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Locating the TeV γ-rays from the shell regions of Cassiopeia A

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Abstract. We have analyzed Chandra X-ray data from different parts of the shell of young supernova remnant (SNR) in the energy range of 0.7 - 8 keV. We observed that X-ray flux level varies over different shell regions of the source. Implications of X-ray observation will be discussed here. We also analyzed Fermi-LAT data in the energy range 0.5 - 50 GeV for the source. The differential spectrum obtained in this way fits with simple power-law. We also present here multi-wavelength modeling of the source considering archival radio and TeV data along with Chandra and Fermi-LAT data.

Keywords. Cassiopeia A, X-rays, Observations

1. Introduction

Cassiopeia is a young shell type supernova remnant and is observed in radio, infra red, X-rays and even further to GeV-TeV high energy γ-rays (Atoyan *et al.* (2000); Aharonian *et al.* 2001; Albert *et al.* 2007; Abdo *et al.* (2010); Araya *et al.* (2010)). Here we have focussed on different shell regions of Cas A instead of the radio knots which have been observed many times. We have analysed X-ray data from different shell regions and have seen that there are significant differences in number of high energy photons from different regions of the shell. Based on the different level of fluxes we see the region of the shell which will be responsible for the production of very high energy γ-rays. We have also estimated contribution to GeV-TeV energy spectra as well as associated magnetic field from different shell regions of the CasA based on the X-ray data.

2. Leptonic model

For multi-wavelength modeling of CasA we use TeV data from MAGIC (Albert *et al.* 2007), GeV data from Fermi-LAT, X-ray data from Chandra and radio data given by Baars *et al.*, 1977.

We have estimated X-ray fluxes from 4 different regions of the Cas A. To be consistent with the magnetic field B = 80 -160 μG estimated by Vink & Laming (2003), we considered magnetic field 90 μG for one region (R1). The magnetic field for other regions (R2, R3 and R4) are estimated w.r.t the magnetic field considered in R1. We then fit the X-ray data for this region and estimate other model parameters as shown in Table 1. The fitted spectrum is then scaled such that it can explain the total X-ray flux from the remnant. The parameters obtained in that way is used to get the inverse Compton spectrum for the whole remnant. Figure 1 shows the fit to the X-ray data from different parts of the remnant by synchrotron spectra and corresponding inverse Compton spectra. We also estimate the contribution of bremsstrahlung process to the TeV energies and see

Table 1. Parameters for Synchrotron spectra for different regions of the filaments.

Region	Magnetic Field (μG)	spectral index	γ_{min}	γ_{max}	Distance (kpc)	Normalization Constant
Region 1 (R1)	90	2.54	1.0	5.5×10^7	3.4	4.1×10^{53}
Region 2 (R2)	170	2.54	1.0	5.5×10^7	3.4	4.1×10^{53}
Region 3 (R3)	120	2.54	1.0	5.5×10^7	3.4	4.1×10^{53}
Region 4 (R4)	90	2.54	1.0	5.5×10^7	3.4	4.1×10^{53}
Region 5 (R5)	100	2.54	1.0	5.5×10^7	3.4	4.1×10^{53}

that bremsstrahlung process cannot explain the TeV data for ambient proton density of $10/cm^3$.

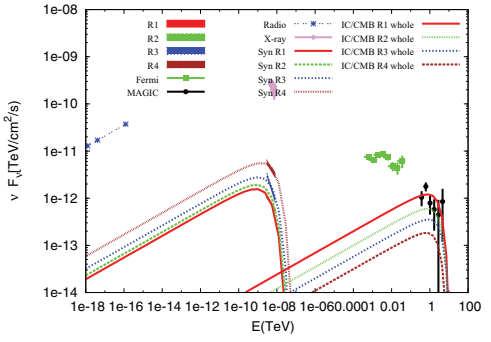

Figure 1. Synchrotron spectra and inverse Compton spectra for different regions of the Cassiopeia A along with the observed multi--wavelength data.

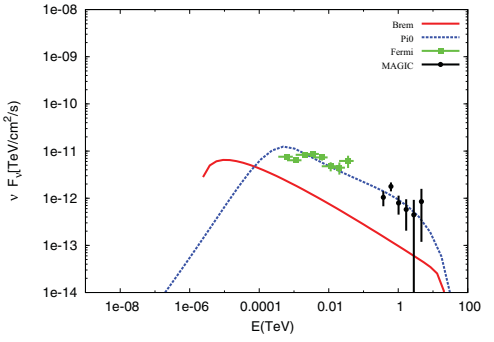

Figure 2. Bremsstrahlung spectrum (solid line) and spectrum due to decay of neutral pi-ons (dotted line) of Cassiopeia A for ambient proton density 10 cm^{-3}.

3. Hadronic model

For hadronic contribution to the γ-ray flux through decay of neutral pions (π^0's), we have considered ambient proton density to be $10/cm^3$ as we have considered for bremsstrahlung process. Accelerated proton spectrum was considered as $dN/dE_p \propto E^{-2.35}$ with an exponential cutoff at 80 TeV. Figure 2 shows the contribution to γ-rays from decay of π^0's. The γ-ray spectrum fits well with the observed data in GeV -TeV range. As we know that the about 10% of the explosion energy of SNR is converted to the energy of relativistic particles, therefore the total explosion energy of the supernova is estimated to be 10^{51} ergs.

4. Conclusion

We show that different shell regions of Cassiopeia differ in X-ray fluxes which can help us to identify the region which is more bright in high energy γ-rays. Apart from that we show that leptonic model cannot explain GeV data. We need to invoke haronic model to explain GeV-TeV data.

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