Science in School
The European journal for science teachers

ISSUE 77 – April 2026 **Topics** Astronomy/space | Physics | Science & Society

Cosmic SOS: exploring light & particles through the lens of space exploration

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Discover how hands-on experiments can introduce students to light and particles through the lens of space exploration.

A set of activities that introduce students to different types of electromagnetic radiation and ionising particles is presented in the context of space exploration. The activities are part of a new workshop offered at CERN Science Gateway[1] and are designed for students aged 13–18. They are modular and can be adapted to different curricula and classroom settings.

Introduction

Cosmic SOS places participants in the role of a space crew who receive a mysterious signal from deep space. To decode the message, students conduct activities exploring electromagnetic radiation and ionising particles. In doing so, they discover how CERN technologies can be used both in terrestrial experiments and in space.[2]

Radiation is a topic that is of great interest to students,[3] yet it is usually introduced in schools in an abstract way.[4,5,6] Teaching radiation in the framework of space travel offers an exciting and relatable context for students,[7] naturally linking to cosmic rays and to the real use of detector technologies beyond Earth.

The workshop utilises equipment varying from every day and easily obtainable materials to setups requiring some teacher tinkering and specialised detectors. Here, we will present each activity independently, so that teachers can select the ones that best suit their teaching needs and material available to them or simply get some inspiration for their teaching practice. These activities can be used for students aged 13–18, allowing teachers to adjust the depth of their explanation accordingly.

In many of these activities, the Predict-Observe-Explain method is encouraged.[8] Research has shown that students tend to be more engaged in an activity and demonstrate increased understanding when asked to make predictions about an experiment's outcome before observing it.[9]

Preparation

The activities are designed for groups of four students. The accompanying worksheet, one per group, can be printed out or displayed on a tablet. The worksheet, printable materials and further equipment can be found in the supporting materials. Each activity takes around 10 minutes.

To ensure active participation and mirror real scientific teamwork, as well as to increase engagement through ownership, we encourage to assign the following roles within each group:

- Systems engineer: responsible for the proper handling of the equipment
- Mission safety officer: responsible for the safe use of equipment and personal protective equipment
- Mission documentation specialist: responsible for keeping notes and writing down results
- Communication officer: responsible for liaising with other peers and tutors

Activity 1: Find the damage

Students inspect a circuit board to identify the faulty resistor(s) by using different tools.

Materials

- A circuit board consisting of 2–4 resistors (at least one should not be connected to the circuit) and cables to connect a 9 V battery. In our setup, we have also included an LED lamp to indicate whether the circuit is working and a switch to easily turn it on/off without needing to disconnect the battery. The circuit should be prepared in advance by the teacher.
- 9 V battery
- RGB torch
- UV torch
- IR camera
- Protective goggles

Safety note

While using the UV torch, students should wear protective goggles and always point the torch downwards.

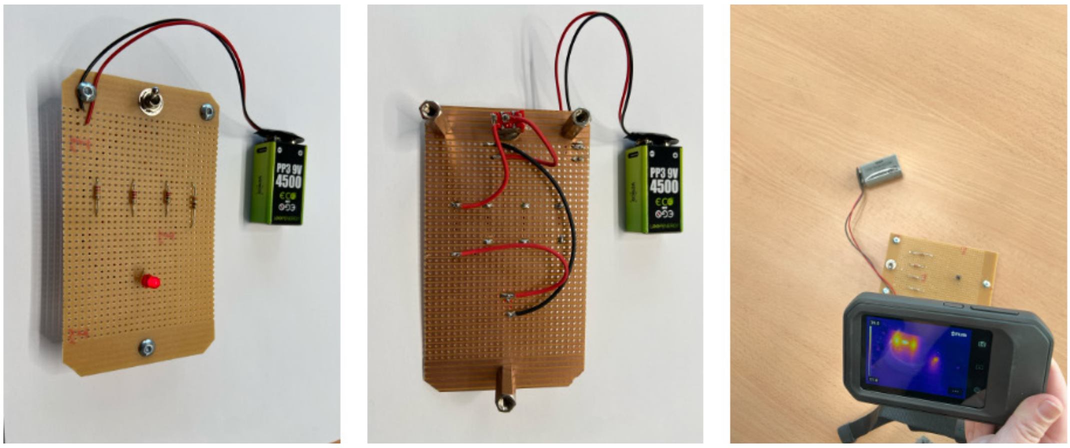
Resistors and batteries might get warm. The battery should be disconnected directly after the observation.

