FRONTIERS

Bringing Nobel Prize Physics in the Classroom

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EGO European Gravitational Observatory
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Overview of this lesson pack:

Name of the activity	**Black hole M87: "*An image that made history*"**
Topics introduced	● how spacetime is curved ● what a black hole is ● the first time man took image from a black hole ● how significant collective work is for big scale science achievements
Curriculum Connection	GREECE: According to **Primary School Natural Science Curriculum for the New School**: *"It is important for teachers to recognise the deficit in any teaching, which is anchored in the textbook and makes little use of the "minds on" and "hands on" approaches. The ambition of this Curriculum, in conjunction with the teacher guide, is to help them design effective learning environments and active learning communities for the Natural Sciences rather than just providing information".* More specific, Natural Science Curriculum for Primary School suggest to: ● Familiarize the students with the s**cientific methodology** ● Cultivate a team and collective spirit of work to **achieve common goals** ● Involve students in **solving real problems with personal meaning** for themselves (think globally, act locally) ● Take advantage of **use of ICT** in Natural Sciences
Reference Demonstrator	Discovering Alien Worlds
Age of students	12 years old primary school students
Duration	7 didactic hours: ● 2 d.h. to watch.ppt presentation and youtube videos. (Includes discussion afterwards) ● 2 d.h. to construct the black hole model ● 2 d.h. create and solve the black hole puzzle ● 1 d.h. to fill in the group worksheet

Overview of this lesson pack:

Type of activity	*"minds on" and "hands on" approaches*: material handling, puzzle solving, argumentation use, critical thinking, problem solving
Description of activity	Teacher activities: • make a powerpoint presentation explaining scientific concepts, such as, black holes and spacetime • present a youtube video showing how the M87 black hole image was created and how difficult and impossible project was considered • present a youtube video showing how to construct a black hole model and give children instructions with details on each step of “building” process • clarify how each group is going to work and each student’s responsibilities • give a short worksheet for each group with questions referring to basic notions mentioned on powerpoint presentation • explain the procedure on how to make a puzzle of a black hole image and send it via internet to another group to solve it (to simulate how scientists worked to make the black hole image) • supervise all student’s activities and help when necessary Student activities: • watch teacher’s powerpoint • watch two relevant youtube videos chosen by the teacher • construct a simplified black hole model • use and improve their IT skills: taking photos of their model, sending and printing photos • solve a black hole puzzle made from another group photos • complete the group worksheet
Equipment requirements	• projector, pc with internet connection for ppt presentations and youtube videos and a printer • mobile phone or tablet with camera to take photos of the black hole model • email or messenger accounts to send images between working groups • worksheet for each group • foam ball, metalic ring, cardboard paper, glue, tripod, printer, scissors.
Prior knowledge for students	**From classical physics:** • newtonian concept of gravity • optical phenomena (how shadows form, light follows straight lines) • what a star is **From modern physics:** • physics laws collapse when it comes to black holes

Background and overview:

This presentation introduces students to the major scientific achievement of imaging the M87 black hole. First, they get familiar with concepts such as spacetime curvature, as is predicted by Einstein's General Relativity Theory. Afterwards, students are introduced to basic concepts regarding black holes creation and their form. Finally, they are shown the historical M87 black hole image and get informed exactly why it is so significant for scientific community, how long it took and how much effort needed to be completed.

In addition, students, working in groups, will be given instructions and materials to construct their own black hole model based on the M87 black hole image. Finally, they construct (also in group work) a puzzle based on their black hole model photographs. Then, they send via email the stirred pieces to another group to solve the puzzle and they download and print another group's photos to solve theirs puzzle.

Finally, students working cooperatively have to complete a working sheet based on the notions mentioned on the presentation and the youtube videos.

