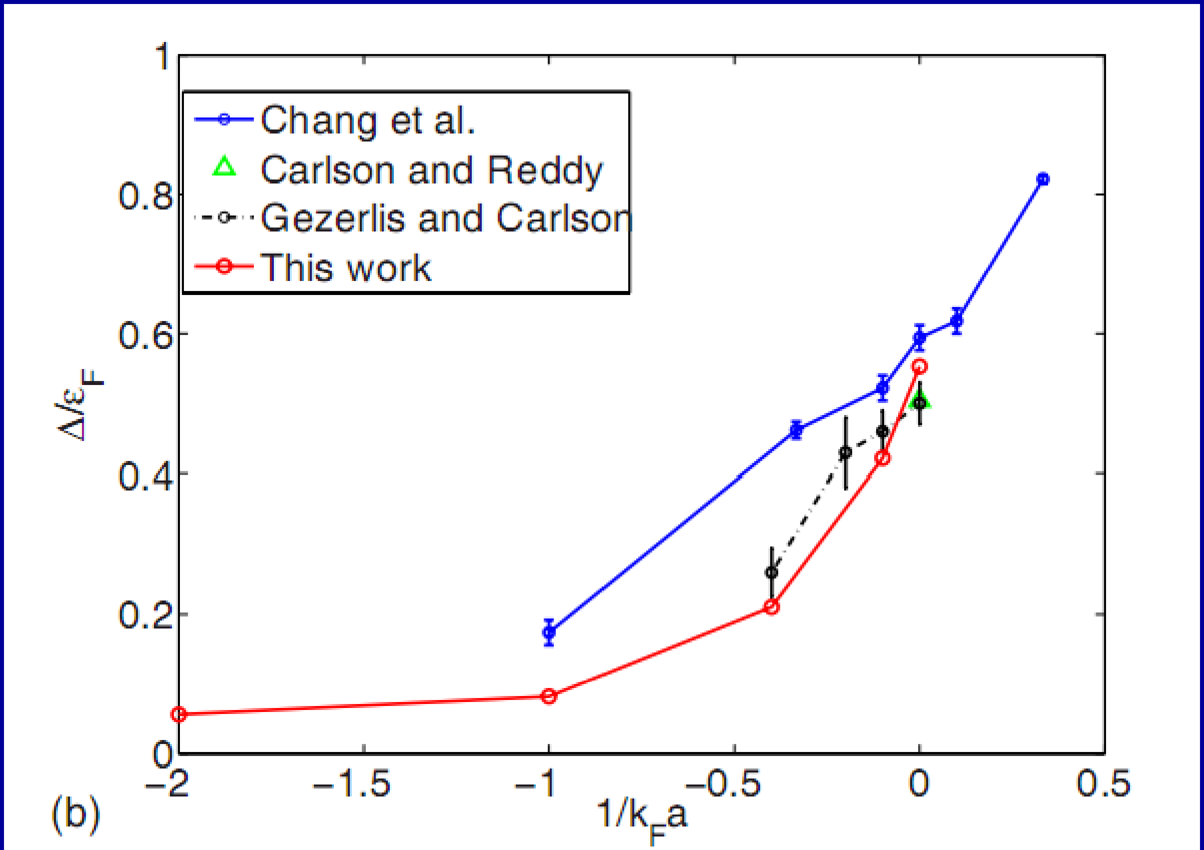
# Report on *some* of the UNEDF work performed by the UW centered group

