Recent surprises in quantum materials among many legacies of Einstein

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I will discuss several surprises we have found in investigating quantum materials that generally involve relativistic effects and novel light-matter interactions. Examples drawn from our recent work include [1-5]: (i) Presence of strong axion coupling in $MnBi_2Te_4$, where the antiferromagnetic order can be reversed with external electric field as well as with circularly polarized light. The material also supports Axion quasiparticles, which are a leading candidate for dark matter. (ii) An unusual light-matter coupling in a reconstructed surface of $SrTiO_3$, which leads to an intense, coherent beam of *secondary* photoemitted electrons, an effect which cannot be understood within the existing theory of photoemission. (iii) How concepts of 'light cones' and 'event horizons' familiar from Einstein's special theory of relativity yield a much richer causality driven structure in quantum materials. And (iv) how the interplay of quantum geometry and topology can yield unique non-linear Hall and other effects. I will comment on these and related issues.

[1] A. Gao et al., *Science* 381, 181 (2023).
[2] C. Y. Hong et al., *Nature* 617, 493 (2023).
[3] B. Ghosh et al., *Science Advances* (2024).
[4] A. Gao et al., *Nature Electronics* 7, 751 (2024).
[5] J-X Qiu et al., *Nature* (2025).