International Meeting on Perspectives of Soliton Physics

Program & Abstracts

16th(Friday)–17th(Saturday) February, 2007

Koshiba Hall, the University of Tokyo

Web page: http://maildbs.c.u-tokyo.ac.jp/~kuniba/psp07

PREFACE

The international meeting on "Perspectives of Soliton Physics" is held at Koshiba hall, University of Tokyo from 16-17 February, 2007. It is dedicated to Professor Miki Wadati on the occasion of his retirement from the University of Tokyo.

This meeting highlights the soliton theory, which has found diverse applications in physics and mathematical sciences. Several relevant topics are covered including nonlinear waves, integrable systems, solvable lattice models and the Bose-Einstein condensation, etc.

The scientific program of the meeting consists of invited and contributed oral presentations, and contributed poster presentations.

This meeting is sponsored by Inoue Foundation for Science.

Organizing Committee

Tetsuo Deguchi (Ochanomizu Univ.)
Tetsuro Konishi (Nagoya Univ.)
Atsuo Kuniba (Univ. of Tokyo, Chair)
Kazumitsu Sakai (Univ. of Tokyo)
Masahiro Shiroishi (Univ. of Tokyo)
Tetsu Yajima (Utsunomiya Univ.)

Program (Oral Presentations)

Friday, February 16

9:30–9:40	Opening
9:40–10:25	**Ryogo Hirota** *Back Ultradiscretized Box and Ball System*
10:25–11:10	**Mark J. Ablowitz** *Nonlinear Waves in Optics and Fluid Dynamics*
11:10–11:30	Break
11:30–12:00	**Kiyoshi Sogo** *Space-Time Discrete Integrable Systems with Periodic Boundary Condition*
12:00–12:30	**Yoshifumi Kimura** *Vortex Motion and Soliton*
12:30–13:45	Lunch
13:45–14:30	**Tetsuro Konishi** *Order and Chaos in Hamiltonian Dynamical Systems*
14:30–15:15	**Murray T. Batchelor** *Phase Transitions and Pairing in Strongly Attractive Fermi Atomic Gases*
15:15–15:35	Break
15:35–16:20	**Miki Wadati** *Soliton in the $F = 1$ Bose-Einstein Condensates*
16:20–18:20	Poster Session
18:30–	Banquet

Program (Oral Presentations)

Saturday, February 17

9:30–10:15	**Shinsuke Watanabe**	
	History of Soliton Experiments	
10:15–11:00	**Yuri S. Kivshar**	
	Nonlinear Optics and Gap Solitons in Periodic Photonic Structures	
11:00–11:20	Break	
11:20–11:50	**Tomohiro Sasamoto**	
	Particle Position Fluctuations in the Asymmetric Exclusion Process	
11:50–12:20	**Shuichi Murakami**	
	Spin Hall Effect: Berry Phase and Topology in Solids	
12:20–13:30	Lunch	
13:30–14:15	**Harvey Segur**	
	The Modulational Instability in the Presence of Damping	
14:15–15:00	**Masayuki Oikawa**	
	Two-Dimensional Interaction of Solitary Waves	
15:00–15:20	Break	
15:20–15:50	**Tetsuo Deguchi**	
	Topological Invariants of Links and Application to Random Knots	
15:50–16:35	**Frank Göhmann**	
	Density Matrix and Correlation Functions of the XXZ Chain	
16:35–	**Miki Wadati**	
	Closing	

Program (Poster Presentations)

PS01 **Kouichi Toda, Tadashi Kobayashi**
Higher-Dimensional Nonlinear Integrable Equations with Variable Coefficients and the Painlevé analysis

PS02 **Rei Inoue**
The Space of Observables for Classical Integrable Systems with Algebro-Geometric Method

PS03 **Kazuaki Nakayama**
Discretization of Vortex Filament

PS04 **Wael Farouk Hamed El-Taibany**
Nonlinear Quantum Dust Acoustic Waves

PS05 **Shintaro Mori**
Correlation Structure of Infectious Default Model

PS06 **Taro Nagao**
Replica Method and Sample Covariance Matrices

PS07 **Naomi Hirayama**
Effects of Topological Constraint for Elasticity of Polymer Networks

PS08 **Ryo Suzuki**
Sine-Gordon Integrability of Classical String Solution on $AdS_5 \times S^5$

PS09 **Hideaki Ujino**
A Super-Integrable Discretization of the Calogero Model

PS10 **Takuji Sakamoto**
Classification of the Ultra-Discrete QRT System

PS11 **Reiho Sakamoto**
Crystal Interpretation of the Kerov-Kirillov-Reshetikhin bijection and N*-Soliton Solutions of the Box-Ball Systems*

PS12 **Akira Takenouchi**
Bethe Ansatz and Periodic Box-Ball Systems

PS13 **Takashi Imamura**
Dynamical Properties of a Tagged Particle in the Totally Asymmetric Simple Exclusion Process with the Step-Type Initial Condition

PS14 **Chikashi Arita**
Phase Diagram of the Two-Species TASEP

PS15 **Tetsu Yajima**
Conservation Laws of Integrable Equations As Kolmogorov's Equation

PS16 **Takahiko Miyakawa**

Interaction of Bright Solitons in Spinor Bose-Einstein condensates

PS17 **Tetsuo Kurosaki**

Propagation of General Bright Solitons in $F = 1$ Spinor Condensates

PS18 **Masaru Uchiyama**

Solitons of $F = 2$ Spinor Bose-Einstein Condensates

PS19 **Toshiaki Iida**

One-Dimensional Delta-Function Fermions with Imbalanced Spin Populations

PS20 **Xi-Wen Guan**

Bethe Ansatz and Generalized Exclusion Statistics of One-Dimensional Strongly Interacting Anyons

