COSMIC RADIATION PHYSICS

Cosmic Radiation (Cosmic Rays, CR) consists of elementary particles and atomic nuclei moving in the Outer Space with high energies. Usually they are classified by their origin as:

- Interplanetary;
- Solar;
- Galactic;
- Extragalactic.

The Galactic and Extragalactic CR are known as Primary Cosmic Rays (PCR), while the particles' flow generated and transformed in the Earth's atmosphere by the primary CR is called usually as Secondary Cosmic Rays (SCR).

The Cosmic Radiation Physics investigates the following problems:

- the processes of PCR generation and acceleration;
- the nature and properties of PCR particles;
- the phenomena induced by PCR in the Outer Space, in the atmosphere and the crust of the Earth and other planets.

At the times before the accelerating technology development the Secondary Cosmic Rays where the only source of elementary particles for investigation at high energies. So, it was the SCR flux where the positron, muon, pion, kaon, etc have been discovered for the first time. It was the time of CR nuclear aspect predominant investigation.

Presently the particles' nuclear interaction physics is under thorough investigation by modern means of huge accelerators. That is why the focus of interest in CR physics is now in the PCR particles generation, acceleration and interstellar substance interactions problems. So the new name of Astroparticle Physics is now adopted for Primary Cosmic Rays' investigation.

The first crucial property of PCR is a superlative isotropy of the movement directions. It is due to the chaotic motion of the charged CR particles under the dynamic impact of a Galactic random magnetic field during the CR escape time of $\approx 10^8$yr. in average.

The second one is the specific energetic spectrum of the observable PCR. The dependence of CR observation frequency on the particle's proper energy is roughly shown in the **figure 1**. (See the review on CR properties for details, i.e. extraction from the present Particle Data Group survey; and the approximation of this spectrum used in our calculations is shown in the part «EAS ENERGY SPECTRUM»). It is obvious that the shown conditional confines of Solar, Galactic and Extragalactic CR are tentative.

The properties and origin of Galactic CR with energies $10^{10}\text{eV} \leq E \leq 10^{16}\text{eV}$ are comparatively well studied at the present time. But the Extragalactic CR properties, due to their rareness, are still under close research at present. Little is known about the origins of extragalactic CR. There are a lot of opinions about the possible processes responsible for cosmic rays acceleration up to such high energies. Proposed locations for this extreme type of acceleration include gamma ray bursts and active galactic nuclei. There are many more possible queer sources under consideration.

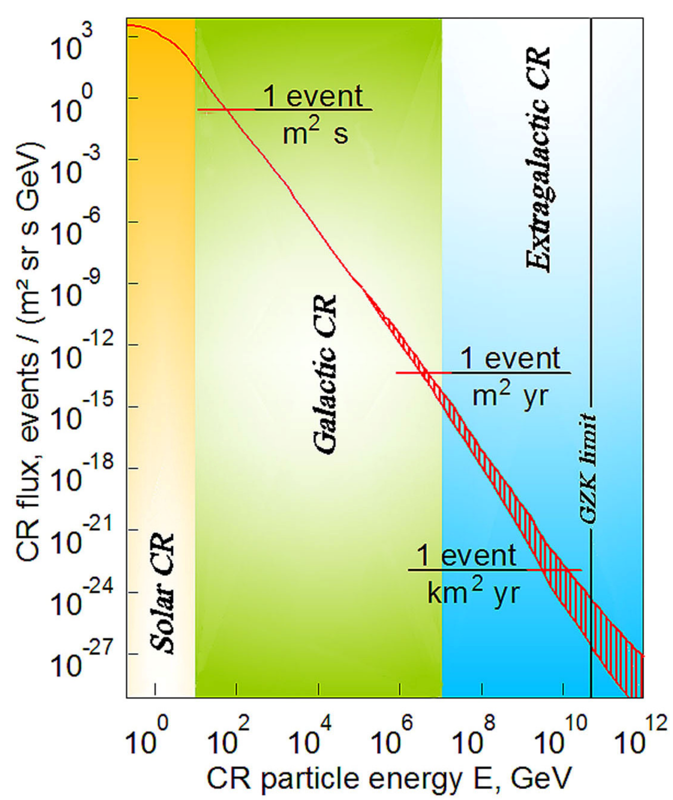

Figure 1 The CR all-particle spectrum as a function of E (energy-per-nucleus)

