I will discuss a novel computing paradigm we named memcomputing inspired by the operation of our own brain. Memcomputing — computing using memory circuit elements or memelements — satisfies important physical 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 then introduce the notion of universal memcomputing machines (UMMs) as a class of general-purpose computing machines based on systems with memory. We have shown that the memory properties of UMMs endow them with universal computing power—they are Turing-complete—, intrinsic parallelism, functional polymorphism, and information overhead, namely their collective states can support exponential data compression directly in memory. We have proved that UMMs can solve NP-complete problems in polynomial time, and as an example I will provide the polynomial-time solution of the subset-sum problem when implemented in hardware. Even though we have not proved NP=P, the practical implementation of these UMMs would represent a paradigm shift from present von Neumann architectures bringing us closer to brain-like neural computation. In fact, I will discuss a practical CMOS-compatible realization of this computing paradigm that uses memcapacitors and we have named Dynamic Computing Random Access Memory (DCRAM).
Short CV:

Massimiliano Di Ventra obtained his undergraduate degree in Physics summa cum laude from the University of Trieste (Italy) in 1991 and did his PhD studies at the Ecole Polytechnique Federale de Lausanne (Switzerland) in 1993-1997. 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 was promoted to Associate Professor in 2003 and moved to the Physics Department of the University of California, San Diego, in 2004 where he was promoted to Full Professor in 2006. 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 200 talks worldwide on these topics (including 6 plenary/keynote presentations, 7 talks at the March Meeting of the American Physical Society, 5 at the Materials Research Society, 2 at the American Chemical Society, and 1 at the SPIE). 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 (13 of these are listed as ISI Essential Science Indicators highly-cited papers of the period 2003-2013), 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).