Dark Matter: Overview of Educational Resources

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Dark Matter: Online Seminar for Teachers 30 Oct 2024

Why teach about dark matter?

One of the most intriguing scientific mysteries of our time

Excellent example of science in the making which illustrates scientific practices and aspects of the nature of scientific knowledge

Can link to standard physics curricula such as gravity, circular and orbital motion, and optics in addition to astronomy, particle physics and general relativity (Woithe & Kersting 2021)

High potential to promote students' interest and curiosity irrespective of age, gender or nationality (Sjøberg & Schreiner 2010)

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Bend it like dark matter!

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Abstract

Dark matter is one of the most intriguing scientific mysteries of our time and offers exciting instructional opportunities for physics education in high schools. The topic is likely to engage and motivate students in the classroom and allows addressing open questions of the Standard Model of particle physics. Although the empirical evidence of dark matter links nicely to many standard topics of physics curricula, teachers may find it challenging to introduce the topic in their classrooms. In this article, we present a fun new approach to teach about dark matter using jelly lenses as an instructional analogy of gravitational lenses. We provide a brief overview of the history of dark matter to contextualise our presentation and discuss the instructional potential as well as limitations of the jelly lens analogy.

Keywords: physics education, dark matter, jelly, lenses, gravitational lensing, instructional analogy

1. Introduction: why should we teach about dark matter?

Dark matter is one of the most intriguing scientific mysteries of our time. While this invisible type of matter seems to be abundant in our cosmos, physicists grope in the dark about its nature and origin. Attempting to verify dark matter directly, scientists investigate possibilities of physics beyond the Standard Model. Recently, an unexpected signal from the dark matter detector XENON1T set off a wave of excitement among dark matter hunters [1]. Likewise exciting are the instructional opportunities of dark matter in the classroom. Not only does the topic engage and motivate high school students while introducing them to fundamental concepts of particle physics, astronomy, and cosmology. The search for dark matter is also an excellent example of science in the making which illustrates scientific practices and aspects of the nature of scientific knowledge.

In this paper, we motivate our interest in teaching dark matter by providing a brief overview of its instructional potential in the classroom. We then turn to the empirical evidence that has led physicists to believe that dark matter exists before presenting different ways of teaching about dark matter based on this evidence. Employing jelly lenses as an analogy of gravitational lenses, we describe an easy and fun experimental set-up for classroom instruction. We then discuss various use cases as well as limitations of the jelly lens analogy to support teachers in

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Overview of hands-on activities

Something is missing & how to study the invisible

NASA JPL activity

Students make observations of two plastic bottles filled with small objects. One bottle is also filled with water. Although the water is invisible, students can observe the different masses of the two bottles.

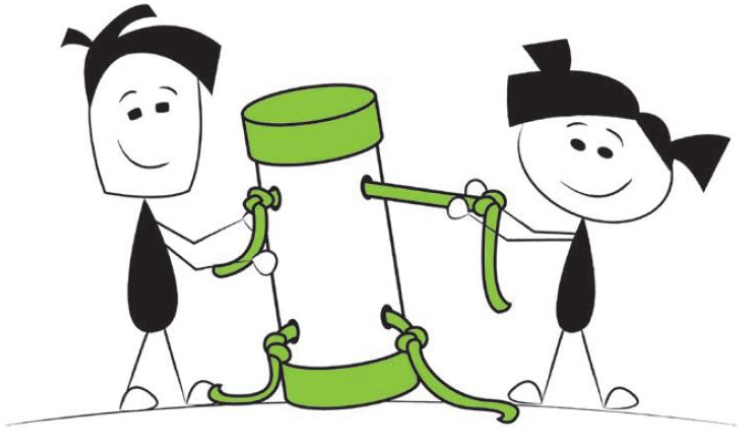
CERN Science Gateway activity

Scattering boxes allow students to explore how balls interact with a hidden structure and develop a scientific model of an invisible obstacle.

How to study the invisible: mystery tubes & boxes

Perimeter Institute extensive lesson plan: the process of science

Activities to practise being scientists and help students develop their curiosity, creativity, and communication and collaboration skills across many age levels and in any science class.



Models can never be proven right, but they can be proven wrong.

CERN education activity: mystery boxes

Experiment with mystery boxes with hidden internal structures to learn about different aspects of nature of science and scientific models. This activity can be linked to the discovery of the Higgs boson (Woithe et al. 2022)

Something rotates weirdly

Perimeter Institute extensive lesson plan: the mystery of dark matter

DIY rotation apparatus to demonstrate that the rotational speed depends on the mass of the object that causes the centripetal acceleration, video with quiz, plot real astronomical data from a galaxy, calculate mass and compare with luminosity of stars, demo of grav. lensing.