Presentation for students

Teacher guidelines can be found in the notes attached to each slide

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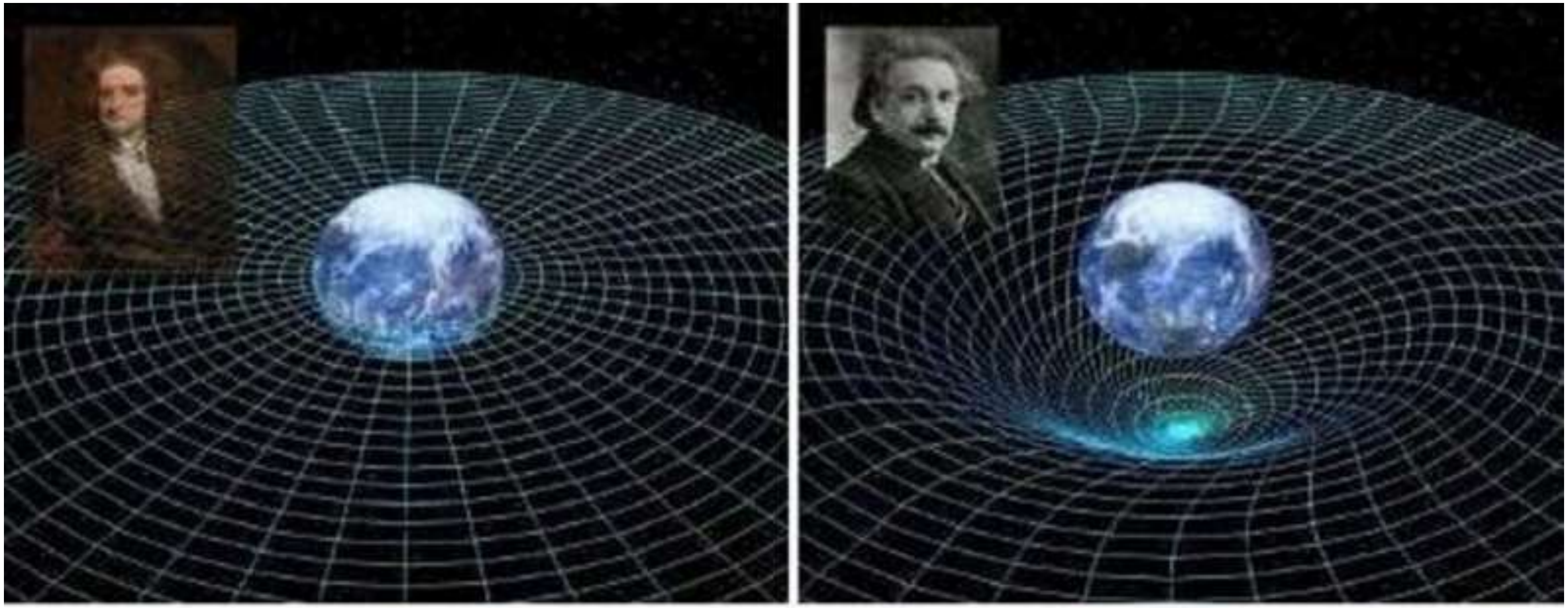
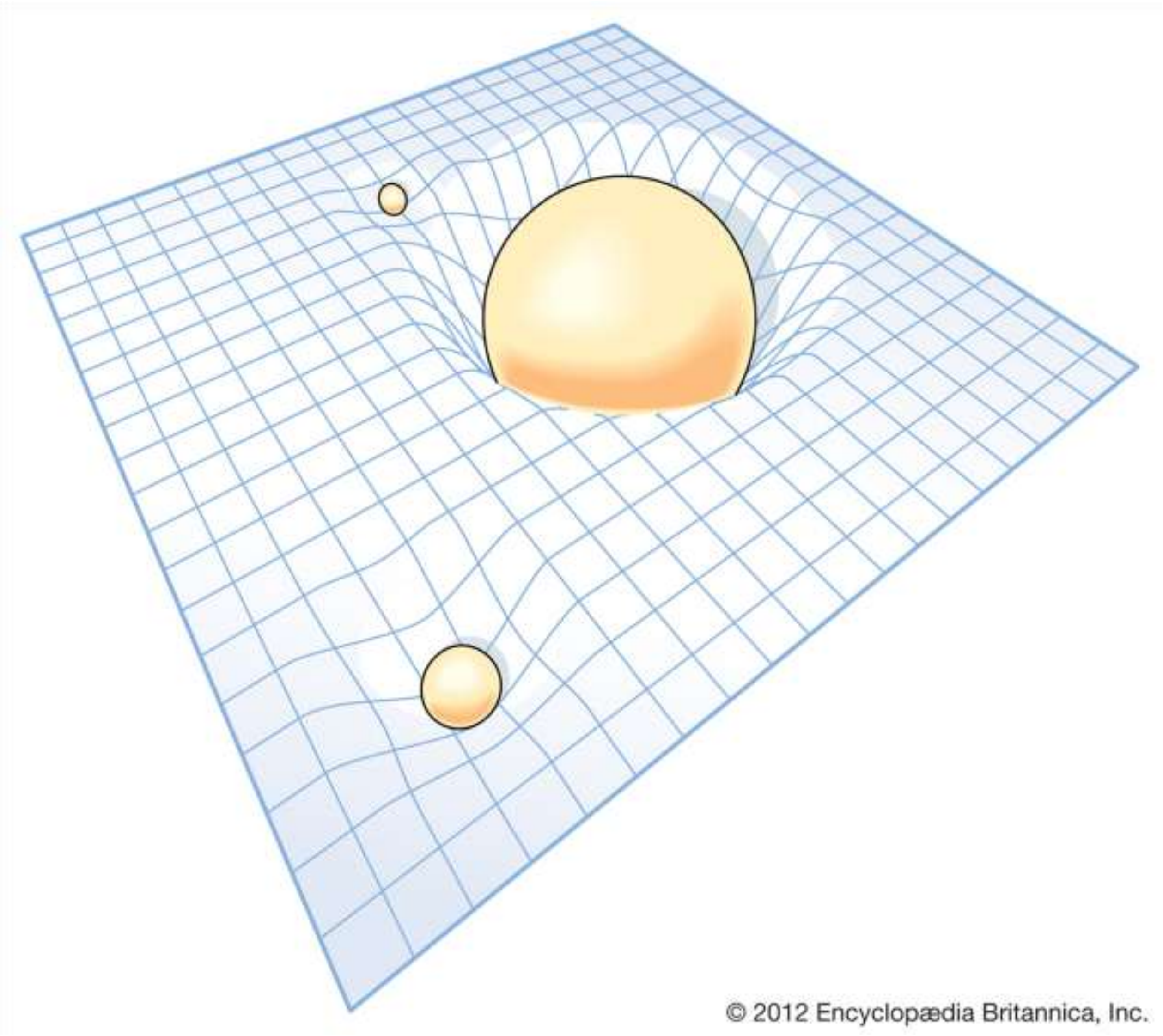
Spacetime Curvature

At 1916 Einstein published ***General Relativity*** which describes the Geometry of Space and revolutionise the way we think of the gravitational force. According to General Relativity **spacetime wraps** around massive objects.



