

# Long time dynamics and blow-up for the focusing inhomogeneous nonlinear Schrödinger equation with spatially growing nonlinearity

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## ABSTRACT

We investigate the Cauchy problem for the focusing inhomogeneous nonlinear Schrödinger equation  $i\partial_t u + \Delta u = -|x|^b |u|^{p-1} u$  in the radial Sobolev space  $H^1_b(\mathbb{R}^N)$ , where  $b > 0$  and  $p > 1$ . We show the global existence and energy scattering in the intercritical regime, i.e.,  $p > \frac{N+1+2b}{N-2}$  and  $p < \frac{N+1+2b}{N-2}$  if  $N \geq 3$ . We also obtain blowing-up solutions for the mass-critical and mass-supercritical nonlinearities. The main difficulty, coming from the spatial growing nonlinearity, is overcome by refined Gagliardo–Nirenberg-type inequalities. Our proofs are based on improved Gagliardo–Nirenberg inequalities, the Morawetz–Sobolev approach of Dodson and Murphy [Proc. Am. Math. Soc. **145**(11), 4859–4867 (2017)], radial Sobolev embeddings, and localized virial estimates.

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## 1. INTRODUCTION

In this paper, we consider the Cauchy problem for the following focusing inhomogeneous nonlinear Schrödinger equation:

$$i\partial_t u + \Delta u = -|x|^b |u|^{p-1} u, \quad (t, x) \in \mathbb{R}_+ \times \mathbb{R}^N, \quad (1.1)$$

where  $b > 0$  and  $p > 1$ . Equation (1.1) is a special case of a more general inhomogeneous nonlinear Schrödinger equation given by

$$i\partial_t u + \Delta u = K(x) |u|^{p-1} u, \quad (1.2)$$

which arises in various physical contexts such as the propagation of a laser beam and plasma waves. Here,  $u$  is the electric field in laser optics and  $K$  is proportional to the electric density.<sup>1,2</sup> For  $p = 3$ , Eq. (1.1) can be viewed as a model of dilute Bose–Einstein condensate when the two-body interactions of the condensate are considered.

The Cauchy problem for (1.2) was first investigated by Merle<sup>3</sup> who proves the existence of blow-up solutions in the mass-critical regime and under some assumptions on  $K$  including in particular  $k_1 \leq K(x) \leq k_2$  with  $k_1, k_2$  being positive constants. Later on, the stability of standing waves was studied in Refs. 7 and 8 for  $K(x) = K(|x|)$  with  $K \in C^2(\mathbb{R}^N) \cap L^\infty(\mathbb{R}^N)$ ,  $\epsilon > 0$  small, and  $p \geq 1 + \frac{2}{N}$ . Recently, the Cauchy problem

# Long Time Prediction In Dynamics

**S. Böhme, U. Esser, W. Fricke, U.  
Güntzel-Lingner, I. Heinrich, F. Henn, D.  
Krahn, L. D. Schmadel, H. Scholl, G.  
Zech**

## **Long Time Prediction In Dynamics:**

*Long-Time Predictions in Dynamics* V.G. Szebehely, B.D. Tapley, 2012-12-06 Proceedings of the NATO Advanced Study Institute Cortina D Ampezzo Italy August 3 16 1975      **Vibro-impact Dynamics** Albert C. J. Luo, Yu Guo, 2013-01-25

