X-ray and Gamma-ray Measurements

Masaki Mori
Institute for Cosmic Ray Research, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8582, Japan

Abstract

This rapporteur paper summarizes the contribution papers submitted for the Session OG2, X-ray and gamma-ray measurements, of the 28th International Cosmic Ray Conference.

1. Introduction

Thick atmosphere of the earth forces direct observations of X-rays and gamma-rays on satellites in space, but at higher energies Cherenkov light (for $E_\gamma \gtrsim 50$ GeV) or particles (for $E_\gamma \gtrsim 10$ TeV) produced in particle showers caused by gamma-rays in the atmosphere reach ground level. Recently ground-based observation of gamma-rays has become a field of astronomy after succeeding in the reduction of overwhelming background of charged cosmic rays with improvement of detection techniques.

Since the last ICRC in 2001, new experiments have started and new exciting results appeared in this field. At the Conference 189 contribution papers in total were submitted for this session (Table 1). This large number indicates the rapid growth of this research area and increased interests in high-energy astrophysics.

Before starting this article, I apologize in advance if I unintendedly omit some important results reported at the Conference. Also the topics mentioned here were selected from papers presented at the Conference but often subject to my prejudice as an experimentalist.

2. Diffuse galactic emission

The bulk of gamma-ray emission in the GeV region is dominated by diffuse galactic emission, i.e., our galactic disk is the strongest source of gamma-rays at these energies. It was supposed that the emission above 100 MeV was due to gamma-rays produced by decay of neutral pions generated in collision of high-energy cosmic rays (hadrons) with interstellar matter. However, the EGRET detector onboard the Compton Gamma Ray Observatory, which was in satellite

pp. 1–21

Table 1. Summary of papers in OG2 appeared in the proceedings volumes.

Subsession	Oral	Poster	Subtotal
2.1 Diffuse galactic emission	7	4	11
2.2 Galactic sources	22	36	58
2.3 Extra-galactic sources	20	16	36
2.4 Gamma ray bursts	9	10	29
2.5 Instrumentation and new projects	17	48	65
Total	75	114	189

orbit from 1991 to 2000, measured the energy spectrum of this emission and found that the power-law index above 1 GeV is about -2.5, harder than expected from hadronic cosmic-ray interaction (-2.7) [1]. If this hard spectrum continues to the TeV region, it might be detectable with modern detectors.

2.1. New observations

Milagro, a water Cherenkov air shower detector in Los Alamos, reported a 2.8σ excess toward the galactic plane ($20° < \ell < 100°$, $-7° < b < 7°$) whose significance was not so high compared with that given in the Proceedings after taking account of number of degree of freedom. If this excess is interpreted as gamma-ray signal, the fraction of gamma-rays to cosmic rays is $F_\gamma/F_{\rm CR} = (5.3 \pm 1.9) \times 10^{-5}$ at 1 TeV [2]. The GRAPES group, operating an air shower array in India, analyzed muon poor events utilizing their muon counter and obtained an upper-limit on gamma-ray fraction: $F_\gamma/F_{\rm CR} < 3 \times 10^{-5}$ at 100-500TeV [3]. The KASCADE group, operating an air shower array in Germany analyzed muon poor events and obtained upper limits on gamma-ray content of showers at the 10^{14}–10^{16} eV range and found no significant point-like sources [4]. The Tibet group analyzed data obtained in their Tibet-II and Tibet-III air shower array and their upper limits for Inner Galaxy and Cygnus region is $F_\gamma/F_{\rm CR} < (2 - 12) \times 10^{-4}$ in the 3-10 TeV region [5]. Thus there is still no positive indication of diffuse gamma-rays in these high energy regions. Fig. 1. is a summary of observations on the galactic region.

2.2. New calculations

Erlykin and Wolfendale proposed a SNR model to explain the GeV excess emission including spatial distribution of the emission [6]. Tateyama and Nishimura analytically calculated diffuse gamma-ray emission from high energy electrons [7]. Shibata et al. assumed an analytic model on matter distribution and calculated emission via π^0 decay, resulting consistent spatial and energy distribution of diffuse emission [8]. Strong and Moskalenko tried to explain the GeV excess

