

Exploring the Universe at X-rays

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What are X-rays?

What are their properties?

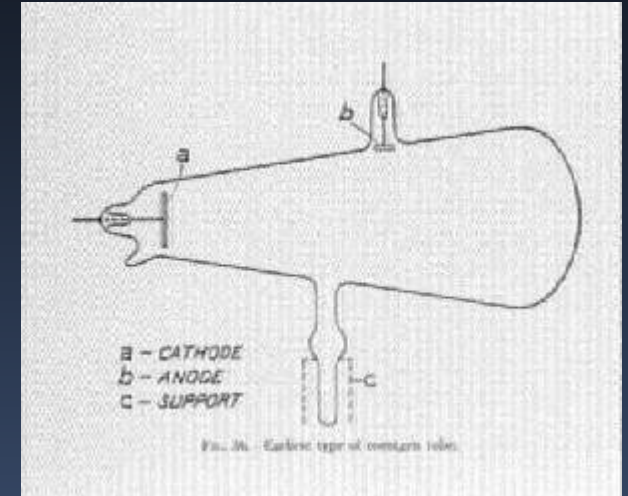
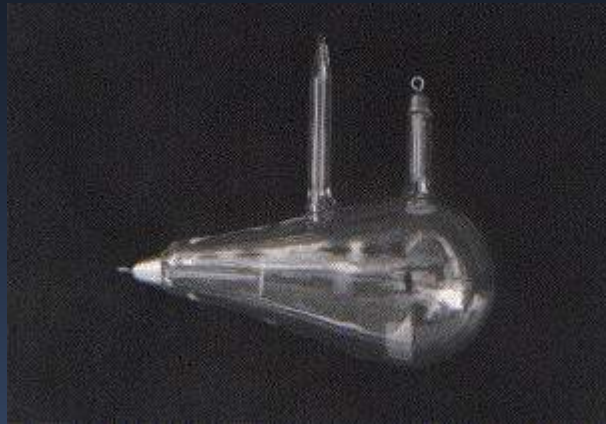
How are X-rays produced ?

Discovery of X-rays



W. C. Rontgen

(8 November 1895)



- Discovered by Rontgen quite by an accident when experimenting with vacuum tubes.
- High Voltage applied to the Electrodes produced **faint glow** on a fluorescent screen.
- The **faint glow** was caused by unknown radiation - **X-rays**.

Properties of X-rays

Rontgen found that

- X-rays pass through lighter elements (paper, wood, aluminum)
- Stopped by heavy elements such as gold.

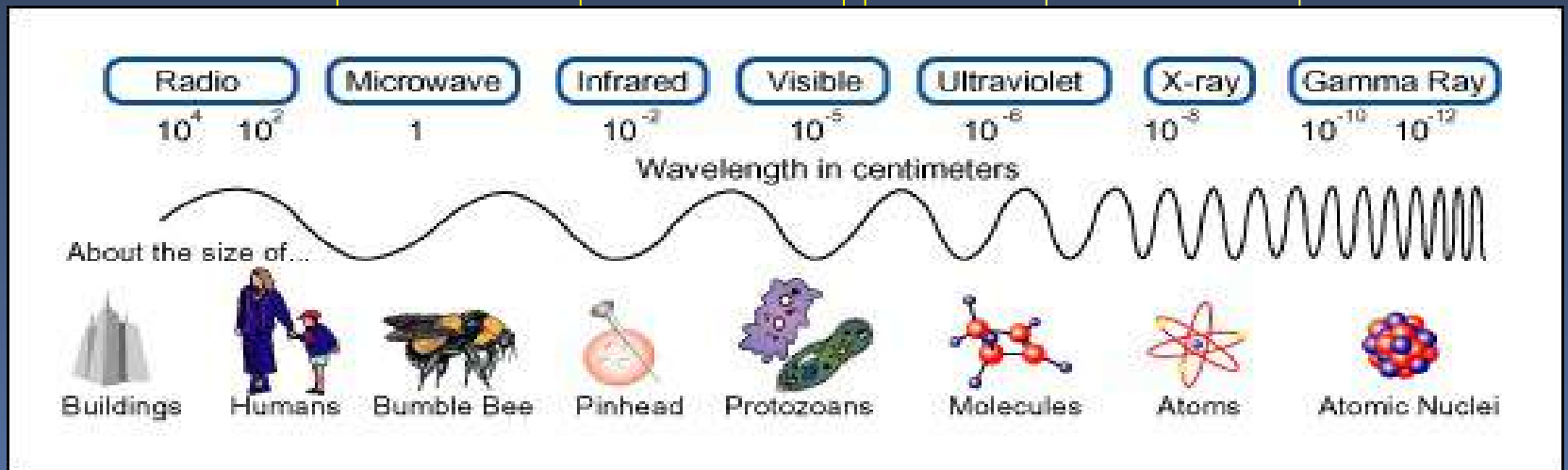
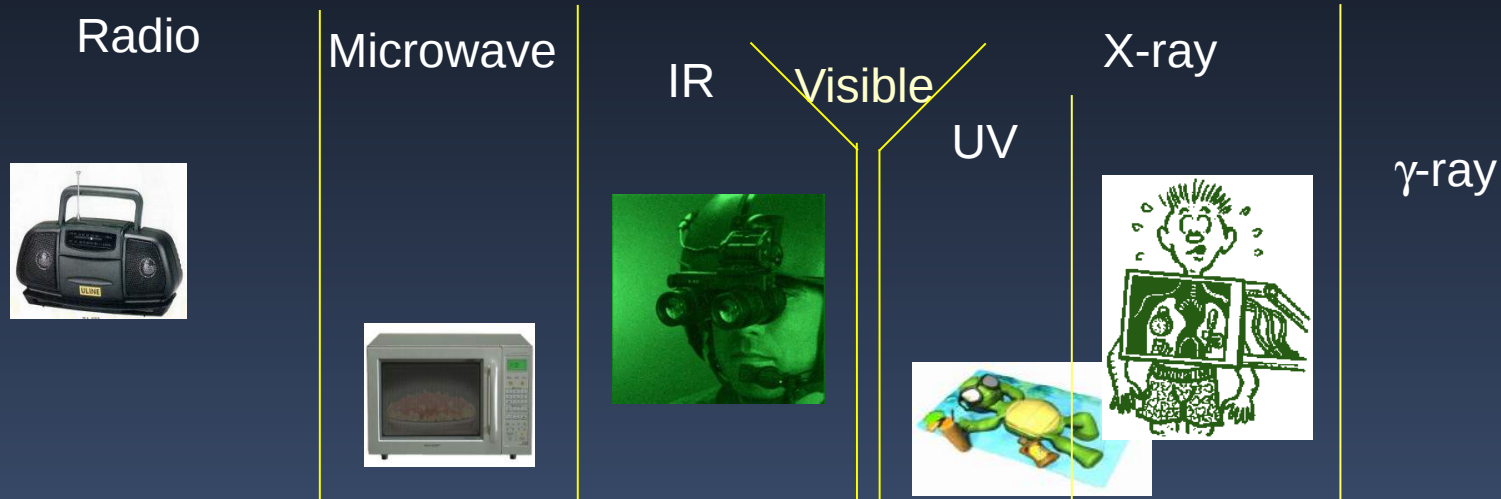
Mrs. Röntgen's hand
- first X-ray picture of the human body.



C (Z=6), O (Z=8) in the flesh,
Ca (Z=20) in the bones,
Gold (Z=79) in the ring

X-rays are electromagnetic radiation, like light but with much higher energy.

