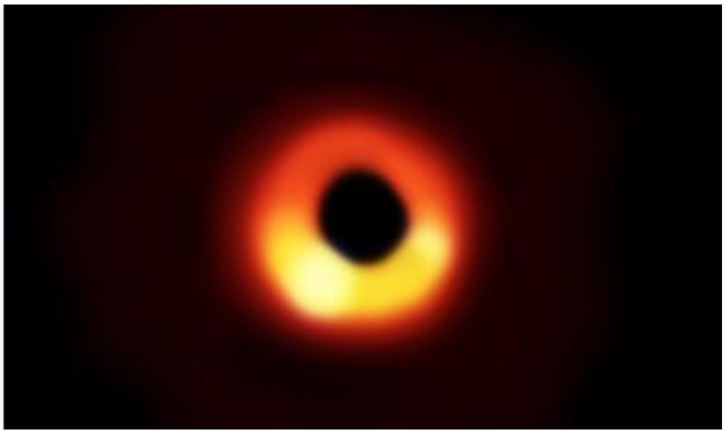
PICTURE 1: BLACK HOLES



BLACK HOLES

- OONA HOORNAERT, GAËLLE DUMON, MARTHE DERMAUT, ANNA FONTANA, ALESSANDRO FERDORI & SARA GULMINELLI
- De Bron Tielt, Liceo Statale "G. Ricci Curbastro"

1 What are black holes?

A black hole is an object of such immense gravity that nothing - not even light - can escape from it. Only three properties of black holes persist: mass, spin, and electric charge. As incredible as that may sound, our current understanding of gravity predicts exactly this. The singularity is a theoretical location in space at the centre of a black hole that has no volume but contains all of the object's mass. We can compare this with singularity in maths: a singularity is a point in mathematics where a mathematical object is no longer defined, or where the mathematical object fails to behave in a certain way.

This centre is where the black hole actually exists. Anything that gets too close to a black hole, whether it's a star, a planet, or a spaceship, will be stretched and squished like flexible in a hypothesized process called spaghettification. Rather, objects fall into them in the same way that they fall toward anything that has gravity, such as the Earth.

2 3 types of black holes and how are they formed

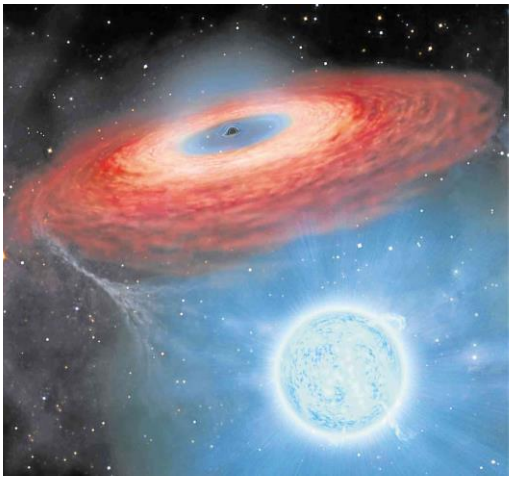
Before you can learn something about black holes, it is important to have some knowledge about stars. Indeed, some black holes are formed after the collapse of a star. Smaller stars typically turn into a more condensed star upon collapse, such as a white dwarf star. If a larger star collapses, it results in a black hole.

PICTURE 2: Earth, Moon and Black hole.

The first ones may have formed immediately after the Big Bang. These are called the primordial black holes. They are very tiny and less massive than the sun. However, scientists think that there are still some left, but these have not yet been discovered.

2.1 Stellar-mass black holes

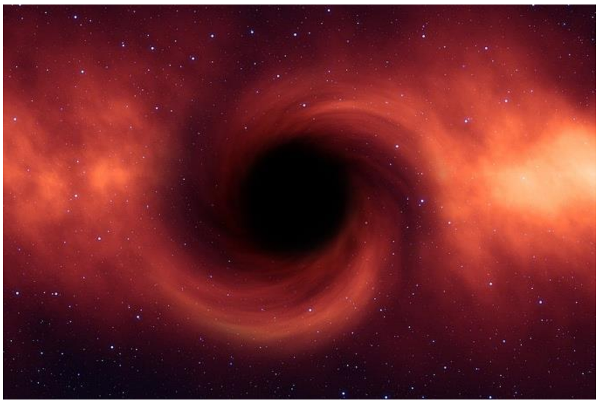
They are formed by the gravitational collapse of a supernova and mass between a few and 100 times the mass of the sun.



