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ORIGINAL ARTICLE

Generalized thermodynamics uncertainty and (anti) de Sitter space

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Abstract The derivation of the thermodynamics uncertainty to anti de Sitter space-time is carried out. The entropy of anti de Sitter space is obtained. Furthermore, for first time, the electromagnetic signal related to the Hawking radiation is suggested to be calculated which may be a key factor in realizing black holes in both cosmos and lab.

Keywords Generalized thermodynamics uncertainty principle · Sakuma-Hattori equation

The temperature of black hole is usually regarded as a kinetic effect, depending on the coordinate chart used by a class of observers such as free falling and fiducial observers, but not properly of the space time geometry in general (Bekenstein 1981; Hawking 1984). The (anti) de Sitter space-time is an attractive and simple model, which describe the observer dependent space-time. In the 4-dimensional space time scenario, the 4-dimensional space time is regarded to the 4-dimensional Minkowski space time embedding in the 5-dimensional (anti) de Sitter space time. The AdS/CFT correspondence relates the physics of black holes in AdS_{d+2} to a thermal (conformal) field theory living on the boundary $S^1 \times S^8$ (Maldacena 1998; Witten 1998). If one tries to view de Sitter space as a true vacuum, there is a tension between the finiteness of its entropy and the infinite dimensionality of its Hilbert space. This problem is considered by Krishnan and Napoli (2007) in details. It should be possible to extend the derivation of the thermodynamics in the Planck regime using the generalized thermodynamics uncertainty principle. In this article, the thermodynamics of anti de Sitter space is studied using a generalized thermodynamics uncertainty relation.

It is believed that the thermodynamics uncertainty actually stems from the *second law* of thermodynamics (Uffink and van Lith 1999). The usual uncertainty between energy ΔU and the inverse temperature $\Delta(1/T) = \Delta\beta$ is (Schlogl 1988; Pennini et al. 2001; Abe and Suzuki 1990; Cadoni 2004; Cai 2002; Lavenda 1987; Mandelbort 1964; Rosenfeld 1961),

$$\Delta U \Delta\beta \geq k \tag{1}$$

Where k is the Boltzmann constant. The application of thermodynamics uncertainty in the black hole space time is interesting. Consider a d-dimensional Schwarzschild (anti) de Sitter black hole with mass M and $(d > 3)$ (Bolen and Cavaglia 2005; Cai 2002; Cadoni 2004).

$$ds^2 = -(1 \pm \lambda^2 r^2 - \theta)c^2 dt^2 + (1 \pm \lambda^2 r^2 - \theta)^{-1} dr^2 + r^2 d\Omega_{d-2}^2 \tag{2}$$

where $\theta = \frac{w_d G_d M}{c^2 r^{d-3}}$, G_d is Newton's constant in d-dimension and $\lambda = 1/b$ is the inverse of the (anti) de Sitter radius and $\pm$ sign is for (anti) de Sitter and de Sitter space time, respectively. The constant w_d is equal to $16\pi/(d-2)\Omega_{d-2}$. In the horizon the Hawking temperature reads,

$$T = \frac{d-3}{4\pi}\left(\frac{1}{r_h} \pm \gamma^2 r_h\right)\hbar c \tag{3}$$

because in (anti) de Sitter space time the radius of the event horizon is large in comparison with the radius of curvature of the (anti) de Sitter space time. So the temperature of such horizon may be as,

$$T_{(anti)deS} = \frac{(d-3)\gamma^2 r_h}{4\pi}\hbar c \tag{4}$$

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