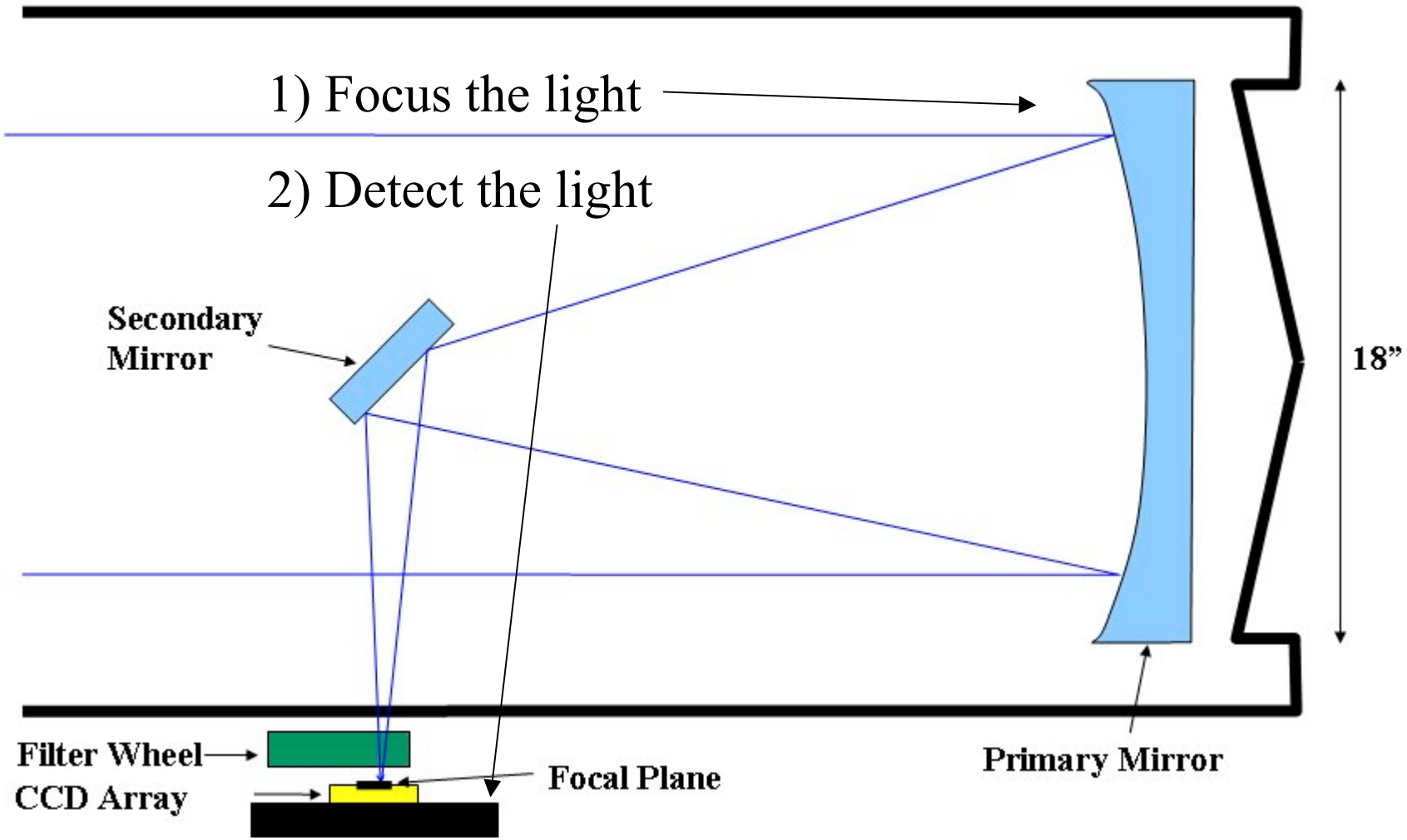
X-ray Instrumentation

Current X-ray Telescopes

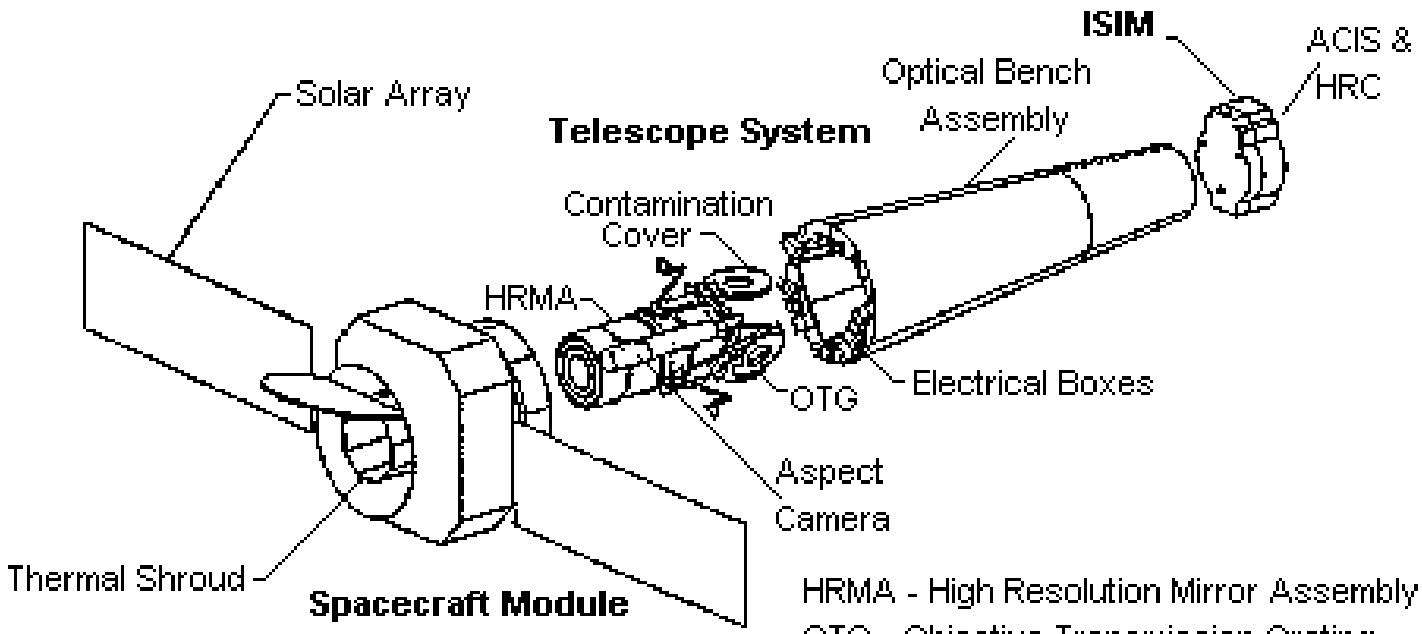
- Chandra - high angular resolution
- XMM - large effective area, medium angular resolution
- RXTE - largest effective area, lowest angular resolution, highest time resolution

