# Unveiling the Invisible Universe

| | English | |
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| | All ancient civilizations have felt the need to study the sky. Their observations were restricted by the capabilities provided by the sole optical instrument they possessed. The human eye. | |
| | All they could see, without being able to understand their nature, were 3500 stars at most. | |
| | But, In our days science has managed to observe the universe at enormous distances of up to almost 13 billion light years. | |
| | One light year is the distance a light ray travels in a year and is about 10 trillion kilometers. | |
| | The modern image of the Universe reveals a huge, complex and impressive environment, in which we exist as we live and evolve on the surface of a small but hospitable planet, called the Earth. | |
| | Earth is the only oasis of life at least in our solar system. | |
| | The conditions prevailing on its surface allow the existence of huge amounts of water in liquid form both in the seas and on land.<br>Water in liquid form is the most essential ingredient for the formation and development of the phenomenon of life. | |
| | Limited to the environment of our planet, so far been able to visit and explore only the very near celestial bodies such as the Moon and the planets of our Solar System. | |
| | But how did we manage to study the universe at such enormous distances and understand its content, its structure and its evolution? How did we unveil many of its secrets? | |
| | Unfortunately, only few people know that all this knowledge is gained by the collection and analysis of the dim starlight that reaches the Earth from the remote heavenly bodies known as Stars. | |
| | This adventure actually begun in 1609, when the Italian scientist Galileo Galilei, turned a small homemade telescope to the sky for the first time. | |
| | His observations opened a huge window to the universe and revealed its greatness. | |
| | The optical telescope operates in the same way as the human eye. | |
| | The telescope collects light and focuses it on a single spot.<br>There are refracting telescopes which employ lenses and reflecting telescopes which use concave mirrors to collect and focus the light. | |
| | The amount of the collected light depends on the area of lens or the mirror of the telescope. A larger optical system collects more light and thus makes visible dim celestial | |

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| | objects which are invisible to the human eye. | |
| | Most dim objects are invisible because they are distant. Their image, traveling at the speed of light takes a long time to cover the enormous distances. Thus, when we observe them through the telescope, we see them as they were in the past. | |
| | In other words, a telescope is a kind of time - machine that allows us to observe the universe as it was in the past and thus understand its evolution. | |
| | As time passed, the telescope evolved from Galileo's simplistic instrument into huge technologically advanced and precise scientific instruments. | |
| | Today we use large optical telescopes placed strategically on remote mountain tops all over our planet. | |
| | Far from the urban areas they avoid light pollution which prevents astronomical observations. | |
| | Furthermore, in the high altitudes on mountains where there are built the atmosphere is much more transparent and stable. | |
| | The larger telescopes in the 8 - 10 meter range aperture that are used by the American astronomers placed on Mauna Kea in Hawaii. | |
| | The European Southern Observatory (ESO) has erected the very large telescope (VLT) on Cerro Paranal in the Chilean Atacama desert. This telescope consists of 4 reflectors with a diameter of 8.2 meters each. | |
| | The Atacama desert is one of the most arid places on Earth thus providing ideal conditions for astronomical observations. | |
| | These telescopes can observe in optical and infrared radiation and can record objects 4 billion times dimmer than those can be observed by the naked eye. | |
| | They weigh hundreds of tons, but are capable of pointing and tracking celestial objects extremely accurately. They also employ adaptive optics which can compensate for atmospheric disturbances. | |
| | And are equipped with many auxiliary instruments such as light sensitive cameras and high technology spectrographs. | |
| | These large telescopes are mostly used for the study of the large scale structure and the evolution of the universe, by observing the remote clusters of galaxies and the interactions between their members. | |
| | Alongside these giant telescopes, the older and smaller telescopes continue to contribute significantly in scientific research. | |
| | In the near future, new giant earth based optical telescopes, such as the European Extremely Large Telescope (ELT), will | |

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| | be available to astronomers. It will have a 40 meter diameter segmented mirror and will be erected at Cerro Armazores in the Atacama desert in a few years. | |
| | Yet, in spite of all these technological advancements, we still cannot eliminate all the problems caused to astronomical observation by the Earth's atmosphere. Thus, we had to put telescopes in space above Earth’s atmosphere. | |
| | Until now, the biggest space telescope is Hubble, which has a mirror of 2.4 meters. | |
| | Since1991, Hubble observes the universe with unprecedented accuracy and is credited with many important discoveries. | |
| | Hubble's successor is the James Webb space telescope.<br>This telescope has a 6.5 meters mirror and is designed to observe light in infrared radiation.<br>It will be able to observe galaxies at a distance of 12.5 billion light years. | |
| | But light is something more than that recorded by all mentioned optical telescopes. | |
| | Light consists of electromagnetic radiations at different frequencies. All these together make up the electromagnetic spectrum. Most of them of course invisible to the human eye but also to even the most advanced optical telescopes. | |
| | The celestial bodies we observe and all astronomical phenomena emit in several frequencies simultaneously. | |
| | But, they emit most strongly in some frequencies according to their energy level. | |
| | These hot and violent processes radiate mostly in short wavelengths whereas the colder and quieter processes radiate in longer wavelengths as microwaves and radio waves. | |
| | Radio waves are observed with giant parabolic antennas, called radio telescopes. These instruments can observe the sky 24 hours a day regardless of atmospheric conditions. There are many radio telescopes around our planet. | |
| | The most sophisticated of them, is ALMA which is situated on a high altitude plateau in the Atacama desert in Chile. | |
| | Most of the electromagnetic radiation cannot pass through the Earth's atmosphere. For this reason we put in orbit space observatories that can observe in all the frequencies of the electromagnetic spectrum. | |
| | Most notably, the high energy ultraviolet, X-rays and Gamma rays cannot be observed from the Earth’s surface at all. | |
| | The only way to observe the Universe at high energies is to use observatories in space. These observatories allow us to study physical processes previously unimaginable. | |

