Asociación Argentina de Astronomía
BAAA, Vol. 52, 2009
J.J. Clariá, E. Brandi, A.E. Piatti & F.A. Bareilles, eds.

PRESENTACIÓN MURAL

On the nature of the episodic gamma-ray flare observed in Cygnus X-1

M.V. del Valle[1,2], G.E. Romero[1,2] & M. Orellana[2,3]

(1) Instituto Argentino de Radiastronomía (CCT−La Plata, CONICET), Argentina.
(2) Facultad de Ciencias Astronómicas y Geofísicas, UNLP, Argentina.
(3) Departamento de Física y Astronomía, Facultad de Ciencias, Universidad de Valparaíso, Chile.

Abstract. The high-mass microquasar Cygnus X-1, the best established candidate for a stellar-mass black hole, has been detected in a flaring state at very high energies, $E > 200$ GeV (Albert et al. 2007). The observation was performed by the Atmospheric Cherenkov Telescope MAGIC. It is the first experimental evidence of very high energy emission produced by a galactic stellar-mass black hole. The observed high energy excess occurred in coincidence with an X-ray flare.

The flare took place at orbital phase $\phi = 0.91$, being $\phi = 1$ the moment when the black hole is behind the companion star. In this configuration the absorption of gamma-ray photons produced by photon-photon annihilation with the stellar field is expected to be the highest.

We present detailed calculations of the gamma-ray opacity due to pair creation along the whole orbit, and for different locations of the emitter (height above the compact object). We discuss the location of the gamma-ray producing region in Cygnus X-1 and the energetics required to produce the flare.

Resumen. El microcuásar de gran masa Cygnus X-1, el candidato mejor establecido para agujero negro de masa estelar, ha sido detectado en un estado de fulguración en muy altas energías, $E > 200$ GeV (Albert et al. 2007). La observación fue realizada con el telescopio Cherenkov MAGIC (*Atmospheric Cherenkov Telescope*). Es la primera evidencia experimental de emisión de muy alta energía producida por un agujero negro de masa estelar galactico. El exceso de muy alta energía observado ocurrió en coincidencia con una fulguración en rayos X.

La fulguración tuvo lugar a fase orbital $\phi = 0.91$, siendo $\phi = 1$ el momento en el cual el agujero negro se encuentra por detrás de la estrella compañera. En esta configuración la absorción de fotones gama producida por aniquilación fotón-fotón con el campo estelar se espera que sea la más alta.

Presentamos cálculos detallados de la opacidad de rayos gama debida a creación de pares a lo largo de toda la órbita, y para diferentes posiciones del emisor (altura sobre el objeto compacto). Discutimos la posición de la región de producción de rayos gama en Cygnus X-1, y la energética requerida para producir la fulguración.

1. Motivations

Cygnus X-1 is a high-mass microquasar and the best established candidate for a black hole in the galaxy. It is a widely studied objected (e.g. Poutanen et al. 1997). Recently Albert et al. 2007 reported on the observations performed by the Cherenkov telescope MAGIC at very high energies (Figure 1). The emission occurred as a flare episode.

In this work we study the physical conditions where such a flare was generated and the resulting constrains on the possible production mechanism.

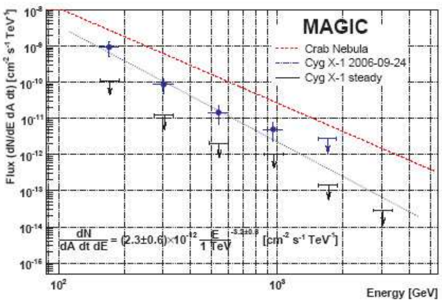

Figure 1. Cyg X-1 high-energy spectrum (Albert et al. 2007).

2. Absorption study

In this system the companion star generates an intense radiation field where gamma-rays are absorbed by photon-photon annihilation if, $\tau > 1$ then

$$\gamma + \gamma \rightarrow e^{-} + e^{+}. \tag{1}$$

The observed high energy flare occurred in superior conjunction, when the absorption is expected to be at a maximum.

We calculated the gamma-ray opacity due to pair creation by photon-photon annihilation, along the whole orbit and for different heights h above the compact object (Dubus 2006, Romero et al. 2007). The parameters considered are shown in Table 1.

Figure 2 shows the obtained absorption maps ($\exp(-\tau)$) as a function of the orbital phase ϕ and height h above the orbital plane, for different energies E. In Figure 3 we show opacity maps as a function of the orbital phase ϕ and different energies E, for different heights h above the orbital plane.

In the superior conjunction the optical depth is greater than 1 for photons with energies between 30 GeV and 1 TeV for $h < 10^{12.5}$ cm.

Parameter	Adopted value
Stellar mass	$30\ M_{\odot}$
Stellar temperature	$3.04 \times 10^{4}\ K$
Stellar radius	$22.11\ R_{\odot}$
Black hole mass	$20\ M_{\odot}$
Semimajor axis	3.4×10^{12} cm
Orbital period	5.6 days
Inclination	$35°$

Table 1. Parameters.

