Research news

Logic operations with active topological defects
R. Zhang, A. Mozaffari and J. J. de Pablo, Science Advances, 8, eabg9060, 2022.

Can soft matter perform logic operations and transmission of information just like semiconductor-based integrated circuits? In this work, the authors show that topological defects can be used as information carriers in active nematics to realise logic operations. Instead of having a uniform activity throughout the entirety of a traditional active nematic system, they introduce gradients of activity by gear-shifting light-sensitive myosin motors. The +1/2 defects can thus be coerced to move along the given activity pattern. By combining patterns of activity with surfaces imparting certain orientations, one can even control the formation and transport of +1/2 defects. When there are multiple defects, the motion of one defect can be facilitated or impeded by the motion of a second defect. Based on these concepts, the authors realise defect gating, tunnelling, and amplification by introducing different designs.

Geometric transformation and three-dimensional hopping of Hopf solitons
J. S. B. Tai, J. S. Wu and I. I. Smalyukh, Nature Communications, 13, 2986, 2022.

Hopf solitons are three-dimensional (3D) particle-like field distortions with nontrivial topology described by the Hopf map. They have been observed in many areas of physics. However, so far, the stability of Hopf solitons in experiments has relied on geometrical confinement or externally applied fields and the 3D mobility and control of Hopf solitons have never been fully utilised. In this work, the authors demonstrate the structure stability of Hopf solitons under different elastic material constants, applied electric fields and confinement conditions. By mixing liquid crystals of rod-like and bent-core molecules, the authors can continuously tune the elastic anisotropy of the liquid crystal system. They show that the Hopf solitons can be transformed from heli-knotons by switching the applied electric field. Such a transformation is reversible and can induce a 3D hopping-like motion of the Hopf solitons.

Digital photoprogramming of liquid-crystal superstructures featuring intrinsic chiral photo-switches
Z. G. Zheng, et. al., Nature Photonics, 16, 226–234, 2022.

Liquid crystals have been broadly used in imaging and display technology due to their brilliant optical properties. However, realising a fully reversible and programmable control of light through liquid crystals is still a formidable challenge due to the lack of suitable chiral molecular photo-switches. In this work, the authors successfully develop a unique intrinsic chiral photo-switch with broad chirality modulation. This photo-switch enables reversible dynamic modulation of the helical structure of cholesteric liquid crystals and solve serious bottlenecks seen with current modulation of superstructures using light, such as thermal instability, limited dynamics tenability of the helical twisting power and regional arrangement disturbance. In addition, it also facilitates multi-stable states that are controlled exclusively by light. With help of the photo-switch, the authors realise an anti-counterfeiting technique, embedded with diverse microstructures, featuring colour-tunability, eras ability, reversibility, multi-stability and viewing angle dependency of pre-recorded patterns.

Interaction and co-assembly of optical and topological solitons
G. Poy, et. al., Nature Photonics, 16, 454–461, 2022.

Topological solitons are continuous but topologically nontrivial field configurations embedded in uniform physical fields that behave like particles and cannot be transformed into a uniform state through smooth deformations. They have been broadly generated and investigated in cholesteric liquid crystals systems. In this work, the authors experimentally demonstrate and theoretically explain optomechanical interactions between these topological solitons, mediated by the local transfer of momentum between light and matter and the nonlocal orientational elasticity of the liquid crystal. They show that the delicate balance arising from these different contributions to the optomechanical forces enables facile dynamical control and spatial localisation of topological solitons.
**Electrically tunable collective motion of dissipative solitons in chiral nematic films**

Y. Shen and I. Dierking, Nature Communications, 13, 2122, 2022.

Active systems composed of self-propelled particles exhibit a plethora of complex emergent collective dynamic behaviours and have received great attention. In this work, the authors introduce an active system composed of dynamics dissipative solitons, called directrons, which mimics the collective motion of living systems. These directrons are particle-like self-confined director deformations that can propagate at a constant velocity in nematics and survive collisions. Driven by external electric fields, hundreds and thousands of directrons emerge form a homogeneously aligned nematic bulk. They start with random motions but self-organise into flocks and synchronise their motions through multi-particle interactions. The directron flocks exhibit rich dynamic behaviours and induce population density fluctuations far larger than those in thermal equilibrium systems. They exhibit turbulent swimming patterns manifested by transient vortices and jets. They even distinguish topological defects, heading towards defects of positive topological strength and avoiding negative ones.

**Active transformations of topological structures in light-driven nematic disclination networks**

J. H. Jiang, et. al., PNAS, 119, e212226119, 2022.

Topological defects are configurations of the order parameter which cannot be transformed continuously into a uniform state. They have been observed in various areas of physics, such as alloys, semiconductors, biological systems, cosmology, etc. and are essential to the understanding of non-equilibrium systems, disordered systems, phase transitions, frustrated media, biological systems. However, controlling the structure of topological defects in active systems is still challenging. In this work, the authors show that programmable transformations of topological structures can be triggered through light irradiation in a predesigned disclination network. The authors firstly introduced various topological patterns to a surface through photo-alignment technique. By confining the nematic liquid crystal with the prepared surfaces, a three-dimensional disclination network with designed topological structures is obtained. These networks can be driven out of equilibrium through light irradiation and undergo a series of dynamics events, ending in different defect structures. The authors demonstrate the dynamics spatiotemporal evolutions of the topological defects through continuum simulations. By dispersing nematic with amphiphilic molecules, they also demonstrate a simultaneous transformation of disclination-guided, molecular self-assembly patterns.

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