National Aeronautics and Space Administration

Chaos at the Heart of Orion

This Orion Nebula image combines a visible light image from the Hubble Space Telescope with an infrared image from the Spitzer Space Telescope.

NASA's Spitzer and Hubble Space Telescopes have teamed up to expose the chaos that baby stars are creating 1,500 light-years away in a huge cosmic cloud called the Orion Nebula. The nebula is about 30,000 light years across, or more than 20,000 times the diameter of our solar system.

The striking infrared and visible-light composite image of the Orion Nebula on the front of this poster indicates that four monstrously massive stars at the center of the cloud may be the main culprits in the familiar Orion constellation. The stars are collectively called the "Trapezium." Their community can be identified as the yellow smudge near the center of the image.

Swirls of green in Hubble's ultraviolet and visible-light view reveal hydrogen and sulfur gas that have been heated and ionized by intense ultraviolet radiation from the Trapezium's stars. Meanwhile, Spitzer's infrared view exposes carbon-rich molecules called polycyclic aromatic hydrocarbons in the cloud. These organic molecules have been illuminated by the Trapezium's stars, and are shown in the composite as wisps of red and orange. On Earth, polycyclic aromatic hydrocarbons are found on burnt toast and barbeque grills and in automobile exhaust.

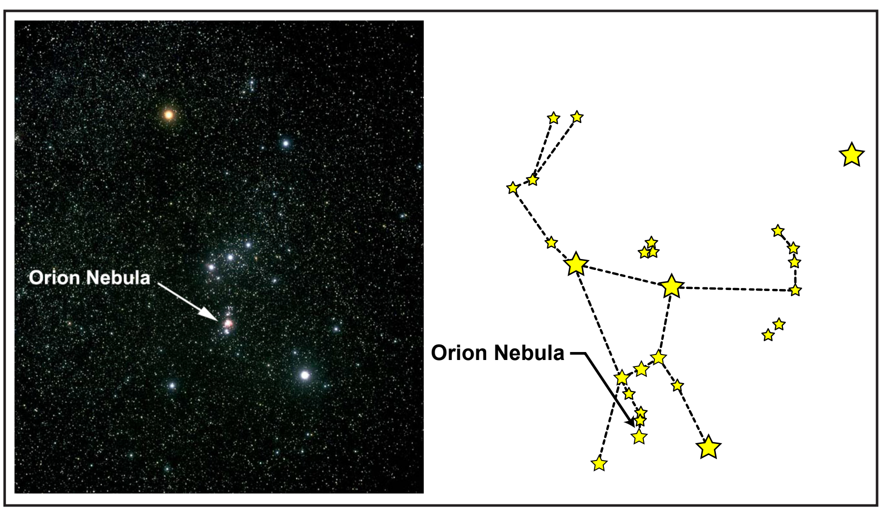
Together, the telescopes expose the stars in Orion as a rainbow of dots sprinkled throughout the image. Orange-yellow dots revealed by Spitzer are actually infant stars deeply embedded in a cocoon of dust and gas. Hubble showed the less embedded stars as specks of green and foreground stars as blue spots.

Stellar winds from clusters of newborn stars scattered throughout the cloud etched all the well-defined ridges and cavities in Orion. The large cavity near the right of the image was most likely carved by winds from the Trapezium's stars.

The Orion Nebula is the brightest spot in the sword of the Orion, or "Hunter," constellation. The cosmic cloud is also our closest massive star-formation factory, and astronomers believe it contains more than 1,000 young stars.

The Orion constellation is a familiar sight in the fall and winter night sky in the northern hemisphere. The nebula is invisible to the unaided eye, but can be seen with binoculars or small telescopes.

The image on the poster is a false-color composite where light detected at wavelengths of 0.43, 0.50, and 0.53 microns is blue; light at wavelengths of 0.6, 0.65, and 0.91 microns is green; light at 3.6 microns is orange; and light at 8.0 microns is red.



The Orion Nebula is found in the area of the sky of the "Trapezium," the four bright stars making up the sword of the constellation Orion the Hunter.

What Is Infrared?

