



# From finite-gap solutions of KdV in terms of theta functions to solitons and positons

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## Abstract

We degenerate the finite gap solutions of the KdV equation from the general formulation in terms of abelian functions when the gaps tends to points, to recover solutions of KdV equations given a few years ago in terms of wronskians called solitons or positons. For this we establish a link between Fredholm determinants and Wronskians.

## 1 The KdV equation and solutions in terms of theta functions

We consider the Riemann surface  $\Gamma$  represented by  $\cup_{k=1}^g \alpha_k b_k \alpha_k^{-1} b_k^{-1}$  of the algebraic curve defined by  $\omega^2 = \prod_{j=1}^{2g+1} (z - E_j)$ , with  $E_j \neq E_k$ ,  $j \neq k$ . Let  $D$  be some divisor  $D = \sum_{j=1}^g P_j$ ,  $P_j \in \Gamma$ . The so-called finite gap solution of the KdV equation

$$u_t = 6uu_x - u_{xxx} \quad (1)$$

can be expressed in the form

$$u(x, t) = -2 \frac{d^2}{dx^2} \ln \theta(xg + tv + t) + C. \quad (2)$$

We recall briefly, the notations. In (2),  $\theta$  is the Riemann function defined by

$$\theta(z) = \sum_{k \in \mathbb{Z}^g} \exp\{\pi i(Bk|k) + 2\pi i(k|z)\}, \quad (3)$$

# M Kdv Solitons On The Background Of Quasi Periodic Finite Gap Solutions

**Richard Warren**



## **M Kdv Solitons On The Background Of Quasi Periodic Finite Gap Solutions:**

**(m)KdV Solitons on the Background of Quasi-Periodic Finite-Gap Solutions** Fritz Gesztesy, Roman Svirsky, 1995 In the introductory section we review the formulation of the Korteweg de Vries KdV equation and of the modified KdV mKdV equation as a compatibility condition for a Lax pair of linear operators We then illustrate Miura's transformation which maps solutions of the mKdV into solutions of the KdV We then give a general overview of the concept of soliton solutions relative to general backgrounds and of the single and double commutation methods Finally we present the main results of the article To avoid the clutter of too many technical details the paper is organized in four sections and five appendices

### **Algebro-Geometric Quasi-Periodic Finite-Gap Solutions of the Toda and Kac-van Moerbeke Hierarchies**

Wolfgang Bulla, 1998 In this work the authors provide a self contained discussion of all real valued quasi periodic finite gap solutions of the Toda and Kac van Moerbeke hierarchies of completely integrable evolution equations The approach utilizes algebro geometric methods factorization techniques for finite difference expressions as well as Miura type transformations Detailed spectral theoretic properties of Lax pairs and theta function representations of the solutions are derived Features Simple and unified treatment of the topic Self contained development Novel results for the Kac van Moerbeke hierarchy and its algebro geometric solutions

Nonlinear Partial Differential Equations and Hyperbolic Wave Phenomena Norske videnskaps-akademi. Research Program on Nonlinear Partial Differential Equations, 2010-10-01 This volume presents the state of the art in several directions of research conducted by renowned mathematicians who participated in the research program on Nonlinear Partial Differential Equations at the Centre for Advanced Study at the Norwegian Academy of Science and Letters Oslo Norway during the academic year 2008-09 The main theme of the volume is nonlinear partial differential equations that model a wide variety of wave phenomena Topics discussed include systems of conservation laws compressible Navier Stokes equations Navier Stokes Korteweg type systems in models for phase transitions nonlinear evolution equations degenerate mixed type equations in fluid mechanics and differential geometry nonlinear dispersive wave equations Korteweg de Vries Camassa Holm type etc and Poisson interface problems and level set formulations

*Soliton Equations and Their Algebro-Geometric Solutions: Volume 2, (1+1)-Dimensional Discrete Models* Fritz Gesztesy, Helge Holden, Johanna Michor, Gerald Teschl, 2008-09-04 As a partner to Volume 1 Dimensional Continuous Models this monograph provides a self contained introduction to algebro geometric solutions of completely integrable nonlinear partial differential difference equations also known as soliton equations The systems studied in this volume include the Toda lattice hierarchy the Kac van Moerbeke hierarchy and the Ablowitz Ladik hierarchy An extensive treatment of the class of algebro geometric solutions in the stationary as well as time dependent contexts is provided The theory presented includes trace formulas algebro geometric initial value problems Baker Akhiezer functions and theta function representations of all relevant quantities involved The book uses basic techniques from the theory of difference equations and spectral analysis some elements of

algebraic geometry and especially the theory of compact Riemann surfaces The presentation is constructive and rigorous with ample background material provided in various appendices Detailed notes for each chapter together with an exhaustive bibliography enhance understanding of the main results

