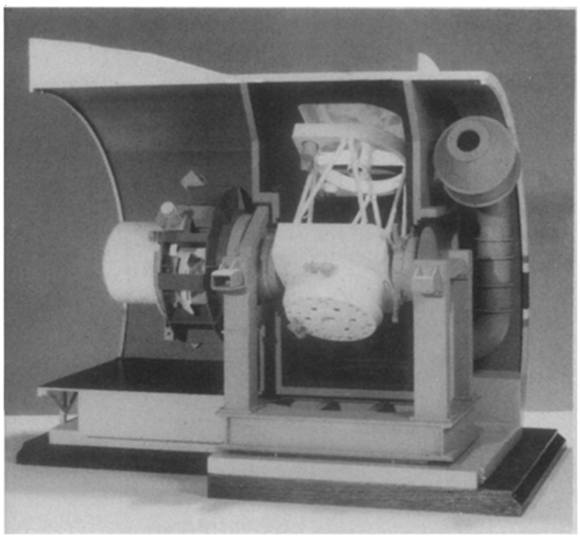
The High-Flying Eyes of KAO

The Kuiper Airborne Observatory cruises above most of the atmosphere to get an infrared view of astronomical phenomena



By DIETRICK E. THOMSEN

The water vapor in the earth's atmosphere makes an essential contribution to human survival. But this same necessary water vapor is highly deleterious to the survival of infrared radiation from astronomical bodies. Most wavelengths of infrared do not survive to the ground at any elevation near sea level.

Astronomers interested in the infrared have to lift their telescopes above as much of the water vapor as possible. High mountains help, and satellites will work, of course, but a solution that gets above more of the water vapor than the highest mountains but is cheaper and more flexible than a satellite is a high-flying airplane. This choice is exemplified by the Kuiper Airborne Observatory (KAO), a telescope-equipped plane based at Moffett Field, Calif., that cruises at 41,000 feet while astronomers make observations, literally on the fly.

Infrared wavelengths are a stretch of the electromagnetic spectrum lying between the visible red and the radio. The cut-off between visible red and infrared is about one micron wavelength. At about a millimeter (1,000 microns) wavelength, infrared shades into radio. A variety of sensing and recording techniques is used over this range: lenses and other optical instruments at shorter wavelengths, radio-style devices at the upper end and heat-sensing apparatus everywhere.