An Optical Telescope

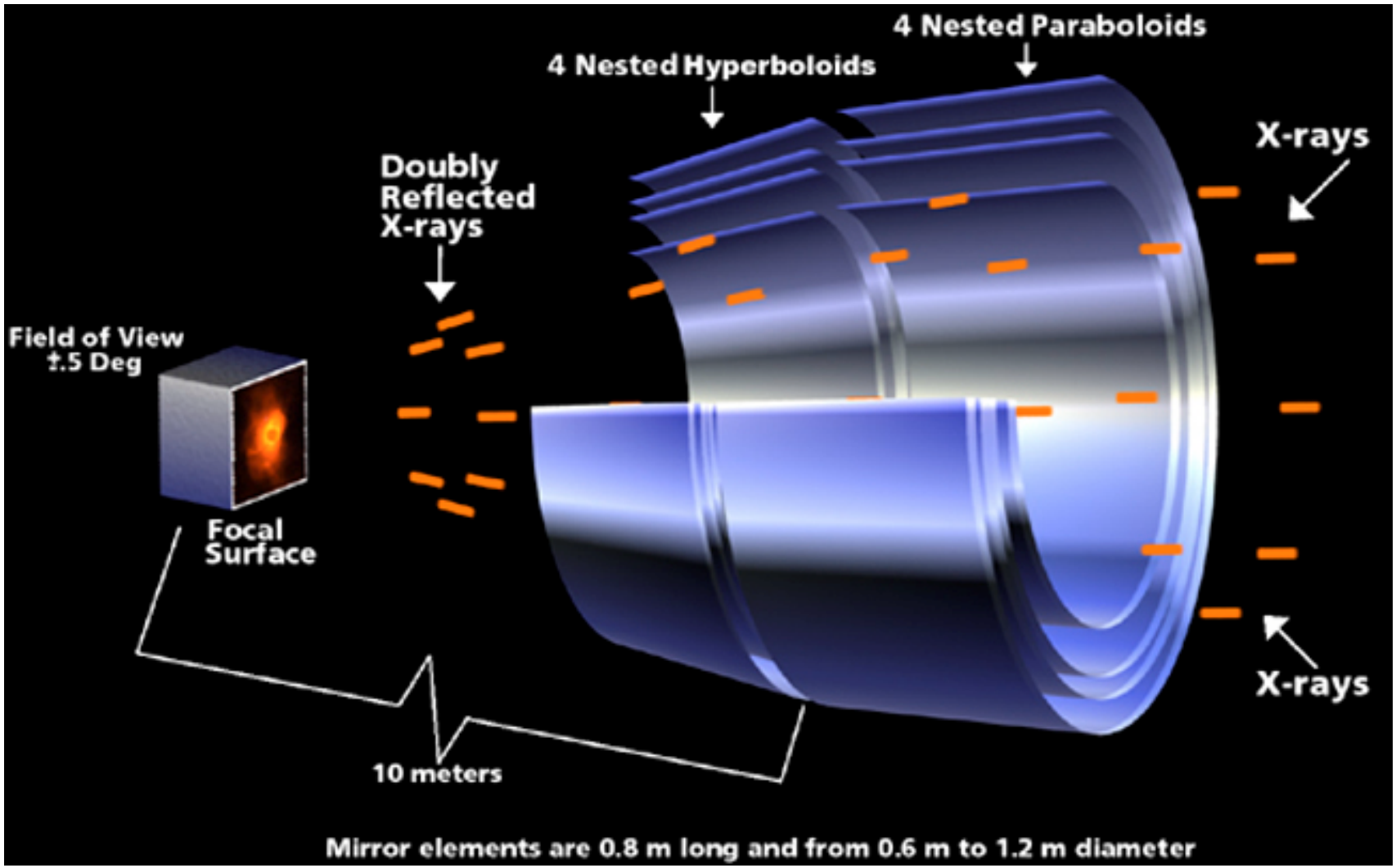


Chandra

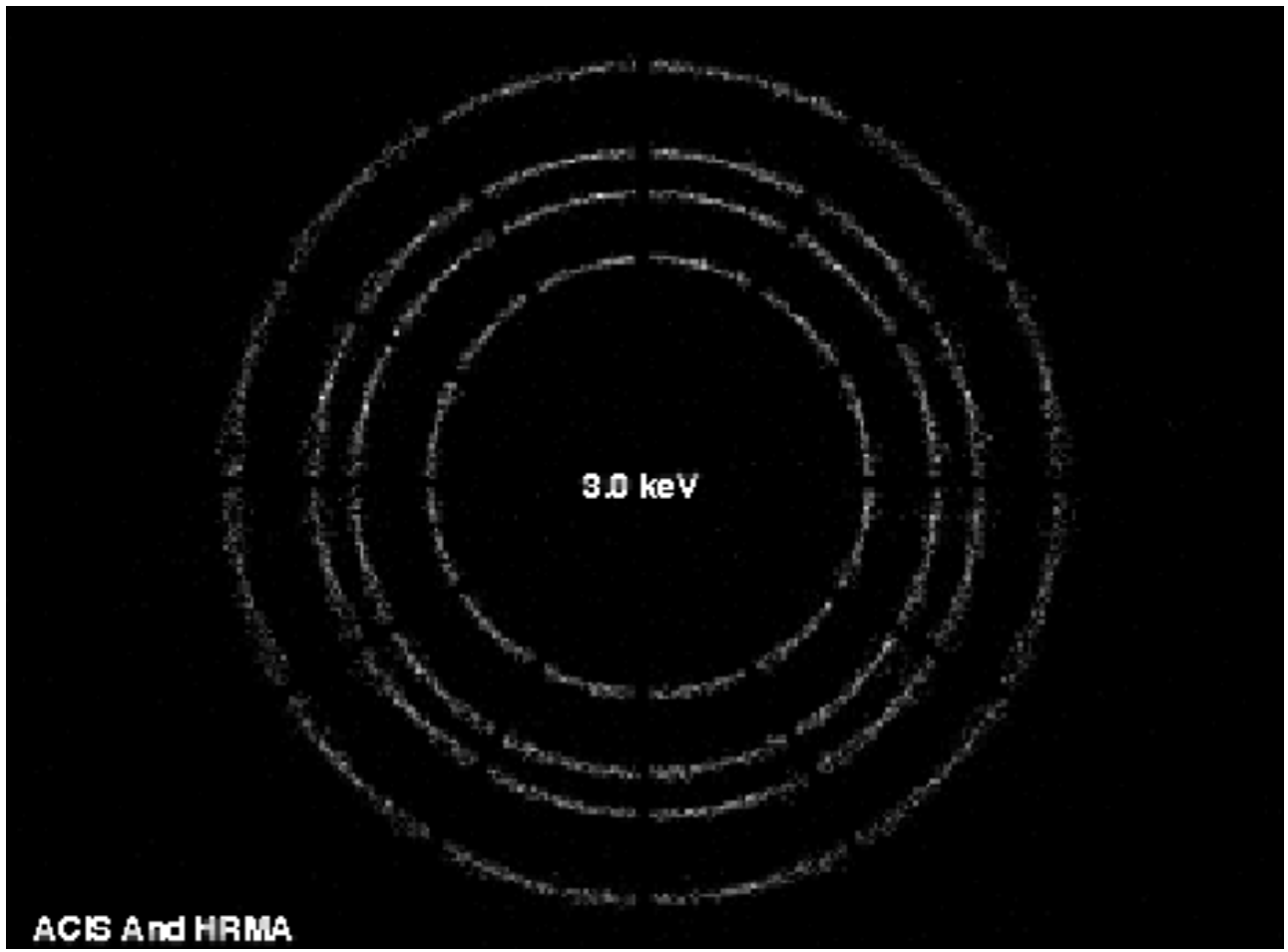
- Chandra's optical design is similar to XMM, ROSAT and Einstein but more precise.



Wolter Telescope (1)

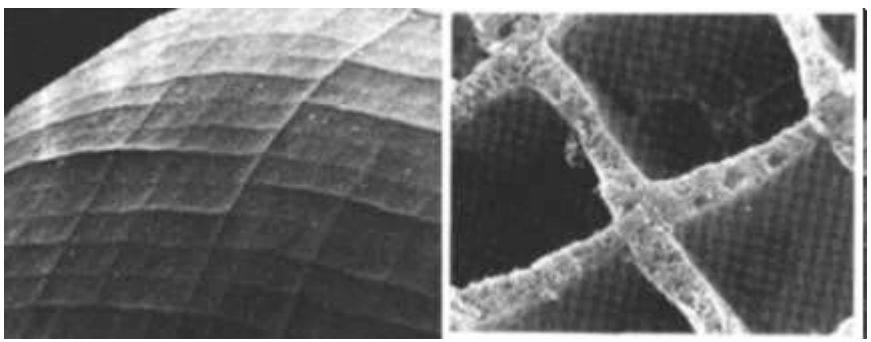


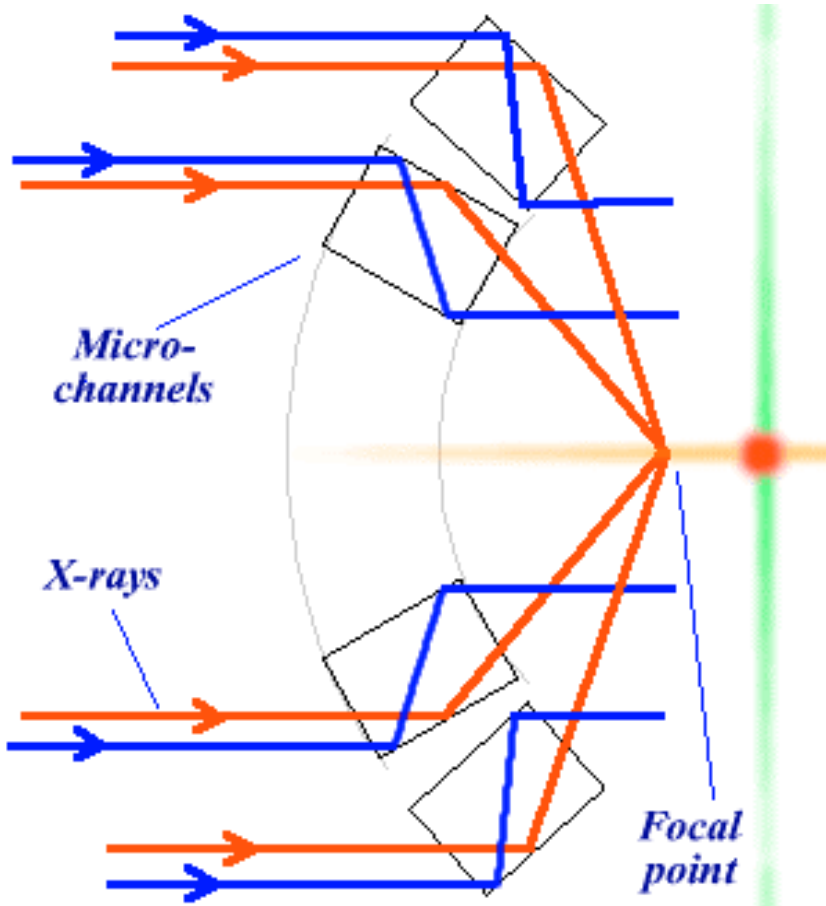
Wolter Telescope (2)