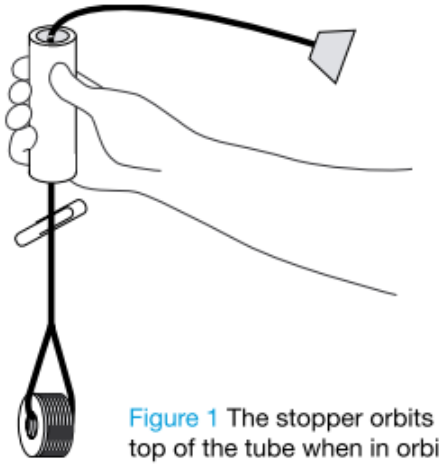
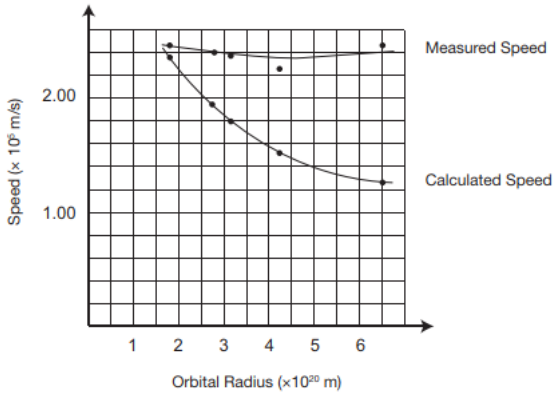
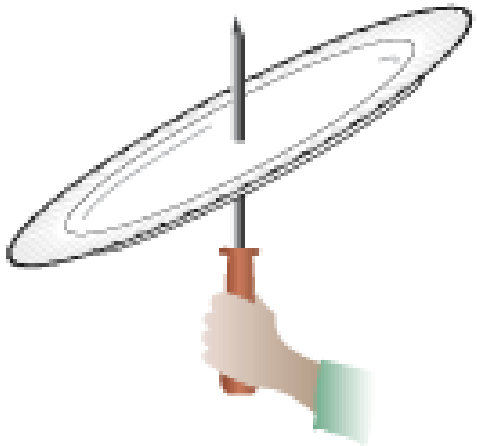


Figure 1 The stopper orbits below the top of the tube when in orbital motion.



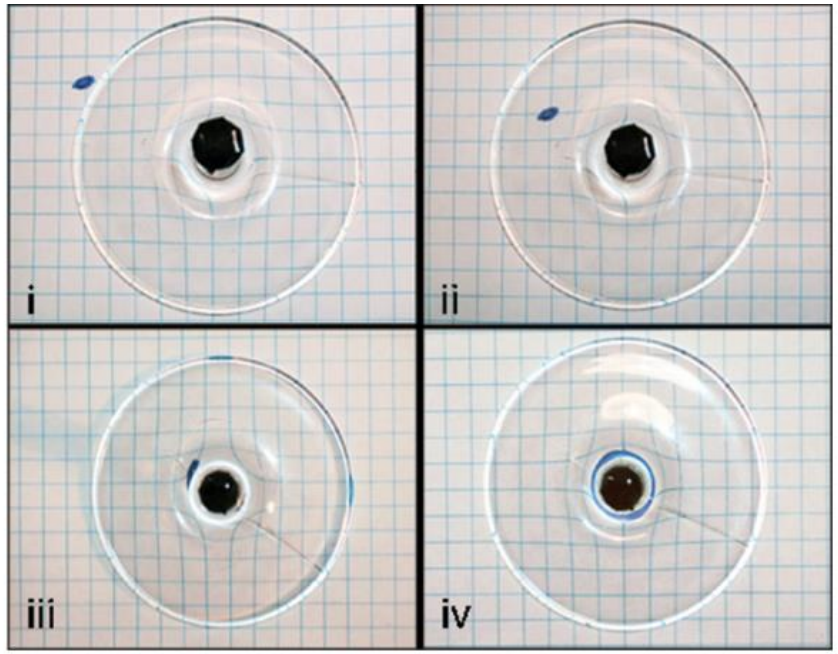
Sanford Underground Research Facility lesson plan: dark matter

Build and study a weirdly spinning paper plate. Students infer the existence of extra hidden mass in the form of washers by observing the rotation behaviour.

