Fiscal Year:	FY 2019	**Task Last Updated:**	FY 05/20/2019
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:**	10/30/2020
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:	1	**Monitoring Center:**	NASA JPL
Contact Monitor:	Callas, John	**Contact Phone:**	
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Flight Program:	ISS		
Flight Assignment:	ISS NOTE: New end date is 10/30/2020 per JPL (Ed., 5/21/19)		
Key Personnel Changes/Previous PI:	April 2019 report: New postdoctoral candidate Ryan Carollo was hired (starting September 2018).		
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 fifth year of this work focused on immediate preparation for CAL launch and 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. After launch in May 2018, several rounds of data were taken through the end of this reporting period and are currently undergoing analysis. Data focused on understanding residual micromotion in the expanded atom traps (‘sloshing’) and validation of trap models--preliminary results largely show agreement at the few-percent level in trap frequencies. Initial attempts at generating shell-trapped ultracold clouds-- the central goal of this project-- were made, and showed preliminary positive signs, although anticipated inhomogeneities appear to play expected roles. Further communication took place between Co-Investigator (Co-I) Aveline and Principal Investigator (PI) Lundblad regarding flight hardware, and detailed communication took place between Co-I Lannert and PI Lundblad regarding numerical simulation of these CAL experiments. Lundblad also extended collaborative work with other theorists in the field regarding specific modeling issues, particularly Barry Garraway of Sussex. Progress on the construction of CAL-like prototype hardware at Bates was begun using a newly-arrived atom chip apparatus from ColdQuanta. 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, as well as beginning to model adiabaticity in these systems. Lannert and Vishveshwara’s work continued to focus on simulation of collective modes, and led to a paper published (Sun, K., Padavic, K., Yang, F., Vishveshwara, S. & Lannert, C. Static and dynamic properties of shell-shaped condensates. Phys Rev A 98, 013609 (2018).)
Bibliography Type:	Description: (Last Updated: 06/20/2023)
Articles in Peer-reviewed Journals	Sun K, Padavic K, Yang F, Vishveshwara S, Lannert C. "Static and dynamic properties of shell-shaped condensates." Phys Rev A. 2018 Jul;98:013609. https://doi.org/10.1103/PhysRevA.98.013609 , Jul-2018
Significant Media Coverage	Gibney E. " 'Universe’s coolest lab set to open up quantum world.' Article in Nature News section about research on the Cold Atom Laboratory." Nature. 2018 May 10;557:151–2. https://www.nature.com/articles/d41586-018-05111-2 , May-2018
Significant Media Coverage	Chen S. "Article about research on the Cold Atom Laboratory, 'The Quest to Make Super Cold Quantum Blobs in Space.' " Wired Magazine, June 25, 2018. https://www.wired.com/story/the-quest-to-make-super-cold-quantum-blobs-in-space/ , Jun-2018