X-Ray Astronomy

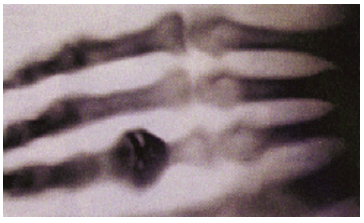
Soft X rays --- E < 1 keV

Hard X rays – 1 keV < E < 0.5 MeV

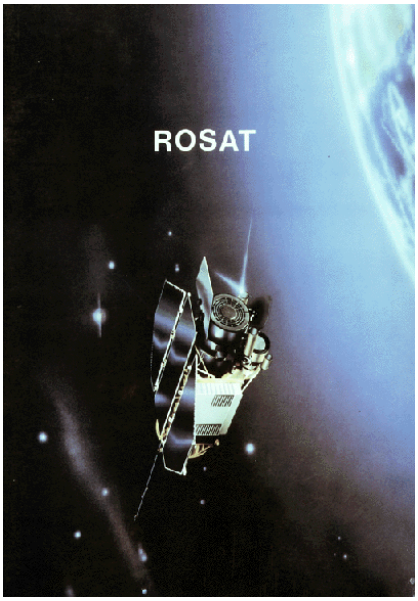
γ Rays --------- E > 0.5 MeV

Electron-positron annihilation → 2 γ-ray photons, and electron rest mass ~0.5 MeV

Wilhelm Conrad Röntgen, a German physicist (1845-1923)



Mrs. Röntgen's hand, the first X-ray picture of the human body ever taken (1895)



A conventional X-ray image is just a shadow.

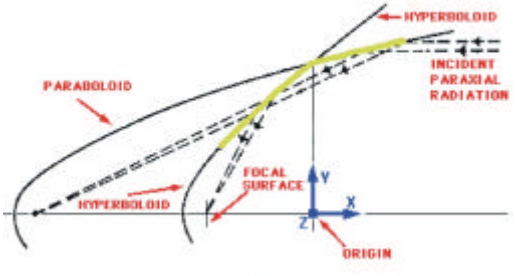
http://www.howstuffworks.com/cat-scan1.htm

↔

Computer-Aided Tomography (CAT) Scan

A scanned liver slice

Grazing-incidence X-ray Optics



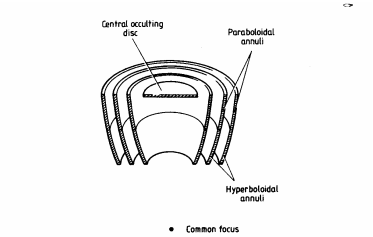


Figure 1.3.10 Section through a nested grazing incidence x-ray telescope.

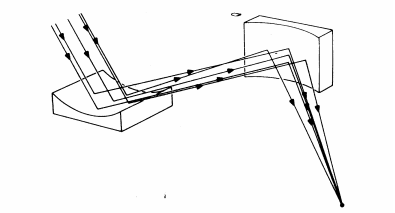
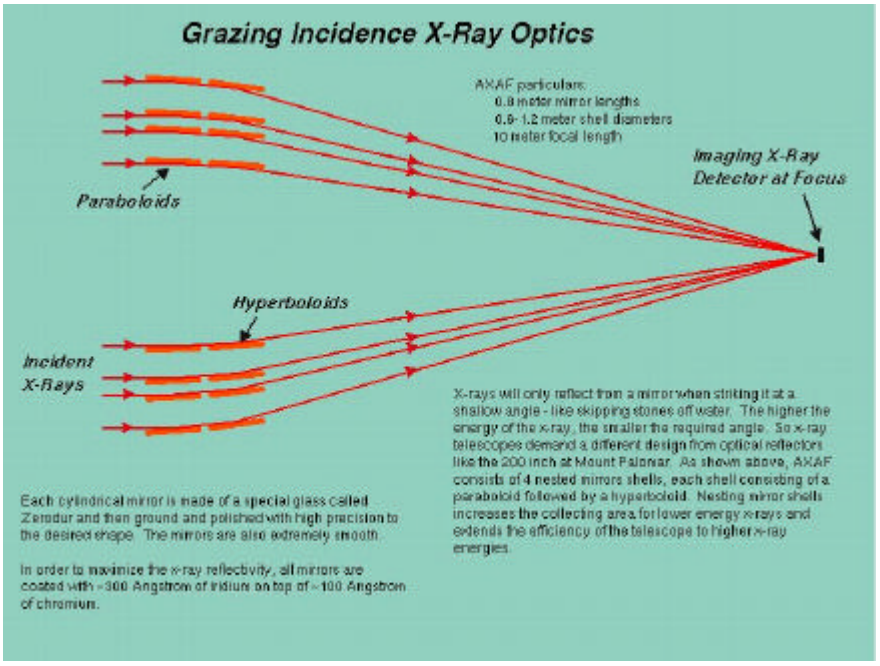
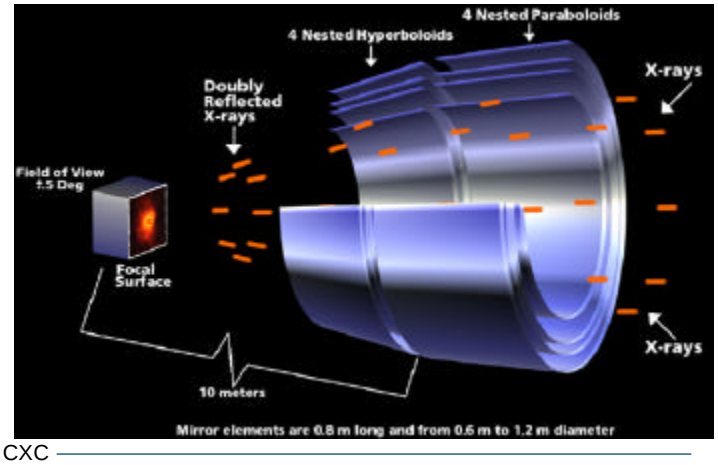


