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:

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

- **Quantum jump**: generate a qualitatively new approach and a qualitatively new set of problems – new quality matters even more.
• 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

An unpublished calculation due to R. Wolff, G. Puddu and J.W. Negele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 $20^3 \times 1000$
- 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 $100 \times O(N_s^6) = 10^{14}$
- Number of stochastic field realizations $10^3 \ldots 10^6$
- Total number of floating point operations per nucleus $10^{18} \ldots 10^{21}$
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