Ordered space- and time-odd multipoles and their relevance in magneto-electrics

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Multi-ferroics are materials were both time and space inversion are broken. We will describe some site specific quantities that accompany these orderings. They are the parts of the magnetic (both spin and orbital) densities that are odd under both space and time inversion. They can be ascribed as anapole multipoles: monopoles, toroidals, and magneto-electric quadrupoles. We will describe how to calculate these quantities from first principles electronic structure calculations and how they will contribute to our understanding of multi-ferroics, especially when we allow for anti-ferro orderings of either magnetic or electric order. This discussion will generalize our knowledge from multipole orderings in space inversion invariant materials. We will focus on systems where monopoles might play an important role.