PS21 **Mari Matsuo**

Analytic Calculation of One Dimensional Tunneling Current Using Nonequilibrium Green's Function

PS22 **Yuichi Nakamura**

Zeros of the Dispersion Relation of the Elementary Excitation and the Correlation Length of Strongly Correlated Quantum Systems

PS23 **Masahiro Shiroishi**

String Correlation Functions of Spin-1/2 Heisenberg XXZ Chain

PS24 **Jun Sato**

Exact Correlation Functions of Spin-1/2 Heisenberg XXZ chain

PS25 **Kohei Motegi**

Some Remarks on Classical Dynamical Equation

PS26 **Akinori Nishino**

The sl2 Loop Algebra Symmetry of the XXZ-Type Spin Chain Associated with the Superintegrable Chiral Potts Model

PS27 **Tetsuo Deguchi**

Irreducibility Criterion of a Highest Weight Representation of the $sl(2)$ Loop Algebra and the XXZ Spin Chain at Roots of Unity

PS28 **Keiichi Shigechi**

Generalized Loop Models and Affine Hecke Algebras

Abstracts of Oral Presentations

Back Ultradiscretized Box and Ball System

Ryogo Hirota

The famous Box and Ball system is a ultradiscrete equation obtained from the discrete Lotka-Volterra equation through the coordinates and dependent variable transformation. We propose the following discrete equation,

$$\frac{1}{u_{n+1}^{m+1}} - \frac{1}{u_n^m} = \delta(u_{n+1}^m - u_n^{m+1}),$$

where m and n are integers and δ is a time-interval. We call it " BBB system "(Back ultradiscretized Box and Ball system). A box and Ball system is obtained by ultradiscretizing BBB system. However in the ultradiscrete BBB system the number of balls in a box is arbitrary. It could be over the capacity of the box or a negative integer. We discuss solutions and higher order conserved quantities of BBB system.

Nonlinear Waves in Optics and Fluid Dynamics

Mark J. Ablowitz

Department of Applied Mathematics University of Colorado, Box 526
Boulder, CO 80309-0526

Nonlinear optics involves quite naturally the study of nonlinear waves, and in particular their is considerable interest in their localized wave solutions, such as solitary waves, or solitons. In optical communications asymptotic analysis leads to the"classical" and "dispersion managed" nonlocal nonlinear Schrodinger (NLS) equations. These equations contain solitary waves, or solitons, as special solutions. Recent research has shown that similar dispersion managed systems find important applications in mode-locked lasers. Nonlinear waves in periodic and irregular lattices will also be discussed. The water wave equations are reformulated and a new non-local system is obtained. Special cases include shallow and deep water. A numerical method is introduced to find localized waves. This method is employed to find solitary waves in the optics and fluids problems including two dimensional water wave lumps to the nonlinear water wave equations with sufficient surface tension.

Space-Time Discrete Integrable Systems with Periodic Boundary Condition

Kiyoshi Sogo
Department of Physics, School of Science, Kitasato University
Sagamihara, Kanagawa 228-8555, Japan

Recently the author showed that several space-time discrete integrable systems, including Lotka-Volterra, KdV, Toda lattice etc., have determinant expressions for time development formulas when we require periodic boundary condition (JPSJ **75** 084001, 2006). Such explicit formulas enable us to perform numerical simulations simply and stably. Real time demonstrations will be given for some familiar models.

Vortex Motion and Soliton

Yoshifumi Kimura
Graduate School of Mathematics, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan

The original observation of vortex soliton in a rotating tank experiment was done ten years after Hasimoto presented the transformation between the Local Induction Equation and the cubic nonlinear Schrödinger equation. The observation pointed out that a soliton transports physical quantities, such as mass, kinetic energy, and linear and angular momenta from a turbulent region to a laminar one. In this talk we will numerically demonstrate that a vortex soliton transport mass by trapping fluid particles around its kink part. To explain the particle trapping, a simple 3D ODE system (chopsticks model) is presented and investigated.

Order and Chaos in Hamiltonian Dynamical Systems

Tetsuro Konishi
Department of Phyics, Nagoya University, Nagoya, 464-8602, Japan

In this talk we show some examples in classical Hamiltonian systems which have ordered structures such as clusters by its own dynamics. The systems consist of particles with long-range interaction, just like many-body systems in astrophysics. Since the systems are Hamiltonian systems, the spatial structures thus formed are not "attractors" or asymptotic states we observe in the infinite future. Rather the states are observed in the course of relaxation to thermal equilibrium, or in the course of itinerancy among several quasi-stationary states.

Phase Transitions and Pairing in Strongly Attractive Fermi Atomic Gases

Murray T. Batchelor
Department of Theoretical Physics, Research School of Physical Sciences and Engineering, and Mathematical Sciences Institute, Australian National University, Canberra ACT 0200, Australia

Recent progress in manipulating quantum gases of ultracold atoms is opening up many exciting possibilities for the experimental study of quantum effects in low-dimensional many-body systems. Among these developments the experimental observation of superfluidity and phase separation in imbalanced Fermi atomic gases has stimulated great interest in exploring exotic quantum phases of matter with two mismatched Fermi surfaces. In this talk I will describe exact results obtained with Xiwen Guan and Chaohong Lee for the 1D two-component strongly attractive Fermi gas of cold atoms with external fields. Results obtained using the thermodynamic Bethe Ansatz include the critical fields, magnetization and local pair correlation function. This model is seen to exhibit a phase diagram reminiscent of type II superconductors. Below the degenerate temperature, bound pairs of fermions behave like hard-core bosons obeying generalized exclusion statistics.

