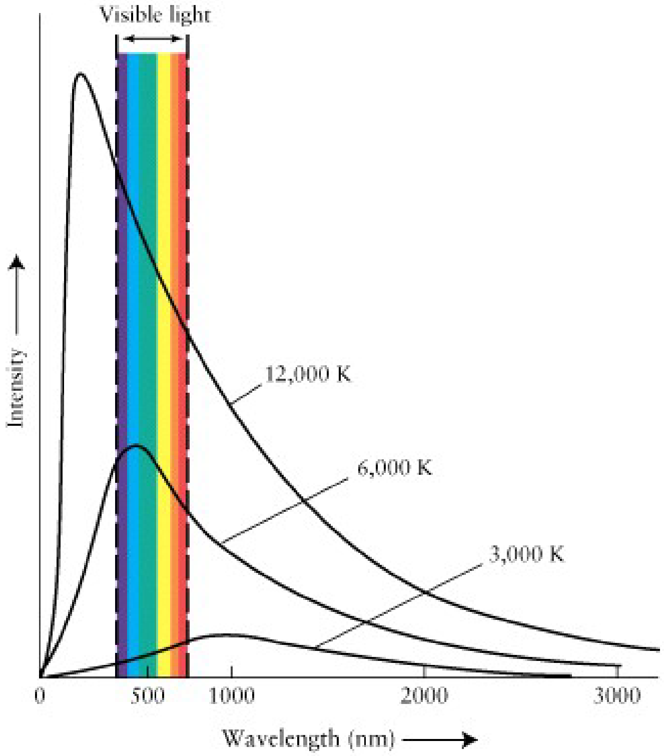
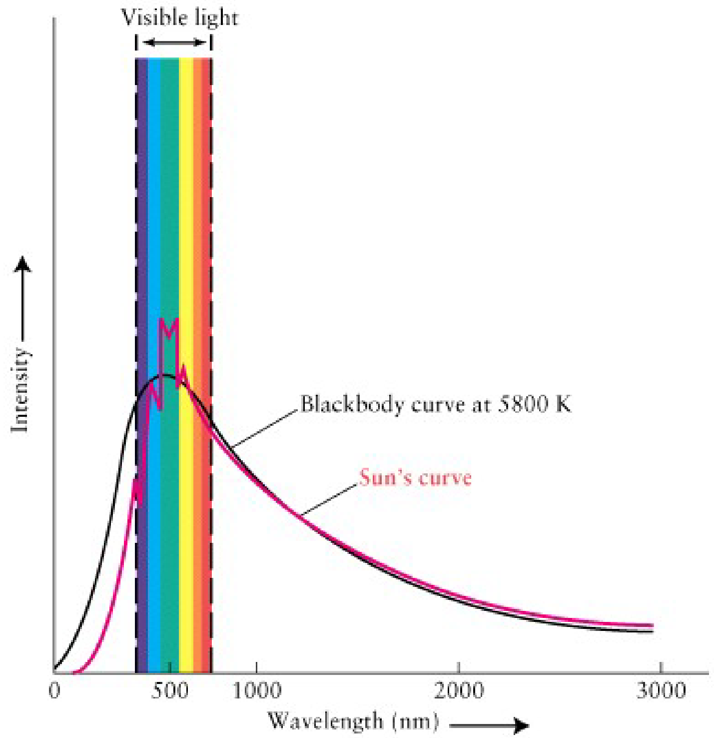
Blackbody Radiation