Presents a systematic view of vibro impact dynamics based on the nonlinear dynamics analysis Comprehensive understanding of any vibro impact system is critically impeded by the lack of analytical tools viable for properly characterizing grazing bifurcation The authors establish vibro impact dynamics as a subset of the theory of discontinuous systems thus enabling all vibro impact systems to be explored and characterized for applications Vibro impact Dynamics presents an original theoretical way of analyzing the behavior of vibro impact dynamics that can be extended to discontinuous dynamics All topics are logically integrated to allow for vibro impact dynamics the central theme to be presented It provides a unified treatment on the topic with a sound theoretical base that is applicable to both continuous and discrete systems Vibro impact Dynamics Presents mapping dynamics to determine bifurcation and chaos in vibro impact systems Offers two simple vibro impact systems with comprehensive physical interpretation of complex motions Uses the theory for discontinuous dynamical systems on time varying domains to investigate the Fermi oscillator Essential reading for graduate students university professors researchers and scientists in mechanical engineering      *Nonlinear Dynamics of the Lithosphere and Earthquake Prediction* Vladimir Keilis-Borok, Alexandre A. Soloviev, 2013-03-14 The vulnerability of our civilization to earthquakes is rapidly growing raising earthquakes to the ranks of major threats faced by humankind Earthquake prediction is necessary to reduce that threat by undertaking disaster preparedness measures This is one of the critically urgent problems whose solution requires fundamental research At the same time prediction is a major tool of basic science a source of heuristic constraints and the final test of theories This volume summarizes the state of the art in earthquake prediction Its following aspects are considered Existing prediction algorithms and the quality of predictions they provide Application of such predictions for damage reduction given their current accuracy so far limited Fundamental understanding of the lithosphere gained in earthquake prediction research Emerging possibilities for major improvements of earthquake prediction methods Potential implications for predicting other disasters besides earthquakes Methodologies At the heart of the research described here is the integration of three methodologies phenomenological analysis of observations universal models of complex systems such as those considered in statistical physics and nonlinear dynamics and Earth specific models of tectonic fault networks In addition the theory of optimal control is used to link earthquake prediction with earthquake preparedness      **Regular and Chaotic Motions in Dynamic Systems** A. S. Wightman, 2013-06-29 The fifth International School Mathematical Physics was held at the Ettore Majorana Centro della Cultura Scientifica Erice Sicily 2 to 14 July 1983 The present volume collects lecture notes on the session which was devoted to Regular and Chaotic Motions in Dynamical Systems The School was a NATO Advanced Study Institute sponsored by the Italian Ministry of Public Education

the Italian Ministry of Scientific and Technological Research and the Regional Sicilian Government Many of the fundamental problems of this subject go back to Poincare and have been recognized in recent years as being of basic importance in a variety of physical contexts stability of orbits in accelerators and in plasma and galactic dynamics occurrence of chaotic motions in the excitations of solids etc This period of intense interest on the part of physicists followed nearly a half a century of neglect in which research in the subject was almost entirely carried out by mathematicians It is an indication of the difficulty of some of the problems involved that even after a century we do not have anything like a satisfactory solution

**Navier-Stokes Predictions of Dynamic Stability Derivatives** James DeSpirito, Sidra I. Sifton, Paul Weinacht, 2008 The prediction of the dynamic stability derivatives roll damping Magnus and pitch damping moments were evaluated for three spin stabilized projectiles using steady state computational fluid dynamic CFD calculations Roll damping CFD predictions were found to be very good across the Mach number range investigated Magnus moment predictions were very good in the supersonic flight regime however the accuracy varied in the subsonic and transonic flight regime The best Magnus moment prediction in the subsonic flight regime was for the square base projectile that did not exhibit highly nonlinear Magnus moments A primary contribution of this report is the demonstration that the pitch damping moment can be adequately predicted via steady state methods rather than resorting to unsteady techniques The predicted pitch damping moment compared very well to experimental data for the three projectiles investigated For one configuration the pitch damping moment was predicted by several CFD codes two different steady state methods and a time accurate planar pitching motion method All methods compared very well to each other and to the experimental data *Literature 1976, Part 1* S. Böhme, U. Esser, W. Fricke, U. Güntzel-Lingner, I. Heinrich, F. Henn, D. Krahn, L. D. Schmadel, H. Scholl, G. Zech, 2013-11-11 Astronomy and Astrophysics Abstracts which has appeared in semi annual volumes since 1969 is devoted to the recording summarizing and indexing of astronomical publications throughout the world It is prepared under the auspices of the International Astronomical Union according to a resolution adopted at the 14th General Assembly in 1970 Astronomy and Astrophysics Abstracts aims to present a comprehensive documentation of literature in all fields of astronomy and astrophysics Every effort will be made to ensure that the average time interval between the date of receipt of the original literature and publication of the abstracts will not exceed eight months This time interval is near to that achieved by monthly abstracting journals compared to which our system of accumulating abstracts for about six months offers the advantage of greater convenience for the user Volume 17 contains literature published in 1976 and received before August 15 1976 some older literature which was received late and which is not recorded in earlier volumes is also included We acknowledge with thanks contributions to this volume by Dr J Bouska who surveyed journals and publications in the Czech language and supplied us with abstracts in English and by the Commonwealth Scientific and Industrial Research Organization CSIRO Sydney for providing titles and abstracts of papers on radio astronomy We want to acknowledge valuable contributions to this volume

by Zentralstelle für Atomkernenergie Dokumentation Leopoldshafen which supported our abstracting service by sending us retrospective literature searches

