Ben-Gurion University of the Negev

The Chemistry department announces

A series of lectures given by the

Prof. Massimiliano Di Ventra

University of California - San Diego

as part of the Faculty of natural sciences Distinguished Scientist Visitors Program.

Schedule & Abstracts attached below.

Massimiliano Di Ventra did his PhD studies at the EPFL (Switzerland) in 1997. He has been Research Assistant Professor at Vanderbilt University and Visiting Scientist at IBM T.J. Watson Research Center before joining the Physics Department of Virginia Tech in 2000 as Assistant Professor. He moved to the Physics Department of the University of California, San Diego, in 2004. Di Ventra's research interests are in the theory of electronic and transport properties of nanoscale systems, non-equilibrium statistical mechanics, DNA sequencing/polymer dynamics in nanopores, and memory effects in nanostructures for applications in unconventional computing and biophysics. He has been invited to deliver more than 180 talks worldwide on these topics. He serves on the editorial board of several scientific journals and has won numerous awards and honors, including the NSF Early CAREER Award, the Ralph E. Powe Junior Faculty Enhancement Award, fellowship in the Institute of Physics and the American Physical Society. He has published more than 140 papers in refereed journals (12 of these are listed as ISI Essential Science Indicators highly-cited papers of the period 2002-2012), co-edited the textbook Introduction to Nanoscale Science and Technology (Springer, 2004) for undergraduate students, and he is single author of the graduate-level textbook Electrical Transport in Nanoscale Systems (Cambridge University Press, 2008).

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Date	Time & Place	Title
Wednesday Dec. 11	1. Nano-center auditorium 12:00 , Bldg 51 Room 15	“Quantum analogies in ionic transport through nanopores”
	2. Tutorial lecture #1 Chemistry seminar room 15:30- 17:30, Bldg 29 Room 307	“Fundamentals of electron transport in nano-structures I: Different approaches”.
Thursday Dec. 12	Tutorial lecture #2 Chemistry seminar room 10:00- 12:00, , Bldg 29 Room 307	“Fundamental of transport II: current-induced effects”
Sunday Dec. 15	Special seminar 14:00, physics seminar room, Building 54 Room 207	“Quantum transport in Ultra-Cold atoms”
Tuesday Dec. 17	Special Seminar 14:00 Alon building seminar room Building 37 Room 202	“Memcomputing: a brain-inspired computing paradigm to store and process information on the same physical platform”

Tutorial Course: Fundamentals of electronic transport in nanoscale junctions

1st meeting: “Fundamentals of transport I: different approaches”

Wednesday Dec.11 15:00-17:00 Chemistry seminar room

Landauer, Kubo and microcanonical pictures of transport: assumptions, comparisons and differences. Chapters 1-3 and 7 of [1].

2nd meeting: “Fundamental of transport II: current-induced effects”

Thursday Dec.12 10:00 Chemistry seminar room

Current-induced forces, electron and ionic heating, turbulence of the electron liquid. Chapters 6 and 8 of [1].

[1] M. Di Ventra, *Electrical transport in nanoscale systems*, (Cambridge University Press, 2008).

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Quantum analogies in ionic transport through nanopores

