CURRICULUM VITAE AND LIST OF PUBLICATIONS

• Personal Details

Name: Golan Bel

Date and place of birth: 26/10/1973 Beer Sheva, Israel

Regular military service: 22/03/1992-07/03/1995

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 Boker Campus, Midreshet Ben-Gurion 84990 ISRAEL, phone:+972-8-659-6845

Address at home: P.O.Box 111, Midreshet Ben-Gurion 8499000 ISRAEL

• Education

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

Ph.D. -2001-2005, Bar-Ilan University, Physics

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 Boker Campus, ISRAEL

2013-Present – Mendel Wasserman career development chair in desert studies

2012-Present – Senior Lecturer

2010-2012 – Lecturer

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

(a) Referee for scientific or professional journal

Physical Review Letters, Physical Review E, 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.

(b) Membership in professional/scientific societies

American Physical Society, European Physical Society

(c) Positions in academic administration

2011—Present, Organizer of the department seminars

2013 —Present, Chair of the department teaching committee

• Educational activities

(a) Courses

Graduate Courses, Department of Solar Energy and Environmental Physics, Ben-Gurion University of the Negev:

Stochastic Processes in Physics, Introduction to Statistics, Statistical Methods in Climate Research, Statistical Methods in Climate Research-II, Physics I (for medicine students in the main campus).

(b) Courses taught as teaching assistant

Undegraduate Courses, Physics Department, Bar-Ilan University:

Electric Circuits, Electronics, Electrodynamics and the special theory of relativity

Graduate Courses, Physics Department, Bar-Ilan University:

Advanced Statistical Mechanics

(c) Research Students

Udi Strubach, Ph. D. , Ben-Gurion University of the Negev.

Yuval Zelnik, Ph. D. , Ben-Gurion University of the Negev, co-supervised with Prof. E. Meron.

• Awards, Citations, Honors, Fellowships

(a) Honors, Citation Awards

2014 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 Dean's Fellowship for Ph.D. Students.

2001 Wolf Foundation- Scholarship for excellence.

2000 Dean's List –top students in the faculty of exact sciences.

2000 Physics Department - top student of the physics department.

2000 Faculty of Natural Science - Jacobs Award.

(b) Fellowships

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

• Scientific Publications

(a) 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. **G. Bel** and E. Barkai, Weak ergodicity breaking in the continuous time random walk, Phys. Rev. Lett. **94**, 240602 (2005).

4. **G. Bel** and E. Barkai, Random walk to a non-ergodic equilibrium concept, Phys. Rev. E **73**, 016125 (2006).

5. **G. Bel** and E. Barkai, Occupation times and ergodicity breaking in biased continuous time random walks, J. Phys.: Condens. Matter, 17, S4287–S4304 (2005).

6. **G. Bel** and E. Barkai, Weak ergodicity breaking with deterministic dynamics, Europhys. Lett., **74**, 15 (2006).

7. **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).

8. **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).

9. **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).

10. A. Zilman, J. Pearson and **G. Bel**, Effects of jamming on transport times in nano-channels, Phys. Rev. Lett. **103**, 128103 (2009).

11. **G. Bel** and I. Nemenman, Ergodic and non-ergodic anomalous diffusion in coupled stochastic processes, New Journal of Physics **11**, 083009 (2009).

12. B. Munsky, **G. Bel** and I. Nemenman, Specificity and Completion Time Distributions of Biochemical Processes, J. Chem. Phys. **131**, 235103 (2009).

13. **G. Bel**, B. Munsky and I. Nemenman, The simplicity of completion time distributions for common complex biochemical processes, Physical Biology **6**, 016003 (2010).
Featured in: ScienceDaily, The Chemisty Pot, PhysOrg.com and others.

14. A. Zilman and **G. Bel**, Crowding effects on transport through nano-channels, J. of Phys.:Cond. Matt. 22, 454130 (2010).

15. **G. Bel**, A. Hagberg and E. Meron, Gradual regime shifts in spatially extended ecosystems, Theoretical Ecology **5**, 591-604 (2012).

16. **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).

17. 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).
18. S. Kinast, Y. Zelnik, **G.Bel** and E. Meron, Interplay between Turing mechanisms can increase pattern diversity, Phys. Rev. Lett. **112**, 078701 (2014).
19. H. Yizhaq, S. Sela, T. Svoray, S. Assouline and **G. Bel**, Effects of heterogeneous soil-water diffusivity on vegetation pattern formation, Water Resour. Res. **50**, 5743-5758 (2014).
20. **G. Bel** and Y. Ashkenazy, The role of psammophilous plants in sand dunes dynamics, J. Geophys. Res. Earth Surf., **119**, 1636–1650 (2014).

(b) Refereed conference proceedings publications

1. B. Ya. Shapiro, B. Rosenstein, I. Shapiro and **G. Bel**, Coreless vortex in p-wave superconductor, Physica C **388-389**, 515 (2003).
2. B. Shapiro, **G. Bel**, B. Rosenstein and I. Shapiro, Hot Spot in type II superconductors: Dynamics and Instabilities, Physica C **404**, 335 (2004).
3. **G. Bel** and B. Rosenstein, Dynamics of the vortex glass transition, AIP conference proceedings **850**, 833 (2006).

(c) 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).

(d) 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).