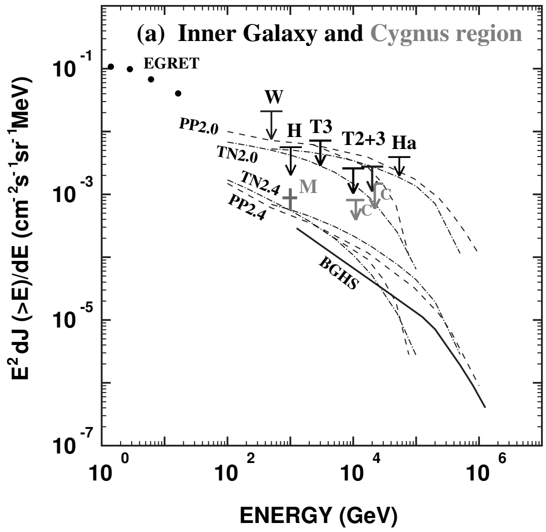

Fig. 1. Compilation of results on diffuse gamma-ray emission in the galactic region. Results on Cygnus region are displayed in gray color. (Modified from a figure given in [5] with 'M' indicating the Milagro result [2].)

by assuming hard gamma-ray sources and hard electron injection spectrum [9]. Berezhko and Völk studied inverse Compton emission from supernova remnants as a possible explanation of the GeV excess [10]. Huang used a new parametrization of π^0 production in nuclear interaction and gave gamma-ray source function for various cosmic-ray injection spectra [11].

2.3. New ideas

Tanuma and Shibata proposed magnetic reconnection as origin of diffuse X and gamma emission [12]. Yoshida et al. [13] proposed existence of extended electron halo around the starburst galaxy to explain the "gamma-ray halo" around NGC253 to conform the results reported by the CANGAROO group [14].

3. Galactic sources

Supernova remnants are assumed to be the origin of galactic cosmic rays for long time. From energetics argument they can supply enough power to the total power of cosmic rays. However, the maximum energy accelerated in the expanding blast waves in supernova remnants is around 10^{14} eV and this fact has been dissuade many times in relation to the existence of "knee", the break in the all-particle cosmic ray energy spectrum around 10^{15} eV. We know there are more than 200 supernova remnants in our galaxy but we do not know how much of them could be the source of cosmic rays.

The first firm detection of TeV gamma-rays was that of the Crab nebula [15], which is known to be powered by the spin-down energy of a central fast-spinning pulsar. TeV emission is unpulsed and is believed to come from the pulsar wind nebula (so-called plerion system) via synchrotron-self-Compton mechanism in which synchrotron photons are scattered up to high energies by accelerated electrons. Now the Crab is the "standard candle "in TeV gamma-ray astronomy as well as in X-ray astronomy. There are other TeV sources similar to this category: Vela and PSR1706-44, but their emission mechanism seems to be different from that of the Crab nebula and is not fully understood.

Recent reports on detection of TeV gamma-rays from supernova remnants [16] [17] [18] support the supernova origin of cosmic rays, but the TeV emission could be ascribed to high-energy electrons so the evidence of proton acceleration, which is the proof of the supernova remnant origin of cosmic rays, is not strong, although there is an indication of proton acceleration in the TeV data measured by the CANGAROO group [19], of which interpretation may not be mandatory [20] [21].

3.1. Supernova remnant SN1006

New observations of SN1006 have been reported to verify the CANGAROO detection [16] of TeV gamma-rays, which was the first direct evidence of existence of accelerated particles in supernova remnants. The HEGRA CT1 group reported a 5σ excess of events toward the CANGAROO "hot spot" based on 219-hr observation at large zenith angles which corresponds to $E_\gamma > 18$ TeV [22] (Fig. 2.). While the observation by the first two telescopes of H.E.S.S. did not reveal a gamma-ray signal although their observation is less than 10 hours [23].

Theoretical studies of SN1006 suggested a curved electron spectrum [24]. Detailed X-ray study with the Chandra observation revealed the magnetic field configuration of this SNR which is closely related to particle acceleration [25]. While the general belief of the TeV emission is inverse Compton emission by high energy electrons, Berezhko et al. showed that efficient proton acceleration can also explain the emission [26].

3.2. Crab nebula/pulsar

The Crab is now the standard candle of TeV gamma-ray astronomy but still it is a good target to study the detailed emission mechanism. The Whipple group placed an upper limit on pulse component of TeV emission [27]. Using the HEGRA CT1 telescope Oña-Wilhelmi et al. showed optical pulse signal so the unpulsed signal cannot be an artifact [28]. However, the PACT group reported a pulsed signal with their timing-based non-imaging Cherenkov telescope [29] [30].

