Final Report on Ratchets in point-particle systems and in extended models: Mechanisms, control and applications

Ratchets-2007: Carmona (Sevilla) February 5-7, 2007

Contents:

"Ratchets in point-particle systems and in extended models: Mechanisms, control and applications"

Carmona (Sevilla), Spain, February 5-7 2007

Summary

The activity consisted of a 3-day Workshop where 37 leading scientists and young Researches, working on the transport phenomena involving ratchet mechanisms, discussed and revised the most recent advances in this field. Specifically, the meeting was focused on the control mechanism of ratchets, the biophysics and biomathematics of molecular motors, and the application of the ratchet effect in nanotechnology, biotechnology and optical lattices. A remarkable profit of the Meeting was to put together the leading experimental groups with the theoretical ones.

Scientific content

The field of ratchets and rectification at micro- an nanoscales has grown rapidly in the last decade. The first theoretical models were proposed originally as simple mechanisms for energy transduction in protein motors, but their applications have expanded to include synthetic chemical motors, superconductor vortices, magnetic walls, fluids, quantum dots, and cold atoms.

These experimental implementations make the field of ratchets even more exciting nowadays than when it started more than ten years ago. The combination of thermal fluctuations, asymmetric potentials and non-equilibrium forcing is becoming a major tool for the design of nanodevices.

The conference "Ratchets-2007" has joined outstanding representatives of all these experimental research lines, as well as some of the most prominent theoreticians in the field. In this direction the invited talks of the ***experimental*** groups were focused on synthetic chemical motors (Leigh and Flood), superconductor vortices (Vicent), fluids (Linke), quantum dots (Linke), and cold atoms (Renzoni) and the ***theoretical*** ones on Brownian motors and molecular motors (Van der Broeck and Parrondo), random walks (Casado-Pascual), transport properties in ratchets-type potentials (Mateos and Schimansky-Geier), soliton ratchets (Mertens and Salerno), and transport properties in Josephson junctions (Reimann). The detailed information of each lecture is given in the Book of Abstract enclosed below. The Scientific Program was closed with 8 short communications given by active young researches in the area, as well as 6 posters (see the the Book of Abstract for further information).

The exchange of ideas, specially between experimental and theoretical groups, has been one of the most satisfying aspects of the workshop.

Economic Report

Sponsors:

1. Sevilla University: **2000** euros
2. University Carlos III of Madrid: **2500** euros
3. SIMUMAT: Grupo de Investigación en Modelización Matemática y Simulación Numérica en Ciencia y Tecnología. Consejería de Educación de la Comunidad de Madrid **2000** euros
4. INGENIO MATHEMATICA. Programa Consolider-Ingenio 2010. Spanish Ministerio de Educación y Ciencia. **3600** euros
5. Project FIS2006-27277-E for organization of Research Meetings of the Spanish Ministerio de Educación y Ciencia **6000** euros
6. STOCHDYN Programm, ESF **6700** euros

SPONSORED TOTAL: **22800** euros

7. Registration Feeds **1800** euros

TOTAL: **24600** euros

The ESF grant was the 27% of the total budget and 29% (6700 of 22800) of the sponsored one.

All the above subventions (22800 euros) has been used for paying the total amount of **24600** euros of the Meeting as follows:

The 22800 euros of sponsored part of the budged was used as follows:

The 6000 euros from the MEC of Spain (granted already but not yet transferred) will be used for paying the travel expensive of the invited speakers and members of the Scientific and Organizing Committees.

16000 euros are paid to the Hotel for covering the full boarding (Hotel rooms and meals) of the 35 participants (1 invited speaker (Marconi) has been cancel out in the last moment (Saturday February 3) because a personal reason) and Meeting facilities, etc.

800 euros were used for paying some photocopies and Meeting's materials.

The 1800 euros of the Registration Feeds were used for paying extra photocopies, consumables, and extra social activities.

Ratchets in point-particle systems and in extended models: Mechanisms, control and applications.

Ratchets-2007: Sevilla February 5-7, 2007

http://euler.us.es/~ratchets/

Book of Abstracts

Sponsored by

- Universidad de Sevilla
- Universidad Carlos III de Madrid
- European Science Fundation, STOCHDYN Program
- Ingenio Mathematica (Programa Consolider-Ingenio 2010, MEC Spain)
- Group on Orthogonal Polynomials and Approximation Theory (Univ. de Sevilla)
- Grupo Interdisciplinar de Sistemas Complejos
- SIMUMAT: Programa de Actividades en Modelización Matemática y Simulación Numérica en Ciencia y Tecnología
- Ministerio de Educación y Ciencia: FIS2006-27277-E
- Grupo de Física Cuántica y Matemáticas, Universidad de Granada

Presentation

Transport phenomena of ratchet type in non-linear systems is a major subject of study in different fields of Science. Indeed, motion of atoms in optical lattices, propagation of fluxons in superconducting devices, mechanical and electrical rectifiers, electron currents in quantum devices, separation of particles or DNA molecules and unidirectional motion taking place in molecular motors inside the cells, to name only a few examples, appear as a consequence of the non-linear response of such systems to zero-average external forces. Beginning with the proposals of Smoluchowski and Feynman many years ago, several particle-like-ratchet models have been developed and improved to describe the above class of phenomena. On the other hand, the so-called soliton ratchet is a very recent generalization of the ratchet phenomenon to spatially extended systems (supporting nonlinear coherent excitations), where several models have also been suggested and studied from the theoretical and experimental points of view.

