GT3 – Quelles sont les nouvelles frontières dans la description microscopique des noyaux ?

Saclay meeting – November 12-13 2018

Program – First day

- **Interdisciplinary aspects of the many-body problem**
- **7 review talks**
  - 3 nuclear physics
  - 2 cold atoms
  - 1 quantum chemistry
  - 1 condensed matter

Monday November 12

09h30-10h15 Status and perspectives in the modelling of nuclear interactions (H.-W. Hammer)

10h15-10h45 Coffee

10h45-11h30 Recent progress and open questions in ab initio simulations of nuclei (V. Somà)

11h30-12h15 Equation of state of nuclear matter: ab initio versus EDF approaches (D. Lacroix)

12h15-13h00 Ultra-cold fermion gases: status and perspectives (C. Salomon)

13h00-14h00 Lunch

14h00-14h45 Cold bosonic few- and many-body systems (D. Petrov)

14h45-15h30 Molecular systems: status and perspectives of ab initio calculations (E. Giner)

15h30-16h00 Coffee

16h00-16h45 Many-body calculations of condensed matter systems (L. Reining)

Program – Second day

- **7 focused talks**
  - Ab initio reaction theory
  - Energy density functional
  - Effective field theory
  - Non-empirical shell model
  - Microscopic optical potential
  - Energy production
- **Discussion on challenges in many-body theories**

Tuesday November 13

09h00-09h35 Selected outcomes from ab initio methods for reactions and weakly-bound nuclei (G. Hupin)

09h35-10h10 Relativistic range-separated density-functional theory (J. Paquier)

10h10-10h30 Coffee

10h30-11h05 Parametrizing the nuclear EDF: the troubles with and without density dependences (M Bender)

11h05-11h40 Few nucleons near unitarity (S. Koenig)

11h40-12h15 Microscopic effective interactions for the sd shell from no-core shell model (N. Smirnova)

12h15-14h00 Lunch

14h00-14h35 Microscopic optical potentials for nucleon-nucleus scattering (G. Blanchon)

14h35-15h10 Role of electronic interactions on properties of actinides (B. Amadon)

15h10-15h30 Coffee

15h30-16h30 Discussion: Challenges in many-body theories

Main points requiring efforts/of potential inter-disciplinary interest

1. **How to best solve the static A-body Schroedinger equation for doubly open-shell/heavier (A>100) nuclei?**

2. **How to go about improving inter-nucleon interactions?**

3. **How about pushing reaction theory**

4. **How to expand the nuclear EDF method to make it a systematically improvable method?**

5. **How/where to cross benefit from cold atoms/quantum chemistry/condensed matter?**

- ❑ **Excellent feedback from participants**
- ❑ **Interdisciplinary character particularly praised ► already leading to explicit future connections**

1. **How to best solve the static A-body Schroedinger equation for doubly open-shell/heavier (A>100) nuclei?**
   - Strong (non-dynamical) correlations: multi-reference vs symmetry breaking & restoration MBPT/CC/SCGF/IMSRG?
   - Detailed features/spectroscopy: best truncation schemes?
   - Heavier: storage/CPU reduction when dealing with $N^{4,6}$ tensors/$N^{7,8}$ sums with N~1000s?

2. **How to go about improving inter-nucleon interactions?**
   - What are calculations without error bars for a « NxLO (539.951437) + NyLO (457.33333) » type chiral potential telling us?
   - Isn't it time to check whether « leading order » is leading, and a systematic improvement is achieved at high orders?
   - Is there evidence for significant regulator effects? If so, should we continue to play the game of finding the « best » regulator? How is that different to comparing, say, the AV18 and Bonn potentials?
   - Existing solutions require perturbative treatment of corrections. Can this be implemented in existing many-body methods? Shouldn't we try with NCSM to go test these solutions accross p-shell nuclei?

3. **How about pushing reaction theory**

- Beyong p-shell nuclei in an ab initio fashion?
- In heavy nuclei?
- Want to predict: use « best » chiral potential, but error? How is that different from any model?
- Can Halo EFT help? « Hybrid approach »?
- « The relevant model which aims at describing excited states should be unitary already at and above the first particle emission threshold. If for some reason it is not the case, arguments should be put forward to explain why unitarity could be neglected. »   (Marek Ploszajczak)

4. How to expand the nuclear EDF method to make it a systematically improvable method?

- No spuriosity in multi-reference calculations?
- Connection to ab initio calculations/exact known limits/quantum simulators?
- How about formulating it as a proper effective theory (which DOFs? Which PC?)?

5. **How/where to cross benefit from cold atoms/quantum chemistry/condensed matter?**
   - Old Bertsch problem: shouldn't we hone our many-body methods for the simplest case, two-state fermions at unitarity, and compare with atomic experiment?
   - Few-neutron resonances need clarification!
   - Salomon's sword: what kind of atomic experiments would be most desirable to learn about nuclear physics?
   - What can we learn from bosonic atoms?
   - Multi-reference vs symmetry breaking & restoration methods (quantum chemistry)?
   - Best truncation schemes for detailed spectroscopy (condensed matter)?