Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

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Version of record first published: 28 Mar 2007.

To cite this article: M. V. Kurik & O. D. Lavrentovich (1982): Topological defects of cholesteric liquid crystals for volumes with spherical shape, Molecular Crystals and Liquid Crystals, 72:7-8, 239-246

To link to this article: http://dx.doi.org/10.1080/01406568208084686

Mol. Cryst. Liq. Cryst. Vol. 72 (Letters), pp. 239-246
0140-6566/82/7207-0239$06.50/0

TOPOLOGICAL DEFECTS OF CHOLESTERIC LIQUID CRYSTALS FOR VOLUMES WITH SPHERICAL SHAPE

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(Submitted for publication December 14, 1981)

ABSTRACT: The existence of the monopoles both with one χ (+2) line and two χ (+1) lines in cholesteric volumes with spherical shape is shown experimentally by microscopic observations with polarized light. The effect of disappearance of χ lines near the cholesteric-smectic A transition is discovered.

In recent time the interest has been increasing to the investigations of defects in cholesterics because of their analogy with singularities in superfluid ^{3}He-A and in magnetic field.It has been shown theoretically that such defects,as boojum[1],analogous to boojum in ^{3}He-A,and monopole[2],analogous to Dirac monopole,can exist in cholesterics.These defects can occur in the spherical containers with tangential boundary conditions for molecular director $\vec{d}$ (and normal boundary conditions for twist axis $\vec{t}$).The conclusion that spherical shape of cholesteric volume and tangential boundary conditions for

$\vec{d}$ promote the formation of boojum and monopole, is founded on the following ideas. According to the topological theorem, the sum of vortices' strengthes of the smooth (except of a finite number of points) tangential to the closed surface vector field (in our case - director field $\vec{d}$) is defined by the Euler characteristic E of this surface:

$$E = \sum_i m_i \, , \qquad (1)$$

where m_i is the strength of the i vortice. For the spherical surface E=2 and, for example, one vortice with the strength m=2 or two vortices with the strengthes m=1 may exist on this surface. These vortices may represent either single surface point defect with m=2 (boojum[1]) or the ends of lines starting on the centre of bulk and terminating on the surface of vessel (monopoles with $\chi(+2)$ or $\chi(+1)$ lines[2]). Distribution of cholesteric layers for all these structures is shown in Figure 1.

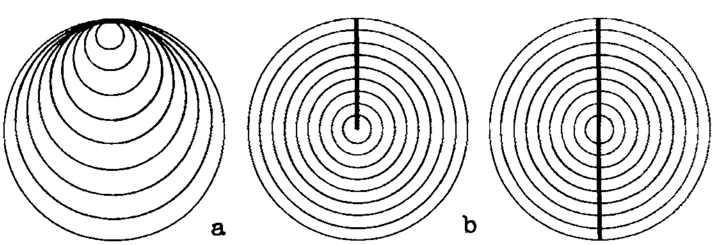

FIGURE 1 Distribution of cholesteric layers for boojum (a), monopole with one χ (+2) line (b) and monopole with two χ (+1) lines (c)

For cholesterics such topological ideas are true only in the case when the helical pitch P is much less than the characteristic size of the sample (radius of sphere R).The experimental investigations of textures in the spherical volumes were carried out only for the case $P/R \sim 0.1$ for polypeptides[3] and for nematics doped by cholesterics[4].These experiments cannot give an unequivocal evidence,that monopole or boojum structures are being formed in the spherical volumes of cholesterics.

In this article in order to find out experimentally the existence of boojum or monopole structures in cholesteric liquid crystals we investigated the textures of various mixtures of cholesterol derivates with helical pitch 0.2-2.0 μm in the spherical droplets with radii 5 - 30 μm.The droplets were dispersed in the isotropic polymer liquid.The condition $P/R \sim 0.01$ was fulfilled.

The results of the experimental study are shown in Figure 2.The important elements of observed textures in the droplets,viewed between crossed linear polarizers,are four extinction arms.They are visible both in parallel light beams and in conoscopic regime.The directions of arms coincide with the directions of polarizers.The arms do not change their positions when the sample is rotated both in vertical and horizontal planes.It means that the spherical concentric systems of cholesteric layers are being formed in the droplets.

The presence of defect lines starting on the centers of spherical systems of cholesteric layers and terminating on the surface of droplets is the second important element of textures.These lines have the thick cores with radii $r \sim P$ and are flexible.The cores are dark when the lines coincide with the directions of polarizers and are bright when they arrange in the gapping positions.This suggests,that the orientation of molecules in cores is non-singular,but the twist axis $\vec{t}$ configuration is singular and the escape of these lines is concentrated only in the region of order P. These peculiarities give evidence,that the observed lines are represented as χ lines[5,6].

Droplets both with one line and two lines were observed.Since there were no more defects in these droplets we may define the strengthes of χ lines from eq.(1): the strength of line m=2 if this line is the only one and m=1 if there are two lines in the droplet.

So,the character of the experimentally observed textures in spherical droplets gives evidence,that monopole structures may really exist in cholesterics and represent the spherical concentric systems of layers with one χ(+2) or two χ(+1) lines starting on the centres of such systems,as it was theoretically predicted by Volovick[2].