Figure 1.3.11 X-ray imaging by a pair of orthogonal cylindrical mirrors.



Chandra X-ray Observatory

Schematic of Grazing Incidence, X-ray Mirrors



CXC

X-ray Detectors

- Proportional Counters
- Microchannel Plates
- Semiconductor detectors
- Scintillators
- Phosphors
- Negative Electron Affinity Detectors (NEADs)
- Single-Photon Calorimeters
- …

http://imagine.gsfc.nasa.gov/docs/science/how_l2/xray_detectors.html

Gas-filled ionization detectors

- Geiger counters
  electrodes with potential difference, ready to discharge by an incoming photon → pulse of current

- Proportional counters

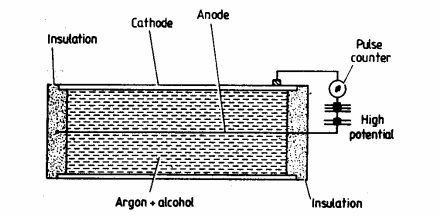
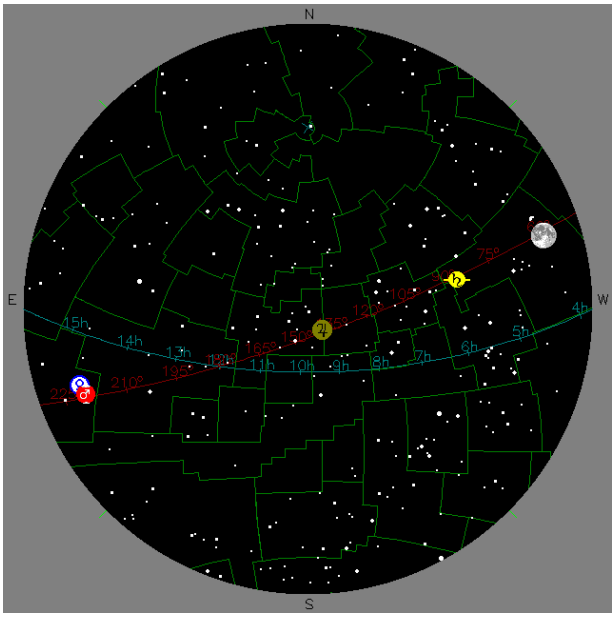
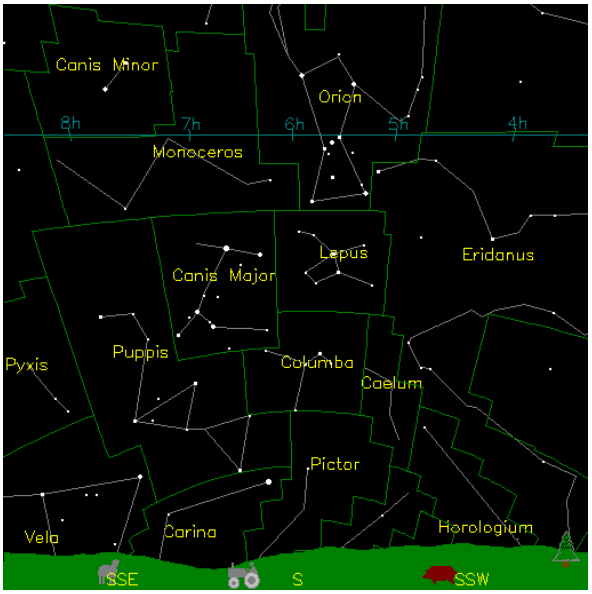


Figure 1.3.1 A typical arrangement for a Geiger counter.

