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Quarkonium States in Strongly Magnetized Deconfined Matter of Compact Astrophysical Objects

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The possible formation of deconfined quark matter in the cores of massive neutron stars and magnetars provides an extreme environment for studying quarkonium in ultra-strong magnetic fields. In this work, quarkonium states and their annihilation through the $q\bar{q} \to 2\gamma$ channel in hot magnetized quark matter are investigated, taking into account Landau-level quantization and the interaction with the surrounding thermal quark-antiquark medium. The thermal quark-antiquark pairs are assumed to be produced through the decay (timelike splitting) of virtual gluons in the deconfined medium.

An analytical description of the annihilation width is developed, with an extended formulation including the full Landau-level structure, screened interactions, and relativistic thermal averaging. In the lowest-Landau-level ultrarelativistic limit, the thermally averaged width scales as $\langle\Gamma\rangle \propto T^4$. In the light-quark limit, the two-photon annihilation channel is related to the $\pi^0 \to 2\gamma$ decay, with a characteristic width of order 10 eV. Order-of-magnitude estimates give annihilation times of ~10^6 years for light quarks and ~1.5×10^3 years for heavier quarks with $m_q \geq 100$ MeV.

The light-quark timescale is comparable to the characteristic ~10^6-year magnetic-field evolution timescale of a stable magnetar, whereas heavy-quark states can annihilate much faster. This suggests that the $q\bar{q} \to 2\gamma$ channel may play a more pronounced role in the thermalization of deconfined matter for heavier quarks during the evolution of strongly magnetized compact astrophysical objects.

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