Transient Pulses from Exploding Primordial Black Holes as a Signature of an Extra Dimension

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Pheno 2008
April 29, 2008

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arXiv:0801.4023 [astro-ph], 2008.

Primordial Black Hole Evaporation

It is possible that a multitude of small mass black holes formed in the early universe following the end inflation. These so called primordial black holes (PBHs) would evaporate as conjectured by Hawking.

$$T \sim \frac{1}{M} \qquad \frac{dM}{dt} \sim \frac{\alpha(T)}{M^2}$$

M. J. Rees, Nature 266, 333 (1977)
R. D. Blandford, Mon. Not. R. Astron. Soc. 181, 489 (1977)

Transient Pulse Production

It was suggested by Rees that this type of explosive event could produce a coherent electromagnetic pulse. If significant numbers of electron-positron pairs are produced in the event, the relativistically expanding shell of these particles a "fireball" of Lorentz factor γ_f acts as a perfect conductor, reflecting and boosting the virtual photons of the interstellar magnetic field. The observed characteristic wavelength of the pulse is given by

$$\lambda_{crit} \simeq \frac{r_{max}}{\gamma_f^2} \qquad \nu_{crit} \sim \frac{\gamma_f^2 c}{r_{max}}$$

over an observed a time scale

$$t_{observed} \simeq \frac{r_{max} c}{\gamma_f^2}$$

Transient Pulse Production

The Lorentz factor is determined by the mass of the black hole at the time of the final explosive event. $\gamma_f \sim T \sim \frac{1}{M}$

The range of Lorentz factors appropriate to produce a transient pulse is constrained by three considerations.

- How large a radius can the fireball attain before the energy in the swept up field decelerates it?
- Is the fireball a good enough conductor to sweep up the field?
- Would the fireball sweep up external plasma as well as the ambient magnetic field?

This constrains the Lorentz factor of a fireball capable of producing a coherent transient pulse to be,

$$10^5 \lesssim \gamma_f \lesssim 10^7.$$

Exploding PBHs and the Black String/Black Hole transition

B. Kol, hep-ph/0207037 (2002).
B. Kol, Phys. Rept. 422, 119 (2006).

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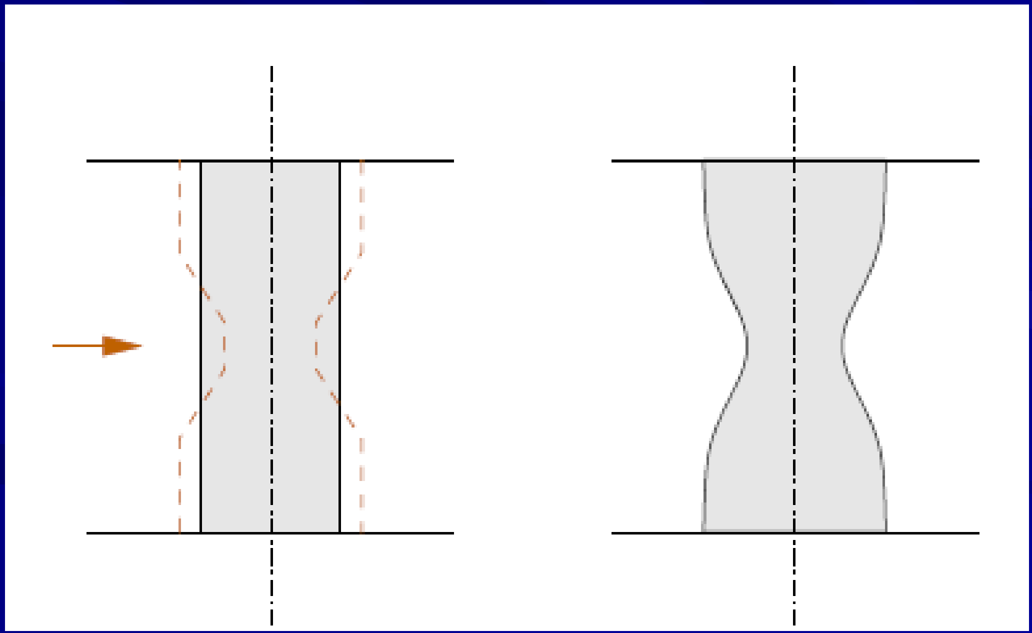
The Black String/Black Hole transition

As the mass of the black string reduces due to evaporation its horizon size becomes comparable to the size of the extra dimension and it become unstable (Gregory-Laflamme instability) and undergoes a first order phase transition to a "caged" black hole.