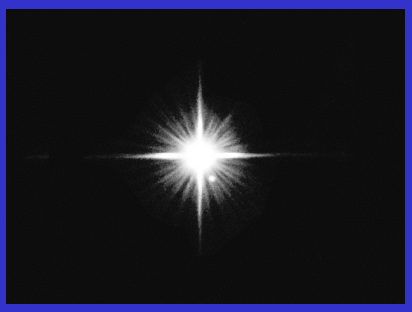


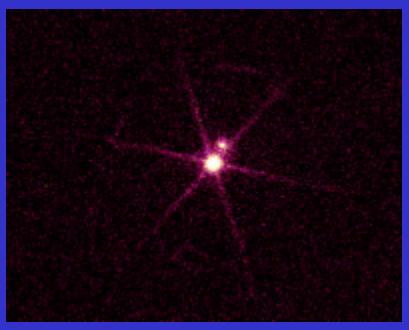
The sky tonight at 8 pm; stars brighter than 4th mag

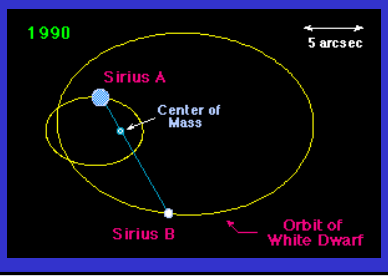
http://www.fourmilab.ch/yoursky/

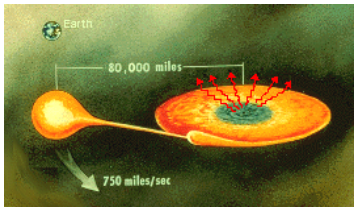


View toward southern horizon

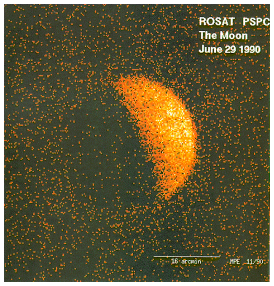






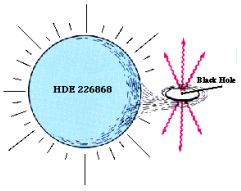


Mass exchange in X-ray binary stars

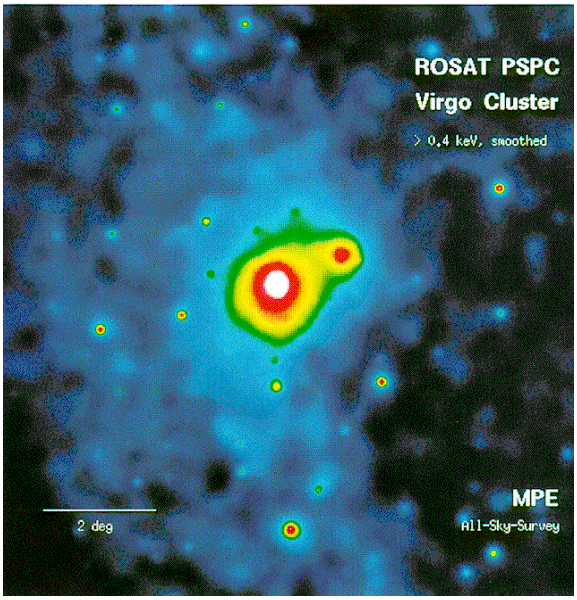


X rays from the moon

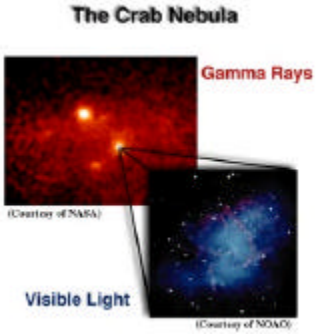
Cyg X-1 B0 supergiant (30 $M_\odot$) and a black hole (7 $M_\odot$)

