

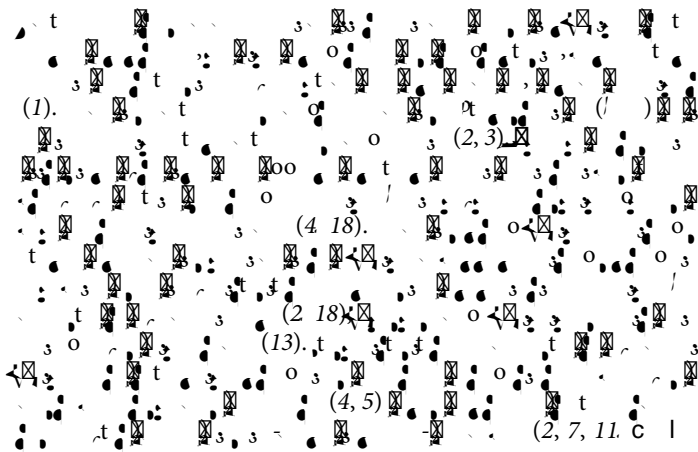
MATERIALS SCIENCE

Transformation between elastic dipoles, quadrupoles, octupoles, and hexadecapoles driven by surfactant self-assembly in nematic emulsion

Bohdan Senek¹, Ali Moaffari², Kevin Crandall¹, Rui Zhang^{2,3},
Juan J. de Pablo^{2,4*}, Ian I. Skelton^{1,5,6*}

Emulsions comprising isotropic fluid drops within a nematic host are of interest for applications ranging from biodetection to smart windows, which rely on changes of molecular alignment structures around the drops in response to chemical, thermal, electric, and other stimuli. We show that absorption or desorption of trace amounts of common surfactants can drive continuous transformations of elastic multipoles induced by the droplets within the uniformly aligned nematic host. Out-of-equilibrium dynamics of director structures emerge from a controlled self-assembly or desorption of different surfactants at the drop-nematic interfaces, with ensuing forward and reverse transformations between elastic dipoles, quadrupoles, octupoles, and hexadecapoles. We characterize inter-transformations of droplet-induced surface and bulk defects, probe elastic pair interactions, and discuss emergent prospects for fundamental science and applications of the reconfigurable nematic emulsions.

INTRODUCTION



(2, 7, 11). c l e 3 7 9 9 T w - t s (-) T j - 0 . 0

$\nabla \cdot \mathbf{t} = \rho \mathbf{a}$ (16, 31)

$\nabla \cdot \mathbf{t} = \rho \mathbf{a}$ (17, 19)

$\nabla \cdot \mathbf{t} = \rho \mathbf{a}$ (17, 18)

$\rho(\mathbf{r}) = \sum_{i=1}^N \delta(\mathbf{r} - \mathbf{r}_i)$ (7, 13, 21, 34).

Elastic adicapole i hmi edpa ch anchoring

The elastic adicapole \mathbf{h}_i is defined as the gradient of the adicapole potential $\phi(\mathbf{r})$ with respect to the position \mathbf{r} of the particle i . The adicapole potential $\phi(\mathbf{r})$ is a scalar field that represents the interaction energy between the particle and the surface. The adicapole potential is given by the following equation:

$$\phi(\mathbf{r}) = \int_V dV' \rho(\mathbf{r}') \frac{1}{|\mathbf{r} - \mathbf{r}'|} \quad (17, 19)$$

The adicapole potential is a scalar field that represents the interaction energy between the particle and the surface. The adicapole potential is given by the following equation:

$$\phi(\mathbf{r}) = \int_V dV' \rho(\mathbf{r}') \frac{1}{|\mathbf{r} - \mathbf{r}'|} \quad (17, 19, 31)$$

The adicapole potential is a scalar field that represents the interaction energy between the particle and the surface. The adicapole potential is given by the following equation:

$$\phi(\mathbf{r}) = \int_V dV' \rho(\mathbf{r}') \frac{1}{|\mathbf{r} - \mathbf{r}'|} \quad (17, 19, 31)$$

The adicapole potential is a scalar field that represents the interaction energy between the particle and the surface. The adicapole potential is given by the following equation:

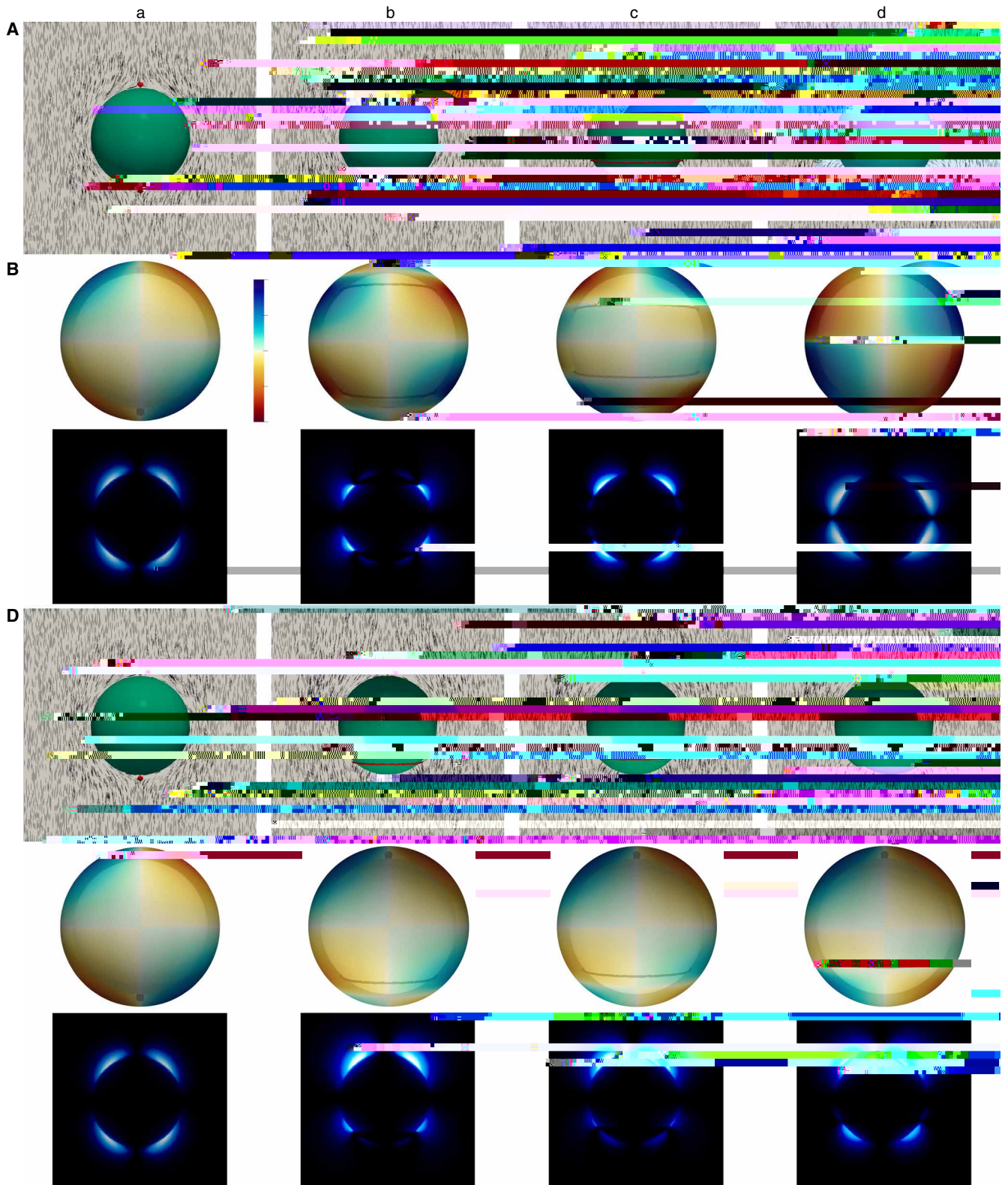
$$\phi(\mathbf{r}) = \int_V dV' \rho(\mathbf{r}') \frac{1}{|\mathbf{r} - \mathbf{r}'|} \quad (7, 25)$$