Microchannel Plate

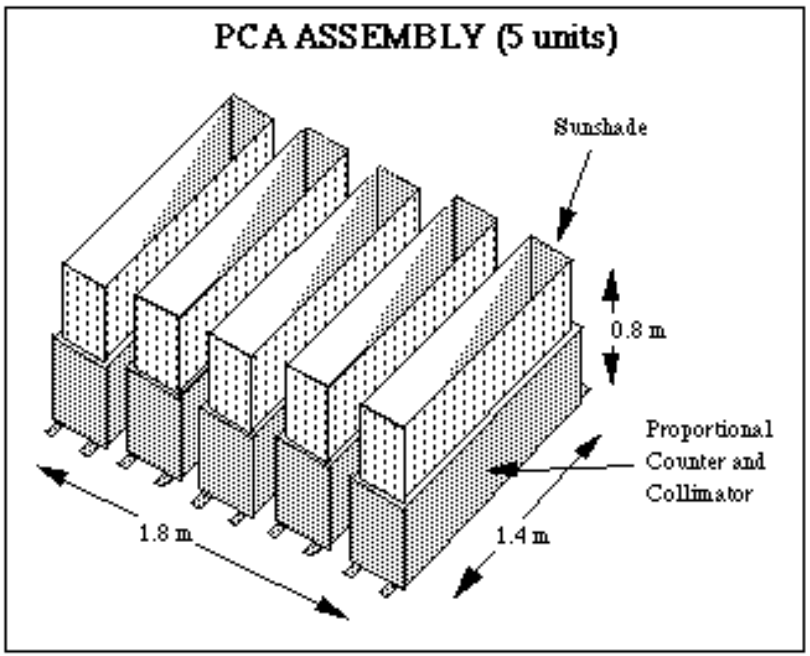
- Lobster-ISS
- MCPs are used in night-vision goggles.
- The idea is relatively straightforward and inspired by the compound eye of the lobster.

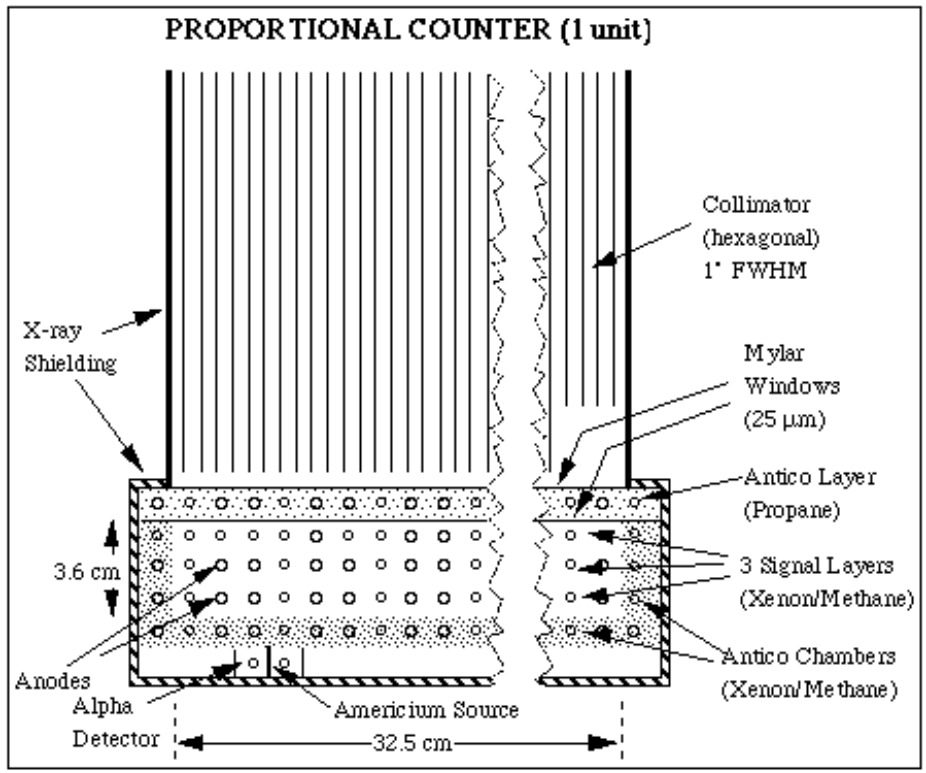




Collimator

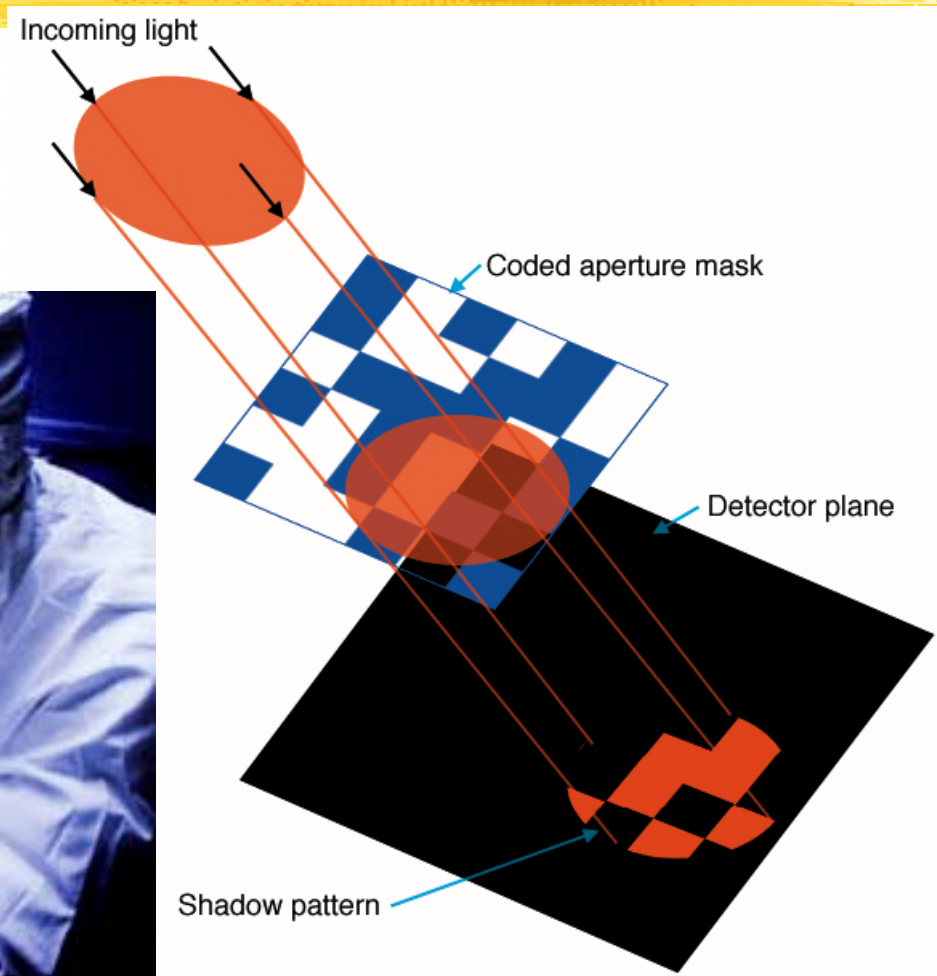
- RXTE uses collimators.