Wednesday Dec. 11, 12:00 Nano Center Auditorium

Ionic transport in nanopores or nanochannels is key to many cellular processes and is now being explored as a method for DNA/polymer sequencing and detection [1]. Although apparently simple in its scope, the study of ionic dynamics in confined geometries such as nanopores - when the microscopic details of the surrounding environment are properly taken into account - has revealed interesting new phenomena that have an almost one-to-one correspondence with the quantum regime. The picture that emerges is that ions can form two `quasi-particle' states, one in which they surround themselves with other ions of opposite charge – ionic atmosphere - and one in which semi-bound water molecules form layers at different distances from the ions - hydration layers. While the first quasi-particle state has less relevance in experiments of ionic flow in nanochannels that are presently pursued, the second state gives rise to two additional effects. In the first, which is a single quasi-particle effect, the ionic conductance through a nanopore of given radius is predicted to be "quantized" as a function of pore radius, with the corresponding "quantization units" not related to universal constants - like the Plank constant, *h*, and the elementary charge *e*, but rather to the radii of the hydration layers [2,3]. The second effect instead involves the many-body interaction among ionic quasi-particles of the same sign, and occurs when the pore has a finite capacitance to accommodate ions so that there is a threshold concentration beyond which ions of the same sign are not energetically allowed to enter the pore [4]. This effect is the equivalent of the Coulomb blockade effect one encounters in mesoscopic and nanoscopic systems of finite capacitance set out of equilibrium. Like the same effect in the electron transport case, the ionic counterpart appears only in the "quantum" regime, namely when the hydration layers forming the ionic quasi-particles need to break in order to pass through at least one of the openings of the pore. I will discuss these phenomena and the conditions under which they may be detected. Along the way, I make the analogy with the electronic quantum transport case, pointing out both the similarities and differences. Since nanopores are being considered for a host of technological applications in DNA sequencing and detection, we expect these phenomena will become very much relevant in this field and their understanding paramount to progress [5].

[1] M. Zwolak, M. Di Ventra, *Rev. Mod. Phys*. 2008, **80**, 141.
[2] M. Zwolak, J. Lagerqvist, M. Di Ventra, *Phys. Rev. Lett.* **103**, 128102 (2009).
[3] M. Zwolak, J. Wilson, M. Di Ventra, *Journal of Physics: Condensed Matter* **22**, 454126 (2010).
[4] M. Krems and M. Di Ventra, *Journal of Physics: Condensed Matter* **25** (6), 065101 (2013).
[5] A. Meyertholen and M. Di Ventra, arXiv:1305.7450

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Transport in ultra-cold atoms

Sunday Dec. 15, 14:00 Physics Seminar room

Spin statistics is a fundamental physical law of quantum mechanics. I will show that, when competing with particle interactions, it gives rise to interesting non-equilibrium phenomena [1], such as non-classical flow patterns of Fermi gases [2], dynamical conducting-nonconducting transitions [3], negative temperatures and current instabilities [4]. All these phenomena can be verified by loading ultra-cold atoms into artificial optical lattices.

[1] M. Di Ventra, *Electrical transport in nanoscale systems*, (Cambridge University Press, 2008).

[2] M. Beria, Y. Iqbal, M. Di Ventra, and M. Mueller, arxiv:1306.0422

[3] C.-C. Chien, D. Gruss, M. Di Ventra, and M. Zwolak, New J. Phys. (in press).

[4] S. Peotta and M. Di Ventra, arxiv:1303.6916

Memcomputing: a brain-inspired computing paradigm to store and process information on the same physical platform

Tuesday Dec. 17, 14:00 Alon building seminar room

Conventional computers store information in volatile — random-access memory — and non-volatile — hard drives and solid-state drives — memories. A central processing unit (CPU) then sequentially processes the data. This mode of operation requires a significant amount of information transfer to and from the CPU and the memories. This necessarily imposes limits on the performance and scalability of the architecture. A significant improvement in computing performance therefore requires a fundamental change in approach, moving from the well-established von Neumann architecture (or those based on it) to novel and efficient massively parallel computing schemes, which would most likely take advantage of non-traditional electronic devices.

I will discuss the implementation of a novel approach to computing named memcomputing [1] inspired by the operation of our own brain. Memcomputing — computing using memory circuit elements or memelements [2] — satisfies important requirements: (i) it is intrinsically massively parallel, (ii) its information-storing and computing units are physically the same, and (iii) it does not rely on active elements as the main tools of operation. I will discuss the various possibilities offered by memcomputing, the criteria that need to be satisfied to realize this paradigm, and provide several examples showing the massively-parallel solution of optimization problems.

[1] M. Di Ventra and Y.V. Pershin, *Nature Physics*, **9**, 200 (2013).

[2] M. Di Ventra, Y.V. Pershin, and L.O. Chua, *Proc. IEEE*, **97**, 1717 (2009).