Journal of Physics A
Mathematical and Theoretical

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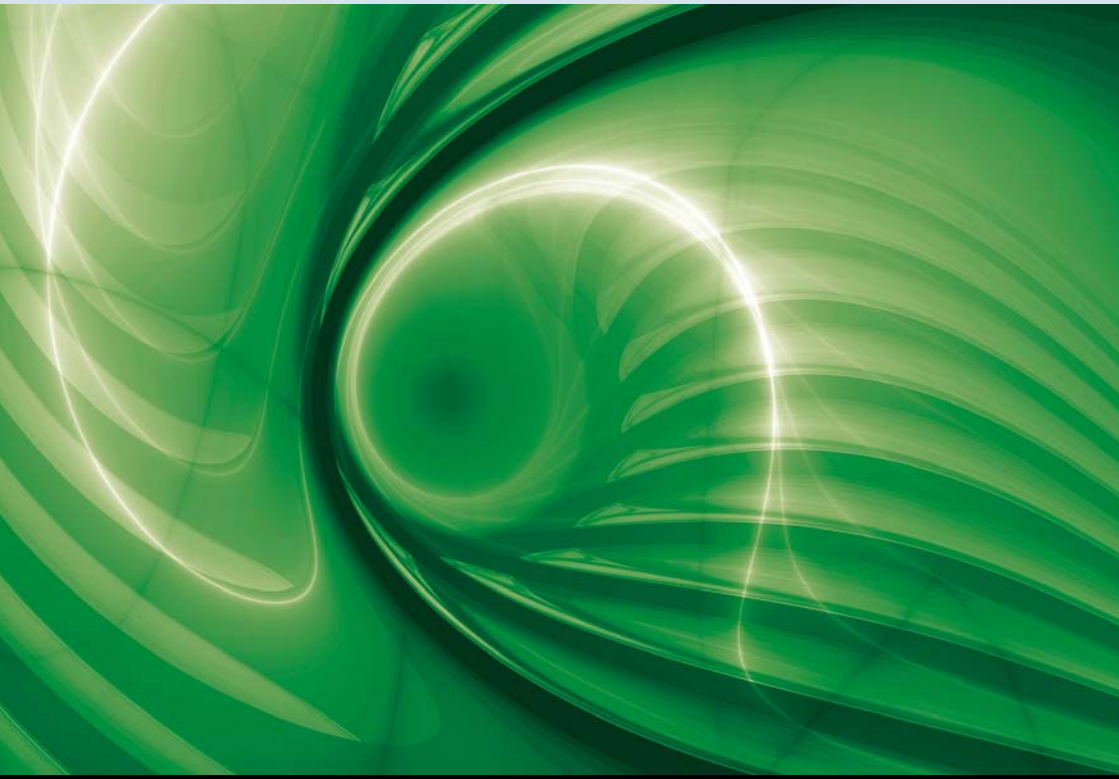
Highlights

A compilation of some of the best papers published during 2012



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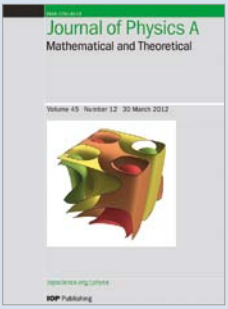

How to submit your research

Journal of Physics A: Mathematical and Theoretical is a major journal of theoretical physics reporting research on the mathematical structures that describe fundamental processes of the physical world and on the analytical, computational and numerical methods for exploring these structures. Mathematical papers must be clearly motivated by actual or potential application to physical phenomena.

Research papers

Reports of original research work; not normally more than 8500 words (16 journal pages).

Fast Track Communications

Outstanding short papers reporting new and timely developments in mathematical and theoretical physics. Fast Track Communications are not required to meet any criteria of 'general interest' and conjectural articles are welcome. Fast Track Communications should not exceed eight journal pages in length.

When preparing your article give some thought to your abstract; it should very concisely describe the content of your paper, and encourage readers to view the entire article. As the journal caters for a broad readership, we discourage the use of overly technical terms or undefined abbreviations in your abstract. Please be clear and concise when writing your article and clearly position it with regard to existing literature in the field.

To submit to the journal, simply visit the journal homepage at **iopscience.org/jphysa** and click on the 'Submit an article' link. This will take you through to our online submission pages, where you will need to follow the steps described. For any questions regarding submissions please contact us at **jphysa@iop.org**.

To help early career researchers prepare their papers for publication, we have published a digital brochure 'Introductory guide for authors' available at **iopscience.org/author-guide**.

Welcome

Murray Batchelor
Editor-in-Chief

Welcome to the *Journal of Physics A: Mathematical and Theoretical* Highlights collection. This collection showcases some of the most highly rated articles published in the journal over the course of 2012.

This selection of articles displays the broad scope of the journal and demonstrates how it is a meeting place for researchers to share mathematically rich work across different disciplines. Readers of the journal enjoy high-quality research articles from across the breadth of theoretical and mathematical physics.

Some important discoveries in mathematical and theoretical physics have been published as Fast Track Communications (FTCs). FTCs are short timely articles that benefit from accelerated publication; some of our most highly rated FTCs are included in this collection.

Also included in this collection are details of the topical reviews published in 2012. These were commissioned by our board members and provide timely overviews of the current state of research in areas of great interest and activity.

In 2012 we published four special issues, all of which attracted high-quality papers from leaders in their fields. These special issues were on 'Coherent states: mathematical and physical aspects', 'Applications of zeta functions and other special functions in mathematics and physics: a special issue in honour of Stuart Dowker's 75th birthday', 'Quantum physics with non-Hermitian operators' and 'Lattice models and integrability: a special issue in honour of F Y Wu's 80th birthday'. Coming up in 2013 we have three special issues planned on 'Higher spin theories and holography', 'Lyapunov analysis: from dynamical systems theory to applications' and 'Logarithmic conformal field theory'.

From the Publisher

Alexandra Haywood
Publisher

As you will see from this collection, we published some excellent papers in 2012. We would like to thank all of our authors for choosing to submit their high-quality work to the journal and thank our referees and board members for providing constructive peer review and maintaining the quality standards of the journal.

We hope that you will find this collection of articles interesting and that you will consider *Journal of Physics A* for your next paper.

We look forward to working with you during 2013 and into 2014.

Editorial board

Journal scope

Journal of Physics A: Mathematical and Theoretical is a major journal of theoretical physics reporting research on the mathematical structures that describe fundamental processes of the physical world and on the analytical, computational and numerical methods for exploring these structures.

Mathematical papers should be clearly motivated by actual or potential application to physical phenomena.

Research papers published in *Journal of Physics A: Mathematical and Theoretical* are categorized into one of six subject sections:

- statistical physics;
- chaotic and complex systems;
- mathematical physics;
- quantum mechanics and quantum information theory;
- field theory and string theory;
- fluid and plasma theory.

To be acceptable for publication in the journal, papers must make significant, original and correct contributions to one or more of the topics within these sections.

JOURNAL TEAM

Our dedicated *Journal of Physics A: Mathematical and Theoretical* team at IOP Publishing is here to ensure the peer review and production processes run as smoothly as possible for our authors.

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Contents

Featured author

Iddo I Eliazar
Holon Institute of Technology, Israel

Professor Eliazar completed his BSc, MSc and PhD studies at Tel Aviv University. In 2006 he joined the Holon Institute of Technology as an associate professor of stochastics and operations research. His research focuses on stochastic modeling and analysis. He published six articles in *Journal of Physics A* in 2012. Here we ask him about the work in his Fast Track Communication 'Langevin unification of fractional motions'.

What led you to the research that you published in this paper?
The quest to understand how a small set of universal macroscopic statistical structures emerge from an infinitely vast ocean of microscopic statistical structures, and the quest to unveil the common bedrock of 'fractional motions': Brownian motion, Levy motion, fractional Brownian motion and fractional Levy motion.

What do you find particularly interesting about fractional motions?
The emergence of dramatic phenomena on the macroscopic scale: fractality, the 'Noah effect' manifesting wild fluctuations and the 'Joseph effect' manifesting long-ranged correlations.

Where do you see the work in your paper leading in the future?
We hope that this work, together with its corresponding long review paper (forthcoming in *Physics Reports*), will help scientists navigate within the dominion of 'anomalous diffusions', and will provide students with a smooth entry into this fascinating dominion.

Why did you choose *Journal of Physics A* to publish this paper?
Because the journal's FTC platform is a wonderful vehicle to speedily communicate new ideas to the physics community and beyond.

What do you enjoy about publishing in *Journal of Physics A*?
The outstanding attitude of the journal's team: charmingly cordial on the one hand, and highly proficient on the other hand.

Read all of Professor Eliazar's recent articles in *Journal of Physics A*:

- On the invariance of spatially inhomogeneous relaxation processes 2012 *J. Phys. A: Math. Theor.* **45** 015003
- Langevin unification of fractional motions 2012 *J. Phys. A: Math. Theor.* **45** 162002
- Describing the indescribable: the stationary structures of transient Markovian dynamics 2012 *J. Phys. A: Math. Theor.* **45** 282001
- The misconception of mean-reversion 2012 *J. Phys. A: Math. Theor.* **45** 332001
- On the structure and phase transitions of power-law Poissonian ensembles 2012 *J. Phys. A: Math. Theor.* **45** 405003
- Super-stable Poissonian structures 2012 *J. Phys. A: Math. Theor.* **45** 415103

Fast Track Communications

Iddo I Eliazar
Holon Institute of Technology, Israel

Langevin unification of fractional motions

Iddo I Eliazar and Michael F Shlesinger

2012 *J. Phys. A: Math. Theor.* **45** 162002

We present a physical Langevin-based theory explaining the emergence and pervasiveness of the following 'fractional motions': Brownian motion, Lévy motion, fractional Brownian motion and fractional Lévy motion. A general form of micro-level Langevin dynamics, with infinitely many degrees of freedom, is considered. Transcending from the micro-level to the macro-level the infinitely many degrees of freedom collapse to two characteristic exponents, and the aforementioned fractional motions emerge universally. The exponents categorize the fractional motions and determine their statistical and topological properties. The theory establishes a unified 'Langevin bedrock' to fractional motions—which are widely applied prototypical models of random transport in the sciences.