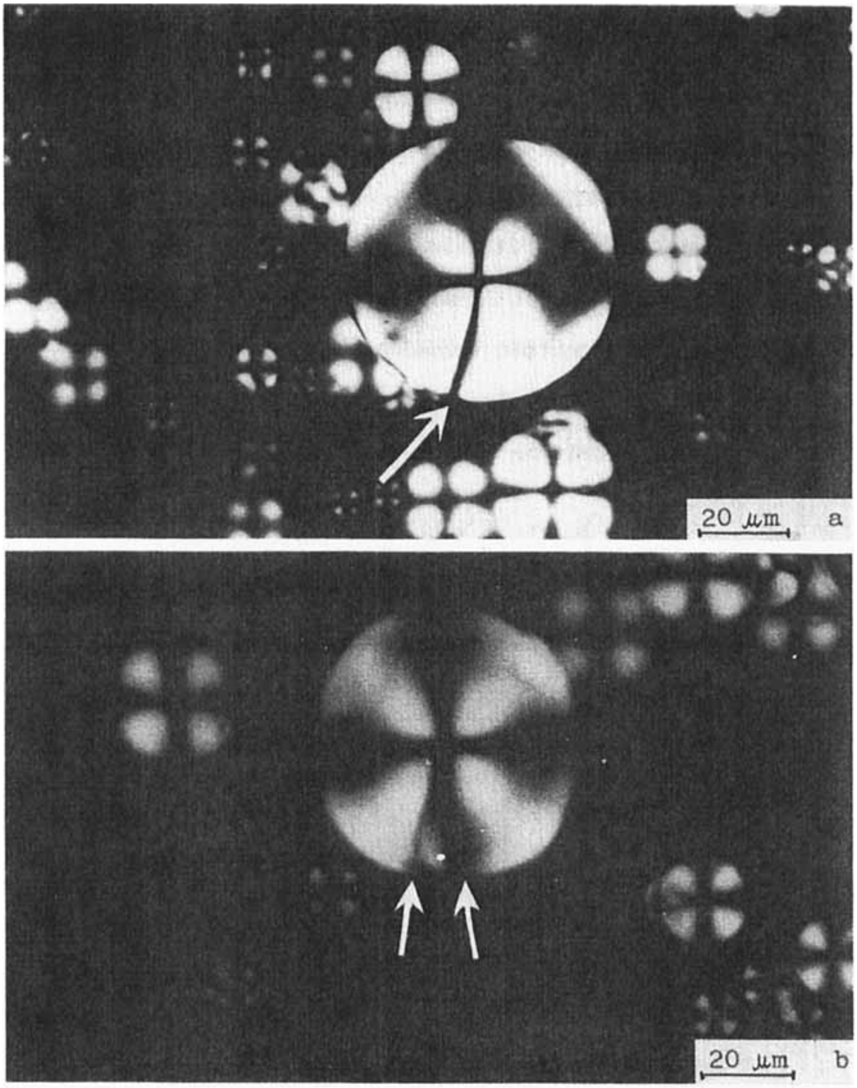

FIGURE 2 Droplets with monopole structures. In the largest droplets: monopole with one $\chi(+2)$ line (a) and monopole with two χ (+1) lines (b). Disclinations are shown by arrows.

Textures, that can be identified as boojum, were not observed. Apparently, this fact is a consequence of a great value of defect energy of such structures in comparison with the energy of monopoles[7]. Really, the equidistant condition for the cholesteric layers[2] in boojum structure is violated (Figure 1a) and the system of disclinations must occur as in the Grandjean-Cano structures. This system consists of 2N closed lines (N is a number of cholesteric layers in the droplet) and its energy can be estimated[8] as

$$E_1 \sim \pi^2 KRN \ln(P/a_1),$$

where K is an average of the Frank's elastic constant, a_1 is a radius of disclination core. The preservation of equidistant condition in the case of monopole structures (Figure 1b,c) leads to the more low values of defect energies,-

$$E_2 \sim 4\pi KR \ln(R/a_2),$$
$$E_3 \sim 2\pi KR \ln(R/a_3),$$

for monopoles with χ (+2) line and two χ (+1) lines respectively.

It is interesting to note, that by cooling the droplets with increasing of P (to value $P/R \sim 0.1$) near the cholesteric - smectic A transition we observed the effect of disappearance of χ lines: from the centres of droplets their ends have been striving to the surface, i.e. the lines "escape" in the third dimension not only

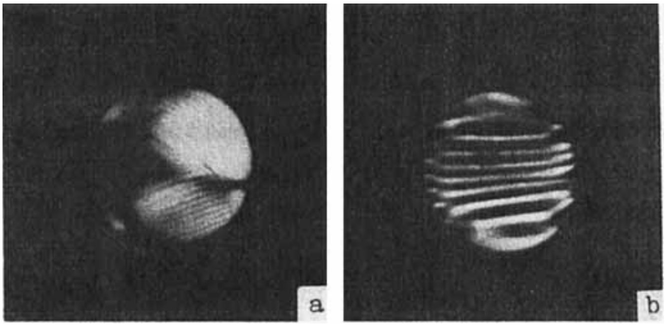

FIGURE 3 The effect of disappearance of $\chi(+2)$ line

from the nematic viewpoint[6],but from cholesteric one also (Figure 3a).Formally this is reminiscent of the transformation of monopole structure into boojum one, but boojum is not formed because of the tangential orientation of $\vec{t}$ in the vicinity of the line exit on the droplet surface.As a result of this process the structure with planar orientation of cholesteric layers is formed (Figure 3b).

So,we can make such conclusion: monopole structures both with $\chi(+2)$ and $\chi(+1)$ lines may really exist in cholesteric liquid crystals.The existence of boojum is less probable. χ lines may disappear near the cholesteric - smectic A transition.

ACKNOWLEDGEMENTS

We are grateful to I.F.Lyuksyutov,G.E.Volovick for the helpful discussions and to N.M.Golovataya, V.G.Tishchenko,A.G.Kleopov for providing us with all the materials needed for investigations.

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