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Microquasar Models for 3EG J1828+0142 and 3EG J1735−1500

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Abstract Microquasars are promising candidates to emit high-energy gamma-rays. Moreover, statistical studies show that variable EGRET sources at low galactic latitudes could be associated with the inner spiral arms. The variable nature and the location in the Galaxy of the high-mass microquasars, concentrated in the galactic plane and within 55 degrees from the galactic center, give to these objects the status of likely counterparts of the variable low-latitude EGRET sources. We consider in this work the two most variable EGRET sources at low-latitudes: 3EG J1828+0142 and 3EG J1735−1500, proposing a microquasar model to explain the EGRET data in consistency with the observations at lower energies (from radio frequencies to soft gamma-rays) within the EGRET error box.

Key words: X-rays: binaries — Stars: winds, outflows — gamma-rays: observations — gamma-rays: theory

1 INTRODUCTION

Microquasars are X-ray binaries (XRB) that present relativistic jets (Mirabel & Rodriguez 1999). In the past decade, microquasars have also been proposed as high energy sources, emitting into the the gamma-ray regime. For instance, Paredes et al. (2000) proposed LS 5039, a high-mass microquasar, as the counterpart of the source 3EG J1824−1514. Otherwise, variable low-latitude EGRET sources seem to follow a similar distribution to that presented by high-mass microquasars (Bosch-Ramon et al. 2004), which are concentrated also in the galactic plane, not too far away from the galactic center (55 degrees). 3EG J1828+0142 and 3EG J1735−1500 are the two most variable EGRET sources in the galactic plane (Torres et al. 2001), presenting quite steep spectra (photon indices of 2.76 and 3.24 respectively) and typical luminosities of about 10^{35} erg s^{-1}, adopting a distance of 4 kpc. We have applied a microquasar model to these particular cases for checking the proposal of association between microquasars and the variable EGRET sources in the galactic plane.

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2 THE VARIABLE EGRET SOURCES IN THE GALACTIC PLANE

EGRET sources in the galactic plane are well-correlated with star forming regions (Romero et al. 1999), and log N-log S studies suggest that they are more abundant toward the inner spiral arms (Gehrels et al. 2000, Bhattacharya et al. 2003). Among these sources, there is a subgroup of variable sources (Nolan et al. 2003) that has been proposed to be the EGRET counterparts of high-mass microquasars (Kaufman Bernadó et al. 2002, Bosch-Ramon et al. 2004). High-mass microquasars are also somehow correlated with star forming regions (Romero et al. 2004). We are interested now in two particular cases: 3EG J1828+0142 and 3EG J1735−1500, exploring the possibility that they can be high-mass microquasars.

3 GAMMA-RAY EMISSION FROM MICROQUASARS

3.1 The Model

We have developed a semi-analytical model based on an inhomogeneous leptonic jet formed by relativistic particles. Those particles interact with the seed photon fields (synchrotron, star, disk and corona photons) through inverse Compton (IC) effect (see Bosch-Ramon et al. 2004). We have accounted for both the Thomson and the Klein-Nishina regimes of IC interaction (Blumenthal & Gould 1970). The different functions that represent the electron energy distribution, the electron energy and the magnetic field within the jet have been parametrized in order to simulate their evolution along the jet (e.g. Ghisellini et al. 1985, Punsly et al. 2000).

3.2 3EG J1828+0142 and 3EG J1735-1500

3EG J1828+0142 (Hartman et al. 1999) is the second most variable low-latitude non-transient gamma-ray source. Within the error box of this EGRET source, there are several faint non-thermal radio sources (Punsly et al. 2000) and X-ray sources (observed in the ROSAT All Sky Survey) with typical luminosities of about 10^{33} erg s^{-1}, adopting distances of 4 kpc. Finally, Comptel upper limits (Shu Zhang 2004) are also known, corresponding to luminosities of about 10^{34}-10^{35} erg s^{-1} in the COMPTEL energy range at the same distance. The error box of 3EG J1735−1500 (Hartman et al. 1999), the most variable EGRET source, has been already explored by Combi et al. (2003), and there are two potential counterparts: a radio galaxy and a compact radio source that presents hard spectrum and flux densities of about 0.3 Jy. High upper limits at X-ray and COMPTEL energies are imposed from observational data to be (10^{34}-10^{35} erg s^{-1}). To model the Spectral Energy Distribution (SED) of a microquasar that could be the origin of the EGRET emission, we account for the known observational data at different wavelengths. We must note that the observations at different frequencies were not simultaneous. Regarding upper limits at radio and X-ray energies, they have been taken as the fluxes of the brightest sources within the EGRET error boxes.

