The Universe in my pocket

The invisible universe

TUIMP
No. 2
THE UNIVERSE IN MY POCKET

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A photo by Wally Pacholka of the Pleiades constellation, that can be seen with the naked eye. For the aboriginal people of northern Australia, the Pleiades are a group of kangaroos that are chased by a pack of dingoes.

Galileo Galilei explains to the Doge of Venice how to use his telescope (Fresco by Giuseppe Bertini).

Galileo's drawing of the Pleiades as seen through his telescope. The small asterisks represent stars not seen without the telescope.

The first photograph of the Orion Nebula made by Henry Draper in 1880 with a 50 min. exposure using a telescope 28 cm in diameter.

The dawn of astronomy

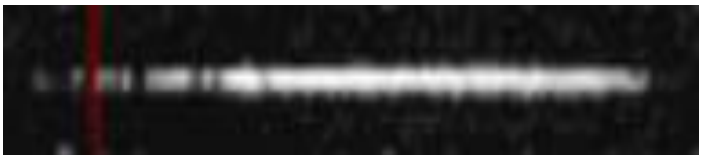
In ancient times, knowledge of the Universe was limited to what the un-aided human eye could see. Myths and legends completed this view of the Universe.

At the beginning of the 17th century, the first telescopes allowed astronomers to detect objects several times weaker than the weakest ones seen with the naked eye. Hundreds of stars were discovered and a lot of nebulae were detected.

By the end of the 19th century, astronomical photography allowed a deeper exploration of space. One could follow an object with a telescope and record its light on a photographic plate during several hours. In this way, one could detect fine details on the planets and many nebular objects.

Newton made a hole in the shutters, and directed the sunray onto a prism. He collected on a white sheet the light that had crossed the prism, which showed the beautiful colours of the rainbow. By placing a second prism in front of the sheet, and playing with its angle he recombined the colours into the white light of the Sun.

The first spectrum of a nebula, made by Huggins in 1860. It shows three bright lines.



The spectrum of another `nebula' taken by Edwin Hubble around 1920. It shows dark lines superimposed on a bright background, which looks like the spectra of stars. This means that this `nebula' is not made of gas but of stars. Such objects are now called `galaxies'.

The beginning of spectroscopy

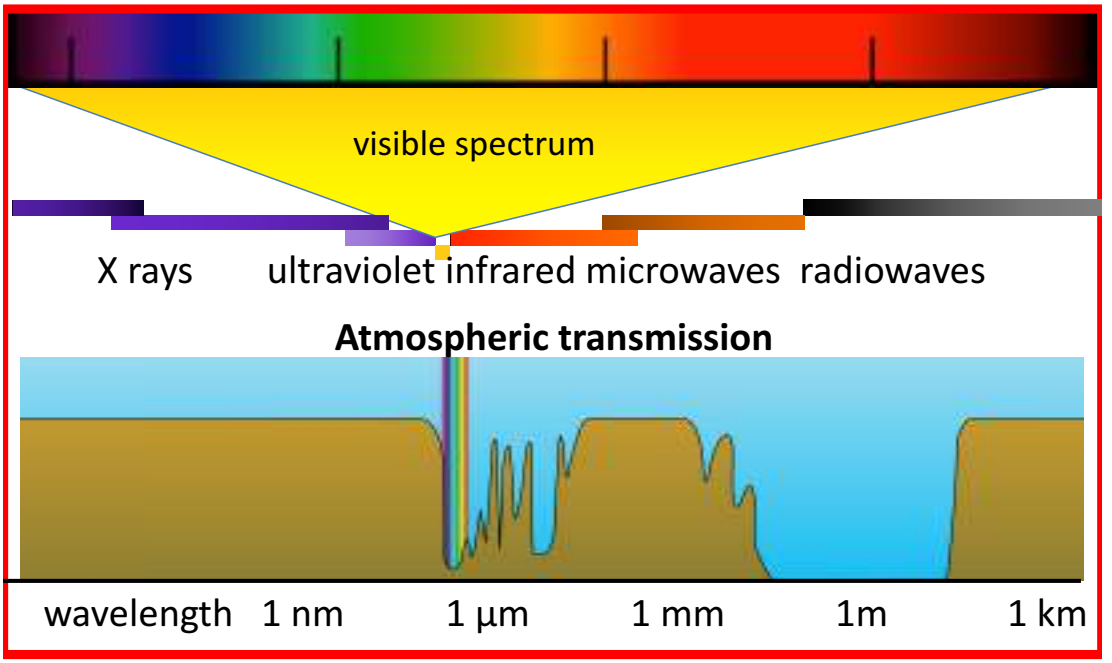
In 1665, Isaac Newton, the same person who later discovered the laws of gravity, showed that the light from the Sun was composed of different colours.

