Golan Bel July, 2020

CURRICULUM VITAE

• **Personal Details**

Golan Bel
Date and place of birth: October 26, 1973 Beer Sheva, Israel
Address and telephone number at work: Department of Solar Energy and Environmental Physics, Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus 8499000 Israel. +972-8-6596845
Address and telephone number at home: P.O.Box 111, Midreshet Ben-Gurion 8499000 Israel. +972-50-8990052

• **Education**

B.Sc. - 1998–2001, Bar-Ilan University, Physics Department

Ph.D - 2001–2006, Bar-Ilan University, Physics Department
Name of advisor: Prof. Boris Shapiro
Title of thesis: Topological defects in unconventional superconductors

• **Employment History**

2010–Present – Department of Solar Energy and Environmental Physics, Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus, Israel
2016–Present – Associate Professor
2013–2014 – Mendel Wasserman career development chair in desert studies
2012–2016 – Senior Lecturer
2010–2012 – Lecturer
2017–Present – Dual affiliation with the Department of Physics, Ben-Gurion University of the Negev
2008–2010 – Postdoctoral research associate, Center for Nonlinear Studies and CCS-3, Los Alamos National Laboratory, Los Alamos, New Mexico, USA
2005–2008 – Postdoctoral Scholar, Department of Chemistry and Biochemistry and Physics Department, University of California, Santa Barbara, California, USA
2001–2005 – Teaching Assistant, Physics Department, Bar-Ilan University, Ramat Gan, Israel

• **Professional Activities**

Positions in academic administration

2017–2019, Chair of the department of solar energy and environmental physics
2013–2017, Head of the department teaching committee
2013–2017, Member of the faculty teaching committee
2014–2018, Member of the University Senate

Ad-hoc reviewer for journals

Physical Review Letters
Physical Review E
Physics Review Research
Euro Physics Letters

Mathematical Biosciences,
Journal of Economics and International Finance (JEIF)
Journal of Chemical Physics
Theoretical Ecology
Journal of Statistical Physics
CATENA
Physical Biology
Proceedings of the Royal Society B
Journal of Climate
SIAM Dynamical Systems
Nature Communications
Renewable and Sustainable Energy Reviews

Membership in professional/scientific societies
2006–Present American Physical Society
2006–Present European Physical Society
2011–Present Israeli Physical Society
2017–Present American Geophysical Union
2019–Present European Geophysical Union

• Educational activities
Courses taught
Advanced topics in Statistical Physics, Graduate – Ben-Gurion University of the Negev (2017–Present).
Stochastic Processes in Physics, Graduate - Ben-Gurion University of the Negev (2012–Present).
Introduction to Statistics, Graduate - Ben-Gurion University of the Negev (2013).
Statistical Methods in Climate Research, Graduate - Ben-Gurion University of the Negev (2013–Present).
Statistical Methods in Climate Research-II, Graduate - Ben-Gurion University of the Negev (2013–Present).
Physics 3A, Undergrduate (Electrical Engineering) – Ben-Gurion University of the Negev (over 200 students) (2019–Present).
Physics I B, Undergraduate (Chemistry and Chemical Engineering) - Ben-Gurion University of the Negev (over 100 students) (2014–2018).
Electric Circuits, Undergraduate - Bar-Ilan University* (2001–2005).
Electronics, Undergraduate - Bar-Ilan University* (2001–2005).
Electrodynamics and the special theory of relativity, Undergraduate - Bar-Ilan University* (2001–2005).
Advanced Statistical Mechanics, Graduate, Bar-Ilan University* (2002–2005).
*taught as teaching assistant

Workshops organized
Geophysical Fluid Dynamics days, 2012 (joint organization with Yossi Ashkenazy, two days of lectures and activities for Israeli researchers and graduate students including a series of lectures by a foreign keynote speaker).

Physics Fete, 2013 (joint organization with Eythan Grosfeld, two days of lectures and activities for undergraduate and graduate physics students).
Geophysical Fluid Dynamics days, 2014 (joint organization with Yossi Ashkenazy, two days of lectures and activities for Israeli researchers and graduate students including a series of lectures by a foreign keynote speaker).
Physics Fete, 2015 (joint organization with Eythan Grosfeld, two days of lectures and activities for undergraduate and graduate physics students).
Open problems in fluid dynamics and soft condensed matter, 2016, two days of presentations and discussions of open problem by faculty members from all universities in Israel.
Physics Fete, 2017 (joint organization with Dganit Meydan, two days of lectures and activities for undergraduate and graduate physics students).
Three sessions on soil-biosphere-atmosphere dynamics at the 6th Drylands, Deserts and Desertification (DDD) conference, 2017, within this international conference I co-organized sessions on modeling of drylands in climate models, soil-water dynamics in drylands and soil-atmosphere gaseous and energy exchange in drylands.