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

***J.E. Drut, M.M. Forbes, G. Wlazlowski (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

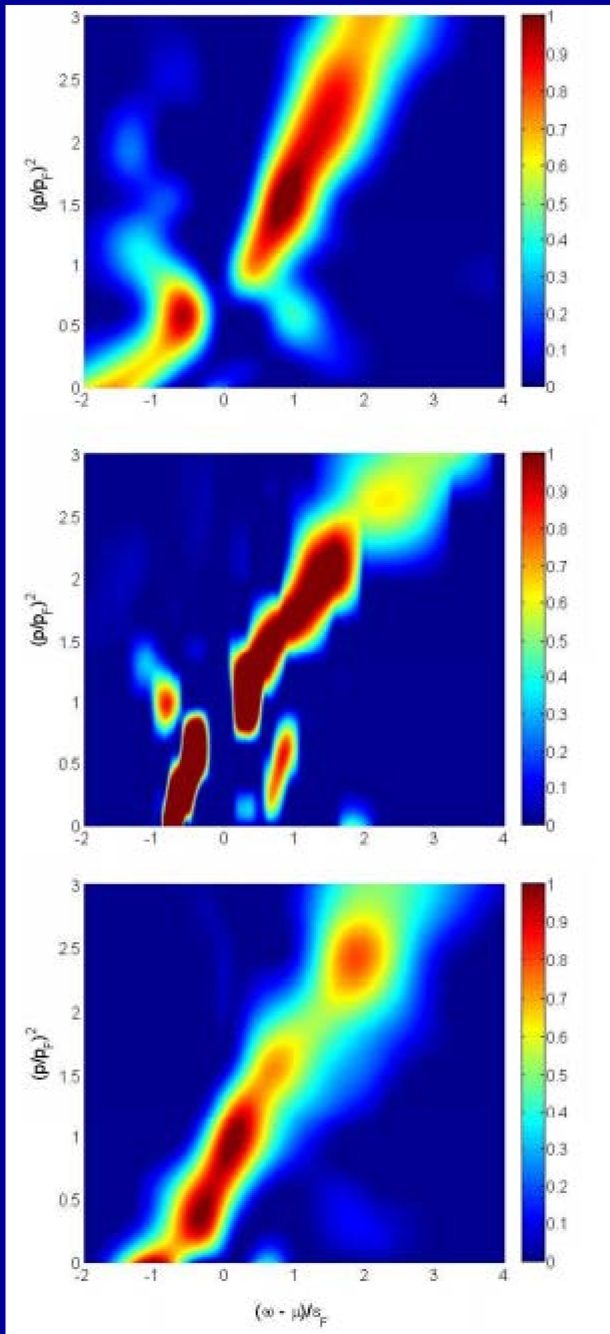
The International Advisory Committee of the International Conferences Series on Recent Progress in Many-Body Theoriesis pleased to announce that the HERMANN KÜMMEL EARLY ACHIEVEMENT AWARD IN MANY-BODY PHYSICS in 2009 is awarded to

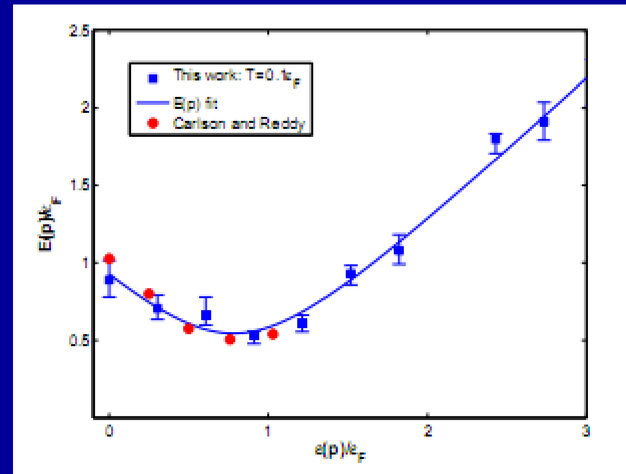
Dr. Joaquín E. Drut, Ohio State University, Columbus, U.S.A.

