Seminari sulla Ricerca

Dipartimento di Fisica e Chimica

Università di Palermo – 11 aprile 2016

Meccanica Statistica di Non Equilibrio

Fisica dei Sistemi Complessi

Group of

Theoretical Interdisciplinary Physics

Staff members

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Post-docs, PhD students, Fellows

E. Anashkina

Angelo Carollo

Giovanni Denaro

Claudio Guarcello

Luca Magazzù

Group of Interdisciplinary Theoretical Physics

C. Guarcello, A.Carollo, A. A. Dubkov, B. Spagnolo,
E. Anashkina, D. Valenti, S. Spezia, L. Magazzù

Group of Interdisciplinary Theoretical Physics - Palermo University

1 - Dinamica stocastica di sistemi biologici fuori dall’equilibrio

Modellizzazione di sistemi biologici (microbiologia predittiva, dinamica di fitoplankton, crescita di cellule cancerogene e traslocazione di polimeri). I modelli teorici sono basati su equazioni differenziali stocastiche (Langevin e diffusione).

2 - Dinamica transiente in giunzioni Josephson (JJ) normali e con grafene.

Dinamica transitoria di non equilibrio dallo stato superconduttivo a quello resistivo di giunzioni Josephson, osservata anche in un materiale emergente, come il grafene.

3 - Ruolo positivo del rumore in sistemi quantistici aperti.

- Stabilizzazione di stati metastabili quantistici indotta dalla interazione sistema-bagno termico. Modello teorico: Caldeira-Leggett.
- Fermioni di Majorana e stati quantistici indotti dal rumore
- Sistemi in stato stazionario fuori dall'equilibrio (nonequilibrium steady states NESS).

Albert Einstein e il suo "annus mirabilis" (1905)

- Effetto fotoelettrico

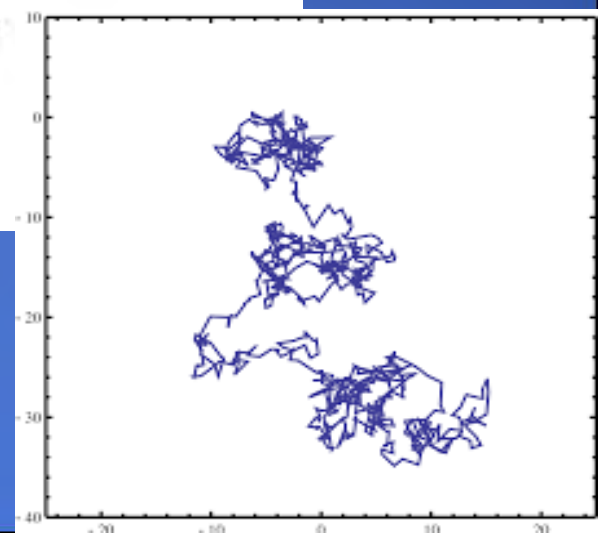
  ("Su un punto di vista euristico riguardo la produzione e trasformazione della luce")

- Moto browniano

  ("Sul moto richiesto dalla teoria cinetica degli atomi a piccole particelle sospese in un liquido")

- Teoria della relativita' ristretta

- ("Sull' elettrodinamica dei mezzi in movimento")

