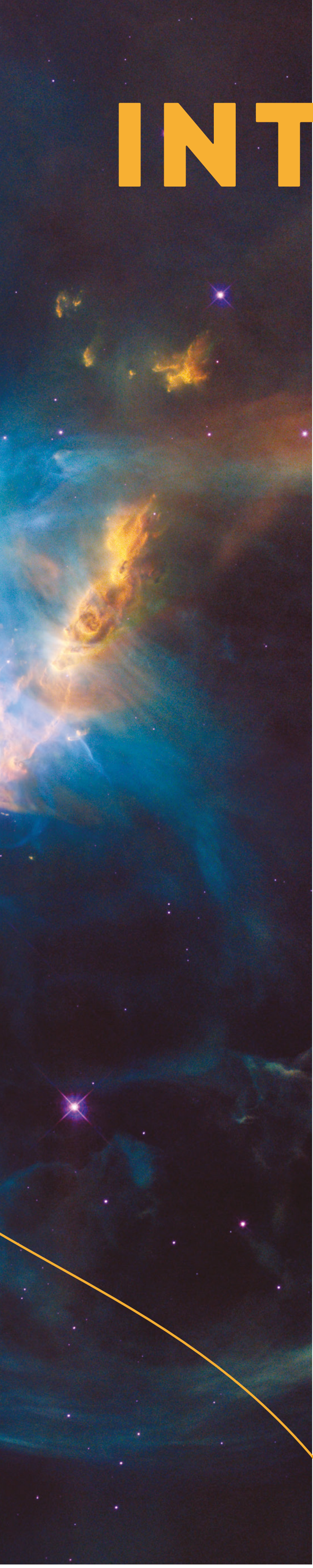
BLACK HOLE

ACTIVITIES

a quick reference guide



INTRO

Black holes are one of the most extraordinary objects in the Universe, they are extremely simple and yet incredibly exotic. A black hole does not have a surface, like a planet or star, instead, it is a region of space where matter has collapsed in on itself such that the pull of gravity is so strong that, once captured, nothing – not even light – is able to escape. This is remarkable when you think about how fast light can travel (nothing can travel faster). If we could move at the speed of light we could travel around the Earth 7.5 times just in one second. Some black holes are thought to be the result of dying (very big) stars, several to hundreds times bigger than our Sun. After formation, a black hole can continue to grow as its gravity pulls in material from the surroundings, such as gas and dust from other stars and even other black holes. Black holes can even be supermassive, with masses of over a million Suns. These supermassive black holes exist at the centres of most galaxies. One exists at the centre of our own galaxy, the Milky Way.

Because of their extreme gravity, black holes create many very interesting effects. Some of these effects allow scientists to indirectly observe black holes. This is important because light can't escape from black holes, making them invisible. Some of these effects also have important implications for their surroundings, which can influence how stars form, galaxies evolve, and even how matter is distributed throughout the Universe. The extreme gravity of a black hole also causes a phenomenon called 'spaghettification', which would be the unfortunate fate of a person falling into a black hole. Because gravity is a central concept in learning about black holes; as students learn about black holes, their understanding about this important science concept will be reinforced. Moreover, black holes are an interesting topic to capture student's attention and stimulate their curiosity and interest for science.

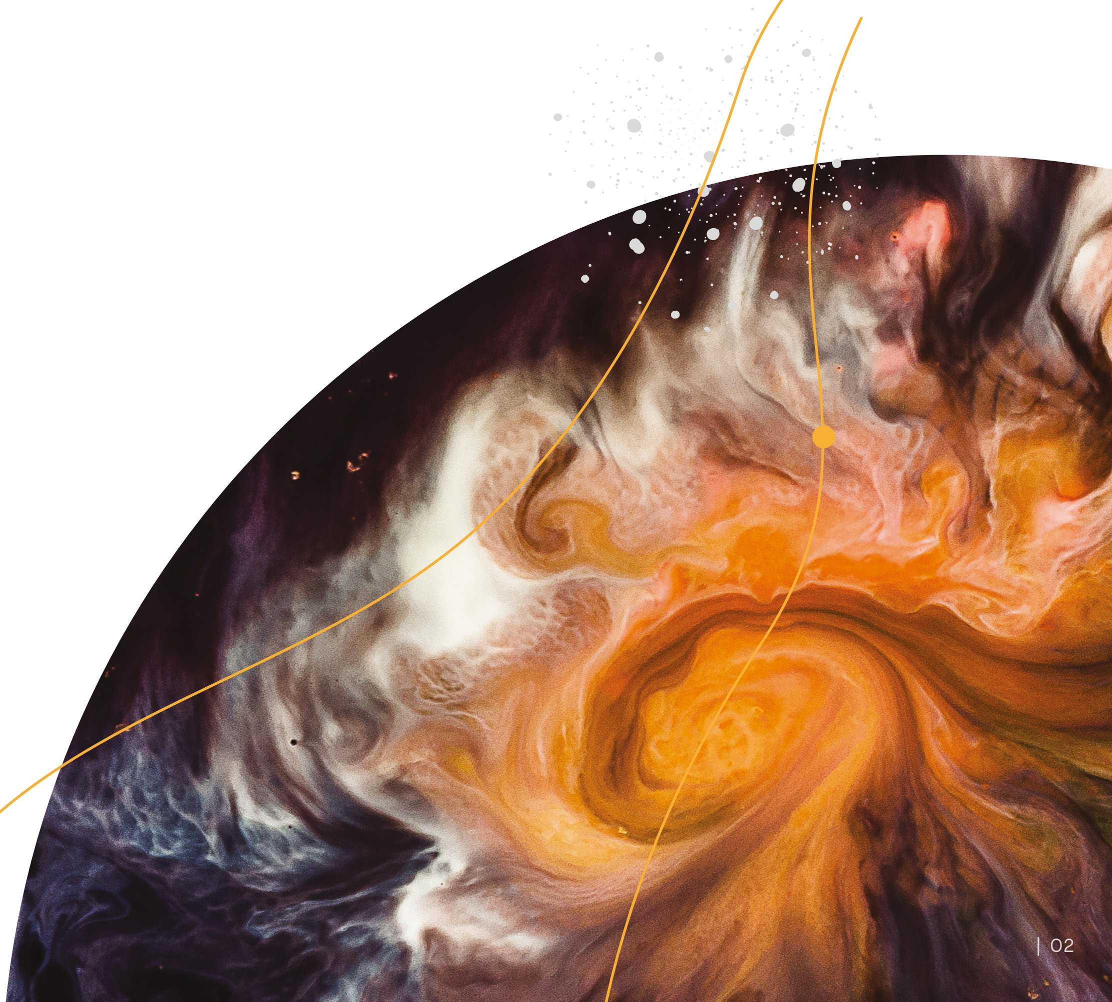


TABLE OF CONTENTS

01 BLACK HOLE FORMATION

Death of a star and birth of a black hole– Aluminum foil covered balloon model | 06

Life cycle of a star – the five stages | 07

Collapse of a star – White dwarfs, neutron stars, pulsars and black holes | 08

Rarity of black hole – producing stars | 09

The collapse of a star demonstrated with a shrunken, frozen balloon | 10

Supernova explosions | 11

Density, volume and size – Factors that determine black hole formation | 12

The death of a star and the birth of a black hole – Determining the radius of a black hole's event horizon | 13

02 GRAVITY, SPACE-TIME AND BLACK HOLES

What does a black hole look like? | 15

Is a black hole a threat to the Earth? | 16

Gravity and the fabric of space | 17

Model of a black hole | 18

03 MODELS OF BLACK HOLE

A scale model of a black hole in the Cygnus X-1 binary system | 20

A mental scale model of a black hole's size and location in the Milky Way galaxy | 21

