Preliminary scientific results from the first six months of the infrared astronomy satellite (IRAS)

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Introduction and goals

The Infrared Astronomy Satellite (IRAS) was successfully launched on 25 January 1983. The goals of this joint US, Dutch, and British project were twofold. The first, and most important, goal was to perform an unbiased all-sky survey at wavelengths of 12, 25, 60, and 100 μm to establish the importance of infrared emission in the energy balance of the universe, to map the diffuse emission from the Galaxy and the material in the solar system, and to obtain low resolution spectra of the brightest sources identified at 12 and 25 μm. A second mission objective was to study specific known astronomical objects in more detail to gain higher sensitivity or higher spatial resolution than that achievable by normal survey observations.

The satellite is now seven months into its one year mission life, and survey operations are exceeding prelaunch expectations. The initial all-sky survey was completed on 26 August 1983. In the last four months of the mission a second all-sky survey will be conducted to enhance the survey completeness. A previous paper in the proceedings of this conference (Low et al, 1983)[1] has described the design and performance of the satellite. In this paper we will describe some of the early scientific results from the IRAS mission.

Early scientific results

Sensitivity

Figure 1 shows the sensitivity of the IRAS all-sky survey compared to what has been achieved in astronomical surveys and pointed observations in other portions of the electromagnetic spectrum. While most of the electromagnetic spectrum has been explored to greater sensitivity than IRAS has achieved, it is important to note that the IRAS survey has enhanced the sensitivity of infrared observations by one to two orders of magnitude over other infrared platforms, and IRAS represents the first all-sky survey at 60 and 100 μm. The prime products from IRAS will be catalogs of the point and small extended sources seen in the survey and images of the diffuse radiation from the whole sky seen in the four survey wavelengths. From extrapolation based on of the number of sources already seen, it is expected that the point source catalog will contain well over one hundred thousand sources. The vast majority of these will be galactic. There will be as many as ten thousand galaxies included in the IRAS catalog, detected mostly at 60 and 100 μm, however.

Thermal emission

The wavelengths of the IRAS survey span the "thermal infrared" portion of the electromagnetic spectrum which is the portion most sensitive to materials with temperatures in the range of 30 to 300 K. In most astrophysical environments, this radiation is produced by "dust" particles which are warmed to the observed temperatures by absorping shorter wavelength radiation emitted by a central "heating source" such as a star.

This mechanism for producing bright sources of infrared radiation is exemplified by IRAS observations of the solar system. In this case, the heating source is the Sun (except for the case of the bright infrared sources, Jupiter and Saturn, which will not be discussed here). Scans of the IRAS telescope across the ecliptic and galactic planes illustrate the general properties of the infrared sky. At 12 and 25 μm the sky brightness is dominated by thermal emission from zodicial particles, while at 60 and 100 μm the sky is dominated by thermal emission from dust particles in the Galaxy.

Comet discovery

In Figure 2 we show a 25 μm image of the first comet discovered by IRAS, comet IRAS-Araki-Alcock. This comet approached closer to the Earth than any comet in the last two hundred years. The close approach allowed astronomers of all disciplines to study a comet with by far the highest linear resolution available to modern astronomy. This comet was originally discovered by the IRAS operations control center at Rutherford Laboratory, England, when the IRAS data was searched for fast-moving asteroids. The IRAS observations of this comet show a dust coma and tail far larger than tails and comae found by other means. Subsequently, IRAS discovered several other comets. These observations will be a boon to the study of these primative remnants of the solar nebula.

