Abstract
The purpose of this project is to find out more about how cosmic rays are affected by the Earth’s atmosphere, if cosmic rays are related to lightning strikes and where they originate from. To test our hypotheses on the behaviour of cosmic rays, we constructed and tested a detector at our school, to be used for collecting data on cosmic rays. This information will be analysed and used by scientists all over the world to aid their research. In years to come, future students will be able to use the scintillator to test other hypotheses and contribute to the scientific community. This article will describe our current progress on constructing the detector.

Funding Statement
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Introduction
The purpose of this project is to find out more about how cosmic rays are affected by the Earth’s atmosphere, if cosmic rays are related to lightning strikes and where they originate from. Our objectives are:

To investigate whether there is a correlation between the atmospheric weather conditions and the number of cosmic rays that enter the Earth’s atmosphere. Cosmic rays can penetrate the atmosphere and influence the electrical properties of the air, as theoretical physicist A.V. Gurevich theorized for lightning. Therefore, the question to investigate is: can cosmic rays be related to lightning strikes?

To investigate the provenance of ultra-high energy cosmic rays: where do cosmic rays come from? Possible sources are the Sun and supernovae explosions in the Milky Way, but the most energetic cosmic rays probably come from extra-galactic sources. Therefore, the question to investigate is: do showers of cosmic rays point to known objects in the sky map?

HiSPARC is an international, hands-on, physics research experiment which allows students to participate in actual European research collaboration. It was created 10 years ago and there are currently around 90 detector stations in the Netherlands, along with many other active detectors in Denmark, Vietnam, Kenya and other countries around the world. The fact that similar detectors to ours are dotted all over the world will give us insight into how weather and climate relate to cosmic rays. The research and investigation of cosmic rays is
fairly new, which means our findings and work could lead to pioneering discoveries. It is a rare opportunity for us to work with professionals and hi-tech equipment, and has opened our eyes to the world of particle physics.

Little is known in depth about the nature and origin of cosmic rays. As they are charged particles, the interstellar magnetic fields cause their trajectories to change numerous times. Cosmic ray detectors allow us to measure the energy these particles have, expanding our scientific understanding of them. Any data that we collect will contribute to the scientific community and our understanding of cosmic rays, providing us with ground-breaking information and widening our knowledge of the universe. We aspire to gain a better understanding of cosmic rays and their behaviour in multiple scenarios as well as answering our specific questions about them.

Background
Prior to starting this project, we were unaware of the nature of cosmic rays, so we carried out research through various means, primarily the internet, to find secondary data and research to aid us. We also asked the professionals working with us about cosmic rays, because they had invaluable past experience with HiSPARC.

Most of the cosmic rays that reach the Earth are muons. A muon is a type of lepton particle, similar to the electron but with a larger mass. The mass of a muon is about 200 times the mass of an electron.

Our detector is made of a slab of a substance which exhibits scintillation; namely, it luminesces when excited by ionising radiation. When a high energy particle passes through the scintillator slab, it gives energy to the atoms in the scintillator, also known as exciting them. The atoms release flashes of light (photons) and return to their ground state, the lowest energy state of an atom or other particle. The detector also includes a photomultiplier tube, which can detect faint amounts of light by taking advantage of the photoelectric effect. This effect involves electrons being emitted from certain metals when light hits them. Within the photomultiplier tube, the photons hit the photocathode, a plate coated with a light sensitive material that has a low work function, meaning the material loses its electrons easily. These electrons are multiplied into a measurable electric current by a chain of electrodes, called dynodes, using potential difference. They travel along the tube, bouncing off the dynodes and producing more and more electrons.

Construction of the Detector
To build the cosmic ray detector, we took the following steps.