Large zenith angle observations by the HEGRA CT system produced a

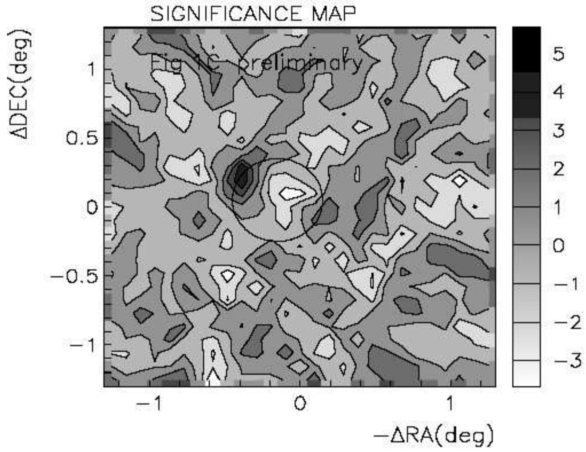

Fig. 2. Significance map of gamma-ray signals observed by the HEGRA CT1 telescope [22].

wide range spectrum spanning from 0.4 to 80 TeV which can be fitted by a single power law ($\propto E^{-2.6}$) without a break [31]. The two H.E.S.S. telescope detected a clear signal of the Crab showing their good initial performance [23] [32]. Fig. 3. is a summary of the unpulsed spectrum of the Crab.

Stephens considered two-component electron spectrum to explain the Crab nebula spectrum [33].

3.3. Newly claimed sources

The Tibet group reported a possible gamma-ray signal at 4.4σ level above 3 TeV from SNR GC40.5-0.5 which may be associated with an EGRET unidentified source, 3EG J1903+0550 [34]. The CANGAROO group reported observations of two supernova remnants from which non-thermal X-ray emissions were observed. SNR RCW86 showed tantalizing 4σ excess [35] and SNR RX J0852.0-4622 was detected above 5σ significance [36]. Also this group observed the Galactic center for two successive years and obtained a preliminary signal above 5σ level [37]. The emission mechanism of the Galactic center is an interesting issue and will be of great importance if the emission is confirmed by other groups.

3.4. Sky survey

The large air-shower database collected by the Tibet-III array in 1999-2001 was used for a search for point sources in the northern hemisphere [38]. 23 directions exceeding 4 standard deviations were found and 5 possible associations of them with the EGRET third catalog sources were reported.

Puelhofer et al. reported a result of a large-area sky survey (3% of the total sky) with the HEGRA CT system [39]. The most promising excess position, ten-

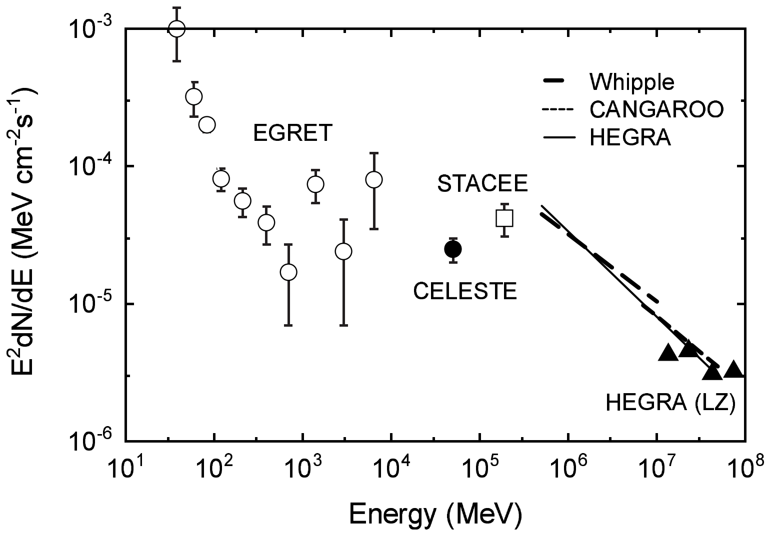

Fig. 3. Compilation of observations of Crab unpulsed spectrum with the new HEGRA result [31].

tatively called TeV J1915.2+11.47, could be a new TeV source with the detection significance of 4.6σ.