Newton's fixed space

Einstein's flexible space-time



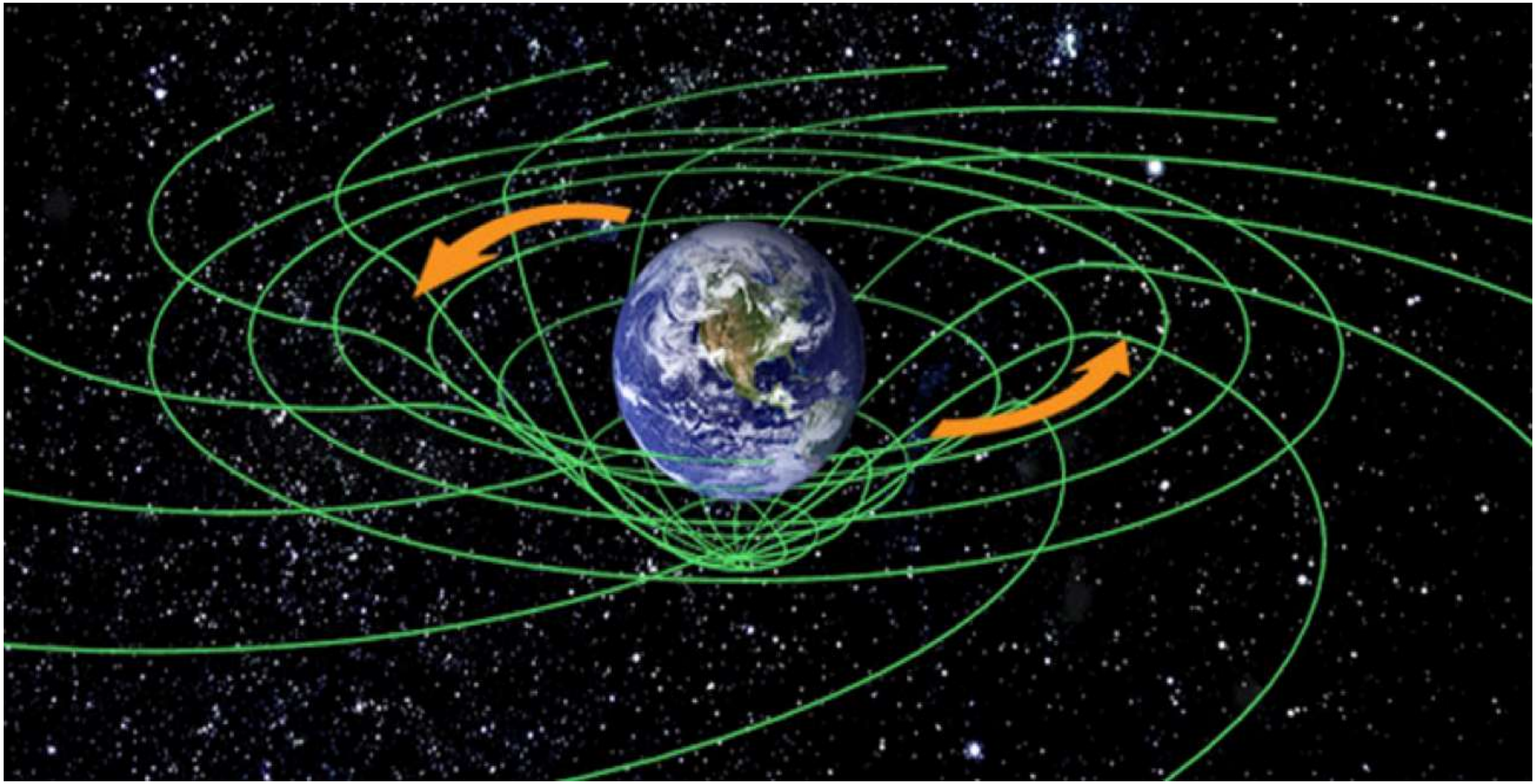
spacetime wraps around massive objects:

black holes

stars

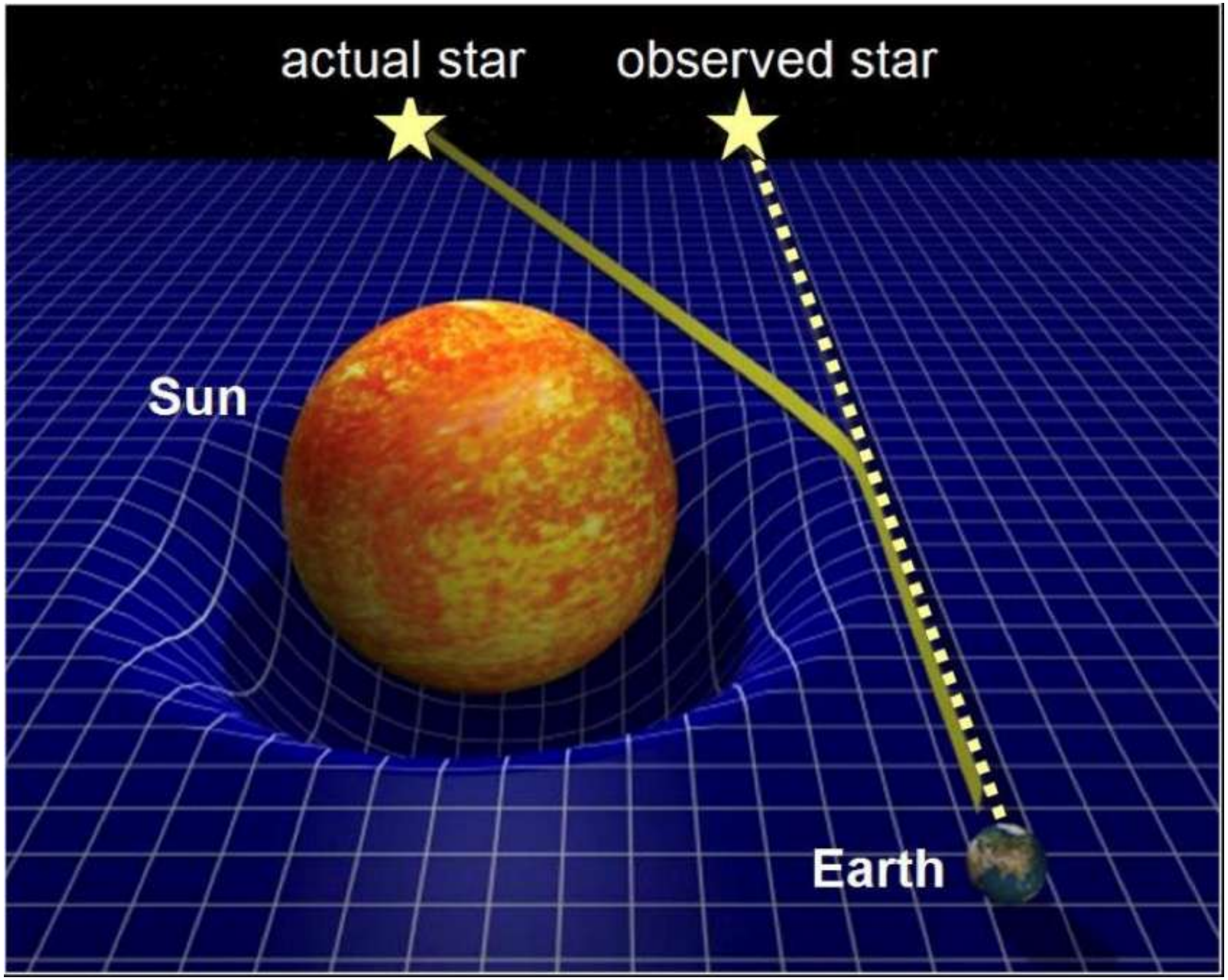
planets

Einstein’s General Theory of Relativity warping of spacetime produces the effects of gravitational force



The curvature of the surface draws other objects inwards.

