Infrared Telescopes

The infrared region of the spectrum covers a wide range of wavelengths—from 0.7 to 1000 μm. However, astronomers usually restrict the term 'infrared' to the more limited region of 1 to 350 μm—though even this is over 100 times wider than the visible region of the spectrum.

Infrared radiation was discovered in 1800 by William HERSCHEL, during his investigations of the visible light spectrum. When he placed a thermometer outside the red end of the rainbow spectrum, Herschel found that an invisible source of radiation caused the instrument to record a rise in temperature. He called the invisible rays 'infrared'.

We now know that the strongest infrared sources are relatively cool objects, such as red giant stars, nebulae, planets and comets, whose temperatures are between about 70 K and 3000 K. In contrast, the Sun is a fairly weak infrared emitter. With its surface temperature of about 5500 K, our nearest star emits most of its radiation at visible wavelengths. Herschel's discovery was only made possible because of the Sun's close proximity.

Little progress towards understanding the infrared universe was made until the invention of more sensitive, electronic detectors in the 1950s. Some notable exceptions were the detection of infrared emission from the Moon by Charles Piazzi SMYTH in 1856, and infrared observations of the Moon through its cycle of phases by the 4th Earl of ROSSE, who attempted to calculate its surface temperature. The first infrared observation of an object outside the solar system seems to have been made in 1878 by Thomas Edison, who observed the star ARCTURUS during a solar eclipse.

Not until 1969 was the first infrared sky survey undertaken by Gerry Neugebauer and Bob Leighton from Caltech. With the aid of lead sulphide detectors, their relatively crude 1.5 m (60 in) diameter telescope scanned 70% of the sky and detected 5612 cosmic infrared sources at 2.2 μm. More recently, detectors have been made from germanium doped with copper, mercury or gallium. Unfortunately, while these are able to probe to longer wavelengths, they require cooling to very low temperatures (2 K) in order to eliminate background interference.

Another problem to be overcome by ground-based observatories was the absorption of infrared radiation by gases such as water vapor and carbon dioxide in the Earth's atmosphere. Fortunately, in the near-infrared and mid-infrared regions, from 1 to 10 μm, there are some clear atmospheric 'windows'. From observatories on high mountain peaks, astronomers are able to use these 'windows' to investigate the infrared sky at certain wavelengths.

Most observations are obtained by means of near-infrared detectors attached to optical telescopes. For example, the 5 m (200 in) Hale telescope on Mount PALOMAR has recently been fitted with a near-infrared camera which operates at 1–2.5 μm, while the 8 m (300 in) units of the Very Large Telescope in Chile utilize a cryogenic infrared spectrometer and array camera (ISAAC) which observes in the spectral region 0.9–5 μm.

Modern instruments attached to smaller telescopes can also return data of major importance. The latest census of the near-infrared sky, known as the Two Micron All Sky Survey (2MASS) project, began in June 1997. 2MASS uses two new, highly automated 1.3 m (51 in) telescopes, one at Mount Hopkins in Arizona, and one at CERRO TOLOLO in Chile. Both telescopes are equipped with a three-color infrared camera, each channel consisting of a 256 $\times$ 256 array of detectors which is capable of observing the sky simultaneously at 1.25, 1.65 and 2.17 μm.

The development of large-format infrared detector arrays, funded by the US Department of Defense and NASA, has made the new survey possible. These mercury–cadmium–tellurium detectors, similar to those developed for the Near Infrared Camera and Multi-Object Spectrometer on the HUBBLE SPACE TELESCOPE, can now detect astronomical objects over 100 million times fainter than those seen by the original Two Micron Survey.

When completed, the 2MASS survey will contain accurate positions and fluxes for some 300 million stars and other unresolved objects, together with positions and total magnitudes for more than a million galaxies and nebulae, including galaxies in the 60° wide 'zone of avoidance', where dust within the Milky Way renders optical galaxy surveys incomplete. Rare objects such as extremely low-luminosity stars and brown dwarfs, or heavily dust-obscured AGNs and globular clusters located in the galactic plane, should also be discovered. (For further information see http://www.ipac.caltech.edu/2mass/)

Despite such advances, the best site for ground-based infrared observations remains the 4200 m (13 800 ft) high Mauna Kea in Hawaii. Located on its summit are the two largest purpose-built infrared telescopes in the world, the 3 m (120 in) NASA INFRARED TELESCOPE FACILITY and the 3.8 m (150 in) UNITED KINGDOM INFRARED TELESCOPE. Nearby are the twin 10 m (400 in) Keck telescopes and the 3.6 m (140 in) CANADA–FRANCE–HAWAII TELESCOPE, which are used for both optical and infrared observations.

However, even the Mauna Kea site is not high enough to allow far-infrared observations. In order to rise above the bulk of the water vapor and the atmosphere, astronomers have turned to placing telescopes on balloons, sounding rockets or high-flying aircraft.

In 1972 and 1974, the US Air Force Cambridge Research Laboratories (later known as the Air Force Geophysics Laboratory) carried out project HISTAR to survey the sky at various wavelengths between 4 and 27 μm. Using a liquid helium-cooled 16.5 cm (6.5 in) telescope on nine suborbital rocket flights, the project cataloged over 2000 infrared sources.

This was soon followed by the introduction of NASA's Kuiper Airborne Observatory (KAO), a modified Lockheed C-141 military aircraft equipped with a 90 cm (36 in) infrared telescope. After 20 years and more than

1500 flights, budget cuts brought the KAO to an end on 13 October 1995.

However, a much larger, more powerful successor is scheduled to become operational in 2002. NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) will fly on board a modified Boeing 747-SP aircraft at an operational height of 12.5 km (nearly 41 000 ft). From this altitude, SOFIA will be above 99.9% of the infrared-absorbing atmospheric water vapor that limits ground-based infrared observations.

With its European-made 2.7 m (106 in) primary mirror, SOFIA will be one of the most capable infrared observatories in the world. It will operate primarily at infrared and submillimeter wavelengths, from 0.3 to 1600 μm, though it can also be used for visible observations. Despite its size, SOFIA has been designed to meet the stringent weight requirements of an airborne telescope, and the complete system is expected to weigh only about 20 tonnes (44 000 lb).

The observatory is expected to provide unprecedented views of regions of star formation in interstellar dust clouds, circumstellar dust disks, distant comets and moons, as well as spectral information on complex molecules in space, planetary atmospheres and nearby galaxies.

SOFIA is being developed by the American Universities Space Research Association (USRA), which will also operate the telescope for NASA once it becomes operational. Under an international agreement between the United States and the German government, the German Aerospace Research Centre (DLR) is responsible for the design and construction of the SOFIA telescope. In return for supplying the telescope and part of the funding for its operation, German astronomers will receive 20% of SOFIA's observing time.

see also: INFRARED SPACE MISSIONS

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