Contribution ID: **23** Type: **not specified**

From supernovae to neutron stars: a systematic approach to axion production at finite density

Thursday 10 July 2025 15:40 (20 minutes)

As an elegant solution to the strong CP problem and promising dark matter candidate, the QCD axion is one of the best motivated particles beyond the SM. On the phenomenological side, it is extremely predictive as all its couplings to SM particles as well as its mass is determined by a single scale, the axion decay constant. The hunt for the QCD axion, both with terrestrial experiments as well as astrophysical observables, has exploded in the last years. As of today, astrophysical observations, such as neutron star cooling and energy loss from supernovae, place the strongest bounds.
In this talk, I will show that astrophysical bounds depend on a non-trivial momentum dependence of the axion-nucleon production in zero- as well as in finite density environments. This dependence is induced by one-loop corrections to that can be systematically calculated within the framework of chiral perturbation theory, both at zero density and in thermal field theory. As a consequence, the supernova bound is strengthened and the momentum dependence further allows us to constrain large parts of parameter space of the axion neutron coupling. I will talk about the current status of this systematic calculation systematically in chiral perturbation theory and elaborate how our findings compare to more phenomenological approaches in literature.
Additionally, I will talk about the model independent axion production mechanism in supernova, leading to a orders of magnitude stricter bound than in current literature.

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Session Classification: Parallel 3