PHYSICAL REVIEW E **89**, 022117 (2014)

Carnot cycle for interacting particles in the absence of thermal noise

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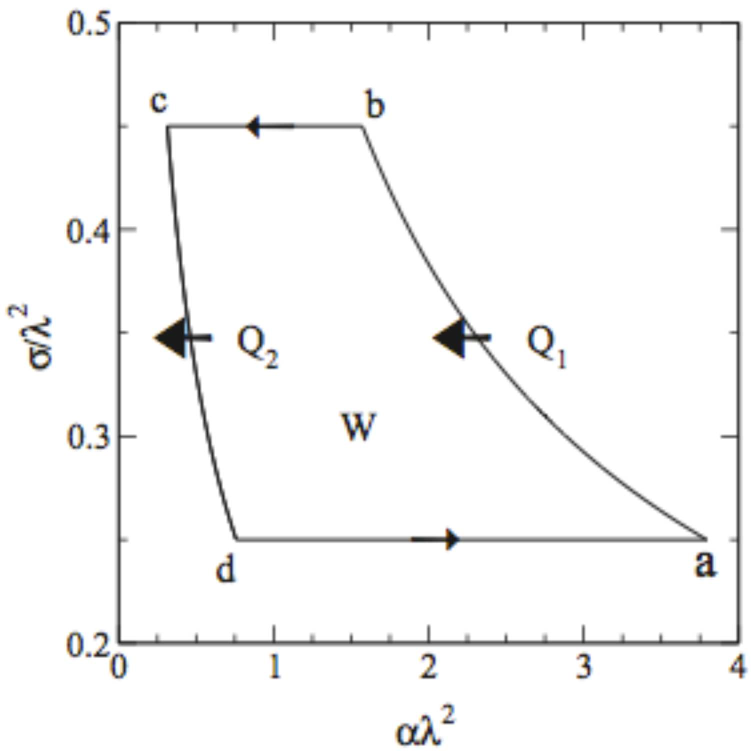
(Received 2 May 2013; published 18 February 2014)



celebrated efficiency of the Carnot cycle,

$$\eta = \frac{\mathcal{W}}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{\theta_2}{\theta_1} \quad (0 \leqslant \eta \leqslant 1)$$

FULL THERMODYNAMICS OF CONTINUOUS SYSTEM WITH $q < 0$

RAPID COMMUNICATIONS

PHYSICAL REVIEW E **93**, 060103(R) (2016)

General continuum approach for dissipative systems of repulsive particles

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(Received 15 February 2016; published 9 June 2016)

We propose a general coarse-graining method to derive a continuity equation that describes any dissipative system of repulsive particles interacting through short-ranged potentials. In our approach, the effect of particle-particle correlations is incorporated to the overall balance of energy, and a nonlinear diffusion equation is obtained to represent the overdamped dynamics. In particular, when the repulsive interaction potential is a short-ranged power law, our approach reveals a distinctive correspondence between particle-particle energy and the generalized thermostatistics of Tsallis for any nonpositive value of the entropic index q. Our methodology can also be applied to microscopic models of superconducting vortices and complex plasma, where particle-particle correlations are pronounced at low concentrations. The resulting continuum descriptions provide elucidating and useful insights on the microdynamical behavior of these physical systems. The consistency of our approach is demonstrated by comparison with molecular dynamics simulations.

DOI: 10.1103/PhysRevE.93.060103

$$V(r) \propto \frac{1}{r^{\lambda}} \left(\text{repulsive interaction, } \lambda > d \text{ and overdamping}\right)$$

$$q = 1 - \frac{\lambda}{d} < 0 \quad \text{(both analytic and numerical)}$$

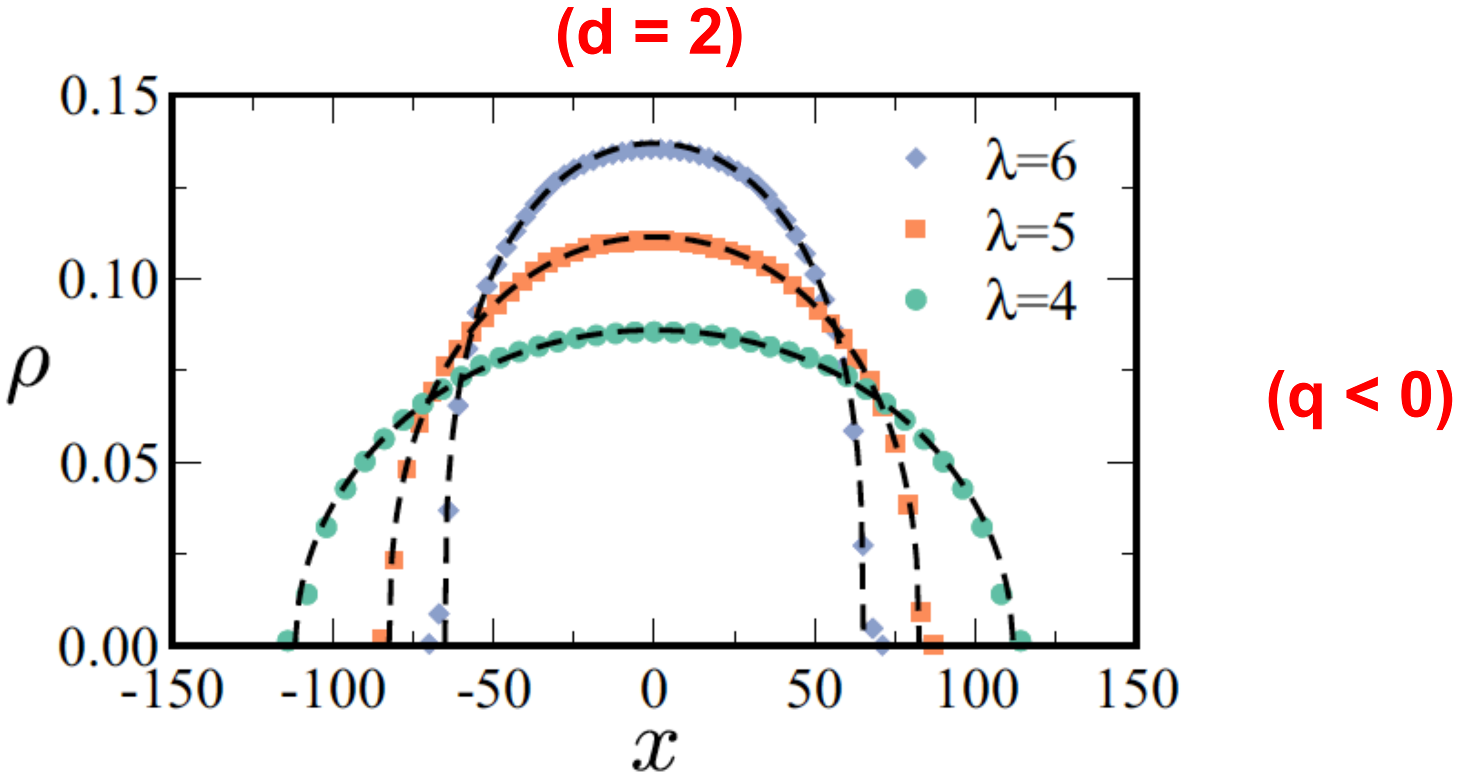

FIG. 1. Density profiles at the stationary state obtained from simulations (symbols). We consider two-dimensional systems of $N = 900$ particles interacting through a power-law repulsive potential $V_\lambda(r) = \varepsilon\sigma^\lambda r^{-\lambda}$. In the x direction, the particles are confined by a quadratic potential $U_{\text{ext}}(x) = kx^2/2$, with $k = 10^{-5}\varepsilon\sigma^{-2}$. In the y direction the simulation cell has a dimension $L_y = 60\sigma$, with periodic boundary conditions. We present results for simulations of this system considering three different values of λ. The dashed lines represent the results of the continuum model via Eq. (20).

