CURRICULUM VITAE

PERSONAL DATA

Name: **Antonio Politi**
Place of birth: **Florence (Italy)**
Date of birth**: 30 March 1955**
Nationality: **Italian**
Status: **married, a son and a daughter**

Current position**: 6th Century Chair in Physics of Life Sciences**
Institute for Complex Systems and Mathematical Biology
Department of Physics
University of Aberdeen
e-mail: a.politi@abdn.ac.uk

EDUCATION

1978 Laurea in Physics cum laude at the University of Florence

1981 PhD in Physics with a Thesis on Optical Bistability

EMPLOYMENT

1981-1992 **Researcher** (equivalent to Assistant Professor) at the Istituto Nazionale di Ottica (INO), Florence, Italy

1986 **Visiting scientist** at the IBM European Laboratory (Rüschlikon, Switzerland)

1988 **Visiting scientist** at Drexel University (Philadelphia, USA)

1992-2001 **Chief researcher** (equivalent to Associate Professor) at INO, Florence

1993 **Visiting professor** at the University of Marseille (France)

1994-2005 **Manager of the Quantum Optics Unit** at INO, Florence.

1998 **Visiting professor** at the University of Navarra (Pamplona, Spain)

2000 **Visiting professor** at the University of Nice (France)

2000 **Visiting professor** at the Ecole Normale Superieure de Lyon (France)

2001-2005 **Director of research** (equivalent to Full Professor) at INO, Florence

2005- **Director of research** (equivalent to Full Professor) at the Institute of Complex Systems (CNR-ISC) of the Italian National Research Council

2005-2011 **Director of the Florence section** of CNR-ISC

2007- **Visiting professor** at Strathclyde University (Glasgow, UK)

2011- **6th Century chair** in Physics of Life Science (Aberdeen)

2013- **Director** of the Institute for Pure and Applied Mathematics - IPAM (Aberdeen)

PROFESSIONAL ACTIVITY

2005- Member of the Managing Committee of the CNR Florence Institutes.

2008 - Member of the Scientific Committee of the Inter-Departmental Center for the Study of Complex Dynamics (CSDC) of the University of Florence.

2010 Co-founder of a joint Israeli-Italian Laboratory for Neuroscience: an initiative between the Institute of Complex Systems and the Tel Aviv University.

2013 - Member of the Executive Committee of SUPA.

2016 - Member of the International Advisory Board of the Research Center on Theoretical Physics of Complex Systems (Daejeon, Korea)

Organization of Workshops

(Co)-organizer of several international events. The list includes:

1993-1996 (with R. Livi and S. Ruffo): Three one-month International Workshops (inclusive of a standard Conference) on *Statistical Dynamics* in Florence&Prato (Italy), within the INFM-FORUM activity program on Nonlinear Physics.

2000 (with R. Livi): Extended workshop on S*tatistical Mechanics of Space-Time Chaos*, at the Max-Planck Institute for Complex Systems in Dresden.

2007 (with M.Tsodyks): Workshop on *Brain Functions: from basic research to clinical applications*, at the Weizmann Institute (Israel).

2007 (with A. D'Andrea and D. Wiersma): Course on *Complex Optics in Mesoscopic Materials* in Erice.

2007 (with Ph. Courteille, R. Kaiser, and G.L. Lippi): *Self-assembling of Particles into Longitudinal and Transverse Structures*, at Porquerolles, (France).

2010 (with J.M. Lopez and A. Pikovsky): Workshop on *Exploring Complex Dynamics in High-Dimensional Chaotic Systems: from Weather Forecasting to Oceanic Flows*, at the Max-Planck Institute for Complex Systems in Dresden.