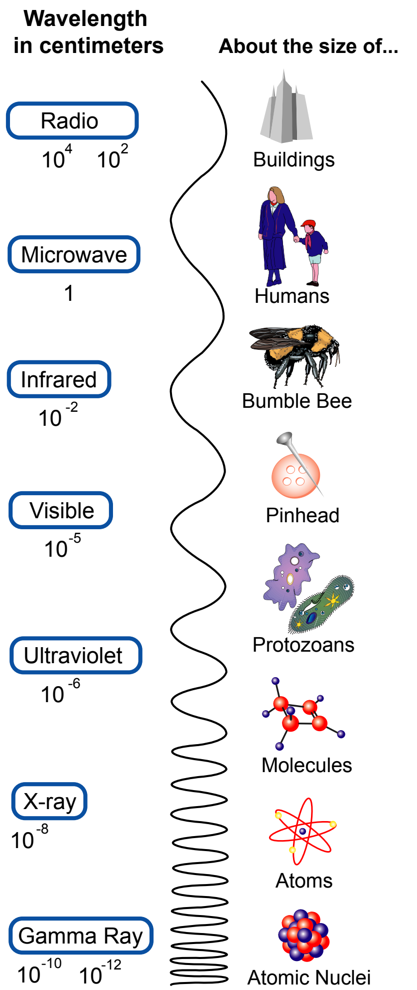


Figure 1.

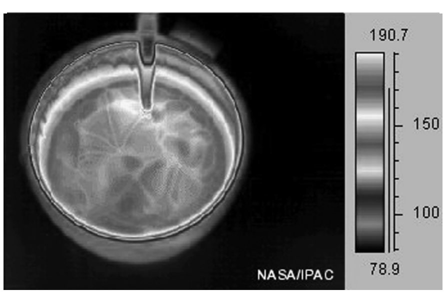


Figure 2.

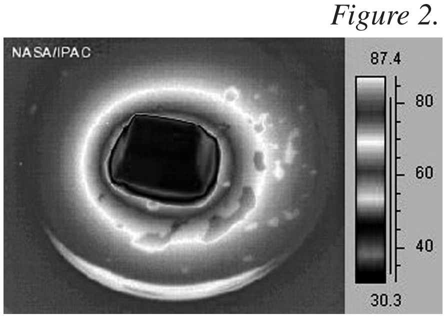


Figure 3.

We learn much about the world around us by using our eyes. Think about all the information you obtain and process by simply looking at the world around you. Our eyes are sophisticated detectors that have biologically evolved to "see" visible (or optical) light. There are, however, many other types of light—or radiation—that we cannot see without the aid of technology. Visible light is one of the few types of radiation that can penetrate our atmosphere and be detected on Earth's surface. We can see only a very small part of the entire range of radiation called the electromagnetic spectrum.

More Than the Eye Can See

As Figure 1 shows, the electromagnetic spectrum includes gamma rays, X-rays, ultraviolet, visible, infrared, microwaves, and radio waves. The only difference among these types of radiation is their wavelength, or frequency. Wavelength increases and frequency (as well as energy and temperature) decreases from gamma rays to radio waves. All these forms of radiation travel at the speed of light (300,000,000 meters or 186,000 miles per second in a vacuum). In addition to visible light, radio, some infrared, and a very small amount of ultraviolet radiation reach Earth's surface from space. Fortunately for us, our atmosphere blocks out the rest, much of which is very hazardous for life on Earth.

Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum. Infrared waves have wavelengths longer than visible light and shorter than microwaves, and have frequencies lower than visible light and higher than microwaves. The primary source of infrared radiation is heat or thermal radiation. This is the radiation produced by the motion of atoms and molecules in an object. The higher the temperature, the more the atoms and molecules move and the more infrared radiation they produce. All objects put out some infrared radiation. Even objects that we think of as being very cold, such as ice cubes, emit infrared radiation. When an object is not quite hot enough to radiate visible light, it emits most of its energy in the infrared. For example, hot charcoal may not give off light but it does emit infrared radiation, which we feel as heat. The warmer the object, the more infrared radiation it emits.

