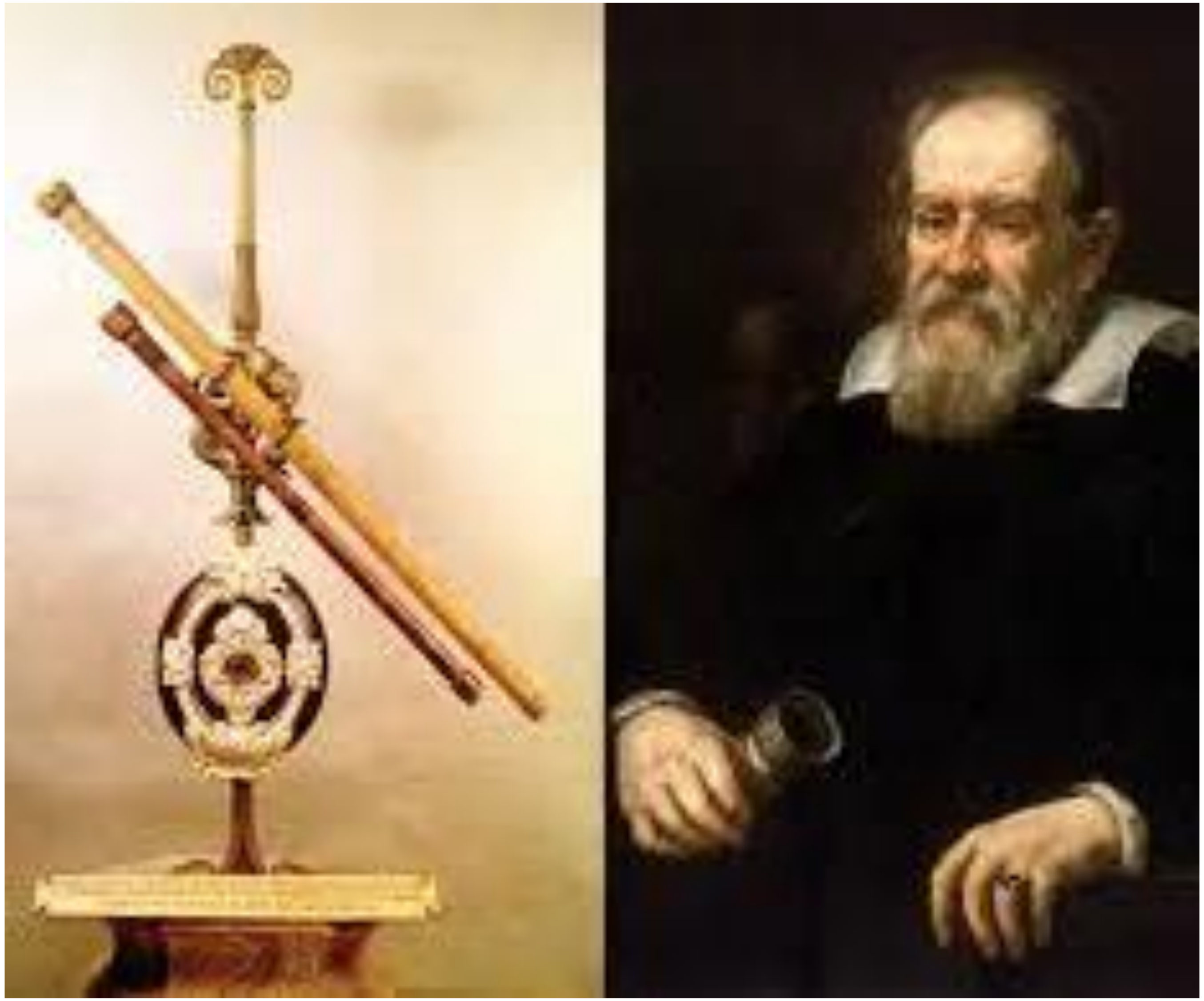
X-ray Astronomy

FROM V-ROCKETS TO ATHENA MISSION

Thanassis Akylas

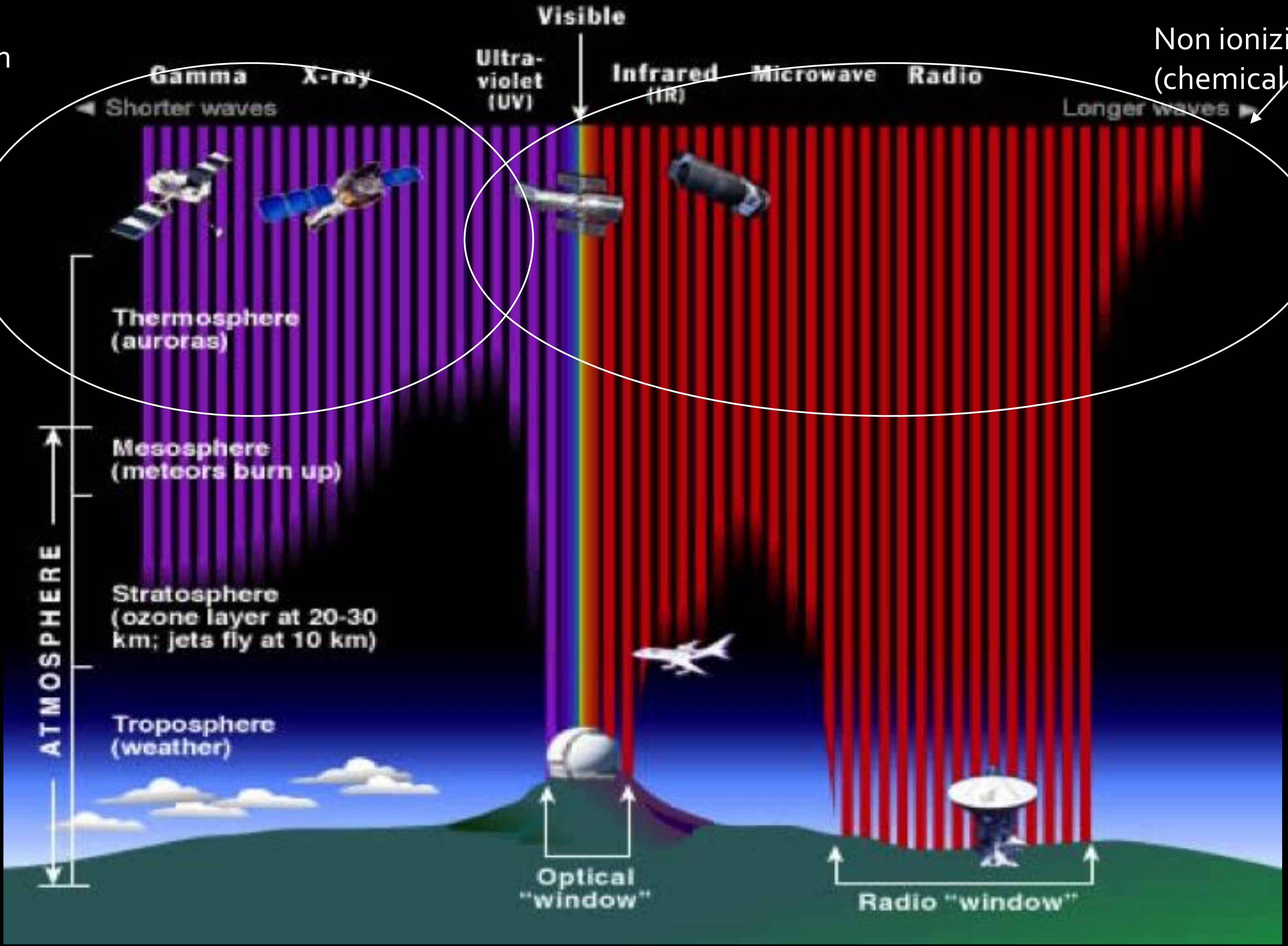
Telescopes & Light

- Gallileo turned his telescope into the sky 400 years ago
- He enhanced his natural vision or the so called natural light using a tool
- This light is just a mere slice of the entire radiation spectrum across the universe
- Today astronomers have built telescope and detectors that can see far beyond the radiation we can detect with the human eye
- There are space based and ground bases instruments depending on the type of the radiation