Procedure

1. Predict which device will best reveal the faulty resistor.
2. Connect the battery to the circuit and turn it on.
3. Identify the faulty resistor(s) by testing the different devices.

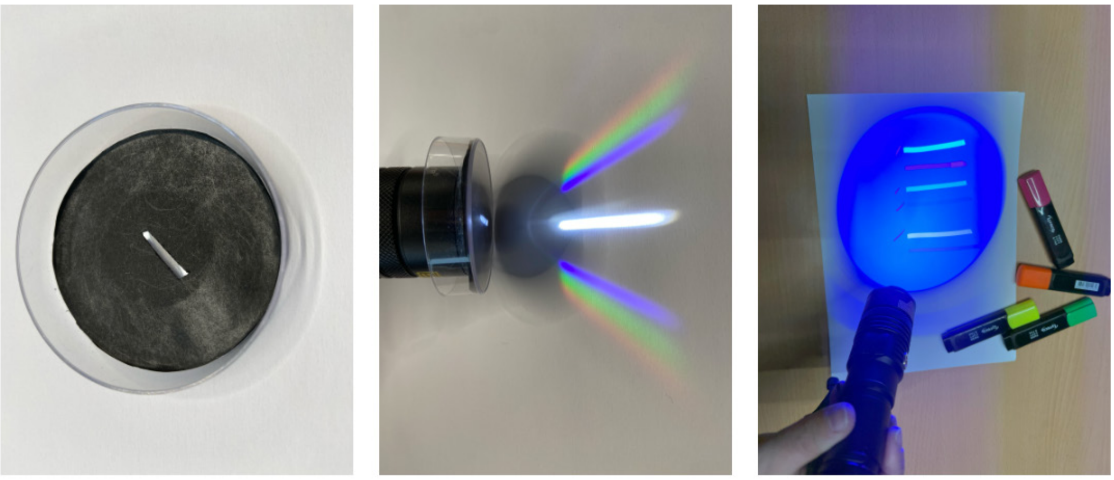
Results/discussion

Students find that the faulty resistor can be most clearly identified using an infrared camera as, when current flows, functioning resistors heat up. This observation provides a concrete link between infrared radiation and heat and helps students understand that not all radiation is visible to the human eye.



Set up of activity 1: using different equipment, the students identify the faulty resistor(s) in the circuit board.

Image courtesy of the authors



Set up of activity 2: white light decomposition with a diffraction grating, and fluorescence experiment.

Image courtesy of the authors

Activity 2: Adjust your sensors

Students decompose white light using a diffraction grating and investigate fluorescence using light and highlighters of different colours.

Materials

- A piece of paper (optional: leave a secret message with a UV marker on it for the students to discover)
- Diffraction grating (Our setup consists of a diffraction grating film placed in a small, round plastic case covered by a sheet of black paper with a narrow slit. This can be prepared in advance by the teacher.)
- UV torch
- RGB torch
- Highlighters of different colours
- Protective goggles

Safety note

While using the UV torch, students should wear protective goggles and should always point the torch downwards.

Procedure

1. Shine white light with the RGB torch through the diffraction grating, while holding it a few centimetres on top of a table, to create a rainbow.
2. Predict which light colour has greater energy (red or blue?).
3. Draw some lines with different highlighter markers.
4. Illuminate each line with red, green and blue light, by using the RGB torch.