*Operator Theory in Harmonic and Non-commutative Analysis* Joseph A. Ball, Michael A. Dritschel, A.F.M. ter Elst, Pierre Portal, Denis Potapov, 2014-06-21 This book contains the proceedings of the 23rd International Workshop on Operator Theory and its Applications IWOTA 2012 which was held at the University of New South Wales Sydney Australia from 16 July to 20 July 2012 It includes twelve articles presenting both surveys of current research in operator theory and original results

*Spectral Analysis, Differential Equations and Mathematical Physics: A Festschrift in Honor of Fritz Gesztesy's 60th Birthday* Helge Holden, Barry Simon, Gerald Teschl, 2013-07-08 This volume contains twenty contributions in the area of mathematical physics where Fritz Gesztesy made profound contributions There are three survey papers in spectral theory differential equations and mathematical physics which highlight in particular

*Large Time Behavior of Solutions for General Quasilinear Hyperbolic-Parabolic Systems of Conservation Laws* Tai-Ping Liu, Yanni Zeng, 1997 We are interested in the time asymptotic behavior of solutions to viscous conservation laws Through the pointwise estimates for the Green's function of the linearized system and the analysis of coupling of nonlinear diffusion waves we obtain explicit expressions of the time asymptotic behavior of the solutions This yields optimal estimates in the integral norms For most physical models the viscosity matrix is not positive definite and the system is hyperbolic parabolic and not uniformly parabolic This implies that the Green's function may contain Dirac lowercase Greek Delta functions When the corresponding inviscid system is non strictly hyperbolic the time asymptotic state contains generalized Burgers solutions These are illustrated by applying our general theory to the compressible Navier Stokes equations and the equations of magnetohydrodynamics

Jacobi Operators and Completely Integrable Nonlinear Lattices Gerald Teschl, 2000 This volume serves as an introduction and reference source on spectral and inverse theory of Jacobi operators and applications of these theories to the Toda and Kac van Moerbeke hierarchy

**Nonlinear Evolution Equations And Dynamical Systems - Proceedings Of The 8th International Workshop (Needs '92)** Vladimir G Makhankov, O K Pashaev, I Puzynin, 1993-08-13 NEEDS 92 was held in Dubna Russia in July 1992 This set of proceedings compiles the lectures and short contributions on the soliton theory and its applications presented during the conference The topics covered included the most recent results on relevant problems of nonlinear evolution systems such as

Multidimensional Integrable Systems Geometric and Algebraic Methods Painleve Property Lie Backlund Symmetries Spectral Methods Solitons and Coherent Structures Computational Methods Quantum Field and String Theories Nonlinear Optics and Hydrodynamics Condensed Matter etc The extent of coverage for these important topics makes this book useful informative and insightful for the mathematics and theoretical physics community both the senior researchers and those just entering the field

The Finite Irreducible Linear 2-Groups of Degree 4 Dane Laurence Flannery, 1997 This memoir contains a complete

classification of the finite irreducible 2 subgroups of  $GL_4 \mathbb{C}$ . Specifically the author provides a parametrized list of representatives for the conjugacy classes of such groups where each representative is defined by generating a set of monomial matrices. The problem is treated by a variety of techniques including elementary character theory a method for describing Hasse diagrams of submodule lattices and calculation of 2 cohomology by means of the Lyndon Hochschild Serre spectral sequence. Related questions concerning isomorphism between the listed groups and Schur indices of their defining characters are also considered.

**Mathematical Physics And Stochastic Analysis: Essays In Honour Of Ludwig Streit** Sergio Albeverio, P Blanchard, L S Ferreira, Takeyuki Hida, Yuri G Kondratiev, Rui Vilela Mendes, 2000-11-24. In October 1998 a conference was held in Lisbon to celebrate Ludwig Streit's 60th birthday. This book collects some of the papers presented at the conference as well as other essays contributed by the many friends and collaborators who wanted to honor Ludwig Streit's scientific career and personality. The contributions cover many aspects of contemporary mathematical physics. Of particular importance are new results on infinite dimensional stochastic analysis and its applications to a wide range of physical domains.

List of Contributors: S Albeverio, T Hida, L Accardi, I Ya Arefeva, I V Volovich, A Daletskii, Y Kondratiev, W Karwowski, N Asai, I Kubo, H H Kuo, J Beckers, Ph Blanchard, G F Dell Antonio, D Gandolfo, M Sirugue Collin, A Bohm, H Kaldass, D Boll, G Jongen, G M Shim, J Bornales, C C Bernido, M V Carpio Bernido, G Burdet, Ph Combe, H Nencka, P Cartier, C DeWitt Morette, H Ezawa, K Nakamura, K Watanabe, Y Yamanaka, R Figari, F Gesztesy, H Holden, R Gielerak, G A Goldin, Z Haba, M O Hongler, Y Hu, B Oksendal, A Sulem, J R Klauder, C B Lang, V I Man'ko, H Ouerdiane, J Potthoff, E Smajlovic, M Rckner, E Scacciatelli, J L Silva, J Stochel, F H Szafraniec, L V zquez, D N Kozakevich, S Jimenez, V R Vieira, P D Sacramento, R Vilela Mendes, D Voln, P Samek.

