This ARO research proposal entitled "SPIN-ORBIT COUPLED BOSE-EINSTEIN CONDENSATES" (SOBECs) explored properties of the fundamentally new class of coherent states of quantum matter that had been predicted by the PI and subsequently experimentally realized with cold atoms. A unique feature of the SOBECs is a topologically protected spin-orbital degeneracy of the ground state that results in a variety of fascinating, previously unseen phenomena, which can be exploited for ultra-sensitive quantum interferometry, gravimetry, and fault-tolerant superfluids.
This ARO research proposal entitled "SPIN-ORBIT COUPLED BOSE-EINSTEIN CONDENSATES" (SOBECs) explored properties of the fundamentally new class of coherent states of quantum matter that had been predicted by the PI and subsequently experimentally realized with cold atoms. A unique feature of the SOBECs is a topologically protected spin-orbital degeneracy of the ground state that results in a variety of fascinating, previously unseen phenomena, which can be exploited for ultra-sensitive quantum interferometry, gravimetry, and fault-tolerant topological quantum computing. The PI has developed a quantum-mechanical description of the new phases and designed specific experimental schemes to realize them. The PI also generalized the new concepts to interacting spin-1/2 bosons in optical lattices and described a superfluid-to-Mott insulator transition in spin-orbit-coupled systems.
Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

<table>
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<th>Received</th>
<th>Paper</th>
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**TOTAL:** 11
Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received  Paper


TOTAL: 1
Number of Papers published in non peer-reviewed journals:

(c) Presentations

2. Invited Physics Department Colloquium at the University of Melbourne, Australia; Title of the Colloquium: "Exotic quantum phenomena and topological phases in spin-orbit-coupled systems" (March, 2011)


4. Invited talk at the program on topological insulators held in the Kavli Institute for Theoretical Physics, Santa Barbara, CA (September - December, 2011). Title: "Dual Approach to Nonequilibrium Quantum Mechanics and Topological Dynamical Systems"


6. Invited talk at the statistical physics seminar at the Institute for Physical Science and Technology, College Park, MD (January, 2012). Title: "Dual Approach to Time-Dependent Quantum Mechanics and Topological Dynamical Systems"


8. Invited talk at the Symposium "Frontiers of Quantum Matter" at the Center for Quantum Science, George Mason University, Fairfax, VA (June, 2012); Title: "Floquet topological insulators"

9. Invited talk at the International Conference, "Dubna -Nano 2012," at the Joint Institute for Nuclear Research, Bogoliubov Laboratory for Theoretical Physics, Dubna, Russia (July, 2012) Title: "Floquet topological insulating states"

10. Invited talk at the 21th International Laser Physics Workshop, University of Calgary, Calgary, Canada (July, 2012). Title: "Floquet topological insulators"

11. Invited talk at the KITP conference, "Dynamics and Thermodynamics in Isolated Quantum Systems," Kavli Institute for Theoretical Physics, Santa Barbara, CA (August, 2012). Title: "Stimulation of Quantum Phases by Time-dependent Perturbations"

12. Invited condensed matter seminar at Penn State University, (September, 2012). Title: "Quantum fluctuation phenomena in low-dimensional superfluids"

13. Invited Departmental Colloquium at the University of Minnesota, Minneapolis, MN (September, 2012). Title: "Exotic Quantum Phenomena and Topological Phases in Spin-Orbit-Coupled Systems"

14. Invited condensed matter seminar, William I. Fine Theoretical Physics Institute, University of Minnesota, Minneapolis (September, 2012). Title: "Stimulation of Quantum Phases by Time-dependent Perturbations"

15. Invited CUA seminar at the Harvard-MIT Center for Ultracold Atoms (CUA), Cambridge, MA (October, 2012). Title: "Stimulation of Quantum Phases by Time-dependent Perturbations"

16. Invited physics Colloquium at PennState University, University Park, PA (December, 2012), Title: "Exotic Quantum Phenomena and Topological Phases in Spin-Orbit-Coupled Systems"

17. Invited physics Colloquium at Monash University, Melbourne, VIC, Australia (January, 2013), Title: "Exotic Quantum Phenomena and Topological Phases in Spin-Orbit-Coupled Systems"

18 Invited seminar at the University of Massachusetts, Amherst, MA (April, 2013), Title: "Spin-orbit coupling in cold atoms"
19. "Quantum Floquet Dynamics of the Order Parameter in Fluctuating Superconductors," Aspen Center for Physics, Aspen, CO (June, 2013)


22. "Synthetic spin-orbit coupling in cold atom systems," invited seminar at the Institute of Theoretical Physics and Astronomy, Vilnius University, Vilnius, Lithuania (July, 2014)


Number of Presentations: 24.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received  Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received  Paper

TOTAL:
Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received  Paper


10/18/2012 10.00 Victor Galitski, Victor Yakovenko, Greg Boyd. Detecting d-wave pairing and collective modes in fermionic condensates with Bragg scattering, Physical Review A (03 2012)


TOTAL:  8
Books

Received       Book


TOTAL:       1

Patents Submitted

Patents Awarded

Awards

1. Named one of the University of Maryland Research Leaders (2013, 2014)
2. University of Maryland's Board of Visitors Faculty Award
3. The Richard A. Ferrell Distinguished Faculty Fellowship (2011)
4. Simons Investigator Award (2013)
5. Future Fellowship Award from the Australian Research Council (2014)

Graduate Students

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Names of Post Doctorates

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FTE Equivalent:  
Total Number:  

Names of Faculty Supported

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FTE Equivalent:  
Total Number:  

Names of Under Graduate students supported

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FTE Equivalent:  
Total Number:  

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

- The number of undergraduates funded by this agreement who graduated during this period: ..... 0.00
- The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields: ..... 0.00
- The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields: ..... 0.00
- Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale): ..... 0.00
- Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering: ..... 0.00
- The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense: ..... 0.00
- The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: ..... 0.00

Names of Personnel receiving masters degrees

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Total Number:  

Names of personnel receiving PHDs

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<th>NAME</th>
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Total Number:  
Scientific Progress

1. A theory of vortex excitations in spin-orbit-coupled condensates developed.
2. A new kind of non-equilibrium topological insulating states introduced, with possible realization in driven optical lattices.
3. Experimental schemes to realize various synthetic spin-orbit-coupled Hamiltonians designed.
5. Theory of unconventional Cooper pairing in spin-orbit-coupled Fermi gases developed.
6. Realistic models that host quantum spin liquid states proposed
7. A theory of superfluid-to-topological insulator developed with applications to optical lattices.
8. Generalized inverse scattering methods to describe soliton motion in quantum superfluids.

Technology Transfer