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Office of Scientific Councils of the University of Warsaw
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Dear Sir or Madam:

As requested, I have reviewed the work of Dr. Jeffrey Everts for his habilitation at the University of Warsaw. I am favorably impressed by his achievements, and I definitely recommend him for this promotion.

Dr. Everts was educated in theoretical physics in the Netherlands. He received his bachelor's degree from the Eindhoven University of Technology in 2010, with a thesis related to chirality in self-assembly. He earned his master's degree in 2012 at Utrecht University, and wrote a thesis on topological phases and superfluidity. Also at Utrecht University, he received his PhD in 2016, with a thesis on colloidal dispersions of nanoparticles. After the PhD, Dr. Everts did postdoctoral research in the University of Ljubljana for 2017-2020, and then moved to a second postdoctoral position at the Institute of Physical Chemistry of the Polish Academy of Sciences. In 2022, he began his current position as an Assistant Professor at the University of Warsaw.

Much of Dr. Everts' recent research has been on the theory of liquid crystals. Liquid crystals are phases of matter with partial order—more order than isotropic liquids, but less than full three-dimensional crystals. The most common liquid crystal phase is the nematic phase, which has orientational order along an axis, called the nematic director. This order is somewhat analogous to the orientational order of a ferromagnet, except that nematic order goes in both directions along the axis, so that it might be represented by a double-headed arrow.

Liquid crystals normally form in organic materials, which have a certain density of ions. Previous theoretical research on liquid crystals has generally neglected ions. One might say that previous research treats ions implicitly, meaning that the presence of ions leads to certain effective interactions in the liquid crystal degrees of freedom, which can be described by effective coupling coefficients. By contrast, Dr. Everts considers ions explicitly as a part of the theory of liquid crystals. Through this explicit treatment, he is able to determine how the orientational order of the liquid crystal affects the distribution of ions, and conversely, how the ions modify the ordering of the liquid crystal. I believe that this research program is really quite innovative, and it makes a novel contribution to the physics of liquid crystals.

For the habilitation, Dr. Everts puts forward a series of five scientific articles on the theme of "Electric double layers in anisotropic fluids." I have read these articles, and I believe that they provide substantial advances in the scientific understanding of ions and liquid crystals.

To describe these articles in chronological order:

- *Topological-defect-induced surface charge heterogeneities in nematic electrolytes* (Physical Review Letters, 2020): This paper sets up the formalism to describe coupling between the tensor order parameter of a nematic liquid crystal, the concentration of ions, and the electrostatic potential. This formalism is a challenging version of Poisson-Boltzmann theory, because the dielectric tensor is anisotropic. It is necessary to solve self-consistently for the nematic order configuration and the charge configuration. The paper applies this formalism to liquid-crystal cells with patterned surfaces, and shows that topological defects can be used to control surface charges.

- *Charge-, salt- and flexoelectricity-driven anchoring effects in nematics* (Liquid Crystals, 2020): This paper applies the same formalism to liquid-crystal cells with patterned configurations of charge on the surfaces. It demonstrates that surface charges induce electric fields that anchor the liquid-crystal director orientation near the surface, and hence influence the director orientation throughout the cell. Hence, the director anchoring can be manipulated by modifying surface charges, or by adding salt to screen the surface electric fields. The paper also emphasizes that these effects are strongly related to flexoelectricity, which is the coupling between director gradients and polar alignment of a liquid crystal.

- *Anisotropic electrostatic screening of charged colloids in nematic solvents* (Science Advances, 2021): This paper considers "dumpling"-shaped colloidal particles as a new type of charged surface on a liquid crystal. If a colloidal particle is immersed in a liquid crystal, the charge on the colloid creates an electric field within the liquid crystal, which is screened by ions. The screened electric field strongly affects the local orientation of the director. This alignment is in addition to the standard anchoring effect of uncharged colloids on liquid crystal, which was already known to give remarkable defect structures, such as Saturn rings. The paper presents both theory and experiments to characterize the director alignment and defects.

- *Ionically charged topological defects in nematic fluids* (Physical Review X, 2021): This paper points out that topological defects in nematic order can be regarded as effective colloidal particles, in that they have the same type of electrostatic effects. A topological defect has sharp gradients in the magnitude and direction of nematic order. These sharp gradients induce localized electric fields, which modify the distribution of ions. The paper considers three types of defects with different geometries: an isotropic-nematic interface as an effective wall, a radial hedgehog as an effective point, and a wedge disclination as an effective line. In all three cases, it determines how ions are distributed through the defect structure. Of the five articles on the list, this paper made the greatest impression on me, because it explicitly shows how topological defects are physical objects with electric charge distributions.

- *Nematronics: Reciprocal coupling between ionic currents and nematic dynamics* (Physical Review Letters, 2023): This final paper addresses a new and innovative aspect of the theory—instead of static structure, it considers the dynamics of ions in a liquid crystal. Here, the main point is that orientational and ionic degrees of freedom are coupled in the Rayleigh dissipation function, as well as in the static free energy. For that reason, any rotation of the orientational order induces a current of ions. This paper makes analogies with the classic screw of Archimedes, in which a screw rotation induces a current of water, and also with the Lehmann effect in chiral nematic liquid crystals. Based on these analogies, it suggests a time-dependent nematic configuration, and calculates the corresponding ionic current. Conversely, it also shows that an ionic current can change the motion of a nematic defect.

Beyond this assessment of the five articles, I should also mention one new development in liquid-crystal research: Recent experiments have discovered ferroelectric nematic phases, in which the orientational order goes predominantly in one direction along an axis, so that it might be represented by a single-headed arrow. Antiferroelectric nematic phases have also been found. Based on these new discoveries, it seems likely that electrostatics will become an essential part of the theory of liquid crystals. I believe that Dr. Everts is in an excellent position to make important contributions to modeling these new phases, based on his experience with modeling ions interacting with orientational order in conventional nematic phases. I will be quite interested in how he might apply the theory in this new context.

Overall, in my opinion, the articles presented here demonstrate significant scientific accomplishments, and they are quite suitable for the habilitation of Dr. Everts. I am very pleased to recommend Dr. Everts for this promotion.

Sincerely yours,

Jonathan V. Selinger

Jonathan V. Selinger

Professor of Physics
Ohio Eminent Scholar