Nonlinear Dyn (2018) 91:1985–1991
https://doi.org/10.1007/s11071-017-3997-9

ORIGINAL PAPER

Dynamics of soliton solutions in the chiral nonlinear Schrödinger equations

Hasan Bulut · Tukur Abdulkadir Sulaiman · Betul Demirdag

Received: 23 October 2017 / Accepted: 7 December 2017 / Published online: 12 December 2017

Abstract In this study, the (1 + 1)- and (2 + 1)-dimensional Chiral nonlinear Schrödinger equations are investigated. These equations describe the edge states of the fractional quantum hall effect. We successfully acquired dark and bright soliton solutions to these equations by using the sine-Gordon expansion method. The constraint conditions for the existence of valid soliton are given. We present the numerical simulations to some of the obtained solutions under the choice of suitable parameters.

Keywords Chiral NLSEs · SGEM · Soliton solutions

1 Introduction

Nonlinear complex aspects in optics, plasma physics, fluid dynamics and other areas in nonlinear sciences can be expressed in the form of nonlinear Schrödinger equations (NLSEs). Nonlinear Schrödinger equations are prototypical dispersive nonlinear partial differential equations which have been derived and analyzed in various fields of nonlinear sciences [1]. These types of equations have a wider range of applications in the fields of nonlinear sciences. Investigation of their soliton solutions is of significant importance in the studies of nonlinear science as they help in explaining the physical mechanism of a complex phenomena in nature, and this area becomes one of the most exciting and extremely active area of research [2–4]. Solitons arise on lake shore and beaches where shallow water is present, in a quantum hall effect and also in biological sciences in the context of neurosciences. Solitons are the stable localized waves that propagate in a nonlinear medium without amplitude attenuation and shape change due to the balance between the dispersion and nonlinearity [5]. Solitons play an important role in the non-perturbative developments in the quantum field theory [6–8]. Dynamics of solitons in various models have been studied by different scientists [9–34].

However, in this study, the sine-Gordon expansion method (SGEM) [35–37] is used in investigating the existence of solitons in the quantum hall effect by studying the (1 + 1)- and (2 + 1)-dimensional Chiral nonlinear Schrödinger equations [38,39].

The (1 + 1)-dimensional Chiral nonlinear Schrödinger equation is given by [38]

$$i\Psi_t + \Psi_{xx} - i\sigma(\Psi^*\Psi_x - \Psi\Psi_x^*)\Psi = 0, \tag{1.1}$$

where Ψ is a complex function of x and t, σ is a nonlinear coupling constant and the $*$ indicates the complex conjugate.

H. Bulut · T. A. Sulaiman (✉) · B. Demirdag
Department of Mathematics, Firat University, Elazig, Turkey
e-mail: sulaiman.tukur@fud.edu.ng

H. Bulut
e-mail: hbulut@firat.edu.tr

B. Demirdag
e-mail: betuldenizd@gmail.com

The $(2+1)$-dimensional Chiral nonlinear Schrödinger equation is given by [39]

$$i\Psi_t + a(\Psi_{xx} + \Psi_{yy}) + i\left(b_1(\Psi\Psi_x^* - \Psi^*\Psi_x) + b_2(\Psi\Psi_y^* - \Psi^*\Psi_y)\right)\Psi = 0, \tag{1.2}$$

where Ψ is the complex function of x and t, a is the coefficient of the dispersion terms and $b_1,\ b_2$ are nonlinear coupling constants.

Equations (1.1) and (1.2) give chiral solitons. Solitons in chiral nonlinear Schrödinger equation play a vital role in the context of quantum Hall effect, where chiral excitations are known to appear [40–42]. Several studies have been conducted on these models. Eslami et. al [39] investigated the solutions of the $(2+1)$-dimensional Chiral nonlinear Schrödinger equation. Younis et al. [43] studied the chiral nonlinear Schrödinger equation, with perturbation term and a coefficient of Bohm potential. Nishino et al. [38] studied Eq. (1.1) and some soliton solutions were constructed. With aid of soliton perturbation theory, Biswas et al. [42] studied the perturbation of soliton due to the chiral nonlinear Schrödinger equation.

2 The SGEM

In this section, we present the analysis of SGEM.

