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General lump-type solutions of the (3+1)-dimensional Jimbo-Miwa equation

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Abstract

In this paper, we study the general lump-type solutions of the (3+1)-dimensional Jimbo-Miwa equation via Hirota bilinear method and the ansatz technique. In contrast with lump solutions presented before, we firstly find a general quadratic function solution of the transformed bilinear Jimbo-Miwa equation and then expand it as the sums of squares of linear functions to satisfy analyticity condition. Especially, we get a lump-type solution with fifteen parameters which possess eleven arbitrary independent parameters and four constraint conditions. This solution supplements the existing lump-type solutions obtained previously in the literature. Finally, we conclude that there are only two linearly independent non-constant linear functions in the summation for a positive quadratic function solution.

Keywords: Lump, Jimbo-Miwa equation, Bilinear method

1. Introduction

As the second member of the KP hierarchy, the (3+1)-dimensional Jimbo-Miwa equation reads as [1]

$$u_{xxxxy} + 3u_{xx}u_y + 3u_xu_{xy} + 2u_{yt} - 3u_{xz} = 0. \quad (1)$$

This is an important example of physically-significant nonlinear evolution equations that can be solved by the inverse scattering transform (IST) method [2, 3]. Different types of exact solutions of the Jimbo-Miwa equation have been obtained by several methods, such as the Hirota bilinear method, the Exp-function method, the rational function transformation method, etc (see [4-12]).

Recently, based on the Hirota bilinear form of the (3+1)-dimensional Jimbo-Miwa equation, ten classes of its lump-type solutions were generated via Maple symbolic computations [13]. But, it should be noticed that these ten classes are actually equivalent with different arbitrary parameters. Later, Chen and Sun discussed the lump solutions and their dynamics of the (3+1)-dimensional Jimbo-Miwa equation and two extended Jimbo-Miwa equations via bilinear forms [14]. Based on the obtained lump solutions, the lump-kink solution which contains interaction between a lump and a kink wave of the (3+1)-dimensional Jimbo-Miwa equation was also obtained. The interaction between one stripe soliton and lump soliton, rogue wave were discussed by Zhang and Chen [15]. In [16], the rational solutions, semirational solutions, and their interactions to the (3+1)-dimensional Jimbo-Miwa equation were obtained by the Hirota bilinear method and long wave limit. Two kinds of new dynamical phenomena, kinky breather degeneracy and kinky periodic degeneracy, were discussed and presented in [17]. But, similar to the discussion about lump solutions to the generalized KP equations in $(N + 1)$ -dimensions [18], one can find that the results mentioned above are actually lump-type solutions but not lump solutions which are a kind of rational function solutions localized in all directions in the space since they do not approach zero in all directions in \mathbb{R}^4 due to the character of (3+1)-dimensions. And it should be noticed that the Hirota bilinear method plays an important role in these works [19–22].

In this paper, we firstly find a general quadratic function solution of the transformed bilinear Jimbo-Miwa equation and then expand it as the sums of squares of linear functions to satisfy analyticity

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