PICTURE 3: Stellar-mass black holes

2.2 Intermediate-mass black holes

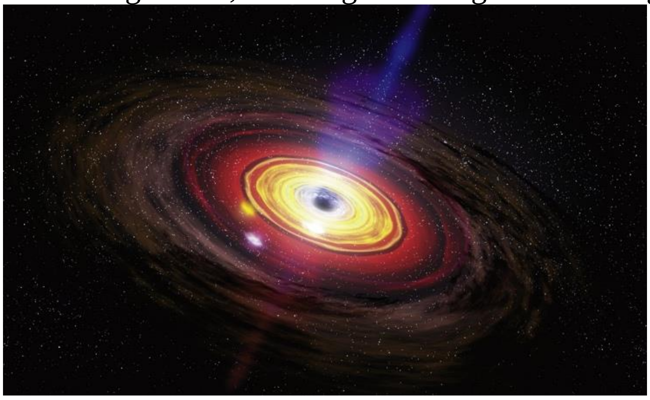
Intermediate black holes, with masses halfway between stellar and supermassive black holes, are thought to be an evolutionary stage in the evolution of these cosmic heavyweights, according to astronomers. Intermediate black holes are fascinating because they may hold the key to figuring out how these weird creatures develop and evolve throughout time. These cosmic juniors, on the other hand, remain a mystery, as they appear to be in low supply across the universe.



PICTURE 4:Intermediate-mass black holes

2.3 Supermassive black holes

These cosmic monsters are thought to lurk at the heart of most galaxies, with masses equal to billions of suns. Scientists are puzzled as to how such massive black holes form. Once born, these giants collect mass from the dust and gas that surrounds them, which is plentiful in the centre of galaxies, allowing them to grow even larger.



PICTURE 5: Supermassive black holes

3 Directly and indirectly observation of black holes

Now that we have clear in our minds what black holes are, and how they are formed, we will try to understand better how they can be observed.

First, we have to say that we can’t talk of a perfect direct observation of this physic phenomenon. A black hole isn’t called ‘black hole’ for no reason. It is an area in space where gravity is so strong that all nearby matter is sucked in and nothing can escape, not even light. Since black holes don't emit any radiation, they are invisible.

However, a black hole does exert an influence on its surroundings and can therefore be observed indirectly. For example, astronomers can measure the movement of stars and clouds of gas in the black hole's gravitational field. From the measured velocities and distances, the mass of the 'central object' can be calculated. If that mass is very large, and if no radiation is received from that central area, it must be a black hole. The matter that falls into the black hole can also be observed. In most cases, the matter first accumulates in a flattened, spinning disc - a so-called accretion disc. The gas in the disc becomes extremely hot (due to friction and pressure) and emits X-rays. Many X-ray sources in the sky turn out to be black holes.

Someday, it may be possible to see the 'shadow' of a black hole. Every black hole has a certain size (the heavier the greater); the so-called horizon marks the edge of the area from which no escape is possible. With future networks of interconnected radio telescopes, it may be possible to observe this horizon. The easiest way to do this will probably be near the supermassive black hole at the core of our own Galaxy.
To observe it directly the researchers had to link up radio telescopes located all around the world and to create a virtual telescope (that has about the same size of our planet Earth), and they had to analyse every single bite of information they reached to create a series of images functional to the study of the phenomenon taken into consideration.

To conclude, the indirect observations of black holes have always been useful to find them and to study their behaviour in relation to other objects, but their direct and clear observation will be very useful in the future to study themselves out of their context.

4 Theoretical evidence of the existence of black holes

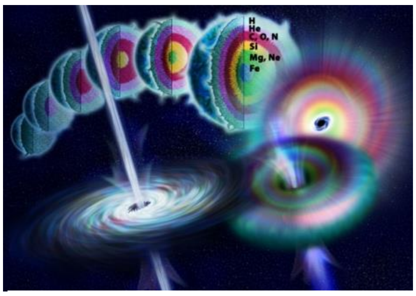
Now, we have talked about what these phenomena are and how they are formed. We studied the ways in which we can observe them. But how did scientists discover them? What are the evidences that these black holes exist? Let’s try to understand it together!

4.1 Einstein’s prediction

Schwarzschild predicted black holes as a theoretical possibility in 1916, considering them to be an inevitable consequence of Einstein's theory of general relativity. Any particle collapsing to a black hole would generate a singularity where the standard rules of physics break down.