Paper model of a black hole bending light | 22

04 SPAGHETTIFICATION

Spaghettification – Fate of everything falling into a black hole | 24

Spaghettified astronaut | 25

05 BLACK HOLE DETECTION

Detecting a black hole through accretion | 27

Spotting a black hole based on the orbit of stars | 28

Stars orbit around a black hole, illustrated by the attraction of loose ball bearings to a hidden magnet | 29

Recording and interpreting distorted images as seen through gravitational lensing | 30

The gravity of a black hole gives away its location, illustrated with marbles and magnets | 31

Gravitational lensed images as seen through the base of a wine glass | 32

06 ANALYZE ASTRONOMICAL IMAGES TO MEASURE THE LIMIT MASS OF BLACK HOLES

Black holes: Gravity's relentless pull | 34

Evaluating black hole candidates | 35

Image credit | 36

01 BLACK HOLE FORMATION

DEATH OF A STAR AND BIRTH OF A BLACK HOLE- ALUMINUM FOIL COVERED BALLOON MODEL

AGE 6+

LEARNING OBJECTIVES

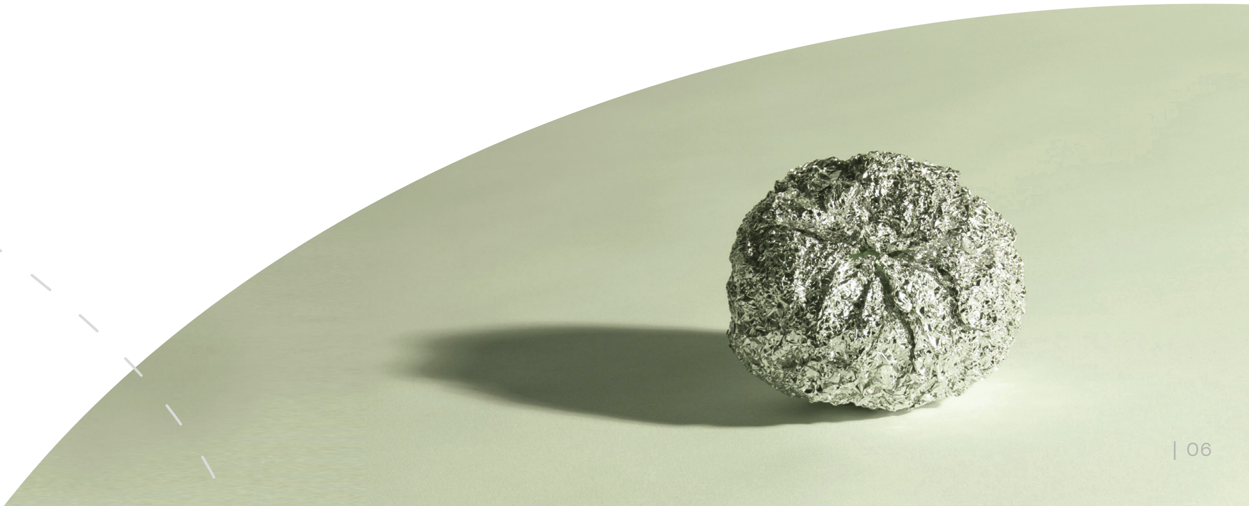
To understand how a black hole is formed through the collapse of a massive star.

COMMENTS

- Good introduction about the core of a star and how it collapses to form a black hole.
- Activity clearly shows how a black hole can be formed after core collapse by compressing an aluminium foil into a much smaller ball than originally.
- Good background explanation on mass, volume and density.

INSTRUCTION

http://www.scienceinschool.org/2013/issue27/blackholes (Activity 1)



LIFE CYCLE OF A STAR – THE FIVE STAGES

AGE 8+

LEARNING OBJECTIVES

Learn about the basic stages in the evolution of a star.
Learn about the different end products for low-mass and high-mass stars.

COMMENTS

Often the audience may not understand the kinesthetic actions they are doing and cannot visualize what is happening to a star. Therefore, to ensure understanding, there needs to be very clear instructions and explanations for each kinesthetic activity representing each stage of a star's life.

INSTRUCTION

- http://www.astc.org/exhibitions/blackholes/BH_TeacherEdGuide.pdf (Page 2-6)

- https://www.dropbox.com/s/pecedib4xh2gar4/astc%20org.pdf?dl=0 (Page 2-6)

COLLAPSE OF A STAR - WHITE DWARFS, NEUTRON STARS, PULSARS AND BLACK HOLES

AGE 8+

LEARNING OBJECTIVES

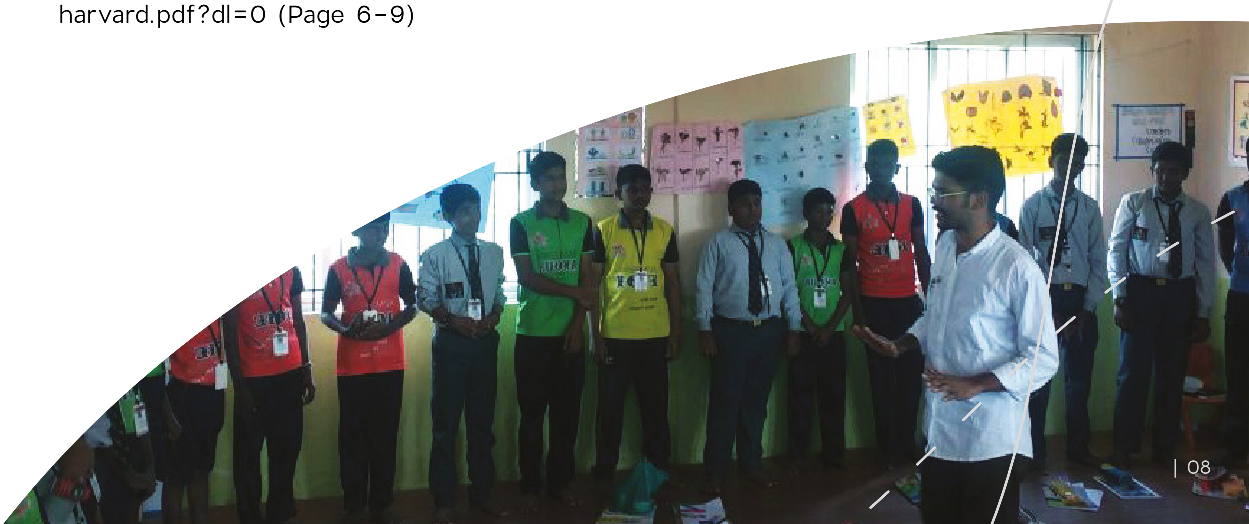
To understand how the collapse of low mass and high mass stars can form white dwarfs, neutron stars and black holes.

COMMENTS

Often the audience may not understand the kinesthetic actions they are doing and cannot visualize what is happening to a star. Therefore, to ensure understanding, there needs to be very clear instruction and explanation for each kinesthetic activity representing each stage of a star's life.

INSTRUCTION

- https://www.cfa.harvard.edu/seuforum/einstein/resources/JourneyBlackHole/JourneyBlackHoleManual.pdf (Page 6-9)
- https://www.dropbox.com/s/3izytmw42aasvec/cfa%20harvard.pdf?dl=0 (Page 6-9)



RARITY OF BLACK HOLE - PRODUCING STARS

AGE 10+

LEARNING OBJECTIVES

This activity enables students to recreate the life cycles of different types of stars, illustrating the rarity of black hole-producing stars.

COMMENTS

Activity uses different balloon colors to clearly explain that stars with different mass (and heat) will evolve differently over the same period of time.

