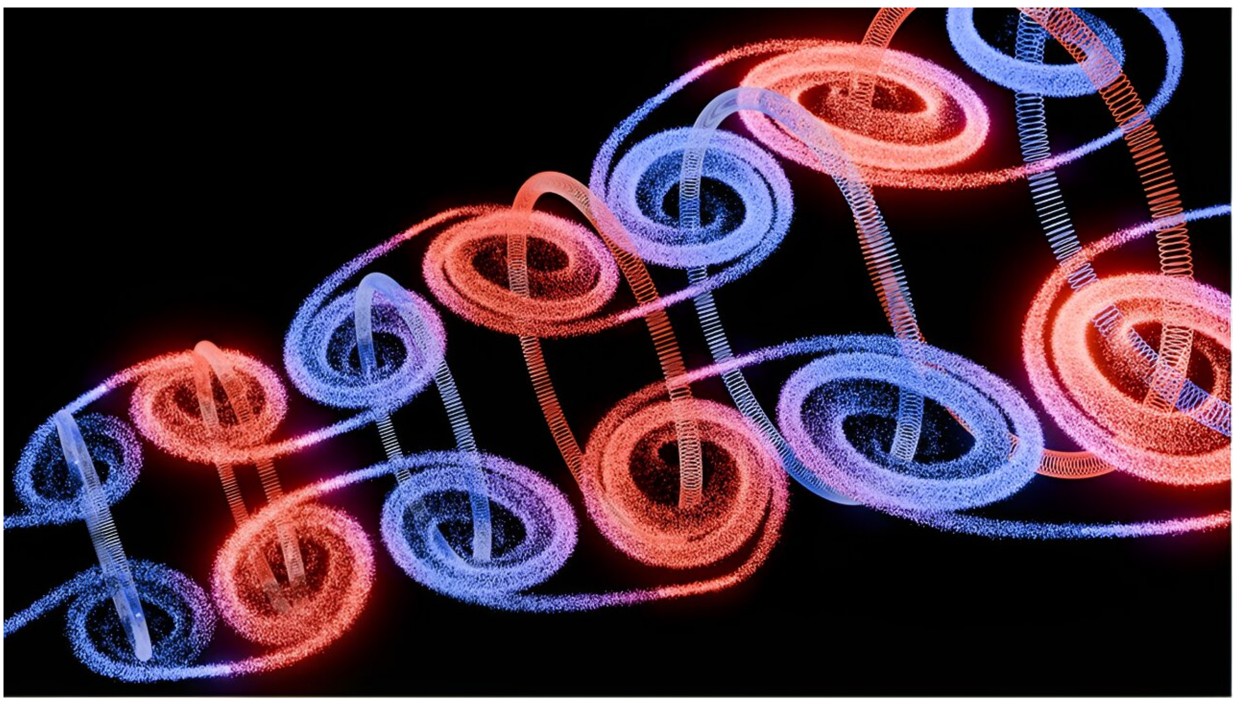
Physicists report optical analog of Kármán vortex street

June 13 2024



An artistic pressions of a vortex-ring street analog to the structure of magnetic field of a NDSTP, where the right- and left- handed vortex rings were highlighted by blue and red, respectively. Credit: Yijie Shen, Nikitas Papasimakis, and Nikolay I. Zheludev

In a study published in *Nature Communications*, collaborating physicists from Singapore and the UK have reported an optical analog of the Kármán vortex street (KVS). This optical KVS pulse reveals fascinating parallels between fluid transport and energy flow of structured light.

Yijie Shen, study lead author from Nanyang Technological University, says, "We introduce a type of light pulse which field structure has an intriguing similarity with a von Kármán vortex street, a pattern of swirling vortices observed in fluid and gas dynamics that is responsible for the 'singing' of suspended telephone lines in wind. The structured light exhibits robust topological structure of skyrmions in condenser matter.

"In sharp contrast to earlier work on optical skyrmionic beams and pulses, the skyrmionic field configuration in nondiffracting supertoroidal pulses (NDSTPs) is not limited by diffraction and persists upon propagation over arbitrary distances. We anticipate that NDSTPs will inspire potential applications such as light-matter interactions, super resolution microscopy, and metrology. "

Skyrmions, sophisticated topological particles originally proposed as a unified model of the nucleon by Tony Skyrme in 1962, behave like nanoscale magnetic vortices with spectacular textures. To date, all known optical skyrmions in free space that do not propagate or only exist around focus and collapse rapidly upon propagation.

Nevertheless, because the light pulses proposed in this paper do not spread during propagation, such skyrmionic fields structures can persist upon the KVS pulse propagation. The pulse allows the study of the propagation dynamics of electromagnetic skyrmionic fields and will be of interest as directed energy channels for information transfer applications.

The analogy between KVS in fluid flows and the pulse can be drawn further by considering for instance the motion of electrons along the vortex streets of a transverse magnetic pulses or the propagation of the pulses in nonlinear media

"We believe the deeply subwavelength singularities of those pulses can be applied in metrology as well as they may interest those studying the spectroscopy of toroidal excitations in matter. Additionally, the pulses could be leveraged for long-distance information transfer encoded in the topological features of the pulses, with potential applications in telecommunications, remote sensing, and LiDAR," the authors say.

The KVS, a classical flow pattern of swirling vortices, is highly organized and typically consists of two sequences of vortices, one from each side of the body, with circulations of opposite signs, famous for its aesthetic beauty and immense power.

In the museum at the Church of St Dominic in Bologne, Italy, there is a painting depicting St. Christopher carrying the infant Jesus across a river. The painter has depicted interlaced vortices behind Christopher's bare feet. Theodore von Kármán stated that his research on vortex streets was inspired by this painting. This represents a fascinating intersection of science and the humanities.

In 1940, a suspension bridge named the Tacoma Narrow Bridge, completed in just four months, suffered damage due to the generation of vortex streets caused by its improper design, leading to vibrations and resonance. This event marked the first-time humanity recognized the immense power of the KVS.

More information: Yijie Shen et al, Nondiffracting supertoroidal pulses and optical "Kármán vortex streets", *Nature Communications* (2024). DOI: 10.1038/s41467-024-48927-5

Provided by Chinese Academy of Sciences