Rings of Heat

Figure 2 on the left is an infrared image of a metal cup holding a very hot drink. Notice the rings of temperature showing heat traveling from the liquid through the metal cup. You can see the rings of temperature in the metal spoon as well. Figure 3 is an infrared image of a melting ice cube. Notice the rings of different temperatures showing how the melt water warms as it travels away from the cube. Although the ice cube is cold, it still puts out heat. Infrared images give us valuable information about the heat being emitted by objects and how this heat is distributed.

By using infrared telescopes, astronomers can detect and learn about objects that are too cold to be seen in visible light. Infrared is useful in the hunt for planets outside of our solar system, the search for asteroids, and the study of regions of cool dust in space.

Figure 4A.

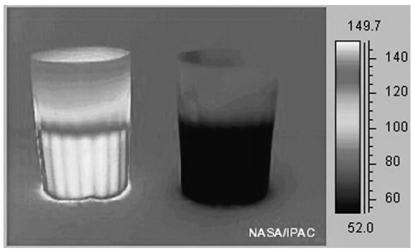


Figure 4B.

Figure 4A is a visible-light picture and Figure 4B is an infrared picture of two cups. One cup contains cold water, while the other contains hot water. In the visible light picture (4A) we cannot tell which cup is holding cold water and which is holding hot water. In the infrared image (4B), we can clearly "see" the glow from the hot water in the cup to the left and the dark, colder water in the cup to the right. If we had infrared eyes, we could tell if an object was hot or cold without having to touch it.

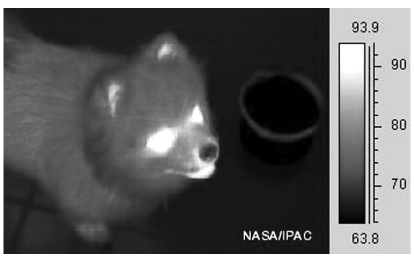


Figure 5A.

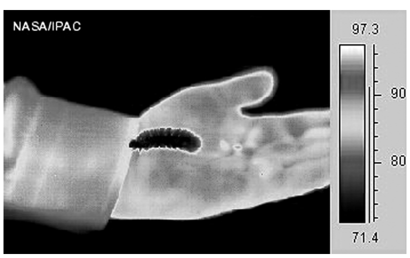


Figure 5B.

Figure 5A is an infrared image of a warm-blooded dog, and Figure 5B is an infrared image of a warm-blooded human holding a cold-blooded caterpillar. Warm-blooded animals, like the dog, make their own heat. In the infrared picture you can see how the dog's fur keeps some of this heat from escaping, keeping the dog warm. Insects are cold blooded, which means that they cannot make their own body heat. Instead they take on the temperature of their surroundings. The cold-blooded caterpillar appears very dark (cool) in the infrared compared to the warm-blooded human who is holding it. Notice how the caterpillar is at about the same temperature as the surrounding air. Infrared images give us a unique view of the world and the Universe around us.

Seeing Through "Walls"

Figure 6A.

Figure 6B.

Infrared light can travel through thick smoke, dust or fog, and even some materials. Figure 6A is a visible view and Figure 6B is an infrared view of a scientist's hand inside a black plastic bag. In the visible image, the hand cannot be seen. In the infrared image, however, the heat from the hand can travel through the bag and can be seen by a thermal infrared camera. Infrared light can pass through many materials that visible light cannot pass through. However, the reverse is also true. There are some materials that can pass visible light but not infrared. Notice the scientist's glasses! Infrared radiation cannot easily travel through glass. Since this person's body heat cannot travel through her glasses, they appear dark. Because infrared light can pass through dust, astronomers use infrared telescopes to study objects in space, like newly forming stars, which are hidden behind thick clouds of dust and gas. These new stars cannot be seen by visible light telescopes.