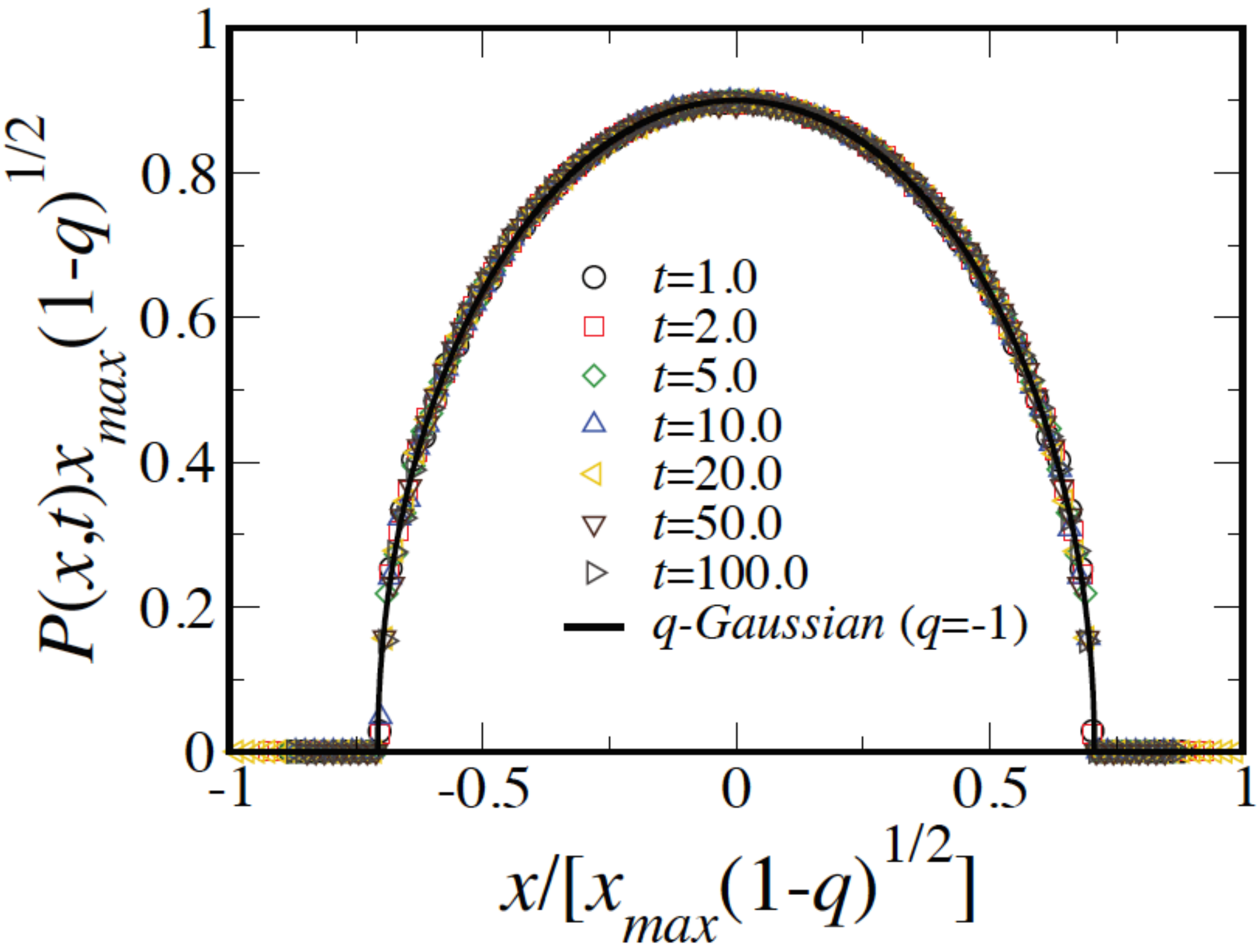

FIG. 3. Distributions of scaled positions at different moments of the dynamics. These results concern particles interacting through the power law potential, $V(r) \sim r^{-4}$. The black line is a q-Gaussian ($q = -1$). Here we used $k = 10^{-3}$.

$$\lambda = 4$$

$$d = 2$$

$$q = 1 - \frac{\lambda}{d} = -1$$

J.S. Andrade et al (2017)

A LETTERS JOURNAL EXPLORING THE FRONTIERS OF PHYSICS

September 2011

EPL, **95** (2011) 68002
doi: 10.1209/0295-5075/95/68002

www.epljournal.org

Universal behaviour of interoccurrence times between losses in financial markets: An analytical description

