Expected *Fermi*-LAT limits on primordial black hole evaporation

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Summary: We derive expected limits from *Fermi*-LAT data on the rate of bursts of primordial black holes (PBHs). Our limits are expected to be an order of magnitude better than the existing limits obtained by other experiments.

Abstract

Fermi Large Area Telescope (LAT) has been extremely successful not only in the study of astrophysical sources, such as Pulsars, Novae, Gamma-ray bursts, Solar flares, but also in putting limits on cosmological models and new physics, e.g., dark matter annihilation, models of extragalactic background light, violations of general relativity. In this work we present the expected limits on the evaporation rate of primordial black holes inferred from the *Fermi*-LAT data. The expected limits are better by an order of magnitude than the limits derived by the H.E.S.S. collaboration and a factor of a few better than the expected limits from the HAWC experiment.

PBHs are produced in the early Universe [1, 2] when

1. There are large fluctuations of density
2. The equation of state is soft (no pressure)

Black hole with a mass M has a temperature [3, 4]

$$T = \frac{M_{\rm Pl}^2}{8\pi M}$$

The temperature leads to evaporation. The lifetime is

$$\tau \propto M^3 \propto T^{-3}$$

Examples:

1. Lifetime is equal to the age of the Universe. M ~ 10^{15} g. T ~ 10 MeV.
2. Lifetime is 30 years. M ~ 10^{12} g. T ~ 10 GeV.
3. Lifetime is 1 second. M ~ 10^{9} g. T ~ 10 TeV.

A black hole with a mass ~ 10^{15} g has

1. the size of a nucleus;
2. the mass of a thousand of largest oil tankers;
3. temperature 10 million times larger than the temperature on the surface of the Sun.

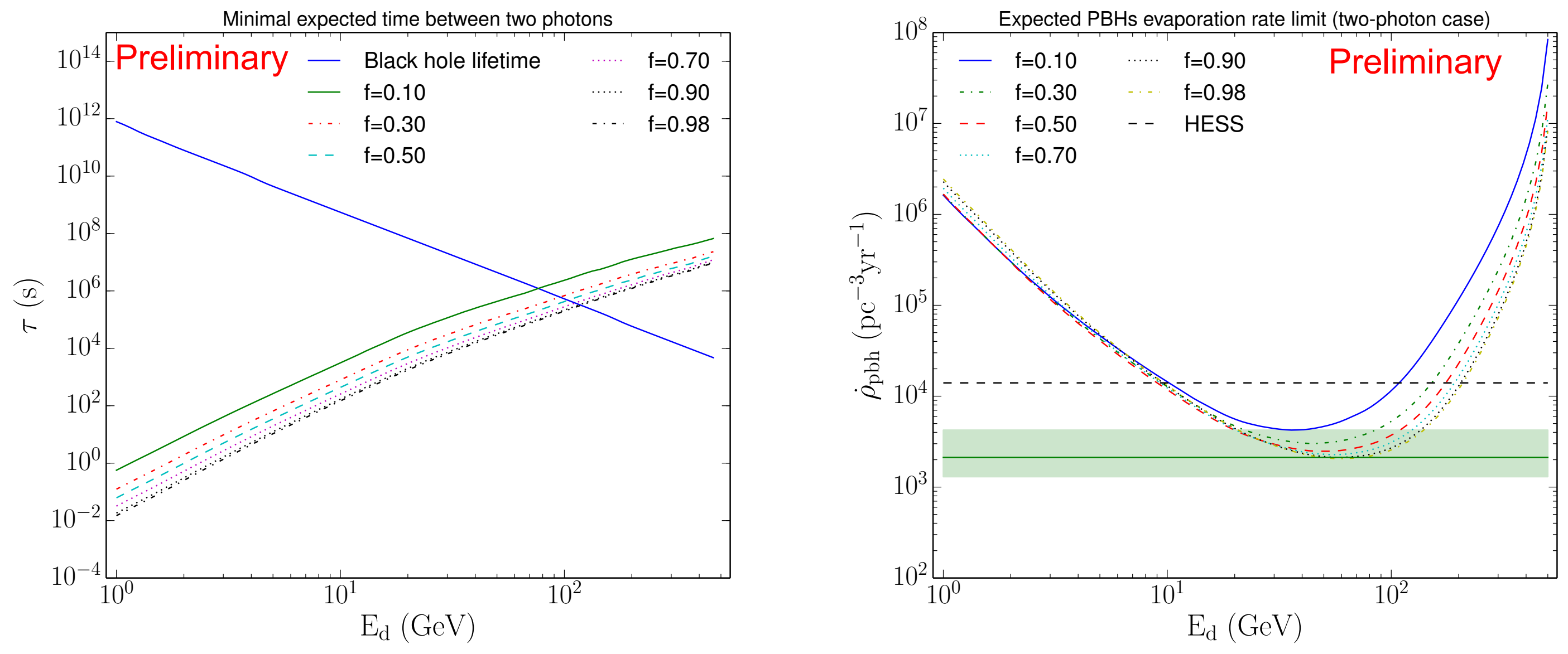
Fermi-LAT limits

1. PBHs at the last stage of evaporation produce a burst of gamma-rays (100 GeV hole lives for a few days).
2. To search for PBHs evaporation we look for pairs of photons with arrival time shorter than the time expected for the Poisson background.
3. If the shortest time is consistent with the background we can put limits on the local PBHs evaporation rate.

