VHE Gamma-ray supernova remnants

S. Funk

Kavli Institute for Particle Astrophysics and Cosmology, SLAC, 2575 Sand Hill Road, PO Box 0029, Stanford, CA-94025, USA

Abstract

Increasing observational evidence gathered especially in X-rays and γ-rays during the course of the last few years support the notion that Supernova remnants (SNRs) are Galactic particle accelerators up to energies close to the “knee” in the energy spectrum of Cosmic rays. This review summarises the current status of γ-ray observations of SNRs. Shell-type as well as plerionic type SNRs are addressed and prospect for observations of these two source classes with the upcoming GLAST satellite in the energy regime above 100 MeV are given.

Key words: Supernova remnant, Pulsar Wind Nebula, Gamma-ray astronomy
PACS: 98.38.Mz, Supernova remnants
PACS: 98.70.Rz, γ-ray sources
PACS: 98.70.Sa, Cosmic rays (origin, acceleration, and interactions)

1 Introduction

Supernova remnants (i.e. remnants of Supernova explosions) are commonly considered to be Cosmic particle accelerators. In this review paper I will summarise experimental evidence, gathered through γ-ray observations mainly in the VHE regime supporting this notion (please note, that in the following γ-ray will be used to stand for VHE γ-rays). Typically, SNRs were detected through radio observations [Green, 2004]. Recent advances in the understanding of these objects has been made through X-ray observations with instruments such as ASCA, BeppoSax, XMM-Newton and Chandra and through γ-ray observations with instruments such as HEGRA (High Energy Gamma

Email address: Stefan.Funk@slac.stanford.edu (S. Funk).

1 previously at: Max-Planck-Institut für Kernphysik, P.O. Box 103980, D 69029, Heidelberg, Germany
Ray Astronomy), and H.E.S.S. (High energy stereoscopic system). Based on morphological properties, SNRs can be classified into three broad categories: shell-like, plerionic (also called Pulsar Wind Nebulae or Crab-like) connected to a Pulsar and composite (in which both, a shell and a Plerion are present), the later often showing markedly different radio and X-ray morphologies. For an excellent detailed review on plerionic SNRs, see e.g. Gaensler & Slane (2006).

SNRs are thought to be responsible for the acceleration of Cosmic rays up to energies around the “knee” ($\sim 10^{15}$ eV) at which the spectrum of Cosmic rays significantly hardens from $\sim 2.7$ to $\sim 3.2$. This statement is backed by experimental facts, as well as by theoretical considerations. Experimental evidence is lent mainly by (1) X-ray observations of young shell-type SNRs such as SN 1006 (Koyama et al., 1995), and Cas A (Vink et al., 2001), in which sites dominated by hard non-thermal X-ray synchrotron emission were found, indicating an electron population extending up to $\sim 100$ TeV, far beyond thermal energies. (2) Very high energy (VHE) $\gamma$-ray observations ($> 100$ GeV) revealed sites of non-thermal particle populations (Aharonian et al., 2004, 2006a,b).

Through theoretical considerations is has been known for a long time that Supernova explosions release just about the right amount of energy into their surrounding to account for the energy budget of the Cosmic rays (assuming that they convert $\sim 10\%$ of their energy into kinetic energy of the Cosmic rays) (Ginzburg & Syrovatskii, 1964). Furthermore well-established theoretical models exists explaining how particles can be accelerated in Supernova shock waves to energies approaching the knee. In shell-type SNRs particles are accelerated in the expanding shock waves through diffusive shock (also called first order Fermi) acceleration (Bell, 1978; Blandford & Ostriker, 1978; Drury, 1983; Blandford & Eichler, 1987; Jones & Ellison, 1991; Malkov & Drury, 2001). In plerionic SNRs particles are accelerated to non-thermal energies in the termination shock between the relativistic outflow of electrons from the pulsar surface and the outer nebula. Predictions on the $\gamma$-ray visibility of SNRs (later confirmed by H.E.S.S. $\gamma$-ray observations although there is still an experimental ambiguity in the underlying particle population responsible for the $\gamma$-ray emission) were given by Drury et al. (1994).

