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Gamma-ray Observation of Nearby Starburst Galaxy IC342

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Regions with high star formation rates (SFR) in starburst galaxies (SBGs) are frequently accompanied by high density clouds of interstellar matter (ISM). This may create nearly perfect conditions for generating diffuse gamma-ray radiation as high energy cosmic rays accelerated in supernovae explosions of massive progenitor stars interact with the ambient protons. If the current paradigm that supernovae are the origin sites of high energy cosmic rays is valid, then the star forming regions rich in supernovae may become the laboratories to test and study this phenomenon. The gamma-ray luminosity of these extragalactic objects is suppressed by a large distance factor compared to supernovae in our own galaxy. However, flux estimates indicate that if star bursting regions have a proper combination of critical parameters (intersteller medium density, age, size, supernova rate, magnetic field strength) the cumulative enhancement of the gamma-ray luminosity resulting from multiple explosions of supernovae into dense ISM may generate an observable flux for nearby SBGs such as M82, IC342. A search for TeV gamma-ray emission from IC342 was conducted with the Whipple 10m gamma-ray telescope from September 2002 to March 2004.

Keywords: Starburst; IC342; gamma-ray.

1. Introduction

It has been more than half a century since the supernova remnant (SNR) origin of very high energy cosmic rays (CRs) with energy up to $\sim 10^{15}$ eV was proposed and discussed. Direct observation of the sources of such high energy CRs is impossible due to deflection by the galactic magnetic field. However, gamma-rays are produced

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in the vicinities of the CR acceleration sites via secondary neutral pion decay from hadronic CR interactions with ambient protons. These high energy gamma-rays can be used as indirect probe of high energy CR acceleration by SNRs. Some local SNRs have recently been observed at TeV energy by several collaborations. Among those, only one source was unambiguously detected in TeV range: SNR RX J1713-3946 observed by the CANGAROO and H.E.S.S collaborations (Enomoto et al. 2002). The gamma-ray emission was suggested by Enomoto et al. as being the result of hadronic interactions at the source. However, there is currently no commonly accepted scenario for the TeV emission of this source. Starburst galaxies (SBGs) have been suggested as another astronomical object for testing the SNR CR acceleration scenario. SBGs are known to have intensive star formation regions often associated with dense molecular gas clouds. Large numbers of SNRs imbedded in such a high density environment can enhance the gamma-ray production, and produce a flux of TeV photons large enough to be detected with the current generation of ground-based instruments. It is important to note that starburst regions must be in right phase of their evolution. They should be old enough to have O and B stars evolve into SN stage, and young enough to retain high density gas environment. The preferable range of the age of the regions is from few million years to few tens million years. This constraint can be avoided if there is a continuous supply of gas into the starburst regions.

After a survey of local SBGs and their parameter values as published, we find that one of the best northern sky candidates for TeV emission is IC342. At present, there is only one reported TeV gamma-ray detection from a SBG, NGC253, a southern SBG detected by the CANGAROO group with large statistical confidence ($\sim 11\sigma$) (Itoh et al. 2002). Though this source has not been confirmed by H.E.S.S collaboration (H.E.S.S workshop 2004).

2. IC342 Morphology

IC342 is nearly face on galaxy, located at distance about 3.5 Mpc. The starburst regions are located near the core, coinciding with major compression areas where mini-arms intersect with high density molecular gas ring (e.g. Böeker et al. 1997). Molecular gas is continuously supplied into the starburst regions along the mini-arms, which seems to prevent evacuation of target protons due to pressures from O and B stars and multiple SN explosions. The proton density in the region is predicted to be as high as $\sim 10^{3.5} H/cm^3$ (e.g. Meier & Turner 2001).

3. Data and Analysis

Observations of IC342 were conducted between September 2002 to March 2004 by 10m atmospheric Čerenkov telescope at the Whipple observatory near Tucson, AZ. The total exposure is about 220 k sec consisting of on source exposure and equivalent background exposure.

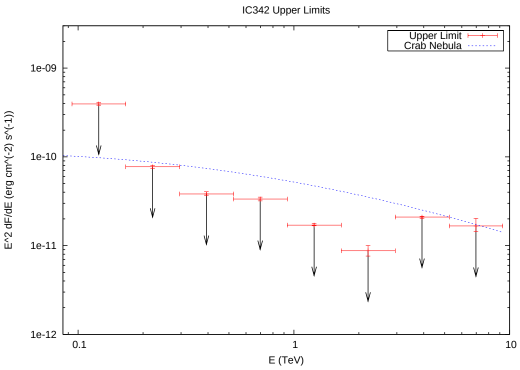

Fig. 1. IC342 Flux upper limits: Horizontal bars show the width of each energy bin. Vertical bars show systematic error due to varying spectra index from 2.0 to 3.5 with 0.5 increments.

Two analysis methods were applied to the IC342 data set. The first is a standard analysis which is most widely accepted for the Whipple sources. The analysis is optimized for Crab nebula-like objects with spectra index ~ 2.5. However, the energy sensitivity of the telescope is dependent on the source spectral index. Since we have no prior knowledge of intrinsic gamma-ray spectrum of IC342, we developed a spectra-dependent analysis utilizing the multidimensional maximal likelihood (MML) method. This method has been successfully tested with the Crab nebula and Mrk 421 data sets.

4. Result and Interpretation

Neither methods resulted in detection ($> 3\sigma$). Possibilities of power spectrum with indices 2.0, 2.5, 3.0 and 3.5 were investigated with the MML method. 95% confidence level flux upper limits were derived for equal logarithmic energy size bins (see figure 1). The Crab nebula flux (Hillas et al. 1998) is shown in the figure for comparison. This result constrain only extreme predictions for SNR hadronic CR acceleration scenario.

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