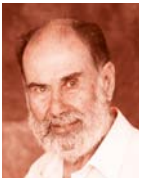
Michael Berry
University of Bristol, UK

Riemann zeros in radiation patterns

M V Berry

2012 *J. Phys. A: Math. Theor.* **45** 302001

Propagation into the far field changes initial waves into their Fourier transforms. This implies that the Riemann zeros could be observed experimentally in the radiation pattern generated by an initial wave whose Fourier transform is proportional to the Riemann zeta function on the critical line. Two such waves are examined, generating the Riemann $\Xi(t)$ function (pattern 1) and the function $\zeta(1/2 + it)/(1/2 + it)$ (pattern 2). For pattern 1, the radiation side lobes are probably too weak to allow detection of the zeros, but for pattern 2 the lobes are stronger, suggesting a feasible experiment.



Pavel Winternitz
Université de Montréal, Canada

Contact transformations for difference schemes

Decio Levi, Christian Scimiterna, Zora Thomova and Pavel Winternitz

2012 *J. Phys. A: Math. Theor.* **45** 022001

We define a class of transformations of the dependent and independent variables in an ordinary difference scheme. The transformations leave the solution set of the system invariant and reduces to a group of contact transformations in the continuous limit. We use a simple example to show that the class is not empty and that such 'contact transformations for discrete systems' genuinely exist.

FAST TRACK COMMUNICATIONS

Gesualdo Delfino
SISSA, Italy

Crossing probability and number of crossing clusters in off-critical percolation

Gesualdo Delfino and Jacopo Viti

2012 *J. Phys. A: Math. Theor.* **45** 032005

We consider two-dimensional percolation in the scaling limit close to criticality and use integrable field theory to obtain universal predictions for the probability that at least one cluster crosses between opposite sides of a rectangle of sides much larger than the correlation length and for the mean number of such crossing clusters.

Peter Jarvis
University of Tasmania, Australia

Hidden supersymmetry—a 'no superpartner' theorem for representations of deformed conformal superalgebra

Peter D Jarvis

2012 *J. Phys. A: Math. Theor.* **45** 322001

A new theoretical scenario for realizations of supersymmetry in nature is proposed, in which the currently known particle spectrum is not embellished by superpartners. Possible origins of such a scheme in terms of supersymmetry breaking at unification scales are discussed. Technically, we establish a general 'no go' theorem, regarding the structure of certain types of degenerate supermultiplets, in a class of quadratic deformations of the conformal superalgebra.

Read the Insight article at **iopscience.org/1751-8121/labtalk-article/50458**

Udo Seifert
Universität Stuttgart, Germany

Efficiency of a Brownian information machine

Michael Bauer, David Abreu and Udo Seifert

2012 *J. Phys. A: Math. Theor.* **45** 162001

A Brownian information machine extracts work from a heat bath through a feedback process that exploits the information acquired in a measurement. For the paradigmatic case of a particle trapped in a harmonic potential, we determine how power and efficiency for two variants of such a machine operating cyclically depend on the cycle time and the precision of the positional measurements. Controlling only the center of the trap leads to a machine that has zero efficiency at maximum power, whereas additional optimal control of the stiffness of the trap leads to an efficiency bounded between 1/2, which holds for maximum power, and 1 reached even for finite cycle time in the limit of perfect measurements.

Statistical physics

M R Evans
University of Edinburgh, UK
Section Editor

Statistical physics encompasses the theory of many interacting entities. Originally founded on the description of states of matter comprising atoms and molecules, the theory now extends to the description of active objects and driven systems.

The development of simple mathematical models to elucidate emergent macroscopic behaviour has gone hand in hand with the development of new mathematical techniques for their solution. Building on our understanding of equilibrium states and phase transitions, the grand challenge now lies in the description of nonequilibrium states and myriad associated out-of-equilibrium phenomena. *Journal of Physics A* is a leading vehicle for mathematical and theoretical progress in the field.

Our nascent understanding of nonequilibrium states is at an exciting stage with new results constantly adding to the overall picture. Recently, the notion of dynamical activity has offered insight into the far-from-equilibrium relaxation of various models of 'glassy' dynamics. Maes *et al* (*J. Phys. A: Math. Theor.* **45** 455001) have shown that under certain conditions a related quantity, the Donsker–Varadhan functional, decreases monotonically in relaxation to a nonequilibrium stationary state, thus furnishing a candidate nonequilibrium analogue of a thermodynamic potential.

Unexpected connections are being made with areas of topical interest, e.g. the study of records is related to the furthest excursion of a stochastic process. A recent study of a random walk with bias by Majumdar *et al* (*J. Phys. A: Math. Theor.* **45** 355002) revealed five distinct qualitative behaviours of record statistics.

At the same time new techniques are being developed and refined to extend our understanding of equilibrium lattice models such as Ising, Potts, percolation and loop models and to compare with predictions of conformal field theory at or near criticality – see Price *et al* (*J. Phys. A: Math. Theor.* **45** 275002), Vernier and Jacobsen (*J. Phys. A: Math. Theor.* **45** 045003) and Flores *et al* (*J. Phys. A: Math. Theor.* **45** 505002).

These and other contributions listed overleaf point to the vitality of the field and the continuing leading role of *Journal of Physics A*.

STATISTICAL PHYSICS

Peter Sollich
King's College
London, UK

Spin glass polynomial identities from entropic constraints

Peter Sollich and Adriano Barra

2012 *J. Phys. A: Math. Theor.* **45** 485001

The core idea of stochastic stability is that thermodynamic observables must be robust under small (random) perturbations of the quenched Gibbs measure. Combining this idea with the cavity field technique, which aims to measure the free energy increment under addition of a spin to the system, we sketch how to write a stochastic stability approach to diluted mean field spin glasses which explicitly gives overlap constraints as the outcome. We then show that, under minimal mathematical assumptions and for gauge-invariant systems (namely those with even Ising interactions), it is possible to 'reverse' the idea of stochastic stability and use it to derive a broad class of constraints on the unperturbed quenched Gibbs measure. This paper extends a previous study where we showed how to derive (linear) polynomial identities from the 'energy' contribution to the free energy, while here we focus on the consequences of 'entropic' constraints. Interestingly, in diluted spin glasses, the entropic approach generates more identities than those found by the energy route or other techniques. The two sets of identities become identical on a fully connected topology, where they reduce to the ones derived by Aizenman and Contucci.

Anthony J Guttmann
The University of
Melbourne, Australia

Off-critical parafermions and the winding angle distribution of the O(n) model

Andrew Elvey Price, Jan de Gier, Anthony J Guttmann and Alexander Lee

2012 *J. Phys. A: Math. Theor.* **45** 275002

Using an off-critical deformation of the identity of Duminil-Copin and Smirnov, we prove a relationship between half-plane surface critical exponents γ_1 and γ_{11} as well as wedge critical exponents $\gamma_2(\alpha)$ and $\gamma_{21}(\alpha)$ and the exponent characterizing the winding angle distribution of the O(n) model in the half-plane, or more generally in a wedge of wedge-angle α. We assume only the existence of these exponents and, for some values of n, the conjectured value of the critical point. If we assume their values as predicted by conformal field theory, one gets complete agreement with the conjectured winding angle distribution, as obtained by CFT and Coulomb gas arguments. We also prove the exponent inequality $\gamma_1 - \gamma_{11} \geq 1$, and its extension $\gamma_2(\alpha) - \gamma_{21}(\alpha) \geq 1$ for the edge exponents. We provide conjectured values for all exponents for $n \in [-2, 2)$.

STATISTICAL PHYSICS

Steven Flores
University of Michigan, Ann Arbor, USA

Cluster pinch-point densities in polygons

S M Flores, P Kleban and R M Ziff

2012 *J. Phys. A: Math. Theor.* **45** 505002

In a statistical cluster or loop model such as percolation, or more generally the Potts models or O(n) models, a pinch point is a single bulk point where several distinct clusters or loops touch. In a polygon $\mathcal{P}$ harboring such a model in its interior and with $2N$ sides exhibiting free/fixed side-alternating boundary conditions, boundary clusters anchor to the fixed sides of $\mathcal{P}$. At the critical point and in the continuum limit, the density (i.e. frequency of occurrence) of pinch-points between s distinct boundary clusters at a bulk point $w \in \mathcal{P}$ is proportional to $\langle \psi_1^c(w_1)\psi_1^c(w_2)\ldots\psi_1^c(w_{2N-1})\psi_1^c(w_{2N})\psi_s(w,\bar{w})\rangle_{\mathcal{P}}$. The w_i are the vertices of $\mathcal{P}$, ψ_1^c is a conformal field theory (CFT) corner one-leg operator, and ψ_s is a CFT bulk $2s$-leg operator. In this paper, we use the Coulomb gas formalism to construct explicit contour integral formulas for these correlation functions and thereby calculate the density of various pinch-point configurations at arbitrary points in the rectangle, in the hexagon, and for the case $s = N$, in the $2N$-sided polygon at the system's critical point. Explicit formulas for these results are given in terms of algebraic functions or integrals of algebraic functions, particularly Lauricella functions. In critical percolation, the result for $s = N = 2$ gives the density of red bonds between boundary clusters (in the continuum limit) inside a rectangle. We compare our results with high-precision simulations of critical percolation and Ising FK clusters in a rectangle of aspect ratio two and in a regular hexagon, and we find very good agreement.