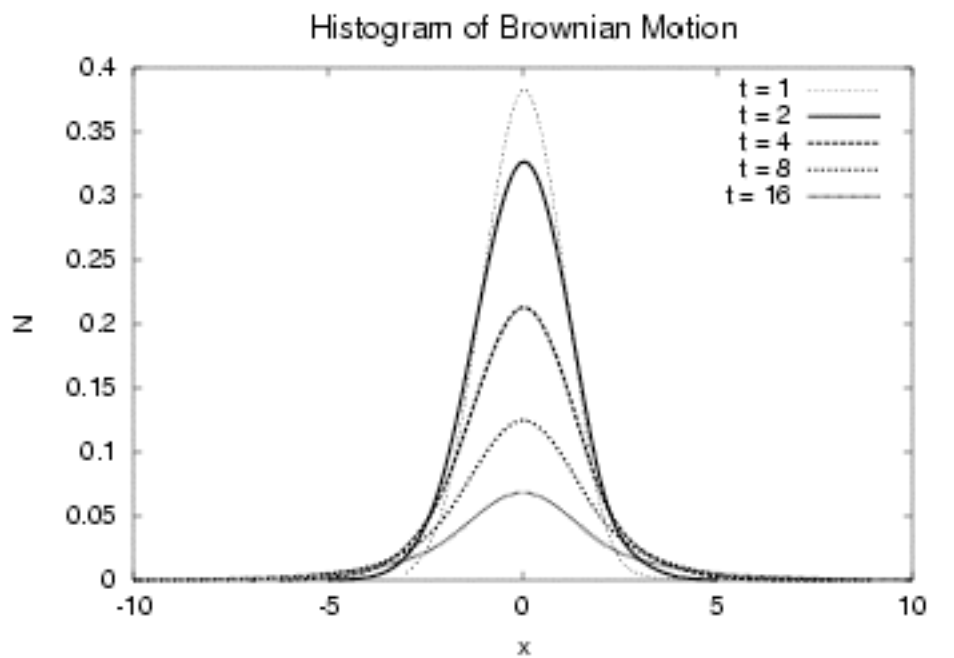


A. Einstein
Annalen der Physik 17 (1905) 549

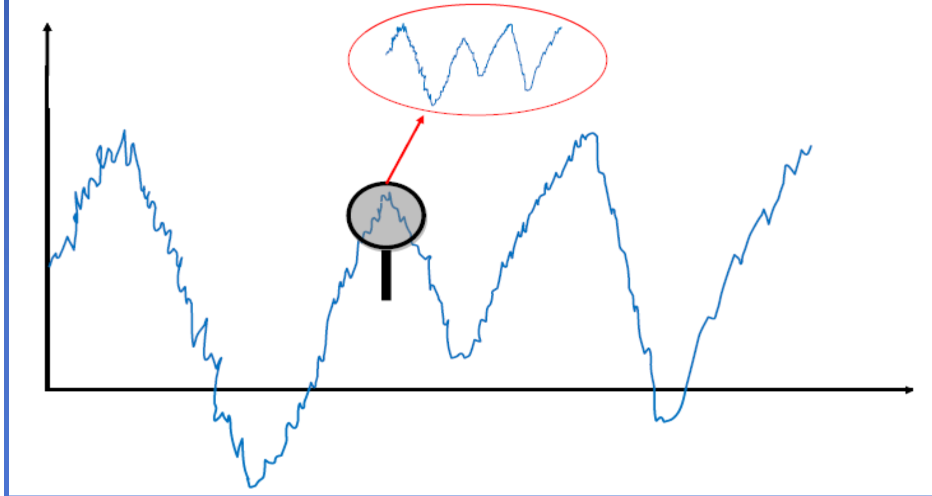
Teoria del moto browniano: la strada di Einstein

- Analisi della diffusione di una particella in un fluido
- Analisi della distribuzione di probabilita' degli spostamenti e come questa dipende dal coefficiente di diffusione
- Formula che lega il rapporto $R/N_{A,}$ il coefficiente di diffusione D, la viscosita' del solvente η, la temperatura T e il raggio molecolare P:

$$D = \frac{RT}{N_A} \frac{1}{6\pi\eta P}$$



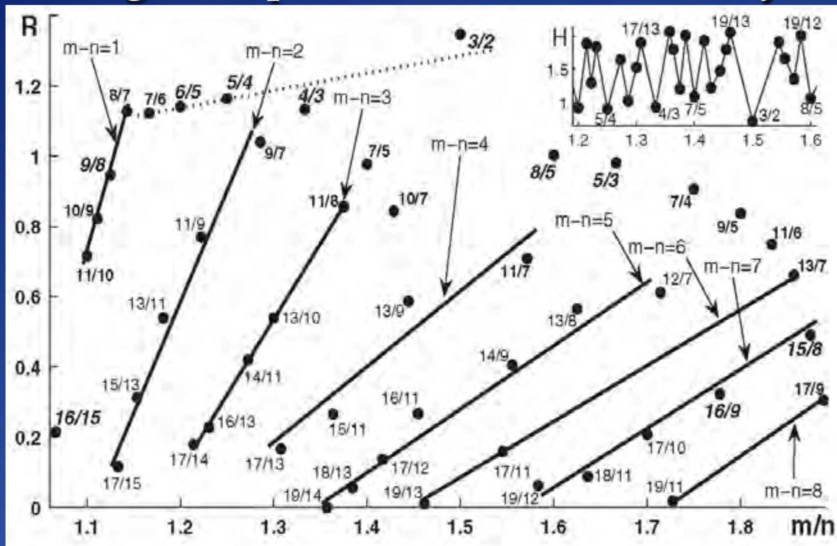
STRUTTURA AUTOSIMILARE



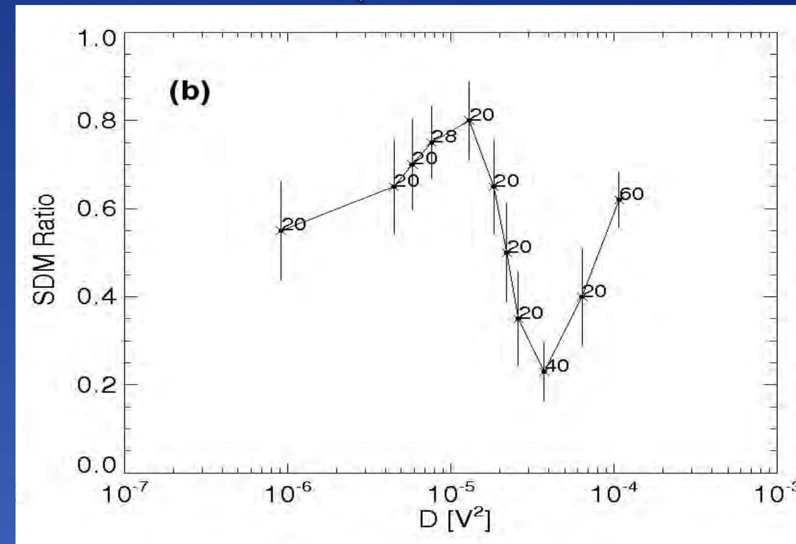
N. Wiener
Joumal of Math. and Phys. 2 (1923) 132

La teoria dinamica del moto browniano ci offre un filo conduttore entro la scienza fisica, dalla termodinamica statistica del non equilibrio alla teoria quantistica

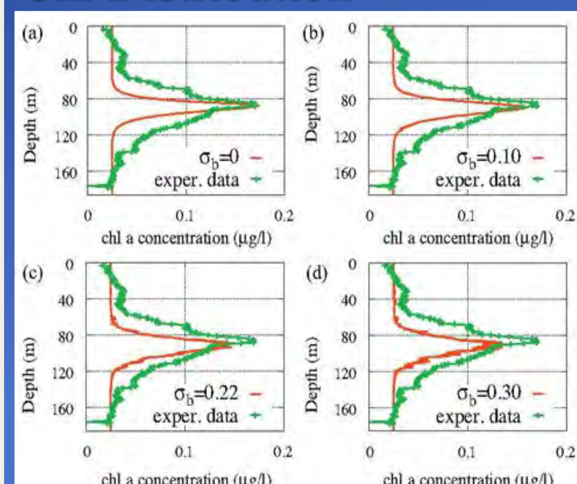
Regular Spike Trains and Harmony



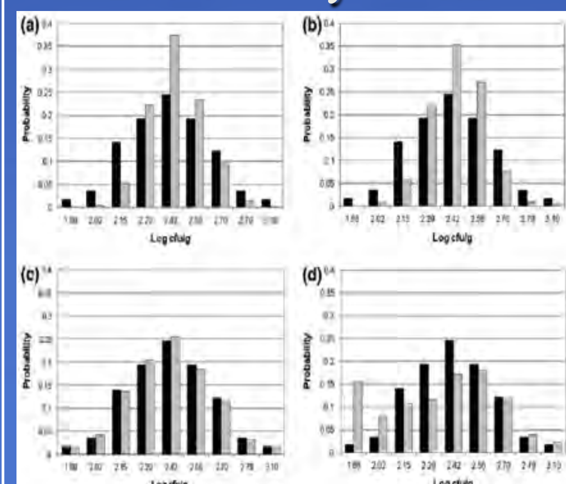
Nezara Viridula (Stochastic Resonance)



