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Criticality and non-reciprocity of catastrophic phase inversion in emulsions

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The production of concentrated emulsions involves high-shear flows and it is well known that at a critical volume fraction the emulsion loses stability, undergoing an extremely rapid process where the continuous and dispersed phases in the emulsion exchange roles. This process, called catastrophic phase inversion, which resembles in several respects a dynamical phase transition, has remained widely elusive from an experimental and theoretical point of view. We present state-of-the-art experimental and numerical data to support a dynamical-system framework capable of precisely highlighting the dynamics occurring in the system as it approaches the catastrophic phase inversion. The study clearly highlights that at high volume fractions, dynamical changes in the emulsion morphology, due to coalescence and breakup of droplets, play a critical role in determining the emulsion rheology and stability. Additionally, we show that at approaching the critical volume fraction, the dynamics can be simplified as being controlled by the dynamics of a correlation length represented, in our systems, by the size of the largest droplet. This dynamics shares a close connection with non-reciprocal phase transition where two different physical mechanisms, coalescence and breakups, can get out of balance leading to large non-symmetric periodic excursions in phase space. We clarify the phenomenology observed and quantitatively explain the essential aspect of the highly complex dynamics of stabilized emulsions undergoing catastrophic phase inversion.

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