European Research Council
Established by the European Commission

Università di Roma Tor Vergata
Dipartimento di Fisica

Seminar

Wednesday, 29 March 2017 - h. 14:30

Sala Struttura della Materia (Dipartimento di Fisica)

Detecting structural complexity by knot polynomials

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ABSTRACT

In the last decades there has been overwhelming evidence that vorticity tends to localize to form coherent structures, such as vortex filaments and tangles in both classical and quantum fluids. The problem of quantifying structural complexity of vortex tangles and possibly relating this complexity to energy transfers is therefore quite important for fundamental research and applications. In the case of vortex tangles structural complexity methods have proven to be useful to investigate and establish new relations between energy, helicity and complexity [1]. In recent years this approach has received further impetus with the introduction of adapted knot polynomials, such as HOMFLYPT, as new invariants of ideal fluid mechanics [2].

Here, by reviewing these later developments, we apply the new findings to the vortex cascade process studied by the laboratory experiments of Kleckner & Irvine (2013) on the production and decay of vortex knots and links in water. Under certain symplifying assumptions we find [3] that the vortex cascade can be detected by a unique, monotonically decreasing sequence of HOMFLYPT numerical values. By comparative analysis with other knot polynomials we show that HOMFLYPT is not only the best quantifier of topological complexity, but for dissipative systems its values may provide robust markers to identify reconnections, topological transitions and associated energy transfers in more general situations.

[1] Ricca, R.L. (2009) Structural complexity and dynamical systems. In *Lectures on Topological Fluid Mechanics* (ed. R.L. Ricca), pp. 169-188. Springer-CIME Lecture Notes in Mathematics **1973**. Springer-Verlag.

[2] Liu, X. & Ricca, R.L. (2015) On the derivation of HOMFLYPT polynomial invariant for fluid knots. *J. Fluid Mech*. **773**, 34-48.

[3] Liu, X. & Ricca, R.L. (2016) Knots cascade detected by a monotonically decreasing sequence of values. *Nature Sci. Rep.* **6**, 24118.

ERC Advanced Grant (N. 339032) "NewTURB"
(P.I. Prof. Luca Biferale)
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