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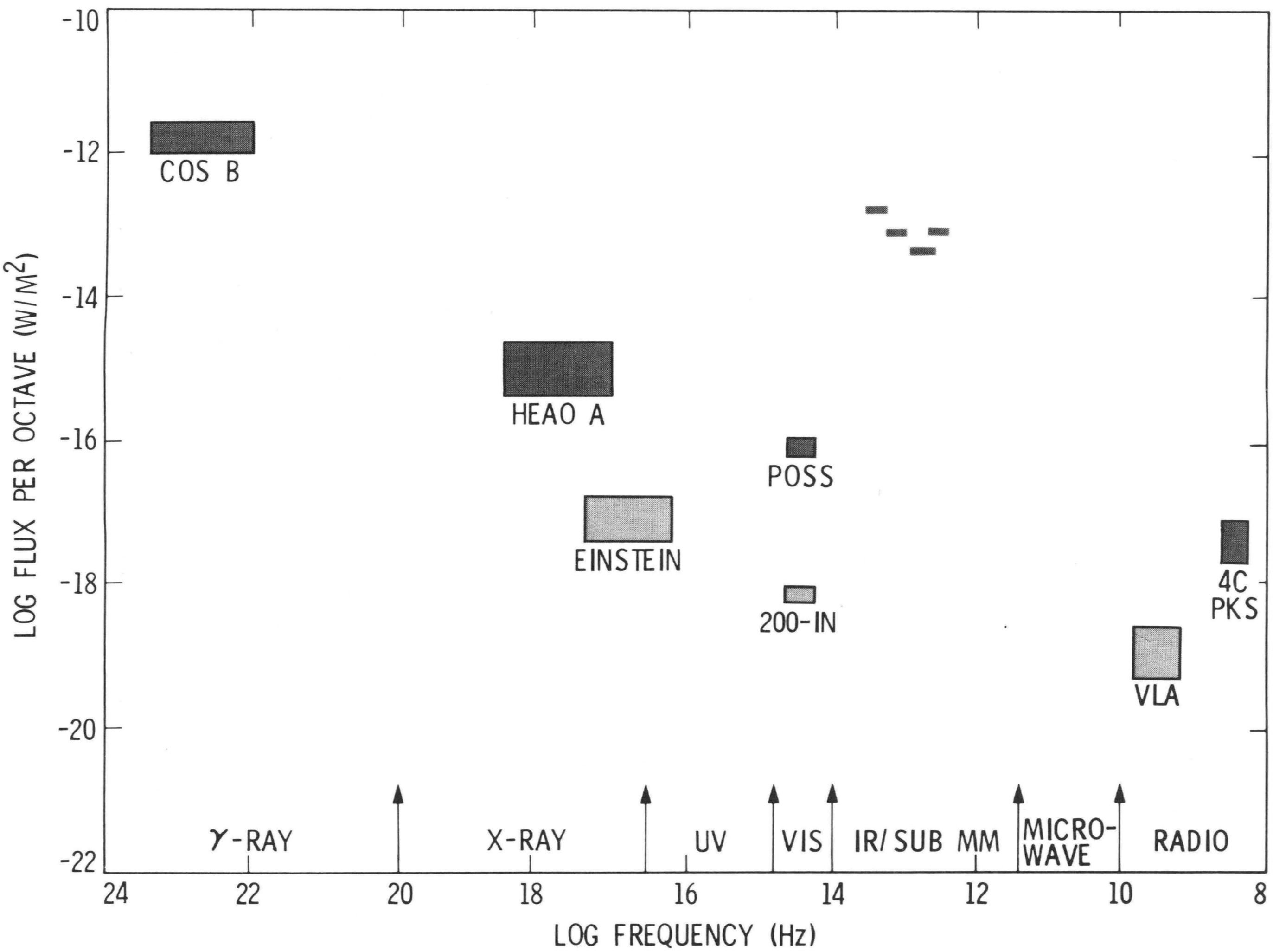

Figure 1. The IRAS survey limits plotted in flux per octave, compared with other astronomical platforms in other portions of the electromagnetic spectrum.

Star Vega

One of the most startling discoveries to date by IRAS has been the detection of a resolved shell of far infrared emission from the nearby star Vega, visually the fifth brightest star in the sky. From detailed studies of this star at other wavelengths, the best explanation is we can rule out mechanisms for producing this emission other than by dust thermal radiation. Upper limits to the mass loss rate from spectroscopic studies preclude circumstellar dust formed in outflowing material that frequently surrounds late type giant stars. These arguments have lead to the conclusion that the material responsible for the far infrared emission from Vega is remnant material from the formation of the star. Furthermore, considerations of the stability of small particles at the roughly 80 astronomical units (AU) from the star required by the observations leads to the conclusion that the particles responsible for the infrared emission are at least as large as a millimeter. This is the first direct evidence for the aggregation outside our solar system of solid material into particles larger than micron size.

Star formation region

One of the major scientific reasons for the IRAS survey was to find regions of current star formation. From the identification of such sites, we can hope to study currently forming stars to gain much greater insight into the formation of objects like our own Sun. Figure 3 illustrates just such a region discovered by IRAS, the dark cloud Barnard 5. The condensate, identified by the arrow in this figure, is a cool cloud, inferred from its low luminosity to be the site of formation of a solar type star. IRAS will identify virtually all such sites of star formation in our Galaxy.

Comparison of galaxies

The comparison of the infrared properties of galaxies is another major scientific goal of the IRAS mission.

