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Research Article

Using and Testing Camera Sensors with Different Devices at Cosmic Ray Detection

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Abstract

Cosmic Ray (CR) is high-energy charged particles that reach the earth from space. CR detection methods and studies have been progressing rapidly since the beginning of the 20th century. One of these methods is the use of digital cameras with Charge Coupled Device (CCD) and Complementary Metal Oxide Semiconductor (CMOS) sensors. Mobile phone cameras or webcams offer an easily using and economical measurement system for CR measurement. The sensors are exposed to CR during a long exposure. CRs leave traces in the background. Cosmic particle tracks are then separated from the background noise and can be classified. Making the traces of the particles visible is important for understanding the subject. In this context, traces of particles such as electrons, muons, and alphas can be seen with the cloud chamber experiments. Help of sensor technology and cameras have developed in recent years, CR traces can be easily detected so that it can be seen. There are many software and international projects that detect CR using CMOS sensors in cell phone cameras. In this study, related projects, programs and studies were researched; CR traces that we captured with the help of Cosmic-Ray Extremely Distributed Observatory (CREDO) and Cosmic Ray Finder (CRF) software with web cam and a mobile phone cam CMOS sensor are presented. Links have been made about astrophysical events coinciding with previously detected particle images.

Keywords: CCD, CMOS, Cosmic Ray, Muon.

Kozmik Işın Tespitinde Farklı Cihazlardaki Kamera Alıcılarının Kullanımı ve Testleri

Öz

Kozmik ışınlar uzaydan yeryüzüne kadar ulaşabilen yüksek enerjili yüklü parçacıklardır. Kozmik ışın tespit yöntemleri ve çalışmaları 20. yüzyılın başlarından bugüne büyük bir hızla ilerlemektedir. Bu yöntemlerden biri Yük Eşleştirmeli Cihaz (CCD) ve Tamamlayıcı Metal Oksit Yarı İletken (CMOS) sensörler içeren dijital kameraların kullanımıdır. Kozmik ışın ölçümü için cep telefonu kameraları veya web kameraların kullanımı kolay ve ekonomik bir ölçüm sistemi sunmaktadır. Uzun pozlama sırasında sensörler kozmik ışınlara maruz kalır ve arka planda izler bırakırlar. Kozmik parçacık izleri daha sonra arka plan gürültüsünden çıkarılıp sınıflandırılabilir. Parçacıkların izlerini gözle görünür hale getirmek konunun anlaşılması için önemlidir. Bu kapsamda bulut odası deneyleri ile elektron, müon, alfa gibi parçacıkların izleri gözle görülebilmektedir. Son yıllarda gelişen sensör teknolojisi ve kameralar yardımıyla da kozmik ışın izleri rahatlıkla tespit edilebilmektedir. Cep telefonu kameralarındaki CMOS sensörleri kullanarak kozmik ışın tespiti yapan birçok yazılım ve uluslararası proje mevcuttur. Bu çalışmada ilgili projeler, programlar ve çalışmalar araştırılmış; Kozmik Işın Aşırı Boyutta Dağıtılmış Gözlemevi (CREDO) ve Kozmik Işın Bulucu (CRF) programları ile web cam ve cep telefonu sensörleri yardımıyla yakaladığımız kozmik ışın izleri sunulmuştur. Daha önce tespit edilen parçacık görüntüleri ile aynı zamana denk gelen astrofiziksel olaylar hakkında bağlantılar incelenmiştir.

Anahtar Kelimeler: CCD, CMOS, Kozmik Işın, Müon.

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1. Introduction

Cosmic rays are charged particles with high energies far above gamma rays in the electromagnetic spectrum. They are mostly composed of protons (90%), helium particles (9%) and other heavy elements and free electrons (1%). Prior to interactions in our atmosphere, these particles are considered high-energy primary cosmic rays. When it interacts with the atmosphere, new particles known as secondary cosmic rays are formed. These secondary rays can be gamma rays, muons, protons, pions, neutrinos and electrons [1]. About 95% of the cosmic particles that reach the ground level are muons [2]. Cosmic rays are particles whose origins have not yet been determined, but mostly thought to come from active galactic centers. Understanding the structure of these particles will provide information about their energies, the world of subatomic particles and the first formation of the universe [3]. For this reason, it is among the most researched topics of recent years. Detection of cosmic rays; It can be done with the help of scintillation detectors, Cherenkov telescopes, cloud chamber experiment and CCD-CMOS cameras. The basis of this study is cosmic ray detection with CCD and CMOS sensors.