The Workshop will cover all the above issues. Namely: Ratchet effect in superconductors, optical lattices, biophysics and biomathematics of molecular motors; control mechanisms for ratchets; applications of the ratchet effect in nano and biotechnology, and optical lattices. Its main objectives are:

1. to review and discuss recent results in the field by the leading experts in each topic, and
2. to provide a stimulating atmosphere that will promote interaction between leading experts and young researchers, providing an opportunity to discuss new challenges in the field.

The Organizing Committee is:

- Renato Alvarez-Nodarse (Universidad de Sevilla, Spain) (secretary)
- Niurka R. Quintero (chair) (Universidad de Sevilla, Spain)
- Angel Sánchez (Universidad Carlos III de Madrid, Spain)

The Scientific Committee is:

- Angel Sánchez (Universidad Carlos III de Madrid, Spain) (chair)
- Peter Hanggi (Universitat Augsburg, Germany)
- Heiner Linke (University of Oregon, USA)
- Juan M. R. Parrondo (Universidad Complutense de Madrid, Spain)
- Jacques Prost (Institut Curie, France)

- Niurka R. Quintero (Universidad de Sevilla, Spain) (secretary)
- José M. Sancho (Universidad de Barcelona, Spain)

The Local Committee is

- Renato Alvarez-Nodarse (Universidad de Sevilla, Spain) (chair)
- José Luis Cardoso (Universidad Trás-os-Montes e Alto Douro, Portugal)
- Francisco J. Esteban (Universidad de Jaén, Spain)

We want to thank for their generous financial support the following institutions and groups: Universidad de Sevilla; Universidad Carlos III de Madrid; European Science Fundation (STOCHDYN Programme); Ingenio Mathematica (Programa Consolider-Ingenio 2010, MEC Spain); OP&AT: The Group on Orthogonal Polynomials and Approximation Theory (Univ. de Sevilla); GISC (Grupo Interdisciplinar de Sistemas Complejos); SIMUMAT: Programa de Actividades en Modelización Matemática y Simulación Numérica en Ciencia y Tecnología, Comunidad Autónoma de Madrid; Ministerio de Educación y Ciencia (Grant FIS2006-27277-E), and Grupo de Física Cuántica y Matemáticas (Univ. de Granada).

Last, but not least, we thank Felipe Guardiola and his team at the Hotel Casa de Carmona for the splendid facilities they provided for the Workshop.

Sevilla, February 5, 2007

The Organizing Committee
R. Álvarez-Nodarse, N.R. Quintero, and A. Sánchez

Book of Abstracts

Schedule

February 5th, Monday

09:00 — 9:20 **Opening**
Chairman: L. Schimansky-Geier
09:30 — 10:30 H. Linke
10:30 — 11:10 C. van den Broeck
11:10 — 11:30 A. Gómez-Marín
11:30 — 12:00 *Coffe break*
Chairman: F. Renzoni
12:00 — 13:00 J.L. Vicent
13:00 — 13:20 L. Dinis
13:20 — 13:40 V. I. Marconi
13:40 — 16:00 S*mall group discussions and lunch*
Chairman: C. van den Broeck
16:00 — 16:30 J. J. Mazo
16:30 — 17:00 E. Goldobin
17:00 — 17:40 M. Morillo
18:30 — Poster Session / Small Group discussions
& Cocktail at the Loggia
21:00 — *Welcome Dinner*

February 6th, Tuesday

Chairman: H. Linke
09:00 — 10:00 D. Leigh
10:00 — 10:40 J.M.R Parrondo
10:40 — 11:20 P. Reimann
11:20 — 12:00 *Coffe break*
Chairman: J. M. Sancho
12:00 — 12:40 J. Casado-Pascual
12:40 — 13:20 M. Salerno
13:20 — 13:40 B. Sánchez-Rey
13:40 — 16:00 *Small group discussions and lunch*
Chairman: M. Salerno
16:00 — 16:40 F. Mertens
16:40 — 17:00 A. B. Kolton
17:00 — 17:20 E. Zamora-Sillero
17:20 — 18:00 J. L. Mateos
18:00 — 19:00 Small group discussions
19:00 — 20:30 Touristic Visit to Carmona
21:30 — *Official Dinner*

February 7th, Wednesday

Chairman: J.M.R. Parrondo
12:00 — 12:40 A. H. Flood
12:40 — 13:20 L. Schimansky-Geier
13:20 — **Closing**
13:30 — 16:00 *Lunch and small group discussions*
16:00 — 18:00 Round Table: **New Challenges in transport phenomena in nonlinear systems.**

Invited Lectures

1. **Chris Van den Broeck**. Hasselt University, Belgium.
E-mail: christian.vandenbroeck@uhasselt.be

   Title: Brownian motors: the fight between the engine and the refrigerator.

   Abstract: We review the issue of Carnot efficiency from the point of view of Brownian motors. We show that it can in principle be achieved, but it requires a very stringent structural constraint. Turning to information processing Brownian engines, we show that the work theorem allows to exact microscopic equalities which in particular verify the Landauer principle.