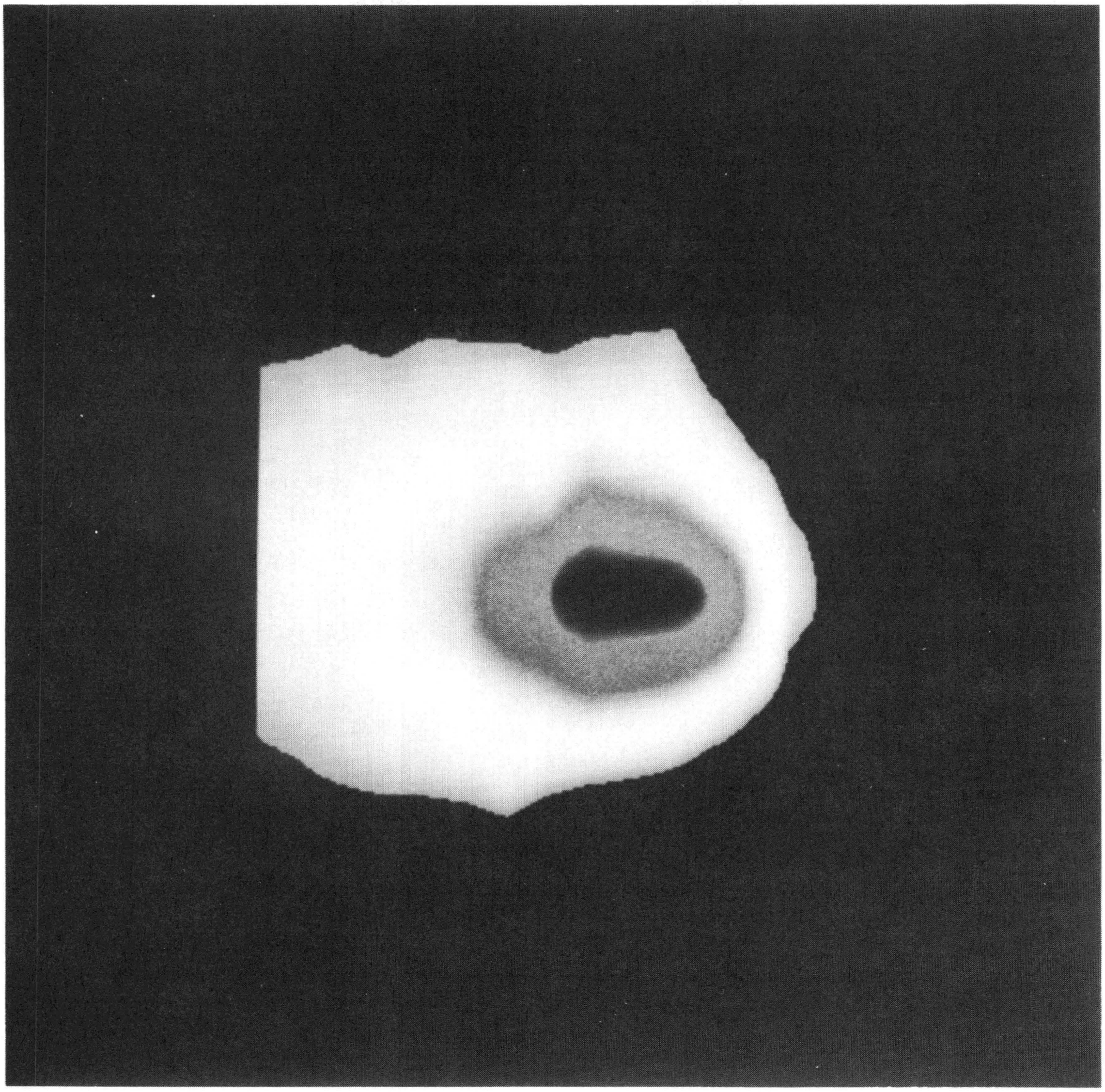

Figure 2. An image of comet IRAS-Araki-Alcock at 15 μm, taken on 8 May 83. Both the coma and tail are visible. The sharp boundary to the left is toward the Sun.

From IRAS data, it will be possible to derive the total infrared luminosity of our own galaxy. Detailed images have been made of M31, the Great Nebula in Andromeda. The IRAS observations of M31 are the first detection of this galaxy in the thermal infrared. The 100 μm image shows the striking ring structure of the dust in this galaxy, the nearest large spiral galaxy to Earth. We believe that the far infrared radiation in this galaxy is tracing out the regions of current star formation.

The total infrared luminosity of M31, compared to its visual luminosity, is much less than that found in many spiral galaxies, including our own. We hope to use the IRAS data on a wide variety of galaxies to understand what factors cause the wide variation in the infrared luminosities of galaxies. Figure 4 shows a visual image and the IRAS signals from an otherwise anonymous galaxy MCG+01-11-013, that is extremely bright in the infrared. This galaxy radiates over 90% of its total luminosity in the infrared, while other more extreme infrared galaxies found by IRAS radiate more than 98% of their luminosity in the infrared. By comparison, M31, our well studied neighbor, radiates 5% of its luminosity at infrared wavelengths. Understanding the wide range of infrared properties of galaxies will be another major application of the data from IRAS.

