

A decade of infrared space astronomy comes to a close

The end of the Herschel Space Observatory mission

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On Monday, April 29, the Herschel Space Observatory exhausted its supply of ultra-cold liquid helium coolant, required to do its most sensitive observations. A ten-year period in which five telescopes gazed at the sky observing the heat of cosmic objects, rather than the light emitted, has come to an end.

Herschel was launched on May 14, 2009 from the European Space Agency launchpad in French Guiana carrying a 3.5 meter (11.5 feet) mirror, the largest ever flown in space, and launched with over 2,300 liters of liquid helium to support at least a three year mission lifetime. The telescope observed wavelengths of light unobserved by previous instruments.

Infrared astronomy is a useful probe of the Universe for three central reasons. Much of the universe is comprised of material which is *cold*, unlike the hot surface of stars. This is invisible in most of the electromagnetic spectrum unless illuminated by nearby hot objects, but *is* visible in the infrared. Cold clouds of gas and dust can be mapped directly through infrared observations. Much of the universe is also *dusty*, and dust extinguishes visible light. Infrared has the ability to reveal the details of events like stellar formation inside obscuring clouds. It permits a full and unbiased census of stellar formation even for extraordinarily distant galaxies. Finally, the universe is *expanding*, and the most distant objects appear to recede from us at enormous velocities. This shifts much of their emitted radiation towards the red and into the infrared.

The history of astronomy in the 20th century is linked to the expansion of technology that allowed the study of wavelengths of light beyond the visible spectrum. The first radio observations of the universe were made

in the 1930s, although radio astronomy as a discipline would not begin in earnest until the 1950s. Microwave astronomy followed in the next decade, leading to the epochal discovery of the remnant radiation signifying the original fireball of the Big Bang. The first views of the universe in ultraviolet, X-rays, and gamma rays were successfully accomplished in the 1970s aboard a series of investigative satellites and a significant observatory that was part of the Skylab space station.

Detecting infrared radiation, the heat given off by matter, posed significant technical challenges to the construction of sensitive telescopes. The water vapor in Earth's atmosphere blocks the bulk of infrared radiation from the ground, requiring that the most sensitive telescopes operate from space. In addition, objects at room temperature emit copious radiation in the infrared—observing a faint remote object with a warm telescope would be akin to looking at a landscape through binoculars heated to thousands of degrees in which the optics and detector are brilliantly glowing.

As a result, infrared telescopes are best operated in space, or at least tens of thousands of feet above sea level. Moreover, both the telescopes and detectors which record infrared radiation must be chilled to within a few degrees of absolute zero. This requires a great deal more understanding of physics and engineering than the construction of visible light detectors, which are far easier to make and produce far more data: a modern cellphone camera contains more pixels than the most sophisticated infrared detectors yet made.

The first explorations of the infrared, in the 1960s, were accomplished through brief forays above the atmosphere by surplus military rockets, in which

telescopes the size of a forearm would briefly observe a handful of targets during observations lasting only a few minutes. A successful flight would require atmospheric reentry with a functioning parachute and retrieval of data from magnetic tapes carried aboard the rocket. An unsuccessful flight meant the craft burning up in the atmosphere as it came back to Earth.

By the 1970s, NASA sponsored flights aboard planes at altitudes exceeding 45,000 feet, above about 85 percent of the atmosphere. On-board first a Learjet, and then a converted C-141, a small telescope would collect infrared light and direct it to instruments which could actually be adjusted and optimized over the course of a flight.

In 1983, the Infrared Astronomical Satellite (IRAS) was launched—the first space-based observatory to operate at infrared wavelengths, and also the first spacecraft to carry liquid helium to cool its components to the ultra-cold temperatures required for effective infrared observations. Over 10 months, it mapped the entire sky in four "colors" of infrared light, using only 62 pixels to record them. Some of the discoveries were astonishing: it was expected entering the mission that only a few hundred targets outside of our own Milky Way galaxy would be bright enough to be recorded. Instead, some 75,000 were cataloged.

We now know that these brilliant infrared sources comprise what are now called starburst galaxies (SBs), Luminous Infrared Galaxies (LIRGs), and Ultra-luminous Infrared Galaxies (ULIRGs). Many of these objects were faint or invisible through even large telescopes in ordinary light.

IRAS had discovered the evidence for the early universe's astonishing period of energetic star formation, in which newly formed galaxies underwent cataclysmic episodes of stellar birth. These were not seen before because clouds of dust cloaked most or all of the ordinary light from escaping.

These findings forced a reappraisal of the infrared as a window into the universe. Originally, the IRAS satellite was conceived as a "one-off" mission, with little follow-up compared to the productive investigations underway using microwave, radio, gamma and x-ray radiation. The glimpse of star formation over the history of the universe convinced a US panel of astronomers meeting in 1990 to outline the highest priority science of the coming decade, to

nominate an improved and mature infrared space observatory as one of the principal recommended missions.

The first modern infrared space mission was the Infrared Space Observatory, operating between 1995 and 1998, by the European Space Agency in cooperation with Japan and NASA. It was followed by the Spitzer Space Telescope (2003-2009), the Akari satellite (2006-2011), the Planck satellite (2009-2012), the WISE satellite (2009-2011) and lastly by Herschel (2009-2013).

One of the many discoveries found in the wavelengths probed by Herschel was the measurement of a particular color of radiation that is critical to the cooling of clouds of gas on their way to becoming new stars. Hundreds of other discoveries have been published and many more will follow.

These observations have now come to a stop. After nearly two decades of data collection, involving telescopes conceived as early as the 1970s, there are no ultra-cold infrared telescopes under construction, or even under detailed design. The much-delayed James Webb Space Telescope will have an infrared capability but the telescope will operate at much warmer temperatures than the most sensitive infrared observations demand.

A unique window for all of mankind on the universe has been closed, not for lack of interest or support among astronomers and the general public, but because the same social system which balances the books of the banks on the backs of the working class has no interest in comprehending the material structure of the universe when there is no profit to be made.



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