INSTRUCTION

- http://sciencenetlinks.com/media/filer/2014/08/29/gravity5-8.pdf (Page 25-28)
- https://www.dropbox.com/s/xb272n6t4ecasha/sciencenetlinks.pdf?dl=0 (Page 25-28)

THE COLLAPSE OF A STAR DEMONSTRATED WITH A SHRUNKEN, FROZEN BALLOON

AGE 11+

LEARNING OBJECTIVES

To understand how a black hole can be formed.

COMMENTS

- Visualize how lower air temperature and pressure results in shrinkage, similar to what happens in collapse of a star.
- Require 30 min waiting time and a freezer.

INSTRUCTION

https://astrosociety.org/edu/publications/tnl/24/blackhole3.html

SUPERNOVA EXPLOSIONS

AGE 11+

LEARNING OBJECTIVES

To understand the life cycle of a star, nuclear fusion inside a star and the role of the star's mass in determining its fate at the end of its life. To understand what happens during core collapse and how the Universe is populated with chemical elements from a supernova explosion.

COMMENTS

This is a compilation of several detailed activities to explain different processes/ phenomena in a supernova explosions.

INSTRUCTION

- https://imagine.gsfc.nasa.gov/educators/programs/bigexplosions/activities/SupernovaExplosions.pdf
- https://www.dropbox.com/s/fy3lcfzkgrmmmxl/imagine%20gsfc.pdf?dl=0

DENSITY, VOLUME AND SIZE – FACTORS THAT DETERMINE BLACK HOLE FORMATION

AGE 12+

LEARNING OBJECTIVES

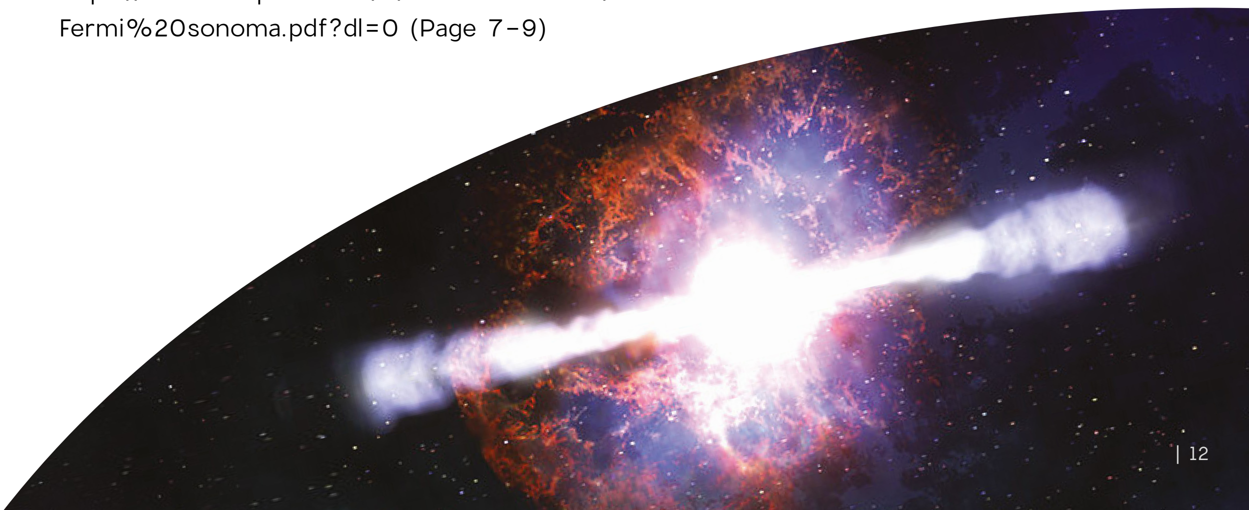
Students conceptualize what happens when a star collapses into a black hole. Students should understand that the mass inside of a black hole is not made up of known matter, like protons, neutrons, and electrons. They will complete exercises involving exponential notation, circumference, volume, and density.

COMMENTS

- Conceptualize that as something gets smaller, the mass does not change so the density increases.
- Good activity for students to investigate size, mass, density and how they relate to black holes.
- Provides a good understanding of how a black hole's mass determines the radius of its event horizon, where objects are pulled in without escape.

INSTRUCTION

- http://fermi.sonoma.edu/teachers/blackholes/bhguide06.pdf (Page 7-9)
- https://www.dropbox.com/s/efhuehea5cdasii/Fermi%20sonoma.pdf?dl=0 (Page 7-9)



THE DEATH OF A STAR AND THE BIRTH OF A BLACK HOLE – DETERMINING THE RADIUS OF A BLACK HOLE'S EVENT HORIZON

AGE 15+

LEARNING OBJECTIVES

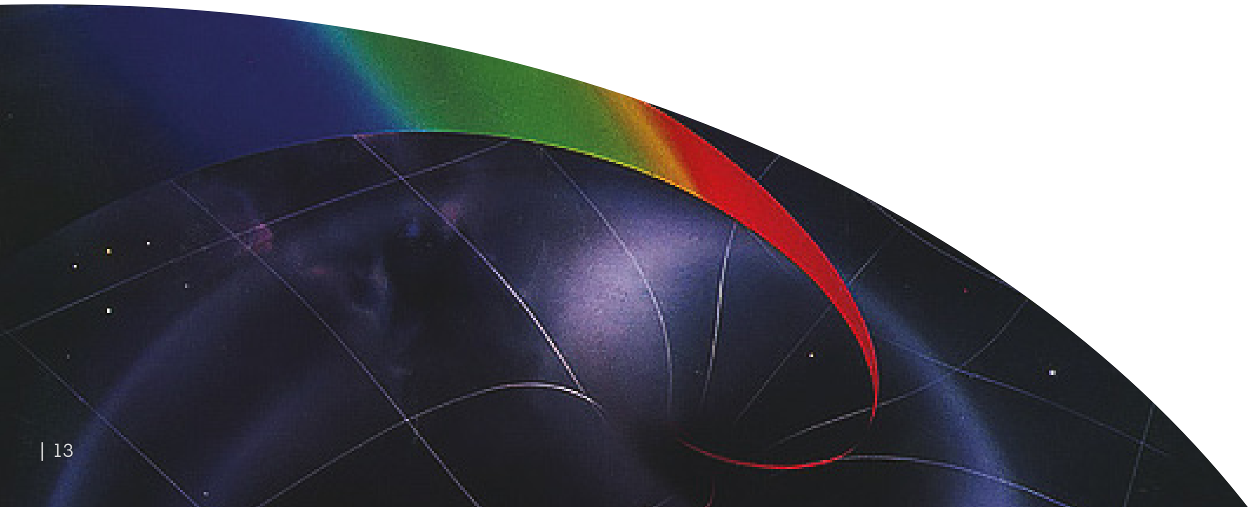
Students learn how a black hole is formed by understanding the implication of increasing density with decreasing size. From this activity, they should understand the major characteristics of a black hole and better understand density, mass and volume.

COMMENTS

- The activity relates black holes to concepts that students are more familiar with, such as volume, density, size.
- Interesting activity, using black holes as a topic in mathematics and physics lessons.

INSTRUCTION

http://www.pbs.org/wgbh/nova/education/activities/3314_blackhol.html



02

GRAVITY, SPACE-TIME AND BLACK HOLES

WHAT DOES A BLACK HOLE LOOK LIKE?

AGE 6+

LEARNING OBJECTIVES

To make an edible model showing what the outside of a black hole might look like in space.

COMMENTS

- Building an edible model is a fun and tasty activity for young children.
- Make sure that children understand that the black hole itself is invisible. What is observed through the telescope i.e. what this model recreates, is the region just outside of the black hole.

