Infrared Astronomical Satellite IRAS

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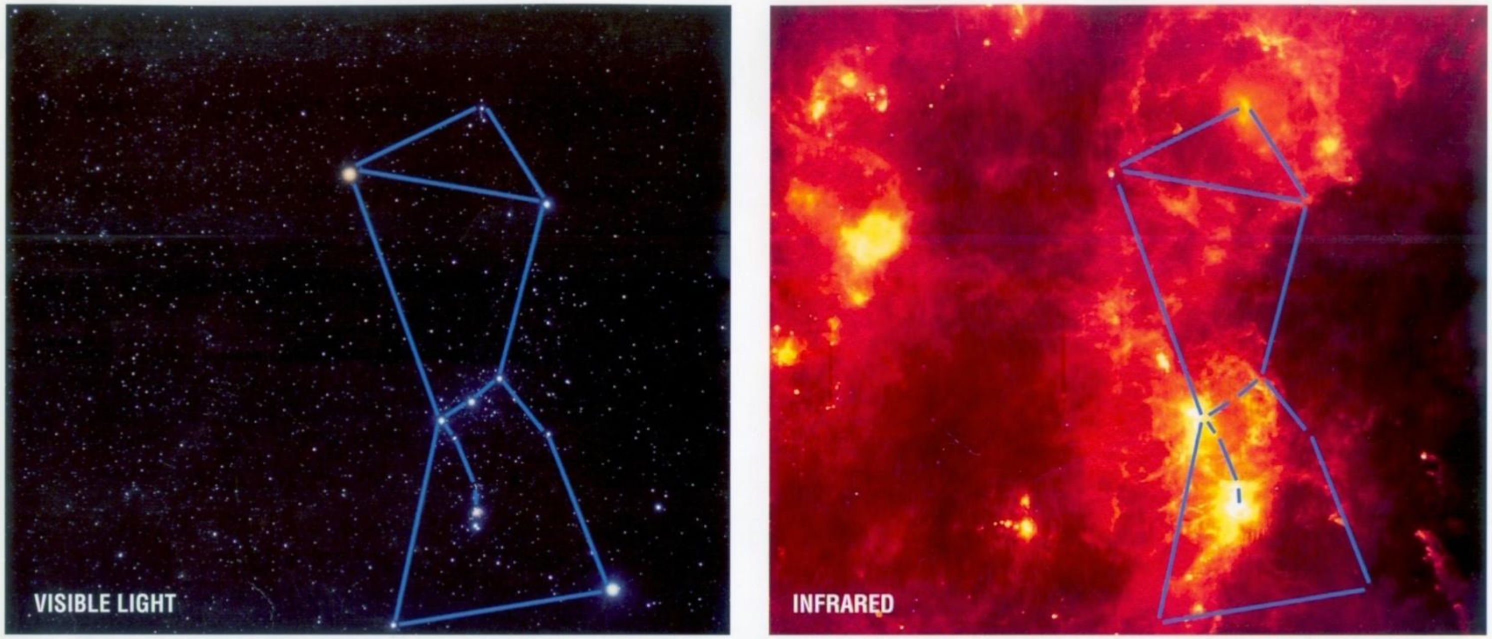
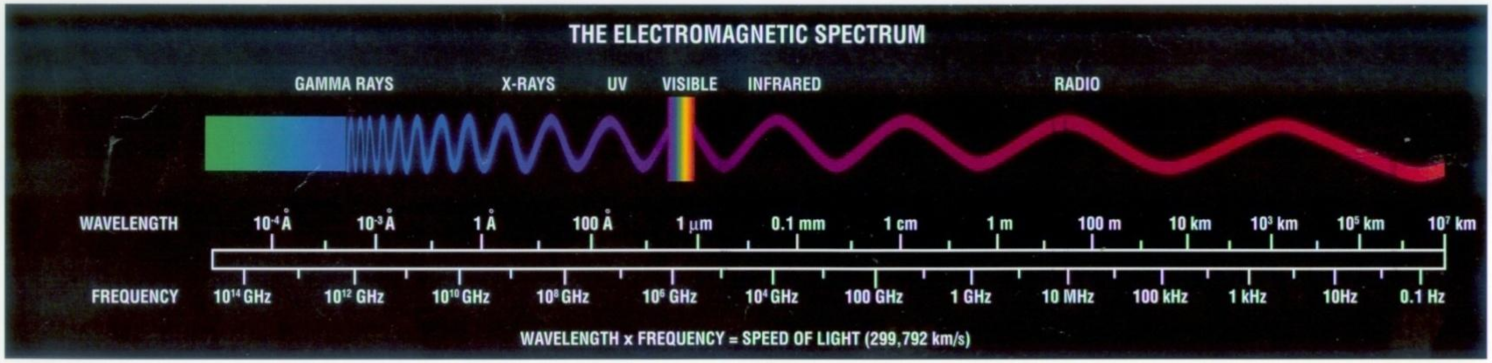
Infrared Astronomy: More than Our Eyes Can See



These views of the constellation Orion dramatically illustrate the difference between the familiar, visible-light view and the richness of the universe that is invisible to our eyes, though accessible in other parts of the electromagnetic spectrum.



IRAS satellite

Collaboration

- IRAS mission was a collaboration between United States - NASA, Netherlands - Netherlands Agency for Aerospace Programmes (NIVR), and United Kingdom Science and Engineering Research Council - SERC.
- By ownership of satellite subsystems:
  - NASA - optics, amplifying electronics, cryogenics, testing and launch.
  - NIVR - satellite bus and processing electronics.
  - SERC - mission operations and data acquisition.

General

- Major contractors: Ball Aerospace, Fokker Space and Hollandse Signaal.
- Launch date – 25 January, 1983
- Launch site – SLC-2 West, Vandenberg AFB, CA
- Launch system – Delta 3910
- Mass – 1083 kg
- Mission duration – 10 months

