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Killing Flows and Thermodynamics in Minkowski Space

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Thermodynamical approach is often fruitful in investigating large scale plasma phenomena. Assuming local equilibrium, one can handle physical processes such as heat flow using thermodynamics. In relativity, however, our non-relativistic common sense on thermodynamics is not always directly applicable. For example, it has been well known that the local temperature of a relativistic rotating wheel is lower at the axis than at the rim. In such a situation, heat can spontaneously flow from low temperature regions to high temperature regions.

Therefore, one must know how the relativistic thermal equilibrium can take place globally to investigate thermal processes. The author has discussed relativistic equilibrium with parallel motion and rotation in the past meetings; the present talk is to treat the four dimensional relativistic equilibrium from a more general view point.

Thermal equilibrium can take place when the matter is moving with rigid motion, in other words, the proper distance of each element is unchanged during the motion. Geometrically this kind of motion can be expressed as motion along Killing flows. There can be ten linearly independent Killing flows in a four dimensional Minkowski space, and the simple way to express them is four parallel motion and six rotational motion. Possible Killing flows are superposition of these ten, and can be more complicated. Letaw and Pfautsch (1981) have shown that various Killing flows can be categorized into six groups. The first two are the parallel and rotational motion, for which the author has reported equilibrium states in the past meetings.

The other four contains so called static limits, which means a matter cannot stay at a point with fixed spatial coordinates beyond these limits. The light cylinder and ergo region of a Karr black hole are examples of such limits. Thermodynamics across the static limit is interesting topic itself, and applicable to the thermodynamics of accretion plasmas falling into a black hole.

Keywords: relativity, thermodynamics, Killng flow, black holes