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Probing Dense Nuclear Matter: Connecting Neutron Stars and Heavy-Ion Collisions

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The study of neutron stars and heavy-ion collisions offers complementary access to the properties of strongly interacting matter at extreme densities. In particular, the simultaneous observation of both massive neutron stars and light stars with small radii suggests a sharp rise in the speed of sound in dense nuclear matter, potentially approaching the causal limit at baryon densities of a few times nuclear saturation. A key question is whether such behavior, inferred from neutron-star phenomenology, is compatible with constraints from terrestrial experiments. In this talk, I present a framework that connects these two regimes by mapping a family of neutron-star equations of state (EOS), characterized by a rapid increase in the speed of sound, into the symmetry energy expansion appropriate for the nearly symmetric matter probed in low-energy heavy-ion collisions. Using the hadronic transport code SMASH with density-dependent mean-field potentials, we simulate collective flow observables and compare them with experimental data. Our results indicate that EOS featuring a peak in the speed of sound squared at 2-3 n_sat, supporting maximum neutron-star masses up to M_max ~ 2.5 M_sun, remain consistent with HIC constraints. I will briefly discuss complementary approaches to constraining dense matter using chiral effective field theory and perturbative QCD, highlighting their roles in bridging the physics of neutron stars and laboratory experiments.

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