Fiscal Year:	FY 2017	**Task Last Updated:**	FY 03/31/2017
PI Name:	Lundblad, Nathan Ph.D.		
Project Title:	Microgravity Dynamics of Bubble-Geometry Bose-Einstein Condensates		
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	FUNDAMENTAL PHYSICS--Fundamental physics		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	04240-6018	**Congressional District:**	2
Comments:			
Project Type:	FLIGHT	**Solicitation / Funding Source:**	2013 Fundamental Physics NNH13ZTT002N (Cold Atom Laboratory--CAL)
Start Date:	04/01/2014	**End Date:**	04/30/2019
No. of Post Docs:	1	**No. of PhD Degrees:**	0
No. of PhD Candidates:	1	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JPL
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Flight Program:	ISS		
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Aveline, David Ph.D. (Jet Propulsion Laboratory) Lannert, Courtney Ph.D. (Smith College) Vishveshwara, Smitha Ph.D. (University of Illinois at Urbana-Champaign)		
Grant/Contract No.:	JPL 1502172		
Performance Goal No.:			
Performance Goal Text:			

Task Description:

Notions of geometry, topology, and dimensionality have directed the historical development of quantum-gas physics. With a toolbox of forces used to confine, guide, and excite Bose-Einstein condensates (BEC) or degenerate Fermi gases (DFG), physicists have used quantum gases to test fundamental ideas in quantum theory, statistical mechanics, and in recent years notions of strongly-correlated many-body physics from the condensed-matter world.
We propose a specific program to explore a trapping geometry for quantum gases that is both tantalizing theoretically and prohibitively difficult to attain terrestrially: a quantum gas in a bubble geometry, i.e., a trap formed by a spherical or ellipsoidal shell structure, confining a 2D quantum gas to the surface of an experimentally-controlled topologically-connected “bubble.” The physics of a quantum gas confined to such a surface has not been explored terrestrially due to the limitations of gravitational sag; interesting work has certainly been done with gases confined to the lower regions of bubble potentials, but the fully symmetric situation has yet to be explored. The low-energy excitations of such a system are unexplored, and notions of vortex creation and behavior as well as Kosterlitz-Thouless physics are tantalizing aims as well. The solid-state modeling goals of the optical-lattice physics community are also fundamentally connected to the system, as the canonical Mott-insulator/superfluid transition features superfluid shells isolated between insulating regions.

The central method to reach the sought-after bubble-geometry BEC or DFG is that of rf or microwave dressing of the bare trapping potentials provided by the Cold Atom Laboratory (CAL) “chip trap.” Radiofrequency dressing has been used conceptually through "rf-knife" evaporative cooling, but more recently through explicit construction of adiabatic potentials for interferometry, and shell-trap construction for both thermal and quantum gases. The proposed work is a window into a physical regime that is quite difficult to achieve terrestrially due to trap distortion; given the advantages of a microgravity environment, NASA CAL is uniquely positioned to realize the physics goals of this proposal.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

Task Progress:

The third year of JPL 1502172 focused on further modeling of the radiofrequency-dressing process that will occur aboard CAL and how it can be used to create shell-geometry Bose-Einstein condensates in the presence of practical limitations. Extensive communication took place between Co-Investigator Aveline and Principal Investigator (PI) Lundblad regarding flight hardware, and extensive communication took place between Co-I Lannert and PI Lundblad regarding numerical simulation of potential CAL experiments. Progress on the construction of CAL-like prototype hardware at Bates continued.
Lundblad’s work continued to focused mostly on understanding potential issues with trap inhomogeneity aboard CAL that could result in incomplete shell-BEC population or asymmetric shells. A significant insight was gained regarding potential correction of antenna-coupling inhomogeneity which should be implemented on future versions of CAL.

Lannert and Vishveshwara’s work continued to focus on simulation of collective modes, and led to a paper currently in review ("Physics of hollow Bose-Einstein condensates." https://).

Work with Aveline continued to address validation issues remaining after the 2015 Science Concept Review (SCR).

Bibliography Type: Description: (Last Updated: 06/20/2023)