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ORIGINAL ARTICLE

Enigmatic aspects of entropy inside the black hole: what do falling comoving observers see?

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Abstract In a recent paper it was suggested that inclusion of mutual gravitational interactions can give a possible scenario for reversing gravitation collapse and averting a singular phase. We extend this idea to the still unsolved problem of matter collapsing beyond black hole event horizons. For a comoving observer there is no change in entropy as he goes through the horizon. Matter collapses to a minimum radius, and then can re-expand with the same entropy. It is shown that phase space inside a collapsing black hole is also invariant.

Keywords Black hole entropy · Mutual gravitational interactions · Gravitational collapse

The problem of black hole entropy, i.e. the drastic increase of entropy (tantamount to information loss) by a factor of about 10^{19} as a star of solar mass collapses, continues to be a major puzzle in astrophysics and has led to a very wide range of intriguing solutions. Most of the current solutions, assume the matter collapsing inside the horizon to go into a super-dense state consisting of exotic states of matter like superstrings or superbranes. The statistical counting of these states is then matched with the entropy (Susskind and Lindsay 2005).

However, for large supermassive black holes for instance, the matter density as it falls into the horizon is less than air. In the reference (Sivaram 1985), it was pointed out that it was puzzling how such rarefied matter could suddenly make a transition to exotic objects. It was pointed out that the black hole entropy is essentially a property of the horizon which demarcates the space-time of outside observer from the comoving observer who continues to collapse along with the matter inside the horizon. The outside observer loses all information about the collapsing matter beyond the horizon, mainly because of the infinite redshift and time dilation of signals emitted at the horizon. For the comoving observer nothing changes.

It was also pointed out that quantum fluctuation of the horizon, would not give an infinite redshift, but a finite value, which in turn would explain the Hawking temperature of the horizon (which is what would be measured by an observer at infinity).

For a solar mass black hole at the horizon, the collapsing matter would be heated to 10^{13} K (which is what the comoving observer would measure!) and this would continue to get higher as the collapse proceeds beyond the horizon. The outside observer would only measure a temperature (Hawking) of 10^{-7} K (the horizon temperature) and this would imply (for the same energy as before), an entropy increase of about 10^{20} (Sivaram 1991). The analogy with black paint has been made (Chapline et al. 2001).

In the following discussion, we consider the comoving observer falling into the black hole. Conventional arguments would imply that the collapsing matter inside the horizon would be crushed into a singularity of infinite density in a finite tine.

However in a recent paper, in connection with the universe, we had pointed out (Sivaram and Arun 2011) that inclusion of mutual gravitational interactions among the collapsing particles (at high densities) gives a possible scenario for reversing the collapse and initiating a re-expanding

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