Research students and postdocs

Ehud Strobach, Ph.D., 2011–2015.
Yuval Zelnik, Ph.D., 2011–2016 (joint supervision with Ehud Meron).
Yariv Tzafrir, M.Sc., 2015–2018 (joint supervision with Shai Arnon).
Ehud Strobach, Postdoc, 2015–2016.
Dan Wexler, M.Sc., 2016–2019.
Gal Weisman, Ph.D., 2016–Present (joint supervision with Ofer Dahan).
Noam Meislish, M.Sc., 2018 (joint supervision with Naftali Lazarovitch).

• Awards, Citations, Honors, Fellowships

Honors, Citation Awards

2014 Ben-Gurion University of the Negev, Toronto Prize for Excellence in Research.
2004 Bar-Ilan University, the Rector Prize for Excellence in Research.
2003 Bar-Ilan University, Salim and Rachel Benin Scholarship.
2001 Bar-Ilan University, Dean's Fellowship for Ph.D. Students.
2001 Bar-Ilan University, Wolf Foundation- Scholarship for excellence.
2000 Bar-Ilan University, Dean's List –top students in the faculty of exact sciences.
2000 Bar-Ilan University, Physics Department - top student of the physics department.
2000 Bar-Ilan University, Faculty of Natural Science - Jacobs Award.

Fellowships

2001 – 2005 President Fellowship, Bar-Ilan University, 10k$/year, Ph.D. fellowship

• Scientific Publications

Authored book chapters

1. Y. Zarmi, **G. Bel** and C. Aflalo, Theoretical Analysis of Culture Growth in Flat-Plate Bioreactors: The Essential Role of Time Scales, *Handbook of Microalgal Culture:*

Applied Phycology and Biotechnology, Edited by A. Richmond and Q. Hu, 2nd edition, Wiley-Blackwell (2013).

Refereed articles and refereed letters in scientific journal

1. **G. Bel**, B. Rosenstein, B. Shapiro and I. Shapiro, Alternating Para/Diamagnetic Domains in a P-Wave superconductor, *Europhys. Lett.* **64**, 503 (2003).
2. B. Rosenstein, Shapiro B. Ya, Shapiro I. and **G. Bel**, Vector Vortices in P-Wave Superconductors with arbitrary Kappa Parameter, *Phys. Rev. B* **67**, 224507 (2003).
3. B. Ya. Shapiro, B. Rosenstein, I. Shapiro and **G. Bel**, Coreless vortex in p-wave superconductor, *Physica C* **388-389**, 515 (2003).
4. B. Shapiro, **G. Bel**, B. Rosenstein and I. Shapiro, Hot Spot in type II superconductors: Dynamics and Instabilities, *Physica C* **404**, 335 (2004).
5. **G. Bel** and E. Barkai, Weak ergodicity breaking in the continuous time random walk, *Phys. Rev. Lett.* **94**, 240602 (2005).
6. **G. Bel** and E. Barkai, Random walk to a non-ergodic equilibrium concept, *Phys. Rev. E* **73**, 016125 (2006).
7. **G. Bel** and E. Barkai, Occupation times and ergodicity breaking in biased continuous time random walks, *J. Phys.: Condens. Matter* **17**, S4287–S4304 (2005).
8. **G. Bel** and E. Barkai, Weak ergodicity breaking with deterministic dynamics, *Europhys. Lett.* **74**, 15 (2006).
9. **G. Bel**, Y. Zhang and F. L. Brown, Single molecule photon counting statistics for quantum mechanical chromophore dynamics, *J. Phys. Chem. B* **110**, 19066 (2006).
10. **G. Bel** and B. Rosenstein, Dynamics of the vortex glass transition, *AIP conference proceedings* **850**, 833 (2006).
11. **G. Bel**, D. P. Li, B. Rosenstein, V. Vinokur and V. Zuravlev, Dynamics of disordered type-II superconductors: peak effect and the I-V curves, Physica C **460-462**, 1213 (2007).
12. **G. Bel** and F. L. H. Brown, Theory for wavelength-resolved photon emission statistics in single-molecule florescence spectroscopy, *Phys. Rev. Lett.* **102**, 018303 (2009).
13. A. Zilman, J. Pearson and **G. Bel**, Effects of jamming on transport times in nano-channels, *Phys. Rev. Lett.* **103**, 128103 (2009).
14. **G. Bel** and I. Nemenman, Ergodic and non-ergodic anomalous diffusion in coupled stochastic processes, *New Journal of Physics* **11**, 083009 (2009).
15. B. Munsky, **G. Bel** and I. Nemenman, Specificity and Completion Time Distributions of Biochemical Processes, *J. Chem. Phys.* **131**, 235103 (2009).
16. **G. Bel**, B. Munsky and I. Nemenman, The simplicity of completion time distributions for common complex biochemical processes, *Physical Biology* **6**, 016003 (2010).
17. A. Zilman and **G. Bel**, Crowding effects on transport through nano-channels, *J. of Phys.:Cond. Matt.* **22**, 454130 (2010).
18. **G. Bel**, A. Hagberg and E. Meron, Gradual regime shifts in spatially extended ecosystems, *Theoretical Ecology* **5**, 591-604 (2012).