Since charged particles below the knee at $10^{15}$ eV are deflected in ubiquitous magnetic fields on their way from the origin to us, we have to turn to neutral messengers to reveal the acceleration sites (the gyroradius of 1 TeV cosmic rays in a magnetic field of $\mu$G-scale is of the order of 0.1 pc, much smaller than the thickness of the Galaxy of 200–300 pc). Since neutrino detectors have not yet proved to be sensitive enough to detect neutrinos from astrophysical sources (apart from the Sun and the direct Supernova explosion SN 1987A), observations in the radio, X-rays and $\gamma$-ray wavebands are so far our best access to non-thermal acceleration processes in SNRs. $\gamma$-rays (and neutrinos) are produced in hadronic interactions with subsequent pionic decay and can reveal the acceleration sites since they travel un-deflected from their origin.
However, $\gamma$-rays not only reveal the sites of hadronic acceleration; they also act as a tracer for energetic electrons that produce $\gamma$-rays via IC scattering off background photon fields (such as star-light or the Cosmic microwave background (CMBR)). An ambiguity or duality therefore exists in the responsible radiating particle population in most cases when detecting $\gamma$-rays from astrophysical objects.

In spite of this ambiguity the detection of $\gamma$-rays above $\sim 1$ GeV from SNRs gives us direct access to particle acceleration processes and the advantage of $\gamma$-rays in comparison to other wavebands is that these are not affected by dust obscuration, which is particularly important for the population of SNRs located within the Galactic plane. A large volume of the Galaxy can thus be probed for $\gamma$-ray emission from SNRs by observations through the Galactic disk. If SNRs are indeed sites of particle acceleration, $\gamma$-ray emission is expected and one of the puzzling aspects of previous $\gamma$-ray observations of SNRs was the rather low level of emission compared to model predictions (Buckley et al., 1998; Hillas, 2005).

The history of soft $\gamma$-ray (or hard X-ray) detection of SNRs started with the detection of the Crab Nebula in 1964 with a scintillation counter detector flown on a balloon launched from Palestine, Texas (Clark, 1965). Today hard X-rays up to 100 keV have been detected from various SNRs both young shell-types such as Cas A (Vink et al., 2001; Vink & Laming, 2003) and SN 1006 (Allen et al., 2001; Vink et al., 2000) and plerionic-types such as the Vela-X PWN (Mangano et al., 2005) and MSH 15-52 (Tamura et al., 1996; Marsden et al., 1997; Mineo et al., 2001; Forot et al., 2006). Thin X-ray filaments in young shell-type SNRs detected with high-angular resolution instruments such as XMM-Newton and Chandra point to regions with high-magnetic fields (up to 0.5 mG) in which electrons rapidly lose energy through synchrotron emission (Koyama et al., 1997; Slane et al., 2001; Bamba et al., 2003; Cassam-Chenaï et al., 2004). In higher energies $\gamma$-rays COMPTEL detected the radioactive $^{44}$Ti-line at 1.157 MeV from the two shell-type SNRs Cas A (Iyudin et al., 1994) and RX J0852.0−4622 (Vela Junior) (Iyudin et al., 1998). However, it should be noted, that higher sensitivity INTEGRAL observations provided a confirmation for this detection for Cas A, but could not detect this $^{44}$Ti-line in RX J0852.0−4622. Therefore, these claims are still somewhat controversial.

EGRET at energies above 100 MeV did not detect prominent young shell-type SNRs such as Tycho, Kepler, Cas A or SN 1006, noticed however several intriguing spatial coincidences of unidentified sources in the Galactic plane with individual prominent radio SNRs, such as W 28, and $\gamma$-Cygni (Sturner & Dermer, 1995; Esposito et al., 1996; Romero, Benaglia & Torres, 1999). The combination of source confusion especially in the Galactic plane, caused by the rather poor angular resolution of the EGRET instrument and the ambiguity in ex-
isting counterparts prevented individual identifications. However, a statistical assessment shows a 4-5σ effect when trying to correlate the population of EGRET unidentified sources with the population of radio SNRs (Sturner & Dermer, 1995). Also plerionic SNRs have not been unambiguously identified with EGRET sources, although again intriguing associations of EGRET unidentified sources with prominent plerions such as PSR B1706–44, and the Kookaburra complex exist (Roberts et al., 2005). From a population point-of-view PWN are one of the best candidates to account for low-latitude slowly varying unidentified EGRET sources as proposed by Roberts et al. (2001). Lately, using VHE γ-ray source positions in the Kookaburra region (Aharonian et al., 2006c) the re-analysis of EGRET data provided strong evidence of correlation of the PWN detected in this region with the confused unidentified EGRET source 3EG J1420–6038 (Reimer & Funk, 2006). This new approach might prove a useful template for connection future GLAST and VHE γ-ray detections. All these possible associations of source classes with unidentified EGRET sources will hopefully be tested following the launch of the upcoming GLAST satellite in late 2007.

