Some arguments for the need of exascale computing for nuclear structure and reactions and for a comprehensive many-body approach to fermionic superfluid phenomena in general (nuclei, neutron stars, condensed matter systems, cold atom in traps)

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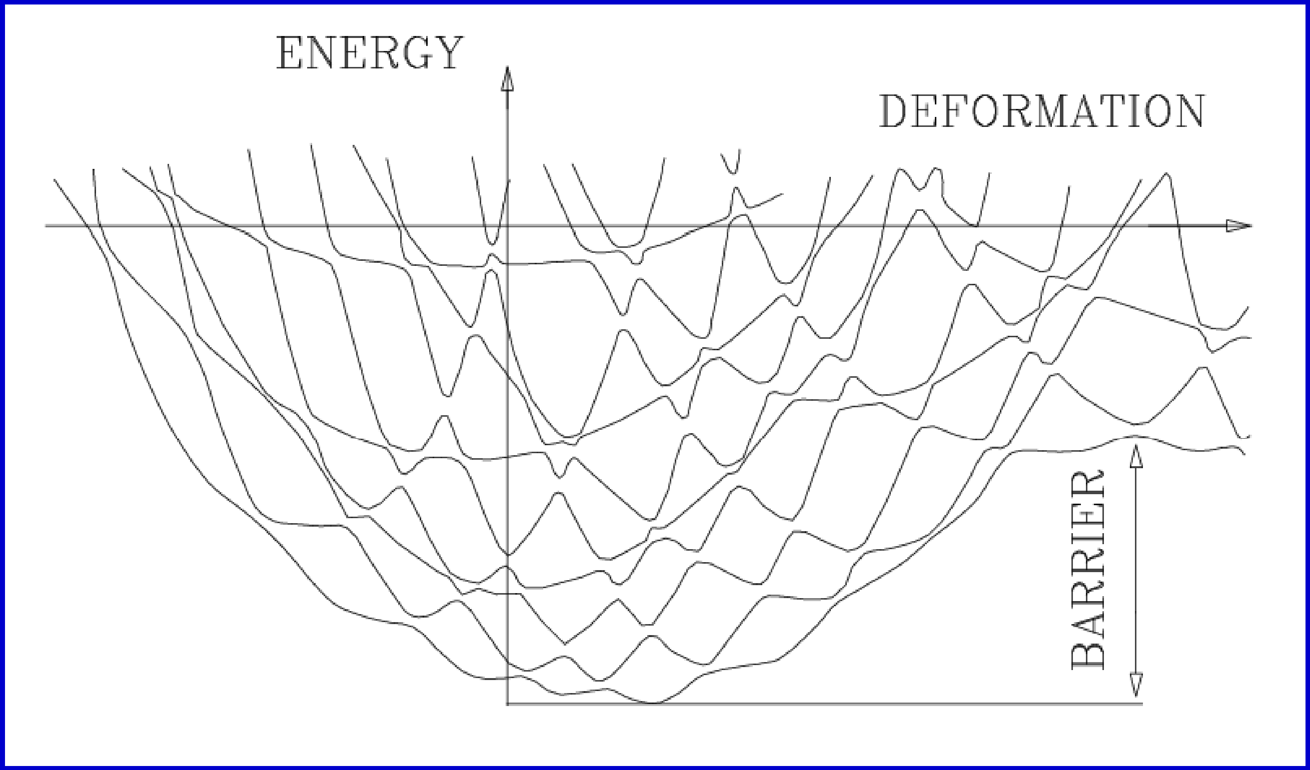
To boldly go where no man has gone before

There are two obvious ways to think of using more powerful computers:

- **<u>Incremental</u>: consider problems and systems of increased size and increase the number of cases studied – size really matters a great deal**

- **<u>Quantum jump</u>: generate a qualitatively new approach and a qualitatively new set of problems – new quality matters even more**