INSTRUCTION

- https://www.cfa.harvard.edu/seuforum/einstein/resources/JourneyBlackHole/JourneyBlackHoleManual.pdf (Page 17-18)
- https://www.dropbox.com/s/3izytmw42aasvec/cfa%20harvard.pdf?dl=0 (Page 17-18)

IS A BLACK HOLE A THREAT TO THE EARTH?

AGE 6+

LEARNING OBJECTIVES

The activity provides answers and illustrations to questions like what happens to space and time around a black hole and what would happen if the Sun became a black hole.

COMMENTS

- Activity is well ordered and able to explain well the concepts of space-time and gravity.
- Good discussion section before starting the activity.

INSTRUCTION

- https://www.cfa.harvard.edu/seuforum/einstein/resources/JourneyBlackHole/JourneyBlackHoleManual.pdf (Page 19-24)
- https://www.dropbox.com/s/3izytmw42aasvec/cfa%20harvard.pdf?dl=0 (Page 19-24)

GRAVITY AND THE FABRIC OF SPACE

AGE 7+

LEARNING OBJECTIVES

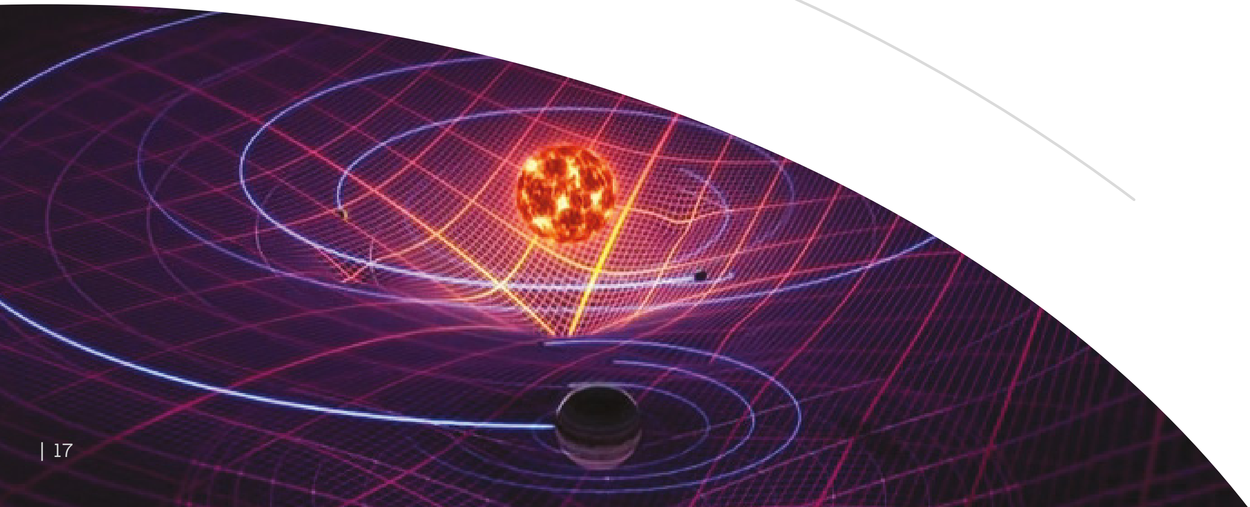
To understand what gravity is and how it works. To learn about black holes using the understanding of gravity.

COMMENTS

A series of small activities explaining gravity in different ways relating astronomical phenomena, including black holes.

INSTRUCTION

- https://nightsky.jpl.nasa.gov/docs/BHManual.pdf
- https://www.dropbox.com/s/j4n919ey9hzikly/Activity%20 guide%20-%20Nightsky.pdf?dl=0



MODEL OF A BLACK HOLE

AGE 8+

LEARNING OBJECTIVES

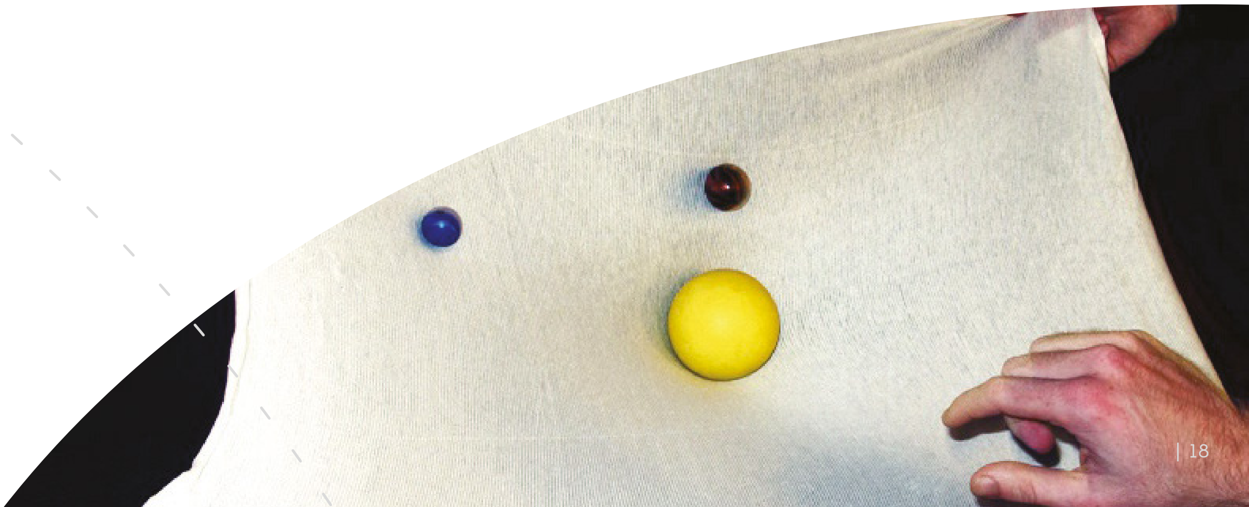
To introduce to students the important astronomical concepts of space-time, gravity and black holes using an interactive, hands-on activity. Students will be able to describe what happens to an object passing by a gravity well, if the gravity well is too deep (like a black hole's) and its velocity is not high enough.

