

Research Article

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On the existence of bound and ground states for some coupled nonlinear Schrödinger–Korteweg–de Vries equations

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Abstract: We show the existence of positive bound and ground states for a system of coupled nonlinear Schrödinger–Korteweg–de Vries equations. More precisely, we prove that there exists a positive radially symmetric ground state if either the coupling coefficient satisfies $\beta > A$ (for an appropriate constant $A > 0$) or if $\beta > 0$ under appropriate conditions on the other parameters of the problem. We also prove that there exists a positive radially symmetric bound state if either $0 < \beta$ is sufficiently small or if $0 < \beta < A$ under some appropriate conditions on the parameters. These results give a classification of positive solutions as well as the multiplicity of positive solutions. Furthermore, we study systems with more general power nonlinearities and systems with more than two nonlinear Schrödinger–Korteweg–de Vries equations. Our variational approach (working on the full energy functional without the L^2 -mass constraint) improves many previously known results and also allows us to show new results for some range of parameters not considered in the past.

Keywords: Variational methods, ground states, bound states, critical point theory, perturbation methods

MSC 2010: 34B18, 34G20, 35J50, 35Q53, 35Q55

1 Introduction

The aim of this work is to study the system of coupled nonlinear Schrödinger–Korteweg–de Vries equations (NLS–KdV for short)

$$\begin{cases} if_t + f_{xx} + |f|^2 f + \beta fg = 0, \\ g_t + g_{xxx} + 2g g_x + \frac{1}{2}\beta(|f|^2)_x = 0, \end{cases} \quad (1.1)$$

where $f = f(x, t) \in \mathbb{C}$, while $g = g(x, t) \in \mathbb{R}$ and $\beta \in \mathbb{R}$ is the real coupling coefficient. System (1.1) appears in phenomena of interactions between short and long dispersive waves arising in fluid mechanics, such as the interactions of capillary-gravity water waves. Indeed, f represents the short wave, while g stands for the long wave; see [2, 18, 23] and the references therein for more details.

We look for solitary “traveling-wave” solutions, namely, solutions to (1.1) of the form

$$(f(x, t), g(x, t)) = (e^{i\omega t} e^{i\frac{c}{\lambda} x} u(x - ct), v(x - ct)) \quad \text{with } u, v \text{ real functions.} \quad (1.2)$$

Choosing $\lambda_1 = \omega + \frac{c^2}{\lambda}$, $\lambda_2 = c$, we get that u, v solve the problem

$$\begin{cases} -u'' + \lambda_1 u = u^3 + \beta uv, \\ -v'' + \lambda_2 v = \frac{1}{2}v^2 + \frac{1}{2}\beta u^2. \end{cases} \quad (1.3)$$

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Kortewegde Vries And Nonlinear Schrodinger Equations Qualitative Theory

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Kortewegde Vries And Nonlinear Schrodinger Equations Qualitative Theory:

Korteweg-De Vries and Nonlinear Schrodinger Equations Peter E. Zhidkov, 2014-01-15 **Korteweg-de Vries and Nonlinear Schrödinger Equations: Qualitative Theory** Peter E. Zhidkov, 2001-04-24 The emphasis of this book is on questions typical of nonlinear analysis and qualitative theory of PDEs The selection of the material is related to the author's attempt to illuminate those particularly interesting questions not yet covered in other monographs though they have been the subject of published articles One chapter for example is devoted to the construction of invariant measures for dynamical systems generated by certain equations and a result from a recent paper on basic properties of a system of eigenfunctions of a stationary problem Also considered is an application of the method of qualitative theory of ODEs to proving the existence of radial solutions of stationary problems and stability of solutions of NLSE nonvanishing as the spatial variable tends to infinity Finally a recent result on the existence of an infinite sequence of invariant measures for the integrable KdV equation is presented

Korteweg-de Vries and Nonlinear Schrödinger Equations: Qualitative Theory Peter E. Zhidkov, 2003-07-01 of nonlinear the of solitons the the last 30 theory partial theory During years has into solutions of a kind a differential special equations PDEs possessing grown and in view the attention of both mathematicians field that attracts physicists large and of the of the problems of its novelty problems Physical important applications for in the under consideration are mo to the observed example equations leading mathematical discoveries is the Makhankov One of the related V G by 60 graph from this field methods that of certain nonlinear by equations possibility studying inverse these to the problem equations were analyze quantum scattering developed this method of the inverse called solvable the scattering problem on subject are by known nonlinear At the the class of for same time currently example 89 94 see the other there is solvable this method is narrow on hand PDEs sufficiently and by of differential The latter called the another qualitative theory equations approach the of various in includes on pr investigations well posedness approach particular solutions such or lems for these the behavior of as stability blowing up equations these and this of approach dynamical systems generated by equations etc properties in wider class of a makes it to an problems maybe possible investigate essentially more general study