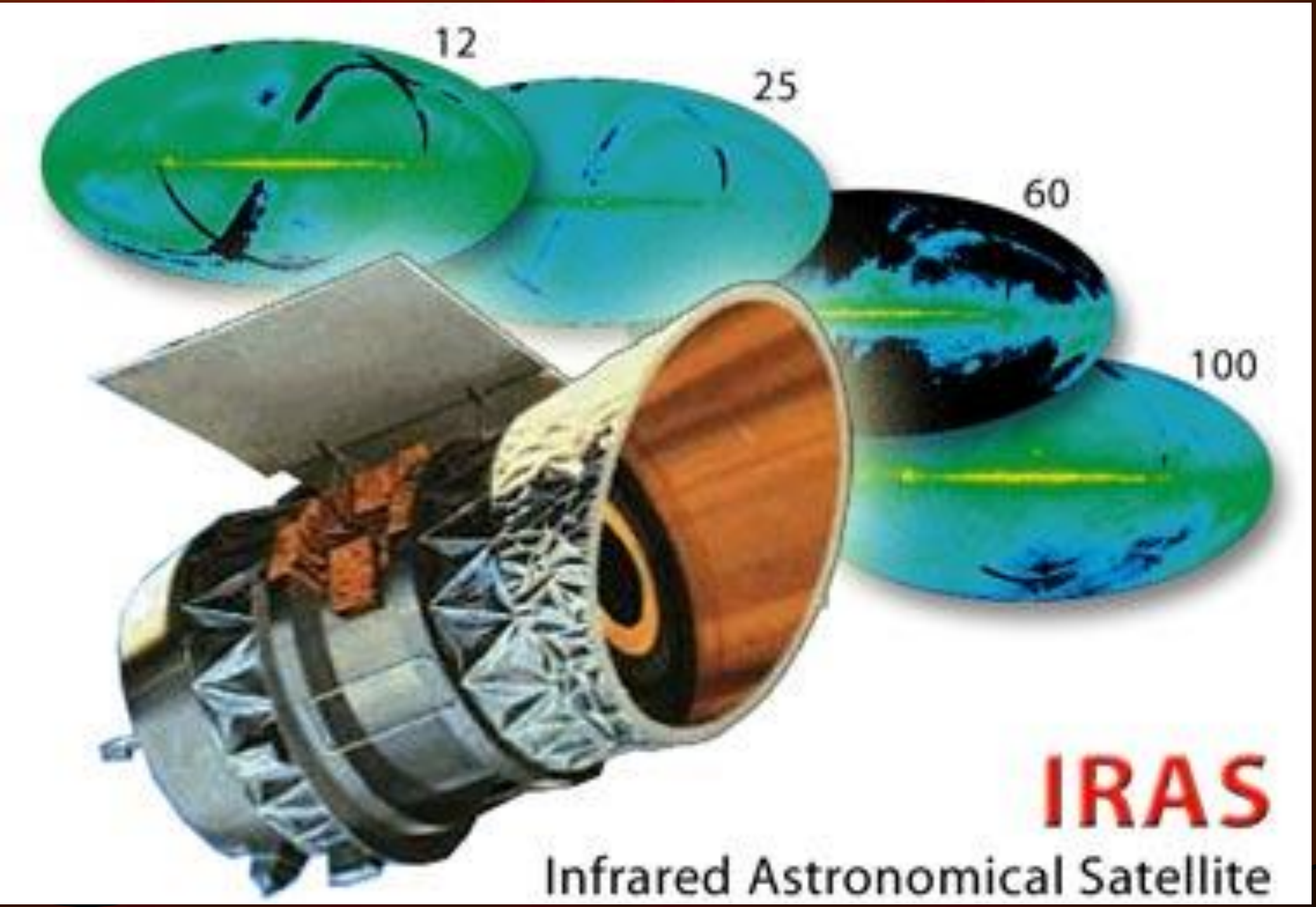
General cont.

- Type of orbit – sun-synchronous polar
- Orbit height – ~900 km
- Orbit period – ~100 minutes
- Current location – in orbit, deactivated
- Telescope style – Ritchey-Chretien
  - Wavelength – infrared
  - Mirror diameter – 0.57m
  - Focal length – 5.5m

Following in IRAS footsteps

- Following spectacular successes of the IRAS mission, last few decades have seen several additional surveyors of our universe in infrared:
  - Infrared Space Observatory - 1995
  - Spitzer Space Telescope - 2003
  - AKARI Space Telescope - 2006
  - Herschel Space Observatory (ESA) - April 2009

Mission design
All-sky survey in four infrared bands



Mission design cont.

- IRAS mission design and survey strategy were optimized for maximally reliable detection of point sources.
- An all-sky survey was done at wavelengths ranging from 8 to 120 microns in four broadband photometric channels
  - Channels were centered at 12, 25, 60 and 100 microns.
- Searches of rejected sources for moving objects led to discovery of three asteroids, six comets and a huge dust trail of comet Tempel 2.

Mission design cont. Survey strategy

- IRAS was launched into a sun-synchronous near-polar (99 degree) orbit, which precessed by about a degree each day.
- Celestial sphere was divided into “lunes” bounded by ecliptic meridians 30 degrees apart.
  - Survey covered the sky by “painting” each lune in overlapping strips as satellite scanned through a given lune during each orbit.
- Most of the sky was covered by at least two hours of confirming scans and two thirds of the sky was covered by a third, which used a slightly different observing strategy.
  - Some sources, near the ecliptic poles, had more than three hours-confirmed coverages.

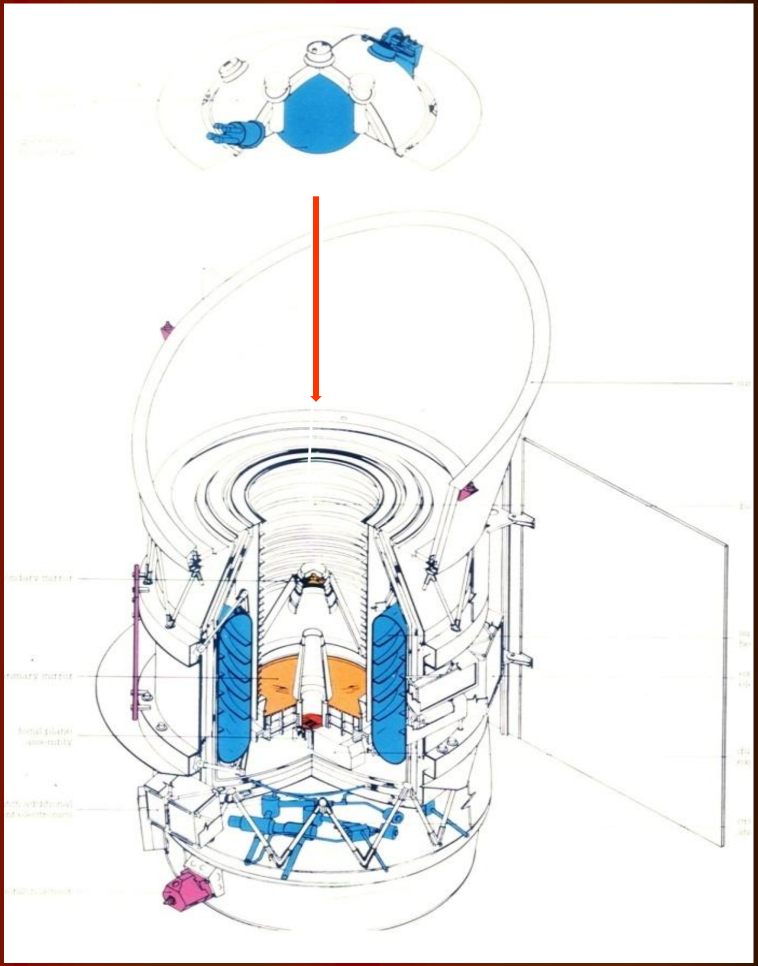
Mission design cont.
Scanning range and image resolution

- During each orbit, IRAS scanned a 30 arc minutes wide strip of the sky.
  - Successive strips overlapped by 15 arc minutes to ensure nothing was missed.
- Resolution of IRAS image data was governed by the size of detectors unlike the telescope resolution, which was diffraction limited longwards of 12um.

