PROBLEMI ATTUALI DI FISICA TEORICA
XIV Edizione
14 - 19 Marzo 2008
Lloyd's Baia Hotel
Vietri sul Mare (SA)

TEMATICHE
The Quantum-Classical Transition
Foundations of Quantum Mechanics
Noncommutative Geometry
Poisson Geometry and Quantum Groups
General Relativity
Nonlinear Evolution Equations
Dynamical Systems
Classical and Quantum Chaos

COMITATO SCIENTIFICO
C. M. Becchi (Genova)
M. Boiti (Lecce)
L. Bonora (Trieste)
G. Casati (Como)
G. Cassinelli (Genova)
L. Lusanna (Firenze)
G. Marmo (Napoli)
O. Ragnisco (Roma)
M. Tarlini (Firenze)
G. Vilasi (Salerno)

COMITATO LOCALE
G. Lambiase, G. Marmo, G. Vilasi

ORGANIZZAZIONE
Dipartimento di Fisica "E.R. Caianiello"
Università di Salerno

PATROCINIO
Università degli Studi di Salerno
Istituto Nazionale di Fisica Nucleare

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| 11:00 – 11:45 **P. Santini**, Dispersionless Nonlinear PDEs |
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| 15:45 – 16:30 **L. Lanz**, Foundations of quantum theory based on quantum field theory for macrosystems |
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| 17:00 – 18:15 **C. Garola/S. Sozzo**, Reinterpreting Quantum Probabilities in a Realistic and Local Framework: The Modified BCHSH Inequalities |
| 18:15 – 19:00 **G. Velo**, Scattering a lungo range per l'equazione di Schroedinger lineare e nonlineare |

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| 9:00 – 9:45 <strong>P. Vitale</strong>, Twisting all the way, from classical mechanics to quantum fields |
| 9:45 – 10:30 <strong>R. Figari</strong>, Models of quantum environments |
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| 11:00 – 11:45 <strong>S. Pascazio</strong>, Entanglement e controllo della coerenze |
| 11:45 – 12:30 <strong>P. Aniello</strong>, An abstract setting for star product |
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Abstracts

The Quantum – Classic Transitions

Foundation of Quantum Mechanics

L. Balduzzi, Near points approach to super manifolds
We review the basic ideas underlying Berezin approach to supermanifolds through the functor of Lambda-points. This is the approach used in physics when dealing with supermanifolds. We present a generalization of such an approach to the case of near points.

G. Benenti, Entanglement, randomness and chaos
Entanglement is not only the most intriguing feature of quantum mechanics, but also a key resource in quantum information science. In particular, for quantum algorithms multipartite (many-qubit) entanglement is necessary to achieve an exponential speedup over classical computation. The entanglement content of random pure quantum states is almost maximal; such states find applications in various quantum information protocols. The preparation of a random state or, equivalently, the implementation of a random unitary operator, requires a number of elementary one- and two-qubit gates that is exponential in the number N of qubits, thus becoming rapidly unfeasible when increasing N. On the other hand, pseudo-random states approximating to the desired accuracy the entanglement properties of true random states may be generated efficiently, that is, polynomially in N. In particular, quantum chaotic maps are efficient generators of multipartite entanglement among the qubits, close to that expected for random states. We will discuss the relationship between entanglement, randomness and chaos. In particular, we will show [1] that the entanglement generated by chaotic maps is robust when taking into account the unavoidable noise sources affecting a quantum computer. That is, the distillable entanglement remains almost maximal up to a noise strength which drops only polynomially with the number N of qubits. We also discuss [2] the detection of the entanglement of random states using witness operators. Our results can be also used to explain the emergence of classicality in coarse grained quantum chaotic dynamics.


G. Bimonte, The Casimir effect: a force from nothing
The existence of an attractive force between two closely spaced surfaces in a vacuum was predicted by Hendrik Casimir over 50 years ago. The effect provides a macroscopic manifestation of quantum vacuum fluctuations of the electromagnetic field, and it is closely related to the familiar van der waals forces in Chemistry. Thanks to recent experimental advances, it is now possible to measure this force with great precision, and intense efforts are being made worldwide to exploit it to actuate micromachined devices. After a general review of this rapidly evolving field of research, I shall present recent results from the experiment ALADIN, currently under way in the Physics Department of naples University, aiming at providing the first direct measurement of the Casimir energy.