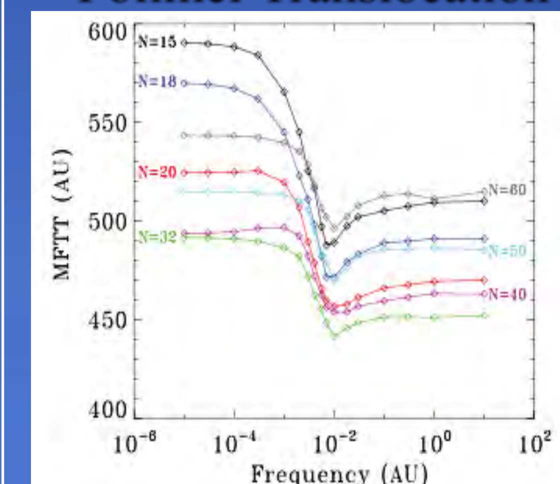
Chl Distribution



Bacterial Dynamics



Polimer Translocation



Highlights

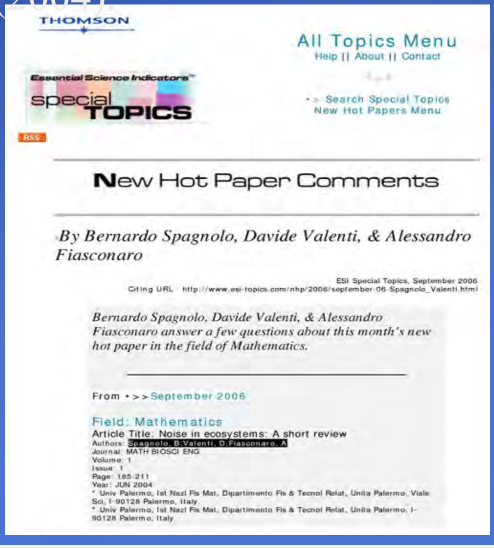
Regularity of spike trains and harmony perception in a model of the auditory system, **PRL 107**, 108103 (4) (2011).

Recensioni su

Focus PRL, ScienceNOW

NewScientist physicsworld.com

Noise in ecosystems: a short review, B. Spagnolo, D. Valenti, A. Fiasconaro, Math. Biosc. Engin. **1**, 185-211 (2004).



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By Bernardo Spagnolo, Davide Valenti, & Alessandro Fiasconaro

ESI Special Topics, September 2006
Citing URL: http://www.esi-topics.com/nhp/2006/september-06-Spagnolo_Valenti.html

Bernardo Spagnolo, Davide Valenti, & Alessandro Fiasconaro answer a few questions about this month's new hot paper in the field of Mathematics.

From • >> September 2006

Field: Mathematics
Article Title: Noise in ecosystems: A short review
Authors: Spagnolo, B;Valenti, D;Fiasconaro, A
Journal: MATH BIOSCI ENG
Volume: 1
Issue: 1
Page: 185-211
Year: JUN 2004
* Univ Palermo, Ist Nazl Fis Mat, Dipartimento Fis & Tecnol Relat, Unita Palermo, Viale Sci, I-90128 Palermo, Italy.
* Univ Palermo, Ist Nazl Fis Mat, Dipartimento Fis & Tecnol Relat, Unita Palermo, I-90128 Palermo, Italy.

A stochastic interspecific competition model to predict the behaviour of Listeria monocytogenes in the fermentation process of a traditional Sicilian salami, A. Giuffrida, D. Valenti, G. Ziino, B. Spagnolo, A. Panebianco, Eur. Food Res. Tech. **228**, 767-775 (2009).

Modelling bacterial fights for safer salami

A COMPUTER model of the battles between bacterial colonies could lead to salamis that are safer to eat and have longer shelf lives. The model could also help food scientists devise new ways to tackle the growth of dangerous bacteria in food.

The bacterium *Listeria monocytogenes* is a leading source of food-borne disease in meats and other products. To understand how it grows in food, scientists often turn to computer models which describe how bacteria reproduce given a source of food and variables such as temperature, pH and humidity.

Unfortunately, these models ignore the competition that *L. monocytogenes* faces from other bacterial species, says food safety specialist Alessandro Giuffrida at the University of Messina in Italy. He and colleagues have now developed a new model for bacterial growth that includes both competition and environmental influences.

The Italian team has focused on the way bacteria grows in traditional Sicilian salami during the fermentation stage of its preparation – a period of curing in which *L. monocytogenes*, if present, competes with a population of harmless lactic acid bacteria.

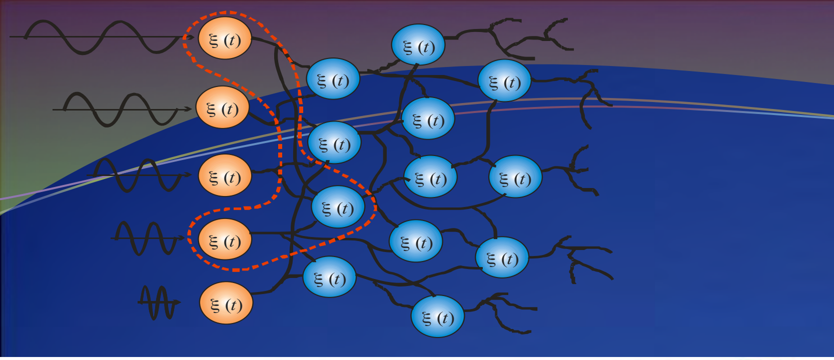
The new model simulates this competition for resources as well as the effects of fluctuations in environmental factors such as temperature and accurately

"Controlling bacterial battles could give food a longer shelf life"

reproduces experimental data on the growth of *L. monocytogenes*.