CMOS receivers are the most economical and easiest option used to detect cosmic rays today. CMOS receivers detect cosmic rays the same way they detect light. When the cosmic ray enters the CMOS receiver, it gives a charge to the receiver. If the receiver is not exposed to any light source, the cosmic ray will leave a mark on the resulting image. Since the receivers operate in much smaller areas (about 1 cm^2) compared to other detection methods, fewer cosmic rays fall on the receiver. However, there is no big change in the flux rate [4]. Muons form flat tracks with GeV energies with thick sensitive regions in CMOS and CCDs. The coiled tracks, called worms, are low-energy electrons. Their energies are at the level of MeV. These are always available in concrete and other materials. They usually occur as a result of compton scattering of gamma rays or beta decay of radioactive particles. Direct betas can be eliminated and compton scattering products can be significantly reduced with proper material selection and protection. Small dot-shaped traces are traces of electrons or alpha particles. The Radiation-CCD images that were investigated by Groom and detected at the NOAO Laboratory in Tuscon with 3600 exposure times are shown in Figure 1 [5].

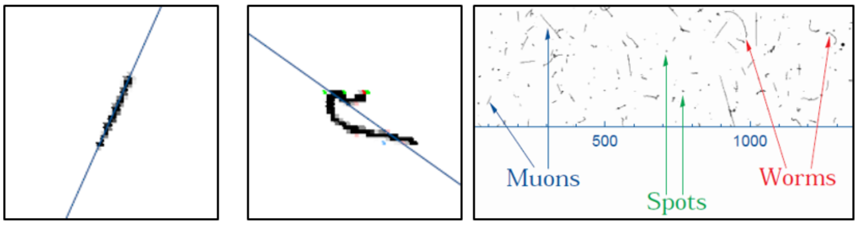

Figure 1. Muon, Electron and Alpha Detection in CCD

There are many international projects created using CMOS receivers. These cosmic ray detecting android programs have been setup so that users around the world can detect cosmic rays. The data determined by the users are saved in the data warehouse of the relevant project. Thus, an international cosmic ray station is established. Examples of these projects are: Distributed Electronic Cosmic-Ray Observatory (DECO), Cosmic Rays Found in Smartphones

(CRAYFIS), Cosmic-Ray Extremely Distributed Observatory (CREDO) and Cosmic Ray Finder (CRF) [6].

In this study, cosmic particle traces were detected with the help of mobile phone and web cam via CREDO and CRF programs used in cosmic ray detection. Previously received data with CRF were examined, abnormal traces were investigated and a supernova explosion of the same date was found.

2. Material and Methods

In this study, CREDO and CRF applications and a web cam material connected to a mobile phone and computer were used for the detection of cosmic particles. Two different measurements were made with two applications and materials.

First, the CREDO program was installed on the LG Q6 mobile phone with Android operating system and run. Project CREDO is a cosmic ray detection project started in 2016 by scientists at the Polish Institute of Nuclear Physics PAS. The aim of the project is to detect and record particles within the same recording time by detectors far from each other [7]. Because of its ease of use, access and analysis, CMOS receivers in phone cameras are an optimal tool for cosmic ray detection. Also, due to their small size and therefore light weight, CMOSs are ideal for use in high altitude balloons. Almost all mobile phones use CMOS cameras [8]. The sensor surface area of the phone camera is 0.16cm2. The front of the camera is covered with black electrical tape. This is done to prevent visible light from entering and exiting the CMOS immediately and contaminating the data [9]. Since the cosmic rays are more perpendicular at ground level, the camera is positioned to look perpendicular to the sky (zenith angle is 0°). The experiment was carried out between March 1-10, 2021 at Atatürk University, Faculty of Science, Department of Astronomy and outdoors during March 11-20. The laboratory is on the first floor of a three-story concrete building. And the measurements were made here. Experiments were carried out under a 60 cm thick concrete. The particle traces obtained are presented in the Result and Discussion section.

In the second part of the study, cosmic ray measurement was made with the help of the CRF program running on windows, prepared by Alexy V. Voronin in 2015, and a web cam. The passage of the particle is captured by the camera and analyzed. Calculations are made with CosmicRays_MATLAB open source code. The basis of the project is the M-file cr.m-MATLAB script. After clicking the start button in the program, the script cyclically captures the image from the connected webcam to the computer. The resulting image is represented as a pixel array with the values of the color channels (RGB/red-green-blue) for each pixel between 0 and 255. When analyzing these images, the brightest pixel is selected (with the maximum color distance) and the color channels (RGB) are checked. Tracks from the particle are fixed on the screen when the value in the channels exceeds the threshold level. The recommended level for the threshold level was taken as 150, as in the DECO project [10]. This limit value can be changed with the program. Such an approach ensures that both background noise (for example, from infrared radiation) and traces from low-energy particles are eliminated. If the Limit drops below 150 it will also catch very small lights. When it is over 150, the particle detection rate drops significantly. The detection of the resulting glow is made by calculating the number of pixels by detecting the colors (RGB) with the codes in the programs used [11]. The data was taken by positioning the camera facing the sky and facing upright. The experimental system made measurements again in the Astronomy Department between March 1-10, 2021, and in open space between March 11-20, 2021. The data obtained are presented in the Result and Discussion section. The properties of the materials used are presented in Table 1.

