ideas and initiated new directions of research in this dynamic laboratory. I have also maintained continuing collaborations with my colleagues M. Barma and D. Dhar at Tata Institute (Bombay, India). I visited Tata Institute on a regular basis as an adjunct professor to the department of theoretical physics. Several graduate students there are working under my co-direction. In addition, I am an adjunct professor at the International Center for Theoretical Sciences (ICTS, Bangalore, India) and the Raman Research Institute (Bangalore, India). I visit both Institutes once every year. I am also a visiting Weston professor at the Weizmann Institute, Israel where I visit annually for a month and collaborate with D. Mukamel and his graduate students. In addition, I'm a Higgs associate (since 2012) at the Higgs Center for Theoretical Physics at the University of Edinburgh (UK), where I have regular collaborations with M. R. Evans and his group.

3 Principal Scientific Contributions, Achievements and Impact

To summarize, I have worked on a broad range of subjects in statistical physics with applications ranging from granular systems all the way to computer science and biology. Despite the diversity of the subjects, there are two basic themes that are common to most of my work:

(i) the physical systems that I am interested in usually involve many degrees of freedom which are '**interacting**' or '**correlated**' and

(ii) there is usually an element of '**randomness**' in them. I mean '**randomness**' in a rather broad sense here: for example, it can be the 'frozen' disorder as in spin-glasses or it can be the 'noise' or 'stochasticity' in the temporal evolution of a system. In the context of data structures and algorithm problems in computer science, 'randomness' is in the underlying data structures.

In the general spirit of statistical physics, my research methods consist in constructing simple yet nontrivial models that essentially capture the physics of the more complicated real systems and then try to solve these models analytically to understand the basic physical mechanism involved behind the collective behavior of the underlying many body systems. The results I have obtained are predominantly analytical in nature. *Many of them are first exact results in the fields.* In my opinion, my principal and most original contributions so far have been in the following areas:

(1) *Self-organized criticality in sandpile models:* (Ph.D thesis, 1992) Exact solution of the Abelian sandpile model (ASM) on the Bethe lattice, exact height-height correlations in ASM, an exact mapping between the avalanche size distribution in ASM and the clusters in the q-state Potts model in the limit $q \to 0$. These results have made impact both in Physics and Mathematics.

(2) *Stress propagation in granular systems:* We contributed two pionnering papers in this field. Our model, now known as the q-model in the literature, describes how an applied stress on a granular heap propagates through the heap —our analytical results are verified in experiments in Chicago. Refs : Science, 269, 513 (1995) and Phys. Rev. E, 53, 4673 (1996).

(3) *Persistence in nonequilibrium systems:* Exact solutions for the first-passage probability for various Markov and Non-Markovian stochastic processes : contributed > 50 papers including 15 PRL's with more than 1500 citations and an extensive recent review on the subject jointly with A.J. Bray and G. Schehr: "Persistence and first-passage properties in nonequilibrium systems", Adv. in Phys. 62, 225-361 (2013).

(4) *Real-space condensation in nonequilibrium steady states:* In many systems where there is a transfer of mass or energy from one sppace point to another, a condensation phenomenon can occur in real space, i.e., at long times the system might develop a single point in space with a thermodynamically large fraction of mass condensing there. Our exact solutions of various mass transport models and more recently in active run-and-tumble dynamics have shed important lights on this phenomena, in particular in characterizing the nature of the

condensate.

(5) *'Sorting and Search' problems in computer science:* An exact mapping between binary search tree problem and the directed polymer problem in random medium helped identify a fundamental 'travelling front' structure in sorting and search algorithms. Many asymptotic results on the efficiency of search algorithms could be derived using this method.

(6) *Extreme value statistics of correlated variables:* I have been working on various aspects of this subject for the last 20 years. Two particularly interesting strongly correlated systems where we made much progress in recent years: (i) Brownian Motion and various other stochastic processes (ii) staistics of eigenvalues in random matrices. Other questions related to extremes have also been studied, such as the statistics of the fluctuations in the positions of fermions confined in an external potential (trapped cold atoms), number of extrema in a random landscape, extremes in fluctuating interfaces, integer partition problem, level density of Bose gas and its relation to extreme statistics, zeros of random polynomials and longest excursions in stochastic processes in nonequilibrium systems etc. Various other questions related to extreme statistics have also been studied, such as the order and the gap statistics, record statistics, density of near-extreme events etc. in random walks and other stochastic processes. We have written a comprehensive review on this subject: S. N. Majumdar, A. Pal, G. Schehr, "Extreme value statistics of correlated random variables: A pedagogical review", Phys. Rep. 840, 1 (2020). My collective work in this field led to the publication of a recent book: S. N. Majumdar and G. Schehr, *Statistics of Extremes and Records in Random Sequences* (Oxford University Press, (2024)).