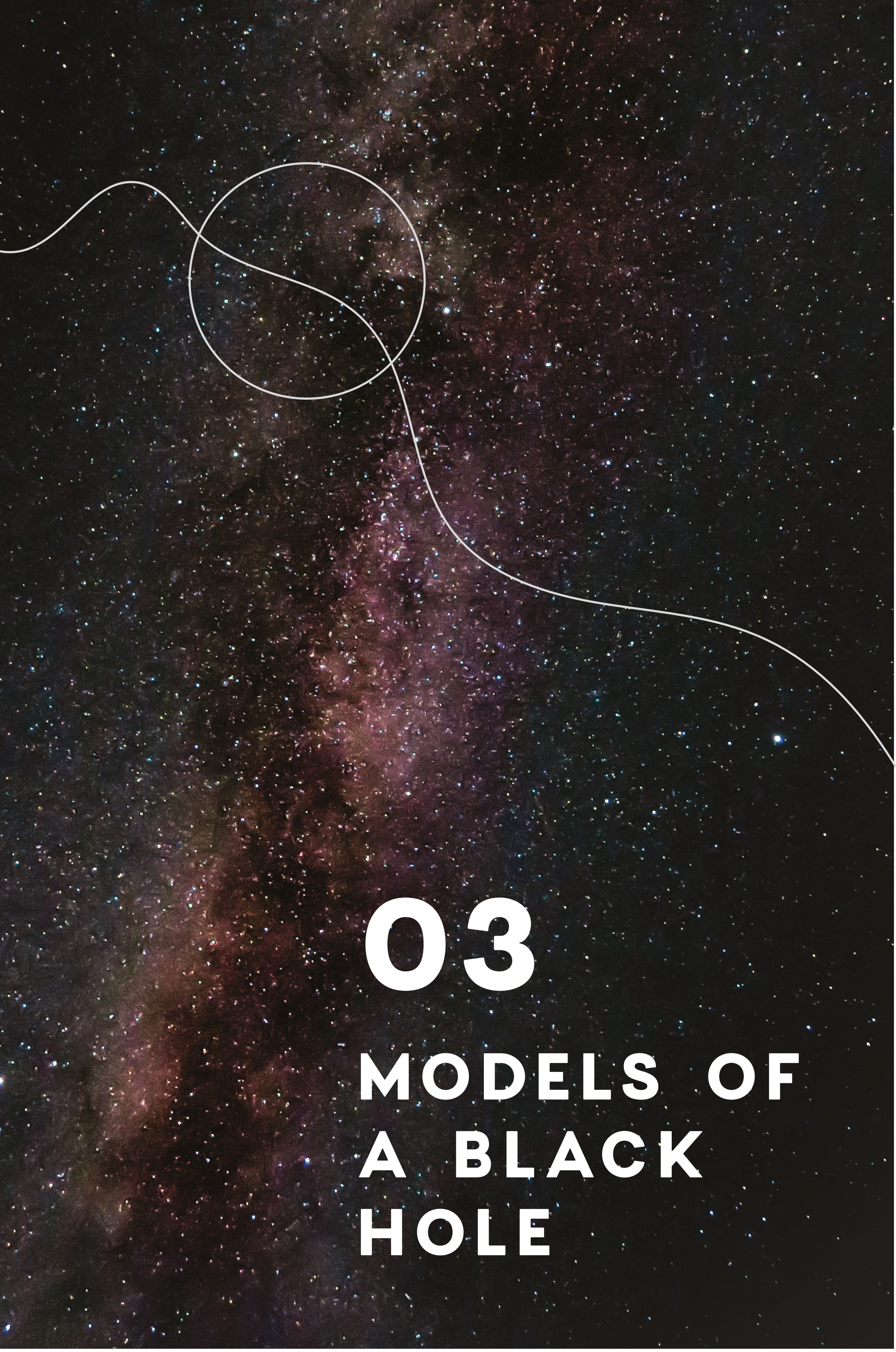
COMMENTS

- Good illustration for how a massive object like a black hole deforms space causing other objects to fall in and not escape.
- The background information includes the concept of space-time, but does not explain clearly what it means to say 'gravity distorts space-time'. This concept might be confusing for younger audience, so space-time can just be referred to as space.

INSTRUCTION

http://astroedu.iau.org/activities/model-of-a-black-hole/





03

MODELS OF A BLACK HOLE

A SCALE MODEL OF A BLACK HOLE IN THE CYGNUS X-1 BINARY SYSTEM

AGE 11+

LEARNING OBJECTIVES

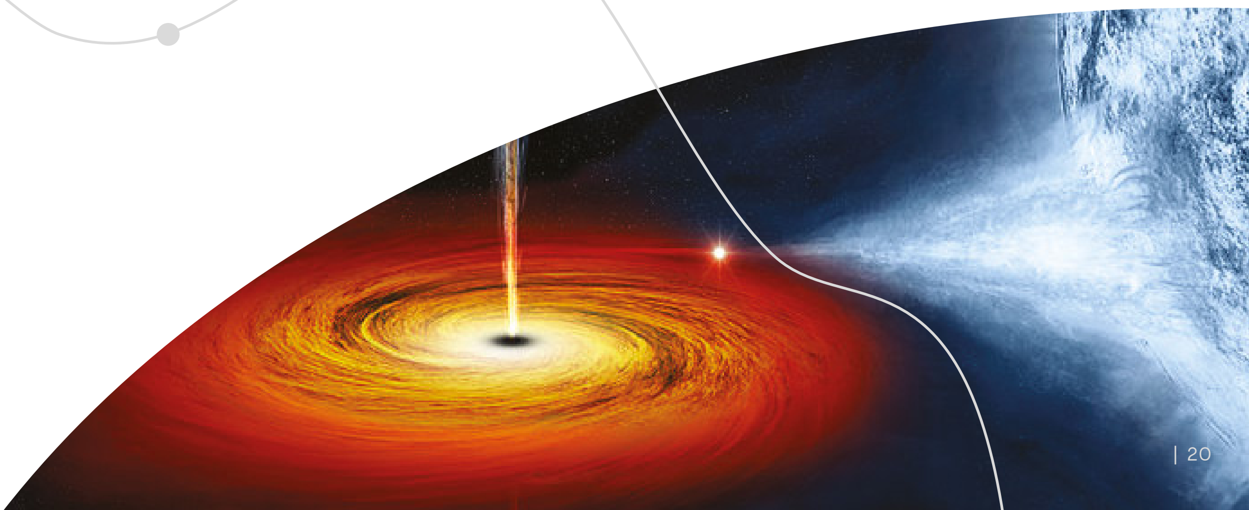
To appreciate the relative size of the normal stars and black holes.

COMMENTS

This activity visualizes the size of a black hole’s event horizon with comparisons to some common objects.

INSTRUCTION

https://astrosociety.org/edu/publications/tnl/24/blackhole4.html



A MENTAL SCALE MODEL OF A BLACK HOLE'S SIZE AND LOCATION IN THE MILKY WAY GALAXY

AGE 11+

LEARNING OBJECTIVES

The model relates the size and scale of astronomical objects to objects on Earth (e.g. an Oreo, a football stadium) to create a context for understanding the size, scale, and location of black holes in the Milky Way galaxy.

COMMENTS

Make sure the audience differentiates between galaxy, solar system and the Universe before constructing the scale model.

INSTRUCTION

- http://www.astc.org/exhibitions/blackholes/BH_TeacherEdGuide.pdf (Page 7-11)
- https://www.dropbox.com/s/pecedib4xh2gar4/astc%20org.pdf (Page 7-11)

PAPER MODEL OF A BLACK HOLE BENDING LIGHT

AGE 12+

LEARNING OBJECTIVES

To make a paper model of black hole and demonstrate how light is bent by a black hole.

COMMENTS

A powerful illustration to how straight lines (like light) are bent in the vicinity of a black hole.

INSTRUCTION

http://www.geoffreylandis.com/blackhole_models/paper_blackholes.html

04 SPAGHETTI FICATION

SPAGHETTIFICATION – FATE OF EVERYTHING FALLING INTO A BLACK HOLE

AGE 6+

LEARNING OBJECTIVES

To understand the effect of the extreme gravity from a black hole such that an object can be stretched out i.e. spaghettification, when it falls into a black hole.

COMMENTS

Good way to illustrate the effect of gravity in causing the stretching (spaghettification) of an object.