1. First, we removed the clear plastic cover from the scintillator plates.
2. Using optical wipes and propanol, we cleaned both sides of the scintillators and all the edges. We decided that propanol was the best solution to clean the scintillators with because it would evaporate quickly and leave almost no oil traces, as compared to alternative solvents.
3. We made sure that everyone wore gloves while handling the scintillators, as dust and fingerprints could decrease the quality of reflectivity or transmission. A good handling of the optics is essential to obtain results of high quality.
4. We wrapped the scintillators with aluminium foil to reflect light, so it would travel to the photodetector without being lost on the way. The aluminium was especially thick to reduce the chance of its tearing and leaving a strip of the scintillator bare.
5. To secure the foil in place, we used black insulation tape.
6. Next, we wrapped the scintillator in black pond liner to prevent light leaks, securing it with black insulation tape (Figure 1). We carried out this process on two rectangular and two triangular pieces of the scintillator, leaving the tops of the triangular pieces bare to be glued onto the rectangles.
7. We used optical glue to make sure that the photons pass through as much as possible without losses (Figure 2). After attaching a photomultiplier to the top of the scintillators, we tested for light leaks as we wanted to make sure that no light would escape or enter. We did this by a computer programme installed in our laptop, specifically created by HiSPARC (Figure 3). In order to create an environment similar to one the detector would be in while in use, we blacked out the room and tested it.
8. The final step is to attach a DAQ (Data Acquisition) system which will translate the signals we receive into a form that can be measured and recognised using computer software. The DAQ electronic box (Figure 4) also gives the necessary high voltage to the photomultipliers. After testing the detector, the final step is to place it into a special ski box (Figure 5) on the roof of our school, and begin research with the data.
Figure 1: Wrapping the scintillators in black pond liner.

Figure 2: Creating the optical glue.

Figure 3: Using the HiSPARC programme to test for light leaks.

Figure 4: The DAQ electronic box.

Figure 5: Ski box containing the scintillator.
Testing the Detector

We had numerous complications with the optical glue. For instance, it would not set properly and the scintillator parts would come apart. To overcome this hurdle, we carefully scraped the glue off, so that the scintillator was not scratched, to create a smooth surface for the new optical glue to be applied. The first time we created the glue, air bubbles were present, so we tried using a vacuum subsequently – however, that approach was unsuccessful. A second attempt also proved unsuccessful. The third time we created the glue, we stirred very slowly and cautiously to prevent any air bubbles from entering. This was successful and the scintillators were glued together, ready to use and collect data.

It is vital for us to carry out light leaking tests consistently; if there are light leaks in the scintillator, they could interfere with the cosmic rays to be detected. That is why we must double check and make any necessary repairs. No light must enter through the black plastic sheet over the aluminium; otherwise, the noise caused by the light leak would overcome the signal from cosmic rays. Voltage is important and must be optimised for the correct use of the photomultipliers. We will test a range of different voltages, keeping a record of the results. We will compare the data inside a room where all lights are off, and finally compare all results to check for light leaks within the scintillator. We want to find the conditions in which all signals from cosmic muons are detected efficiently with minimum noise. This is essential as this data will determine how many cosmic rays pass through the scintillator considering the variables that are provided. After this has been carried out, we will record the events in which muons pass through both our two scintillators at the same time, as this indicates that a shower has passed.

Future Work

The detector now belongs to our school and has been installed on the roof. It will stay there for years to come, so that many students will have the chance to do research with it. It is imperative that we continuously gather the data from the scintillators. This will enable us to collect a sample large enough to find strong, reliable trends that support our hypothesis. All the processed data will be then sent to our collaborators in other parts of the world, like the Netherlands, where they will be collectively analysed using cutting-edge technology. It is to determine whether there are any similar trends or even differences in all the data. A cause for the results can then hopefully be found. We are still in the process of establishing the best working conditions for the scintillators, but we will soon start our investigation on cosmic rays. We are very excited about doing real research with real scientists, and we hope to discover something new and significant! This work has been made possible by funding from the Royal Society. We will present our work at the Summer Exhibition.

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References

3. The HiSPARC website

The Enigma of Cosmic Rays PROJECT

The Bordesley Green Girls’ School HiSpArc Group consists of twelve Sixth Form A Level students with a keen interest in particle physics.

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