The model could be useful for devising ways to control the bacterial growth during the fermentation process. The model suggests that fluctuations of temperature, pH or humidity can be used to limit bacterial growth. In the fermentation

22 | NewScientist | 10 January 2009



- Yu.V. Ushakov, A.A. Dubkov and B. Spagnolo, "*Regularity of spike trains and harmony perception in a model of the auditory system*", Physical Review Letters **107**, 108103 (4) (2011).

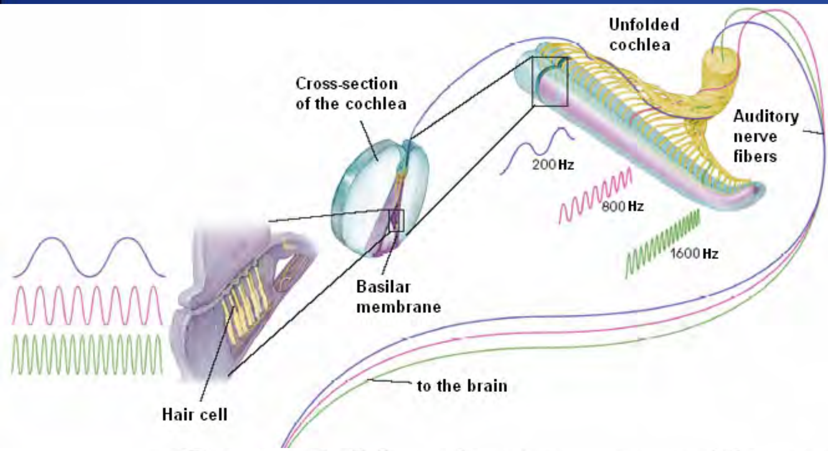
Selected as PRL Editor's Suggestion,

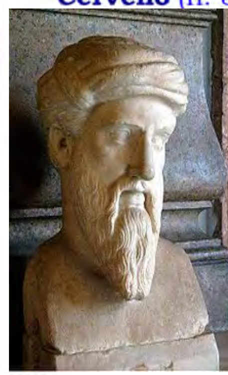
Reviewed by the following scientific magazines:

Focus PRL *(2 sett. 2011),*

Physics **Spotlighting exceptional research**

PhysicsWorld (14 settembre 2011), **ScienceNOW** (9 settembre 2011), **New Scientist** (19 settembre 2011), **PHYS-ORG.com** (Sep 12, 2011), **AUDIOLOGY-TALK** (September 13, 2011), **London Student**, **Londra** (Vol. 32, issue 3, dicembre 2011), **To Vima – Science, Atene** (29 gennaio 2012), **Mente e Cervello** (n. 83, novembre 2011).





physicsworld.com

Physicists in tune with neurons

Sep 13, 2011 3 comments

Sweet Music to your Nerves

Neurons transferring pulses and generating information

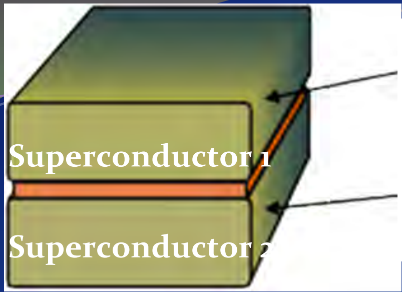
Physical Review Focus

Focus Archive | Image Index | Focus Search

Neural Harmony. Nice-sounding chords cause neurons to fire in a regular way, according to a biologically-motivated theoretical model. New work quantifies precisely what a "nice sounding" chord means for the neural signals going from the ear to the brain.

Have you ever wondered why certain sets of musical notes sound perfectly melodious while others make you want to cover your ears? Now, physicists in Europe have developed a model that suggests that certain notes sound harmonious because of the consistent rhythmic firing of neurons in the auditory system. The researchers say that they have now quantified this effect by showing that the neural signals are regularly spaced for frequencies that are pleasant sounding, but are erratic for those that are not. They say that their model may also provide insights into other senses, such as vision, that employ similar neural processing systems.

Josephson junction



$$\Psi_1 = |\Psi_1| e^{i\theta_1}$$

$$\Psi_2 = |\Psi_2| e^{i\theta_2}$$

Superconducting phase difference
$\varphi = \theta_1 - \theta_2$

Josephson effect

$$j_s = j_c \sin(\varphi)$$

$$V = \frac{\hbar}{2e}\frac{d\varphi}{dt}$$

The dimensionless x and t variables are normalized to λ_J, the Josephson penetration depth, and the inverse of ω_J, the characteristic frequency of the junction, respectively.

Phase dynamics in a noisy LJJ

The **perturbed** sine-Gordon (SG) model is

$$\beta\varphi_{tt} - \varphi_{xx} + \sin(\varphi) = -\varphi_t + \underbrace{i_b(x,t)}_{\text{External bias current}} + \underbrace{i_f(x,t)}_{\substack{\text{Noise source:}\\ \text{Lévy statistic}}}$$

The SG equation can be rearranged highlighting the role of the washboard potential:

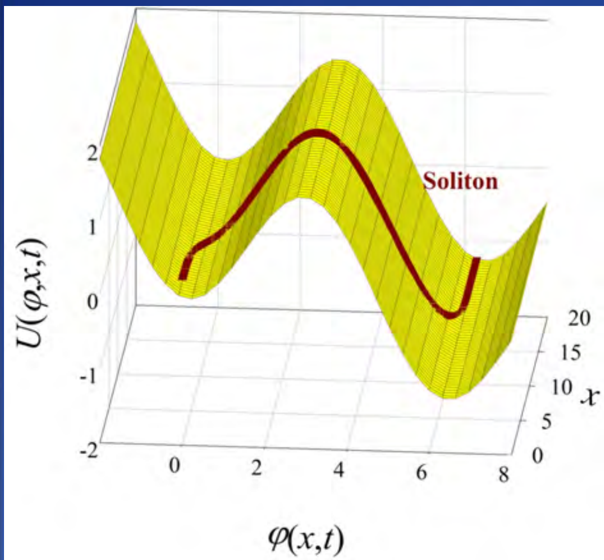
$$\beta\varphi_{tt}(x,t) - \varphi_{xx}(x,t) + \varphi_t(x,t) = -U_\varphi(\varphi,x,t) + i_f(x,t)$$

