Lehmann effect:
The end of the Leslie paradigm

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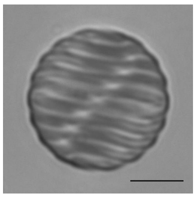
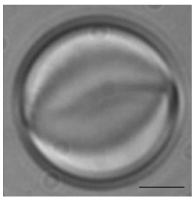
In 1968, Leslie developed nematohydrodynamics. In generalizing the theory to the cholesteric phase, he showed the existence of new thermomechanical terms in the constitutive equations of the phase leading to a torque on the director of expression $\mathbf{\Gamma}_{\mathbf{Leslie}} = \nu \mathbf{n} \times (\mathbf{n} \times \mathbf{G})$ with $\mathbf{G}$ the temperature gradient, ν the Leslie coefficient, and $\mathbf{n}$ the director. Leslie immediately proposed that this torque was responsible for the rotation of the cholesteric droplets observed by Lehmann in 1900 when they are subjected to a temperature gradient. Up to recently this explanation was adopted by the majority of researchers.

In this report, we present two sets of experiments to demonstrate that this explanation must be revised.

First, ν was directly measured by observing the rotation of the helix in cholesteric samples treated for planar sliding anchoring. The main result is that ν is independent of the equilibrium twist of the phase, q. In particular, ν and q are not always of the same sign [1] and ν is different from 0 at the compensation temperature of the phase, when $q = 0$ [2]. This result shows that ν is of microscopic origin, i.e. related to the molecular chirality, and it is not due to the twist of the director field.

(Left) Banded droplet (cholesteric). (Right) Twisted bipolar droplet (nematic).
The black bar represents 10 μm.

Second, the Lehmann effect was reproduced [3]. Measurements with cholesteric phases evidenced that the rotation velocity of droplets such as the banded one shown above is directly connected to q. More precisely, it was shown that the sense of rotation is always given by the sign of q, independently of the sign of ν. In addition, the order of magnitude of the droplet rotation velocities is incompatible with the value of ν [4]. These results cannot be explained by Leslie's model, since the macrocopic twist of the phase determines the Lehmann rotation.

To definitively prove the macroscopic origin of the Lehmann rotation [5], we prepared twisted bipolar droplets of a lyotropic chromonic nematic phase, such as the one shown above. Because the phase is not chiral, the director field inside the droplets can be right- or left-handed. By subjecting these droplets to a temperature gradient, we observed their rotation, half of them rotating clockwise and the other half counterclockwise. This experiment provides evidence that the Lehmann effect also exists in achiral nematics and that it is only due to the macroscopic chirality of the director field. This definitely proves that the Leslie thermomechanical coupling cannot explain the Lehmann effect.

[1] P. Oswald, *Europhys. Lett.*, 2014, **108**, 36001 and 59901 (Erratum).
[2] P. Oswald and A. Dequidt, *Europhys. Lett.*, 2008, **83**, 16005.
[3] P. Oswald and A. Dequidt, *Phys. Rev. Lett.*, 2008, **100**, 217802.
[4] P. Oswald, *Eur. Phys. J. E*, 2012, **35**, 10.
[5] J. Ignés-Mullol, G. Poy and P. Oswald, in preparation.

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