RIKEN-Tsukuba Collaboration

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LIA-EFES workshop on Nuclear energy functional method, 2010.2.26-27

RIKEN-TSUKUBA, RIKEN-Niigata

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Multi-reference EDF

Projection & Config. Mixing in 3D real space representation

Time-dependent energy-density-functional method (TD-EDF)

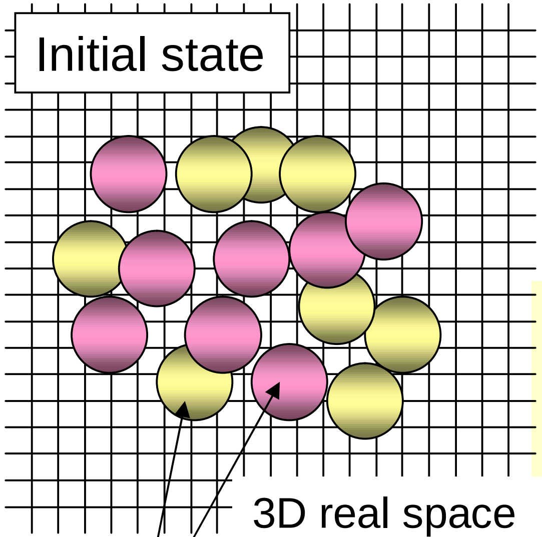
Real-time approaches

- Skyrme-TDHF in 3D real space
- Canonical-basis TDHFB in 3D real space (Ebata)
- Gogny-TDHFB in 3D harmonic oscillator basis (Hashimoto)

RPA, QRPA

- Skyrme QRPA with axially deformed nuclei (Yoshida)
- Finite amplitude method for RPA in 3D real space (Inakura)
- Finite amplitude method for QRPA (Avogadro)