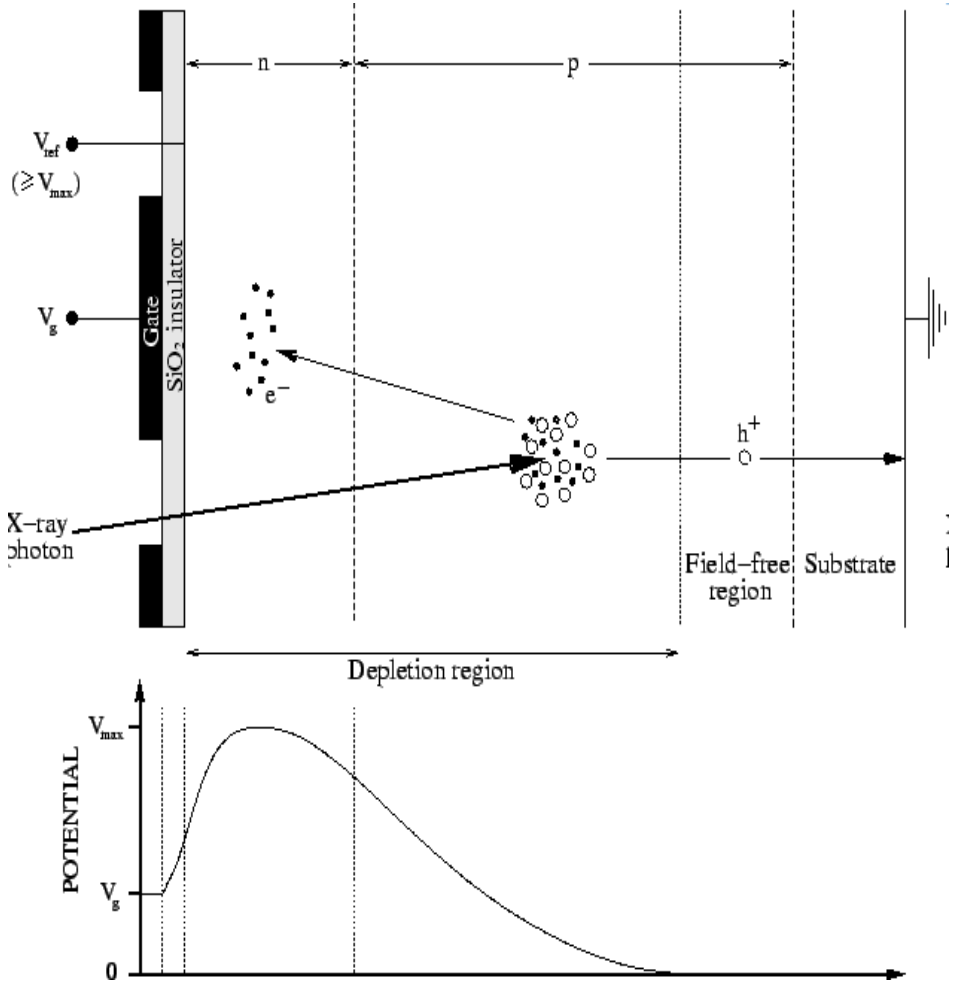
Coded Aperture Mask

- BAT on Swift



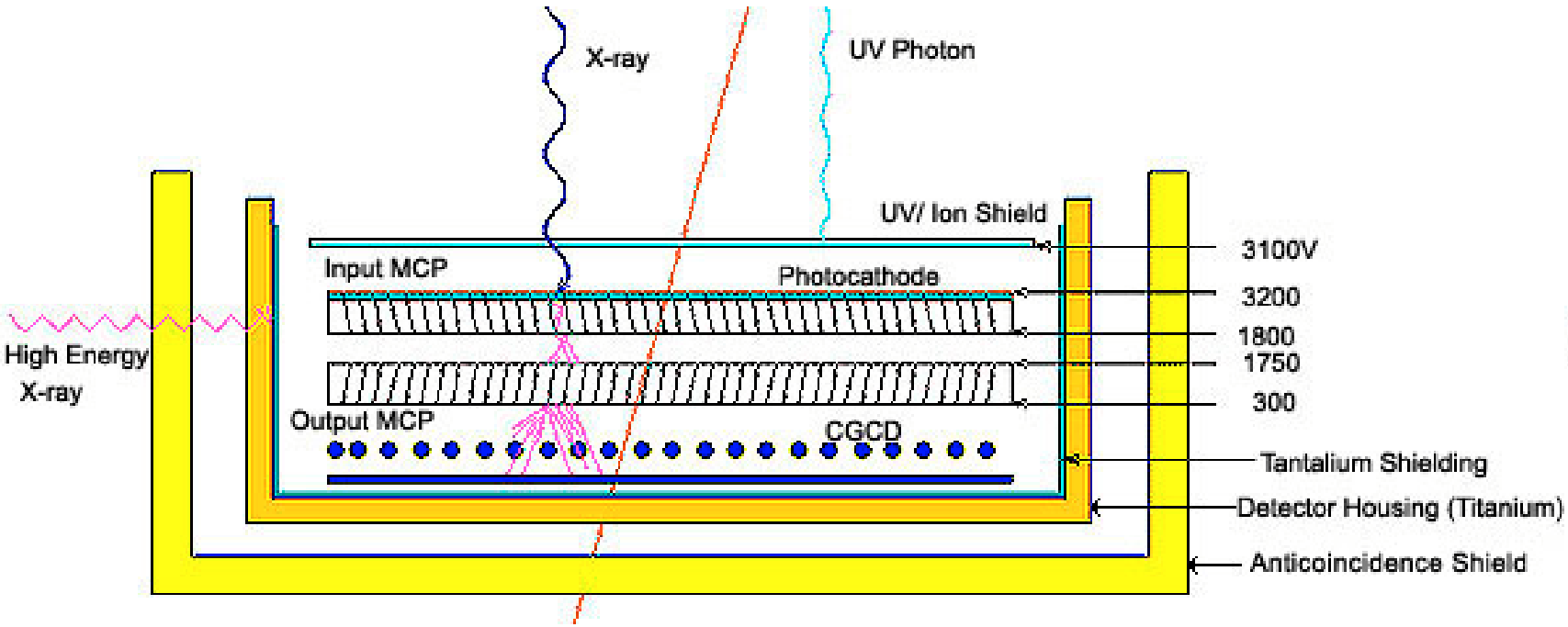
CCDs

- ACIS on Chandra
- Number of electrons and holes create is proportional to the energy of the photon.
- Proton contamination



MCP Photomultiplier

- HRC on Chandra
- The MCPs are made of a material that emits electrons when hit by X-rays or electrons.