We experience infrared radiation every day. The heat we feel from sunlight, a fire, a radiator, or a warm sidewalk is infrared. Our bodies emit infrared radiation at a wavelength of about 10 microns (a micron is one millionth of a meter). The development of infrared detectors has allowed us to see the world and our Universe in this new light, leading to numerous benefits and discoveries. From search and rescue, medicine, and navigation, to the study of weather, oceans, and the cosmos, the ability to "see" in the infrared has not only saved lives, but has opened up a whole, new world to explore.

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Infrared Astronomy

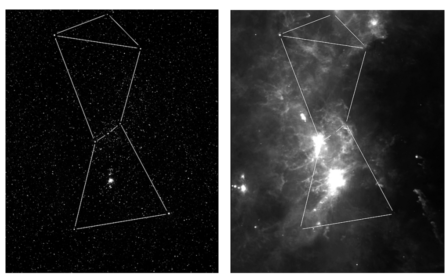
Objects in space emit many types of electromagnetic radiation that cannot be detected by optical telescopes. Each type of radiation (or light) brings us unique information. To get a complete picture of the Universe we need to see it in all of its light, using each part of the electromagnetic spectrum. Technological developments over the past seventy years have led to electronic detectors capable of seeing light that is invisible to human eyes. In addition, we can now place telescopes on satellites and on high-flying airplanes which operate above the obscuring effects of Earth's atmosphere. This combination has led to a revolution in our understanding of the Universe.

Infrared astronomy involves the detection and study of radiation emitted from objects in the Universe in the infrared portion of the electromagnetic spectrum. All objects in the Universe emit infrared radiation. Only a few narrow bands of infrared light can be observed by ground-based observatories. To view the rest of the infrared Universe we need to use space-based observatories or high-flying aircraft. Infrared is primarily heat radiation, and special detectors cooled to extremely low temperatures are needed for most infrared observations. Since infrared can penetrate thick regions of dust in space, infrared observations are used to peer into star-forming regions and into the central areas of our galaxy. Cool stars and cold interstellar clouds invisible in optical light are also observed in the infrared. Many interstellar molecules (including organic molecules) can be detected only in the infrared. Infrared observations also give us valuable information about the early Universe.

Exploring the Hidden Universe

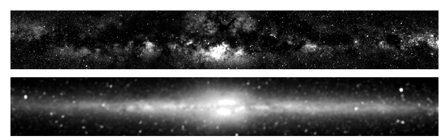
In space, there are many regions hidden from optical telescopes because they are embedded in dense gas and dust. However, infrared radiation, having wavelengths much longer than visible light, can pass through dusty regions of space. This means that we can study objects hidden by gas and dust in the infrared that we cannot see in visible light, such as the center of our galaxy and regions of newly forming stars. Infrared studies of star forming regions give us detailed information on how stars are born and help us learn more about how our own Sun and solar system were formed.

The two views to the right of the constellation Orion (also on the front of this poster), dramatically illustrate the difference between the familiar visible-light view (top) and the richness seen in the infrared (bottom) that is invisible to our eyes. The Orion Nebula is one of



Credit: Visible image courtesy of Howard McCallon; Infrared image NASA/IRAS

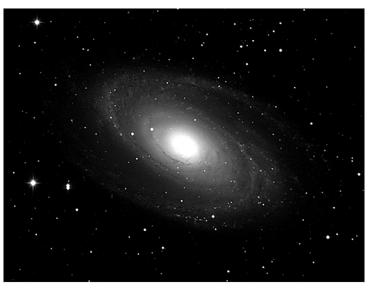
the nearest stellar nurseries where new stars are being formed. The center of our galaxy is not visible at optical wavelengths because it is hidden behind extremely dense regions of gas and dust. However we can view the center of our galaxy in the infrared. The center of our galaxy is one of the brightest infrared sources in the sky. Infrared observations show that the center of our galaxy consists of a very dense crowding of stars, and that stars and gases near the center are orbiting very rapidly (probably due to the existence of a black hole).



Credit: Visible image Axel Mellinger, Univ. of Potsdam, Germany; Infrared image Two-Micron All Sky survey (2MASS).

