John Toner

John Toner is a Professor of Physics at the University of Oregon. He is best known as one of the founders of the field of Active Matter, and co-formulator of the “Toner-Tu” equations for polar ordered active fluids (aka flocking) [1-4], for which he was awarded the 2020 Onsager Prize for Theoretical Statistical Physics by the American Physical Society (that Society’s highest award for Theoretical Statistical Mechanics).

In addition to formulating the Toner-Tu equations, Toner has made major contributions to a wide range of areas of Condensed Matter Physics. His Ph.D. thesis work [5] extended the two-dimensional dislocation mediated theory of melting developed by D.R. Nelson and B. I. Halperin to three dimensions. As a postdoctoral James Frank Fellow at the University of Chicago, among other accomplishments, he solved the vexing problem of the Smectic A to nematic transition [6], demonstrated theoretically that Smectic Liquid crystals are superior soundproofing materials [7, 8] (a result that was quickly confirmed experimentally [9]), and predicted the existence of a new liquid crystalline phase (the ”N+6” phase [10]) which exhibits both molecular and bond orientational order in different directions. This phase was later seen in DNA. He subsequently formulated the first elastic theory of quasicrystals [11], and the first hydrodynamic theory of those strange materials [12]. Major contributions to the theory of tethered membranes [13], the nematic to isotropic phase transition [14, 15], smectic liquid crystals in disordered media [16–20], and disordered superconductors [21] followed.

More recently, Toner has extended of the hydrodynamic theory of systems with p-fold bond orientational order (”p-atics”) to non-linear order [22, 23], which he used to show that shearing such systems can induce long- ranged bond-orientational order even in two dimensions. He has shown that active nematics obey Darcy’s law even in the absence of friction [24] and formulated the first theories of active smectics [25, 26], and of dislocation effects therein [27]. His study of flocks with birth and death (Malthusian flocks) [28] and determination of the scaling laws of such flocks in three dimensions [29] are major new results in Active Matter. The study of membranes has been revitalized by his recent work on asymmetric tethered membranes [30, 31], which prove to exhibit completely different behavior from symmetric membranes. Most recently, he has shown that flocks can undergo a novel kind of liquid-gas phase transition, separating into bands of different speeds and densities [32–34].

Toner has more than 140 publications, which have collectively been cited over 11,400 times, with 24 of them cited more than 100 times, and an h-index of 44. His paper summarizing the Toner-Tu theory of flocking [3] alone has been cited almost 1800 times. His book on this subject: *The Physics of Flocking: Birth, Death, and Flight in Active Matter* was published by Cambridge University Press in 2024. In addition to the Onsager Prize, Toner was a Simons Fellow in 2012-2013 (one of only 28 in all disciplines of Physics nationwide that year), and a Gutzwiller Fellow at the Max Planck Institute for the Physics of Complex Systems in Dresden (awarded to only one recipient annually) in 2019-2020. He is a Fellow of the American Physical Society and a Higgs Fellow at the University of Edinburgh.

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