

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., $p > \frac{N+1+b}{N-2}$ and $p < \frac{N+1+b}{N-2}$ 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.^{1,2} 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 Merle³ 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 $p \geq 1 + \frac{1}{N}$. Recently, the Cauchy problem

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Table of Contents Long Time Predicton In Dynamics

1. Understanding the eBook Long Time Predicton In Dynamics
 - The Rise of Digital Reading Long Time Predicton In Dynamics
 - Advantages of eBooks Over Traditional Books
2. Identifying Long Time Predicton In Dynamics
 - 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 Long Time Predicton In Dynamics
 - User-Friendly Interface
4. Exploring eBook Recommendations from Long Time Predicton In Dynamics
 - Personalized Recommendations
 - Long Time Predicton In Dynamics User Reviews and Ratings
 - Long Time Predicton In Dynamics and Bestseller Lists

5. Accessing Long Time Predicton In Dynamics Free and Paid eBooks
 - Long Time Predicton In Dynamics Public Domain eBooks
 - Long Time Predicton In Dynamics eBook Subscription Services
 - Long Time Predicton In Dynamics Budget-Friendly Options
6. Navigating Long Time Predicton In Dynamics eBook Formats
 - ePub, PDF, MOBI, and More
 - Long Time Predicton In Dynamics Compatibility with Devices
 - Long Time Predicton In Dynamics Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Long Time Predicton In Dynamics
 - Highlighting and Note-Taking Long Time Predicton In Dynamics
 - Interactive Elements Long Time Predicton In Dynamics
8. Staying Engaged with Long Time Predicton In Dynamics
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Long Time Predicton In Dynamics
9. Balancing eBooks and Physical Books Long Time Predicton In Dynamics
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Long Time Predicton In Dynamics
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Long Time Predicton In Dynamics
 - Setting Reading Goals Long Time Predicton In Dynamics
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Long Time Predicton In Dynamics
 - Fact-Checking eBook Content of Long Time Predicton In Dynamics
 - 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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