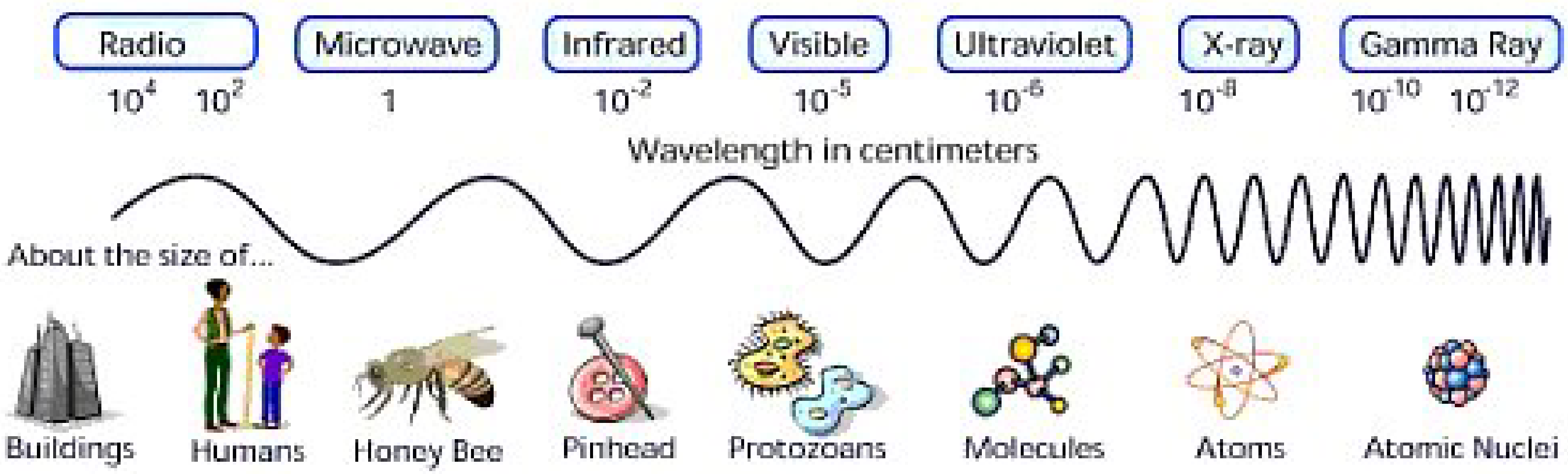
- A blackbody has a Planck spectrum,
  $B_\nu(T)\, d\nu = 2 h\nu^3/c^2 \,[\, e^{-h\nu/kT} - 1 \,]^{-1}\, d\nu$ [$\mathrm{Wm^{-2}Hz^{-1}Ster^{-1}}$]





- If $h\nu << kt$, which holds for almost all radio frequencies (Rayleigh-Jeans approximation) ➔ $B_\nu \approx (2\,h\nu^3/c^2)(kT/\,h\nu) = 2\,kT/\,\lambda^2$
- At a given λ (or ν) → $B_\nu \propto T$
  Define $\boldsymbol{T_B \equiv B_\nu\,\lambda^2\,/2\,k}$ 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

