Section on Supernova remnants and cosmic rays of the White Paper on the Status and Future of Ground-based Gamma-ray Astronomy

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Third EGRET Catalog

$E > 100 \text{ MeV}$

CGRO (Compton Gamma Ray Observatory): April 5, 1991

Fig 2. A photo montage showing the mechanical structure, space-frames and reflectors of the telescopes in their proper positions on the farm Göltschau.

VHE: 100 GeV -- 10 TeV

UHE: > 10 TeV

Detection rate: 10^{-11} /cm²/s (1/yr/m²)

Fig 1. Sensitivity of the IACT array in its final stage relative to the flux from the Crab Nebula as measured by the COMPTEL and EGRET experiments on the Gamma-Ray Observatory (GRO) satellite. Shown on this graph are the inverse Compton (IC) and synchrotron (S) contributions to the Crab spectrum. Also indicated are the sensitivity levels of other ACTs. From the HESS Letter of Intent^[1].

- **SNR**: Supernova remnant,
- **PSR**: Pulsar,
- **XRB**: X-ray binary,
- **Cluster**: Young open clusters,
- **HBL**: High-frequency-peaked BL Lac object (a kind of AGN),
- **LBL**: Low-frequency-peaked BL Lac object (a kind of AGN),
- **IBL**: Intermediate-frequency-peaked BL Lac object (a kind of AGN),
- **FSRQ**: Flat-spectrum radio quasar,
- **unID**: Unidentified object

High-energy gamma rays are a unique probe of CRs and shell-type SNR are particularly beneficial:

- A, relativistic charged particles (their number, composition, and spectrum);
- B, energetic particles & a turbulent B;
- C, the origin of CRs (how the CRs will eventually be released by the SNR);
- D, the energy balance & evolution of the ISM in galaxies;
- E, Diffuse Galactic gamma-ray emission: the CR spectrum, extended gamma-ray sources, and self-consistent limits on the amount of DM;

Figure 1: The left panel shows an image of the acceptance-corrected gamma-ray excess rate in the TeV band as observed with H.E.S.S. from the SNR RX J1713-3946 [28]. The insert labeled PSF indicates how a point source would appear in this image. Overlaid are black contour lines that indicate the X-ray intensity at 1-3 keV. Note the similarity between the X-ray and TeV-band images. The right panel shows the TeV-band spectrum for the entire remnant broken down for three different observing seasons.

- IC of electrons (leptons case);
- Pion-decay from ion-ion interactions (hadrons case)
→ neutrinos;

For leptons case: SN1006, $E(e) > 100$ TeV

Figure 2: X-ray and radio images of SN 1006 [53]. Hard X-rays (left) are mainly produced by very high-energy electrons (~ 100 TeV) emitting synchrotron radiation. Radio emission (right) is produced by electrons with energies in the GeV range emitting synchrotron radiation. Imaging TeV observations will enable us to map the inverse-Compton emission from high-energy electrons and make a measurement of the magnetic field strength in the vicinity of the shock. Such mapping is also essential for distinguishing TeV photons produced by electronic versus hadronic cosmic rays. The angular size of the image is 35 arcmin. (Image courtesy of CEA/DSM/DAPNIA/SAP and ESA.)

electrons

→ synch. X-rays + IC γ -rays

protons

→ γ -rays via π^0 decay

Figure 3: Expected GeV-TeV band gamma-ray emission from Inverse-Compton scattering of the microwave background on highly relativistic electrons, according to recent model calculations [25]. Shown are three spectra for different values of the magnetic field strength upstream of the SNR forward shock. For a high field strength strong radiative losses and evolution make the IC spectrum significantly softer above about 10 GeV, so it becomes similar to the expected gamma-ray spectrum produced by energetic hadrons. The thin vertical line marks 1 TeV photon energy.

- ***For leptons case:***

- A, Spatial correlation between synchrotron X-ray and TeV gamma-ray;
- B, The spectra of both should be similar;
- C, IC is important for the diffuse emission at VHE but less important at UHE;

- ***For hadrons case:***

- A, The TeV emission should be bright in the high-density regions;
- B, Neutrinos should be detected at high energies;
- C, We should see a continuation of gamma-ray emission up to 100TeV if the hadronic CRs beyond the knee at 3PeV;

Figure 6: Shown as red line is the intensity of diffuse Galactic gamma rays, multiplied with $E^{1.6}$, for a standard cosmic-ray spectrum with the knee at 3 PeV and one of the Orion molecular clouds. If near some molecular gas complex the knee was at 0.6 PeV, the spectrum of diffuse gamma rays from that region would follow the blue line. Observing a location dependence of the knee energy would provide important clues on the nature of the knee, as do similar measurement for individual sources of cosmic rays (e.g. [55]). The black bar indicates an estimate of the current H.E.S.S. sensitivity in the 100–300 TeV band, based on published spectra of RX J1713-3946. An increase by a factor 10 in sensitivity around 200 TeV would be needed to discriminate the blue and the red curve.

Problems

- Survey instruments provide good sensitivity to large-scale structures but point sources and extended emission can not be reliably separated.
- ACTs offer a high angular resolution but have small FOV.

Purposes

- An angular resolution of $<1.2'$ at 1 TeV (to separate small structures: thin filaments, point-sources)
- A good energy resolution of $\Delta E/E < 15\%$
- FOV = $4d$ — $10d$ in diameter (truly diffuse emission)
- A high sensitivity up to and possibly beyond 100 TeV (to check hadronic CRs)
- A sensitivity for extended emission: 10-15 Crab/sr (to detect TeV gamma rays from superbubbles)