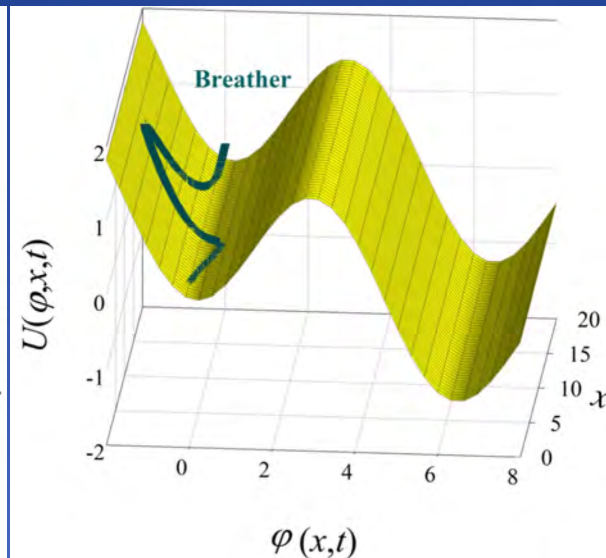
The SG solutions

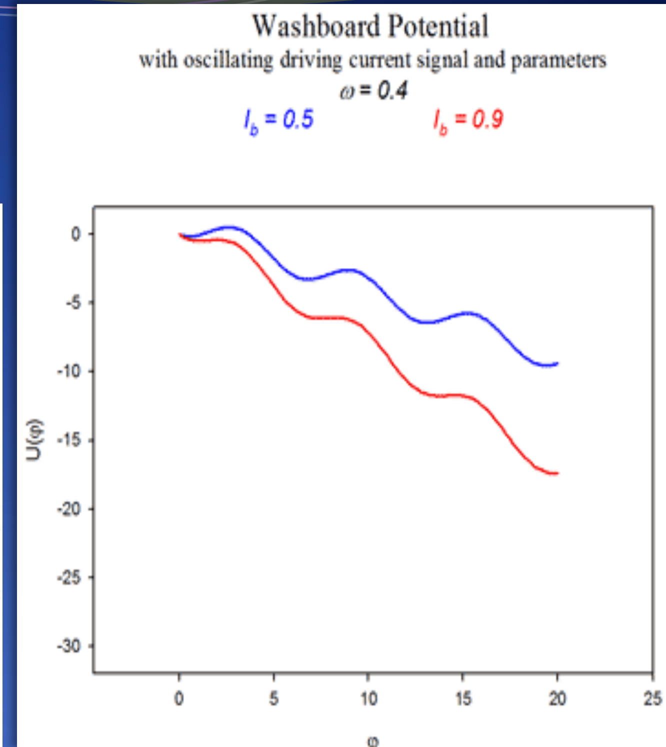
$$U(\varphi,x,t)=1-\cos(\varphi)-i_b(x,t)\,\varphi$$

- Plasma waves
- Soliton/anti-Soliton and Chain of Solitons
- Breathers

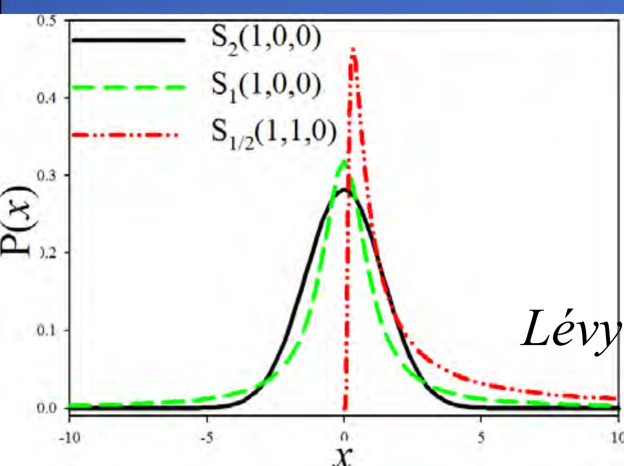
Soliton ***Breather***







The noise term: the Lévy statistic



Lévy Flights

Distribution.	P(x)		$S_\alpha(\sigma,\beta,\mu)$
Gaussian	$\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(x-\mu)^2}{2\sigma^2}}$	$x\in\mathbb{R}$	$S_2(\sigma,0,\mu)$
Cauchy-Lorentz	$\frac{\sigma/\pi}{\sigma^2+(x-\mu)^2}$	$x\in\mathbb{R}$	$S_1(\sigma,0,\mu)$
Lévy-Smirnov	$\sqrt{\frac{\sigma}{2\pi}}\frac{e^{-\frac{\sigma}{2(x-\mu)}}}{(x-\mu)^{3/2}}$	$x\geq\mu$	$S_{\frac{1}{2}}(\sigma,1,\mu)$

Fluctuation and Noise Letters
Vol. 5, No. 2 (2005) L267–L274
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GENERALIZED WIENER PROCESS AND KOLMOGOROV'S EQUATION FOR DIFFUSION INDUCED BY NON-GAUSSIAN NOISE SOURCE

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Received 23 December 2004
Revised 6 March 2005
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Communicated by Werner Ebeling and Bernardo Spagnolo

We show that the increments of generalized Wiener process, useful to describe non-Gaussian white noise sources, have the properties of infinitely divisible random processes. Using functional approach and the new correlation formula for non-Gaussian white noise we derive directly from Langevin equation, with such a random source, the Kolmogorov's equation for Markovian non-Gaussian process. From this equation we obtain the Fokker–Planck equation for nonlinear system driven by white Gaussian noise, the Kolmogorov–Feller equation for discontinuous Markovian processes, and the fractional Fokker–Planck equation for anomalous diffusion. The stationary probability distributions for some simple cases of anomalous diffusion are derived.