19. **G. Bel**, Y. Ashkenazy, The relation between the temporal correlations of the wind and the statistics of open ocean currents, *New Journal of Physics* **15**, 053024 (2013).
20. Y. Zelnik, S. Kinast, H. Yizhaq, **G. Bel** and E. Meron, Regime Shifts in Models of Dryland Vegetation, *Philosophical Transactions of the Royal Society A* **371**, 20120358 (2013).
21. S. Kinast, Y. Zelnik, **G.Bel** and E. Meron, Interplay between Turing mechanisms can increase pattern diversity, *Phys. Rev. Lett.* **112**, 078701(2014).
22. H. Yizhaq, S, Sela, T. Svoray, S. Assouline and **G. Bel**, The effects of heterogeneous soil-water diffusivity of vegetation pattern formation, *Water Resources Research* **50**, 5743-5758 (2014).
23. **G. Bel** and Y. Ashkenazy, The role of psammophilous plants in sand dunes dynamics, *J. Geophys. Res. Earth Surf.* **119**, 1636–1650 (2014).
24. T. Turkeltaub, D. Kurtzman, **G. Bel** and O. Dahan, Examination of groundwater recharge with a calibrated/validated flow model of the deep vadose zone, *Journal of Hydrology* **522**, 618-627 (2015).
25. I. Stavi, R. Shem-Tov, Y. Shlomi, **G. Bel** and H. Yizhaq, Recruitment and decay rate of Acacia seedlings in the hyper-arid Arava Valley, Israel, *CATENA* **131**, 14-21 (2015).
26. **G. Bel** and F. L. Brown, Theory of Single Molecule Emission Spectroscopy, *J. Chem. Phys.* **142**, 174104 (2015).
27. E. Strobach and **G. Bel**, Improvement of Global Climate Projections and Reducing their Uncertainties Using a Sequential Learning Algorithm. *Atmos. Chem. Phys.*, **15**, 8631-8641, (2015).
28. Y. Ashkenazy, H. Gildor and **G. Bel**, The effect of stochastic wind on the infinite depth Ekman layer model. Accepted for publication in *EuroPhys. Lett.* (2015).
29. Y. Zelnik, E. Meron and **G. Bel**, Gradual Regime Shifts in Fairy Circles. *Proc. Nat. Acad. Sci. USA* **112** (40), 12327 (2015).
30. Y. Zelnik, E. Meron and **G. Bel**, Localized states qualitatively change the response of ecosystems to varying conditions and local disturbances. *Ecological Complexity* **25**, 26-34 (2016).
31. **G. Bel**, C. P. Connaughton, M. Toots and M. M. Bandi, Grid-scale fluctuations and forecast error in wind power. *New Journal of Physics* **18**, 023015 (2016).
32. H. Yizhaq and **G. Bel**, Effects of quenched disorder on critical transitions in pattern-forming systems. *New Journal of Physics* **18**, 023004 (2016).
33. E. Strobach and **G. Bel**, Decadal climate predictions using sequential learning algorithms. *Journal of Climate* **29**, 3787-3809 (2016).
34. I. Stavi, G. Bel, and E. Zaady, Soil functions and ecosystem services in conventional, conservation, and integrated agricultural systems. A review. *Agronomy for Sustainable Development* **36**(2), 1-12 (2016).
35. E. Strobach and **G. Bel**, The contribution of internal and model variabilities to the uncertainty in CMIP5 decadal climate predictions, *Climate Dynamics* **49** (9-10), 3221-3235 (2017).
36. H. Yizhaq, Ilan Stavi, Moshe Shachak, and **G. Bel**, Geodiversity increases ecosystem durability to prolonged droughts, *Ecological Complexity* **31**, 96-103 (2017).

