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The TeV emitter structure in LS 5039

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LS 5039 is an X-ray binary detected at very high energies. Along the orbit, there is a significant detection even during the superior conjunction of the compact object, when very large gamma-ray opacities are expected. Electromagnetic cascades, which may make the system more transparent to gamma-rays, are hardly efficient for reasonable magnetic fields in the massive star surroundings. A jet-like flow could transport energy to regions where the photon-photon absorption is much lower and the TeV radiation is not so severely absorbed. Otherwise, in the standard pulsar scenario for LS 5039, the emitter would be located between the star and the compact object, which would imply the violation of the observational constraints at X-rays.

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1. Introduction

LS 5039 is a high-mass X-ray binary located at distances of 2.5 kpc [1] with extended non-thermal radio emission [2]. This source has been detected in the very high-energy (VHE) range all along the orbit and also during the superior conjunction of the compact object [3, 4], when the photon-photon absorption is expected to be the strongest [5]. LS 5039 is formed by an O star and a compact object of unknown nature [1]. Although thought to be a microquasar after the discovery of the extended radio emission (e.g. [2, 6]), the non detection of X-ray accretion features led [7, 8] to suggest the presence of a non-accreting pulsar in the system.

In this work, we point out that, under reasonable values for the ambient magnetic field, whatever its nature the TeV emitter should be located in the borders of the binary system at least around the superior conjunction of the compact object. Otherwise, the electron-positron pairs created via photon-photon absorption in the stellar photon field would radiate overcoming the observed X-ray emission levels.

