Fiscal Year:	FY 2015	**Task Last Updated:**	FY 12/15/2015
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:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	1	**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)		
Grant/Contract No.:	JPL 1502172		
Performance Goal No.:			
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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:	Progress during the first year of the grant revolved around conceptual studies of what possible experiments could be done once the CAL facility is flying. Lundblad at Bates College and Aveline at Jet Propulsion Laboratory (JPL) focused on the details of how precisely a bubble-geometry Bose-Einstein condensate will be formed given the particular nature of the magnetic trap that will lie at the heart of CAL. In particular, they focused on trap symmetry, requisite trap homogeneity, and studied requirements for the actual apparatus. Aveline and Lundblad convened at Bates College for a workshop on this material in the summer of 2014. Lannert at Smith College/UMass performed theoretical calculations of a Bose-Einstein condensate trapped in a shell/bubble potential, in particular characterizing how such gas shakes or quivers when excited. These calculations will inform our plans to do experiments related to this shaking or quivering on the CAL flight experiment. Since bubble-geometry Bose-Einstein condensates do not exist terrestrially this will be a novel experiment. Lannert and Lundblad convened at Bates College for a workshop on this material in August 2014. In summary, considerable progress was made in the understanding of how one might be able to use the CAL apparatus to generate bubble/shell geometries for Bose-Einstein condensates. Further work this coming year will focus on specific implementation of various concept and calibration experiments using the CAL testbed, exploring theoretical modeling of the shell condensate at a more sophisticated level, and beginning construction on a CAL-like machine at Bates College, under the supervision of a postdoctoral fellow.
Bibliography Type:	Description: (Last Updated: 02/04/2025)