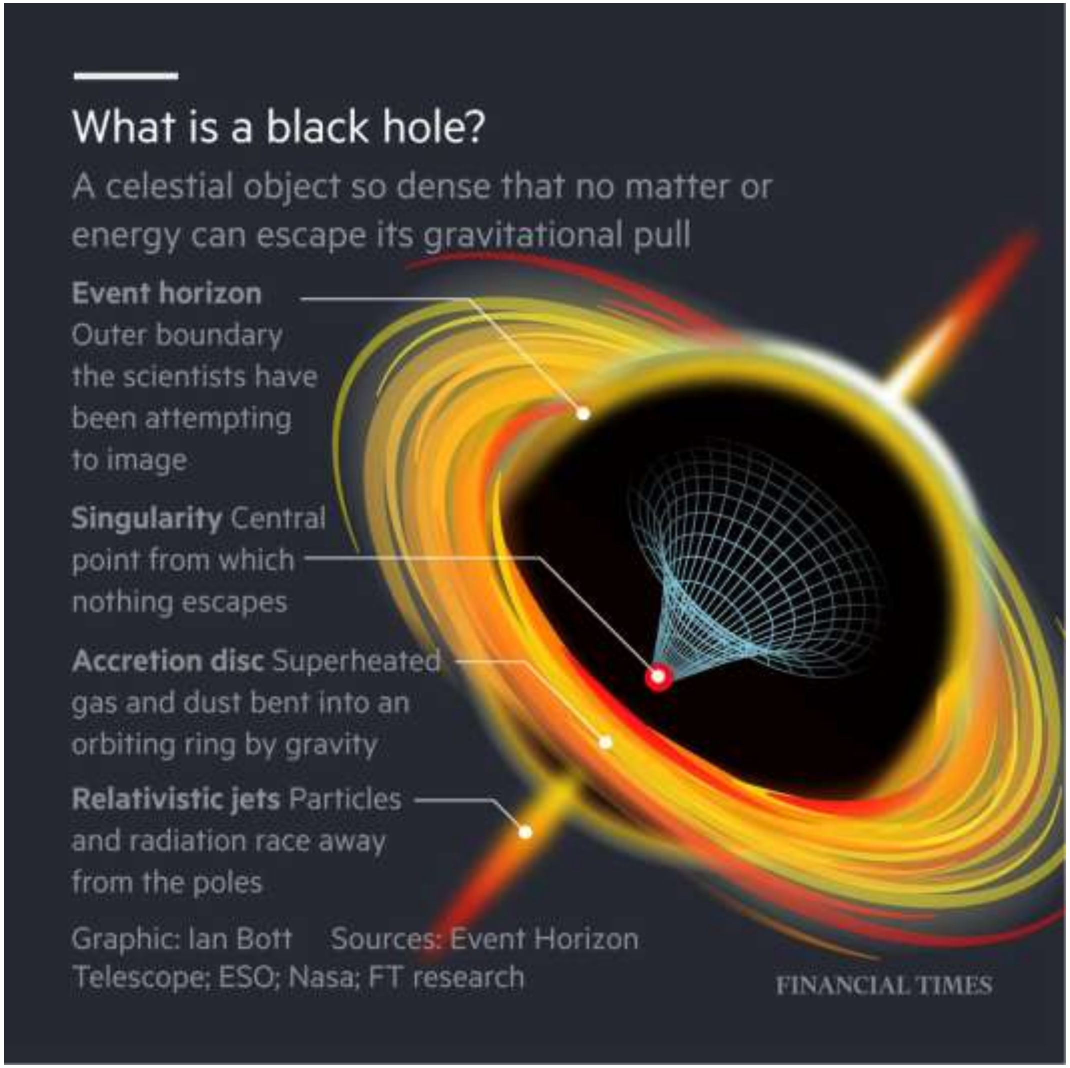
The **Eddington experiment**

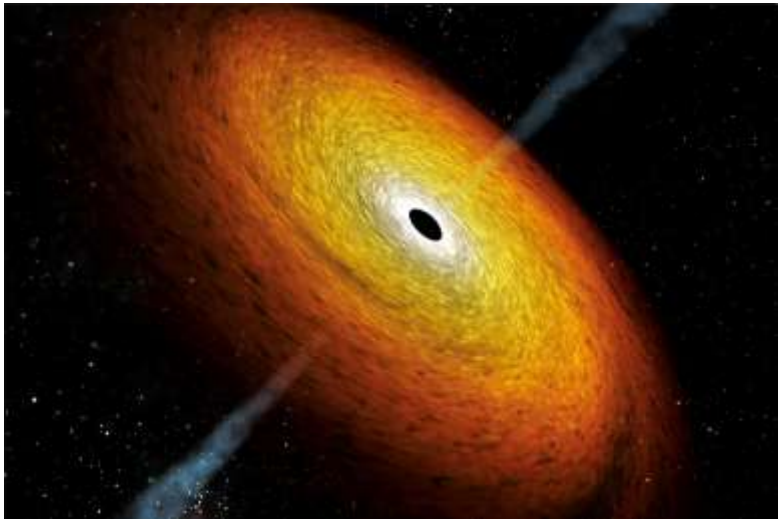


watch

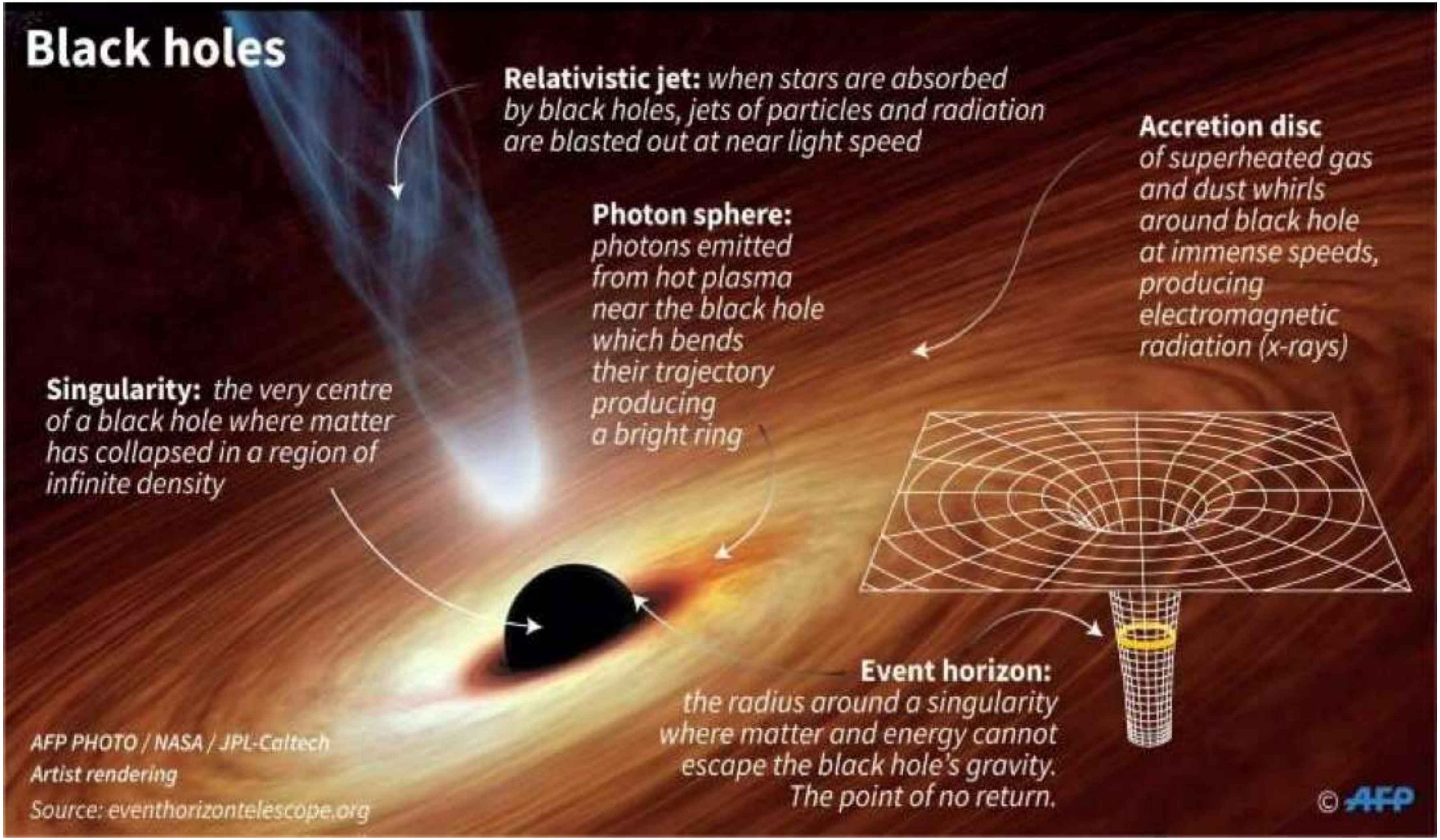
- In **1919** the General Relativity Theory was tested for the first time by a **historical experiment**.
- The aim of Eddington's experiment was to measure the gravitational **deflection of starlight passing near the Sun during a total solar eclipse** at 1919.