   References: C. Van den Broeck, R. Kawai and P. Meurs, Phys Rev Lett 93, 090601 (2004); P. Meurs, C. Van den Broeck and A, Garcia, Phys Rev E70, 051109 (2004); C. Van den Broeck, P. Meurs and R. Kawai, New J Phys 7, 10 (2005); C. Van den Broeck, Phys Rev Lett 95, 190602 (2005); C. Van den Broeck and R. Kawai, Phys Rev Lett 96, 210601 (2006); C. Van den Broeck, Carnot efficiency revisited, Adv Chem Phys, to appear; R. Kawai, JMR Parrondo and C. Van den Broeck, Work theorem and thermodynamics of computation, preprint.

2. **Jesús Casado-Pascual**. Universidad de Sevilla, Spain.
E-mail: jcasado@us.es

   Title: Flux reversal in a simple random-walk model on a fluctuating symmetric lattice.

   Abstract: A rather simple random-walk model on a one-dimensional lattice is put forward. The lattice as a whole switches randomly between two possible states which are spatially symmetric. Both lattice states are identical, but translated by one site with respect to each other, and consist of infinite arrays of absorbing sites separated by two nonabsorbing sites. Exact explicit expressions for the long-time velocity and the effective diffusion coefficient are obtained and discussed. In particular, it is shown that the direction of the steady motion can be reversed by conveniently varying the values of either the mean residence times in the lattice states or the transition rates to the absorbing and nonabsorbing sites.

3. **Serguey Denisov**. Universitat Augsburg, Germany.
E-mail: sergey.denisov@physik.uni-augsburg.de

   Title: ac-driven quantum ratchets.

   Abstract: I will give an introduction into the symmetry analysis of ac driven particles in periodic potentials and the main mechanisms of current rectification for the classical case. I will then present recent results on the

treatment of the quantum problem. The symmetric zero transport case is characterized by a Floquet evolution matrix and eigenstates bearing the symmetry of the generating equations. As a result all Floquet eigenstates contribute with zero average velocity. For the asymmetric case we observe an essential change of Floquet eigenstates which are now characterized by a finite average velocity. In addition we identify an intermediate region of eigenstates which give the strongest desymmetrization and thus contribute most strongly to a direct transport. These states are shown to reside in the classical chaotic phase space part by means of Husimi distributions. We then launch an initial state with zero momentum and compute the corresponding average velocity using the Floquet eigenstates properties. We find several quantum signatures of the rectification effect:

i) the average velocity depends on the initial phase of the ac field

ii) weak and strong resonant enhancement or suppression of the average velocity (as compared to the classical case) happens upon tunning a control parameters due to avoided crossings and

iii) the maximum value and the fluctuations of the average velocity upon tuning a control parameter strongly depend on $\hbar$.

4. **Amar H. Flood**. University of Indiana, USA.
E-Mail: `aflood@indiana.edu`

   Title: Single Power Strokes and Brownian Ratchet Steps from one Family of Molecular Machines

   Abstract: Chemists are looking to engineered and biological varieties of machines and motors to design analogous versions at the molecular level. To this end, a series of synthetic molecular machines from within one family will be presented in order to highlight their biophysical likenesses. The mechanical energy available for work has been measured in a simple molecule that breaks into two parts during its show of force. However, if the two halves are previously tethered together like the Ouroboros image – the Serpent biting its own tail – it is possible to keep a handle on both components when they are split apart. Finally, if the steric constraints are relaxed, the two halves can reform to display single power strokes and Brownian ratchet steps.

5. **David Leigh**. University of Edinburgh, UK.
E-mail: `David.Leigh@ed.ac.uk`

   Title: Exercising Demons: Synthetic Molecular Motors and Machines.

   Abstract: The machines we use in everyday life are made up of ordered assemblies of moving parts (cogs, wheels, spindles, pistons etc), the movement of each of which is used to perform a task necessary for the overall function of the machine. An exciting contemporary area of chemistry is

making molecules with moving parts, with the goal that they can be built up into ordered assemblies that function as nanoscopic machines capable of performing physical tasks. To do so requires the introduction of ratchet principles into synthetic molecular structures. We will discuss some of the latest developments in this field including the experimental realisation of both energy ratchets and information ratchets.

For papers from the Leigh group see: Nature, 406, 608-611 (2000); Science, 291, 2124-2128 (2001); Nature, 424, 174-179 (2003); Science, 299, 531 (2003); Proc. Natl. Acad. Sci. USA, 100, 10-14 (2003); Science, 306, 1532-1537 (2004); Proc. Natl. Acad. Sci. USA, 102, 13378-13382 (2005); Nature Mater., 4, 704-710 (2005).

6. **Heiner Linke**. University of Oregon, USA.
E-mail: `linke@uoregon.edu`

   Title: Experimental Ratchet Systems.

   Abstract: I will review two recent ratchet experiments: (i) the heat-activated motion of millimeter-sized Leidenfrost droplets on hot, ratchet-shaped metal surfaces [1], and (ii) an ongoing program to demonstrate a Brownian heat engine near Carnot efficiency, using semiconductor, heterostructure nanowires [2]. Project (i) may have applications in heat-activated liquid cooling systems, whereas project (ii) is relevant to thermoelectric energy conversion. Time permitting, I will discuss an ongoing effort to set up an experimental system for the realization and test of ratchet-based models for molecular motors. A scanning-line optical trap will be used to produce a time-dependent potential for a bead that represents the motor coordinate. This system will also include feedback-mechanisms.

   [1] H. Linke, B. Alemàn, L. D. Melling, M. J. Taormina, M. J. Francis, et al., Phys. Rev. Lett. 96, 154502 (2006). [2] M. O'Dwyer, T. E. Humphrey, and H. Linke, Nanotechnology 17, S338 (2006).

