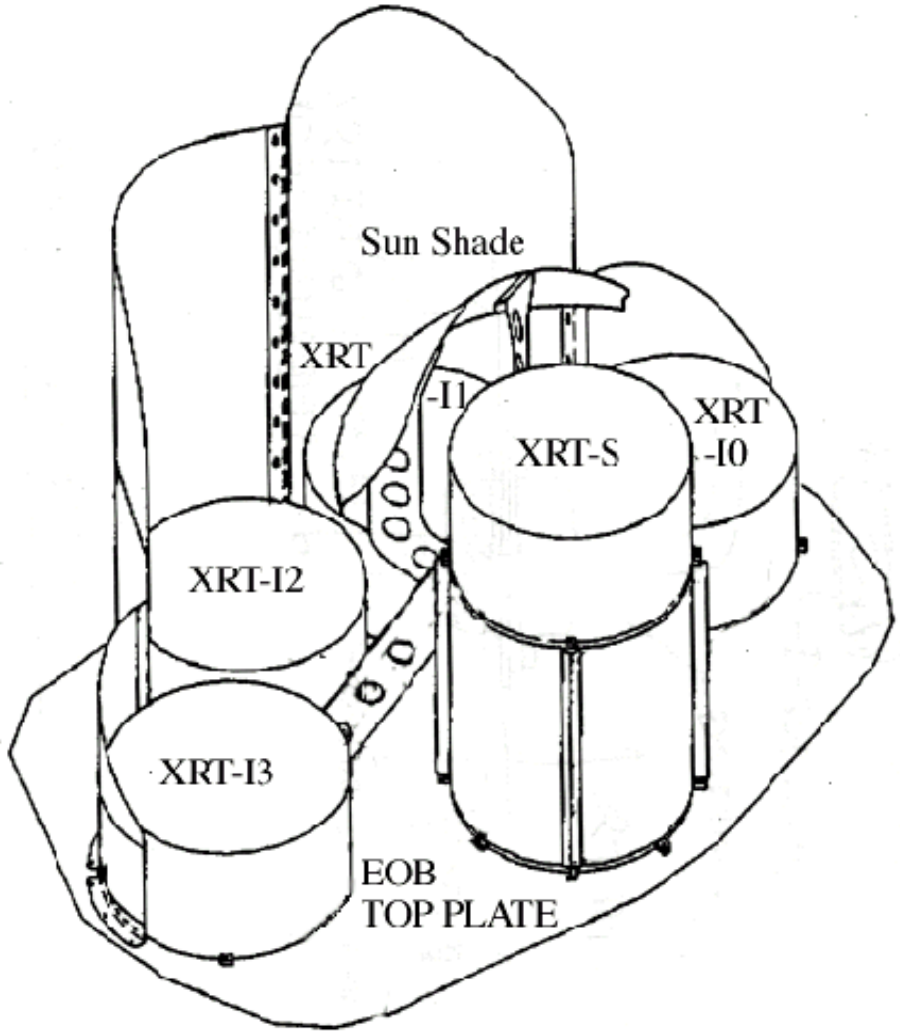
Astro-E2 X-Ray Telescopes

- XRT Setup & Structure
- Performance Characteristics
  - Effective Area
  - Angular Resolution
  - Optical Axes
  - Field of View

XRT Set up

- 5 XRT's on extended bench
  - 4 on imagers with f=4.75m
  - 1 on spectrometer with f=4.50m
- Same external dimension for XRT-I & XRT-S
  - ~ 40 cm diameter, ~25 cm height

