# X-RAY ASTRONOMY

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## Introduction

X-rays are electromagnetic radiation of energy ranging from 0.1keV to a few 100keV.

We see many objects in the sky that emit visible light but some objects emit X-rays and some are even more bright in X-rays than in visible light.

The study of the Universe seen with X-ray eyes is called X-ray Astronomy.

## Properties of X-rays

X-rays have energies a thousand times that of optical photons.

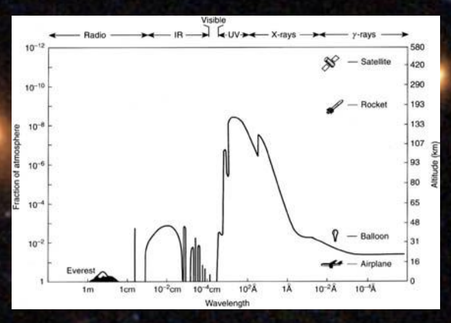
Visible light can be easily reflected but not X-rays. X-rays are either absorbed or scattered or are passed through un-deviated when they hit matter.

Refractive index of most materials at X-ray wavelength is slightly less than 1, which helps X-rays to undergo total external reflection if they fall from vacuum on a smooth denser surface at an angle less than the Grazing angle.

## X-rays and Earth's atmosphere

X-rays do not penetrate earth's atmosphere.
All the X-rays are absorbed until they reach about 40km above the Earth's surface.

So X-rays can not be detected on Earth's surface. Rockets, Balloons and Satellites are used for detection of X-rays from cosmos.




## History of X-ray Astronomy

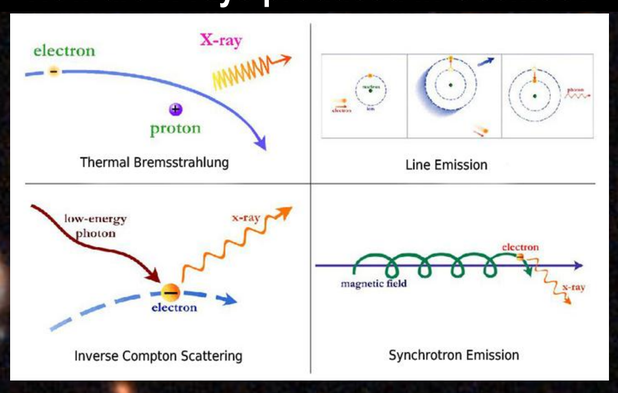
The first technology useful for research above the atmosphere was that of the V2 rockets available after World War II. With these, scientist revealed that Sun is a powerful source of UV and X-radiation. This is only because Sun is extremely close to us. But this discovery caused many scientist to lose interest in search for other sources of X-rays.

Surprise Guest!!
In 1962, Ricardo Giacconi surprisingly discovered very bright source of X-rays, Sco X-1 in the constellation of Scorpius while observing X-rays from the Moon. Sco X-1 was found to be about thousand times luminous in X-rays than Sun. This discovery lead the foundations of modern X-ray astronomy.

Giacconi received Nobel prize in 2002 for his pioneering work in X-ray astronomy.

There have been may remarkable discoveries in X-ray astronomy till now and it has become a tool to study High Energy Astrophysics as X-rays are produced by high energy processes.

## How are X-rays produced in Cosmos?



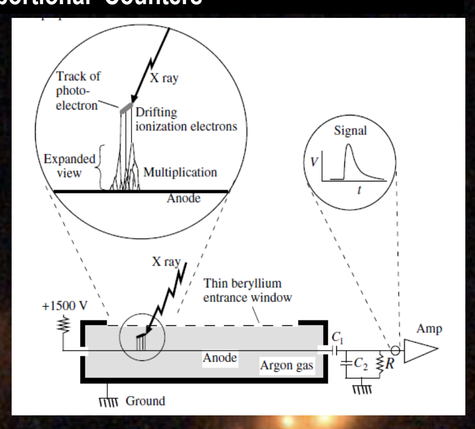

## X-ray Detectors

Almost all the detectors of X-rays work on the basic principle of photoelectric effect. These detectors respond to energy deposited by photoelectrons.

### 1. Proportional Counters

Proportional counters consist of a tube with a central anode filled with Argon gas at pressure slightly more than 1atm.

Proportional counters measure energy of incoming photon and time of arrival.




## X-ray Detectors

### 2. Scintillation Counters

In case of proportional counters, the gas becomes less opaque to X-rays at high energies(>20keV); so the photon detection efficiency decreases. High-Z materials have very good detection efficiency at such high energies.

