Commun. math. Phys. 51, 121—133 (1976)

Communications in Mathematical Physics

Thermal Particle Production in Two Taub-Nut Type Spacetimes

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Abstract. The Hartle-Hawking method of deriving black hole radiance (the "Hawking Process") has been extended to non-asymptotically flat de Sitter spacetime by Gibbons and Hawking. They derive a thermal spectrum of radiation detectable by suitable observers. We extend this work to Taub-Nut spacetime and a related and more physical spacetime constructed from it by Siklos by complex analytic continuation and unwrapping. Suitable observers are found to detect thermal spectra in these two spacetimes as well.

Introduction

In this paper particle production in two related homogeneous and anisotropic spacetimes is considered. We use the framework for calculating particle production in non-asymptotically flat spacetime developed by Gibbons and Hawking [1] for de Sitter space as an extension of the Hartle-Hawking [2] path integral method of deriving black hole radiance. The first spacetime we will consider is Taub-Nut space which is not only non asymptotically flat (topology $R \times S^3$) but is non Hausdorff (however without bifurcating geodesics), has closed time-like and null lines and suffers from geodesic incompleteness. In this spacetime a suitable observer (unfortunately one moving on a closed time-like line) would detect a thermal spectrum, however it is truncated at a low fundamental frequency and is discrete in integer multiples of this fundamental frequency. We consider this pathological spacetime mainly as an illustration of the elegance and power of the path integral method.

The second more physical spacetime considered is a Bianchi-type VIII spacetime constructed by Siklos [3] from Taub-Nut space by complex analytic continuation and unwrapping. The resultant manifold is Hausdorff, and although there still exist closed time-like lines in this Type VIII Taub-Nut space we choose an observer who does not move on one. This observer is also found to observe a thermal spectrum.

The paper is divided into five sections. In Section 1 we review the global properties of Taub-Nut space. In Section 2 we review the Hartle-Hawking path