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The lightest neutron star formed from a binary system

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The exceptionally low mass $0.77^{+0.2}_{-0.17} M_\odot$ inferred of the central compact object (CCO) XMMU J173203.3–344518 within the SNR HESS J1731–347, of age ≈ 4.5 kyr, challenges the standard core-collapse scenario of NS formation. The observed (likely post-AGB) star of $\approx 0.6 M_\odot$, at 0.3 pc from XMMU J1732, also within the SNR, enriches the scenario. To address this puzzle, we advance the possibility that the gravitational collapse of a rotating iron core of an evolved star can produce a light NS. We estimate the structure of the rotating pre-SN iron core of $\approx 1.2 M_\odot$ and examine its gravitational collapse. We show that the angular momentum conservation during the collapse of an iron core rotating at $\approx 45\%$ of the Keplerian limit leads to an $\approx 0.9 M_\odot$ stable newborn NS. Assuming magnetic dipole radiation for a 10^{11} G field, the CCO must rotate relatively slowly with the upper limit of its rotation frequency being ≈ 530 Hz. Thus, the CCO mass and radius measurement probes the non-rotating NS mass-radius relation in the low-mass region. We show that a canonical NS thermal evolution agrees with the XMMU J1732 observed surface temperature of $\approx 2 \times 10^6$ K, assuming 4.5 kyr as its age. We propose the pre-SN evolved star, likely an ultra-stripped core of $\approx 4.2 M_\odot$, formed a tidally locked binary of ≈ 1.43 days orbital period with the post-AGB star. The SN produces a mass loss of $\approx 3 M_\odot$, imparting a kick velocity < 670 km s^{-1}, disrupting the binary. This scenario agrees with the observed projected offset of 0.3 pc between XMMU J1732 and IRAS 17287–3443. Therefore, our findings support the possibility of CCOs originating in binaries, the relevant role of rotation in core-collapse events, and the CCO XMMU J1732 being the lightest NS ever observed.

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