7. **Fabio Marchesoni**. Universita di Perugia, Italy.
E-mail: `fabio.marchesoni@pg.infn.it` (**cancel out on Saturday February 3, for personal reason**)

   Title: Brownian diffusion in restricted geometries.

   Abstract: In 1D and for long times, the mean square displacement $\delta x^2(t)$ of a freely diffusing particle with unit mass, subject to thermal fluctuations, grows with time, that is $\delta x^2(t) = 2D_0 t$, where $D(T) = kT/\gamma = D_0$ is the Einstein's diffusion coefficient. However, for restricted diffusive dynamics, a variety of different effects can occur:

(a) If the particle diffuses on a tilted periodic substrate (washboard potential), mimicking e.g. a narrow channel, then $D(T)$ gets anomalously large at or close to the depinning tilt; the normal diffusion excess increasing with lowering T and the damping constant γ;

(b) In a 1D assembly of identical non-passing Brownian particles (stochastic single-file), the diffusion law itself becomes anomalous, i.e. $\delta x^2(t) = 2Ft^{1/2}$, with F a function of the particle density and D_0.

The microscopic mechanisms underlying anomalous diffusion in restricted geometries will be discussed in impact representation.

8. **José L. Mateos**. Universidad Nacional Autónoma de México, México.
E-mail: `mateos@fisica.unam.mx`

Title: Phase Synchronization in Inertial Deterministic Ratchets.

Abstract: We analyze the transport properties of deterministic inertial particles in a tilted ratchets potential with an external periodic forcing. The ratchet potential has to be tilted in order to obtain a rotator or self-sustained nonlinear oscillator that can be synchronized with the external driving force. We introduce a linear phase through a set of discrete time events and the associated average frequency, and show that this frequency can be synchronized with the frequency of the external driving. In this way, we can properly characterize the phenomenon of synchronization through Arnold tongues, and discuss their implications for transport in ratchets.

9. **Franz Mertens**. University of Bayreuth, Germany.
E-mail: `Franz.Mertens@uni-bayreuth.de`

Title: Optimization of soliton ratchets in inhomogeneous sine-Gordon systems.

Abstract: Unidirectional motion of solitons can take place, although the applied force has zero average in time, when the spatial symmetry is broken by introducing a potential $V(x)$, which consists of periodically repeated cells with each cell containing an asymmetric array of strongly localized inhomogeneities. A collective coordinate approach shows that the positions, heights and widths of the inhomogeneities (in that order) are the crucial parameters so as to obtain an optimal effective potential that yields a maximal average soliton velocity. The optimal potential essentially exhibits two features: double peaks consisting of a positive and a negative peak, and long flat regions between the double peaks. Such a potential can be obtained by choosing inhomogeneities with opposite signs (e.g., microresistors and microshorts in the case of long Josephson junctions) that are positioned close to each other, while the distance between

each peak pair is rather large. These results of the collective variables theory are confirmed by full simulations for the inhomogeneous sine-Gordon system.

10. **Manuel Morillo**. Universidad de Sevilla, Spain.
E-mail: morillo@us.es

    Title: Forced synchronization in a quantum dissipative system.

    Abstract: We study, within the spin-boson dynamics, the synchronization of a quantum tunneling system with an external, time-periodic driving signal. As a main result we find that at a sufficiently large system-bath coupling strength the thermal noise plays a constructive role in yielding forced synchronization. This noise-induced synchronization can occur when the driving frequency is larger than the zero-temperature tunneling rate. As an application evidencing the effect, we consider the charge transfer dynamics in molecular complexes.

11. **Juan M. R. Parrondo**. Universidad Complutense de Madrid, Spain.
E-mail: parrondo@fis.ucm.es

    Title: Reading DNA by molecular motors: the RNA polymerase.

    Abstract: We will present some recent experimental results on the RNA polymerase, a molecular motor responsible of DNA transcription, and a simple model explaining the motion of the motor and its step-time statistics.

12. **Peter Reimann**. Universität Bielefeld, Germany.
E-mail: reimann@physik.uni-bielefeld.de

    Title: Anomalous response behavior of a Josephson junction

    Abstract: We predict three quite unusual transport properties of a Josephson junction in the form of current and voltage of opposite sign. Numerical simulations are complemented by intuitive explanations of the basic mechanism and analytical approximations. Suitable parameter values are quite realistic experimentally.

13. **Ferruccio Renzoni**. University College London, UK.
E-mail: ucapfre@ucl.ac.uk

    Title: Symmetry and transport in a rocking ratchet for cold atoms.

    Abstract: Brownian motors, or ratchets, are devices which "rectify" Brownian motion, i.e. they can generate a current of particles out of unbiased fluctuations.

    We experimentally implemented a Brownian motor using cold atoms in an optical lattice. This is quite an unusual system for a Brownian motor

as there is no a real thermal bath, and both the periodic potential for the atoms and the fluctuations are determined by laser fields.

With the help of such a system, we investigated experimentally the relationship between symmetry and transport in a rocking ratchet, both in the periodic and in the quasiperiodic case.