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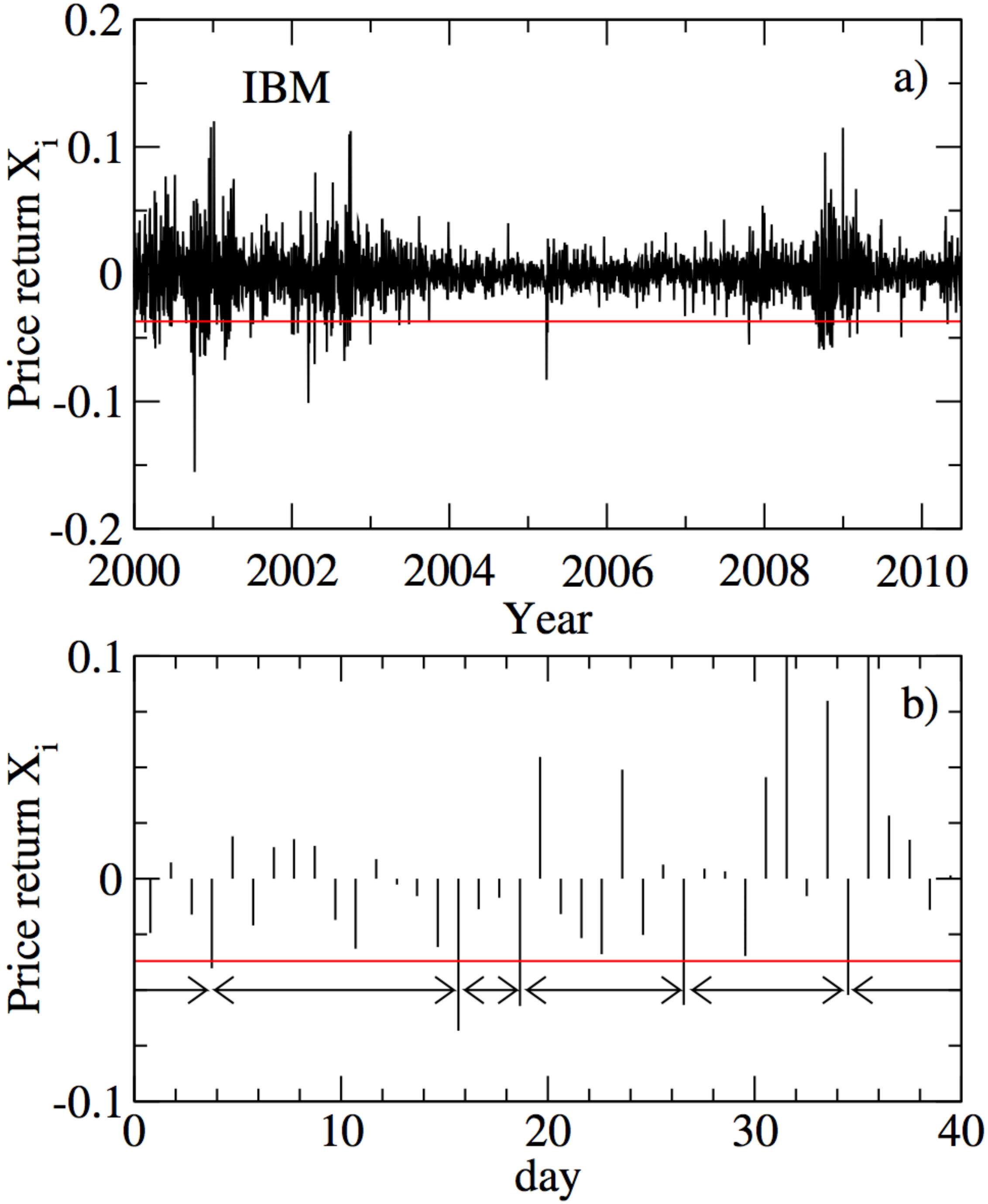
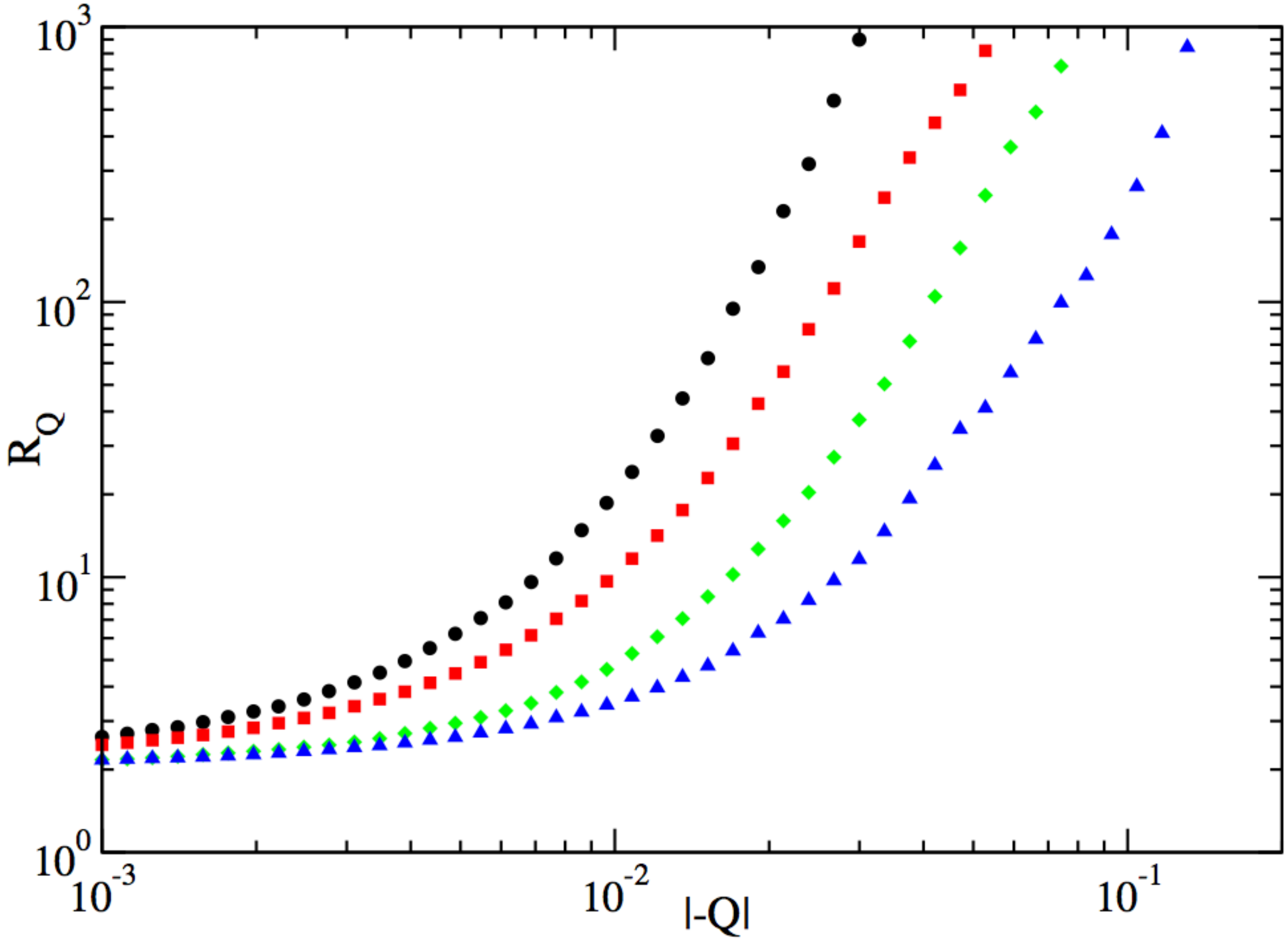
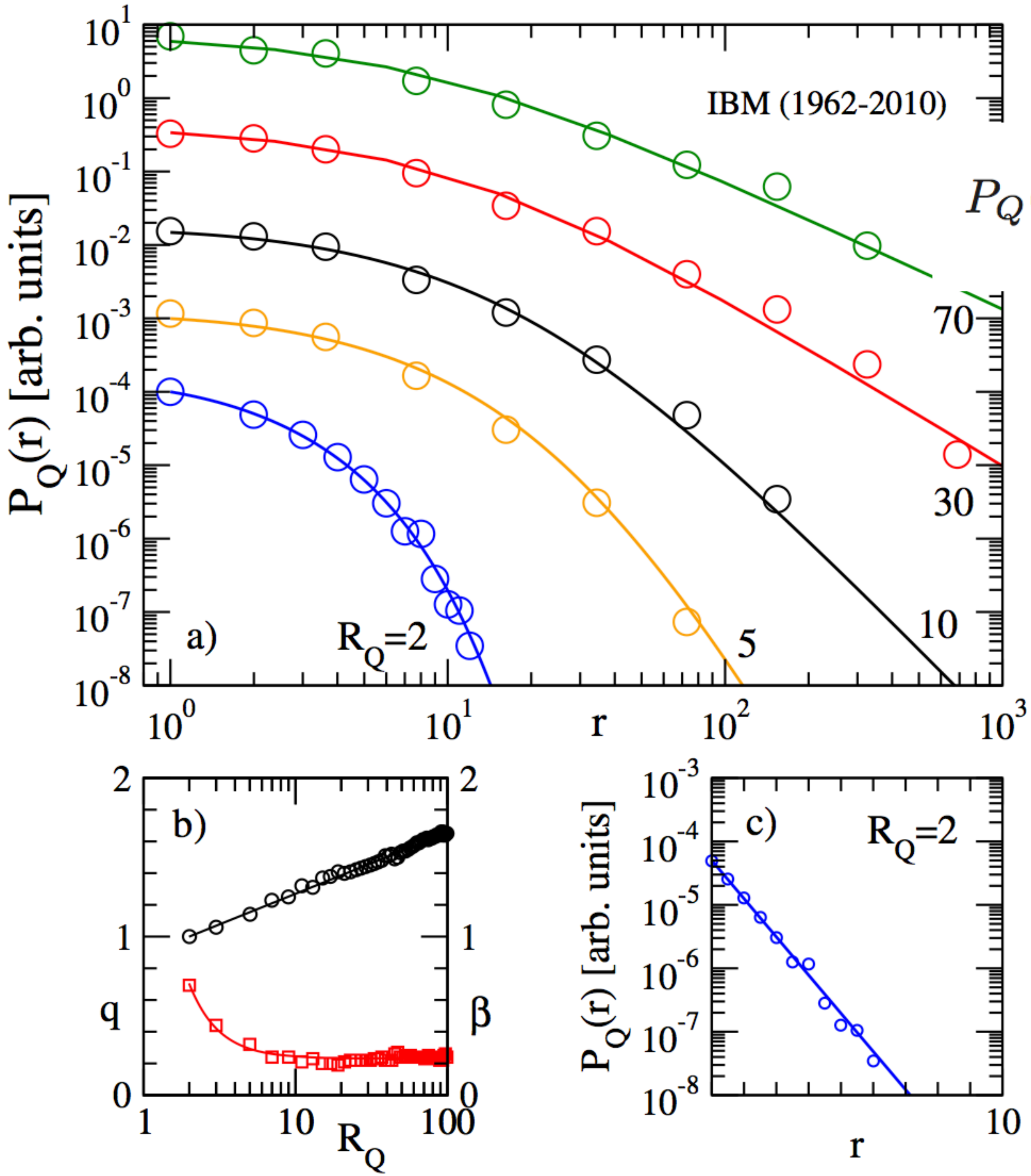

