Supernova Remnants and the Origin of Cosmic Rays

Peter L. Biermann (MPI for Radioastronomy, Germany)

The new TeV gamma ray observations of individual supernova remnants as well as the inner Galaxy by the Cerenkov telescopes HESS, MAGIC and MILAGRO make it possible to begin to test some predictions about the origin of cosmic rays. Additional information comes from high resolution X-ray observations, with detailed spectroscopy, as well as isotopic information on the chemical composition of cosmic rays from Antarctic balloon flights. Sofar these observations are consistent with the well established theory that cosmic rays are accelerated in the shocks of supernova explosions. The concept that much of the acceleration happens in the winds and near neighborhoods of very massive stars is supported by much circumstantial evidence. Further X-ray, gamma-ray and in the future neutrino-observations will be the final test, and will almost certainly require further refinement. We may soon have a fully tested theory of the origin of Galactic cosmic rays.

Observational Evidences of Particle Acceleration at SNRs

Bamba, Aya (RIKEN, Japan)

Ever since the discovery of cosmic rays, the origin and the acceleration mechanism up to more than ~TeV have been long-standing problems. Accelerated electron emits synchrotron X-rays in the interstellar magnetic field, then hard X-rays are the best tool for the study of cosmic rays. We found that synchrotron X-rays are concentrated on very thin "filaments", with Chandra. It means that the magnetic field around the shock fronts is turbulent, and as a result, the acceleration efficiency of electrons is quite high. How about protons? We have no information. In this paper, we propose two methods with Suzaku and possibly NeXT, which we can "observe" accelerated protons and "measure" the acceleration efficiency.

Diffusive Shock Acceleration of Cosmic Rays

Kang, Hyesung (Pusan National University, Korea) and Jones, Tom W. (University of Minnesota, USA)

Shocks are ubiquitous in astrophysical environments and cosmic rays (CRs) are known to be accelerated at collisionless shocks via diffusive shock acceleration (DSA). We review recent progress on the studies of diffusive shock acceleration at parallel and perpendicular shocks: 1) CRs and turbulent magnetic fields are natural byproducts of the collisionless shock formation process. They are ubiquitous in cosmic plasmas. 2) DSA produces a nearly universal power-law spectrum with the correct slopes. 3) With turbulent magnetic fields, thermal leakage injection works well at perpendicular shocks as well as parallel shocks. 4) With turbulent magnetic fields, cross-field diffusion is smaller than parallel diffusion, so perpendicular shocks are faster accelerators. 5) About 50 % of shock kinetic energy can be transferred to CRs for strong shocks with $M_s > 30$. 6) About 10^{-4} - 10^{-3} of incoming particles become CRs at shocks via thermal leakage injection at parallel shocks. 7) Observations of supernova remnants support the dominance of CR ions through amplified magnetic field and the proton-to-electron ratio $K_{p/e} \sim 100$.

Oral Presentations

Observational Evidences of CR Acceleration at Shocks

Ko, Chung-Ming (National Central University Taiwan)

Theoretical and observational studies over the past few decades left little doubt that particles can be accelerated by collisionless shocks. From small scale interplanetary shocks, to supernova remnant shocks, to large scale shocks at radio lobes, shocks are ubiquitous in astrophysical context. In this presentation, I shall give an overview of energetic particles accelerated by shocks from observations. As more remote shocks, such as SNR shocks, will be addressed elsewhere in the workshop, I shall concentrate on interplanetary shocks, including solar wind termination shock, where in situ measurements are available and detail comparisons can be made. Various aspects of accelerated particles near shocks, such as their temporal variation, energy spectrum, isotopic composition, self-excited waves, seed population, will be discussed.

Active Galaxies and Particle Acceleration

Longair, Malcolm (University of Cambridge, UK)

Some aspects of the physics of active galaxies and their role in the acceleration of high energy particles will be reviewed. The particular topics which will be covered will be new evidence for the effects of strong shocks in the most luminous radio galaxies and new information about the probabilities of the occurrence of powerful radio source events at small and large redshifts.

Galactic nuclei: jets and other outflows

Gopal-Krishna (NCRA-TIFR, Pune, India) and Wiita, Paul J.

