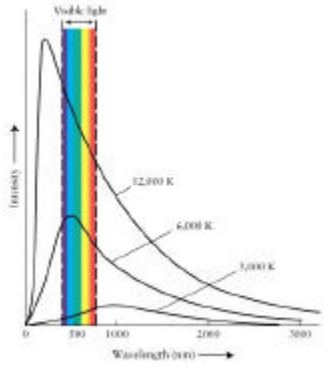
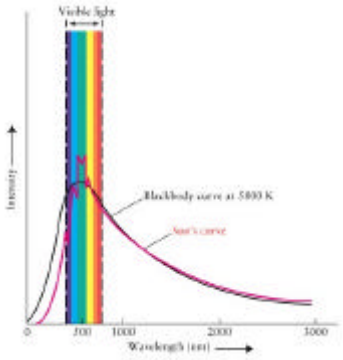
# Blackbody Radiation

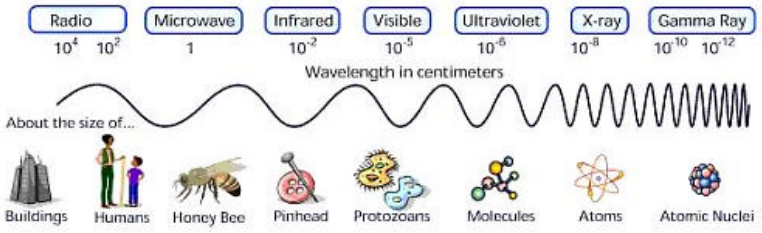
- A blackbody has a Planck spectrum,
  $B_n(T)\, dn = 2\, hn^3/c^2\, [\, e^{-hn/kT} - 1\, ]^{-1}\, dn$ [$Wm^{-2}Hz^{-1}Ster^{-1}$]



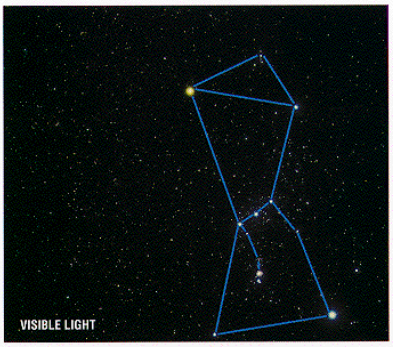

- If $hn << kt$, which holds for almost all radio frequencies (**Rayleigh-Jeans approximation**)
  ➔ $B_n \approx (2\, hn^3/c^2)(kT/\, hn) = 2\, kT/\, l^2$
- At a given $l$ (or $n$) ➔ $B_n \propto T$
  Define $\boldsymbol{T_B \equiv B_n\, l^2/2\, k}$ as the **brightness temperature** of a source
- Using a temperature equivalence as a convenient measure of intensity is common in radio astronomy,
  e.g., signal ➔ source brightness temperature
  *vs* noise temperature
  *vs* system temperature