(7) *Random Matrix Theory and its diverse applications:* My research interests covered various applications of the random matrix theory such as the study of (i) fluctuations of the number of eigenvalues in a given spectral interval–the so called Index problem (ii) transport in mesoscopic cavities (ii) distribution of entanglement entropy in random pure states of bipartite systems (iv) nonintersecting Brownian motions and its connection to Yang-Mills gauge theory (v) matrix integrals and the associated fluid dynamics (vi) application of random matrix theory in cold atoms (free fermions in a harmonic trap at zero and finite temperature). One of my major contributions was to find a third-order phase transition in the karge deviation tail of the largest eigenvalue of a random matrix and consequently explain why the Tracy-Widom distribution appears so frequently in many different problems, sometimes not directly related to random matrix theory. I have also studied various integrable models related to random matrices, such as random growth models (of the Kardar-Parisi-Zhang varieties), biological sequence matching problems, random permutations and interacting particle systems in low dimensions. My collective contributions in this area include > 50 papers including > 15 PRL's.

(8) *Stochastic resetting and its applications:* In 2011, with M. R. Evans (Edinburgh, UK), I introduced a new area of research in statistical physics that has become rather popular recently under the name '**stochastic resetting**'. It simply means interrupting the natural dynamics of a system (classica;/quantum/deterministic/stochastic) at random times and re-starting the system from its initial configuration. This simple random interruption leads to many interesting phenomena, notably (i) it typically drives the system into a nonequilibrium stationary state with nontrivial properties and (ii) in search problems, stochastic resetting leads to an efficient algorithm where one can optimize the mean search time to find a target by varying the resetting rate. This simple idea led to several applications across

disciplines: physics, chemistry, biology, ecology and computer science. Our original paper, "Diffusion with Stochastic Reseting" by M. R. Evans and S. N. Majumdar, Phys. Rev. Lett. 106, 160601 (2011), has by now gathered more than 950 citations (source: Google Scholar, 15/08/2026). **In 2021, Phys. Rev. E has declared it as the 'PRE spotlights' of 'emergent areas' and J. Phys. A is bringing out a special issue honoring this work**. We have recently written an exhaustive review on the subject: M. R. Evans, S. N. Majumdar, and G. Schehr, "Stochastic resetting and applications", J. Phys. A. : Math. Theor. 53, 193001 (2020).

(9) *Order, Gap and Record statistics for stochastic time series* We have introduced new analytical tools to study the statistics of records and orders for strongly corelated time series with a wide ranging applications from climates to finance. Several examples and applications can be found in my recent book: S. N. Majumdar and G. Schehr, *Statistics of Extremes and Records in Random Sequences* (Oxford University Press, (2024)).

The strong points of my scientific research are:

(1) *Diversity of subjects* (Extreme Value Statistics, Random Matrix theory and applications, first-passage properties in out of equilibrium systems, Brownian motion and its diverse applications, stochastic resetting, statistics of records, gaps and orders in stochastic processes, sorting and search problems in computer science, transport in high temp. superconductors, stress propagation in granular systems, self-organized criticality in sandpile models, etc.)

(2) *Development of novel analytical techniques* for simple yet nontrivial and outstanding problems.

(3) *Strong international collaborations* (more than 100 collaborators internationally) and (¿30 collaborators in France). At LPTMS I have collaborated with 12 permanent members My international collaborations include mathematicians on one hand and experimentalists on the other.

(4) Many of my results are *first exact results* in the field

(5) *Useful applications* of my results : many of my analytical predictions have been verified experimentally.

Achievements and Impact:

My collective work includes **408** publications (till 15/08/2026) in reviewed journals (including **74** PRL's, 1 Science, 1 PNAS etc.), 4 conference proceedings and 9 invited reviews and book chapters. In addition, I have written a book: S.N. Majumdar and G. Schehr,*Statistics of extremes and records in random sequences* (Oxford University Press) (2024). My collective work have gathered > 28200 citations (source: Google Scholar dated 15/08/2026) with an h-index: 86 (GS).