The images above, of the central region of our own Milky Way Galaxy, show how areas which cannot be seen in visible light (left) can show up very brightly in the infrared (right). The visible light image shows us the light from billions of stars, particularly the largest, brightest ones. Note the dark bands where vast clouds of dust block our view of more distant objects. In the infrared image, we can see the "glow" from these visibly dark regions. The thick dust, which is colder than the coldest arctic night on earth, is still warm enough to emit the infrared radiation seen here.

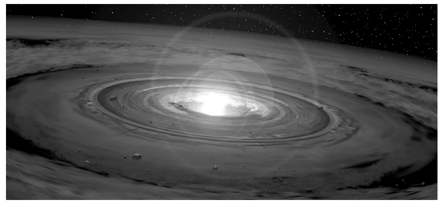
The dusty, star-studded arms of a nearby spiral galaxy, Messier 81, are illuminated in the infrared image below (top) from Spitzer. Much of the infrared emission comes from dustier parts of the galaxy where new stars are forming. The image shows the power of infrared telescopes to explore regions invisible in optical light (below, bottom) and to study star formation on a galactic scale.



Credit: Infrared (top)--NASA/JPL-Caltech/K. Gordon (University of Arizona) and S. Willner (Harvard-Smithsonian CfA). Visible (bottom)--N.A. Sharp (NOAO/AURA/NSF).

Detecting Cool Objects: The Hunt for Planets

Many objects in the Universe that are much too cool and faint to be detected in visible light can be detected in the infrared. These include cool stars, infrared galaxies, clouds of particles around stars, cool interstellar clouds, interstellar molecules, brown dwarfs and planets. In the 1980s, astronomers using the first infrared telescope in space, IRAS, discovered about two dozen stars that had infrared-emitting dust surrounding them. This discovery inspired astronomers to make more detailed observations of these stars.



What they found around these stars were flat, disk-shaped areas of dust in which planets had formed or could be forming (as in artist's rendering above). These findings have led the way to one of the most exciting new areas of research in astronomy—the search for planets around other stars. The discovery of these disks provided the first significant evidence that other solar systems might exist. Since then, infrared observations have led to the discovery of many more planet-forming disks. The visible light from a planet is hidden by the brightness of the star that it orbits. In the infrared, where planets have their peak brightness, the brightness of the star is reduced, making it possible to detect a planet in the infrared. Future infrared telescopes are planned that will have the resolution needed to image possible extrasolar planets directly.

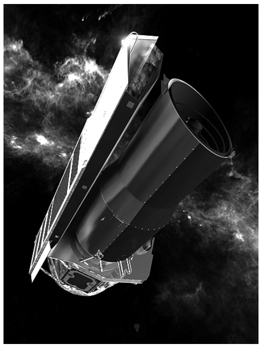
Exploring the Early Universe

In the infrared, astronomers can gather information about the Universe as it was a very long time ago and study the early evolution of galaxies. As a result of the Big Bang (the tremendous event that marked the beginning of our Universe), the Universe is expanding and most of the galaxies within it are moving away from each other. Astronomers have discovered that all distant galaxies are moving away from us and that the farther away they are, the faster they are moving. This recession of galaxies away from us has an interesting effect on the light emitted from these galaxies. When an object is moving away from us, the light it emits is "red shifted." This means that the wavelengths get longer and are shifted towards the red part of the spectrum. This effect, called the Doppler effect, is similar to what happens to sound waves emitted from a moving object. For example, if you are standing next to a railroad track and a train passes you while blowing its horn, you will hear the sound change from a higher to a lower frequency as the train passes you by. As a result of this Doppler effect, at very large red shifts, much of the visible and ultraviolet light from distant sources is shifted into the infrared part of the spectrum by the time it reaches our telescopes. This means that the only way to study this light is in the infrared. To understand how the first stars and galaxies were formed in the early Universe, it is essential to probe at infrared wavelengths. Infrared astronomy can provide valuable information about how and when the Universe was formed and about what conditions in the early Universe were like.

Adding to Our Knowledge of Visible Objects

Objects that can be seen in visible light can also be studied in the infrared. Infrared astronomy not only allows us to discover new objects and view previously unseen areas of the Universe, but it can add to what we already know about visible objects. To get a complete picture of any object in the Universe we need to study all the radiation it emits. Infrared astronomy has added, and will continue to add, a great deal to our knowledge about the Universe and the origins of our solar system.

