γ-Ray Generation in Microquasars: the Link With AGN

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Abstract

We investigate the link between the physical processes, which are responsible for high energy emission from relativistic jets in AGN and microquasars. We are producing a model based on an existing inhomogeneous, synchrotron-self-Compton (SSC) model [3, 4], designed for AGN, to predict gamma-ray emission from relativistic jets in microquasars. Initially this concentrates on the SSC process but will later include inverse Compton scattering of the photon fields produced by the companion star and the accretion disk. Supported by future gamma-ray observations of these objects, with e.g. the H.E.S.S. telescope array, links between the physical processes in the two morphologically similar objects can be made.

1. Introduction

Microquasars are a class of X-ray binary (XRB) with basic morphology similar to some AGN, but on a much smaller scale i.e. a central black hole, an accretion disk and collimated jets of relativistic particles. These properties have been observed in AGN for many years but it is only in the last decade that substantial study of such phenomena in XRBs has been conducted. One class of AGN, blazars, are known to emit radiation at VHE γ-ray frequencies. If the smilarity between AGN and microquasars is anything more than structural, then the processes responsible for γ-ray emission should be common to both objects. One feature, detected in blazars over 30 years ago and recently detected in an XRB [7], is the apparent superluminal velocity of the jet. This well documented illusion, see e.g. [8], where the apparent jet velocity is greater than speed of light, is created by the high intrinsic velocity of the jet and a small angle, θ, to the line of sight of the observer (Fig.1.).

Although it is not possible to place upper limits on the bulk Lorentz factors for individual objects because of distance uncertainties [2], the existence of superluminal velocities in microquasars may indicate the possibility of γ-ray emission.

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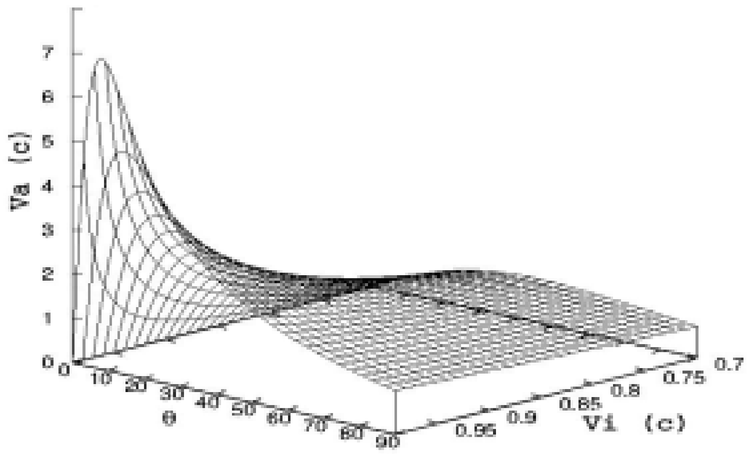


Fig. 1. Variation of apparent jet velocity, Va, with intrinsic jet velocity, Vi < c and angle of line of sight, θ

The configuration of blazar jets also leads to Doppler boosting of the emitted radiation. Blazars are the only AGN that have been detected in the VHE γ-ray regime, which may suggest that 'microblazars' could be the only microquasars detectable at these energies. This makes detection very difficult as most microquasars are transient and jet events happen on a much shorter timescale than with AGN. This will be shortened even further in microblazars by the Doppler effect when θ is small e.g. V4641-SGR [6, 9], LS5039 [10, 11] and references therein.

2. Predicting γ-ray Emission from Microquasars

We are writing a code based on an existing inhomogeneous SSC model [3, 4] to predict under what conditions microquasars could produce γ-ray emission. It is assumed that the jet is transparent to photon-photon interaction. Initially the model is limited to SSC within the jet but later inverse Compton scattering (ICS), of the local photon field through which the jet propagates, will be included. We concentrate on the inner part of the jet where the magnetic field intensity is largest, on the assumption that the greatest energies are present there. The nature of the power law determining the shape of the jet, ε, has to be selected with care. This ensures that when physical values for r_0 and R_0 (see [4] for definitions) are used, the opening angle of the jet, defined by the second part of the jet where ε=1, remains below 15° [8]. All the physical parameters are described by power laws as per the model. The coefficients for synchrotron emissivity, ε^s_ν, and absorption, K^s_ν are derived from [1] and [5] respectively and are given by,

$$\varepsilon_\nu^s(\nu, x) = \left(\frac{e^3}{mc^2}\right)\left(\frac{3e}{4\pi mc}\right) a(p) K_0 B_0^{(1+\alpha_0)} x^{-\varepsilon(n+m(1+\alpha_0))} \nu^{-\alpha_0} \quad (1)$$

$$K_\nu^s(\nu, x) = \left(\frac{e^3}{2\pi m^2 c^2}\right)\left(\frac{3e}{2\pi mc}\right)^{(0.5+\alpha_0)} g(p) K_0 B_0^{(1.5+\alpha_0)} x^{-\varepsilon(n+m(1.5+\alpha_0))} \nu^{-(0.5+\alpha_0)} \quad (2)$$