References

[1] P.H. Jones, M. Goonasekera and F. Renzoni, Rectifying fluctuations in an optical lattice, Phys. Rev. Lett. 93, 073904 (2004)

[2] R. Gommers, P. Douglas, S. Bergamini, M. Goonasekera, P.H. Jones and F. Renzoni, Resonant activation in a nonadiabatically driven optical lattice, Phys. Rev. Lett. 94, 143001 (2005)

[3] R. Gommers, S. Bergamini and F. Renzoni, Dissipation induced symmetry breaking in an driven optical lattice, Phys. Rev. Lett. 95, 073003 (2005)

[4] R. Gommers, S. Denisov and F. Renzoni, Quasiperiodically Driven Ratchets for Cold Atoms, Phys. Rev. Lett. 96, 240604 (2006)

14. **Mario Salerno**. University of Salerno, Italy.
E-mail: `salerno@sa.infn.it`

Title: Soliton ratchets in continuous and discrete systems.

Abstract: We review the mechanism underlying the formation of soliton ratchets both in continuous and in discrete nonlinear systems. In particular, we discuss the existence of asymmetric internal modes which couple, through the damping in the system, to the soliton translational degree of freedom. Effective soliton transport is shown to be achieved when the internal mode and the external force are phase locked. The role played by the spatial temporal symmetries in establishing soliton ratchets is also investigate. For discrete systems we show that the phenomenon becomes more complicated due to the existence of nonzero depinning thresholds for the onset of the motion, locking to rational fractions of the driving frequecy and existence of diffusive ratchet dynamics. As specific examples we consider the damped and driven double sine-Gordon equation with asymmetric potential, the damped sine-Gordon equation with temporal asymmetric drivers and the Gross-Pitaevskii equation with time dependent asymmetric optical lattices.

15. **Lutz Schimansky-Geier**. Humboldt - Universität zu Berlin, Germany.
E-mail: `alsg@physik.hu-berlin.de`

Title: Low randomness in ratchets and steppers.

Abstract: We introduce the diffusion coefficient and the Peclet-number as a measure of quality for transport in ratchets and for the motion of

steppers. We calculate both for simple discrete ratchet models and give conditions which reduce randomness of the transport. In addition periodic forcing can be used to synchronize the motion of Brownian steppers which corresponds to a state with low randomness.

In the second part we discuss coupling of particles in flashing ratchets and calculate the mean velocity in dependence on the coupling parameters.

References

J. A. Freund, and L. Schimansky-Geier, Phys. Rev. E 60, 1304 -1309 (1999).

B. Lindner, M. Kostur, and L. Schimansky-Geier, Fluctuations and Noise Letters 1, R25 (2001).

B. Lindner and L. Schimansky-Geier, Phys.Rev.Lett. 89, 230602 (2002).

T. Prager, L. Schimansky-Geier and I.M. Sokolov, J. of Physics: Cond. Matter 17, 3661 (2005).

J. Menche and L. Schimansky-Geier, Phys. Lett. A 359, 90 (2005)

16. **José Luis Vicent**. Universidad Complutense de Madrid, Spain.
E-mail: `jlvicent@fis.ucm.es`

Title: Experimental ratchet effect in nanostructured superconductors.

Abstract: Superconducting vortex lattice is a powerful tool to study the ratchet effect due to interacting particles and to explore the commensurability effects between the vortex lattice and the array of asymmetric defects which govern rocking ratchet behavior.

In this talk we will show that:

i) A reversible ratchet occurs in nanostructured superconductors.

ii) The interaction between the whole vortex lattice and the array of asymmetric pinning potentials is the mechanism which leads the ratchet effect.

Short Talks

17. **Luis Dinis**. Universidad Complutense de Madrid, Spain.
E-Mail: ldinis@seneca.fis.ucm.es

Title: Influence of lattice configurations in a superconducting vortex ratchet.

Abstract: We present 2D Langevin simulations for vortices in a periodic lattice of triangular pinning sites. When vortices are rocked applying an AC force, rectification of the signal is observed in the movement of the vortex lattice, and a net current appears. Simulations show the proper current reversal behavior as compared to experimental data, when the applied force is changed. In our simulations vortices move coherently as a lattice with some defects, and the current reversal correspond to a change in the conformation of the vortex lattice. An specific change in the separation of the pinning sites can favour one of the lattice configurations over the other, resulting in the disappearance of the inversion phenomenon. These results provide new insights to increase control over the vortex ratchet device.

18. **Edward Goldobin**. University of Tuebingen, Germany.
E-mail: gold@uni-tuebingen.de

Title: Josephson vortex ratchet: experiments and simulations.

Abstract: Deterministic Josephson vortex ratchet consists of a fluxon moving in an asymmetric periodic potential driven by a deterministic force with zero time average. In experiment the highly asymmetric periodic potential is created in an underdamped annular long Josephson junction by means of a current injector. The rectification is demonstrated in adiabatic as well as in the non-adiabatic (high frequency) regime. For monochromatic high-frequency drive the rectified voltage becomes quantized and the fluxon velocity reaches 91% of the Swihart velocity in some cases (relativistic ratchet). We also observe chaos, sub-harmonic dynamics and voltage reversal that can be reproduced in numerical simulations.

19. **Alex Gómez-Marin**. Universidad de Barcelona.
E-mail: agomezmarin@gmail.com

Title: Tight coupling in thermal Brownian motors.

Abstract: We study analytically a thermal Brownian motor model and calculate exactly the Onsager coefficients. We show how the reciprocity relation holds and that the determinant of the Onsager matrix vanishes. Such condition implies that the device is built with tight coupling. This explains why Carnot's efficiency can be achieved in the limit of infinitely slow velocities. We also prove that the efficiency at maximum power has the maximum possible value, which corresponds to the Curzon-Alhborn bound. Finally, we discuss the model acting as a Brownian refrigerator.

