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Fiscal Year:	FY 2022	Task Last Updated:	FY 12/02/2021
PI Name:	Clark, Noel A. Ph.D.		
Project Title:	Ferromagnetic Liquid Crystal Colloids in Microgra	avity	
Division Name:	Physical Sciences		
Program/Discipline:			
Program/Discipline Element/Subdiscipline:	COMPLEX FLUIDS/SOFT MATTERComplex	Fluids	
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:	80309-0001	Congressional District:	2
Comments:			
Project Type:	Flight	Solicitation / Funding Source:	2015 NNH15ZTT002N MaterialsLab Open Science Campaigns for Experiments on the International Space Station
Start Date:	12/02/2016	End Date:	12/01/2022
No. of Post Docs:	2	No. of PhD Degrees:	2
No. of PhD Candidates:	2	No. of Master' Degrees:	
No. of Master's Candidates:		No. of Bachelor's Degrees:	6
No. of Bachelor's Candidates:	8	Monitoring Center:	NASA GRC
Contact Monitor:	Hatch, Tyler	Contact Phone:	216.433.5073
Contact Email:	tyler.r.hatch@nasa.gov		
Flight Program:	ISS		
Flight Assignment:	Liquid Crystal Facility NOTE: End date changed to 12/01/2022 per NSSC	C information. Previous end date	was 12/01/2021. (Ed., 12/2/21)
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Glaser, Matthew Ph.D. (University of Colorado, Boulder) Maclennan, Joseph Ph.D. (University of Colorado, Boulder) Park, Cheol M.S. (University of Colorado, Boulder) Shuai, Min Ph.D. (University of Colorado, Boulder)		
Grant/Contract No.:	NNX17AC74G		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Paramagnetic ferrofluids are familiar as suspensions of magnetic particles in solvents that become strongly magnetized in applied fields. A longstanding challenge has been to make such fluids ferromagnetic, so that they exhibit spontaneous macroscopic ferromagnetic ordering even in the absence of an applied field. Recently, ferromagnetic fluid phases have been achieved by the ferromagnetic orientation of magnetic nanoplates in colloidal suspensions, either by dispersion in a thermotropic nematic liquid crystal (LC) host or by spontaneous nematic ordering in an isotropic solvent. These novel materials are optically birefringent, dichroic, and translucent, so that structures and textures can easily be visualized in polarized light. They manifest a variety of interesting and distinctive magnetic interaction effects and, because of the static magnetization, display ultrahigh sensitivity to externally applied magnetic fields. Field-induced changes in the shape of fluid drops, such as interfacial magnetic splic instabilities, occur even in the Earth's magnetic field, and readily achievable benchtop magnetic fields are expected to induce spectacular magnetofluidir responses. Fereomagnetic nematics also exhibit distinctive magnetic self-interactions, including liquid crystal textures of fluid magnetic domains arranged in closed flux loops that in microgravity should strongly affect the shape of free-floating drops. Freely suspended smeetic LC films in the form of bubbles, the LC geometry currently studied in OASIS (Observation and Analysis of Smeetic Islands in Space), will be rendered ferromagnetic by doping with magnetic anoplates and manipulated magnetically. In suspensions studied on Earth, the typically more dense liquid crystal phase sediments to the lower parts of test cells, leaving a sharp interface with the co-existing isotropic phase. Microgravity offers the opportunity to perform critical experiments that are not possible on Earth, such as the observation of ferromagnetic droplets and other fluid interface		
Rationale for HRP Directed Research	Rationale for HRP Directed Research:		
Research Impact/Earth Benefits:	Paramagnetic ferrofluids are familiar as suspensions of magnetic particles in solvents that become strongly magnetized in an applied field. A longstanding challenge has been to make such fluids ferromagnetic, so that they exhibit spontaneous macroscopic ferromagnetic ordering even in the absence of an applied field. Recently, ferromagnetic fluid phases have been achieved by the ferromagnetic orientation of magnetic nanoplates in colloidal suspensions, either by dispersion in a thermotropic nematic liquid crystal host or by spontaneous nematic ordering in an isotropic solvent. These novel materials are optically birefringent, dichroic, and translucent, so that structures and textures can easily be visualized in polarized light.		
Task Progress:	Dynamic process of phase separation between isotropic and ferromagnetic nematic and ferromagnetic droplets in isotropic fluids We have shown previously that suspensions of disk-shaped, ferromagnetic barium hexaferrite nanoplates in isotropic solvent spontaneously form a ferromagnetic nematic phase at nanoplate concentrations higher than the Onsager isotropic-nematic phase transition point for hard disks. At an overall nanoplate concentration below this value and within the coexistence region, such suspensions phase-separate into ferromagnetic nematic and isotropic domains. Under these conditions, the suspension can be driven into a uniform state by mechanical or magnetic stirring, and undergoes a dynamic process of phase separation immediately after the removal of stirring forces, which we have investigated by polarized optical microscopy under Earth's gravity. Liquid crystal droplets have attracted intense study, focused on understanding their topological structures and their potential optical applications. With coupled spontaneous ferromagnetic and liquid crystal order, ferromagnetic nematics exhibit novel magnetic domain structures. The structures of the semagnetic liquid crystal domains are controlled by the shape of the container, i.e., the boundary conditions, and are very sensitive to external magnetic fields. Previously, we studied the deformation of ferromagnetic droplets suspended in fluorinated oil. We quantitatively characterized the shape changes of the magnetic droplets with the application of a magnetic field. More recently, we have investigated ferromagnetic nematic droplets in isotropic suspension, the surface tension at the interface is negligible. This provides a convenient way of studying the effects of forces on domain shape other than surface tension, such as the magnetic elef-interactions of 1 sotropic Oil and Ferromagnetic liquid crystal films, allowing the equilibrium structures and hydrodynamics to be studied in a quasi-two-dimensional geometry. Paraffin oil droplets are observed to ha		

	interactions between the droplets, while the droplet dynamics are mediated by hydrodynamic interactions with the smectic film.
Bibliography Type:	Description: (Last Updated: 12/04/2024)
Abstracts for Journals and Proceedings	Chowdhury R, Hedlund E, Green AAS, Park CS, MacLennan J, Clark NA. "Tracking islands on smectic bubbles using machine learning." 37th Annual Meeting of the American Society for Gravitational and Space Research, Baltimore, MD, November 3-6, 2021. Abstracts. 37th Annual Meeting of the American Society for Gravitational and Space Research, Baltimore, MD, November 3-6, 2021. , Nov-2021
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Abstracts for Journals and Proceedings	Green AAS, Chowdhury R, Minor E, Howard S, Park C, Clark N. "Defect annihilation in liquid crystal physics: using deep learning to probe the dynamics of defects." APS March Meeting 2021, Virtual, March 15-19, 2021. Bulletin of the American Physical Society. 2021;66:Abstract: Y05.00011. https://meetings.aps.org/Meeting/MAR21/Session/Y05.11, Mar-2021
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Articles in Peer-reviewed Journals	Stannarius R, Trittel T, Klopp C, Eremin A, Harth K, Clark NA, Park CS, Maclennan JE. "Freely suspended smectic films with in-plane temperature gradients." New J Phys. 2019 Jun 21;21:063033. https://doi.org/10.1088/1367-2630/ab2673, Jun-2019
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