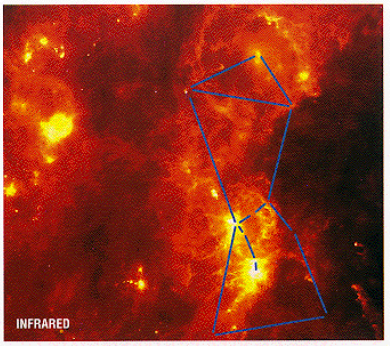
# Infrared Observations



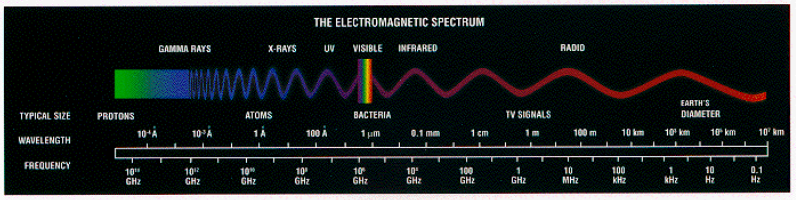

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

## Infrared Astronomy: More than Our Eyes Can See

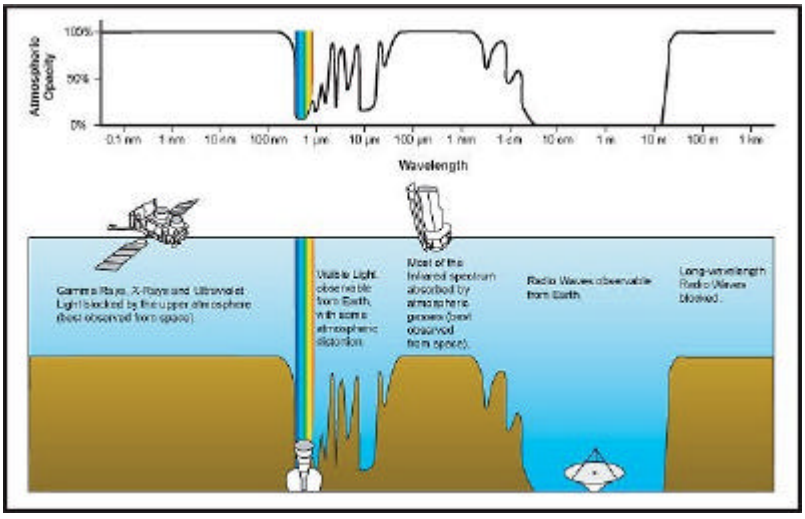


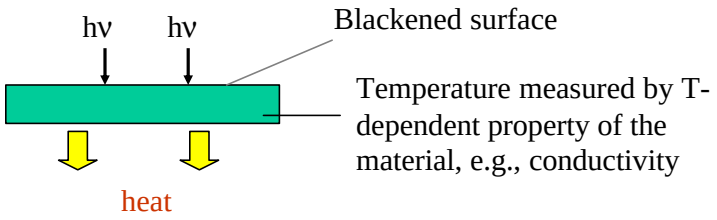

*These views of the constellation Orion dramatically illustrate the difference between the familiar, visible-light view and the richness of the universe that is invisible to our eyes, though accessible in other parts of the electromagnetic spectrum.*



| Spectral Region | Wavelength Range (microns) | Temp. Range (Kelvin) | What We See |
|---|---|---|---|
| **Near-Infrared** | **(0.7-1) to 5** | **740 to (3,000-5,200)** | **Cooler red stars<br>Red giants<br>Dust is transparent** |
| **Mid-Infrared** | **5 to (25-40)** | **(92.5-140) to 740** | **Planets, comets and asteroids<br>Dust warmed by starlight<br>Protoplanetary disks** |
| **Far-Infrared** | **(25-40) to (200-350)** | **(10.6-18.5) to (92.5-140)** | **Emission from cold dust<br>Central regions of galaxies<br>Very cold molecular clouds** |



# IR Detection




- Early days --- uncooled thermal bolometers
- *Disadvantage*
  - poor temperature resolution
  - affected by ambient temperature fluctuations

# IR Detection (cont)

- $\lambda < 5\ \mu m$ →

  photoconductive detectors

  - illumination → electrons in the valence band elevate to the conduction band → conductivity ↑

  photovoltaic detectors

  - illumination → electron-hole pairs in a p-n junction of a semiconductor → current

→ Detectors need to be cooled, e.g., by liquid Nitrogen (T~77K) or liquid helium (T~1-2K)

# IR Detection --- Difficulties

- **Thermal Background**

  $l_{max}$ T $\approx$ 3000 *m*m K (Wien's displacement law)

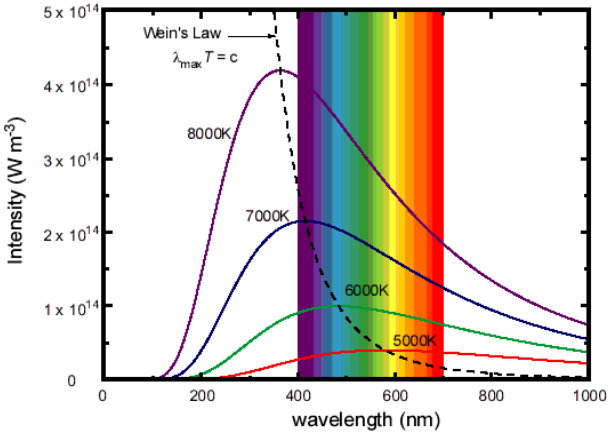
  So if T~ 300 K (room) → $l_{max}$ ~ 10 *m*m