Jean-Sébastien Caux
Universiteit van Amsterdam, The Netherlands

Generalized TBA and generalized Gibbs

Jorn Mossel and Jean-Sébastien Caux

2012 *J. Phys. A: Math. Theor.* **45** 255001

We consider the extension of the thermodynamic Bethe Ansatz to cases in which additional terms involving higher conserved charges are added to the Hamiltonian, or in which a distinction is made between the Hamiltonian used for time evolution and that used for defining the density matrix. Writing down equations describing the saddle-point (pseudo-equilibrium) state of the infinite system, we prove the existence and uniqueness of solutions provided simple requirements are met. We show how a knowledge of the saddle-point rapidity distribution is equivalent to that of all generalized inverse temperatures and how the standard equilibrium equations for e.g. excitations are simply generalized.

STATISTICAL PHYSICS

Jesper Lykke Jacobsen
Ecole Normale Supérieure de Paris, France

Corner free energies and boundary effects for Ising, Potts and fully packed loop models on the square and triangular lattices

Eric Vernier and Jesper Lykke Jacobsen

2012 *J. Phys. A: Math. Theor.* **45** 045003

We obtain long series expansions for the bulk, surface and corner free energies for several two-dimensional statistical models, by combining Enting's finite lattice method (FLM) with exact transfer matrix enumerations. The models encompass all integrable curves of the Q-state Potts model on the square and triangular lattices, including the antiferromagnetic transition curves and the Ising model ($Q = 2$) at temperature T, as well as a fully packed O(n) type loop model on the square lattice. The expansions are around the trivial fixed points at infinite Q, n or $1/T$. By using a carefully chosen expansion parameter, $q \ll 1$, all expansions turn out to be of the form $\prod_{k=1}^{\infty}(1-q^k)^{\alpha_k+k\beta_k}$, where the coefficients α_k and β_k are periodic functions of k. Thanks to this periodicity property, we can conjecture the form of the expansions to all orders (except in a few cases where the periodicity is too large). These expressions are then valid for all $0 \leq q < 1$. We analyse in detail the $q \longrightarrow 1^-$ limit in which the models become critical. In this limit the divergence of the corner free energy defines a universal term which can be compared with the conformal field theory (CFT) predictions of Cardy and Peschel. This allows us to deduce the asymptotic expressions for the correlation length in several cases. Finally we work out the FLM formulae for the case where some of the system's boundaries are endowed with particular (non-free) boundary conditions. We apply this in particular to the square-lattice Potts model with Jacobsen–Saleur boundary conditions, conjecturing the expansions of the surface and corner free energies to arbitrary order for any integer value of the boundary interaction parameter r. These results are in turn compared with CFT predictions.

Christian Maes
KU Leuven, Belgium

Monotonicity of the dynamical activity

Christian Maes, Karel Netočný and Bram Wynants

2012 *J. Phys. A: Math. Theor.* **45** 455001

The Donsker–Varadhan rate function for occupation-time fluctuations has been seen numerically to exhibit monotone return to stationary non-equilibrium (Maes *et al* 2011 *Phys. Rev. Lett.* **107** 010601). That rate function is related to dynamical activity and, except under detailed balance, it does not derive from the relative entropy for which the monotonicity in time is well understood. We give a rigorous argument that the Donsker–Varadhan function is indeed monotone under the Markov evolution at large enough times with respect to the relaxation time, provided that a 'normal linear-response' condition is satisfied.

STATISTICAL PHYSICS

Satya N Majumdar
Université Paris Sud 11 and CNRS, France

Record statistics and persistence for a random walk with a drift

Satya N Majumdar, Grégory Schehr and Gregor Wergen

2012 *J. Phys. A: Math. Theor.* **45** 055002

We study the statistics of records of a one-dimensional random walk of n steps, starting from the origin, and in the presence of a constant bias c. At each time step, the walker makes a random jump of length η drawn from a continuous distribution $f(\eta)$, which is symmetric around a constant drift c. We focus in particular on the case where $f(\eta)$ is a symmetric stable law with a Lévy index $0 < \mu \leq 2$. The record statistics crucially depends on the persistence probability, which, as we show here, exhibits different behaviors depending on the sign of c and the value of the parameter μ. Hence, in the limit of a large number of steps n, the record statistics is sensitive to these parameters (c and μ) of the jump distribution. We compute the asymptotic mean record number $\langle R_n \rangle$ after n steps as well as its full distribution $P(R, n)$. We also compute the statistics of the ages of the longest and the shortest lasting record. Our exact computations show the existence of five distinct regions in the (c, $0 < \mu \leq 2$) strip where these quantities display qualitatively different behaviors. We also present numerical simulation results that verify our analytical predictions.

Paul Krapivsky
Boston University, USA

Discrete analogue of the Burgers equation

E Ben-Naim and P L Krapivsky

2012 *J. Phys. A: Math. Theor.* **45** 455003

We propose the set of coupled ordinary differential equations $dn_j/dt = n_{j-1}^2 - n_j^2$ as a discrete analogue of the classic Burgers equation. We focus on traveling waves and triangular waves, and find that these special solutions of the discrete system capture major features of their continuous counterpart. In particular, the propagation velocity of a traveling wave and the shape of a triangular wave match the continuous behavior. However, there are some subtle differences. For traveling waves, the propagating front can be extremely sharp as it exhibits double exponential decay. For triangular waves, there is an unexpected logarithmic shift in the location of the front. We establish these results using asymptotic analysis, heuristic arguments, and direct numerical integration.

Chaotic and complex systems

Arkady Pikovsky
Universität Potsdam, Germany
Section Editor

Furious development of nonlinear physics in the last decades of the 20th century, due to progress in such fields as chaos, nonlinear pattern formation and turbulence along with the non-trivial role of noise in nonlinear systems, resulted in establishing it, together with statistical physics, as a major methodological interdisciplinary approach to the study of classical dynamical phenomena.

This success story continues in the field of complexity science, fulfilling the expectation of Stephen Hawking, who in 2000 said: 'I think the next century will be the century of complexity'.

Journal of Physics A offers an optimal platform both for presenting theoretically and mathematically oriented contributions to the basics of nonlinear and complex systems, and for publishing diverse applied studies in this truly interdisciplinary field.

Excellent examples are the recent review article 'Networking—a statistical physics perspective' from Yeung and Saad (*J. Phys. A: Math. Theor.* **46** 103001) and the upcoming special issue 'Lyapunov analysis: from dynamical systems theory to applications'.

Did you know?
Journal of Physics A is abstracted in a number of places including ISI and Scopus

Did you know?
All papers in *Journal of Physics A* are free to read for **30 days** after online publication

CHAOTIC AND COMPLEX SYSTEMS

Martin Sieber
University of Bristol, UK

Semiclassical approach to discrete symmetries in quantum chaos

Christopher H Joyner, Sebastian Müller and Martin Sieber

2012 *J. Phys. A: Math. Theor.* **45** 205102

We use semiclassical methods to evaluate the spectral two-point correlation function of quantum chaotic systems with discrete geometrical symmetries. The energy spectra of these systems can be divided into subspectra that are associated with irreducible representations of the corresponding symmetry group. We show that for (spinless) time-reversal invariant systems, the statistics inside these subspectra depends on the type of irreducible representation. For real representations the spectral statistics agrees with those of the Gaussian orthogonal ensemble of random matrix theory (RMT), whereas complex representations correspond to the Gaussian unitary ensemble (GUE). For systems without time-reversal invariance, all subspectra show GUE statistics. There are no correlations between non-degenerate subspectra. Our techniques generalize recent developments in the semiclassical approach to quantum chaos allowing one to obtain full agreement with the two-point correlation function predicted by RMT, including oscillatory contributions.

M Y Choi
Seoul National University, Korea

How cells grow and divide: mathematical analysis confirms demand for the cell cycle

Hyun Woong Kwon and M Y Choi

2012 *J. Phys. A: Math. Theor.* **45** 135101

Eukaryotes usually grow through cell growth and division. How cells grow and divide is essential to life because too small or too large cells cannot function well. In order for an organism to survive even under a condition where cell growth and division processes are independent of each other, cells must have an appropriate growth factor, growth rate and division rate. To determine them, we derive a time evolution equation for the size distribution of cells from the master equation describing changes in the cell size due to growth and in the total number of cells due to division. It is found that long-time behaviors of moments of the size distribution divide the parameter space, consisting of the growth factor and the ratio of the division rate to the growth rate, into infinitely many regions. Examining the properties of each region, we conclude that growth with a small growth factor may be disastrous; this demonstrates the demand for the cell cycle consisting of coordinated growth and division processes.