The history of VHE γ-ray (E > 100 GeV) detections of SNRs started again with the detection of the Crab Nebula, the first object to be reported in this waveband by the Whipple collaboration (Weekes et al., 1989). Various claims of detections of shell-type SNRs have been made before the advent of the H.E.S.S. telescope system. Cas A was detected by HEGRA in a very deep (~ 200 hours) exposure (Aharonian et al., 2001). Detections of SN 1006 (Tanumori et al., 1997) and RX J1713.7–3946 (Enomoto et al., 2002) have been reported by the CANGAROO collaboration. With the advent of the H.E.S.S. telescope system, for the first time a number of Galactic SNRs, both shell-type and plerionic in nature could be established. In the following I will describe these populations of cosmic accelerators along with prospects for Supernova remnant observations with the upcoming GLAST satellite. The outline of this paper is as follows: Section 2 provides a description of advances made through the VHE γ-ray detections of shell-type Supernova remnants, Section 3 provides the corresponding description for Pulsar Wind Nebulae. Section 4 describes Supernova remnants found in γ-rays and later identified as Supernova remnants, while Section 5 summarises prospects for Supernova remnant observations with the upcoming GLAST satellite.

2 Gamma-ray observations of shell-type SNRs

By means of data taken with the H.E.S.S. telescope system during the first few years of operation for the first time in VHE γ-ray astronomy resolved images of shell-type SNRs above 100 GeV could be taken. In particular the SNRs RX J1713.7–3946 and RX J0852.0–4622, with diameters of ~ 1° and ~ 2° re-
spectively could be resolved with unprecedented detail in this energy band. On the other hand, SN 1006, one of the SNRs most expected to emit $\gamma$-rays in the energy band (due to the strong non-thermal X-ray emission from the rims) was not detected in deep H.E.S.S. observations \cite{Aharonian2005a}. The upper limit derived by this observations turned out to be an order of magnitude below the previously reported CANGAROO detection. A reanalysis of the CANGAROO data along with newer data from the CANGAROO-III detector is consistent with the H.E.S.S. upper limits \cite{Tanimori2005}. Therefore in the following the H.E.S.S. upper limits will be used in the discussion of $\gamma$-ray emission from SN 1006. Since several papers on both RX J1713.7–3946 \cite{Aharonian2004,Aharonian2006a,b} and RX J0852.0–4622 \cite{Aharonian2005b,2006d} have been published by the H.E.S.S. collaboration, the main focus of this review will lie on similarities and differences between the two objects with the addition of comparisons to SN 1006 as the most prominent non-detected SNR where appropriate.

Figure 1 shows $\gamma$-ray excess maps for RX J1713.7–3946, RX J0852.0–4622, and SN 1006. Both $\gamma$-ray emitting objects show a shell-like structure with a surprising resemblance of their respective X-ray morphology (the correlation coefficients between $\gamma$-ray and X-ray counts are $\sim 60\%-80\%$). For both objects the X-ray emission is completely dominated by non-thermal X-ray emission without traces of line emission, exhibiting small filamentary structures that are interpreted as zones where the magnetic field is high ($\sim 50\mu G$) such that electrons rapidly lose energy through synchrotron emission in these areas \cite{Cassam-Chenaï2004,Uchiyama2003,Aschenbach1998,Iyudin2005}. Both objects appear rather faint in radio with typical fluxes below or in the several tenth of Jansky-regime for the whole shell, certainly lower than what would be expected from equipartition arguments \cite{Lazendic2004}. The distance to both objects is somewhat uncertain, for RX J1713.7–3946 it seems that a distance of $\sim 1$ kpc is preferred from the column density inferred from X-ray data. This distance would make RX J1713.7–3946 most likely the remnant of the historical Supernova event of AD393. For RX J0852.0–4622 distance estimates range from as close as the Vela pulsar ($\sim 250$ pc) to as far as the Vela Molecular Ridge ($\sim 1$ kpc). The age ranges from $\sim 500$ years in the close case to $\sim 5000$ years in the far case. Morphologically their $\gamma$-ray emission, in particular the width of the shells is rather different. The apparent width of the shell for RX J1713.7–3946 comprises 45\% of the radius of the SNR, while the for RX J0852.0–4622 it approximates to 20\% of the radius. There is no apparent correlation between the dense molecular material surrounding RX J1713.7–3946 as measured by the NANTEN telescope and the VHE $\gamma$-ray emission as measured by H.E.S.S., but in fact, assuming a typical energy of $1 \times 10^{50}$ ergs in accelerated protons, the density needed to explain the $\gamma$-ray flux through hadronic interactions is only $1 \text{ cm}^{-3}$.

