The Hot And Energetic Universe

The Universe was always the final frontier of the Human quest for knowledge
Through all its history, humanity has observed the sky trying to understand the Cosmos outside the limits of our planet
Today, this effort has yielded significant results.
Now we know that our sun is a typical star, which does not differ significantly from the other stars of the starry sky.
We have discovered the planets of our Solar System and we have studied the conditions prevailing in them.
We studied asteroids and comets and found their important role in the formation of planets.
We understand the basic principles of the formation, the life and the death of stars.
We have also discovered thousands of exoplanets orbiting other stars.
We studied giant star clusters.
We have discovered dense clouds of interstellar dust and gas where new stars are born continuously.
We have managed to describe the gigantic complex of stars to which we belong. Our Galaxy.
We realized that our Galaxy is not alone in the universe and that there are hundreds of billions of galaxies.
We discovered that the universe of galaxies is extremely violent and in constant motion.
Finally we found that the whole universe is in accelerating expansion and we are searching urgently for its origin.
This quest is an epic journey towards knowledge, which abolish superstitions and defines human existence.
Vehicles for the journey of humanity in the universe are scientific instruments called telescopes, which are installed at various observatories.
Telescopes collect light. Their performance depends on the diameter of the lens or mirror used.
Today we have giant telescopes with mirror diameters up to 10 meters.
Most of these telescopes are installed in remote areas of the Earth, away from cities, the artificial lighting of which prevents serious astronomical observations.
The European Southern Observatory is building a giant telescope with a diameter of 40 meters that will penetrate and study the universe across cosmic time.
The most important step in the exploration of the Universe is the use of orbital telescopes that observe the universe outside of the Earth's atmosphere, such as the Hubble space telescope.
Light is much more than the optical telescopes can record.

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Light consists of electromagnetic radiation at many different frequencies. Most of them are invisible by the human eye and the optical telescopes.
There are radio waves, microwaves, Infrared radiation, optical light, Ultraviolet radiation, X-rays and Gamma-rays. All these forms of light comprise the Electromagnetic spectrum.
The human eye can only see a small part of the Electromagnetic spectrum that consists of the basic colors.
Celestial bodies usually radiate at many wavelengths simultaneously. They emit more in some wavelengths than others depending on their temperatures.
The hottest and most violent processes emit at small wavelengths, that is X-rays and Gamma rays, while the cold and calm processes emit at larger wavelengths, such as in the Infrared and radio .
Radiowaves are observed with giant antennas, the radio telescopes, that have the ability to observe the whole sky 24 hours a day and in all weather.
The vast majority of the Electromagnetic radiation cannot penetrate the Earth's atmosphere, so we are using orbital Observatories. Most notably, the high energy ultraviolet, X-rays and Gamma rays cannot be observed from the Earth's surface.
But X-rays and Gamma rays allow us to observe the most violent and impressive phenomena of the Universe. For example, the usual image of the night sky is completely different when observed at these wavelengths.
The only way to observe the hot and violent Universe at high energies is to use observatories in space.
These observatories allow us to study physical processes invisible to the human eye.
X-rays or Rontgen radiation are named after the German physicist Wilhelm Rontgen who studied them in 1895. They have been used for many years now in medical diagnosis. Gamma rays are discovered from the French physicist Paul Villard in 1900 and are well known for the catastrophic effect they have on living creatures.
In 1948 American scientists observed X-rays emitted from the Sun, using special detectors on German V-2 Rockets. In 1962 a team of scientists under Ricardo Giacconi, observed for the first time X-rays emitted outside the Solar system, a source towards the constellation of Scorpio.
The first successful record of Gamma rays from space was done in 1961 from Explorer 11.
The contribution of the first American space station, the Skylab, was also important. The station was launched in 1973 and for 6 years observed the Sun at X-ray wavelengths.
Since then, tens of orbiting observatories have been launched, observing with increasing sensitivity the Universe in X-rays and Gamma rays, providing us with a more detailed picture of the most violent processes

in the Universe.
Today, one of the most successful observatories is the Chandra X-ray Telescope, that was launched on 23rd of July 1999, from the space shuttle Columbia.
Chandra has the sharpest view of the X-ray Universe.
The XMM – Newton satellite, which was named after the famous Isaac Newton, was put in orbit by employing the Arianne 5 rocket of the European Space Agency.
Its main goals are the detection of X-ray emission from Solar System objects, detailed studies of star-forming regions, investigation of the formation and evolution of galaxy clusters, the environment of super massive black holes and the mapping of the mysterious dark matter.
Nustar was launched in June of 2012 and its main mission is to observe super massive Black Holes hidden by large amounts of dust and gas
The US Fermi mission and the European INTEGRAL mission detect the most energetic radiation that comes from space, gamma rays.
With these observatories we study celestial bodies like our Sun, to understand the mechanisms that create solar flares as well as the high temperatures of its external atmosphere, named the corona.
We observe the birth of new stars in regions where large molecular interstellar clouds exist. In these regions small gravitational instabilities can cause the collapse of these clouds and give birth to the formation of new stars and planets.
We also study the violent death of massive stars that take place during Supernovae explosions.
After the explosion, the cores of 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. Their strong gravitational field distorts time and space around them.
Black Holes attract everything that goes near them, increasing their mass in this way. Matter, as it collapses onto black holes, creates an accretion disk around them. In this disk, the temperature and kinetic energy are so high that gamma rays and X-rays are generated. At the same time, strong gravitational fields create jets, that move with a speed close to the speed of light and interact violently with the interstellar matter that surrounds them.
The death of medium mass stars creates what we call neutron stars. These objects spin at very high velocities and their radiation can most easily beobserved 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 can also have accretion disks and jets, but their scales are smaller compared to black holes.
We also observe binary stars that are very close together and interact strongly with each other.
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, which eventually results in the violent explosion of a supernova.
We observe the results of the merging of two common stars or the more violent merging of two neutron stars. These mergers always end up in the brightest explosions known that produce X-rays and Gamma rays – the Gamma-ray Bursts
Gamma-ray Bursts are the most energetic events known in the universe. The Italian satellite, BeppoSAX played a crucial role in the identification and understanding of what Gamma-ray Bursts are. The Swift mission is a dedicated mission to find and study Gamma-ray Bursts.
Less often, but at larger scales and more impressive are the mergers of two black holes. These are the most violent phenomena in the universe and generate inconceivable amounts of an exotic form of energy, gravitational radiation.
We also observe the centre of our Galaxy, where a black hole interacts with the surrounding matter. Studying the motion of nearby stars has revealed that the mass of the black hole is 4 million times the mass of our Sun.
Obervations 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 were generated by the interaction of relativistic particles that were emitted from the accretion disk of the central black hole of our Galaxy.
We study in detail 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 massive black holes in their centre, with masses a million or even a billion times the mass of our Sun and accrete huge amounts of matter and have jets that extend out into the intergalactic medium.
We observe the interactions, collisions and mergers of whole galaxies, that 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 mergers of the galaxies was taking place more often.
All these observations help us understand the evolution of our Universe and the physical laws that govern it.
The European Space Agency's ATHENA mission will be launched in 2028. It will revolutionize our knowledge of the high energy Universe carrying the largest X-ray telescope ever constructed. ATHENA will observe the first black holes in the early Universe and will understand how they interact and they affect the evolution of their host galaxy.

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The Universe seen in X-rays and Gamma rays is an inhospitable and violent environment. We live under the safety of an atmosphere and reside on the spaceship we call Earth, without realizing all these amazing phenomena that take place next to us.

Credits

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