It took many years, however, for astronomers to take advantage of this fact to study the light emitted by astronomical objects.

A spectrum, which is the name given by Newton to the light decomposed by a prism, contains a lot of information on the composition, the temperature and the density of the emitting source.

The first spectra of celestial objects were taken more than 200 years after Newton's discovery.

The entire spectrum of light



The wavelength of light goes from less than 1/1000000000 m for X-rays to more than 1 km for radiowaves. The visible spectrum goes from 0.4 to 0.8 µm, which is a tiny portion of the entire spectrum.

Astronomical images are usually shown in false colours, rendering invisible parts of the spectrum by means of visible colours.

The Earth's atmosphere is transparent to visible light, to radiowaves and partly to infrared light. To observe far-infrared or ultraviolet light or X-rays from celestial objects, astronomers must use satellites.

Invisible light

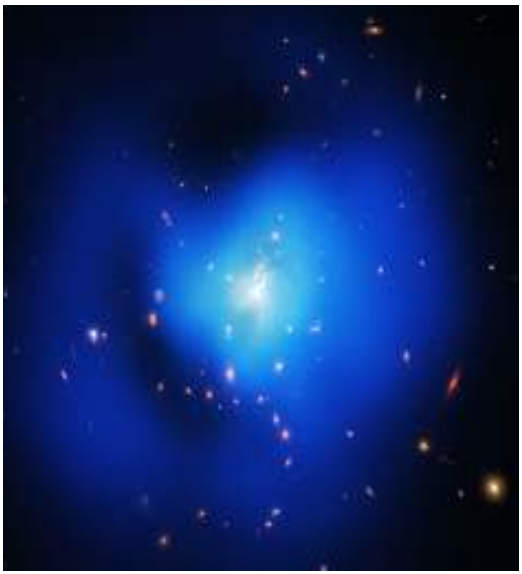
Visible light, which is the light that the human eye can see, represents only a very small part of the total radiation spectrum.

Light can be described by its wavelength. From long to short wavelength, light is composed of

- radiowaves (like the ones received by our radios and televisions),
- microwaves (like the ones used to heat food in our microwave ovens),
- infrared (emitted by warm objects, can be seen with special glasses),
- visible (sunlight, lamps),
- ultraviolet (invisible light from the Sun that causes tanning and sunburns),
- X-rays (used to visualize our bones).

The higher the temperature of a body, the shorter the wavelength of the emitted light.

The Sombrero galaxy is a massive galaxy with a huge nuclear bulge made mainly of old stars, and a thin disc made of stars, gas, and dust. Left: image obtained with the ESO 1.5 m telescope in visible light. Right: false colour composition: infrared image (in red) by the Spitzer Space Telescope, superimposed on a Hubble Space Telescope image in visible light (in blue).



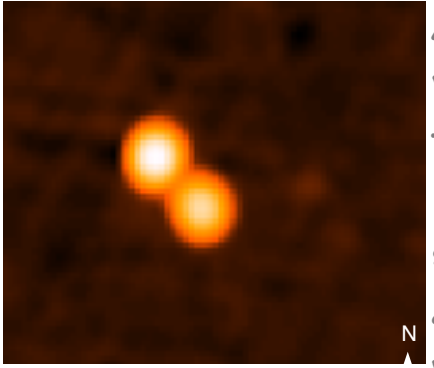
The Phoenix cluster of galaxies. Images of galaxies (in yellow) are superimposed on the blue X-ray image obtained by the Chandra X-ray telescope, revealing a huge cloud of gas at more than one million degrees.