M. Blasone, Cariche di flavor e stati di flavor di neutrino mixed

G. Cassinelli, SU(1, 1) Quantum Tomography
We describe the mathematical structure of the reconstruction formula of an unknown quantum state of a system carrying an irreducible representation of the discrete series of SU(1,1). Such a reconstruction formula is of interest in Quantum Optics.

E. Ercolessi, Quantum phase transitions and entanglement in (quasi)1d spin and electron models.
We will discuss the zero-temperature phase diagram of some strongly correlated (quasi)1d spin and electron models and discuss their quantum phase transitions. The role of entanglement will also be considered.

R. Figari, Models of quantum environments
È diffusa l'idea che l'interazione con l'ambiente di un sistema quantistico microscopico abbia un ruolo centrale nel processo di perdita di coerenza e della conseguente transizione ad un comportamento dinamico classico. Vogliamo analizzare dinamiche solubili di sistemi quantistici a molte componenti che possano servire da modello di ambiente per una particella quantistica. In particolare verranno trattati i casi di reticoli di spin come modelli di camera a ionizzazione e gas di bosoni interagenti con un atomo-modello.

C. Garola/S. Sozzo, Reinterpreting Quantum Probabilities in a Realistic and Local Framework: The Modified BCHSH Inequalities
Most physicists uphold that the tests of the Bell inequalities (BI) performed up to now confirm the predictions of standard quantum mechanics (SQM) and refute local realism. But some scholars criticize this conviction, defending local realism in various ways. We present here a new viewpoint based on an improved version of the extended semantic realism (ESR) model that has been recently worked out in Lecce. The ESR model embodies the mathematical formalism of SQM into a more general framework in which objectivity of physical properties, hence local realism, holds (which avoids the quantum measurement problem and other quantum paradoxes) and the probabilities of SQM are reinterpreted as conditional instead of absolute. As a consequence, the ESR model provides some predictions that are formally identical to those of SQM but have a different physical interpretation, and further predictions that differ also formally from those of SQM. In particular, we show that the BI introduced by Clauser, Horne, Shimony and Holt (standard BCHSH inequalities) must be replaced by modified BCHSH inequalities. These depend on detection probabilities which are not predicted by SQM and may be such that the new inequalities are never violated by the conditional expectation values predicted by the model. The condition that no violation occurs implies the existence of upper bounds on detection probabilities, which makes the ESR model falsifiable. Finally, we show that, according to the ESR model, different inequalities (standard BCHSH, modified BCHSH and standard quantum) hold at different, microscopic and macroscopic, levels, which constitutes a "conciliatory" result and provides an intuitive explanation of the data obtained in actual experiments.

R. Giachetti, Stati legati di equazioni fermioniche relativistiche
L. Lanz, Foundations of quantum theory based on quantum field theory for macrosystems
We are developing an approach to foundations of quantum theory, looking at particles as systems emerging from macroscopic phenomenology when the deterministic evolution of typical macroscopic variables breaks down. Quantum theory can indeed be focused to dynamics of relevant hydrodynamical observables built in terms of quantum fields: this is the main point in Zubarev's approach. Such approach becomes more fundamental if these fields are taken as suitable composed structures in terms of elementary ones. When these elementary fields emerge directly in the dynamics of the system, quantum mechanics of the particles associated with these fields should naturally appear, unavoidably embedded in a macroscopic environment. Some first step concerning the structure of the composed field will be discussed.

A. Naddeo, Fully frustrated Josephson junction ladders with Mobius boundary conditions as topologically
We show how to realize a "protected" qubit by using a fully frustrated Josephson Junction ladder with Mobius boundary conditions. Such a system has been recently studied within a twisted conformal field theory approach [1] and shown to develop the phenomenon of flux fractionalization [2]. The relevance of a "closed" geometry has been fully exploited in relating the topological properties of the ground state of the system to the presence of half flux quanta and the emergence of a topological order has been predicted [3]. In this contribution the stability and transformation properties of the ground states under adiabatic magnetic flux change are analyzed and the deep consequences on the realization of a solid state qubit, protected from decoherence, are presented [4].