37. E. Strobach and **G. Bel**, Quantifying the uncertainties in an ensemble of decadal climate predictions. Journal of Geophysical Research: Atmospheres **122**, 13191-13200 (2017).
38. **G. Bel**, B. Alexandrov, A. Bishop and K. Rasmussen, Double-period breathers in a driven and damped lattice. Physical Review E 98, 062205 (2018).
39. A. Cochavi, S. Rachmilevitch and **G. Bel**, The effect of irrigation regimes on plum (Prunus cerasifera) root system development dynamics. *Plant Biosystems* (2019).
40. H. Yizhaq, **G. Bel**, S. Silvestro, T. Elperin, J. Kok, M. Cardinale, A. Provenzale, and I. Katra, The origin of the transverse instability of aeolian megaripples. *Earth and Planetary Science Letters* **512**, 59–70 (2019).
41. E. Strobach and **G. Bel**, Regional Decadal Climate Predictions Using an Ensemble of WRF Parameterizations Driven by the MIROC5 GCM. *Journal of Applied Meteorology and Climatology* **58**, 527–549 (2019).
42. **G. Bel** and M. M. Bandi, Geographic dependence of the Solar Irradiance Spectrum at Intermediate to High Frequencies. *Phys. Rev. Applied* **12**, 024032 (2019).
43. E. Strobach and **G. Bel**, Learning algorithms allow for improved reliability and accuracy of global mean surface temperature projections, *Nature Communications* **11**, 1–7 (2020).
44. D. Wexler, N. S. Gov, K. O. Rasmussen and G. Bel, Dynamics and escape of active particles in a harmonic trap, *Physical Review Research* **2**, 013003 (2020).
45. G. Weissman, **G. Bel**, U. Yermiyahu, A. Ben-Gal, B. S. Alexandrov, K. Ø. Rasmussen, and O. Dahan, Increased salinity of irrigation water enhances nitrate transport to deep unsaturated soil, *Vadose Zone Journal*, **19**, e20041 (2020).
46. R. Vangara, K. Ø. Rasmussen, D. N. Petsev, **G. Bel** and B. S. Alexandrov, Identification of anomalous diffusion sources by unsupervised learning, *Physical Review Research* **2**, 023248 (2020).
47. **G. Bel**, A. Zilman and A. B. Kolomeisky, Different time scales in dynamic systems with multiple outcomes, *Journal of Chemical Physics*, Accepted (2020).

Unrefereed professional articles and publications

1. **G. Bel** and B. Rosenstein, Dynamics of disordered vortex matter in type-II superconductors, cond-mat/0509.677 (2005).

• **Lectures and Presentations at Meetings and Invited Seminars**

Invited plenary lectures at conferences/meetings

2006, Ergodicity Breaking in Continuous Time Random Walk, First passage and extreme value problems in random processes, Isaac Newton Institute for Mathematical Sciences, Cambridge, UK

2009, Photon Counting Statistics in Single Molecule Spectroscopy, Single Molecule Dynamics, Telluride Science Research Center, Telluride, CO, USA

2011, Frequency Resolved Photon Counting Statistics in Single Molecule Flourescnce Spectroscopy, Telluride Science Research Center, Telluride, CO, USA

2012, Desertification as a Gradual Regime Shift in Spatially Extended Ecosystems, 4th International conference Drylands, Desert and Desertification, Sede Boqer Campus, ISRAEL
2014, Critical and Gradual Regime Shifts in Spatially Extended Ecosystems, 5th International conference Drylands, Desert and Desertification, Sede Boqer Campus, ISRAEL
2015, Gradual Regime Shifts in Fairy Circles, International Symposium on Fairy Circles, Wolwedans Namibrand Nature Reserve, Namibia.
2016, Gradual Regime Shifts in Spatially Extended Systems, Warwick University, UK.
2017, Regime Shifts in Spatially Extended Systems, Potsdam – Tau University Workshop, Tel-Aviv University, Israel.