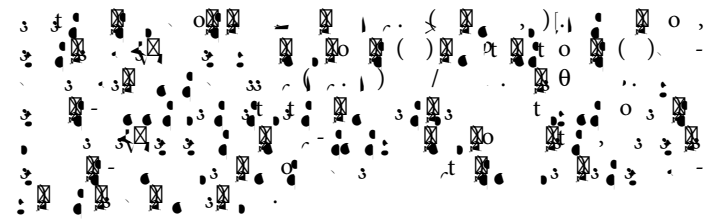
The adicapole potential is a scalar field that represents the interaction energy between the particle and the surface. The adicapole potential is given by the following equation:

$$\phi(\mathbf{r}) = \int_V dV' \rho(\mathbf{r}') \frac{1}{|\mathbf{r} - \mathbf{r}'|} \quad (7, 25)$$

The adicapole potential is a scalar field that represents the interaction energy between the particle and the surface. The adicapole potential is given by the following equation:

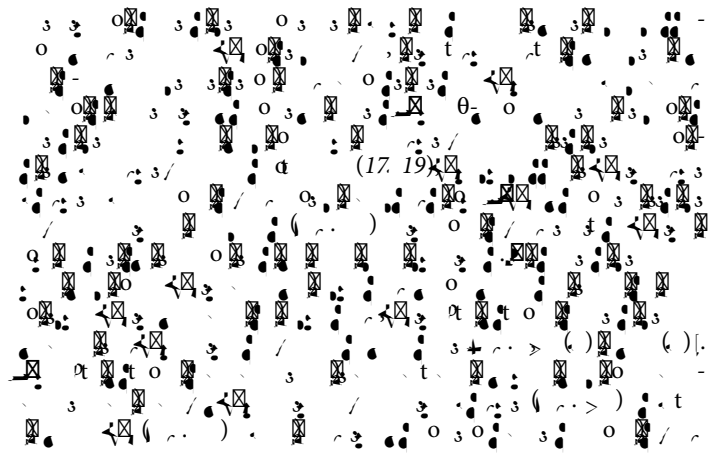
$$\phi(\mathbf{r}) = \int_V dV' \rho(\mathbf{r}') \frac{1}{|\mathbf{r} - \mathbf{r}'|} \quad (7, 25)$$