20. **Alejandro B. Kolton**. Universidad Complutense de Madrid, Spain.
E-mail: alejandro.kolton@fis.ucm.es

    Title: Transverse rectification of disorder-induced fluctuations in a driven system.

    Abstract: We study numerically the overdamped motion of particles driven in a two dimensional ratchet potential. In the proposed design, of the so-called geometrical-ratchet type, the mean velocity of a single particle in response to a constant force has a transverse component that can be induced by the presence of thermal or other unbiased fluctuations. We find that additional quenched disorder can strongly enhance the transverse drift, in spite of reducing the transverse mobility. We show that, under general conditions, the rectified transverse velocity of a driven particle fluid is equivalent to the response of a one dimensional flashing ratchet working at a drive-dependent effective temperature, defined through generalized Einstein relations.

21. **Veronica I. Maroni**. Universidad Complutense de Madrid, Spain.
E-mail: veromarconi@fis.ucm.es

    Title: Rocking ratchets in 2D Josephson networks: collective effects and current reversal.

    Abstract: A detailed numerical study on the directed motion of ac-driven vortices and anti vortices in 2D Josephson junction arrays (JJA) with an asymmetric periodic pinning potential is reported. Dc-voltage rectification shows a strong dependence on vortex density as well as an inversion of the vortex flow direction with ac amplitude for a wide range of vortex density around f=1/2 (f=$Ha2/\Phi_0$), in good agreement with recent experiments by Shalóm and Pastoriza [Phys. Rev. Lett. **94**, 177001 (2005)]. The study of vortex structures, spatial and temporal correlations, and vortex-anti vortex pairs formation gives insight into a purely collective mechanism behind the current reversal effect.

22. **Juan J. Mazo**. Universidad de Zaragoza, Spain.
E-mail: juanjo@unizar.es

    Title: Ratchet effects in 1D Josephson arrays.

    Abstract: A fluxon in a Josephson-junction parallel array behaves like a single particle in a periodic pinning potential. Different configurations of critical currents and cell areas result in different profiles for the fluxon potential. We analyze the minimal conditions to achieve an effective potential in which mirror symmetry is absent, namely a fluxon ratchet potential. Following one of the configurations, we designed circular arrays and probed some of the fluxon properties. Theoretical predictions are fulfilled by the experiments.

23. **Bernardo Sánchez-Rey**. Universidad de Sevilla, Spain.
E-mail: bernardo@us.es

Title: Kink ratchet in a two-state symmetric potential.

Abstract: We present a simple model that exhibits kink ratchet dynamics using a symmetric periodic potential that alternates between two possible states. A symmetry analysis shows that the direction of motion depends sensitively on the duration of the two states so that we can reverse or cancel the energy flux adjusting those parameters. Numerical simulations also show interesting resonant behaviors of the kink averaged velocity. The system preserves both, symmetry properties and resonant behaviors, when periodic switching between the two states is replaced by random fluctuations.

24. **Elías Zamora Sillero**. Universidad de Sevilla, Spain.
E-mail: ezamora80@hotmail.com

Title: Flux of Energy in symmetrical extended systems.

Abstract: Recent studies show that to produce a net flux of energy in Nonlinear Klein Gordon Systems is necessary to break the spatial symmetry, destroying the symmetry of the on-site potential, or breaks temporal symmetry [1,2,3] by means of the addition of a non symmetric ac driving force. In this talk I want to show how by coupling an additive and a parametrical general and symmetric ac forces it is possible to obtain a net flux of energy [4]. Necessary conditions of the on-site potential and between the frequencies of both forces to obtain a net transport of energy [5] will be presented. Finally we will show how these results generalize previous ones that only deal either with additive or nonsymmetric potentials.

References

[1] Mario Salerno and Yaroslav Zolotaryuk, Phys. Rev. E 65 056603 (2002). Luis Morales-Molina, Niurka R. Quintero, Franz G. Mertens and Ángel Sánchez, Phys. Rev. Lett. 91 234102 (2003)

[2] Niurka R. Quintero, Bernardo Sánchez Rey, Mario Salerno , Phys. Rev. E. 72 016610 (2005)

[3] G. Costantini, F. Marchesoni, and M. Borromeo, Phys. Rev. E 65, 051103 (2002).

[4] Elías Zamora-Sillero, Niurka R. Quintero, Franz G. Mertens, Phys. Rev. E. 74, 046607 (2006).

[5] Elías Zamora-Sillero, Niurka R. Quintero, Franz G. Mertens, preprint

Posters

25. **José Pablo Baltanás**. Universidad de Sevilla, Spain.
E-Mail: baltanas@us.es

Title: Stochastic resonance with weak monochromatic driving: gains above unity induced by high-frequency signals.

Abstract: We study the effects of a high-frequency (HF) signal on the response of a noisy bistable system to a low-frequency subthreshold sinusoidal signal. We show that, by conveniently choosing the ratio of the amplitude of the HF signal to its frequency, stochastic resonance gains greater than unity can be measured at the low-frequency value. Thus, the addition of the HF signal can entail an improvement in the detection of weak monochromatic signals. The results are explained in terms of an effective model and illustrated by means of numerical simulations.

26. **Martin Brown**. University College London, UK.
E-Mail: ucapmbr@ucl.ac.uk

Title: Ratchet effect in driven dissipative optical lattices: the case of intense standing waves.