4 RESULTS

The Figs. 1 and 2 show the computed SED for 3EG J1828+0142 and 3EG J1735−1500 respectively. In Tables 1 and 2 the adopted parameters for both systems are listed. These SED respect the observational constraints and reproduce pretty well the EGRET spectrum. It is worth noting that the used EGRET spectrum for comparison with our model is the averaged one for the four viewing periods. Nevertheless, concerning variability, microquasars can naturally present the variable nature observed in these two objects due to several factors: precession of the jet, orbital motion, etc... (i.e. Kaufman Bernado et al. 2002, Bosch-Ramon & Paredes 2004).

Regarding the high-mass star emission of these systems, it could be dust-enshrouded, as it has been suggested, for instance, for INTEGRAL obscured sources thought to be XRB and

Table 1 Common parameters for 3EG J1828+0142 and 3EG J1735–1500

Parameter	Value
Jet kinetic luminosity	5×10^{35} erg s^{-1}
Stellar bolometric luminosity	10^{38} erg s^{-1}
Distance from jet's apex to the compact object	$\sim 10^8$ cm
Initial jet radius	$\sim 10^7$ cm
Orbital radius	3×10^{12} cm
Viewing angle to jet's axis	10°
Magnetic field	300 Gauss

Table 2 Particular Parameters for 3EG J1828+0142 and 3EG J1735–1500

Parameter	Adopted values for 3EG J1828+0142	Adopted values for 3EG J1735–1500
Jet Lorentz factor	1.5	3
Maximum Lorentz factor for electrons in jet (jet frame)	3×10^3	2.5×10^3
Electron power-law index	1.5	2
Total disk/corona luminosity	10^{32} erg s^{-1}	10^{33} erg s^{-1}

microquasars (i.e. Walter et al. 2003, Combi et al. 2004). This effect can be very important if the sources are located in the inner regions of the galactic plane, being strong enough to obscure a high-mass star from IR wavelengths to soft X-rays. Furthermore, emission in the far infrared can be too weak to be detected by the satellite IRAS (i.e. Filliatre & Chaty 2004).

To compute the overall SED presented in the Figs. 1 and 2, we have adopted a strong magnetic field and a low maximum energy for the electrons (see Tables 1 and 2). For 3EG J1828+0142, the synchrotron emission is dominant in the entire EGRET detection range, which reached only several hundreds of MeV. Moreover, the jet is mildly relativistic. In the other hand, 3EG J1735−1500 was detected up to few GeV. For this second case, we have modelled the emission up to several hundreds of MeV through synchrotron self-Compton scattering, and through comptonization of coronal seed photons further up. For this second case, the jet Lorentz factor has been taken higher than for the first one. For both sources, accounting for X-ray emission must be dim since otherwise it would imply a clear counterpart at energies beyond 1 keV, corona and disk components have been taken to be weak.

5 CONCLUSIONS

The possibility of computing a radio-to gamma microquasar SED, at all in accord with observational constraints, suggests that microquasars may be the counterparts of these two particular sources: 3EG J1828+0142 and 3EG J1735−1500. Other possible objects cannot be discarded as possible counterparts (i.e. an isolated black-hole, see Punsly et al. 2000; accreting neutron stars, see Romero et al. 2001; early-type binaries, see Benaglia & Romero 2003; etc...). However, microquasars appear to be attractive candidates due to the presence of a jet with a relativistic leptonic population and strong seed photon fields provided by the stellar companion, the accreting matter and the electrons themselves. In the near future, instruments like AGILE and GLAST will help us to improve the location of unidentified EGRET sources and further observations at lower energies will help us to better constrain the models as well.

