

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

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Van Duong Dinh,^{1,2} Mohamed Majdoub,^{3,4} and Tarek Saanouni^{3,4}

AFFILIATIONS

¹École Normale Supérieure de Lyon & CNRS, UMPA (UMR 5069), Lyon, France
and Department of Mathematics, HCMC University of Education, 280 An Duong Vuong, Ho Chi Minh City, Vietnam

²Department of Mathematics, College of Science, Imam Abdulrahman Bin Faisal University, P.O. Box 1982, Dammam, Saudi Arabia and Basic and Applied Scientific Research Center, Imam Abdulrahman Bin Faisal University, P.O. Box 1982, 31441 Dammam, Saudi Arabia

³Department of Mathematics, College of Sciences and Arts of Uqailat Asugout, Qassim University, Buraydah, Saudi Arabia

⁴E-mail: contact@vduongdinh.com

⁵E-mail: mmajdoub@iau.edu.sa

⁶Author to whom correspondence should be addressed: t.saanouni@qu.edu.sa

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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