
Teaching material INTEGRAL (Teachers)

Overview

Topics:	Astronomy, remote sensing
Subjects:	Physics (astronomy), geography
Grade:	9-13
Media & Material:	Thematic videos, worksheet
Duration:	90 minutes
Key question:	"How does the continuous gamma-ray observation by the INTEGRAL satellite help to improve our understanding of distant galaxies and our solar system?"

Competences

Subject competences

The students...

... describe the mission and the various instruments of INTEGRAL and place them in the context of space observation.

... show which geophysical and astronomical questions are suitable for the measurements of the INTEGRAL satellite.

Methodological competences

The students...

... use a combination of worksheets and INTEGRAL material to find ways of presenting more complex presentation materials and working materials, graphically and linguistically.

... experience the process of gaining knowledge by discussing their procedures and results.

Judgmental competences

The students...

... evaluate their methodological approach regarding the INTEGRAL materials provided and classifying them in the context of the observation of distant galaxies and our solar system.

... assess how suitable the materials provided are for the work assignments and to what extent there is room for improvement in the materials.

Executive competences

The students...

... present their work results in a relevant and technically appropriate manner.

Curriculum

This lesson focuses on the process of gaining knowledge, a process-related skill. Content links can be established to all core curricula of the German federal states. There are opportunities to link to existing content areas. In physics, this refers to the astronomical component as well as dynamics, mechanics, and wave theory. In geography, there are links to the structure of the Earth's atmosphere and the electromagnetic spectrum.

This unit covers many sub-skills of knowledge acquisition that are evident in scientific ways of thinking and working. Examples of curriculum references can be found in the table below. Note, that all presented topics are implemented into the curriculum of the German federal states only.

Subject	Geography	Physics
Topics	Remote sensing, planetary processes, atmosphere, electromagnetic spectrum	Astronomy, black holes, planetary processes, wave theory
Baden-Württemberg	9/10: Digital orientation (GIS, remote sensing), exogenous processes 11/12: Spheres in the Earth system (processes in the atmosphere)	9/10: Mechanics and dynamics 11/12: Astrophysics

Bavaria	10: Geographical working techniques and methods 11/12/13: Geographical working techniques and methods, atmosphere, electromagnetic spectrum	11: Astronomical world views, cosmology 12/13: Astrophysics
Bremen	Q: Physical geography fundamentals and processes (exogenous forces, atmospheric processes)	EPH: Mechanics of the planetary system Q: Development of the astronomical world view, electromagnetic spectrum
Berlin / Brandenburg	EPH and Q: Geosphere, exogenous processes	Upper secondary: Movement of artificial satellites, rotation of the Earth, space travel, complete topic area on the gravitational field, electric and magnetic fields
Lower Saxony	Upper secondary level: physical-geographical factors	EPH: Dynamics (uniform circular motion), optical imaging (satellites)
North Rhine Westphalia	EPH and Q: Atmospheric and climate physics processes	EPH and Q: Circular motion, gravity, and physical worldviews
Thuringia	12: Atmospheric circulation	11: Gravitation (weight, planetary motion), circular motion 12: Gravity

Didactic commentary:

The teacher introduces the unit by giving the students a silent prompt about the INTEGRAL satellite. This is done using a picture of the satellite, which is projected onto the projector/board. The students are then asked to think about the function of the satellite and discuss it as a class before moving on to the key question of the lesson.

The teacher provides the students with the worksheet and video materials covering various aspects of the INTEGRAL satellite and its measuring instruments. The students are then introduced to the topics of gamma radiation, supernovae, and black holes. In the first section, they examine the texts and illustrations in the

material.

This is followed by tasks 1.1 and 1.2, which focus on understanding what has been read. The students should summarize what they have read in their own words.

After that, task 2 is about the orbit of the INTEGRAL satellite. Here, the students should examine the information text and the visual representation of the orbit. They should assess why this type of elliptical orbit was chosen, which should stimulate a discussion about the large difference in distance from Earth.

Thereafter, an interim review follows in a group discussion, during which the results of the tasks and questions about the information learned can be clarified.

In the second part of the module, students learn about the structure of the Earth's atmosphere and particle physics, and how this relates to the INTEGRAL satellite. In task 3, students are asked to highlight the extent to which the different layers of the Earth's atmosphere influence gamma ray measurements and how these differ from the measurements taken by INTEGRAL from Earth orbit.

Task 4 then discusses in more detail the extent to which particle physics plays a role in this and how particles, such as those in gamma radiation, decay in the Earth's atmosphere.

In the final consolidation phase, the results, difficulties, and potential conflicts are presented, discussed, and consolidated in a plenary session. Reference is also made to the guiding question formulated at the beginning, which is to be answered in task 5. The teaching unit is thus intended to promote a holistic understanding of the role of the INTEGRAL satellite in space research.