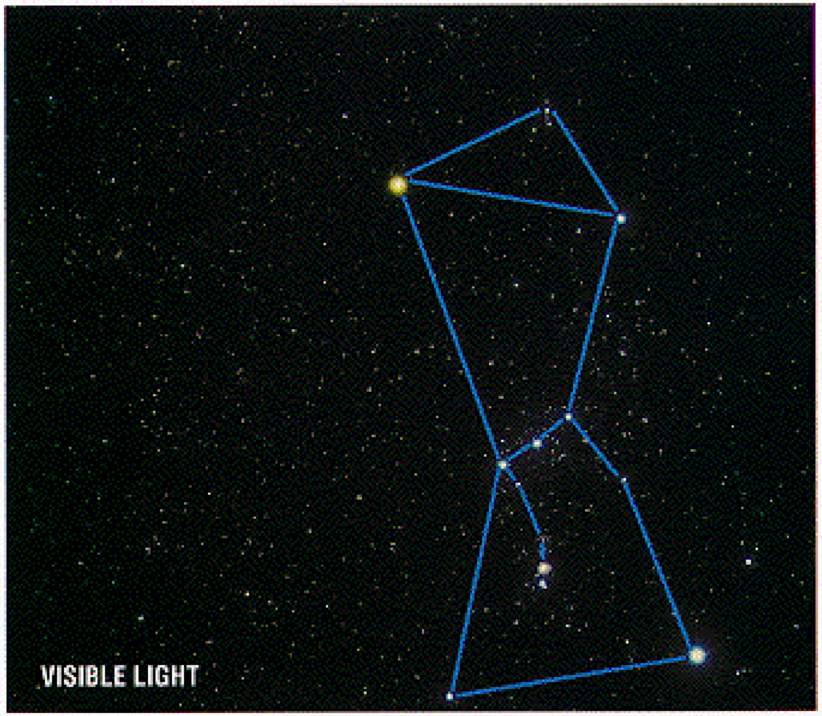
Infrared Observations

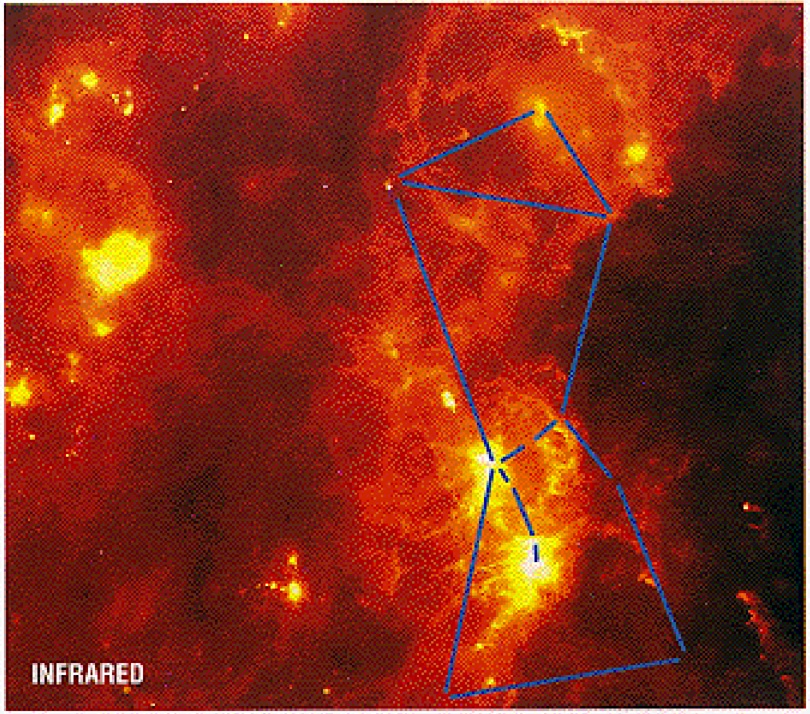


National Aeronautics and
Space Administration

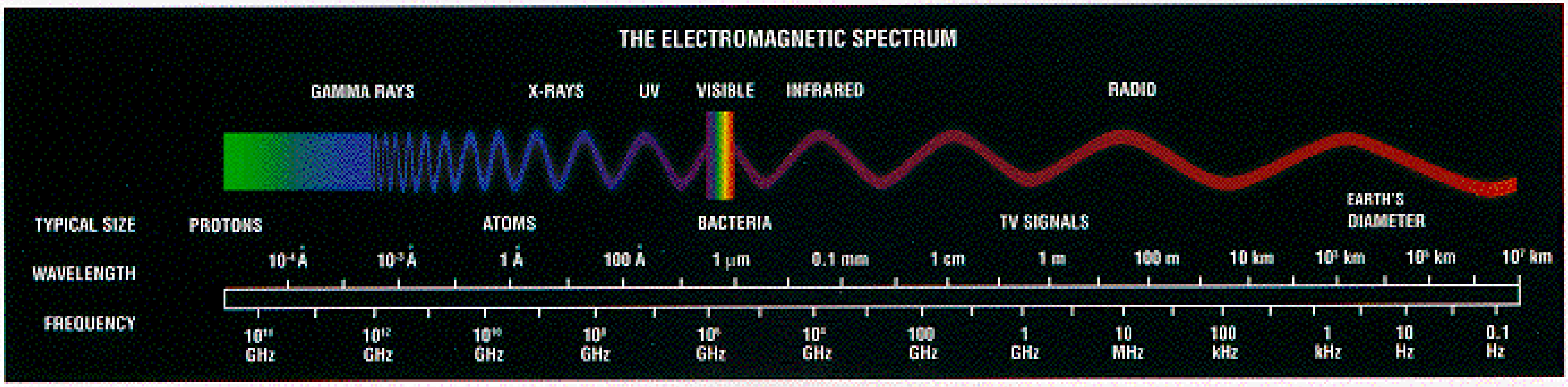
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Infrared Astronomy: More than Our Eyes Can See