Conclusions

The examples of IRAS results described here are a potpourri of the early scientific returns from the IRAS mission. It is quite clear from such a cursory study of the IRAS data that these data are a true treasure chest for astronomers and astrophysicists for years to come. The ultimate outcome of this mission will be a

Figure 3. An image of the region of the dark cloud Barnard 5 made at 100 μm from IRAS data. The arrow points to a condensation believed to be a star like the Sun in the process of formation.

major advancement in our understanding of many of the most important problems in modern astrophysics.

Acknowledgments

It is truly a pleasure to thank our many colleagues in the IRAS project who have worked so diligently to make this mission the successful project that it is. We are grateful to our colleagues on the IRAS science team for allowing us to share the results of their labors.

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References

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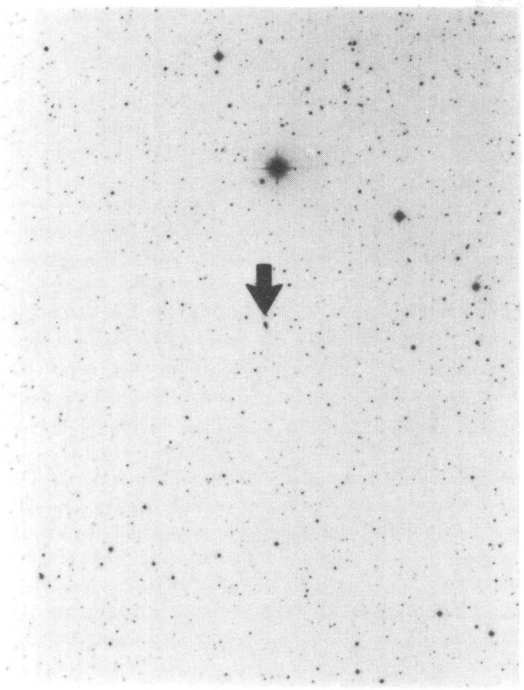

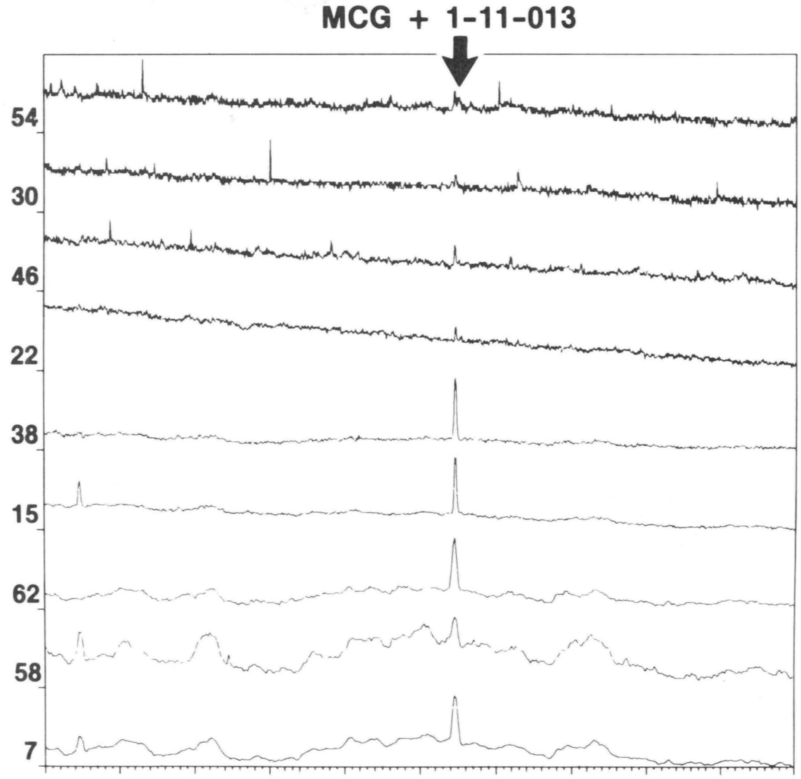

Figure. 4. On the left is a visual photograph of an otherwise anomalous galaxy known as MCG+01-11-013. The right panel shows the infrared detector outputs as the IRAS telescope scanned across this galaxy. The top two traces are 12 μm detector outputs, the next two traces are 25 μm detector outputs, the next two traces are 60 μm detector outputs, and the last three traces are 100 μm detector outputs. Note the faint visual galaxy is quite bright at infrared wavelength.