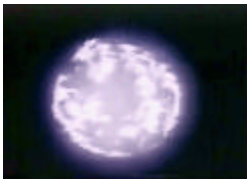


SB1 P=5.6 d

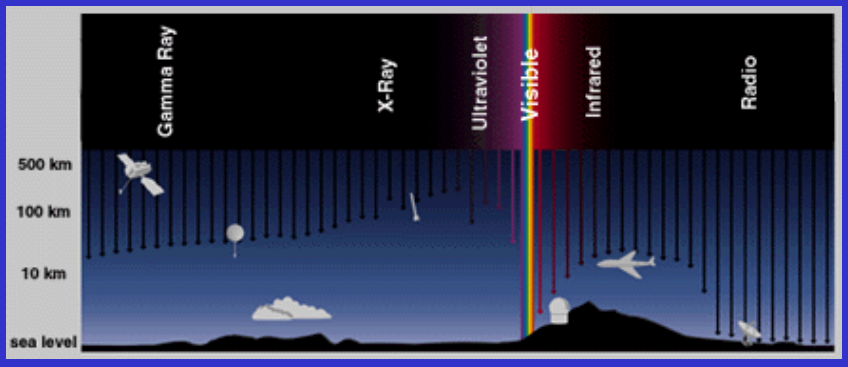


Gamma-Ray Astronomy





Gamma-ray moon
by EGRET

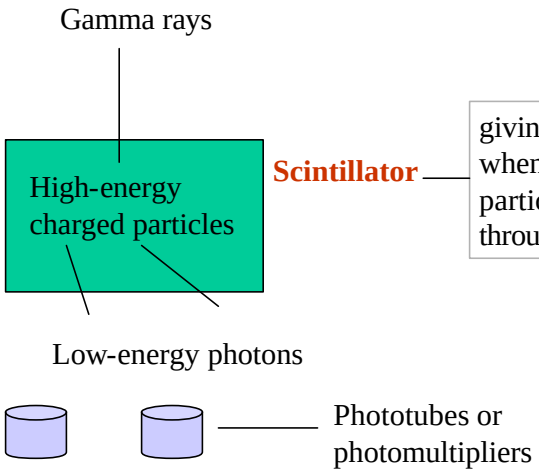


http://imagers.gsfc.nasa.gov/ems/gamma.html

Gamma-Ray Detectors

- Scintillation Detectors
- Solid-State Detectors
- Compton Scattering
- Pair Telescopes
- Atmospheric Cerenkov Detectors

Scintillation Detectors



Solid-State Detectors

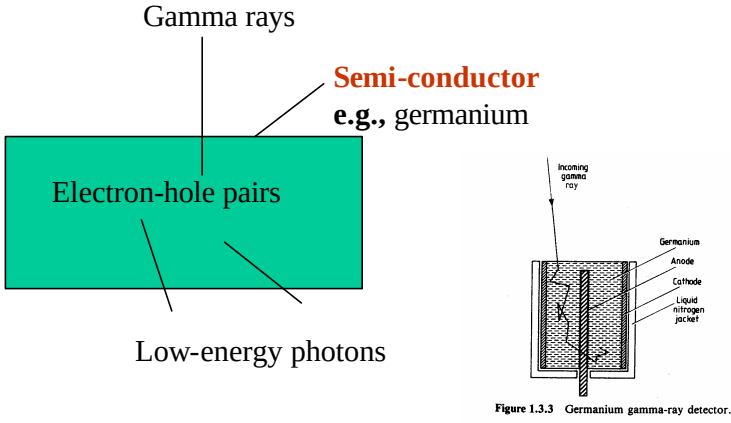
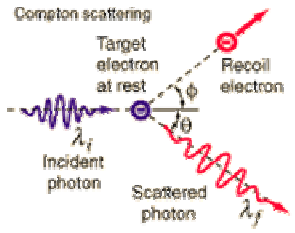


Figure 1.3.3 Germanium gamma-ray detector.

Compton Scattering

Dominant interaction for E = 1-30 MeV



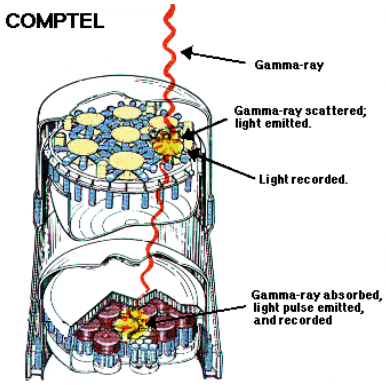
$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

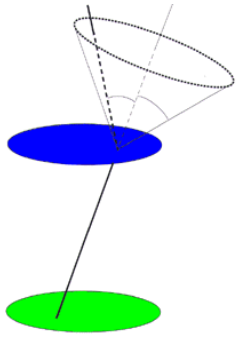
Compton scattering occurs when a photon "hits" an electron with some of the photon energy being transferred to the charged particle.

