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Quantum dynamics and topological excitations in interacting dipolar particles[1]

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Dipole-dipole interactions, long-range and anisotropic interactions that arise due to the virtual exchange of photons, are of fundamental importance in optical physics, and are enabling a range of new quantum technologies including quantum networks and optical lattice atomic clocks. In this talk I will first discuss how arrays of dipolar particles with a simple J=0-J=1 internal level structure can naturally host topological and chiral excitations including Weyl quasi-particles [1]. Weyl fermions were first predicted to exist in the context of high energy physics but only recently have been observed in solid state systems. I will discuss a proposal of using Mott insulators of Sr atoms to observe and probe the Weyl excitation spectrum and its non-trivial chirality. Finally I will report on a recent experiment done at JILA [2] which validates the underlying microscopic model that predicts the existence of these excitations. The experiment measured the collective emission from a coherently driven gas of ultracold ^{88}Sr atoms and observed a highly directional and anisotropic emission intensity and a substantial broadening of the atomic spectral lines. All of the measurements are well reproduced by the theoretical model. These investigations open the door for the exploration of novel quantum many-body systems involving strongly interacting atoms and photons, and are useful guides for further developments of optical atomic clocks and other applications involving dense atomic ensembles. [1] S. V. Syzranov *et al*, Emergent Weyl quasiparticles in three-dimensional dipolar arrays, arXiv:1512.08723 [2]S. L. Bromley *et al*, Collective atomic scattering and motional effects in a dense coherent medium, arXiv:1601.05322

[1]AFOSR, MURI-AFOSR, ARO,NSF-PHY-1521080, JILA-NSF-PFC-1125844