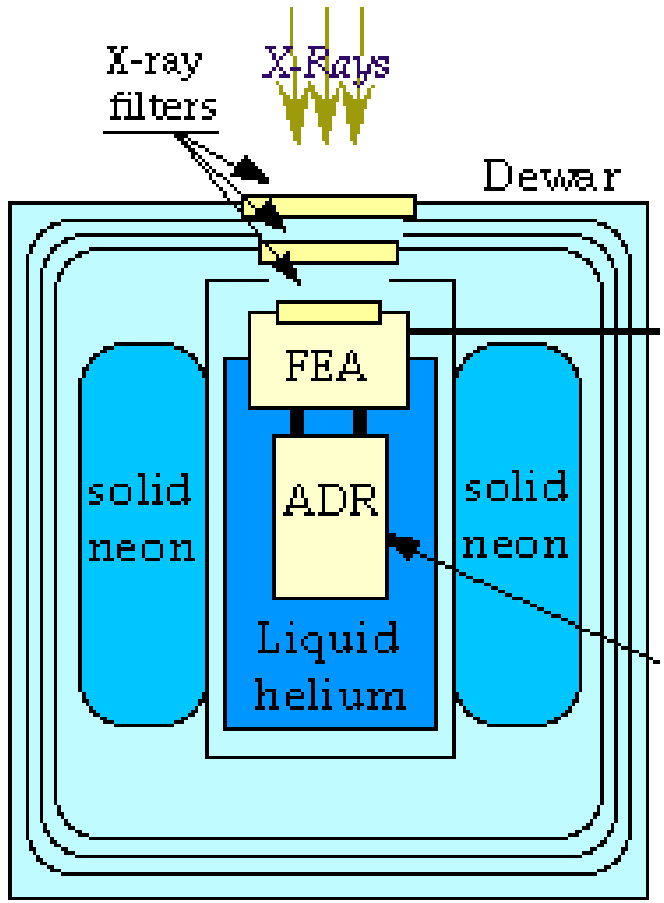


Bolometers

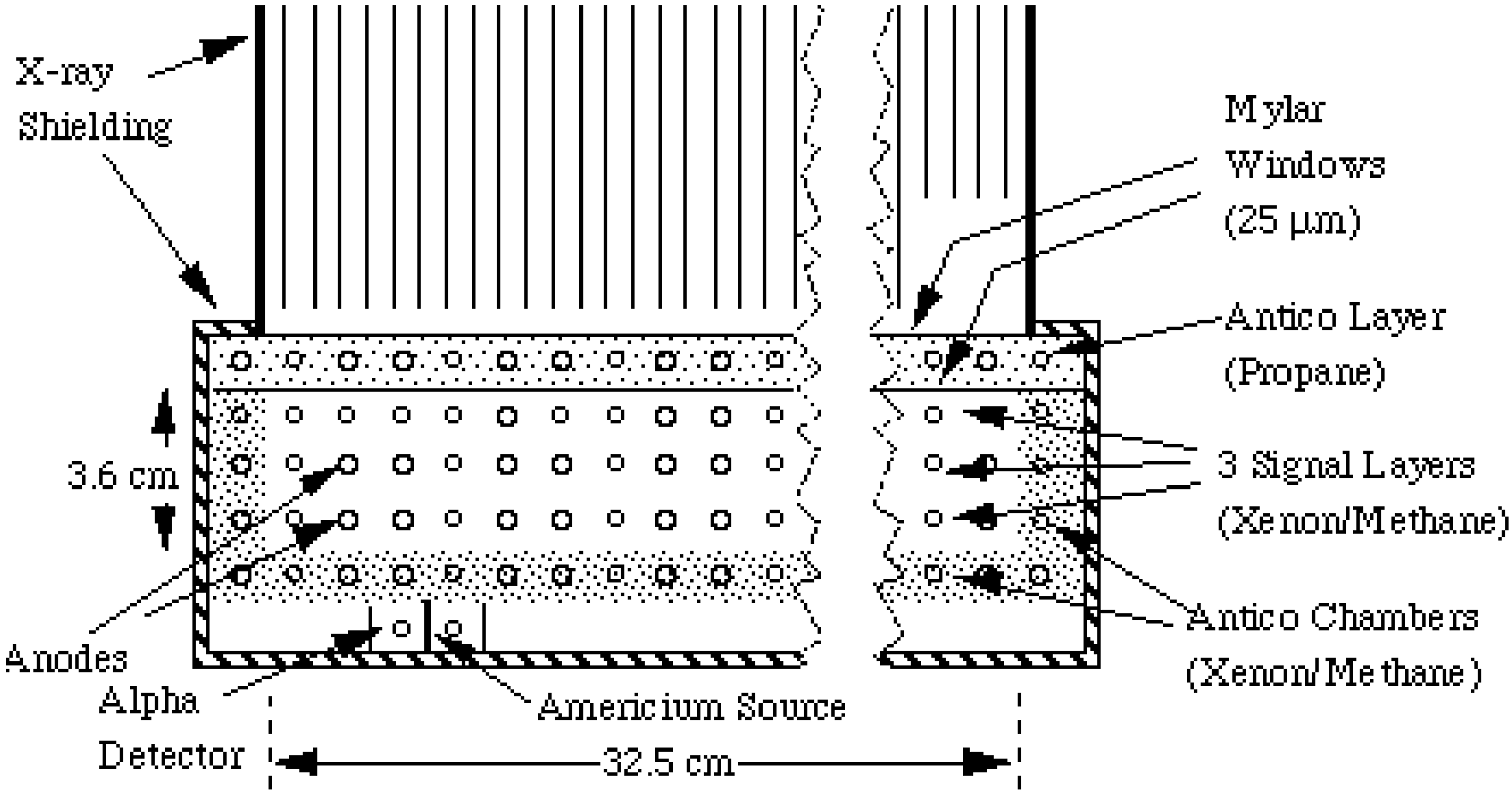
- X-rays carry energy, so when they are absorbed by some material, the material heats up.

$$\Delta T = E_\gamma / C_p$$

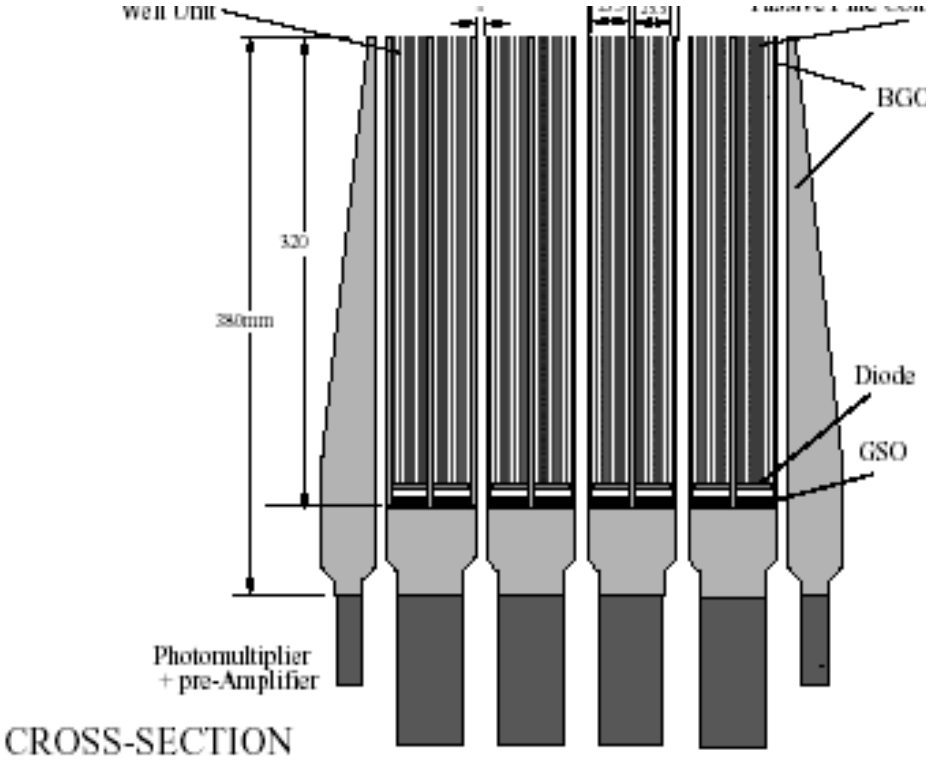
  - Good absorber
  - Thermalization
  - Low-heat capacity
- HgTe has the last two.