2011 (with J.M. Lopez): Minisymposium within SIAM Meeting (Salt Lake City) on C*ovariant Lyapunov vectors.*

2011*:* Minisymposium within Dynamics Days Europe (Oldenburg) on *Lyapunov exponents.*

2013: (with H. Kantz) Workshop on *From Dynamics to Statistical Physics and Back* (Dresden)

2014*:* (with G.-L Oppo) Workshop on *Absolute negative temperatures* (Glasgow)

2015*:* (with A. Pikovsky and M. Rosenblum) Workshop on *Dynamics of coupled oscillators: 40 years of the Kuramoto model* (Dresden)

2016*:* (with M. Abel, U. Feudel, P. Grassberger, and M. Rosenblum) Workshop on *Advances in the collective behaviour of complex systems* (Potsdam)

International Workshops and Conferences.

More than 70 invitations. The list includes events organized in: Austria (Vienna); Bruxelles (Belgium); Brasilia, Sao Paulo (Brasil); Tampere (Finland); Cargese, Les Houches, Lyon, Paris (France); Bad Honnef, Berlin, Dresden, Warnemunde (Germany); Heraklion, Rhodos (Greece); Leiden (Holland); Budapest, Szeged (Hungary); Chennai (India); Catania, Trieste, (Italy); Daejeon (Korea); Cuernavaca, Puebla (Mexico); Cusco (Peru); Krakow (Poland); Moscow, Novosibirsk (Russia); Singapore; Palma de Mallorca (Spain); Lavin (Switzerland); Glasgow, London, Perth, Warwick (UK); Crimea, Kiev (Ukraine); Rio de la Plata (Uruguay); Ann Arbor, Columbus, Santa Fe (USA); Tashkent (Uzbekistan).

Seminars and colloquia.

More than 40 invitations. The list includes: University of Texas, University of California San Diego, Penn State University, University of Chicago, IBM Yorktown Research Center, University of Augsburg (Germany), Humboldt University (Berlin, Germany), University of Würzburg, Ossietzky University (Oldenburg, Germany), Max-Planck-Institute for Dynamics and Self-Organization (Göttingen), Jülich Research Center (Germany), Max-Planck-Institute for Mathematics in the Sciences (Leipzig, Germany), University of Navarra (Pamplona, Spain), Strathclyde University (UK), University of Toronto (Canada), Institut des Systemes Complexes (Paris, France), Porto Alegre (Brasil), University of Exeter (UK), INLN (Nice), University of Porto (Portugal), University of Potsdam (Germany), University of Lancaster (UK), Free University (Berlin, Germany); Humboldt University (Germany); Scuola Normale Superiore (Pisa, Italy); St. Andrews (Scotland, UK).

Reviewing activity

Referee for: Physical Review Journals, Chemical Reviews, CHAOS, Physics Letters A, Physica D, Frontiers in Neuroscience, Journal of Statistical Mechanics, CHAOS, Journal of the Acoustical Society of America, European Physical Journal B&D.

EDITORIAL ACTIVITY

1992-1994 Member of the Editorial Board of Journal of Physics A

1998- Associate Editor of Physical Review E (first researcher with a non-US affiliation covering such a position in a Physical Review Journal).

1999-2004 Associate Editor of the European Physical Journal D.

2009- Member of the Editorial Board of Frontiers in Neuroscience

2006- 2011 Editor of the *Chaos and Complex Systems* section of Journal of Physics A.

PAPERS

~195 papers published in peer-reviewed journals (17 of his publications have been cited more than 100 times).

~ 10,400 citations

H-factor = 49 (Google Scholar)

BOOKS AND REVIEWS

1997 (with R. Badii) *Complexity: hierarchical structures and scaling in physics*, book published by CUP and later translated in Japanese.

2003 (with F. Bagnoli, F. Bignone, and F. Cecconi), *Information, Complexity and Biology,* chapter of *The Kolmogorov legacy in Physics*, edited by R. Livi and A. Vulpiani, Lecture Notes in Physics **636** (Springer).

2006 *Complex Systems*, chapter of *The New Physics for the 21st century* edited by Gordon Fraser (Cambridge University Press).