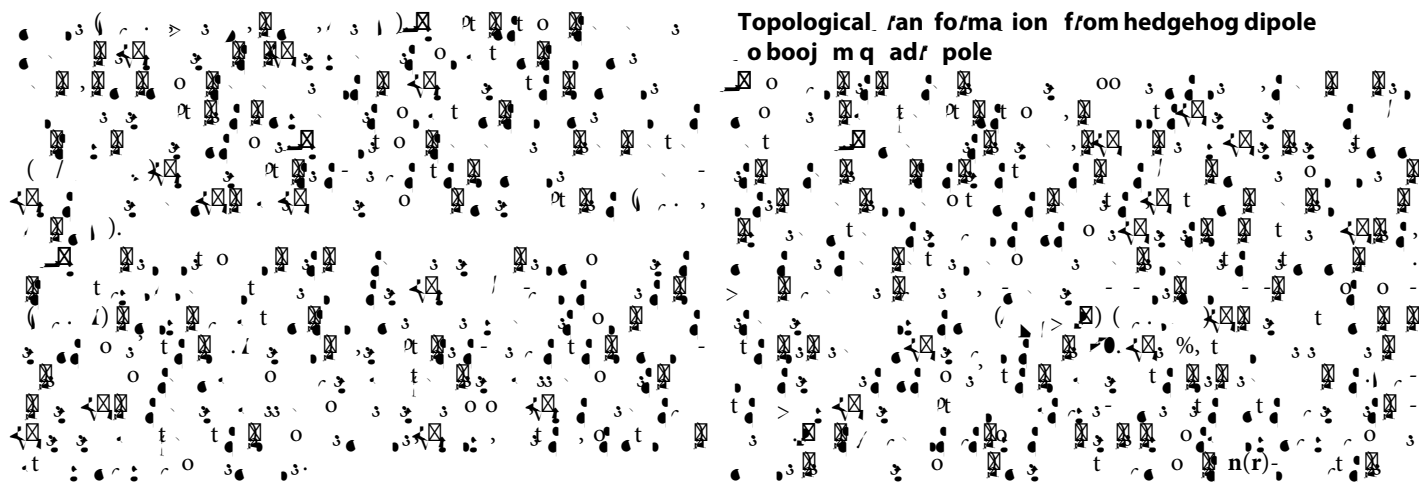
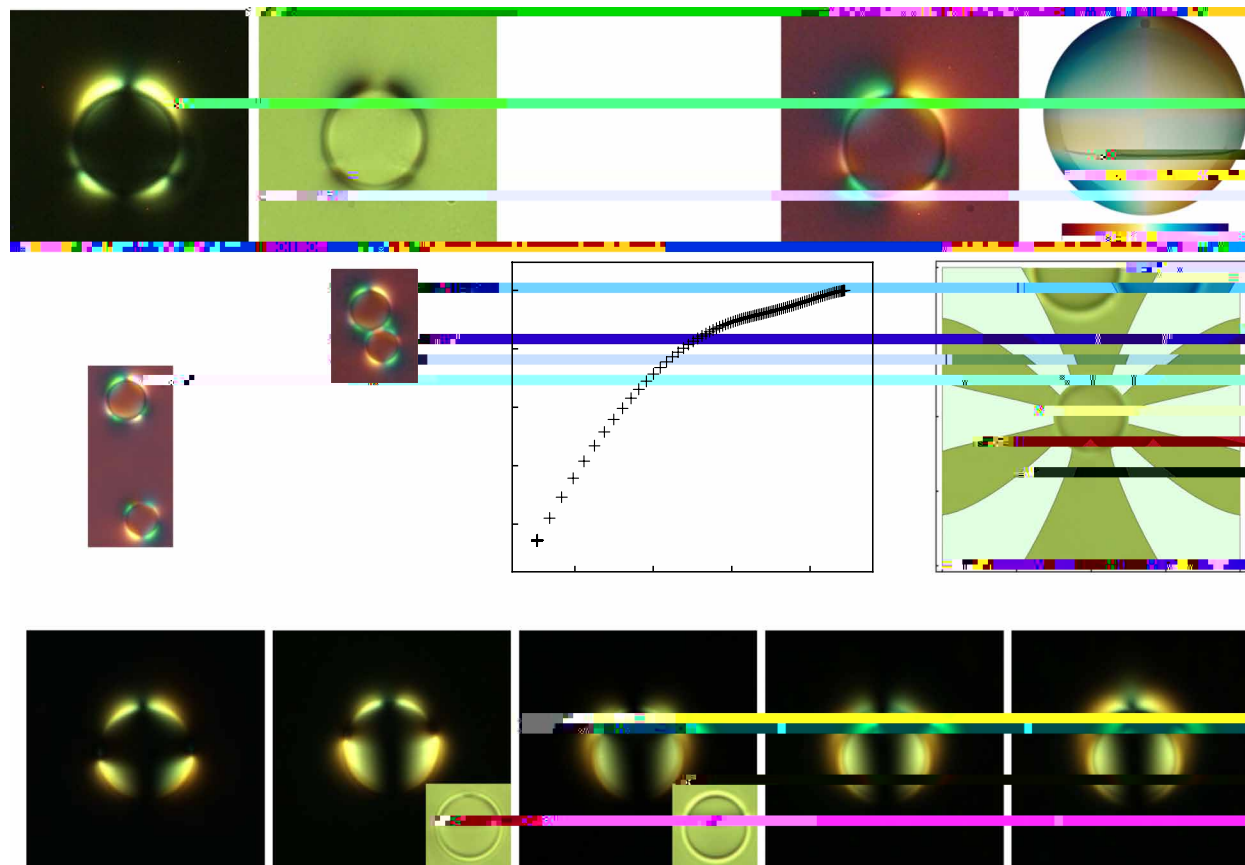