E. Recami, Localized solutions to the wave equations (and to the Schroedinger equation): Theory and Applications
By going on studying the new "Localized [nondiffracting] Solutions" to linear equations (like the wave-equations and, mutatis mutandis, the Schroedinger equation), we have investigated---besides the ones endowed with luminal or superluminal group velocities, well established since 1992 from the theoretical and experimental points of view---the SUB-luminal ones, and even the static ones ("Frozen Waves") with an envelope at rest.
Let us recall that, anyway, such Localized Waves (LW) are important, rather than for their group-velocity, for their soliton-type propagation and self-reconstruction properties: Actually, they are of interest in all fields in which an essential role is played by a wave-equation (like electromagnetism, optics, acoustics, seismology, geophysics, gravitation, elementary particle physics, etc.).

Our work has been, and is, devoted to analyze the general structure of the LWs, and to discover mathematical methods for the construction of analytic exact solutions, even in the cases of finite-energies, for propagation in vacuum or in material media, unbounded or bounded, with or without dispersion or loss.

These new solutions, obtained as superpositions of Bessel beams, are a priori much more suitable than the Gaussian waves for describing (for instance) elementary particles.

Let us add some details on the particular case of the Frozen Waves: We have shown how a suitable superposition of Bessel beams can be used to construct stationary localized wave fields with high transverse localization, and with a longitudinal intensity pattern that assumes any desired shape within a chosen interval of the propagation axis.

The potential applications of the LWs (up to now realized only partially) range from micro or nano-particle guiding to new types of optical or acoustic tweezers and scalpels (=bisturi), to tumour curing, and so on.

Another aspect of our research has consisted, e.g., in a careful study of the Tunnelling Times, and of the behaviour of evanescent waves (and/or tunnelling photons).

Some references:

P.S.

B. Vacchini, Applications of translation-covariant master and Levy processes to decoherence experiments

Translation-covariant Markovian master equations used in the description of decoherence and dissipation are considered in the general framework of Holevo's results on the characterization of generators of covariant quantum dynamical semigroups. A general connection between the characteristic function of a classical Levy process and loss of coherence of the statistical operator describing the center of mass degrees of freedom of a quantum system interacting through momentum transfer events with an environment is established.

The relationship with both microphysical models and experimental realizations is considered, focusing in particular on recent interferometric experiments exploring the boundaries between classical and quantum world. Extending the description to internal degrees of freedom also allows for non-Markovian dynamic

S. Pascazio, Entanglement e controllo della coerenze

L'entanglement bipartito puo' essere quantificato in termini di vari indicatori, fra loro fisicamente equivalenti. Proporremo una caratterizzazione dell'entanglement multipartito in un sistema di N qubit facendo uso della distribuzione della purity su tutte le possibili bipartizioni. La caratterizzazione ha legami interessanti con la complessita'. Analizzeremo poi il fenomeno della decoerenza in alcuni prototipi di computer quantistico (con qubit a superconduttore) e analizzeremo alcune tecniche di controllo della decoerenza.

De Pasquale, Entanglement, phase transitions and tomography

We study a random matrix model for the statistical properties of the purity of a bipartite quantum system at a finite (fictitious) temperature. It also unveils an unexpected feature of the system, namely the existence of two phase transitions, characterized by different spectra of the density matrices. One of the critical phases is described by the statistical mechanics of 2-D gravity, the other is a second-order phase transition. We finally discuss a generalized tomographic approach to the reconstruction of a quantum state.

G. Velo Scattering a lungo range per l'equazione di Schroedinger lineare e nonlineare
Si richiameranno brevemente le idee che stanno alla base della teoria dello scattering. Seguirà una discussione sulla differenza fra interazioni a corto e lungo range. Saranno infine illustrati alcuni risultati.

F. Ventriglia Some geometrical aspects of quantum tomography.

K. Yuasa, Neutron antibunching.
Lateral effects are analyzed in the antibunching of a beam of free non-interacting fermions. The emission of particles from a source is dynamically described in a 3D full quantum field-theoretical framework. The size of the source and the detectors, as well as the temperature of the source are taken into account and the behavior of the visibility is scrutinized as a function of these parameters. The fundamental implications of antibunching are discussed.

