Early Detection of Infrared Radiation -
( Og et al. 7321 B.C. )
Discovery of the Infrared (Herschel 1800)

1804 Experimental determination that 'dark rays' do not penetrate glass (Leslie)

Herschel, W, 1800 Philosophical Transactions, v 90, p284.
http://www.sciencemuseum.org.uk/on-line/treasure(objects/1876-565.asp
Discovery of Thermoelectricity – Quantitative Bolometry

• In **1821** Thomas Seebeck discovered that dissimilar metals in contact would produce a voltage which could drive a current if the two metals were at different temperatures.

• Conversely, an electric current through dissimilar metals can produce a temperature difference across the junction (Peltier effect).

A thermo-electric battery

http://physics.kenyon.edu/EarlyApparatus/Thermodynamics/Thermoelectric_Battery/Thermoelectric_Battery.html
Thermocouples and Thermopiles

- The current generated by a single thermocouple is quite week – especially when the input is small.
- **1830-1840** - Melloni implemented multiple thermocouples in a “thermopile”

Thermocouples and Thermopiles

- Thermopiles were paired so that one was observing "signal" the other "background" in a "differential thermopile" (at right)

First Infrared Solar Spectrum

- 1840 – Sir John Herschel (William Herschel's Son) produces an infrared spectrum of the Sun using thermopile detectors and glass prisms.
- The spectrum shows absorption features into the infrared but
  - Nobody at the time had any characterization of the infrared dispersion (or transmission) of glass.
- Draper (by phosphorescence?), Foucault, and Fizeau all made similar observations.
- By the 1860's it was apparent that 2/3 of the solar energy was arriving outside the visible spectrum.
Detection of Infrared from the Moon

- 1856 – Lord Rosse
  - Using thermopile on the 36-inch speculum mirror telescope.

“The greater part of the heat received from the Moon consists of Solar heat that has first been absorbed by the lunar crust, and then given off in dark radiation. No evidence of cosmic heat was obtained.”
Refinement of Knowledge of the Solar Spectrum

- Through the 1880's improved measurements of the Solar spectrum were made
  - but were still hindered by poor knowledge of prism dispersion/transmission
  - It was evident, however, that absorption was occurring in the Earth's atmosphere
    - Changes observed with weather and altitude
Samuel Pierpont Langley

- Langley, Secretary of the Smithsonian in the late 1800's was a pioneer of infrared astronomy as well as of flight.
- He came close to beating the Wright Brothers to manned powered flight.
  - He flew powered drones nearly a mile in 1896.
Quantitative Solar Infrared Spectroscopy

- Keen interest in constancy of the Sun and net solar insolation
- Two significant innovations
  - 1881 - Invention of the “bolometer” - combined with using precise galvanometry to measure tiny resistance changes
    - Langley (1903) “The thermopile is limited in its action to the current directly generated by a difference of potential...The writer sought to devise an instrument of unlimited capacity which should act to control the current from an unlimited source of potential and be at once more sensitive than the thermopile.”
    - Resistive metal strips in one arm of a “Wheatstone Bridge”
Quantitative Solar Infrared Spectroscopy

- Two significant innovations
  - Use of “rock salt” as an optical material for prisms
    - NaCl is transmissive from the ultraviolet through the mid-infrared
    - It has otherwise horrible hygroscopic properties, but can be used with care
Quantitative Solar Infrared Spectroscopy
Quantitative Solar Infrared Spectroscopy

- Combine this with experimental rigour

PLATE VII.

BLOGORPHIC ENERGY CURVES OF THE PRISMATIC SOLAR SPECTRUM.

Each curve made in fifteen minutes. The three upper curves taken on a day of moderate water vapour absorption; the two lower curves indicate much greater absorption. See bands $\rho \tau$, $\Phi$, $\Psi$.

* Shutter closed at these points to give zero line.
† Height of slit altered at these points.
Quantitative Solar Infrared Spectroscopy

- Combine this with experimental rigour
Quantitative Solar Infrared Spectroscopy

- Combine this with experimental rigour
Quantitative Solar Infrared Spectroscopy

- In the end, Langley was able to measure deflections induced by temperature changes in the bolometer of < 1/10000 C
- He was quite sensitive to the need for instrumental sensitivity and differential measurement.
  - “The difficulties of the research lay less with the use of the bolometer than with the galvanometer..., and especially in the tendency of the needle to wander.... This wandering of the needle, here called the “drift”... was not only the grate obstacle to accuracy but a great consumer of time. It was customary to go over the spectrum several times daily making observations each separate minute of arc, by opening and closing the slit at each observation.”
The Beginnings of Infrared Astronomy

- Measuring the Sun and Moon are fine baby steps, but real progress in infrared astronomy required measuring the feeble light from stars.

- Langley's pioneering of sensitive galvanometry opened the way to stellar and planetary measurements starting around 1910.
  - Coblentz (1914) and Pettit and Nicholson (1922) reported hundreds of stellar infrared magnitudes (conducted with thermocouples – a demonstration of improving electronic amplification and sensitivity?).
Two Breakthroughs

- World War II drove the development of better thermal sensors – particularly the Lead Sulfide photoconductor which was first applied in astronomy in 1951.
- In 1961, Frank Low working at Texas Instruments recognized the extreme thermal sensitivity of germanium and developed the liquid helium cooled germanium bolometer.
  - This innovation is the watershed event in modern infrared astronomy.
  - Shortly thereafter, a small 12” cassegrain telescope was installed in a NASA Lear Jet enabling sensitive photometry and spectroscopy of stars, galaxies and nebulae out to 100um.
The NASA Lear Jet
So where do you point your telescopes?

- Low et al. pointed their telescopes at known visible sources of radiation.
  - Although they discovered intriguing infrared properties of these objects – for example that galaxies were emitting most of their flux in the mid-to-far infrared – the “infrared zoo” remained to be discovered.
  - Neugebauer and Leighton (late 1960's) carried out the first unbiased large-scale infrared sky survey – the Two Micron Sky Survey (TMSS).
    - Lead sulphide photomultipliers scanning the Northern sky with 2' resolution and sensitivity to about 4th magnitude at K-band.
    - Data recorded on strip-chart recorders and reduced by hand.
    - 5600 objects detected – many with no visible counterpart
TMSS telescope (in the Smithsonian)
The Engine of Astrophysical Discovery

Most... discoveries came as huge surprises, which shows that theoretical anticipation had little to do with discovery. What mattered most was the implementation of powerful new observing tools.

-- Martin Harwit

Cosmic Discovery: The Search, Scope and Heritage of Astronomy
So where do you point your telescopes?

Part II

- The TMSS characterized the infrared sky to “visual” depth – about 4\textsuperscript{th} magnitude.

- A deeper, more sensitive sky survey – at longer wavelengths was essential for progress in the field (mid – 1970's)
  - This in an era dominated by optical/UV/X-ray astronomers.

  - Those technologies had been demonstrated in space. Infrared from space was untried and considered a gamble.
  - The 1970's decadal survey allocated 25% of the funding to space visible astronomy, 25% to X-ray/ultraviolet and 4% to infrared.
The Infrared Astronomy Satellite (IRAS)

- International cooperation/competition fostered a project leading to the launch of a (for the time) sophisticated infrared focal plane and liquid helium cooled 60 cm telescope.
- IRAS was build on a heritage of ground based rocket-borne astronomy.
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The Infrared Astronomy Satellite (IRAS)

- IRAS introduced the era of “database” astronomy producing a catalog 250,000 sources.
- As Martin Harwit promised, many new phenomena
  - Ultraluminous infrared galaxies
  - Infrared Cirrus
  - Debris disks