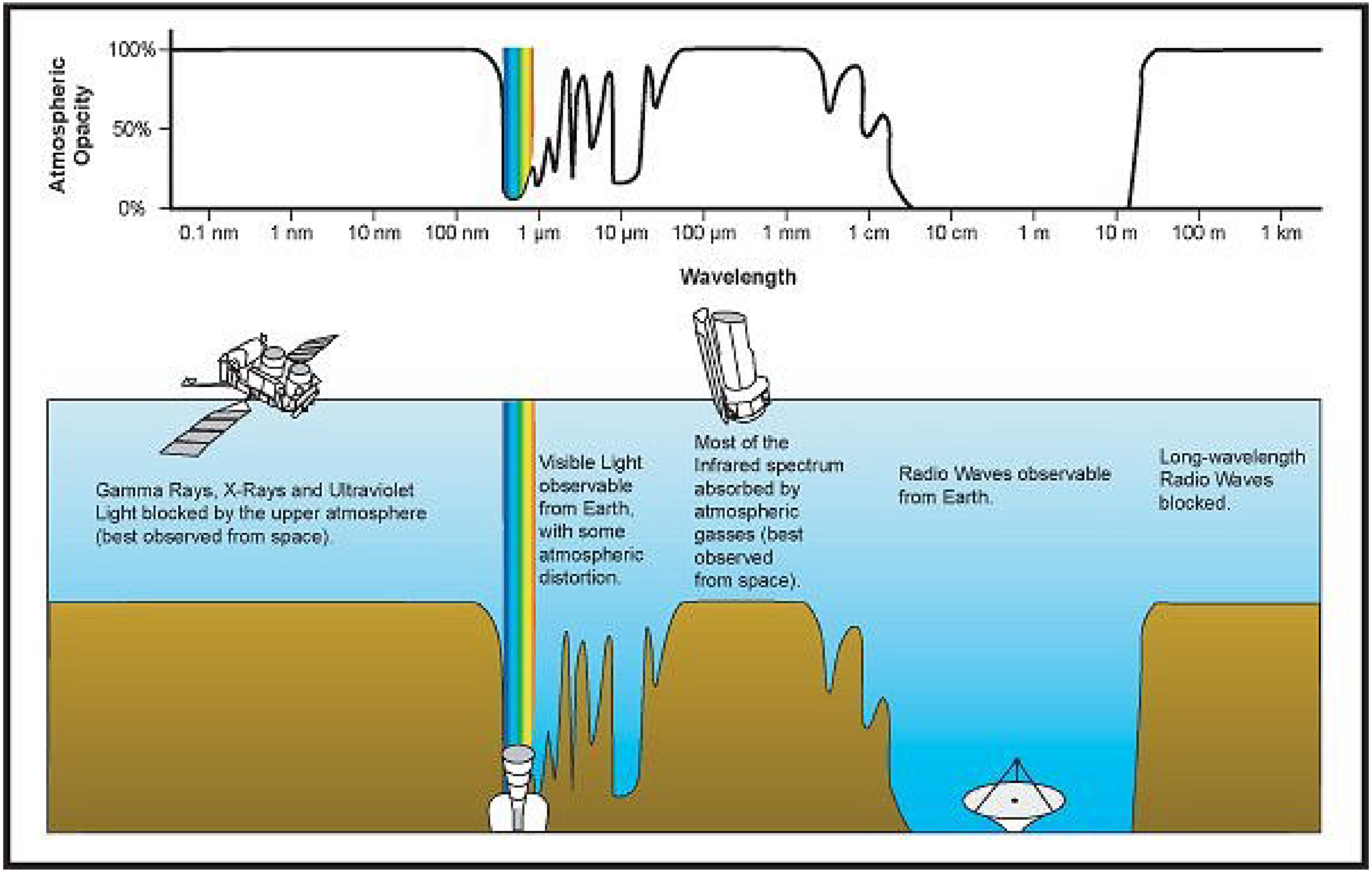




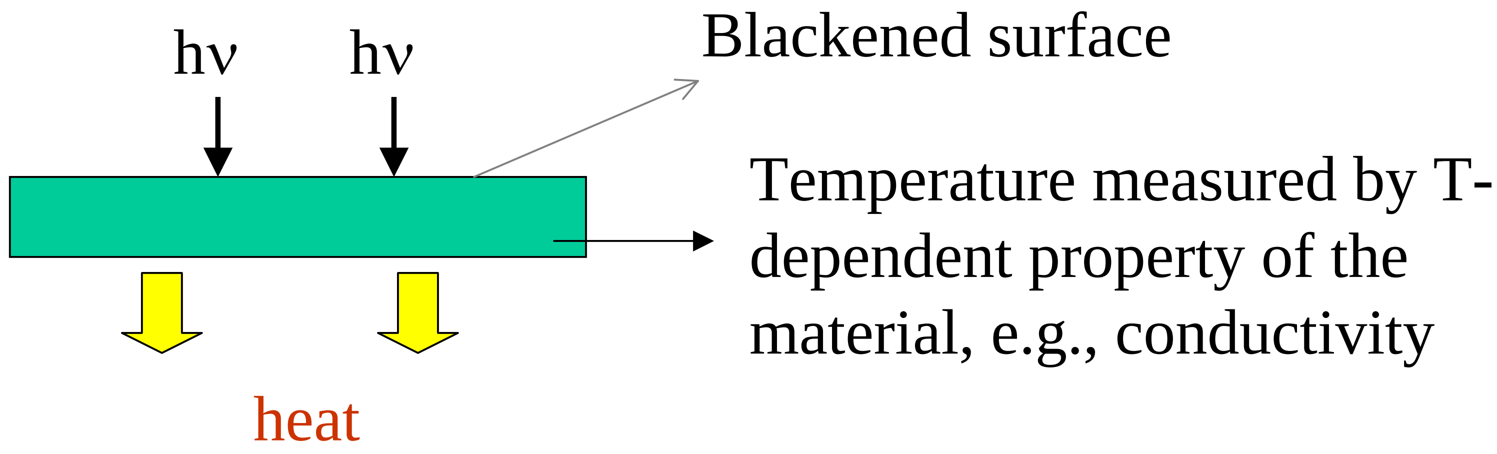
These views of the constellation Orion dramatically illustrate the difference between the familiar, visible-light view and the richness of the universe that is invisible to our eyes, though accessible in other parts of the electromagnetic spectrum.



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 Red giants Dust is transparent
Mid-Infrared	5 to (25-40)	(92.5-140) to 740	Planets, comets and asteroids Dust warmed by starlight Protoplanetary disks
Far-Infrared	(25-40) to (200-350)	(10.6-18.5) to (92.5-140)	Emission from cold dust Central regions of galaxies Very cold molecular clouds


Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.

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**

  λ_{max} T $\approx$ 3000 μm K (Wien's displacement law)

