Nonadditivity of critical Casimir forces

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Abstract: We provide the first experimental evidence of nonadditivity for critical Casimir forces: the force that two colloidal particles exert together on a third one differs from the sum of the forces they exert separately.
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In soft condensed matter physics, effective interactions often emerge due to the spatial confinement of fluctuating fields. For instance, microscopic particles dissolved in a binary liquid mixture are subject to critical Casimir forces whenever their surfaces confine the thermal fluctuations of the order parameter of the solvent close to its critical demixing point. These forces are theoretically predicted to be nonadditive on the scale set by the bulk correlation length of the fluctuations. Here, we provide direct experimental evidence of this fact by reporting the measurement of the associated many-body effects. We consider three colloidal particles in optical traps[1] and observe that the critical Casimir force exerted on one of them by the other two differs from the sum of the forces they exert separately (Fig. 1). This three-body effect depends sensitively on the distance from the critical point and on the preference of the colloid surfaces for one of the components of the mixture[2].

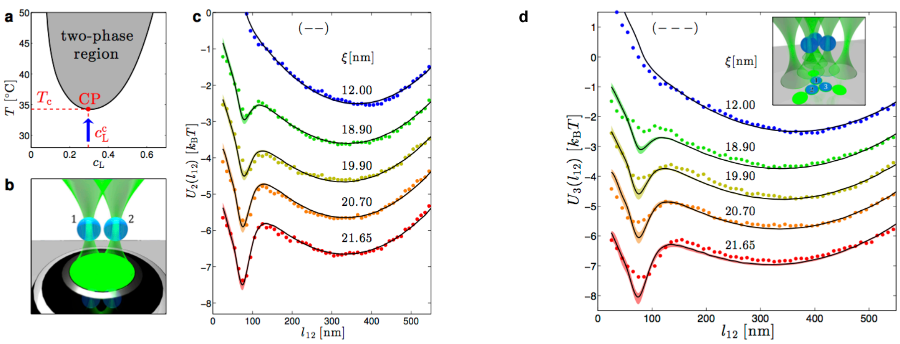

Figure 1: (a) phase-diagram of the mixture water-lutidine; (b) pictorial representation for the trapping; (c) two-body potentials as a function of the temperature; (d) two-body potentials in presence of a third near particle as a function of the temperature: experimental (dot) and simulations (line). From [2]

[1] P. H. Jones, O. M. Maragò & G. Volpe. Optical Tweezers: Principles and Applications. Cambridge University Press (2015). ISBN:9781107051164

[2] S. Paladugu, A. Callegari, Y. Tuna, L. Barth, S. Dietrich, A. Gambassi, and G. Volpe, “Nonadditivity of critical Casimir forces”, Nat. Comm. 7, 11403 (2016).