I also gave 200 invited talks in international conferences/workshops/summer schools (including the **plenary** talks at STATPHYS-25 (Seoul, 2013) and 'Extreme Value Analysis' (Lyon, 2011). I have also taught in various prestigious summer schools in statistical physics including Les Houches, Beg-Rohu, Leuven, Bangalore etc. In addition, I have been invited to give several prestigious named lectures/colloquiuum across the world, including M. L. Mehta lectures (Tata Institute, India), S. Chandrasekhar lectures (ICTS, India), Higgs Colloquiuum (Edinburgh University, UK), Boltzmann lecture (SISSA, Italy) etc.

I have received several international honors/awards during my career. Very recently, I gave a **plenary** lecture at STATPHYS-25 (Seoul, South Korea, 2013)–the biggest conference in statistical physics held every three years in different countries. Also, I was a **plenary** speaker at one of the important conferences in Statistics, namely, 'Extreme Value Analysis' (EVA) (Lyon, France, 2011), held every three years in different countries. I received the 'Geeta Udgaonkar medal' (for outstanding Ph.D thesis at Tata Institute in 1992) and later the 'Young Scientist medal' awarded by the Indian National Science Academy in 1998. In France I received the "Prix Paul Langevin" of the French Physical Society in 2005. Since 2009, I am a recipient of the 'Prime d'excellence Scientifique' (PES) awarded by CNRS in France. Also, in 2009, I recieved the 'Excellence Award' (2009) for outstanding contributions to statistical physics from the prestigious Tata Institute Alumni Association. In 2018, I was awarded the prestigious VAJRA fellowship of the department of Science and Technology of the government of India.

In 2019, I received three prestigious prizes. I was the recipient of the **EPS (European Physical Society) prize** for Statisical and Nonlinear Physics.

The citation for my EPS prize reads:

The 2019 EPS-SNPD prize is awarded to Satya Majumdar

" *for his seminal contributions to non-equilibrium statistical physics, stochastic processes, and random matrix theory, in particular for his groundbreaking research on Abelian sandpiles, persistence statistics, force fluctuations in bead packs, large l* deviations of eigenvalues of random matrices, and applying the results to cold atoms and other physical systems."

http://www.epsnews.eu/2019/03/eps-snpd-prizes-2019/

In 2019, I was awarded the **CNRS silver medal (medaille d'argent)**. Also, in 2019, I received the **Gay-Lussac-Humboldt prize** from the Alexander von Humboldt foundation in Germany for my outstanding contributions to Statistical Physics.

I have been the divisional associate editor of PRL (2011-2013). Currently, I am the Editor in Chied of J. Phys. A: Math. Theor. and an associate editor of J. Stat. Phys. (since 2008), editorial board member of J. Stat. Mech. (since 2003) and Springer 'Lecture Notes in Physics' (since 2023).

The impact and the international visibility of my work is reflected in a number of news articles/research highlights in science journals. Here are few examples:

- The citation for my EPS prize can be found in the official EPS website:

http://www.epsnews.eu/2019/03/eps-snpd-prizes-2019/

• Following my EPS prize and CNRS silver medal in 2019, the following press article appeared in the official Universite Paris-Saclay website:

https://www.universite-paris-saclay.fr/en/news/satya-majumdar-modeling-the-random

• My recent work with E. Trizac on 'When random walkers help solving intriguing integrals' (Phys. Rev. Lett., 123, 020201 (2019)) got highlighted in Physics Today (Search and Discovery):

https://physicstoday.scitation.org/do/10.1063/PT.6.1.20190808a/full/

It also got a press coverage in Phys.org:

https://phys.org/news/2019-07-illusive-patterns-math-ideas-physics.html

• A popular science article on our work on third order phase transition behind the universality of Tracy-Widom distribution, written by Natalie Wolchover appeared in the Quanta magazine (published by Simon's foundation) in the October 15 (2014) issue, with the title "At the Far Ends of a New Universal Law".

