THE INFRARED ASTRONOMICAL SATELLITE SURVEY OF THE SKY

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ABSTRACT. The Infrared Astronomical Satellite (IRAS) surveyed 98% of the sky during 1983 at the wavelengths of 12, 25, 60, and 100 µm. The survey was enormously successful, producing catalogs containing more than 300,000 sources as well as digital images of the entire covered sky. The IRAS survey has revolutionized several fields of astronomy and impacted nearly every field. This paper discusses the general characteristics of the IRAS survey and lists the major results obtained so far.

1. INTRODUCTION

''IRAS has brought infrared astronomy into the big league'' (Becklin 1987). This comment, taken only slightly out of context, aptly sums up what IRAS hath wrought. Before IRAS, infrared astronomy was primarily the domain of infrared astronomers. After IRAS, infrared data were in the public domain and are now being used by astronomers in all specialities as an integral part of their research.

The IRAS legacy includes easily useable catalogs containing over 300,000 sources and digital all-sky maps that are the infrared analog of the Palomar and ESO/SRC sky surveys. This has made it possible for any astronomer to immediately discover how much infrared flux exists for any given astronomical object or at any position on the celestial sphere.

All of this derives from performing a sensitive all-sky survey. The IRAS survey in particular highlights the necessity of performing surveys at different wavelengths to truly understand the sky. Most of the major results have resulted from information obtained from many different wavelengths.

There have been many detailed reviews of the IRAS results (Neugebauer et al 1984, Chester 1986, Neugebauer 1986, Beichman 1987, and Soifer, Houck, and Neugebauer 1987, for example), so I will not attempt to duplicate those works. Instead, I will discuss here the general characteristics of the IRAS data set. I will concentrate

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especially on comparing the IRAS sky survey with other surveys at different wavelengths. Section 2 will describe the various IRAS products and discuss the general characteristics. Section 3 will briefly mention the major results that have been produced so far.

2. GENERAL CHARACTERISTICS OF THE IRAS DATA

An all-sky survey is characterized by the wavelengths observed, the sky coverage, and the sensitivity, resolution, flux and position accuracy of the products of the survey. These items are discussed in this section. A list of products is also given. For more information on these topics, consult the IRAS Explanatory Supplement (1987).

IRAS surveyed the sky in four broad bands, nominally centered at 12, 25, 60, and 100 μm. The bands span 8-15, 17-30, 40-80, and 80-120 μm. Because the bands are so broad, color corrections are important. All flux densities quoted by IRAS have assumed a spectrum with flux density proportional to inverse frequency. A table at the back of the Explanatory Supplement gives the correction factors for different assumed blackbody and power law spectra. A Low Resolution Spectrometer obtained spectra of 5,000 sources from 8-22 μm with a resolution $\lambda/\Delta\lambda$ of 20-60.

The IRAS survey filled a significant gap in our knowledge of the sky. The entire sky had not previously been surveyed at these infrared wavelengths due to atmospheric extinction. Ground based observers have narrow windows accessible at 10 μm and at 20 μm, but it requires a large telescope (with a small field of view) to match the IRAS sensitivity. Airborne observers with the Kuiper Airborne Observatory (KAO) can access out to 1000 μm, and the KAO has about the same sensitivity, but the KAO has a small field of view and short observing times. The AFGL did a rocket survey which was essentially concentrated to the Galactic Plane. It is impractical to do a sensitive all-sky survey at any of these wavelengths except through the use of a satellite.

IRAS surveyed the sky in February-November 1983. Image data exists for 98% of the sky, whereas 96% of the sky had enough coverage to satisfy the confirmation requirements of the IRAS catalogs. Pointed observations were also obtained covering 3% of the sky.

IRAS surveyed most of the sky in a systematic manner. The typical coverage unit was an hours-confirmation (HCON), which consists of two scans separated usually by one hour with coverage by two detectors per band on each scan. Almost the entire sky was observed with two HCON's with a time separation of 1-2 weeks. 72% of the sky was covered by three HCON's, with the third HCON occurring 6 months after the first two HCON's. Thus there is limited time information in the IRAS data, but enough so that IRAS was able to discover a significant number of new variable stars (mostly long period variables) and to demonstrate variability of some quasars.