Phyisics and hardware

IRAS satellite

Operational testing in acoustic chamber



IRAS cross section

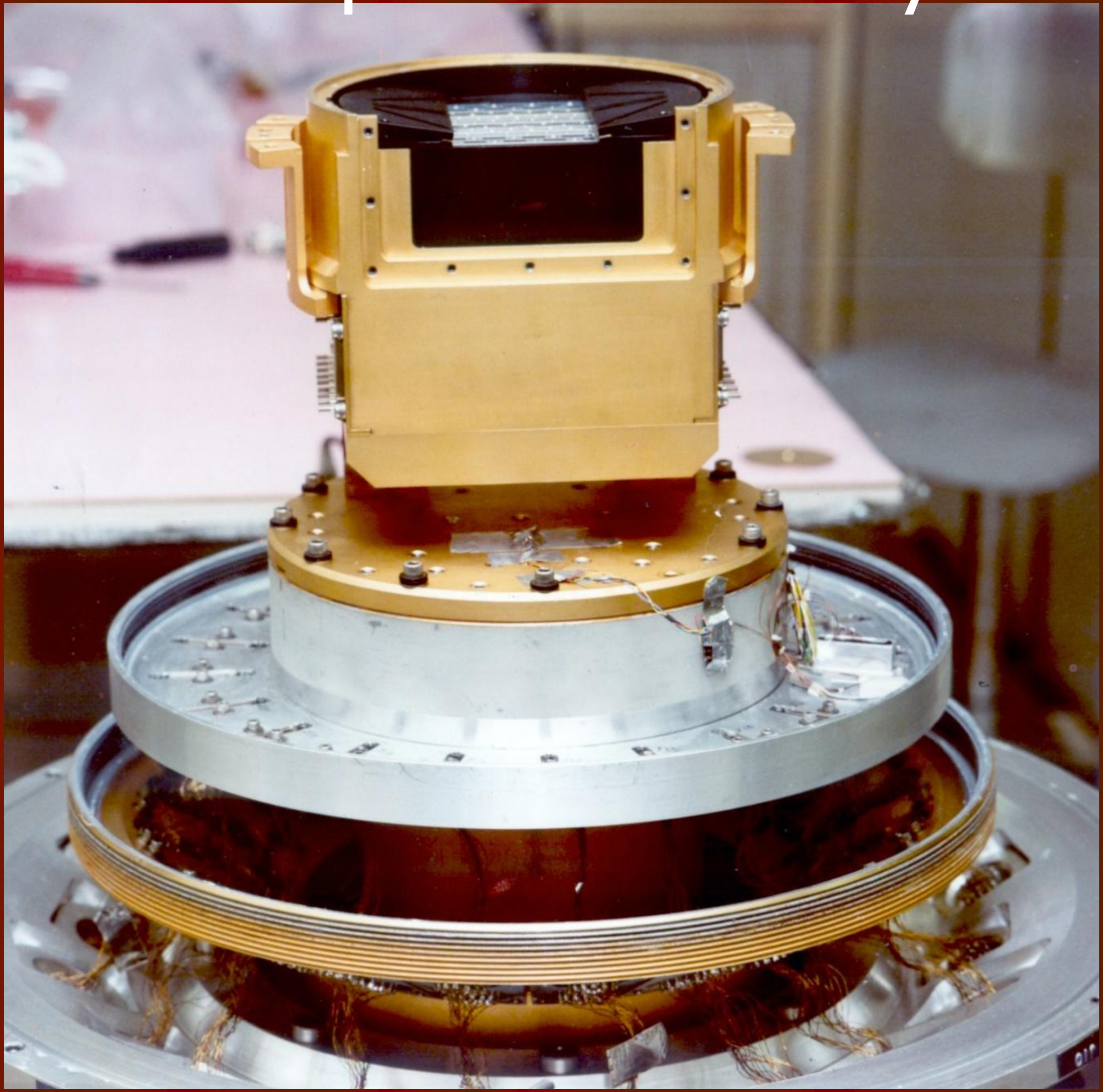
IRAS telescope

- The telescope was mounted in a liquid He cooled cryostat.
  - Beryllium mirrors were cooled to ~ 4K.
- Focal plane assembly contained: survey detectors, visible star sensors for position reconstitution, Low Resolution Spectrometer (LRS) and Chopped Photometric Channel (CPC).
- Focal plane assembly, located at the Cassegrain focus, was cooled to 3K.
  - It had an array of 62 rectangular infrared detectors.
  - Angular resolution varied between about 0.5′ at 12 microns to about 2′ at 100 microns.

LRS and CPC

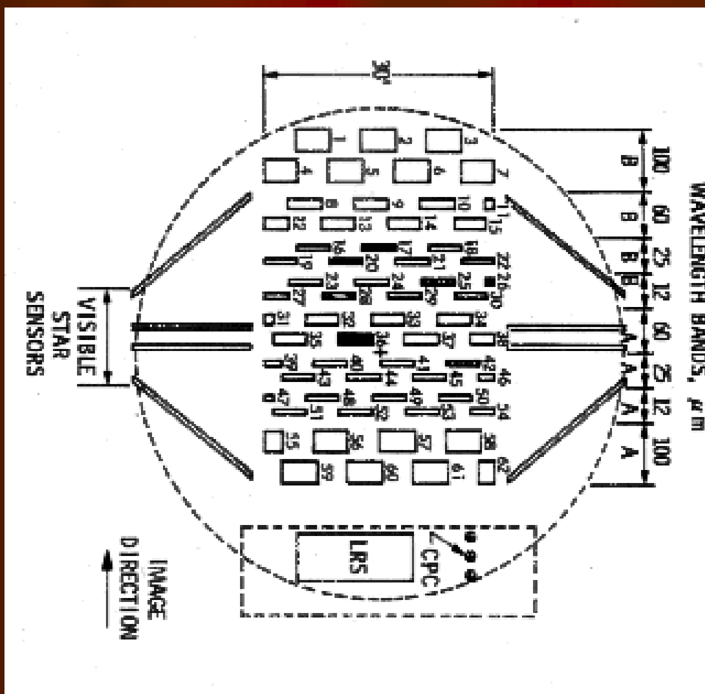
- Low Resolution Spectrometer (LRS) and Chopped Photometric Channel (CPC) were located in photometric detector array in focal plane.
- LRS was a slitless spectrometer sensitive from 7.5 um with resolving power of ~20.
  - It provided 8-22 micron spectra of approximately 5000 survey sources brighter than 10 Jy at 12 and 25 microns.
- CPC made 50 and 100 micron maps by scanning in raster fashion with a circular 1.2′ diameter aperture.
  - CPC operated during some pointed observations - it mapped simultaneously at 50 and 100um.