Non Commutative Geometry

P. Aniello, An abstract setting for star products

M. Arzano, Non-locality, quantum symmetries and kappa-quantum fields
We start by reviewing a general argument showing how non-local effects in quantum field theory lead to a description of space-time symmetries in terms of quantum algebras rather than ordinary Lie algebras. We then focus on a particular example of such quantum algebras, the $\kappa$-Poincaré Hopf algebra, discuss its relation to noncommutative spacetime and present the salient properties of classical fields enjoying these symmetries. A novel approach to the canonical quantization of a linear scalar field with such Hopf algebra symmetries will be then outlined and we will show how $\kappa$-quantum fields exhibit a natural mode cutoff at the Planck scale and a deformed energy-momentum dispersion relation. Finally we will discuss work in progress in the understanding the rich structure emerging in the multiparticle sector of the theory, in particular the \`momentum dependent\' statistics of $\kappa$-bosons and the possible emergence of entanglement for modes of the free field in the UV.

G. Fiore, Sulla seconda quantizzazione e quantizzazione dei campi su spazi non commutativi con simmetrie twisted

P. Vitale, Twisting all the way, from classical mechanics to quantum fields
We discuss the effects that a noncommutative geometry induced by a twist has on physical theories. The presence of the twist deforms all products and we describe the canonical procedure which deforms all products of the formalism. We discuss classical mechanics and in particular the effects on the Poisson bracket and hence on the time evolution. The twisting is then extended to classical fields, and then to the real interest of this work: quantum fields. This canonical procedure enables us to establish the (deformed) commutation relation among quantum fields following the canonical quantization procedure, that is the replacement of the (deformed) Poisson brackets with the (deformed) commutators. We find that the star product among creation and annihilation operators holds in a twisted form.

Poisson Geometry and Quantum Groups

F. Bonechi, Il modello sigma di Poisson sulla sfera

E. Celeghini, Basi e algebre

A. Marzuoli, Efficient quantum processing of 3-manifold topological invariants

M. Tarlini, Quantizzazione delle varietà di Poisson tramite gruppoidi simplettici

A. Sciarrino. Un mutation-selection mode per i codoni basato sulla crystal basis

G. Vitiello, Aspetti algebrici comuni a diversi sistemi in teoria quantistica dei campi
**General Relativity**

**A. Capolupo, Flavor vacuum structure and dark energy**
We show that the vacuum condensate induced by particle mixing can be interpreted as a dark energy component of the Universe.

**D. Bini, Extended bodies in black hole spacetimes**
The motion of an extended body up to the quadrupolar structure is studied in the Schwarzschild and Kerr background following Dixon's model and within certain restrictions (constant frame components for the spin and the quadrupole tensor, center of mass moving along a circular orbit, etc.). We find a number of interesting situations in which deviations from the geodesic motion, due to the internal structure of the particle, can originate measurable effects.

**L. Lusanna, Clock synchronization in special and general relativity: from ACES to the York map and beyond**
After a review of the chrono-geometrical structure of special and general relativity, it is shown that the problem of clock synchronization lies at the heart of the following problems:
A) quantum field theory in non-inertial frames (Torre-Varadarajan no-go theorem);
B) relativistic atomic and bound-state physics and relativistic entanglement (relevance of interpolating fields instead of the S-matrix framework);
C) ACES mission of ESA to put high precision laser-cooled atomic clocks on the space station to test Earth's gravitational redshift to order 1/c^3 and to arrive to define relativistic geodesy beyond GPS (Einstein's geometric view of gravity at the post-Newtonian level in the solar system);
D) the possible role of the gauge variable connected with the definition of the instantaneous 3-space (the York time in the York canonical basis) in the attempts to explain dark matter (Cooperstock) and dark energy (Buchert, Ellis) only in terms of Einstein's general relativity (geometric view outside the solar system and in cosmology).

