

Fragmentation in the region of nuclear surface

V. G. Kartavenko K. A. Gridnev W. Greiner

Institut für Theoretische Physik, J. W. Goethe Universität, Frankfurt am Main

Recent progress in modern experimental techniques gives new experimental data confirming that the following collective modes: heavy cluster radioactivity, bimodal fission, cold fission, and inverse processes, such as (subbarrier) fusion, could belong to the general phenomena of cold nuclear fragmentation (See e.g. Proceedings [1]). Cold fragmentation leads to the large density redistribution and indicates the formation of a binary or possibly multi-center quasistationary nuclear systems, which lives $\sim 10^{-21}$ sec without reaching statistical equilibrium. Fragmentation in the surface and between nuclear surfaces, especially the neck region, is the object of a special interest. Nuclear scission can be described by random neck rupture, which could be traced back to a series of instabilities. Nuclear density falls considerably down in the region of nuclear surface. This fact is very important due to the possibility of clustering and other fluctuations of the nuclear density leading to instability in the surface region.

Dynamics of shapes of any complicated systems inevitably leads to mathematical problem to describe global geometric quantities such as the surface and the enclosed volume in different dimensions (polymer, cell membranes, 3D droplets etc.). The important feature of nonlinear dynamics is, that after scale transformations the same dimensionless nonlinear differential equations, which can be used in the very different micro and macro systems. We suggested the general formalism to describe the nonlinear evolution of the nuclear surface without the usual additional assumptions about the shape of a nuclear system [2]. An uniformly charged incompressible nuclear fluid bounded by a closed axisymmetric surface $\Gamma(\vec{r}, t) \equiv \sigma - P(z, t) = 0$, $\vec{r} = (\sigma, \phi, z)$ was considered. A nonlinear integro-differential equation for the contour $P(z, t)$ was derived. It was shown the direct correspondence between $P(z, t)$ and a local curvature, that gave possibility to use methods of differential geometry to analyse an evolution of an axisymmetric nuclear surface.

In the framework of nonlinear quantum hydrodynamics we formulated new approach to describe evolution of a localized density fluctuation in the region of nuclear surface [3]. The general quantum scheme to analyse the large amplitude vibrational and vortical modes and their coupling is given. In the semiclassical limit one derives the semi hydrodynamical equations of motion, allowing to use the existing codes. The initial conditions has been formulated. The preliminary numerical results has been presented recently [3]. The problem of dynamical instability and clustering (stable fragments formation) in a breakup of excited nuclear systems are considered from the points of view of the soliton concept [4]. It is shown that the volume (spinodal) instability can be associated with nonlinear terms, and the surface (Rayleigh-Taylor type) instability, with the dispersion terms in the evolution equations. The both instabilities may compensate each other and lead to stable solutions (solitons). A static scission configuration

in cold ternary fission is considered in the framework of mean field approach. We suggest to use the inverse mean field method to solve single-particle Schrödinger equation, instead of constrained selfconsistent Hartree-Fock equations. It is shown, that it is possible to simulate one-dimensional three-center system in the approximation of reflectless single-particle potentials.

The analogy between fragmentation into parts of nuclei and buckyballs has led us to the idea of light nuclei as quasi-crystals. We established that the quasi-crystalline structure can be formed when the distance between the alpha-particles is comparable with the length of the De Broglia wave of the alpha-particle [5]. Applying this model to the scattering of alpha-particles we obtain that the form factor of the clusterized nucleus can be factorized into the formfactor of the cluster and the density of clusters in the nucleus. It gives possibility to study the distribution of clusters in nuclei and to resolve what kind of distribution we are dealing with: a surface or volume one [6].

The investigation of fragmented cluster states in light nuclei leads us to the Bose-Einstein condensate of α -particles and to its description with the help of Gross-Pitaevsky equation. The last equation has also a vortex solution. We found that candidates for the vortex states in ^{12}C may be 0_2^+ and 2_1^+ states [6].

References

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