Fiscal Year:	FY 2023	**Task Last Updated:**	FY 09/28/2022
PI Name:	Weeks, Eric R Ph.D.		
Project Title:	Thermal Fluctuations of Colloidal Gels		
Division Name:	Physical Sciences		
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Program/Discipline--Element/Subdiscipline:	COMPLEX FLUIDS/SOFT MATTER--Complex Fluids		
Joint Agency Name:		**TechPort:**	No
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Space Biology Element:	None		
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PI Email:	erweeks@emory.edu	**Fax:**	FY 404-727-0873
PI Organization Type:	UNIVERSITY	**Phone:**	404-727-4479
Organization Name:	Emory University		
PI Address 1:	Physics Department		
PI Address 2:	400 Dowman Drive, Mail Stop 1131/002/1AB		
PI Web Page:	http://www.physics.emory.edu/		
City:	Atlanta	**State:**	GA
Zip Code:	30322-2430	**Congressional District:**	5
Comments:			
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No. of Bachelor's Candidates:	1	**Monitoring Center:**	NASA GRC
Contact Monitor:	Hatch, Tyler	**Contact Phone:**	216.433.5073
Contact Email:	tyler.r.hatch@nasa.gov		
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Task Description:	We propose to study colloidal gels using the data from the Advanced Colloids Experiment-Microscopy-1 (ACE-M-1) experiments. Colloidal gels are formed from sticky micron-sized solid particles in a liquid, where over time the particles stick together and form random clumps that eventually bridge across the entire sample chamber in tangled networks. The ACE-M-1 data set consists of a large number of optical microscopy movies of colloidal gels. In microgravity, these gels are long-lived, rather than collapsing under their own weight as happens in ground-based experiments. Our group has expertise in analyzing microscope images, using particle tracking, particle image velocimetry, and differential dynamic microscopy. The movies reveal the gels have visible thermal fluctuations that likely reveal information about their rheological properties, local elasticity, etc. There is also some clear sense of length scales: some gels have thick aggregated regions, while others have more tenuous gel strands and free particles. We can connect structure and dynamics. We propose to analyze these movies to pull out this information, and to perform complementary ground-based experiments to validate the observations. For example, the Physical Sciences Informatics (PSI) movies are all 2D cuts through 3D samples, and we will use ground-based confocal microscopy to cross-check the samples with some 3D data sets; to confirm inferences about 3D structure from the 2D images. A particular appealing feature of the ACE-M-1 experiments is that they studied polydispersity (gels made of mixtures of two distinct particle types) and polydisperse systems are a long-time interest of the Principal Investigator (PI). We will use our ground-based experiments to study gels with higher polydispersity, which should in turn suggest new microgravity investigations in the future. This PSI investigation will be done by the Weeks lab at Emory University; there will not be any other collaborators.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Colloids are suspensions of small solid particles suspended in a liquid. Examples include paint, ink, pastes, and blood. "Small" means the particle diameters range from ~10 nm to ~10 microns. Thermal motion is relevant: Brownian motion allows particles to diffuse. Often precautions are taken to prevent the solid particles from sticking together. If particles have attractive interactions, they can stick together in free-floating aggregates, or large tendrils that can span across the system. The latter is a colloidal gel. Colloidal gels are used in applications such as water purification, skin creams, and also show up in some food products such as jellies and jams. In food, colloidal gels modify the texture and shelf-life stability of the food. Our NASA-funded study of colloidal gels should improve our understanding of long-term stability of colloidal gels, as well as how they initially form.
Task Progress:	Our project primarily involves analyzing data from NASA's Physical Systems Informatics (PSI) database. In particular, we are analyzing microscope images of colloidal gels from the Advanced Colloids Experiment-Microscopy-1 (ACE-M-1). The ACE-M-1 experiment resulted in 530 GB of images, so the first step of our work was to download these images from the PSI database. This took many hours over several weeks. Colloids are small (micron-sized) particles in a liquid. In these experiments, the particles are made to be sticky, so they stick together into a network of tendrils of particles; this is the colloidal gel state. The ACE-M-1 experiment was done on the International Space Station, so that the colloidal gels could be studied in microgravity conditions. The reason microgravity is important is that as the particles begin to stick together, they form heavy clusters which can sink in normal gravity. This ultimately limits the shelf-life of a colloidal gel, but also, changes the overall structure. We wish to understand what the gel structure would be like if this limit is overcome in microgravity conditions. The ACE-M-1 data set has 9 distinct experiments on 8 different samples, where the different samples are made with different levels of attractive interaction – that is, different levels of particle stickiness. Undergraduate student Swagata Datta studied the ACE-M-1 data this past year, working with the Principal Investigator (PI) Eric Weeks. In our analysis of the microscope images, we have learned several useful things. First, we observe that the stickier particles form stronger gels – not surprisingly, there are more particles stuck together, which we can measure from the microscope images. Second, we can observe the increase in aggregated particles over time. The experiments have up to 60 hours of data, and a gradual increase in touching particles is observable in most experiments. The exception is the least sticky particles, which do not form a gel. In addition to this structural information, we also study the Brownian motion of the particles. As expected, the stickier particles have less Brownian motion, especially as they stick together more strongly in the gel structure. We can see the particle motion slows down as the gels change over the 60 hours of observation. This slowing is more dramatic for the stickiest particles, but still apparent even for some less sticky particles, although the least stickiest particles do not change their motion, consistent with them not forming a gel. This past year we have additionally done new ground-based experiments on colloidal gels. This work is being done by graduate student Waad Paliwal and PI Eric Weeks. Waad made mixtures of colloids, solvent, and "depletant." A depletant is a polymer added to the liquid which causes particles to stick together. By controlling how much depletant is added, we control how sticky the particles are. Waad and Eric then took confocal microscopy movies of these colloidal gels. Waad's analysis of these movies shows similar behaviors to what are described above in the ACE-M-1 data. Additionally, Waad is investigating what can be seen in three-dimensional images of these gels (made using confocal microscopy) as compared to two-dimensional images. This is to help us calibrate the ACE-M-1 data, which are only 2D images. The question she is studying in particular is to understand how 2D observations are related to 3D reality. For example, suppose initially we see in a 2D gel image that each particle is stuck to two other particles on average. Perhaps in the 3D data, we'll be able to see that, in reality, the particle is stuck to five other particles on average – with those "extra" particles being out-of-plane, and thus unseen in the 2D image. Waad's experiments will help us better understand the 3D structure underlying the 2D ACE-M-1 images. Our plans for the upcoming year are to finish the analysis of all 530 GB of ACE-M-1 images. We will continue taking and analyzing new confocal microscopy images of our lab's newly created colloidal gels. Finally, we hope to do new experiments looking at gels composed of mixtures of particles with much different sizes to see how their structures might differ from gels composed of identical particles and/or particles of similar sizes.
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