➔ Photon gets 'redshifted'

http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/comptint.html

COMPTEL (COMPton TELescope) aboard NASA's Compton Gamma-Ray Observatory is a Compon Scatter Telescope

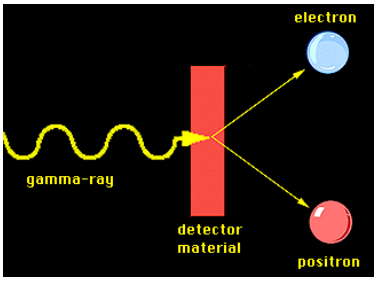




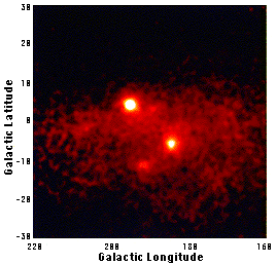
http://imagine.gsfc.nasa.gov/docs/science/how_l2/compton_scatter.html

Pair Telescope

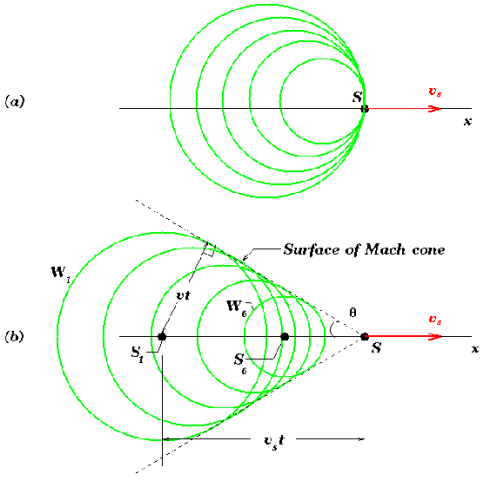
For E> 30 MeV, **pair production** dominates photon interaction with material



Can take 'images', much like an optical telescope

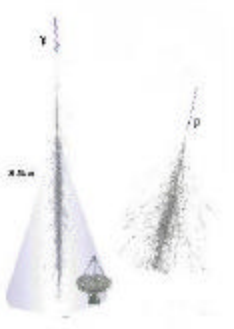


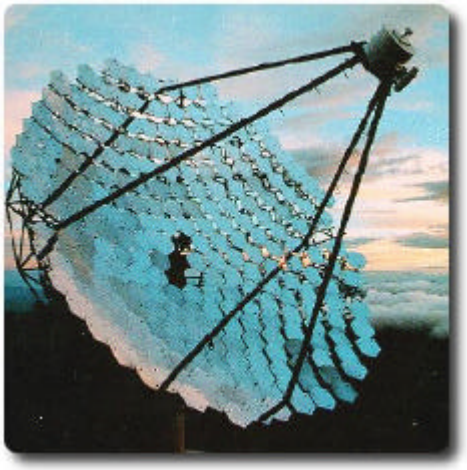
Cerenkov Radiation



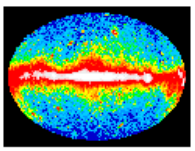
When the source travels at a speed faster than the speed of light through the medium

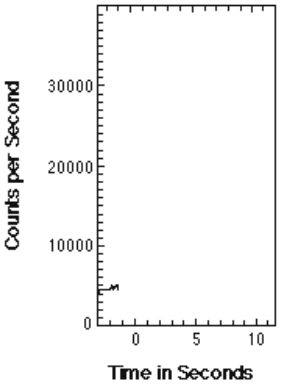
http://dept.physics.upenn.edu/balloon/cerenkov_radiation.html





Gamma-Ray Burst: energy released in 10 s equals to the sun gives off in entire 10 byr lifetime; the most violet cosmic event after the Big Bang!





Nighttime cloud-to-ground lightning. Credit: C. Clark, NOAA

Red sprite

The Compton Gamma Ray Observatory, designed to detect gamma ray sources in deep space, has also noticed gamma rays coming from the Earth. Credit: NASA

http://science.nasa.gov/newhome/headlines/essd26may99_1.htm