Focal plane assembly

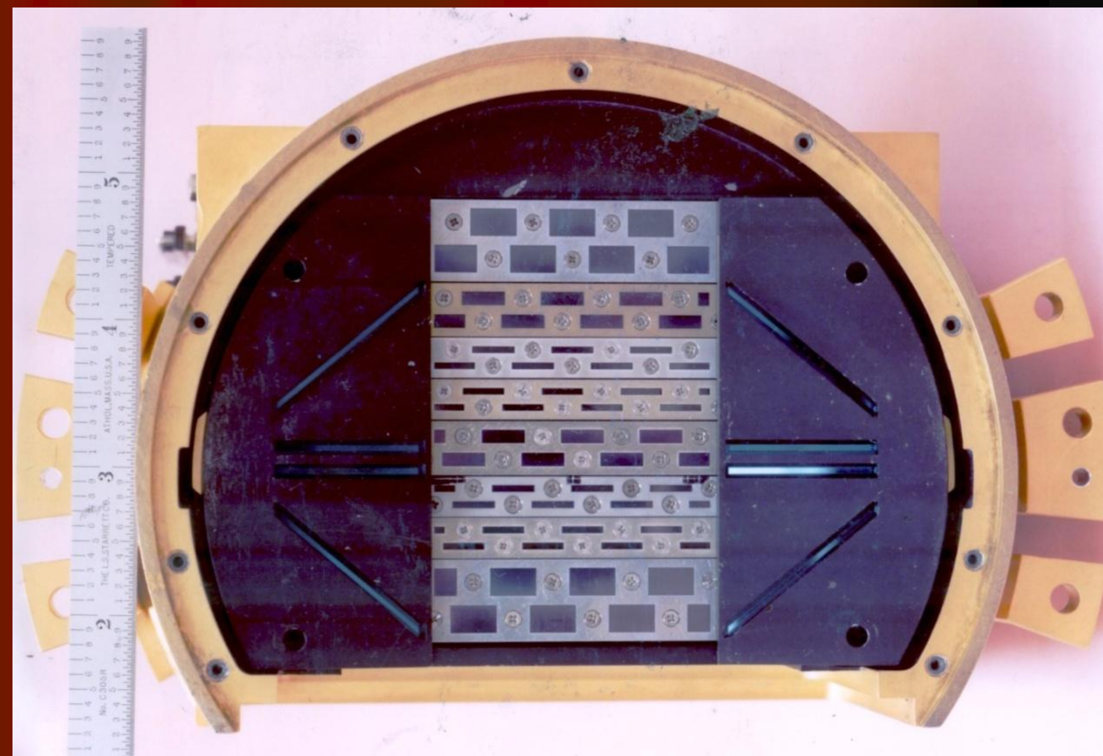


Infrared focal plane configuration testing in “cold cryostat” at liquid He temperatures

Focal plane assembly



IRAS focal plane array schematic



IRAS focal plane array

Survey Array – focal plane

- Focal plane array consisted of 62 rectangular infrared detectors arranged in staggered rows.
- Any real point source crossing the focal plane as the satellite scanned would be seen by at least two detectors in each wavelength band.
- Most detectors in each band had standard size aperture, with one or two being half-sized.

Cooling of IR telescopes

- IR telescopes require extreme cooling because all objects emit IR radiation at normal temperatures.
- Certain parts of an IR telescope must be cooled to prevent distortions during observation.
- To have made IRAS work, its telescope assembly had to be cooled to 2 Kelvin (-271C) and maintained there throughout the mission.

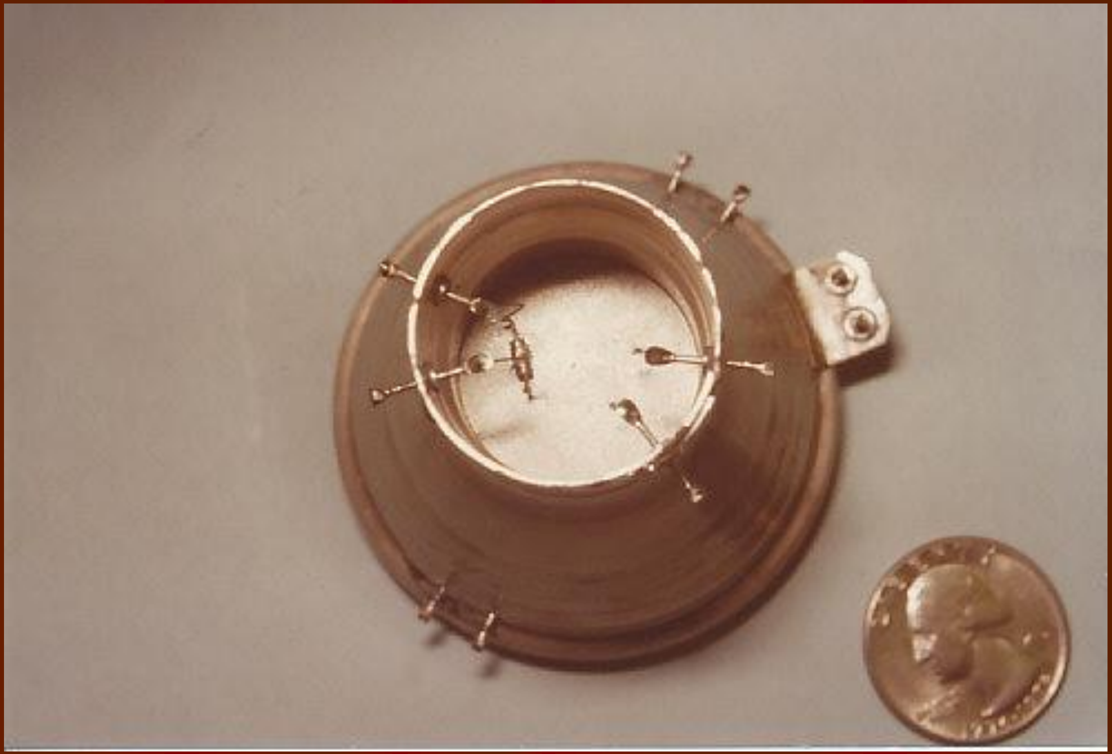
Why such low temperature?