Consider the sine-Gordon equation [36]

$$\Psi_{xx} - \Psi_{tt} = V^2 \sin(\Psi), \tag{2.1}$$

where $\Psi = \Psi(x, t)$ and V is a nonzero real constant.

Utilizing the wave transformation $\Psi = \Psi(x,\ t) = U(\zeta),\ \zeta = k(x - vt)$ in Eq. (2.1), gives the following nonlinear ordinary differential equation (NODE):

$$\Psi'' = \frac{V^2}{k^2(1-v^2)}\sin(\Psi), \tag{2.2}$$

where $U = U(\zeta)$ and ζ stands for the width and v the velocity of the traveling wave, respectively. One can simplify Eq. (2.2) to the following forms:

$$\left[\left(\frac{U}{2}\right)'\right]^2 = \frac{V^2}{k^2(1-v^2)}\sin^2\left(\frac{\Psi}{2}\right) + q, \tag{2.3}$$

where q is the integration constant.

Inserting $q = 0$, $w(\zeta) = \frac{U}{2}$ and $a^2 = \frac{V^2}{k^2(1-v^2)}$ into Eq. (2.3), yields:

$$w' = a\sin(w), \tag{2.4}$$

inserting $a = 1$ into Eq. (2.4), yields

$$w' = \sin(w), \tag{2.5}$$

simplifying Eq. (2.5), we get the two significant equations as follows:

$$\sin(w) = \sin(w(\zeta)) = \left.\frac{2qe^{\zeta}}{q^2e^{2\zeta}+1}\right|_{q=1} = \operatorname{sech}(\zeta), \tag{2.6}$$

$$\cos(w) = \cos(w(\zeta)) = \left.\frac{q^2e^{2\zeta}-1}{q^2e^{2\zeta}+1}\right|_{q=1} = \tanh(\zeta), \tag{2.7}$$

where q is the integration constant.

The solution of any given nonlinear partial differential equation (NPDE) is assumed to be of the following form:

$$U(\zeta) = \sum_{i=1}^{n} \tanh^{i-1}(\zeta)\left[B_i \operatorname{sech}(\zeta) + A_i \tanh(\zeta)\right] + A_0, \tag{2.8}$$

according to Eqs. (2.6) and (2.7), one may rewrite Eq. (2.8) as:

$$U(w) = \sum_{i=1}^{n} \cos^{i-1}(w)\left[B_i \sin(w) + A_i \cos(w)\right] + A_0. \tag{2.9}$$

The value of n is determined by balancing the highest power nonlinear term and highest derivative the NODE. Inserting Eq. (2.9) and its possible derivatives into the NODE, gives an equation in different power of trigonometric functions "$\sin^i(w)\cos^j(w)$, $(0 \le i \le n, 0 \le j \le n)$". We collect some set of algebraic equations by summing the coefficients of trigonometric identities of the same power and equating each summation to zero. We solve this set of algebraic equations for the values of the coefficients involved. We finally insert the values of these coefficients into Eq. (2.8) to get the solutions of the given NPDE.

3 Applications

In this section, we present the applications of SGEM to the $(1+1)$- and $(2+1)$-dimensional Chiral nonlinear Schrödinger's equations [38,39].

3.1 Application of SGEM to Eq. (1.1)

In this subsection, the SGEM is used in acquiring soliton solutions to the $(1+1)$-dimensional Chiral nonlinear Schrödinger's equation [38].

Substituting the following complex wave transformation:

$$\Psi = U(\zeta)e^{i\Omega},\ \zeta = c(x+vt),\ \Omega = kx+\omega t+\varphi \quad (3.1)$$

into Eq. (1.1), one can get the relation

$$v = -2k \quad (3.2)$$

from the imaginary part and

$$c^2U'' + 2k\sigma U^3 - (\omega + k^2)U = 0 \quad (3.3)$$

from the real part.

Balancing the terms U'' and U^3 in Eq. (3.3), yield $n = 1$.