Solitons in the $F = 1$ Bose-Einstein Condensates

Miki Wadati
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Bose-Einstein condensate with internal degrees of freedom has attracted much attention of experimental and theoretical physicists. Internal degrees of freedom which are frozen under magnetic traps are liberated, and are expected to play a significant role with wide possibilities now under optical traps.

We study soliton solutions of a multi-component Gross-Pitaevskii equation for hyperfine spin $F = 1$ spinor Bose-Einstein condensates. The interactions are supposed to be inter-atomic repulsive (attractive) and anti-ferromagnetic (ferromagnetic) ones of equal magnitude [1,2]. The solutions are obtained from those of a new integrable 2×2 matrix nonlinear Schrödinger equation [3] with non-vanishing boundary conditions [4,5]. Note that the equation is different from the Manakov equation. By the inverse scattering method, both coupling cases are studied and the multiple-soliton solutions are explicitly obtained.

We investigate the one-soliton and two-soliton solutions in detail. One-soliton is classified into two kinds. The ferromagnetic state has waveforms of domain-wall shape and its total spin is nonzero. The polar state exhibits a hole (peak) soliton and its total spin is zero. These two states are selected by choosing the type of the boundary conditions. In two-soliton collisions, we discover a novel phenomenon, which we call the spin-mixing or spin transfer, for ferromagnetic and polar solitons. This indicates that, as magnetic carriers, solitons in the ferromagnetic state are operative for the spin-mixing while those in the polar state are passive.

References

1) J. Ieda, T. Miyakawa and M. Wadati, Phys. Rev. Lett. 93, 194102 (2004).
2) J. Ieda, T. Miyakawa and M. Wadati, J. Phys. Soc. Jpn. 73, 2996 (2004).
3) T. Tsuchida and M. Wadati, J. Phys. Soc. Jpn. 67, 1175 (1998).
4) M. Uchiyama, J. Ieda and M. Wadati, J. Phys. Soc. Jpn. 75, 064002 (2006).
5) J. Ieda, M. Uchiyama and M. Wadati, J. Math. Phys. in press (2007).

History of Soliton Experiments

Shinsuke Watanabe
Yokohama National University

In the theory of a soliton, or a solitary wave, we often encounter the situation that a soliton has the maximum amplitude. One example is an ion acoustic solitary wave in a plasma with zero ion temperature, $T_{\mathrm{i}} = 0$, and finite electron temperature, $T_{\mathrm{e}} \neq 0$. In the wave frame of a solitary wave, all the ions in front of a solitary wave approach a solitary wave with the velocity c which means the velocity of a solitary wave in the laboratory frame. The ions are decelerated in the leading edge of the wave potential φ and then accelerated in the trailing edge. In this case, the solitary wave is stable. When the wave potential becomes large and the condition $e\varphi > Mc^2/2$ is satisfied, the ions are reflected from the wave potential, which leads to the collapse of a solitary wave. Here the ion charge is designated by e and the ion mass, by M. In the real plasma, the ion temperature is much smaller the electron temperature, but it is finite. Then a part of ions are reflected by the wave potential, which brings about the damping of a solitary wave.

The second example is a shallow water solitary wave. Since the observation of a solitary wave by John Scott Russell, the theoretical and experimental studies on nonlinear shallow water wave have been carried out extensively. The breakdown of perturbation approach leads to find the existence of the maximum energy of a solitary wave. At present, we know that the solitary wave is stable when the amplitude is lower that the maximum amplitude corresponding to the maximum energy, and then becomes unstable when the amplitude exceeds the critical one. The instability is characterized by a breaking of a solitary wave.

In this talk, I will present a brief history of the experiments on soliton together with our experimental results of the maximum amplitude and the instability of the shallow water solitary wave.

Nonlinear Optics and Gap Solitons in Periodic Photonic Structures

Yuri S. Kivshar
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We will overview the nonlinear physics in periodic photonic structures such as fiber Bragg gratings, waveguide arrays and optical lattices. First, we will discuss the small-amplitude approximation and refer to an earlier derivation of M. Wadati and T. Iizuka of the effective nonlinear Schroedinger equation. Then, we will discuss more general case of self-focusing in the structures with bandgap spectra and the formation of gap solitons in one- and two-dimensional photonic lattices. Next, we will analyze nonlinear collective effects near surfaces of semi-infinite periodic systems with multi-gap transmission spectra and report on the first observation of surface gap solitons existing at the interface between uniform and periodic dielectric media with defocusing nonlinearity, an optical analog of nonlinear Tamm states. We will also discuss reshaping of polychromatic beams due to collective nonlinear self-action of multiple-frequency components in periodic photonic lattices, predict theoretically and demonstrate experimentally the formation of polychromatic discrete solitons facilitated by localization of light in spectral gaps.

Particle Position Fluctuations in the Asymmetric Exclusion Process

Tomohiro Sasamoto
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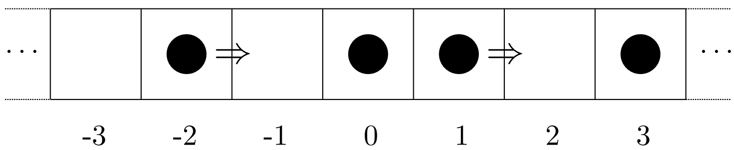
Time dependent properties of the one-dimensional asymmetric exclusion process(ASEP) are considered. The fluctuation of the particle positions in the ASEP are calculated explicitely using a combination of methods from exactly solvable models. We also discuss the connection to the random matrix theory, free fermions and the importance of the initial condition.



