

## Renormalization and transition to chaos in area preserving nontwist maps

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### Abstract

The problem of transition to chaos, i.e. the destruction of invariant circles or KAM (Kolmogorov–Arnold–Moser) curves, in area preserving *nontwist* maps is studied within the renormalization group framework. Nontwist maps are maps for which the twist condition is violated along a curve known as the shearless curve. In renormalization language this problem is that of finding and studying the fixed points of the renormalization group operator  $\mathcal{R}$  that acts on the space of maps. A simple period-two fixed point of  $\mathcal{R}$ , whose basin of attraction contains the nontwist maps for which the shearless curve exists, is found. Also, a critical period-12 fixed point of  $\mathcal{R}$ , with two unstable eigenvalues, is found. The basin of attraction of this critical fixed point contains the nontwist maps for which the shearless curve is at the threshold of destruction. This basin defines a new universality class for the transition to chaos in area preserving maps.

### 1. Introduction

A fundamental problem of Hamiltonian dynamics is to understand the behavior of an integrable Hamiltonian system when subject to perturbation. In terms of the action–angle variables  $(J, \theta)$  of the integrable system, the Hamiltonian for the perturbed system in the case of one degree-of-freedom can be written as

$$H = H_0(J) + H_1(J, \theta, t), \quad (1)$$

where  $H_0$  is the Hamiltonian of the integrable system and the perturbation is represented by  $H_1$ . Since the pioneering work of Poincaré, it has been known that the dynamics for Hamiltonians of this form is far from trivial. Typically, the phase space consists of a complicated mixture of integrable (confined to invariant tori) and nonintegrable (chaotic) trajectories. Thus, the problem of the transition to chaos is to determine which trajectories of  $H_0$  remain integrable and which become chaotic under the effect of  $H_1$ .

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# Renormalization In Areapreserving Maps

**Alexander V. Getling**



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**Renormalisation In Area-preserving Maps** Robert S Mackay,1993-08-31 This book is adapted and revised from the author s seminal PhD thesis in which two forms of asymptotically universal structure were presented and explained for area preserving maps Area preserving maps are the discrete time analogue of two degree of freedom Hamiltonian systems How they work and much of their dynamics are described in this book The asymptotically universal structure is found on small scales in phase space and long time scales The key to understanding it is renormalisation that is looking at a system on successively smaller phase space and longer time scales Having presented this idea the author briefly surveys the use of the idea of renormalisation in physics The renormalisation picture is then presented as the key to understanding the transition from regular to chaotic motion in area preserving maps Although written ten years ago the subject matter continues to interest many today This updated version will be useful to both researchers and students **Renormalisation in**

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*Holomorphic Dynamics and Renormalization* Mikhail Lyubich,Michael Yampolsky,2008 Collects papers that reflect some of the directions of research in two closely related fields Complex Dynamics and Renormalization in Dynamical Systems This title contains papers that introduces the reader to this fascinating world and a related area of transcendental dynamics It also includes open problems and computer simulations *Directions In Chaos - Volume 2* Bailin Hao,1988-04-01 Volume 2

of *Directions in Chaos* consists of the contributions made to the Beijing Summer School on Chaotic Phenomena in Nonlinear Systems held in August 1987 **Positive Transfer Operators and Decay of Correlations** Viviane Baladi,2000 Although individual orbits of chaotic dynamical systems are by definition unpredictable the average behavior of typical trajectories can often be given a precise statistical description Indeed there often exist ergodic invariant measures with special additional features For a given invariant measure and a class of observables the correlation functions tell whether and how fast the system mixes i e forgets its initial conditions This book addressed to mathematicians and mathematical or mathematically inclined physicists shows how the powerful technology of transfer operators imported from statistical physics has been used

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**Microscopic Chaos, Fractals and Transport in Nonequilibrium Statistical Mechanics** Rainer Klages, 2007 A valuable introduction for newcomers as well as an important reference and source of inspiration for established researchers this book provides an up to date summary of central topics in the field of nonequilibrium statistical mechanics and dynamical systems theory Understanding macroscopic properties of matter starting from microscopic chaos in the equations of motion of single atoms or molecules is a key problem in nonequilibrium statistical mechanics Of particular interest both for theory and applications are transport processes such as diffusion reaction conduction and viscosity Recent advances towards a deterministic theory of nonequilibrium statistical physics are summarized Both Hamiltonian dynamical systems under nonequilibrium boundary conditions and non Hamiltonian modelings of nonequilibrium steady states by using thermal reservoirs are considered The surprising new results include transport coefficients that are fractal functions of control parameters fundamental relations between transport coefficients and chaos quantities and an understanding of nonequilibrium entropy production in terms of fractal measures and attractors The theory is particularly useful for the description of many particle systems with properties in between conventional thermodynamics and nonlinear science as they are frequently encountered on nanoscales