Table 1. Basic Features of Experimental Systems

	Experimental System I: CREDO	**Experimental System II: CRF**
Material Properties	The material used is Lg Q6 Cell Phone Camera, Sensor Type CMOS, Sensor area is 0.16 cm^2. The software used is CREDO, run on the android operating system.	Material Used Web Cam, Resolution 640x480, Sensor Type CMOS. The software used, CRF, was run on the Windows operating system.

In addition to the experimental studies, it was noticed that the images captured by Voronin on 20 July 2021 were above the usual images. The reasons for this have been investigated. Celestial events such as nova, supernova and solar activity that took place on the relevant dates were investigated.

3. Results and Disscussion

With CREDO, an average of 4 particles per day in the concrete building and 6 particles in the external environment were detected. The concrete thickness on the test system is approximately 60 cm. Concrete structures significantly reduce the number of cosmic rays. The reason why the number of particles is so low is that the area of the CMOS camera is very small and old model. The electron, muon and point source captured by the CREDO detector are shown in Figure 2.

Figure 2. Cosmic Ray Traces Captured with the CREDO

If still image capture becomes feasible, it becomes possible to perform trace analysis. Giving some known dimensions of the receiver and the orientation of the receiver, it becomes possible to trace the direction in which the cosmic ray enters the CMOS. This also allows events to be classified based on their images. For example, an event that passes directly through the receiver and creates a point will not be able to provide any trace information. However, an event that follows a worm-like path within the CMOS can be described as an electron worm. There are many different ways to classify events, the only requirement is higher resolution. The benefit of using the CREDO detector is that it is economical and simple. But this method can only be used as a detection method.

The second measurement study was made over the CRF program. Web cam detected an average of 10 particles in the building and 14 particles in the outdoor environment for 10 days. Most of the particles we detect consist of point or coiled electrons. Few straight-line muons have been captured. Obtained images are presented in Figure 3. In most laboratories, worms and sunspots outnumber muons. With 1 cm thick lead material, the count of worms and sunspots is reduced to a lower level. It should also be noted that recorded events are very rare. The detection amount is low due to the small size of the camera receiver. The interval between events can take hours or even days [5].

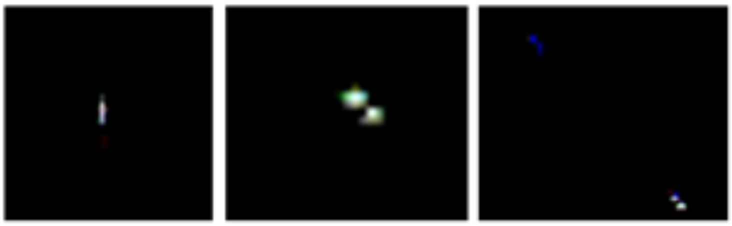

Figure 3. Cosmic Ray Traces Captured with the CRF Program

The data taken in the laboratory and outside environment in the reinforced concrete building are shown in Figure 4 and Figure 5. The fact that the number of particles captured in the external environment is higher indicates that concrete structures stop cosmic rays. When the CREDO and CRF data are compared, it is observed that more particles fall on the CRF. Because the surface area of the web camera used with the CRF program is larger. With the CREDO program, the decrease in the count in the measurements in the concrete building is around 33%. With CRF, there was a 28% reduction in the concrete building. This shows that cosmic rays are stopped in concrete structures.