Keywords: Non-Gaussian white noise; infinitely divisible distribution; Kolmogorov's equation; Wiener process.

1. Introduction

Stochastic dynamics is useful to model many biological, chemical, economical and physical systems. The random driving forces have very different origins, in most cases they are Gaussian white or colored noise sources, but often these forces must be considered as non-Gaussian ones, for example, in sensory and biological systems [1]. Moreover, in many physical and biological systems a deviation of real statistics of fluctuations from Gaussian law, leading to anomalous diffusion, is observed [2,3]. A suitable mathematical model to describe the anomalous diffusion is the fractional

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LÉVY FLIGHT SUPERDIFFUSION: AN INTRODUCTION

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Received February 6, 2008; Revised February 20, 2008

After a short excursion from the discovery of Brownian motion to the Richardson "law of four thirds" in turbulent diffusion, the article introduces the Lévy flight superdiffusion as a self-similar Lévy process. The condition of self-similarity converts the infinitely divisible characteristic function of the Lévy process into a stable characteristic function of the Lévy motion. The Lévy motion generalizes the Brownian motion on the base of the α-stable distributions theory and fractional order derivatives. Further development on this idea lies on the generalization of the Langevin equation with a non-Gaussian white noise source and the use of functional approach. This leads to the Kolmogorov's equation for arbitrary Markovian processes. As a particular case we obtain the fractional Fokker–Planck equation for Lévy flights. Some results concerning stationary probability distributions of Lévy motion in symmetric smooth monostable potentials, and a general expression to calculate the nonlinear relaxation time in barrier crossing problems are derived. Finally, we discuss the results on the same characteristics and barrier crossing problems with Lévy flights, recently obtained by different approaches.

Keywords: Lévy process; Lévy motion; Lévy flights; stable distributions; fractional differential equation; barrier crossing.

1. Introduction

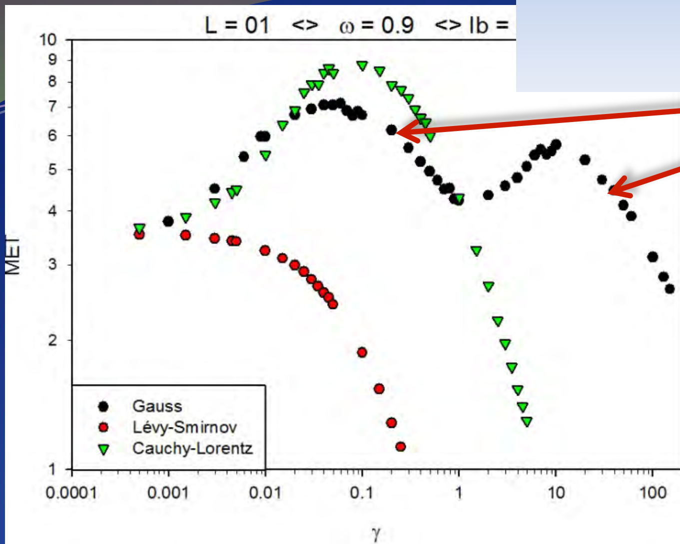
Two kinds of motions can easily be observed in Nature: smooth, regular motion, like Newtonian motion of planets, and random, highly irregular motion, like Brownian motion of small specks of dust in the air. The first kind of motion can be predicted and consequently, described in the frame of deterministic approach. The second one demands the statistical approach.

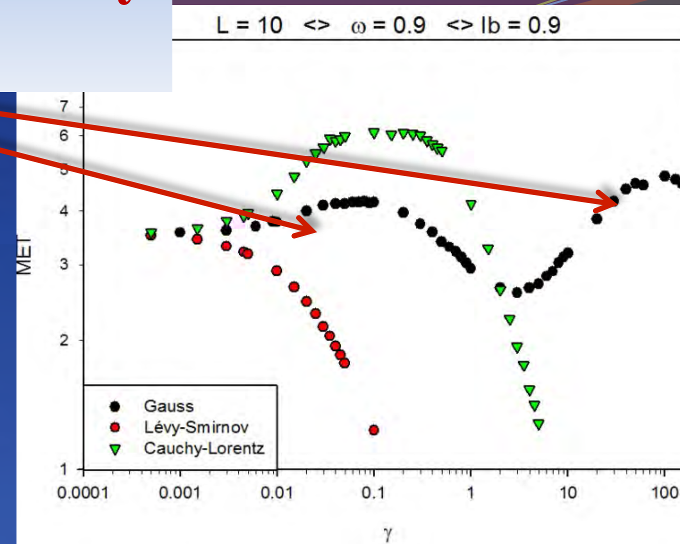
The first man who noted the Brownian motion was the Dutch physician, Jan Ingen-Housz in 1794, who, while in the Austrian court of Empress Maria Theresa, observed that finely powdered charcoal floating on an alcohol surface executed a highly

