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Mixed lump-soliton solutions of the (3+1)-dimensional soliton equation

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Abstract

Many mixed lump-soliton solutions for the $(3+1)$-dimensional integrable equation are obtained by using the Hirota bilinear method. These mixed lump-soliton solutions with arbitrary constants are given out analytically and graphically.

Keywords: The $(3+1)$-dimensional integrable equation; Mixed lump-soliton solutions; Hirota bilinear method

1. Introduction

The nonlinear integrable systems, which are of great importance in the field of physics and mathematics, have been paid more and more attention and many exact solutions of the nonlinear integrable systems are obtained by using different effective methods, such as the inverse scattering transform method, the tanh expand method, the Darboux transform method, the first integral method, the Hirota bilinear method, and so on [1]-[13]. Lump solutions are a kind of rational function solutions, localized in all directions in the space, which appear in many physical phenomena, such as plasma, shallow water wave, optic media and Bose-Einstein condensate. Many authors study lump solutions of different nonlinear systems [14]-[16]. On the other hand, the interaction solutions of the lump solutions and other soliton solutions are also an important and interesting phenomenon in many physical fields. The collisions of the interaction of lump and solitons may be elastic or completely non-elastic [17, 18].

In this paper, we focus on the (3+1)-dimensional soliton equation

$$3u_{xz} - (2u_t + u_{xxx} - 2uu_x)_y + 2\left(u_x \partial_x^{-1} u_y\right)_x = 0. \tag{1}$$

and try to find the mixed lump-soliton solutions based on Hirota bilinear method with the help of symbolic computation. The traveling wave solution, the multiple soliton solutions, the kink-breather solution and other interesting exact solutions are studied extensively by many authors [19]-[29]. The (3+1)-dimensional soliton equation (1) can be changed to its bilinear form

$$\left(3D_xD_z - 2D_yD_t - D_yD_x^3\right) f \cdot f = 0, \tag{2}$$

by taking the transformation $u = -3\left(\ln f\right)_{xx}$, which is equivalent to

$$3ff_{xz} - 3f_xf_z - 2ff_{yt} + 2f_yf_t + f_{xxx}f_y + 3f_{xxy}f_x - 3f_{xx}f_{xy} - ff_{xxxy} = 0, \tag{3}$$

where $f = f(x, y, z, t)$ and the Hirota operators D_x, D_y, D_z are defined by [30]

$$D_x^m D_y^n \left(f(x,y) \cdot g(x',y')\right) = \left(\frac{\partial}{\partial x} - \frac{\partial}{\partial x'}\right)^m \left(\frac{\partial}{\partial y} - \frac{\partial}{\partial y'}\right)^n \cdot f(x,y)g(x',y')|_{x=x',y=y'}. \tag{4}$$

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