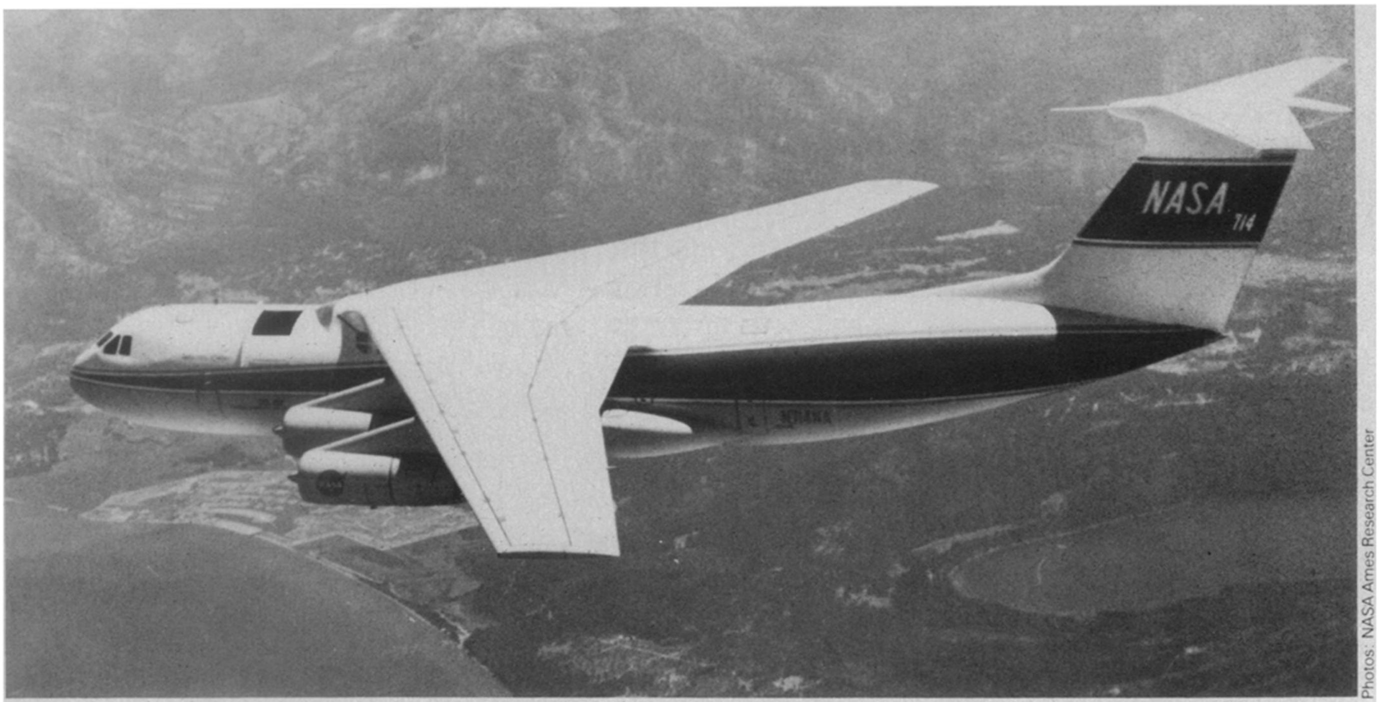
Infrared is one way of "seeing" astronomical bodies that are too cool to be incandescent. Thus it is the prime medium for studying the earliest stage of star formation before the infant star is hot enough to glow in visible light. It is also very useful for studying the clouds of gas and dust that permeate interstellar space. Visible bodies too emit in the infrared, which can give information about them that is not available from their visible light. Thus, almost everything in the sky, seen and unseen, is a possible candidate for infrared observation.

Therefore, it is hardly surprising that the KAO has been a busy operation in the nearly 10 years that it has been flying. At the recent meeting of the American Astronomical Society in Troy, N.Y., two invited oral presentations and two entire sessions of poster presentations were devoted to recent activities of the KAO.

Managed by the NASA Ames Research Center at Moffett Field in California, the KAO is a national facility for infrared observations used by astronomers from universities, government agencies and industrial research organizations. The aircraft is a C-141 jet, which carries a 91.5 centimeter telescope in an unpressurized, "open-port" compartment. According to L.C. Haughney of Ames, it makes between 70 and 80 observational flights a year, in a program accommodating the work of 20 to 25 teams of researchers. A typical flight lasts about 7.5 hours, ranging from about 11.8 to 13.7 km altitude, where it is above about 99 percent of the atmosphere's water vapor.

Planets are one class of objects for which infrared observation is highly rewarding. The planets absorb and reprocess solar radiation, and the infrared component of the outflow gives information about their surfaces and atmospheres. Furthermore, three of the larger planets, Jupiter, Saturn and Neptune, emit more heat (as infrared) than they absorb from the sun, indicating that there are internal sources of energy in them.

Infrared reveals information about the compositions of the planetary atmospheres and their chemical reactions and physical dynamics. According to Harold P. Larson and D. Scott Davis of the University of Arizona's Steward Observatory, infrared studies address certain very basic questions about the atmospheres of Jupiter and Saturn — questions so basic that a child would be likely to ask them: What are the major planets made of? "More compositional information has been produced with the KAO than from any other facility," Larson and Davis claim. "Why are the clouds colored? KAO spectra have yielded evidence for an abundance of phosphine (PH_3) in the Jupiter and Saturn atmospheres. Phosphine is one of several compounds involved with the formation of the chromophores — coloring agents — in the clouds. What is beneath the clouds? Five-micron infrared waves can come through the clouds, providing a view of the planet's deeper physics and chemistry. Why are the outer planets different? This is an important question for both comparative planetology and the theory of star formation.



A 36-inch infrared telescope (opposite page) is mounted inside an open cavity recessed into the left side of the Lockheed C-141 jet transport, just ahead of the wing.

