Title: Soliton solutions and dynamical analysis of the time fractional Kadomtsev–Petviashvili-I equation

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Abastact: In this study, we develop various soliton solutions to the (3 + 1)-dimensional time fractional Kadomtsev–Petviashvili-I equation, which is relevant to fluid dynamics under strong surface tension and provides a comprehensive dynamical analysis of the system. Using the (G /G,1/G)-expansion scheme and the improved F-expansion method together with the beta fractional derivative, hyperbolic, trigonometric, and algebraic soliton solutions are obtained. The obtained solutions represent diverse wave structures, including bell-shaped, kink-shaped, compacton, and singular periodic solitons. It is shown that the soliton profiles and dynamical behavior vary significantly with changes in the fractional-order parameter. The dynamical analysis identifies both stable center points and unstable saddle equilibrium states. We also demonstrate that the system's behavior is highly sensitive to the choice of initial conditions. This work improves the theoretical understanding of the phenomena by extending the class of soliton solutions and revealing new dynamical features. It also shows that the adopted methods are effective for studying fractional nonlinear wave models.

Keywords: Time fractional Kadomtsev–Petviashvili-I equation · Beta fractional derivative · Improved F-expansion technique · G /G,1/G -expansion method · Soliton solution · Stability analysis · Sensitivity analysis

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