Structure Factor Scaling in Dense Nonequilibrium Systems

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A wide variety of nonequilibrium systems show a wave vector (q) dependent scattered light intensity that exhibits a peak or maximum at a wave vector q_m. Moreover, this q_m decreases and the peak intensity $I(q_m)$ increases with time. These systems include first order phase transitions as two phases coarsen with time and dense aggregating systems. At late stages, the scattered intensity exhibits dynamic scaling according to

$$I(q,t) \sim q_m^{-D} \; F(q/q_m)$$

where D is related to the dimensionality of the growing droplets or clusters. The current interpretation is that q_m^{-1} represents a characteristic length scale of the system that coarsens with time.

To study these phenomena we have used a two-dimensional DLCA simulation to create a dense system of fractal aggregates. We show that two length scales exist in the system, cluster size and nearest neighbor separation, and that they evolve with different time dependencies. Thus dynamic scaling cannot occur. In fact, experiment has shown that scaling does not occur early in aggregation systems, and the two different length scales explain this fact. On the other hand, experimental scaling apparently does occur later in the aggregation. We show that this apparent scaling occurs once these two length scales become comparable in magnitude so that their individual effects on the structure factor overlap and thereby cancel each other. This apparent scaling, however, is an artifact, and the length scale q_m^{-1} is not fundamentally related to either of the inherent length scales of the system.