IBM
a)
Price return X_i
0.2
0.1
0
-0.1
-0.2
2000
2002
2004
2006
2008
2010
Year
b)
Price return X_i
0.1
0
-0.1
0
10
20
30
40
day



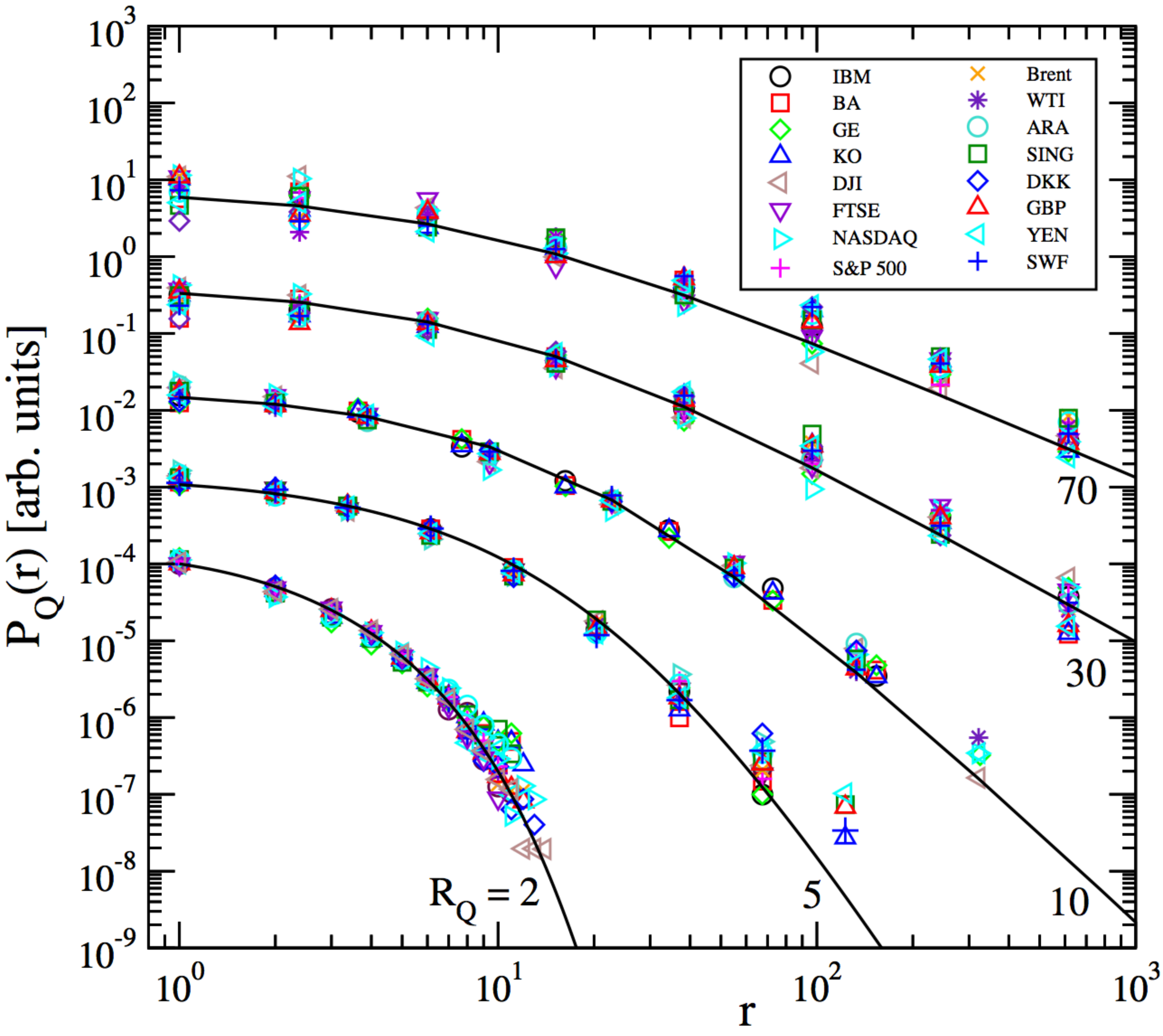
The mean interoccurrence time R_Q *vs.* the absolute value of the loss threshold $-Q$, for the exchange rate US Dollar against British Pound, the index S&P500, the IBM stock, and crude oil (WTI), from left to right.



$$P_Q(r) = \frac{A}{(1+(q-1)\beta\, r)^{1/(q-1)}}$$

$$q = 1 + q_0 \ln(R_Q/2)$$

$q_0 \simeq 0.168$



IBM
BA
GE
KO
DJI
FTSE
NASDAQ
S&P 500
Brent
WTI
ARA
SING
DKK
GBP
YEN
SWF
70
30
10
5
$R_Q = 2$
$P_Q(r)$ [arb. units]
r