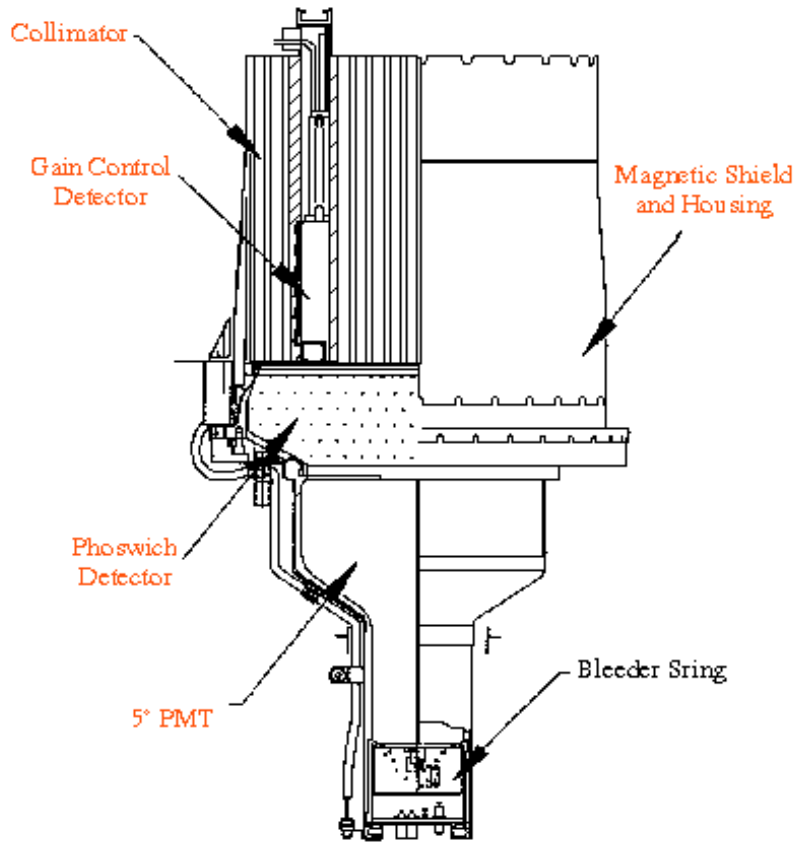


Gas Detectors



Scintillators

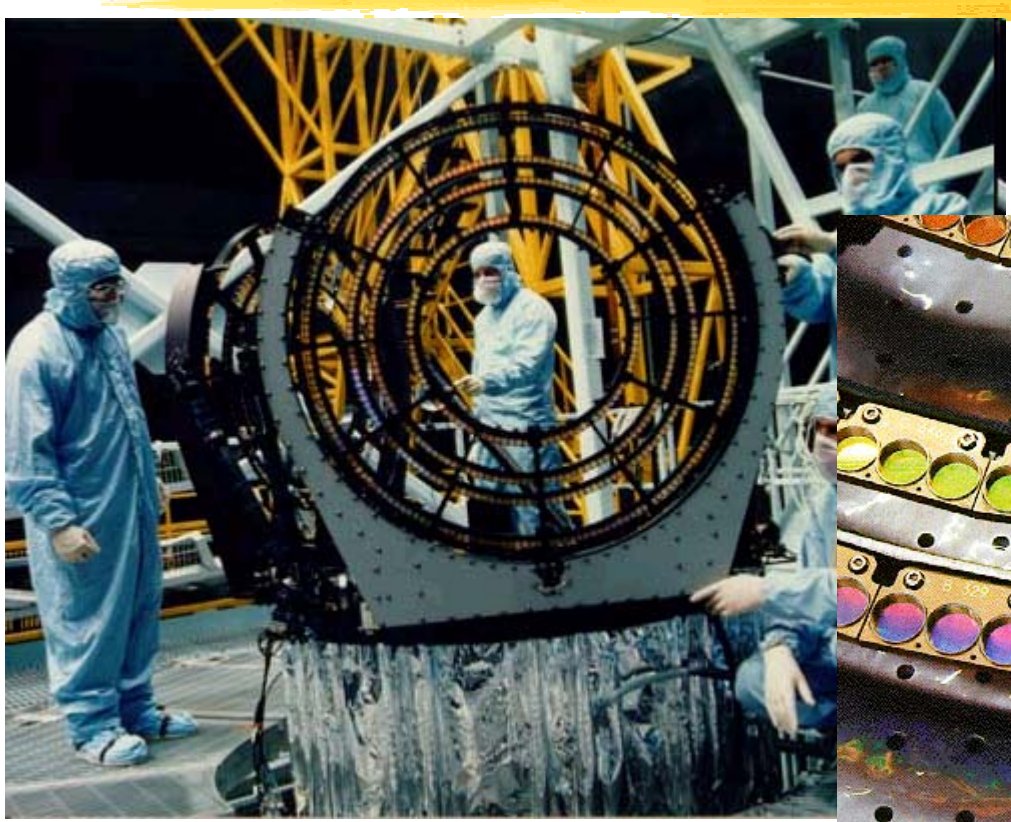


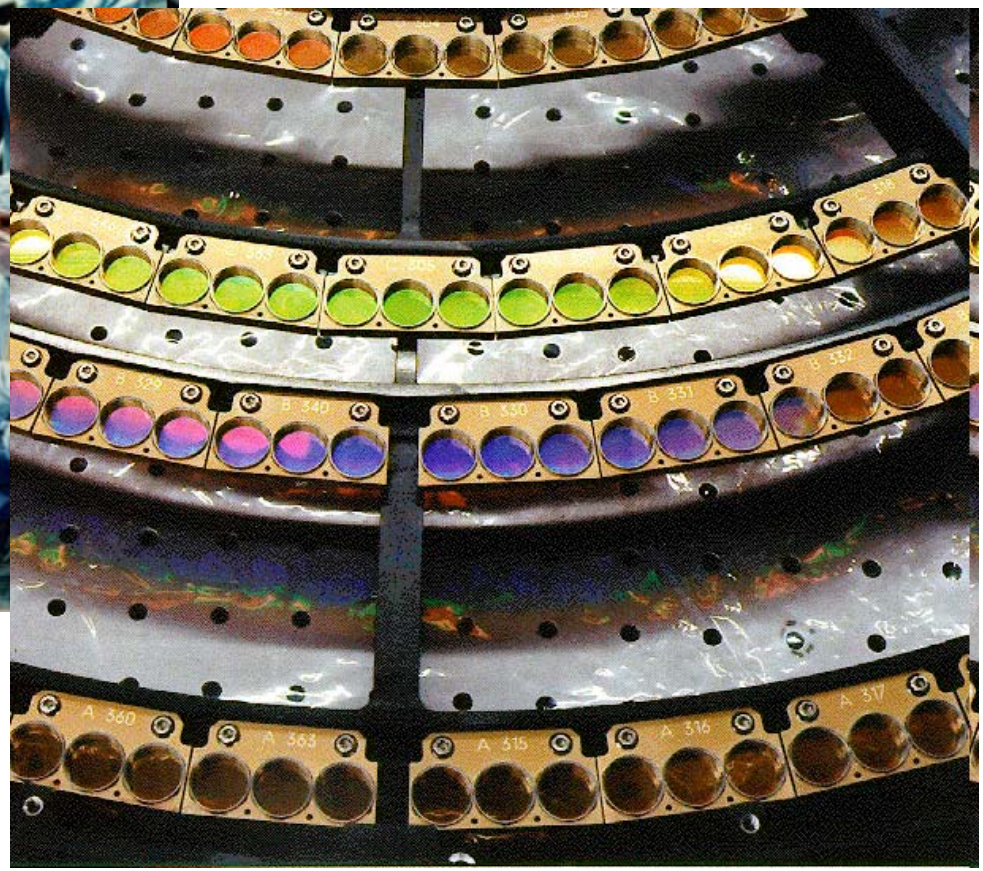


Spectroscopy

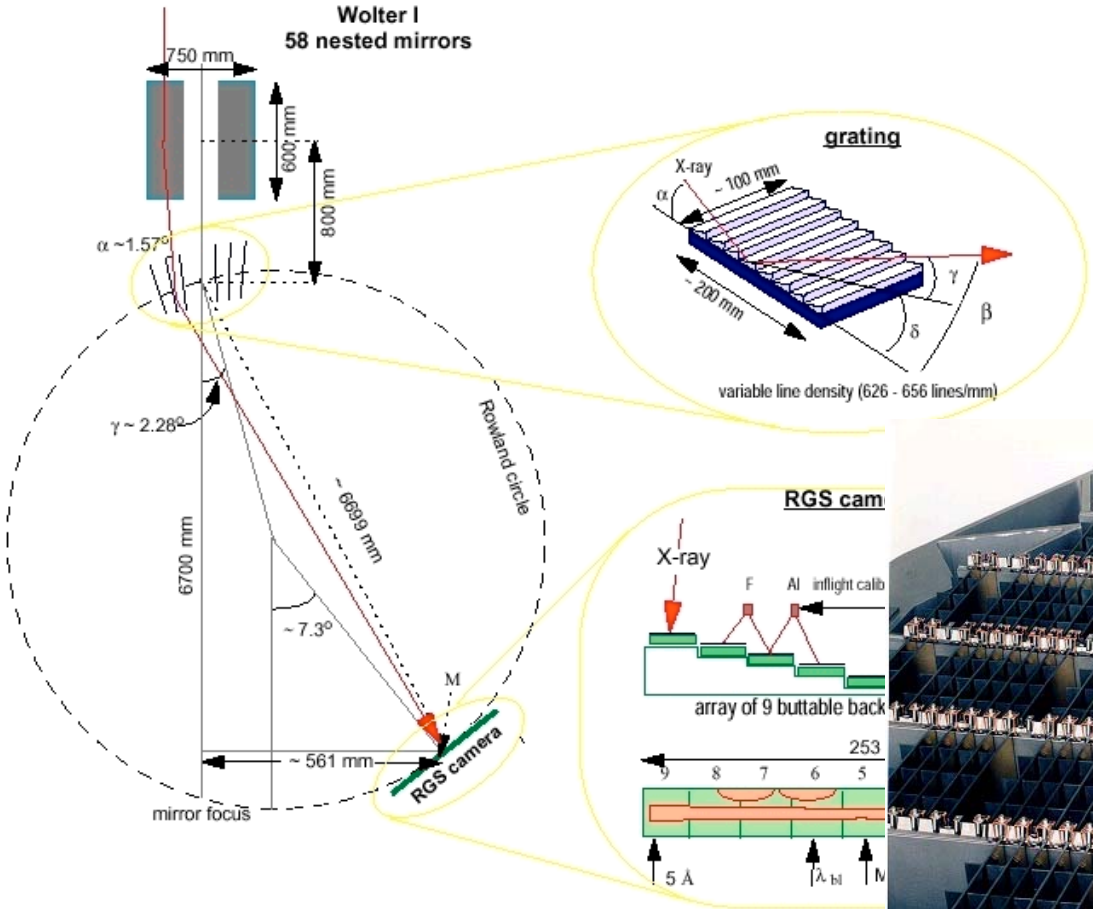
- CCDs, bolometers, gas and scintillators have some energy resolution
- The MCP photomultiplier does not
- However, to do really well especially at low energies you need a grating.