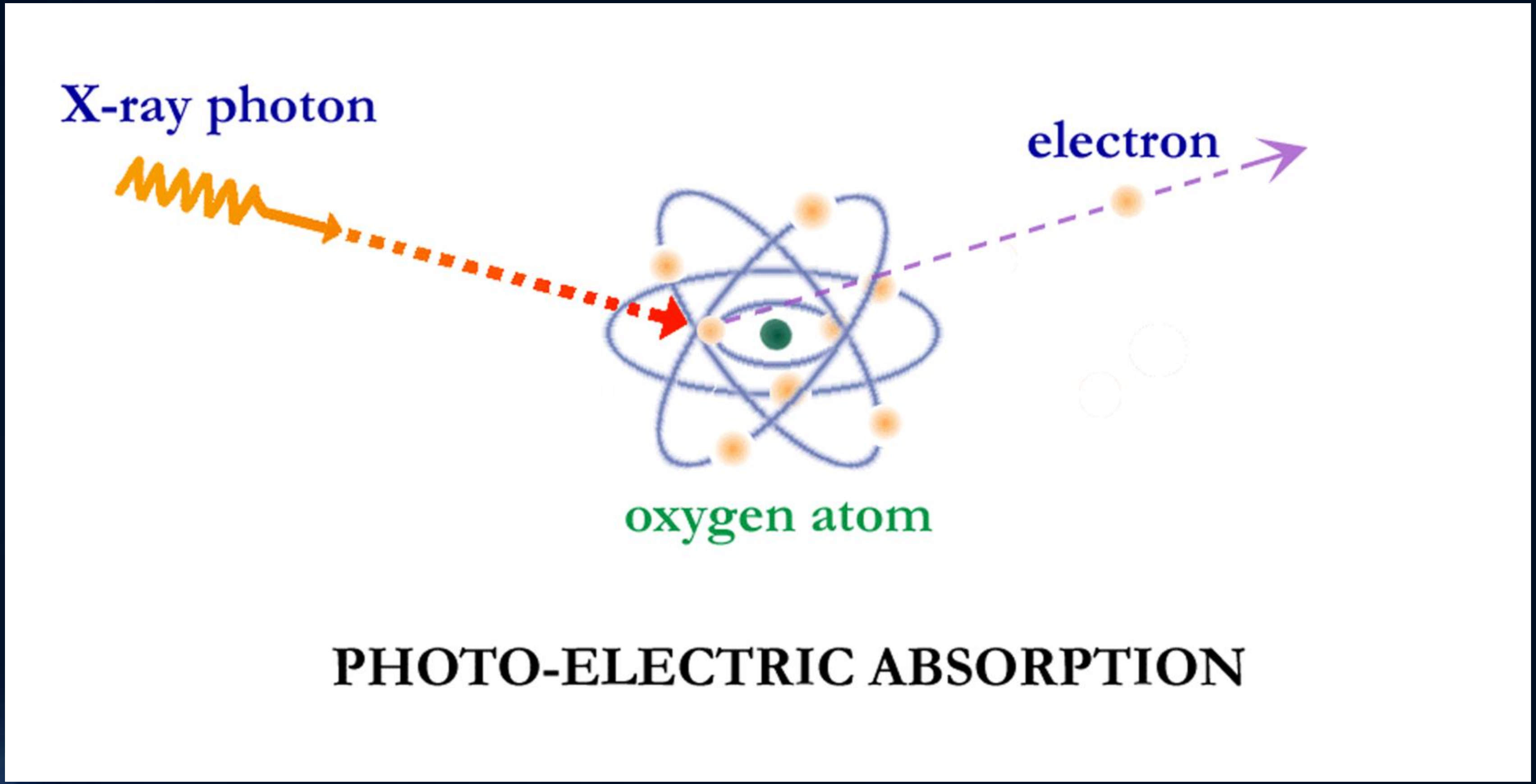


Ionizing radiation

Non ionizing radiation (chemical reactions-heat)



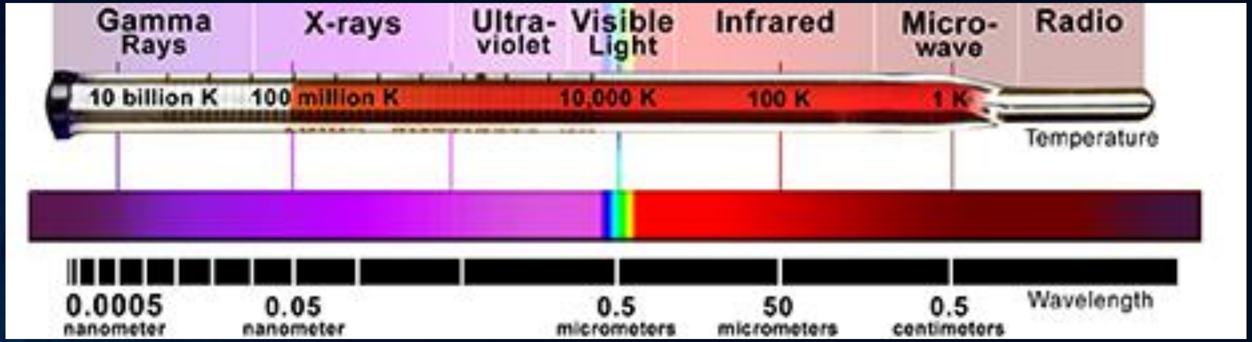
What happens when an X-ray energy photon is absorbed in the atmosphere?

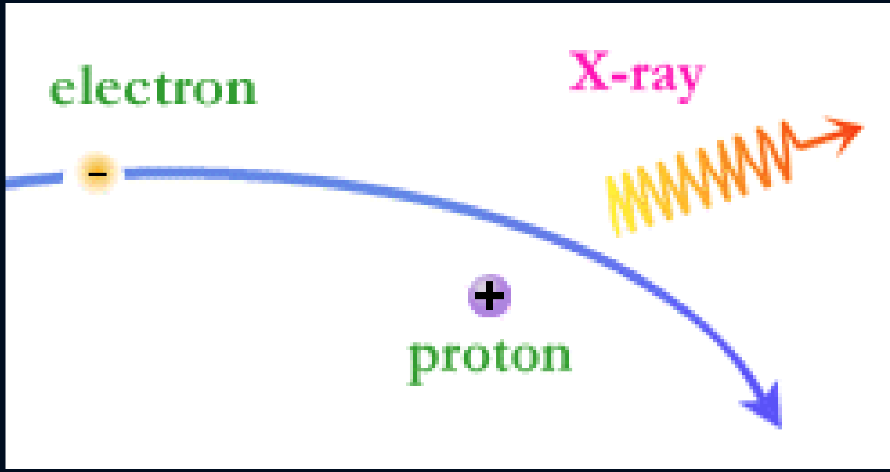


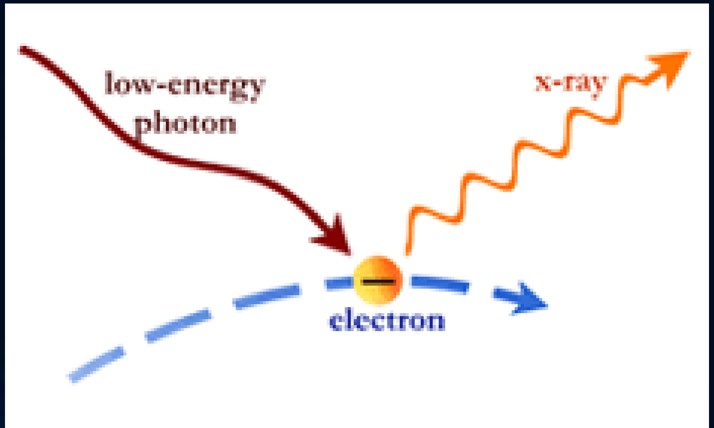
X-Ray Absorption

- Absorption by the Earth's atmosphere restricts ground-based observations to radio, near infrared, and visible wavelengths. X-rays are absorbed high above the Earth
- Even though the atoms in the atmosphere are widely spaced, the total thickness of the atmosphere is large and the total number of atoms is enormous. Show that an X-ray photon passing through the atmosphere will encounter as many atoms as it would in passing through a 5 meter thick wall of concrete!
- The only alternative is to go outside the earth atmosphere

Is out there an X-ray universe?







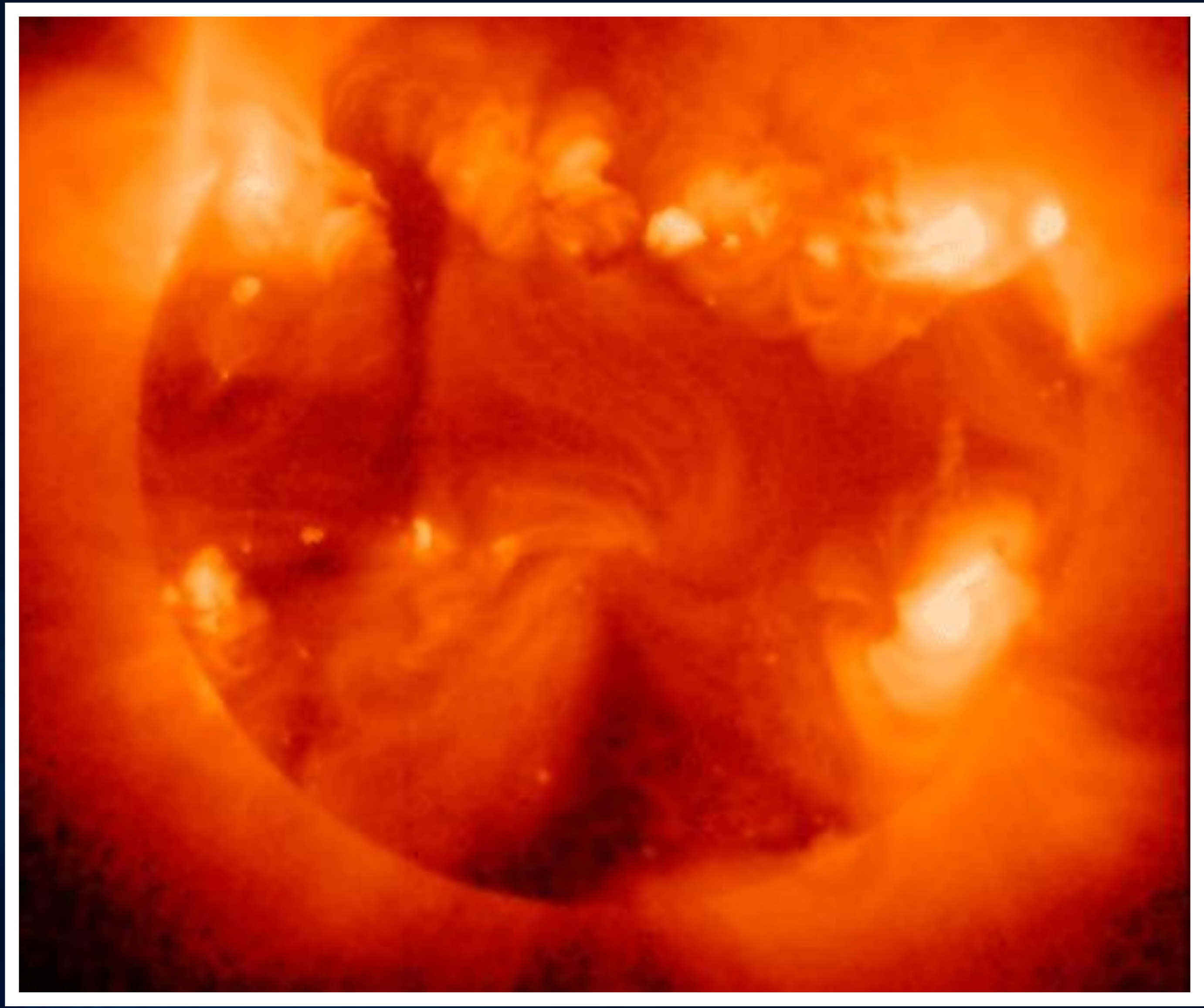
Is out there an X-ray universe?

- The photons collected in space by X-ray telescopes reveal the hot spots in the universe
- Regions where particles have been energized or raised to high temperatures by gigantic explosions or intense gravitational, electric and magnetic fields
- Where do such conditions exist? In an astonishing variety of places, ranging from the vast spaces between galaxies to the bizarre, collapsed worlds of neutron stars and black holes.

