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Gamma rays from a primordial black hole evaporation

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Introduction

In 1974, S. Hawking predicted that black holes (BH) can radiate particles of any spin following a Planckian spectrum with temperature [1]

$$kT_{BH} = \frac{\hbar c^3}{8\pi GM} \tag{1}$$

This radiation leads to a BH to lose its mass while its temperature increases until total evaporation. The time needed for a BH of mass M to evaporate is $\tau \sim 10^{-24}(M/\text{kg})^3$ yr . Then a BH with 1 solar mass has a temperature of 10^{-7} K and a lifetime $\tau \sim 10^{66}$ yr, much large that the age of the Universe. Nevertheless, BHs of smaller masses, in the order of 10^{15} g would be evaporating today. Such objects, known as primordial black holes (PBH) would be formed at early stages of the Universe. The temperature reached by PBHs is high enough to emit primary photons (directly emitted by the BH) with energy above 100 GeV in last days before it vanishes. Moreover, BH emits all elementary particles with mass below kT, so secondary photons are emitted from the decay of hadrons. The signal is typically parametrized in the literature as

$$\frac{dN_\gamma}{dE_\gamma} \simeq 9\times 10^{35} \begin{cases} E_\gamma^{-3}\ [\text{GeV}^{-1}] & E_\gamma \geq kT_\tau \qquad \text{Primary} \\ (E_\gamma\, kT_\tau)^{-3/2}\ \ [\text{GeV}^{-1}] & E_\gamma < kT_\tau \qquad \text{Secondary} \end{cases} \tag{2}$$

where kT_τ is the initial temperature of the PBH with lifetime τ.

Results

Our work verify that BH spectrum is not Planckian. In other words, BH radiation can not be obtained from a cavity with temperature T_{BH}. Also, we found that the primary spectrum can be parametrized as in equation 2 just for $E_\gamma \geq 10\, kT_\tau$. Then, we compared our calculations with spectra obtained from simulations in `BlackHawk` (a program to simulate the Hawking radiation from a distribution of BHs). Based on this analysis, we estimated the photon flux on Earth N_γ (number of photons per m^2 per lifetime τ) at certain energy range, given the radiation of a PBH located at fixed distance d [pc]. Finally, we used `Corsika` (a program to simulate extensive air showers) to simulate the electromagnetic shower that a gamma ray should produce. With this study we prepare for future strategies for PBHs detection with the next generation of gamma ray observatories such as the Southern Wide field Gamma ray Observatory (SWGO) currently in its design phase, and the Cherenkov Telescope Array (CTA), under construcction phase.

Referencias

[1] S. W. Hawking. Black hole explosions?. *Nature*, 248(5443):30-31, Mar 1974.