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Fast "swarm of detectors" and their application in cosmic rays

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Abstract. New opportunities in science appeared with the latest technology of the 21st century. This paper points to creating a new architecture for detection systems of different characteristics in astrophysics and geophysics using the latest technologies related to multicopter cluster systems, alternative energy sources, cluster technologies, cloud computing and big data.

The idea of a quick-deployable scaleable dynamic system of a controlled drone with a small set of different detectors for detecting various components of extensive air showers in cosmic rays and in geophysics is very attractive. Development of this type of new system also allows to give a multiplier effect for the development of various sciences and research methods to observe natural phenomena.

1. Introduction

Traditionally, cosmic ray studies of extensive air showers (EAS) systems use different detectors with different geometry and sensitivity to the components of the EAS. Currently we know the most popular type of installation of YakuShAL [1], TAIGA [2,3], TA [4], Auger [5,6]. For example the size of the Auger installation is 3000 square kilometers and consists of 1600 water Cherenkov detectors. All these settings are collected in stages and initially deployed on a given grid on the earth's surface and detect the various components of the EAS with different types of detectors. Of course, for decades, these units were the best available at the time, and in the presence of an appropriate infrastructure with special conditions of service data units could produce great results in the field of ultra-high energies.

We have proposed the concept of a system with a rapidly deployable detection system architecture. This system can be used to measure various characteristics of the EAS Cherenkov radiation using the latest technology related to multicopter systems, alternative energy sources, cluster technologies, cloud computing and big data.

2. Cherenkov light from EAS

Cherenkov radiation plays an important role in the study of EAS. A large enough light output in the optical range and weak absorption in a pure, clear atmosphere can effectively help determine the total energy of the EAS, as well as the history of the shower development in the atmosphere.

The history of EAS Cherenkov radiation research began in the 1940s in Gttingen (1947), when photo-electron multipliers were first used to collect the Cherenkov light, and the Cherenkov light experiment conducted by Jelley (1951). The first measurements of Cherenkov light showers were made by Goldanskiy and Zhdanov [7] and independently by Galbraith [8]. Especially valuable at that time was the pioneering work of Chudakov [9] and the design work he made in conjunction with V.I. Zatsepin [10] for detecting Cherenkov light from EAS, made on the basis of the cascade theory of electron-photon showers primary gamma ray proton and two levels of observation.

At sea level, the Cherenkov angle is equal to 1.3° and decreases with height (Figure 1). The threshold energy for particles producing the Cherenkov light is, for example for electrons, protons and muons at sea level, 21 MeV, 4.4 GeV and 39 GeV respectively, and increases exponentially with height.

The pioneering work on Cherenkov light measurements by Chudakov also included the contribution of ionization and emission (fluorescent light) as the background to Cherenkov experiments. He later suggested to use this glow in experimental studies of EAS.

In our case we need to use a Cherenkov detector with small size and weight. A surface area of the Cherenkov detector of about 78.5 cm^2 is sufficient. It may also be used as a direct light Cherenkov detector or a Cherenkov aerogel detector [11]. Nanosecond timing collection of EAS Cherenkov light allows the determination of the arrival direction of showers and the characteristics of the shower front.

3. Drones or multicopter

The basic unit of the proposed system is a multicopter drone with a set of detectors on board. We called it a dedron (dedron - detecting drone) (Fig. 2).

Civil use of drones and multicopters [12] is quickly developing in the world.

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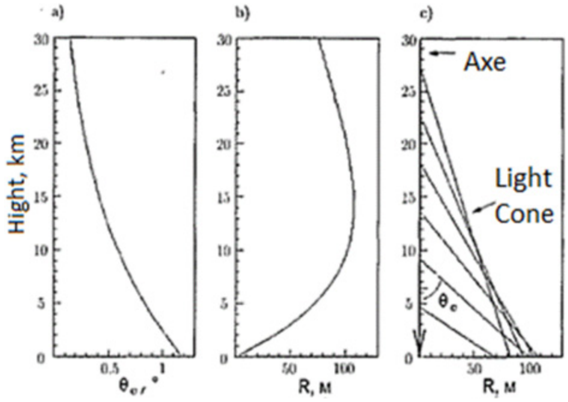

Figure 1. Cherenkov light height dependence from a) angle and b) circle radius. c) Shows the change of the Cherenkov light cone for different heights in the atmosphere.