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| | But X-rays and Gamma rays allow us to observe the most violent and impressive phenomena of the Universe.<br>For example, the sky seen at these wavelengths is completely different from the usual image of the quiet, night sky. | |
| | But light is not the only source of information about physical processes in the Universe. | |
| | During violent high-energy natural processes in the Universe, elementary particles called neutrinos are produced in inconceivably large numbers. | |
| | Neutrinos are elusive particles that move at relativistic speeds, have minimal mass, and rarely interact with the rest of matter. | |
| | To detect them we use special sensors deep in the ground or at sea to minimize the various interferences. | |
| | Finally, as the General Theory of Relativity predicts, the space-time web is altered by the existence of mass and Energy. | |
| | Some of the most violent and energetic processes in the Universe, produce ripples, the gravitational waves, in the fabric of space-time.<br>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. | |
| | Recently, we have managed to develop special observatories for recording these ripples as they pass through our planet. | |
| | 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. | |
| | Let's have a look to some of the most violent phenomena in the Universe that must be observed by all our instruments in order to have a clear picture of the underlying natural processes. | |
| | The most massive stars suffer violent death during Supernovae explosions.<br><br>After these explosions, the cores of stars can end as white dwarfs, neutron stars or black holes. | |
| | In particular the stars with high masses end up in what we call black holes. From these stellar remnants nothing can escape. Even light gets trapped, making these objects invisible. | |
| | Black Holes attract everything that goes near them, thus increasing their mass. | |

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| | Matter, as it collapses onto black holes, creates an accretion disk around them as it spirals inward.<br>In this disk, the temperature and kinetic energy are so high that gamma rays and X-rays are generated.<br>At the same time, strong gravitational fields create jets, which move with a speed close to the speed of light and interact violently with the interstellar matter that surrounds them. This produces radiation at all light frequencies. | |
| | The death of medium mass stars creates what we call neutron stars. These small but very dense objects spin at very high velocities and their radiation can most easily be observed when the beam of emission is pointing toward Earth. | |
| | This creates periodical changes in their luminosities and this is why we call them pulsars. | |
| | Pulsars may also have accretion disks and jets, but their scales are smaller compared to black holes. | |
| | Binary stars can be very close together interacting strongly with each other or eventually merging.<br><br>There are special cases, where one of the binary stars is very dense, like a neutron star or a stellar mass black hole. In these cases, mass is transferred to the neutron star or stellar black hole from the accompanying star. | |
| | The results of the merging of two common stars or the more violent merging of two neutron stars.<br><br>These mergers always end up in the brightest explosions known, which produce copious amounts of X-rays and Gamma rays – the Gamma-ray Bursts.<br><br>Furthermore, they also produce detectable gravitational waves. | |
| | Less often, but at larger scales and more impressive are the mergers of two black holes.<br>These are the most violent phenomena in the universe and generate inconceivable amounts of energy in the form of gravitational waves. | |
| | The environment at the centre of our Galaxy is a super massive black hole which interacts with the surrounding matter. Studies of the motion of nearby stars revealed that the mass of the black hole is 4 million times the mass of our Sun. | |

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| | Observations from the Fermi telescope showed that there are two large lobes of gamma rays that expand out to 25000 light years from the centre of our Galaxy. These lobes are ejected by violent phenomena at the very center of our galaxy. | |
| | Galaxies that emit huge amounts of energy from their nuclei and are known as Active Galactic Nuclei: radio galaxies, quasars and blazars. | |
| | These galaxies have supermassive black holes in their centers, with masses a million or even a billion times the mass of our Sun and accrete huge amounts of matter and jets that extend out into the intergalactic medium. | |
| | The interactions, collisions and mergers of whole galaxies, play a crucial role in their evolution. | |
| | Finally, we can observe the primordial universe, where the death of the first stars was much more violent and the interactions and merging of the galaxies was taking place more often. | |
| | The decoding of the hidden messages that the light of stars carry, as well as the torrents of exotic particles and space itself, reveal to us the Universe in all its grandeur. | |
| | Humans although bound on the surface of a small planet called Earth, have the ability with science to glimpse the limits of the visible and invisible Universe. | |



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