SN 1006 is somewhat distinct in its multi-frequency picture in that its surface
Fig. 1. Acceptance-corrected smoothed excess maps of the 3.5° × 3.5° fov surrounding the two prominent H.E.S.S. Supernova remnants RXJ1713.7–3946 (2004 and 2005 data) (Aharonian et al., 2006b) and RXJ0852.0–4622 (2005 dataset) (Lemoine-Gourmard et al., 2006; Aharonian et al., 2006d) and non-detected SN 1006 (2004 dataset with VLA radio contours in white) (Aharonian et al., 2005a). The sky-regions shown are of similar size, indicating the large extent (2° diameter) of RXJ0852.0–4622.

Brightness is higher in radio (∼100 Jy) (Gardner & Milne, 1965; Roger et al., 1998) showing a pronounced shell-like structure. The X-ray emission, especially in the shell is dominated by non-thermal emission up to ∼10keV. SN 1006 was not detected in a deep (1000 ksec) INTEGRAL exposure above 20 keV (Kalemci et al., 2006) and was also not detected in sensitive H.E.S.S. observations (Aharonian et al., 2005a). The density surrounding the source was estimated from X-ray as well as optical observations and values as low as n = 0.05 cm⁻³ have been invoked to explain the apparent absence of γ-ray emission in a hadronic scenario. From the H.E.S.S. non-detection assuming a leptonic γ-ray emission scenario on the CMBR a lower limit on the post-shock magnetic field of $B > 25\mu G$ can be derived (Aharonian et al., 2005a). Higher values of the magnetic field in excess of 40μG have been derived from X-ray observation and application of diffusive shock acceleration scenarios, so the
Comparing the energy spectra of the two $\gamma$-ray detected SNRs, strong similarities can be made out. The spectral energy distribution (SED) for the three shell-type SNRs discussed here is shown in Figure 2 along with model spectra, showing typical leptonic and hadronic $\gamma$-ray emission models. As can be seen from this plot RX J1713.7–3946 and RX J0852.0–4622 show a remarkably similar $\gamma$-ray energy spectrum with a rather flat $E^{-2}$-type distribution at lower energies with a deviation from this power-law at higher energies. The flat spectrum at lower energies has advocated claims that the $\gamma$-rays might be generated by pionic decays rather than Inverse Compton scattering (Aharonian et al., 2006a,b). However, Porter et al. (2006) claim that the data can be well fitted in terms of a leptonic model when applying an unbroken electron spectrum along with the Galactic radiation fields. Therefore, at the moment, no strong conclusions can be drawn from the spectral shape on the particle population responsible for the $\gamma$-ray emission. The upcoming GLAST satellite, measuring in the energy range between 30 MeV and 300 GeV might be able to distinguish between hadronic and leptonic $\gamma$-ray production mechanisms. Also interesting to note is that the H.E.S.S. $\gamma$-ray upper limit for SN 1006 is more than an order of magnitude below these $\gamma$-ray detections and therefore starts to be rather constraining for the values of the magnetic field (in a leptonic scenario) or the ambient matter density (in a hadronic scenario).
These first unambiguous detections of individual shell-type SNRs allowed for important advances in the understanding γ-ray emission from these objects. However, the open question remains what differentiates non-detected SNRs such as SN 1006 from prominent γ-ray emitters such as RX J1713.7–3946.

3 Gamma-ray observations of Pulsar Wind Nebulae

Pulsar wind nebulae (PWN) or Plerions are objects powered by a relativistic particle outflow (electrons and positrons) from a central source – a pulsar. This pulsar is a rapidly rotating neutron star generated in the Supernova event. The wind of relativistic particles flows freely out until the outflow pressure is balanced by that of the surrounding medium. At that point a standing termination shock is formed at which particles are accelerated [Kennel & Coroniti, 1984; Aharonian, Atoyan & Kifune, 1997]. The existence of electrons accelerated to energies > 100 TeV in such PWN has been established by X-ray observations of synchrotron emission, e.g. in the Crab nebula (Weisskopf et al., 2000). VHE γ-rays are generated in PWN from the high-energy electrons by non-thermal bremsstrahlung or inverse Compton (IC) scattering on photon target fields, such as the cosmic microwave background (CMBR) or star-light.