The most unusual is the certain observable existence of CR with energies $E > 5\times10^{19}$eV, i.e. exceeding the so-called Greisen–Zatsepin–Kuzmin limit (GZK limit on the **figure 1**). The GZK effect predicts that all CR protons with energies exceeding this limit ought to be efficiently decelerated by Cosmic Microwave Background due to threshold actuation of π-meson electroproduction.

Nevertheless, the Ultra High Energy CR events observation with the Pierre Auger Observatory shows the existence of this extra-GZK charged particles and even indication of correlation between their arrival directions and the positions of nearby active galaxies. (Take notice that the Galactic magnetic field weakly distorts the trajectory of charged particle with extra-GZK energy.)

Observations of the PCR energy spectrum and chemical composition in the energy range $E > 10^{16}$eV will make it possible to improve the conceptions of the processes of generation and propagation of PCR particles.

EXTENSIVE AIR SHOWERS' INVESTIGATION

The little flux of the Galactic and Extragalactic PCR particles makes the **E**xtensive **A**ir **S**howers (EAS) effect in the Earth's atmosphere to be the only device for regular investigation. Especially the Extragalactic CR investigations need large-area EAS observatories due to their little flux. Some large (and expensive) installations are now operating over the world, for instance: AGASA (**A**keno **G**iant **A**ir **S**hower **A**rray, Tokyo, JAPAN); HiRes (**Hi**gh **Res**olution Fly's Eye Cosmic Ray Detector, Utah USA); Yakutsk (Yakutsk EAS Array, Russia); Pierre Auger Observatory (Mendoza Province, Argentina).

However it appears that the study of such rare EAS events is available via a lot more affordable systems – with fewer details, of course. This current interest in CR both with the relative accessibility of detecting of high energy CR showers, the availability of "retired" detectors from spent particle physics experiments and advances in timing technology have helped to develop the large number of educational arrays around the world. There are developing now some networks of small CR stations for EAS events detection in America (**figures 2, 3**) (QuarkNet, WALTA, CANLACT, etc), Europe (**figure 4**) (ALTA/CZELTA, HiSPARC, etc) and Asia (**figure 5**) (LAAS). Any station of this type consists of a few straddled detectors for registration of the shower's charge particles passage and consequent fixation of EAS event arrival by the coincidence of the signals from detectors within the sufficiently small time interval.

The stations (nodes) of the network considered are placed usually in the areas of local universities or high schools. The node-to-node distance varies within the range from kilometers to thousands of kilometers. The instants of EAS arrivals are determined with the **G**lobal **P**ositioning **S**ystem (GPS) at every station.

Figure 2 QuarkNet centers in the USA

Figure 3 Small CR arrays in North America

Figure 4 Small CR arrays in Europe

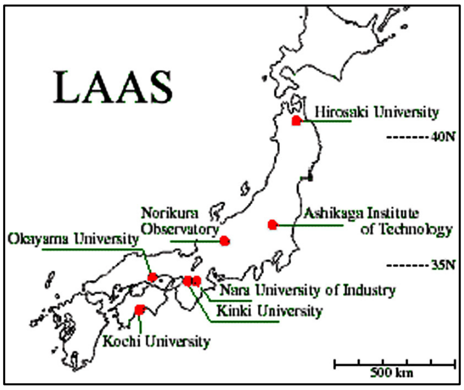

Figure 5 The LAAS experiment centers in Japan