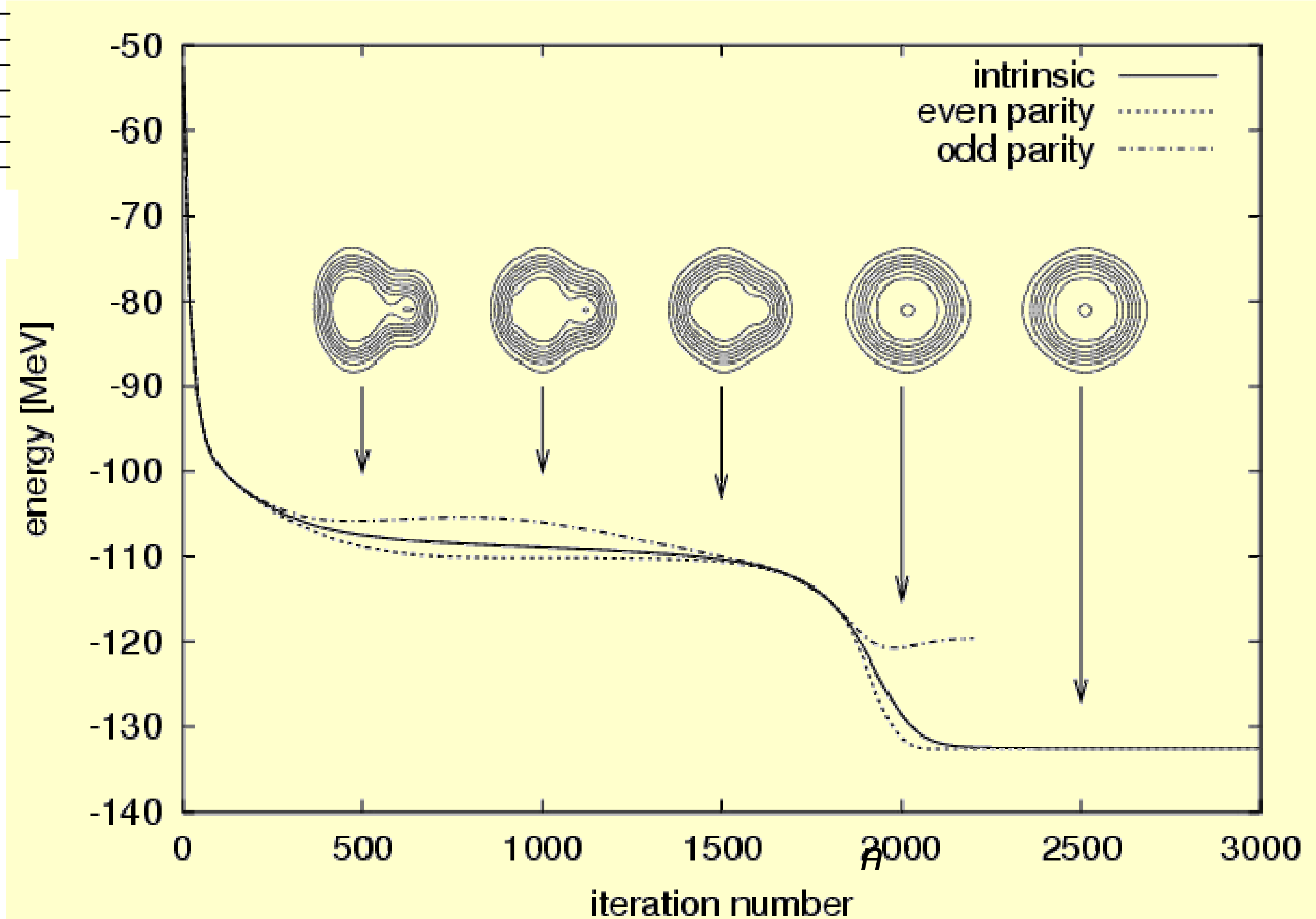
Generation of many S-det's



Gaussian wave packets (n & p) whose positions are determined by random numbers.

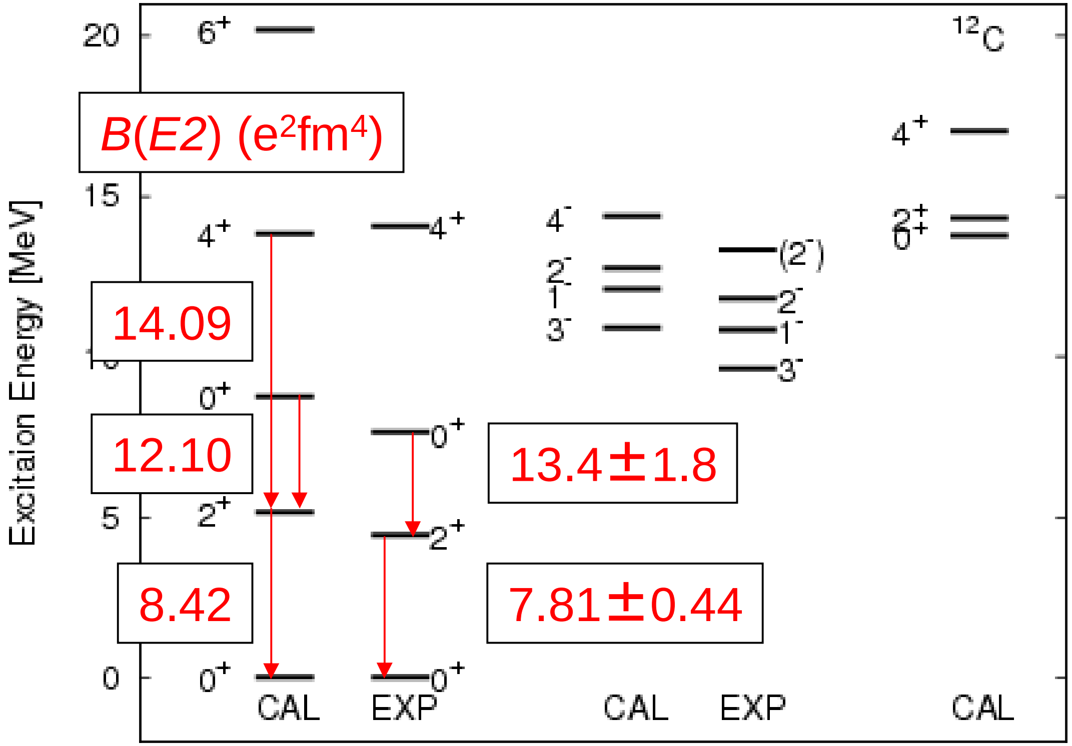
$$\left|\phi_i^{(n+1)}\right\rangle = e^{-\Delta t\, h[\rho]}\left|\phi_i^{(n)}\right\rangle, \quad i = 1, \cdots A$$