3.5. Confirmed sources

The HEGRA CT system detected an unidentified source near Cygnus OB2 association [40] and now it has been confirmed by new observations [41]. This source, called as TeV J2032+4130, shows a hard spectrum ($dN/dE \propto E^{-1.9}$) but there found no counterpart object in X-rays or optical wavelengths. Its nature is mysterious but Bednarek et al. proposed its possible emission mechanism assuming injection of high-energy electrons and nuclei by a young energetic pulsar [42]. Photon absorption through $\gamma\gamma$ collision in the vicinity of early type stars in OB associations is also discussed [43] but it is not significant in the direction toward the reported TeV gamma-ray source. Also its relation to Cyg X-3, which was claimed to be a strong 10^{15} eV gamma-ray source (see also [44]) was discussed but the position is well apart from the putative source [41].

3.6. Upper limits

Upper limits on gamma-ray flux on various type of objects were also reported. The GRAPES-3 array set upper limits on the Crab and an SNR IC443 [45]. The HEGRA CT system gave upper limits to CTB1, LSI+61°303, GeV J2026+4124, GeV J2035+4214 [46]. Hadronless events detected by the SYS air shower array on Mt. Chacaltaya showed no excess toward a binary X1822-377 but there is a hint of periodicity correlated with X-rays [47]. The Tibet group placed upper limits on 10 SNRs [48] . The CANGAROO group could not see excess from PSR J1420-6048 [49] nor SS433 [50]. The Whipple group gave upper limits to PSR B1823-13 [51], the Galactic center [52], and a globular cluster M15 [53].

3.7. Source studies

Shock acceleration of particles in SNRs and relation to the origin of cosmic rays have been extensively discussed by various authors [10] [54] [55] [56] [57] [58]. Erlykin and Wolfendale suggested the EGRET unidentified sources with $|b| < 10°$ should be pulsars and those with $|b| > 10°$ could be spun-up pulsars [59]. They also discussed observabilty of the SNR assumed in their 'single source model', in which one recent, local SNR is responsible for cosmic rays up to the 'knee' energy region, and concluded it is difficult since the gamma-ray emission will be extended up to 40° [60].

Kushida et al. found a small X-ray nebula around PSR 1706-44 using the Chandra archival data and discussed its relation to the TeV emission [61]. Ueno et al. reported non-thermal X-rays from SNR W28 [62].

Various high-energy emission models were presented for pulsar wind nebulae [63], the Galactic center [64], LSI+61°303 (=2CG 135+01?) [65] and Cyg X-3 [66] [67]. Gamma-ray emission from microquasars were discussed [68] [69] and suggested they could be TeV gamma-ray source candidates [70].

4. Extragalactic sources

Active galactic nuclei are the most common objects identified in the GeV gamma-ray sky and most of them are classified as blazars. The second established TeV gamma-ray object following the Crab was Mrk 421 which is a nearby blazar [71]. Blazars show nonthermal emission spectra and there can be seen two peaks in general which is interpreted as synchrotron peaks caused by accelerated electrons in magnetic fields and inverse Compton peaks where synchrotron (or external) photons are up-scattered by high energy electrons. While hadronic models, where proton-initiated cascades produce high-energy emissions, are still viable, the synchrotron-self-Compton (SSC) model is a popular one on its simpleness. In addition to Mrk 421, large gamma-ray flares were detected on other nearby blazars, Mrk 501 (observed by many groups in 1997) and H 1426+428 (observed in 2001). Thus the number of blazars detected at TeV energies are increasing and providing good samples to test these models.

Radio galaxies were long-sought TeV gamma-ray candidates for more than 40 years ago. TeV gamma-rays are lost by pair creation process with EBL (Extragalactic Background Radiation) photons in the infrared region and the spectra at these energies contain information on this EBL whose direct detection is difficult and often measurements are controversial.

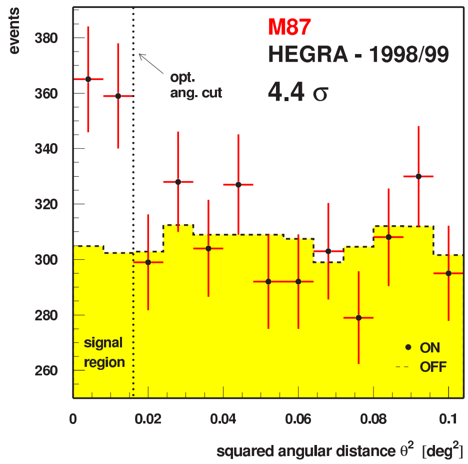

Fig. 4. Gamma-ray signal of M87 observed by the HEGRA CT system [73].

