Bidimensional Empirical Mode Decomposition and Dynamic Differential Microscopy Reveals Multiscale Dynamics of Critical Fluctuations

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Critical fluids have diverging compressibility, which hampers the study of critical phenomena due to convection, sedimentation, and buoyancy. Microgravity environments on the International Space Station (ISS) eliminate the experimental limitations due to compressibility near the critical point. We used a multiscale approach to investigate the dynamics of fluctuations near the critical point of sulfur hexafluoride (SF6) in microgravity. The Dynamic Differential Microscopy (DDM) has been extensively used for extracting the structure factor and the intermediate scattering function (ISF) of critical fluctuations. Oftentimes, the ISF has a complicated structure with multiple overlapping relaxation processes. Instead of fitting the ISF with multiple weighted exponentials, we first separated different spatial scales from the original images using the Bidimensional Empirical Mode Decomposition (BEMD) technique. Each spatial scale is represented by an Intrinsic Mode Function (IMF) image. We computed the ISF and the structure factor of each IMF. We found over 90% correlation between the ISF of the first IMF and the original image. The ISF determines the correlation time of fluctuations, which providing thus thermal diffusivity coefficient above the critical temperature and effective diffusion coefficients below the critical temperature very close in magnitude. The relaxation time associated with the distinguishable structures observed in the second IMF could be attributed to the fractal nature of fluctuations and light scattering at low wavenumber during the stationary behavior and the transient evolution of the critical fluid cell, which are not easy to detect in the original image.