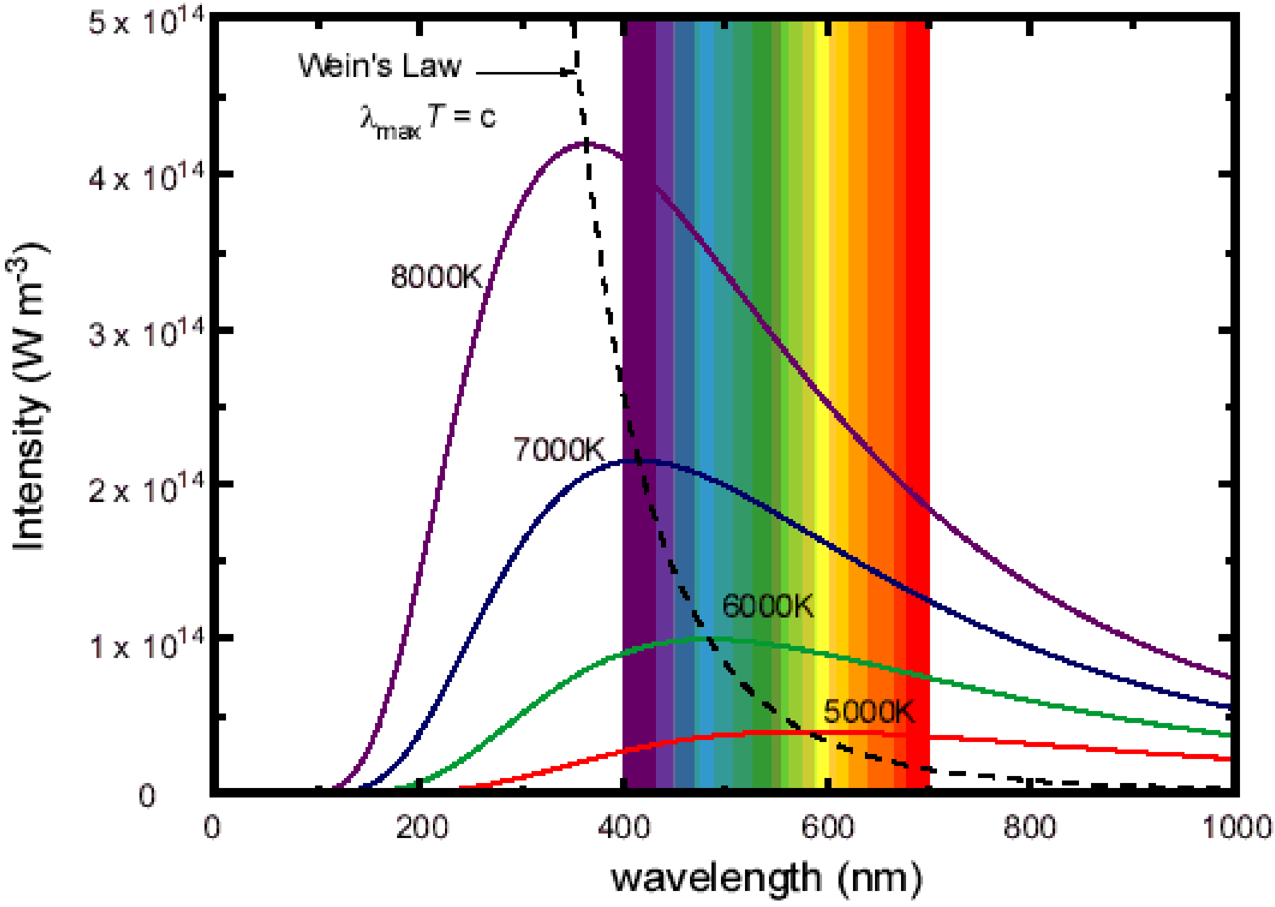
  So if T~ 300 K (room) → λ_{max} ~ 10 μm

To reduce background

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

→ 2D detectors

→ cool down the detector



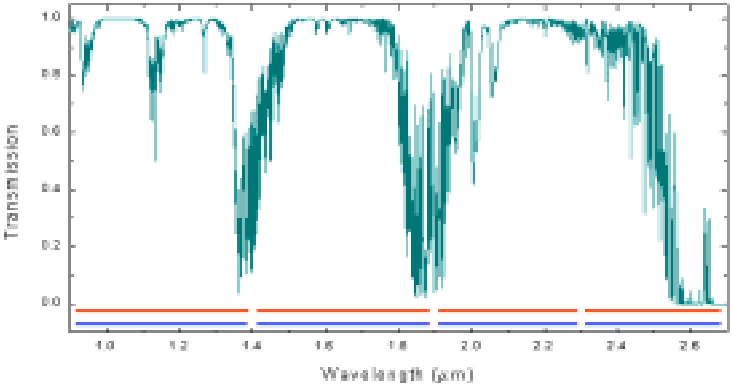
http://www.lancs.ac.uk/users/spc/teaching/py135/em_radiation.htm

