Cosmic-ray spectrum and composition; direct observation (*)

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Summary. — This paper covers anti-particles, positrons and electrons, isotopes, ultra-heavy nuclei, energy spectrum and composition which have been obtained by direct observation, using mainly balloons and spacecraft. As the above title suggests, I would like to discuss particularly the source spectrum and «knee» problem from the direct observational point of view, based on the data presented in this Conference as well as those reported previously.

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1. – Introduction

I have received 58 papers from the Conference organizing committee, the subjects of which are

— antiproton and antihelium: 10 papers (OG 7.3),  
— positron and electron: 15 papers (OG 7.1, 7.2),  
— isotope: 13 papers (OG 5.1, 5.2),  
— ultra-heavy nuclei (UHN): 5 papers (OG 5.1),  
— composition and spectrum: 15 papers (OG 5.3, 6.1, 6.2).

In this field which I am going to cover, the central problems of our present-day concern may be listed up as follows:

1) Are minor components, such as \( \bar{p}, e^+, ^3\text{He}, \ldots \), consistent with the secondary products created during the passage of primary components (p, He, \ldots) through our Galaxy? If not, what does the excess part come from?

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2) Does a cutoff in the electron energy spectrum appear anywhere beyond the TeV region?

3) Is the fraction of heavy isotopes to the stable nuclei at the source the same as that found in the Solar System? If not, what kind of star could synthesize them effectively?

4) How is the rate of UHN synthesized by rapid neutron capture process to that of slow capture at the source? Is this rate similar to that estimated in the Solar System?

5) Does an acceleration limit for galactic cosmic rays, particularly proton component, appear anywhere in higher-energy region?

6) What is the source spectrum of individual cosmic-ray elements? Do all elements have the same spectrum index at the source or different ones?

7) Does the all-particle spectrum connect smoothly with that observed by air shower experiments? If not, is the break so drastic as to suggest something «new»?

The experimental data presently available are of course too poor, in both direct and indirect observations, to get a definite conclusion. This is a good opportunity for me to summarize the direct observational data presented both in this Conference and previously, particularly those on the spectrum and the composition in the wide energy region from a few GeV to several hundred TeV, and to compare them with those obtained by air shower experiments.

2. - Antiproton and antihelium

In this Conference, three groups presented $\bar{p}/p$-ratio obtained from the superconducting magnet on board balloons. I was very impressed by the data presented, which seem quite different from those reported in the early days of the antiproton puzzle [1, 2]. In fig. 1, I show in the lump all the experimental data presented in this Conference as well as those reported previously. It is remarkable that the BESS-group (OG 7.3.5) covered the very low-energy region, down to 200 MeV, low enough for the threshold of $\bar{p}$-production $\sim 6$ GeV in p-p interaction, and gave $\sim 6 \cdot 10^{-6}$ for $\bar{p}/p$ ratio (not upper limit!). I remark also on two other results. One is a point (filled square) in the higher-energy region, $\sim 10$ GeV, obtained by MASS2 (OG 7.3.1), much lower than previous values [1], while the other (filled triangle) covered a very wide energy region, 0.2 to 3.2 GeV, obtained by IMAX (OG 7.3.2).

In fig. 1, I show the theoretical curves expected from the standard leaky-box model (SLBM), obtained by Webber and Potgieter [3], and Gaisser and Schaeffer [4]. The small difference between the curves maybe comes from the choice of the parameters necessary for the calculation, such as the mean escape length, solar modulation parameter, the cross-section of $\bar{p}$-production and/or the composition of interstellar medium. From this figure, we find that the experimental data reported in this Conference seem to be consistent with the theoretical curves expected from the secondary products during the passage of proton (helium, ...) in our Galaxy.

Simon and Heinbach (OG 8.1.17) also reported numerical results based on the leaky box model with and without a reacceleration process. They emphasized that the $\bar{p}/p$