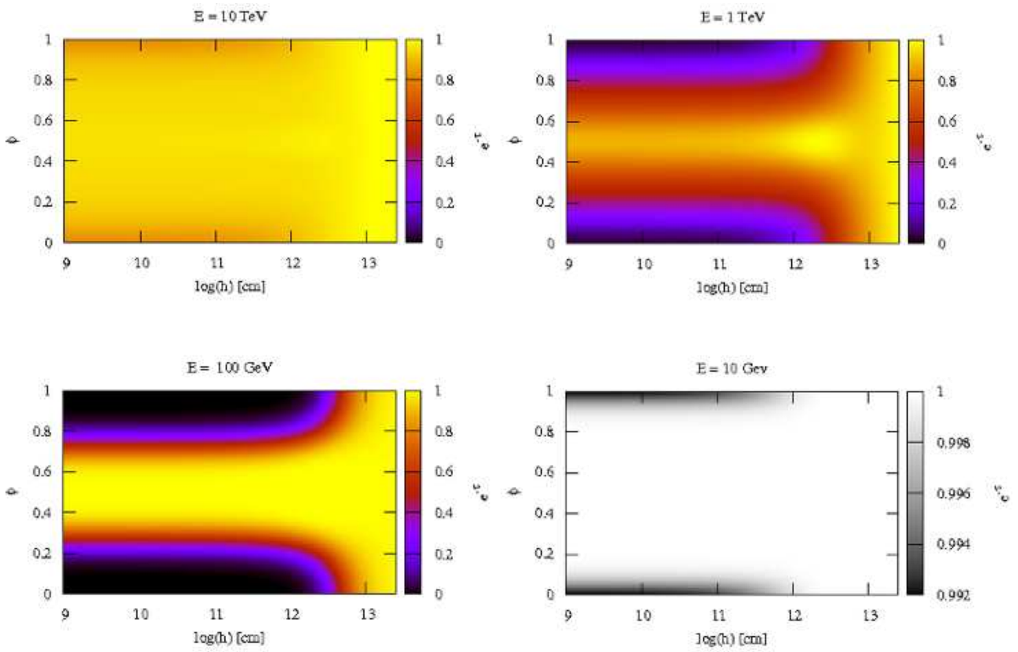

Figure 2. Absorption map as a function of h, ϕ for different E.

3. Implications for gamma-rays production

The opacity results and the emitted luminosity calculated as deabsorbed luminosity (Figure 4), $L_{\rm emit} = L_{\rm obs} \times \exp(\tau)$, imply that the flaring emission occured at distances larger than 10^{12} cm above the compact object (for similar conclusions see Bosch-Ramon et al. 2008). The jet-clump interaction scenario seems to be the most appropiate one to explain the generation of the gamma-ray flare (see Araudo et al. 2009).

Acknowledgments. M.V. d. V. thanks the Asociación Argentina de Astronomía for a fellowship. This work was partially supported by the Argentine agency ANPCyT (BID 1728/OC -AR PICT-2007-00848).

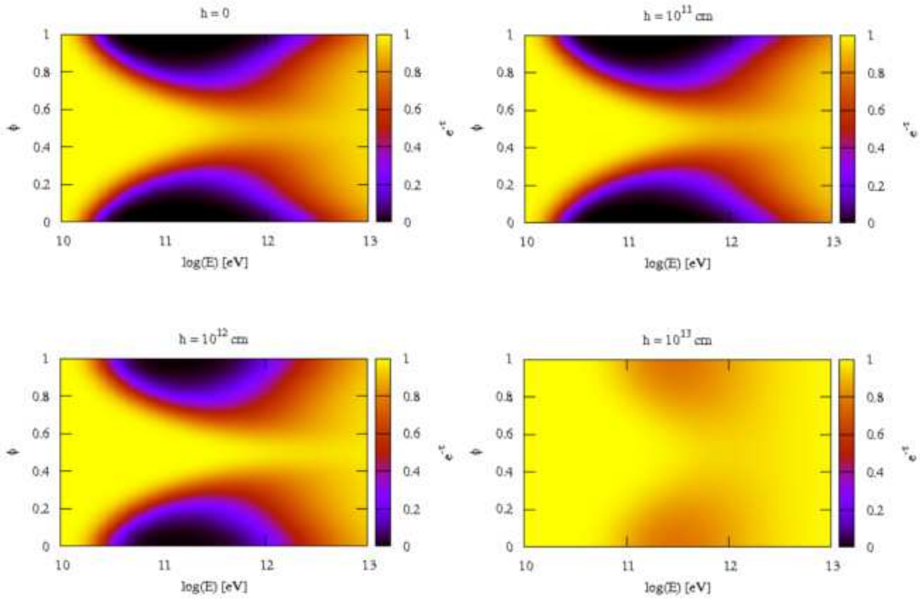

Figure 3. Absorption maps as a function of E, ϕ for different h.

References

Albert J. et al. 2007, ApJ, 665, L51.
Araudo A.T. et al. 2009, A&A, 503,3, 673.
Bosch−Ramon V. et al. 2008, A&A, 489, L21, L24.
del Valle M.V. 2009, Tesis de grado FCAGLP.
Dubus G. 2006, A&A, 151, 9.
Poutanen J. et al. 1997, MNRAS, 292, L21.
Romero G. E. et al. 2007, A&A, 474, 15.

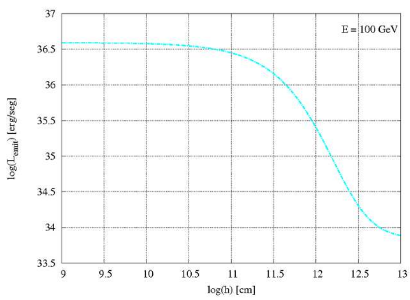

Figure 4. Intrinsic luminosity L_{emit} as a function of h.