Three-dimensional simulation suggests dark matter is accumulated near the center of galaxies and gamma-rays could be produced in their pair annihilation process, which could be a new class of gamma-ray objects.

The origin of extragalactic background radiation seen at GeV energies is also a mystery. New estimate of extragalactic diffuse emission was presented favoring the extragalactic emission based on the blazar population [72].

4.1. Newly claimed sources

A radio galaxy, M87, or Vir A ($z = 0.00436$ or 16 Mpc), was detected by the HEGRA CT system based on 83.4-hr observations [73] (Fig. 4.). While upper limits were given by the Whipple group [74], these are not inconsistent with the HEGRA detection. Thus this is a new type of TeV gamma-ray objects. While the emission from M87 with its parsec scale jet could be accounted for by the SSC model, theoretical studies were presented to explain this emission utilizing proton blazar model and supposing emission from torus around the central supermassive black hole [75] [76] which could produce highest-energy cosmic rays.

4.2. Confirmed sources

1ES 1959+650 (blazar, $z = 0.048$) was once reported as a TeV gamma-ray emitter by the Utah 7TA group [77] with marginal significance of 3.9σ. In 2002 large flares occurred and were observed by the HEGRA CT system [78], HEGRA CT1 [79], and Whipple [80]. Now this source became an established source of TeV gamma-rays.

1ES 2344+514 (blazar, $z = 0.044$) was once reported as a TeV gamma-ray emitter by the Whipple group [81]. Observation by the HEGRA CT system showed emission at 4.4σ level [82].

PKS 2155-304 (blazar, $z = 0.116$) was detected by Durham Mark6 telescope before [83]. The CANGAROO group reported upper limit in their 2000-2001 observations [84]. In 2002 H.E.S.S. detected this blazar repeatedly at high significance level (11.9σ in total) in July and October [85] and this source has been confirmed as a TeV emitter.

4.3. Detailed study of established sources

The first extragalactic objects found at TeV energies, Mrk 421 (blazar, $z = 0.031$), was studied in detail by various groups. STACEE, a large-area non-imaging Cherenkov detector utilizing solar power array, detected this source at median energy of 140 GeV [86]. CELESTE, another detector utilizing solar power array, studied its spectrum in the 70-400 GeV region which is compatible with contemporary results from the CAT telescope [87]. Milagro, a water Cherenkov detector, detected Mrk 421 at 4.4σ level in their 2.4 yr data [88]. Tibet array, a high-altitude air shower array, observed Mrk 421 at 5.5σ significance around 3 TeV in 2 years [89]. At sub-TeV energies, the Whipple group observed its flaring activity in Dec. 2002-Jan. 2003 period [90]. Study of hourly variability showed the spectral variations were observed for one burst but no variations seen for another, which may not be accounted for using a simple one-component model [91].

Activities of H 1426+428 (blazar, $z = 0.129$) at TeV energies between 1999 and 2002 were studied by Whipple [92] and the HEGRA CT system [93] and the long-range light curve was obtained, showing correlation with X-ray activities.

Lipari and Morlino [94] discussed ambiguities in the determination of model parameters in the synchrotron and inverse Compton emission from blazars and stressed the necessity of measuring all three (synchrotron, SSC and external Compton) components.

4.4. TeV gamma-ray absorption on EBL

Spectra of Mrk 421 and Mrk 501 was compared with the homogeneous SSC model taking account of EBL absorption and consistent results are obtained [95]. The EBL model dependence was also studied for H 1426+428 by the HEGRA group [93]. There is an evidence of spectral hardening above 1 TeV but the intrinsic spectrum after correction of EBL absorption depends depends on the EBL models, reflecting the uncertainty in the infrared measurements. Similar studies for Mrk 421 and Mrk 501 using the Whipple data were also reported [96].

4.5. Upper limits

Many other extragalactic objects were given upper limits for their emission at TeV energies. The HEGRA CT system set upper limits on 50 AGNs observed during 6 years [82]. STACEE gave limits on W Comae and H 1426+428 [86]. Whipple set limits on 29 BL Lacs based on observations between 1995 and 2000

[97]. CANGAROO limited TeV emission from a blazar PKS 2005-489 ($z = 0.072$) [84]. H.E.S.S. set limits to blazars PKS 2005-489 and PKS 0548-322 [85].