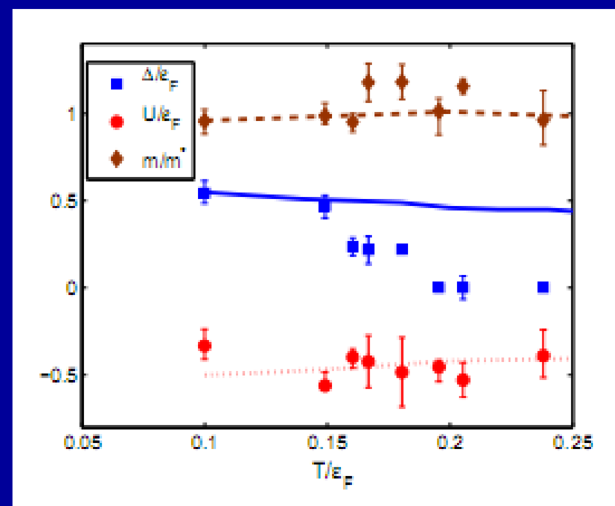
``For establishing the thermodynamic and pairing properties of a dilute spin-1/2 Fermi gas in the unitary regime using Quantum Monte Carlo and Field Theory methods."

This award honors Prof. Kümmel'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**

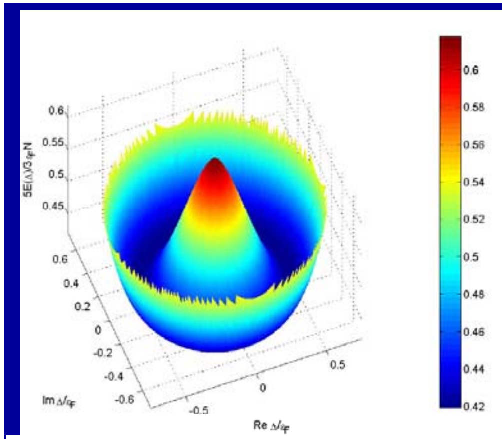


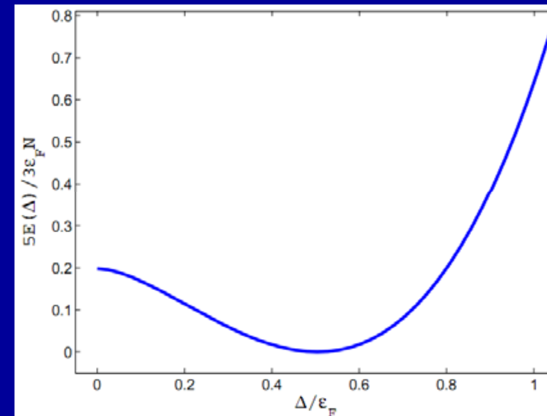



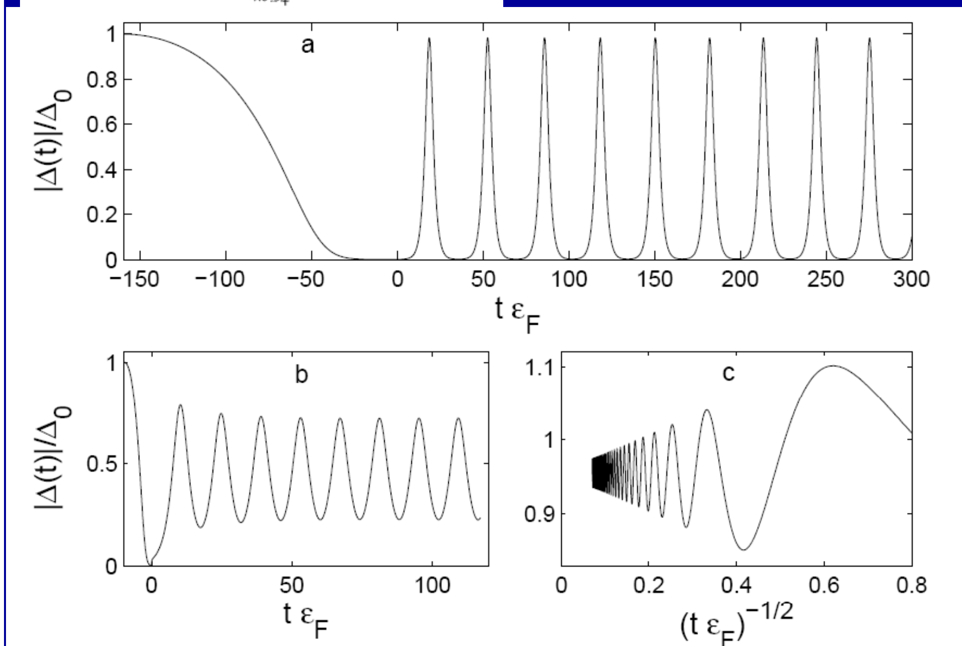



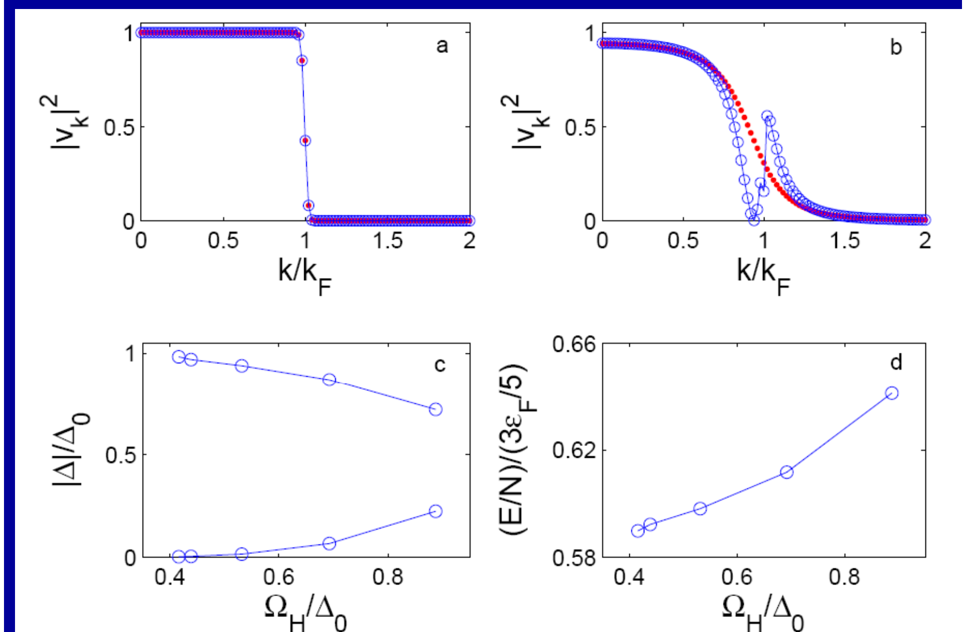

**The *ab initio* calculation of the spectral weight function, quasi-particle spectrum and its properties at finite T's.**