We summarize the current observational status of the lower energy cut-off of the relativistic electron population in cosmic radio sources and we discuss its relevance to the question of the bulk speed of AGN jets on parsec and subparsec scales, with special reference to TeV blazars. In contrast to most blazars, VLBI observations of TeV blazars have revealed a strikingly high occurrence rate of subluminal or mildly superluminal motions of the radio knots. At the same time, however, several observations hint at the existence of ultra-relativistic jet speeds in the TeV blazars. We argue that the disparate observational results can be reconciled by considering ultra-relativistic jets of conical shape, with modest opening angles of a few degrees on the parsec scale (instead of the usual practice of assuming perfectly collimated nuclear jets, i.e., zero opening angle). We also discuss a new scenario for expansion of these jets to kilo-parsec scales and their interaction with the powerful thermal wind associated with the AGN activity. Striking morphological signatures of such a dynamical interaction between the relativistic and non-relativistic plasma outflows from AGN are presented and modelled.

Photons and Neutrinos Originating from Accelerated Protons in GRBs

Asano, Katsuaki (National Astronomical Observatory of Japan), Nagataki, S., Inoue, S., and Takahara, F.

GRBs are considered to be sources of CRs. I shortly review CR acceleration in GRBs. I show our numerical results of neutrino and photon emission due to cascading high-energy particles triggered by photomeson production. We include the effects of photoproductions of pions and kaons, electron-positron pair production, synchrotron and inverse compton emissions of protons, pions, muons, electrons and positrons, and synchrotron self-absorption. Future observations with e.g. GLAST, H.E.S.S. or Ice-Cube may detect such high-energy radiations.

UHECRs: Spectrum, Composition and Arrival Distribution

Jones, Tom W. (University of Minnesota, USA)

I will briefly review the current information on the energy distribution of cosmic rays as well as their composition and isotropy, with an emphasis on particle energies around and above the so-called ankle. Available results from new experiments such as Auger and ANITA will be included.

Discovery of a Narrow Shock Precursor in the Tycho SNR: A CR Precursor?

Lee, Jae-Joon (Seoul National University, Korea)

Diffusive shock acceleration requires a precursor in which particles scatter back and forth between the shock jump and MHD turbulence. Balmer-dominated filaments found in some SNRs can serve as a usefull to study such a precursor. We report our new discovery of narrow (~10^{16} cm) precusor from SUBARU H_α echelle spectroscopy of a Balmer-dominated filament in Tycho, which we interpret as a CR precursor.

Astrophysical Sources of UHECRs

Jones, Tom W. (University of Minnesota, USA)

The existence of cosmic rays with energies approaching 10^{21} eV presents an exciting challenge in both astrophysics and particle physics. Explanations must account not only for their existence, but also their composition and spatial distributions. Their existence is now clear, whereas their origins are not. Origins explanations generally get divided into 'bottom up' and 'top down' scenarios, to distinguish acceleration from decay processes. Here I will briefly address constraints and ideas for bottom up scenarios.

Top-down Models for UHECRs

Kim, Hang-Bae (Hanyang University, Korea)

Shock Waves in the Large Scale Structure of the Universe and Cosmic Rays Accelerated

Ryu, Dongsu (Chungnam National University, Korea) and Kang, Hyesung (Pusan National University, Korea)

Shock waves are ubiquitous in the intergalactic space. They have formed as a consequence of the formation of large scale structure of the Universe. In this talk we present the study of the cosmological shock waves in three N-body/hydrodynamic simulations for the large scale structure formation: 1) adiabatic simulation, 2) simulation with radiative cooling and heating, and 3) simulation with feedback of galactic winds. The distribution, statistics, and energetics of those cosmological shock waves are discussed. Especially the amount of cosmic rays accelerated at the shocks is estimated, based on a diffusive shock acceleration model.

High Energy Radiation and Cosmic Rays from Clusters of Galaxies

Inoue, Susumu (National Astronomical Observatory of Japan), Aharonian, F., Sugiyama, N., Sigl, G., Armengaud, E., and Miniati, F.