This can be found online at: https://www.quantamagazine.org/20141015-at-the-far-ends-of-a-new-universal-law/

• My work with Gregory Schehr on the large deviations of the top eigenvalue of a random matrix and the ubiquity of third order phase transitions (see S. N. Majumdar and G. Schehr, "Top eigenvalue of a random matrix: large deviations and third order phase transition", J. Stat. Mech. 01012 (2014).) was recently highlighted by the CNRS-Institut National de Physique (INP) with the title "L'universalité de la distribution de Tracy-Widom proviendrait d'une transition de phase"

see online at: http://www.cnrs.fr/inp/spip.php?article3403

• "Equivalence Principle", an essay by M. Buchanan, published in **Nature Physics**, **10**, 543 (August, 2014), based on my talk on "KPZ/Tracy-Widom story" given at the international conference "Viewpoints on Emergent Phenomena in Non-equilibrium Systems", held at the Higgs Centre for Theoretical Physics, University of Edinburgh, UK, June, 2014.

see http://www.nature.com/nphys/journal/v10/n8/pdf/nphys3064.pdf

• An article 'A walk in the park' that appeared in the research highlights section of **Nature Physics** [Nature Phys., **4**, 829 (2008)] that reviewed my work on the connection between vicious walkers problem and random matrix theory [with G. Schehr, A. Comtet and J. Randon-Furling, published in Phys. Rev. Lett. 101, 150601 (2008)].

see http://www.nature.com/nphys/journal/v4/n11/full/nphys1119.html

• "Une puce qui saute au hasard" (**La Recherche**, mathématiques - 01/10/2005 par Benoît Rittaud dans mensuel n°390 à la page 26), that reviewed my work with A. Comtet on us the maximum of a random walk (published in J. Stat. Mech. P06013 (2005)).

see http://www.larecherche.fr/actualite/mathematiques/ puce-qui-saute-au-hasard-01-10-2005-71971

• "Persistence Pays Off in Defining History of Diffusion" by A. Watson in the research news section of **Science** [vol-274, page 919-920, 1996], that reviewed my work on persistence in diffusion equation [with A.J. Bray, S.J. Cornell and C. Sire, published in Phys. Rev. Lett. **77**, 2867 (1996)].

see https://www.sciencemag.org/content/274/5289/919

• "Clues About How a Sand Pile Holds Itself Up:Scientists Get 3-D View of Force Chains in Granular Materials" by S. Koppes (University of Chicago press news) that reviewed our work on the force chains in granular materials [published in **Science**, 269, 513 (1995)].

see http://www-news.uchicago.edu/releases/95/950820.granular.forces.shtml

4 A list of 10 important publications with brief descriptions

Here I provide a list of 10 important publications. The full list (along with PDF's) can be found in my homepage:

https://www.lptms.universite-paris-saclay.fr/satya-majumdar/publications-and-invited-talks/

Making a choice of 10 publications (out of 408 with 74 in PRL) is not easy. This choice reflects the diversity of subjects I have worked on (and not just based on citations) : sandpile models, polymers, granular systems, high temperature superconductivity, persistence and first-passage properties in stochastic processes, record statistics, random matrix theory, large deviations, stochastic resetting, dynamics of active particles, quantum measurement theory, all the way to the physics of cold atoms. It also demonstrates that I have worked with experimentalists on one hand, and mathematicians on the other. Diversity apart, the choice of 10 papers above is also dictated by two other facts:

- These papers are not incremental: each of them contained original ideas that led to many further developments and applications.
- I personally enjoyed very much working on these problems

(1) S.N. Majumdar and D. Dhar, "Equivalence of the Abelian Sandpile Model and the q-¿0 Limit of the Potts Model", Physica A, 185, 129 (1992).

This paper showed that the nonequilibrium sadpile model can be mathematically mapped to an equilibrium Potts model and many exact results could be obtained for sandpile model exploiting this mapping. It also provided an original 'burning' algorithm to generate the configurations of the Abelian sandpile model.

Link : https://doi.org/10.1016/0378-4371(92)90447-X

(2) C.-h. Liu, S.R. Nagel, D.A. Schecter, S.N. Coppersmith, S. Majumdar, O. Narayan and T.A. Witten, "Force Fluctuations in Bead Packs", Science, 269, 513 (1995).

This paper provided the first model and the experiment to study and measure how stress progates in a granular medium, which is neither a solid nor a liquid. The q-model of stress propagation, proposed and solved exactlyin this paper, is now a standard model of stress propagation in granular medium.

Link : https://doi.org/DOI: 10.1126/science.269.5223.513

(3) S.N. Majumdar, C. Sire, A.J. Bray and S.J. Cornell, "Nontrivial Exponent in Simple Diffusion", Phys. Rev. Lett. 77, 2867 (1996).