4.2 Gamma- ray bursts

An astronomer investigated what happens to a star when it has depleted its nuclear fuel supply. The outcome is determined on the mass of the star. If the star is massive enough, its dense core will collapse into a black hole. This occurs in a matter of seconds and results in a massive release of energy in the form of a gamma-ray burst. These are the strongest and brightest explosions in the universe, and they produce as much energy as the sun will do during its entire existence.



PICTURE 6: Gamma-ray bursts

4.3 Gravitational waves

When two black holes collide, the gravitational interaction between them causes space-time ripples that spread outward as gravitational waves. We can now detect these waves because to observatories like the Laser Interferometer Gravitational-Wave Observatory. Gravitational waves are also produced by others cataclysmic events (for example colliding supernovae or neutron stars). Einstein had predicted their existence, but his hypostasis was demonstrated after his death.

4.4 Invisible companion

While the short-lived, high-energy events that create gamma-ray bursts and gravitational waves may be seen halfway across the observable universe, black holes will be nearly invisible for most of their existence. We can observe lots of events in our universe, but what happen in a black hole is a mystery for us. In fact, a black hole doesn't emit any light or radiation so it's impossible to see one of them using only a telescope. We can discover them because their gravitation had an important impact on the other stars near them. Observing the strange motion of stars, astronomers can deduce that between them there is a black hole that modify their activity. However, there is one sure-fire technique to discover the dark beasts: their gravitational impacts on other stars. Astronomers detected oddities in the motion of the two visible stars when monitoring the ordinary-looking binary system, or pair of circling stars, that could only be explained if there was a third, fully unseen object there. When the researchers calculated its mass, they realized there was only one option left. It had to be a black hole, as it was the nearest one to Earth yet identified, only a thousand light-years distant from our own galaxy.

4.5 X-ray vision

The first observable evidence for a black hole was discovered in a binary star system within our own galaxy. The system generates some of the universe's brightest X-rays. These don't come from the black hole's visible companion star or from the black hole itself. When gas enters a black hole, it releases a large quantity of energy, which may sometimes be seen as x-rays. They are created by a convergence of supercharged particles and magnetic field activity above the black hole. Astronomers can use observed star motion to determine the mass of the unknown object in Cygnus X-1. According to the most recent estimations, the dark object has 21 solar masses condensed into such a compact space that it can only be a black hole.

4.6 Supermassive black holes

Scientists noticed that the high orbital velocities of stars and gas can be easily explained if we suppose that there is a supermassive black hole that accelerate their motion using its strong gravitational field. Evidence implies that supermassive black holes, each million or perhaps billions of solar masses, have been hiding in the cores of galaxies since early in the universe's existence, in addition to black holes produced by stellar collapse. These galaxies' core black holes are surrounded by accretion disks that emit tremendous radiation at all wavelengths. There's also evidence that our galaxy contains a black hole at its core. Because the stars in that area are flying around so quickly, they must be circling something very tiny and enormous.

4.7 Spaghettification

Spaghettification is what happens when you fall into a black hole. The intense gravitational force of the black hole stretches you (or the star) vertically and compressed horizontally. This may be the destiny of a star that approaches a supermassive black hole too closely. It can happen before or after an object crosses a black hole. It depends on the black hole's size.

4.8 A direct image

A direct glimpse of the supermassive black hole at the heart of the galaxy Messier 87 was the evidence that sealed the deal in April 2019. The greater the final image quality, the more telescopes that can participate and the more widely separated they are. The finding vividly depicts the black hole's dark shadow against the orange light of its accretion disk, which has a mass of 6.5 billion solar masses.

4.8.1 How did scientists succeeded in taking a picture of a black hole?

The Event Horizon Telescope, a global network of radio telescopes, was used to picture the black hole in M87. An international group of astronomers working toward a same goal had achieved something spectacular: the pinnacle of astrophotography. It was once considered that photographing a black hole would be impossible since an image of something from which no light can escape would appear dark.

Though scientists thought that they could photograph black holes by catching their outlines against their light surrounds, they were still unable to image an object so far away. The Event Horizon Telescope, EHT, is a network of telescopes that was formed to take on the issue. They set out to take an image of a black hole by improving on a technique known as Very Long Baseline Interferometry, VLBI, that allows for imaging of far-away objects. The aperture of this giant telescope was as large as the distance between the South Pole and Spain, and it permitted to create an aperture that is quite the same as the diameter of Earth. Scientist made their observation with the special telescope in April 2017, and they spent two years analyzing the data that they had discovered.