Abstract: We theoretically investigate, via numerically simulations, a ratchet set-up for cold atoms based on ac-driven blue-detuned standing waves. We aim to understand whether this set-up allows us to study the overdamped limit of rocking-ratchets, which was shown theoretically to lead to a new symmetry, termed supersymmetry.

27. **Jesús Cuevas Maraver**. Universidad de Sevilla, Spain.
E-mail: jcuevas@us.es

Title: Ratchets and defect migration in solids.

Abstract: Interstitials and vacancies, in one-dimensional lattices, are point defects that can be modelled by means of kinks or antikinks in a discrete Frenkel-Kontorova model, with a sine-Gordon on-site potential. The properties of kinks and antikinks are the same if a harmonic interaction potential is considered. The ratchet properties of these defects in the above mentioned context has been studied by Zolotaryuk and Salerno when the system is driven by a biharmonic field. The properties of these solutions are strongly altered when an anharmonic interaction potential is introduced in the model, as the Peierls-Nabarro barrier is higher for antikinks than for kinks. The aim of this poster is to show the effects of the anharmoniciy of the interaction potential in the properties of kinks and antikinks focusing in the assymetry between the properties of these two species of topological solitons.

[1] Y. Zolotatyuk, M. Salerno. Phys. Rev. E 73 (2006) 066621

[2] J. Cuevas, C. Katerji, J.F.R. Archilla, J.C. Eilbeck, F.M. Russell. Phys. Lett. A 315 (2003) 364

[3] J. Cuevas, J.F.R. Archilla, B. Sánchez-Rey, F.R. Romero. Physica D 216 (2006) 115

28. **David Cubero**. Universidad de Sevilla, Spain.
E-mail: dcubero@us.es

Title: Flux reversal in a two-state symmetric lattice.

Abstract: We study a simple random-walk model on a one-dimensional lattice. The lattice as a whole switches periodically between two possible states which are spatially symmetric. Both lattice states are identical, but translated by one site with respect to each other, and consist of infinite arrays of absorbing sites separated by two nonabsorbing sites. Exact explicit expressions for the long-time velocity and the effective diffusion coefficient are obtained and discussed. This model can be regarded as a simple approximation for the experiment studied by Lee and Grier in [1]. A comparison between the exact results obtained from our simple model and those expected from the experiment is achieved by numerical simulations.

[1] S.-H. Lee and D. G. Grier, Phys. Rev. E 71, 060102(R) 2005 .

- **Elías Zamora-Sillero**. Universidad de Sevilla, Spain.
E-mail: ezamora80@hotmail.com

Title: Soliton Ratchet effect in Nonlinear Klein Gordon equations analyzed by symmetry, Collective Coordinates and perturbational techniques.

Abstract: During the last five years an intense impulse has been done in the study of the ratchet effect in extended systems. Two approaches have been used to understand the causes, properties and dynamics of the extended structures subjected to the ratchet effect. Salerno and Zolotaryuk and also Flach and coworkers [1] used symmetry analysis to obtain necessary conditions to obtain a non zero mean flux of energy in the system. After it other authors [2,3,4] using CC techniques obtained results in agreement with whose based in symmetry methods. In this poster using a generalization of the system proposed in [1], with additive and parametrical forces, we show how the collective coordinates equations and its perturbational approach fulfills the same symmetry properties than the original PDE equation that impose a zero mean velocity in the flux of energy of the system [5], explaining the agreement between both techniques.

[1] Mario Salerno and Yaroslav Zolotaryuk, Phys. Rev. E 65 056603 (2002). S. Flash et al. Phys. Rev. Lett. 88 184101 (2002)

[2] Luis Morales-Molina, Niurka R. Quintero, Franz G. Mertens and Ángel Sánchez, Phys. Rev. Lett. 91 234102 (2003)

[3] Elías Zamora-Sillero, Niurka R. Quintero, Franz G. Mertens, Phys. Rev. E. 74, 046607 (2006).

[4] Niurka R. Quintero, Bernardo Sánchez Rey, Mario Salerno , Phys. Rev. E. 72 016610 (2005).

[5] Elías Zamora-Sillero, Niurka R. Quintero, Franz G. Mertens, preprint

29. **Yaroslav Zolotaryuk**. Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine. E-Mail: `yzolo@bitp.kiev.ua`

Title: Ratchet effect for solitary waves in discrete media due to biharmonic AC drive.

Abstract: Directed motion of topological solitons (kinks or antikinks) in the damped and AC-driven discrete sine-Gordon system is investigated. We show that if the driving field breaks certain time-space symmetries, the soliton can perform unidirectional motion. The phenomenon resembles the well known effects of ratchet transport and nonlinear harmonic mixing. Direction of the motion and its velocity depends on the shape of the AC drive. Necessary conditions for the occurrence of the effect are formulated. In comparison with the previously studied continuum case, the discrete case shows a number of new features: non-zero depinning threshold for the driving amplitude, locking to the rational fractions of the driving frequency, and diffusive ratchet motion in the case of weak intersite coupling.

[1] Y. Zolotaryuk, P. L. Christiansen and M. Salerno, AC Driven Directed Motion of Solitary Waves, Int. J. Mod. Phys. B bf 17 (2003) 4428-4433.

[2] Y. Zolotaryuk and M. Salerno, Discrete soliton ratchets driven by biharmonic fields, Phys. Rev. E 73 (2006) 066621.