**Rayleigh-Bénard Convection** Alexander V. Getling, 1998 This invaluable book presents a concise but systematic account of the formation of spatial flow structures in a horizontal fluid layer heated from below Flows of this type known as Rayleigh Bénard convection show important features of behaviour inherent not only in various hydrodynamic instability phenomena but also in nonlinear pattern forming processes in other contexts The book describes the basic methods of investigating convection patterns and the types of two and three dimensional flows pattern defects and sequences of convection regime changes The author pays special attention to the question of how various factors mainly reducible to initial and boundary conditions determine the shapes and sizes of the structures which develop In this way the role of order and disorder in flow patterns as a factor strongly affecting the character of the evolution of structures is revealed The presentation emphasizes the physical picture of these phenomena without excessive mathematical detail

*Topics In Nonlinear Time Series Analysis, With Implications For Eeg Analysis* Andreas Galka, 2000-02-18 This book provides a thorough review of a class of powerful algorithms for the numerical analysis of complex time series data which were obtained from dynamical systems These algorithms are based on the concept of state space representations of the underlying dynamics as introduced by nonlinear dynamics In particular current algorithms for state space reconstruction

correlation dimension estimation testing for determinism and surrogate data testing are presented algorithms which have been playing a central role in the investigation of deterministic chaos and related phenomena since 1980 Special emphasis is given to the much disputed issue whether these algorithms can be successfully employed for the analysis of the human electroencephalogram

Time Reversibility, Computer Simulation, and Chaos William Graham Hoover, 1999 A small army of physicists chemists mathematicians and engineers has joined forces to attack a classic problem the reversibility paradox with modern tools This book describes their work from the perspective of computer simulation emphasizing the author's approach to the problem of understanding the compatibility and even inevitability of the irreversible second law of thermodynamics with an underlying time reversible mechanics Computer simulation has made it possible to probe reversibility from a variety of directions and chaos theory or nonlinear dynamics has supplied a useful vocabulary and set of concepts which allow a fuller explanation of irreversibility than that available to Boltzmann or to Green and Kubo and Onsager Clear illustration of concepts is emphasized throughout and reinforced with a glossary of technical terms from the specialized fields which have been combined here to focus on a common theme The book begins with a discussion contrasting the idealized reversibility of basic physics and the pragmatic irreversibility of real life Computer models and simulation are next discussed and illustrated Simulations provide the means to assimilate concepts through worked out examples State of the art analyses from the point of view of dynamical systems are applied to many body examples from nonequilibrium molecular dynamics and to chaotic irreversible flows from finite difference finite element and particle based continuum simulations Two necessary concepts from dynamical systems theory fractals and Lyapunov instability are fundamental to the approach Undergraduate level physics calculus and ordinary differential equations are sufficient background for a full appreciation of this book which is intended for advanced undergraduates graduates and research workers The generous assortment of examples worked out in the text will stimulate readers to explore the rich and fruitful field of study which links fundamental reversible laws of physics to the irreversibility surrounding us all

Smooth Particle Applied Mechanics: The State Of The Art William Graham Hoover, 2006-11-02 This book takes readers through all the steps necessary for solving hard problems in continuum mechanics with smooth particle methods Pedagogical problems clarify the generation of initial conditions the treatment of boundary conditions the integration of the equations of motion and the analysis of the results Particular attention is paid to the parallel computing necessary for large problems and to the graphic displays including debugging software required for the efficient completion of computational projects The book is self contained with summaries of classical particle mechanics and continuum mechanics for both fluids and solids computer languages the stability of numerical methods Lyapunov spectra and message passing parallel computing The main difficulties faced by meshless particle methods are discussed and the means of overcoming them are illustrated with worked examples

The Mathematical Theory of Permanent Progressive Water-waves Hisashi Okamoto, Mayumi Shoji, 2001 This book is a self contained introduction to the theory of periodic

progressive permanent waves on the surface of incompressible inviscid fluid The problem of permanent water waves has attracted a large number of physicists and mathematicians since Stokes pioneering papers appeared in 1847 and 1880 Among many aspects of the problem the authors focus on periodic progressive waves which mean waves traveling at a constant speed with no change of shape As a consequence everything about standing waves are excluded and solitary waves are studied only partly However even for this restricted problem quite a number of papers and books in physics and mathematics have appeared and more will continue to appear showing the richness of the subject In fact there remain many open questions to be answered The present book consists of two parts numerical experiments and normal form analysis of the bifurcation equations Prerequisite for reading it is an elementary knowledge of the Euler equations for incompressible inviscid fluid and of bifurcation theory Readers are also expected to know functional analysis at an elementary level Numerical experiments are reported so that any reader can re examine the results with minimal labor the methods used in this book are well known and are described as clearly as possible Thus the reader with an elementary knowledge of numerical computation will have little difficulty in the re examination