INSTRUCTION

- http://www.sjsu.edu/education/docs/mcc/Spaghettify.pdf
- https://www.dropbox.com/s/8h52jdkfnnkr529/sjsu%20edu.pdf?dl=0

SPAGHETTIFIED ASTRONAUT

AGE 6+

LEARNING OBJECTIVES

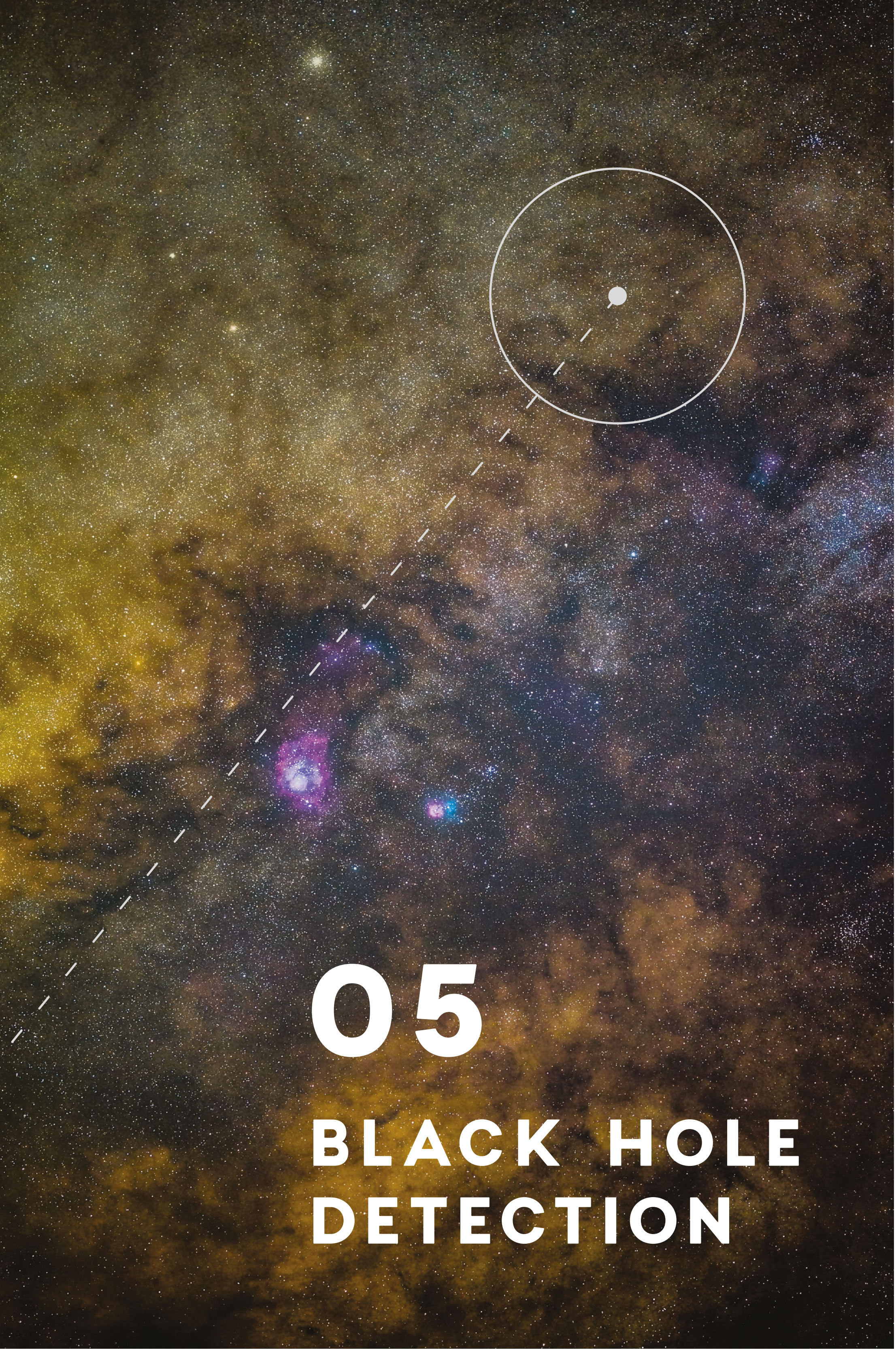
To visualize how an object is stretched out during spaghettification when fallen into a black hole.

COMMENTS

Simple activity making a flip book to visualize spaghettification. However, the activity does not explain how spaghettification occurs.

INSTRUCTION

- https://www.cfa.harvard.edu/seuforum/einstein/resources/JourneyBlackHole/JourneyBlackHoleManual.pdf (Page 37-39)
- https://www.dropbox.com/s/3izytmw42aasvec/cfa%20harvard.pdf?dl=0 (Page 37-39)



05 BLACK HOLE DETECTION

DETECTING A BLACK HOLE THROUGH ACCRETION

AGE 6+

LEARNING OBJECTIVES

Understand that a black hole can form an accretion disk that emits light, allowing it to be detected.

COMMENTS

The activity requires a space for the activity to be conducted safely in the dark.

INSTRUCTION

- https://imagine.gsfc.nasa.gov/educators/programs/bigexplosions/activities/BlackHoles.pdf (Page 8-9)
- https://www.dropbox.com/s/fy3lcfzkgrmmmxl/imagine%20gsfc.pdf?dl=0 (Page 8-9)

SPOTTING A BLACK HOLE BASED ON THE ORBIT OF STARS

AGE 6+

LEARNING OBJECTIVES

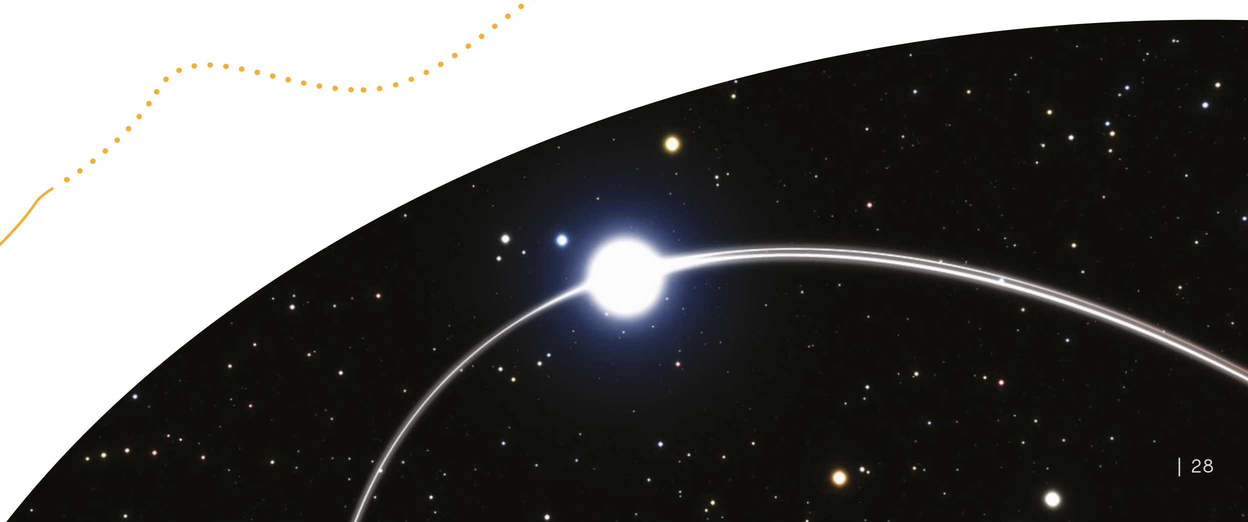
To illustrate where a black hole could be, nearby stars can appear to orbit around nothing, but in fact there is a hidden black hole that causes the stars to keep this orbit.

COMMENTS

The activity requires a free space for activity to be conducted in the dark safely. Alternatively, white or bright color shirt can be used to represent stars instead of glow stick if dark room is not available.

INSTRUCTION

- https://www.cfa.harvard.edu/seuforum/einstein/resources/JourneyBlackHole/JourneyBlackHoleManual.pdf (Page 25-28)
- https://www.dropbox.com/s/3izytmw42aasvec/cfa%20harvard.pdf?dl=0 (Page 25-28)



STARS ORBIT AROUND A BLACK HOLE, ILLUSTRATED BY THE ATTRACTION OF LOOSE BALL BEARINGS TO A HIDDEN MAGNET

AGE 6+

LEARNING OBJECTIVES

Using magnets and loose ball bearings to understand the effect black holes have on nearby stars

COMMENTS

Simple and straightforward activity to show how stars orbit, are captured or deflected by a black hole.

