УДК: 539.12.01

Viscosity in an accelerated relativistic medium from the Unruh effect vs string theory bound

***D.D. Lapygin*[1], *G.Y. Prokhorov*[2]**

E-mail: dmitrijlapygin@gmail.com

[1]*Southern Federal university, Rostov-on-Don, Russia*

[2] *Joint Institute for Nuclear Research, Bogoliubov Laboratory of Theoretical Physics, Dubna, Russia*

This project investigates the dissipative properties of an accelerated relativistic medium and their connection to the Unruh effect and effective black hole radiation. The thermodynamic properties in spaces with a horizon is one of the most discussed in modern fundamental physics. A notable 2005 string theory limit sets a minimum shear viscosity.

The aim of the work is to investigate issues related to entropy and viscosity in appropriate media, in particular, to verify the viscosity constraint from string theory. Formula, obtained in [1].

We calculated viscosity in an accelerated frame for a photon medium, where no holographic description exists, treating the black hole horizon as a membrane of finite thickness [2]. While the average viscosity meets the string theory limit, local values are described by a universal function that is independent of particle spin. Specifically, on the membrane surface, the ratio of local viscosity to local entropy is half the string theory limit. Importantly, this result is gauge-independent, with the positive contribution from gauge fixing exactly canceling the negative contribution from Faddeev-Popov ghosts.

1. The viscosity of photons in an accelerated reference frame at the Unruh temperature was calculated for the first time.

2. The ratio of the average viscosity to the average entropy for photons in a Minkowski vacuum in an accelerated medium has been clearly shown. This value is equal to 1/4pi, which corresponds to the limit derived from string theory.

3. It is shown that the ratio of local viscosity to local entropy on the membrane surface is two times less than the limit from string theory and is equal to 1/8pi.

4. The ratio of local viscosity to local entropy is found at an arbitrary distance from the membrane of the extended horizon for photons. It is clearly shown that this function is universal for massless particles with different spins.

5. Various approaches to calculating entropy are analyzed and it is shown that the thermodynamic definition through the pressure derivative is in agreement with the limit on the ratio of viscosity to entropy from string theory.

6. It is clearly shown that the viscosity of photons does not depend on the choice of gauge and there is a mutual compensation of the contributions of the members fixing the gauge and the Faddev-Popov ghosts. Thus, all the tasks were completed.

This work for a scalar massless field has already been done in [3]. However, such a solution remains not obvious for other types of fields, due to the different values of entropy. We performed a calculation for a vector massless field using the Kubo formula, where we used the average value of the correlator of two energy-momentum tensors, and also used the point-splitting technique to eliminate uncertainties. In the end, we also turned to the theory of functions of complex variables, using Cauchy's theorem for residues. We also separately counted contributions from Maxwell's, gauge's, and ghost's tensor members to show their role in the calculations.

1. D.T. Son. “Hydrodynamics and gauge/gravity duality”. In: (2009). doi: 10.1016/j.nuclphysbps.2009.07.048. eprint: 1005.0475.
2. Wilczek F. Parikh M. K. “An action for black hole membranes”. In: Physical Review D (1998). doi: 10.1103/physrevd.58.064011.
3. G. Chirco. “The universal viscosity to entropy density ratio from entanglement”. In: (2010). doi:10.1103/PhysRevD.82.024010. eprint: 1005.0475.