Lesson plan

Time	Phase	Lesson activities	Methodological-didactic comments	Social form	Media
10 min	Introduction + Problematisation	The teacher begins with a silent image stimulus.	Students are asked to use the silent image stimulus to think about what function the INTEGRAL satellite could fulfill in space observation. The teacher notes the students' thoughts on the board in bullet points. The discussion serves as a starting point for the module. The teacher writes the guiding question on the board so that it is clearly visible.	Class discussion	Board / Projector
25 min	Development 1	The teacher provides the students with the worksheet and the video materials. The students read the information texts and complete tasks 1.1, 1.2, and 2.	The students look at the information texts and illustrations presenting the various measuring instruments of INTEGRAL. They also read the background information on black holes, supernovae, and gamma radiation. This is followed by task 1.1, 1.2 and 2. regarding the explanation of the INTEGRAL orbit.	Individual or partner work (if necessary)	Worksheet, Videos

15 min	Interim review	The results from tasks 1.1, 1.2, and 2 are presented and compared in a plenary session.	The teacher has the opportunity to intervene and correct any mistakes. If necessary, an initial interim assessment can be carried out earlier.	Class discussion	Board / Projector
20 min	Development 2	The students work on tasks 3 and 4.	In tasks 3 and 4, the students deal with the structure of the Earth's atmosphere and the associated particle decay (particle physics).	Individual or partner work (if necessary)	Worksheet
15 min	Review	The results from tasks 3 and 4 are discussed and compared in a group discussion. This is followed by answering the guiding question with task 5. in a group discussion.	The teacher has the opportunity to intervene and correct any mistakes. If necessary, another interim assessment can be carried out earlier.	Class discussion	Board / Projector
5 min	Outlook			Class discussion	

Possible solutions to the students' tasks

1. Introduction

1.1 Summary of INTEGRAL measuring instruments

1.2 Summary of black holes, supernovae, and gamma radiation / gamma-ray bursts

2. Orbit

The main reason for the eccentric orbit is the need to avoid the Earth's radiation belts. These radiation belts could significantly interfere with the sensitive measurements of gamma radiation. Due to its highly elliptical orbit, INTEGRAL spends about 90% of its time outside the radiation belt, which enables significantly better data quality. The distance from the Earth's radiation belts enables INTEGRAL to detect even weak gamma rays that other spectrometers cannot detect.

INTEGRAL orbits the Earth at a distance of 3,300 to 159,000 kilometers. Its orbital period is approximately 72 hours (3 days). This enables optimal coverage by ground stations and allows repeatable work shifts for ground personnel.

3. Structure of the Earth's atmosphere

As you can see, the atmosphere consists of different layers. These protect life on Earth from cosmic radiation (such as gamma radiation). At an altitude of 20 km, cosmic radiation produces particle showers, i.e. it reacts with atoms in the atmosphere. This creates new particles, known as secondary particles. These particles can be detected on Earth, allowing certain events to be recorded indirectly, as these particles can be traced back to gamma radiation. However, due to the "decay" of gamma radiation in the atmosphere, it does not make sense to measure gamma radiation from the ground. This is because it does not reach the ground.

4. Particle physics

4.1 Reading comprehension

4.2 Particles in the Earth's atmosphere

Neutrons (N), protons (p), and three different types of pions (π^+ , π^- , π^0) can be detected. In addition, electrons and positrons (e^- , e^+) as well as muons (μ^+ , μ^-) can be seen. The final type are neutrinos (ν).

4.3 Effects of particle showers on the Earth and the human body

Since particle showers begin at an altitude of approximately 20 km, both people in aircraft and astronauts are exposed to slightly higher levels of radiation. When flying, the exposure is only slightly higher, while astronauts are actually at greater risk of developing cancer or various eye diseases, for example, due to direct contact with primary cosmic radiation. On the ground itself, cosmic radiation has no harmful effects on humans.

5. Answer the key question: "How does the continuous gamma-ray observation by the INTEGRAL satellite contribute to improve our understanding of distant galaxies and our solar system?"

INTEGRAL enables the study of high-energy phenomena in distant galaxies:

The satellite can detect gamma-ray bursts, which are among the brightest explosions in the observable universe. These observations help astronomers to better understand the formation and evolution of galaxies.

INTEGRAL can also study the centers of galaxies, where supermassive black holes are located.

Although INTEGRAL was primarily designed to observe distant objects, it also contributes to our understanding of our solar system:

The satellite can observe high-energy phenomena such as solar flares in our solar system. Continuous observation makes it possible to track changes in gamma-ray activity over long periods of time.

INTEGRAL's special orbit allows for long, uninterrupted observation periods: The satellite is in a highly elliptical orbit with a period of 72 hours.

This orbit allows INTEGRAL to use more than 80% of its orbital time for scientific observations. Unlike satellites in low Earth orbits, INTEGRAL can observe continuously for several days without being interrupted by the Earth.

INTEGRAL's advanced instruments enable precise measurements:

The satellite can simultaneously observe objects in gamma rays, X-rays, and visible light. The instruments on board enable fine spectroscopy and accurate imaging of gamma-ray sources.

Through this continuous and precise observation, INTEGRAL contributes significantly to deepening our understanding of high-energy phenomena in distant galaxies and gaining new insights into our solar system.