CHAOTIC AND COMPLEX SYSTEMS

D del-Castillo-Negrete
Oak Ridge National Laboratory, USA

Transport in the spatially tempered fractional Fokker–Planck equation

A Kullberg and D del-Castillo-Negrete

2012 *J. Phys. A: Math. Theor.* **45** 255101

A study of truncated Lévy flights in super-diffusive transport in the presence of an external potential is presented. The study is based on the spatially tempered, fractional Fokker–Planck (TFFP) equation in which the fractional diffusion operator is replaced by a tempered fractional diffusion (TFD) operator. We focus on harmonic (quadratic) potentials and periodic potentials with broken spatial symmetry. The main objective is to study the dependence of the steady-state probability density function (PDF), and the current (in the case of periodic potentials) on the level of tempering, λ, and on the order of the fractional derivative in space, α. An expansion of the TFD operator for large λ is presented, and the corresponding equation for the coarse grained PDF is obtained. The steady-state PDF solution of the TFFP equation for a harmonic potential is computed numerically. In the limit $\lambda \to \infty$, the PDF approaches the expected Boltzmann distribution. However, nontrivial departures from this distribution are observed for finite ($\lambda > 0$) truncations, and $\alpha \neq 2$. In the study of periodic potentials, we use two complementary numerical methods: a finite-difference scheme based on the Grunwald–Letnikov discretization of the truncated fractional derivatives and a Fourier-based spectral method. In the limit $\lambda \to \infty$, the PDFs converges to the Boltzmann distribution and the current vanishes. However, for $\alpha \neq 2$, the PDF deviates from the Boltzmann distribution and a finite non-equilibrium ratchet current appears for any $\lambda > 0$. The current is observed to converge exponentially in time to the steady-state value. The steady-state current exhibits algebraical decay with λ, as $J \sim \lambda^{-\zeta}$, for $\alpha \geq 1.75$. However, for $\alpha \leq 1.5$, the steady-state current decays exponentially with λ, as $J \sim e^{-\xi\lambda}$. In the presence of an asymmetry in the TFD operator, the tempering can lead to a current reversal. A detailed numerical study is presented on the dependence of the current on λ and the physical parameters of the system.

Petr Braun
Universität Duisburg-Essen, Germany

Beyond the Heisenberg time: semiclassical treatment of spectral correlations in chaotic systems with spin 1/2

Petr Braun

2012 *J. Phys. A: Math. Theor.* **45** 045102

The two-point correlation function of chaotic systems with spin 1/2 is evaluated using periodic orbits. The spectral form factor for all times thus becomes accessible. Equivalence with the predictions of random matrix theory for the Gaussian symplectic ensemble is demonstrated. A duality between the underlying generating functions of the orthogonal and symplectic symmetry classes is semiclassically established.

Mathematical physics

Atsuo Kuniba
University of Tokyo, Japan
Section Editor

In this section, we welcome papers in which the ideas, techniques and applications flow between theoretical physics and mathematics in either direction. We had the pleasure of publishing excellent papers in 2012 with some of the most interesting contributions listed in this Highlights collection. Here is a brief summary from them.

Random matrix is the approach that leads to the most universal predictions on the statistical distributions of physically interesting quantities in many complex systems. Fischmann *et al* (*J. Phys. A: Math. Theor.* **45** 075203) generalized the Ginibre ensemble of non-Hermitian square matrices to the one induced from rectangular Gaussian matrices by a quadratization procedure, offering many new problems of calculating correlation functions and finding applications to real systems.

PT-symmetry is the subject of active research from a variety of aspects including the spectral problem in ODE, quasi-exact solvability, Bethe ansatz and even experimental realizations. Eremenko and Gabrielov (*J. Phys. A: Math. Theor.* **45** 175206) presented an elaborate analysis on PT-symmetric quartic oscillators involving two coupling constants. Exploring their relations to the Nevalnlinna parameters, they have established an accurate description of the real spectral locus of the system.

Supersymmetry on the lattice system has been an important issue in mathematical physics as well as in condensed matter physics. Beccaria and Hagendorf (*J. Phys. A: Math. Theor.* **45** 365201) have set up a staggered fermion chain with supersymmetry and demonstrated remarkable connections between ground-state components and the Hirota tau functions associated with the Painlevé VI equation, extending a similar result on the XYZ chain by Bazhanov and Magazeev (*J. Phys. A: Math. Theor.* **45** 085206).

MATHEMATICAL PHYSICS

Uzy Smilansky
The Weizmann Institute of Science, Israel

Stability of nodal structures in graph eigenfunctions and its relation to the nodal domain count

Gregory Berkolaiko, Hillel Raz and Uzy Smilansky

2012 *J. Phys. A: Math. Theor.* **45** 165203

The nodal domains of eigenvectors of the discrete Schrödinger operator on simple, finite and connected graphs are considered. Courant's well-known nodal domain theorem applies in the present case, and sets an upper bound to the number of nodal domains of eigenvectors: arranging the spectrum as a non-decreasing sequence, and denoting by ν_n the number of nodal domains of the nth eigenvector, Courant's theorem guarantees that the nodal deficiency $n - \nu_n$ is non-negative. (The above applies for generic eigenvectors. Special care should be exercised for eigenvectors with vanishing components.) The main result of this work is that the nodal deficiency for generic eigenvectors is equal to a Morse index of an energy functional whose value at its relevant critical points coincides with the eigenvalue. The association of the nodal deficiency to the stability of an energy functional at its critical points was recently discussed in the context of quantum graphs Band *et al* (2011 *Commun. Math. Phys.* at press (doi:10.1007/s00220-011-1384-9)) and Dirichlet Laplacian in bounded domains in $\mathbb{R}^d$ Berkolaiko *et al* (2011 arXiv:1107.3489). This work adapts this result to the discrete case. The definition of the energy functional in the discrete case requires a special setting, substantially different from the one used in Band *et al* and Berkolaiko *et al* and it is presented here in detail.

Karol Życzkowski
Jagiellonian University, Poland

Induced Ginibre ensemble of random matrices and quantum operations

Jonit Fischmann, Wojciech Bruzda, Boris A Khoruzhenko, Hans-Jürgen Sommers and Karol Życzkowski

2012 *J. Phys. A: Math. Theor.* **45** 075203

A generalization of the Ginibre ensemble of non-Hermitian random square matrices is introduced. The corresponding probability measure is induced by the ensemble of rectangular Gaussian matrices via a quadratization procedure. We derive the joint probability density of eigenvalues for such an induced Ginibre ensemble and study various spectral correlation functions for complex and real matrices, and analyse universal behaviour in the limit of large dimensions. In this limit, the eigenvalues of the induced Ginibre ensemble cover uniformly a ring in the complex plane. The real induced Ginibre ensemble is shown to be useful to describe the statistical properties of evolution operators associated with random quantum operations for which the dimensions of the input state and the output state do differ.

MATHEMATICAL PHYSICS

Gernot Akemann
Universitat Bielefeld, Germany

Universal microscopic correlation functions for products of independent Ginibre matrices

Gernot Akemann and Zdzislaw Burda

2012 *J. Phys. A: Math. Theor.* **45** 465201

We consider the product of n complex non-Hermitian, independent random matrices, each of size $N \times N$ with independent identically distributed Gaussian entries (Ginibre matrices). The joint probability distribution of the complex eigenvalues of the product matrix is found to be given by a determinantal point process as in the case of a single Ginibre matrix, but with a more complicated weight given by a Meijer *G*-function depending on *n*. Using the method of orthogonal polynomials we compute all eigenvalue density correlation functions exactly for finite *N* and fixed *n*. They are given by the determinant of the corresponding kernel which we construct explicitly. In the large-*N* limit at fixed *n* we first determine the microscopic correlation functions in the bulk and at the edge of the spectrum. After unfolding they are identical to that of the Ginibre ensemble with $n = 1$ and thus universal. In contrast the microscopic correlations we find at the origin differ for each $n > 1$ and generalize the known Bessel law in the complex plane for $n = 2$ to a new hypergeometric kernel ${}_0F_{n-1}$.

Jean-Marie Maillard
Paris 6 University, France

Diagonal Ising susceptibility: elliptic integrals, modular forms and Calabi–Yau equations

M Assis, S Boukraa, S Hassani, M van Hoeij, J-M Maillard and B M McCoy

2012 *J. Phys. A: Math. Theor.* **45** 075205

We give the exact expressions of the partial susceptibilities $\chi^{(3)}_d$ and $\chi^{(4)}_d$ for the diagonal susceptibility of the Ising model in terms of modular forms and Calabi–Yau ODEs, and more specifically, ${}_3F_2([1/3, 2/3, 3/2],[1, 1]; z)$ and ${}_4F_3([1/2, 1/2, 1/2, 1/2], [1, 1, 1]; z)$ hypergeometric functions. By solving the connection problems we analytically compute the behavior at all finite singular points for $\chi^{(3)}_d$ and $\chi^{(4)}_d$. We also give new results for $\chi^{(5)}_d$. We see, in particular, the emergence of a remarkable order-6 operator, which is such that its symmetric square has a rational solution. These new exact results indicate that the linear differential operators occurring in the n-fold integrals of the Ising model are not only 'derived from geometry' (globally nilpotent), but actually correspond to 'special geometry' (homomorphic to their formal adjoint). This raises the question of seeing if these 'special geometry' Ising operators are 'special' ones, reducing, in fact systematically, to (selected, *k*-balanced, ...) ${}_{q+1}F_q$ hypergeometric functions, or correspond to the more general solutions of Calabi–Yau equations.

MATHEMATICAL PHYSICS

Alexandre Eremenko
Purdue University, USA

Andrei Gabrielov
Purdue University, USA

Two-parametric PT-symmetric quartic family

Alexandre Eremenko and Andrei Gabrielov

2012 *J. Phys. A: Math. Theor.* **45** 175206

We describe a parametrization of the real spectral locus of the two-parametric family of PT-symmetric quartic oscillators. For this family, we find a parameter region where all eigenvalues are real, extending the results of Dorey *et al* (2007 *J. Phys. A: Math Theor.* **40** R205–83) and Shin (2005 *J. Phys. A: Math. Gen.* **38** 6147–66; 2002 *Commun. Math. Phys.* **229** 543–64).