- Entire surface of IRAS's telescope (60 cm in diameter) was cooled by superfluid He at around 1.8K.
- Structure itself was chilled to 10K (-263 C) while infrared detectors were chilled to between 2 and 3K (-271C).
- Such low temperature were imperative to assure that IR sensors operated in their most sensitive temperature range.

How IRAS cooling worked

- Evaporation of He helped maintain IRAS telescope at the designated extremely low temperature.
- Satellite was kept cool by He evaporation through porous media.
- This approach was a pioneering solution, designed explicitly for this ,likewise pioneering mission , with great success.
  - 475 liters of super-fluid He kept the telescope at a temperature of 2K (about -271 degrees C) throughout.
- Cooling systems performed flawlessly - entire “load” was put to work. No liquid He escaped from the containment vessel.

The new physics
IRAS porous plug

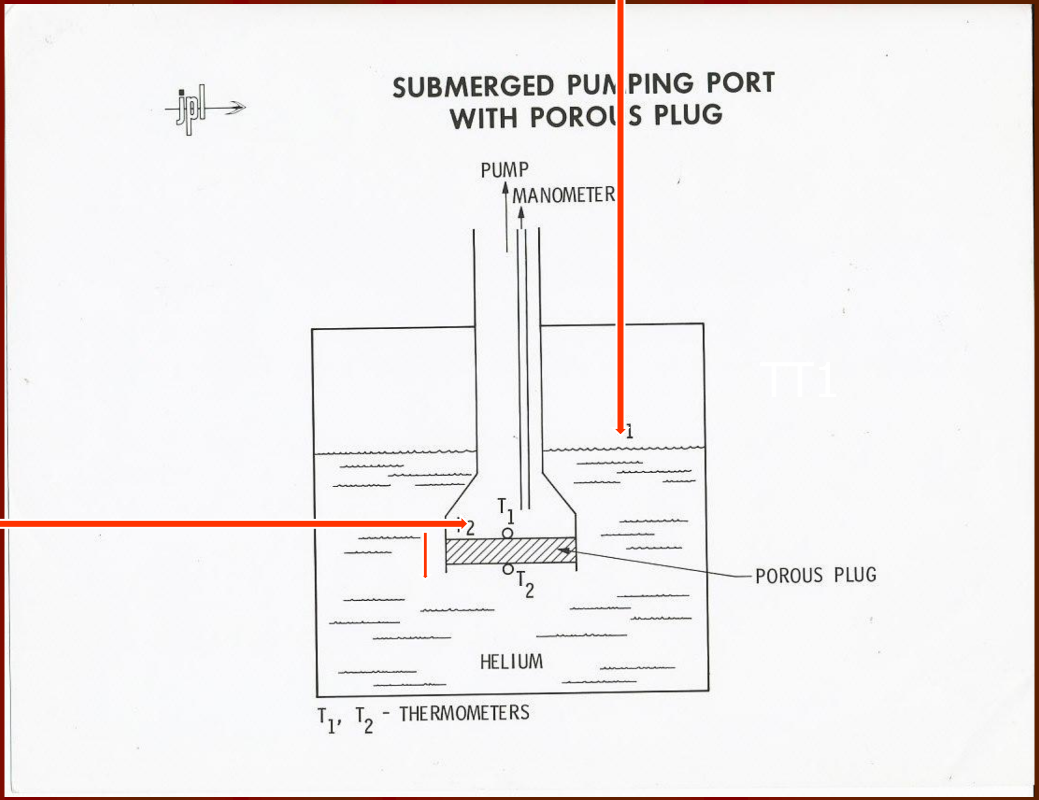


P2 is pressure inside the vessel

P2

P1 is pressure on the venting side - downstream

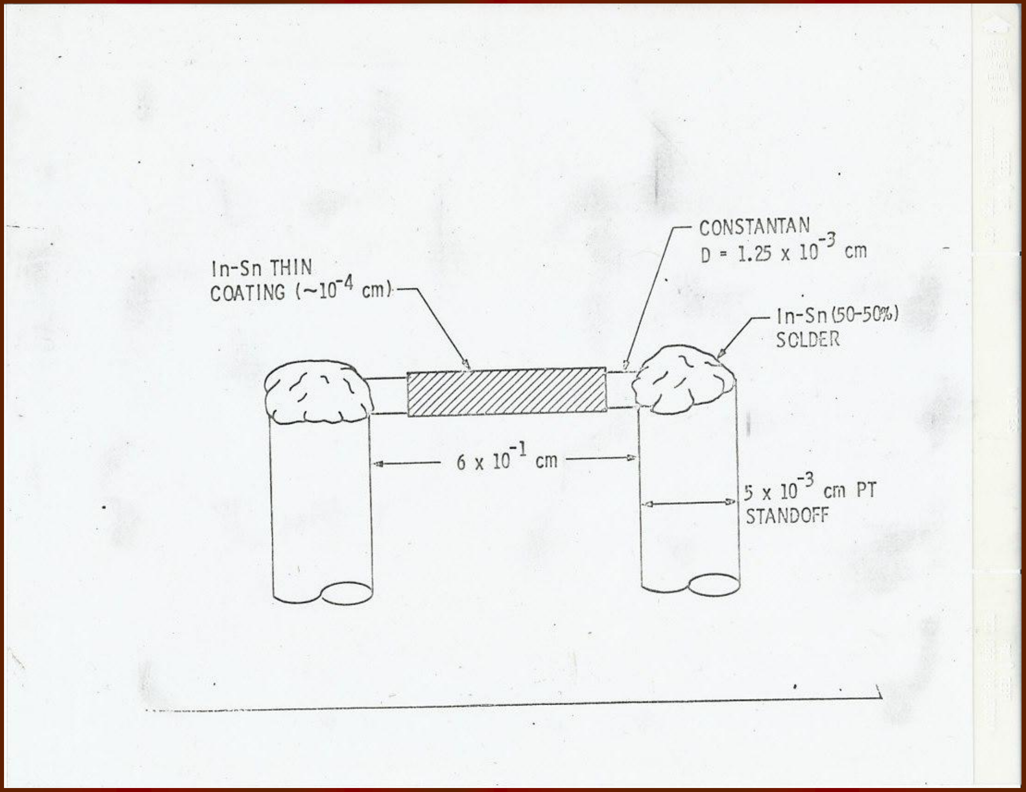
P1



$T1 < T2$
$P1 < P2$

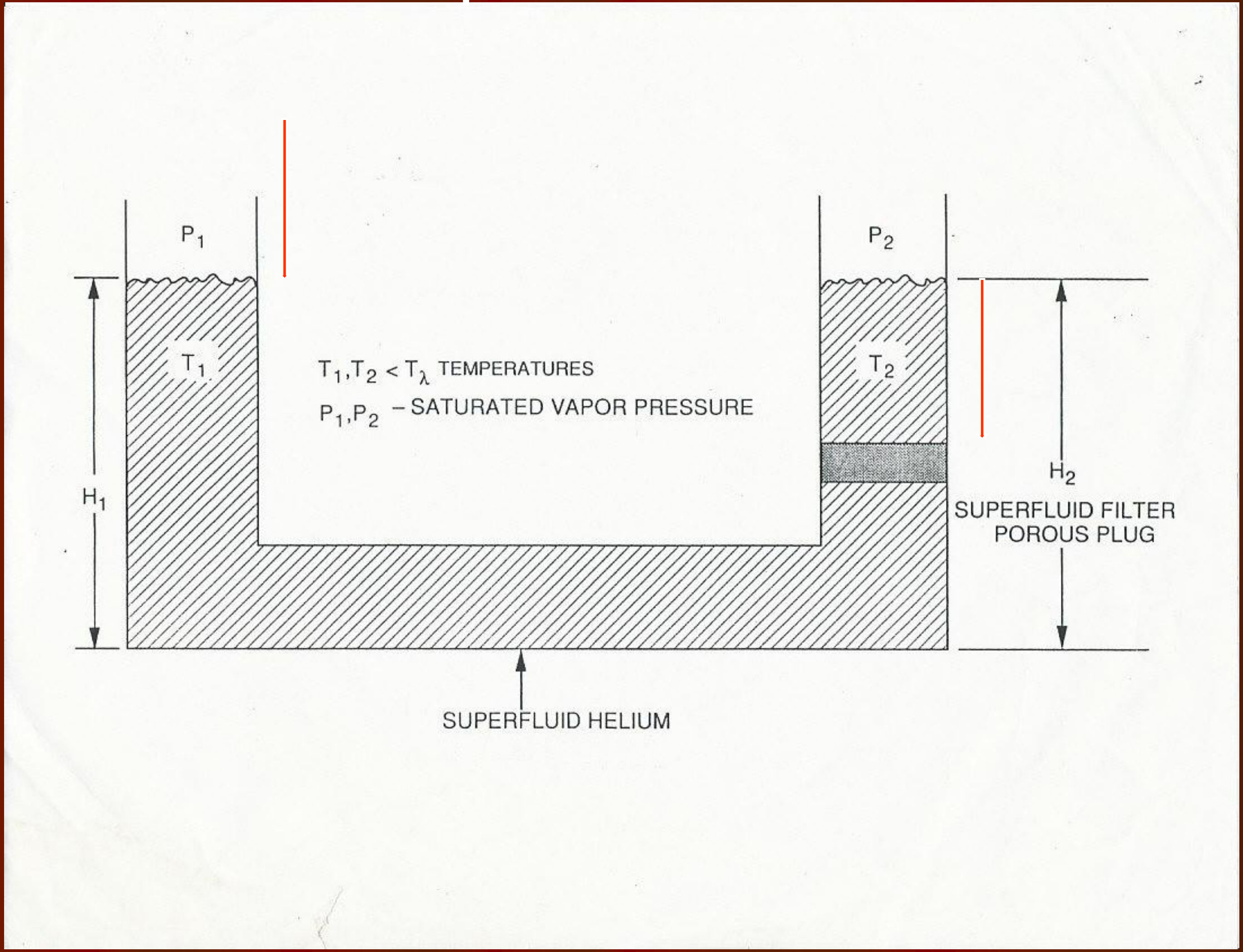
Downstream temperature is cooler.
Thermomechanical pressure is directed from downstream to the inside.
The harder you pump, the better is superfluid He containment .

Structure of superfluid liquid He detector



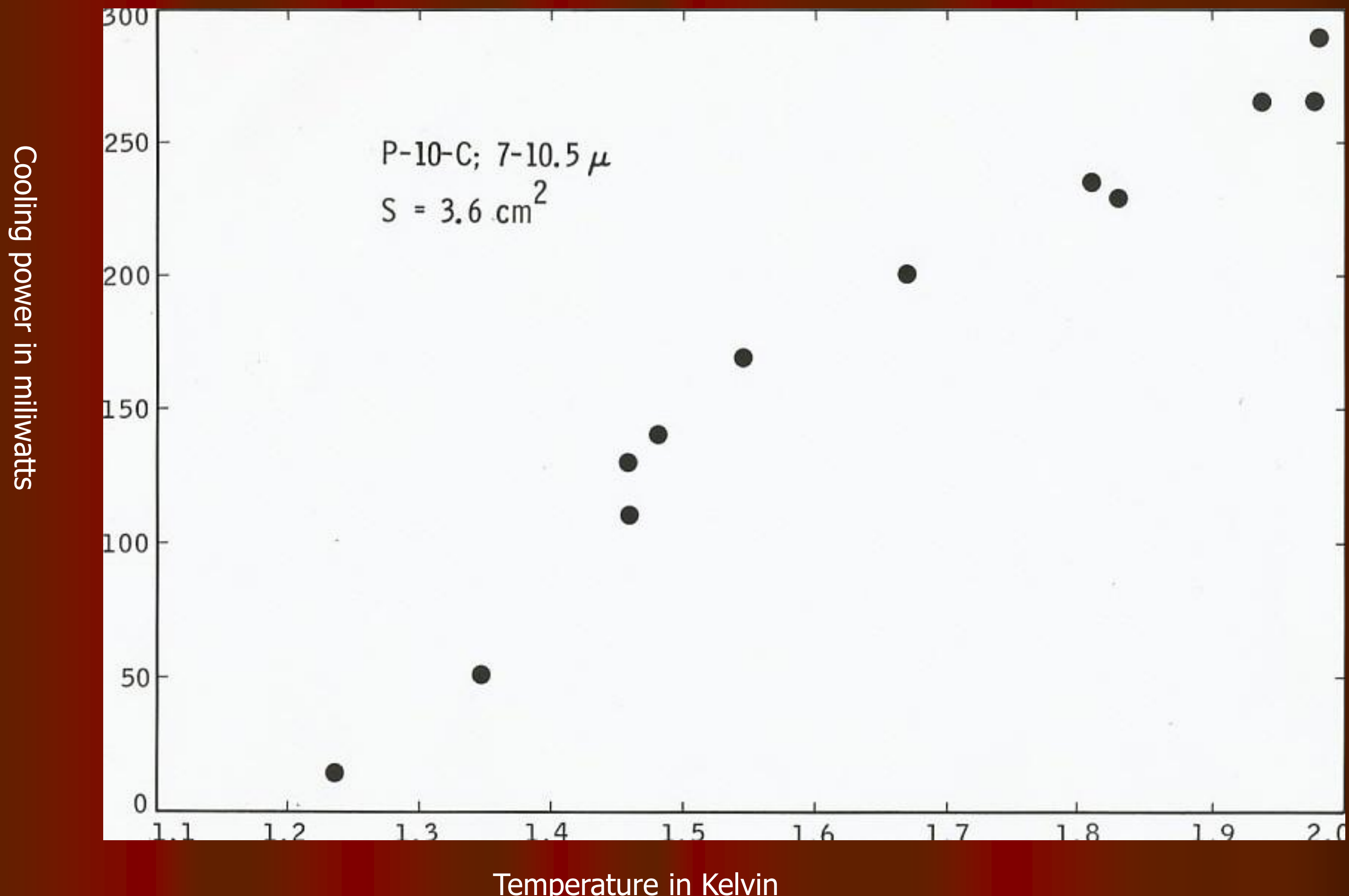
Resistance is low when detector is in liquid and high when it is in vapor.