Results/discussion

When light passes through the diffraction grating, it is decomposed into a spectrum of colours, like a rainbow. Highlighter ink fluoresces most strongly under blue or ultraviolet light, illustrating that blue light carries more energy than red light.

Activity 3: Explore the electromagnetic spectrum

Set up of activity 3: match the application cards to each spectral region.

Image courtesy of the authors

Students arrange the electromagnetic spectrum cards from lowest to highest energy and match real-world applications to each spectral region.

Materials

- 1 set of electromagnetic spectrum and applications cards

Procedures

1. Arrange the cards from lowest to highest energy.
2. Match each application card to the corresponding spectral region.

Results/discussion

This activity provides a visual and engaging way for students to classify different regions of the electromagnetic spectrum and link them to applications they are already familiar with from everyday life.

Activity 4: Examine radiation emitted by different objects!

Students measure radiation emitted from different everyday objects using a Geiger counter and compare the results with their predictions.

Materials

- 1 Geiger counter
- Various objects, e.g. LEGO bricks, uranium glass beads, slightly radioactive rock containing natural thorium
- 1 timer (or a phone)

Safety notes

The Geiger counter requires careful handling.

Procedure

1. Predict which object will be the most radioactive.
2. Measure each object with the Geiger counter for 30 seconds.
3. Identify which object is the most radioactive.

Results/discussion

Students usually observe measurable differences between the tested objects. They also detect a non-zero count rate even when no object is present. These observations open a discussion about background radiation and natural radioactivity.

Set up of activity 4: examine radiation emitted by different objects.
Image courtesy of the authors

Activity 5: Build a detector

Students assemble a model MiniPIX EDU detector,[10] a miniature pixel detector whose technology was originally developed at CERN, using LEGO bricks.

Materials

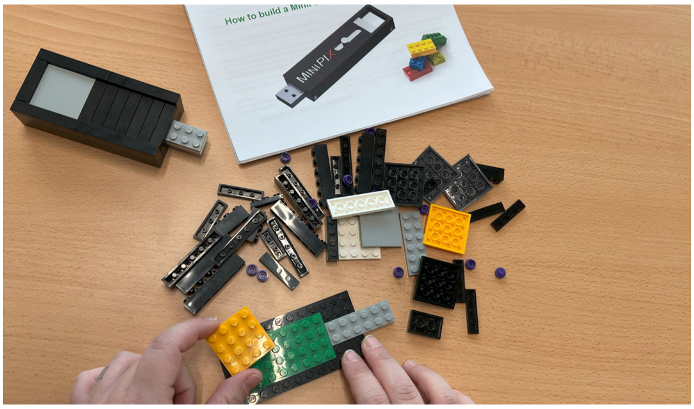
- LEGO bricks (list available on the website)
- 1 LEGO instructions booklet

Procedure

1. Assemble the detector following the instructions.
2. Match the detector's components to the corresponding functions.

Results/discussion

This exercise provides a hands-on way for students to understand that the model pixel detector is composed of multiple layers, each playing a role in the signal creation and readout.



Set up of activity 5: build a MiniPIX detector with LEGO.
Image courtesy of the authors

Activity 6: Identify particle tracks

Students use a real MiniPIX EDU detector connected to a laptop to observe particle tracks from background radiation and, optionally, from selected objects.

Materials

- 1 MiniPIX EDU detector (info available on the website)
- 1 laptop
- Objects from activity 4 (optional)

Safety notes

The MiniPIX EDU detector is quite fragile. Students should open the protective cover just before taking a measurement and then close it again. Nothing should touch the detector surface.

Procedure

1. Predict the tracks that each type of particle (alpha particles, muons, electrons and photons) will create when interacting with the detector.
2. Connect the MiniPIX EDU detector to the laptop and launch the detector's software.
3. Take measurements of the background radiation and compare the observed tracks to the predictions.
4. Optionally, take measurements of the different objects by placing them close to the detector window.

