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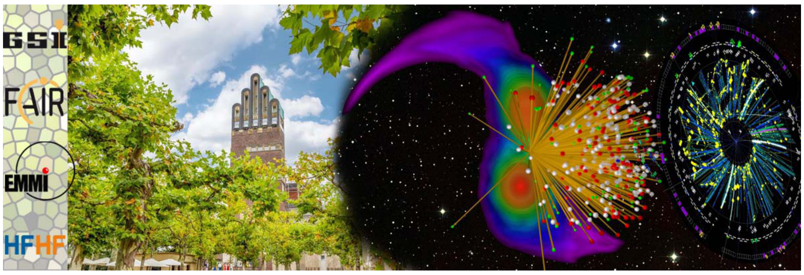

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Self-energy of pion and its impact on equation of state

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We study the pionic self-energy and its impact on the energy-momentum dispersion relation of pion in neutron-rich conditions such as interior of a neutron star. In such neutron-rich state, the negatively charged pions can be produced copiously. Furthermore, these negatively charged pions can form a Bose-Einstein condensate with zero momentum above nuclear saturation densities. In this paper, we evaluate the self-energy of the negatively charged pion using the phase shift data from the pion-nucleon scattering as well the pion-pion scattering experiments. The self-energy is determined at material conditions present in a neutron star during binary merger. We notice that the pion-nucleon scattering can lead to both positive (attractive) and negative (repulsive) pionic self-energy. This pion-nucleon interaction can lead to a few percent change in the pion energy from its free value at supranuclear densities. On the other hand, the repulsive pion-pion interaction results in purely positive self-energy. While evaluating the self-energy related to the purely pionic interaction, we consider both the condensed pions with zero momentum, and the thermal pions with finite momenta. At zero temperature, the self-energy due to the pion-pion interaction is dominated by the condensate part. Whereas, the thermal part can prevail over the condensate part at finite temperatures. Similar to the pion-nucleon case, the self-energy due to the pion-pion interaction also results in a few percent change in the pion energy compared to that of the free pion. Overall, we see that the pionic self-energy is dominated by the pion-pion interaction at lower pion momenta and by the pion-nucleon interaction at greater momenta. Moreover, the pion momentum, where the pion-nucleon interaction becomes dominant over the pion-pion interaction, depends on the matter condition. Furthermore, we studied the impact of the interacting pions on the high-density nuclear equation of state, and on the neutron star structure under the β-equilibrium condition. For this study, we modified the non-pionic SFHo equation of state is modified to include pions. The introduction of pions softens the equation of state and reduces the maximum neutron star mass compared to that of the equation of state without pions. Moreover, the pion production leads to the shrinking of the NS radius for a given central baryonic number density. Furthermore, we notice rather similar mass-radius, and mass-density relations of the neutron star between the EOS with interacting pions and the EOS with free/non-interacting pions.

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