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2009 : December 2009 - Fast Breaking Papers : Peter Hänggi & Fabio Marchesoni Discuss Artificial Brownian Motors

FAST BREAKING PAPERS - 2009

December 2009



Peter Hänggi & Fabio Marchesoni talk with *ScienceWatch.com* and answer a few questions about this month's Fast Breaking Paper in the field of Physics. The authors have also sent along images of their work.



Peter Hänggi



Fabio Marchesoni

Article Title: Artificial Brownian motors: Controlling transport on the nanoscale

Authors: Hanggi, P;Marchesoni, F

Journal: REV MOD PHYS

Volume: 81

Issue: 1

Page: 387-442

Year: JAN-MAR 2009

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* Univ Camerino, Dipartimento Fis, I-62032 Camerino, Italy.

* Korea Inst Adv Study, Sch Phys, Seoul 130722, South Korea.

SW: Why do you think your paper is highly cited?

With this comprehensive paper, we survey and discuss the role of symmetry breaking and its potential for applications for novel transport schemes and separation methods on the length scales of micrometers right down to the nanoscale. It's an everyday experience that the elements of symmetry breaking such as that of left-right symmetry, or forward-backward symmetry, rule our daily life when we use, for example, a screwdriver or drive a car.

This all becomes a challenge at small length scales, where thermal fluctuations assume a dominating role. To obtain directed transport, one must then learn how to overcome the limits imposed by the laws of equilibrium thermodynamics and take advantage of those nonequilibrium processes which happen to remain applicable at the molecular scales.

This objective is by no means a trivial task at the submicron scale, as mastering these issues would pave the way for the design and engineering of nanodevices operating in the presence of haphazard Brownian noise, so that quantum and classical objects can be directed along pre-assigned routes (Brownian motors).

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

The theme of artificial Brownian motors requires a synthesis of different

principles in physics, such as breaking of time-reversal symmetry, the inclusion of a description of fluctuating variables, and the solution of balance equations for probabilistic flow of matter and/or information.

SW: Would you summarize the significance of your paper in layman's terms?

Since the turn of the 20th century, Brownian noise has continuously disclosed a rich variety

of phenomena both in and around physics. The understanding of this jittering motion of suspended microscopic particles has undoubtedly helped reinforce and substantiate the pillars of modern physical theories. Its formal description provided the key to great achievements in statistical mechanics, the foundations of quantum mechanics, and also astrophysical phenomena, to name only a few.

Although noise is usually thought of as the enemy of order, in fact it also plays a constructive role. In our work we show how random Brownian dynamics and external control forces can be combined so as to enhance detection and/or in facilitating the directed transmission of information. Prominent applications range from innovative information processing devices in physics, chemistry, and physical biology, as well as toward new hardware for medical rehabilitation.

SW: How did you become involved in this research, and were there any problems along the way?

Peter Hanggi:

I have a long standing experience in the field of physics and in developing methods for systems that are driven far from equilibrium; both classical and quantum. A prominent case is the phenomenon of stochastic resonance—i.e., the possibility of boosting the transduction of information by applying a suitably chosen dose of additional randomness. This, by now widely appreciated phenomenon, shares some common principles with the topic of designing machinery fueled by ambient thermal noise and nonequilibrium perturbations—the theme of Brownian motors—a notion coined by me in early 1995.

Fabio Marchesoni:

A new generation of micro- and nano-devices for information & communication technologies (ICT), including sensors, processors and actuators, will be impossible unless we figure out how to power such devices. On addressing issues related to nanoscale energy management, such as noise harvesting, I've been impressed by how Nature has solved the very same problem at the cell level.

Relatively large stationary fluctuations seem to sustain a surprisingly efficient molecular network, where mass, charge, and information are being exchanged inside the cell body. In this work we have further pursued the notion of "biology inspired nano-devices," regarding the cell molecular machinery as a blueprint for the engineering of new artificial devices.