*http://gip.dft.unipa.it

Group of Interdisciplinary Theoretical Physics

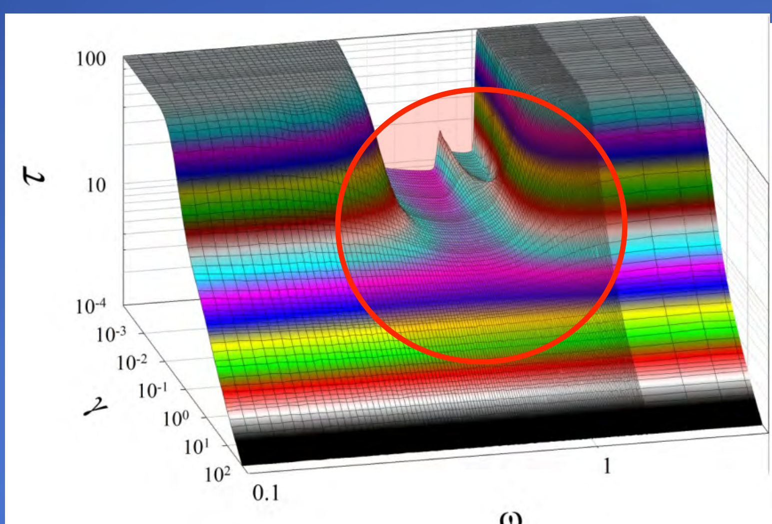
Noise Enhanced Stability effects

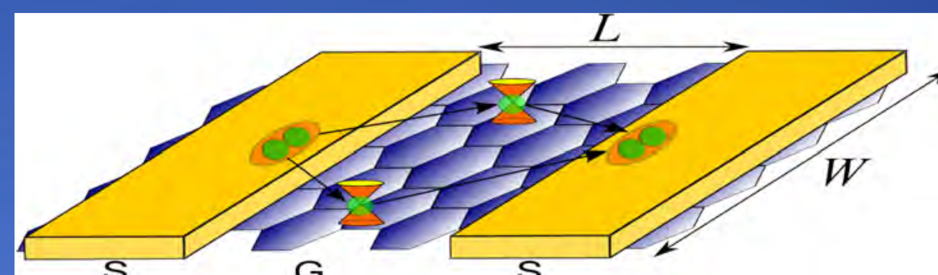




Short ballistic graphene-based JJ

$$\varphi_{tt} + \alpha\varphi_t = -U_\varphi(\varphi, x, t) + i_f(t)$$





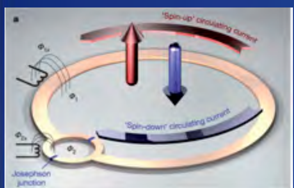
Dynamical and Stochastic Resonant Activation

Open Quantum Systems

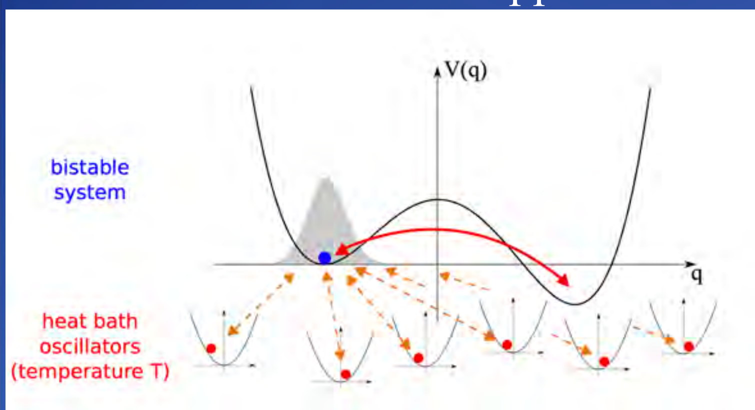
Un qubit (*quantum bit*, o bit quantistico) è un sistema quantistico a due stati (gli stati logici 0 e 1) che può essere preparato e operare in una *sovrapposizione* di tali stati → computer quantistici

La ricerca è mirata a realizzare dei sistemi affidabili e scalabili (a molti qubit):

E' importante lo studio del rumore nei dispositivi quantistici.



Esempio: il qubit di flusso, un loop superconduttivo in cui ai versi di circolazione della supercorrente (orario o antiorario → flusso del c. m. attaverso il loop positivo o negativo), sono associati gli stati logici ***0*** e ***1***: il qubit di flusso può trovarsi in una sovrapposizione della supercorrente circolante nei due versi opposti.



Le sorgenti di rumore che influenzano il comportamento dei qubit sono a loro volta dei sistemi quantistici: ad esempio il campo elettromagnetico (→ fotoni) o le vibrazioni reticolari (→ fononi). Infatti, anche a temperatura criogenica tali '*ambienti*' in cui i dispositivi sono immersi, hanno fluttuazioni.

Può la dissipazione aumentare la stabilità di uno stato quantistico metastabile?