Presentation of papers at conferences/meetings (oral or poster)
(poster) G. Bel and B. Rosenstein, 2005, Dynamics of disordered vortex matter, LT 24, Orlando, FL, USA
(poster) G. Bel and E. Barkai, 2005, Weak Ergodicity Breaking, Ageing, Luxemburg
(oral) G. Bel and E. Barkai, 2007, Ergodicity Breaking in Continuous Time Random Walk, StatPhys 23, Genova, Italy
(oral) G. Bel and I. Nemenman, 2009, Anomalous diffusion in coupled stochastic processes, APS March Meeting, Pittsburgh, PA, USA
(oral+poster) G. Bel, B. Munsky and I. Nemenman, 2009, Simplicity of Completion Time Distributions, q-bio, Santa Fe, NM, USA
(oral) G. Bel and F. Brown, 2010, Frequeny Resolved Single Molecule Spectroscopy, APS March Meeting, Portland, OR, USA
(oral) G. Bel and Y. Ashkenazy, 2012, The relation between open ocean current statistics and the temporal correlations of the wind, Symposium on Geophysical Fluid Dynamics, Sede Boqer Campus, Israel.
(oral) G. Bel and Y. Ashkenazy, 2013, The relation between open ocean current statistics and the temporal correlations of the wind, APS March Meeting, Baltimore, USA.
(oral) G. Bel and H. Yizhaq 2014, The effects of quenched disorder on critical transitions in spatially extended systems, IPS Annual Meeting, Ben-Gurion University, Israel.
(oral) G. Bel, 2017, Regime shifts in spatially extended systems, IGS Annual meeting, Ben-Gurion University, Israel.
(oral) G. Bel, 2019, Double period breather, APS March meeting, Boston MA, USA.
(oral) G. Bel, 2019, Improved climate projections, EGU 2019, Vienna, Austria.

Presentations at informal international seminars and workshops
2009, Bacteria meet physics, Aspen Center for Physics, USA

Seminar presentations at universities and institutions
2005, Chemistry – University of California, Santa Barbara, CA, USA

2006, Physics – Bar-Ilan University, Ramat-Gan, Israel

2009, Physics – Technion, Israel

2009, Chemistry – Technion, Israel

2009, Physics – Bar-Ilan University, Israel

2009, Chemistry – Bar-Ilan University, Israel

2009, Physics – Tel-Aviv University, Israel

2009, Physics – Ben-Gurion University, Israel

2009, Physics – Hebrew University, Israel

2009, Physics – Nuclear Research Center Negev, Israel

2009, Physics – Weizmann Institute of Science, Rehovot, Israel

2009, Physics – H. I. T., Holon, Israel

2009, Molecular Physics – Leiden University, Leiden, The Netherlands

2009, Chemical Physics – E. T. H., Zurich, Switzerland

2009, Theoretical Biology – Los Alamos National Laboratory

2009, Physics – Bar-Ilan University, Ramat-Gan, Israel

2009, BIDR, Physics – Ben-Gurion University, Sde Boker, Israel

2013, Physics – The Hebrew University, Israel

2013, Institute for Quantum Optics – Ulm University, Germany

2014, Okinawa Institute of Science and Technology, Japan – Two invited seminars

2014, Earth and Planetary Sciences – Weizmann Institute of Science, Rehovot, Israel

2015, Chemistry Department – Bar-Ilan University, Ramat-Gan, Israel

2015, Physics Department – Ben-Gurion University, Beer Sheva, Israel

2017, Physics Department – Toronto University, Toronto, Canada

2017, Earth Sciences – The Hebrew University, Jerusalem, Israel

2019, Earth and Planetary Sciences—Harvard University, Boston MA, USA

• **Research Grants**

2011–2015, European Comission, FP7, Marie Curie CIG, Golan Bel, Stochastic Modeling of Spatially Extended Ecosystems and Ecological and Climate Data Analysis, 4 years – 25k Euro/year – Total 100k Euro. PI (individual).

2012–2013, German-Israeli Foundation for Scientific Research and Development, Golan Bel, Frequency-Resolved Single-Molecule Spectroscopy , 1.5 years – 31k Euro/year – Total 31k Euro. PI (individual).