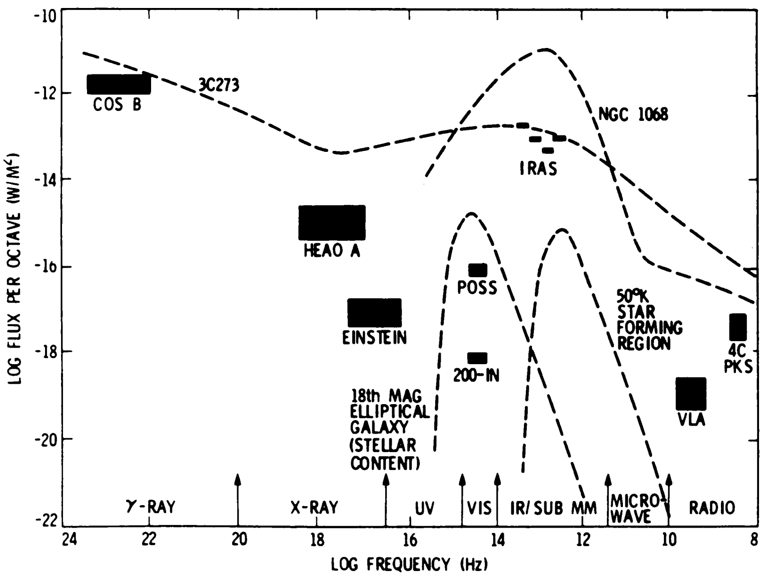

Fig. 1. A comparison of the limiting sensitivities for several surveys and non-survey observations over the range of the full electromagnetic spectrum is shown. (Figure reproduced from Neugebauer 1986 with permission.)

The sensitivity of IRAS compared to other wavelengths is shown in Figure 1, reproduced from Neugebauer (1986). That Figure plots the flux per octave, equal to frequency times flux, versus frequency for major sky surveys. For comparison, the spectra of various astronomical objects are also shown. The Figure reveals that:

1. IRAS helped to fill in a major gap in previous surveys.
2. The relative sensitivity of IRAS for typical ''UV loud'' or ''radio loud'' quasars is orders of magnitudes behind that of other surveys.
3. IRAS has good sensitivity for galaxies like NGC 1068 which emit most of their energy in the infrared.
4. Only IRAS is able to survey cool objects, such as a 50 K star forming region.

Typical limiting sensitivities of IRAS are 0.4, 0.5, 0.6, and 1-2 Jy at 12, 25, 60, and 100 μm, respectively, for the Point Source Catalog. The Faint Source Survey will reach a factor of 3 deeper, and the Serendipitous Survey, which utilizes the Pointed Observations, reaches a factor of 4-5 deeper, but only in 3% of the sky. The all-sky images are primarily limited by the zodiacal and galactic backgrounds.

The resolution of IRAS as compared to other wavelengths is shown in Figure 2. Note that for an initial sky survey, IRAS has the best

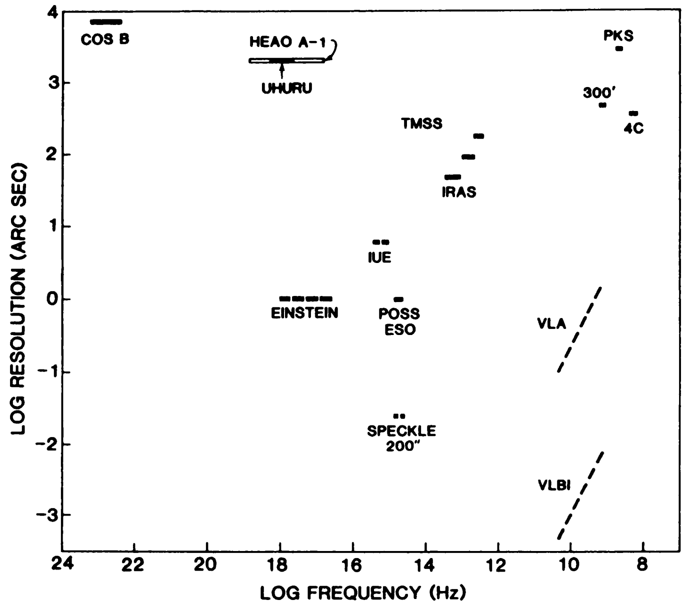

Fig. 2. A comparison of the resolution for several surveys and non-survey observations over the range of the full electromagnetic spectrum is shown.

resolution of any wavelength band except for the photographic optical sky surveys. The IRAS detectors were roughly 1' X 5' in size.

The flux accuracy of the products is typically about 10%, and the one sigma position errors of point sources is typically 3'' x 15''.

Table I lists the major IRAS products that are now available, as well as two products that are currently in production.

1.1 Point Sources

A point source in the original IRAS processing was a source with a <u>one-dimensional</u> extent of less than approximately 1' in the scan direction. Only objects that were inertially fixed on the sky were placed in the Point Source Catalog. Thus asteroids and solar-system objects were excluded from the Point Source Catalog, whereas filaments such as infrared cirrus are sometimes present in the Catalog.

In spite of the relative insensitivity of IRAS, the number of cataloged IRAS point sources exceeds that of all other wavelength bands except the optical, which has produced comparable sized catalogs (see

Figure 3). This is primarily due to the presence in the Galaxy of so many stars with circumstellar dust shells that absorb a significant amount of the total stellar output and reradiate it in the infrared. These objects can be seen by IRAS unattenuated past the center of the Galaxy (Chester 1986).

The IRAS Point Source Catalog contains roughly 158,000 stars; 35,000 cold sources within our Galaxy such as HII regions, planetary nebulae, molecular clouds, and star formation regions; 33,000 cirrus sources; and 22,000 galaxies (Chester 1986).

1.2 All-sky images

The IRAS all-sky images are the infrared equivalent of the optical Palomar and ESO/SRC sky surveys. Unlike the optical surveys, they are in digital form, facilitating their use by computer.