The values of p, $a(p)$ and $g(p)$ for various values of spectral index, α are tabulated below.

Table 1. Values of p, $a(p)$ and $g(p)$ for different α

α	p	$a(p)$	$g(p)$
0.25	1.5	0.149	0.7860
0.5	2.0	0.103	0.6981
0.75	2.5	0.0831	0.6564
1.0	3.0	0.0741	0.6453

α	p	$a(p)$	$g(p)$
1.25	3.5	0.0712	0.6583
1.5	4.0	0.0725	0.6928
1.75	4.5	0.0777	0.7493
2.0	5.0	0.0866	0.8302

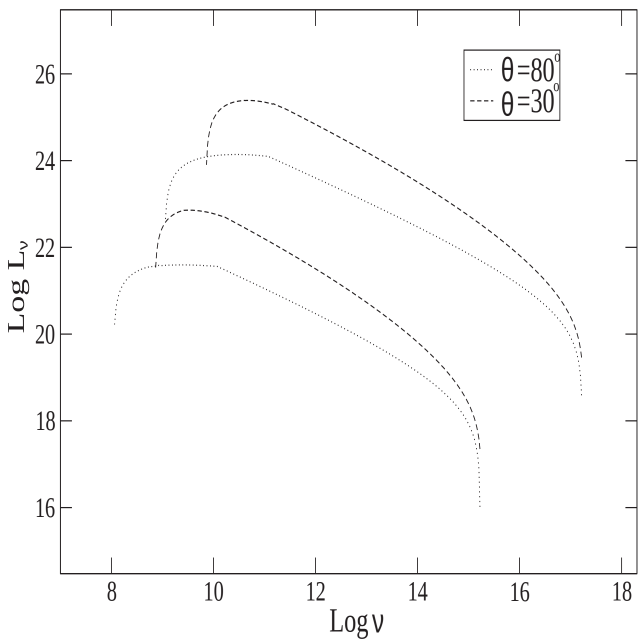
Integrating along the jet for frequencies between the synchrotron self-absorption frequency and the maximum synchrotron frequency, produces a synchrotron luminosity from the distribution of electrons present there. The model is adaptable as there are a number of parameters that can be adjusted to suit the particular jet.

3. The Microquasar LS5039

LS5039 is a persistent microquasar lying close to the Galactic plane. Radio observations show this object to have well collimated jets and a possible correlation with the EGRET source 3EG J1824-1514 [10]. This makes it an ideal candidate for testing the parameters in this model. Using various values, given in Fig. 2., the synchrotron luminosity can be plotted. Future considerations of this object will include ICS of the optical and UV photon field of the companion star. Fig. 2. illustrates the different results obtainable from the adjustment of just two of the parameters, K_0, the electron distribution density parameter and the local Lorentz factor, γ. Varying the strength of the magnetic field, B_0, also has a significant effect on the results.

4. The Future

The application of this model to microquasars is in its early stages and further work, combined with observational data, will be able to constrain the



Input Parameters (c.g.s. units)
$\alpha = 0.5$
$R_0 = 1.272 \times 10^{13}$ [11]
$r_0 = 1.346 \times 10^{13}$
$R_{max} = 1.196 \times 10^{16}$
$B_0 = 12$ [11]
$\varepsilon = 0.5$ [11]

Fig. 2. Synchrotron emission for a jet with paraboloid shape. The lower two curves represent emission from a distribution of electrons with density parameter K_0 and local lorentz factor of 10^4. In the upper two curves the density parameter is increased by 10^3 and the Lorentz factor to 10^5. The two values for θ, the angle to the line of sight of observer, are taken from [11] and references therein.

parameters more closely. Ultimately we will be able to suggest which processes are most likely to be responsible for γ-ray emission, if present, in microquasars and compare them to AGN.

5. References

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