With $n = 1$, Eqs. (2.8) and (2.9) become

$$U(\zeta) = B_1\text{sech}(\zeta) + A_1\tanh(\zeta) + A_0 \quad (3.4)$$

and

$$U(w) = B_1\sin(w) + A_1\cos(w) + A_0. \quad (3.5)$$

Inserting Eq. (3.5) and its second derivative, we get an equation in trigonometric functions. After making some trigonometric identities substitutions, we collect a group of algebraic equations by equating each summation of the coefficients of the trigonometric functions with the same power to zero. To find the soliton solutions to Eq. (1.1), we insert the acquired values of the coefficients into Eq. (3.4).

Case 1:

$$A_0 = 0,\ A_1 = 0,\ B_1 = -\frac{c}{\sqrt{k\sigma}},\ \omega = (c-k)(c+k),$$

these coefficients give the following solution to Eq. (1.1):

$$\Psi_1(x,t) = -\frac{c}{\sqrt{k\sigma}}\text{sech}[c(x-2kt)]e^{i(kx+(c-k)(c+k)t+\varphi)}, \quad (3.6)$$

with $k,\ \sigma \neq 0$ for valid soliton.

Case 2:

$$A_0 = 0,\ A_1 = 0,\ B_1 = -\frac{c(c^2-\omega)^{1/4}}{\sqrt{\sigma(c^2-\omega)}},\ k = \sqrt{c^2-\omega},$$

these coefficients give the following solution to Eq. (1.1):

$$\Psi_2(x,t) = -\frac{c(c^2-\omega)^{1/4}}{\sqrt{\sigma(c^2-\omega)}}\text{sech}\left[c(x - 2\sqrt{c^2-\omega}t)\right] e^{i(\sqrt{c^2-\omega}x+\omega t+\varphi)}, \quad (3.7)$$

with $\sigma \neq 0$ and $c^2 - \omega > 0$ for valid soliton.

Case 3:

$$A_0 = 0,\ A_1 = 0,\ B_1 = -\frac{\sqrt{k^2+\omega}}{\sqrt{k\sigma}},\ c = \sqrt{k^2+\omega},$$

these coefficients give the following solution to Eq. (1.1):

$$\Psi_3(x,t) = -\frac{\sqrt{k^2+\omega}}{\sqrt{k\sigma}}\text{sech}[\sqrt{k^2+\omega}(x-2kt)] e^{i(kx+\omega t+\varphi)}, \quad (3.8)$$

with $k,\ \sigma \neq 0$ and $k^2 + \omega > 0$ for valid soliton.

3.2 Application of SGEM to Eq. (1.2)

In this subsection, we apply the SGEM to the $(2+1)$-dimensional Chiral nonlinear Schrödinger's equation [39].

Substituting the following complex wave transformation:

$$\Psi = U(\zeta)e^{i\Omega},\ \zeta = \alpha x+\beta y-vt,\ \Omega = px+qy+\omega t+\varphi \quad (3.9)$$

into Eq. (1.2), one can get the relation

$$v = 2a(\alpha p + \beta q) \quad (3.10)$$

from the imaginary part and

$$a(\alpha^2+\beta^2)U''+2(pb_1+qb_2)U^3-(a(p^2+q^2)+\omega)U=0 \tag{3.11}$$

from the real part.

Balancing the terms U'' and U^3 in Eq. (3.3), yield $n=1$.

Proceeding as before, we get the following solutions for Eq. (1.2):

Case 1:

$$A_0=0,\ A_1=0,\ B_1=\frac{\sqrt{a(p^2+q^2)+\omega}}{\sqrt{pb_1+qb_2}},$$
$$\alpha=\frac{\sqrt{a(p^2+q^2-\beta^2)+\omega}}{\sqrt{a}},$$

we have

$$\Psi_1(x,y,t)=\frac{\sqrt{a(p^2+q^2)+\omega}}{\sqrt{pb_1+qb_2}}\operatorname{sech}\times\left[\beta y+\frac{\sqrt{a(p^2+q^2-\beta^2)+\omega}}{\sqrt{a}}x-2a\left(\beta q+p\frac{\sqrt{a(p^2+q^2-\beta^2)+\omega}}{\sqrt{a}}\right)t\right]e^{i(px+qy+\omega t+\varphi)}, \tag{3.12}$$

with $a(a(p^2+q^2-\beta^2)+\omega)>0$ for valid soliton.