**P. Magierski, G. Wlazlowski, A. Bulgac and J.E. Drut**



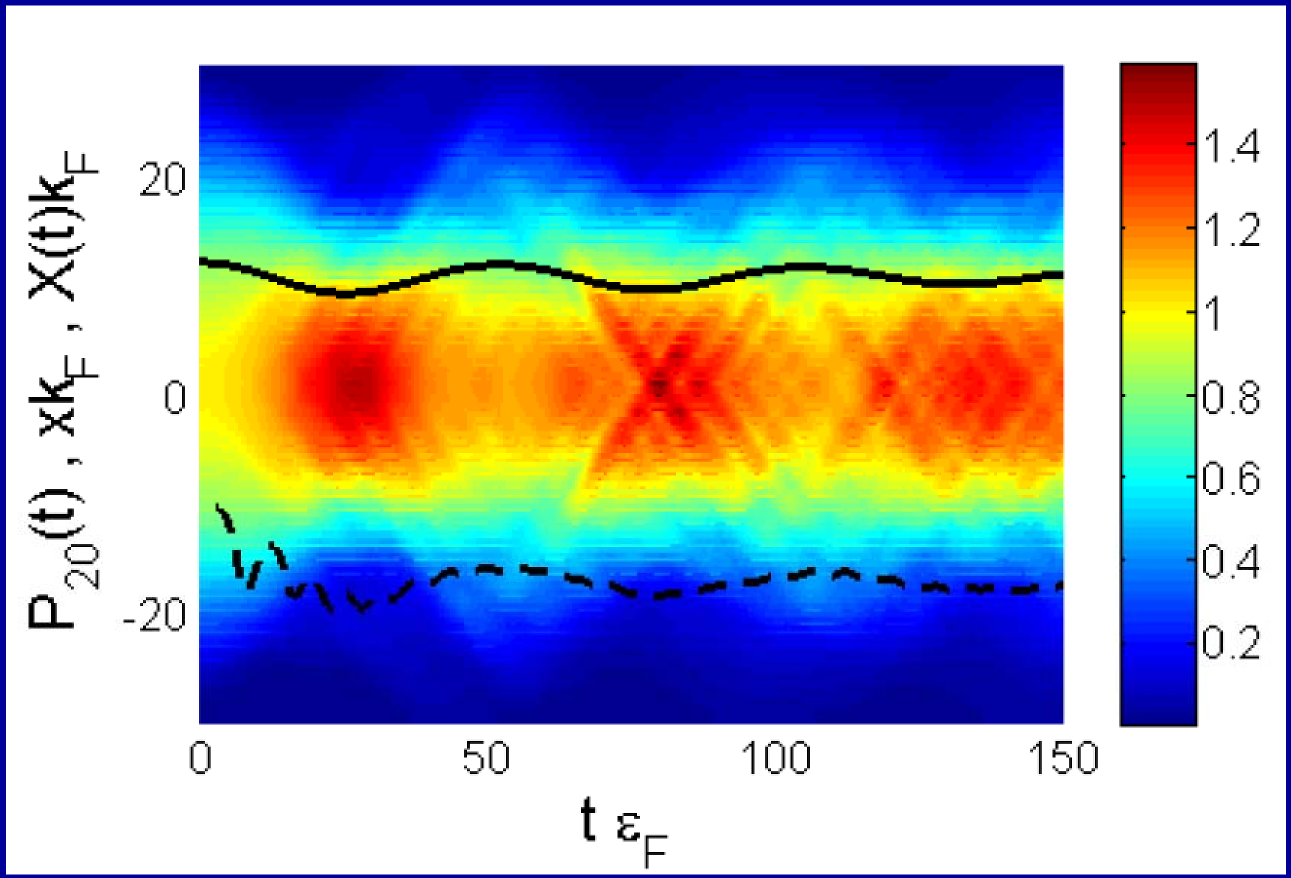




- **All these modes have a very low frequency below the pairing gap and a very large amplitude and excitation energy as well**
- **None of these modes can be described either within Quantum Hydrodynamics or Landau-Ginzburg like approaches**

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)