The Sun

Solar Corana:2 million degrees

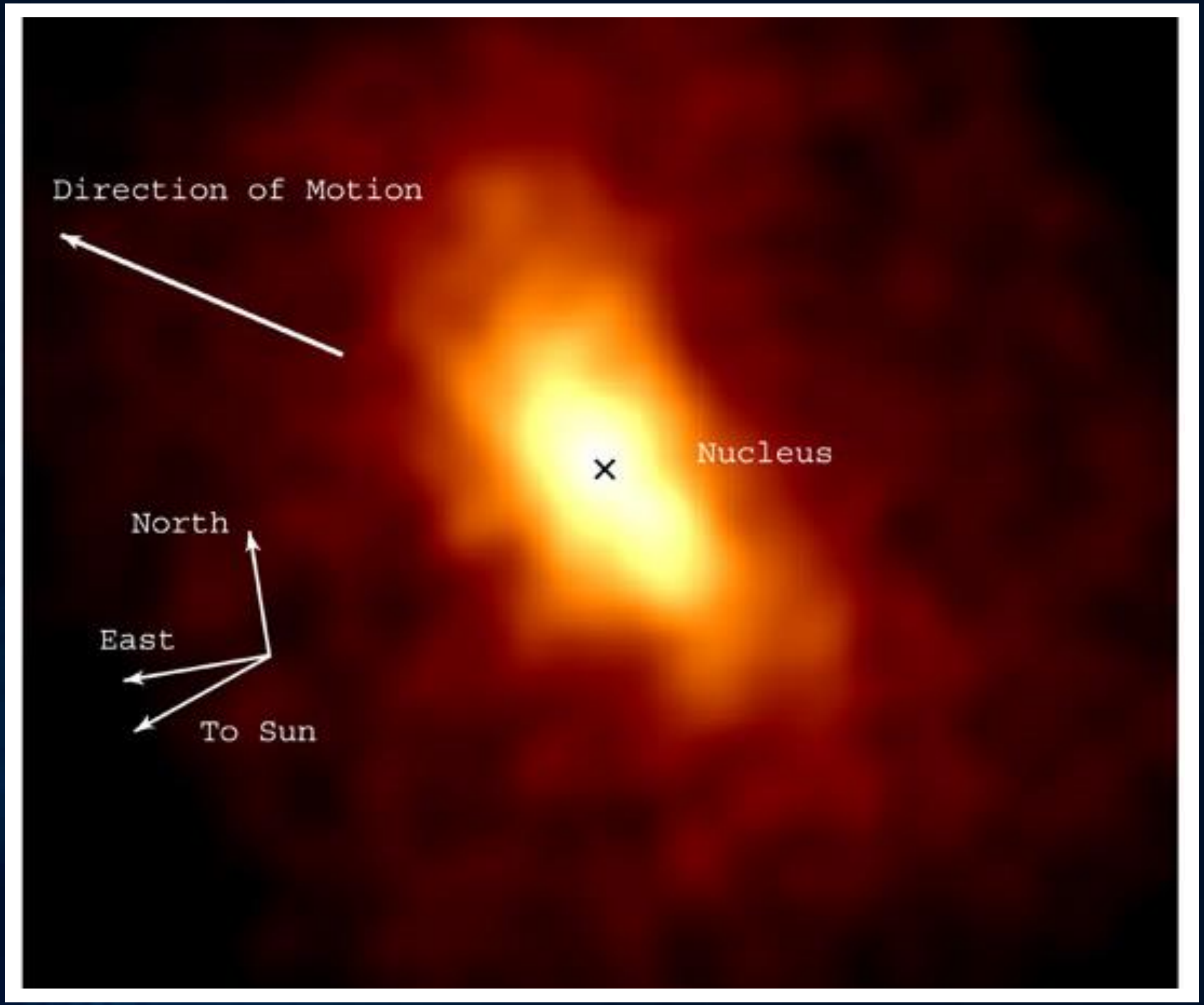
What X-rays are produced?



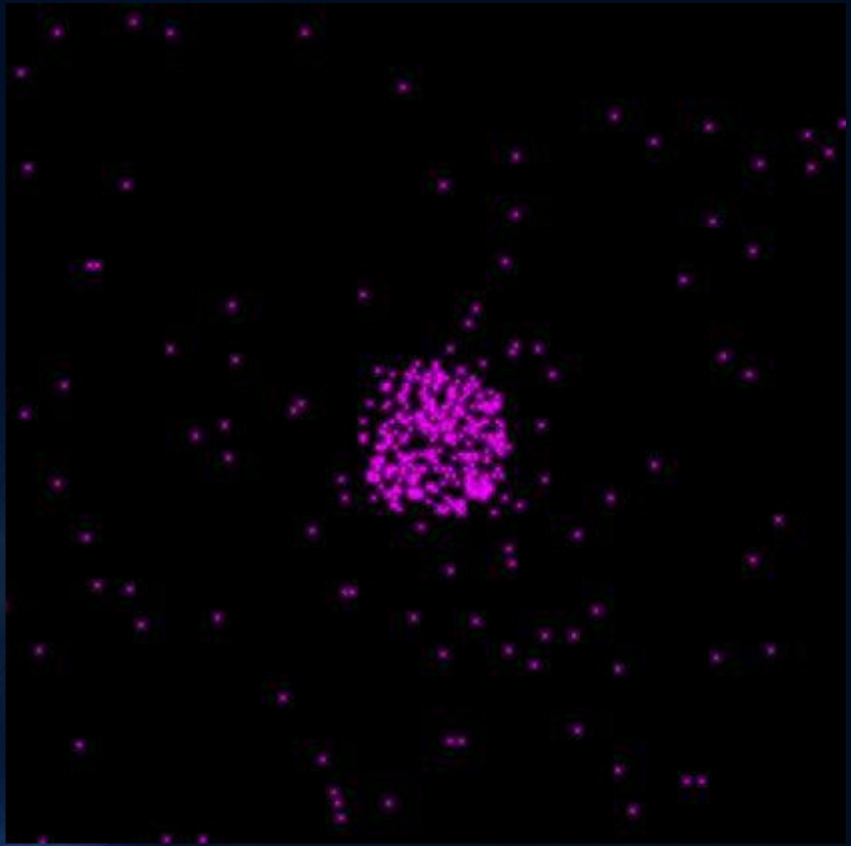
What about a comet?

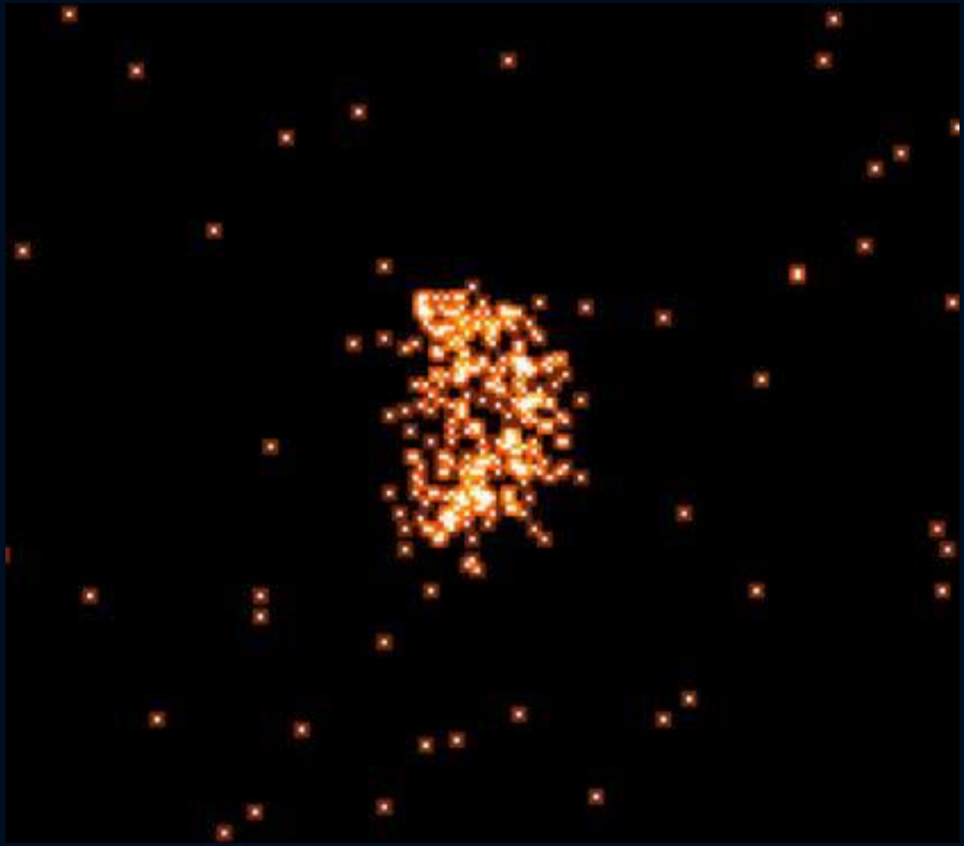
Comet C/1999

X-rays from oxygen and nitrogen ions. The X-rays are produced by collisions of ions racing away from sun with gas in the comet (charge exchange)