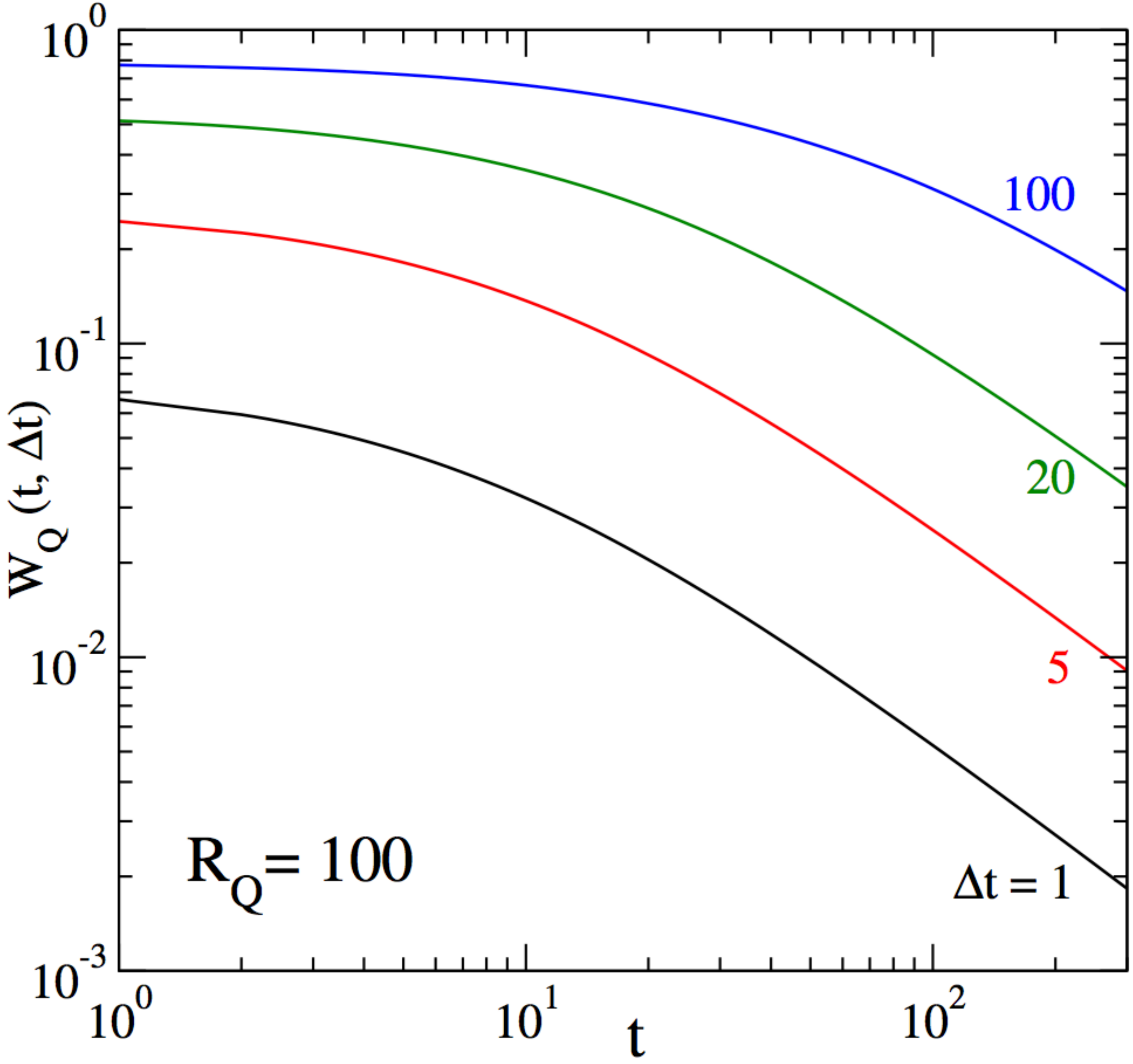
Universal risk function:

$$W_Q(t;\Delta t) = \frac{\int_t^{t+\Delta t} P_Q(r)\,\mathrm{d}r}{\int_t^{\infty} P_Q(r)\,\mathrm{d}r}$$

$$= 1 - \left(1 + \frac{\beta(q-1)\Delta t}{1+\beta(q-1)t}\right)^{\frac{q-2}{q-1}}$$

$$= 1 - \frac{e_{\tilde{q}}^{-(\beta/\tilde{q})(t+\Delta t)}}{e_{\tilde{q}}^{-(\beta/\tilde{q})\,t}}$$

$$\tilde{q} = 1/(2-q)$$



10^0
10^{-1}
10^{-2}
10^{-3}
10^0
10^1
10^2
t
$W_Q(t, \Delta t)$
100
20
5
$\Delta t = 1$
$R_Q = 100$

Physica A 409 (2014) 71–77

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journal homepage: www.elsevier.com/locate/physa

Evidence of q-exponential statistics in Greek seismicity

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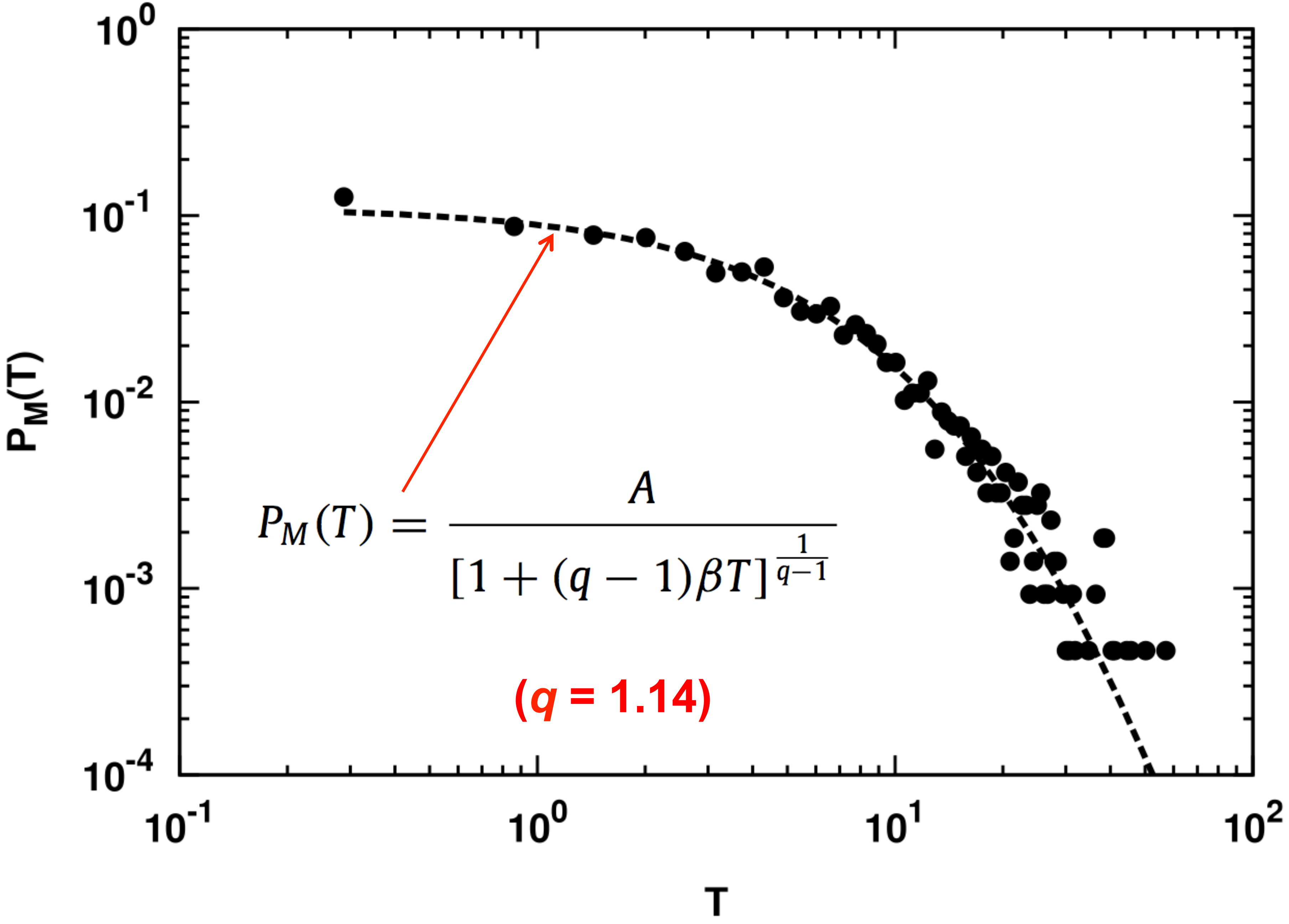
INTEROCCURRENCE TIME DISTRIBUTION OF DECLUSTERED SEISMIC DATA (GREECE, 1976-2009)