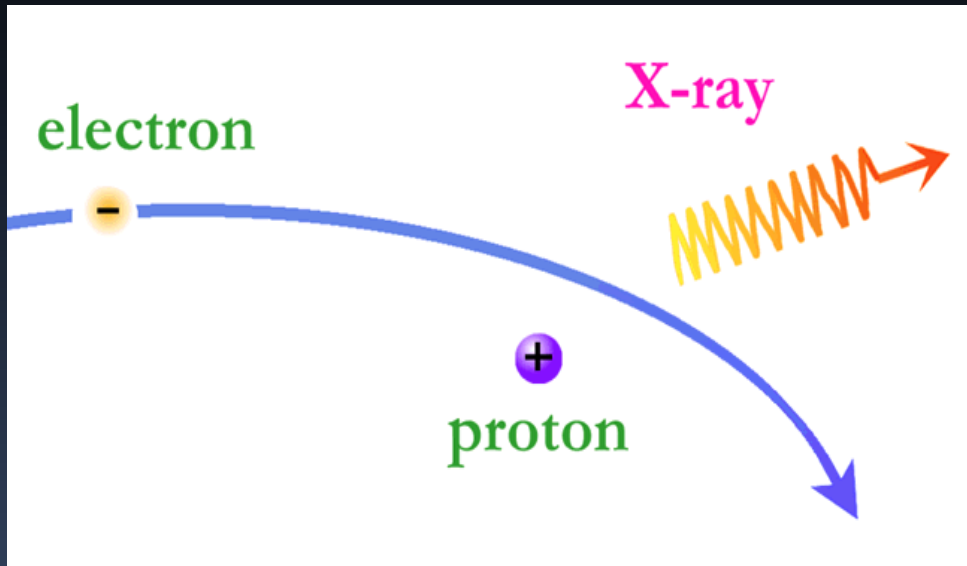
Different types of radiation



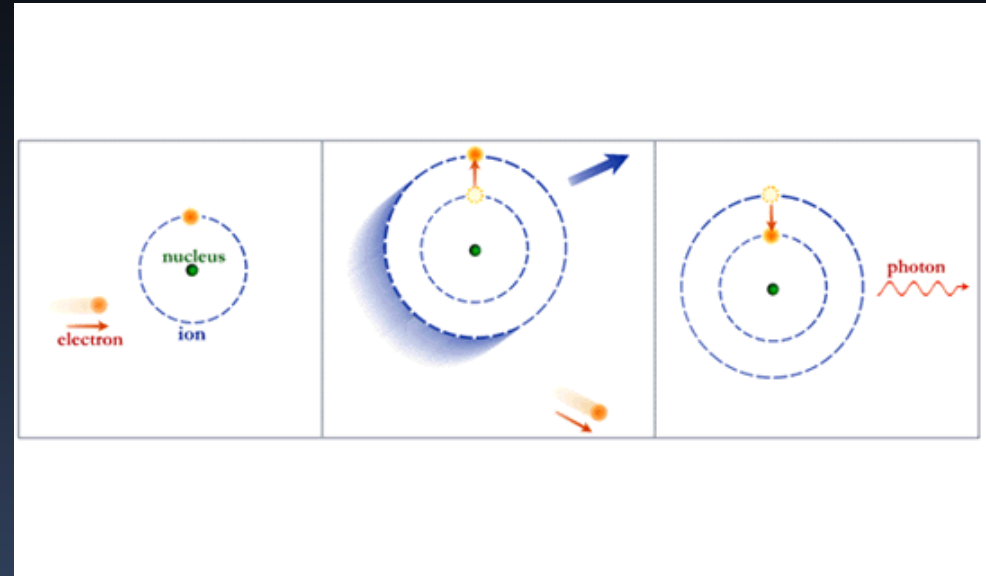
How are X-rays generated?

- X-ray photons are nearly 1000 times more energetic than optical photons
- Produced in Hot plasma (more than million degree K)
- High energy particles

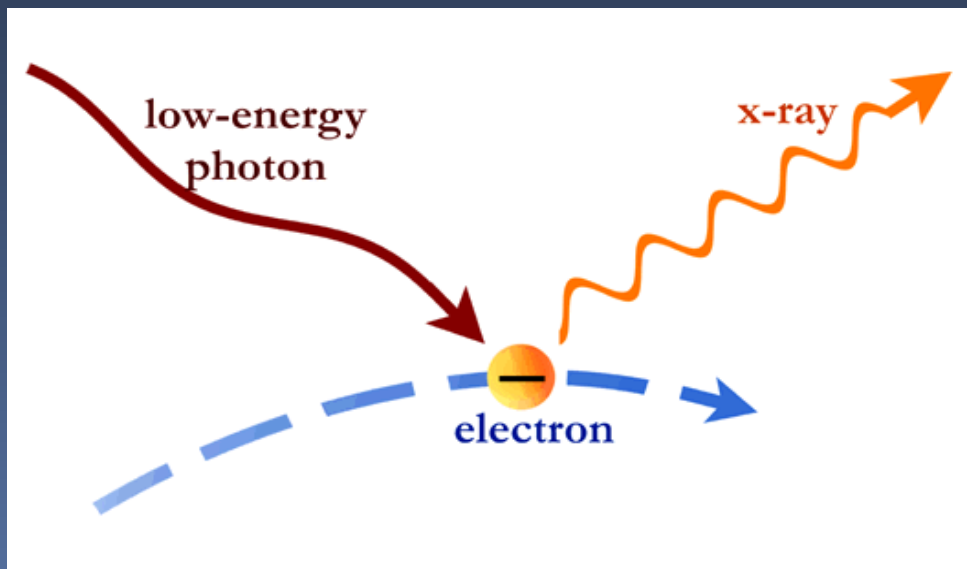
How X-rays are generated?



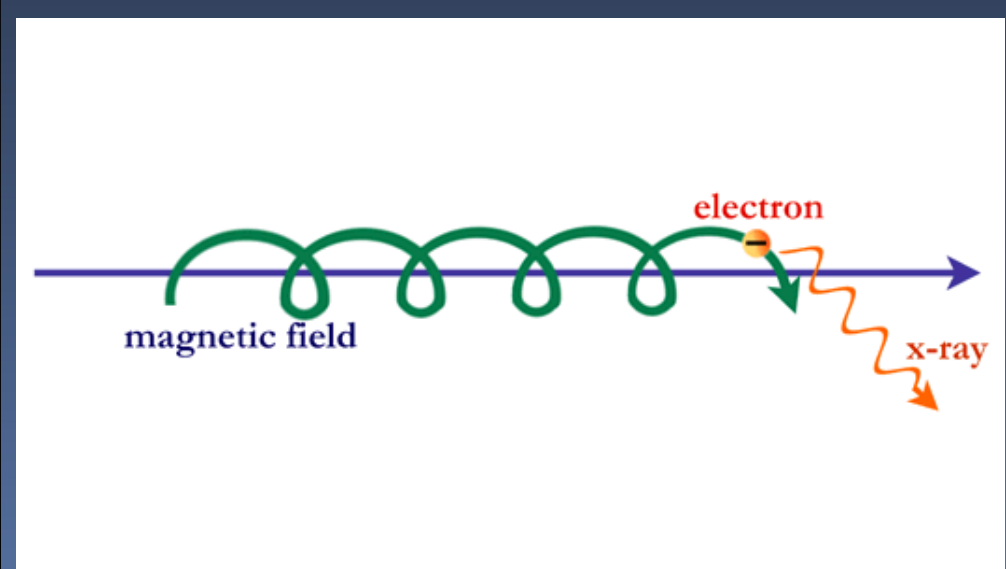
X-ray Producing Collision



Atomic Emission



Inverse Compton Scattering



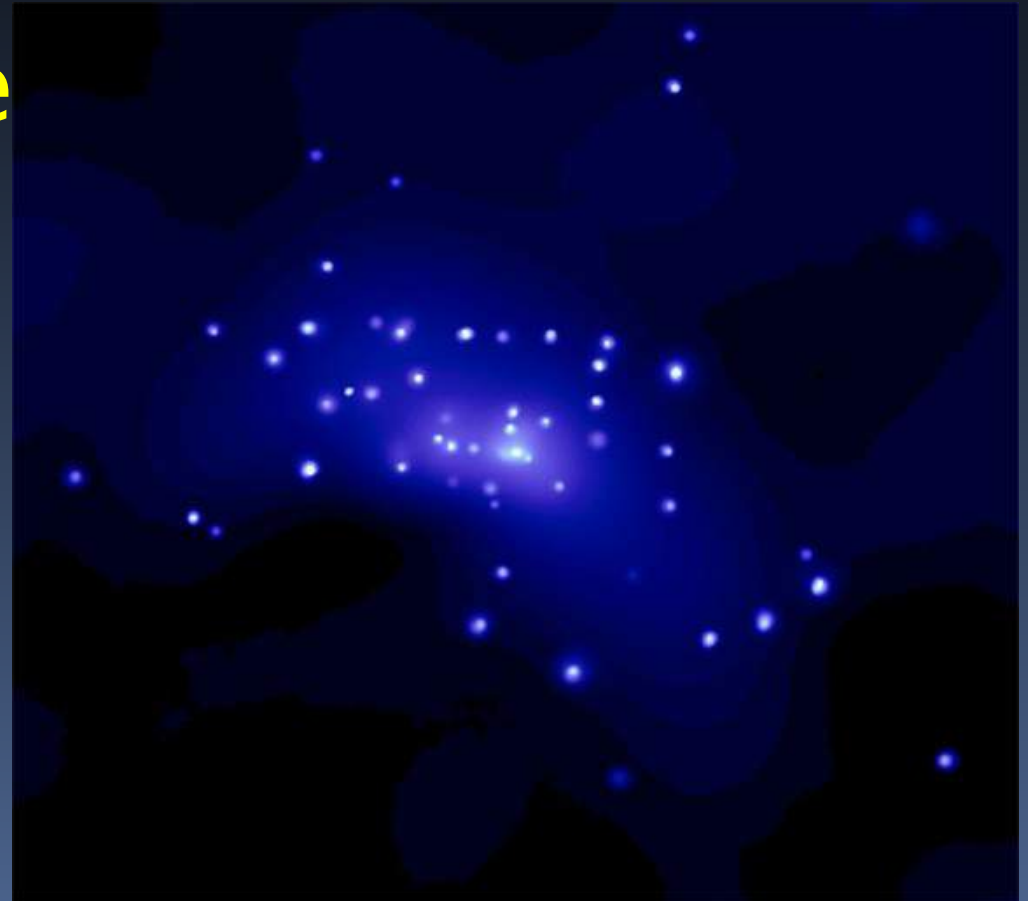
Synchrotron Radiation

What is X-ray astronomy
?

X-ray astronomy is the study of X-rays that come from natural sources in the Universe.