Apart from the Crab Nebula, no individual PWNe have been unambiguously associated with EGRET sources, although several unidentified EGRET sources are located in close proximity to prominent PWN, such as in the Kookaburra region, or MSH–15–52. PWN are however one candidate for the population of slowly varying low-latitude unidentified sources. GLAST will shed more light on this population and possibly establish PWN as emitters in the MeV to GeV range. In VHE γ-rays PWN make up the majority of the identified Galactic sources detected so far [Funk, 2006; Gallant, 2006]. Apart from the Crab Nebula (the brightest steady VHE γ-ray source) several prominent PWN were identified in VHE γ-rays in the last two years. These detections include MSH–15–52 (Aharonian et al., 2005c), Vela X (Aharonian et al., 2006c), the two sources in the Kookaburra region (Aharonian et al., 2006f) and lately HESS J1825–137 (Aharonian et al., 2005d, 2006g). VHE γ-ray emission from PWN comes in various disguises as shown in Figure 3: These include a) point-like emission such as from the Crab Nebula (Aharonian et al., 2006h) and from the composite SNR G 0.9+0.1, where the γ-ray emission was shown to originate from the central PWN (Aharonian et al., 2005c), b) emission tracing the X-ray contours around a central pulsar such as in MSH–15-52 or c) asymmetrically extending to one side and tracing the X-ray contours such as in Vela X and finally d) the emerging new class of offset PWN exemplified by HESS J1825–137 where the γ-ray emission shows a similar morphology to the X-ray emission but on a much larger scale (Aharonian et al., 2006g). Calculating the efficiency of the energetic pulsars powering the PWN that is necessary
Fig. 3. Acceptance-corrected smoothed excess maps of MSH–15–52 (top left) (Aharonian et al., 2005c), the Kookaburra region showing the \( \gamma \)-ray emission coincident with the two non-thermal wings of the Kookaburra (top right) (Aharonian et al., 2006f), HESS J1825–137 (bottom left) (Aharonian et al., 2005d, 2006g) and Vela X (bottom right) (Aharonian et al., 2006e). Also shown are the energetic pulsars that are thought to power the PWNe.

to account for the VHE \( \gamma \)-ray luminosity, values between 0.02\% (Crab Nebula) and 7.5\% (HESS J1825–137) of the spin-down luminosity are found. The broadband SEDs of the VHE \( \gamma \)-ray PWN can typically be well described by lepton models, although claims have been made for a hadronic component at the high-energy end of the spectrum (Horns et al., 2006). Vela X is the first VHE \( \gamma \)-ray source in which the peak in the Inverse Compton energy flux has been detected within the H.E.S.S. energy range (Aharonian et al., 2006e).

Figure 4 shows that while the ranges of \( \gamma \)-ray fluxes for the detected PWN is rather small, the differences in the X-ray energy fluxes span a large range. This might be alluded to largely different magnetic fields, to different angular scales on which the X-ray emission has been measured or simply to the fact, that different populations of electrons are responsible for the X-ray and the \( \gamma \)-ray emission.
The most prominent example of the new class of offset PWN is HESS J1825–137. This object can serve as a template for a whole new class of γ-ray PWN in which a) the γ-ray emission is shifted away from the pulsar, possibly due to dense material on one side that prevents an isotropic expansion of the PWN and b) the size of the VHE γ-ray PWN is on a much larger scale (∼1°) than the X-ray PWN (∼1′) (Gaensler et al., 2003). Concerning the offset morphology, asymmetric reverse shock interactions were first proposed to explain the offset morphology of the Vela X PWN based on hydro-dynamical simulations by Blondin, Chevalier & Frierson (2001). The different sizes for the γ-ray and X-ray PWNe can be explained by the difference in the synchrotron cooling lifetimes of the (higher energy) X-ray emitting and the (lower energy) IC-γ-ray emitting electrons. The γ-ray sources that can be explained in this framework are typically extended, their emission region overlaps with energetic pulsars (energetic enough to explain the γ-ray flux by their spindown power) and very importantly also show evidence for an X-ray PWN. So far only Vela X and HESS J1825–137 match this picture, several other unidentified VHE γ-ray sources have been proposed to be offset PWN, but all these cases lack the detection of an X-ray PWN.