PLOS ONE | DOI:10.1371/journal.pone.0112534 December 1, 2014

PLOS | ONE

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RESEARCH ARTICLE

Universal Internucleotide Statistics in Full Genomes: A Footprint of the DNA Structure and Packaging?

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*Mikhail.Bogachev@physik.uni-giessen.de

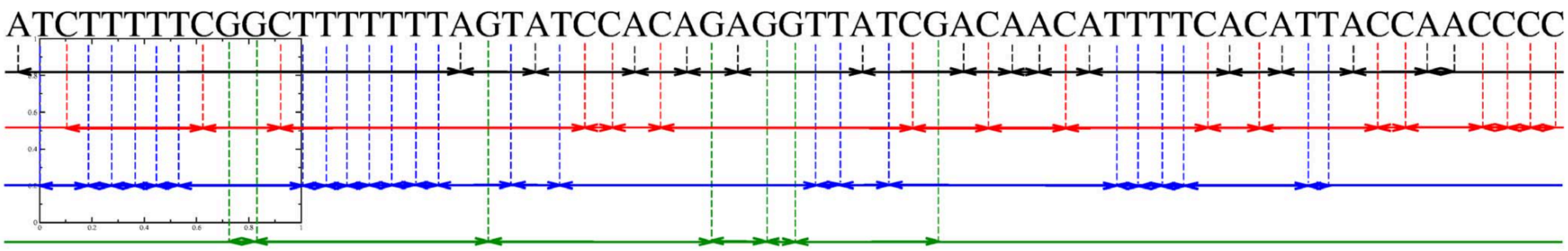
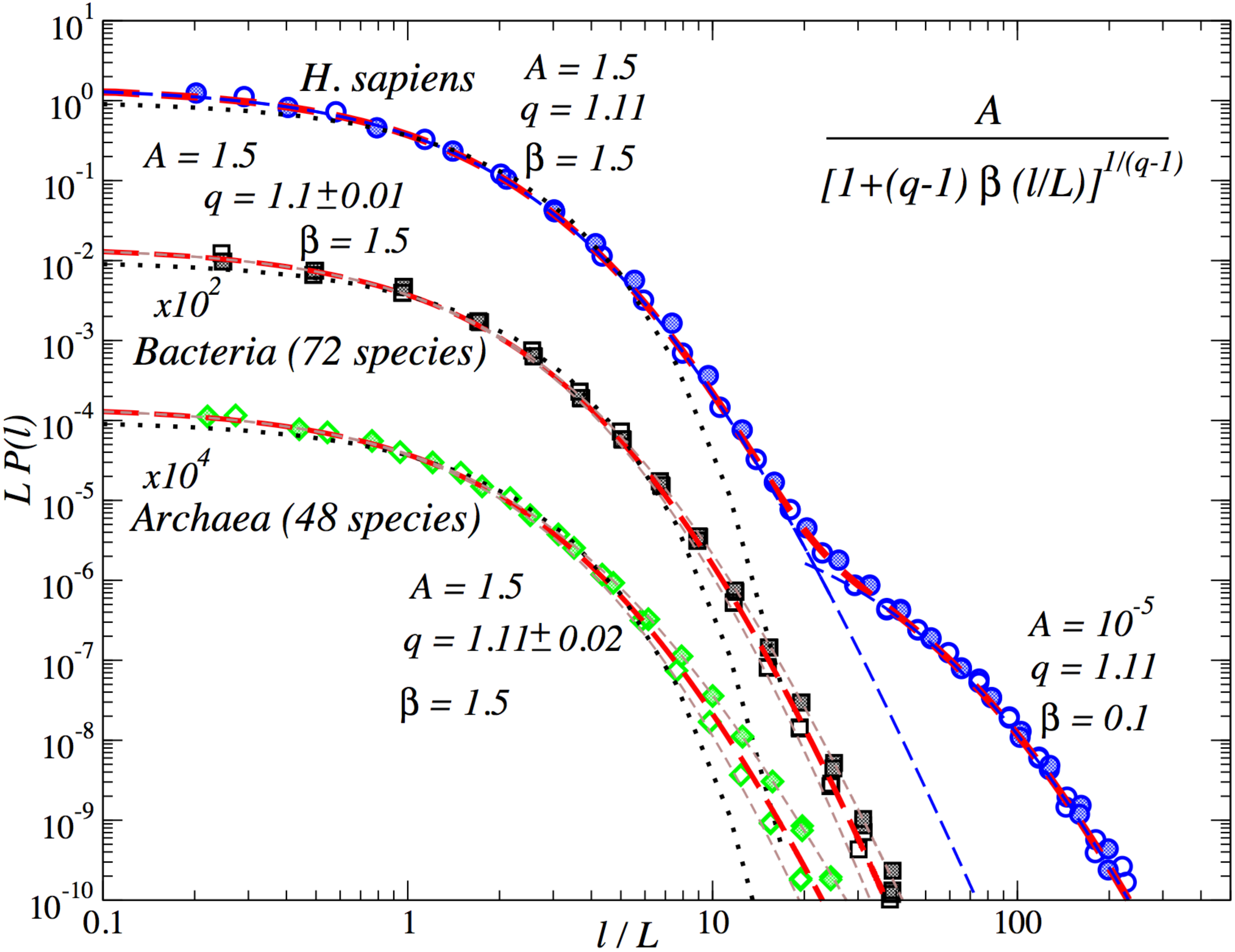


Figure 1. The procedure of the assessment of the four internucleotide interval sequences from the DNA primary sequence.