Case 2:

$$A_0=0,\ A_1=0,\ B_1=\frac{\sqrt{a(p^2+q^2)+\omega}}{\sqrt{pb_1+qb_2}},$$
$$\beta=\frac{\sqrt{a(p^2+q^2-\alpha^2)+\omega}}{\sqrt{a}},$$

we have

$$\Psi_2(x,y,t)=\frac{\sqrt{a(p^2+q^2)+\omega}}{\sqrt{pb_1+qb_2}}\operatorname{sech}\times\left[\alpha x+\frac{\sqrt{a(p^2+q^2-\alpha^2)+\omega}}{\sqrt{a}}y-2a\left(\alpha p+q\frac{\sqrt{a(p^2+q^2-\alpha^2)+\omega}}{\sqrt{a}}\right)t\right]e^{i(px+qy+\omega t+\varphi)}, \tag{3.13}$$

with $a(a(p^2+q^2-\alpha^2)+\omega)>0$ for valid soliton.

Case 3:

$$A_0=0,\ A_1=\frac{\sqrt{\omega(\alpha^2+\beta^2)}}{\sqrt{(pb_1+qb_2)(p^2+q^2+2(\alpha^2+\beta^2))}},$$
$$B_1=0,$$
$$a=-\frac{\omega}{p^2+q^2+2(\alpha^2+\beta^2)},$$

we have

$$\Psi_3(x,y,t)=\frac{\sqrt{\omega(\alpha^2+\beta^2)}}{\sqrt{(pb_1+qb_2)(p^2+q^2+2(\alpha^2+\beta^2))}}\tanh\times\left[\alpha x+\beta y+\frac{2\omega(\alpha p+\beta q)}{p^2+q^2+2(\alpha^2+\beta 2)}t\right]e^{i(px+qy+\omega t+\varphi)}, \tag{3.14}$$

with $\omega(\alpha^2+\beta^2)(pb_1+qb_2)(p^2+q^2+2(\alpha^2+\beta^2))>0$ for valid soliton.

Case 4:

$$A_0=0,\ A_1=\frac{\sqrt{-a(\alpha^2+\beta^2)}}{\sqrt{pb_1+qb_2}},\ B_1=0,$$
$$\omega=-a(p^2+q^2+2(\alpha^2+\beta^2)),$$

we have

$$\Psi_4(x,y,t)=\frac{\sqrt{-a(\alpha^2+\beta^2)}}{\sqrt{pb_1+qb_2}}\tanh[\alpha x+\beta y-2a(\alpha p+\beta q)t]e^{i(px+qy-a(p^2+q^2+2(\alpha^2+\beta^2))t+\varphi)}, \tag{3.15}$$

with $-a(\alpha^2+\beta^2)(pb_1+qb_2)<0$ for valid soliton.

4 Results and discussion

This section discusses the reported results in this study. For Eq. (1.1), bright soliton solutions which are Eqs. (3.6), (3.7) and (3.8) are reported. For (1.2), bright and dark soliton solutions which are Eqs. (3.12), (3.13) and (3.14), (3.15), respectively, are reported. Bright and dark solitons propagate in a nonlinear dispersive media. Dark soliton describes the solitary waves with lower intensity than the background while bright soliton describes the solitary waves whose peak intensity is larger than the background [44].

In order to have clear and good understanding of the physical properties of the constructed dark and bright soliton solutions, under the choice of the suitable values of parameters, the 3D, 2D and the contour graphs are plotted. The perspective view of the bright and dark solitons, Eqs. (3.7), (3.12) and (3.15) can be seen in the 3D graphs which appear in the (a) parts of Figs. 1, 2 and 3, respectively. The propagation pattern of the wave along the x-axis for Eqs. (3.7), (3.12) and (3.15) is illustrated in the 2D graphs which are located at the