Behaviour of superfluid He in containment



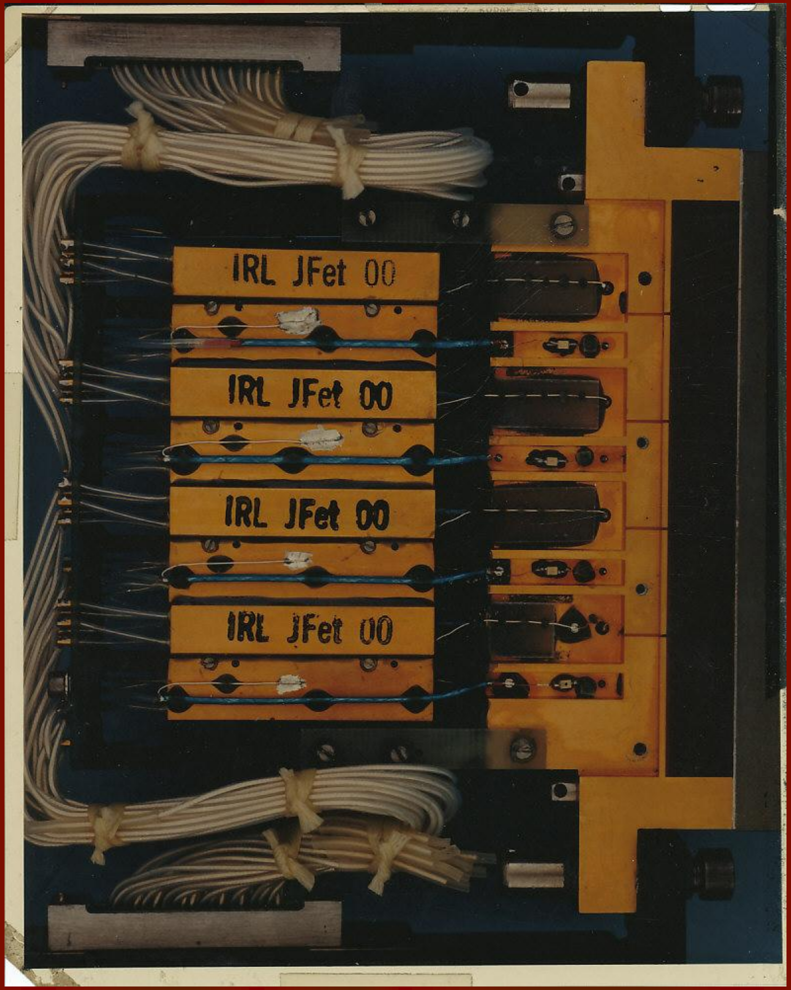
Behaviour of superfluid He in "U" tube with added filter in right arm.

Cooling power of He vapor



Cooling power of evaporating He downstream of liquid vapor separator

Cold electronics



Cold electronics housing at 2K

Discoveries

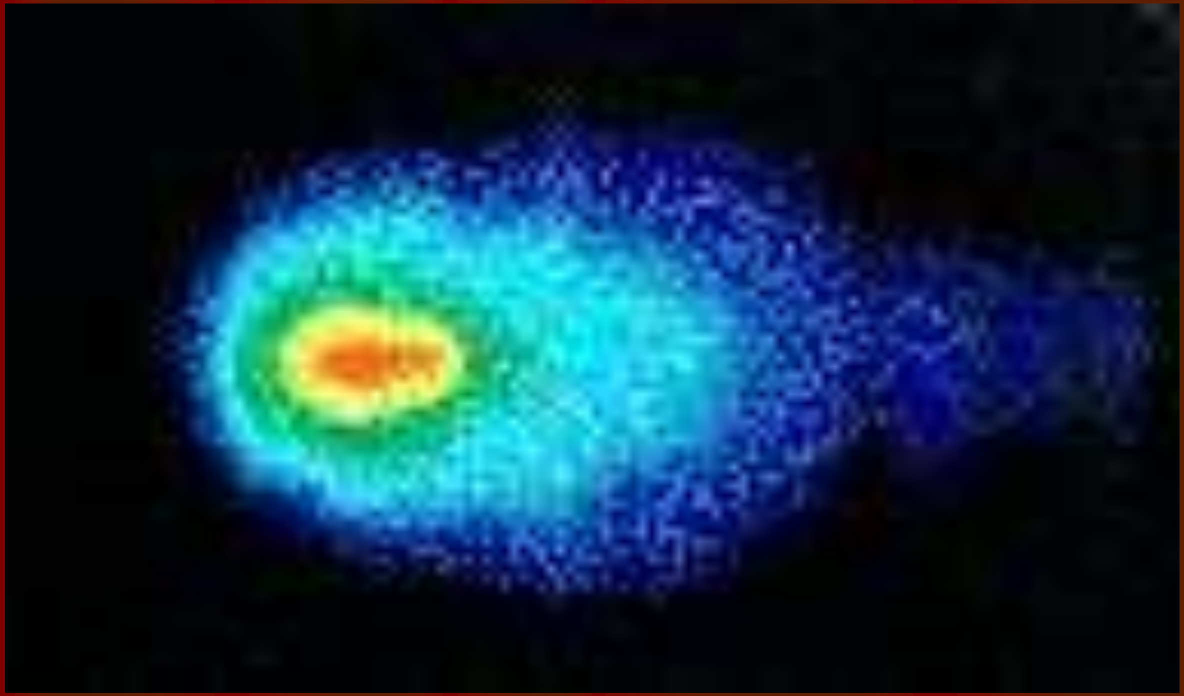
All-sky survey

Cross section of Milky Way galaxy in IR

IRAS discoveries

- IRAS mission had a major impact on almost every area of astronomy.
  - It increased the number of cataloged astronomical sources by almost 70 percent.
- IRAS scanned more than 96 percent of the sky, four times at four infrared bands, centered at 12, 25, 60 and 100 microns.
- Some 250,000 point sources were detected down to a limiting flux density.