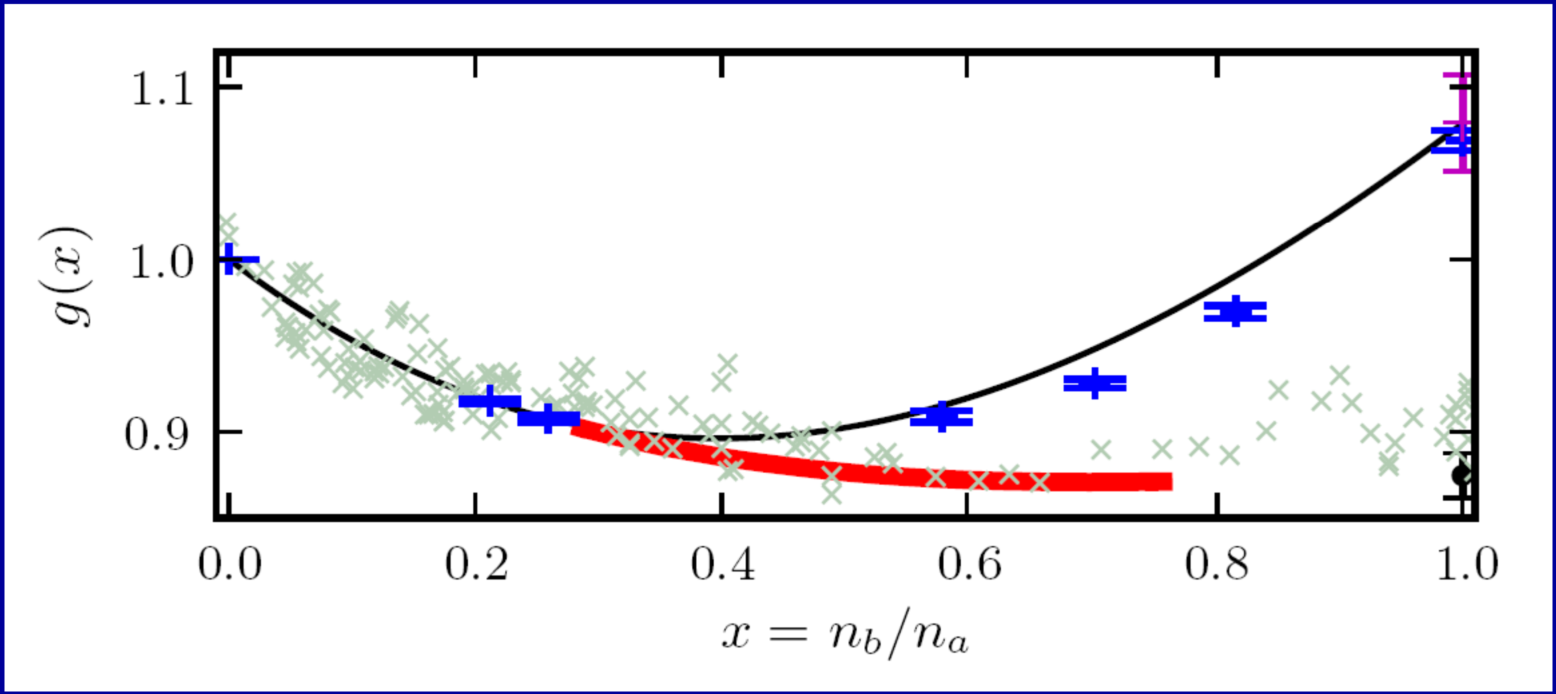
**Vortex generation and dynamics (Alan Luo)**

**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

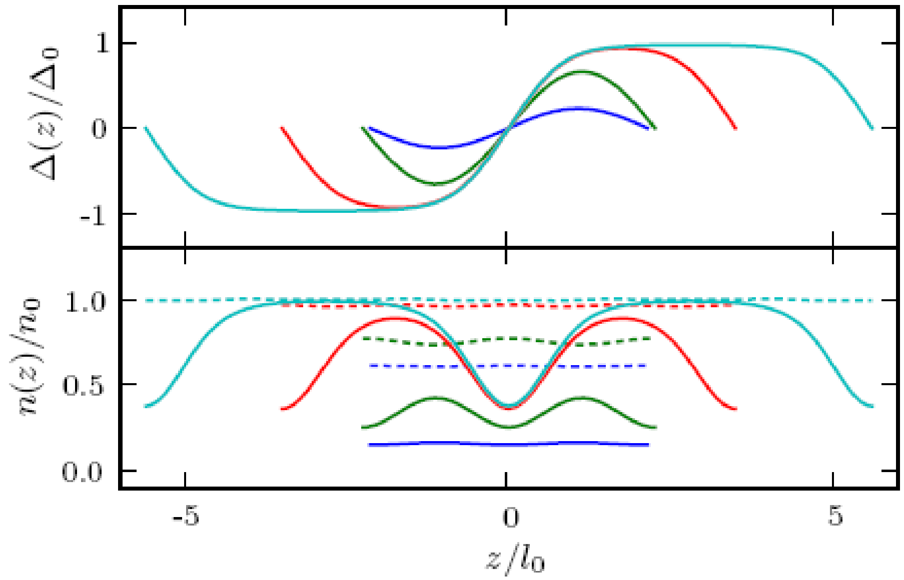
**Blue points:** DMC calculations for normal state, Lobo et al, PRL 97, 200403 (2006)