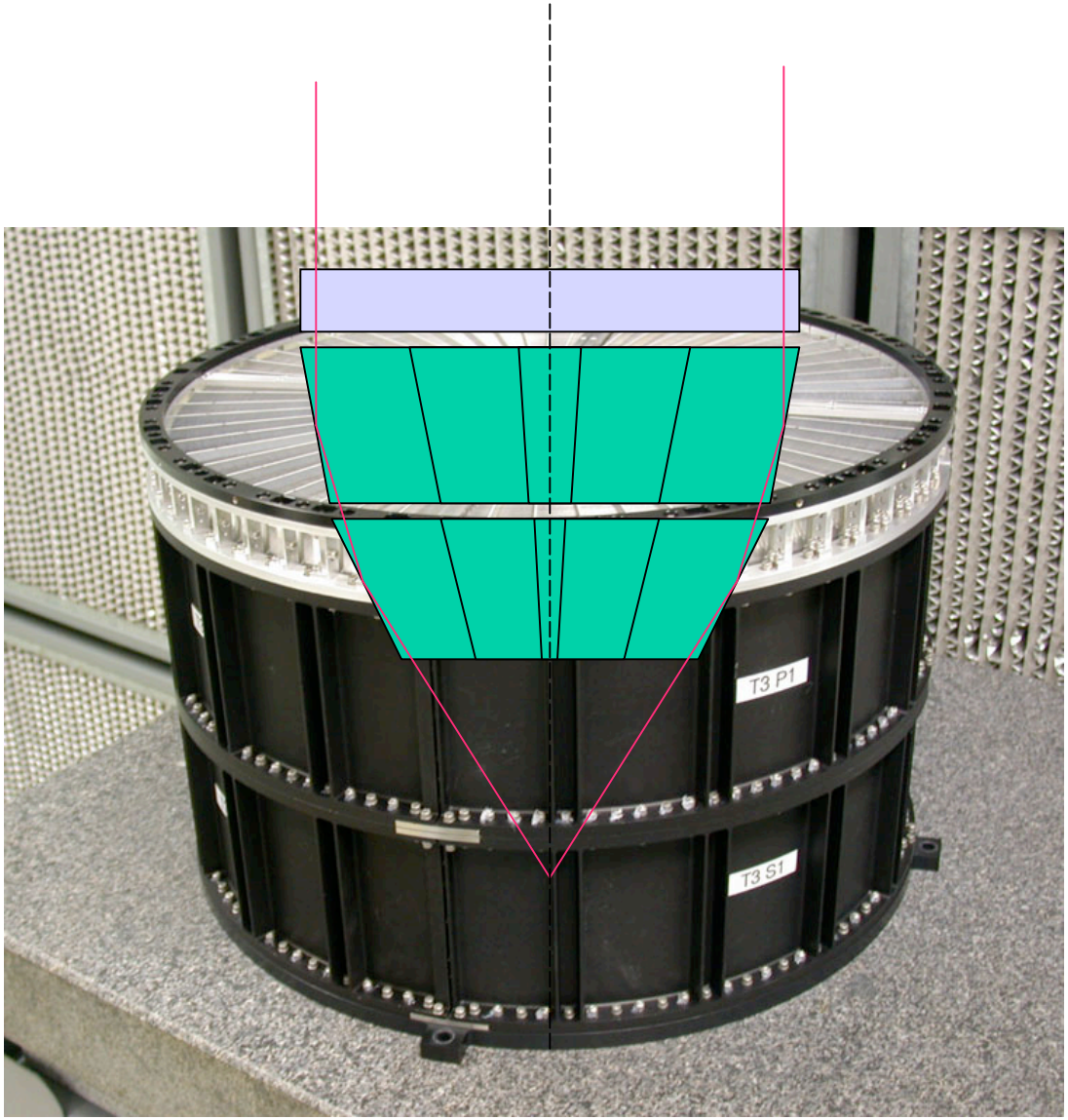


Structure

- Optic
  - Reflective optics
  - Grazing incidence
  - Conical approximation to Wolter type I
  - 2 reflections in 2 stages
  - Collimation 1 stage
  - Gold surface
  - Nested shells of segmented "cylinder"