Eugene Ferapontov
Loughborough University, UK

On the central quadric ansatz: integrable models and Painlevé reductions

E V Ferapontov, B Huard and A Zhang

2012 *J. Phys. A: Math. Theor.* **45** 195204

It was observed by Tod (1995 *Class. Quantum Grav.* **12** 1535–47) and later by Dunajski and Tod (2002 *Phys. Lett. A* **303** 253–64) that the Boyer–Finley (BF) and the dispersionless Kadomtsev–Petviashvili (dKP) equations possess solutions whose level surfaces are central quadrics in the space of independent variables (the so-called central quadric ansatz). It was demonstrated that generic solutions of this type are described by Painlevé equations P_{III} and P_{II}, respectively. The aim of our paper is threefold: (1) Based on the method of hydrodynamic reductions, we classify integrable models possessing the central quadric ansatz. This leads to the five canonical forms (including BF and dKP). (2) Applying the central quadric ansatz to each of the five canonical forms, we obtain all Painlevé equations P_I– P_{VI}, with P_{VI} corresponding to the generic case of our classification. (3) We argue that solutions coming from the central quadric ansatz constitute a subclass of two-phase solutions provided by the method of hydrodynamic reductions.

MATHEMATICAL PHYSICS

Christian Hagendorf
Université de Genève, Switzerland

A staggered fermion chain with supersymmetry on open intervals

Matteo Beccaria and Christian Hagendorf

2012 *J. Phys. A: Math. Theor.* **45** 365201

A strongly interacting fermion chain with supersymmetry on the lattice and open boundary conditions is analysed. The local coupling constants of the model are staggered, and the properties of the ground states as a function of the staggering parameter are examined. In particular, a connection between certain ground-state components and solutions of nonlinear recursion relations associated with the Painlevé VI equation is conjectured. Moreover, various local occupation probabilities in the ground state have the so-called scale-free property, and allow for an exact resummation in the limit of infinite-system size.

Murray R Bremner
Saskatchewan University, Canada

Higher identities for the ternary commutator

M R Bremner and L A Peresi

2012 *J. Phys. A: Math. Theor.* **45** 505201

We use computer algebra to study polynomial identities for the trilinear operation $[a, b, c] = abc - acb - bac + bca + cab - cba$ in the free associative algebra. It is known that $[a, b, c]$ satisfies the alternating property in degree 3, no new identities in degree 5, a multilinear identity in degree 7 which alternates in 6 arguments, and no new identities in degree 9. We use the representation theory of the symmetric group to demonstrate the existence of new identities in degree 11. The only irreducible representations of dimension <400 with new identities correspond to partitions 2^5, 1 and 2^4, 1^3 and have dimensions 132 and 165. We construct an explicit new multilinear identity for partition 2^5, 1 and we demonstrate the existence of a new non-multilinear identity in which the underlying variables are permutations of $a^2b^2c^2d^2e^2f$.

MATHEMATICAL PHYSICS

Atsuo Kuniba
University of Tokyo, Japan

Tetrahedron and 3D reflection equations from quantized algebra of functions

Atsuo Kuniba and Masato Okado

2012 *J. Phys. A: Math. Theor.* **45** 465206

Soibelman's theory of quantized function algebra $A_q(\mathrm{SL}_n)$ provides a representation theoretical scheme to construct a solution of the Zamolodchikov tetrahedron equation. We extend this idea originally due to Kapranov and Voevodsky to $A_q(\mathrm{Sp}_{2n})$ and obtain the intertwiner K corresponding to the quartic Coxeter relation. Together with the previously known three-dimensional (3D) R matrix, the K yields the first ever solution to the 3D analogue of the reflection equation proposed by Isaev and Kulish. It is shown that matrix elements of R and K are polynomials in q and that there are combinatorial and birational counterparts for R and K. The combinatorial ones arise either at $q = 0$ or by tropicalization of the birational ones. A conjectural description for type B and F_4 cases is also given.

Giampaolo Cicogna
University of Pisa, Italy

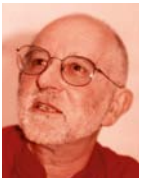
A generalization of λ-symmetry reduction for systems of ODEs: σ-symmetries

G Cicogna, G Gaeta and S Walcher

2012 *J. Phys. A: Math. Theor.* **45** 355205

We consider a deformation of the prolongation operation, defined on sets of vector fields and involving a mutual interaction in the definition of prolonged ones. This maintains the 'invariants by differentiation' property, and can hence be used to reduce ODEs satisfying suitable invariance conditions in a fully algorithmic way, similarly to what happens for standard prolongations and symmetries.

Featured author



Michael Berry
University of Bristol, UK

Professor Sir Michael Berry gained his honours degree from the University of Exeter in 1962. He then went on to study for his PhD at St Andrews before moving to the University of Bristol where he is now Professor Emeritus. During his career he has published more than 200 articles and has won many awards including the Dirac Medal, the Wolf Prize in Physics and an Ig Nobel Prize. In 1996 he was knighted.

Professor Berry has a long-standing relationship with the journal and has served on the Editorial board for a number of years. He published five articles with us in 2012 and here we discuss one of his recent papers 'Superluminal speeds for relativistic random waves'.

What inspired you to work on the research that you published in this paper?
The sudden realization that some of my earlier quantum work (also published in *Journal of Physics A*) could be applied to relativity, to show how likely it is that some parts of a collective wave can travel faster than light, even though all the individual component waves are travelling slower than light. (Without paradox: this effect cannot be used to send signals.)

Do you think research in the area of superluminal motion could lead to a better understanding of quantum mechanical effects?
The quantum effect here – superoscillations and weak measurement, developed by Aharonov and his collaborators – is well understood already. This new work uses it to give insight into quantum relativity.

What do you enjoy about publishing in *Journal of Physics A*?
The near-perfect customer experience provided by this and other IOP Publishing journals: rapid referee response and editorial decision, careful, accurate and unobtrusive copy editing, and a system that after many years I know well and that does not distract me from communication of the science. The journal is perfectly suited to mathematical physics of the type in this paper: theoretical analysis inspired by experimentally validated physics but not directly connected with an existing or proposed experiment.

Read all of Professor Berry's recent articles in *Journal of Physics A*:

- Pointer supershifts and superoscillations in weak measurements 2012 *J. Phys. A: Math. Theor.* **45** 015301
- Superluminal speeds for relativistic random waves 2012 *J. Phys. A: Math. Theor.* **45** 185308
- Classical dynamics with curl forces, and motion driven by time-dependent flux 2012 *J. Phys. A: Math. Theor.* **45** 305201
- Riemann zeros in radiation patterns 2012 *J. Phys. A: Math. Theor.* **45** 302001
- Hearing the music of the primes: auditory complementarity and the siren song of zeta 2012 *J. Phys. A: Math. Theor.* **45** 382001

Quantum mechanics and quantum information theory

Valerio Scarani
National University of Singapore
Section Editor

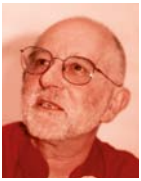
This section publishes work from across the breadth of quantum mechanics and quantum information theory. The section has grown over the last few years and we are publishing more high-quality quantum information theory papers than ever before, which demonstrates how active this research area is.

The papers in this collection include Facchi *et al* (*J. Phys. A: Math. Theor.* **45** 105302) introducing the notion of quantumness witnesses and showing that any entanglement witness is also a quantumness witness; Horodecki and Piani (*J. Phys. A: Math. Theor.* **45** 105306) demonstrating the quantum advantage of dense coding; and Peschel and Eiser (*J. Phys. A: Math. Theor.* **45** 155301) finding exact results for the entanglement across defects in critical chains.

As well as the research on quantum information theory, the journal continues to publish strong papers on quantum mechanics. For example, in 2012 Berry published an article (*J. Phys. A: Math. Theor.* **45** 185308) that demonstrated superluminal speeds for relativistic waves and Uzdin *et al* discussed time-dependent Hamiltonians with 100% evolution speed efficiency (*J. Phys. A: Math. Theor.* **45** 415304).

We hope that you enjoy reading these papers and we look forward to publishing more work from this broad field in 2013.

QUANTUM MECHANICS AND QUANTUM INFORMATION THEORY



Michael Berry
University of Bristol, UK

Superluminal speeds for relativistic random waves

M V Berry

2012 *J. Phys. A: Math. Theor.* **45** 185308

For Klein–Gordon and Dirac waves representing massive quantum particles, the local group velocity v (weak value of the velocity operator) can exceed c. If the waves consist of superpositions of many plane waves, with different (but subluminal) group velocities u, the superluminal probability P_{super}, i.e. that $|v| > c$ for a randomly selected state, can be calculated explicitly. P_{super} depends on two parameters describing the distribution (power spectrum) of u in the superpositions, and lies between 0 and $1/2$ for Klein–Gordon waves and $1-1/\sqrt{2}$ and $1/2$ for Dirac waves. Numerical simulations display the superluminal intervals in space and regions in spacetime, and support the theoretical predictions for P_{super}.

I Lesanovsky
University of Nottingham, UK

Universal time evolution of a Rydberg lattice gas with perfect blockade

B Olmos, R González-Férez, I Lesanovsky and L Velázquez

2012 *J. Phys. A: Math. Theor.* **45** 325301

We investigate the dynamics of a strongly interacting spin system that is motivated by current experimental realizations of strongly interacting Rydberg gases in lattices. In particular, we are interested in the temporal evolution of quantities such as the density of Rydberg atoms and density–density correlations when the system is initialized in a fully polarized state without Rydberg excitations. We show that in the thermodynamic limit the expectation values of these observables converge at least logarithmically to universal functions and outline a method to obtain these functions. We prove that a finite one-dimensional system follows this universal behavior up to a given time. The length of this universal time period depends on the actual system size. This shows that the study of small systems allows us to make precise predictions about the thermodynamic limit provided that the observation time is sufficiently short. We discuss this for various observables and for systems with different dimensions, interaction ranges and boundary conditions.