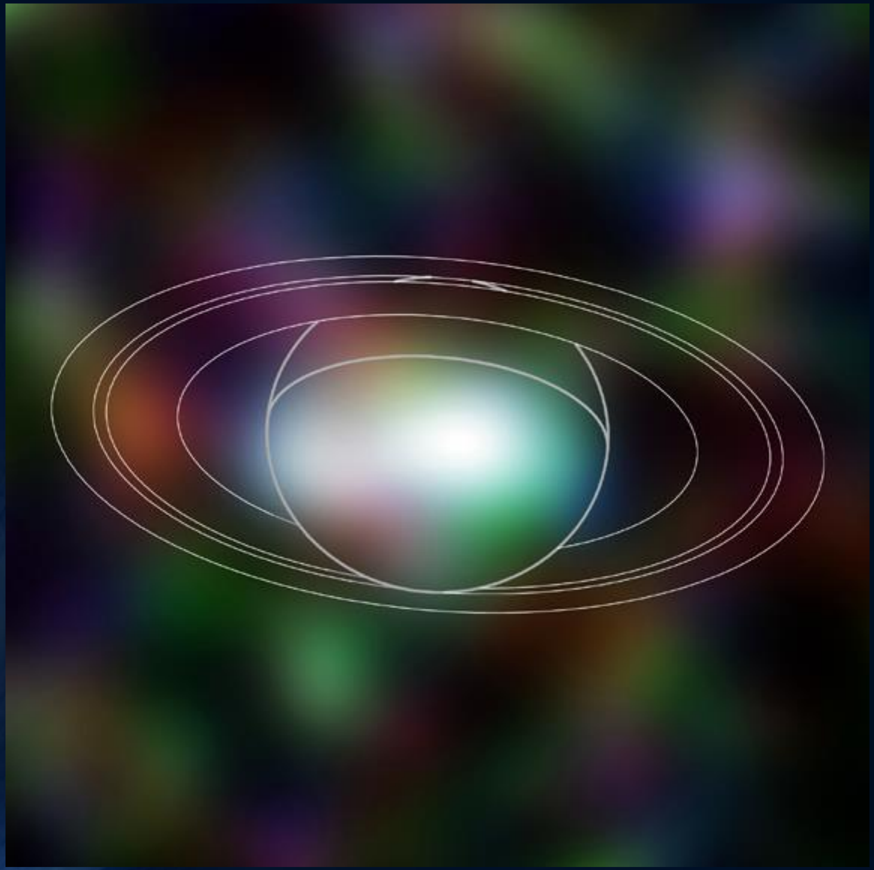


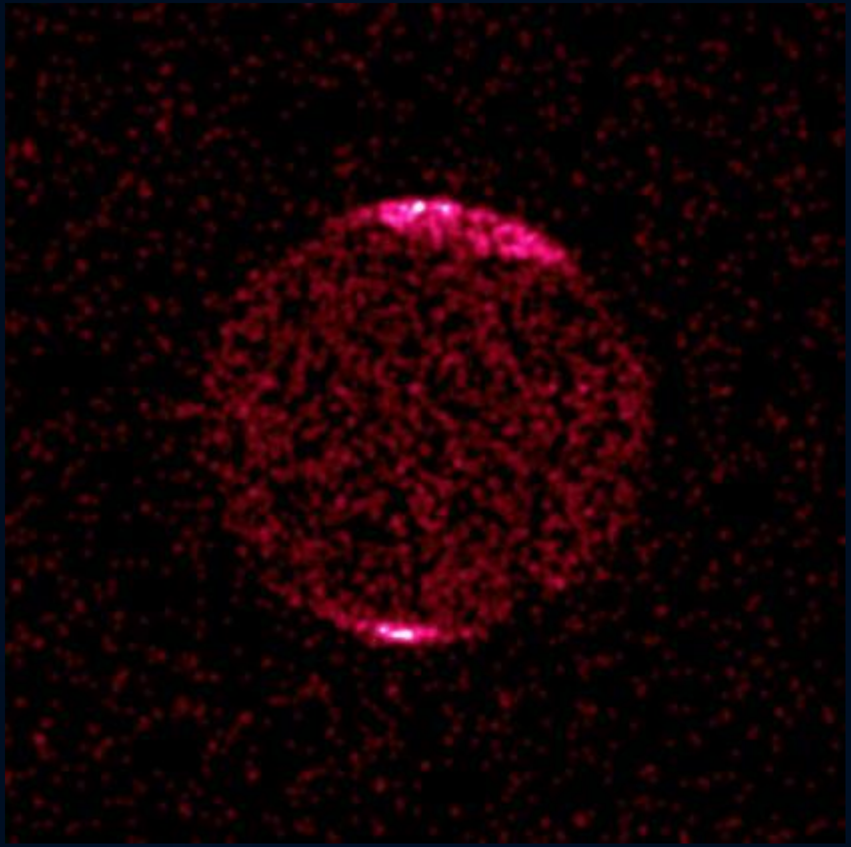
Planets?





Planets?

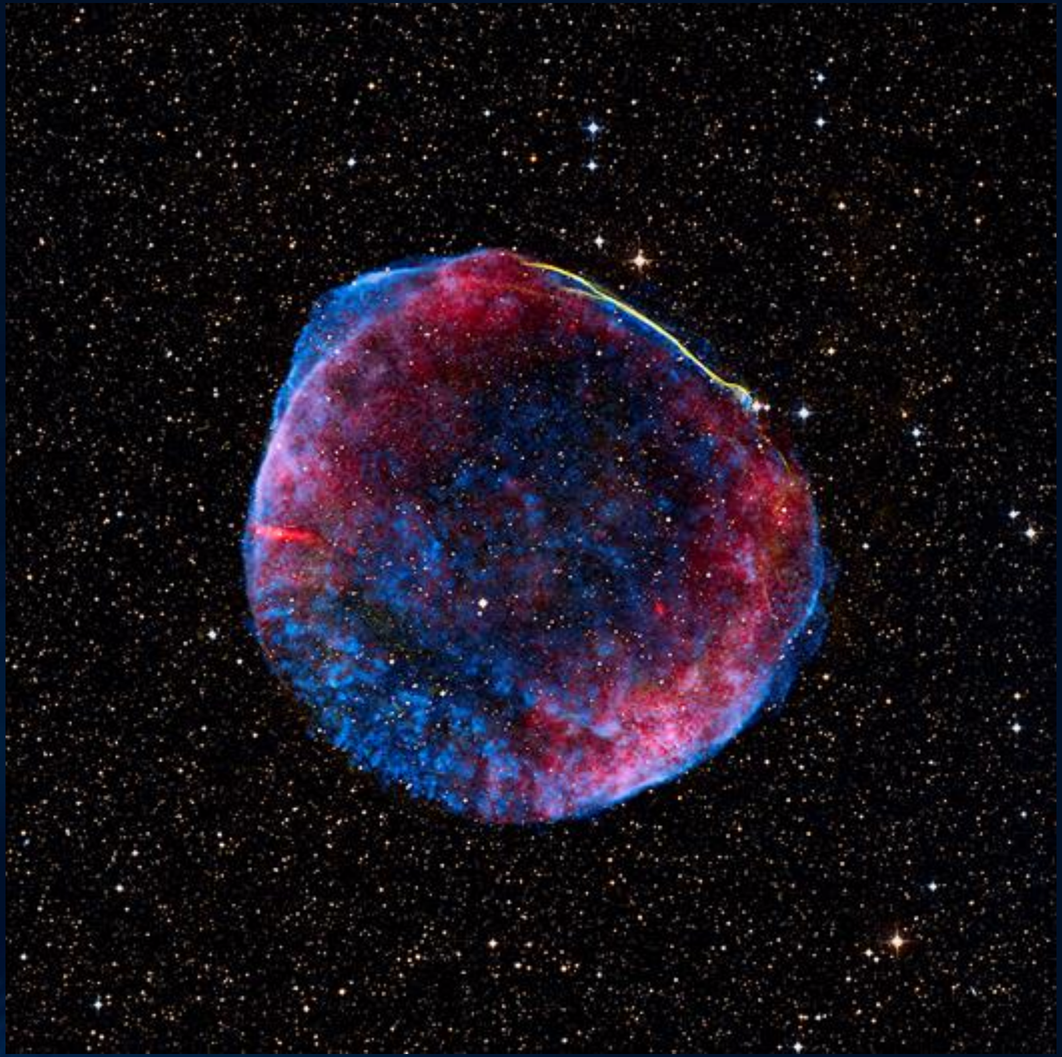




SN 1006: The Hot Remains of a 1000 Year-Old Supernova

Blue: X-rays

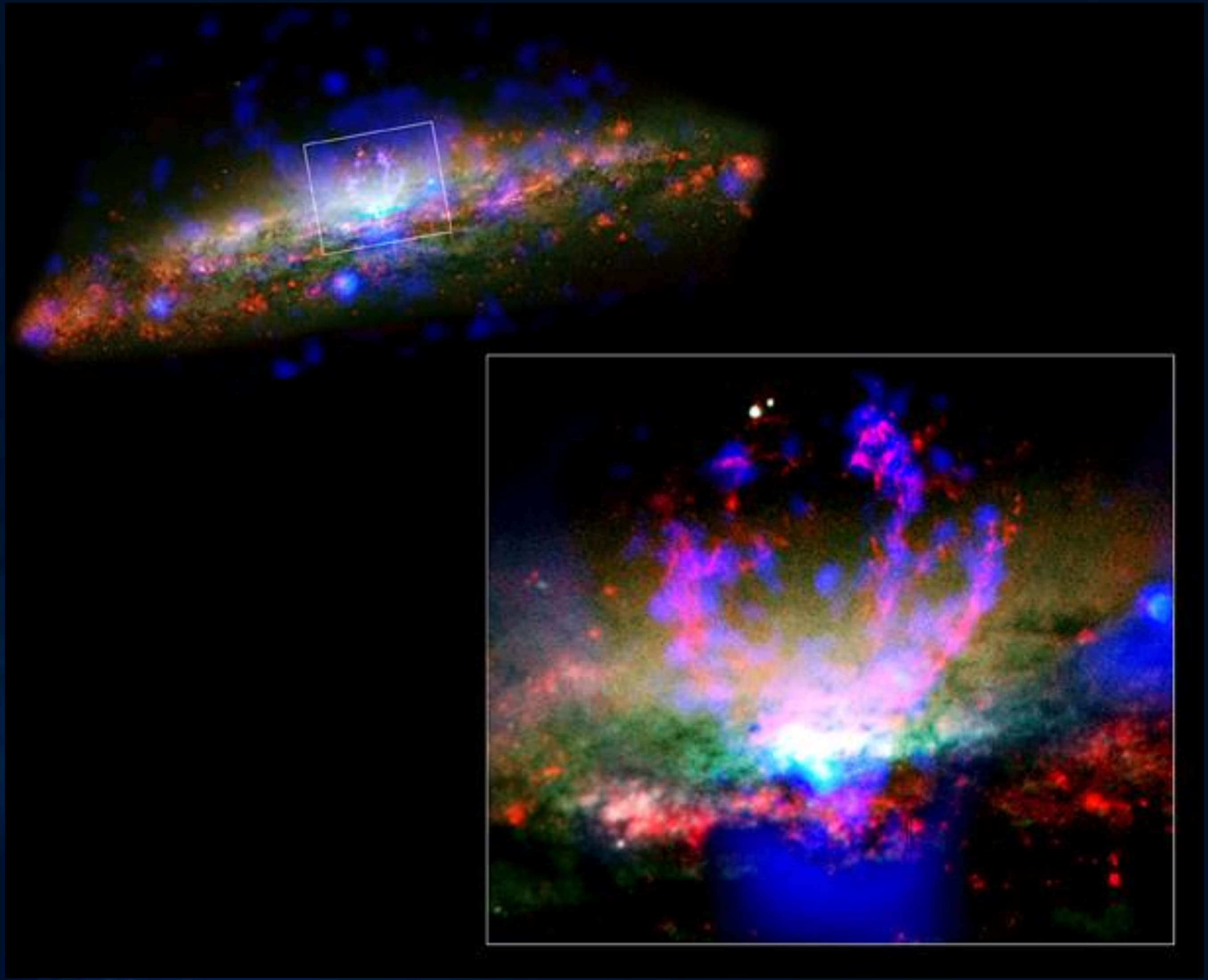
Red: Radio



Normal Galaxies

Chandra's X-ray image (blue): Hot (about ten million degrees Celsius) originates from the center of the galaxy

Hubble's optical image (red and green)



Quasars and Active Galaxies

Centaurus A: Jet Power and Black Hole Assortment

They are the most powerful type of X-ray source yet discovered. Some quasars are so bright that they can be seen at a distance of 12 billion light years.