To reduce background

→ 'chopping', e.g., by a wobbling secondary mirror, with a typical throw angle of 1' at 10-100 Hz

→ 2D detectors

→ cooling down the detector



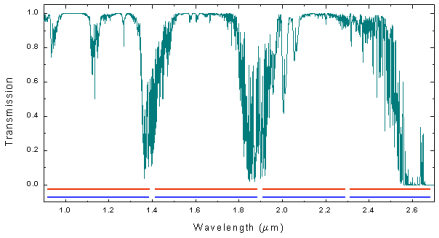

http://www.lancs.ac.uk/users/spc/teaching/py135/em_radiation.htm

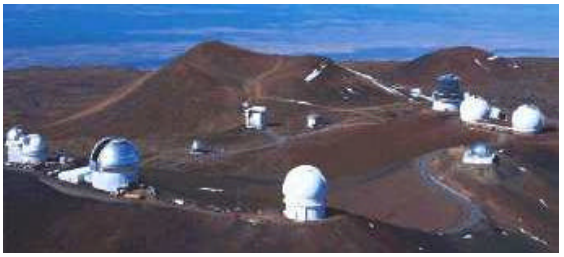
# IR Detection --- Difficulties (cont)

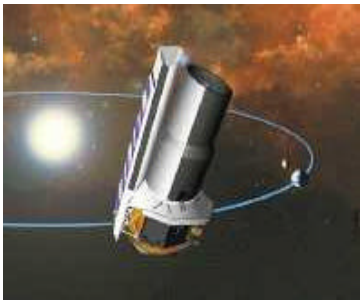
- **Atmospheric Absorption**

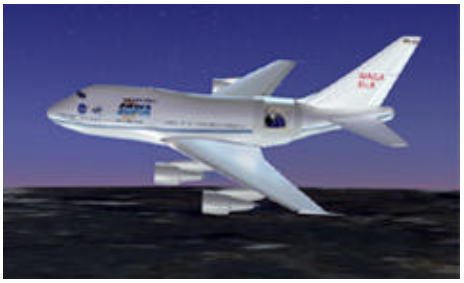
  by $CO_2$, $H_2O$, etc.

  ➔ high altitudes:
  - mountain tops (4-5 km)
  - aircraft (< 20 km)
  - balloons (< 40 km)
  - rockets
  - space craft







# Infrared Astronomical Satellite (IRAS)

- 1983 by USA, Netherlands, and UK
- In vacuum → cooled entire telescope in liquid helium without condensation → background ↓$10^{12}$ X
- All-sky survey found $10^6$ sources down to 1 Jy

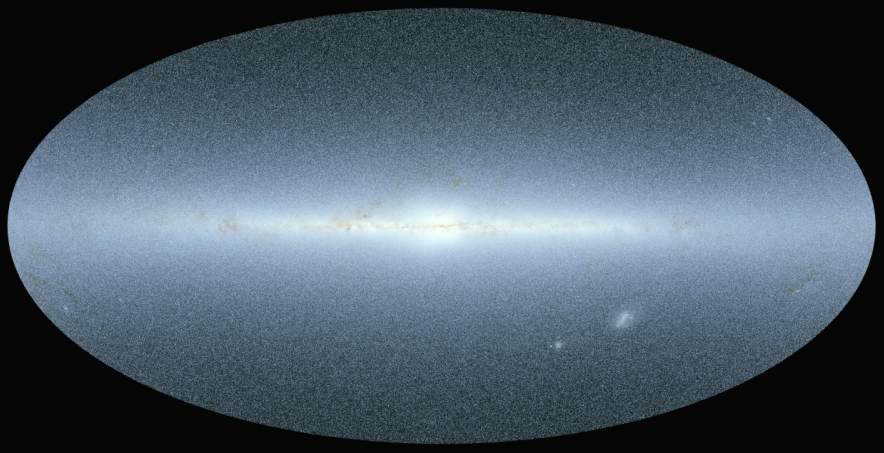
Disadv: limited lifetime of cryogenics, ~300 d for *IRAS*

IRAS in orbit - Artist Rendition

2MASS has uniformly scanned the **entire sky** in three **near-infrared bands** to detect and characterize point sources brighter than about **1 mJy** in each band, with signal-to-noise ratio greater than 10, using a pixel size of **2.0"**. This has achieved an 80,000-fold improvement in sensitivity relative to earlier surveys.