Figure 2. Quadrocopter dedron.

There are also studies testing working management systems for drones [13]. Due to this, the purchase prices for them are falling rapidly.

The most effective power source for drones is a LiPo battery pack [14]. The voltage of the 4S LiPo battery assembly will be around 14.8 V. The discharge rate of the battery with a capacity of 1000 mAh will determine its maximum output current. It is necessary to choose the correct combination of power and discharge rate. It is also important to know that the battery cells are not taken into account for the maximum current consumption. The number of elements only define the voltage of the LiPo element needed for the hardware.

For example, the calculation of the rate of discharge shows that the A 2200 mAh / 30C LiPo can only provide 66A max. Therefore, the rate of discharge capacity is essential.

For example, 1A maximum current is required for the 4 motors of quadrocopters, and, for other equipment, 1A (detectors, lights, etc.), the required number of voltage 11.1V 8800 mAh and we have 134 minutes flying time and 8.8 Ampere given speed discharge.

A Quadrocopter with 1–2 kg weight drifted around 50 seconds over a distance of 1 km. It also depends on the mode of flight and other factors such as weight, wind resistance. The gyroscope, which allows quadrocopters to stay in the air also allows it to land vertically on the surface.

With the development of charging technology from alternative sources, time and efficiency will increase.

4. Communications technology, management, data collection and analysis

Technology at the beginning of the 2000s made great advances (4G [15], LTE [16] and WiMax [17]), and their use does not require special permission in everyday life. The Glonass module [18] and GPS [19] allow precise positioning of drones with detectors in space that allows the choice of positioning any network detectors structure. Controlling from a central control server connected with drone clusters will be optimal.

Deployment of the system will be possible taking into account the weather conditions and the transparency of the atmosphere on clear, moonless nights. Operation of the detection system starts after landing the chosen distribution of units on the surface. In fact, the position of dedrons is synchronized by GPS and wireless communication with a central base station. Dedrons land after flying to a predetermined coordinate, blades engines are turned off and the detection system switched on. After an overnight detection session the dedrons fly back to the central base station for safe charging from an alternative power source or solar cells. That also eliminates all sorts of negative scenarios with security detectors from both natural and man-made phenomena. It also prolongs the life of the detector system.

All signals detected by dedrons are taken simultaneously with their time stamps and stored in the server. The volume of incoming data for each event at each node can be evaluated in a few kilobytes of information. A server in online mode, following the data and the coincidence of signals on multiple nodes, classifies and stores the recorded events.

Subsequent data processing is performed in an offline mode by physics specialists with work skills on BIG DATA [20].

5. Summary

Due to the rapid emergence of new technologies we propose to develop a new direction in the detection and monitoring of various parameters of natural phenomena (EAS, storm effects, the consequences of natural and manmade disasters) by placing different types of sensors and detectors on each dedron.

A special interest is the study of Cherenkov light and the fluorescent light from EAS.

In this type of experiment, a study of the spectrum and mass composition of cosmic rays in the energy range 10^9–10^{18} eV can be carried out by a single method - registration of EAS Cherenkov radiation. By covering an area of 1–2 sq. km. and positioning 100 optical detectors at distances of 1 meter to 100 meters from each other, one can study the structure of the EAS front. The grid can be both regular or irregular. The nodes can be either positioned centrally symmetricly relative to the central base station or distributed uniformly in a polygonal structure.

In fact, this system is a telescope with a variable focal length. If this solution is technically implemented in practice, it will create a revolutionary ”telescope of the XXI century”.

Widespread use is possible for other types of detectors on this type of system for geophysical studies and real-time monitoring of deep structures of the Earth’s surface.

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