Starburst galaxies, M82, M81, IC 342, and NGC 3079 were observed by the Whipple group but there were no positive signals [98]. Nearby galaxies, Dra/UMi dwarf, M33 were looked by the Whipple group to search for signals from dark matter neutralino annihilation [99]. Five Tibet "hotspots" were observed by the Whipple group but no gamma-ray signals were found [100].

5. Gamma Ray Bursts

Gamma-ray bursts (GRBs) were discovered serendipitously in the late 1960s by military satellites to watch for atmospheric nuclear testings and remained a big mystery in high energy astrophysics until recently. The BATSE detector onboard the Compton Gamma Ray Observatory satellite observed a few thousand gamma-ray bursts (GRBs) between 1991 and 2000 and showed their distribution in the sky is quite uniform, which indicated the cosmological origin of GRBs. However, its angular resolution was limited and identification of GRBs with known astronomical objects was not possible. The BeppoSAX satellite, launched in 1996, measured the positions of GRBs accurately enough to allow followup observations of fading emission in day scale (afterglows) in various wavelength, leading to the identification of some bursts with distant galaxies. This is a breakthrough in the study of GRBs and its mysteries are now being disclosed, but the central engine of GRBs emitting energies as large as 10^{53} ergs in 10^{-3} to 10^{3} seconds is still unknown.

5.1. New missions

The HETE-2 satellite, which has localization ability of $30'$ (real-time in flight) to $2'$ (ground analysis), was launched on October 9, 2000 and detected 39 gamma-ray bursts (GRBs) till April 2003 [101] [102] [103], and is working as a successor of the BeppoSAX satellite which ended its mission on April 30, 2002. The burst alert system has been providing quick alert of burst locations through VHE radio broadcast and the Internet [104]. The fastest alert was only 22sec after the burst. Fig. 5. shows the history of GRB observation by HETE-2 since its launch.

HETE-2 observed a "Monster burst" GRB030329 [101]: its duration in the 30-400 keV band was > 25 s and the fluence of the burst was $\sim 1 \times 10^{-4}$ erg cm^{-2}. The peak flux over 1.2 s was $> 7 \times 10^{-6}$ erg cm^{-2} s^{-1} i.e., $> 100\times$ Crab flux in the same energy band. Its X-ray afterglow was observed by RXTE showing 7 mCrab intensity after 5 hours. The connection to supernova explosion was again supposed.

Timing properties of HETE bursts were analyzed [105] which suggest clas-

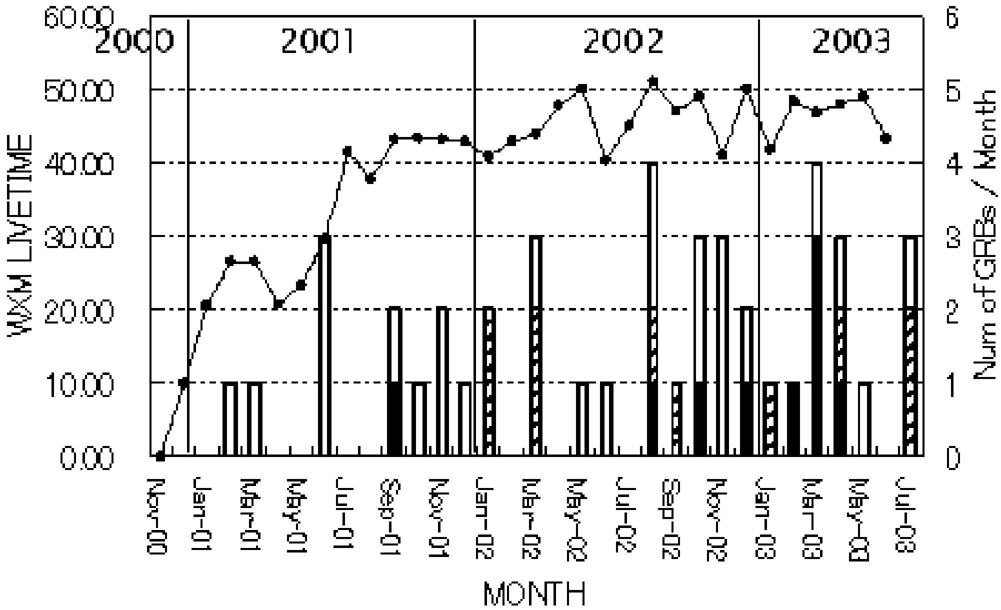

Fig. 5. History of gamma-ray burst observation by HETE-2. Histograms show located GRBs; out of them hatched ones are those whose after glow emission was observed, and filled ones are those redshifts were measured [101].

sical GRBs, X-ray rich GRBs, and X-ray flashes could be a single phenomenon without gaps.

