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Experiment SPHERE status 2008.

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The expedition carried out in March, 2008 to Lake Baikal became an important stage in the development of the SPHERE experiment. During the expedition the SPHERE-2 installation was hoisted, for the first time, on a tethered balloon, APA, to a height of 700 m over the lake surface covered with ice and snow. A series of test measurements were made. Preliminary results of the data processing are presented. The next plan of the SPHERE experiment is to begin a set of statistics for constructing the CR spectrum in the energy range $10^{16} - 10^{18}$ eV.

1. Introduction

The idea of detecting the Cherenkov light (ChL) from extensive air showers (EAS), generated by cosmic rays (CR) of ultra-high energies, reflected from a snow surface was first suggested by A.E.Chudakov. One of the first published works [1] was an article in the report of the All-Union CR conference at Yakutsk in 1972. It was proposed to place an installation consisting of two photomultipliers (PM) and two electron-optical converters (EOC) with identical angles of sight $\pm 45°$ on board an aeroplane. All four devices would survey the snow surface of the Earth from a height of about 10 km. The simultaneous operation of the PM amplitude discriminators would serve as a trigger condition for managing the EOC cameras. The subsequent processing of images in pictures would give information on the energy and angles of arrival of primary particles.

The first attempt to carry out experimental measurements using this technique was undertaken by G.Navarra [2] in the late seventies - the beginning of the 1980s in Italy. Measurements were made by means of four parabolic mirrors 0.6 m^2 with one PM at the focus of each mirror, and also seven PMs connected in parallel. The experiment was carried out at mountain altitude at a height of 3500 m above sea level. Detectors with an angle of sight 3° were located at a distance of 1000 m from a glacier and examined an area with a radius of 27.5 m. Various configurations of the installation were investigated. The integral spectrum in which the intensity of events corresponded to that expected was measured. This work was not developed further.

At the same time a number of proposals [3–5] were made to use a Schmidt optical system consisting of a spherical mirror and a correcting aperture diaphragm. The PM's were placed at the mirror focus. The advantage of such a system is that the angle of sight of the installation extends to 1 sr, and, with sufficient PMs at the mirror focus, the possibility arises to analyze images of the light spots without using EOCs. In

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addition, in these proposals it was suggested to use a balloon to raise the detectors above a snow-covered surface. In the early nineties the first measurements of the power spectrum of primary CRs using a prototype of SPHERE-1 were made in the Tien-Shan mountains. This installation consisted of a spherical mirror of diameter 1.2 m, with a radius of curvature 0.75 m, a window of diaphragm diameter 0.8 m and a mosaic of 19 PM-110, located at the mirror focus. The installation viewed the snow-covered surface of the big Alma-Ata lake from the flank of a hill. The impossibility of using a balloon at that time and, as a consequence, the geometrically unprofitable arrangement of the installation led to a strong degradation threshold area and to a distortion of the image of the ChL spot. However, two points of a spectrum with the greatest energies around 10^{17} eV agreed with results of other installations [6]. By the end of the 1990s the electronics of SPHERE-1 were modernized: the measurement of PM pulse duration was added and the energy consumption was reduced, allowing us to feed the equipment from accumulators. As a result a few test hoists of the installation were made using the balloon -55.

About 400 events were registered and the CR spectrum measured in the energy region of $10^{16} - 10^{17}$ eV in February 2000 during 10 hour flights of a tethered balloon at a height of 900 m. Processing of the experimental data allowed us to detect for the first time images of ChL spots from EAS on a snow "screen" [7]. In the following years preparations were made for balloon flights in Antarctica during the polar winter, and flights of some hundreeds of hours were anticipated. However, in 2004 SPHERE-1 was lost near the Russian station, Novolazarevskaya, due to an accident. As a result of processing the experimental data of SPHERE-1 and modelling work it became clear, that, to increase the accuracy of EAS characteristics such as energy, direction definition as well as LDF of the ChL, it was necessary to modernize the installation.

2. Installation SPHERE-2

The balloon installation of SPHERE-2 [8] consists of a seven-segment spherical mirror of diameter 1.5 m and radius of curvature 0.94 m with a mosaic of 109 PM-84-3 established at the focus. The diaphragm of diameter 0.93 m is placed before the mirror for the best spatial resolution. The total angle of the optical system equals 52°. The installed electronics register the profile of light pulses in each channel during 12.8 μs in bins of 25 ns. There are two fast ADCs in each channel covering a dynamic range of 10^4. Tiny sources of high voltage are attached to each PM. Each source has a control block permitting a change in high voltage over a range from 800 to 1400 V with an accuracy 1 V, and to receive information about the PM temperature and anode current with an accuracy of 0.1 μA. The regulation of each of the 109 sources is realized by an onboard computer across the LPT port and commutator. The nearby source consumption 80-90 mW for an anode current 100 μA and 35-50 mW at the minimum anode current. The PM anode pulses induced by a source do not exceed 0.1 mV thanks to the addition of a shielding case and specially developed filters. The signals from all channels go to the trigger system which produce a master pulse if a few close PMs have pulse heights higher than the discriminator level inside a time interval of 1 μs. SPHERE-2 has been hoisted to a height of 1-3 km on dark nights by a tethered balloon and works like a camera, registering images of ChL light spots produced by EAS on the snow covered Earth's surface. Each PM examines an area of diameter about 50 m from a height of 1 km and about 160 m for 3 km height.