Strong accretion shocks surrounding massive clusters of galaxies are plausible sites of ultra-high energy particle acceleration. Protons can attain energies 10^{18}-10^{19} eV and induce synchrotron hard-X ray and inverse Compton TeV gamma-ray emission from secondary pairs, which should be observable with current satellites and ground-based telescopes such as Suzaku and HESS. Heavy nuclei such as iron may reach $> 10^{20}$ eV and constitute the observed highest energy cosmic rays, in which case characteristic features in the spectra, anisotropy and composition should be distinguishable with facilities like Auger, TA and EUSO. Other aspects of cosmic rays and high energy emission from clusters will also be discussed.

CR Acceleration at Clusters of Galaxies

Hwang, Chorng-Yuan (National Central University, Taiwan)

We will discuss the origin and acceleration of cosmic rays in clusters of galaxies. We will consider the constraints imposed by observed magnetic fields on a variety of models in regards to the origins of the non-thermal emission from cosmic-ray electrons for several clusters of galaxies. In particular, we will investigate the constraints for the cosmic rays originating from the annihilation of dark matter consisting of weak interacting massive particles (WIMP).

Diffusive Propagation of UHECRs

Berezinsky, Veniamin (INFN, Laboratori Nazionali del Gran Sasso, Italy)

Propagation of UHE protons in extragalactic space is studied for weak and strong magnetic fields. In presence of energy losses magnetic fields affect the energy spectrum. If distance between sources is much smaller than all propagation lengths, the spectrum does not depend on propagation mode and has the universal shape. The universal spectrum has dip, which is well confirmed by observational data. At energy E sim 1 EeV the dip has flattening, which provides transition to galactic cosmic rays. The exact solution of diffusion equation with arbitrary time- dependent energy losses for propagation in expanding universe is obtained.

Magnetic Fields and propagation of UHECRs in the Local Universe

Dolag, Klaus (Max-Planck-Institut fuer Astrophysik, Germany) et al.

Based on a constraint realization of the Local Super Cluster Structure we performed a MHD simulation of the evolution of Magnetic Field within the grow of Cosmological Structure. A detailed comparison of the obtained Magnetic Field in Galaxy Clusters with Observations is given. We also discuss implication for the creation and propagation of relativistic particles within the Local Universe.

Propagation and Acceleration of High Energy Cosmic Rays

Cho, Jungyeon (Chungnam National University, Korea)

I will talk about interaction of cosmic rays with magnetic field. Magnetic field can not only affect trajectories of charged particles but also change their energy, when the medium has internal motions. I will first briefly review theories of MHD turbulence and properties of large-scale magnetic fields. Then, I will talk about acceleration of cosmic rays by the second order Fermi acceleration mechanisms, especially by MHD turbulence. MHD turbulence can accelerate charged particles through large scale compressional motions, pitch-angle scattering, and transit time damping. Finally, I will talk about current issues regarding propagation of cosmic rays.

Propagation of Ultra-high Energy Cosmic Rays in Local Magnetic Fields

Takami, Hajime (University of Tokyo, Japan), Yoshiguchi, H., and Sato, K.

We perform numerical simulations on the propagation of Ultra-high energy cosmic rays (UHECRs) above 10^{19} eV in local magnetic fields. It is some numerical problems when the arrival distribution of UHECRs is simulated from results of the propagation in cosmic magnetic fields. We have developed a new method for the calculation to solve the problems. Using this method, we calculate the propagation in a structured extragalactic magnetic field and Galactic magnetic field and simulate the arrival ditribution of UHECRs at the Earth from our source models that reflect the structures actually observed. The results is compared with the observation statistically and we can estimate number density of UHECR sources that best reproduces the observational results. I will talk about our method for the calculation and physical results from the simulation.

Energy spectrum of primary CRs from 10^{15} to 10^{20}eV

Teshima, Masahiro (MPI for Physics, Germany)

Results from HiRes

Martens, Kai (University of Utah, USA) for HiRes Collaboration

HiRes has completed data taking in April of this year. After introducing the experiment the following results will be discussed: Monocular spectra and composition with fit to an injection spectrum and redshift evolution for extragalactic sources, a "tandem" stereo spectrum, and anisotropy studies.