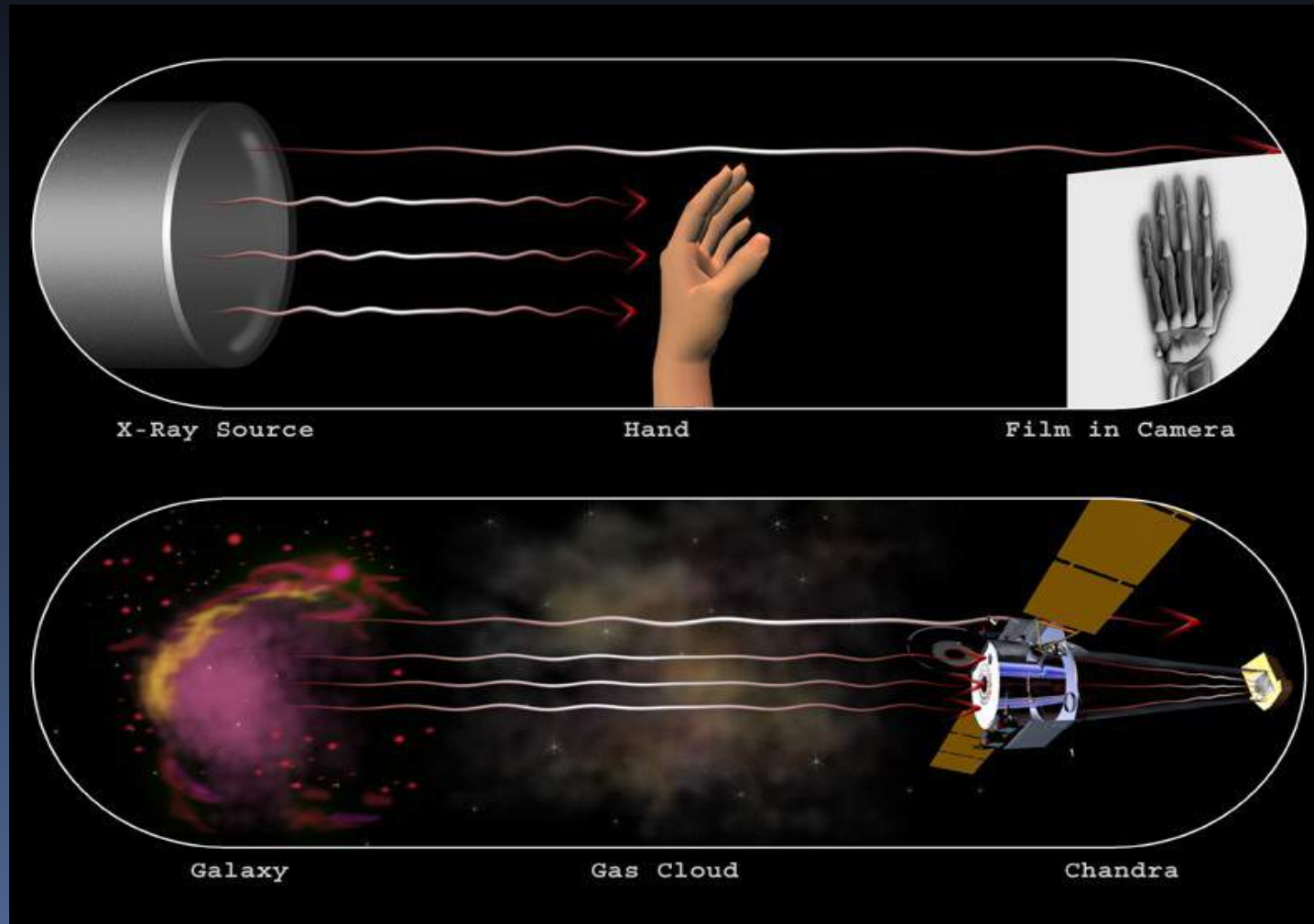
Sources like

- Sun
 - X-ray binaries
 - Supernova
 - Active Galaxies
 - Galaxy Clusters
- etc.



NGC 4697: X-ray sources in Elliptical Galaxy

X-ray Astronomy Vs Medical X-rays



Where are all the X-ray observatories?

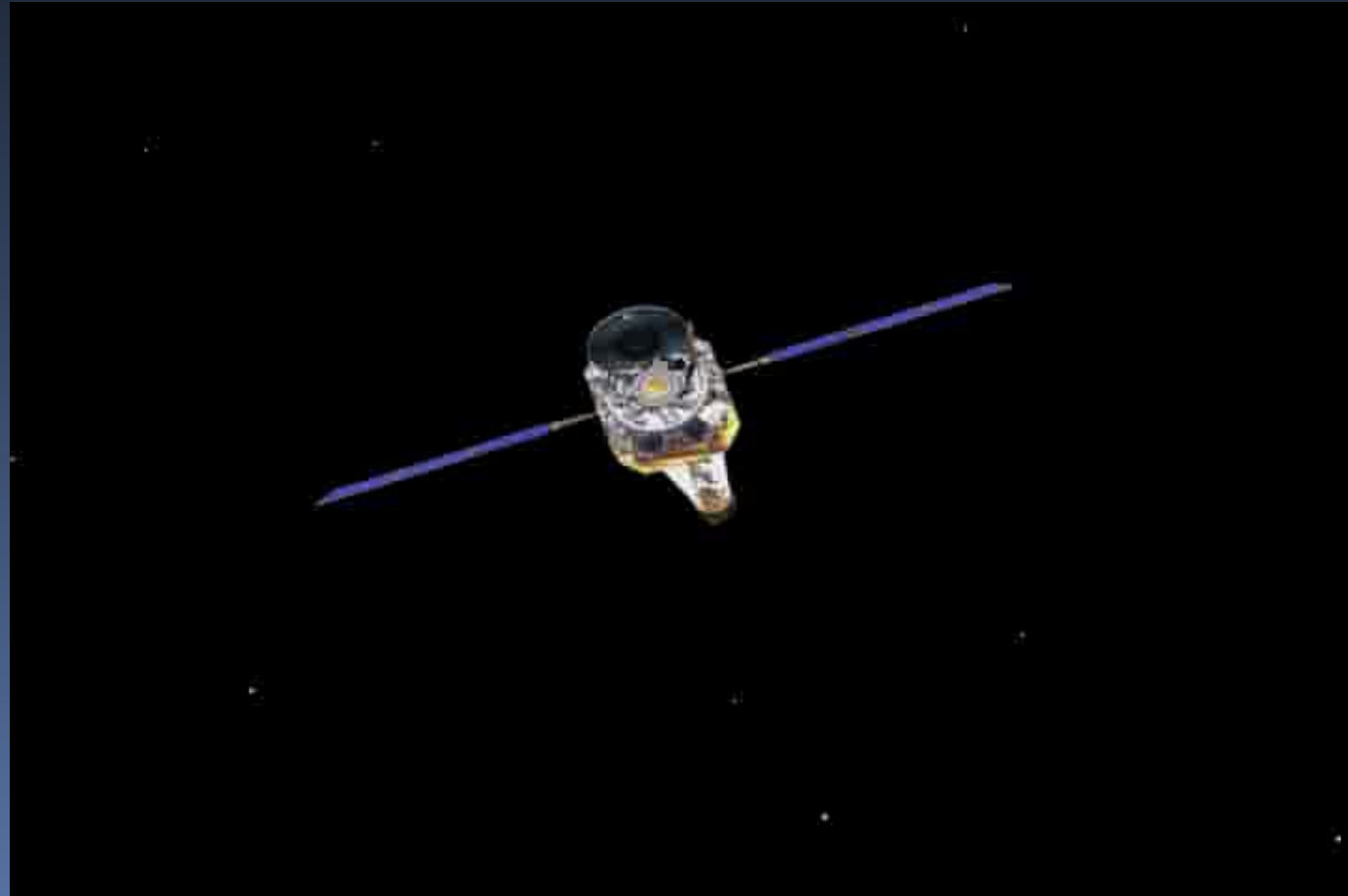
X-rays are high in energy but have short wavelengths.

X-rays from space are absorbed by oxygen and nitrogen molecules in the Earth's atmosphere.

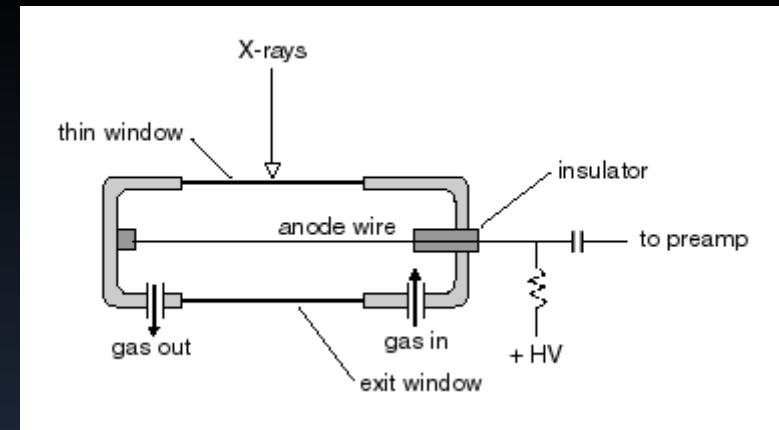
These detectors are placed above the Earth's atmosphere.

Also, due to their short wavelengths they pass right through traditional mirrors used to focus visible light.

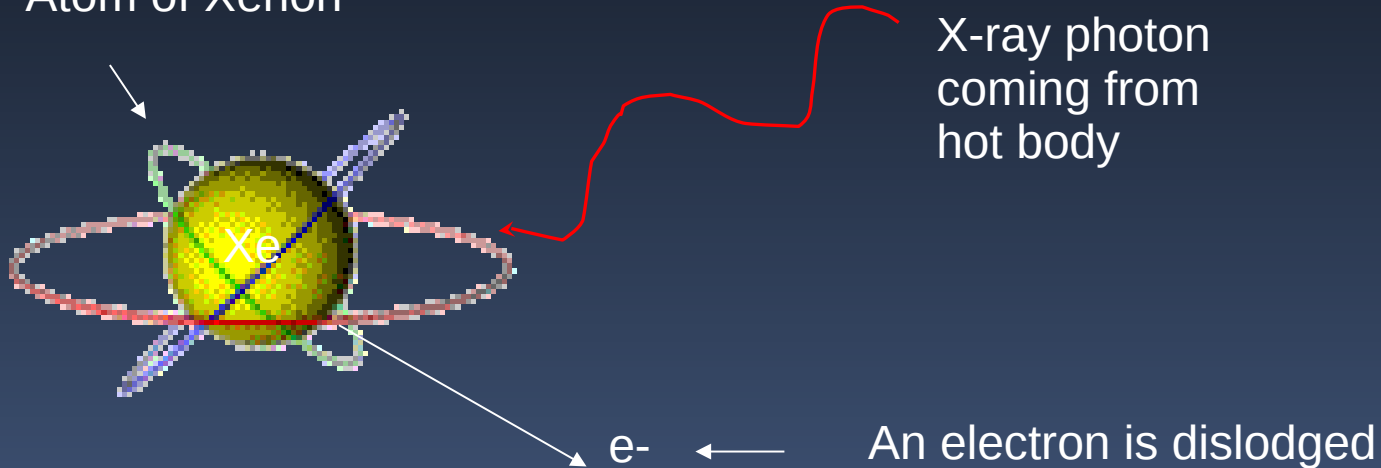
Astronomers must build special detectors to observe X-rays.