X-rays from quasars and AGNs are produced when in-falling matter is heated to temperatures of millions of degrees as it swirls toward the supermassive black hole

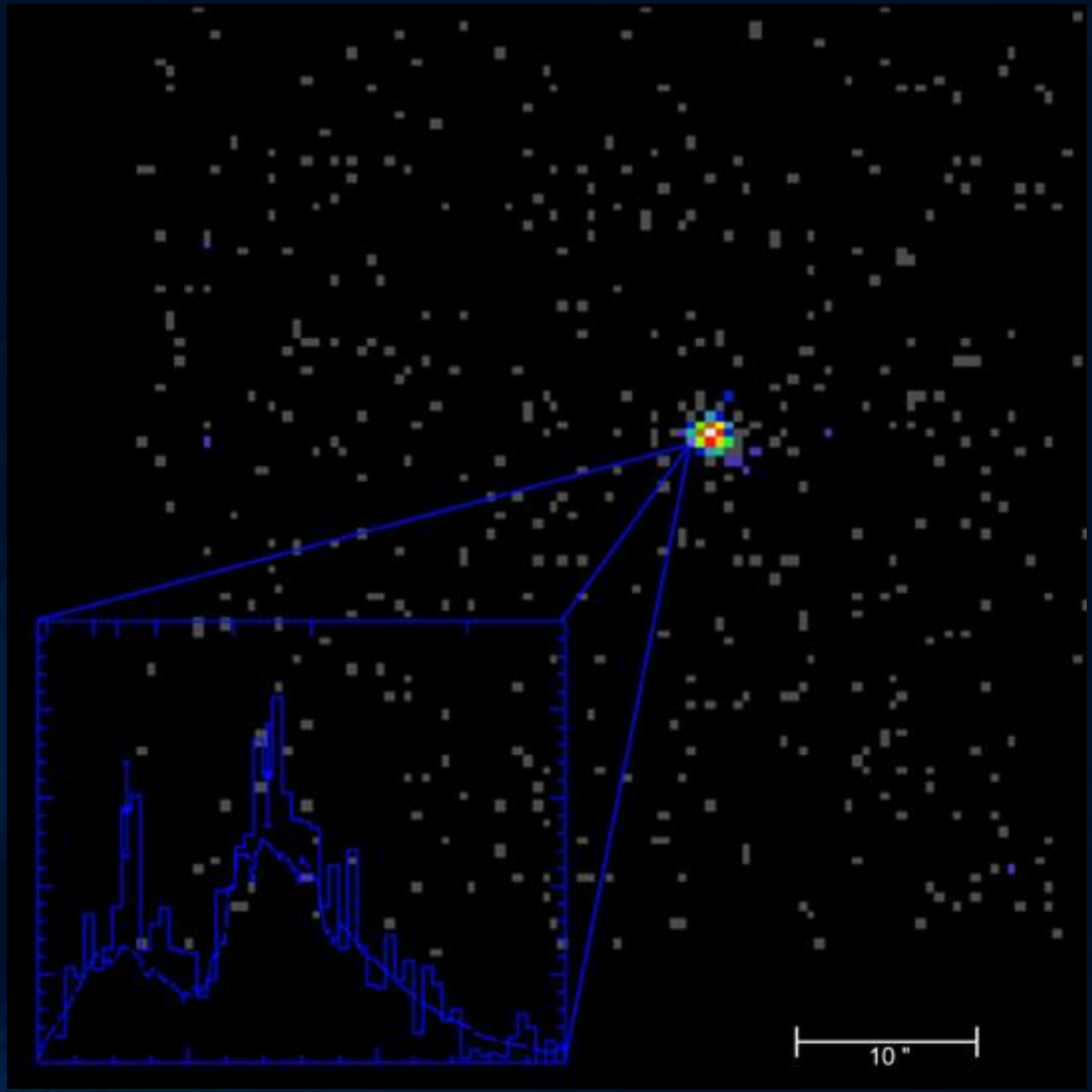
Energy: Red (0.5-1.0); Green (1.0-1.5); Blue (1.5-2.0 keV)

GRB's

A GRB produce enormous amounts of energy. At their peak, which lasts only a few seconds, they have a power output that is comparable to that of all the galaxies in the Universe.

Theories include the merging of neutron stars, or black holes, or the collapse of an extremely massive star to produce what has been called a hypernova.

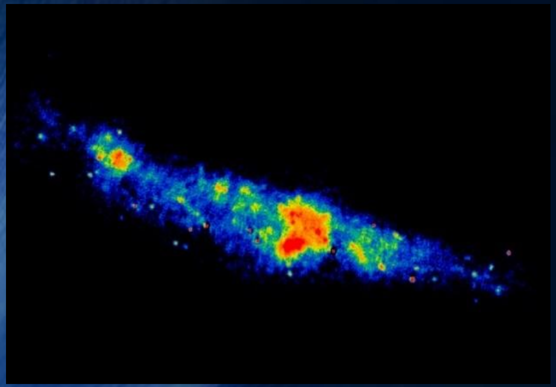
By studying the X-ray afterglow, we can measure the amount of gas in the vicinity of the burst, and tell which elements are present.



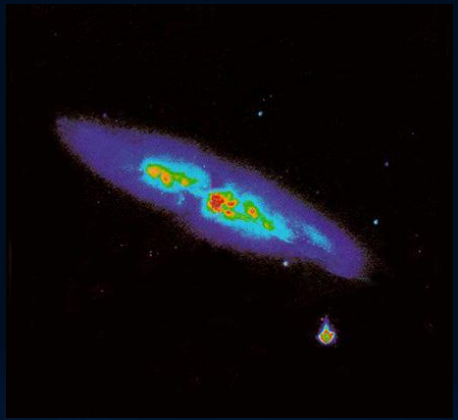
Star forming Galaxies

- A starburst galaxy is a galaxy experiencing a period of intense star forming activity.
- The bright spots in the center are supernova remnants and X-ray binaries.
- The diffuse X-ray light in the image extends over several thousand light years, and is caused by multimillion degree gas flowing out of M82

