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Synchrotron radiation from giant $e^{\pm}$ pair halos

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Abstract. A giant $e^{\pm}$ pair halo is formed by electromagnetic cascades developing around an AGN under the intergalactic magnetic field (1nG - 1μG). Many studies have been focussed on the pair halos in the gamma band because it has been predicted that the $e^{\pm}$s in the pair halos up-scatter the Cosmic Microwave Background (CMB) to be gamma-rays. However, the pair halos do not emit only gamma photons but also X-ray photons via synchrotron radiation. In this paper, the Spectral Energy Distributions (SEDs) and the angular distributions of the synchrotron radiation of the pair halos from the Monte Carlo simulations will be discussed.

Keywords. electromagnetic cascades, giant electron/positron pair halos, intergalactic magnetic field

1. Introduction

In 1994, the model of giant $e^{\pm}$ pair halo was proposed (Aharonian *et al.* 1994). It shows the calculated spectral energy distributions of the gamma-rays from pair halos. Later on, the angular distributions of the gamma-ray from the pair halos were calculated (Eungwanichayapant & Aharonian 2009). Most of the works on the giant $e^{\pm}$ pair halos have been focused on radiation in the gamma band. Observing of the pair halos have also been done only in the gamma-rays. The first attempt was done by the HEGRA group (Aharonian *et al.* 1999) and recently by Ando and Kusenko (2010).

X-rays from synchrotron radiation is another band that might have the potential for searching the pair halos. We started in this direction by calculating the SEDs and angular distributions of the X-ray from pair halos in various situations.

Giant $e^{\pm}$ Pair Halos Model

The absorption of intrinsic gamma-rays via $\gamma\gamma$ pair production produces $e^{\pm}$ pairs. If the intergalactic magnetic field is strong enough (1nG - 1μG), the $e^{\pm}$ will gyrate before scattering the CMB photons because the gyro radius of the $e^{\pm}$s is smaller than the inverse Compton scattering mean free path (Fig. 2). As a result, the electromagnetic cascades developing around the central source produce a spherical cloud of $e^{\pm}$ pairs. During the gyration of the pairs, they radiate potentially observable synchrotron photons.

2. Methodology

Monte Carlo simulations were used to follow the cascades developing around an AGN. The emission time distributions, $T(E)$, of every cascading $e^{\pm}$ were computed for the calculation of the synchrotron energy distribution:

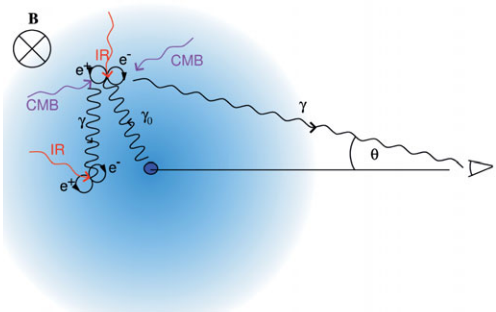

Figure 1. Physical model of a giant e$^{\pm}$ pair halo.

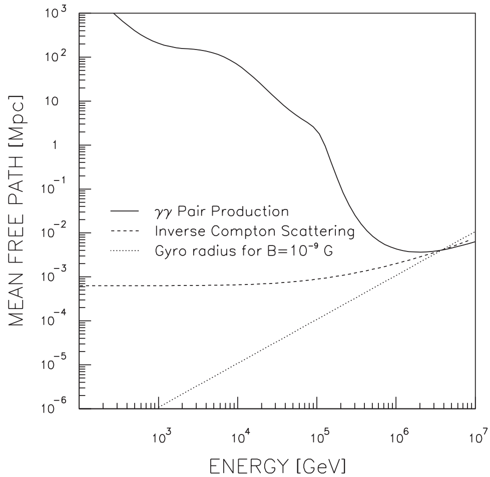

Figure 2. Comparison of the important lengths

$$\frac{dE}{d\nu} = \int \frac{\sqrt{3}e^3 B \sin\alpha}{2\pi mc^2} G(\frac{\nu}{\nu_c}) T(E) dE, \tag{2.1}$$

and converted to the pair halo flux by

$$F = \frac{\mathrm{L}_0}{\mathrm{E}_{\gamma_0} 4\pi d_s^2} E, \tag{2.2}$$

where L_0 is gamma luminosity of the AGN, E_{γ_0} is the total energy of the intrinsic gamma photons emitted by the AGN, and d_s is the distance from the AGN.