Status of the Telescope Array

Sagawa, Hiroyuki (ICRR, University of Tokyo, Japan)

The status of AUGER

Peter L. Biermann (MPI for Radioastronomy, Germany)

The AUGER experiment array was built by an international consortium of scientists and their countries to detect ultra high energy cosmic rays. The array has both a ground array and air fluorescence detectors, and is the first detector to use both techniques. The location of the array is near the town of Malargue, south of Mendoza in Argentina. The data taking has started some time ago, and first results can be shown. There is a discussion underway to include the option of radio detectors to also use and calibrate the radio techniques. Furthermore we hope to also build a Northern array, to completely survey the entire sky continuously. What we hope to decipher over the next years, is first to understand whether there is a GZK turn-down as predicted and seen by HiRes, or whether the spectrum continues basically flat as seen by AGASA. Second we wish to verify the isotropy and/or clustering of arrival directions on the sky. Third we hope to be able to discern the nature of the primary particles, light nuclei, heavy nuclei, photons, neutrinos or new particles. Finally we hope to be able to associate events with sources. The physics of ultrahigh energy cosmic ray particles promises to reach new levels of understanding with the arrival of AUGER.

JEM/EUSO Project to Study Extreme Universe by Large and Wide-angle Telescope

Kajino, Fumiyoshi (Konan University, Japan) for JEM/EUSO collaboration

JEM/EUSO has been planed as a space mission for the investigation of Ultra-High-Energy Cosmic- Rays(UHECRs), with the large and wide-angle telescope mounted at ISS to detect photons accompanying air showers in the earth's atmosphere. Unsolved mysteries on UHECRs (i.e. the origin, propagation and chemical composition), are essential targets for this experiment and to derive undoubted results is the great challenge of JEM/EUSO through the determination of UHECR spectrum above the GZK energy and the reconstruction of atmospheric shower development with an improvement of event statistics compared to the current ground-based UHECR experiments. JEM/EUSO will be launched by Japanese H-II Transfer Vehicle(HTV) and mounted at the Exposed Facility of Japanese Experiment Module(JEM/EF) in the second phase of utilization plan. The telescope which consists of the high transmittance optical lens with a diameter of 3.5m and the advanced photo-sensitive device at the focal surface, will allow us to detect cosmic rays with energies $> 10^{19}$ eV and will also open up the investigation of UHE neutrino astronomy as the most powerful apparatus. JEM/EUSO will slso be able to study various luminous phenomina in the atmosphere such as thunder lightning, meteors and so on.

New Results from MAGIC

Teshima, Masahiro (MPI for Physics, Germany)

IceCube: A Neutrino Telescope at The South Pole

Song, Chihwa (University of Wisconsin, USA)

IceCube is a cubic kilometer neutrino telescope under construction at the South Pole. IceCube consists of the InIce and IceTop detector arrays. The InIce array will have 80 strings of 60 digital optical modules from 1,450 to 2,450 meters below the surface, and the strings are to be placed 125 meters apart in a triangular grid. Eighty pairs of IceTop frozen water tanks will be located at the top of InIce strings, and will be used for calibration and cosmic ray composition studies, and will serve as a partial veto shield. Neutrinos are detected indirectly by observing Cherenkov photons from charged particles produced when neutrinos interact near or in the detector. IceCube will be able to detect high energy neutrinos from astrophysical objects such as Supernova Remnants, Active Galactic Nuclei, or Gamma Ray Bursts, and will be used in the search for neutralino dark matter and magnetic monolpoles. IceCube is highly sensitive to galactic Supernova neutrino bursts. Moreover, IceCube has the potential to discover unexpected new phenomena. After the 2005-06 austral summer season, IceCube consists of 9 strings and 32 surface tanks. A summary of the performance of the current IceCube and capabilities of the full array will be given.

Ultra High Energy Cosmic Ray and Neutrino Research in China

Cao, Zhen (Institute of High Energy Physics, China)

A brief review on the ultra high energy cosmic ray and neutrino research will be given. Currently operational China-Italy joint experiment ARGO and China-Japan joint experiment AS_gamma at Tibet Yangbajing and on-going CRTNT prototype experiment will be introduced. Foreseen progresses in the near future in the cosmic rsy and neutrino experiments and corresponding researches will be discussed.

