

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, θ) 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

Lauren Gardner



Renormalization In Areapreserving Maps:

Renormalisation in Area-preserving Maps R. S. MacKay, 1993 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 Area Preserving Maps* Robert Sinclair Mackay, 1986 [Holomorphic Dynamics and Renormalization](#) Mikhail Lyubich, Michael Yampolsky, Schwarzian derivatives and cylinder maps by A Bonifant and J Milnor Holomorphic dynamics Symbolic dynamics and self similar groups by V Nekrashevych Are there critical points on the boundaries of mother hedgehogs by D K Childers Finiteness for degenerate polynomials by L DeMarco Cantor webs in the parameter and dynamical planes of rational maps by R L Devaney Simple proofs of uniformization theorems by A A Glutsyuk The Yoccoz combinatorial analytic invariant by C L Petersen and P Roesch Bifurcation loci of exponential maps and quadratic polynomials Local connectivity triviality of fibers and density of hyperbolicity by L Rempe and D Schleicher Rational and transcendental Newton maps by J Ruckert Newton's method as a dynamical system Efficient root finding of polynomials and the Riemann zeta function by D Schleicher The external boundary of M_2 by V Timorin Renormalization Renormalization of vector fields by H Koch Renormalization of arbitrary weak noises for one dimensional critical dynamical systems Summary of results and numerical explorations by O Diaz Espinosa and R de la Llave KAM for the nonlinear Schrodinger equation A short presentation by H L Eliasson and S B Kuksin Siegel disks and renormalization fixed points by M Yampolsky **Renormalization Group Applications in Area-preserving Nontwist Maps and Relativistic Quantum Field Theory** Alexander Wurm, 2002 [Directions In Chaos - Volume 1](#) Bailin Hao, 1987-12-01 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 **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 **The Transition to Chaos** Linda Reichl, 2021-04-12 Based on courses given at the universities of Texas and California this book treats an active field of research that touches upon the foundations of physics and chemistry It presents in as simple a manner as possible the basic mechanisms that determine the dynamical evolution of both

classical and quantum systems in sufficient generality to include quantum phenomena The book begins with a discussion of Noether's theorem integrability KAM theory and a definition of chaotic behavior continues with a detailed discussion of area preserving maps integrable quantum systems spectral properties path integrals and periodically driven systems and concludes by showing how to apply the ideas to stochastic systems The presentation is complete and self contained appendices provide much of the needed mathematical background and there are extensive references to the current literature while problems at the ends of chapters help students clarify their understanding This new edition has an updated presentation throughout and a new chapter on open quantum systems

Nonlinearity, 2009-10 **Discrete and Continuous Dynamical Systems**, 2005 *Physical Review*, 2000-02 Publishes papers that report results of research in statistical physics plasmas fluids and related interdisciplinary topics There are sections on 1 methods of statistical physics 2 classical fluids 3 liquid crystals 4 diffusion limited aggregation and dendritic growth 5 biological physics 6 plasma physics 7 physics of beams 8 classical physics including nonlinear media and 9 computational physics *Statistical Physics and Chaos in Fusion Plasmas* C. W. Horton, Jr., Linda E. Reichl, 1984-04-24 Papers from twenty nine of the world's leading scientists investigate the statistical properties of nonlinear dynamical systems emphasizing their relation to the problem of plasma confinement A powerful new diagrammatic perturbation theory is presented for a first principles calculation of the Clump Kinetic equation and for the first time detailed calculations and experimental considerations describe the practical consequences of these correlations Unique to this book is the collection of works on the problem of long lived correlations in phase space of the Vlasov Poisson system A new method of computing Lyapunov exponents from experimental data and a method for calculating the splitting of periodic orbits in conservative systems are developed *Chaos and Integrability in Nonlinear Dynamics* Michael Tabor, 1989-01-18 Presents the newer field of chaos in nonlinear dynamics as a natural extension of classical mechanics as treated by differential equations Employs Hamiltonian systems as the link between classical and nonlinear dynamics emphasizing the concept of integrability Also discusses nonintegrable dynamics the fundamental KAM theorem integrable partial differential equations and soliton dynamics Deterministic Chaos Heinz Georg Schuster, 1988 Journal of the Korean Mathematical Society, 1992 *Dynamical Systems and Ergodic Theory* Karol Krzyżewski, 1989 **Chaotic Phenomena in Astrophysics** J. Robert Buchler, Heinrich Karl Eichhorn, 1987 Hamiltonian Systems and Fourier Analysis Daniel Benest, Claude Froeschlé, Elena Lega, 2005 **Statistical Plasma Physics**, 1986 The Dynamics of Numerics and the Numerics of Dynamics David S. Broomhead, A. Iserles, 1992 This collection of conference papers presents the applications of dynamical systems in numerical analysis and of numerical problems and techniques in dynamical systems **Smooth Particle Applied Mechanics** William Graham Hoover, 2006 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

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