Read the Insight article at **iopscience.org/1751-8121/labtalk-article/50540**

QUANTUM MECHANICS AND QUANTUM INFORMATION THEORY

Viktor Eisler
University of Vienna, Austria

Exact results for the entanglement across defects in critical chains

Ingo Peschel and Viktor Eisler

2012 *J. Phys. A: Math. Theor.* **45** 155301

We consider fermionic and bosonic quantum chains where a defect separates two subsystems and compare the corresponding entanglement spectra. With these, we calculate their Rényi entanglement entropies and obtain analytical formulae for the continuously varying coefficient of the leading logarithmic term. For the bosonic case we also present numerical results.

B L Hu
University of Maryland, USA

Non-Markovian dynamics and entanglement of two-level atoms in a common field

C H Fleming, N I Cummings, Charis Anastopoulos and B L Hu

2012 *J. Phys. A: Math. Theor.* **45** 065301

We derive the stochastic equations and consider the non-Markovian dynamics of a system of multiple two-level atoms in a common quantum field. We make only the dipole approximation for the atoms and assume weak atom–field interactions. From these assumptions, we use a combination of non-secular open- and closed-system perturbation theory, and we abstain from any additional approximation schemes. These more accurate solutions are necessary to explore several regimes: in particular, near-resonance dynamics and low-temperature behavior. In detuned atomic systems, small variations in the system energy levels engender timescales which, in general, cannot be safely ignored, as would be the case in the rotating-wave approximation (RWA). More problematic are the second-order solutions, which, as has been recently pointed out (Fleming and Cummings 2011 *Phys. Rev. E* **83** 031117), cannot be accurately calculated using any second-order perturbative master equation, such as RWA, Born–Markov, Redfield, etc. The latter problem, which applies to all perturbative open-system master equations, has a profound effect upon calculation of entanglement at low temperatures. *We find that even at zero temperature all initial states will undergo finite-time disentanglement* (sometimes termed 'sudden death'), in contrast to the previous work. We also use our solution, without invoking the RWA, to characterize the necessary conditions for Dicke subradiance at finite temperature. We find that the sub-radiant states fall into two categories at finite temperature: one that is temperature independent and one that acquires temperature dependence. With the RWA, there is no temperature dependence in any case.

QUANTUM MECHANICS AND QUANTUM INFORMATION THEORY

Vlatko Vedral
University of Oxford, UK and National University of Singapore, Singapore

Quantumness and entanglement witnesses

Paolo Facchi, Saverio Pascazio, Vlatko Vedral and Kazuya Yuasa

2012 *J. Phys. A: Math. Theor.* **45** 105302

We analyze the recently introduced notion of quantumness witnesses and compare it to that of entanglement witnesses. We show that any entanglement witness is also a quantumness witness. We then consider some physically relevant examples and explicitly construct some witnesses.

Huan-Qiang Zhou
Chongqing University, People's Republic of China

Ground-state fidelity and Kosterlitz–Thouless phase transition for the spin-1/2 Heisenberg chain with next-to-the-nearest-neighbor interaction

Hong-Lei Wang, Ai-Min Chen, Bo Li and Huan-Qiang Zhou

2012 *J. Phys. A: Math. Theor.* **45** 015306

The Kosterlitz–Thouless transition for the spin-1/2 Heisenberg chain with the next-to-the-nearest-neighbor interaction is investigated in the context of an infinite matrix product state algorithm, which is a generalization of the infinite time-evolving block decimation algorithm (Vidal 2007 *Phys. Rev. Lett.* **98** 070201) to accommodate both the next-to-the-nearest-neighbor interaction and spontaneous dimerization. It is found that, in the critical regime, the algorithm automatically leads to infinite degenerate ground-state wavefunctions, due to the finiteness of the truncation dimension. This results in *pseudo*-symmetry spontaneous breakdown, which is reflected as a catastrophe point in the ground-state fidelity per lattice site. In addition, this allows the introduction of a pseudo-order parameter to characterize the Kosterlitz–Thouless transition. Our work demonstrates that the ground-state fidelity per lattice site is able to capture the Kosterlitz–Thouless transition, which is in sharp contrast to the fidelity susceptibility that fails to detect it.

QUANTUM MECHANICS AND QUANTUM INFORMATION THEORY

M Horodecki
University of Gdańsk, Poland

On quantum advantage in dense coding

M Horodecki and M Piani

2012 *J. Phys. A: Math. Theor.* **45** 105306

The quantum advantage of dense coding—the increase in the rate of classical information transmission due to shared entanglement—is studied. General encoding quantum operations are considered. Particular attention is devoted to the case of many senders and one receiver. It is shown that restrictions on the possible operations among the many senders can strongly affect the usefulness of a shared quantum state for dense coding. It is shown, e.g., that there are states that do not provide any quantum advantage if communication among the senders is not allowed, but are useful for dense coding as soon as the senders can communicate classically. These results are actually independent of the particular quantification of the quantum advantage, being valid for any reasonable definition of such a rate increase. It is further shown that the quantum advantage of dense coding satisfies a monogamy relation with the so-called entanglement of purification.

Time-dependent Hamiltonians with 100% evolution speed efficiency

Raam Uzdin, Uwe Günther, Saar Rahav and Nimrod Moiseyev

2012 *J. Phys. A: Math. Theor.* **45** 415304

The evolution speed in projective Hilbert space is considered for Hermitian Hamiltonians and for non-Hermitian (NH) ones. Based on the Hilbert–Schmidt norm and the spectral norm of a Hamiltonian, resource-related upper bounds on the evolution speed are constructed. These bounds are valid also for NH Hamiltonians and they are illustrated for an optical NH Hamiltonian and for a NH $\mathcal{PT}$-symmetric matrix Hamiltonian. Furthermore, the concept of quantum speed efficiency is introduced as measure of the system resources directly spent on the motion in the projective Hilbert space. A recipe for the construction of time-dependent Hamiltonians which ensure 100% speed efficiency is given. Generally these efficient Hamiltonians are NH but there is a Hermitian efficient Hamiltonian as well. Finally, the extremal case of a NH non-diagonalizable Hamiltonian with vanishing energy difference is shown to produce a 100% efficient evolution with minimal resources consumption.

QUANTUM MECHANICS AND QUANTUM INFORMATION THEORY

Valerio Scarani
National University of Singapore, Singapore

Robust self-testing of the singlet

M McKague, T H Yang and V Scarani

2012 *J. Phys. A: Math. Theor.* **45** 455304

In this paper, we introduce a general framework to study the concept of robust self-testing which can be used to self-test maximally entangled pairs of qubits (EPR pairs) and local measurement operators. The result is based only on probabilities obtained from the experiment, with tolerance to experimental errors. In particular, we show that if the results of an experiment approach the Cirel'son bound, or approximate the Mayers–Yao-type correlations, then the experiment must contain an approximate EPR pair. More specifically, there exist local bases in which the physical state is close to an EPR pair, possibly encoded in a larger environment or ancilla. Moreover, in these bases the measurements are close to the qubit operators used to achieve the Cirel'son bound or the Mayers–Yao results.

A R P Rau
Louisiana State University, USA

Quantum discord for qubit–qudit systems

Sai Vinjanampathy and A R P Rau

2012 *J. Phys. A: Math. Theor.* **45** 095303

We present two formulae to calculate quantum discord, a kind of quantum correlation, between a qubit and a second party of arbitrary dimension d. The first formula is the original entropic definition and the second is a recently proposed geometric distance measure which leads to an analytical formulation. The tracing over the qubit in the entropic calculation is reduced to a very simple prescription. And, when the d-dimensional system is a so-called X-state, the density matrix having non-zero elements only along the diagonal and anti-diagonal, the entropic calculation can also be carried out analytically. Such states of the full bipartite qubit–qudit system may be named 'extended X-states', whose density matrix is built of four block matrices, each visually appearing as an X. The optimization involved in the entropic calculation is generally over two parameters, reducing to one for many cases, and avoided altogether for an overwhelmingly large set of density matrices as our numerical investigations demonstrate. In the case of $N = 2$, extended X-states encompass the entire 15-dimensional parameter space, that is, they represent the full qubit–qubit system.

Field theory and string theory

Arkady Tseytlin
Imperial College
London, UK
Section Editor

The field theory and string theory section publishes high-quality and significant new results in areas including general methods of quantum field theory, supersymmetric field theories in various dimensions, conformal field theories, integrable theories, string theory and its applications.

Recently, much attention was devoted to string theory–gauge theory interface, with integrability-based methods used to obtain new results and insights. AdS/CFT duality was under active study not only in four but also in three dimensions (Chern–Simons-matter supersymmetric theories). There are also remarkable connections between massless higher spin theories and conformal theories in two and three dimensions that are currently under active study (with a special issue to appear in 2013).

In addition to the investigation of the string spectrum problem and anomalous dimensions of composite gauge theory operators the section saw an influx of papers on scattering amplitudes, which is now a very active research area. Some of these developments are reflected in the highlighted papers.

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FIELD THEORY AND STRING THEORY

Arkady Tseytlin
Imperial College
London, UK

Leading quantum correction to energy of 'short' spiky strings

Matteo Beccaria, Carlo Alberto Ratti and Arkady A Tseytlin

2012 *J. Phys. A: Math. Theor.* **45** 155401

We consider semiclassical quantization of spiky strings spinning in the AdS_3 part of $AdS_5 \times S^5$ using an integrability-based (algebraic curve) method. In the 'short-string' (small-spin) limit the expansion of string energy starts with its flat-space expression. We compute the leading quantum string correction to 'short' spiky string energy and find the explicit form of the corresponding one-loop coefficient a_{01}. It turns out to be rational and expressed in terms of the harmonic sums as functions of the number n of spikes. In the special case of $n = 2$ when the spiky string reduces to the single-folded spinning string, the coefficient a_{01} takes the value $(-1/4)$ found in Gromov *et al* (2011 *J. High Energy Phys.* JHEP08(2011)046). We also consider a similar computation for the m-folded string and more general spiky string with an extra 'winding' number, finding similar expressions for a_{01}. These results may be useful for a description of energies of higher excited states in the quantum $AdS_5 \times S^5$ string spectrum, generalizing earlier discussions of the string counterparts of the Konishi operator.

