Tilted and standard ring solitons: from plasma to shallow water

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Abstract

In many nonlinear systems, ranging from plasma to the ocean, the interplay between the nonlinearity and dispersion leads to the formation of a very robust coherent and localized structures, the solitons. In cylindrical symmetry, the theory of the large amplitude waves predicts the existence of nonlinear ring waves in the form of multi-solitons, whose spatiotemporal evolution is governed by the concentric (or cylindrical) Korteweg-de Vries equation (cKdVE). Here, we solve both analytically and numerically the cKdVE. The analytical multi-soliton ring waves are associated with the tilted boundary conditions (tilted solitons) i.e., for large values of the spatial coordinate, the solution approaches an oblique asymptote. Furthermore, the ring solitons obtained from numerical solutions are associated with standard boundary conditions for a bright multi-soliton, i.e., the solutions tend to zero asymptotically. Although the maximum amplitudes of both analytical and numerical solutions decrease as the timelike variable increases, they exhibit a different scaling law. Remarkably, it is shown that the numerical cylindrical multi-soliton solutions exhibit a behaviour that is very similar to the planar KdV multi-soliton. .