Radio

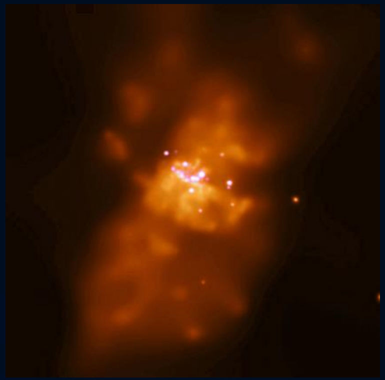


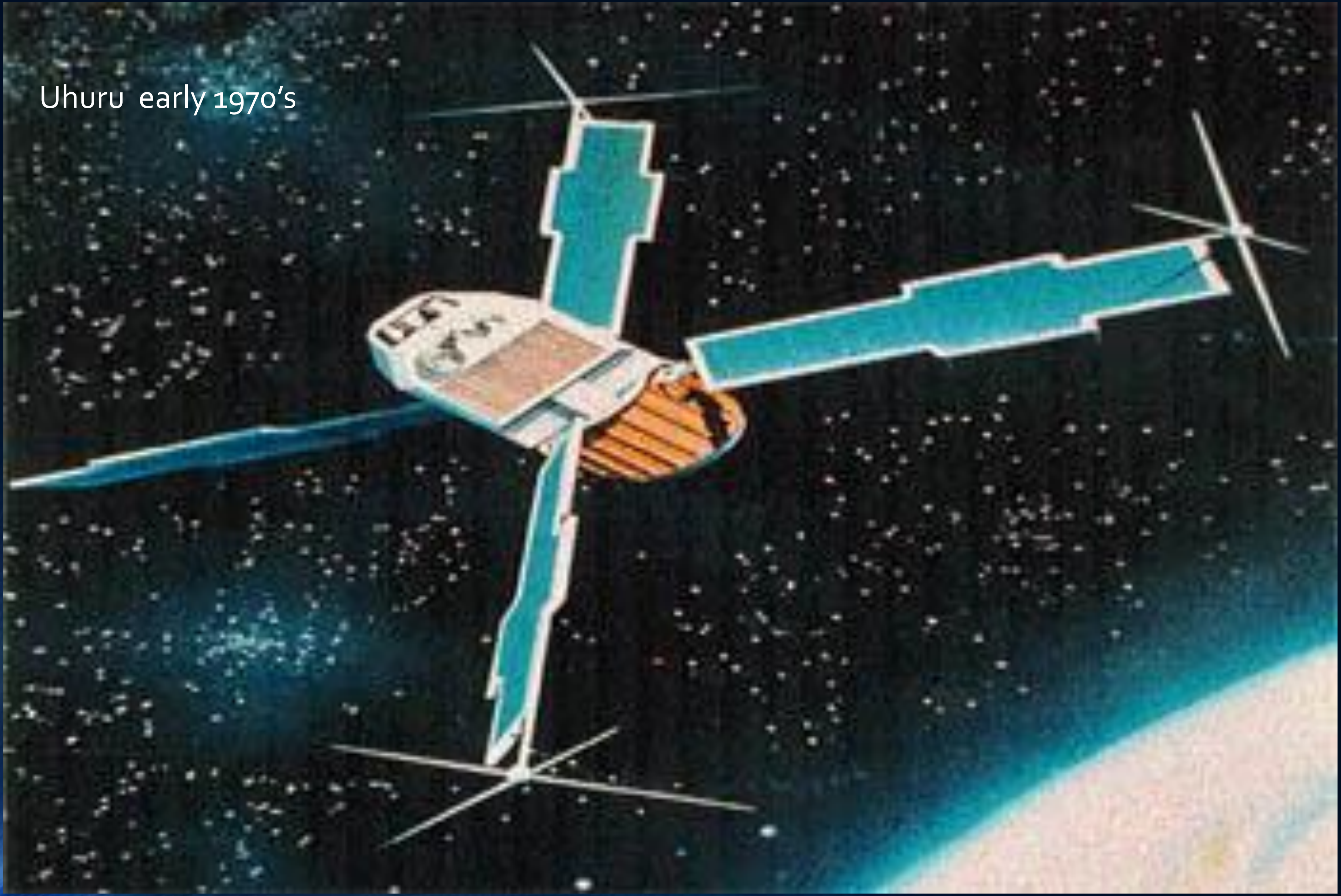
Infrared



Optical

X-rays





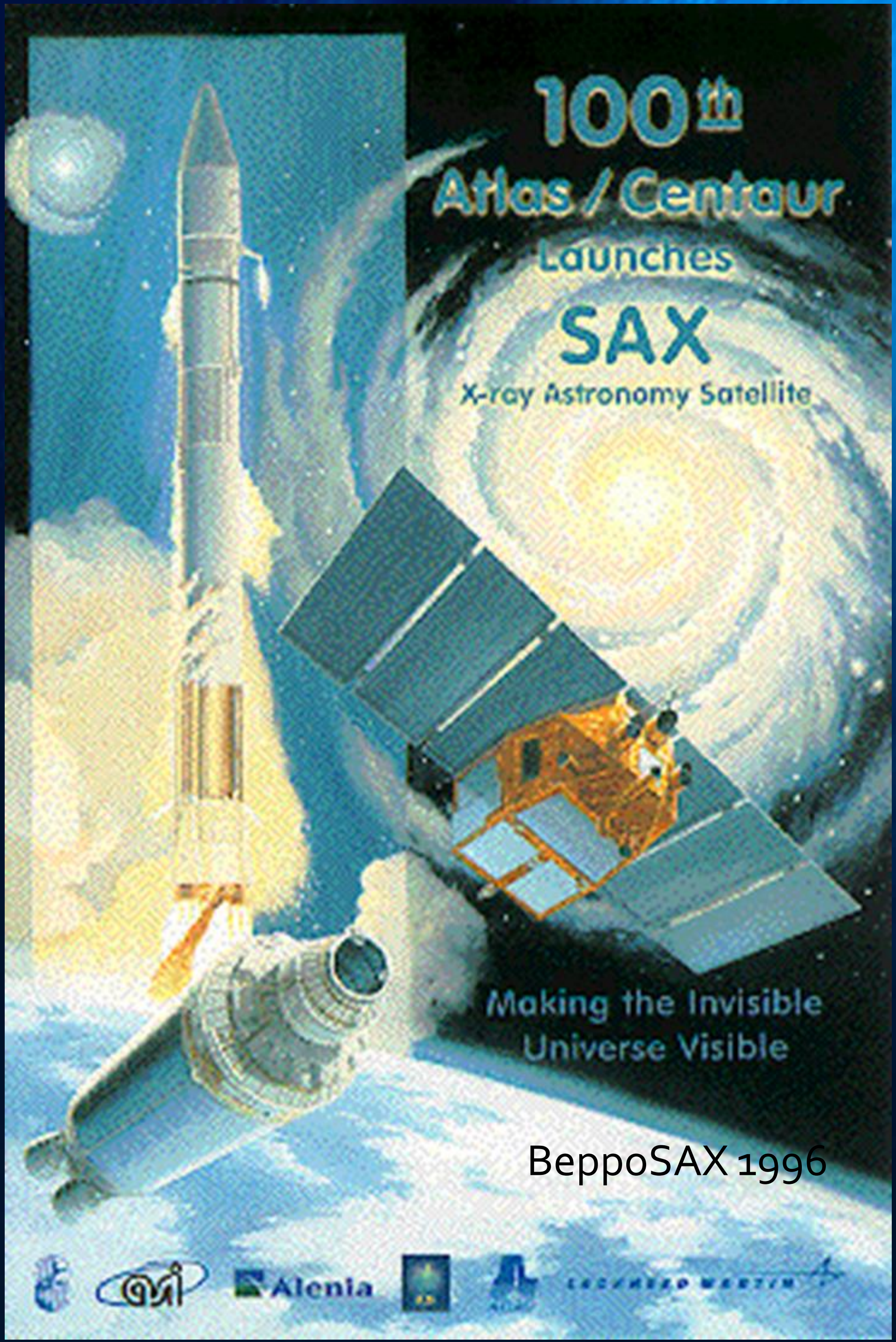
Uhuru early 1970’s

Uhuru early 1980's

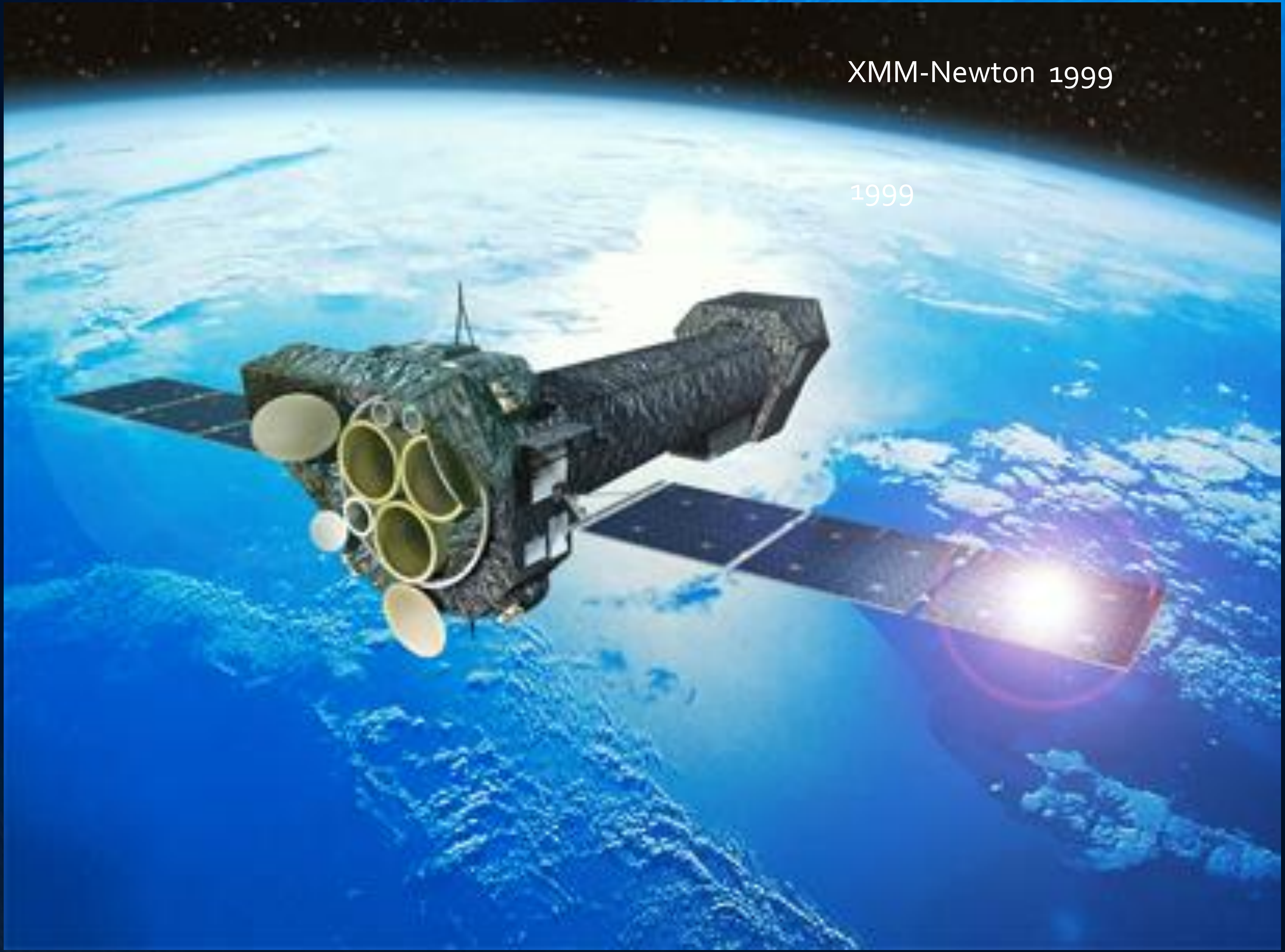

ROSAT 1990

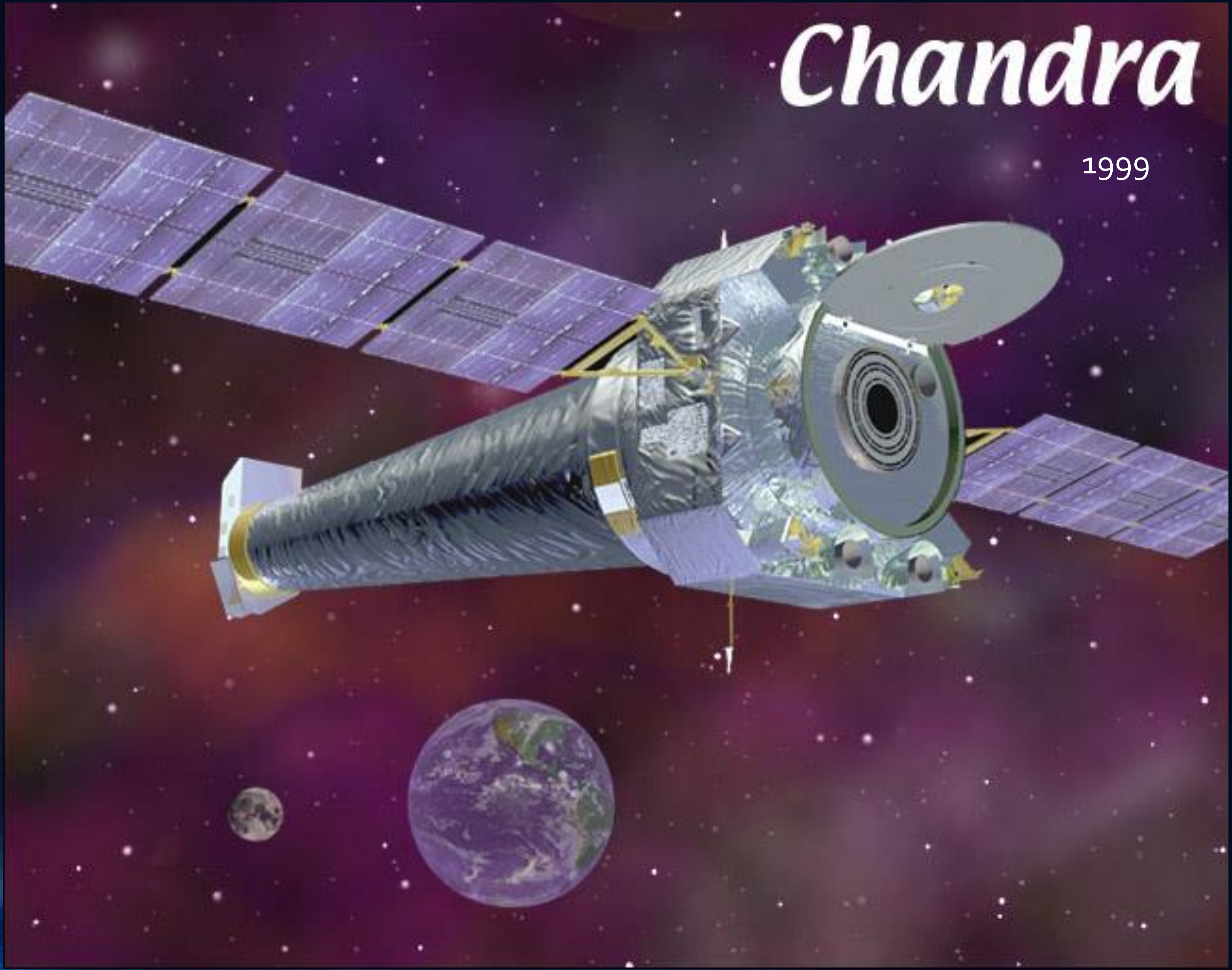

ASCA 1993


RXTE 1995

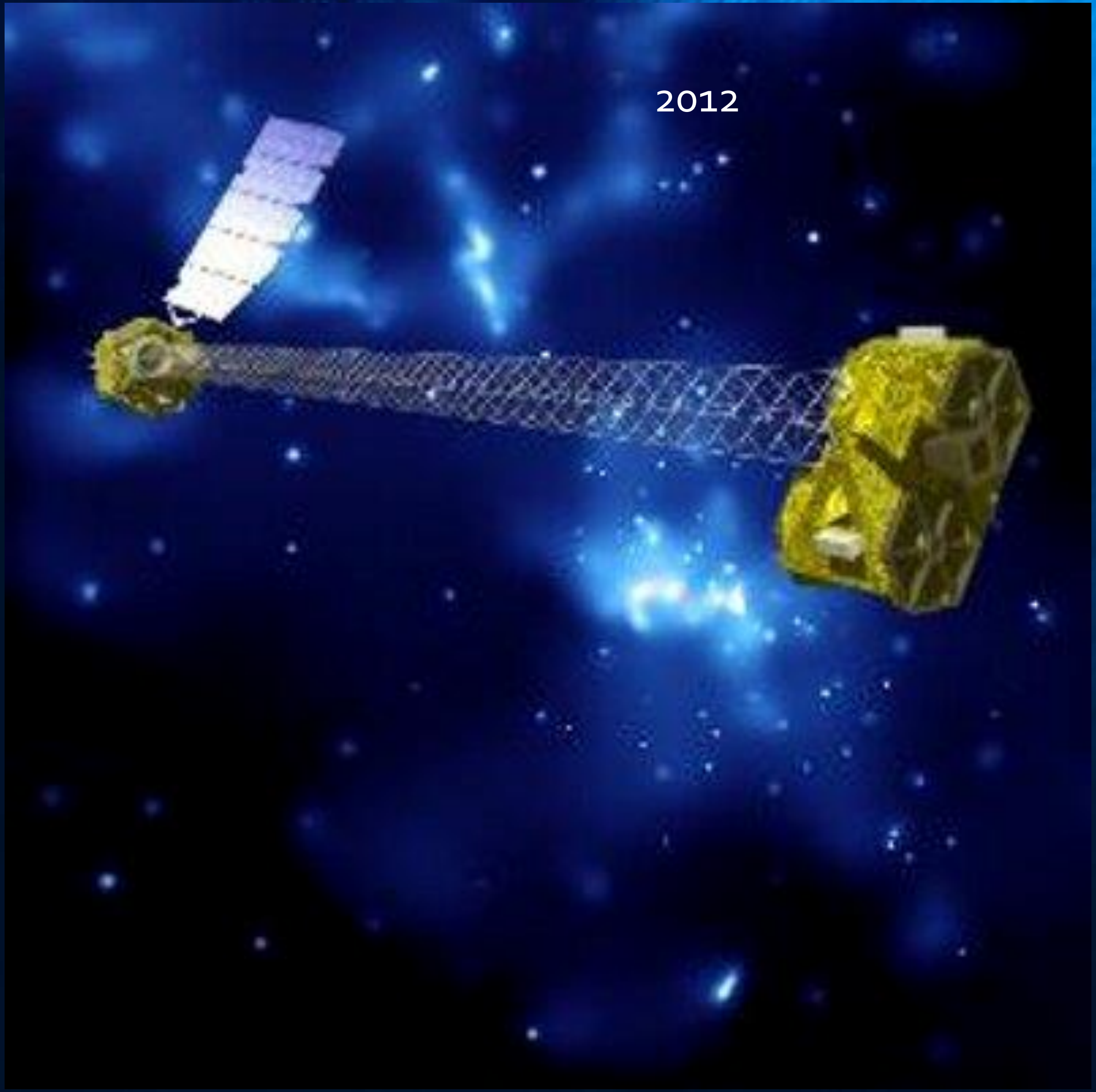