Imaginary-time evolution



SGII

Energy spectrum in ^{12}C



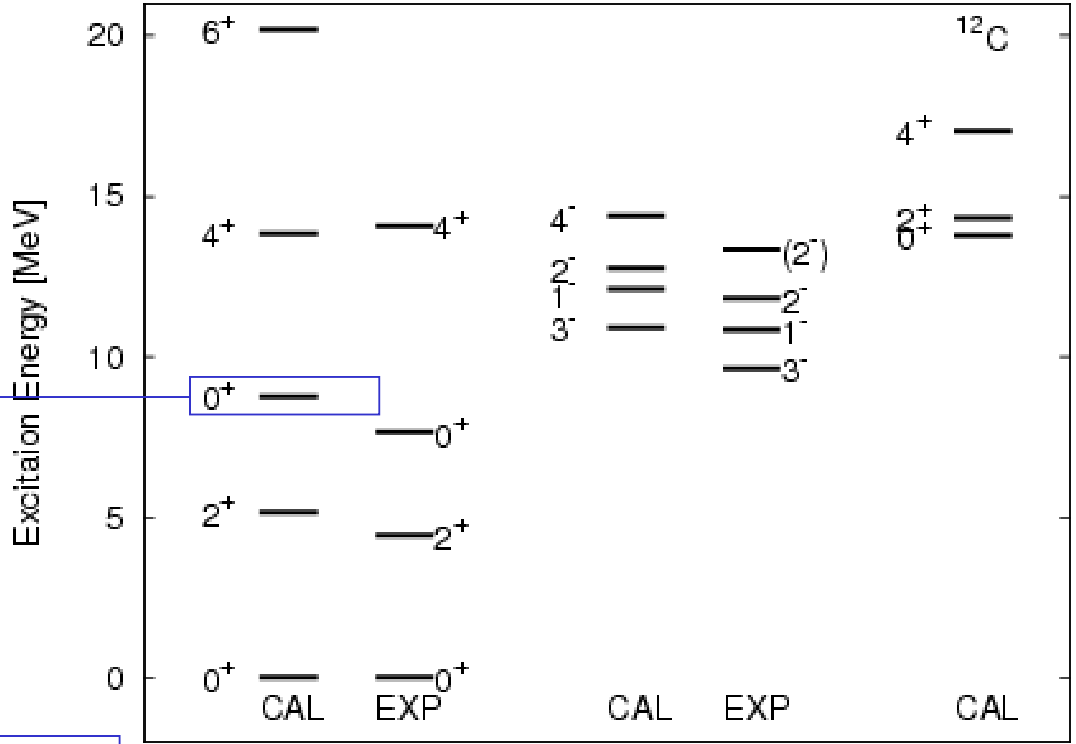
Similar results:

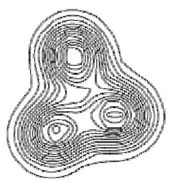
Kanada-En'yo (AMD+VAP), PRL81 (1998) 5292