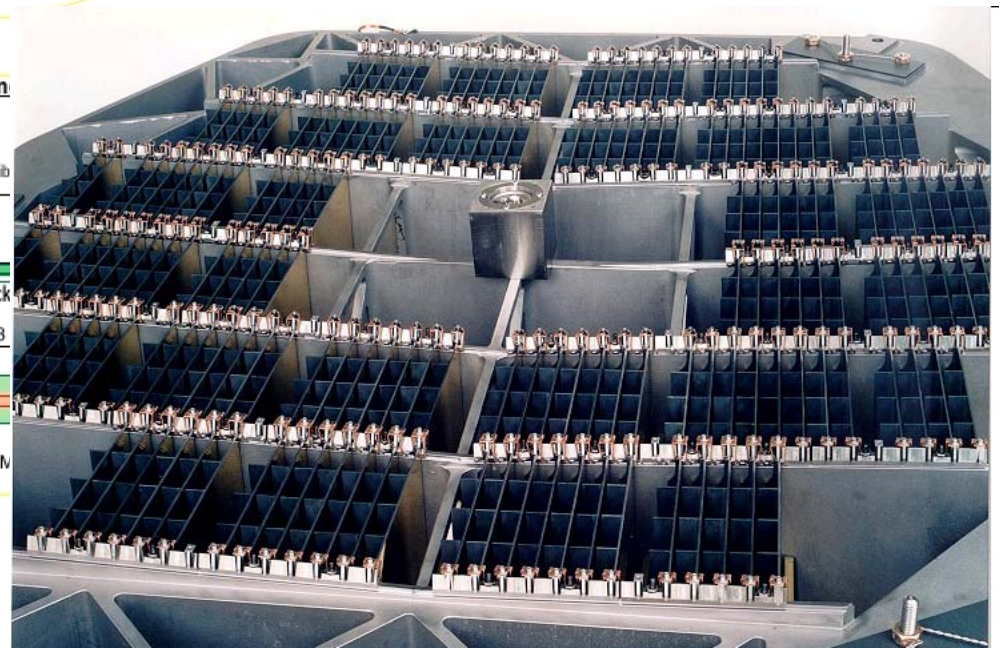
Chandra (LETG and HETG)





