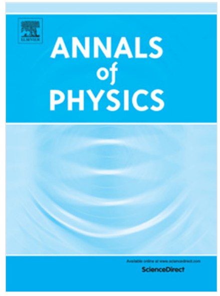
Accepted Manuscript



Anomalous elasticity, fluctuations and disorder in elastic membranes

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PII: S0003-4916(17)30253-1
DOI: http://dx.doi.org/10.1016/j.aop.2017.08.033
Reference: YAPHY 67485

To appear in: *Annals of Physics*

Received date : 22 August 2017
Accepted date : 24 August 2017

Please cite this article as: P. Le Doussal, L. Radzihovsky, Anomalous elasticity, fluctuations and disorder in elastic membranes, *Annals of Physics* (2017), http://dx.doi.org/10.1016/j.aop.2017.08.033

Anomalous elasticity, fluctuations and disorder in elastic membranes

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Motivated by freely suspended graphene and polymerized membranes in soft and biological matter we present a detailed study of a tensionless elastic sheet in the presence of thermal fluctuations and quenched disorder. The manuscript is based on an extensive draft dating back to 1993, that was circulated privately. It presents the general theoretical framework and calculational details of numerous results, partial forms of which have been published in brief Letters [1, 2]. The experimental realization atom-thin graphene sheets [3] has driven a resurgence in this fascinating subject, making our dated predictions and their detailed derivations timely. To this end we analyze the statistical mechanics of a generalized D-dimensional elastic "membrane" embedded in d dimensions using a self-consistent screening approximation (SCSA), that has proved to be unprecedentedly accurate in this system, *exact* in three complementary limits: (i) $d \to \infty$, (ii) $D \to 4$, and (iii) $D = d$. Focusing on the critical "flat" phase, for a homogeneous two-dimensional ($D = 2$) membrane embedded in three dimensions ($d = 3$), we predict its universal roughness exponent $\zeta = 0.590$, length-scale dependent elastic moduli exponents $\eta = 0.821$ and $\eta_u = 0.358$, and an anomalous Poisson ratio, $\sigma = -1/3$. In the presence of random uncorrelated heterogeneity the membrane exhibits a glassy wrinkled ground state, characterized by $\zeta' = 0.775, \eta' = 0.449, \eta'_u = 1.101$ and a Poisson ratio $\sigma' = -1/3$. Motivated by a number of physical realizations (charged impurities, disclinations and dislocations) we also study power-law correlated quenched disorder that leads to a variety of distinct glassy wrinkled phases. Finally, neglecting self-avoiding interaction we demonstrate that at high temperature a "phantom" sheet undergoes a continuous crumpling transition, characterized by a radius of gyration exponent, $\nu = 0.732$ and $\eta = 0.535$. Many of these universal predictions have received considerable support from simulations. We hope that this detailed presentation of the SCSA theory will be useful to further theoretical developments and corresponding experimental investigations on freely suspended graphene.

Contents

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