The asymmetric simple exclusion process(ASEP)

Spin Hall effect: Berry phase and topology in solids

Shuichi Murakami

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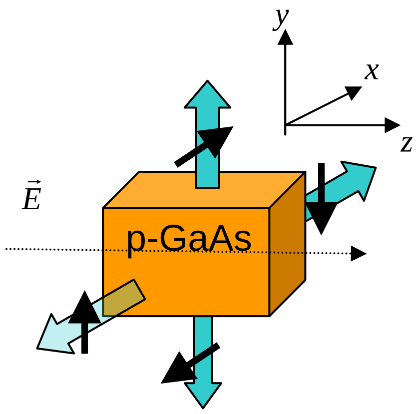

A spin Hall effect is an effect where an external electric field applied to a nonmagnetic system induces spin current in a transverse direction [1,2]. This effect has been known to occur extrinsically by impurity scattering since more than three decades ago. On the other hand, in 2003, we theoretically proposed that this effect occurs intrinsically, without impurity scattering. This is by the Berry phase of an electron in the momentum space. Since its theoretical predictions on semiconductors [1,2], it has been extensively studied theoretically and experimentally, partly due to a potential application to spintronics devices. In my presentation I review on recent progress in theories and experiments on the spin Hall effect.

One of the topics of recent interest is quantum spin Hall systems, which are spin analogues of the quantum Hall systems. These systems are insulators in the bulk, and have gapless edge states which carry a spin current. These edge states are characterized by a Z_2 topological number [3] of a bulk Hamiltonian. If the topological number is odd, there appear gapless edge states which carry spin current. This topological number protects these edge states against nonmagnetic impurities and interactions. While the quantum spin Hall systems are intensively studied theoretically, experimental reports are yet to come. We discuss general features of the quantum spin Hall systems, and explain some theoretical proposals for the candidate materials of the quantum spin Hall systems [4-7].

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[2] J. Sinova et al., Phys. Rev. Lett. 92, 126603 (2004).

[3] C. L. Kane and E. J. Mele, Phys. Rev. Lett. 95, 146802, 226801 (2005).

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[7] B. A. Bernevig, T. L. Hughes, S.-C. Zhang, Science 314 1757 (2006).

The Modulational Instability in the Presence of Damping

Harvey Segur
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The discovery of solitons by Zabusky and Kruskal in 1965 revolutionized nonlinear physics. About the same time, several people in several fields discovered the modulational instability (or "Benjamin-Feir instability"), and this discovery also changed nonlinear physics in fundamental ways. In recent work, we have explored how damping affects this instability, both mathematically and experimentally. Mathematically, we have found that modulational instability changes fundamentally in the presence of damping: damping (of the right kind) stabilizes the instability. Experimentally, we observe stable wavetrains within the lengths of our wavetanks, and we find that the damped theory predicts measured wave data much more accurately than earlier theories. The talk concludes with some consequences of this revised thinking about the modulational instability. [Several people participated in the research described herein, especially Diane Henderson of Penn State University.]

Two-Dimensional Interaction of Solitary Waves

Masayuki Oikawa
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I will talk about two topics. One is two-dimensional interaction of solitary waves in a two-dimensionalized intermediate long-wave equation. The other is interaction of curved solitary waves in shallow water . In this case, it is shown by numerical computation that a localized wave of very large amplitude is generated by the interaction.

Topological Invariants of Links and Application to Random Knots

Tetsuo Deguchi
Department of Physics, Faculty of Science, Ochanomizu University, 2-1-1 Ohtsuka, Bunkyo-ku, Tokyo 112-8610, Japan

We first review several topological invariants of knots and links studied in the 1980s. There are indeed many approaches to formulate them in mathematics and physics. We then discuss application of knot invariants to statistical mechanics of polymers with fixed topology. In particular, we show that knot invariants are fundamental tools to investigate topological properties of DNA.

Density Matrix and Correlation Functions of the XXZ Chain

Frank Göhmann
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I review recent progress on the exact evaluation of static correlation functions of the antiferromagnetic XXZ chain. Static correlation functions can be obtained from the density matrix of a finite chain segment. The density matrix for either the infinite chain at finite temperature and finite longitudinal magnetic field or for the finite chain at zero temperature and zero field can be represented as a multiple integral. We put forward the hypothesis that the multiple integral factorizes and present explicit results for short range correlation functions and a conjectured general formula for the inhomogeneous density matrix of the isotropic chain at zero magnetic field.

Abstracts of Poster Presentations

PS01

Higher-Dimensional Nonlinear Integrable Equations with Variable Coefficients and the Painlevé Analysis

Kouichi Toda and Tadashi Kobayashi
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It is showed mainly that higher-dimensional Korteweg-de Vries, modified Korteweg-de Vries and Nonlinear Schrödinger equations with variable coefficients are integrable in the sense of the Painlevé analysis(; the WTC and Log-WTC methods).