X-ray detection in a Proportional Counter



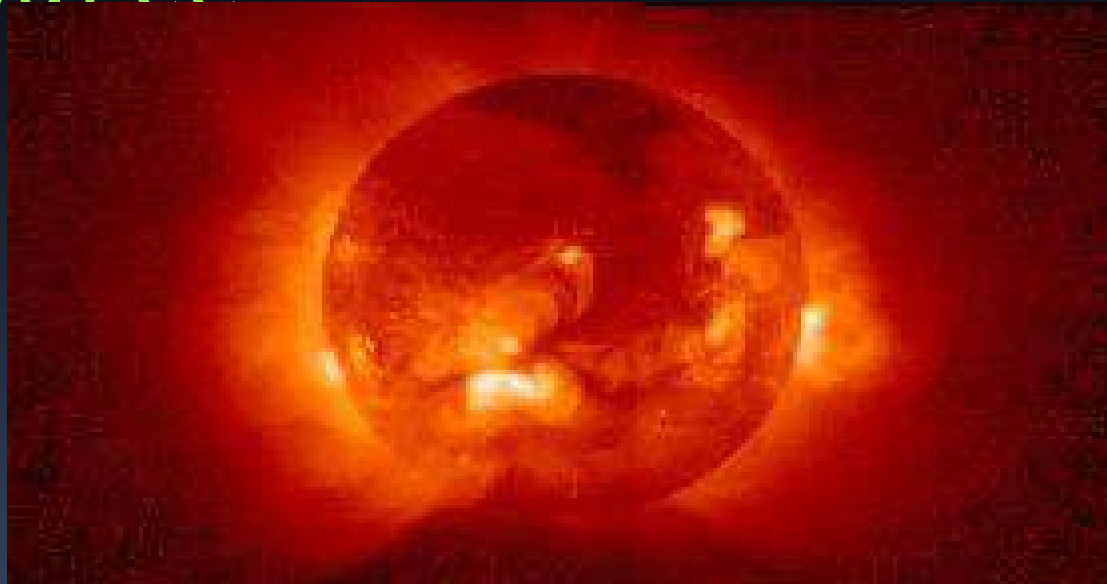
Atom of Xenon



The free electron is accelerated by the detector electric field, bumping out even more electrons in other Xenon atoms along its route to the anode wire. This process happens over and over again for EACH photon that hits the Xe gas!!

How did X-ray astronomy begin?

Our Sun as an X-ray Source



- September 1949: first detection of X-rays from Sun using captured German rockets from WW-II.
- Weak X-ray emission – about one millionth of its total energy radiated
- X-rays from solar corona – hot outer layers of sun's atmosphere.

X-rays from Stars

People thought that X-rays from distant stars not possible to detect.

In 1950s & 60s, many thought NO X-ray astronomy!

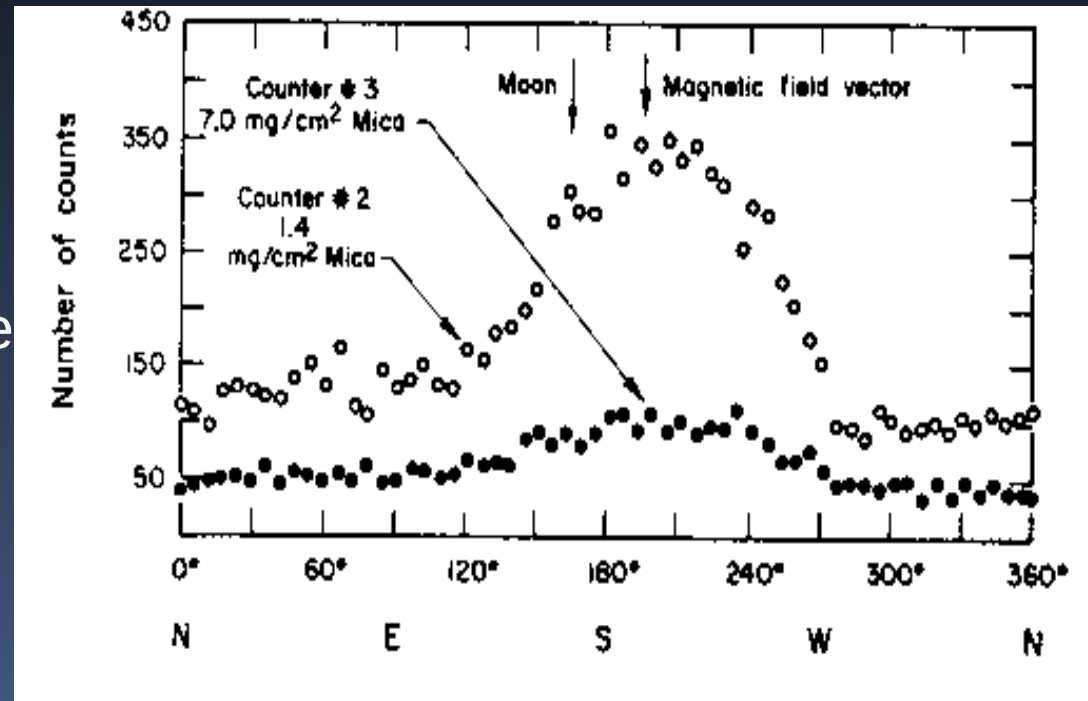
Breakthrough experiment in 1962 by Bruno Rossi, Riccardo Giacconi, and collaborators at AS&E in Cambridge, MA.

After two failures of the Aerobee rocket, they successfully launched a detector to look for X-ray emission from the moon.

The first extra-solar X-ray detection

Scorpius X-1.

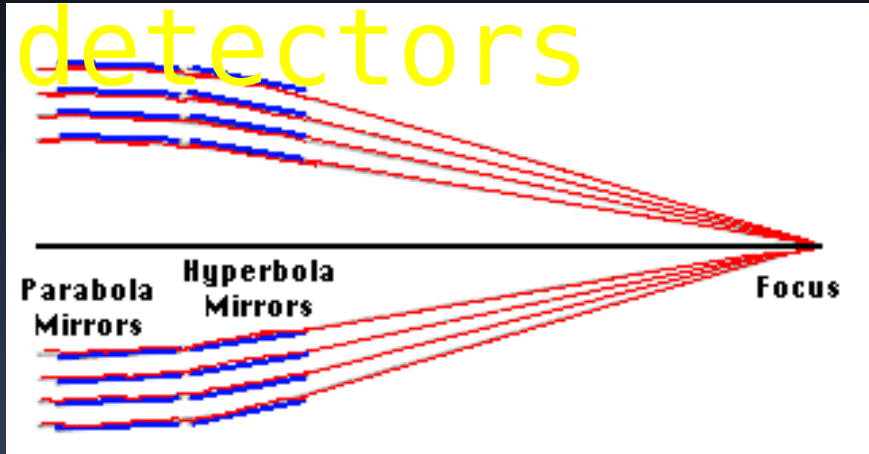
Further rocket experiments in the 1960s found many other X-ray sources.



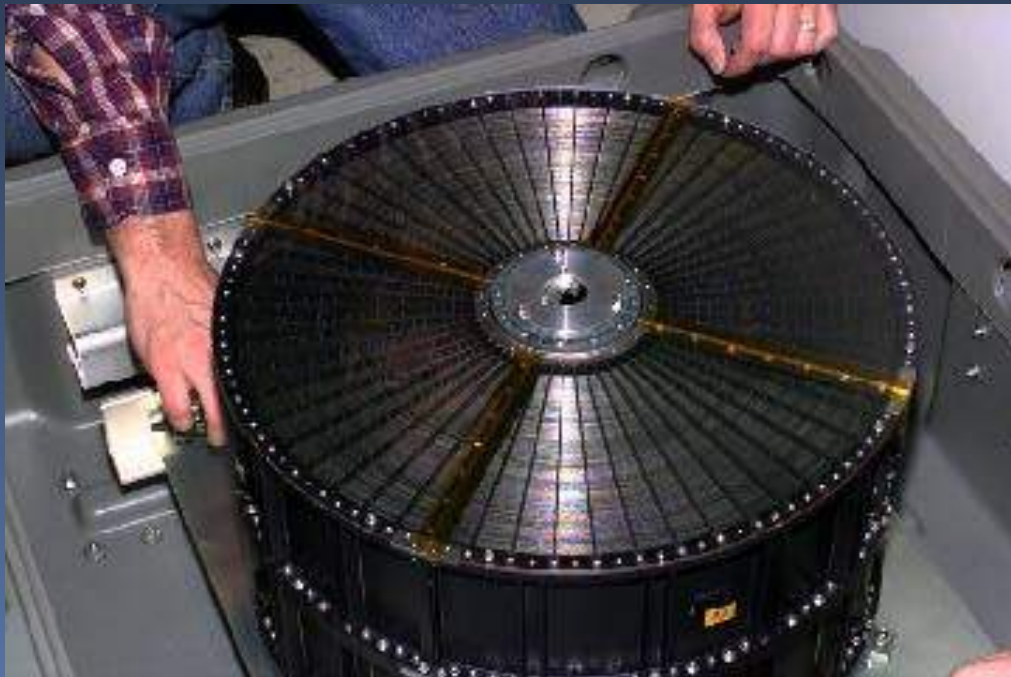
Giacconi et al., 1962

- and thus X-ray astronomy born!