2012–2013, Daniel E. Koshland Fund, Root system development—a new perspective $20k. PI (together with Shimon Rachmilevich, BGU).

2015–2016, Daniel E. Koshland Fund, Effects of Soil Heterogeneity on Nutrients Redistribution $25k. PI (together with Shai Arnon, BGU)

2015–2016, Reliance Industries Ltd., Physics of Algal Biomass Production $50k. Collaboration with the largest private sector company in India. PI (together with Yair Zarmi and Jeffrey Gordon, BGU).

2016–2019, Ministry of Agriculture, The root of the matter, total budget $1.5M, GB GB's budget $30k/year for three years.

• Synopsis of research, including reference to publications and grants in above lists
My field of research is statistical and non-equilibrium theoretical physics. The recent projects focus on problems in environmental physics where statistical physics and non-linear dynamics play an important role. Other projects focus on the foundations of these fields.
Ocean current statistics: Using the Ekman layer model for the integrated currents, we investigated, analytically and numerically, the relation between the wind distribution and its temporal correlations and the statistics of the open ocean currents. We found that temporally long-range correlated wind results in currents whose statistics is proportional to the wind-stress statistics. On the other hand, short-range correlated wind leads to Gaussian distributions of the current components, regardless of the stationary distribution of the winds, and therefore, to a Rayleigh distribution of the current amplitude if the wind stress is isotropic. An interesting result is the existence of an optimum in the amplitude of the ocean currents as a function of the correlation time of the wind stress. The results were validated using an oceanic general circulation model. The effects of periodicity in the wind-stress were also studied and a modification of the Ekman layer model was suggested to eliminate the non-physical divergence of the currents due to resonance. For more details see publications 19 and 28.
Climate predictions using learning algorithms:
Ensembles of climate models are commonly used to improve decadal climate predictions and assess the uncertainties associated with them. Weighting the models according to their performances holds the promise of further improving their predictions. We considered an ensemble of decadal climate predictions to demonstrate the ability of sequential learning algorithms (SLAs) to reduce the forecast errors and reduce the uncertainties. Three different SLAs were considered, and their performances were compared with those of an equally weighted ensemble, a linear regression, and the climatology. Predictions of four different variables—the surface temperature, the zonal and meridional wind, and pressure—were considered. The spatial distributions of the performances were presented, and the statistical significance of the improvements achieved by the SLAs was tested. The reliability of the SLAs was also tested, and the advantages and limitations of the different measures of the performance were discussed. It was found that the best performances of the SLAs are achieved when the learning period is comparable to the prediction period. The spatial distribution of the SLAs performance showed that they are skillful and better than the other forecasting methods over large continuous regions. This finding suggests that, despite the fact that each of the ensemble models is not skillful, they were able to capture some physical processes that resulted in deviations from the climatology and that the SLAs enabled the extraction of this additional information. For more details see publications 27, 35, and 41.
Reducing uncertainties in future climate predictions: One of the grand challenges for climate scientists nowadays is to provide accurate climate predictions along with quantification of uncertainties. Uncertainties in climate predictions are extracted using two main schemes. The first involves running the same model simulation using different initial conditions and establishing the uncertainty from the distribution of the results. The second scheme involves the distribution of the results of different models. While the use of an ensemble of simulations outperforms the individual simulations in predicting the averages of physical observables, it was always understood that the uncertainties are not fully meaningful as they do not reflect the actual uncertainty but rather the ensemble spread. We suggested a method which relies on studying the relation between the ensemble spread and the actual uncertainty (the error range of the predictions) in the past. We showed that our method significantly increases the reliability of the predictions both for equally weighted and performance based weighted ensembles. Applying the method to long-term climate projections is shown to reduce the uncertainties associated with future global mean surface