The all-sky images were released individually for each HCON. This was necessary so that users could confirm one HCON set versus the others in order to remove moving sources such as asteroids or comets. Also, because both the Zodiacal emission from the Solar System and the emission from Galactic sources contribute strongly to the observed emission, retaining the separate HCON's allows the Zodiacal emission to be subtracted more readily.

The all-sky images are primarily useful to Solar System and Galactic astronomers. They have given us beautiful pictures of the dusty components of the Galaxy and the Solar System, and thereby revealed much new information.

The all-sky images were produced with 2′ pixels, with a true resolution between 4′ and 5′. Each image covers 16.7° X 16.7°.

2. MAJOR RESULTS FROM IRAS

Table II lists the major results, organized by distance from the sun, that have come from IRAS so far. For more information, consult the references given in the introduction.

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Table I

IRAS Data Products

Product	Description
Explanatory Supplement	Detailed description of hardware, data processing, and products
Point Source Catalog	245,889 point sources
LRS Spectra Catalog	Spectra of 5,426 catalog sources
Zodiacal History File	Time-ordered data at 0.5^{o} X 0.5^{o} resolution
All-sky images	3 sets (one for each HCON) of 16.7^{o} X 16.7^{o} fields with 2' pixels
Additional Observations	13,853 images with 0.25'-1.0' pixels, each covering ~1 square degree
Small Scale Structure Catalog	16,740 sources of size 1-8'
CPC data	1508 Chopped Photometric Channel images
IRAS Asteroid and Comet Data	IRAS and derived data on 1811 known asteroids and 25 comets
Serendipitous Survey Catalog	43,866 point sources derived from the Additional Observations
Faint Source Survey	3 times more sensitive Point Source Catalog in production
Improved All-sky Images	6 times more sensitive all-sky images in production

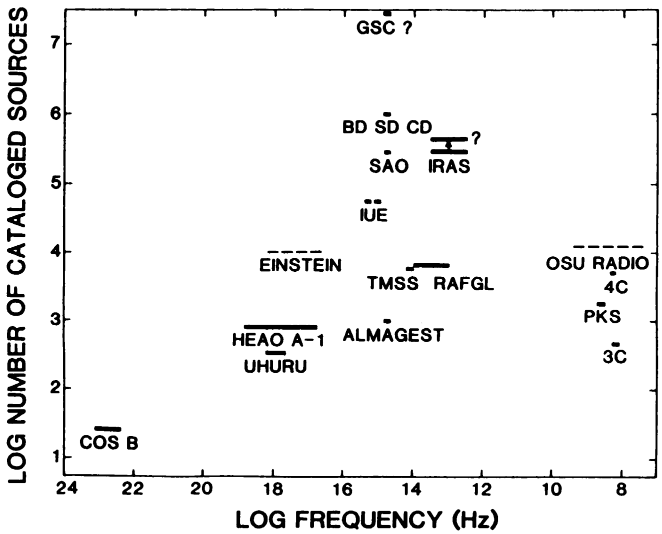

Fig. 3. A comparison of the number of sources cataloged by several surveys versus frequency.

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TABLE II

IRAS SKY SURVEY -- MAJOR RESULTS

- 0 Measured thermal emission from interplanetary dust
- 0 Discovered almost one new comet per month of operation (Best comet detection system ever)
- 0 Discovered comets to be much dustier than previously believed
- 0 Discovered comet trails
- 0 Discovered dust bands near the asteroid belt
- 0 Measured thermal emission from 1811 known asteroids and 25 comets
- 0 Have not yet discovered any tenth planets or brown dwarfs!
- 0 Discovered that one third of nearby F,G, and K stars have solid material around them probably related to planetary formation
- 0 Discovered infrared cirrus
- 0 Discovered many very young stars embedded in gas clouds, many of low mass never before observed
- 0 Mapped star formation areas throughout the Galaxy
- 0 Cataloged vast numbers of mass losing stars
- 0 Demonstrated that mass loss rates and elemental abundances of ejecta can change dramatically in only a few thousand years
- 0 Delineated bulge of our Galaxy
- 0 Measured diffuse Galactic emission
    - Heated dust emits 1/3 of total bolometric luminosity
    - Short wavelength IR radiation is 1/4 of Galactic IR, caused by transient heating of very small grains
- 0 Cataloged over 20,000 galaxies in the most uniform extragalactic survey to date
- 0 Measured 20% density enhancement toward north Galactic pole compared to south on scale of 100 Mpc
- 0 Allowed preliminary estimate of Omega Ω in range 0.5-1.0
- 0 Discovered many galaxies dominated by IR emission
- 0 Discovered that IR galaxies dominate universe at high luminosities
- 0 Discovered IR quasars

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Discussion:

GLIESE You mentioned discovery of "Low-Mass Objects". What do you mean by "Low Mass"?
CHESTER We discovered for the first time, stars of about one solar mass being formed. Previously, only the formation of higher mass stars was observed. Unfortunately, we have not yet found any brown dwarfs of new or lower mass stars.

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