To see faraway objects, various types of telescopes are utilized. The larger the telescope's diameter (or aperture), the lighter it can collect and the higher its resolution (or ability to image fine details). We need to gather as much light as possible with very high resolution to see features in objects that are far away and appear small and faint from Earth, therefore we need to utilize a telescope with a big aperture.

That's why the VLBI technique was crucial in catching the image of the black hole. They photographed it by combining a few smaller telescopes into a huge virtual telescope that can be synchronized to concentrate on the same target at the same time. Smaller telescopes can be an array of numerous telescopes in some instances. This method has been used to follow spacecraft and view faraway cosmic radio objects like quasars.

(Characters: 11 559 spaces included)

5 REFERENCES

- *Black hole observed first time ever*. (2019, April 11). Seti. https://www.seti.org/black-hole-observed-first-time-ever
- *Black Holes | Science Mission Directorate*. (2021). NASA. Retrieved 28 January 2022, from https://science.nasa.gov/astrophysics/focus-areas/black-holes
- C. (2021a). *Recherche par image - iStock*. IStock. Retrieved 28 January 2022, from https://www.istockphoto.com/fr/search/search-by-image?assetid=1142005022&affiliateredirect=true&utm_source=pixabay&utm_medium=affiliate&utm_campaign=SRP_image_sponsored&utm_content=http%3A%2F%2Fpixabay.com%2Fnl%2Fimages%2Fsearch%2Fblack%2520hole%2F&utm_term=black+hole
- *Detecting dark matter: seven hints point to primordial black holes*. (2019, January 19). UCLouvain. https://uclouvain.be/en/sciencetoday/news/seven-hints-point-to-primordial-black-holes.html
- *Exploring Black Holes*. (2021, December 24). National Science Foundation. Retrieved 28 January 2022, from https://www.nsf.gov/news/special_reports/blackholes/
- *Gamma ray burst*. (2020). Wikimedia. Retrieved 28 January 2022, from https://upload.wikimedia.org/wikipedia/commons/6/63/Gamma_ray_burst.jpg
- *How Scientists Captured the First Image of a Black Hole - Teachable Moments*. (2021). NASA/JPL Edu. Retrieved 28 January 2022, from https://www.jpl.nasa.gov/edu/news/2019/4/19/how-scientists-captured-the-first-image-of-a-black-hole/
- *HubbleSite: Black Holes: Gravity's Relentless Pull interactive: Encyclopedia*. (2005). STSCI. Retrieved 28 January 2022, from https://www.stsci.edu/%7Emarel/black_holes/encyc_mod1_observatories.html#:%7E:text=Ultraviolet%20telescopes%20allow%20astronomers%20to,light%20is%20called%20infrared%20light
- *Intermediate-mass black hole discovered*. (2020, April 2). Breave. https://breave.com/stories/intermediate-mass-black-hole-discovered
- Mann, A. (2020, January 16). *What Is a Gamma-Ray Burst?* Space.Com. Retrieved 28 January 2022, from https://www.space.com/gamma-ray-burst.html
- May, A. (2021, August 25). *8 ways we know that black holes really do exist*. Livescience.Com. Retrieved 28 January 2022, from https://www.livescience.com/how-we-know-black-holes-exist.html
- O. (2021b). *Evidence for Black Holes | Astronomy*. Lumen Learning. Retrieved 28 January 2022, from https://courses.lumenlearning.com/astronomy/chapter/evidence-for-black-holes/
- *Observational Evidence for Black Holes*. (2015). Harvard. https://lweb.cfa.harvard.edu/~narayan/Benefunder/Narayan_McClintock.pdf
- Patel, N. V. (2021, August 3). *Astronomers have spotted x-rays from behind a supermassive black hole*. MIT Technology Review. Retrieved 28 January 2022, from https://www.technologyreview.com/2021/07/28/1030233/x-rays-behind-supermassive-black-hole/
- Resnick, B. (2019, April 11). *The very first image of a black hole, explained by 2 astrophysicists*. Vox. Retrieved 28 January 2022, from https://www.vox.com/science-and-health/2019/4/11/18306110/first-image-black-hole-eht-event-horizon-singularity