Results/discussion

By comparing shapes and sizes of the tracks, students can distinguish between different types of particles, which reinforces the idea that different particles interact with matter in different ways.

Set up of activity 6: identify particle tracks from background radiation or everyday objects with a real MiniPIX EDU detector.
Image courtesy of the authors

Activity 7: Final task

Students examine MiniPIX measurements taken at three different locations: a CERN office, an aeroplane and a satellite. They then match each measurement to its corresponding location.

Materials

- 1 set of cards with MiniPIX measurements

Procedure

1. Place the cards in the correct order (office, aeroplane, space).

Results

Cosmic radiation levels increase with altitude because there is less shielding provided by the Earth's atmosphere. In outer space, where there is no protection from the Earth's magnetic field, radiation levels are even higher.

Discussion

We hope that these activities offer inspiration for teachers' practice, whether they are looking to implement cost-free ideas, take on a hands-on tinkering project, or have the possibility to purchase more specialised equipment. The activities also highlight how knowledge and technologies originally developed at CERN are applied in aerospace science, linking this work to real scientific contexts. Silicon detectors based on the same technology as the MiniPIX EDU device are, for example, deployed on the International Space Station (ISS) and on NASA's Orion spacecraft. In addition, CERN operates radiation experiments such as the Alpha Magnetic Spectrometer (AMS) on the ISS are with a continuous 24/7 connection. Lastly, many materials intended for use either in space or in underground experiments at CERN are tested in its facilities to ensure they can withstand extremely harsh conditions, including temperature, pressure and radiation.

TIMEPIX@school

We recognise that access to advanced detector technologies such as MiniPIX EDU can be challenging for most schools. TIMEPIX@school is a new CERN-led educational initiative designed to lower this barrier by bringing Timepix-based detectors, which were originally developed at CERN and are currently used in medical and space applications, into classrooms around the world.[11]

Acknowledgements

We would like to thank Pinelopi Christodoulou for her guidance and support regarding the use and capabilities of the MiniPIX EDU detector. We are also grateful to Francesca Giovacchini and Sonia Natale for their valuable insights into CERN's involvement in aerospace research, particularly through the AMS experiment.

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[9] Crouch C et al. (2004) Classroom demonstrations: Learning tools or entertainment? *American journal of physics* **72**: 835-838. doi: 10.1119/1.1707018

[10] *MiniPIX EDU*: https://advacam.com/camera/minipix-edu/

[11] TIMEPIX@school website: https://timepix-at-school.web.cern.ch/

Resources

- Find the Cosmic SOS activity also on the CERN website.
- Read an introduction on the electromagnetic spectrum: Mignone C, Barnes R (2011) More than meets the eye: the electromagnetic spectrum. *Science in School* **20**: 51–59.
- Build your own spectrometer to explore the delights of colour: Westra MT (2007) A fresh look at light: build your own spectrometer. *Science in School* **4**: 30–34.
- Get inspired by the story of a European astronaut: Voak H (2018) Becoming an astronaut: interview with Matthias Maurer. *Science in School* **43**: 26–30.
- Identify tracks of subatomic particles from their ‘signatures’ in bubble-chamber photos: Woithe J, Schmidt R, Naumann F (2019) Track inspection: how to spot subatomic particles. *Science in School* **46**: 40–47.
- Explore physics in a new way by creating a model of particle collisions using craft materials: Rivett A (2015) Glitter, glue and physics too. *Science in School* **33**: 52–56.
- Build a cloud chamber with your students: Barradas-Solas F, Alameda-Meléndez P (2010) Bringing particle physics to life: build your own cloud chamber. *Science in School* **14**: 36–40.
- Build a particle accelerator in your classroom: Brown A, Merkert J, Wilson R (2014) Build your own particle accelerator. *Science in School* **30**: 21–26.

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