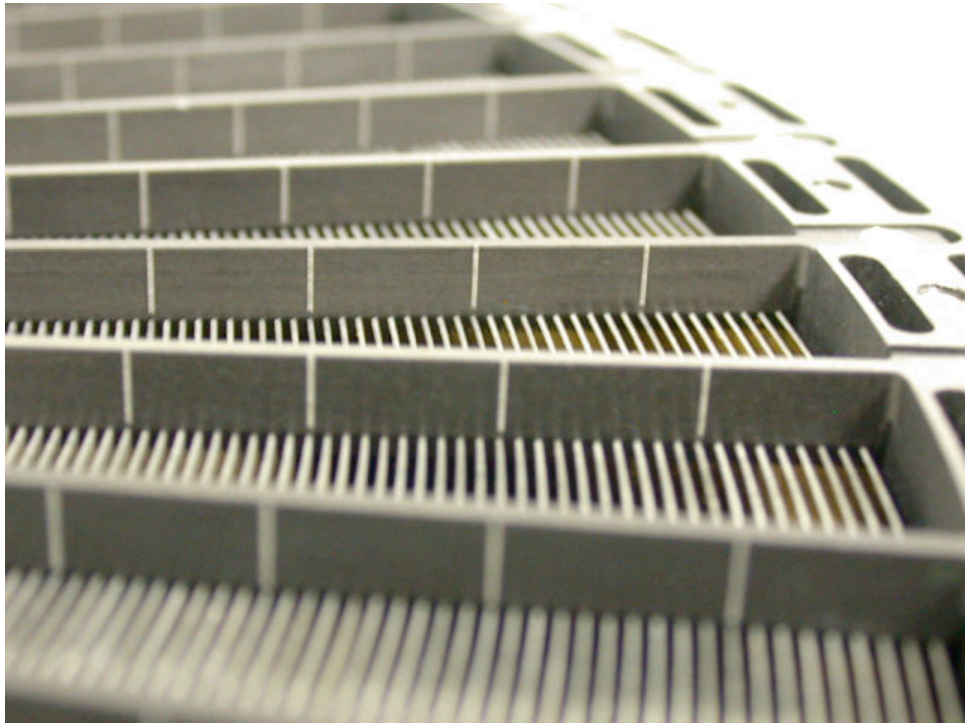
Angle of incidence (on-axis) varies from inner (smaller) to outer (larger)

spectral response: Critical angle ~ $1/E$



- Geometry and Mechanics
  - Segmented circular elements
  - Reflectors positioned in slots
  - (Almost) all constructed out of Al
  - Sandwiched elements: Gold surface / epoxy adhesion layer / aluminum substrate
- Thermal properties
  - Operational T: 20 +/- 7.5 C
  - Sun shields
  - Heating elements
  - Thermal Shields

