Task Book Report Generated on: 04/26/2024

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Project Title: Microgravity Dynamics of Bubble Geometry Bose-Finstein Condensates  Program/Discipline:  Some  Program Research Program Richemetts  None  Some  Human Research Program Richemetts  None  Space Biology Cross-Element  None  Space Biology Cross-Element  None  Space Biology Cross-Element  None  Space Biology Special Category:  None  Space Biology Special Category:  None  Pl Email:  Programization Type:  UNIVERSITY  ONIVERSITY  Programization Name:  Base College  Pl Address 1:  Department of Physics and Astronomy  Pl Address 2:  Pl Address 2:  Pl Address 2:  Address 3:  Address 4:  Address 4:  Address 4:  Address 4:  Address 5:  Address 5:  Address 6:  Project Type:  FLOHT  Solicitation / Funding Source:  Project Type:  Project Type:  Proformance Modificate:  A Od 10:  A Od 1			Task Last Updated:	FY 03/31/2017	
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Finements Subdiscipline:  Joint Agency Name:  Joint Agency Name:  None  None  Space Biology Cross-Element  None  Space Biology Cross-Element  Space Biology Cross-Element  Space Biology Special Category:  None  Pl Email:  Pl Organization Type:  UNIVERSITY  Pl Organization Type:  UNIVERSITY  Pl Organization Name:  Bates College  Pl Address 2:  Pl Address 3:  At Campus Ave  Pl Weision  Agency Solicitation / Funding Source  Pl Weision  Agency Solicitation / Funding Source  Pl Address 2:  Advance Solicitation / Funding Source  Pl Address 3:  Advance Solicitation / Funding Source  Pl Address 4:  Advance Solicitation / Funding Source  Advance Solicitation / Funding So	Program/Discipline:				
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Human Research Program Risks:         None           Space Biology Cross-Element         None           Space Biology Cross-Element Space Biology Cross-Element Discipline:         None           Space Biology Special Category:         None           PI Cramil:         nbmdbla@bates.edu         Fax: FY           PI Organization Type:         UNIVERSITY         Phone: 207-786-6321           Organization Name:         Bate College           PI Address 1:         Department of Physics and Astronomy           PI Address 2:         44 Campus Ave           PWeb Page:         User Medical District         State: ME           Zip Code:         04240-6018         Congressional District:         2           Comments:         FLIGHT         Solicitation / Funding Source:         2013 Fundamental Physics Nathard Medical District:         2           Project Type:         ELIGHT         Solicitation / Funding Source:         2013 Fundamental Physics Nathard Medical District:         2           Project Type:         LIGHT         Solicitation / Funding Source:         2013 Fundamental Physics Nathard Medical District:         2           Start: Date:         Half Date:         Monor Physics and Astronomy:         2         2         3         4         4         4         3         9         3	Joint Agency Name:		TechPort:	No	
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Space Biology Cross-Element Discipline:         None           Space Biology Special Category:         None           PI Email:         nlundbla@bates.edu         Fax: FY           PI Organization Type:         UNIVERSITY         Phone: 207-786-6321           Organization Name:         Bates College           PI Address 1:         Department of Physics and Astronomy           PI Address 2:         44 Campus Ave           PI Web Page:           City:         Lewiston         State: ME           Zip Code:         04240-6018         Congressional District: 2           Comments:         Comments:         2013 Fundamental Physics           Project Type:         FLIGHT         Solicitation / Funding Source: 2013 Fundamental Physics and Astronomy         No. 17 Funding Source: 2013 Fundamental Physics           Project Type:         FLIGHT         Solicitation / Funding Source: 2013 Fundamental Physics           Start Date:         O401/2014         End Date: 04/30/2019           No. of Pob Docs:         1         No. of PhD Degrees: 0           No. of PhD Docardidates:         1         No. of Bachelor's Pegrees: 0           No. of Bachelor's Candidates:         0         Monitoring Center: NASA.JPL           Contact Monitor:         Callas, John         Contact Phone:	Human Research Program Risks:	None			
Discipline:         None           Space Biology Special Category:         None           PI Email:         nlundbla@hates.edu         Fax: FY           PI Organization Type:         UNIVERSITY         Phone: 207-786-6321           Organization Name:         Bases College           PI Address 1:         Department of Physics and Astronomy           PI Address 2:         44 Campus Ave           PI Web Page:         Usewiston         State:         ME           Zip Code:         04240-6018         Congressional District:         2           Comments:         Very Code:	Space Biology Element:	None			
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Organization Name: Bates College PI Address 1: Department of Physics and Astronomy PI Address 2: 44 Campus Ave PI Web Page:  City: Lewiston State: ME  Zip Code: 04240-6018 Congressional District: 2  Comments:  Project Type: FLIGHT Solicitation / Funding Source: NNH13ZTTTOON (Cold Atom Laboratory - CAL)  Start Date: 04/01/2014 End Date: 04/03/2019  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 No. of Bachelor's Degrees: 0  No. of Bachelor's Candidates: No. of Ba	PI Email:	nlundbla@bates.edu	Fax:	FY	
PI Address 1: Department of Physics and Astronomy PI Address 2: 44 Campus Ave PI Web Page:  City: Lewiston State: ME  Zip Code: 04240-6018 Congressional District: 2  Comments:  Project Type: FLIGHT Solicitation / Funding Source: NNH13/ZT1002N (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 Master's Candidates: 0 Monitoring Center: NASA JPL  Contact Monitor: Callas, John Contact Phone:  Contact Email: john Leallas@ipl.nasa.gov  Flight Program: ISS  Flight Assignment:  Key Personnel Changes/Previous PI:  COI Name (Institution): Lannert, Courtney Ph.D. (Smith College) Vishveshwara, Smitha Ph.D. (University of Illinois at Urbana-Champaign)  Grant/Contract No.: JPL 1502172  Performance Goal No.:	PI Organization Type:	UNIVERSITY	Phone:	207-786-6321	
PI Address 2: 44 Campus Ave PI Web Page:  City: Lewiston State: ME  Zip Code: 04240-6018 Congressional District: 2  Comments:  Project Type: FLIGHT Solicitation / Funding Source: 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  Contact Monitor: Callas, John Contact Phone:  Contact Email: john.leallas@ipl.nasa.gov  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.:	Organization Name:	Bates College			
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No. of Master's Candidates:  No. of Bachelor's Candidates:  Contact Monitor:  Callas, John  Contact Email:  John.l.callas@jpl.nasa.gov  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.:	No. of Post Docs:	1	No. of PhD Degrees:	0	
No. of Bachelor's Candidates:  Contact Monitor:  Callas, John  Contact Phone:  Contact Email:  john.l.callas@jpl.nasa.gov  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.:	No. of PhD Candidates:	1	No. of Master' Degrees:	0	
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Task Book Report Generated on: 04/26/2024

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:

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." <a target="\_blank" href="https://arxiv.org/abs/1612.05809">https://</a>).

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

**Bibliography Type:** 

Task Progress:

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