Among the other objects in the heavens that are too cool for incandescence—and which are thus truly important candidates for study by infrared — are the clouds of gas and dust in various parts of our own and other galaxies, and the clumps inside these clouds that appear to be stars in the process of formation. It is necessary to map the clouds and study the densities and motions of the material in them to determine just where and how new stars may be forming.

At the AAS meeting, KAO studies were reported of the Sharpless 156 cloud, the W5 cloud, clouds in associations of young class R stars, and the most famous of all, the Orion nebula. Data were also presented about some of the compact infrared objects in these clouds that are thought to be protostars — the Becklin-Neugebauer object in Orion, S140 and W3IRS5. Previous studies had produced spectra of these objects showing absorption features at 6.0 and 6.8 microns, which were tentatively attributed to mantles of ice or organic material on dust grains in the neighborhoods of these sources. The newly reported work, representing the efforts of 15 researchers from seven different institutions, combines to support that proposal. (Also described at the meeting was the detection, by D. Jaffe and colleagues from the University of Chicago, of a new class of compact far-infrared sources in the same kind of cloud regions, but whose characteristics don't coincide with previously known ones.)

Luminous objects may be surrounded by dust clouds that absorb their light and re-emit it as infrared. Certain young stars in Orion are one example. Another is whatever strange energetic processes are going on in the center of our galaxy. According to M.L. Werner of NASA-Ames, the KAO is being used to study the composition and motions of the clouds there. One recent development is the discovery of ionized argon in those clouds.

Surrounding our galaxy are the globular clusters of stars. They contain hundreds and thousands of stars each and are scattered in the space above and below the disk of the galaxy. Werner says that continuing improvements in KAO photometry finally made it possible to "see" them in 1981. These globular cluster stars are thought to be the oldest associated with the galaxy and so their study is important for both the history of star formation and the history of the formation of the galaxy. J.A. Davidson of the University of Chicago and colleagues report the detection of a compact infrared source in the globule B335. This source has a diameter of less than 30 arcseconds and a temperature significantly higher than that of the diffuse infrared from similar globules.

Galaxies other than our own also have gas clouds and star formation. Studies of the continuous spectra of more than two dozen spiral galaxies between 40 and 160 microns by L.J. Rickard of Howard University and P.M. Harvey of the University of Texas and comparison of the infrared with the same galaxies' carbon monoxide radio emission support the notion that the heat sources for the infrared are massive stars forming in molecular clouds.

The KAO has also provided the first detection of infrared spectral emission lines (as distinct from continuous spectra) from an extragalactic object. R.L. Genzel of the University of California at Berkeley and co-workers reported lines of singly ionized oxygen (63.2 microns) and triply ionized oxygen (88.4 microns) in the galaxy M82, one of the nearest to us.

Finally a note from the far reaches of the universe. In 1982 the KAO became able to see quasars. Two of them have been detected, 3C345 and 3C273. Not only are quasars very far away, most of them are extremely bluish and ultraviolet objects and are very weak in infrared emission.

The detection of such faint infrared objects as quasars and globular clusters illustrates the improvement over the years in the equipment built for use with the KAO, says Martin Harwitt of Cornell University. Spectroscopy — the ability to distinguish one wavelength from another, to detect emission and absorption lines and to measure the Doppler shifts in wavelengths caused by motion — is the most important thing for astrophysicists. In 1975 the KAO's ability to resolve one wavelength from another was one part in 30. "Spectrophotometry was hardly possible," says Harwitt. Today the resolution is one in a hundred thousand. Recent application of heterodyne receiving techniques, a borrowing from radio technology, now makes possible the measure of Doppler shifts representing motion of slightly less than one kilometer per second.

Both spectroscopic resolution and the general receiver sensitivity of the KAO's instrumentation continue to improve. In a year or two, says Harwitt, it should be able to detect any source that the Infrared Astronomy Satellite, which NASA plans to launch this year, will be able to detect. Thus, when the IRAS is up and functioning, the KAO, with its ability to make quick changes in programs and to mount equipment designed ad hoc for particular investigations, will be able to serve as a back-up and follow-up observatory. KAO will be able to conduct studies of particularly interesting phenomena discovered in IRAS studies that may require special equipment or programs not on the satellite or that may take more time than the satellite's equipment can devote to any one object. □