The technique of the observer sphere as described in Eungwanichayapant & Aharonian (2009) was applied to find the angle distance. Every time an e$^{\pm}$ emits synchrotron photons, a synchrotron ray was generated randomly. The ray would cross the sphere of radius d_s somewhere and make an angle, θ, to the normal of the sphere at the crossing point. The angle θ is interpreted as the angular distance from the source of the e$^{\pm}$.

3. Results

The spectral energy distributions and angular distributions of the Synchrotron photons from giant e$^{\pm}$ pair halos shown here are the pair halos from monoenergetics sources located at z= 0.129 †.

The results in Fig. 3 and Fig. 4 show that when the intrinsic gamma energy, E_0, increased, the SED extended to higher energy, more energy flux contained in higher energy band, but remain the same level in lower energy band. Interestingly, the angular distributions were sensitive to the intrinsic gamma energy between 100 - 500 TeV.

The results in Fig. 5 and Fig. 6 show that when intergalactic magnetic field, B, is increased, the SED extends to higher energy, the energy flux increasing in all bands. The synchrotron pair halos were more extended when the magnetic field got close to 1 μG. However, when the magnetic field was stronger than $\approx 3\mu$G‡ the pair halos became more

† the redshift of 1ES1426+428, one of the promising candidate for detecting a pair halo
‡ This is the level that energy density of the magnetic field and background photon field are equal

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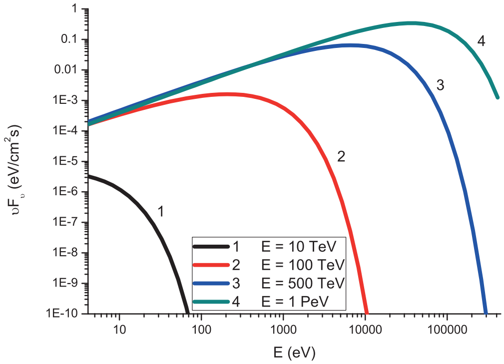

Figure 3. Pair halo SEDs in difference monoenergetic spectra.

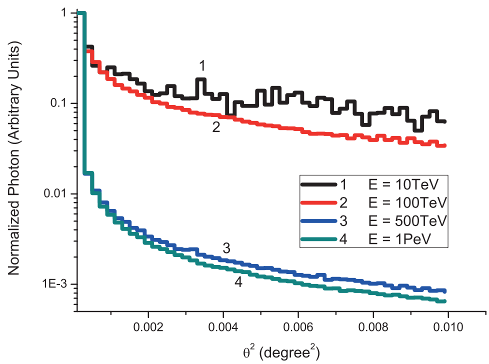

Figure 4. Pair halo angular distributions in difference monoenergetic spectra.

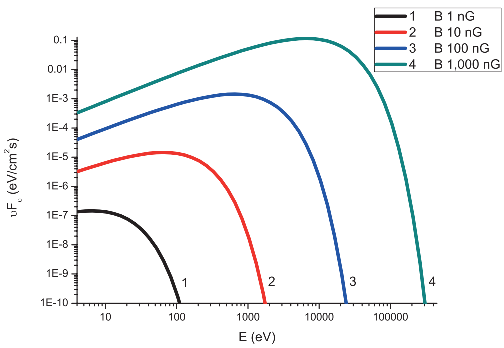

Figure 5. Pair halo SEDs in difference magnetic field strengths.

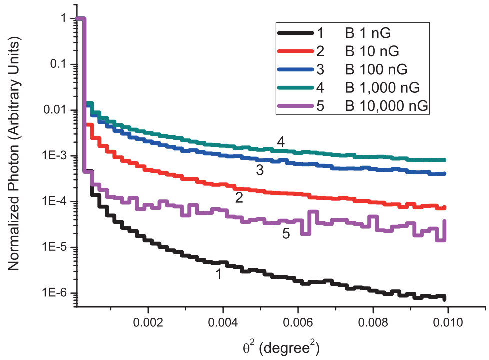

Figure 6. Pair halo angular distributions in difference magnetic field strengths.

centrally peaked since $e^{\pm}$s lose most of their energy via synchrotron radiation and could not generate next generation cascades.

4. Conclusion

The giant $e^{\pm}$ pair halos not only radiate gamma-rays but also X-rays via synchrotron radiation. Our results show that we can gain information about the intergalactic magnetic field at the central source redshift from the SEDs and angular distributions of the pair halos. However, observing the pair halos can be challenging for present X-ray observatories because their energy flux sensitivities do not go down to the predictions for the pair halo levels.

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