INSTRUCTION

- https://nightsky.jpl.nasa.gov/docs/BHManual.pdf (Page 86-93)
- https://www.dropbox.com/s/j4n919ey9hzikly/Activity%20guide%20-%20Nightsky.pdf?dl=0 (Page 86-93)

RECORDING AND INTERPRETING DISTORTED IMAGES AS SEEN THROUGH GRAVITATIONAL LENSING

AGE 8+

LEARNING OBJECTIVES

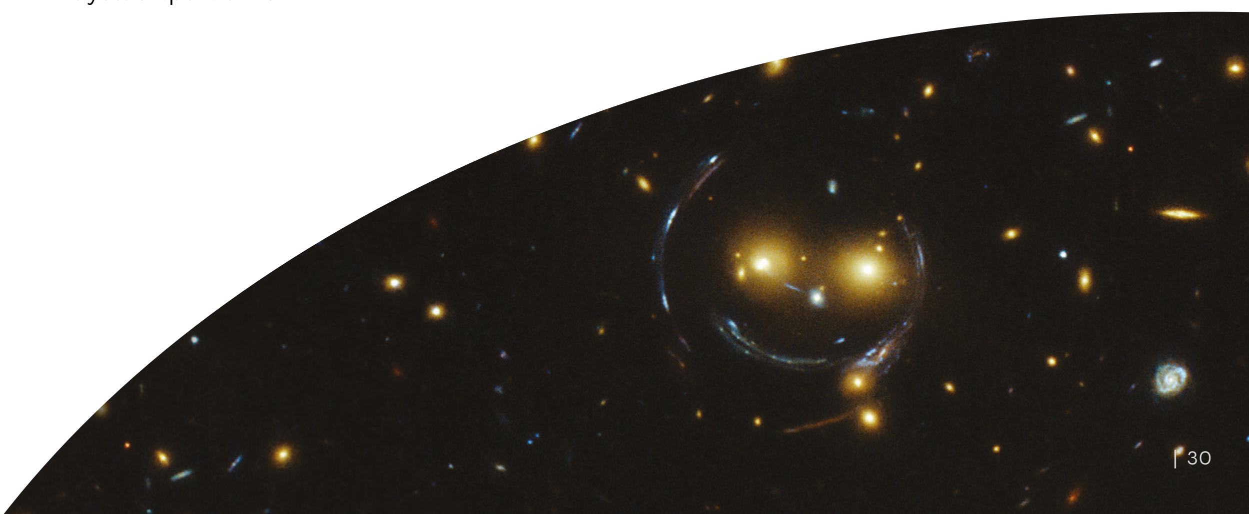
Understand how images appear after being gravitationally lensed (as seen through a curved glass) and how astronomers use the distorted images to reconstruct the original image.

COMMENTS

This activity allows students to realize the gravitational lensing phenomenon by themselves.

INSTRUCTION

- ftp://gemini.haystack.mit.edu/pub/edu/pcr/blackholes/Physics%20Modules/04%20-%20The%20Electromagnetic%20Spectrum%201%20-%20Gravitational%20Lensing/03%20-%20Gravitational_Lensing_Activity.pdf
- https://www.dropbox.com/s/tno9fa8qhs4mb8y/gemini%20haystack.pdf?dl=0



THE GRAVITY OF A BLACK HOLE GIVES AWAY ITS LOCATION, ILLUSTRATED WITH MARBLES AND MAGNETS

AGE 11+

LEARNING OBJECTIVES

Understand that the gravity of a black hole could allow it to be detected.

COMMENTS

- The principle behind gravitational lensing is illustrated; as light passes near a black hole, it gets deflected.
- Develop observation and analytical thinking skills.

INSTRUCTION

- https://www.cfa.harvard.edu/seuforum/einstein/resources/JourneyBlackHole/LensingDemos.pdf (Page 7-9)
- https://www.dropbox.com/s/gewbywfdzbtrkbq/cfa%20harvard%20lensing.pdf?dl=0 (Page 7-9)

GRAVITATIONAL LENSED IMAGES AS SEEN THROUGH THE BASE OF A WINE GLASS

AGE 11+

LEARNING OBJECTIVES

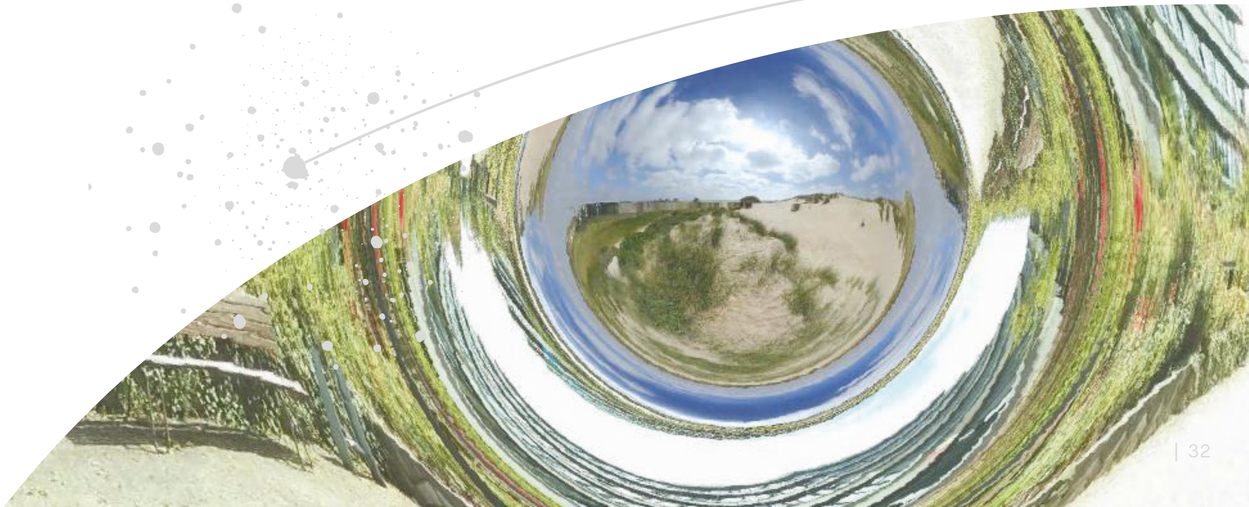
To familiarize with how light and images are distorted through gravitational lensing by a black hole.

