On 9 November, as the Infrared Astronomy Satellite (IRAS) was nearing its tenth month of near-flawless operation, exuberant scientists of the American-Dutch-British collaboration met in Washington, D.C., to review the early results and present them to the press. IRAS is sending down 700 million bits of information per day and is well on its way towards finishing the first complete survey of the infrared sky. By the time its liquid helium coolant runs out in late December or early January, it will have scanned each point in the sky at least six times.

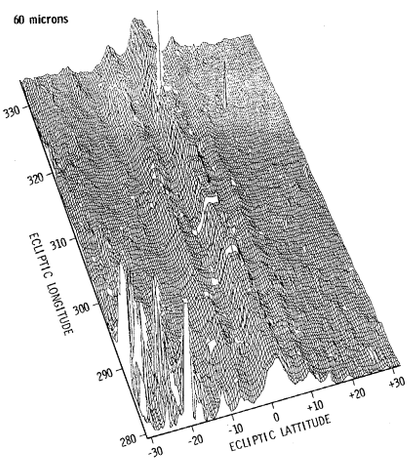
"We're overwhelmed by the largess," said Frank Low of the University of Arizona. The infrared radiation imaged by IRAS signals the presence of the cold objects of the universe, objects such as planets, asteroids, and the dark, dusty clouds where stars are born; moreover, that radiation is able to penetrate the masses of gas and dust that obscure so much of our galaxy from conventional telescopes. Only a few percent of the IRAS data have been analyzed so far. But already, the hints are tantalizing. Some examples:

Dust at the asteroid belt: IRAS has looked outward through the solar system at the thin veil of interplanetary dust that continually drifts into the sun and found signs of dust apparently forming in the asteroid belt. This dust may be a source of the faint pyramid of zodiacal light visible to the naked eye near dawn and dusk.

As IRAS scanned across the orbital plane of the planets, called the ecliptic, it detected the relatively bright infrared glow of dust centered on the ecliptic and extending with diminishing intensity to about 60 degrees above and below it. Filtering of the data to remove this broad hump of infrared emission revealed three relatively tiny emission peaks superimposed on it, the larger one being centered on the ecliptic and two smaller ones flanking it 8 to 10 degrees from the ecliptic.

Judged from the 165 to 200 K temperature of this dust, says Low, it must be orbiting the sun in the vicinity of the asteroid belt between Mars and Jupiter, although the Pioneer spacecraft could find no more dust there than elsewhere. Because no zodiacal dust particles can resist the forces that drag them toward the sun, this banded structure of dust distribution could not survive more than a few tens of thousands of years without being replenished.

Low suggests that the most likely way to renew this particular bit of dust in the zodiacal cloud would be through collisions between asteroids whose orbits are also inclined about 9 degrees. A less likely source would be a collision between an asteroid and a comet having an orbit inclined 9 degrees to the ecliptic.



Asteroidal dust bands?

These three bands of infrared emission have been extracted from the far brighter zodiacal background. The flanking bands, which represent dust in slightly inclined orbits, may be produced by repeated collisions of asteroids.

Low hopes to use such fine detail in the distribution of the zodiacal dust to decipher its origins. Recent opinion has favored a cometary origin.

A burned-out comet: When IRAS discovered it on 11 October, it was labeled a "fast-moving object," a solar system speedster of interest to those astronomers searching for asteroids sweeping through the inner solar system inside the orbit of Earth. When they photographed the object, which is tentatively identified as minor planet 1983TB, the sharpness of its trail on the photographic plate testified to its asteroidal rather than cometary nature.

IRAS's first discovery of an Earth-crossing asteroid was complicated by later developments. It turned out that 1983TB shares the same orbit about the sun as the dust and debris that collides with Earth each 14 December and creates the Geminid meteor shower. Other meteor showers have been associated with known comets actively shedding debris under the blistering heat of the sun, but meteor showers have not been associated with asteroids. Presumably, 1983TB is a comet that has had all of its volatile ices boiled away, leaving a core of dust and rock.