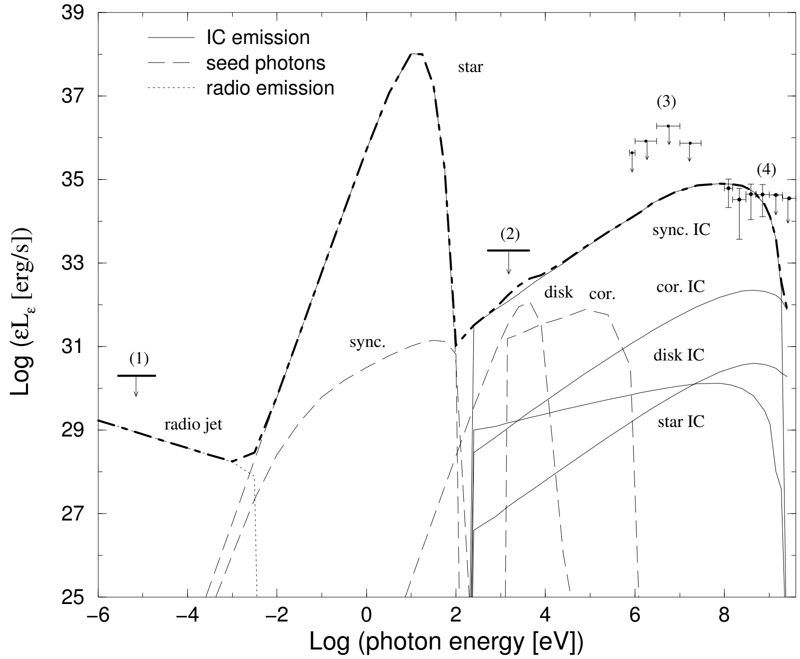

Fig. 1 SED for an unabsorbed broadband microquasar model of the source 3EG J1828+0142. The adopted parameter values are shown in Tables 1 and 2. There are represented the upper limits at radio (1), X-ray (2) and COMPTEL (3) energies, as well as the EGRET spectrum (4).

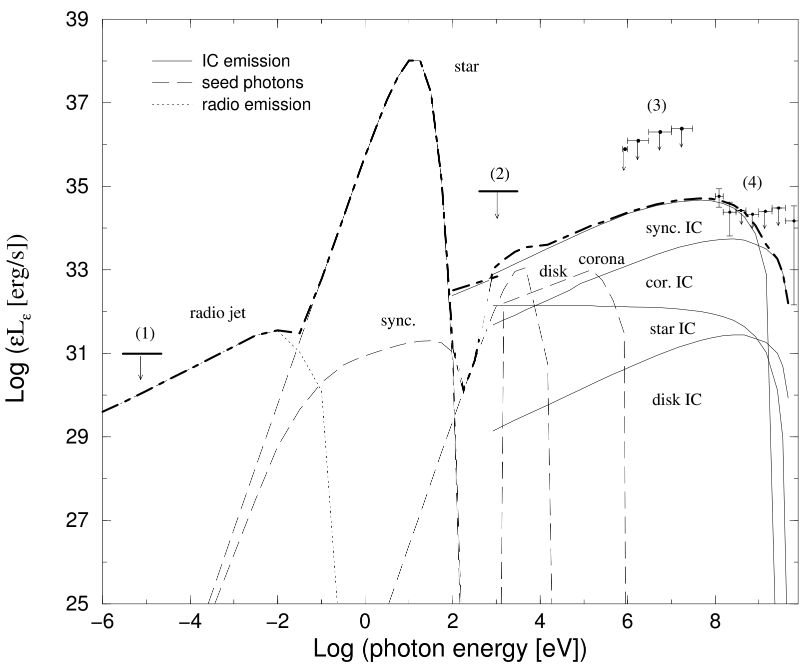

Fig. 2 The same as in Fig. 1 but for the source 3EG J1735+1500.

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