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Exploring CP Violation beyond the Standard Model and the PQ Quality with Electric Dipole Moments

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In some models of physics beyond the Standard Model (SM), one of the leading low energy consequences of the model appears in the form of the chromo-electric dipole moments (CEDMs) of the gluons and light quarks. We examine if these CEDMs can be distinguished from the QCD θ-term through the experimentally measurable nuclear and atomic electric dipole moments (EDMs) in both cases with and without the Peccei-Quinn (PQ) mechanism solving the strong CP problem. We find that the nucleon EDMs show a distinctive pattern when the EDMs are dominantly induced by the light quark CEDMs without the PQ mechanism. In the presence of the PQ mechanism, the QCD θ-parameter corresponds to the vacuum value of the axion field, which might be induced either by CEDMs or by UV-originated PQ breaking other than the QCD anomaly, for instance the PQ breaking by quantum gravity effects. We find that in case with the PQ mechanism the nucleon EDMs have a similar pattern regardless of what is the dominant source of EDMs among the CEDMs and θ-term, unless there is a significant cancellation between the contributions from different sources. In contrast, some nuclei or atomic EDMs can have characteristic patterns significantly depending on the dominant source of EDMs, which may allow identifying the dominant source among the CEDMs and θ-term. Yet, discriminating the gluon CEDM from the QCD θ-parameter necessitates additional knowledge of low energy parameters induced by the gluon CEDM, which is not available at the moment. Our results imply that EDMs can reveal unambiguous sign of CEDMs while identifying the origin of the axion vacuum value, however it requires further knowledge of low energy parameters induced by the gluon CEDM.

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