- S. (2013, September 25). *Scientists Reveal Past Outburst from the Supermassive Black Hole at the Center of Our Galaxy*. SciTechDaily. Retrieved 28 January 2022, from https://scitechdaily.com/scientists-reveal-past-outburst-supermassive-black-hole-center-galaxy/
- S. (2015, November 14). *Black holes..are they going to destroy earth?? All you want to know about black holes.* Space Sciences. Retrieved 28 January 2022, from Https://spacesciencs.blogspot.com/2015/11/black-holesare-they-going-to-destroy.html
- *Science*. (2021). AAAS. Retrieved 28 January 2022, from https://www.science.org/content/article/black-hole
- *Supermassive Black Hole | COSMOS*. (2021). Cosmos. Retrieved 28 January 2022, from https://astronomy.swin.edu.au/cosmos/s/supermassive+black+hole
- tech2 News Staff. (2019, November 29). *Astronomers spot stellar black hole so massive, it 'shouldn't exist'*. Tech2. Retrieved 28 January 2022, from https://www.firstpost.com/tech/science/astronomers-spot-stellar-black-hole-so-massive-it-shouldnt-exist-7714651.html
- Tillman, N. T., & Biggs, B. (2021, December 4). *What are black holes? Facts, theory & definition*. Space.Com. Retrieved 28 January 2022, from https://www.space.com/15421-black-holes-facts-formation-discovery-sdcmp.html
- Todd, I. (2021, September 27). *How we photographed the first image of a black hole*. BBC Sky at Night Magazine. Retrieved 28 January 2022, from https://www.skyatnightmagazine.com/space-science/m87-black-hole-photograph-how/#:%7E:text=In%20April%202019%2C%20astronomers%20announced,first%20time%20%E2%80%93%20a%20black%20hole.&text=The%20black%20hole%20in%20M87,called%20the%20Event%20Horizon%20Telescope.
- Wei-Haas, M. (2021, May 3). *Black Holes, explained*. Science. Retrieved 28 January 2022, from https://www.nationalgeographic.com/science/article/black-holes
- *What are Gravitational Waves?* (2021). LIGO Lab | Caltech. Retrieved 28 January 2022, from https://www.ligo.caltech.edu/page/what-are-gw
- Wikipedia contributors. (2022, January 21). *Black hole*. Wikipedia. Retrieved 28 January 2022, from https://en.wikipedia.org/wiki/Black_hole
- Wild, F. (2018, August 22). *What Is a Black Hole?* NASA. Retrieved 28 January 2022, from https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-is-a-black-hole-k4.html
- World of Phenomena. (2019, August 16). *Spaghettification - Facts and Information*. Retrieved 28 January 2022, from https://www.phenomena.org/space/spaghettification/

5.1 REFERENCES OF THE PICTURES

PICTURE 1: C. (2021a). Recherche par image - Stock. IStock Retrieved 28 January 2022, from https://www.istockphoto.com/fr/search/search-by-image?assetid=1142005022&affiliateredirect=true&utm_source=pixabay&utm_medium=affiliate&utm_campaign=SRP_image_sponsored&utm_content=http%3A%2F%2Fpixabay.com%2Fnl%2Fimages%2Fsearch%2Fblack%2520hole%2F&utm_term=black+hole

PICTURE 2: *Attention Required! | Cloudflare*. (2021). Pixabay. Retrieved 17 February 2022, from https://pixabay.com/nl/images/search/black%20hole/

PICTURE 3: Beijing Planetarium/Chinese Academy of Sciences. (2019, November 29). *ASTRONOMERS SPOT STELLAR BLACK HOLE SO MASSIVE, IT SHOULDN'T EXIST'* [Photo]. Www.Firstpost.Com. https://www.firstpost.com/tech/science/astronomers-spot stellar-black-hole-so-massive-it-shouldnt-exist-7714651.html

PICTURE 4: *Intermediate-mass black hole discovered*. (2020, April 2) [Photo]. Www.Breave.Com. https://breave.com/stories/intermediate-mass-black-hole-discovered

PICTURE 5: NASA. (n.d.). *Scientists Reveal Past Outburst from the Supermassive Black Hole at the Center of Our Galaxy* [Photo]. Www.Scitechdaily.Com https://scitechdaily.com/scientists-reveal-past- outburst-supermassive-black-hole-center-galaxy/

PICTURE 6: *Gamma ray burst*. (2020). Wikimedia. Retrieved 28 January 2022, from https://upload.wikimedia.org/wikipedia/commons/6/63/Gamma_ray_burst.jpg