Jan Govaerts
Louvain Catholic
University, Belgium

Dressed fermions, modular transformations and bosonization in the compactified Schwinger model

Michaël Fanuel and Jan Govaerts

2012 *J. Phys. A: Math. Theor.* **45** 035401

The celebrated exactly solvable 'Schwinger' model, namely massless two-dimensional QED, is revisited. The solution presented here emphasizes the non-perturbative relevance of the topological sector through large gauge transformations whose role is made manifest by compactifying space into a circle. Eventually the well-known non-perturbative features and solution of the model are recovered in the massless case. However, the fermion mass term is shown to play a subtle role in order to achieve a physical quantization that accounts for gauge invariance under both small and large gauge symmetries. Quantization of the system follows Dirac's approach in an explicitly gauge-invariant way that avoids any gauge-fixing procedure.

FIELD THEORY AND STRING THEORY

J A Minahan
Uppsala University, Sweden

Four-loop anomalous dimensions in Leigh–Strassler deformations

J A Minahan and C Sieg

2012 *J. Phys. A: Math. Theor.* **45** 305401

We determine the scalar part of the four-loop chiral dilatation operator for Leigh–Strassler deformations of $\mathcal{N} = 4$ super Yang–Mills. This is sufficient to find the four-loop anomalous dimensions for operators in closed scalar subsectors. This includes the *SU*(2) subsector of the (complex) β-deformation, where we explicitly compute the anomalous dimension for operators with a single impurity. It also includes the '3-string null' operators of the cubic Leigh–Strassler deformation. Our four-loop results show that the rational part of the anomalous dimension is consistent with a conjecture made in Minahan (2011 *J. High Energy Phys.* JHEP12(2011)093) based on the three-loop result of Sieg (2011 *Phys. Rev. D* **84** 045014) and the $\mathcal{N} = 4$ magnon dispersion relation. Here, we find additional $\zeta(3)$ terms.

OPEN ACCESS

Niklas Beisert
ETH Zurich, Switzerland

Conformal anomaly for amplitudes in $\mathcal{N}$=6 superconformal Chern–Simons theory

Till Bargheer, Niklas Beisert, Florian Loebbert and Tristan McLoughlin

2012 *J. Phys. A: Math. Theor.* **45** 475402

Scattering amplitudes in three-dimensional $\mathcal{N} = 6$ Chern–Simons theory are shown to be non-invariant with respect to the free representation of the $\mathfrak{osp}(6\,|\,4)$ symmetry generators. At tree and one-loop level these 'anomalous' terms occur only for non-generic, singular configurations of the external momenta and can be used to determine the form of the amplitudes. In particular we show that the symmetries predict that the one-loop six-point amplitude is non-vanishing and confirm this by means of an explicit calculation using generalized unitarity methods. We comment on the implications of this finding for any putative Wilson loop/amplitude duality in $\mathcal{N} = 6$ Chern–Simons theory.

FIELD THEORY AND STRING THEORY

Jan Plefka
Humboldt University, Berlin, Germany

Bosonic string quantization in static gauge

George Jorjadze, Jan Plefka and Jonas Pollok

2012 *J. Phys. A: Math. Theor.* **45** 485401

The bosonic string in D-dimensional Minkowski space–time is quantized in a static gauge. It is shown that the system can be described by $D-1$ massless free fields constrained on the surface $L_m = 0$, for $m \neq 0$, where L_m are the generators of conformal transformations. The free fields are quantized and the physical states are selected by the conditions $L_m |\Psi_{ph}\rangle = 0$, for $m > 0$. The Poincaré group generators on the physical Hilbert space are constructed and the critical dimension $D = 26$ is recovered from the commutation relations of the boost operators. The equivalence with the covariant quantization is established. A possible generalization to the AdS string dynamics is discussed.

From scattering amplitudes to the dilatation generator in $\mathcal{N}$=4 SYM

Benjamin I Zwiebel

2012 *J. Phys. A: Math. Theor.* **45** 115401

The complete spin chain representation of the planar $\mathcal{N} = 4$ SYM dilatation generator has long been known at one loop, where it involves leading nearest-neighbor $2 \to 2$ interactions. In this work, we use superconformal symmetry to derive the unique solution for the leading $L \to 2$ interactions of the planar dilatation generator for arbitrarily large L. We then propose that these interactions are given by a scattering operator that has $\mathcal{N} = 4$ SYM tree-level scattering amplitudes as matrix elements. We provide compelling evidence for this proposal, including explicit checks for $L = 2, 3$ and a proof of consistency with superconformal symmetry.

FIELD THEORY AND STRING THEORY

A Pinzul
Brasilia University, Brazil

UV/IR mixing as a twisted Poincare anomaly

A Pinzul

2012 *J. Phys. A: Math. Theor.* **45** 075401

We analyze symmetries of the one-loop effective action of ϕ^4 noncommutative field theory. It is shown that despite the twisted Poincaré invariance of the classical noncommutative action, its one-loop quantum counterpart lacks this invariance. Although the Noether analysis of the model is somewhat obscure, it is still possible to interpret this symmetry breaking as a quantum anomaly due to inappropriate choice of the quantization method.

Chong-Sun Chu
Durham University, UK

D1-strings in large RR 3-form flux, quantum Nambu geometry and M5-branes in the *C*-field

Chong-Sun Chu and Gurdeep S Sehmbi

2012 *J. Phys. A: Math. Theor.* **45** 055401

We consider D1-branes in an RR flux background and show that there is a low energy–large flux double-scaling limit where the D1-brane action is dominated by a Chern–Simons–Myers coupling term. As a classical solution to the matrix model, we find a novel quantized geometry characterized by a quantum Nambu 3-bracket. Infinite-dimensional representations of the quantum Nambu geometry are constructed, which demonstrate that the quantum Nambu geometry is intrinsically different from the ordinary Lie algebra-type noncommutative geometry. Matrix models for the II B string, II A string and M-theory in the corresponding backgrounds are constructed. A classical solution of a quantum Nambu geometry in the II A matrix string theory gives rise to an expansion of the fundamental strings into a system of multiple D4-branes and the fluctuation is found to describe an action for a non-Abelian 3-form field strength, which is a natural non-Abelian generalization of the PST action for a single D4-brane. In view of the recent proposals [1, 2] of the M5-branes theory in terms of the D4-branes, we suggest a natural way to include all the KK modes and propose an action for the multiple M5-branes in a constant *C*-field. The worldvolume of the M5-branes in a *C*-field is found to be described by a quantum Nambu geometry with self-dual parameters. It is intriguing that our action is naturally formulated in terms of a 1-form gauge field living on a six-dimensional quantum Nambu geometry.

Fluid and plasma theory

Gregory Falkovich
Weizmann Institute of Sciences, Israel
Section Editor

The fluid and plasma theory section of *Journal of Physics A* offers a place for researchers working in these areas across a wide range of disciplines to interact with each other, and a place to publish theoretical and mathematical contributions in their diverse fields.

The papers in this collection highlight the range of subjects that have been published in the section in 2012. They include Liu and Ricca (*J. Phys. A: Math. Theor.* **45** 205501) who explore a topological approach to complex fluid flows by considering the helicity of fluid knots, and Pilarczyk *et al* (*J. Phys. A: Math. Theor.* **45** 125502) who consider a dynamical model of transitions in magnetically confined plasmas including the effects of turbulence, shear flow and zonal flow.

Hannay (*J. Phys. A: Math. Theor.* **45** 065501) discusses the idealised swimming problem in an Euler fluid, while Melrose and Weise (*J. Phys. A: Math. Theor.* **45** 395501) generalise the description of the response of a magnetised relativistic quantum electron gas to include spin dependence.

We hope that you enjoy these articles and look forward to publishing more high-quality work across the section in 2013.

FLUID AND PLASMA THEORY

Renzo Ricca
University of Milano-Bicocca, Italy

The Jones polynomial for fluid knots from helicity

Xin Liu and Renzo L Ricca

2012 *J. Phys. A: Math. Theor.* **45** 205501

In this paper we prove that under ideal conditions the helicity of fluid knots, such as vortex filaments or magnetic flux tubes, provides a fundamentally new topological means by which we may associate a topological invariant, the Jones polynomial, that is much stronger than prior interpretations in terms of Gauss linking numbers. Our proof is based on an extension of the Kauffman bracket polynomial for unoriented knots. Explicit calculations of the Jones polynomial for the left- and right-handed trefoil knots and for the Whitehead link via the figure-of-eight knot are presented for illustration. This novel approach establishes a topological foundation of classical field theory in general, and of mathematical fluid dynamics in particular, by opening up new directions of work both in theory and applications.

Read the Insight article at **iopscience.org/1751-8121/labtalk-article/49655**

Donald Melrose
University of Sydney, Australia

Spin-dependent relativistic quantum magnetized electron gas

Donald B Melrose and Jeanette I Weise

2012 *J. Phys. A: Math. Theor.* **45** 395501

The covariant form of the response 4-tensor is derived for a spin-dependent, relativistic magnetized quantum electron gas. The electron gas is described by its occupation number, $n^{\epsilon}_{ns}(p_z)$, where $\epsilon = \pm 1$ labels electron and positron states, n the Landau level, p_z the parallel momentum, and $s = \pm 1$ the spin, which corresponds to the parallel component of the magnetic moment operator. A spin-dependent electron gas corresponds to $n^{\epsilon}_{n+}(p_z) \neq n^{\epsilon}_{n-}(p_z)$. We evaluate the spin-dependent contribution to the response tensor and show that it can be written such that its tensorial form is independent of the occupation number, which appears only in relativistic plasma dispersion functions that are independent of the perpendicular wave vector, $k_{\perp}$. We discuss the special cases of parallel propagation, complete degeneracy, the synchrotron-emitting limit, and $n^{\epsilon}_{ns}(p_z) \propto \delta(p_z)$. We expand the exact quantum result in powers of $\hbar$ and find that the correction of order is nonzero for the spin-dependent part, with the lowest order correction for the spin-independent part being of order $\hbar^2$. We find inconsistencies when the result is compared with quasi-classical calculations of the spin-dependent response. We conclude that until these inconsistencies are understood and resolved, the validity of the quasi-classically derived, spin-dependent results is uncertain.