[1] Ya. B. Zel'dovich, I. D. Novikov, Sov.Astron. **10**, 602 (1967)
[2] S. Hawking, Mon.Not.Roy.Astron.Soc. **152**, 75 (1971)
[3] J. Bekenstein, Phys.Rev. **D7**, 2333 (1973)
[4] S. Hawking, Commun.Math.Phys. **43**, 199 (1975)

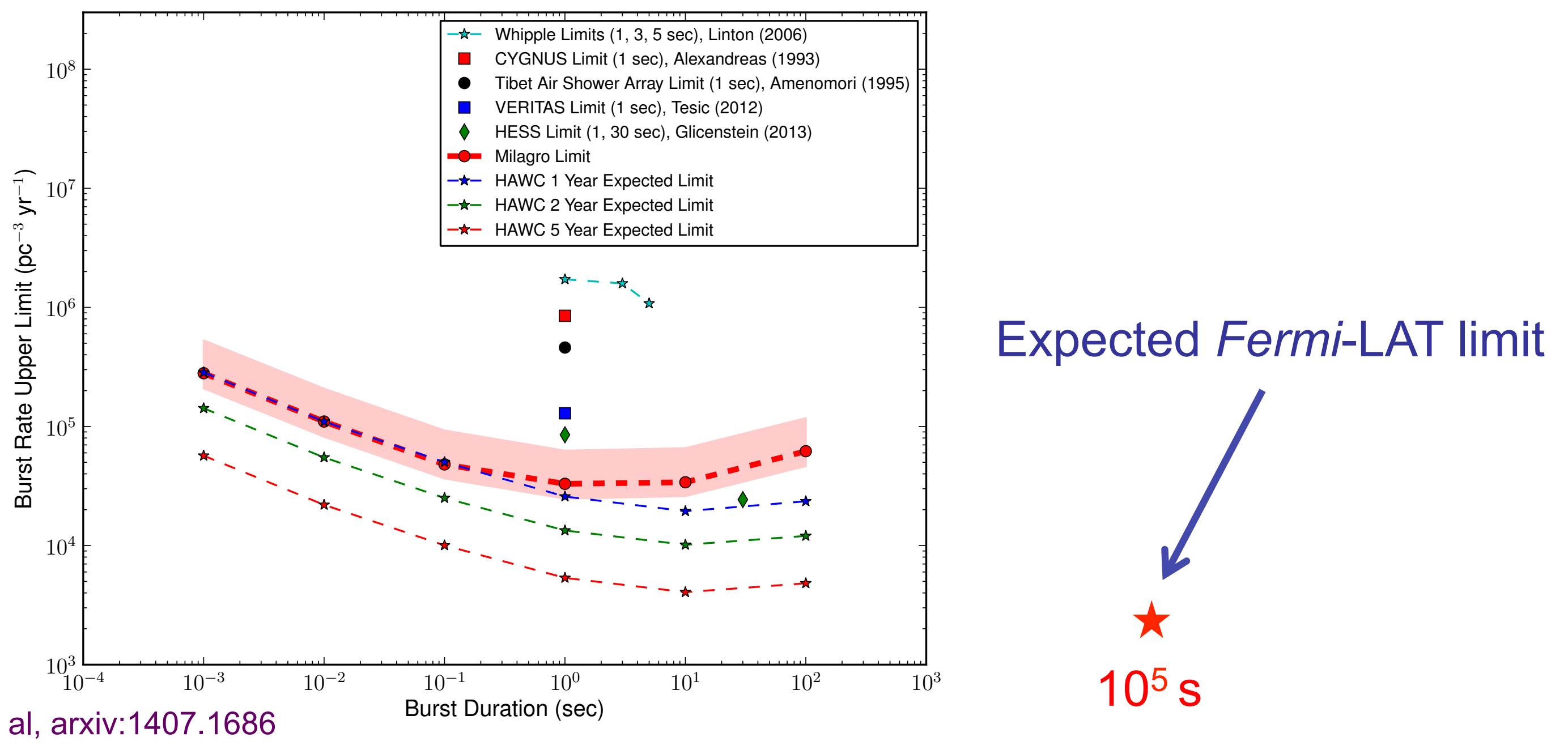
Search strategy.

1. Mask fractions f=0.1, 0.2, …, 0.98 of the sky with largest flux above 1 GeV (to reduce background).
2. Select a set of low energy thresholds E_d.
3. For each E_d search for a pair of gamma-rays with energies above E_d within 68% containment and with minimal arrival time difference.



Comparison between PBH lifetime and minimal expected time between gamma-rays for the Poisson background (left) and expected limit on PBHs evaporation rate, assuming that the shortest arrival times are consistent with background (right). The band represents an envelope of the limits obtained for different fractions of the sky and an estimate of the uncertainty on the gamma-ray production from PBHs [5, 6].

Comparison with current and future experiments



Abdo et al, arxiv:1407.1686

Conclusions

1. *Fermi*-LAT can provide better limits on PBH evaporation rate than the best existing limits and the limits projected with the HAWC experiment.
2. Limit on existence of PBHs can be used to constrain models of inflation by constraining the equation of state and the level of fluctuations at small scales which are inaccessible to CMB measurements.

[5] F. Halzen, *et al*, Nature **353**, 807 (1991)
[6] T. U. Ukwatta, *et al*, arXiv:1308.4912