2MASS used two highly-automated **1.3-m telescopes**, one at Mt. Hopkins, AZ, and one at CTIO, Chile. Each telescope was equipped with a three-channel camera, each channel consisting of a 256×256 array of HgCdTe detectors, capable of observing the sky simultaneously at J (1.25 microns), H (1.65 microns), and $K_s$ (2.17 microns), with 10-sigma limit of **15.8 (J), 15.1 (H), 14.3 (K) mag**.

Data are fully accessible online at IPAC with substantial interfaces.



Map of the 2MASS Point Source Catalog (~471 M sources) integrated flux in 5 ×5 ◦bins in a galactic Aitoff projection

Optical (left) and near-infrared (right) image of IC348, an embedded star cluster

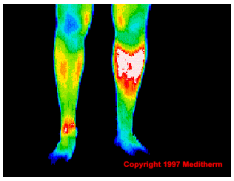
Visible (courtesy of Howard McCallon), near-infrared (2MASS), and mid-infrared (ISO) view of the Horsehead Nebula. Image assembled by Robert Hurt.

Visible photograph of M31 by WH Wang

IRAS infrared view of the Andromeda Galaxy (M31) - notice the bright central region.

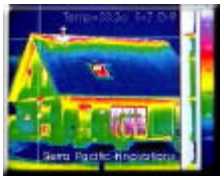
For infrared astronomy, refer to
http://www.ipac.caltech.edu/Outreach/Edu/

For more information about other infrared applications, e.g., in environment, medicine, navigation, etc, see
http://sirtf.caltech.edu/EPO/IRapp/benefits.html



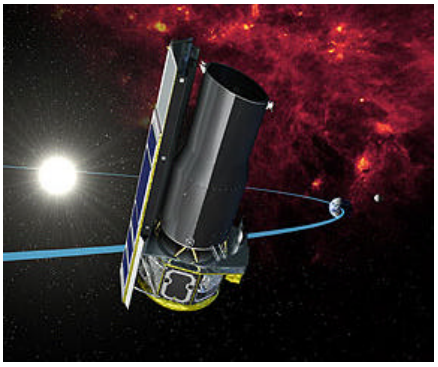

Infrared study of blood flow in legs (showing injured right ankle and weight transfer to the left leg

Invisible text on the Dead Sea Scroll



Infrared image of a house reveals areas of heat loss, indicating poor insulation.

## Space Infrared Telescope Facility
## ---- Spitzer Space Telescope



http://www.spitzer.caltech.edu/

Launched August 25, 2003, the fourth (last) of NASA's **Great Observatories**

--- **Hubble Space Telescope (HST)**
(visible and UV; D=2.4 m; 600 km orbit)

--- **Compton Gamma-ray Observatory (CGRO)**
(30 keV-30 GeV; 5 Apr 1991 - 4 Jun 2000)

--- **Chandra X-ray Observatory (CXO)**
(23 Jul 1999- ; 139,000 km orbit)

--- **Spitzer Space Telescope**
(infrared; detects 3-80 microns; D=0.85 cm)

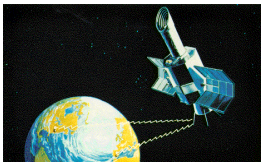
## Ultraviolet Observations

- Detection techniques similar to that in optical, except for $\lambda \leq 300$ nm, observations must be done **above earth's atmosphere**

UV: 300 nm to 90 nm

$\lambda \leq 91.2$ nm
→ Ly continuum absorption

# International Ultraviolet Explorer (IUE)



- The most successful UV satellite (may well be any scientific space mission in terms of investment/return)
- 1978 launched by National Aeronautics and Space Administration (NASA, USA), European Space Agency (ESA, Europe), and Science and Engineering Research Council (SERC, UK) as a 2-3 year mission
- turned off in 1996 only because of budget limit