*The Basis of Atmospheric Mesoscale Dynamics and a Dynamical Method of Predicting Rainstorms* Shouting Gao, Lingkun Ran, Xiaofan Li, 2021-07-28 This book serves to deepen the theoretical understanding of mesoscale dynamics and makes its basic concepts clear reflecting new research results It emphasizes important theories that have not been given enough attention in recent years such as generalized potential temperature and the moist potential vorticity theory of non uniform saturated moist atmospheres By integrating theory with practice the book also introduces the forecast method of rainstorms and other disastrous weathers using dynamic factors This book can be used as a point of reference for operational forecasters researchers and graduate and undergraduate students whose research interests are atmospheric sciences and ocean and water sciences It will also be of interest to scholars who study geological disasters such as multiphase flow mountains debris flows and landslides as well as geological seismologists

**Applied Symbolic Dynamics And Chaos (Second Edition)** Hao Bailin, Zheng Wei-mou, 2018-05-11 Symbolic dynamics is a coarse grained description of dynamics It has been a long studied chapter of the mathematical theory of dynamical systems but its abstract formulation has kept many practitioners of physical sciences and engineering from appreciating its simplicity beauty and power At the same time symbolic dynamics provides almost the only rigorous way to understand global systematics of periodic and especially chaotic motion in dynamical systems In a sense everyone who enters the field of chaotic dynamics should begin with the study of symbolic dynamics However this has not been an easy task for non mathematicians On one hand the method of symbolic dynamics has been developed to such an extent that it may well become a practical tool in studying chaotic dynamics both on computers and in laboratories On the other hand most of the existing literature on symbolic dynamics is mathematics oriented This book is an attempt at partially filling up this apparent gap by emphasizing the applied aspects of symbolic dynamics without mathematical rigor

Contents Preface to the Second Edition Preface to the First Edition Introduction Symbolic Dynamics of Unimodal Maps Maps with Multiple Critical Points Symbolic Dynamics of Circle Maps Symbolic Dynamics of Two Dimensional Maps Application to Ordinary Differential Equations Counting the Number of Periodic Orbits Symbolic Dynamics and Grammatical Complexity Symbolic Dynamics and Knot Theory Appendix References Index Readership Researchers and students interested in chaotic dynamics Keywords Symbolic Dynamics Chaos Review Key Features No previous knowledge of dynamical systems theory is required in order to read this book The revisions concern mainly the application to ordinary differential equations via constructing two dimensional symbolic dynamics of the corresponding Poincare maps

