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Disordered Hyperuniform Materials

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Disordered hyperuniformity (DHU) is a recently proposed new state of matter, which has been observed in a variety of classical and quantum many-body systems. DHU systems lack the traditional long-range translational and orientational order like liquids and glasses, yet they structurally behave like a crystal on large-length scales, characterized by a complete suppression of infinite-wavelength density fluctuations. This "glass-crystal" duality endows DHU materials with many unique physical properties such as large complete isotropic photonic and phononic band gaps and robustness to defects. In this talk, we will discuss a few exotic examples of DHU systems and their emergent novel properties, including (i) hard-particle colloids at the jamming point (i.e., structural glasses), (ii) photoreceptor patterns in avian retina, (iii) and amorphous 2D material. We show that each of the aforementioned DHU system is in an effective "critical" state, which endow them with a unique form of "optimality" (i.e., maximally random jammed for the structural glasses, optimal light sampling efficiency for the photoreceptor patterns, and insulator-to-metal transition in 2D silica). We make an attempt to devise a theory combining topological transformation and inherent structures to rationale the apparent universality of DHU states, and conclude with several open questions, including the generalization of classical theory of DHU to quantum systems.