This poster is based on the following manuscripts:

・ T. Kobayashi and K. Toda, Extensions of nonautonomous nonlinear integrable systems to higher dimensions, Proceedings of 2004 International Symposium on Nonlinear Theory and its Applications, Vol. 1, pp.279 282 (2004)

・ T. Kobayashi and K. Toda, A generalized KdV-family with variable coefficients in (2 + 1) dimensions, IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. E88-A, pp.2548 - 2553 (2005)

・ T. Kobayashi and K. Toda, The Painlevé analysis and reducibility to the canonical forms for nonautonomous soliton equations in higher-dimensions and their exact solutions, Symmetry, Integrability and Geometry: Methods and Application (SIGMA), Vol. 2, paper 063, 10pages (2006)

・ T. Kobayashi and K. Toda, Extensions of nonautonomous nonlinear integrable systems to higher dimensions, Preprint (2007)

PS02

The Space of Observables for Classical Integrable Systems with Algebro-Geometric Method

Rei Inoue
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Led by an analogous problem for the quantum Toda lattice, Nakayashiki and Smirnov studied the space of observables for a classical integrable system known as the Mumford system. They conjectured this space is generated, under the action of the Hamilton vector fields, by a finite dimensional vector space which can be interpreted as a cohomology of a certain variety. In this talk, we develop a similar problem for systems related to the Toda lattice and Lotka-Volterra lattice, where we see an unexpectedly difficult problem in algebraic geometry. (This is a joint work with Takao Yamazaki.)

PS03

Discretization of Vortex Filament

Kazuaki Nakayama
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Discretization of vortex filament is studied. Proposed is a discrete vortex model and a discrete version of the LIA, which guarantees the vortex filament to obey the dNLS.

PS04

Nonlinear Quantum Dust Acoustic Waves

Wael Farouk Hamed El-Taibany
Department of Physics, Graduate School of Science, University of Tokyo

The quantum hydrodynamic model (QHD) for plasmas is employed to study the dynamics of the nonlinear quantum dust acoustic (QDA) wave in a nonuniform quantum dusty plasma (QDP). Through the reductive perturbation technique, it is shown that the quantum hydrodynamical basic equations describing the nonlinear QDA waves yield a modified Korteweg-de Veries (MKdV) equation with slowly varying coefficients in the system inhomogeneity. Applying generalized expansion method (GEM), it is found that the system admits only rarefactive solitons. The properties of the solitons such as the velocity, the amplitude and the width of the nonlinear QDA waves are analyzed using appropriate choice for initial ion and electron density numbers. For the homogeneous QDP, no critical value is found. Because of the system inhomogeneity, a new criticality is found forcing with the usage of a new stretching coordinates. A higher evolution equation with third-order nonlinearity is derived at the critical values. The solution of the latter equation admits rarefactive shock wave attached with an amplitude factor. The present investigations should be useful for researchers on astrophysical plasmas as well as for ultrasmall micro- and nano- electronic devices.

PS05

Correlation Structure of Infectious Default Model

Shintaro Mori
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We discuss the correlation structure of an infectious default and recovery model for N obligors. Obligors are assumed to be exchangeable and their states are described by N Bernoulli random variables S_i. They are expressed by multiplying independent Bernoulli variables $X_i, Y_ij, Y_i'j$, and default and recovery infections are described by Y_{ij} and $Y_i'j$. From the default probability function $P(k)$ for k defaults, we study the correlation structures, the conditional default probabilities and conditional correlation coefficients. By comparing them with those of an implied default distribution function inferred from the quotes of iTraxx-CJ, we show that to explain the behavior of the implied distribution, the recovery effect is necessary.

PS06

Replica Method and Sample Covariance Matrices

Taro Nagao
Graduate School of Mathematics, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan

Eigenvalue distribution of the random matrix (sample covariance matrix) of the form $A^T A$, where A is a rectangular matrix and A^T is the transpose of A is analyzed by the replica method in statistical mechanics. Approximation schemes are developed to extend the analysis to sparse random matrices.

PS07

Effects of Topological Constraint for Elasticity of Polymer Networks

Naomi Hirayama
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2-1-1 Ohtsuka, Bunkyo-ku, Tokyo 112-8610

We study the issue of rubber elasticity of polymer networks from the viewpoint of topological constraint. A network topology is conserved because that the entanglement structure of loops which are components of systems does not change - this means that loops are not broken or not joined - when the network is deformed by external forces. We regard the effect as the main cause of the nonlinear elasticity of rubberlike substances and investigate these elastic properties. As the result, the behavior governed by Mooney-Rivlin's law well known as the experimental law of rubber elasticity appears when there are only few entanglements. It is suggested that the contribution of entanglements becomes dominant in the region of large deformation.

PS08

Sine-Gordon Integrability of Classical String Solutions on $AdS_5 \times S^5$

Ryo Suzuki
Department of physics, Graduate school of science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033

Gauge/gravity correspondence gives us important ideas to study various aspects of gauge, gravity and string theories. A famous example is the one between maximally supersymmetric Yang-Mills theory in 1+3 dimensions and superstring theory on the $AdS_5 \times S^5$ spacetime background, which is called (but not yet proven) AdS/CFT correspondence.

Among the nontrivial tests for the AdS/CFT correspondence, comparison of the integrability of the both sides has recently been well investigated. For instance, there is correspondence between 'long' gauge-invariant, single-trace operators in gauge theory side and classical string solutions with a large angular momentum in S^5 in string theory side.

To be more precise: one calculates the anomalous dimension matrix of SYM operators, which we expect to be diagonalizable by Bethe Ansatz. And one compares it with (Energy) - (the total angular momentum in S^5) of the solutions of classical string sigma model, which is again an integrable system. Then both quantities will agree if the conjectured AdS/CFT correspondence is true.

In this work, we construct quasi-periodic closed string solutions on R x S^3 that interpolate various string solutions whose SYM counterparts have already been known.

