Supermassive Black Holes

Show Script — English

No	NARRATION
1	When we gaze at the stars on a calm summer night, we perceive a beautiful, peaceful and ordered universe. We do not realize that it is alive, fierce and sometimes extremely violent.
2	But science doesn't gaze at these heavenly objects. Science, meticulously observes them and records a wealth of data which must be processed and interpreted in order to reveal all the hidden information they might contain.
3	For this purpose, scientists employ huge optical telescopes placed strategically on remote mountain tops all over our planet. These instruments collect as much light as possible, in an effort to penetrate as deeply as possible into the universe.
4	Situated far from urban areas they avoid light pollution from cities which can prevent astronomical observations. Furthermore, in the high altitudes on mountains, where there are usually built, the atmosphere is much more transparent and stable.
5	In recent decades, scientists have managed to send in space big optical telescopes that without the interference of the layers of our terrestrial atmosphere are capable of capturing even the faintest light from remote astronomical objects.
6	But the light we receive from the Universe is not just the optical light that our eyes and optical telescopes can detect. Light is emitted by astronomical sources at all wavelengths, thus human beings have built telescopes able to detect light at all frequencies.
7	For example, millimeter and radio waves are observed with giant parabolic telescopes or arrays of antennas from the ground. These instruments can observe the sky 24 hours a day regardless of atmospheric conditions.
8	The most sophisticated of this type of telescope is ALMA, which is situated on a high altitude plateau in the Atacama desert of Chile.
9	High energy radiations such as Gamma rays: X-rays: and Ultraviolet: unfortunately cannot be observed from the Earth's surface.
10	The only way to observe the Universe at these high energies is to use special observatories in space. These observatories and their instruments allow us to study physical processes previously unimaginable.
11	X-rays and Gamma rays allow us to observe the most violent and impressive (unprecedented) phenomena of the Universe.

12	These observations have radically changed our view of the Cosmos and revealed the most terrifying objects.
13	TITLES
14	Ordinary stars shine for tens of millions to billions of years, depending on their masses. Their energy comes from the intense nuclear fusion of light chemical elements – like hydrogen and helium – being converted to heavier ones, in their cores.
15	The most massive stars suffer violent deaths during Supernovae explosions. When they consume their fuels and their cores are filled with elements that cannot be fused any more, they collapse and subsequently erupt in a very violent way, expelling their outer shells into space. After these explosions, their cores shrink under their own gravity and become the extreme and bizarre objects called stellar black holes. But this is not the whole story. Much heavier black holes, called supermassive since their masses range from millions up to billions of solar masses are to be found all over the center of galaxies. Their formation pattern is even more mysterious than for stellar ones.
16	From these bizarre objects nothing can escape. Even light gets trapped, making them invisible, thus the name “black holes”.
17	Black Holes bend space – time heavily and grow in time by attracting and swallowing everything that enters their gravitational pull.
18	Matter, as it collapses onto black holes, creates an accretion disk around them as it spirals inward. In this disk, the temperature and kinetic energy are so high that gamma and X-rays are generated.
19	At the same time, strong gravitational and magnetic fields create jets, which move with a speed close to the speed of light and interact violently with the interstellar matter that surrounds them producing all kinds of light frequencies.
20	These objects and their processes were predicted since the beginning of the 20^{th} century by many famous scientists who have worked on their own individual theories over the years. But how can black holes be observed and confirmed observationally?
21	Although they are invisible by definition, because they do not emit any light, astronomers can still infer their existence in different and indirect ways.
22	Black holes are invisible, but their gravity, their accretion disk and their jets are observable.

	Therefore, astronomers can infer their presence in a particular spot by observing the jets of matter emanating from their environment, or by observing their accretion disks in hard radiations such as X and gamma rays.
23	Another way is by observing the orbits of stars which revolve around an invisible object with a strong gravitational field.
24	And by observing the bending of light around them, as if by a lens.
25	In 2019, a group of radio telescopes from all over the world operated together forming a giant interferometer. This collaboration known as "The Event Horizon Telescope", achieved to produce the very first images of the emission around a black hole in the center of a galaxy named M87. The images showed a ring, predicted by using the theory of general relativity. The size of the ring indicates that the black hole has a mass that is 6.5 billion times that of the Sun.
26	Sometimes, two stellar corpses such as neutron stars, might approach so closely to each other that via gravitational attraction they can end up merging. These mergers always trigger bright explosions, accompanied by the release of copious amounts of X and Gamma rays. Furthermore, they also produce detectable gravitational waves.
27	Less often, but more impressive are the mergers of two black holes. Black Hole merging is one of the most violent phenomena in the universe and produces vast amounts of energy in the form of gravitational waves.
28	These cosmic ripples travel at the speed of light, carrying with them information about their origins, as well as clues to the nature of gravity itself.
29	Recently, scientists have managed to develop special observatories for recording these ripples as they pass through our planet.
30	LIGO – the Laser Interferometer Gravitational Wave Observatory in the US and the Virgo antenna hosted at the European Gravitational Observatory (EGO) at Pisa Italy, employ very sensitive laser interferometers to detect them.