Advanced Technology – X-ray mirrors & solid state detectors



X-rays bouncing off of the mirrors and converging at one specific spot (the focus).



The shape is round and it is made up of individual sections of mirrors.

Chandra X-ray Satellite

- ray passing



High Resolution X-ray Images

Nobel Prize in X-ray astronomy

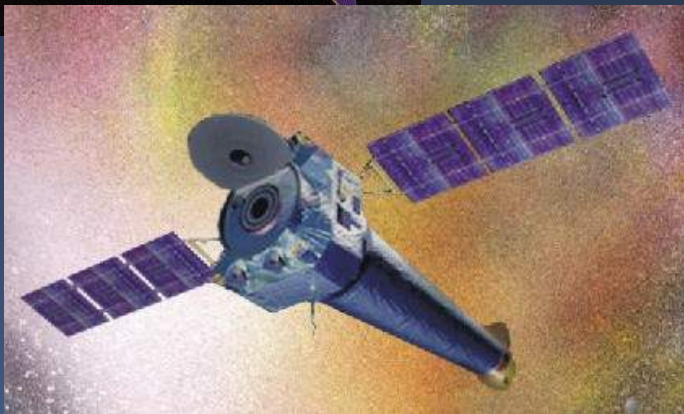


Riccardo Giacconi
receives 2002
Physics Nobel Prize
from King of
Sweden

All X-ray observatories are on satellites



Rossi X-ray Timing Explorer
(XTE, launched 1995)



Chandra
(launched 1999)



XMM-Newton
(launched 1999)

What are the various types of X-ray sources in the Universe?

X-rays from Stars

Young stars in the Orion nebula



Pre-Main Sequence Stars - X-ray emission from solar like magnetic activity

Planetary nebula

Expanding glowing shell of ionized gas ejected during the red giant phase of sun-like stars



Speed of the filaments ~ 6 million km/hour

Supernova & Remnants

- End stages of massive stars



Artist's animation + Cas A observed Chandra

2000 yrs old supernova remnant and the central neutron star



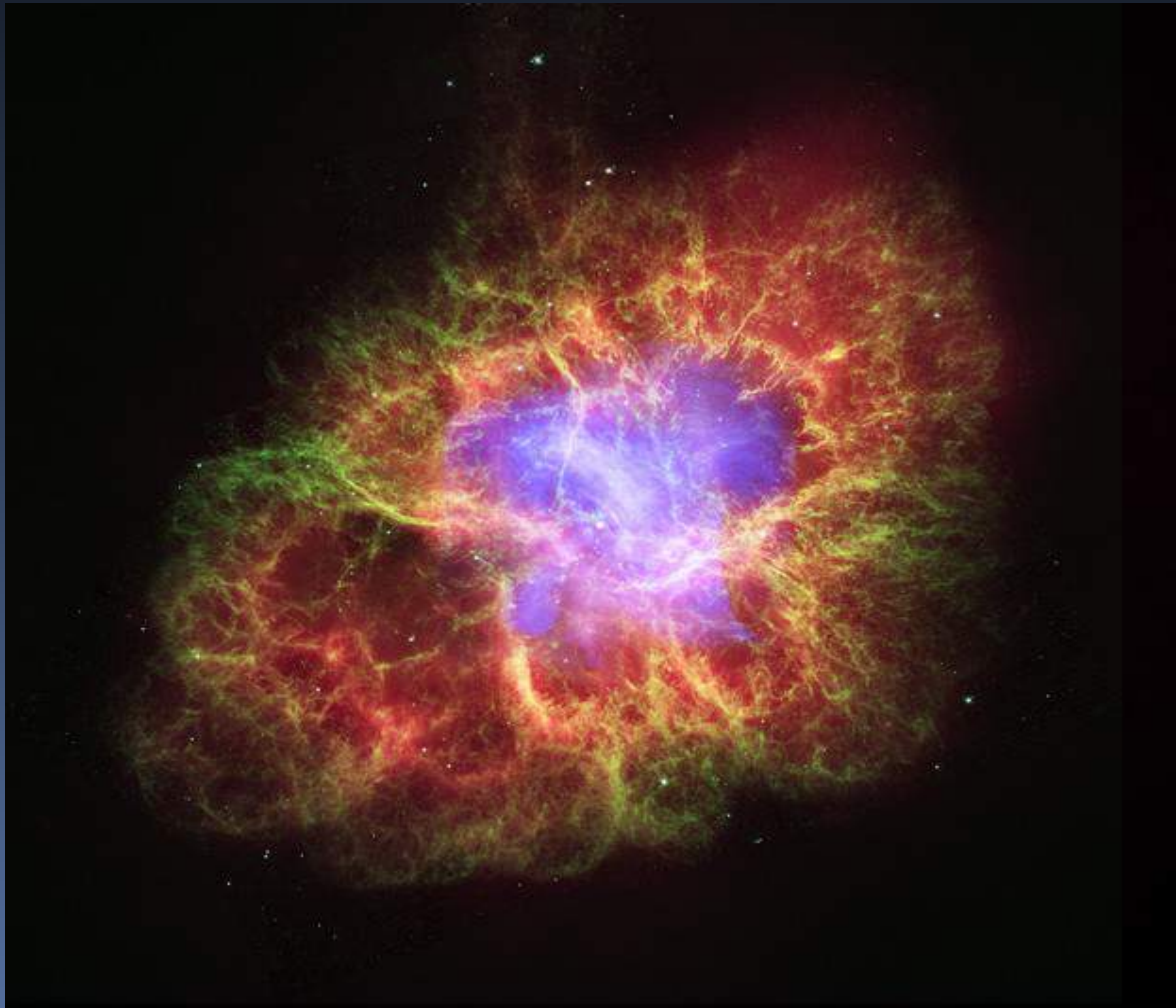
RCW 103

10000 ly
away

One
rotation in
5.7 hours

Too slow
for a NS
of this
age

Pulsars & pulsar wind Nebula (Crab nebula & pulsar)