They also have two interesting features from an integrability point of view: (1) In certain limit, our solution is identical to spinning string solutions found by Frolov and Tseytlin, which has interpretation as finite-gap solutions of genus 1. So one can expect that our solutions have similar interpretation as finite-gap solutions. (2) Our construction is based on Pohlmeyer-Lund-Regge reduction, which relates string theory on $R \times S^3$ with Complex sine-Gordon system. So eventually we will be able to construct explicitly a map between the finite-gap solutions of string sigma model on $R \times S^3$ and those of Complex sine-Gordon system.

This presentation is based on the work hep-th/0609026 done in collaboration with K. Okamura (Tokyo Univ.).

PS09

A super-integrable discretization of the Calogero model

Hideaki Ujino
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A time discretization that preserves the super-integrability of the Calogero model is obtained by application of the integrable time discretization of the harmonic oscillator to the projection method for the Calogero model with continuous time.

PS10

Classification of the Ultra-Discrete QRT System

Takuji Sakamoto
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An 8-parameter family of 2-dimensional piecewise linear mappings, the ultra-discrete QRT (u-QRT) system , is obtained from the QRT (Quispel-Roberts-Thompson) system through elimination of parameters and ultra-discretization. The u-QRT system has an 8-parameter family of invariant curves, and the mappings of the u-QRT system are reversible. Therefore the u-QRT system is considered to be integrable. We classify the u-QRT system into four types by the extended Newton polytopes constructed from the conserved quantities through inverse-tropicalization (in Tropical Geometry). Moreover we conjecture on the explicit formula of the period.

PS11

Crystal Interpretation of the Kerov-Kirillov- Reshetikhin Bijection and N-Soliton Solutions of the Box-Ball Systems

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We review recently discovered interplay between the box-ball system which is the celebrated example of soliton cellular automata and the Kerov-Kirillov-Reshetikhin (KKR) bijection which arose from the Behte ansatz. Especially we show (1) the KKR bijection plays the role of the inverse scattering formalism for the box-ball systems, (2) representation theoretic origin of the combinatorial algorism of the KKR bijection is clarified, (3) explicit analytic formula for the KKR bijection and general N-soliton solution for the box-ball systems are obtained – the expression has intimate relationship with the Fermionic formula of the Kostka polynomial, (4) N-soliton solutions for the periodic box-ball system are obtained in terms of ultradiscrete analogue of the Riemann (multivariable) theta function. The part of the talk is based on joint work with A.Kuniba, M.Okado, T.Takagi and Y.Yamada.

PS12

Bethe Ansatz and Periodic Box-Ball Systems.

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Based on the Bethe ansatz at q=0 and q=1, we formulate the inverse scattering method for the most fundamental periodic box-ball system and solve the initial value problem. Moreover we propose explicit formulae for the dynamical period and the number of states characterized by conserved quantities in the most general periodic box-ball system for $A_n^{(1)}$ case. (Joint work with A. Kuniba and T .Takagi)

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PS13

Dynamical Properties of a Tagged Particle in the Totally Asymmetric Simple Exclusion Process with the Step-Type Initial Condition

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The one-dimensional totally asymmetric simple exclusion process (TASEP) is considered. We study the time evolution property of a tagged particle in TASEP with the step-type initial condition. Calculated is the multi-time joint distribution function of its position. Using the relation of the dynamics of TASEP to the Schur process, we show that the function is represented as the Fredholm determinant. We also study the scaling limit. The universality of the largest eigenvalue in the random matrix theory is realized in the limit. When the hopping rates of all particles are the same, it is found that the joint distribution function converges to that of the Airy process after the time at which the particle begin to move. On the other hand, when there are several particles with small hopping rate in front of a tagged particle, the limiting process changes at a certain time from the Airy process to the process of the largest eigenvalue in the Hermitian multi-matrix model with external sources.

PS14

Phase Diagram of the Two-Species TASEP

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The two-species totally asymmetric exclusion process (TASEP) on a chain with an open boundary condition is considered. The model is formulated as a master equation. Its exact stationary-state solution is obtained as a matrix product form and explicit expressions of physical quantities are found. In the thermodynamic limit, the physical quantities exhibit boundary-induced phase transitions. The phase diagram of the current and the densities consists of three regions: maximal-current phase, low-density phase and high-density phase. The phase diagram of the localization lengths consists of eight regions, which is a feature that one-species TASEP does not have.

PS15

Conservation Laws of Integrable Equations As Kolmogorov's Equation

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The density function $p(x, t)$ for an Ito's diffusion process satisfies Kolmogorov's forward equation, which is a conservation law of p. We shall consider some of the conservation laws of the sine-Gordon (SG) and nonlinear Schrödinger (NLS) equations and regard them as Kolmogorov's equation, to generate stochastic differential equations associated with the integrable equations. In addition, we shall analyze the derived stochastic processes numerically generated from soliton solutions, and explain the behavior of the sample paths of the stochastic variables by the equation of motion related to the nonlinear equations. We shall introduce the following results:

- By virtue of the structure of propagating wave solution one of the conservation laws of the SG equation is reduced to Kolmogorov's equation. As for the NLS equation, we can apply the method of stochastic quantization to derive the equation of motion in addition to Kolmogorov's equation.

- The behavior of the sample paths can be interpreted by using the potentials or potential-like functions of the equations of motion associated with the SG or NLS equations. The stochastic variables moves together with a attractive point generated from the solitary pulse or kinks or the equations.