Sandwiched structure: dependence on temperature from CTE mismatch



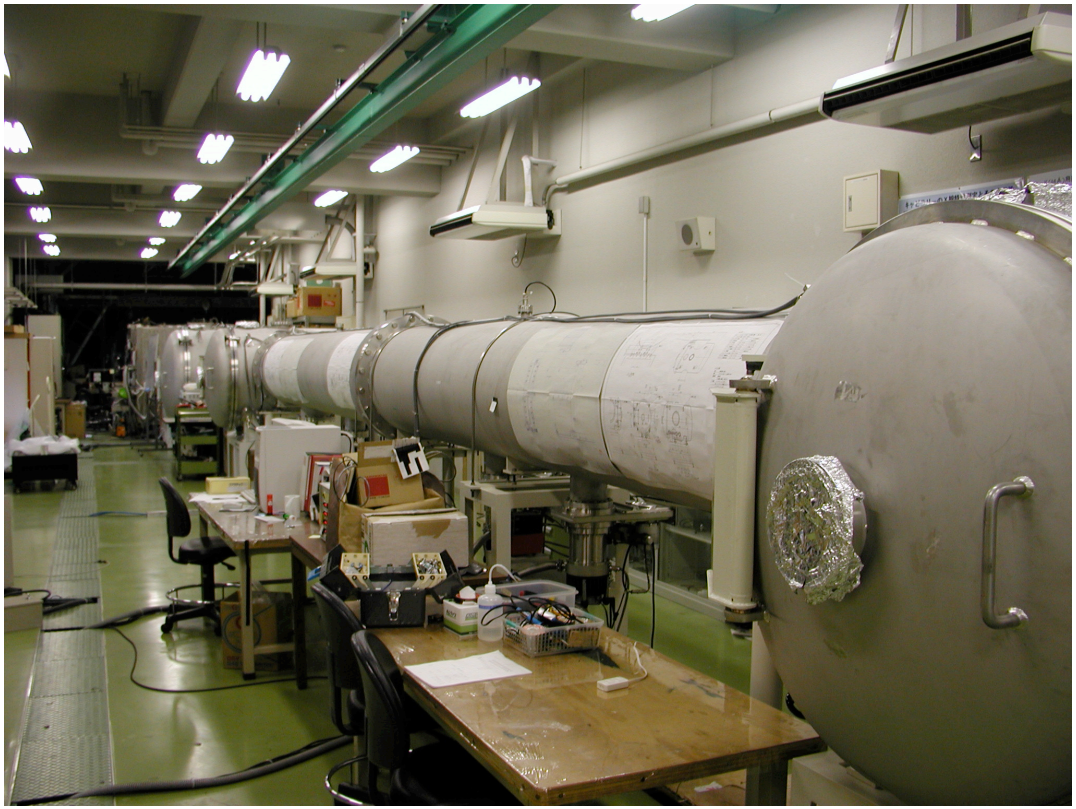
Quadrant construction: 4- fold symmetry in image

On ground, slight resolution dependence on orientation: displacement & gravity sag

Basic parameters of XRT

	Astro-E2 XRT-I	**Astro-E2 XRT-S**	**ASCA**
Number of telescope	4	1	4
Focal length	4.75 m	4.5 m	3.5 m
Inner Diameter	118 mm	119 mm	120 mm
Outer Diameter	399 mm	400 mm	345 mm
Height	279 mm	279 mm	
Mass/Telescope	19.5 kg	18.5 kg	9.8 kg
Number of nested shells	175	168	120
Reflectors/Telescope	1400	1344	960
Geometric area/Telescope	873 cm^2	887 cm^2	558 cm^2
Reflecting surface	Gold	Gold	Gold
Substrate material	Aluminum	Aluminum	Aluminum
Substrate thickness	155 μm	155 μm	127 μm
Reflector slant height	101.6 mm	101.6 mm	101.6 mm

