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FLARES FROM GALACTIC BLACK HOLES

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RESUMEN

En este trabajo estudiamos el efecto de una inyección dependiente del tiempo de una distribución no térmica de partículas en una corona alrededor de un agujero negro. En particular, presentamos un modelo para fulguraciones de alta energía en este escenario. Se consideran las interacciones de partículas con campos magnéticos, de fotones y de materia en la corona. Las ecuaciones de transporte correspondientes son resueltas para todas las especies de partículas y se predice la emisión electromagnética para el caso de agujeros negros galácticos.

ABSTRACT

In this work we study the effects of a time-dependent injection of a non-thermal particle population in a corona around an accreting black hole. We present a specific model for high-energy flares in this scenario. We consider particle interactions with magnetic, photon, and matter fields in the corona around the black hole. Transport equations are solved for all species of particles and the electromagnetic output is computed for the case of Galactic black hole binaries.

Key Words: accretion, accretion disks — black hole physics — gamma rays: theory

1. INTRODUCTION

Several Galactic gamma-ray sources have been recently found to be rapidly variable. One of such sources is the well-known microquasar Cygnus X-1, which is a binary system composed by a massive star and an accreting black hole (Poutanen et al. 1997). The flaring nature of Cyg X-1 in gamma rays has been confirmed with the AGILE satellite (Sabatini et al. 2010). Different models have been proposed to explain the origin of these episodes (e.g., Romero et al. 2010a; Zdziarski 1998; Bosch-Ramon et al. 2008). These works are mainly focused on the analysis of gamma-ray emission that might be produced in the jet. The approach of this work is different: we consider the effect of the injection of non-thermal particles in the magnetized corona around the black hole. These particles can be locally accelerated by reconnection events and subsequent diffusive processes taking place on the plasma. Our main goal is to study coronal flares and their output in both electromagnetic radiation and neutrinos. In what follows, we outline the basic model and present some results of our calculations.

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2. NON-THERMAL PROCESSES IN STEADY STATE CORONA

The model considered here is a static corona where the relativistic particles can escape by diffusion. We consider a two-temperature corona in steady state, with a thermal emission characterized by a power-law with an exponential cutoff at high energies, as observed in several X-ray binaries in the low-hard state. For more details, an extensively description of this model can be found in Romero et al. (2010b).

We solved the transport equation in steady state obtaining particle distributions. Then the spectral energy distributions of all radiative processes were estimated. We also took into account the effect of secondary pairs created by photon-photon pair production. Figure 1 shows the total SED together with the spectrum of Cygnus X-1, as measured by COMPTEL McConnell et al. (2000) and the radio detection of the jet by Stirling et al. (2001).

It can be seen that emission in the range 100 MeV to 1 TeV is suppressed by absorption by photon annihilation in the soft thermal photon fields. All emission detected in this range should be produced in the jet at some distance from the black hole (e.g., Bosch-Ramon et al. 2008; Romero et al. 2010a).

3. FLARE MODEL

The time dependence of the particle injection is characterized by a FRED (Fast Rise and Exponential

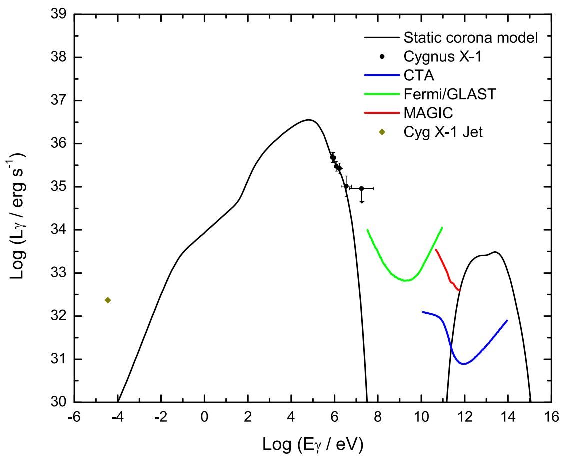

Fig. 1. Spectral energy distribution obtained with the steady state model of a static corona. The model fits well the soft gamma-ray emission measured by COMPTEL of Cygnus X-1 (McConnell et al. 2000). The non-thermal radio emission from the jet is also shown (Stirling et al. 2001).

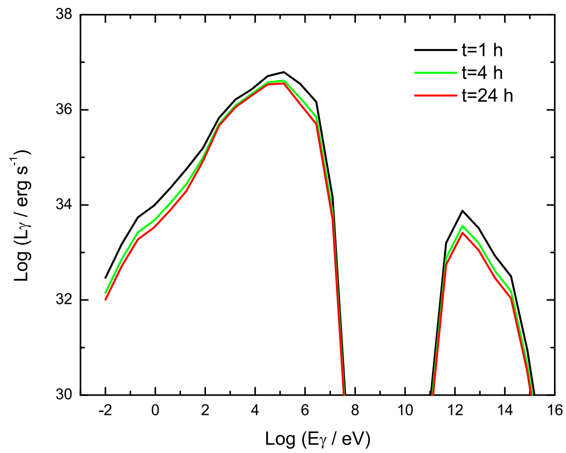

Fig. 2. SED evolution during the flare.

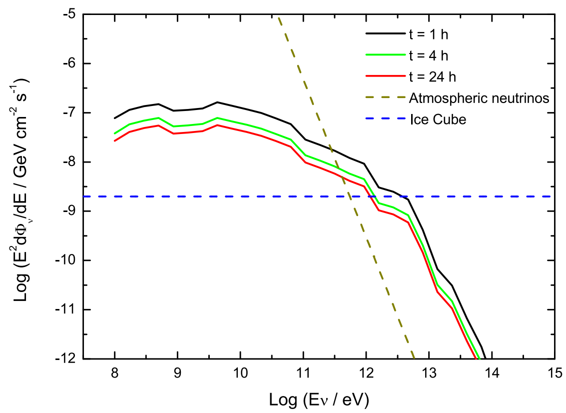

Fig. 3. Neutrino flux and atmospheric neutrinos.

Decay) behavior, whereas the energy dependence is a power-law with an index of $\alpha = 2.2$.

In order to estimate the electromagnetic emission, the particle distributions $N(E,t)$ ought to be known. These can be derived from the solution to the transport equation (Ginzburg & Syrovatskii 1964)

$$\frac{\partial N(E,t)}{\partial t} + \frac{\partial}{\partial E}\Big(b(E)N(E,t)\Big) + \frac{N(E,t)}{t_{\rm esc}} = Q(E,t). \qquad (1)$$

where $b(E) = \frac{dE}{dt}\Big|_{\rm loss}$.

Figure 2 shows the evolution of the total luminosity. As it can be seen from the figure, the final SED does not change its shape as the flare evolves.

We also estimate the neutrino output; we consider neutrino injection by charged pion and muon decay. The differential flux of neutrinos arriving at the Earth can be seen in Figure 3.

4. DISCUSSION

According to our results, a cumulative signal from recurrent neutrino bursts might be detectable in accreting black holes (few years of integration for duty cycles of about ten percent). The electromagnetic part of the flare can also be detectable at some energies, depending of the optical depth for photon annihilation.

The effect of the presence of the photon field of the star is also relevant. The photon absorption due to this field depends on the position of the black hole in its orbit, and the electromagnetic output is different for flares starting at different orbital phases (Vieyro & Romero 2011, in preparation).

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