Interstellar Polarization and Grain Alignment

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Interstellar polarization is well-known to arise from the alignment of aspherical grains with the magnetic field. This fundamental effect has opened a new window into studying magnetic fields and its effect on star formation, leading to a golden age of interstellar polarimetry with many big instruments (e.g., with SOFIA, SMA, Planck, ALMA). In particular, polarized thermal emission from aligned grains is a critical challenge for the detection of CMB B-mode signal. To achieve a realistic understanding of the role of magnetic fields in star formation process and precise measurement of B-mode signal, a quantitative theory of grain alignment is required. In this talk, I will review the successful development of such a quantitative grain alignment theory and observational tests. I will first review our quantitative theory of radiative torque (RAT) alignment based on radiative torques arising from the interaction of anisotropic radiation fields with irregular grains. I will discuss RAT alignment for both ordinary paramagnetic grains and grains with iron inclusions. Second, I will present our ab-initio modeling of dust polarization by radiatively aligned grains for a variety of environments and compare modeling results with observations. Finally, I will present our latest work on mechanical torque alignment, outline environment conditions where MAT alignment may be important, and suggest observational tests.