Black Holes

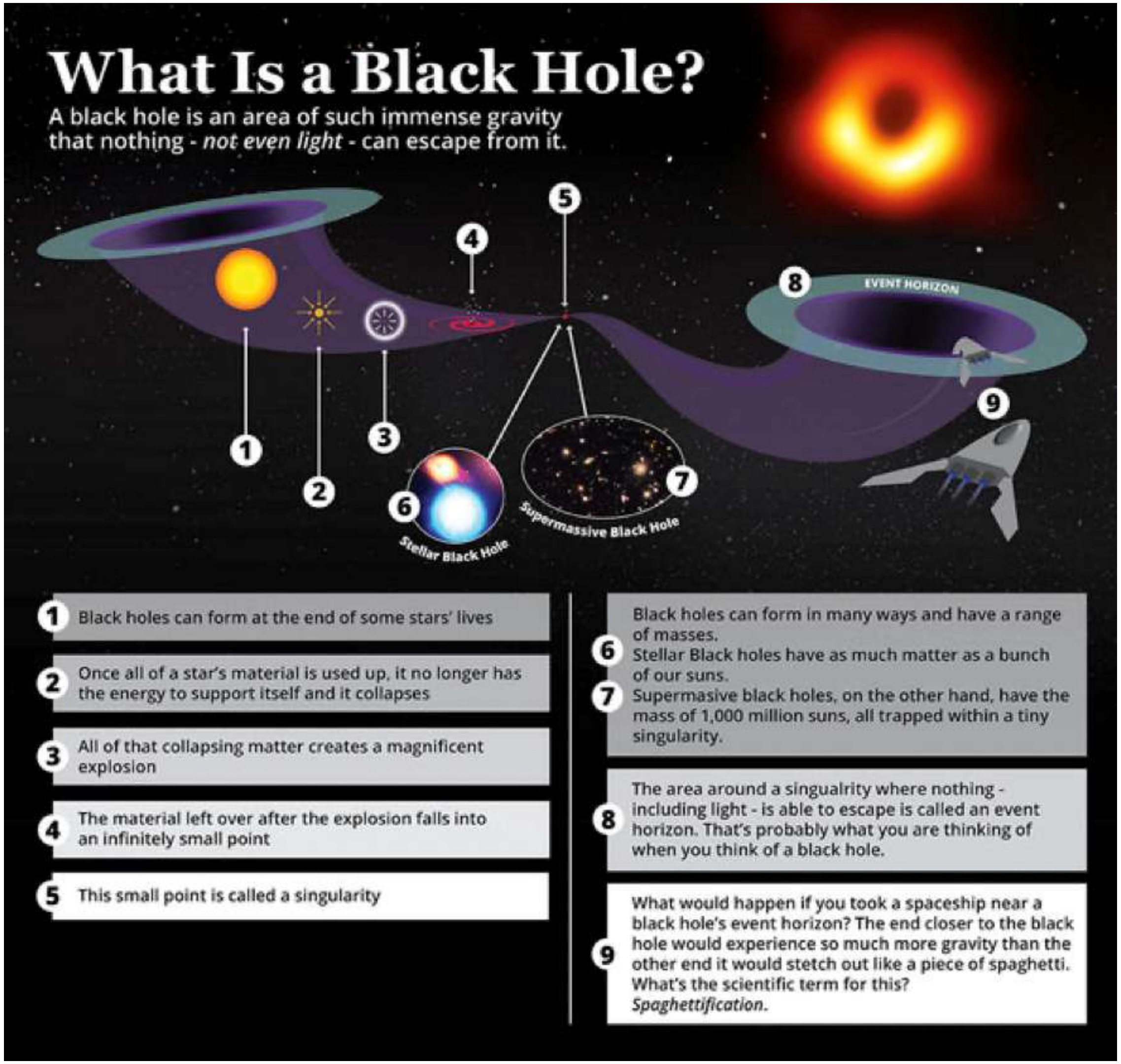

What is a black hole?
A celestial object so dense that no matter or energy can escape its gravitational pull
Event horizon Outer boundary the scientists have been attempting to image
Singularity Central point from which nothing escapes
Accretion disc Superheated gas and dust bent into an orbiting ring by gravity
Relativistic jets Particles and radiation race away from the poles
Graphic: Ian Bott Sources: Event Horizon Telescope; ESO; Nasa; FT research
FINANCIAL TIMES