3. The results of the Baikal expedition

The first test lifting of SPHERE-2 was made over the ice of Lake Baikal on the night of 13 March 2008. The starting place was close to the Baikal neutrino center of the Nuclear Research Institute of the Russian Academy of Sciences at a distance of 800 m from the coast line as shown in Fig. 1.

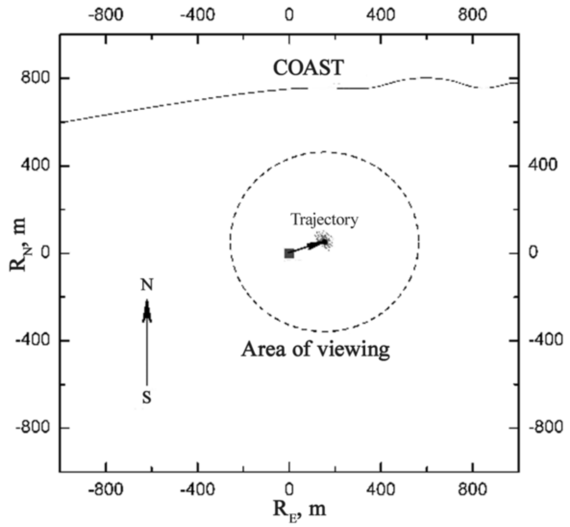

Figure 1. The layout of the experiment and the trajectory of flight of the tethered balloon according to GPS.

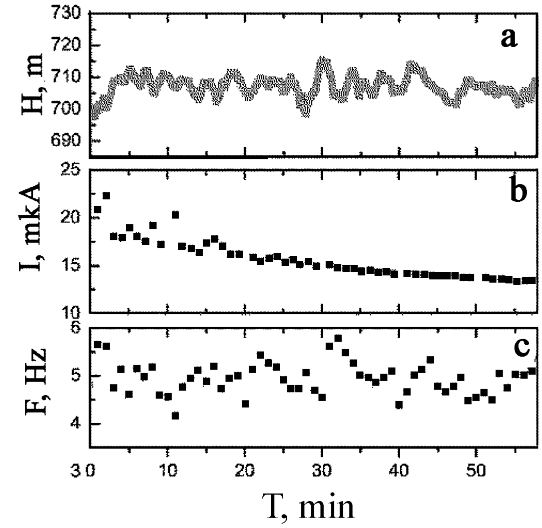

Figure 2. The information on equipment work. (a - installation height above the surface of Lake Baikal, b - an anode current for one PM in the mosaic, c - frequency of operation of the trigger)

The expedition purposes were to check the working of a balloon and the SPHERE-2 apparatus in real climatic conditions and interactions with air services of the Irkutsk area. The installation was lifted by means of a specially developed tethered balloon APA to a height of about 710 m above Lake Baikal, and remained at this height for about three hours. The SPHERE-2 installation was tested using a configuration with a minimum number of 20 PMs. The most liberal condition of event registration was used during exposure (M1), i.e. operation of any discriminator by a PM anode signal started recording of the time development (oscillogram) of all 20 channels. This was necessary in order to increase the statistics of events in a limited exposure time. The equipment test was carried out in real time using wireless Wi-Fi communications. Part of the information about the equipment operation is shown in Fig. 2. Fig. 2a illustrates the work of the GPS built in equipment, which registered the installation co-ordinates during the flight as well as world time with an accuracy 1 μs. The real accuracy of co-ordinates determination by the GPS is close to 5 m. Results of flight measurements have shown that the operation of SPHERE-2 can be synchronized with the work of other detectors, placed on the earth or at any depth in Lake Baikal.

The effect of changing the PM current during night exposure is shown in Fig. 2b (for one PM). The gradual decrease of current is connected with a reduction of the luminescence of the night sky after the moon set. The trigger rate (M1 mode) is shown in Fig. 2c. Most of the registered events were caused by fluctuations of the light background of the night sky.

4. Conclusions

The results of carrying out the first test flight of the SPHERE-2 installation have shown the working capacity of all elements of the equipment and system of lifting by a tethered balloon. In the course of the tests necessary completions and improvements of the installation for future operation have been revealed. Now the analysis of the registered events is taking place.

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