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Reheating neutron stars with the annihilation of self-interacting dark matter

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Compact stellar objects such as neutron stars (NS) are ideal places for capturing dark matter (DM) particles. We study the effect of self-interacting DM (SIDM) captured by the nearby NS that can reheat NS to an appreciated surface temperature. Recently, DM self-interaction was considered as an negligible effect due to its small geometric cross section in NS. However, we will demonstrate when DM-nucleon cross section σχn is much smaller than the current direct search limits, DM self-interaction will dominate the capture process. As a result of small σχn, DM will not thermalize with NS and its decoupled temperature Tx(dec) is as high as a certain temperature of NS in the early evolution stage. In particular, a higher Tx(dec) will induce a larger DM thermal radius. It increases DM self-capture rate and leads to the stronger DM annihilation rate. The energy injection to NS will be more thus reheat the star. Such effect results from DM self-interaction but it behaves as DM having a relatively large σχn. The NS temperatures are produced from the interplays between DM-nucleon and DM-DM interactions. In certain parameter region, there are two possible solutions that will generate the same NS temperature. We will also show that the reheating NS surface temperature by SIDM cannot be arbitrary high. It saturates at hundreds of Kelvins depending on the DM mass. The corresponding blackbody peak wavelength is potentially detectable in the future telescopes.

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