Images in invisible light

Observing celestial objects in `invisible' light, such as radiowaves, microwaves, infrared, ultraviolet, X-rays or gamma rays, allows astronomers to better understand what the objects are made of.

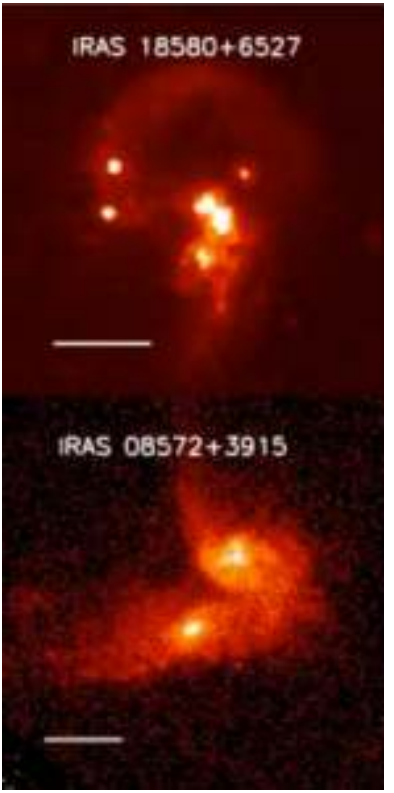
For example, interstellar dust particles are heated by the stars to temperatures lower than that of the human body. Such cool objects emit mostly in the infrared, while stars, with temperatures between 3,000 and 50,000 degrees, emit in the visible.

On the other hand, some dilute interstellar and intergalactic gas is heated to temperatures of millions of degrees or higher. It is brightest in X-rays.



A radio image obtained with the VLA telescope of the radio source 3C273. In 1963, Martin Schmidt showed that at its centre is a blue, star-like object at a very large distance. This was the first discovered quasar. An image in visible light obtained with the Hubble Space Telescope shows a jet of high-velocity gas emerging from the quasar.

A Hubble Space Telescope image in the visible of two galaxies discovered by the IRAS satellite in the infrared. They are 100 times more luminous in the infrared than in the visible, and are called ULIRGs (ultra luminous infrared galaxies). Many ULIRGs have close companion galaxies and show signs of interaction.



Discoveries in invisible light

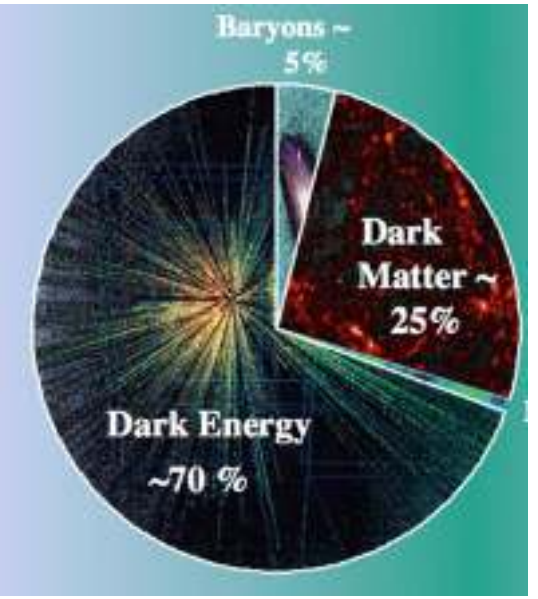
Some objects in the Universe remained completely hidden until astronomers observed them with telescopes sensitive to `invisible light'. Objects that are extremely cold or extremely hot emit mostly in the invisible parts of the spectrum and were discovered by their invisible light. It was only later, when astronomers observed the same regions with very large optical telescopes, which collect a lot of light and so are very sensitive, that they could finally see these objects in visible light.

This was the case with quasars, for example, which were discovered in the radio, and also for galaxies hosting gamma-ray bursts, where the gamma-rays were detected before the host galaxies were known.

The gravitational mirage LRG 3-757. The blue ring is the distorted image of a blue galaxy lying exactly behind the massive red galaxy.

The massive galaxy and the dark matter it contains act as a gravitational lens for the light of the galaxy behind it. The curvature of light rays by gravity was predicted by Einstein in 1915.

