

The foundamental parameters of X-ray telescopes

INAF OAS BOLOGNA

What happens



.. a X-ray source...



INPUTS Source photons+ Mirrors response+ Detector response All kinds of Background s





Take into account telescope response... and remaining bgds

INPUTS

Source photons+ Mirrors response+ Detector response+ All kinds of Background s ...<u>mirrors,</u> <u>concentrators</u> or <u>collimators</u> board ellites.. ctors icrocal., etc.)



Remove "some" backgrounds and malfunctioning

things to do

..since the birth of X-ray Astronomy in 1962, improvements were carried out in terms of sensitivity, angular resolution, energy resolution (and energy bandpass)





Counts > 0 from all directions \rightarrow diffuse background radiation

Giacconi et al. (1962). Nobel prize in 2002

The functioning of a X-ray telescope







Grazing incidence



Einstein (HEAO-2): 1978-1981



What we are going to talk about...

....where we were in 1999.... and we are still there...





Chandra

XMM-Newton

A foundamental concept.....



First fundamental element of the telescope: PSF



Point Spread Function (PSF) – describes the response of an imaging system to a point source or point object.

HEW (PSF), FWHM (PSF) = angular resolution

PSF = function of (x,y) or (r, ϑ) (...usually a couple of Gaussian/King profiles....)



the ESA (XMM-Newton) way

Chandra = "extreme" angular resolution



Only four, robust shells High-quality of shell production to allow <arcsec on-axis angular resolution (the best so far in X-rays)





Background "may depend" on the angular resolution...

High Resolution Mirror Assembly (HRMA)





Chandra focal-plane detectors: CCDs



XMM-Newton = large effective area

3 modules, 58 shells



$$\vartheta_{crit} \propto \frac{\sqrt{
ho}}{E}$$



XMM-Newton: all instruments at work simultaneously





High Resolution Mirror Assembly (HRMA): On-axis PSF





On-axis PSF size and shape

High Resolution Mirror Assembly (HRMA): Off-axis PSF





CDF-N 2Ms exposure

ACIS EEF



XMM-Newton: the EPIC on-axis PSF



spider-like pattern due to the support of the Wolter I mirrors

Mirror module	2	3	4
Instr. chain ^a	\mathbf{pn}	MOS-1+RGS-1	MOS-2+RGS-2
	orbit/ground	orbit/ground	orbit/ground
FWHM ["]	$< 12.5^{b}/6.6$	4.3/6.0	4.4/4.5
HEW["]	15.2/15.1	13.8/13.6	13.0/12.8

PSF FWHM higher than in *Chandra* but much larger effective area Background (and confusion limit) can be an issue

XMM-Newton: the EPIC on-axis PSF



XMM-Newton: the EPIC off-axis PSF







Chandra: High Resolution Mirror Assembly (HRMA): Effective Area





Chandra: quantum efficiency



Chandra: effective area



XMM-Newton: mirror effective (geometric) area



XMM-Newton: quantum efficiency



Strong decrease in the QE above 10 keV, where also the effective area due to the mirrors has a significant decrease

XMM-Newton: effective area



Energy [keV]

Chandra

XMM-Newton



Chandra: vignetting

Ratio of the off-axis vs. on-axis counts at different off-axis angles



Hard X-ray photons are more difficult to focus → Vignetting

XMM-Newton: vignetting



Strong vignetting (as expected) for high-energy photons, partly compensated by the large effective area (e.g., wrt. *Chandra*)

You will account for all this information creating a file named arf (ancillary response file)

Last but not least....

Energy resolution

Chandra: energy resolution



XMM-Newton: energy resolution



Typical CCD resolution 100-150 eV

 $\Delta E(FWHM)/E \propto E^{-1/2}$ (E in keV)

You will account for all this information creating a file named rmf (redistribution matrix file)

What about high-resolution Spectrospcopy?



Resolution R ~ 100-500 (FWHM) What's missing?