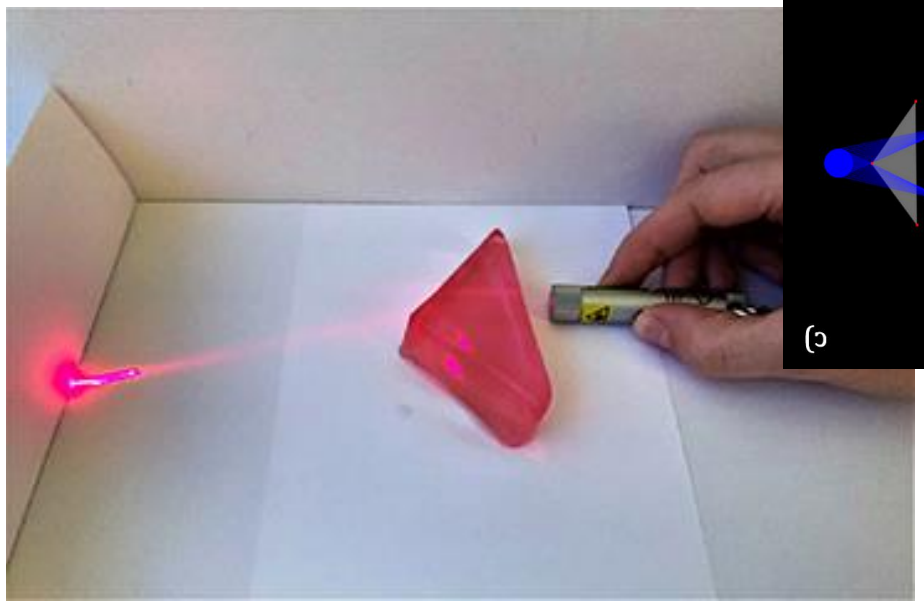


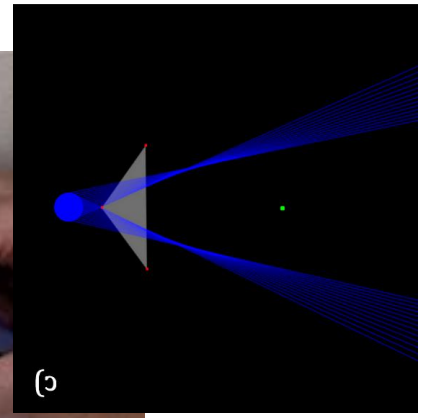
Gravitational lensing

Wine glass analogy
(e.g. Ros 2008, Huwe & Field 2015)
Use base of a wine glass to distort an image.



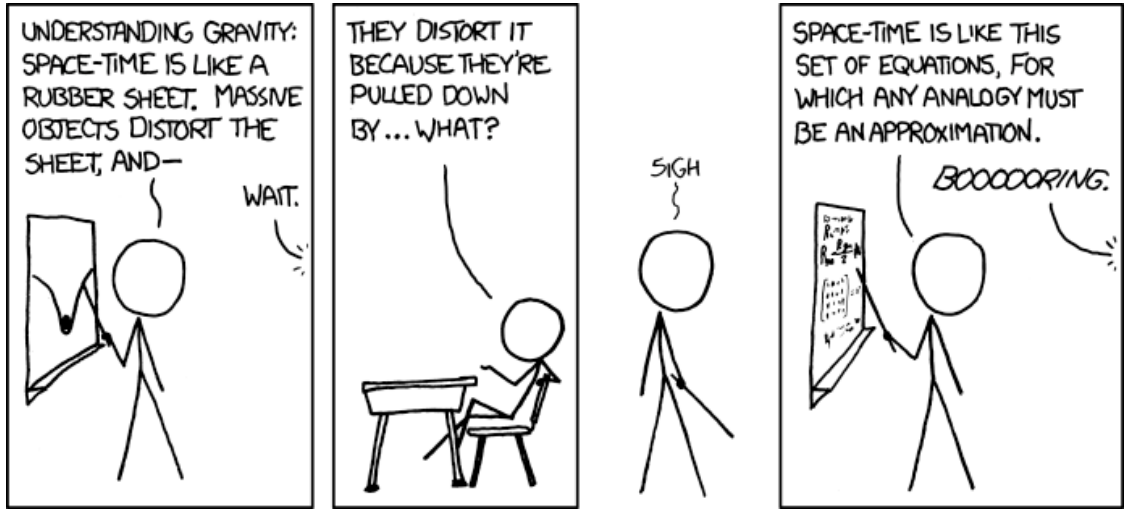
Jelly lenses (Woithe & Kersting 2021)
Gravitational lenses in 2 dimensions with home-made jelly lenses (simpler than wine glass), use simulations such as Ray Optics Simulation to compare observations with predictions.