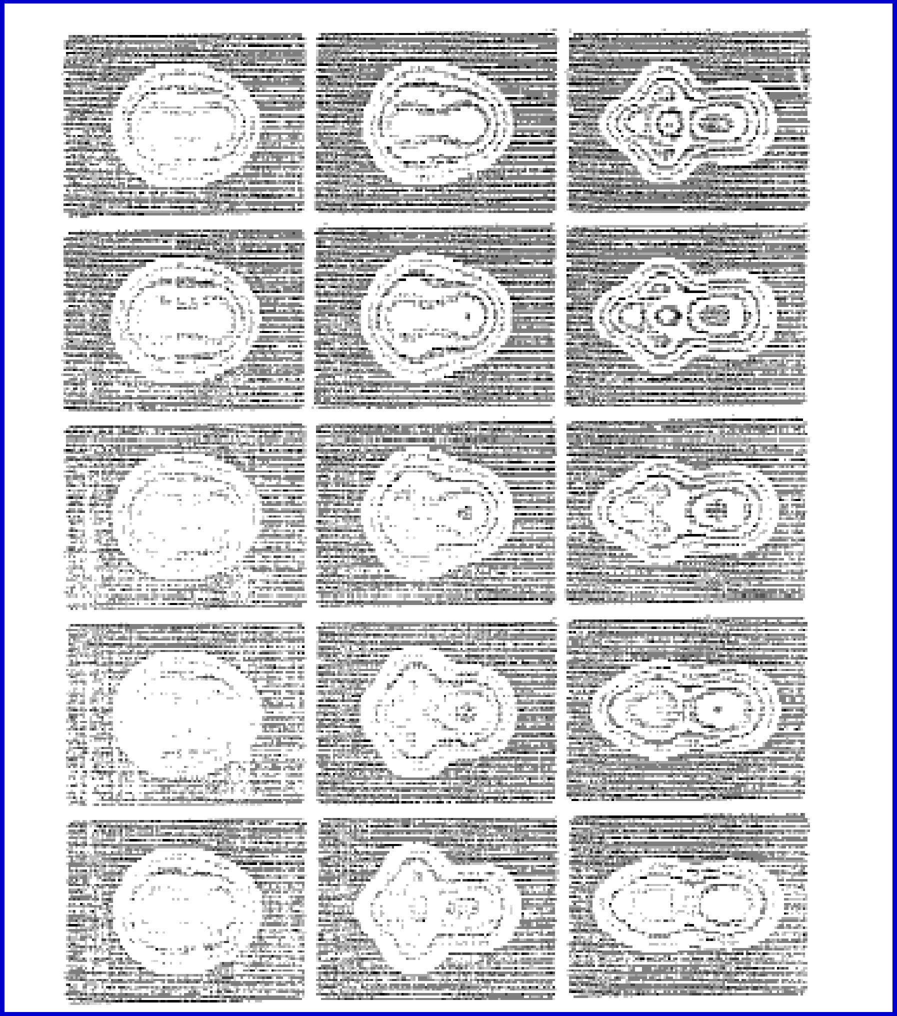
Generic adiabatic large amplitude potential energy <u>SURFACES</u>



- **In LACM adiabaticity is not a guaranteed**
- **Level crossings are a great source of :**

  entropy production (dissipation)
  dynamical symmetry breaking
  non-abelian gauge fields

``Spontaneous fission" of ^{32}S



J.W. Negele, Nucl. Phys. A 502, 371c (1989)
An unpublished calculation due to R. Wolff, G. Puddu and J.W. Negele

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- 8 occupied orbitals evolved in 3D and imaginary time on a mesh 20^3x1000
- no isospin dof, no pairing, simplified nuclear EDF

Stochastic Time-Dependent Superfluid Local Density Approximation

A traditional approach to LACM within a typical collective description (ATDHF, GCM, CC, etc.) is both unreasonable in a large collective space and insufficient on physics grounds

In order to allow full dynamics on many energy surfaces, onset of entropy production in the simplest realization one has to introduce a stochastic element

- **3D spatial lattice $N_s^3=100^3$**
- **Number of time steps $N_t=10^4 \ldots 10^6$**
- **Number of orbitals $O(N_s^3)=10^6$ on $O(N_s^3)=10^6$ spatial mesh points**
- **Memory requirements 100 x $O(N_s^6)= 10^{14}$**
- **Number of stochastic field realizations $10^3 \ldots 10^6$**
- **Total number of floating point operations per nucleus $\underline{10^{18} \ldots 10^{21}}$**

Stochastic Time-Dependent Superfluid Local Density Approximation

This is a general many-body problem with direct applications in:

- **Nuclear physics: fission, heavy-ion collision, nuclear reactions**
- **Neutron star crust, dynamics of vortices, vortex pinning mechanism**
- **Cold atom physics**
- **Condensed matter physics**
- **Time dependent response of superfluid fermionic systems to a large variety of external probes**