Using Topological Defects as Glue:
Hierarchical self-assembly of nematic colloidal superstructures
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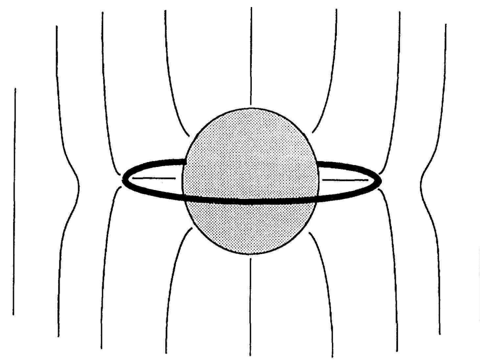
Recommended and a commentary by Randall D. Kamien, University of Pennsylvania

The nematic phase is the workhorse of liquid crystals. Indeed, you are probably reading this commentary through the power of the twisted nematic display. Nematics also serve as exemplars for the study of topological defects and have been used as a laboratory model of cosmic strings [1]. Unlike the more famous Abrikosov flux lines, line and point defects in nematics can be directly observed via crossed polarizers and, in fact, the word nematic originates from the dark lines (Greek: $\nu\epsilon\mu\alpha$) seen in so-called Schlieren textures (see `http://www.lci.kent.edu/purple.html` for example). Moreover, because boundary conditions play such an important role in both topology and devices, the technology to enable the latter is available to study the former.

More than ten years ago [2] colloids and nematics were brought together – the colloidal inclusions, with the proper surface chemistry, serve as sources for topological defects. The long range order of the nematic phase and the global nature of the topological defects resulted in the spontaneous assembly of bead-on-a-string chains of colloidal particles. It was possible to alter the surface chemistry to modify the alignment of the nematic; two common boundary conditions are *homeotropic* wherein the nematic director is perpendicular to the surface, and *homogeneous* or *planar* alignment when the molecules lie in the tangent plane of the inclusion. The remarkable images have now given way to remarkable *devices*. Škarabot, *et al.* have co-opted the stable line defects [3] in a nematic to assemble colloids of various sizes into a coherent and possibly useful superstructure. Just as impurities are driven to grain boundaries and dislocations in crystals, small colloidal particles are attracted to the topological defects induced by large colloidal particles. Using laser tweezers the authors bring the small colloids near the large ones and find both through experiment and simulation that the small inclusions are attracted to the defect produced by the large one.

The resulting complexes are especially interesting because of the geometry of the topological defects. A "hedgehog" texture, also present in a Heisenberg magnet, is a stable, point defect. However, when the large colloid with homeotropic boundary conditions is pushed into a uniform texture, a charge balancing point defect opens up into a disclination ring of charge $-1/2$, making the whole structure appear as a "Saturn Ring", as predicted by Terentjev [4] (see figure). This geometry, coupled with the self assembly, creates microscopic cogs on a larger wheel. This might be useful for mechanical and flow applications or, as suggested by the authors, as a THz resonator when the small colloids are conducting. No longer need we justify our interest in string-like defects by citing cosmology. Line defects in nematics are the route to new materials!



The Saturn Ring. The dark line is the disclination loop,
the lighter lines are the director field. From [4].

[1] I. Chuang, R. Durrer, N. Turok, and B. Yurke, Science **251** (1991) 1336.
[2] P. Poulin, H. Stark, T.C. Lubensky, and D.A. Weitz, Science **275** (1997) 1770.
[3] There are no stable line defects in a Heisenberg magnet since the unit spins live on S^2; since the nematic director "has no head", its spins live on RP^2 and stable line defects abound. See P.E. Lammert, D.S. Rokhsar, and J. Toner, Phys. Rev. Lett. **70** (1993) 1650 for more.
[4] E.M. Terentjev, Phys. Rev. E **51** (1995) 1330.