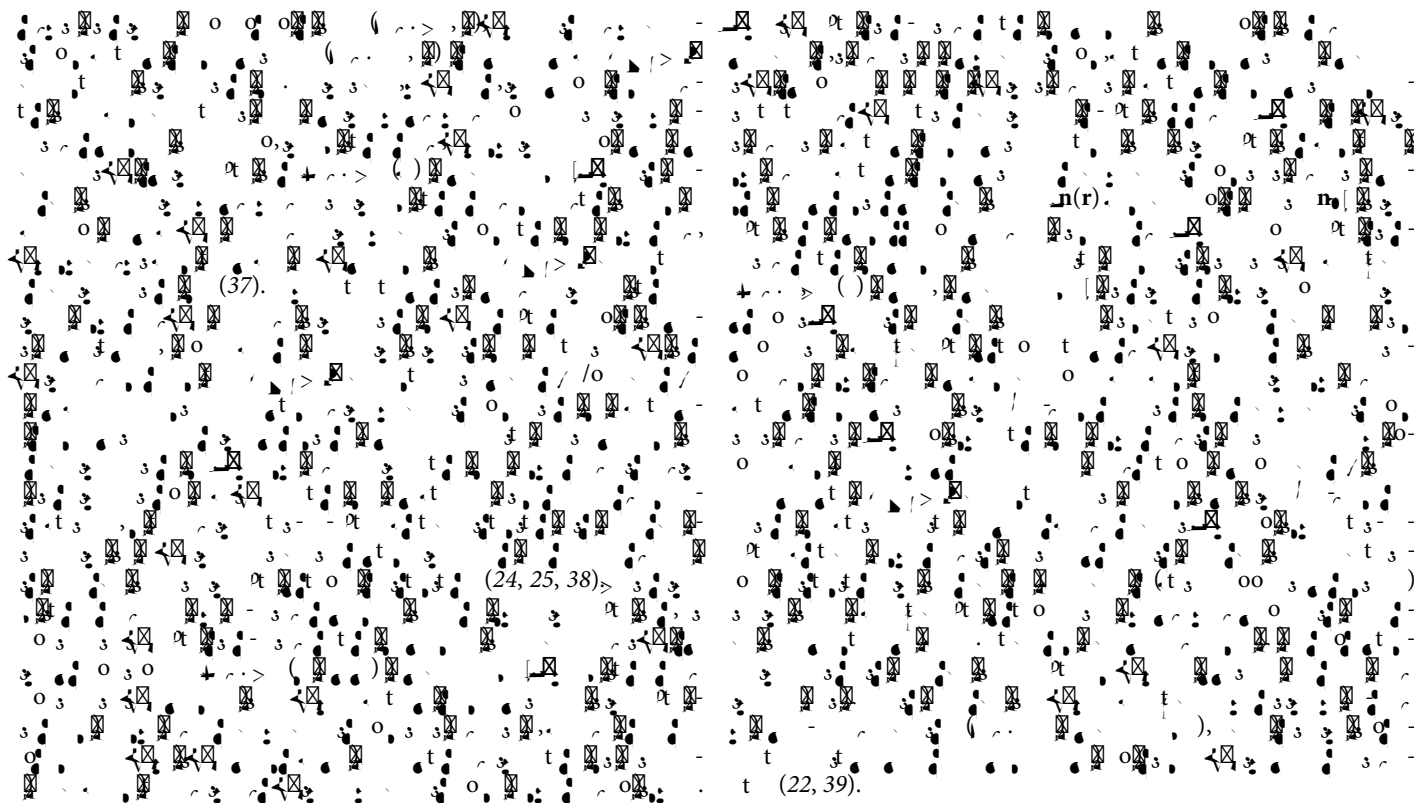
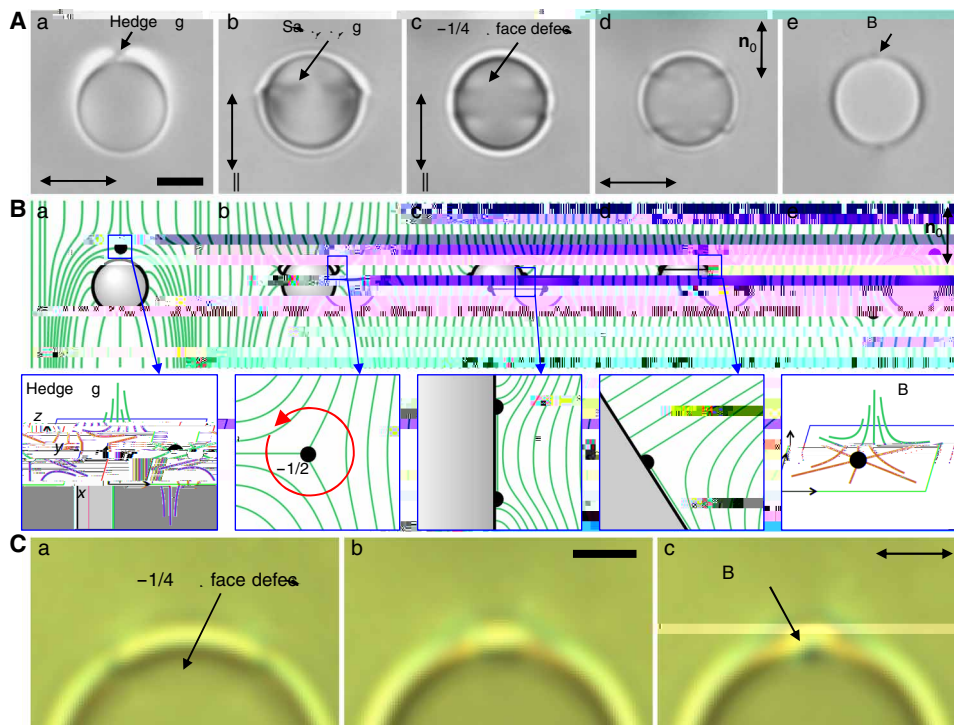