temperature by up to 80% compared with those reported in the IPCC. For more details see publications 37 and the unpublished work (currently under review, arXiv:1904.06773).
Fluctuations in renewable energy production: One of the limiting factors in renewable energy production is the fluctuation at different time scales which affect the stability of the network. Therefore, an analysis of the fluctuations and characterization of the errors in models which attempt to predict the power produced are crucial. Our works on wind and solar energy productions quantified the nature of the fluctuations (and explained their origin) and suggested improvement to the state-of-the-art models in order to reduce the errors. For more details see publications 31 and 42 (42 was accepted for publication and is available at arXiv:1810.13269).
Algae culture growth in flat-plate bioreactors: Qualitative characteristics of biomass production in ultra-high density algal bioreactors with a small optic path (specifically, thin flat-plate reactors) were analyzed and explained in terms of models, which combine the random motion of cells across the optic path with simple models for the photosynthetic process. An analogy between flashing light illumination and the light regime experienced by the randomly moving cells provides basic insight into the important role of time scales in reactor performance. The emergence of an optimal culture density (OCD), at which the volumetric and areal production rates are maximal, is understood in simple terms. It is shown to be the results of the interplay between the time spent in the illuminated zone and the time needed for the harvesting of the photons for the photosynthetic process. For more details see book chapter 1.
Gradual regime shifts in spatially extended ecosystems: Ecosystem regime shifts are regarded as abrupt global transitions from one stable state to an alternative stable state, induced by slow environmental changes or by global disturbances. Spatially extended ecosystems, however, can also respond to local disturbances by the formation of small domains of the alternative state. Such a response can lead to gradual regime shifts involving front propagation and the coalescence of alternative-state domains. When one of the states is spatially patterned, a multitude of intermediate stable states appears, giving rise to step-like gradual shifts with extended pauses at these states. Using a minimal model, we study gradual state transitions and show that they precede abrupt transitions. We propose indicators to probe gradual regime shifts, and suggest that a combination of abrupt-shift indicators and gradual-shift indicators might be needed to unambiguously identify regime shifts. Our results are particularly relevant to desertification in drylands where transitions to bare soil take place from spotted vegetation, and the degradation process appears to involve step-like events of local vegetation mortality caused by repeated droughts. For more details see publications 18, 20—22, 29, 30 and 32.
Effects of jamming on transport through nano-channels: Many biological channels perform highly selective transport without direct input of energy and without transitions from a ’closed’ to an ’open’ state during transport. Mechanisms of selectivity of such channels serve as an inspiration for the creation of artificial nano-molecular sorting devices and bio-sensors. To elucidate the transport mechanisms, it is important to understand the transport on the single molecule level in the experimentally relevant regime when particles are crowded in the channel. We analyzed the effects of inter-particle crowding on the non-equilibrium transport times through a finite-length channel by means of analytical theory and computer simulations. For more details see publication 13 and 17.
Temporal characteristics of kinetic proofreading: Biochemical processes typically involve huge numbers of individual reversible steps, each with its own dynamical rate constants. For example, kinetic proofreading processes rely upon numerous sequential reactions in order to guarantee the precise construction of specific macromolecules. We studied the transient properties of such systems and fully characterized their completion time distributions. We found that as the system size grows, the completion time behavior simplifies: it becomes either deterministic or exponentially distributed, with a very narrow

transition between the two regimes. In both regimes, the dynamical complexity of the full system is trivial compared to its apparent structural complexity. In particular, these findings suggest not only that one may not be able to understand individual elementary reactions from macroscopic observations, but also that such understanding may be unnecessary. We have also studied the dynamical properties of discrete stochastic two branch kinetic proofreading schemes. Using the Laplace transform of the corresponding chemical master equation, we obtained an analytical solution for the completion time distribution. We also showed that, for a wide range of parameters, a process distinguishing between two different products can be reduced to a much simpler three point process. Our results allow for the systematic study of the interplay between specificity and completion times as well as testing the validity of the kinetic proofreading model in biological systems. For more details see publications 15 and 16.

Anomalous diffusion in coupled over-damped Langevin processes: Inspired by problems in biochemical kinetics, we studied statistical properties of an over-damped Langevin process whose friction coefficient depends on the state of a similar, unobserved process. Integrating out the latter, we derived the long time behavior of the mean square displacement. Anomalous diffusion is found. Since the diffusion exponent cannot be predicted using a simple scaling argument, anomalous scaling appears as well. We also found that the coupling can lead to ergodic or non-ergodic behavior of the studied process. We compared our theoretical predictions with numerical simulations and found an excellent agreement. The findings caution against treating biochemical systems coupled with unobserved dynamical degrees of freedom by means of standard, diffusive descriptions. For more detail see publication 14.