**J. Nelson, A quantum Goldman bracket in (2+1) quantum gravity**
In the context of quantum gravity for spacetimes of dimension $2+1$, I describe progress in the understanding of a quantum Goldman bracket for loops on surfaces. Using a quantum connection with noncommuting components, holonomies and Wilson loops for two homotopic loops on the spatial manifold (the torus) are related by phases in terms of the signed area between them. Using a piecewise linear representation in $\mathbb{R}^2$ (representing loops on the torus), the concept of integer points inside the parallelogram spanned by two intersecting paths is introduced. Paths rerouted at intersection points with other paths occur in the Goldman bracket. Such rerouted paths must necessarily pass through integer points inside the parallelogram formed by the intersecting paths.

**Non Linear Evolution Equations**

**R. Droghei, New classes of orthogonal polynomials from isochronous systems**
We introduce the isochronous version of integrable dynamical systems obtained by applying to the equations of motion the standard trick. By investigating the motion of this systems near the equilibrium positions some diophantine relations are obtained. From this machinery we obtain tridiagonal matrices whose the eigenvalues are all integer numbers. It is well known that the eigenvalues of tridiagonal matrices can be identified with the zeros of polynomials satisfying three-term recursion relations and being therefore members of an orthogonal set. We identify new classes of such orthogonal polynomials some of which feature zeros given by simple formulae involving integer numbers. Another finding identifies classes of orthogonal polynomials, defined by three-term recursion relations and depending on a parameter, which moreover also satisfy a second recursion involving that parameter. The machinery developed can be applied to (almost) all the “named” polynomials of the Askey scheme, as defined by their standard three-term recursion relations. Finally we show the connection between this results with standard approaches to discrete integrability.

We treat the different types of one-soliton solutions for nonlinear evolution equations (NLEE) related to the $sl(n)$ Zakharov-Shabat systems. Along with the well known soliton solutions we show that the $N$-wave equations with a $\mathbb{Z}_2 \times \mathbb{Z}_2$ symmetry allow doublet and quadruplet soliton solutions (analogues to the topological and breather solutions of the sine-Gordon equation). We analyze also more complicated solitons using generic projectors of rank $s \geq 1$. Using special choices for the polarization vectors defining the projector we can get one-soliton solutions taking values in a subalgebras of $sl(n)$ [1]. Along with the typical $sl(2)$ solitons we derive spin $J$ $sl(2)$ solitons for which $sl(2)$ is embedded in $sl(n)$ by spin $J$ representation.

Next we discuss the effects of the reductions on the different types of one-soliton solutions. By applying an additional pair of $\mathbb{Z}_2 \times \mathbb{Z}_2$ reductions we obtain NLEE related to the symmetric spaces of BD.I-type (see [2]). They acquire a form generalizing the $n$-component vector NLS [3]:

\begin{align}
    \text{i} \vec{q}_t + \vec{q}_{xx} + 2(\vec{q}, \vec{p})\vec{q} - (\vec{q}, s_0 \vec{q})s_0 \vec{p} &= 0, \\
    \text{i} \vec{p}_t - \vec{p}_{xx} - 2(\vec{q}, \vec{p})\vec{p} + (\vec{p}, s_0 \vec{p})s_0 \vec{q} &= 0,
\end{align}

(1)

where for odd $n$ $(\vec{p}, s_0 \vec{q}) = \sum_{j=1}^{n} (-1)^{j+1} p_j q_{n+1-j}$. If we choose $n = 3$, introduce $\Phi_{-1} = q_1$, $\Phi_0 = q_2/\sqrt{2}$, $\Phi_1 = q_3$ and impose the reduction $p_k = q_k^2$ we obtain the equations that describe Bose-Einstein condensates (BEC) of spin $F = 1$; similarly for $n = 5$ we get BEC with $F = 2$ respectively [4]. Considering dressing Zakharov-Shabat factor with rank 1 and 2 projectors we derive the 1-soliton solutions for these equations. For rank 1 we get the solutions derived by other means in [4].

New $\mathbb{Z}_2$-reductions of these equations are found using automorphism related to a specific Weyl reflections. We end by briefly discussing the case of constant boundary conditions extending the results in [5].

References


D. Levi, *Miura Transformations and Symmetries of nonlinear equations defined on a lattice*

After reviewing the construction of Lax pairs for the integrable lattice equations belonging to the Adler-Bobenko-Suris (ABS) list, we provide explicit Miura transformations mapping their scalar spectral problems into the discrete Schroedinger spectral problem associated with Volterra-type equations.