An Explosive Outburst

The first order phase transition is accompanied by a release of energy

$$E = \eta M c^2 = \eta \frac{R_s c^4}{2G} = \eta \mu L \frac{c^4}{G},$$

where the efficiency parameter η is expect to ~.01. This outburst will take place over the timescale

$$\tau = L/c$$

Producing a Transient Pulse

As in the case of a final explosive phase the BH/ BS transition would produce a fireball. We may relate the energy released during the transition to the Lorentz factor fireball produced in the outburst.

$$E \approx \eta_{01} \gamma_{f5}^{-1} \; 10^{23} \text{ J}$$

which we may in turn relate to the size of the extra dimension

$$L \approx \mu_{07}^{-1} \gamma_{f5}^{-1} \; 10^{-18} \text{ m},$$

Constraints on Transient Pulse Production

As in the case of the final explosive phase the Lorentz factor that will produce a transient pulse is constrained to be

$$10^5 \lesssim \gamma_f \lesssim 10^7.$$

This implies that in order for the BH/BS phase transition to produce a transient pulse the extra dimension must be of size

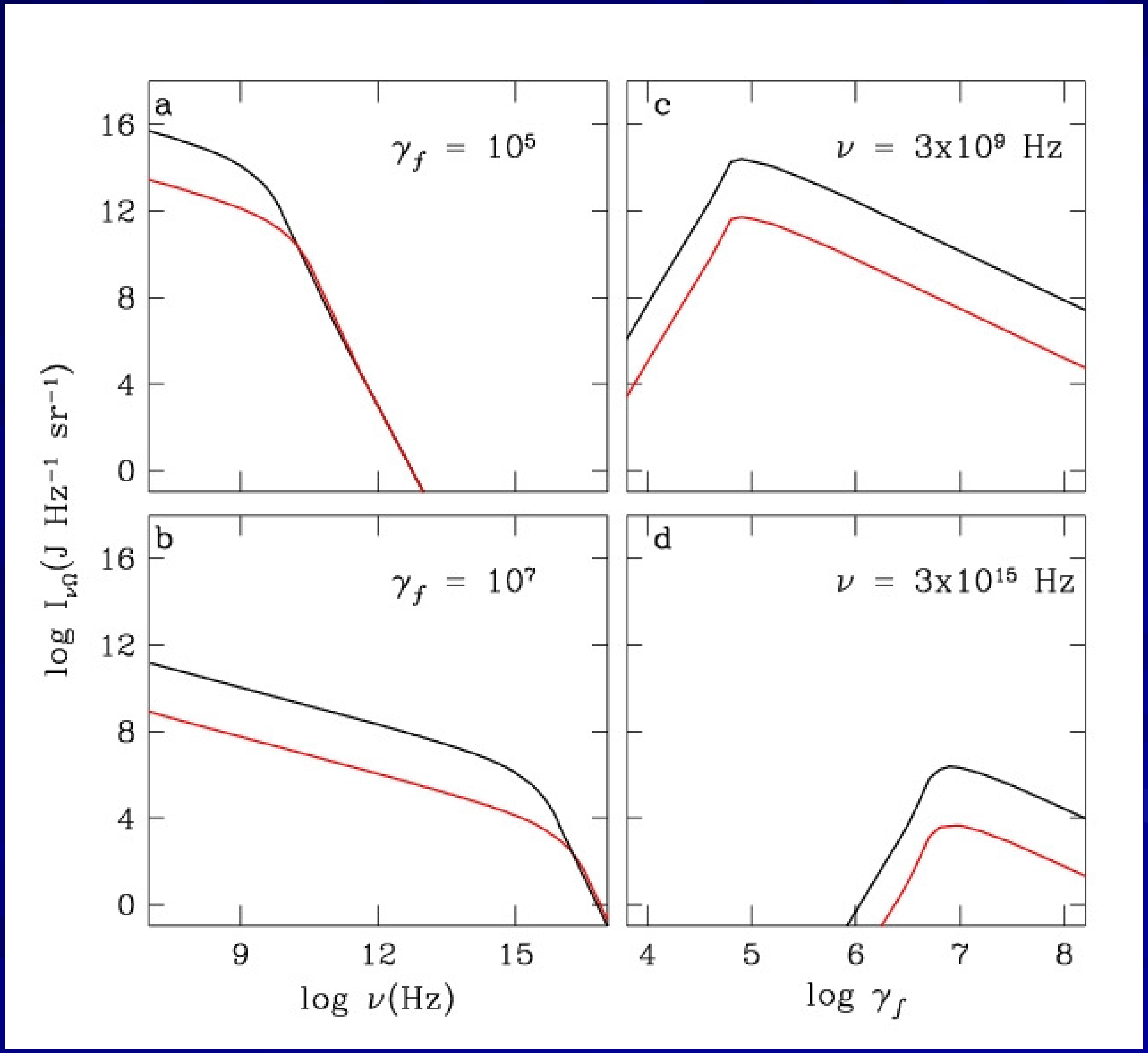
$$10^{-20}\ \mathrm{m} \lesssim L \lesssim 10^{-18}\ \mathrm{m},$$

$$.1\mathrm{TeV}^{-1} \lesssim L \lesssim 10\mathrm{Tev}^{-1},$$

with characteristic frequency

$$10^9\ \mathrm{Hz} \lesssim \nu_c \lesssim 10^{15}\ \mathrm{Hz},$$

Pulse Discrimination



ETA

Pisgah Astronomical Research Institute (PARI)
35° N, 83° W
Rural, mountainous region, western North Carolina

Arial view of PARI showing location of ETA

Array site near bottom of "bowl" formed by surrounding terrain