Crab pulsar

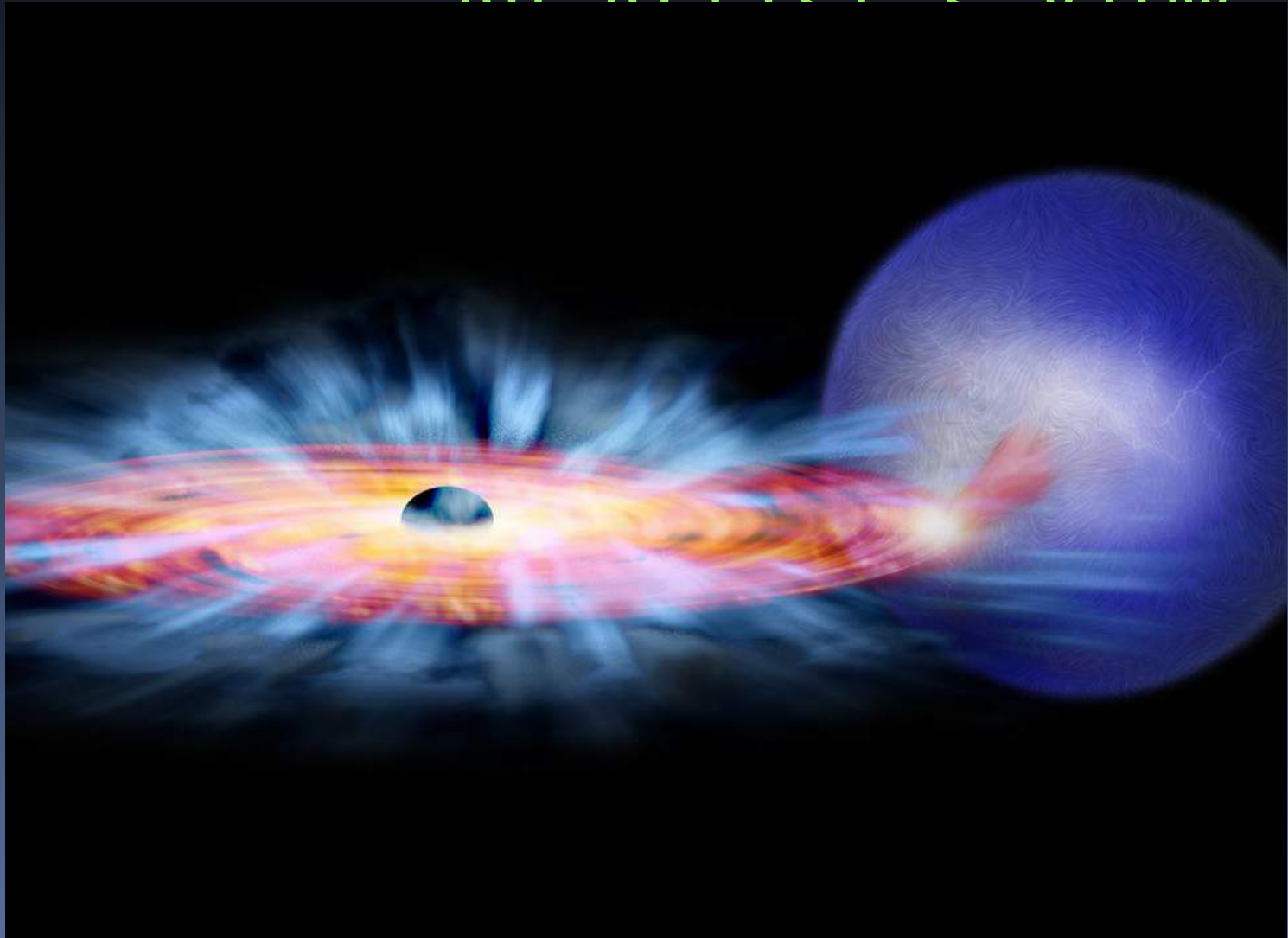
Chandra
HST
Spitzer

The Crab Pulsar & Nebula

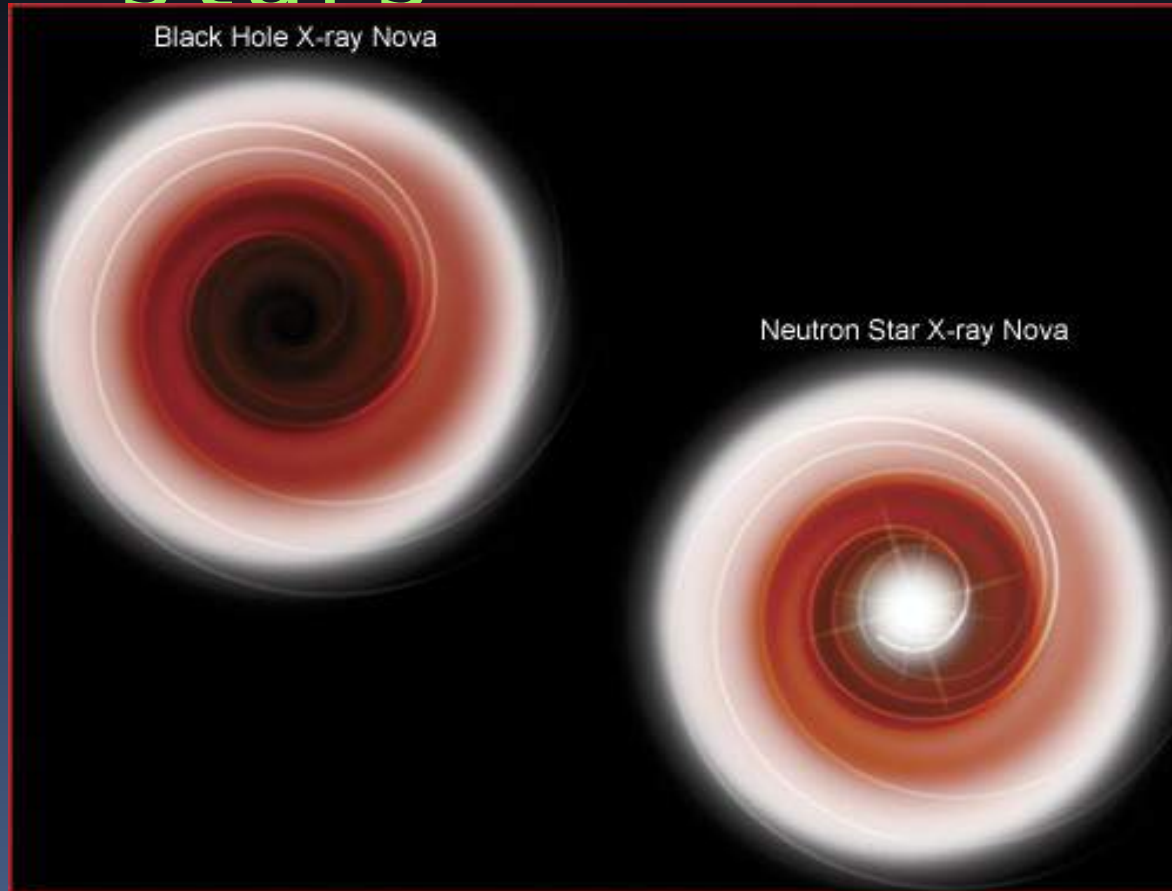


Neutron star in a binary

An Artist's View



Black Holes & Neutron stars



Nuclear reactions
Efficiency $\sim 0.7\%$

Accretion of matter
Onto a neutron star
Efficiency $\sim 10\%$

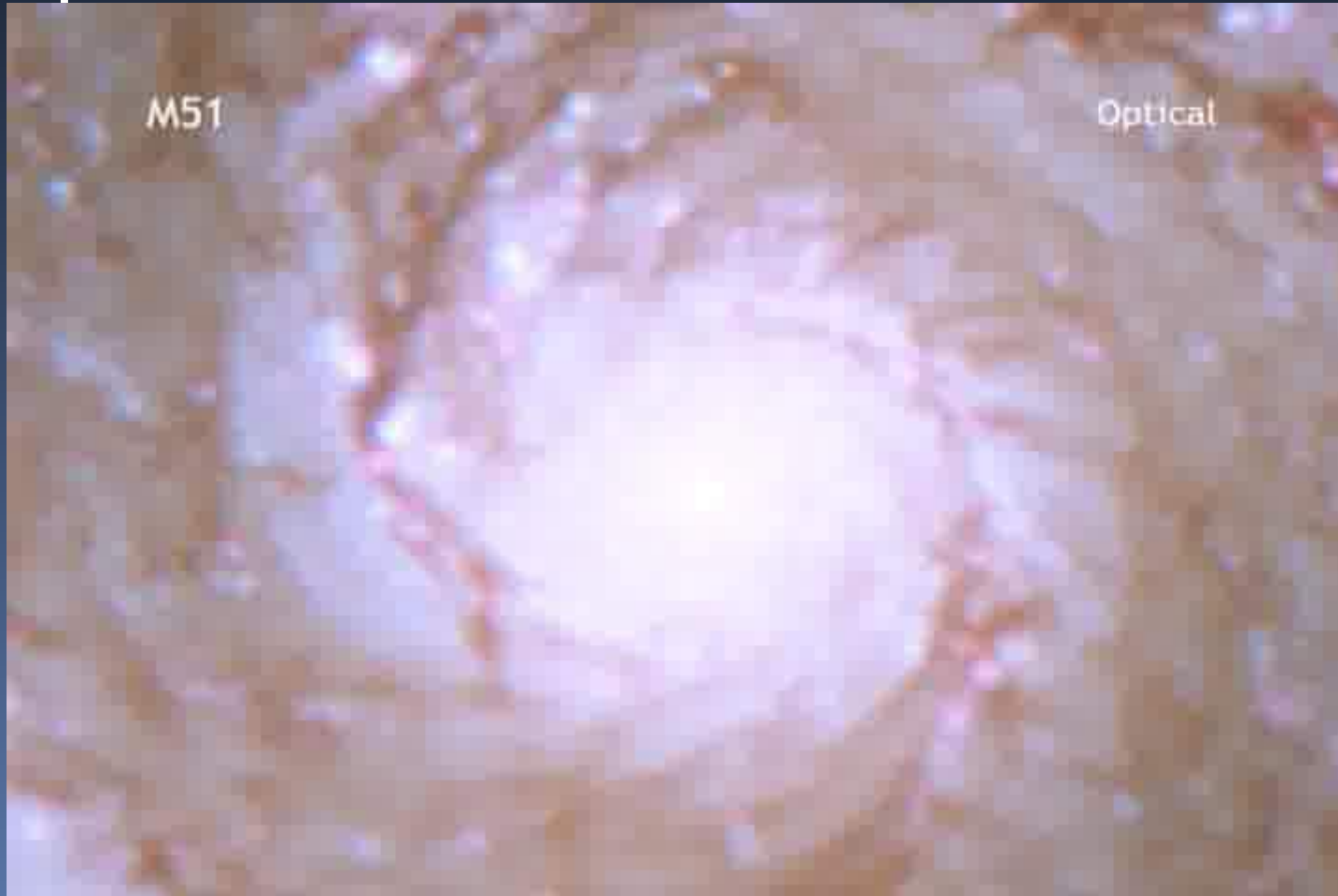
Sco X-1 is powered by accretion on to a neutron star.

Black Hole X-ray Binary



Galaxies

- Massive, gravitationally bound systems with multiple components
 - stars, gas, dust, black holes, NS,