**Locally Finite, Planar, Edge-Transitive Graphs** Jack E. Graver, Mark E. Watkins, 1997. The nine finite planar 3 connected edge transitive graphs have been known and studied for many centuries. The infinite locally finite planar 3 connected edge transitive graphs can be classified according to the number of their ends. The 1 ended graphs in this class were identified by Gr nbaum and Shephard. Watkins characterized the 2 ended members. Any remaining graphs in this class must have uncountably many ends. In this work infinite ended members of this class are shown to exist. A more detailed classification scheme in terms of the types of Petrie walks in the graphs in this class and the local structure of their automorphism groups is presented.

**Tilting in Abelian Categories and Quasitilted Algebras** Dieter Happel, Idun Reiten, Sverre O. Smalø, 1996. We generalize tilting with respect to a tilting module of projective dimension at most one for an Artin algebra to tilting with respect to a torsion pair in an Abelian category. Our construction is motivated by the connection between tilting and derived categories. We develop a general theory for such tilting and are led to a generalization of tilting algebras which we call quasitilted algebras. This class also contains the canonical algebras and we show that the quasitilted algebras are characterized by having global dimension at most two and each indecomposable module having projective dimension at most one or injective dimension at most one. We also give other characterizations of quasitilted algebras and

give methods for constructing such algebras

**On Finite Groups and Homotopy Theory** Ran Levi, 1995 In part 1 we study the homology homotopy and stable homotopy of capital Greek Omega italic capital B lowercase Greek Pi up arrowhead over subscript italic p where italic capital G is a finite italic p perfect group In part 2 we define the concept of resolutions by fibrations over an arbitrary family of spaces

*Higher Multiplicities and Almost Free Divisors and Complete Intersections* James Damon, 1996 Almost free divisors and complete intersections form a general class of nonisolated hypersurface and completer intersection singularities They also include discriminants of mappings bifurcation sets and certain types of arrangements of hyperplanes such as Coxeter arrangements and generic arrangements Associated to the singularities of this class is a singular Milnor fibration which has the same homotopy properties as the Milnor fibration for isolated singularities This memoir deduces topological properties of singularities in a number of situations including complements of hyperplane arrangements various nonisolated complete intersections nonlinear arrangements of hypersurfaces functions on discriminants singularities defined by compositions of functions and bifurcation sets

Reductive Subgroups of Exceptional Algebraic Groups Martin W. Liebeck, Gary M. Seitz, 1996 The theory of simple algebraic groups is important in many areas of mathematics The authors of this book investigate the subgroups of certain types of simple algebraic groups and obtain a complete description of all those subgroups which are themselves simple This description is particularly useful in understanding centralizers of subgroups and restrictions of representations

*The Operator Hilbert Space  $\mathcal{OH}$ , Complex Interpolation and Tensor Norms* Gilles Pisier, 1996 In the recently developed duality theory of operator spaces bounded operators are replaced by completely bounded ones isomorphism by complete isomorphisms and Banach spaces by operator spaces This allows for distinguishing between the various ways in which a given Banach space can be embedded isometrically into italic capital B italic capital H with H being Hilbert One of the main results is the observation that there is a central object in this class there is a unique self dual Hilbertian operator space which we denote by italic capitals OH which seems to play the same central role in the category of operator spaces that Hilbert spaces play in the category of Banach spaces

The Structure of  $k$ -CS-Transitive Cycle-Free Partial Orders Richard Warren, 1997 The class of cycle free partial orders CFPOs is defined and the CFPOs fulfilling a natural transitivity assumption called k connected set transitivity k CS transitivity are analysed in some detail Classification in many of the interesting cases is given This work generalizes Droste's classification of the countable k transitive trees k 1 In a CFPO the structure can be branch downwards as well as upwards and can do so repeatedly though it never returns to the starting point by a cycle Mostly it is assumed that k 2 and that all maximal chains are finite The main classification splits into the sporadic and skeletal cases The former is complete in all cardinalities The latter is performed only in the countable case The classification is considerably more complicated than for trees and skeletal CFPOs exhibit rich elaborate and rather surprising behaviour

**Symmetric Automorphisms of Free Products** Darryl McCullough, Andy Miller, 1996 The authors construct a complex italic capital K italic capital G on which the

automorphism group of  $G$  acts and use it to derive finiteness consequences for the group  $\Sigma$   
 $\text{Aut } G$  They prove that each component of  $K$  is contractible and describe the  
vertex stabilizers as elementary constructs involving the groups  $G_i$  and  $\text{Aut } G_i$   
subscript  $i$      **Orders of a Quartic Field** Jin Nakagawa, 1996 In this book the author studies the Dirichlet series  
whose coefficients are the number of orders of a quartic field with given indices Nakagawa gives an explicit expression of the  
Dirichlet series Using this expression its analytic properties are deduced He also presents an asymptotic formula for the  
number of orders in a quartic field with index less than a given positive number

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