The satellite INTEGRAL was launched October 17, 2002 [106]. It is equipped with 4 co-aligned cameras (JEMX, IBIS, SPI, OMC). Although its main purpose is to persistent sources, the anti-coincidence system of SPI covers most of the 4π steradian and is monitoring GRBs. The INTEGRAL Burst Alert System provides fast localization alert to be distributed on the Internet. 6 GRBs were detected before the conference, but unluckily no GRB detected by all instruments.

SZ2/XD, a small hard X-ray detector system for transient phenomena, were operated in orbit for 6 months since January 2001. Its observations were reported with 30 candidates and 10 confirmed GRBs [107].

5.2. Afterglows

Afterglows of GRBs are not rare phenomena and they were found for about half (16 out of 39) of HETE-2 GRBs [101]. Follow-up optical observations of GRB021004 by Kiso observatory was reported, showing re-increase of brightness at about 2 hours after the burst which may come from two components of the afterglow [108].

5.3. Ground-based experiments

If the energy spectrum of gamma-ray bursts extends to high energies, they could be detected in ground-based experiments. Tibet-III [109] group analyzed the air shower rate and searched for burst-like events and gave upper limits. Time correlation of single particle rate measured by the GRAND air shower array [110], ARGO-YBJ [111], Tibet-III [112] with BATSE bursts was studied but only upper limits were given. The new MAGIC atmospheric Cherenkov telescope will detect a few GRB per year at TeV energies [113].

If GRBs have hadronic origin, neutrinos could be detected at the same time of GRBs. Super-Kamiokande events observed for four years were correlated with BATSE bursts, giving upper limit on fluence [114]. At higher energies, AMANDA also gave upper limits for BATSE-detected GRBs [115].

5.4. Theories/Models

CME (Coronal Mass Ejection) model for GRBs was introduced, where log-normal distribution seen in various distributions of GRBs can be reproduced [116]. Parizot and Allard showed that accumulation of past GRBs can be detectable in our Galaxy within a few thousands years as Compton trail [117]. Gravitational collapse of rotating magnetized stars are considered as possible mechanism for GRBs [118] [119].

6. Instrumentation and new projects

6.1. Cherenkov telescopes

The advances for the "Big Four" Cherenkov telescopes were reported in details: CANGAROO-III (to be completed in 2003) is an array of four 10m telescopes in South Australia [120] [121] [122] [123] [124]. H.E.S.S. (to be completed in 2004) is an array of for 12m telescopes in Namibia [125] [126] [127] [128] [129] [130] [131] [132] [32] [133] [134]. MAGIC (to be completed in 2003) is a 17m telescope in Canary Island [135] [136] [137] [138] [139] [140] [141] [142] [143] [144] [145] [146] [147] [148]. VERITAS (to be completed in 2006) is an array of seven (initially four) 12m telescopes in Arizona [149] [150] [151] [152] [153] [154] [155] [156] [157].

6.2. New ground-based projects

ARGO-YBJ is a full coverage air shower detector in Tibet and started taking data with half of its area [158] [159] [160]. HAGAR is a project at Hanle (Himalaya, 4517m a.s.l.) and an array of 7×7 telescope with 2 mϕ will be installed in 2004 [161]. ASHRA is a wide-area detector to be installed on Hawaii island with $50^\circ \times 50^\circ$ field-of-view utilizing Baker-Nun optics and image intensifier readout [162]. By 2006 one full detector at Mauna Loa and one-third detector at Mr. Hualalai will start operation. It will also detect air fluorescence light emitted by extremely high-energy cosmic rays and neutrinos. ECO-1000 (European Cherenkov Observatory 1000 m^2 Telescope) is a proposal to build a 35mϕ (1000m^2) atmospheric Cherenkov telescope with 5 GeV energy threshold. If it is installed at Canary Island, the rigidity cutoff due to geomagnetic field allows no charged particle below $\sim$ 10 GeV [163].