The Spitzer Space Telescope



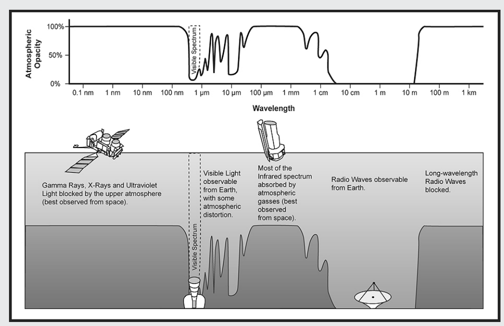
The Spitzer Space Telescope was launched into space by a Delta rocket from Cape Canaveral, Florida, on August 25, 2003. Spitzer's mission is to obtain images and spectra by detecting the infrared energy, or heat, radiated by objects in space between wavelengths of 3 and 160 microns (1 micron is one-millionth of a meter).

Consisting of an 85-centimeter telescope and three cryogenically-cooled science instruments, Spitzer is the largest infrared telescope ever launched into space. It has given us a unique view of the Universe and allowed us to peer into regions of space hidden from optical telescopes. Many areas of space are filled with vast, dense clouds of gas and dust that block our view. Infrared light, however, can penetrate these clouds, allowing us to peer into regions of star formation, the centers of galaxies, and into newly forming planetary systems. Infrared also brings us information about the cooler objects in space, such as smaller stars too dim to be detected by their visible light, extrasolar planets, and giant molecular clouds. Also, many molecules in space, including organic molecules, have their unique signatures in the infrared.

Because infrared is primarily heat radiation, the telescope must be cooled to near absolute zero (-273 degrees Celsius or -459 degrees Fahrenheit) so that it can observe infrared signals from space without interference from the telescope's own heat. Also, the telescope must be protected from the heat of the Sun and the infrared radiation emitted from Earth. Thus, Spitzer carries a solar shield to protect it from the heat of the Sun, and it was launched into an Earth-trailing solar orbit. This unique orbit places Spitzer far enough away from the Earth to allow the telescope to cool rapidly without having to carry large amounts of coolant. This innovative approach has significantly reduced the cost of the mission.

Why Send Telescopes into Space?

The amazing variety of objects in our Universe send us light all across the electromagnetic spectrum. However, much of this light (or radiation) does not reach us at ground level here on Earth. Why? Because we have an atmosphere that blocks out certain types of radiation, while letting other types through. Fortunately for life on Earth, our atmosphere blocks out harmful high-energy radiation like x-rays, gamma rays and most of the ultraviolet rays. The atmosphere also absorbs most of the infrared radiation that reaches Earth from space. On the other hand, our atmosphere is transparent to visible light, most radio waves, and small windows within the infrared region.



Most of the infrared light coming to us from the Universe is absorbed by water vapor and carbon dioxide in Earth's atmosphere. Only in a few narrow wavelength ranges can infrared light make it through (at least partially) to a ground-based infrared telescope. Earth's atmosphere causes another problem for infrared astronomers. The atmosphere itself radiates strongly in the infrared, often putting out more infrared light than the object in space being observed.

So the best view of the infrared Universe from ground-based telescopes is at infrared wavelengths that can pass through Earth's atmosphere and at which the atmosphere is dim in the infrared. Ground-based infrared observatories are usually placed near the summits of high, dry mountains to get above as much of the atmosphere as possible. Even so, most infrared wavelengths are completely absorbed by the atmosphere and never make it to the ground. The only way to observe these wavelengths is to get high above the atmosphere.

For the most part, everything we learn about the Universe comes from studying the light (or electromagnetic radiation) emitted by objects in space. To get a complete picture of any object in the Universe, we need to examine it in all of its light, using the information sent to us at all wavelengths. This is why it is so important to send observatories, like the Spitzer Space Telescope, into space, to get above our atmosphere, which prevents so much of this valuable information from reaching us.

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