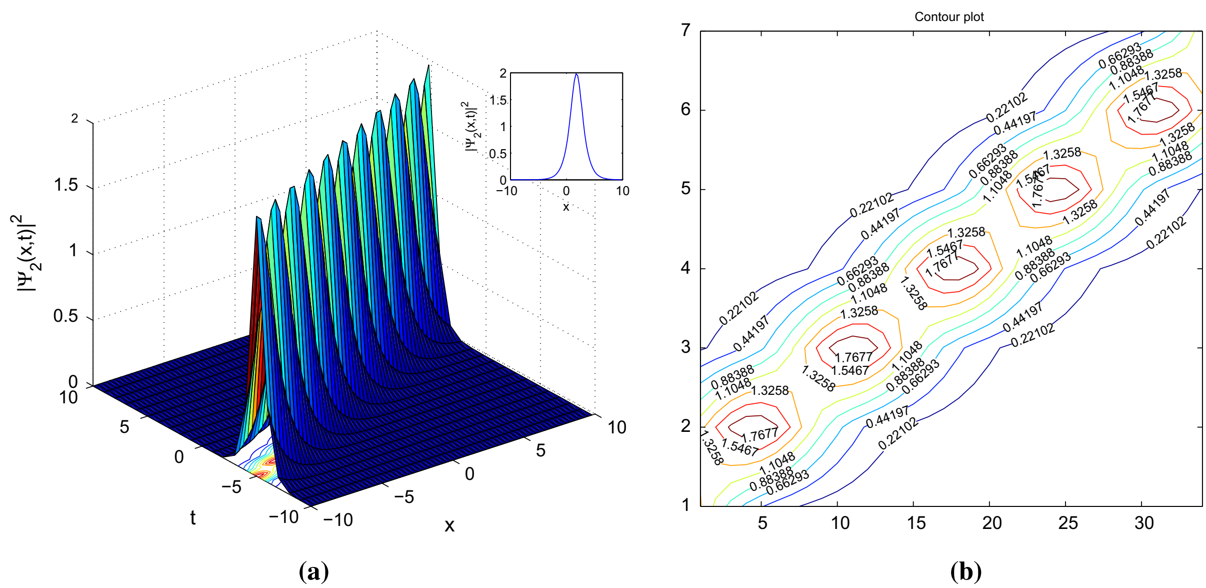


Fig. 1 **a** The 2D and 3D, **b** contour plots of Eq. (3.7)