2008 (with S. Lepri and R. Livi), *Anomalous Conduction*, chapter of *Anomalous Transport: foundations and applications*, edited by R. Klages, Wiley VCH.

2010 (with A. Torcini), *Stable chaos*, chapter of *Nonlinear Dynamics and Chaos:Advances and Perspectives*, edited by M. Thiel, J. Kurths, M.C. Romano, G. Károlyi, and A. Moura (Springer).

2010 (with S. Luccioli), *Dynamics of networks of leaky-integrate-and-fire neurons*, chapter o*f Complex Networks across the Natural and Technological Sciences*, edited by M. Fox, D. Higham, G.-L. Oppo and E. Estrada, (Springer).

2014 *Stochastic fluctuations in deterministic systems*, chapter of *Large deviations in Physics* , edited by A. Vulpiani et al., (Springer).

2017 (with A. Pikovsky) *Lyapunov exponents*, published by CUP.

TEACHING ACTIVITY

1994 PhD Course on Complexity at the Italian National Doctoral School of Condensed Matter Physics

1996 PhD Course on Time Series Analysis at the Doctoral School of Physics of the University of Florence

1998 PhD Course on Complexity at the Technical University (Lingby, DK)

2004 Course on Introduction of Quantum Mechanics (Physics Department, Florence University)

2009 Course on Theory of Dynamical Systems (Physics Department, Florence University)

2011 Supervisor of a Thesis on Neural Networks

2013 Course of Chaos and Complexity at the Summer School on Physics of Complex and Small System(Palma de Mallorca)

2013- PhD Course on Collective properties of Biophysical Systems (50%)

2013- Undergraduate course on Electricity and Magnetism (Aberdeen)

2015-2017 Undergraduate course on Analytical mechanics (50%)

TRAINING

(Co) supervisor of 10 Laurea (MS) Theses. (Co) supervisor of 10 PhD Theses. Host of 4 individual Marie Curie Fellowships (Freddy Christiansen, Martin Buenner, Thomas Kreuz -- internal and outgoing).

Among his former "students": G.-L. Oppo is currently Professor ad Strathclyde (Glasgow, UK); S. Lepri, A. Torcini, and F. Cecconi are researchers at CNR; G. D'Alessandro is Senior Lecturer at the Southampton University (UK); F. Christiansen works at the Danish Meteorological Institute; M. Perrin is researcher at CNRS. The younger J. Javaloyes is PostDoc at Glasgow University; F.Ginelli is Post Doc at the Institut des Systemes Complexes in Paris; G. Meacci is Post Doc at the Columbia University (New York, USA).

FUNDING

Most of the career has been carried out at the National Institute of Optics, directly funded by the Italian Ministry for the University and Public Research. Funds were distributed by the Governing Body on the basis of the scientific reports.

1995: NATO bilateral project with A. Pikovsky for the investigation of *Space-time chaos*

1997: Vigoni project with A. Pikovsky for the investigation of *Hamiltonian chaos*

2003: NATO bilateral project with Y. Maistrenko for the investigation of *Phase synchronization*

2005-2007: CNR Ricerche a tema libero: S*tructure and dynamics of complex networks*

2007-2009: EU-NEST *Global Approach to Brain Activity: from Cognition to Disease.*

2010-2012: (PRIN-2008) Italian national project: *Increasing thermoelectric efficiency.*

2015-2018: EJD European training networks on oscillatory dynamics (COSMOS): 800,000 GBP (Aberdeen share)

2015-2016: Invitation of Prof P. Grassberger (funded by Leverhulme trust)

HONORS and AWARDS

1987 Prize yearly awarded by the *Gruppo Nazionale Struttura della Materia* for important theoretical results

2004 Appointed Fellow of the Institute of Physics

2004 Awarded the Gutzwiller Fellowship from the Max-Planck Institute for Complex System in Dresden (Prize awarded yearly to a single person) to acknowledge and promote exceptional research in the field of nonlinear dynamics in complex systems.