Elastic pole in helical anchoring

$$\nabla \cdot \mathbf{S} = \mathbf{f}(\mathbf{r}), \quad \mathbf{t} = \mathbf{t}(\mathbf{r})$$







MATERIALS AND METHODS

Sample preparation and imaging technique

Sample preparation and imaging technique

(13)

DISCUSSION

Discussion text containing various symbols and mathematical notations.

(13)

(4, 14, 15)

$$L \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + L \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \quad (7)$$

$$L \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + L \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \quad (8)$$

$$L \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + L \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \quad (9)$$

$$L \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \otimes A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + A_0 \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) + L \left(\begin{matrix} \cdot \\ \cdot \\ \cdot \end{matrix} \right) \quad (10)$$

27. M. Melle, S. Schlotthauer, M. G. Mazza, S. H. L. Klapp, M. Schoen, Defect topologies in a nematic liquid crystal near a patchy colloid. *J. Chem. Phys.* **136**, 194703 (2012).
28. Š. Šopar, M. Ravnik, S. Žumer, Janus nematic colloids with designable valence. *Mol. Cryst. Liq. Cryst.* **7**, 4272–4281 (2014).
29. R. Mangal, K. Nayani, Y.-K. Kim, E. Bokusoglu, U. M. Córdova-Figueroa, N. L. Abbott, Active Janus particles at interfaces of liquid crystals. *Langmuir* **33**, 10917–10926 (2017).
30. X. Wang, Y. Zhou, Y.-K. Kim, M. Tsuei, Y. Yang, J. J. de Pablo, N. L. Abbott, Thermally reconfigurable Janus droplets with nematic liquid crystalline and isotropic perfluorocarbon oil compartments. *Soft Matter* **15**, 2580–2590 (2019).
31. B. Senyuk, J. Aplinc, M.



Transformation between elastic dipoles, quadrupoles, octupoles, and hexadecapoles driven by surfactant self-assembly in nematic emulsion

Bohdan Senyuk, Ali Mozaffari, Kevin Crust, Rui Zhang, Juan J. de Pablo and Ivan I. Smalyukh

Sci Adv 7 (25), eabg0377.
DOI: 10.1126/sciadv.abg0377

ARTICLE TOOLS

<http://advances.sciencemag.org/content/7/25/eabg0377>

SUPPLEMENTARY MATERIALS

<http://advances.sciencemag.org/content/suppl/2021/06/14/7.25.eabg0377.DC1>

REFERENCES

This article cites 49 articles, 5 of which you can access for free
<http://advances.sciencemag.org/content/7/25/eabg0377#BIBL>

PERMISSIONS

<http://www.sciencemag.org/help/reprints-and-permissions>

Use of this article is subject to the [Terms of Service](#)

Science Advances (ISSN 2375-2548) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science Advances* is a registered trademark of AAAS.

Copyright © 2021 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. No claim to original U.S. Government Works. Distributed under a Creative Commons Attribution NonCommercial License 4.0 (CC BY-NC).