Report on *some* of the UNEDF work performed by the UW centered group

A. Bulgac, Y.-L. (Alan) Luo, P. Magierski, K.J. Roche, I. Stetcu, S. Yoon

*J.E. Drut, M.M. Forbes, G. Wlazłowski*  *(none UW UNEDF funded)*

See also talks of P. Magierski, K.J. Roche and I. Stetcu
One of the last year’s UNEDF achievements:

Two independent *ab initio* calculations of the pairing gap in dilute fermion matter
THE HERMANN KÜMMEL EARLY ACHIEVEMENT AWARD IN MANY-BODY PHYSICS

The International Advisory Committee of the International Conferences Series on Recent Progress in Many-Body Theories is pleased to announce that the HERMANN KÜMMEL EARLY ACHIEVEMENT AWARD IN MANY-BODY PHYSICS in 2009 is awarded to

Dr. Joaquin E. Drut, Ohio State University, Columbus, U.S.A.

"For establishing the thermodynamic and pairing properties of a dilute spin-1/2 Fermi gas in the unitary regime using Quantum Monte Carlo and Field Theory methods."

This award honors Prof. Kümmler's long and distinguished career as a leader in the field of many-body physics and as a mentor of younger generations of many-body physicists. This inaugural award will be presented to Dr. Drut at the 15th International Conference on Recent Progress in Many-Body Theories, to be held in Columbus, USA, 27-31 July 2009.

Joaquin also received the 2009 Henderson prize for the best PhD thesis in the UW Department of Physics
The *ab initio* calculation of the spectral weight function, quasi-particle spectrum and its properties at finite T’s.

P. Magierski, G. Wlazlowski, A. Bulgac and J.E. Drut
All these modes have a very low frequency below the pairing gap and a very large amplitude and excitation energy as well. None of these modes can be described either within Quantum Hydrodynamics or Landau-Ginzburg like approaches.

Bulgac and Yoon, Phys. Rev. Lett. 102, 085302 (2009)
3D unitary Fermi gas confined to a 1D HO potential well (pancake)

New qualitative excitation mode of a superfluid Fermi system (non-spherical Fermi momentum distribution)

Black solid line – Time dependence of the cloud radius
Black dashed line – Time dependence of the quadrupole moment of momentum distribution

Bulgac and Yoon, Phys. Rev. Lett. 102, 085302 (2009)
Vortex generation and dynamics (Alan Luo)

See movies at

http://www.phys.washington.edu/groups/qmbnt/vortices_movies.html

Ionel Stetcu will show tomorrow night movies of real time 3D dynamics of superfluid nuclei
A refined EOS for spin unbalanced systems

Red line: Larkin-Ovchinnikov phase
Black line: normal part of the energy density

\[ E(n_a, n_b) = \frac{3}{5} \frac{(6\pi^2)^{2/3} \hbar^2}{2m} \left[ n_a g \left( \frac{n_b}{n_a} \right) \right]^{5/3} \]

A Unitary Fermi Supersolid: the Larkin-Ovchinnikov phase

Bulgac and Forbes

\[
P[\mu_a, \mu_b] = \frac{2}{30\pi^2} \left( \frac{2m}{\hbar^2} \right)^{3/2} \left[ \mu_a h \left( \frac{\mu_b}{\mu_a} \right) \right]^{5/2}
\]
Summary of results:
• Implemented nuclear version of the TD-SLDA code
• Implemented the initial conditions into TD-SLDA, for now from HFBRAD only
• Performed extensive testing of the TD-SLDASA code under 1D, 2D and 3D conditions
• Parallel version of the code scales essentially perfectly (see talk of Kenny Roche) on various architectures
• Developed a 1D and 2D DVR solvers, and the 3D solver is close to completion (see talk of P. Magierski)
• Established a number of new physical results: Higgs pairing mode in unitary gas, unitary Fermi supersolid, pseudo-gap (2 published PRLs and one submitted)

Remainder of year 3
• Extensive testing of the TD-SLDA code, optimization, generate a C version of the nuclear code, extensive use of NERSC and ORNL computers
• Further optimization (and extension) of 2D and 3D solvers
• Apply the TD-SLDA code to a number of physical situations (Coulomb excitation, Collective states, LACM, Vortex dynamics, …)

Year 4 (and year 5)
• Our major challenge is now the generation and implementation of correct and accurate initial conditions for TD-SLDA code.
• Study various EDFs for neutron droplets, dilute fermion systems and nuclear systems
What aspects of our work require HPC?

- 2D and 3D solvers, large dense eigenvalue problems
- TD-SLDA it will easily fill up Cray XT5 and larger systems

Interest to other physicists

Both (A)SLDA and TD-SLDA are of great to condensed matter studies, structure and dynamics of neutron star crust, cold atoms, ... apart from relevance to nuclear dynamics

Showcase results?

- 3D real time nuclear superfluid dynamics
- Vortex generation and dynamics in real time in 2D and 3D, emergence of quantum turbulence, elucidation of the pinning and de-pinning vortex mechanism