2011 Awarded the Humboldt Prize

2011 Appointed Fellow of the American Physical Society

MEMBERSHIP OF SOCIETIES

Member of the American Physical Society

Member of the Institute of Physics

Scientific achievements

The characterization of nonlinear dynamical systems represents the backbone of my research activity and has often represented the starting point to explore different environments. Over the years, the focus of my activity has greatly changed, moving from the analysis of low-dimensional to statistical models with an increasing interest for out-of-equilibrium and biological systems.

The initial part of my scientific career was motivated by the willingness to develop general methods to describe the strange attractors that were starting to be experimentally observed and by the search for general relationships among the relevant dynamical indicators (Lyapunov exponents, fractal dimensions, Kolmogorov-Sinai entropy). The main achievements, obtained in collaboration with R. Badii, in fact consisted in the development of a powerful algorithm for determining the fractal dimension: this is the so-called fixed-mass method that proved, in many instances, to be superior to the famous Grassberger-Procaccia algorithm. A further highly relevant result for the experimentalists was the rigorous analysis of filtered time-series which allowed to: (i) understand when and why the widely used technique of filtering can lead to spurious estimates of the fractal dimension: (ii) give a primary example of the much searched “phase transitions” in the language of the *thermodynamic formalism*. On the more theoretical side, I contributed by extending the Kaplan-Yorke formula to connect generalized fractal dimensions with generalized Lyapunov exponents. The apex was a joint paper with R. Badii and P. Grassberger where we discuss the application of all those ideas to non-hyperbolic systems, a paper that has been cited more than 400 times and keeps being cited more than 20 years after its publication.

As the most effective and compact characterization of a chaotic dynamics can be obtained by transforming it into a sequence of symbols, and this can be done whenever a *generating partition*

(GP) is available, I started to work on the problem of constructing GP's in generic dynamical systems. In collaboration with F. Christiansen, I successfully extended the idea of Kantz and Grassberger, initially developed for strongly dissipative systems (and based on the identification of the so called primary homoclinic tangencies), to symplectic systems such as the famous standard map (both in the regime of weak and strong chaos). As a result, we have been able to show that powerful ideas like the pruning front introduced to characterize the complexity of 2d maps carry over to Hamiltonian dynamics. This is a very difficult problem and not much progress has been made afterwards.

My interest for the symbolic encoding of chaotic trajectories drove me to introduce a suitable complexity measure that received some attention in those days when many where developing similar indicators and it was commented in an editorial note of Nature in 1992 and is presumably one of the motivations for a later invitation to write a book on Complexity for the Nonlinear Science series of Cambridge University Press. Such a book, written with R. Badii, was translated in japanese, had a chinese edition, and was defined as the most complete review on the subject by S. Wolfram in his *A new kind of science*.

Already in the '80s, I was attracted by the perspective of extending the methodologies developed for low-dimensional chaos to the characterization of space-time chaos. My first contribution was the first evidence (with R. Livi and S. Ruffo) for the existence of a limit Lyapunov spectrum in Hamiltonian systems (by numerically studying a Fermi-Pasta-Ulam chain): this is a conceptually relevant result, in that it implies the extensivity of chaos, i.e., that fractal dimensions and entropies are proportional to the system volume. In a subsequent series of joint papers with S. Lepri and A. Torcini, I worked to the extension of Lyapunov exponents to account for spatial as well as temporal dependence of generic perturbation (sort of dispersion relations). The efforts led to the development of the so-called *chronotopic* approach which can, e.g., yield the growth rate of initially localized perturbations in generic moving frames. Another relevant result of the *chronotopic* approach is the existence of what I called *entropy potential*, which in turn entails that the (dynamical) entropy density is an *invariant* property of a space-time pattern (i.e., it remains unchanged if time and space axes are exchanged in a 1d system). These results contributed to the award of the Gutzwiller Fellowship by the Max Planck Institute in Dresden in year 2004.