What a strange object a black hole is

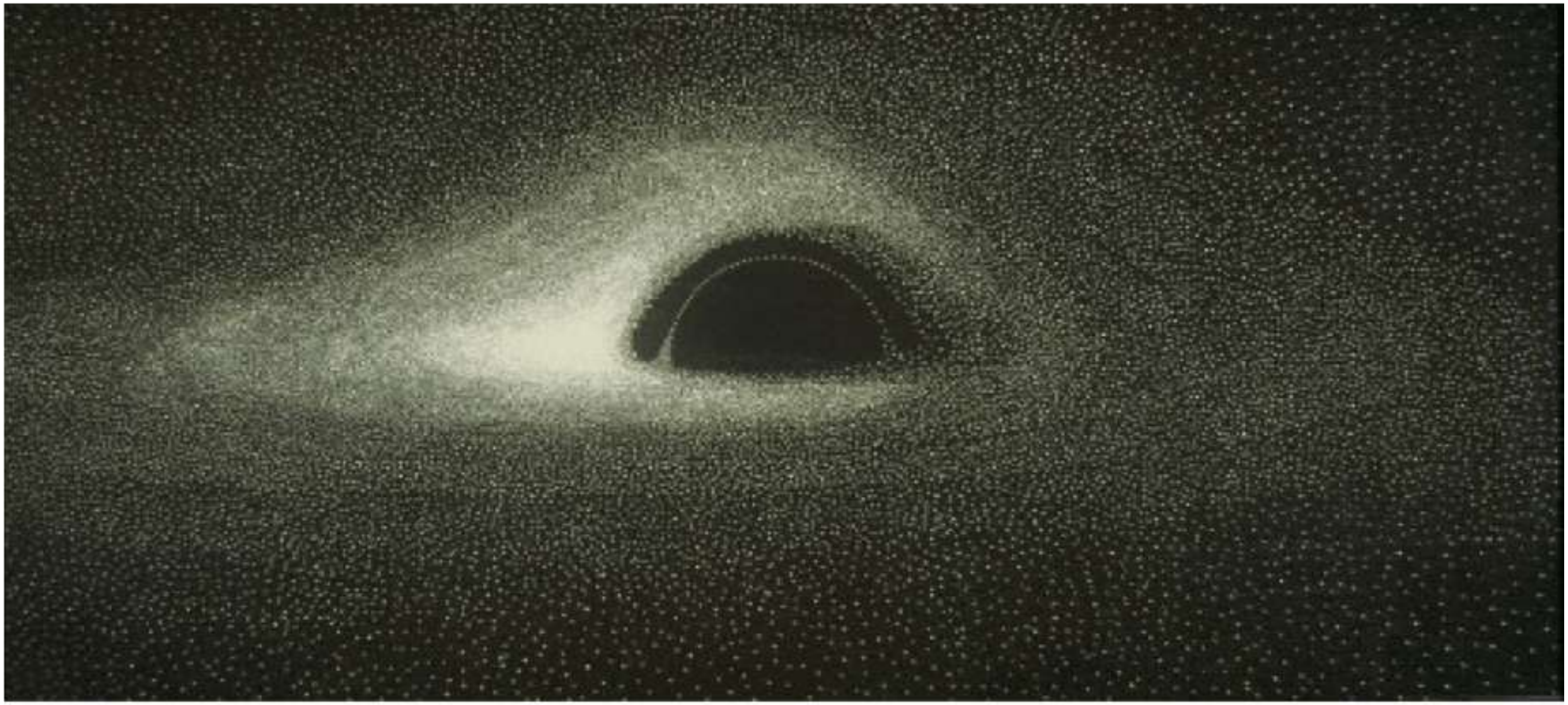


How a black hole is created



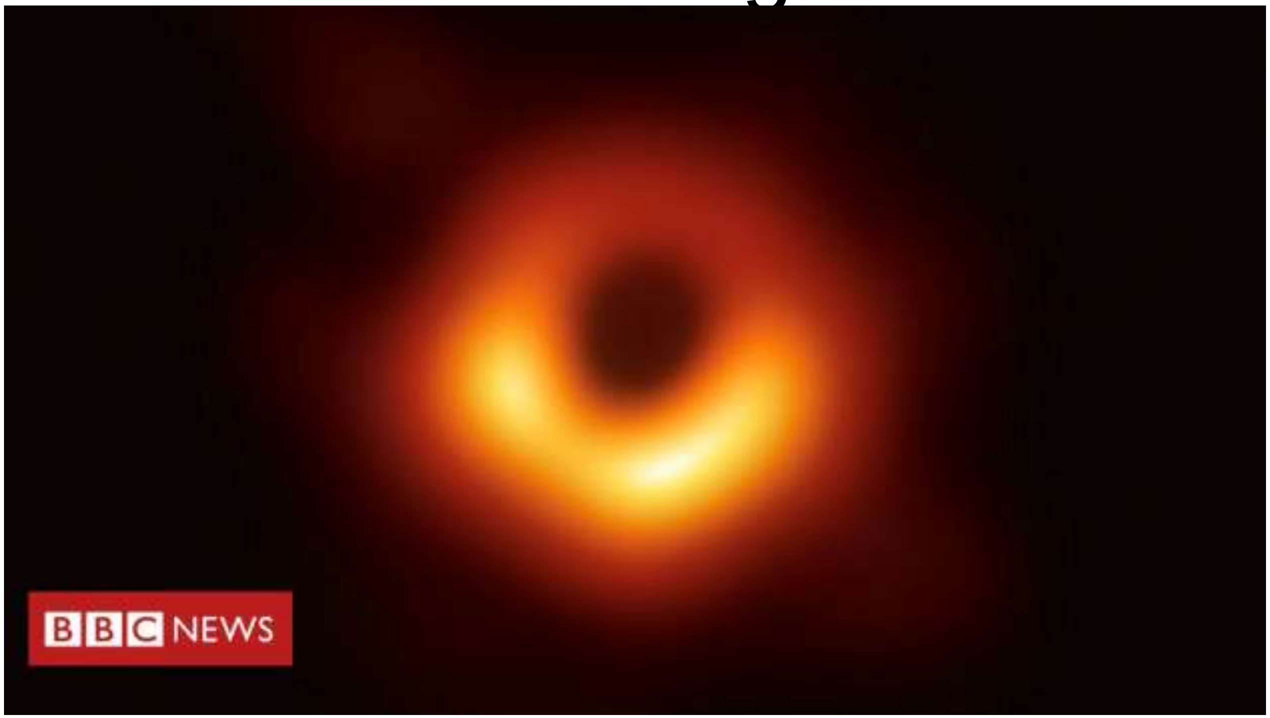
- A black hole is a point in spacetime -called **Singularity**- where once was the core of a giant star contained matter more than 2.5 solar masses.
- In the final phase of its evolution, the star lost the battle with gravity, causing its material to collapse and be compressed more than a neutron star.
- Black holes supposed to be observed in the center of every galaxy