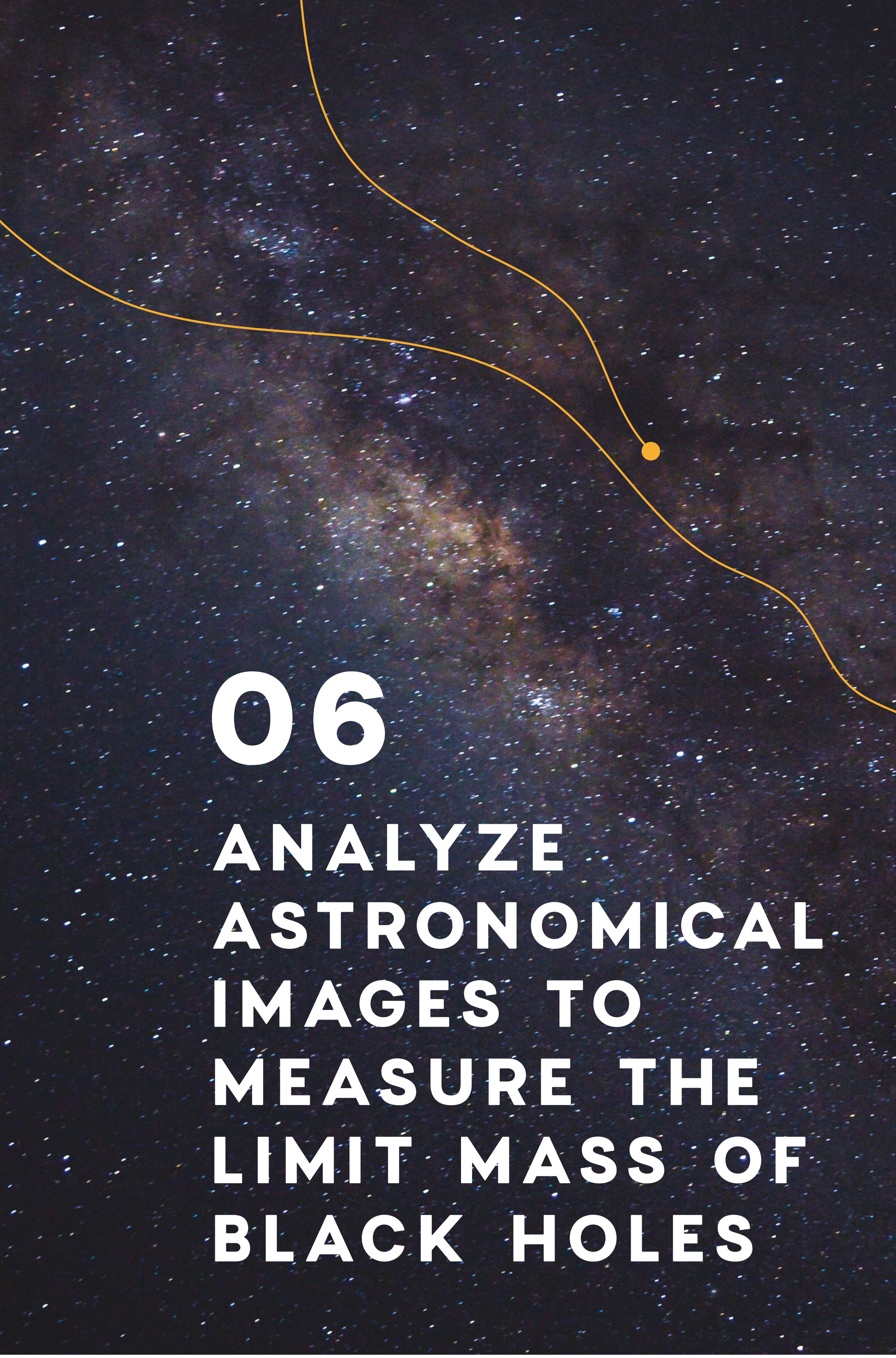
COMMENTS

This activity requires the base of a wine glass to be cut off. However, a similar activity can be conducted by observing through the base without separating it from the glass.

INSTRUCTION

- https://www.cfa.harvard.edu/seuforum/einstein/resources/JourneyBlackHole/LensingDemos.pdf (Page 2-6)
- https://www.dropbox.com/s/gewbywfdzbtrkbq/cfa%20harvard%20lensing.pdf?dl=0 (Page 2-6)





06

ANALYZE ASTRONOMICAL IMAGES TO MEASURE THE LIMIT MASS OF BLACK HOLES

BLACK HOLES: GRAVITY'S RELENTLESS PULL

AGE 10+

LEARNING OBJECTIVES

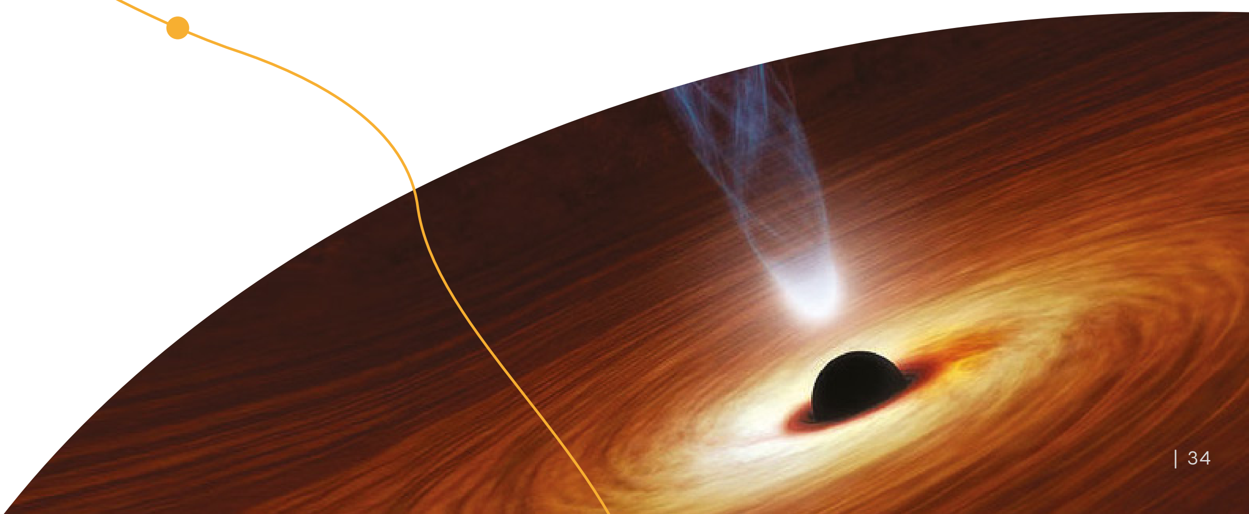
An online interactive multimedia resource with activities such as locating black holes in the Milky Way, determining the mass of black hole by orbit of stars, etc.

COMMENTS

A fast internet connection is required.

INSTRUCTION

http://www.nea.org/tools/lessons/56124.htm



EVALUATING BLACK HOLE CANDIDATES

AGE 15+

LEARNING OBJECTIVES

Students explore stellar mass black hole candidates just as scientists do, and conduct their own research project by observing with research quality robotic telescopes.

COMMENTS

Advanced activity allowing students to roleplay as of a researcher.

INSTRUCTION

http://graasp.eu/ils/57221f65c3ddb608c844b6c3/?lang=en

IMAGE CREDIT

P.	PHOTO
00	ESO/M. Kornmesser, eso.org
01	NASA, unsplash.com
02	Joel Filipe, unsplash.com
03	NASA, unsplash.com
05	Bryan Goff, unsplash.com
06	Yuelanliu, pixabay.com
07	UNAWE, flickr.com
08	UNAWE, flickr.com
09	UNAWE, flickr.com
10	Pxhere.com
11	NASA, imagine.gsfc.nasa.gov
12	NASA/GSFC/Dana Berry, wikimedia.org
13	Helmut Karl Wimmer, wikimedia.org
14	Jeremy Thomas, unsplash.com
15	Garyperlman, wikimedia.org
16	Martin, flickr.com
17	Roma, fenixclub.com
18	AstroEdu, astroedu.iau.org
19	Jason Blackeye, unsplash.com
20	NASA/CXC/M.Weiss, wikimedia.org
21	Thomson200, wikimedia.org
22	UNAWE, flickr.com
23	NASA, unsplash.com
24	Airman 1st Class Donald Hudson, yokota.af.mil
25	UNAWE, flickr.com
26	Bryan Goff, unsplash.com

P.	PHOTO
27	UNAWE. flickr.com
28	European Southern Observatory
29	UNAWE, flickr.com
30	NASA Jet Propulsion Laboratory
31	UNAWE, flickr.com
32	Corvin Zahn, spacetimetravel.org
33	Max McKinnon, unsplash.com
34	NASA/JPL-Caltech, wikimedia.org
35	UNAWE, flickr.com
36	Benjamin Davies, unsplash.com

EDITORS

Han Tran and Pedro Russo, Leiden University
Thomas Russell, University of Amsterdam

DESIGNER

Aneta Margraf-Druć

www.iau.org/astroedu
www.unawe.org

Universiteit Leiden
The Netherlands

Netherlands Organisation for Scientific Research

UNIVERSITY OF AMSTERDAM

ASTROEDU
Peer-reviewed Astronomy Education Activities