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hydrology geophysics and seismology indicated the need for the first symposium on Variational Methods in Geosciences to be organized and held in Norman on October 15 17 1985 The value of this symposium was enhanced by the number of stimulating and informative papers presented *Applied Symbolic Dynamics and Chaos* Bai-lin Hao, Wei-Mou Zheng, 1998 Symbolic dynamics is a coarse grained description of dynamics It provides a rigorous way to understand the global systematics of periodic and chaotic motion in a system In the last decade it has been applied to nonlinear systems described by one and two dimensional maps as well as by ordinary differential equations This book will help practitioners in nonlinear science and engineering to master that powerful tool *Understanding and Predicting the Gulf of Mexico Ocean Dynamics* Julio Sheinbaum, Eric Chassignet, Steven L. Morey, Ruoying He, 2024-04-08 For the past several years a number of research programs have funded significant efforts to advance understanding of and forecasting capabilities for the Gulf of Mexico circulation including the Loop Current its associated eddies and abyssal dynamics One such program is the National Academies Understanding Gulf Ocean Systems initiative which focuses on improving forecasts of the physical dynamics of the open Gulf of Mexico in space and time scales useful for the reduction of risks to offshore energy exploration and production as well as for other challenges such as forecasting hurricane intensification and managing fisheries What has been learned how can this scientific progress be incorporated into operational models and what are the remaining gaps in knowledge impeding predictive skill **Physics and Chance** Lawrence Sklar, 1993 Lawrence Sklar offers a comprehensive non technical introduction to statistical mechanics and attempts to understand its foundational elements **Meteorological Fluid Dynamics** Radyadour K. Zeytounian, 2008-10-09 The author considers meteorology as a part of fluid dynamics He tries to derive the properties of atmospheric flows from a rational analysis of the Navier Stokes equations at the same time analyzing various types of initial and boundary problems This approach to simulate nature by models from fluid dynamics will be of interest to both scientists and students of physics and theoretical meteorology **Forecast Error Correction using Dynamic Data Assimilation** Sivaramakrishnan Lakshmivarahan, John M. Lewis, Rafal Jabrzemski, 2016-10-21 This book introduces the reader to a new method of data assimilation with deterministic constraints exact satisfaction of dynamic constraints an optimal assimilation strategy called Forecast Sensitivity Method FSM as an alternative to the well known four dimensional variational 4D Var data assimilation method 4D Var works with a forward in time prediction model and a backward in time tangent linear model TLM The equivalence of data assimilation via 4D Var and FSM is proven and problems using low order dynamics clarify the process of data assimilation by the two methods The problem of return flow over the Gulf of Mexico that includes upper air observations and realistic dynamical constraints gives the reader a good idea of how the FSM can be implemented in a real world situation *The Dynamics of Vehicles on Roads and Tracks* Martin Rosenberger, Manfred Plöchl, Klaus Six, Johannes Edelmann, 2016-03-30 The IAVSD Symposium is the leading international conference in the field of ground vehicle dynamics bringing together scientists and engineers from academia and industry

The biennial IAVSD symposia have been held in internationally renowned locations In 2015 the 24th Symposium of the International Association for Vehicle System Dynamics IAVSD **Numerical Computations: Theory and Algorithms** Yaroslav D. Sergeyev, Dmitri E. Kvasov, Annabella Astorino, 2024-12-31 The three volume set LNCS 14476 14478 constitutes the post conference proceedings of the 4th International Conference on Numerical Computations Theory and Algorithms NUMTA 2023 held in Pizzo Calabro Italy during June 14 20 2023 The 45 full papers presented in this book together with 60 short papers were carefully reviewed and selected from 170 submissions The papers focus on topics such as continuous and discrete single and multi objective problems local global and large scale optimization classification in machine learning optimal control and applications computational and applied mathematics such as approximation theory computational geometry computational fluid dynamics dynamical systems and differential equations numerical algebra etc and applications in engineering and science numerical models methods and software using traditional and emerging high performance computational tools and paradigms including the infinity and quantum computing and their application in artificial intelligence and data science bioinformatics economics and management engineering and technology mathematical education number theory and foundations of mathematics etc **Forest Dynamics** Henk Koop, 2012-12-06 No matter what forests are used for forest managers have to deal with interactions between individual trees and between trees and other forest organisms To understand these interactions long term monitoring of spontaneous forest development is necessary A complete monitoring system has been developed including a computer package for analysis of long term observation of forest dynamics The system's name SILVI STAR is an acronym of SILVIgenesis and Single tree Three dimensional Architecture A method of nested plot data collection on forest architecture and plant species composition has been developed out for monitoring purposes **Impact of Advances in Computing and Communications Technologies on Chemical Science and Technology** National Research Council, Division on Engineering and Physical Sciences, Commission on Physical Sciences, Mathematics, and Applications, Chemical Sciences Roundtable, 1999-08-31 The Chemical Sciences Roundtable provides a forum for discussing chemically related issues affecting government industry and government The goal is to strengthen the chemical sciences by foster communication among all the important stakeholders At a recent Roundtable meeting information technology was identified as an issue of increasing importance to all sectors of the chemical enterprise This book is the result of a workshop convened to explore this topic **Recent Advances in Traffic Engineering** Ashish Dhamaniya, Sai Chand, Indrajit Ghosh, 2023-10-28 This book comprises select peer reviewed proceedings of the National Conference on Recent Advances in Traffic Engineering RATE 2022 The contents includes in depth insights into the domain of traffic engineering and planning and presents the latest advancements by focusing on traffic engineering traffic flow road safety advanced techniques for transportation surveys and data collection It covers topics including travel demand modeling and transportation planning issues The contents of this book offer up to date and practical knowledge on different aspects of

traffic engineering It will be useful for researchers as well as practitioners

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