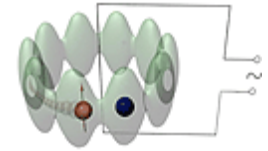
SW: Where do you see your research leading in the future?

The theme of Brownian machinery is very timely these days. It leads to new possibilities for designing "cars and wheels" on the micro- and nanoscale. A recent development is the challenge to devise the transport of only a few cold atoms, which proceeds fully quantum mechanically (i.e., coherently) in the absence of environmental disturbances. The only "noise" remaining in fueling directed quantum motion is then the zero-point quantum fluctuations!

Peter Hanggi, Ph.D.
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Institute of Physics
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Augsburg, Germany
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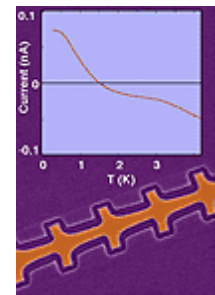
Fabio Marchesoni, Ph.D.

Figure 1 [\[+\] details](#)



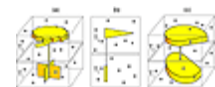
The world's smallest electric motor... [->|](#)

Figure 2 [\[+\] details](#)



A quantum Brownian motor fabricated... [->|](#)

Figure 3 [\[+\] details](#)



Taming Brownian motion with... [->|](#)

Z

Professor
Department of Physics
University of Camerino
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KEYWORDS: BROWNIAN MOTION; FLUCTUATIONS; MICROFLUIDICS; QUANTUM THEORY;
SUPERCONDUCTING DEVICES; TRANSPORT PROCESSES.



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Peter Hänggi



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Figures and descriptions:

Figure 1:

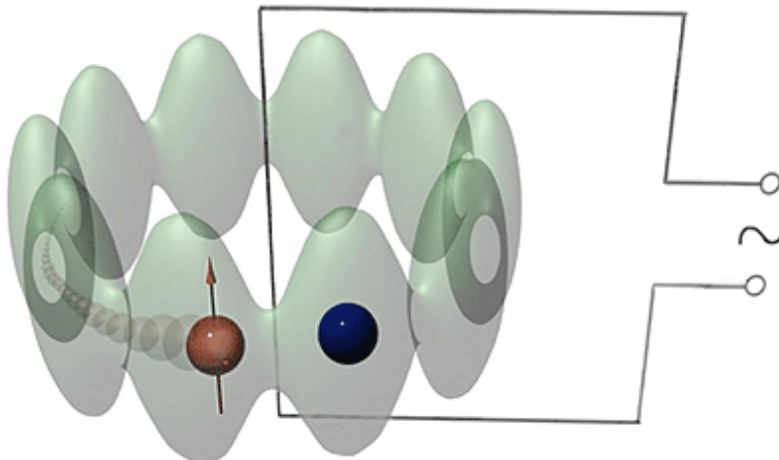


Figure 1:

The world's smallest electric motor consisting of only two atoms being powered by quantum noise and a time-dependent sinusoidal magnetic field containing a fundamental and its second harmonic frequency (see also).

Figure 2:

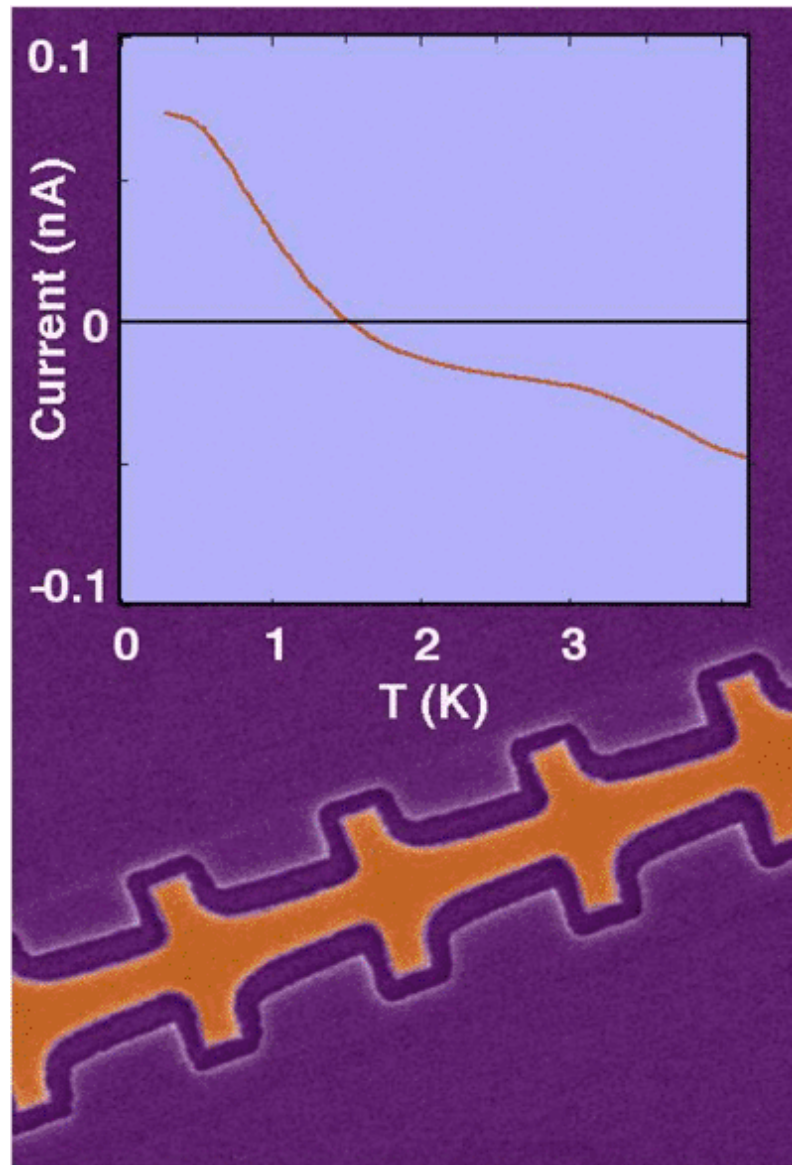


Figure 2:

A quantum Brownian motor fabricated from a tailored GaAs/AlGaAs heterostructure is able to shuttle electrons quantum mechanically alongside the micrometer-sized ratchet structure. quantum tunneling allows for a characteristic with a current reversal, crossing zero. At this very zero-current temperature the device operates as a quantum refrigerator, separating "hot" electrons from oppositely moving "cold" electrons in absence of a net electric current. (Fig. 34 in *Rev. Mod. Phys.* 81: 381 [2009]).

Figure 3:

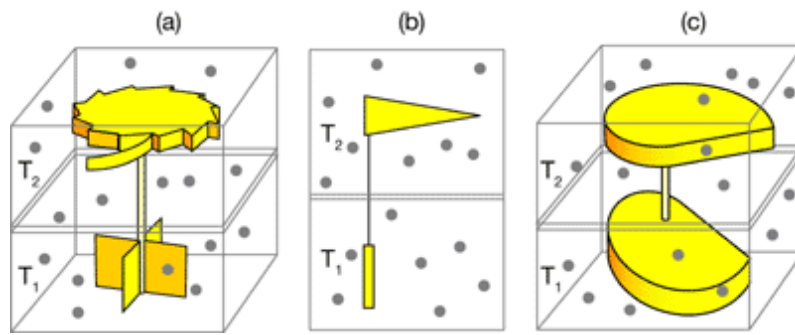



Figure 3:

Taming Brownian motion with idealized motor designs undergoing directional translational (b) or rotational (a, c) motion by harvesting random collisions with thermal gas particles which are held at two different temperatures. (Fig. 22 in *Rev. Mod. Phys.* 81:381 [2009]).

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