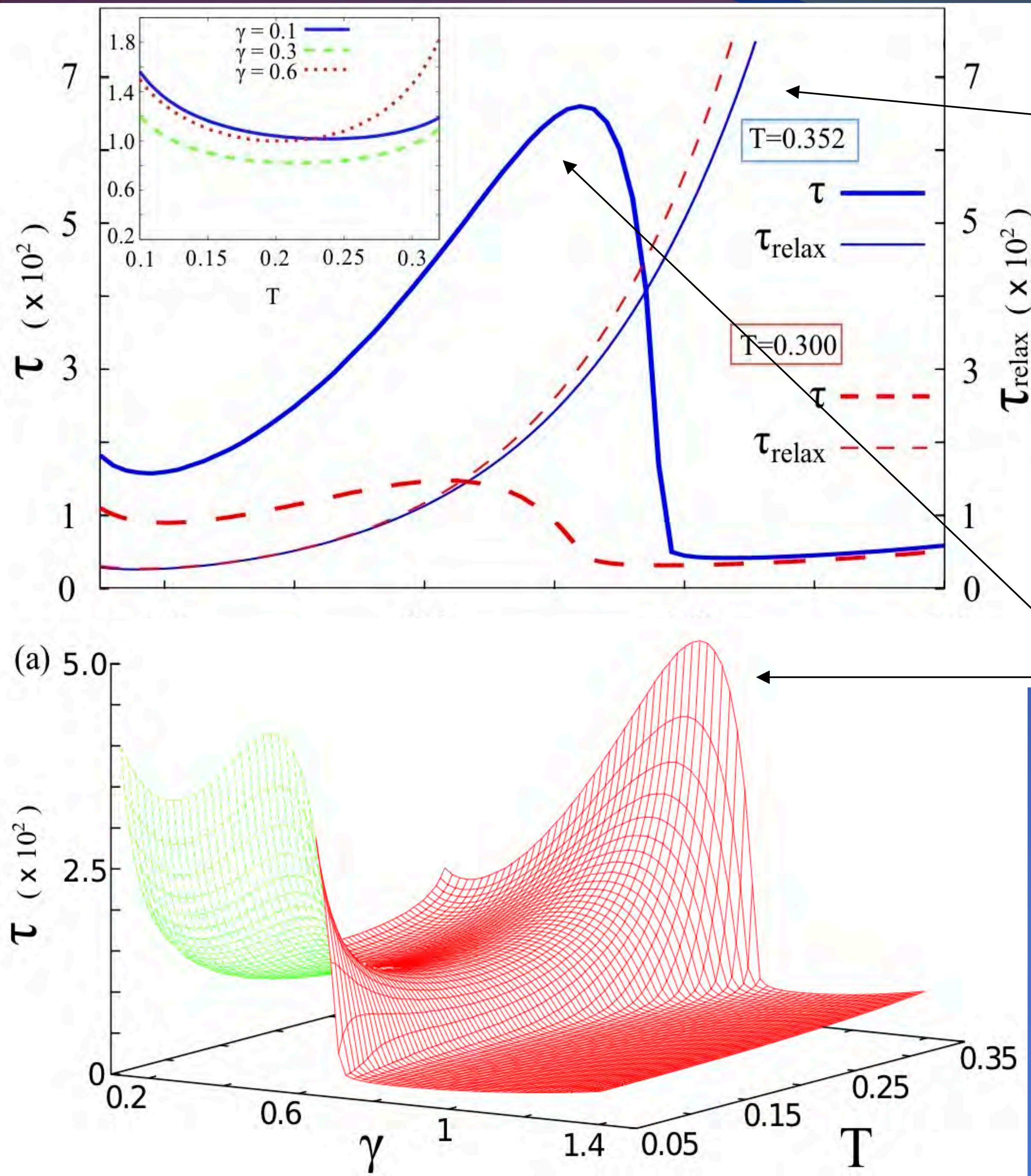
Caldeira-Leggett Hamiltonian

$$H(t) = \frac{p^2}{2M} + V(t) + H_R + H_{SR}$$

$$H_R + H_{SR} = \sum_{j=1}^{N} \frac{1}{2}\left[\frac{p_j^2}{m_j} + m_j\omega_j^2\left(x_j - \frac{c_j}{m_j\omega_j^2}q\right)^2\right]$$

$N \to \infty$: heat bath $\qquad J(\omega) = M\gamma_s\omega_{\rm ph}^{1-s}\omega^s e^{-\omega/\omega_c}$

$s = 1$: Ohmic damping $\qquad \gamma$: damping constant



Relaxation time:
The time scale of the relaxation towards equilibrium.

- Independent of the initial condition

- increases monotonically as a function of the coupling strength

Escape time:

- Depends on the initial condition

- Nonmonotonic behaviour with a maximum as a function of the coupling strength:

Quantum noise enhance stability

D. Valenti, L. Magazzù, P. Caldara, and **B. Spagnolo**, Phys.Rev.B **91**, 235412 (2015)

Fermione di Majorana: l'elusiva particella *"ermafrodita"*
-antiparticella di se stessa
-teorizzata nel 1937 da Ettore Majorana, mai osservata con certezza!
*-prime possibili evidenze in **superconduttori topologici** (2012)*

Chi l'ha visto?

Ettore Majorana, ordinario di fisica teorica all'Università di Napoli, è misteriosamente scomparso dagli ultimi di marzo. Di anni 31, alto metri 1,70, snello, con capelli neri, occhi scuri, una lunga cicatrice sul dorso di una mano. Chi ne sapesse qualcosa è pregato di scrivere al R. P. E. Marianecci, Viale Regina Margherita 66 - Roma.

Perché è importante?

- *Fisica fondamentale*
- *Esempio di "Anyone": **né bosone né fermione**!*
- *Implicazioni nello studio di **nuovi stati** della materia condensata*
- *Sviluppo di **computer quantistici**, inerentemente **robusti** contro il rumore*

Stati esotici della materia: <u>ordine topologico</u>
-Nuovo concetto per descrive ordine in sistemi a "tanti corpi"
-Esempio: Quantum Hall effect (1980)
*-Isolante topologico (2006): materiale **isolante** al suo **interno**, perfetto **conduttore** sulla **superficie***

Fermioni di Majorana indotti dal rumore

- *La dissipazione normalmente aumenta il disordine di un sistema*
- *Tuttavia, e' possibile usare il rumore per "ingegnerizzare" stati quantistici della materia!*
- *Al confine tra fisica della **materia condensata** e **ottica quantistica***
- ***Ordine topologico+dissipazione -> robustezza alle perturbazioni***

Collaborazioni nazionali

- Dipartimento di Fisica, Università di Catania
- NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Pisa
- CNR – Istituto per l'ambiente marino costiero (IAMC) – Capo Granitola (Mazara del Vallo)
- Dipartimento di Fisica e di Scienze della Terra, Università di Messina
- Dipartimento di Scienze Veterinarie, Università di Messina

Collaborazioni internazionali

-Physics Department and International Laser Center, Lomonosov State University of Moscow, Russia
- Radiophysics Department, Lobachevsky State University of Nizhni Novgorod, Russia
- Institut für Physik, Universität Augsburg, Augsburg, Gernany
- Physics Department, Humboldt University, Berlin, Germany
- Institute for Theoretical Physics, University of Regensburg, Regensburg, Germany
- Institute of Physics, Karlsruhe Institute für Technologie (KIT), Karlsruhe, Germany
- Marian Smoluchowski Institute of Physics, Jagellonian University, Mark Kac Complex Systems Research Center, Krakow, Poland
- Institut of Environmetal Systems Research, School of Mathematics, Universität Osnabrück, Germany
- Institute for Physics of Microstructures, Russian Academy of Science, Nizhny Novgorod, Russia

Pubblicazioni (2015)

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