Nonlinear Dispersive Equations Christian Klein, Jean-Claude Saut, 2022-02-23 Nonlinear Dispersive Equations are partial differential equations that naturally arise in physical settings where dispersion dominates dissipation notably hydrodynamics nonlinear optics plasma physics and Bose Einstein condensates The topic has traditionally been approached in different ways from the perspective of modeling of physical phenomena to that of the theory of partial differential equations or as part of the theory of integrable systems This monograph offers a thorough introduction to the topic uniting the modeling PDE and integrable systems approaches for the first time in book form The presentation focuses on three universal families of physically relevant equations endowed with a completely integrable member the Benjamin-Ono Davey-Stewartson and Kadomtsev-Petviashvili equations These asymptotic models are rigorously derived and qualitative properties such as soliton resolution are studied in

detail in both integrable and non integrable models Numerical simulations are presented throughout to illustrate interesting phenomena By presenting and comparing results from different fields the book aims to stimulate scientific interactions and attract new students and researchers to the topic To facilitate this the chapters can be read largely independently of each other and the prerequisites have been limited to introductory courses in PDE theory

Handbook of Exact Solutions to Mathematical Equations Andrei D. Polyanin, 2024-08-26 This reference book describes the exact solutions of the following types of mathematical equations Algebraic and Transcendental Equations Ordinary Differential Equations Systems of Ordinary Differential Equations First Order Partial Differential Equations Linear Equations and Problems of Mathematical Physics Nonlinear Equations of Mathematical Physics Systems of Partial Differential Equations Integral Equations Difference and Functional Equations Ordinary Functional Differential Equations Partial Functional Differential Equations The book delves into equations that find practical applications in a wide array of natural and engineering sciences including the theory of heat and mass transfer wave theory hydrodynamics gas dynamics combustion theory elasticity theory general mechanics theoretical physics nonlinear optics biology chemical engineering sciences ecology and more Most of these equations are of a reasonably general form and dependent on free parameters or arbitrary functions The Handbook of Exact Solutions to Mathematical Equations generally has no analogs in world literature and contains a vast amount of new material The exact solutions given in the book being rigorous mathematical standards can be used as test problems to assess the accuracy and verify the adequacy of various numerical and approximate analytical methods for solving mathematical equations as well as to check and compare the effectiveness of exact analytical methods

Handbook of Dynamical Systems A. Katok, B. Hasselblatt, 2005-12-17 This second half of Volume 1 of this Handbook follows Volume 1A which was published in 2002 The contents of these two tightly integrated parts taken together come close to a realization of the program formulated in the introductory survey Principal Structures of Volume 1A The present volume contains surveys on subjects in four areas of dynamical systems Hyperbolic dynamics parabolic dynamics ergodic theory and infinite dimensional dynamical systems partial differential equations Written by experts in the field The coverage of ergodic theory in these two parts of Volume 1 is considerably more broad and thorough than that provided in other existing sources The final cluster of chapters discusses partial differential equations from the point of view of dynamical systems

Stationary and Time Dependent Gross-Pitaevskii Equations Wolfgang Pauli Institute. Thematic Program, Alberto Farina, Jean-Claude Saut, 2008 This volume looks at the Gross Pitaevskii equation an example of a defocusing nonlinear Schrodinger equation which is a model for phenomena such as the Bose Einstein condensation of ultra cold atomic gases the superfluidity of Helium II and the dark solitons of nonlinear optics

Nonlinear Optical and Atomic Systems Christophe Besse, Jean-Claude Garreau, 2015-08-26 Focusing on the interface between mathematics and physics this book offers an introduction to the physics the mathematics and the numerical simulation of nonlinear systems in optics and atomic physics The text covers a wide spectrum of current