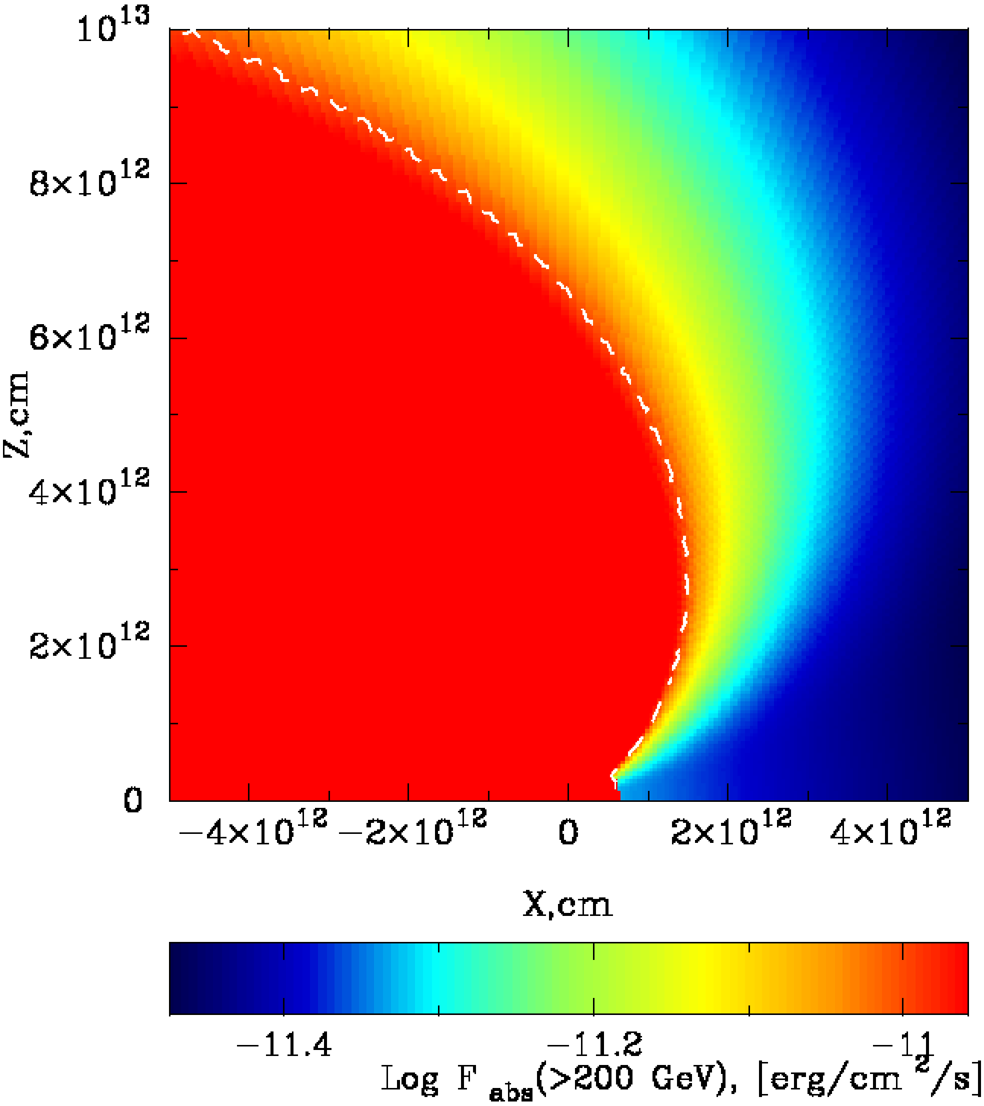
2. The TeV emitter in LS 5039

We have plotted a 2-dimensional map of the absorbed luminosity via photon-photon absorption depending on the location of the emitter in LS 5039. This is presented in Figure 1. The XZ coordinates correspond to the plane formed by the emitter and the star (0,0) positions, and the observer line of sight. To compute these maps, we have deabsorbed the observed spectra and fluxes >100 GeV from LS 5039 around the superior conjunction of the compact object. The regions forbidden by the X-ray observational constraints are limited by a contour line. The VHE emitter cannot be located to the left of the dashed line or the X-ray observed fluxes will be overcome by the secondary pair synchrotron emission, expected to be the dominant secondary pair cooling channel for reasonable magnetic field values in the stellar surroundings. O-star surface magnetic fields may reach $\sim$ kG [9], and values of ≥ 10 G could be realistic at few stellar radii from the stellar surface, more than enough to suppress electromagnetic cascades [10]. In the plot, the compact object is located in the left half of the XZ plane at 1.4×10^{12} cm from the star independently of the orbital inclination.

In Fig. 2, we show the spectral energy distribution (SED) of the synchrotron emission produced by the secondary pairs created in the surroundings of the VHE emitter during the superior conjunction of the compact object. The emitter location has been taken close to the compact object, with an ambient magnetic field of 10 G, and an inclination angle of 60°. This value for the inclination angle would correspond to the case of a neutron star as the compact object [1], e.g. a pulsar. As seen in the figure, the resulting X-ray luminosity is seven orders of magnitude larger than the one found by observations [11]. As noted in Fig. 1, only in case the emitter were located far from the compact object, and far as well from the line joining the compact object and the star, the synchrotron radiation would not overcome the observed fluxes (see also [12]).

Summarizing, the detection by HESS of VHE radiation from LS 5039 during the superior conjunction of the compact object, plus a realistic ambient magnetic field, point strongly to an emitter located far away from the compact object, and far as well from the region between the pulsar and the star. A jet-like emitter may play such a role, transporting energy to regions of lower

Figure 1: Absorbed luminosity $\times 1/4\pi d_{\odot}^2$, depending on the location of the emitter in the binary system. The contour line limits the region to the left, in which the emitter, if located there, would overcome the observed X-ray fluxes if the synchrotron emission is the dominant radiation channel.



opacities; otherwise, the detected X-ray fluxes would be violated. This makes any scenario in which the TeV emission would come from the region close to the compact object (the inner jet regions), or between the star and the compact object (pulsar scenario for LS 5039; e.g. [8, 13, 14, 15]), unlikely.

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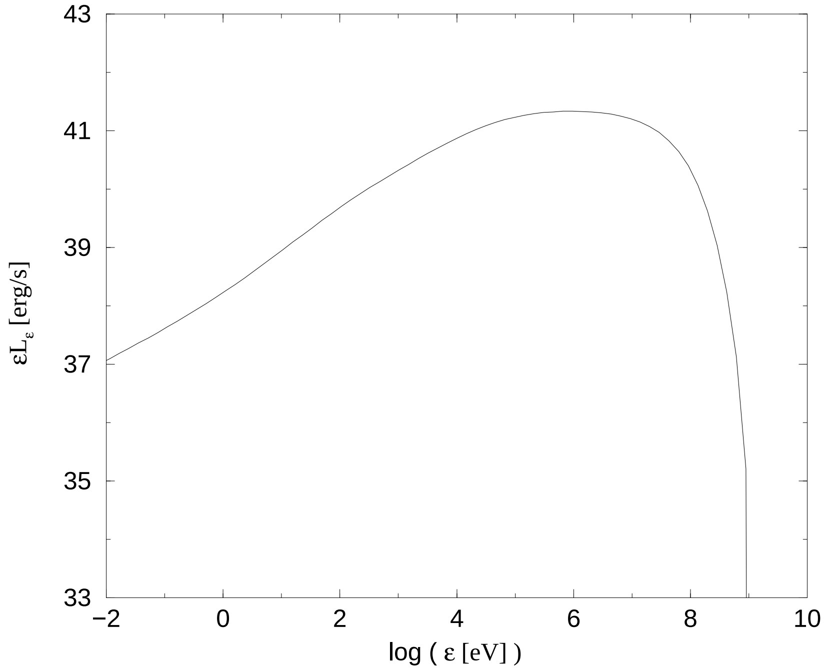
Figure 2: Computed spectral energy distribution of the synchrotron emission produced by the secondary pairs created in the surroundings of the VHE emitter during the superior conjunction of the compact object. The emitter location has been taken close to the compact object, with a magnetic field of 10 G, and an inclination angle of 60°.



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