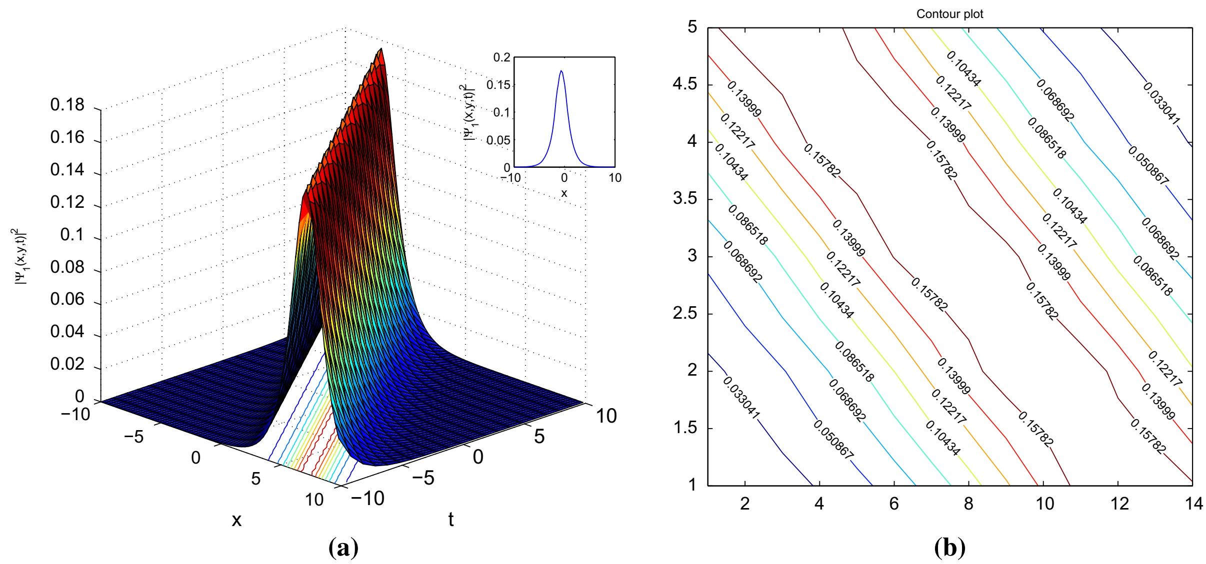
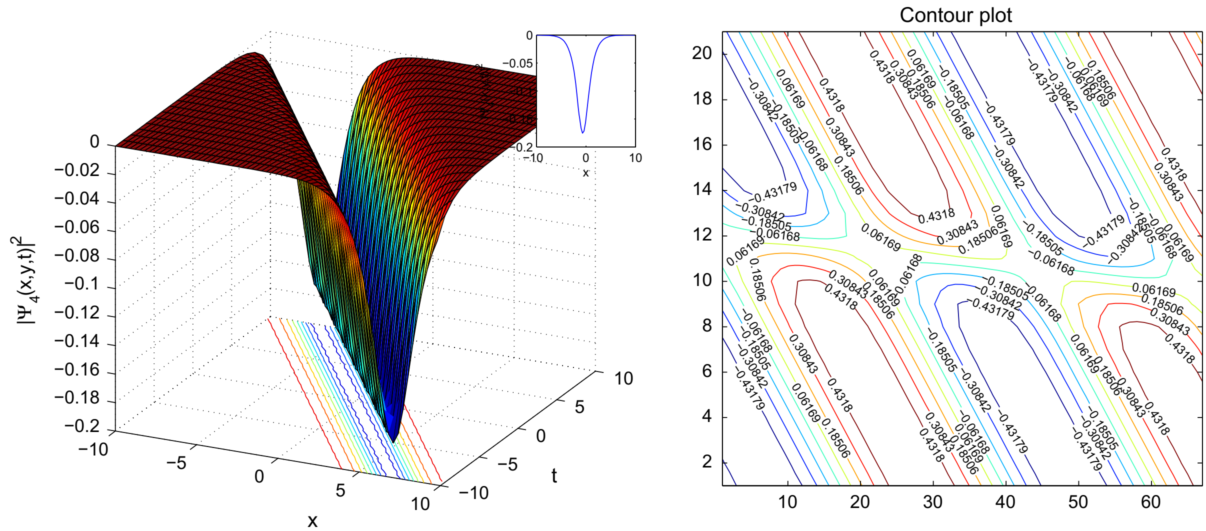