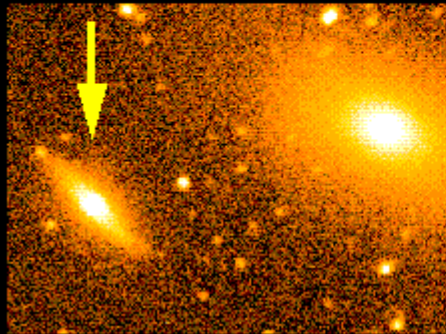


Active Galaxies

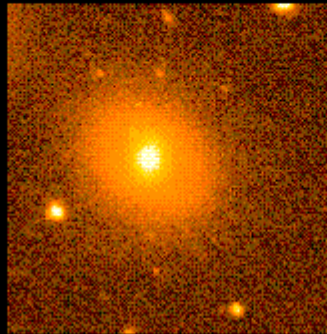
-Very bright nucleus

Seyfert Galaxies

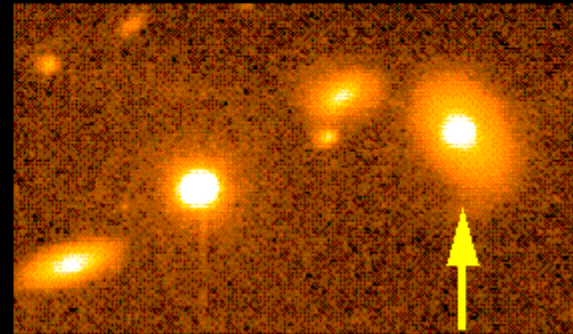
IC 4329A



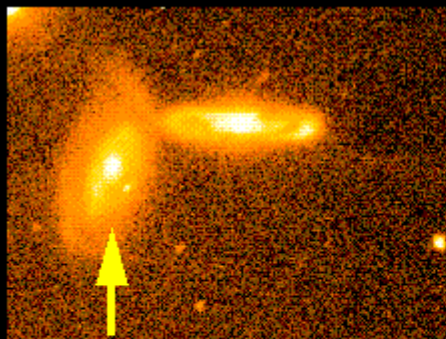
NGC 3516



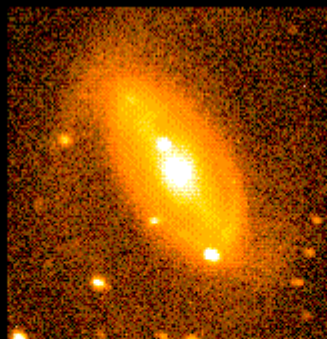
Markarian 279



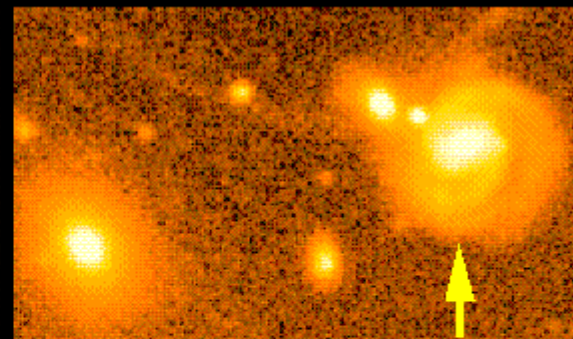
NGC 3786



NGC 5728



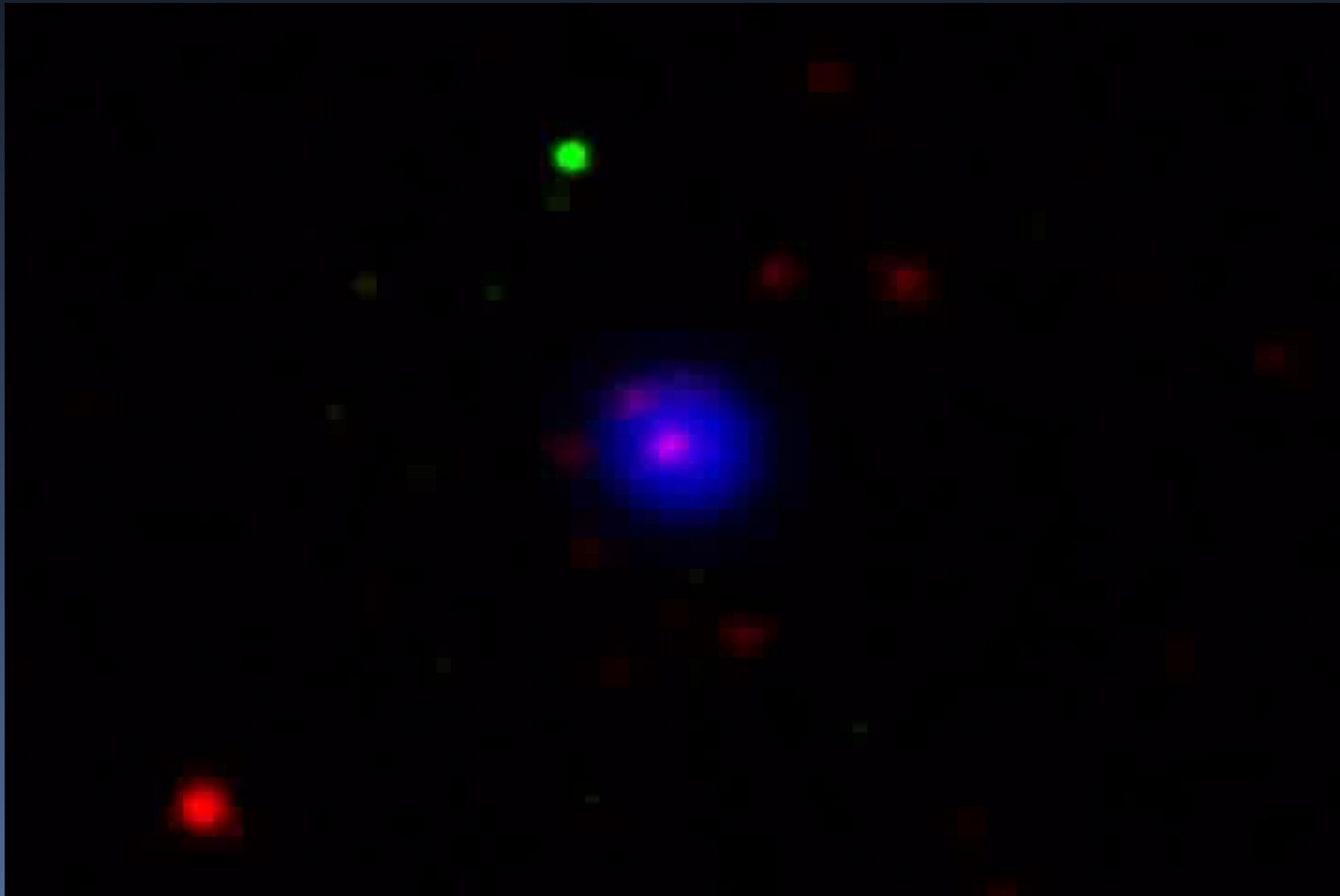
NGC 7674



Active Galactic Nuclei

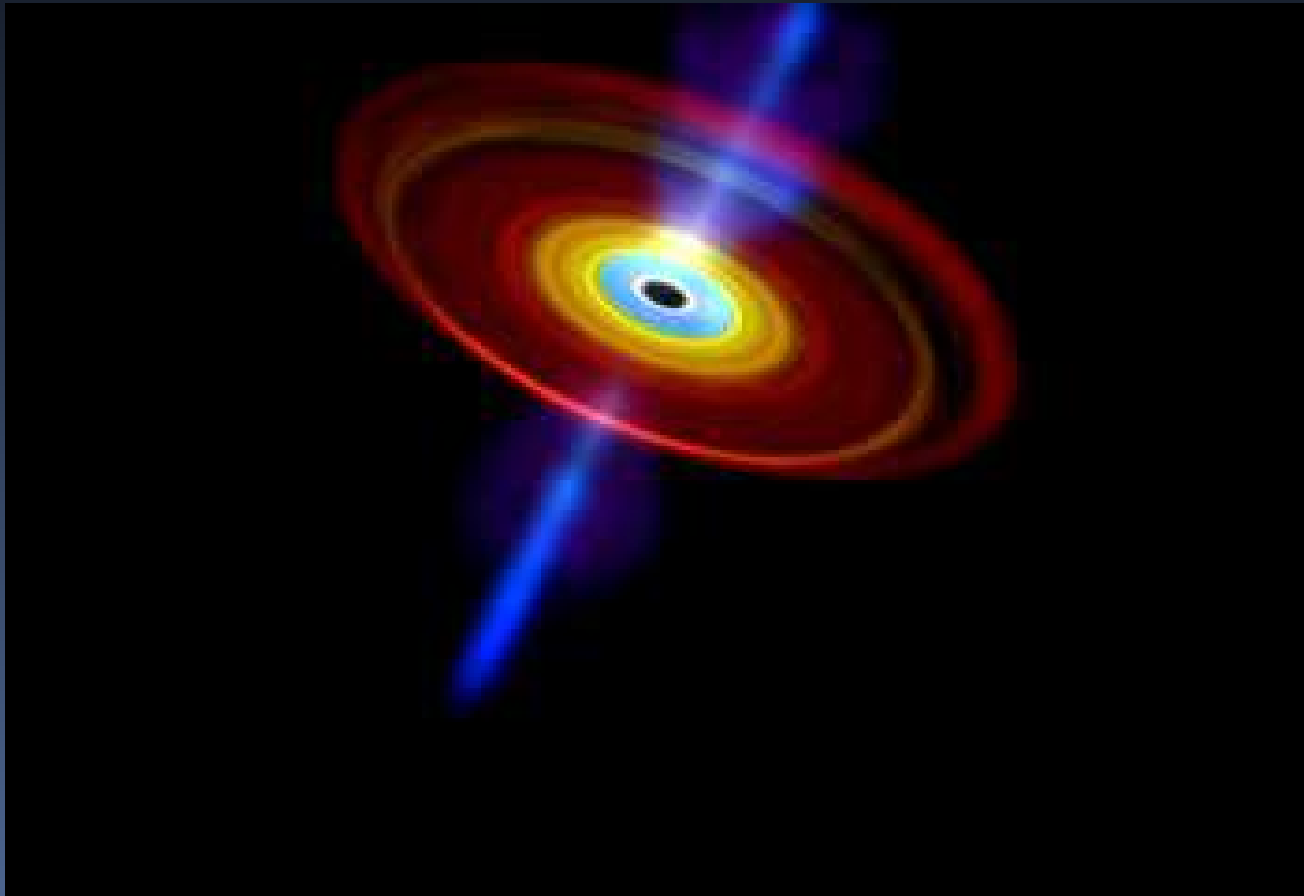


Active Galactic Nuclei



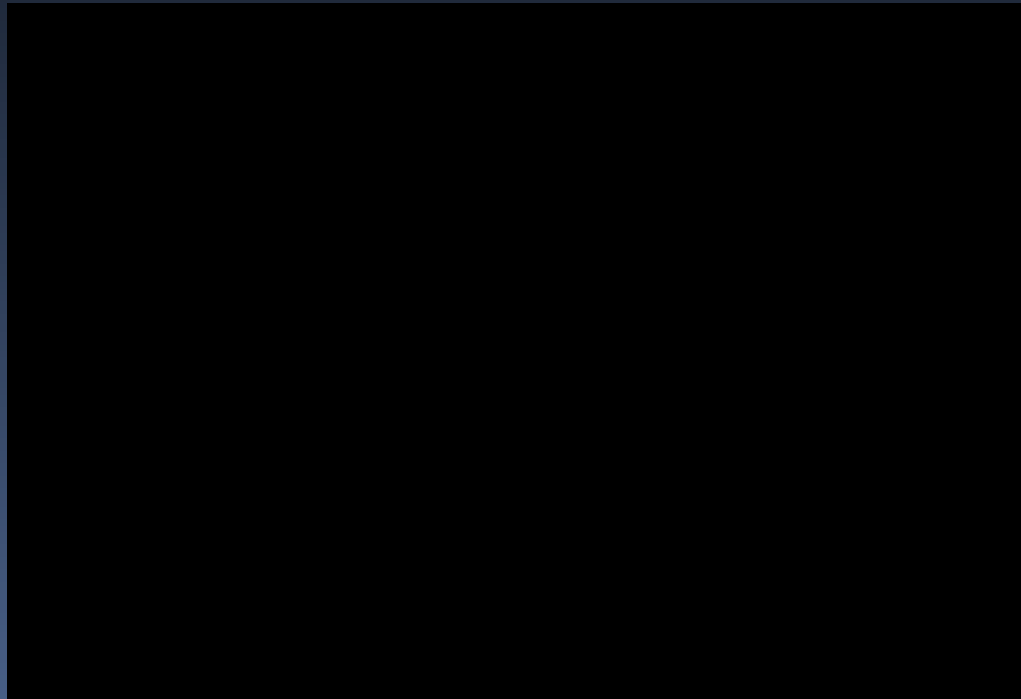
Active Galactic Nuclei

-Effects of BH on X-ray
emission



Active Galactic Nuclei

- Spinning and Non-Spinning BHs



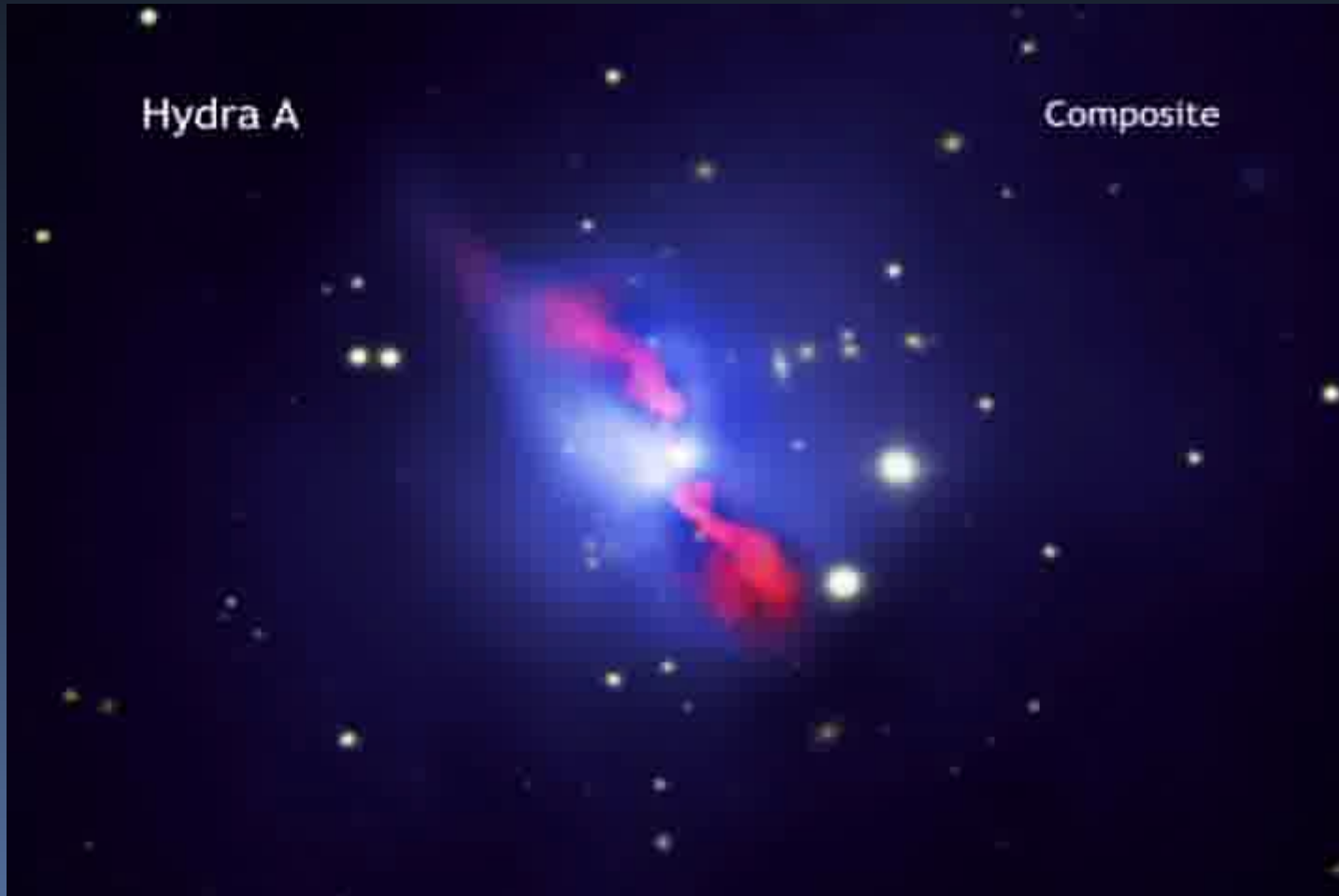
