Fiscal Year:	FY 2016	**Task Last Updated:**	FY 06/01/2016
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:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	2
No. of Bachelor's Candidates:	2	**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 second year of Jet Propulsion Laboratory (JPL) 1502172 focused on more detailed studies of what possible experiments could be done once CAL is launched, and specific planning in terms of validation and the SCR process. Extensive communication took place between Co-Investigator (Co-I) 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 focused mostly on understanding potential issues with trap inhomogeneity aboard CAL that could result in incomplete shell-BEC population or asymmetric shells. The significant insights here were that the asymmetric anharmonicity of the atom-chip trap, as well as the impossibility of unity aspect ratio, are prime sources of inhomogeneity. Additionally, the rf antenna results in an inhomogeneous rf coupling which we continue to model. The model outputs are potential-energy surfaces for various chip-current configurations. Lannert’s work focused on numerical simulations (Gross-Pitaevskii) of collective excitations and ballistic-flight interference of shell BECs. They were guided by model potential-energy surfaces provided by Lundblad. This work has led to a publication in preparation, and resulted in a new collaboration with Prof. Smitha Vishveshwara of the University of Illinois. Together with JPL testbed work performed by Aveline allowing validation of the general proposed concepts, this collaboration passed the NASA Science Concept Review in August 2015.
Bibliography Type:	Description: (Last Updated: 06/20/2023)