Fig. 2 **a** The 2D and 3D, **b** contour plots of Eq. (3.12)

top right corner of the (a) parts of Figs. 1, 2 and 3. The contour graphs are an alternative of the 3D plots. The contour graphs in the (b) parts of Figs. 1 and 2 illustrated the stable propagation of the exact fundamental bright soliton, and the contour graph in the (b) part of Fig. 3 illustrated the unstable propagation of the exact dark soliton.

5 Conclusions

In this study, the powerful sine-Gordon expansion method is used in searching the presence of soliton solutions in quantum hall effect via the $(1 + 1)$- and $(2 + 1)$-dimensional Chiral nonlinear Schrödinger's equations. We successfully obtained some dark and bright soliton solutions to the two studied models. All



(a) **(b)**

Fig. 3 **a** The 2D and 3D, **b** contour plots of Eq. (3.15)

the obtained solutions satisfy their corresponding equation. We plot the 2D, 3D and contour plots of some of the obtained solutions. The results presented in this study may be important in explaining the physical meaning of some nonlinear models arising in nonlinear sciences. We observed that sine-Gordon expansion method is a simple and powerful mathematical tool that gives good results when applied to complex nonlinear models.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Eslami, M.: Soliton-like solutions for the coupled Schrodinger–Boussinesq equation. Opt. Int. J. Light Electron Opt. **126**(23), 3987–3991 (2016)
2. Gibbon, G.D.: A survey of the origins and physical importance of soliton equations. Philos. Trans. R. Soc. Lond. Ser. A **315**, 335–365 (1985)
3. Guo, R., Hao, H.Q.: Breathers and multi-soliton solutions for the higher-order generalized nonlinear Schrödinger equation. Commun. Nonlinear Sci. Numer. Simul. **18**, 2426–2435 (2013)
4. Yang, Z.J., Yang, Z.F., Li, J.X., Dai, Z.P., Zhang, S.M., Li, X.L.: Interaction between anomalous vortex beams in nonlocal media. Results Phys. **7**, 1485–1486 (2017)
5. Liu, D.Y., Tian, B., Jiang, Y., Xie, X.Y., Wu, X.Y.: Analytic study on a $(2+1)$-dimensional nonlinear Schrödinger equation in the Heisenberg ferromagnetism. Comput. Math. Appl. **71**, 2001–2007 (2016)
6. Jackiw, R., Pi, S.Y.: Time-dependent Chern–Simons solitons and their quantization. Phys. Rev. D **44**(8), 2524–2532 (1991)
7. Cebulla, C., Goeke, K., Ossmann, J., Schweitzer, P.: The nucleon-form factors of the energy-momentum tensor in the Skyrme model. Nucl. Phys. A **794**(1–2), 87–114 (2007)
8. Wadati, M., Sogo, K.: Gauge transformations in soliton theory. J. Phys. Soc. Jpn. **52**(2), 394–398 (1983)
9. Zuo, D.W., Jia, H.X., Shan, D.M.: Dynamics of the optical solitons for a $(2+1)$-dimensional nonlinear Schrödinger equation. Superlattices Microstruct. **101**, 522–528 (2017)
10. Arnous, A.H., Mahmood, S.A., Younis, M.: Dynamics of optical solitons in dual-core fibers via two integration schemes. Superlattices Microstruct. **106**, 156–162 (2017)
11. Younis, M., ur Rehman, H., Rizvi, S.T.R., Mahmood, S.A.: Dark and singular optical solitons perturbation with fractional temporal evolution. Superlattices Microstruct. **104**, 525–531 (2017)
12. Qiao, L.: Weak solutions for the stationary Shrödinger equation and its application. Appl. Math. Lett. **63**, 34–39 (2017)
13. Zhang, L., He, Z., Conti, C., Wang, Z., Hu, Y., Lei, D., Li, Y., Fan, D.: Modulational instability in fractional nonlinear Shrödinger equation. Commun. Nonlinear Sci. Numer. Simul. **48**, 531–540 (2017)
14. Xiang, R., Ling, L., Lü, X.: Some novel solutions for the two-coupled nonlinear Shrödinger equations. Appl. Math. Lett. **68**, 163–170 (2017)
15. Arbabi, S., Najafi, M.: Exact solitary wave solutions of the complex nonlinear Shrödinger equations. Opt. Int. J. Light Electron Opt. **127**(11), 4682–4688 (2016)