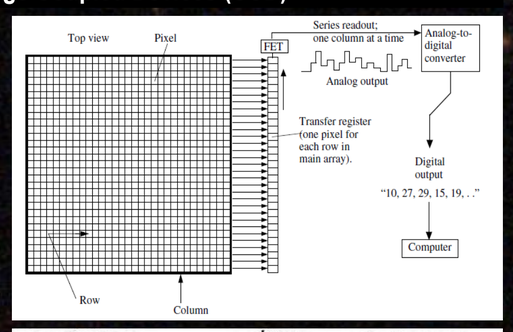
The scintillation counter uses crystals of NaI or CsI doped with Thallium.

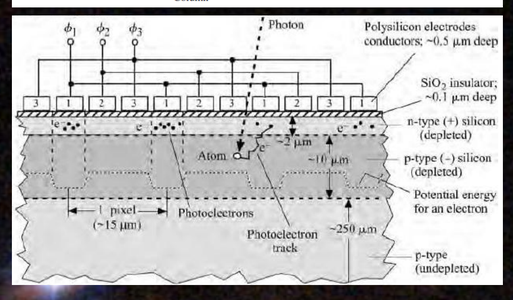
The photon energy is absorbed by an atom within the crystal and some of this energy immediately reappears as a pulse of light or scintillation.

A photomultiplier tube detects the scintillation. The amount of light in scintillation is proportional to incident X-ray photon energy.

### 3. Charge Coupled Devices (CCD)

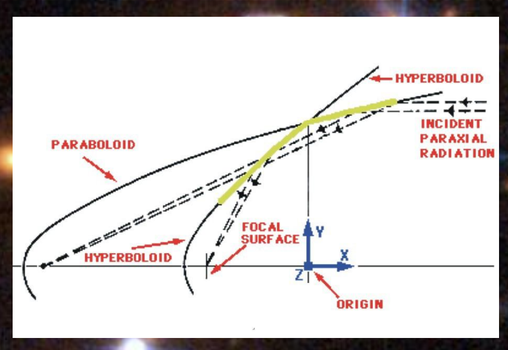
A CCD chip consists of an array of pixels. Each pixel stores an amount of charge proportional to the energy of photon fallen onto the pixel. The charge in each pixel is measured. Thus CCDs not only give the energy and timing analysis, but also give the image of the source.
The working of a CCD is described in adjoining diagrams.




## Focusing X-rays

X-ray telescopes consist of closely nested thin foil Walter I type reflectors, reflecting X-rays at small grazing angles.




A reflecting material of high-Z and roughness of the order of ~1A$^0$ is required to reflect X-rays. Al mirrors coated with thin layer of gold or platinum are used.

## X-ray Satellites and ASTROSAT

Almost 60 X-ray satellites have been launched till now since 1960s.

XMM Newton (launched by ESA), RXTE, Chandra, Swift (all launched by NASA) are some active X-ray observatory satellites.

India Is going to launch a multi-wavelength astronomy satellite called ASTROSAT.

ASTROSAT will become a leading X-ray astronomy satellite n the near future.

## XMM Newton

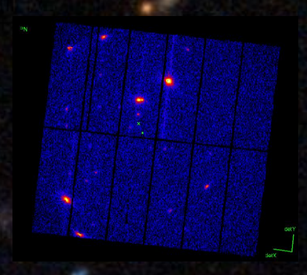
XMM Newton is an ESA satellite launched on Dec. 10$^{th}$ , 1999.

It carries three X-ray mirror modules and six instruments viz. two EPIC MOS detectors, one EPIC pn detector, two Reflection Grating Spectrometers and one optical monitor. In addition to these, there are two additional instruments namely Particle detector and EPIC Radiation Monitor System.

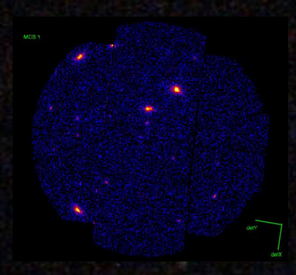
The telescopes have a focal length of 7.5m with a field of view of 30arcmin.

## European Photon Imaging Cameras

These cameras offer possibility to perform extremely sensitive imaging observations over a field of view of 30' and energy range from 0.3eV to 10keV, with moderate spectral resolution (E/ΔE ~20 to 50) and angular resolution (~6" FWHM).