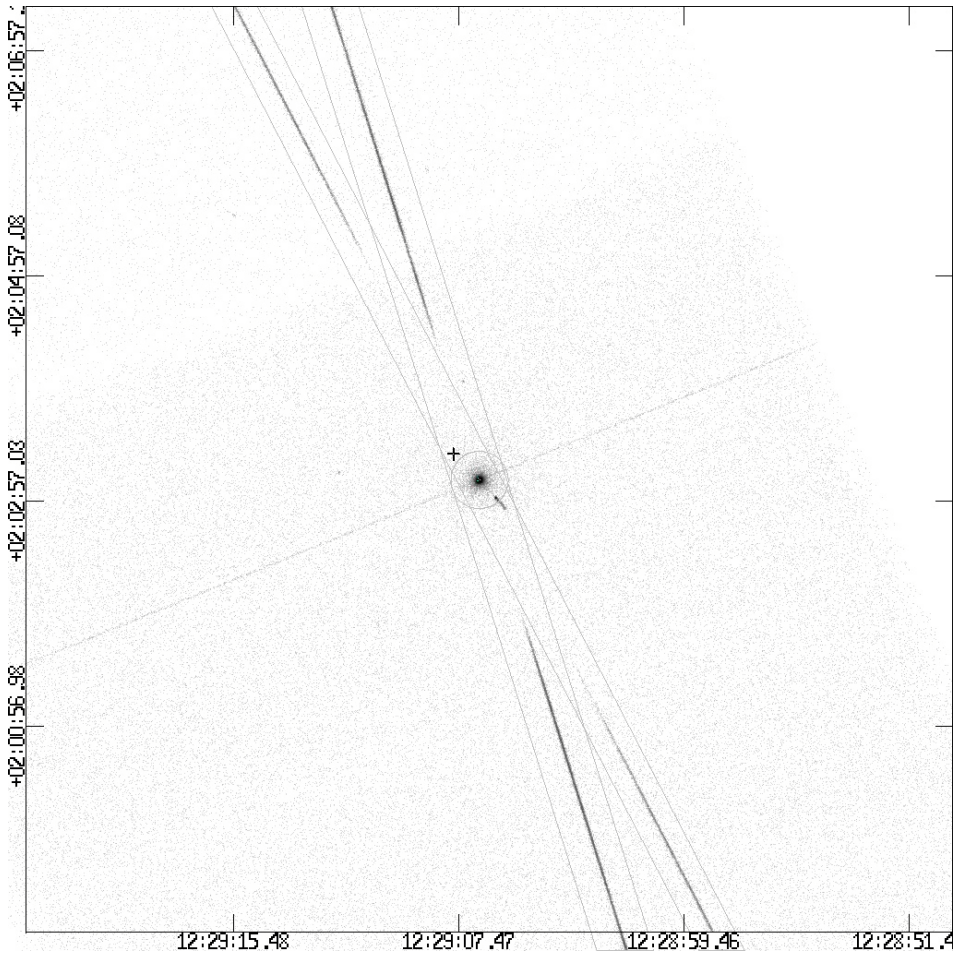
XMM-Newton RGS



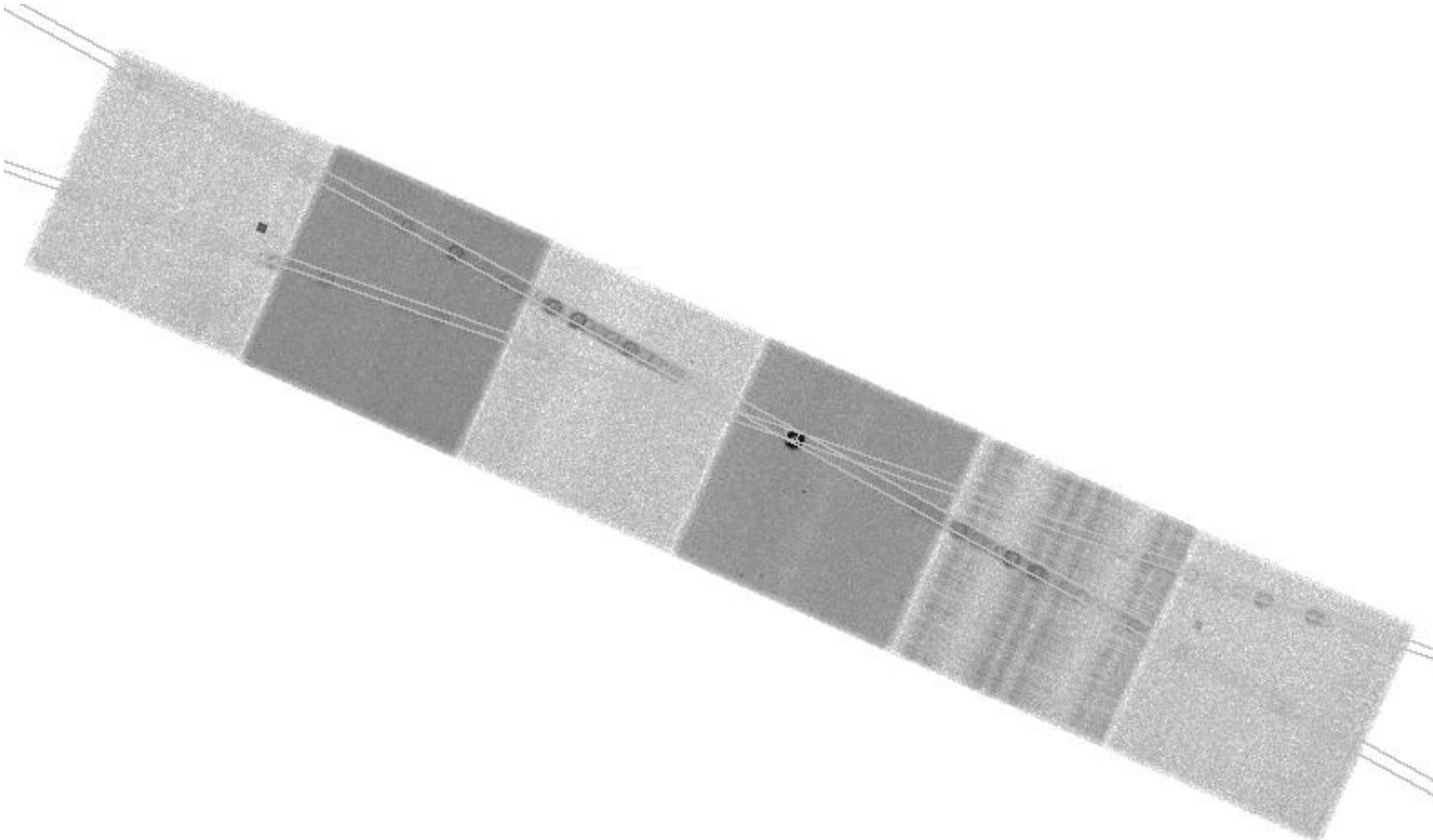


What does the data look like? (1)

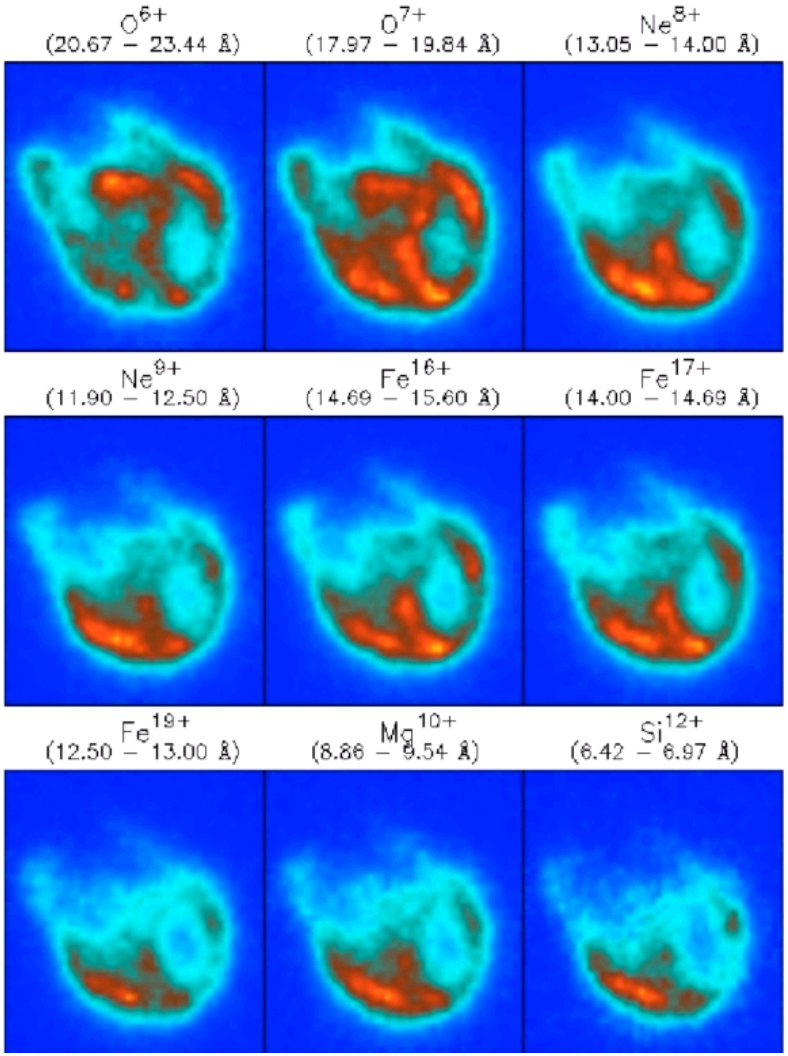
- GRB021004
- ACIS with HETG grating on top.
- Unlike in the optical, the chip is read out every few seconds, so you get the position, time and energy of each photon.

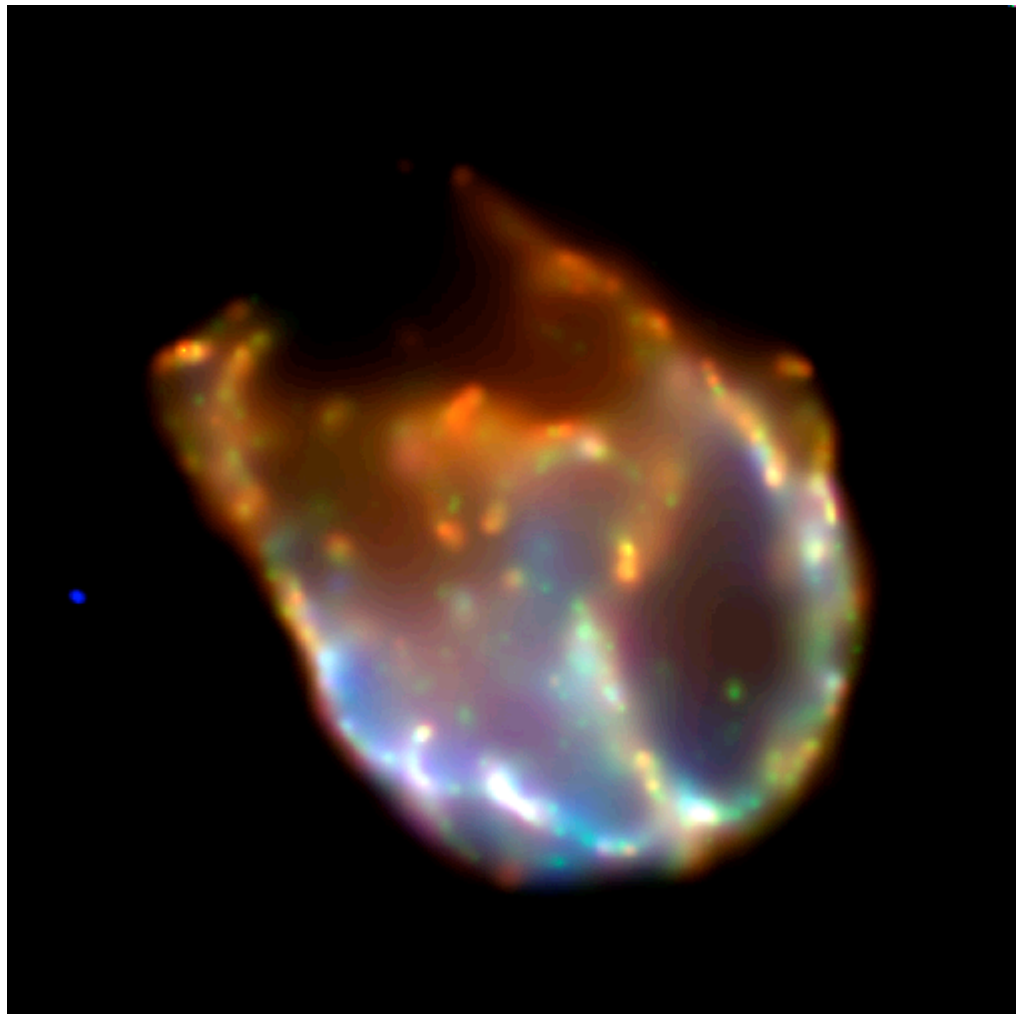


What does the data look like? (2)



XMM vs. Chandra





Future

- Missions: Con-X, Gen-X, EXIST, MAXIM
- Technologies: X-ray interferometry, multilayer optics
- Detectors: X-ray polarimetry

Constellation-X

Constellation-X

- Microcalorimeters at high energy
- Gratings at low energy
- Chandra-like telescope for low energy
- Multilayer coated optics for high energy
- Formation flying

Multilayer Optics (1)

- The reflectivity of a mirror decreases as the energy of the photon increases. The photons would rather just pass through the mirror.
- High-energy photons can skip on the surface of the mirror if their angle of incidence is close enough to 90°.

Multilayer Optics (2)

- We can design special materials to maximize the reflectivity.
- Multiple layers give photons more chances to reflect.