16. Ali, A., Seadawy, A.R., Lu, D.: Soliton solutions of the nonlinear Shrödinger equation with the dual power law nonlinearity and resonant nonlinear Shrödinger equation and their modulation instability analysis. Opt. Int. J. Light Electron Opt. **145**, 79–88 (2017)
17. Sabry, R., Moslem, W.M., El-Shamy, E.F., Shukla, P.K.: Three-dimensional nonlinear Shrödinger equation in electron-positron-ion magnetoplasmas. Phys. Plasmas **18**, 032302 (2011)
18. Zedan, H.A., Alaidarous, E., Shapll, S.: Erratum to: exact solutions for a perturbed nonlinear Shrödinger equation by using Bäcklund transformations. Nonlinear Dyn. **74**(4), 1153–1153 (2013)
19. Eslami, M.: Exact traveling wave solutions to the fractional coupled nonlinear Shrödinger equations. Appl. Math. Comput. **285**, 141–148 (2016)
20. Eslami, M., Mirzazadeh, M.: Optical solitons with Biswas–Milovic equation for power law and dual-power law nonlinearities. Nonlinear Dyn. **83**(1–2), 731–738 (2016)
21. Eslami, M.: Solitary wave solutions for perturbed nonlinear Schrodinger's equation with Kerr law nonlinearity under the DAM. Opt. Int. J. Light Electron Opt. **126**(13), 1312–1317 (2015)
22. Eslami, M., Mirzazadeh, M.A., Neirameh, A.: New exact wave solutions for Hirota equation. Pramana **84**(1), 3–8 (2015)
23. Eslami, M., Neyrame, A., Ebrahimi, M.: Explicit solutions of nonlinear $(2+1)$-dimensional dispersive long wave equation. J. King Saud Univ. Sci. **24**(1), 69–71 (2012)
24. Eslami, M., Rezazadeh, H., Rezazadeh, M., Mosavi, S.S.: Exact solutions to the space–time fractional Schrödinger–Hirota equation and the space–time modified KDV–Zakharov–Kuznetsov equation. Opt. Quantum Electron. **49**(8), 279 (2017)
25. Eslami, M., Neirameh, A.: New solitary and double periodic wave solutions for a generalized sinh-Gordon equation. Eur. Phys. J. Plus **129**(4), 54 (2014)
26. Eslami, M., Rezazadeh, H.: The first integral method for Wu–Zhang system with conformable time-fractional derivative. Calcolo **53**(3), 475–485 (2016)
27. Neirameh, A., Eslami, M.: An analytical method for finding exact solitary wave solutions of the coupled $(2+1)$-dimensional Painlevé Burgers equation. Sci. Iran. Trans. B Mech. Eng. **25**(2), 715 (2017)
28. Mirzazadeh, M., Eslami, M., Biswas, A.: Soliton solutions of the generalized Klein–Gordon equation by using (G'/G)-expansion method. Comput. Appl. Math. **33**(3), 831–839 (2014)
29. Rizvi, S.T.R., Ali, K., Salman, M., Nawaz, B., Younis, M.: Solitary wave solutions for quintic complex Ginzburg–Landau model. Optik **149**, 59–62 (2017)
30. Afzal, S.S., Younis, M., Rizvi, S.T.R.: Optical dark and dark-singular solitons with anti-cubic nonlinearity. Optik **147**, 27–31 (2017)
31. Ali, K., Rizvi, S.T.R., Ahmad, S., Bashir, S., Younis, M.: Bell and kink type soliton solutions in birefringent nano-fibers. Optik **142**, 327–333 (2017)
32. Ashraf, M., Ahmad, M.O., Younis, M., Ali, K., Rizvi, S.T.R.: Dipole and Gausson soliton for ultrashort laser pulse with high order dispersion. Superlattices Microsturct. **109**, 504–510 (2017)
33. Rizvi, S.T.R., Ali, K.: Jacobian elliptic periodic traveling wave solutions in the negative-index materials. Nonlinear Dyn. **87**(3), 1967–1972 (2017)
34. Younis, M., Mehmood, S.A., Aslam, M., Rizvi, S.T.R.: Combo-solitons in two-core nonlinear optical fibers. J. Comput. Theor. Nanosci. **13**, 9109–9111 (2016)
35. Baskonus, H.M., Bulut, H., Sulaiman, T.A.: New solitary wave solutions to the $(2+1)$-dimensional Calogero–Bogoyavlenskii–Schiff and the Kadomtsev–Petviashvili hierarchy equations. Indian J. Phys. **135**, 327–336 (2017)
36. Yan, C.: A simple transformation for nonlinear waves. Phys. Lett. A **22**(4), 77–84 (1996)
37. Baskonus, H.M., Sulaiman, T.A., Bulut, H.: On the novel wave behaviors to the coupled nonlinear Maccari's system with complex structure. Optik **131**, 1036–1043 (2017)
38. Nishino, A., Umeno, Y., Wadati, M.: Chiral nonlinear Schrödinger equation. Chaos Solitons Fractals **9**(7), 1063–1069 (1998)
39. Eslami, M.: Trial solution technique to chiral nonlinear Schrödinger equation in $(1+2)$-dimensions. Nonlinear Dyn. **85**(2), 813–816 (2016)
40. Lee, J.H., Lin, C.K., Pashev, O.K.: Shock waves, chiral solitons and semi-classical limit of one-dimensional anyons. Chaos Solitons Fractals **19**(1), 109–128 (2004)
41. Griguolo, L., Seminara, D.: Chiral solitons from dimensional reduction of Chern–Simons gauged nonlinear Schrödinger equation: classical and quantum aspects. Nuclear Phys. B **516**(1–2), 467–498 (1998)
42. Biswas, A.: Perturbation of chiral solitons. Nuclear Phys. B **806**, 457–461 (2009)
43. Younis, M., Cheemaa, N., Mahmood, S.A., Rizvi, S.T.R.: On optical solitons: the chiral nonlinear Schrödinger equation with perturbation and Bohm potential. Opt. Quant. Electron. **48**, 542 (2016)
44. Scott, A.C.: Encyclopedia of Nonlinear Science. Routledge, Taylor and Francis Group, New York (2005)