H. sapiens
A = 1.5
q = 1.11
β = 1.5
A = 1.5
q = 1.1±0.01
β = 1.5
x10^2
Bacteria (72 species)
x10^4
Archaea (48 species)
A = 1.5
q = 1.11± 0.02
β = 1.5
A = 10^-5
q = 1.11
β = 0.1
A / [1+(q-1) β (l/L)]^1/(q-1)
L P(l)
l / L

COLD ATOMS IN DISSIPATIVE OPTICAL LATTICES:

RAPID COMM

PHYSICAL REVIEW A **67**, 051402(R) (2003)

Anomalous diffusion and Tsallis statistics in an optical lattice

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(Received 26 February 2003; published 27 May 2003)

We point out a connection between anomalous transport in an optical lattice and Tsallis' generalized statistics. Specifically, we show that the momentum equation for the semiclassical Wigner function which describes atomic motion in the optical potential, belongs to a class of transport equations recently studied by Borland [Phys. Lett. A **245**, 67 (1998)]. The important property of these ordinary linear Fokker-Planck equations is that their stationary solutions are exactly given by Tsallis distributions. An analytical expression of the Tsallis index *q* in terms of the microscopic parameters of the quantum-optical problem is given and the spatial coherence of the atomic wave packets is discussed.

(i) The distribution of atomic velocities is a *q*-Gaussian;

(ii) $q = 1 + \frac{44 E_R}{U_0}$ where $E_R \equiv$ recoil energy

$U_0 \equiv$ potential depth

Tunable Tsallis Distributions in Dissipative Optical Lattices

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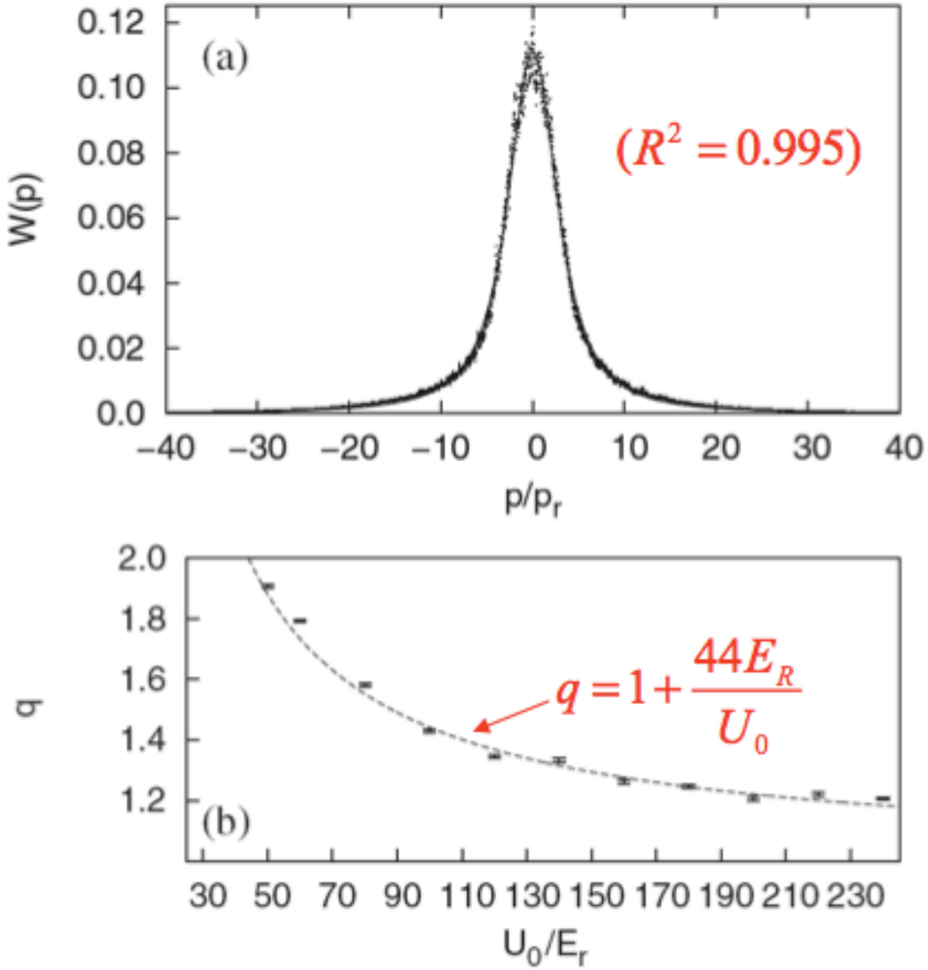
Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom

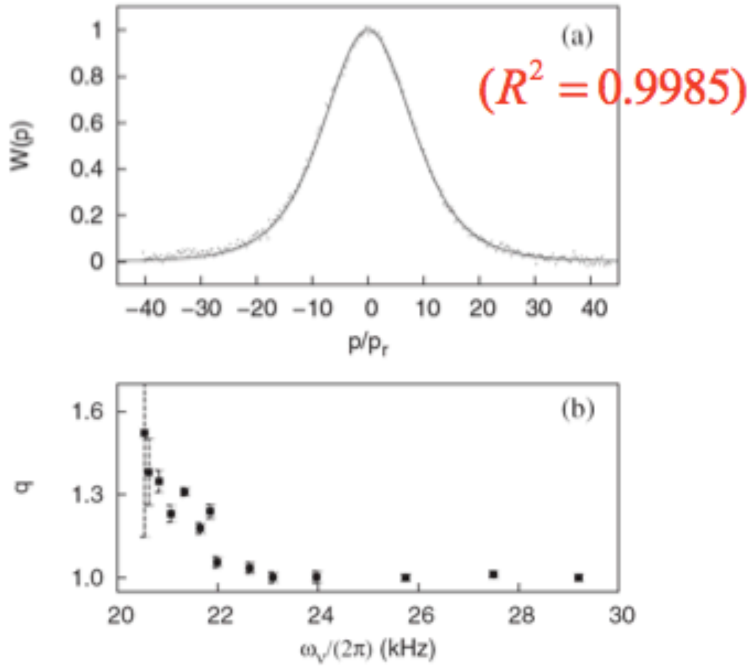
(Received 10 January 2006; published 24 March 2006)

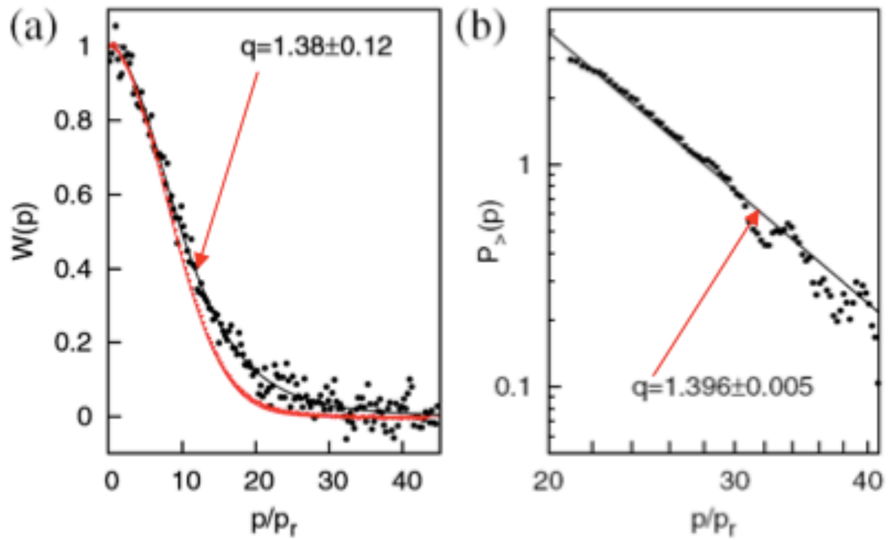
We demonstrated experimentally that the momentum distribution of cold atoms in dissipative optical lattices is a Tsallis distribution. The parameters of the distribution can be continuously varied by changing the parameters of the optical potential. In particular, by changing the depth of the optical lattice, it is possible to change the momentum distribution from Gaussian, at deep potentials, to a power-law tail distribution at shallow optical potentials.