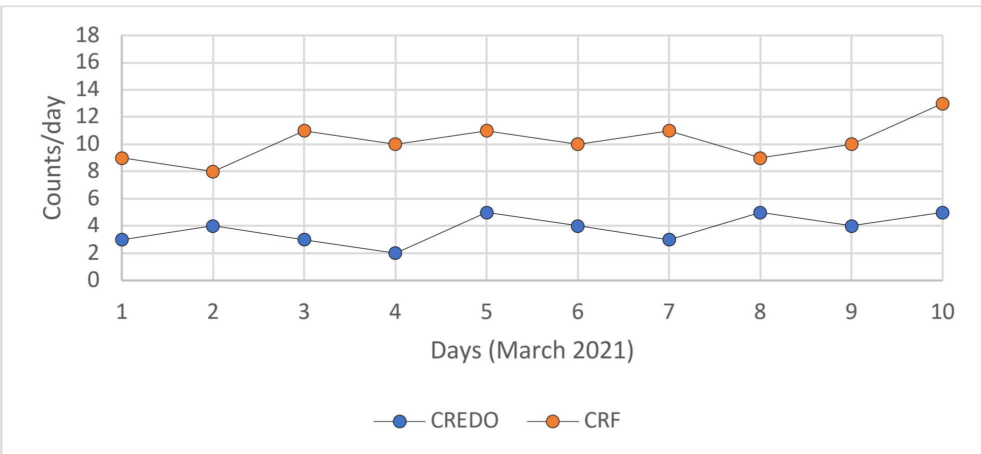

Figure 4. Data Received in the Laboratory

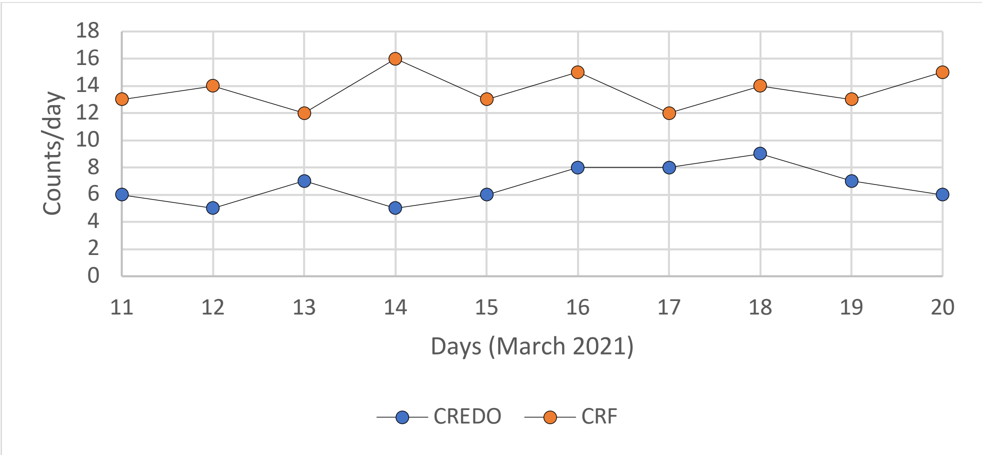

Figure 5. Data Received in the External Environment

Apart from the findings, Figure 6 shows the particle traces Voronin detected on July 20, 2021 [11]. These traces are much larger and brighter than the normal daily cosmic ray traces we capture with CRF. Examining these images, the cause of which is incomprehensible, it is seen that Virtual Telescope Project employees discovered a supernova named supernova SN 2021sjt in the intermediate spiral galaxy NGC 6951 on July 20, 2021 [12].

Figure 6. Particle Traces Captured by Voronin on July 20, 2021

The effects of the relevant supernova are thought to be related to the images detected by CRF. Because while the particles detected outside of the relevant day are very small, these images have an area 10 times larger than normal. The size of the image is proportional to the energy of the particle. However, more measurements and investigations of astrophysical phenomena are needed to make this interpretation. For this reason, these experimental studies will continue continuously for one year.

4. Conclusion

It can use digital cameras or webcams to detect cosmic rays and other sources of ionizing radiation in our environment. These cameras work through internal CCD or CMOS receivers. Many studies have been carried out with these methods today and continue to be done. For example, in the LHC experiment in the ATLAS experiment, cosmic ray detection is done with CMOS receivers. Detection of particle traces with CCD sensors is also used in dark matter studies. One of the most recent studies has been the detection of a large gap in the Cheops pyramid by radiography of muons produced by cosmic rays.

Cosmic ray measurement studies with devices such as mobile phones are one of the measurement methods that have become widespread in recent years. This is a scientific method that is both economical and easy for everyone to work with. International cosmic ray detection programs such as CREDO, CRAYFIS and DECO are considered to be the first examples of these studies. With these systems, only traces/images of particles are detected. Images detected with CREDO and CRF are presented in the Findings. Depending on the development of CCD and CMOS receiver technologies, particle detection studies will also gain a new course.

This research, which enables the cosmic ray traces to become visible, can be considered a start for cosmic ray studies. The new cosmic ray detector designs we will make in this study constitute the first step of making energy and flux measurements of cosmic rays at different altitudes such as the Eastern Anatolia Observatory (DAG) with 3170 altitude and at different latitudes such as Antarctica. Observations will be continued for a long time with the CRF and CREDO programs, so that in cases where abnormal traces are detected, the data of telescopes that can make scientific observations will be examined and a connection will be established with the causes of these events.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

Authors' Contributions

The authors did not declarate any contributions.

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