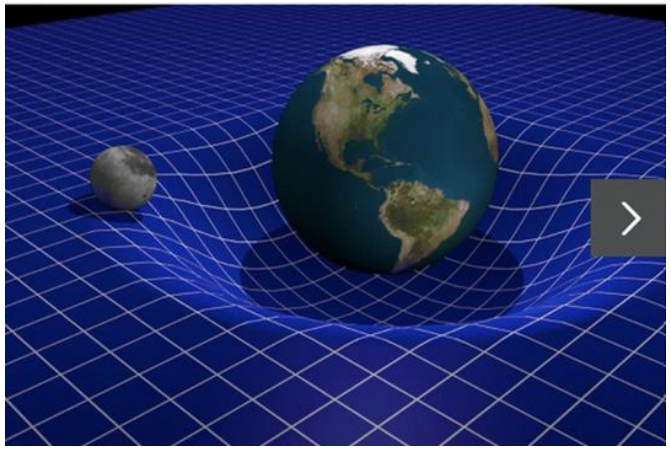




Curved spacetime

Rubber sheet analogy
To explain gravitational lensing, we need to introduce students to spacetime curvature. A popular analogy compares the distortion of spacetime to the distortion of a two-dimensional rubber sheet by massive objects (e.g. Kersting & Steier 2018, Ford et al. 2015)

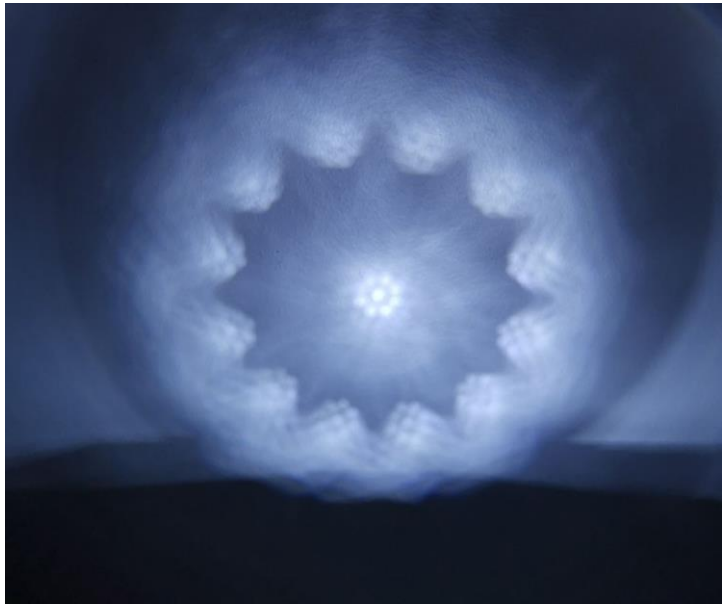




Science-art and bake activities

ARC Centre Activity: images of light

This science-art activity makes use of the refractive and reflective properties of materials to create unique and interesting photographs of light.



CERN Universe chocolate cake

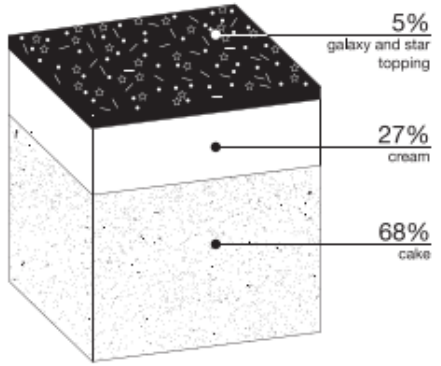
INGREDIENTS

CAKE

4	large eggs
120 g	sugar
105 g	flour
10 g	potato starch
4 g	baking powder
25 g	cocoa powder

CREAM

210 g	66% dark chocolate
120 g	cream
120 g	milk



More resources including reading material & videos

https://www.interactions.org/dark-matter-day/educational-resources
(attention: no longer maintained)

The Universe Adventure: Dark Matter

The Universe Adventure, sponsored by Lawrence Berkeley National Laboratory's Physics Division,

http://universeadventure.org/final_frontier/dkmttr-whatis.htm

Additional teacher resources:

The Particle Adventure: Unsolved Mysteries—Dark Matter

A discussion on dark matter's possible particle makeup. Also available as a mobile app.

http://particleadventure.org/dark.html

NASA Education: What Is Dark Matter?

Audience: Ages 9-12

https://www.nasa.gov/audience/forstudents/9-12/features/what-is-dark-matter.html

NASA's Imagine the Universe: The Nature of Dark Matter

Audience: Ages 14+

https://imagine.gsfc.nasa.gov/science/questions/dark_matter1.html

Thanks a lot for your attention!

Let‘s discuss ☺

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