Cosmic Ray Experiments in India

Tonwar, Suresh Chandra (Tata Institute of Fundamental Research, Mumbai, India) et al.

Cosmic ray experiments in India are focussed on two aspects of cosmic ray physics: (a) Studies on CR sources and acceleration mechanisms through TeV gamma rays using the atmospheric Cherenkov technique, and (b) Studies on CR sources and acceleration mechanisms through detection of gamma rays and measurements on the composition of primary CR flux over the 0.1-10 PeV energy range through observations on the electron and muon components of air showers. Details of these experiments and some recent results will be presented at the conference.

Research Activity of Neutrino Physics and Astrophysics in Taiwan

Huang, Ming-Huey Alfred (National United University, Taiwan)

Neutrino physics and astrophysics research is growing in Taiwan in recent years. TEXONO (Taiwan EXperiment On NeutrinO) is a reactor neutrino experiment, which try to measure property low energy neutrinos. TEXONO also developed a ultra low energy Germanium detector for future dark matter search experiment. Theoretical studies of atmospheric and galactic neutrino, especially tau neutrino, had been conducted for several years. Recently, an Earth-skimming neutrino experiment, NuTel, was proposed. Many supporting works on neutrino interaction with Earth are followed. Some of these recent results will be discussed.

Laboratory Astrophysics Program in Taiwan

Lin, Guey-Lin (National Chiao Tung University, Taiwan)

MEMS Tracking Telescope for EECR Study

Park, Il-Heung (Ewha Woman's University, Korea)

We introduce a new space borne project for Extreme Energy Cosmic Ray study approved recently in Korea. The idea of a new type of space telescope based on MEMS technology and our plan will be presented.

Oral Presentations

COREA Experiment

Kwon, Youngjoon (Yonsei University, Korea)

Poster Presentations

FLASH_TW Status Report

Lin, G. L., Huang, M. H., and Liu, Tsung-Che (National Chiao Tung University, Taiwan)

We perform the shower profile measurements by shooting the 1.5 GeV electron beams in NSRRC on targets made of 15 aluminum blocks, each with a thickness of 2.9 cm. A mirror is placed behind the targets, collecting the Cherenkov light from thesecondary shower particles. The light is recorded by a CCD camera. The CCD system has been successfully implemented in the run 2 and run 3 of the experiment FLASH at SLAC. This runs measures the shower lateral and longitudinal profiles by Cherenkov light in March 2006.

Stability of Cosmic Rays and Waves System

Lo, Ying Yi (National Central University, Taiwan)

We investigate the stability of cosmic-ray plasma system in the hydrodynamic approach. The system we are considering comprises cosmic rays and two oppositely propagating Alfven waves. The thermal plasma flow is treated as a background, such that the feedback of the cosmic rays and waves is neglected. Steady state solutions exist for the system, and when two waves are present, the steady state is non-uniform. Linear stability analysis on the steady state solutions shows that for short wavelength, large cosmic ray energy density, and small wave energy density the system is stable. We present in detail the case of uniform background flow. The system is most unstable in the upstream region and becomes stable in the downstream region in the linear regime for short enough wavelengths. We also speculate on the implication of the instability.

Search and Characterization of Shocks in Simulated Galaxy Clusters

Vazza, Franco (INAF-Bologna University, Italy)

Space VLBI Observations of Southern EGRET Identifications

Wajima, Kiyoaki (Korea Astronomy and Space Science Institute)

We made high-resolution VLBI observations of six southern gamma-ray loud quasars with the HALCA spacecraft and ground radio telescopes at 1.6 and 5 GHz. All sources show a compact core-dominant structure and the core component of four sources has a brightness temperature of greater than 10^{12} K in the source's rest frame. In comparison with previous VLBI observations, we also found that those have smaller viewing angle. These results suggest that the gamma-ray emission from those sources are highly Doppler-boosted. On the other hand, an observation of PKS 1622-297, exhibiting a spectacular GeV gamma-ray flare, shows rather lower Doppler factor and larger jet viewing angle than those of other gamma-ray loud AGNs. We examine the gamma-ray emission mechanism in light of these observations and introduce future possible instruments with high-resolution VLBI observations.