According to present estimates, dark energy constitutes 70% of the Universe, dark matter 25%, and the known Universe (galaxies with all their components and the intergalactic medium) only 5%.



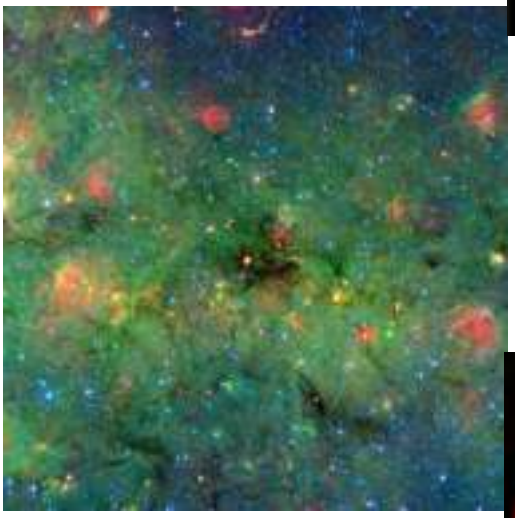
Dark matter and dark energy

Some properties of the observed Universe suggest that there exists a large amount of as yet undetected matter, called `dark matter', which acts by gravitation on the visible objects. Astronomers agree that this dark matter cannot be small stars or planets, nor dark clouds, nor black holes, nor antimatter.

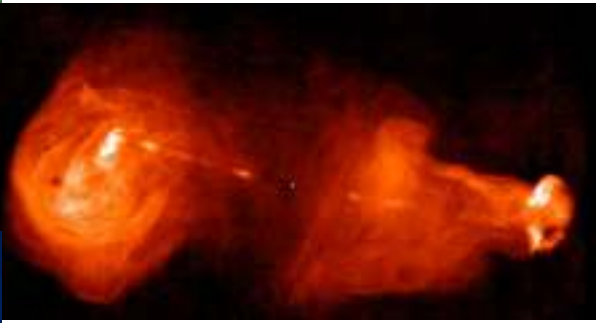
Observations of distant galaxies indicate that the expansion of the Universe is accelerating. The standard interpretation is that there is an unknown form of energy causing this acceleration, called `dark energy'.

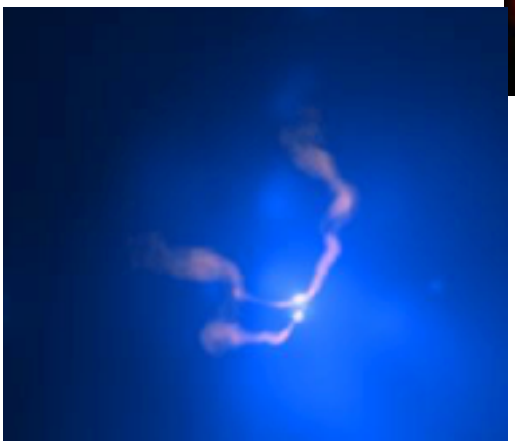
Some alternative theories do not require the presence of dark matter or dark energy, but these theories must be able to explain all the observations, just as the standard theory does.

Quiz



Which of these images was obtained with visible light?





Answers on overleaf

Digitally processed HST image of the Cat's Eye planetary nebula in visible. light

Image of the galaxy M31 taken by the Ultraviolet Telescope aboard NASA's Swift spacecraft

A composite infrared image of an interstellar cloud by the Spitzer Space Telescope. The red clumps are zones where stars form.

A VLA radio image of the jets of the radiogalaxy 3C353.

A composite X-ray (blue) /radio (pink) image of the galaxy cluster Abell 400. The radio jets arise from the double core of the central galaxy.

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This booklet was written in 2017 by Grażyna Stasińska from Paris Observatory (France) and revised by Stan Kurtz from the UNAM Radio Astronomy Institute in Morelia (Mexico).

Cover image: A portion of the Chandra Deep Field South, a composite image taken in X-rays with the Chandra Space Telescope. It shows hundreds of quasars at distances up to 12 billion light-years.
Most images in this booklet come from the Hubble, Spitzer and Chandra Space telescopes, and from the Very Large Array radio telescope.

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