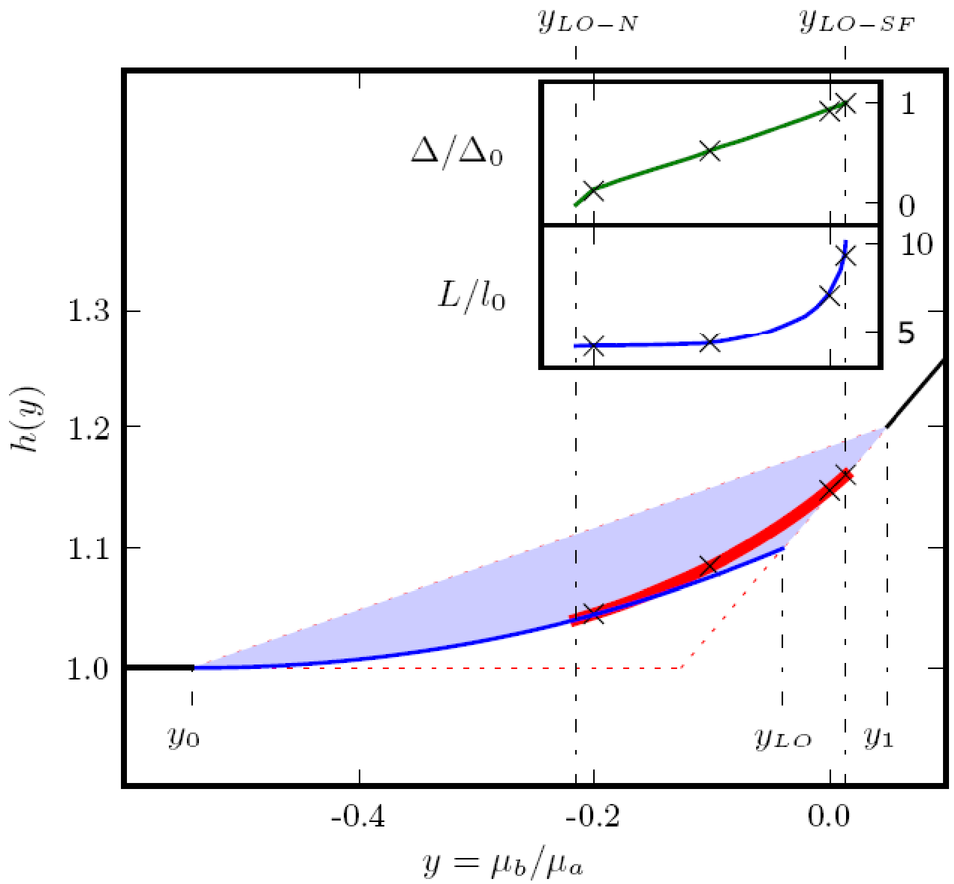
**Gray crosses:** experimental EOS due to Shin, Phys. Rev. A 77, 041603(R) (2008)

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

**Bulgac and Forbes,**
**Phys. Rev. Lett. 101, 215301 (2008)**

# A Unitary Fermi Supersolid: the Larkin-Ovchinnikov phase




**Bulgac and Forbes**
**Phys. Rev. Lett. 101, 215301 (2008)**

$$P[\mu_a,\mu_b] = \frac{2}{30\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2}\left[\mu_a h\left(\frac{\mu_b}{\mu_a}\right)\right]^{5/2}$$

**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-SLDSA 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