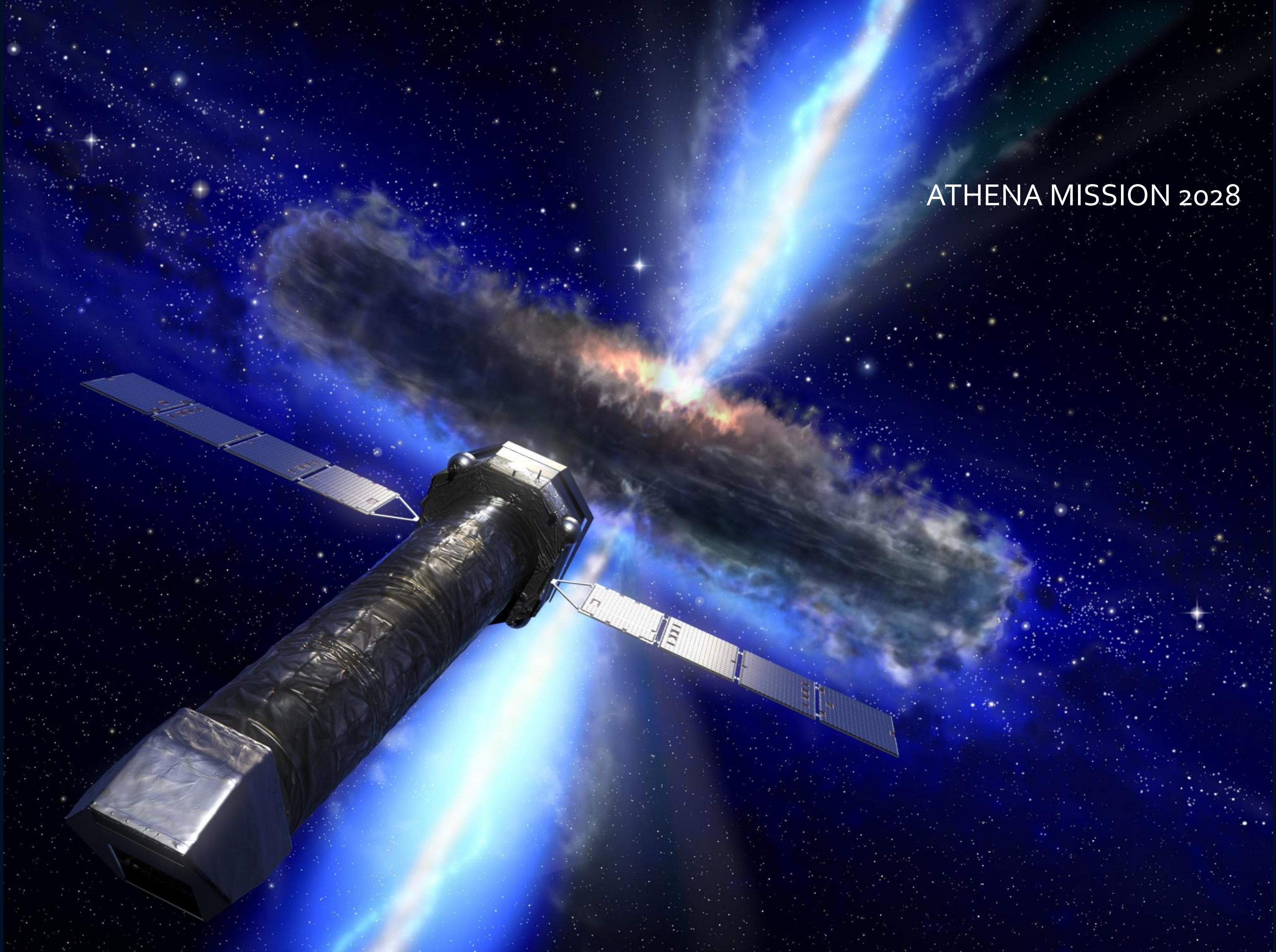
BeppoSAX 1996


XMM-Newton 1999
1999



1999


2012


ATHENA MISSION 2028

- Retrieve information on XMM-Newton and ATHENA missions from ESA
- Compare the characteristics of each mission
- Some specifications remains the same. Why this is happening?
- Make a short presentation for your results