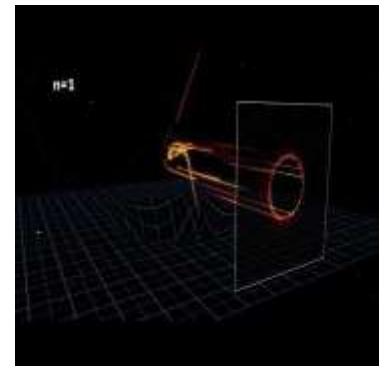
Steven Hawking in 1974 realised that black holes are not completely black.



The first ever simulation of a black hole, by Dr. Jean-Pierre Luminet in 1979

What the real image of a black hole is



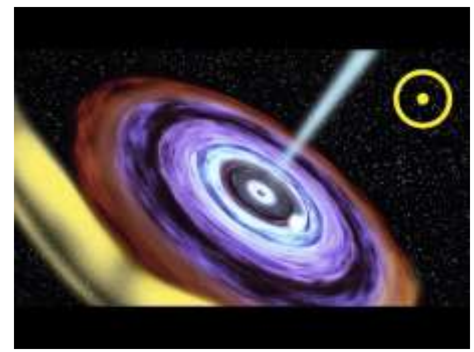


- It was found in a **galaxy** called **M87** and is larger than the size of our entire Solar System.
- The black hole is 500 million trillion km away and it was captured by the **Event Horizon Telescope** (EHT), a network of eight linked telescopes around the world.
- *"It has a mass 6.5 billion times that of the Sun. And it is one of the heaviest black holes that we think exists. It is an absolute monster, the heavyweight champion of black holes in the Universe"*, says **Prof Heino Falcke**, of Radboud University in the Netherlands, who **proposed the experiment**.

Watch the history and the importance of the M87 black hole picture:

watch how to construct a simplified black hole model:

Additional very interesting videos:



Group Worksheet for Black Holes and Spacetime

Group 's name:____

Date:_______________________________

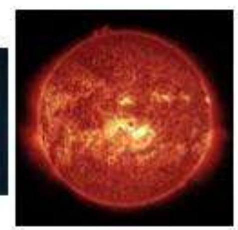
(You have to collaborate with your team and you are allowed to use the powerpoint presentation, the youtube videos, google, or any other source you wish)

1. Fill in the missing word to find **Black Hole Acrostic**

M87 black hole is .... times as massive as the sun	
Event Horizon Telescope is a network of eight ... telescopes around the world	
... Einstein proposed the General Relativity Theory	
General Relativity says Spacetime is ...	
... Schwarzschild proposed the modern version of a black hole in 1915 and name the core of it "Singularity"	
The radius around a singularity where matter and light cannot escape is called Event ...	
Spacetime warps around heavy ...	
... can be curved due to spacetime	
The first historical experiment that tested General Relativity during 1919 's total eclipse was ...	

2. Choose which of the images show black holes and which don't. How do you explain your choice. Can you recognize any other object?





3. In this image can you mark where the singularity, the event horizon and the jets are (draw a line with an arrow to indicate each and write outside the image)

4. Choose the right answer

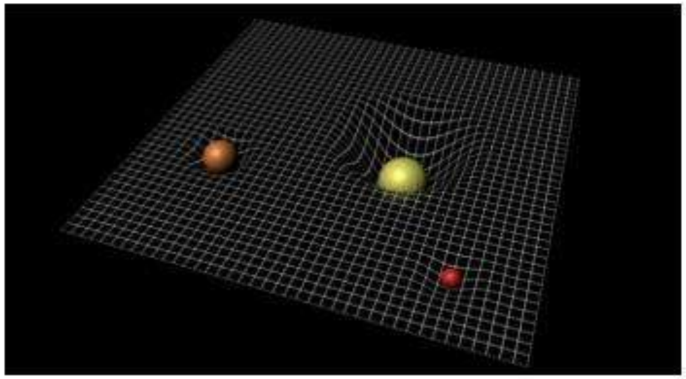
a) Spacetime is curved around:

- objects with big masses
- only at black holes
- no where in the universe

b) Spacetime

- is a (central) gravity force
- operates like gravity because of the curvature
- obligates planets to follow orbits around the sun
- makes light goes slower and even stops it

c) which mass (orange, yellow or red) warps spacetime more and why?



Thank you