31	The first direct observation of gravitational waves was made on 14 September 2015 and was announced by the LIGO and Virgo collaborations on 11 February 2016. Since those observations, gravitational waves have been detected on several occasions. In the near future, LISA, a giant space Laser Interferometer Space Antenna, will be able to detect gravitational waves from the interaction of supermassive black holes.
32	At the centre of our Galaxy, lies a dormant massive black hole. Studies of the motion of nearby stars in close orbits revealed that the mass of the black hole is about 4 million times the mass of our Sun.
33	Observations showed that there are two large lobes of gamma rays that expand out up to 25000 light years from the centre of our Galaxy. These lobes are ejected by violent phenomena at the very center of our galaxy.
34	Galaxies who emit huge amounts of energy from their nuclei are known as Active galaxies, radio galaxies, quasars and blazars.
35	These galaxies have supermassive black holes in their centers, with masses a million or even few billion times the mass of our Sun and accrete huge amounts of matter. Long, high speed jets emanate from their centers and extend far out into the intergalactic medium.
36	Most of these active galaxies are billions of light years far away from us. Therefore, their activity happened billions of years ago. Galaxies close to us are practically inactive, although there is indirect evidence that almost every galaxy contains a massive black hole in its center.
37	It seems that some supermassive black holes formed early, just a few hundred million years after the big bang. They increased their masses by capturing matter from their surroundings until space around them was cleaned by the radiation emitted from their accretion disks. They have and continue become dormant, with only sporadic rejuvenation episodes that are triggered by some gas clouds or stars falling into their gravitational grasp.
38	But how did these extreme objects formed? How did they manage to become so huge? The first stars formed shortly after the big bang, were much larger and when they died violently, they formed stellar black holes larger than

	those forming today. Then, they grew by swallowing the rich material that surrounded them…
39	This scenario seems plausible, but recent studies have shown that there wasn't enough time for them to grow that big, since we have observe active galaxies with super massive black holes existing when the universe was very young.
40	Thus, scientists propose that they might be formed directly by the collapse of huge gaseous clouds, or the rate at which they eat material or at which they merge together in these early stages, possibly increasing in size with respect to the standard lore.
41	Supermassive black holes are believed to play an important role in the evolution of galaxies by releasing huge amounts of energy that can stop the birth of new stars. However clear evidence in support of this important theory is still lacking.
42	We need more brain power to solve the riddle of the formation and evolution of supermassive black holes. In anticipation of the wealth of new observational data arriving especially from the new space missions, BiD4BEST, an initiative with strong European involvement that has recruited a team of talented early stage researchers from across the world with the aim of producing transnational science on the formation of supermassive black holes in galaxies.
43	The efforts of all these scientists, have and will continue to shed some light on the darkness of these exotic and mysterious astronomical objects and the in the future we might decode black holes and learn more about them and the universe we live in.
	Film Credits: Film Director: Theofanis Matsopoulos (www.matsopoulos.com) Script/Scientific Advisors: Prof. David Alexander, Dr. Cristina Ramos Almeida, Dr. Silvia Bonoli, Prof. Marcella Brusa, Prof. Klaus Dolag Dr. Antonis Georgakakis, Dr. Andrea Lapi, Nicolas Matsopoulos Msc, Prof Joop Schaye, Prof. Francesco Shankar, Prof. Carolin Villforth Narration: Gregory Patrick Karr Produced by: BiD4BEST (Which is a consortium of: University of Southampton, University of Durham, Donostia International Physics Center, Università di Bologna, Max Planck Institute for Astrophysics,

	National Observatory of Athens, Scuola Internazionale Superiore di Studi, Intituto de Astrofisica de Canarias, Leiden Observatory, University of Bath) This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 860744. https://www.bid4best.org/ **Credit: BiD4BEST/T. Matsopoulos**