6.3. New technologies

Various new technologies were reported for Cherenkov telescopes. Scalzo et al. discussed a method to improve angular and energy resolution of non-imaging solar tower Cherenkov experiment using" paracanting "[165]. One of such experiments, STACEE, is now equipped with 1 GHz FADCs and significant increase in signal-to-noise ratio is expected [164]. A new method to determine the shower direction with a single imaging Cherenkov telescope was discussed and the angular resolution of 0.1° could be achieved [169]. Use of image intensifiers for imaging cameras which may achieve fine angular resolution was tested [167]. In order to realize very large Cherenkov telescopes, Aye et al. presented to use vacuum-forming aluminium mirrors which are light and less expensive [166]. Wide-angle telescopes are required to monitor GRBs in the TeV energy region, and one such design was discussed [168].

Other technical reports are also reported, such as X-ray polarimeter [170], diamond Compton recoil telescope [171], ground-based GRB detector at Mt. Chacaltaya [172], photoelectron number calibration [173], signal search using Likelihood ration [174].

6.4. Space observatories

MAXI is an all-sky X-ray imager on International Space Station (ISS) to be launched in 2008 [175]. GLAST is a wide-angle GeV gamma-ray observatory to monitor the whole sky with high sensitivities to be launched in 2006 and its radiation hardness tests of CsI(Tl) crystals were reported [176]. CALET is a calorimeter to be installed on ISS and is capable of separating electrons and gamma-rays in the energy range from 20 MeV to 10 TeV [177]. HXMT is a hard X-ray modulation telescope using the direct demodulation technique to obtain wide field and high resolution images from a simple collimated detector, and a prototype has been built [178].

7. Summary

X-ray/gamma-ray astrophysics is a rapidly growing field and its activity is roughly proportional to the number of contribution papers presented at those sessions in ICRC. Also the number of sources in the TeV sky has been increased

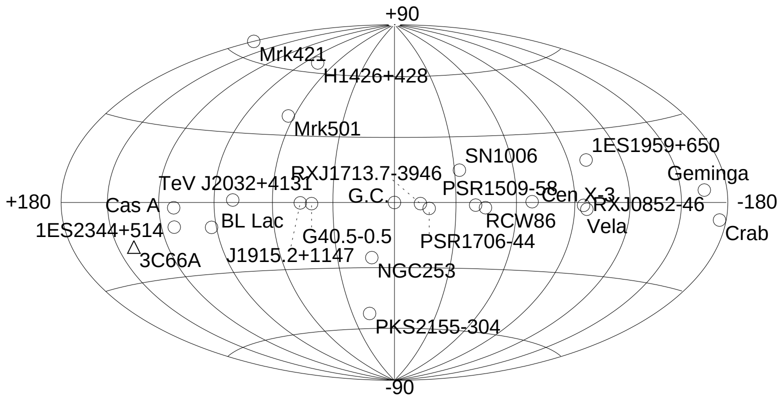

Fig. 6. Skymap of TeV gamma-ray sources.

in the past decade as seen in Fig.6. and Fig. 7. Many advances in understanding the underlying high-energy phenomena have been reported, but we still lack firm evidence on long-standing mystery of cosmic ray origin. With the "third generation" Cherenkov telescopes distributed in the northern and southern hemisphere to cover the whole sky and new ground-based and space-based experiments to participate in this field in near future, more gamma-rays sources are being found and energy spectrum will be measured in wider range in conjunction with other wavelengths. We can surely expect more exciting results in ICRC 2005.

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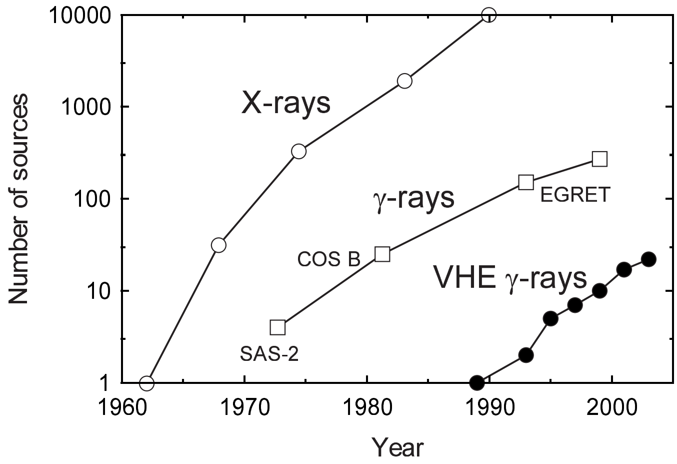

Fig. 7. Number of detected point sources versus time.

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