EPIC pn



EPIC MOS

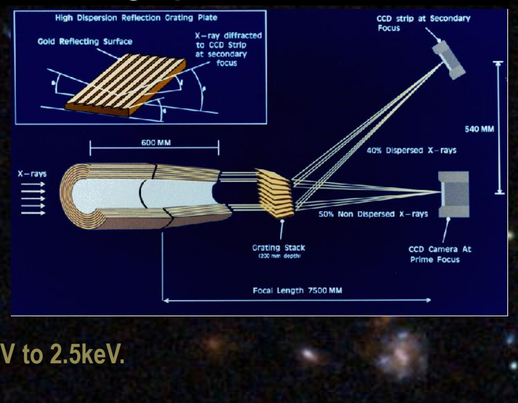
## European Photon Imaging Cameras

A comparison between two cameras (EPIC MOS and EPIC pn) is shown below.

| EPIC MOS | EPIC pn |
|---|---|
| Registers photons in soft portion of X-rays (below 10keV). | Has a good detection efficiency for hard X-rays(up to 15keV). |
| Low quantum efficiency. | High quantum efficiency. |
| Slower readout time. | Faster readout time. |
| Better angular resolution (4.4" FWHM) | Low angular resolution (12.5" FWHM) |

## Reflection Grating Spectrometer

There are two identical spectrometers for high resolution spectroscopy and spectrophotometry. RGS gives high spectral resolution E/ΔE ~ 100 to 500 FWHM with spectral energy range of. 0.33keV to 2.5keV.



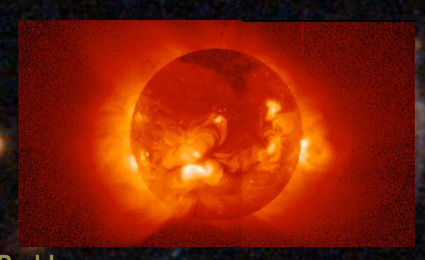

For an astrophysical source, the position and the size of the peaks in the spectrum are a measure of temperature and relative abundance of different elements.

## X-ray sources

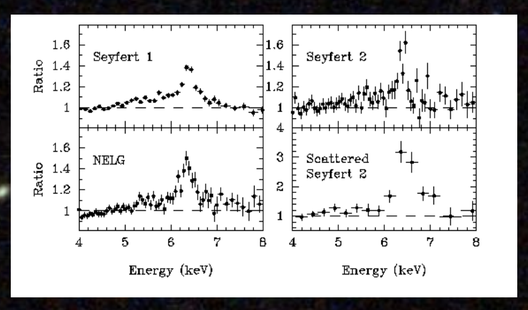
Accreting Neutron Stars and Black Holes are brightest sources of X-rays.
Solar type stars, remnants of supernovae, active galactic nuclei, diffuse hot gas in galaxies and clusters, gamma ray burst sources are among other prominent sources of X-rays

## Some Discoveries....

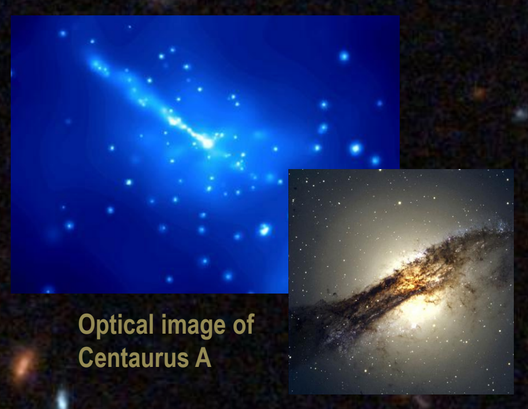
First X-ray image of Sun.
The X-rays detected from the Sun actually come from solar corona, not the solar surface. The discovery of hot corona created a big problem for astronomers and physicists. It is called the Coronal Heating Problem.



Relativistic Fe K lines in AGN.
The shape of the profile of the lines is due to gravitational broadening and redshift; which indicate that they are formed deep in the potential of central black hole.




Chandra image of Centaurus A shows a bright central source: the active galactic nucleus suspected of harbouring a supermassive black hole. A jet emanating from the core is also seen.



Optical image of Centaurus A

Crab Nebula
The observations of crab nebula in X-rays revealed the existance of a pulsar at the center of nebula.

The pulsar at the center of crab nebula is a neutron star that spins around about 30 times a second.

The pulsar was created from a supernova explosion in our galaxy that was observed by astronomers in China and other countries in the year 1054.



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