Viscosity: From air to hot nuclei

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The recent observations of the charged particle elliptic flow and jet quenching in ultrarelativistic Au-Au and Pb-Pb collisions performed at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and Large Hadron Collider (LHC) at CERN have been the key experimental discoveries in the creation and study of quark-gluon plasma (QGP). The analysis of the data obtained from the hot and dense system produced in these experiments revealed that the strongly interacting matter formed in these collisions is a nearly perfect fluid with extremely low viscosity. In the verification of the condition for applying hydrodynamics to nuclear system, it turned out that the quantum mechanical uncertainty principle requires a finite viscosity for any thermal fluid. In this respect, one of the most fascinating theoretical findings has been the conjecture by Kovtun, Son and Starinets (KSS) that the ratio η/s of shear viscosity η to the entropy volume density s is bound below for all fluids, namely the value $\eta/s=\hbar/(4\pi k_B)$ is the universal lower bound (the KSS bound or KSS unit) [1]. The QGP fluid produced at RHIC has $\eta/s\approx$ (2 - 3) KSS units. Given this conjectured universality, there has been an increasing interest in calculating the ratio η/s in different systems.

After a brief account on the history of the viscosity from classical to quantal fluids, the present lecture discusses how the shear viscosity η of a finite hot nucleus is calculated directly from the width and energy of the giant dipole resonance (GDR) of this nucleus. The ratio η/s is extracted from the experimental systematic of GDR in copper, tin and lead isotopes at finite temperature T. These empirical results are then compared with the predictions by several independent models, as well as with almost model-independent estimations. Based on these results, it is concluded that the ratio η/s in medium and heavy nuclei decreases with increasing T to reach (1.3 - 4) KSS units at T= 5 MeV, i.e. almost the same value as that obtained for QGP at T > 170 MeV [2].

Reference:

[1] P.K. Kovtun, D.T. Son, and A.O. Starinets, Phys. Rev. Lett. 94 (2005) 111601.

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