Clusters of galaxies

- Largest bound



Clusters of galaxies

- Radio jets/lobes in the X-ray cavity



The distant universe

Chandra Deep Field



Rapid Progress ...

- In the last 50 years, X-ray Astronomy has progressed so much that optical astronomy took four hundred years.
- Detailed X-ray nature of nearby sources.
- X-ray emission from the farthest of the universe.
- Probing the most energetic phenomena in the universe.

Indian X-ray Astronomy

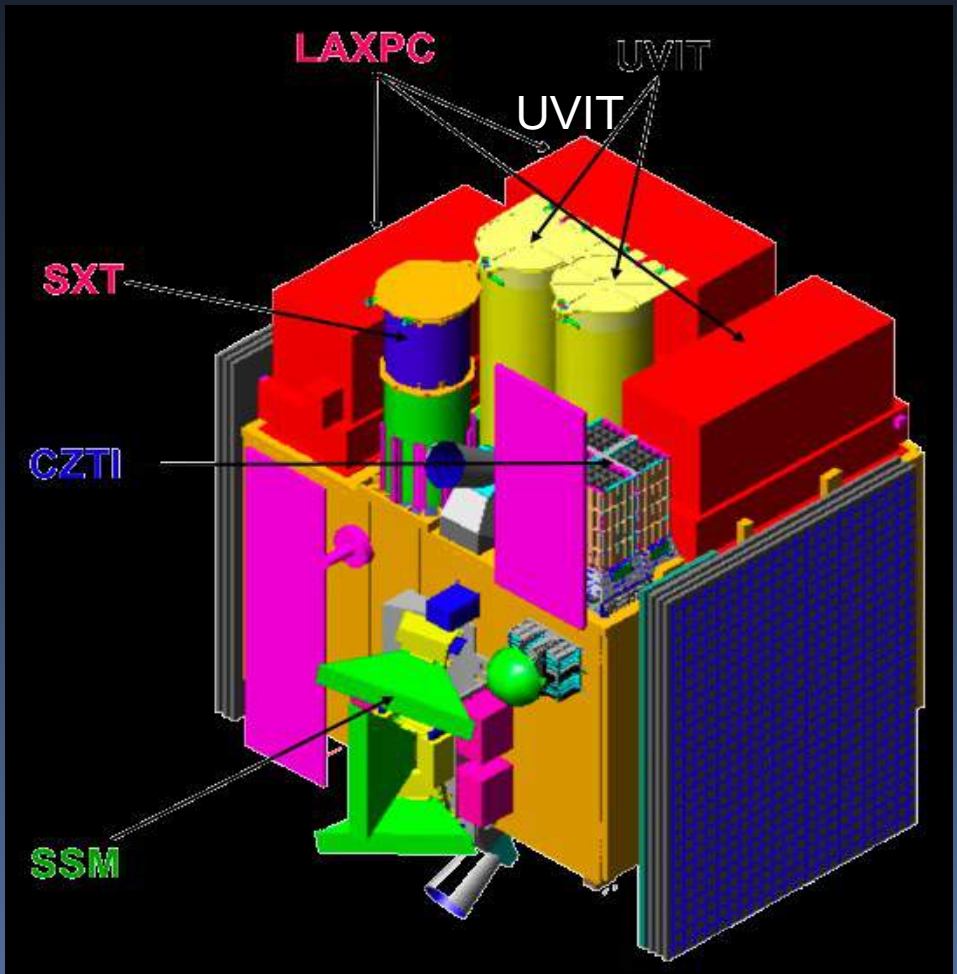
ASTROSAT - Indian X-ray/UV astronomy Satellite

To be launched in 2013

4 X-ray & one UV/Optical instrument

Simultaneous multi-wavelengths observations

All sky X-ray monitor for Transients



Thank You