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Superheavy Dark Matter, GUT Axions and High Frequency GWs from Structure Formation and X Miracle

We propose a new framework based on structure formation at the free-streaming scale and a modified “X miracle” beyond the standard WIMP paradigm. Both point to nonthermal, superheavy fermionic dark matter of 10^{12}GeV . Unlike WIMPs that are light, semi-relativistic, and unaffected by gravity at freeze-out, the X miracle incorporates gravity, introducing a new fundamental scale $r_X = 10^{-13}\text{m} \gg m_X^{-1}$ that breaks the unitarity bound and allows for a large cross section $10^{-21}\text{m}^3/\text{s}$. At this mass, free streaming mass matches the particle mass, enabling the earliest gravitationally bound structures to form at 10^{-6}s and release binding energy as 100kHz gravitational waves or as GUT-scale axions. Superheavy sterile neutrinos are natural candidates, addressing dark matter, neutrino mass, and baryogenesis. Boltzmann equation suggests a relic abundance from early annihilation, with one in a billion particles surviving. This offers explanations for ultra-high-energy cosmic rays and Hubble tension.

References

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