Experimental and computational verifications

by P. Douglas, S. Bergamini and F. Renzoni, Phys Rev Lett **96**, 110601 (2006)







(Computational verification: quantum Monte Carlo simulations)

(Experimental verification: Cs atoms)

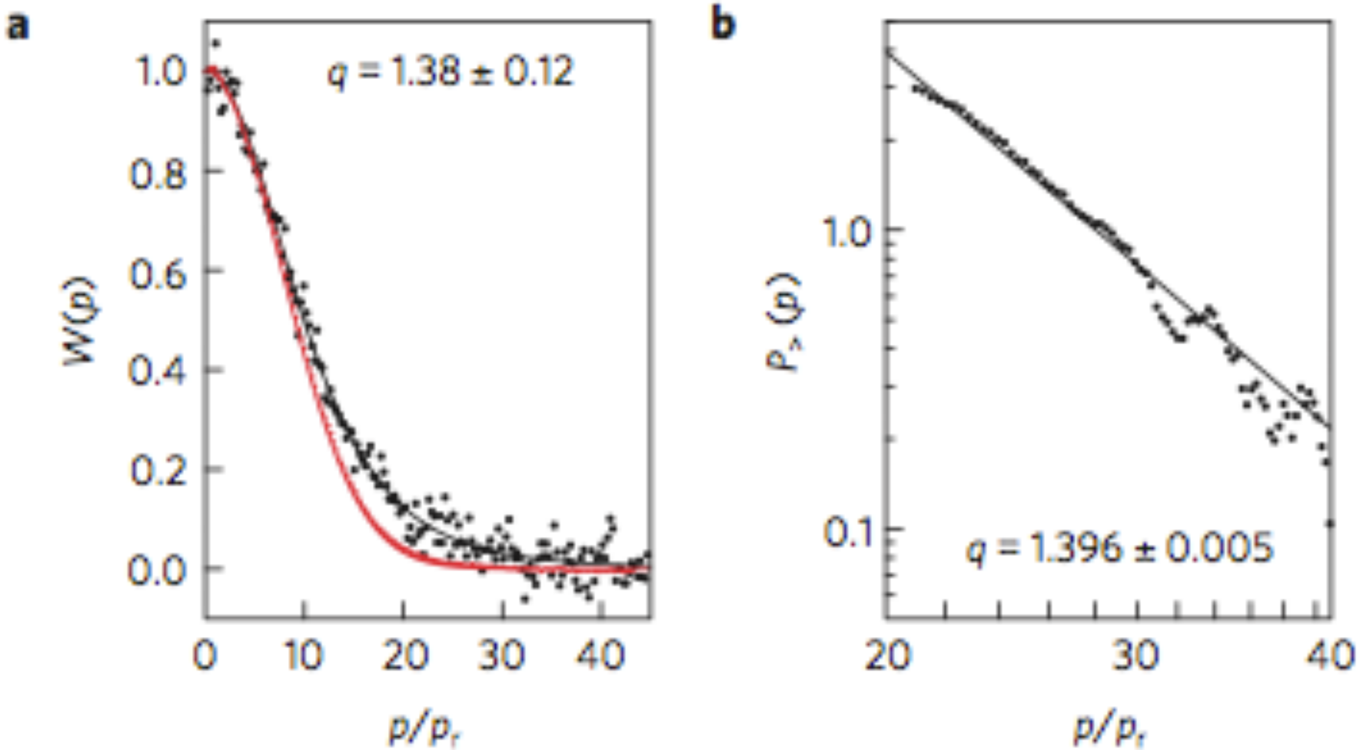
nature physics

PROGRESS ARTICLE

PUBLISHED ONLINE: 1 OCTOBER 2013 | DOI: 10.1038/NPHYS2751

Beyond Boltzmann–Gibbs statistical mechanics in optical lattices

Eric Lutz[1,2] and Ferruccio Renzoni[3]*



J.W. GIBBS

Elementary Principles in Statistical Mechanics - Developed with Especial Reference to the Rational Foundation of Thermodynamics

C. Scribner's Sons, New York, 1902; Yale University Press, New Haven, (1981), page 35

In treating of the canonical distribution, we shall always suppose the multiple integral in equation (92) [the partition function, as we call it nowadays] *to have a finite valued, as otherwise the coefficient of probability vanishes, and the law of distribution becomes illusory. This will exclude certain cases, but not such apparently, as will affect the value of our results with respect to their bearing on thermodynamics. It will exclude, for instance, cases in which the system or parts of it can be distributed in unlimited space […]. It also excludes many cases in which the energy can decrease without limit, as when the system contains material points which attract one another inversely as the squares of their distances. […]. For the purposes of a general discussion, it is sufficient to call attention to the assumption implicitly involved in the formula (92).*

Laszlo TISZA

Generalized Thermodynamics
(MIT Press, Cambridge, Massachusetts, 1961)

The situation is different for the additivity postulate Pa2, the validity of which cannot be inferred from general principles. We have to require that the interaction energy between thermodynamic systems be negligible. This assumption is closely related to the homogeneity postulate Pd1. From the molecular point of view, additivity and homogeneity can be expected to be reasonable approximations for systems containing many particles, provided that the intramolecular forces have a short range character.

Peter LANDSBERG

Thermodynamics and Statistical Mechanics (1978)

The presence of long-range forces causes important amendments to thermodynamics, some of which are not fully investigated as yet.

Is equilibrium always an entropy maximum?
J. Stat. Phys. **35**, 159 (1984)

[...] in the case of systems with long-range forces and which are therefore nonextensive (in some sense) some thermodynamic results do not hold. [...] The failure of some thermodynamic results, normally taken to be standard for black hole and other nonextensive systems has recently been discussed. [...] If two identical black holes are merged, the presence of long-range forces in the form of gravity leads to a more complicated situation, and the entropy is nonextensive.

CLASSICAL LONG-RANGE-INTERACTING MANY-BODY HAMILTONIAN SYSTEMS

$$V(r) \sim -\frac{A}{r^{\alpha}} \qquad (r \to \infty) \qquad (A > 0, \;\; \alpha \geq 0)$$

integrable if $\alpha / d > 1$ *(short-ranged)*

non-integrable if $0 \leq \alpha / d \leq 1$ *(long-ranged)*