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Emergent phenomena in mesoscopic nuclear systems

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For the lightest nuclei numerical solutions of few-body problem are constructed with increasing accuracy. The theory focuses on finding the correct nucleon-nucleon interaction and an accurate description of the individual nucleonic motion. Such approach becomes quickly intractable with increasing particle number. On the other hand, certain simple features begin to emerge, which reflect collective properties of many nucleons. Some of them become familiar macroscopic properties as compressibility, surface tension, viscosity, heat capacity, entropy when the particle number becomes very large. Phase transitions or hydrodynamic behavior may develop in this limit. Other features, as shell structure or rotational bands, remain mesoscopic, i.e. they are only important up to not too large a number of particles. Since these emergent phenomena are not sensitive to the details of the interactions between the constituent particles, they may appear in non-nuclear mesoscopic systems quite analogous to nuclei. Fluctuations of the average quantities become very important in the mesoscopic regime, which may lead to qualitatively new behavior. The nuclei that can be studied experimentally are essentially mesoscopic in nature. Strong fluctuations combined with a pronounced shell structure restrict the accuracy with which the macroscopic properties of neutron matter can be determined from finite nuclei. However macroscopic characteristics as compressibility, binding energy, and symmetry energy of neutron matter determine the properties of neutron stars.