Other Participants

30. Renato Alvarez-Nodarse. Universidad de Sevilla, Spain.
E-mail: `ran@us.es`

31. José Luis Cardoso. Universidade de Trás-os-Montes e Alto Douro, Portugal. E-Mail: `jluis@utad.pt`

32. Francisco J. Esteban. Universidad de Jaén, Spain.
E-Mail: `festeban@ujaen.es`

33. Steven Lade. The Australian National University, Canberra, Australia.
E-Mail: `sjl124@rsphy1.anu.edu.au`

34. Niurka R. Quintero. Universidad de Sevilla, Spain.
E-Mail: `niurka@us.es`

35. Angel Sánchez. Universidad Carlos III de Madrid, Spain.
E-Mail: `anxo@math.uc3m.es`

36. José M. Sancho. Universidad de Barcelona, Spain.
E-Mail: `jmsancho@ecm.ub.es`

Ratchets in point-particle systems and in extended models: Mechanisms, control and applications

Casa de Carmona, Carmona (Sevilla), February 5-7, 2007

Ratchets in point-particle systems and in extended models: Mechanisms, control and applications.

RATCHETS-2007: CARMONA (SEVILLA), FEBRUARY 5-7, 2007

List of Participants

Invited Talks

1. Christian Van den Broeck. Hasselt University, Belgium.
   E-mail:christian.vandenbroeck@uhasselt.be
2. J. Casado-Pascual. Universidad de Sevilla, Spain.
   E-mail:jcasado@us.es
3. S. Denisov. Universitat Augsburg, Germany.
   E-mail:sergey.denisov@physik.uni-augsburg.de
4. Amar Flood. Indiana University, USA.
   E-mail:aflood@indiana.edu
5. D. Leigh University of Edinburgh, UK.
   E-mail:David.Leigh@ed.ac.uk
6. Heiner Linke. University of Oregon, USA.
   E-mail:linke@uoregon.edu
7. J. L. Mateos (pendiente de confirmar) Universidad Nacional Autónoma de México, México.
   E-mail:mateos@fisica.unam.mx
8. Franz Mertens, University of Bayreuth, Germany.
   Franz.Mertens@uni-bayreuth.de
9. M. Morillo. Universidad de Sevilla, Spain.
   E-mail:morillo@us.es
10. J.M.R. Parrondo, Universidad Complutense de Madrid, Spain.
    E-mail:parrondo@fis.ucm.es
11. P. Reimann. Universit"at Bielefeld, Germany.
    E-mail:reimann@physik.uni-bielefeld.de
12. F. Renzoni. University College London, UK.
    E-mail:ucapfre@ucl.ac.uk

13. M. Salerno. University of Salerno, Italy.
E-mail:salerno@sa.infn.it

14. Lutz Schimansky-Geier, Humboldt-University at Berlin, Germany.
E-mail:alsg@physik.hu-berlin.de

15. J. L. Vicent. Universidad Complutense de Madrid, Spain.
E-mail:jlvicent@fis.ucm.es

Short Talks

16. Luis Dinis. Universidad Complutense de Madrid.
E-mail:ldinis@seneca.fis.ucm.es

17. Edward Goldobin. University of Tuebingen, Germany.
E-mail:gold@uni-tuebingen.de

18. Alex Gómez-Marin. Universidad de Barcelona, Spain.
E-mail:agomezmarin@gmail.com

19. Alejandro B. Kolton. Universidad Complutense de Madrid, Spain.
E-mail:alejandro.kolton@fis.ucm.es

20. Veronica I. Maroni. Universidad Complutense de Madrid, Spain.
E-mail:veromarconi@fis.ucm.es

21. Juan J. Mazo. Universidad de Zaragoza, Spain.
E-mail:juanjo@unizar.es

22. Bernardo Sánchez-Rey. Universidad de Sevilla, Spain.
E-mail:bernardo@us.es

23. Elías Zamora Sillero. Universidad de Sevilla, Spain.
E-mail:ezamora80@hotmail.com

Posters

24. José Pablo Baltanás. Universidad de Sevilla, Spain.
E-mail:baltanas@us.es

25. Martin Brown. Department of Physics and Astronomy University College London, UK.
E-mail:ucapmbr@ucl.ac.uk

26. Jesús Cuevas. Universidad de Sevilla, Spain.
E-mail:jcuevas@us.es

27. David Cubero. Universidad de Sevilla, Spain.
E-mail:dcubero@us.es

* Elías Zamora Sillero. Universidad de Sevilla, Spain.
E-mail:ezamora80@hotmail.com

28. Yaroslav Zolotaryuk. Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine.
E-mail:yzolo@bitp.kiev.ua

Other participants

29. Renato Alvarez-Nodarse. Universidad de Sevilla, Spain.
ran@us.es

30. José Luis Cardoso. Universidade de Trás-os-Montes e Alto Douro, Portugal.
jluis@utad.pt

31. Francisco J. Esteban. Universidad de Jaén, Spain.
festeban@ujaen.es

32. Steven Lade. The Australian National University, Canberra, Australia.
sjl124@rsphy1.anu.edu.au

33. Niurka R. Quintero. Universidad de Sevilla, Spain.
niurka@us.es

34. Angel Sánchez. Universidad Carlos III de Madrid, Spain.
anxo@math.uc3m.es

35. José M. Sancho. Universidad de Barcelona, Spain.
jmsancho@ecm.ub.es