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Supercritically charged objects and electron-positron pair creation

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We investigate the stability and e^+e^- pair creation of supercritically charged superheavy nuclei, udQM nuggets, strangelets, and strangeon nuggets based on the Thomas-Fermi approximation. The model parameters are fixed by reproducing masses and charge properties of these supercritically charged objects reported in earlier publications. It is found that udQM nuggets, strangelets, and strangeon nuggets may be more stable than ^{56}Fe at the baryon number $A \geq 315$, 5×10^4, and 1.2×10^8, respectively. For those stable against neutron emission, the most massive superheavy element has a baryon number $\sim$965, while udQM nuggets, strangelets, and strangeon nuggets need to have baryon numbers larger than 39, 433, and 2.7×10^5. The e^+e^- pair creation will inevitably start for superheavy nuclei with charge numbers $Z \geq 177$, for udQM nuggets with $Z \geq 163$, for strangelets with $Z \geq 192$, and for strangeon nuggets with $Z \geq 212$. A universal relation $Q/R_e = (m_e - \bar{\mu}_e)/\alpha$ is obtained at a given electron chemical potential $\bar{\mu}_e$, where Q is the total charge and R_e the radius of electron cloud. The maximum number of Q without causing e^+e^- pair creation is then fixed by taking $\bar{\mu}_e = -m_e$. For supercritically charged objects with $\bar{\mu}_e < -m_e$, the decay rate for e^+e^- pair production is estimated based on the Jeffreys-Wentzel-Kramers-Brillouin (JWKB) approximation. It is found that most positrons are emitted at $t \leq 10^{-15}$ s, while a long lasting positron emission can be observed for large objects with $R \geq 1000$ fm. The emission of positrons and electron-positron annihilation from supercritically charged objects may be partially responsible for the short γ-ray burst during the merger of binary compact stars, the 511 keV continuum emission, as well as the narrow faint emission lines in X-ray spectra from galaxies and galaxy clusters.

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