FLUID AND PLASMA THEORY

Benjamin A Carreras
University of Alaska at Fairbanks, USA

A dynamical model for plasma confinement transitions

Paweł Pilarczyk, Luis García, Benjamin A Carreras and Irene Llerena

2012 *J. Phys. A: Math. Theor.* **45** 125502

A three-equation model describing the evolution of the turbulence level, averaged shear flow and sheared zonal flow is analyzed using topological properties of the asymptotic solutions. An exploration in parameter space is done, identifying the attractor sets, which are fixed points and limit cycles. Then a more detailed analysis of all Morse sets is conducted using topological-combinatorial computations. This model allows the description of different types of transitions to improved plasma confinement regimes.

J H Hannay
University of Bristol, UK

Swimming holonomy principles, exemplified with a Euler fluid in two dimensions

J H Hannay

2012 *J. Phys. A: Math. Theor.* **45** 065501

The idealized problem of swimming—the self-propulsion phenomenon whereby a cyclic change of shape of a 'swimmer' produces a net movement—is well studied for the case of a very viscous incompressible liquid. The opposite limit of zero viscosity, the ideal or 'Euler' fluid, has also received some attention. (i) Perhaps surprisingly, both limits are purely geometric effects, 'holonomies', not dependent on any timings or rates, but only on the sequence of shapes adopted by the swimmer. (ii) A principle fully determining swimming in a Euler fluid is simply stated: the fluid moves at every moment so as to minimize the sum of its and the swimmer's kinetic energy. (iii) Euler swimming would be solvable explicitly were it not for the standard impasse of potential theory: to find the boundary normal derivative of a function obeying Laplace's equation given its value around the boundary (or vice versa). As usual more analytical progress is possible in two dimensions (by complexifying) than three, but full tractability still requires the extreme of slight, rapid swimming strokes, and a simple example is given. In both limits, for a non-symmetrical swimming stroke, a rotation or orientation holonomy accompanies the translational one—the swimmer has turned somewhat as well as translated. The whole holonomy is non-Abelian (the order of the shape sequence matters), but (iv) for two dimensions the rotation part is Abelian. A benefit (albeit cosmetic) is that the one-stroke displacement and turning can be written down as a complex line integral. (v) Another benefit is that while Stokes's theorem (in shape space) is normally sacrificed in non-Abelian holonomies, a partial recovery of the theorem is possible in two-dimensional swimming. To illustrate this last principle, a completely solvable case is analyzed: that of a Euler fluid where the swimmer's shape is fixed but its internal mass distribution varies cyclically.

Topical reviews

Spatiotemporal dynamics of continuum neural fields
Paul C Bressloff 2012 *J. Phys. A: Math. Theor.* **45** 033001

Integrable structure of box–ball systems: crystal, Bethe ansatz, ultradiscretization and tropical geometry
Rei Inoue, Atsuo Kuniba and Taichiro Takagi 2012 *J. Phys. A: Math. Theor.* **45** 073001

Cold atoms in the presence of disorder
Boris Shapiro 2012 *J. Phys. A: Math. Theor.* **45** 143001

Superconformal mechanics
Sergey Fedoruk, Evgeny Ivanov and Olaf Lechtenfeld 2012 *J. Phys. A: Math. Theor.* **45** 173001

Supersymmetric many-particle quantum systems with inverse-square interactions
Pijush K Ghosh 2012 *J. Phys. A: Math. Theor.* **45** 183001

Finite flavour groups of fermions
Walter Grimus and Patrick Otto Ludl 2012 *J. Phys. A: Math. Theor.* **45** 233001

Geometrical and topological aspects of graphene and related materials
A Cortijo, F Guinea and M A H Vozmediano 2012 *J. Phys. A: Math. Theor.* **45** 383001

The information-theoretic costs of simulating quantum measurements
Mark M Wilde, Patrick Hayden, Francesco Buscemi and Min-Hsiu Hsieh 2012 *J. Phys. A: Math. Theor.* **45** 453001

Laplace operators on fractals and related functional equations
Gregory Derfel, Peter J Grabner and Fritz Vogl 2012 *J. Phys. A: Math. Theor.* **45** 463001

Lectures on hydrodynamic fluctuations in relativistic theories
Pavel Kovtun 2012 *J. Phys. A: Math. Theor.* **45** 473001

Phases of gauge theories
Michael C Ogilvie 2012 *J. Phys. A: Math. Theor.* **45** 483001

Nonlinear supersymmetric quantum mechanics: concepts and realizations
A A Andrianov and M V Ioffe 2012 *J. Phys. A: Math. Theor.* **45** 503001

2012 special issues

Coherent states: mathematical and physical aspects

Guest editors: S Twareque Ali, Jean-Pierre Antoine, Fabio Bagarello and Jean-Pierre Gazeau

This special issue captures a snapshot of the developments within this area and includes some articles by the originators of the field. Featuring the following papers:

- Review of entangled coherent states **Barry C Sanders** 2012 *J. Phys. A: Math. Theor.* **45** 244002
- Bosonic and k-fermionic coherent states for a class of polynomial Weyl–Heisenberg algebras **M Daoud and M R Kibler** 2012 *J. Phys. A: Math. Theor.* **45** 244036

Applications of zeta functions and other spectral functions in mathematics and physics: a special issue in honour of Stuart Dowker's 75th birthday

Guest editors: Fay Dowker, Emilio Elizalde and Klaus Kirsten

This issue contains a mix of review and original research articles that touch on the various topics Stuart Dowker has worked on in the course of his career. Featuring the following papers:

- String partition functions, Hilbert schemes and affine Lie algebra representations on homology groups **Loriano Bonora, Andrey Bytsenko and Emilio Elizalde** 2012 *J. Phys. A: Math. Theor.* **45** 374002
- Wedges, cones, cosmic strings and their vacuum energy **S A Fulling, C S Trendafilova, P N Truong and J Wagner** 2012 *J. Phys. A: Math. Theor.* **45** 374018

Quantum physics with non-Hermitian operators

Guest editors: Carl Bender, Andreas Fring, Uwe Günther and Hugh Jones

This collection of original research articles is intended to reflect the current state of this rapidly developing field. Featuring the following papers:

- Stationary states of a PT symmetric two-mode Bose–Einstein condensate **Eva-Maria Graefe** 2012 *J. Phys. A: Math. Theor.* **45** 444015
- Unbounded $\mathcal{C}$-symmetries and their nonuniqueness **Carl M Bender and Sergii Kuzhel** 2012 *J. Phys. A: Math. Theor.* **45** 444005

Lattice models and integrability: a special issue in honour of F Y Wu's 80th birthday

Guest editors: A J Guttmann and J L Jacobsen

This special issue presents some of the best new research inspired by F Y Wu's interests and work. Featuring the following papers:

- Transfer matrix computation of generalized critical polynomials in percolation **Christian R Scullard and Jesper Lykke Jacobsen** 2012 *J. Phys. A: Math. Theor.* **45** 494004
- Simple asymmetric exclusion model and lattice paths: bijections and involutions **R Brak and J W Essam** 2012 *J. Phys. A: Math. Theor.* **45** 494007

Forthcoming special issues

Higher spin theories and holography
Guest editors: Matthias Gaberdiel and Mikhail Vasiliev

Lyapunov analysis: from dynamical systems theory to applications
Guest editors: Massimo Cencini and Francesco Ginelli

Logarithmic conformal field theory
Guest editors: Azat Gainutdinov, David Ridout and Ingo Runkel

Best Paper Prize

Since 2009, *Journal of Physics A* has awarded a Best Paper Prize, which serves to celebrate and applaud well written papers that make a significant contribution to their field.

The Editorial Board awarded the 2012 Best Paper Prize to the following papers, which were considered to excel in the criteria of novelty, achievement, potential impact and presentation.

- Coupling constant metamorphosis and *N*th-order symmetries in classical and quantum mechanics
  E G Kalnins, W Miller Jr and S Post
  2010 *J. Phys. A: Math. Theor.* **43** 035202

- An exact formula for the statistics of the current in the TASEP with open boundaries
  Alexandre Lazarescu and Kirone Mallick
  2011 *J. Phys. A: Math. Theor.* **44** 315001

- *Y*-system for scattering amplitudes
  Luis F Alday, Juan Maldacena, Amit Sever and Pedro Vieira
  2010 *J. Phys. A: Math. Theor.* **43** 485401

You can read these papers and see the previous Best Paper Prize winners at **iopscience.org/jphysa/best-paper-prize2012**.

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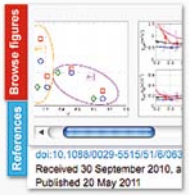

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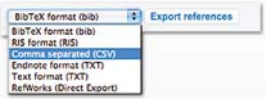

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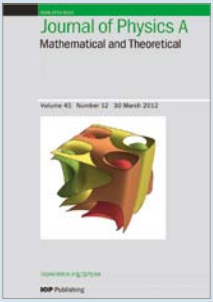

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