Single molecule spectroscopy: We introduced the generating function technique for calculation of single molecule photon emission statistics in systems governed by multi-level quantum dynamics. This opens up the possibility to study phenomena that are outside the realm of purely stochastic and mixed quantum-stochastic models. In particular, this methodology allows for calculation of photon statistics for photons emitted from a particular transition and which are subject to quantum coherence. Several model calculations illustrate the generality of the technique and highlight quantitative and qualitative differences between quantum mechanical models and related stochastic approximations when they arise. Calculations suggest that studying photon statistics as a function of photon frequency has the potential to reveal more about system dynamics than the usual broadband detection schemes. In order to better understand the interaction of a single molecule with light, we derived the moment generating function for photon emissions from a single molecule driven by laser excitation. The frequencies of the fluoresced photons are explicitly considered. Calculations are performed for the case of a two level dye molecule, showing that measured photon statistics will display a strong and non-intuitive dependence on detector bandwidth. Moreover, it is demonstrated that the anti-bunching phenomenon, associated with negative values of Mandel's Q-parameter, results from correlations between photons with well separated frequencies. For more details see publications 9, 12 and 26.

Weak ergodicity breaking: Single molecule tracking became an essential tool in almost every field of science. Many experiments tracking single molecules have reported anomalous diffusion. In order to extract new and useful information from those experiments, it is important to study the properties of anomalous diffusion models and to find characteristics which can distinguish between the different models. Continuous time random walk (CTRW) models are widely used to model diffusion in condensed matter. There are two classes of such models, distinguished by the convergence or divergence of the mean waiting time. Systems with a finite average sojourn time are ergodic and thus Boltzmann–Gibbs statistics can be applied. We investigated the statistical properties of CTRW models with an infinite average sojourn time; in particular, the occupation time

probability density function is obtained. It is shown that, in the non-ergodic phase, the distribution of the occupation time of the particle on a given lattice point exhibits a bimodal U or trimodal W shape, related to the arcsine law. The key points are as follows: (a) In a CTRW with a finite or infinite mean waiting time, the distribution of the number of visits on a lattice point is determined by the probability that a member of an ensemble of particles in equilibrium occupies the lattice point. (b) The asymmetry parameter of the probability distribution function of occupation times is related to the Boltzmann probability and to the partition function. (c) The ensemble average is given by Boltzmann–Gibbs statistics for either finite or infinite mean sojourn time, when detailed balance conditions hold. (d) A non-ergodic generalization of the Boltzmann–Gibbs statistical mechanics for systems with an infinite mean sojourn time was found. We have also studied the concept of weak ergodicity breaking in the context of deterministic dynamics. We showed that weak ergodicity breaking describes a system whose dynamics is governed by a nonlinear map which generates sub-diffusion deterministically. For more details see publications 5–8.

Dynamics of disordered vortex matter: We considered the dynamics of homogeneous moving vortex matter beyond the linear response. Our framework is the time dependent Ginzburg - Landau equation within the lowest Landau level approximation. Both disorder and thermal fluctuations are included using the Martin-Siggia-Rose formalism. We determined the critical current as a function of magnetic field and temperature. The critical current defines a surface in the current-magnetic field-temperature space which separates between the dissipative moving vortex matter regime (flux flow) and an amorphous vortex ”glass”. Both the thermal depinning and the depinning by a driving force were taken into account. The static irreversibility line, determined by the vanishing critical current, was compared to experiments in layered HTSC and is consistent with the one obtained using the replica approach. The non-Ohmic I-V curve (in the depinned phase) was obtained and compared with an experiment in layered superconductors and thin films. For more details see publications 10, 11 and unpublished work available at cond-mat/0509.677.

Topological defects in unconventional superconductors: We have studied new possible vortices in p-wave superconductors. Due to the fact that the order parameter is a vector and not a scalar, we showed that it is possible to have a vortex in which the order parameter does not vanish at the center (soft core vortex). We have studied the shapes of the new kinds of vortices and showed that the kappa parameter (the ratio between the penetration depth and the coherence length) determines the structure of the vortex. We also showed that alternating dia/para magnetic domains appear in a p-wave superconductor which is subject to a magnetic field in opposite directions at its ends. We have studied analytically and numerically the relaxation of a quenched normal spot in a type-II superconductor. Various instabilities accompanying the recovery of superconductivity were found. It was shown that the relaxation of the normal spot starts with the appearance of a microscopic instability triggering the creation of vortex clusters. For more details see publications 1–4.