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EVOLUTION OF QUANTUM KNOTS DRIVEN BY MINIMAL SURFACES

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ABSTRACT

The origin and dynamics of some quantum knots and links are studied under the Gross-Pitaevskii equation in an infinitely extended, unitary background density. Several direct numerical simulations are carried out by employing a new numerical code [1] that resolves the limits of boundary conditions on a truncated domain. The head-on collision of quantum vortex rings and the creation of a trefoil knot from initially unlinked, unknotted loops are realized for the first time. Three generic scenarios are identified: (i) direct topological cascade and collapse, (ii) structural and topological cycles, and (iii) inverse topological cascade of complex structures. Thanks to defect localization, we can apply geometric and topological techniques to get physical insight on the dynamics of these evolutionary processes. Writhing number proves to be an appropriate detector of direct topological cascade that governs the decay of complex structures to small-scale vortex rings, whereas picks of total curvature provide a clear signature of reconnection events. We show that isophase minimal surfaces spanning knots and links have a privileged role in the decay process by detecting surface energy relaxation of complex systems [2].

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[1] Caliari ,M. & Zuccher, S. 2021 A fast time splitting finite difference approach to Gross-Pitaevskii equations. *Commun. Comput. Phys.* **29**, 1336-1364.

[2] Zuccher, S. & Ricca, R.L. 2022 Creation of quantum knots and links driven by minimal surfaces. *J. Fluid Mech.* **942**, A8.