This paper showed that the persistence and first-passage properties in many-body out-of-equilibrium systems are non-Markovian and hence nontrivial even for simple diffusing fields starting from random initial condition. Nontrivial persistence exponents predicted, which were later verified in experiments using NMR technology by a Harvard group.

Link : https://doi.org/10.1103/PhysRevLett.77.2867

(4) S.N. Majumdar and A. Comtet, " Exact Maximal Height Distribution of Fluctuating Interfaces", Phys. Rev. Lett., 92, 225501 (2004).

This paper computed exactly the distribution of the maximal relative height for one dimensional interfaces in the steady state and showed how it is related to computer science problems. This remains one of the rare exact solution for the extreme value statistics (EVS) of a set of strongly corelated random variables, leading to numerous later applications of EVS.

Link : https://doi.org/10.1103/PhysRevLett.92.225501

(5) D.S. Dean and S.N. Majumdar, " Large Deviations of Extreme Eigenvalues of Random Matrices", Phys. Rev. Lett., 97, 160201 (2006).

In this paper, the 'left' large deviation function of the distibution of the top eigenvalue of a Gaussian random matrix was compoputed exactly using a Coulomb gas method. This is the first paper that showed a third order phase transition in the strong coupling regime of the Coulomb gas, paving the way for similar third order phase transition in numerous models.

Link : https://doi.org/10.1103/PhysRevLett.97.160201

(6) S.N. Majumdar and R.M. Ziff, " Universal Record Statistics of Random Walks and Levy Flights", Phys. Rev. Lett., 101, 050601 (2008).

This paper provided the exact calculation of the statistics of records in a strongly correlated time-series, namely the positions of an n-step random walk (including Levy flights) in one dimension. It was shown that the record statistics is completely universal for any n, i.e., independent of jump distributions of the random walk.

Link : https://doi.org/10.1103/PhysRevLett.101.050601

(7) M.R. Evans and S.N. Majumdar, "Diffusion with Stochastic Resetting", Phys. Rev. Lett. 106, 160601 (2011).

This paper introduced the concept of stochastic resetting in search processes and established two paradigms: existence of a nonequilibrium stationary state and an optimal resetting rate that minimizes the search time of a traget. These results were verified by experiments on colloidal particles in an optical trap set-up and led to enormous activities later across disciplines (from ecology to computer science), making 'stochastic resetting' a major area of current research in statistical physics.

Link : https://doi.org/10.1103/PhysRevLett.106.160601

(8) D. S. Dean, P. Le Doussal, S. N. Majumdar, and G. Schehr, "Finite-Temperature free fermions and the Kardar-Parisi-Zhang equation at fiinite time", Phys. Rev. Lett., 114, 110402 (2015).

This paper made an important connection between noninteracting fermions in a harmomnic trap, random matrix theory (RMT) and the Kardar-Parisi-Zhang equation for fluctuating interfaces. This proved the existence of an universal edge regime in cold atoms where Tracy-Widom distribution of RMT appears.

Link : https://doi.org/10.1103/PhysRevLett.114.110402

(9) F. Mori, P. Le Doussal, S. N. Majumdar, and G. Schehr, "Universal Survival Probability for a d-Dimensional Run-and-Tumble Particle", Phys. Rev. Lett., 124, 090603 (2020).

This paper provided an exact solution for the first-passage probability of a run-and-tumble active particle in d dimensions with arbitrary post-tumble velocity distribution. Amazingly the result was found to be totally universal at all times, independent of d and the velocity distribution.

Link : https://doi.org/10.1103/PhysRevLett.124.090603

(10) M. Biroli, H. Larralde, S. N. Majumdar, G. Schehr, "Extreme Statistics and Spacing Distribution in a Brownian Gas Correlated by Resetting", Phys. Rev. Lett., 130, 207101 (2023) [Editor's suggestion].

This paper introduced the idea of siimulatneous resetting by N particles and provided a simple mechanism to generate a strongly correlated gas in a nonequilibrium stationary state, but still solvable due to a special algebraic structure of the joint distribution of particles in the stationary state. Several observables such as the gap statistics, full counting statistics etc. were computed, which were recently verified in the experiments of colloidal particles in an optical laser trap (in collaboration with S. Ciliberto at ENS-Lyon and published in M. Biroli et. al., "Experimental evidence for strong emergent correlations between particles in a switching trap", Phys. Rev. Lett., 137, 037102 (2026)).

Link : https://doi.org/10.1103/PhysRevLett.130.207101