*Methods In Equivariant Bifurcations And Dynamical Systems* Pascal Chossat,Reiner Lauterbach,2000-02-28 This invaluable book presents a comprehensive introduction to bifurcation theory in the presence of symmetry an applied mathematical topic which has developed considerably over the past twenty years and has been very successful in analysing and predicting pattern formation and other critical phenomena in most areas of science where nonlinear models are involved like fluid flow instabilities chemical waves elasticity and population dynamics The book has two aims One is to expound the mathematical methods of equivariant bifurcation theory Beyond the classical bifurcation tools such as center manifold and normal form reductions the presence of symmetry requires the introduction of the algebraic and geometric formalism of Lie group theory and transformation group methods For the first time all these methods in equivariant bifurcations are presented in a coherent and self consistent way in a book The other aim is to present the most recent ideas and results in this theory in relation to applications This includes bifurcations of relative equilibria and relative periodic orbits for compact and noncompact group actions heteroclinic cycles and forced symmetry breaking perturbations Although not all recent contributions could be included and a choice had to be made a rather complete description of these new developments is provided At the end of every chapter exercises are offered to the reader

Energy Localisation And Transfer Thierry Dauxois,Anna Litvak-hinenzon,Anna Spanoudaki,Robert S Mackay,2004-02-09 This book provides an introduction to localised excitations in spatially discrete systems from the experimental numerical and mathematical points of view Also known as discrete breathers nonlinear lattice excitations and intrinsic localised modes these are spatially localised time periodic motions in networks of dynamical units Examples of such networks are molecular crystals biomolecules and arrays of Josephson superconducting junctions The book also addresses the formation of discrete breathers and their potential role in energy transfer in such systems

**Directions in Chaos**

Bai-lin Hao,1987 This volume the first of a two volume book consists of a collection of comprehensive reviews and lectures written by active researchers on topics in chaotic phenomena      *Discrete Dynamics and Difference Equations* Saber N. Elaydi, Henrique Oliveira, Jose Manuel Ferreira,2010 This volume holds a collection of articles based on the talks presented at ICDEA 2007 in Lisbon Portugal The volume encompasses current topics on stability and bifurcation chaos mathematical biology iteration theory nonautonomous systems and stochastic dynamical systems      *From Order to Chaos* Leo P. Kadanoff,1993 World Scientific has made available a collection of Leo s reviews essays columns and commentaries which is a feast in several senses the strategy and tactics of science the science itself the history of several important developments in science and as a bonus a beautifully illustrated collection of essays on computational science The average reader may find this the final section of the book most interesting but for me the account of his discovery of scaling for which inexplicably he did not receive the Nobel prize is most intriguing Leo s combination of verve frankness and insight makes this a very good read P W Anderson Princeton Univ Publication of this volume will be very useful especially for young readers The papers disseminated over many journals acquire a new quality by being collected together Readers not only can see a result in its final form but also can trace its evolution J Fluid Mechanics 1994 The book is an invaluable source of information and inspiration on a variety of important problems in modern physics EMS 1999      **Chaos, Order, and Patterns** Roberto Artuso, P. Cvitanovic, Giulio Casati, 2012-12-06 Proceedings of a NATO ASI held in Lake Como Italy June 25 July 6 1990  
*Chaotic Dynamics of Nonlinear Systems* S. Neil Rasband, 2015-08-19 Introduction to the concepts applications theory and technique of chaos Suitable for advanced undergraduates and graduate students and researchers Requires familiarity with differential equations and linear vector spaces 1990 edition

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## **Table of Contents Renormalization In Areapreserving Maps**

1. Understanding the eBook Renormalization In Areapreserving Maps
  - The Rise of Digital Reading Renormalization In Areapreserving Maps
  - Advantages of eBooks Over Traditional Books
2. Identifying Renormalization In Areapreserving Maps
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Renormalization In Areapreserving Maps
  - User-Friendly Interface



4. Exploring eBook Recommendations from Renormalization In Areapreserving Maps
  - Personalized Recommendations
  - Renormalization In Areapreserving Maps User Reviews and Ratings
  - Renormalization In Areapreserving Maps and Bestseller Lists
5. Accessing Renormalization In Areapreserving Maps Free and Paid eBooks
  - Renormalization In Areapreserving Maps Public Domain eBooks
  - Renormalization In Areapreserving Maps eBook Subscription Services
  - Renormalization In Areapreserving Maps Budget-Friendly Options
6. Navigating Renormalization In Areapreserving Maps eBook Formats
  - ePub, PDF, MOBI, and More
  - Renormalization In Areapreserving Maps Compatibility with Devices
  - Renormalization In Areapreserving Maps Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Renormalization In Areapreserving Maps
  - Highlighting and Note-Taking Renormalization In Areapreserving Maps
  - Interactive Elements Renormalization In Areapreserving Maps
8. Staying Engaged with Renormalization In Areapreserving Maps
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Renormalization In Areapreserving Maps
9. Balancing eBooks and Physical Books Renormalization In Areapreserving Maps
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Renormalization In Areapreserving Maps
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Renormalization In Areapreserving Maps
  - Setting Reading Goals Renormalization In Areapreserving Maps
  - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Renormalization In Areapreserving Maps
  - Fact-Checking eBook Content of Renormalization In Areapreserving Maps
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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