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Statistical mechanics of microscopically thin thermalized shells

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Recent explosion in fabrication of microscopically thin free standing structures made from graphene and other two-dimensional materials has led to a renewed interest in the mechanics of such structures in presence of thermal fluctuations. Since late 1980s it has been known that for flat solid sheets thermal fluctuations effectively increase the bending rigidity and reduce the bulk and shear moduli in a scale-dependent fashion. However, much is still unknown about the mechanics of thermalized flat sheets of complex geometries and about the mechanics of thermalized shells with non-zero background curvature. In this talk I will present recent development in the mechanics of thermalized ribbons, spherical shells and cylindrical tubes. Long ribbons are found to behave like hybrids between flat sheets with renormalized elastic constants and semi-flexible polymers, and these results can be used to predict the mechanics of graphene kirigami structures. Contrary to the anticipated behavior for ribbons, the non-zero background curvature of shells leads to remarkable novel phenomena. In shells, thermal fluctuations effectively generate negative surface tension, which can significantly reduce the critical buckling pressure for spherical shells and the critical axial load for cylindrical tubes. For large shells this thermally generated load becomes big enough to spontaneously crush spherical shells and cylindrical tubes even in the absence of external loads. I will comment on the relevance for crushing of microscopic shells (viral capsids, bacteria, microcapsules) due to osmotic shocks and for crushing of nanotubes.