PS16

Interaction of Bright Solitons in Spinor Bose-Einstein Condensates

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We consider a cold atomic gas with hyperfine spin $F = 1$ in one dimension. It was proven that the system possesses an integral point leading to the existence of multiple bright solitons. We examine the inelastic collision of solitons in the non-integral case. We show some aspects of the spin dynamics and bound state formation in low-energy collisions.

PS17

Propagation of General Bright Solitons in $F = 1$ Spinor Condensates

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Bose-Einstein Condensates (BEC) with internal degrees of freedom have been vigorously studied by both theoretical and experimental researchers. Most of the alkali atoms have the ground state with $F = 1$ hyperfine spin and their BEC system is characterized by a three-component vectorial order parameter in the mean field theory. The Gross-Pitaevskii (GP) equation extended to the $F = 1$ spinor-type describes the evolution of such a three-component field. Recently, an important result has been reported that the three-component GP equation, in spite of its complexity, possesses a completely integrable point in a 1D and uniform system when two coupling constants are equal and exact analysis is allowed via the inverse scattering method (ISM).

We apply the ISM formulated for nonvanishing boundary conditions to the integrable three-component GP equation and consider general bright soliton solutions with a finite background. In particular, we derive one-soliton solutions explicitly. We investigate their spin texture based on analytical calculation. In addition, we discuss the behavior of two-soliton collisions.

The presented results agree with the previous research for bright solitons under vanishing boundary conditions and dark solitons. We hope that our analysis contributes to understanding dynamical properties of matter-wave solitons in spinor BEC, which should be demonstrated experimentally in the near future.

PS18

Solitons of $F = 2$ Spinor Bose-Einstein Condensates

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Nonlinear dynamics of Bose–Einstein condensate (BEC) is a fascinating feature and a lot of studies have been focused on this subject. One novel property of BEC is an internal degree of freedom. Thanks to this freedom, we are guaranteed to have multi-component generalizations of nonlinear dynamics. In the one-dimensional uniform system, the dynamics of BEC is described by the Gross–Pitaevskii equation, well-known as a soliton equation. Many studies about soliton dynamics of BEC and its stability have appeared.

Recently, solitons of BEC with hyperfine spin $F = 1$ in the one-dimensional systems both with vanishing boundary conditions and nonvanishing boundary conditions were studied in detail. The method was the use of the integrability and explicit solutions of the matrix type of nonlinear Schrödinger equation. However, it seems that the application of the matrix nonlinear Schrödinger equation is only valid to the $F = 1$ BEC, and it has been a problem how to obtain solitons for higher spins.

We present several one-solitons for the $F = 2$ spinor BEC's with special choice of interaction. The alternative method is Hirota's bilinear transform. By generalizing the method for the multi-component equations, regardless of whether integrable or not the equations are, we can have one-soliton solutions. As a result, a novel shape of one-soliton has appeared.

PS19

One-Dimensional Delta-Function Fermions with Imbalanced Spin Populations

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We discuss a one-dimensional integrable system of two- component Fermi gas with arbitrary spin polarization at zero temperature. This model has been studied extensively by use of the Bethe ansatz. The ground state is described by the set of integral equations for the distribution of quasi-momenta and that of spin rapidities.

The first few terms of the asymptotic expansions of these distribution functions are calculated explicitly for three cases: strong attractive, weak attractive, and weak repulsive case. We then study some physical quantities, such as the groundstate energy and the chemical potentials.

PS20

Bethe ansatz and generalized exclusion statistics of one-dimensional strongly interacting anyons

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We investigate Bethe Ansatz solvability, ground state, thermodynamics and the generalized exclusion statistics (GES) of the 1D δ-function interacting anyon gas. It is found that the anyonic statistical parameter and the dynamical coupling constant induce Haldane exclusion statistics interpolating between bosons and fermions. In the strongly interacting regime the thermodynamics and the local two-particle correlation function derived from the GES are seen to agree for low temperatures with the results derived for the anyon model using the thermodynamic Bethe Ansatz. The anyonic and dynamical interactions implement a continuous range of GES, providing a signature of strongly interacting anyons, including the strongly interacting one-dimensional Bose gas as a special case.

PS21

Analytic Calculation of One Dimensional Tunneling Current Using Nonequilibrium Green's Function

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Using nonequilibrium green function, we study tunneling current in a one-dimensional free fermion spin less model. We calculate various green's functions, derive tunneling currents analytically, and discuss their properties. Previous studies formally calculated tunneling current in one-dimensional lattice metal - insulator - metal tight binding model by using of Keldysh formalism, solving a Dyson Equation exactly. One dimensional lattice model we treat consists of two ideal leAdS coupled to two or three site on which there is a chemical potential and which includes Pauli's principle. The leAdS have open boundary condition.

PS22

Zeros of the Dispersion Relation of the Elementary Excitation and the Correlation Length of Strongly Correlated Quantum Systems

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We argue that the imaginary part of a zero of the dispersion relation of the elementary excitation of quantum systems is equal to the inverse correlation length. We confirm the relation for the Hubbard model[1] in the half-filled case; it has been confirmed only for the S=1/2 antiferromagnetic XXZ chain[2]. In order to search zeros of the dispersion relation in the complex momentum space efficiently, we introduce a non-Hermitian generalization of quantum systems by adding an imaginary vector potential ig to the momentum operator[3]. We also show for the half-filled Hubbard model the reason why the non-Hermitian critical point[4] is equal to the inverse correlation length[5] by noting the dispersion relation of the charge excitation.