More or less in parallel, in the '90s, I also systematically studied *stable chaos*, i.e., linearly stable and yet *irregular* dynamics. Such a phenomenon that seems to be an oxymoron can indeed *steadily* arise only in the thermodynamic limit and depends on the existence of highly localized nonlinearities (quasi-discontinuities). Although it initially looked as a mathematical curiosity, we (in collaboration with R. Zillmer et al.) recently discovered that this phenomenon manifests itself within neural-network dynamics and represents a promising mechanism involved in the information processing.

My most important contribution over the last ten years concern the problem of heat conductivity in classical one-dimensional systems. First, in joint paper with R. Livi and S. Lepri, I re-opened the problem of a microscopic foundation for the Fourier law (that was formerly believed to be set by tracing it back to the existence of microscopic chaos, as stated in an editorial note published in Nature 1985). In fact, we clearly showed that the transport coefficient generically diverges as power law with the system size in chaotic systems. Then, over the years, we have contributed to clarify the problem, by suggesting the existence of two distinct universality classes (on the basis of both careful simulations and by analytically solving suitable mode-coupling equations). Very recently, this scenario has been accepted by the entire community and also experimentally confirmed. A side, but illuminating result of this activity has been the discovery that energy diffuses exactly as a Levy walk: the result is important because there are very few examples where a power-law behaviour sets in without assuming a priori the presence of some power laws.

In the last years, I have come back to the “old-fashioned” problem of Lyapunov analysis of chaotic dynamics, by developing a powerful tool to determine the so-called covariant Lyapunov vectors: such vectors, formally defined in the `70s by Ruelle escaped the researchers attention

due to the lack of methods to determine them. Now they are becoming one of the standard tools for a “nonlinear dynamicist” who aims at highlighting phenomena such as deviations from hyperbolicity and the presence of collective dynamics.
Finally the occurrence of collective dynamics is another topic that has attracted my attention, as I am convinced it is a key feature of true neural networks: some recent results of mine show indeed that even a small connectivity (~10) can support a nontrivial collective motion. More than that, an irregular collective dynamics may even appear in networks that are linearly stable (this phenomenon is the most striking manifestation of the above mentioned stable chaos).
I have clarified to what extend various classes of phase-oscillator models are equivalent to one another.

Current scientific activity

Transport properties: I am currently investigating the thermodynamic properties of physical systems involving more than one transport phenomenon (such as energy and mass). This has already led to the discovery of an intriguing phase transition.

Globally coupled oscillators: I am exploring a new phase-transition of Kuramoto-type, where the collective dynamics is much richer and could explain the background activity of the brain when it is not performing specific tasks.
I am also exploring the possibility to establish a connection between different levels of descriptions (while going from a microscopic towards a macroscopic level).

LIST OF PAPERS PUBLISHED in 2017

S. Iubini, S. Lepri, R. Livi, G.-L. Oppo, A. Politi,
A chain, a bath, a sink, and a wall
Entropy, **19**, 445 (2017)

S. Iubini, A. Politi, P. Politi,
Relaxation and coarsening of weakly-interacting breathers in a simplified DNLS chain
J. Stat. Mech. 073201 (2017)

P. Clusella, A. Politi,
Noise-induced stabilization of collective dynamics
Phys. Rev. E **95**, 062221 (2017)

A. Politi, A. Pikovsky, E. Ullner
Chaotic macroscopic phases in one-dimensional oscillators
Eur. Phys. J. Special Topics **226**, 1791 (2017)

A. Politi,
Quantifying the Dynamical Complexity of Chaotic Time Series
Phys. Rev. Lett. **118**, 144101 (2017)

G. Robb and A. Politi,
Collective dynamics out of thermodynamic equilibrium
Phys. Rev. E **95**, *040201(R) (2017)*