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Twin stars and the QCD phase diagram

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It has been suggested [1] that the observation of pulsars with the same mass but significantly different radii (twin stars) would prove that the existence of a critical endpoint in the QCD phase diagram since this phenomenon requires a strong phase transition in cold neutron star matter [2].
We explore whether such a phase transition in neutron star cores, possibly coupled with a secondary kick mechanism such as neutrino or electromagnetic rocket effect, may provide a formation path for isolated and eccentric millisecond pulsars (MSPs) [3].
We find that in compact binary systems (P_orb = 8 days) the accretion-induced phase transition occurs towards the end of mass transfer, specifically during the spin equilibrium phase. In contrast, in binary systems with wider orbits (P_orb ⪆ 22 days), this transition takes place during the subsequent spin-down phase, leading to a delayed collapse. We find that a gravitational mass loss of approximately ΔM ~ 0.01 M⊙ suffices to produce an eccentricity of the order of 0.1 without the need of a secondary kick mechanism. Wider systems are more prone to yielding highly eccentric orbits and be disrupted, presenting a formation path for isolated MSPs [3].
We show that in hot neutron star matter during supernova and merger events, thermal twin stars can be formed [4], even when in the mass-radius diagram of cold neutron stars the branch of hybrid stars with color superconducting quark matter cores is connected to that of pure neutron stars (no twins). Investigating systematically star sequences for increasing entropy per baryon s/n_B = const, we find a correlation between the transition to normal quark matter in hybrid star cores, the change from enthalpic to entropic character of the transition and the occurrence of thermal twin stars at s/n_B ~ 2. We speculate about a correlation of the thermal twin phenomenon with the supernova explodability of massive blue supergiant stars [4]. The result of these investigations has consequeences for the accessibility of color superconducting quark matter phases in heavy-ion collisions [5].

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