• Lectures and Presentations at Meetings and Invited Seminars not followed by Published Proceedings

(a) Invited plenary lectures at conferences/meetings

2012, Desertification as a Gradual Regime Shift in Spatially Extended Ecosystems, 4th International conference Drylands, Desert and Desertification, Sede Boqer Campus, ISRAEL
2011, Frequency Resolved Photon Counting Statistics in Single Molecule Flourescnce Spectroscopy, Telluride Science Research Center, Telluride, CO, USA
2009, Photon Counting Statistics in Single Molecule Spectroscopy, Single Molecule Dynamics, Telluride Science Research Center, Telluride, CO, USA

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

(b) Presentation of papers at conferences/meetings

(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 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 F. Brown, 2010, Frequeny Resolved Single Molecule Spectroscopy, APS March Meeting, Portland, OR, 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 I. Nemenman, 2009, Anomalous diffusion in coupled stochastic processes, APS March Meeting, Pittsburgh, PA, USA

(oral) G. Bel and E. Barkai, 2007, Ergodicity Breaking in Continuous Time Random Walk, StatPhys 23, Genova, Italy

(poster) G. Bel and E. Barkai, 2005, Weak Ergodicity Breaking, Ageing, Luxemburg

(poster) G. Bel and B. Rosenstein, 2005, Dynamics of disordered vortex matter, LT 24, Orlando, FL, USA

(c) Presentations at informal international seminars and workshops

2009, Bacteria meet physics, Aspen Center for Physics, USA

(d) Seminar presentations at universities and institutions

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

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

2013, Physics – The Hebrew University, Israel

2013, Institute for Quantum Optics – Ulm University, Germany

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

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

2005, Chemistry – University of California, Santa Barbara, CA, 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

2012, German-Israeli Foundation for Scientific Research and Development, Golan Bel, Frequency-Resolved Single-Molecule Spectroscopy , 1 year – 31k Euro/year – Total 31k Euro

2012-2013, Daniel E. Koshland Fund, Root system development—a new prespective $20k.

• **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: We studied the statistics of wind-driven open ocean currents. 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 are being studied and show interesting interplay between the periodicty and Corilolis time scales.

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 are probably underestimated. The common approach in climate prediction is to consider all members of the ensemble of models as equally reliable, although it is widely recognized that this assumption ignores quality differences between the different models. Several studies showed that even naive construction of ensembles provides insights into the hierarchy of climate model components and the Atmosphere-Ocean-Global-Circulation-Models (AOGCMs). Using the record of past climate observations we build weighted forecasting ensembles adjusted to specific climate variables (e.g., monthly averages of surface temperature, precipitation, sea level, snow cover) and specific grid locations. Inter-comparison of the models is done on the basis of the weights assigned to the models in predicting the various local and global observables. This analysis will guide the construction of improved climate models. The use of a dynamic weighting function ensures a continuous outcome, which is crucial for establishing mitigation and adaptation strategies.

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) are 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, at which the volumetric and areal production rates are maximal, is understood in simple terms. While higher density implies an increase in the number of photosynthesizing cells, it leads to narrowing of the illuminated (photic) zone, hence to a decrease in the time spent by these cells in the photic zone. When the time spent by cells in the photic zone is longer than the time needed to collect the photons required for the photosynthetic process, the addition of cells increases the volumetric production rate. When the time spent by cells in the illuminated zone falls below the time needed for the collection of photons, the volumetric production rate is decreased. The combined effects of changes in density are the cause of the emergence of an optimal culture density (OCD). At the OCD,

the time spent by cells in the thin illuminated layer of the culture and the time needed for the collection of the photons required for the photosynthetic process coincide.

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.

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.

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.

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 behaviour of the mean square displacement. Anomalous diffusion is found. Since the diffusion exponent can not 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.

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.

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 subdiffusion deterministically.

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.

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 structre 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.

• **Present Academic Activities**

The relation between the statistics of open ocean currents and the temporal correlations of the wind, In collaboration with Prof. Y. Ashkenazy, 1 year

The role of stochastic effects on the dynamics of vegetation in the presence of localized states, In collaboration with Prof. Ehud Meron, 4-5 years

Reducing the uncertainties in climate model predictions, Udi Strubach (Ph.D. student), 4 years

Transport through nano-channels, Anton Zilman, Physics Department, Toronto University, 6-9 months

Frequency resolved single molecule spectroscopy, Frank Brown, University of California, Santa Barbara, 3-6 months

Articles to be published

Submitted:

1. H. Yizhaq and **G. Bel**, Effects of quenched disorder on critical transitions in pattern-forming systems (2014).
2. T. Turkeltaub, D. , G. Bel and O. Dahan, Examination of groundwater recharge with a calibrated/validated flow model of the deep vadose zone (2014).
3. E. Strobach and **G. Bel**, Improvement of Global Climate Projections and Reducing their Uncertainties Using a Sequential Learning Algorithm (2014).
4. Y. Zelnik, E. Meron and **G. Bel**, Gradual Regime Shifts in Fairy Circles (2014).

In preparation:

1. **G. Bel** and F. L. Brown, Frequency resolved photon counting statistics in single molecule flouresence including vibrational levels.

2. A. Zilman and **G. Bel**, Distinguishing between models of transport through nano-channels using single molecule measurements.

5. Y. Zarmi and **G. Bel**, Time scales in mathematical modeling of algae biomass production.

6. H. Yizhaq and **G. Bel**, Stable scale free vegetation patterns.

7. H. Yizhaq and G. Bel, Vegetation patterns --from self-organized to imposed due to soil heterogeneity.