4 New Supernova remnants found in VHE γ-rays

Originally Supernova remnants have been detected by means of radio observations sensitive to synchrotron emission in magnetic fields. Radio observations
Fig. 5. Comparison of radio, and X-ray data of HESS J1813–178. Left: XMM-Newton counts map above 4.5 keV of the region surrounding HESS J1813–178 (colour contours) smoothed with a Gaussian kernel of width 0.002°. The extended tail towards the north-east is visible in this figure. Overlaid is the 20 cm shell-like emission (white contours) as detected by the VLA (Brogan et al., 2005). Also shown are the positional contours of the best fit position of HESS J1813–178 (dashed circles correspond to the 1, 2, and 3σ positional confidence contours) as given in Aharonian et al. (2006i). Right: Slice through the emission in radio and X-rays as plotted on the left hand side. The box in which the slices were determined is also given in the left panel (white box). The X-ray slice shows the compact core with the slice towards the north-east, whereas the radio slice shows the shell-like structure of the emission.

are particularly suited to detect Supernova remnants in the inner Galaxy since they are insensitive to the prevailing dust emission within the Galactic plane. The same holds for hard X-ray emission and is particularly true for γ-rays. A survey of the Galaxy in the γ-ray regime proved to be a good means to detect new γ-ray SNRs, that are inconspicuous in other wavebands. H.E.S.S. observations of the inner part of the Galactic plane revealed ~ 20 new γ-ray sources (Aharonian et al., 2005f, 2006i; Funk, 2006). While some could be identified at other wavebands, such as the Supernova remnants described in the previous sections or the microquasar LS 5039 (Aharonian et al., 2005g, 2006j), most objects were left unidentified following their detection. A programme of detailed MWL studies using existing radio and X-ray facilities is underway to establish positional counterparts of the γ-ray sources.

A particularly interesting object found in the survey of the Galactic plane is HESS J1813–178. At first flagged unidentified (Aharonian et al., 2005f), it was quickly found to be positionally coincident with: a) A previously unpublished archival faint radio (VLA) source (20 cm) showing a shell-like morphology (Brogan et al., 2005) b) a previously unpublished archival bright X-ray ASCA source (2–10 keV) (Brogan et al., 2005), and c) a hard X-ray INTEGRAL source 10–100 keV (Ubertini et al., 2005). H.E.S.S., ASCA as well as INTEGRAL lacked the spatial resolution to resolve the object. The VLA radio source showed a shell-like morphology, suggesting that the VHE γ-ray emis-
sion originates in the shell of a Supernova Remnant. However, in a 30 ksec XMM-Newton X-ray observation non-thermal synchrotron emission was found not from a shell, but rather from an object embedded within the shell with a faint tail towards the north-east (see Figure 5) resembling in its shape a PWN [Funk et al., 2006]. This detection reveals that HESS J1813–178 is connected to a composite SNR similar to e.g. the γ-ray source G0.9+0.1 [Aharonian et al., 2005c]. In HESS J1813–178 for the first time, an SNR initially detected in VHE γ-rays and subsequently confirmed with superior angular resolution radio and X-ray data. This detection shows, that γ-ray observations especially in the Galactic plane are well suited to detect SNR, that are otherwise hard to detect due to obscuration and dust absorption. Other objects tentatively connected to shell-type or composite SNRs are HESS J1640–465 [Aharonian et al., 2006i; Funk et al., 2007], and HESS J1834–087 [Aharonian et al., 2006i; Funk, 2006].

5 Summary and Prospects for GLAST

The upcoming GLAST satellite, in its energy range between 30 MeV and 300 GeV the successor to EGRET will provide a unique tool for studying Supernova remnants. Especially in crowded regions in the Galactic plane dominated by diffuse emission, the improved angular resolution of the instrument in comparison to EGRET will be important for disentangling source confusion and identification of counterparts. As obvious from Figure 2, GLAST will provide spectral measurements in an energy regime in which differences between hadronic and leptonic production γ-ray production mechanisms are significant. Thus GLAST might finally disentangle whether the γ-ray emission detected by H.E.S.S. is in fact the first direct evidence of accelerated hadrons in shell-type SNRs, a question that directly relates to the origin of cosmic rays. GLAST will provide a highly even sky-coverage on long timescales and therefore population studies of SNRs will be possible. Since EGRET is thought to have just not been sensitive enough to single out individual PWNe and enable us to conclude about their population, it is expected that these objects will appear as a source class in the GLAST sky. Population studies of SNRs provides information not only on individual objects but on spatial-statistical aspects that can be used to understand the transition of source populations through the regime of GeV-cutoffs as already evident in numerous EGRET sources. Already now SNRs are an established source class in VHE γ-ray astronomy. Observations in this wavebands provide an important tool to understand the acceleration processes within these Galactic accelerators.
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