Comet IRAS-Araki-Alcock



IRAS discoveries cont.

- IRAS detected about 500,000 infrared sources, doubling the number of cataloged astronomical sources.
- In the Solar system:
  - Discovered six new comets
  - Found that comets are dustier than previously thought and that dust from comets fills the Solar system
  - Detected useful infrared data for 2004 asteroids
- Detected zodiacal dust bands – infrared emissions - that girdle our Solar system, likely debris from asteroid collisions.

Inside Our Galaxy in IR

Inter-gallactic center

Barred spiral galaxy

IRAS discoveries cont.

- Our galaxy:
  - Revealed for the first time the core of our galaxy
  - Found infrared cirrus (wisps of warm dust) in almost every direction of space.
  - Data from IRAS was used to show that our galaxy is a barred spiral galaxy – a galaxy which has an elongated bar-like bulge from which its spiral arms unwind.

IRAS discoveries cont.

- Found that some Bok globules contain protostars.
- Cataloged thousands of hot, dense cores within clouds of gas and dust which could be newly forming stars.
- Cataloged over 12,000 variable stars, the largest collection known to date.

Andromeda galaxy in IR

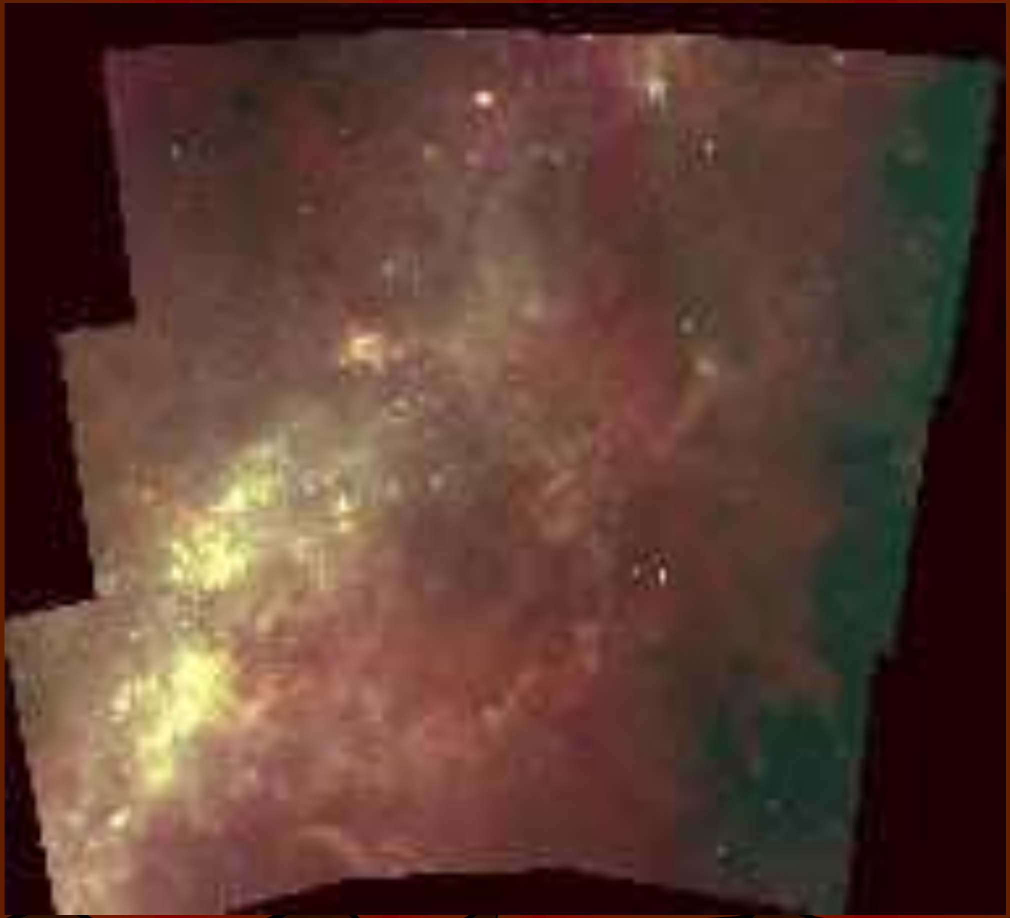
IRAS discoveries cont.

- Galaxies – The most significant of IRAS's discoveries was a new type of galaxy, called starburst galaxy. Compared to normal galaxies, formation of new stars is more rapid in starburst galaxies.
  - Approximately 75,000 starburst galaxies were detected – they are extremely bright in the infrared due to its intense star formation.
  - It was found that many of these starburst galaxies have "superwinds" emerging from their centers due to the large number of supernova explosions which occur in these galaxies.

IRAS discoveries cont.

- Stars and star formations:
  - Found evidence of zodiacal dust bands around other stars.
  - Discovered a disk of dust grains around star Vega and disk material around several other stars.
  - Detected several probable protostars embedded in clouds of gas and dust.

Vela Pupis region in the sky



IRAS discoveries cont.

- Detected strong infrared emissions from interacting galaxies.
- First identified IRAS F10214+4724 – at the time the most luminous object known in the Universe by a factor of 2.
  - This object may be the best candidate for a forming spiral galaxy yet discovered.

Constellation Cameleon

Available star satalogues

- The Infrared Science Archive (IRSA) makes available a number of IRAS star catalogues.
  - Copies are accessible from the National Space Science Data Center (NSSDC).
- IRSA also makes available the IRAS SKY SERVER ATLAS (ISSA) and two IRAS Galaxy Atlases.
  - All mentioned astronomical data products may be studied interactively and fused with data from other missions through OASIS Java interface.

Cygnus Loop Supernova Region

Contributions

Delta rocket ready for IRAS launch

Concept development and demonstration

- Designed and performed a conclusive demonstration of temperature control and containment of superfluid He in weightlesness.
  - Demonstration was performed in a suborbital rocket flight with small He cryostat.
- Experimental flight data convinced NASA to give the "green light" for IRAS mission.

Science lead

- Organized and headed Low Temperature Laboratory.
- Responsible for development, calibration and validation of all cryogenic flight components.
- Developed algorithms for prediction of He temperatures and its consumption in flight.

Science lead cont.

- Designed and build infrared testing filters for 100-micrometer band.
- Designed and tested removable and reproduceable thermal joints between helium tank and IR focal plane.

Science lead cont.

- Redesign of containment and control of superfluid He temperature (1.8K).
- Replaced and retested cold amplifying electronics.
  - Mosfets had to be replaced with FET operating at around 80 K.

Science lead cont.

- Developed procedure for maximum mass fill of He before launch.
- This was a big deal – it extended the IRAS mission by more than 50%.
- Mission so extended enabled a full accomplishment of IRAS sky survey in infrared.

Another look…

All-sky point sources in Milky Way galaxy in IR