research on the subject which is an extremely active field in physics and mathematical physics with a very broad range of implications both for fundamental science and technological applications light propagation in microstructured optical fibers Bose Einstein condensates disordered systems and the newly emerging field of nonlinear quantum mechanics Accessible to PhD students this book will also be of interest to post doctoral researchers and seasoned academics *Hamiltonian Partial Differential Equations and Applications* Philippe Guyenne, David Nicholls, Catherine Sulem, 2015-09-11 This book is a unique selection of work by world class experts exploring the latest developments in Hamiltonian partial differential equations and their applications Topics covered within are representative of the field's wide scope including KAM and normal form theories perturbation and variational methods integrable systems stability of nonlinear solutions as well as applications to cosmology fluid mechanics and water waves The volume contains both surveys and original research papers and gives a concise overview of the above topics with results ranging from mathematical modeling to rigorous analysis and numerical simulation It will be of particular interest to graduate students as well as researchers in mathematics and physics who wish to learn more about the powerful and elegant analytical techniques for Hamiltonian partial differential equations *Introduction to non-Kerr Law Optical Solitons* Anjan Biswas, Swapan Konar, 2006-11-10 Despite remarkable developments in the field a detailed treatment of non Kerr law media has not been published Introduction to non Kerr Law Optical Solitons is the first book devoted exclusively to optical soliton propagation in media that possesses non Kerr law nonlinearities After an introduction to the basic features of fiber optic com **Posn(R) and Eisenstein Series**, 2005 Improved Bonferroni Inequalities via Abstract Tubes Klaus Dohmen, 2003 **Inverse Problems and Imaging** Ana Carpio, Oliver Dorn, Miguel Moscoso, Frank Natterer, George C. Papanicolaou, 2008-04-17 In the CIME Summer School on Imaging experts in mathematical techniques and applications presented useful introductions to many aspects of the field This volume contains updated lectures as well as additional contributions on other related topics **Hypoelliptic Estimates and Spectral Theory for Fokker-Planck Operators and Witten Laplacians** Francis Nier, Bernard Helffer, 2005-01-17 There has recently been a renewal of interest in Fokker Planck operators motivated by problems in statistical physics in kinetic equations and differential geometry Compared to more standard problems in the spectral theory of partial differential operators those operators are not self adjoint and only hypoelliptic The aim of the analysis is to give as generally as possible an accurate qualitative and quantitative description of the exponential return to the thermodynamical equilibrium While exploring and improving recent results in this direction this volume proposes a review of known techniques on the hypoellipticity of polynomial of vector fields and its global counterpart the global Weyl H rmander pseudo differential calculus the spectral theory of non self adjoint operators the semi classical analysis of Schr dinger type operators the Witten complexes and the Morse inequalities **Harmonic Analysis and Nonlinear Partial Differential Equations** Tohru Ozawa, Mitsuru Sugimoto, 2010 **Tutorials in Mathematical Biosciences II** James Sneyd, 2005-06-13 This book presents

a series of models in the general area of cell physiology and signal transduction with particular attention being paid to intracellular calcium dynamics and the role played by calcium in a variety of cell types Calcium plays a crucial role in cell physiology and the study of its dynamics lends insight into many different cellular processes In particular calcium plays a central role in muscular contraction olfactory transduction and synaptic communication three of the topics to be addressed in detail in this book In addition to the models much of the underlying physiology is presented so that readers may learn both the mathematics and the physiology and see how the models are applied to specific biological questions It is intended primarily as a graduate text or a research reference It will serve as a concise and up to date introduction to all those who wish to learn about the state of calcium dynamics modeling and how such models are applied to physiological questions

Library of Congress Subject Headings Library of Congress,2011 **Library of Congress Subject Headings** Library of Congress. Cataloging Policy and Support Office,2007 Handbook of Dynamical Systems B. Fiedler,2002-02-21 This handbook is volume II in a series collecting mathematical state of the art surveys in the field of dynamical systems Much of this field has developed from interactions with other areas of science and this volume shows how concepts of dynamical systems further the understanding of mathematical issues that arise in applications Although modeling issues are addressed the central theme is the mathematically rigorous investigation of the resulting differential equations and their dynamic behavior However the authors and editors have made an effort to ensure readability on a non technical level for mathematicians from other fields and for other scientists and engineers The eighteen surveys collected here do not aspire to encyclopedic completeness but present selected paradigms The surveys are grouped into those emphasizing finite dimensional methods numerics topological methods and partial differential equations Application areas include the dynamics of neural networks fluid flows nonlinear optics and many others While the survey articles can be read independently they deeply share recurrent themes from dynamical systems Attractors bifurcations center manifolds dimension reduction ergodicity homoclinicity hyperbolicity invariant and inertial manifolds normal forms recurrence shift dynamics stability to name just a few are ubiquitous dynamical concepts throughout the articles *Advances in Differential Equations* ,2004

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