SEARCH FOR TEV γ-RAYS FROM WOLF-RAYET STARS

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Abstract. A search for TeV γ-rays from the non-thermal radio stars WR125, WR140, WR144 and WR147 has yielded only upper limits. The implications are discussed.

Key words: stars: Wolf-Rayet – γ-rays

1. Introduction

The 10m Optical Reflector of the *Whipple Observatory* (Cawley *et al.* 1990) on Mount Hopkins in southern Arizona (elevation 2.3 km) has been used in studies of very high energy gamma rays (γ-rays) and cosmic rays (CR) since 1968. When either a CR or a γ-ray reaches the atmosphere, it generates a shower of particles. Due to the extension of the Cherenkov-light distribution around the air-shower axis at ground level (typically 200 m diameter), the telescope can detect γ-ray showers with axis as far as 100 m from the telescope which means it has a very large collection area (typically $3\text{x}10^4$ m^2). The diameter of the overall field of view is 3.5°. Most of the events recorded during the observation are produced by CR air showers, only a few are γ-ray initiated air showers (order of 0.3%). Basically the images obtained with the camera are parameterized and some cuts on those parameters applied. Those cuts are determined from predicted properties of γ-ray images from Monte Carlo simulations. Then, the significance of the detection and the flux from the source comes from the analysis of the γ-events selected with this procedure. To date two sources have been detected with some certainty: the Crab Nebula (Vacanti *et al.* 1991) and Markarian 421 (Punch *et al.* 1992).

2. Models; γ-ray emission?

Since the discovery of non-thermal radiation from early-type stars, many authors have argued that in the strong stellar winds of hot, massive stars, electrons can be accelerated to relativistic energies (*e.g.,* Pollock 1987). White & Chen, 1992, have considered non-thermal emission in O early-type stars where radiative wind and shock-wave models can be applied. Once multiple strong shocks are generated in the winds, a natural consequence (White 1985) is that some of the thermal particles can be first-order Fermi-accelerated to relativistic energies by the shocks. The collisions between relativistic ions and thermal ions in the winds produce neutral pions

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which decay to γ-rays. Such reactions are most likely to occur in the dense winds of WR stars. The α-particles (He nuclei) in WR winds see a larger velocity jump at shocks and thus can be accelerated to higher energies than protons. The resulting particle spectrum (and thus the γ-ray spectrum) in WR winds will be harder than that in the winds of O-type stars (White & Chen 1992). A possible antecedent of WR source in TeV energies could be the γ-ray source Cyg X-3. Recently van Kerkwijk *et al.* (1992) suggested that Cyg X-3 has a WN7 component.

3. Data and results

Based on the above suggestions, we observed four WR stars which satisfy at least one of the conditions suggested by the models. Data were taken in June, September and November, 1993. No significant detection for steady emission was obtained but upper-limits were determined for integral fluxes at the energy threshold of the telescope (0.3 TeV = 3×10^{11}eV). Table I summarizes conditions that apply to the models (from van der Hucht 1992) and our results. If the flux at *COS-B* energies suggested by Pollock (1987) is considered together with the flux upper-limit derived in this work, the integral energy spectral index for WR140 would be steeper than -1.55 between 0.3 GeV and 0.3 TeV.

TABLE I

Observed stars, some characteristics (from van der Hucht 1992) and our results.

WR	d (kpc)	n-t radio	L_x/L_{bol} (10^{-7})	possible *COS-B*	observed time (min)	integral flux upper limits (ph/cm^{2}s)	(erg/cm^{2}s)
125	4.66	yes	23	yes	115	2.46×10^{-11}	1.04×10^{-11}
140	1.34	yes	25	yes	358	1.23×10^{-11}	0.59×10^{-11}
144	1.74	yes			56	3.63×10^{-11}	1.53×10^{-11}
147	0.63	yes	2.5		56	3.19×10^{-11}	1.59×10^{-11}

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