Neff & Feldmeier (FMD+GCM), NPA738 (2004) 357

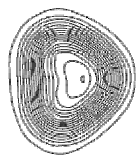
Energy spectrum in ^{12}C

SGII

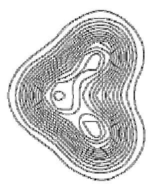




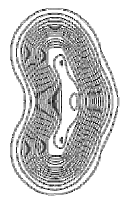
second 0^+: 42.4%



ground 0^+: 94.8%

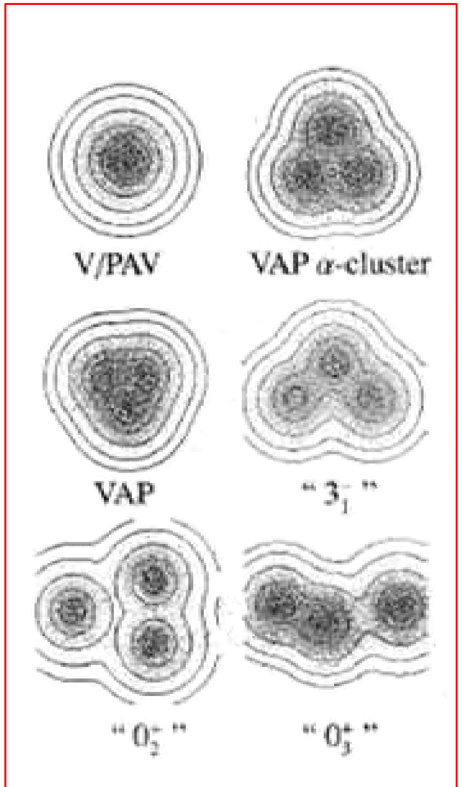


3^-: 78.7%



third 0^+: 62.1%

T. Neff et al. (2004)



Skyrme TDDFT in real space

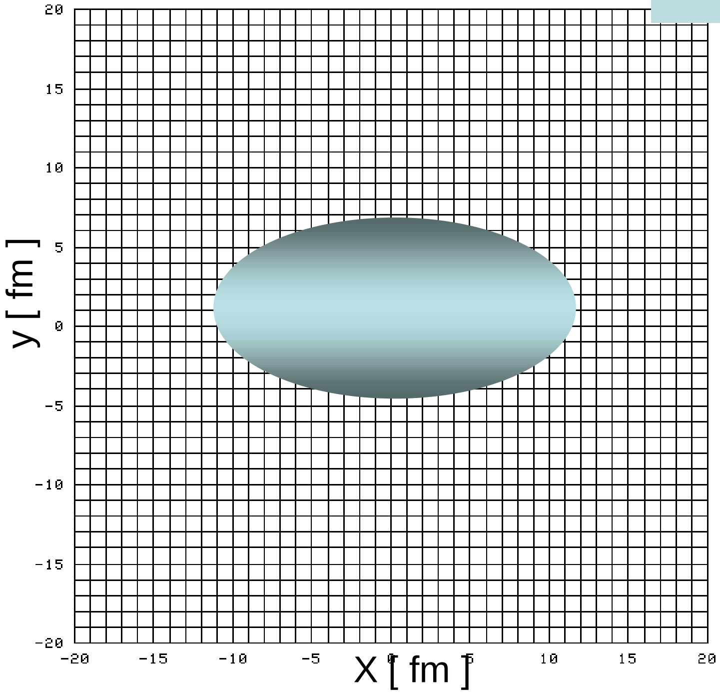
Time-dependent Kohn-Sham equation

$$- i \tilde{\eta}(r)$$

$$i \frac{\partial}{\partial t} \psi_i(\mathbf{r}\sigma\tau, t) = \left(h_{KS}[\rho, \tau, \mathbf{j}, \mathbf{s}, \overleftrightarrow{\mathbf{J}}](t) + V_{ext}(t) \right) \psi_i(\mathbf{r}\sigma\tau, t)$$

3D space is discretized in lattice

Single-particle orbital: $\varphi_i(\mathbf{r}, t) = \{\varphi_i(\mathbf{r}_k, t_n)\}_{k=1,\cdots Mr}^{n=1,\cdots Mt}, \quad i = 1, \cdots, N$



N: Number of particles

Mr: Number of mesh points

Mt: Number of time slices

Spatial mesh size is about 1 fm.

Time step is about 0.2 fm/c

Nakatsukasa, Yabana, Phys. Rev. C71 (2005) 024301

Inclusion of pairing (superfluidity)

- Simple formulation in Canonical basis
  - Canonical-basis TDHFB (→ Ebata)
  - Simultaneous equations for canonical states and (u,v)-factors
  - Special pairing functional only
- TDHFB
  - Gogny in 3D harmonic-oscillator basis (→ Hashimoto)
  - Linear-response and non-linear dynamics

Finite Amplitude Method

T.N., Inakura, Yabana, PRC76 (2007) 024318.

A method to avoid the explicit calculation of the residual fields (interactions)

$$\omega \left| X_i(\omega) \right\rangle = \left(h_0 - \varepsilon_i \right) \left| X_i(\omega) \right\rangle + \hat{Q} \left\{ \delta h(\omega) + V_{\text{ext}}(\omega) \right\} \left| \phi_i \right\rangle$$
$$\omega \left\langle Y_i(\omega) \right| = -\left\langle Y_i(\omega) \right| \left(h_0 - \varepsilon_i \right) - \left\langle \phi_i \right| \left\{ \delta h(\omega) + V_{\text{ext}}(\omega) \right\} \hat{Q} \qquad (1)$$

Residual fields can be estimated by the finite difference method:

$$\delta h(\omega) = \frac{1}{\eta} \left(h\left[\left\langle \psi' \right|, \left| \psi \right\rangle \right] - h_0 \right)$$
$$\left| \psi_i \right\rangle = \left| \phi_i \right\rangle + \eta \left| X_i(\omega) \right\rangle , \quad \left\langle \psi_i' \right| = \left\langle \phi_i \right| + \eta \left\langle Y_i(\omega) \right|$$

Starting from initial amplitudes $X^{(0)}$and $Y^{(0)}$, one can use an iterative method to solve eq. (1).

Programming of the RPA code becomes very much trivial, because we only need calculation of the single-particle potential, with different bras and kets.

Developments in FAM

- Large-scale linear response calculation (→ Inakura)
- Extension to QRPA (→ Avogadro)

Other participants

- Masaaki Kimura (Hokkaido)
  - Anti-symmetrized Molecular Dynamics + HFB
- Hitoshi Nakada (Chiba)
  - Gogny-HFB, RPA, with gaussian basis
  - M3Y-HFB