We show that the ABS equations correspond to Backlund transformations for some particular cases of the discrete Krichever-Novikov equation found by Yamilov.

This enables us to construct new generalized symmetries for the ABS equations.

P. Michor, *Riemannian geometries on shape space*

The $L2$ or $H0$ metric on the space of smooth plane regular closed curves induces vanishing geodesic distance on the quotient $Imm(S^1,R^2)/Diff(S^1)\mathbb S$.

This is a general phenomenon and holds on all full diffeomorphism groups and spaces $Imm(M,N)/Diff(M)$ for a compact manifold $M$ and a Riemannian manifold $N$. Thus we have to consider more complicated Riemannian metrics using length or curvature, and we do this in a systematic Hamiltonian way, we derive geodesic equations and split them into horizontal and vertical parts, and compute all conserved quantities via the momentum mappings of several invariance groups (Reparameterizations, motions, and even scalings).

The resulting equations are relatives of well known completely integrable systems (Burgers, Camassa Holm, Hunter Saxton).

A certain scale invariant geometry on $Imm(S^1,\mathbb R^2)/Diff(S^1)\mathbb S$ is diffeomorphic to the Grassmannian of 2-planes in a pre-Hilbert space. Since for the latter one write down geodesics explicitly, following Neretin, we have explicit solutions for the distance, geodesics, and curvature. This gives a computable distance on shape space $Imm(S^1,\mathbb R^2)/Diff(S^1)\mathbb S$, with curvature.

P. Santini, *Commuting vector fields, integrable multidimensional PDEs and the analytic description of the gradient catastrophe of 2D water waves near the shore.*

We make use of the recently developed Spectral Transform for one-parameter families of commuting vector fields to study the dynamics of localized waves evolving according to the heavenly equation of Plebansky, describing self-dual Einstein fields, and to the dispersionless Kadomtsev-Petviashvili (dKP) equation, describing the evolution of two-dimensional shallow water waves near the shore. In particular, in the dKP case, we obtain the exact analytic description of the gradient catastrophe of 2D water waves near the shore.

G. Satta, *Analytical Bethe ansatz for supersymmetric spin*

We compute the Bethe Ansatz equations for spin chains based on the gl(m|n) superalgebra, for any representation and Dynkin diagram. The analytical Bethe Ansatz approach allows one to treat open chains with general boundary conditions.

C. Scimiterna, *Multiscale expansion and integrability of lattice equations*

Sommario: Perturbative multiscale reduction techniques are fundamental tools in finding approximate solutions of nonlinear systems offering a regularization of the spurious diverging secular solutions. We present an integrability preserving multiscale procedure applied to (integrable and nonintegrable) nonlinear partial differences equations, illustrating how is possible to use the beyond-nLS orders of the expansion to develop an integrability test.

**Dynamical Systems**

M. Boiti, *Extended resolvent approach to inverse Scattering in multidimensions*

We study the KPI and KPII equations which can be considered as two prototypes of integrable equations in 2+1 dimensions. They are associated respectively to the Nonstationary Schroedinger operator and to the heat operator. Being two generalizations of the KdV equation, they admit solutions behaving at space infinity like the solutions of the KdV equation.

Any effort of building Inverse Scattering for solutions with constant behavior along some rays in the plane clashes with unsuccessful attempts to regularize the divergent integral equations defining the Jost solutions of the Schroedinger and heat equation.

One needs to explore the nature of the associated linear operators by considering the entire family of their Green's functions in a very general class. In our language this corresponds to consider the extended resolvent of the two operators.

Then, one can proceed in two successive steps: first, by considering the pure N soliton solution and, afterwards, by adding an arbitrary smooth decaying background. Since we are able to get the explicit form of the extended resolvent
for the pure N soliton solution, when we introduce the perturbation, we can deal successfully with the singularities due to the constant behavior at large space and, then, solve completely the direct and inverse problem for KPI and KPII.

**L. Martina,** *Topologically Ordered Phase States: from Knots and Braids to Quantum Dimers*

**B. Konopelchenko,** *Deformation of algebras and surfaces and integrable systems: theory and applications*

**B. Prinari,** *Inverse scattering transform for NLS systems with non-vanishing boundary conditions*

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