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# A super Sasa–Satsuma hierarchy and bi-Hamiltonian structures

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## Abstract

A super Sasa–Satsuma hierarchy associated with a  $3 \times 3$  matrix spectral problem is proposed with the aid of the zero-curvature equation and Lenard recursion equations. A typical member in the hierarchy is the super Sasa–Satsuma equation. The super bi-Hamiltonian structures of the super Sasa–Satsuma hierarchy are constructed by utilizing the super trace identity. The infinite conservation laws of the super Sasa–Satsuma equation are presented by resorting to the spectral parameter expansion.

*Keywords:* Super Sasa–Satsuma equation; Bi-Hamiltonian structures; Conservation laws

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## 1. Introduction

During the last decades, the conception of super integrable system has aroused great interests in theoretical physics and mathematics, in which the fermion superfields are added together with the boson fields [1]. So far, many classical integrable equations have been extended to super forms that maintain the complete integrability, for instance, the super KdV equation [1–3], super KP equation [4], super AKNS equations [5], super vector NLS equations [6], super coupled derivative NLS equations [7] and super Camassa–Holm equation [8]. It should be noted that if the extended equation is invariant under the supersymmetric transformation, then it is called as the supersymmetric equation, such as the supersymmetric KdV equation [2], supersymmetric KP equation [4] and supersymmetric AKNS equations [5]. Furthermore, various systematic methods in the classical integrable systems have been developed to derive exact solutions of the super integrable systems such as the inverse scattering transform [9], the Darboux transformation and the Bäcklund transformation [10], the Hirota bilinear method [11].

The Sasa–Satsuma equation, called also the higher-order nonlinear Schrödinger equation, can be written in the form

$$u_t + u_{xxx} + 6|u|^2 u_x + 3u(|u|^2)_x = 0, \quad (1.1)$$

which is completely integrable and has important applications in physics [12]. Recently, this equation has caught considerable attention and been studied extensively. For example, various different kinds of explicit solutions of Eq. (1.1) have been obtained [12, 13]. In this paper, we propose a super Sasa–Satsuma hierarchy associated with a  $3 \times 3$  matrix spectral problem, in which the first nontrivial member takes the form as

$$\begin{aligned} \alpha_t &= -\alpha_{xxx} + 3\alpha\beta\alpha_x, \\ \beta_t &= -\beta_{xxx} + 3\alpha\beta\beta_x, \end{aligned} \quad (1.2)$$

where  $\alpha$  and  $\beta$  are both fermion superfields. The paper is organized as follows. In Section 2, we introduce a  $3 \times 3$  matrix spectral problem with two anticommuting potentials, which is an extension of the spectral problem

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