Some relevant information can be found in the links below

XMM-Newton mission

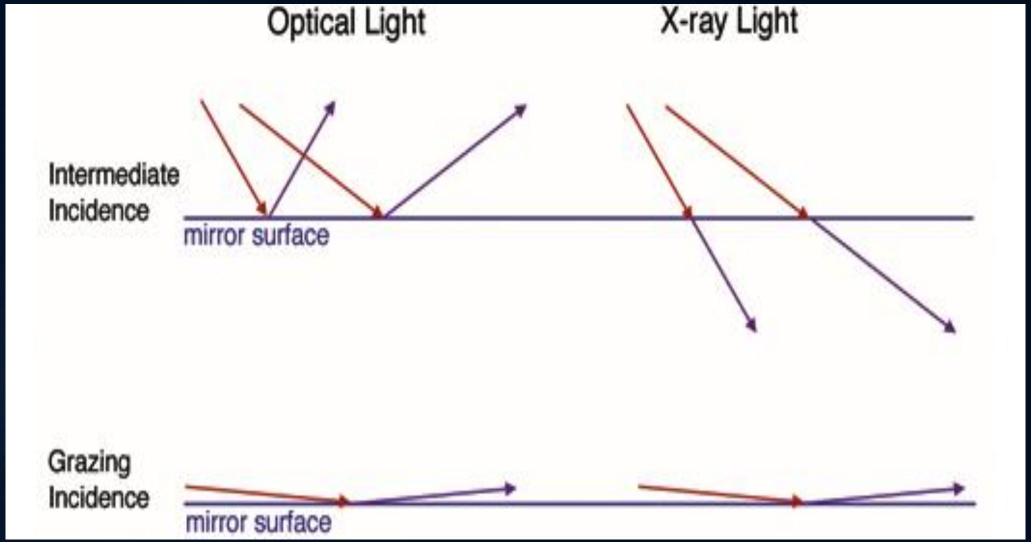
1. http://www.cosmos.esa.int/web/xmm-newton (general info)
2. https://heasarc.gsfc.nasa.gov/docs/xmm/uhb/basics.html (instrument info)

ATHENA mission

1. http://www.the-athena-x-ray-observatory.eu/ (general info)
2. http://www.the-athena-x-ray-observatory.eu/images/Mission/ScienceRequirementsTable.pdf (instrument info)

X-ray optics

Creating a telescope to image and focus X-rays might seem like it should be an easy task.
BUT…
X-rays are so energetic that they tend to pass through most matter.



X-ray optics

To achieve grazing incidence for incoming photos, an X-ray telescope has to be oriented such that the mirror surfaces are nearly parallel to the incoming light.

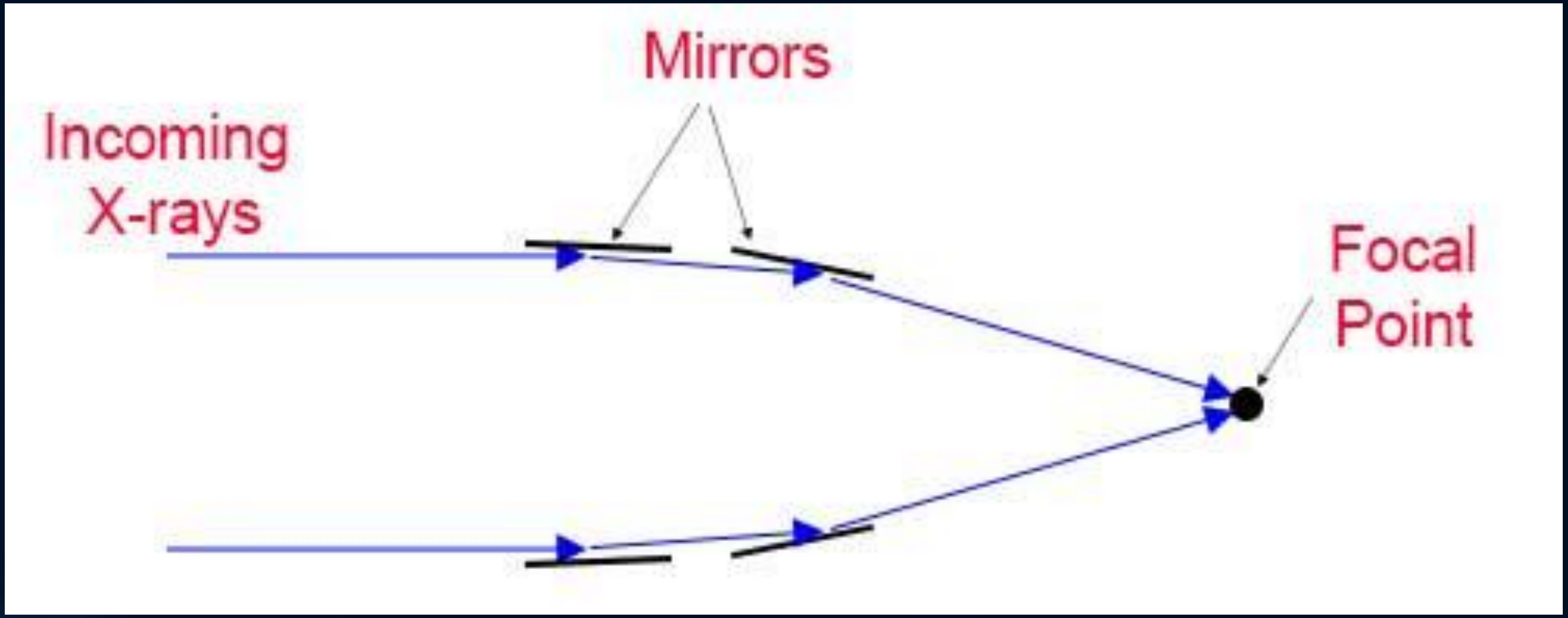
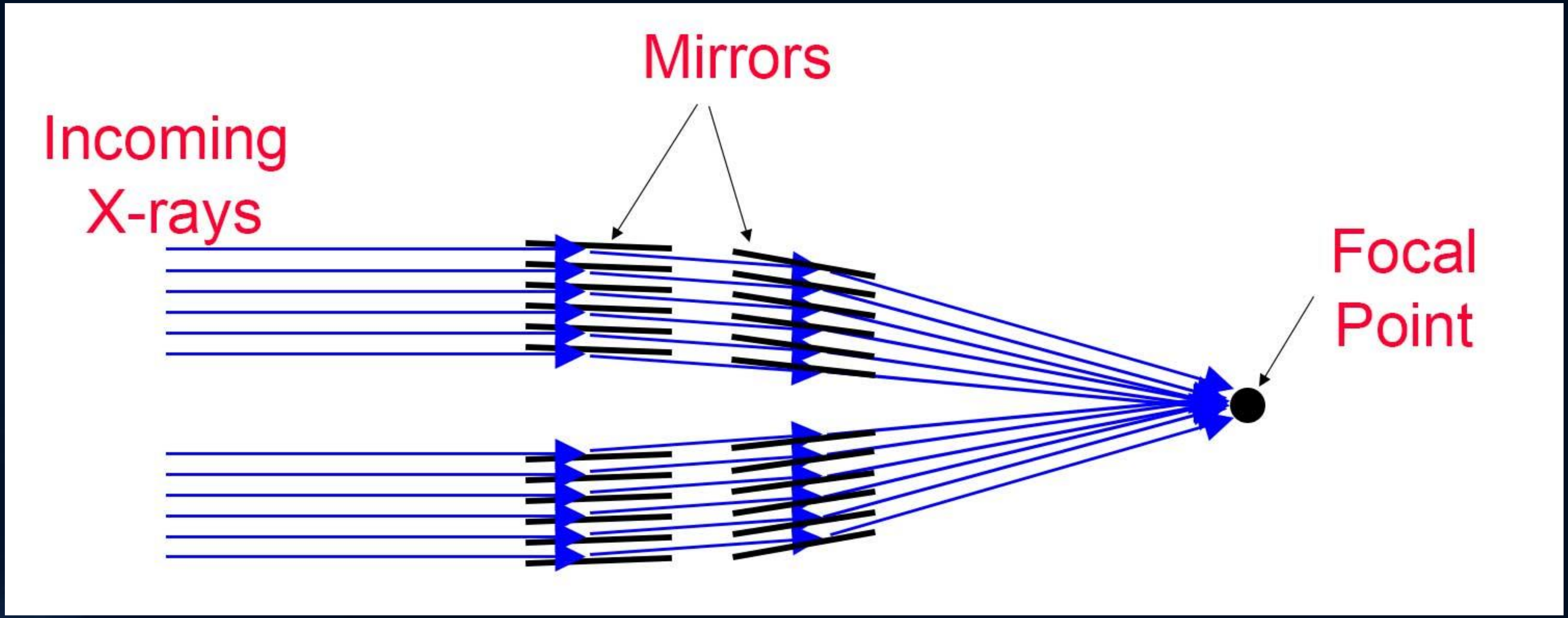


Diagram of a cut-away of an X-ray telescope with one set of mirrors. The incoming X-rays bounce off the two mirrors with a grazing incidence to be focused at the focal point.

X-ray optics

By turning the mirrors on the side, however, there is a large hole in the middle of the telescope, so the telescope misses a lot of X-rays. To solve this problem, X-ray telescopes use cylindrical mirrors and nest them, one inside the other. (Wolter type telescope)



By nesting the mirrors one within the other, more X-rays are focused, giving astronomers a brighter image.

Exercise

- In a Wolter type telescope find an expression for the maximum critical angle in order to have total external reflection of the incident photons. Can optical photos be detected using wolter type telescopes? The reflection index for gold for photon energies of 12.4 keV is $n = 1\text{-}1.88\cdot10^{-5}$. Can we have refractive index less than 1? What is the use of this property? Find the critical angle for 12.4 keV photons. For 1 keV photons n=0.9991. Low or high energy xray photons are more easily detected ?