If 1983TB was once a comet, it had good reason to lose its ices. Now less than 2 kilometers across, its orbit carries it from the asteroid belt between Mars and Jupiter to within 15 million kilometers of the sun. That is inside the orbit of Mercury, ten times closer to the sun than Earth, and 7.5 million kilometers closer than the aptly named asteroid Icarus ever comes. The highly elongated and steeply inclined orbit of 1983TB also argues that it was once a comet, since comets often have such orbits.

Astronomers have suspected that other asteroids, including 8 of the 58 known Earth crossers, were once active comets. Their elongated orbits and apparent carbonaceous composition suggested that they were burned-out comets. The problem was that astronomers do not know for certain what comets are made of. But now they believe that they may have a specific object that they can use to link observed asteroid properties to a known comet nucleus. They must still scramble to get telescope time under good observing conditions in order to refine 1983TB's orbit further and eliminate any possibility of a faint comet coma.

Infrared "cirrus": IRAS has identified a faint, wispy network of clouds that cover virtually the entire infrared sky. Dubbed "cirrus" by the science team, the clouds are quite cold: they only appear in the 100-micrometer channel, corresponding to a temperature of roughly 30 K. This means they are probably made of graphite dust; the only other plausible candidate material, silicate dust, has a characteristic temperature of 15 K.

A key question is the distance to the cirrus. Some of it does appear to be associated with clouds of neutral hydrogen out in the galactic arms. But most of it does not. Indeed, the fact that the cirrus is spread across the whole sky instead of being concentrated along the Milky Way seems to suggest that it is relatively close to the solar system. On the other hand, IRAS has seen no parallax in the cirrus as Earth moves around the sun, which means that the network is at

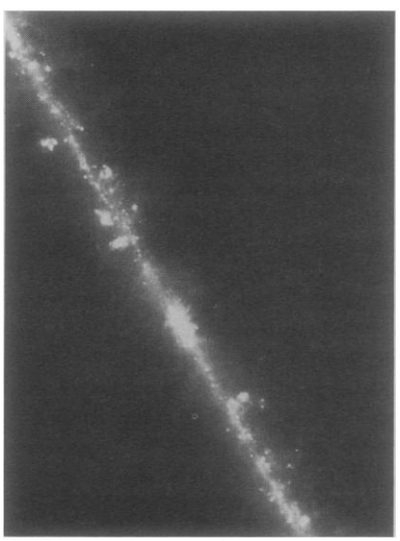
least 1000 astronomical units away. One idea is that the cold cirrus dust is associated with the Oort cloud, a sphere of millions or billions of celestial icebergs that orbit the sun some 50,000 astronomical units out, and occasionally plunge into the inner solar system to become the apparitions we know as comets.

Mysterious background emissions: Showing up only as a subtle asymmetry in the 100-micrometer IRAS scans, these emissions appear to represent a large component of galactic material of an unknown nature. The finding could have great significance, considering that so much of our galaxy (and other galaxies) appears to consist of "missing" mass. That is, the galaxy is rotating much too fast for the visible stars to hold it together gravitationally, and there must be a great deal of invisible matter making up the difference (*Science*, 4 March, p. 1050).

New kinds of star-forming regions: Ground-based studies of star formation have primarily focused on the birth of very massive, very luminous stars in giant molecular cloud complexes similar to the one in Orion (*Science*, 5 February 1982, p. 647). Unfortunately, none of these giant complexes is close enough to tell us much about the formation of faint stars like our own sun. However, IRAS has discovered that star formation is far more prevalent in the galaxy than anyone realized. A surprising number of small gas and dust globules within about 650 light-years of the sun—objects once thought to be quiescent—have turned out to harbor newformed stars in a state of evolution much like that of the sun when it formed 4.6 billion years ago. "If you extrapolate this to the galaxy as a whole, it means that the galaxy is forming about 1 solar mass star per year," says Charles Beichman of the Jet Propulsion Laboratory. "We don't fully understand what triggers gas and dust to collapse into a star. But this certainly extends the range of cloud masses and star masses we can examine."

