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Time Dependent Model of Young Pulsar Wind Nebulae

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Abstract. A time dependent leptonic model is developed in order to explain the broadband non-thermal radiation from pulsar wind nebulae.

1. Introduction

The ultra-relativistic particle winds from pulsar is injected to energize the surrounding medium and forms a nebula around the pulsar. Here we describe a time dependent leptonic model which gives the electron energy distribution as a function of time by solving the diffusion loss equation. The broadband photon spectrum can be obtained via different non thermal emission mechanisms. We apply the model to explain the non-thermal emission from the Crab nebula.

2. Model

The simplified diffusion equation used in this work is give by(Zhang, Chen and Fang (2008))

$$\frac{\partial n(\gamma,t)}{\partial t} = Q(\gamma,t) - \frac{n(\gamma,t)}{\tau_{syn}} - \frac{n(\gamma,t)}{\tau_{Bohm}} \quad (1)$$

where $n(\gamma, t), \gamma$ represent the differential electron density and Lorentz factor of corresponding electron, τ_{syn} is the lifetime of relativistic electron with respect to synchrotron loss and τ_{Bohm} is escape timescale with respect to Bohm diffusion. The time variation of electron density in RHS is balanced by particle injection from pulsar and loss of electron due to synchrotron emission and Bohm diffusion. A significant fraction of spin down luminosity of central pulsar is converted into particle kinetic energy. The flow of electrons from pulsar forms a termination shock which again accelerates a

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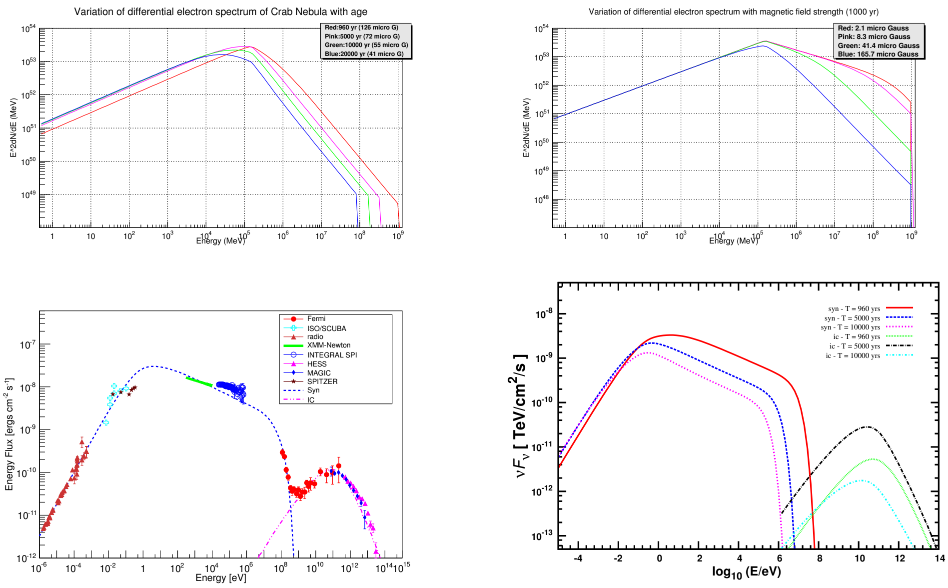

Figure 1. Upper Left panel: Electron spectrum of Crab nebula at different ages. Upper right panel: Variation of electron spectrum with different magnetic field strength at age T=1000 yr. Lower left panel: Comparison of multi-wavelength photon spectrum of the Crab nebula with available data. Lower right panel: The predicted photon spectrum of Crab at higher ages

new generation of electrons. The injection spectrum at shock radius is considered as

$$Q(\gamma, t) = Q_0(t) \begin{cases} \left(\frac{\gamma}{\gamma_b}\right)^{-\alpha_1} & \gamma \leq \gamma_b, \\ \left(\frac{\gamma}{\gamma_b}\right)^{-\alpha_2} & \gamma > \gamma_b, \end{cases} \tag{2}$$

where $Q_0(t)$ can be obtained from energy conservation principle.

2.1 Photon Spectrum

The non-thermal photon spectrum can be calculated using the time-dependent electron spectrum. The present day electron spectrum of Crab is used to produce the broadband photon spectrum of Crab and is compared with the available multi-wavelength data (Aharonian et al. 2006). The broadband photon spectra for 5000 and 10000 years are shown in lower right panel of Figure. 1.

References

Zhang L., Chen S. B., Fang J., 2008, ApJ, 676, 1210
Aharonian F., et al., 2006, AA, 457, 899 (HESS)