IR Detection --- Difficulties (cont)

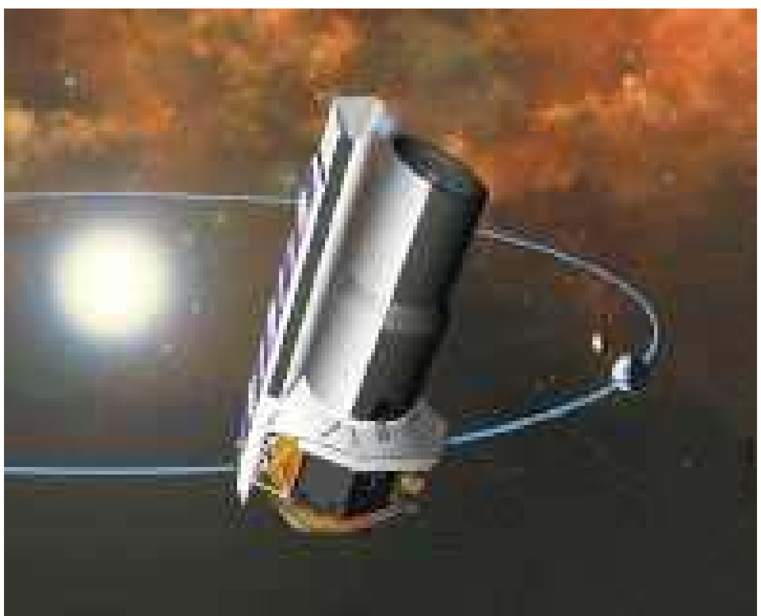
- **Atmospheric Absorption** by CO_2, H_2O, etc.

➔ high altitudes:

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







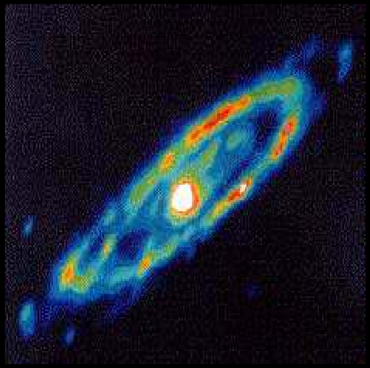

Infrared Astronomical Satellite (IRAS)

- 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

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

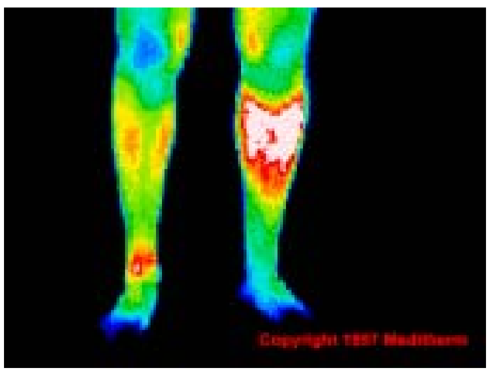


Visible photograph of M31 by WH Wang

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

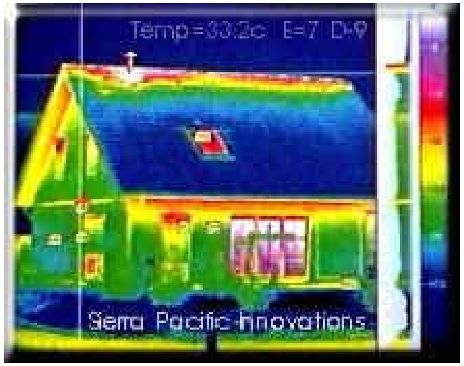
For infrared astronomy, refer to
http://www.ipac.caltech.edu/Outreach/Edu/

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.

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
- Was not turned off until 1996 because of budget