Vega: One of IRAS's most spectacular discoveries to date has been the ring of solid particles orbiting the star Vega (*Science*, 26 August, p. 845). The ring is thought to consist of material leftover after Vega's formation about a billion years ago; the particles may resemble the meteoroids and zodiacal dust found in our own solar system. The Vega ring is thus the first direct evidence for the formation of a solar system outside our own.

So far, however, it is still the only such ring. A new ring would show up as an enhancement in the infrared brightness of its parent star. Yet IRAS has surveyed the 9000 brightest stars in the sky and has found only about 50 candidates, which in itself indicates that the Vega phenomenon is rare. Moreover, those infrared enhancements could also come from such prosaic sources as stellar winds, a chance encounter from a dust cloud, or a faint, cool stellar companion. The IRAS astronomers clearly have a lot of sorting out to do. On the other hand, even if Vega-type rings are rare, that does not mean that solar systems are rare: if IRAS were orbiting Alpha Centauri, just 4.5 light-years away, it would not notice a thing unusual about the sun.



IRAS views the galactic center

To infrared eyes the Milky Way looks a bit like a phonograph record held edge on. In part this is because the sources are some 30,000 light-years away, far beyond the star clouds we see on a summer's night; in part it is because the warm dust imaged by IRAS is confined quite closely to the galactic mid-plane. Star-forming regions spangle the foreground in this image; the infrared cirrus seems to stream from the plane like a wispy fog; and the core itself is an oval mass glowing at 25 K.

A dust shell around Betelgeuse: Famous as the ruby at the shoulder of Orion, Betelgeuse is a red supergiant star, known to be shedding material at a prodigious rate. IRAS now finds evidence for a series of dust shells extending some 4.5 light-years from the star, which suggests that Betelgeuse experienced at least three major eruptions between 50,000 and 100,000 years ago. The surprising thing is the asymmetry of the shells: they only extend to the north. One idea is that, as Betelgeuse moves through the dense interstellar medium of the Orion region, it emits symmetrical shells that are then swept away like puffs of smoke trailing an old-time steam locomotive.

Infrared galaxies: At 60 and 100 micrometers, the vast majority of stars are invisible. What IRAS sees as it points away from the galactic plane is a sky full of galaxies, perhaps 10,000 or 20,000 of them. Most of them are known spiral galaxies, which is understandable enough since spiral arms are lined with warm gas and dust, and are hotbeds of star formation. But a surprising number are odd, disturbed objects, including one galaxy that looks like nothing so much as a diamond ring. Still others, including some of the brightest infrared galaxies, show up only as inconspicuous smudges in visible light. The peculiar thing is that the Milky Way, which is a fairly typical spiral galaxy, would be just about as luminous either way; yet these "inconspicuous smudges" are showing an infrared to visible luminosity ratio of about 50. Is it just a matter of their being so densely shrouded in dust that their visible light is masked? Or is there something very strange going on?

Blank fields: Perhaps most intriguing of all are the infrared sources where photographic plates show—nothing. About 10 percent of the sources fall into this catagory. Some seem to be associated with known infrared objects, or with some wider field of emissions. But many more are not. What are they? They seem to be uniformly distributed across the sky, which suggests that they are extragalactic. But if they are simply extreme examples of the faint infrared galaxies, then they are still intriguing because they would have to have an infrared to visible luminosity ratio of more than 100. Of course, they could also represent something totally new. The IRAS scientists are now trying to refine the positions of these sources in preparation for very deep optical searches using ground-based telescopes.

—M. MITCHELL WALDROP and RICHARD A. KERR