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PS23

String Correlation Functions of Spin-1/2 Heisenberg XXZ Chain

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Recent developments of the exact calculation of the correlation functions for spin-1/2 Heisenberg XXZ chain have brought us lots of new features of the model especially at the ground state. Among them, we have found that a certain kind of string correlation functions $\mathcal{O}(n,\theta)$ can be evaluated exactly in the thermodynamic limit. These string correlation functions were originally introduced by den Nijs-Rommelse ($\theta = \pi$) and Oshikawa ($\theta =$ general) as possible order parameters to characterize the Haldane state of integer spin Heisenberg XXX chains. The same string correlation functions was considered by Hida as well as Lou *et al* for spin-1/2 systems. In particular Hida has reported the asymptotic form of $\mathcal{O}(n,\pi)$ is given by $\sim n^{-1/4}$ by use of the bosonization method, which is remarkably slower than the usual spin-spin correlation functions. More recently the asymptotic formula was generalized to $\mathcal{O}(n,\theta) \sim n^{-\theta^2/4\pi^2}$ by Lou *etal*. In this work, we have generalized these asymptotic formulas to general XXZ chain with the anisotropy parameter Δ in the critical region. We have also found the exact correlation amplitude, which allows us to compare with the newly obtained exact results for $\Delta = 1, 1/2$ and numerical data for other Δ. In the special case $\Delta = 0$, we have applied the Fisher-Hartwig conjectures for Toeplitz determinant to obtain both exact short range values and asymptotic formulas.

PS24

Exact Correlation Functions of Spin-1/2 Heisenberg XXZ Chain

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The spin-1/2 antiferromagnetic Heisenberg XXZ chain is one of the most fundamental models for one-dimensional quantum magnetism. The exact eigenvalues and eigenvectors of this model can be obtained by the Bethe ansatz method. Many physical quantities in the thermodynamic limit such as specific heat, magnetic susceptibility, elementary excitations, etc..., have been exactly evaluated even at finite temperature by this method.

The exact calculation of the correlation functions, however, is still a difficult problem even in the simplest case for static correlation functions at zero temperature. The exceptional case is $\Delta = 0$, where the system reduces to a lattice free-fermion model by the Jordan-Wigner transformation. In this case, we can calculate arbitrary correlation functions by means of Wick's theorem.

However, there have been rapid developments recently in the exact evaluations of correlation functions for $\Delta \neq 0$ case also. We would like to present our recent results for them, concentrating mainly on the static correlation functions of the XXX model $\Delta = 1$ at zero temperature.

PS25

Some Remarks on Classical Dynamical Equation

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We introduce some kind of classical dynamical reflection equation and study its properties: solutions in the simplest case, gauge transformation, and so on.

PS26

The sl_2 Loop Algebra Symmetry of the XXZ-Type Spin Chain Associated with the Superintegrable Chiral Potts Model

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The sl_2 loop algebra $L(sl_2)$ symmetry is found in a sector of the XXZ-type spin chain at a root of unity whose transfer matrix commutes with that of the superintegrable chiral Potts model. The regular Bethe state which is an eigenstate of the spin chain is shown to be a highest weight vector of $L(sl_2)$. The highest weight representation space generated by the Bethe state gives a $L(sl_2)$-degenerate eigenspace of the spin chain. The Drinfeld polynomial which characterizes the $L(sl_2)$-degenerate eigenspace of the spin chain is calculated. The Drinfeld polynomial is equivalent to the superintegrable chiral Potts polynomial which characterizes a subspace with the Ising-like spectrum of the superintegrable chiral Potts model. (Joint work with Tetsuo Deguchi)

PS27

Irreducibility Criterion of a Highest Weight Representation of the sl(2) Loop Algebra and the XXZ Spin Chain at Roots of Unity

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Recently it has been shown that the XXZ spin chain at roots of unity has the sl(2) loop algebra symmetry. In this poster presentation we present a necessary and sufficient condition for a finite-dimensional highest weight representation of the sl(2) loop algebra to be irreducible (T. Deguchi, math-ph/0610002.) The irreducibility criterion is fundamental to investigate the degenerate multiplicity of a given energy level of the XXZ spin chain at roots of unity. In fact, every finite-dimensional representation should be given by a highest weight representation or a collection of highest weight representations.

PS28

Generalized Loop Models and Affine Hecke Algebras

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We briefly review the Razumov-Stroganov (RS) conjectures which relate the $O(1)$-loop model to alternating sign matrices. Many research areas play important roles: alternating sign matrices in combinatorics, the XXZ spin chain and the six-vertex model in statistical mechanics, and the representation theory of the Temperley-Lieb and the Hecke algebras. We will discuss the A_k generalization of the $O(1)$-loop model on a cylinder by using representation theory of the Affine Hecke algebra and the qKZ equation. We introduce a class of the affine Hecke algebra which is characterized by the cylindric relation. We construct the states for this model through the correspondence among an unrestricted path, a rhombus tiling and a word. The RS sum rule for the A_k model and the relation with the spin chain model are also discussed.

PS29

Effect of Atomic Bose-Einstein Condensation on Molecular Conversion Efficiencies

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We study formations of heteronuclear Feshbach molecule in population imbalanced atomic gases. At low temperature in quantum degenerate regime, quantum statistics of atoms plays an important role in conversion efficiencies. Maximum conversion efficiencies are determined by quantum statistics, the number ratio and trap frequencies. When *atoms* condense, the molecular conversion efficiency does not reach 100% and has a plateau.

In the region where the gases does not condense, the conversion efficiency is described as a function of initial peak phase space density of a major component.