A Massive Star Odyssey, from Main Sequence to Supernova
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Gamma-ray production in selected Wolf-Rayet binaries

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Abstract. In the colliding wind region of early-type binaries, electrons can be accelerated up to relativistic energies, as demonstrated by the detection of non-thermal radio emission from several WR+OB systems. The particle acceleration region is exposed to strong photon fields, and inverse-Compton cooling of the electrons could result in a substantial high-energy non-thermal flux. We present here preliminary results of a study of the binaries WR 140, WR 146, and WR 147 in the light of recent radio and γ-ray observations. We show that under reasonable assumptions WR 140 can produce the γ-ray flux from the *GRO*-EGRET source 3EG J 2022+4317. WR 146 and WR 147 are below the detection threshold.

1. Introduction

In a typical WR+OB binary the collision of the winds from both stars produces a strong shock at some point between the stars, in a region exposed to strong UV stellar fields. Both electrons and protons can be accelerated in these colliding wind regions (CWRs) (Eichler & Usov 1993). Electrons will cool through synchrotron and inverse-Compton (IC) radiation. In fact, the detection of non-thermal radio emission in many early-type binaries corroborates the existence of a population of relativistic electrons in some of these systems.

Physical conditions in WR binary systems with non-thermal CWRs can be probed through γ-ray observations. For certain systems, the magnetic field in the shocked region can be estimated. Even in case of a lack of γ-ray detection, due to the instrument sensitivity, we can set bounds on the magnetic field strength, and hence make inferences on the stellar fields.

2. Selected binaries: WR 140, WR 146 and WR 147

For this investigation we have chosen the Wolf-Rayet stars WR 140, WR 146 and WR 147, because they fulfill the following conditions: they are colliding wind binaries, monitored at high resolution radio continuum and presenting non-thermal emission. The stellar parameters were taken from Setia Gunawan *et al.* (2000), (2001a), and (2001b) and references therein. Only WR 140 is positionally coincident with an unidentified γ-ray source, namely 3EG J 2022+4317 (Hartman *et al.* 1999).

Table 1. Gamma-ray luminosities in the CWRs of WR 140, WR 146 and WR 147, for the energy range $0.1 < E < 20\,\mathrm{GeV}$.

γ-ray emission mechanism	expected γ-ray luminosities L_γ		
	WR 140 ($\mathrm{erg\,s^{-1}}$)	WR 146 ($\mathrm{erg\,s^{-1}}$)	WR 147 ($\mathrm{erg\,s^{-1}}$)
inverse-Compton scattering	$\sim 4.5\times10^{34}$	$\sim 3.0\times10^{32}$	$\sim 1.9\times10^{33}$
relativistic *Bremsstrahlung*	$\sim 1.2\times10^{30}$	$\sim 5.6\times10^{28}$	$\sim 5.9\times10^{28}$
neutral pion decay	$\sim 1.2\times10^{21}$	$\sim 2.5\times10^{21}$	$\sim 1.0\times10^{23}$
	observed γ-ray luminosities L_γ[1]		
	$\sim 4.4\times10^{34}$	$< 8.0\times10^{34}$	$< 2.2\times10^{34}$

Note 1: from EGRET data, if the γ-ray sources are at the distances of the stars.

3. Results

For each system we have computed the synchrotron luminosity $L_{\rm sync}$ coming from electrons having frequencies between ν_1 and ν_2. The limiting frequencies were derived assuming that the same population of electrons can produce γ-ray emission, in the *GRO*-EGRET energy range. The ratio of $L_{\rm sync}$ and $L_{\rm IC}$ can be expressed in terms of the magnetic field near the shock B, the stellar luminosity L_i, and the distance from the i-th star to the colliding wind region r_i. We have assumed a B value of about four times the equipartition value, which allows to predict the observed γ-ray luminosity of 3EG J 2022+4317 as produced by WR 140.

Contributions from relativistic *Bremsstrahlung* and neutral pion decay were estimated in the same way as described by Benaglia *et al.* (2001).

The expected luminosities at the CWRs due to the processes mentioned above appear in Table 1. The observed values — or upper limits — are listed for comparison. We conclude that in the case of WR 140, it is reasonable to expect strong γ-ray emission, at EGRET level, as predicted by Eichler & Usov (1993). In the case of WR 146 and WR 147 the fluxes are below the current detection thresholds, but forthcoming experiments could detect them. Further refinements, taking into account spectral changes produced by energy losses, are in progress.

References

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