XRT Characterization from ISAS Measurements

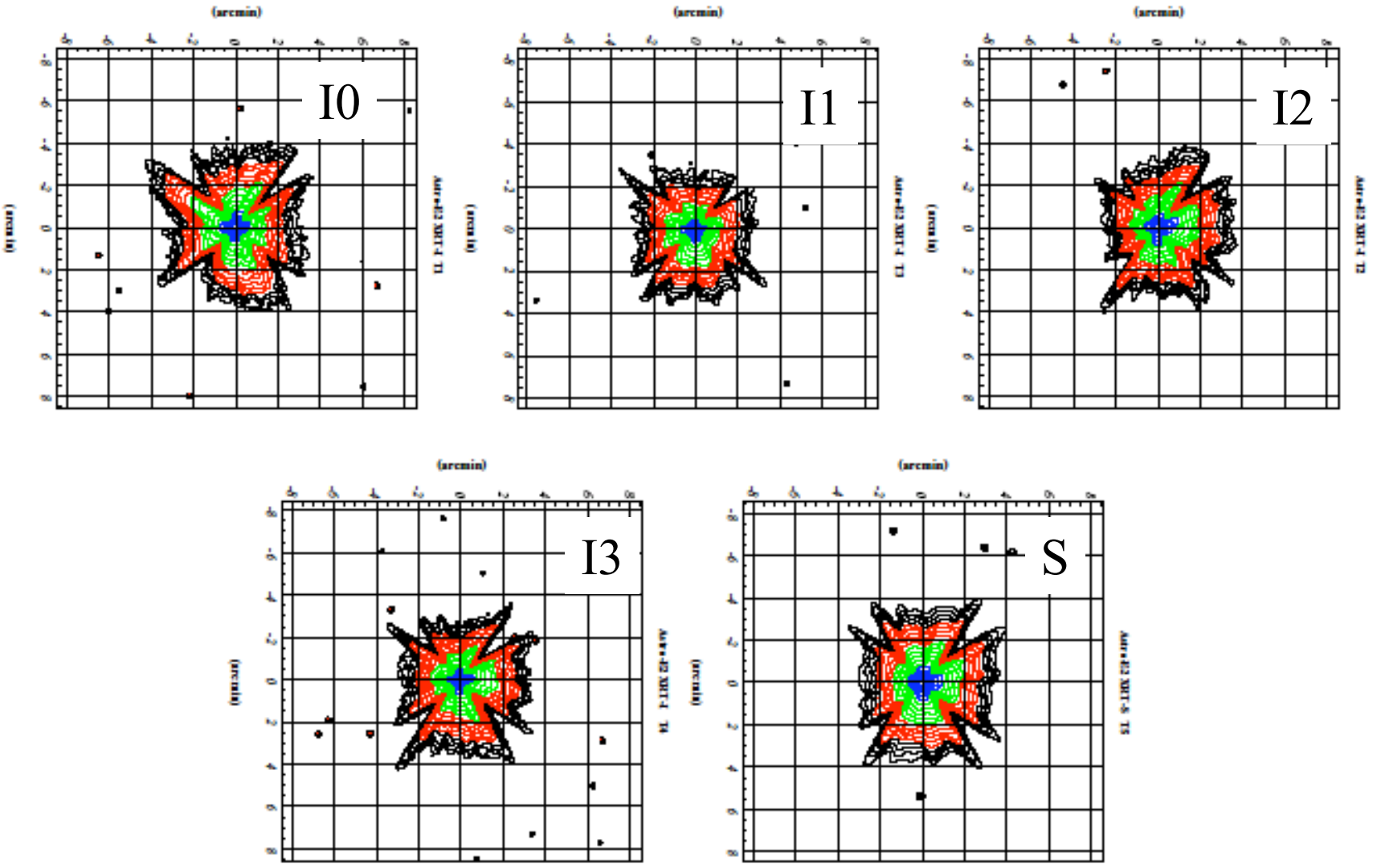


ISAS 30 m pencil beam

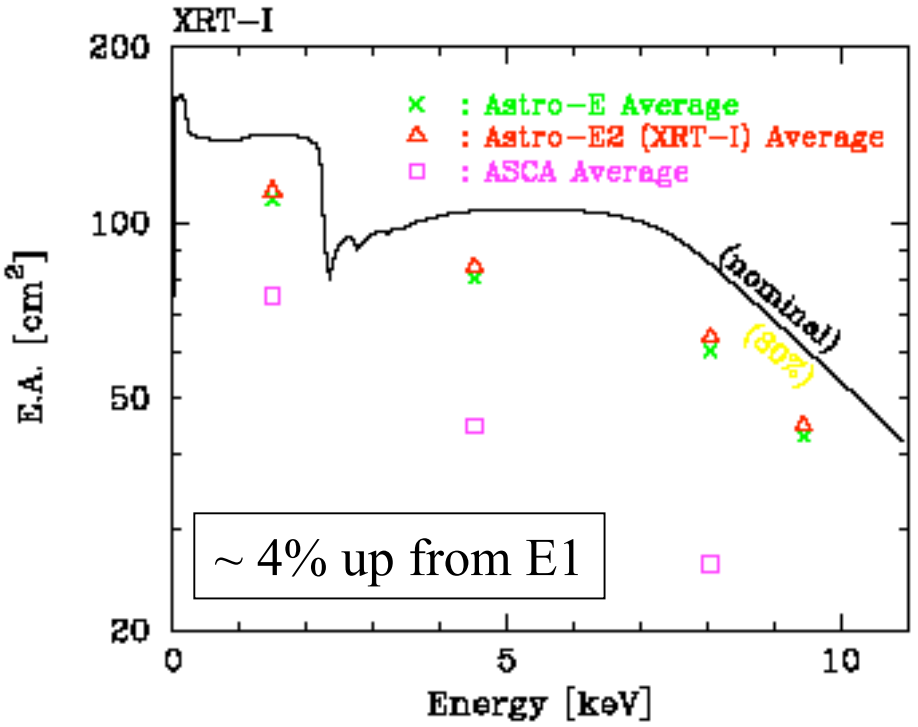
- ISAS pencil beam
- Full illumination

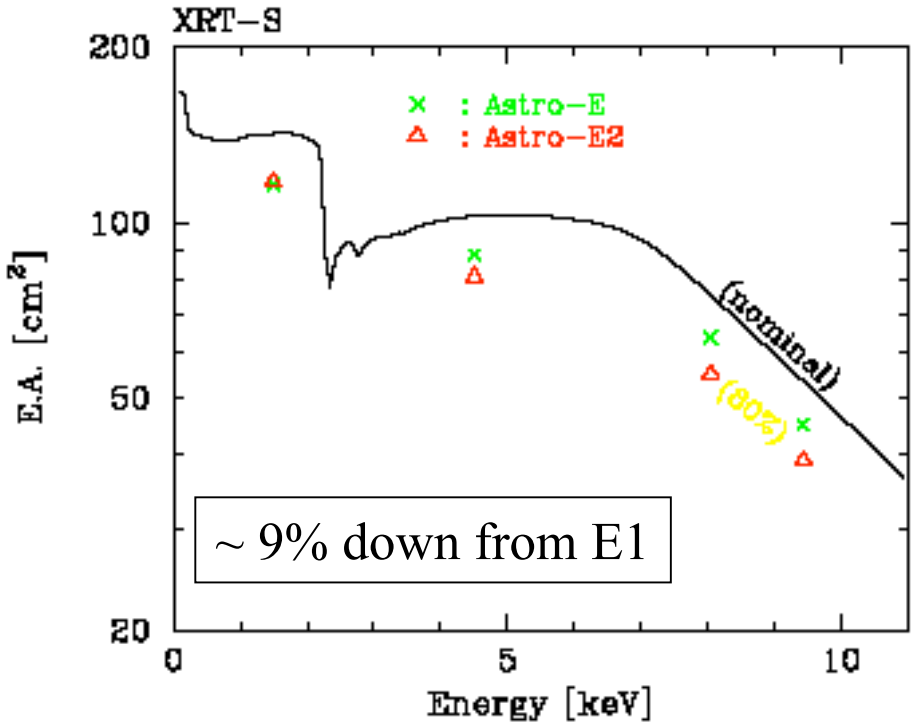
Data from JAXA/ISAS
Y.Maeda

Full XRT Images



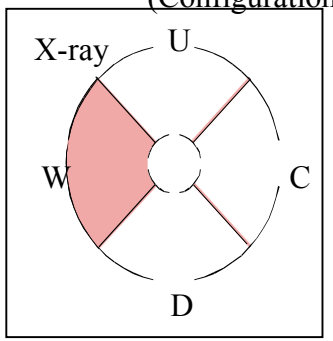
Effective Area





Full Telescope Effective Area at 4.51 keV:
XRT-I: I0-I3: 340 / 334 / 331 / 335 cm^2
XRT-I average 335 cm^2
XRT-S: 332 cm^2

(Configuration)

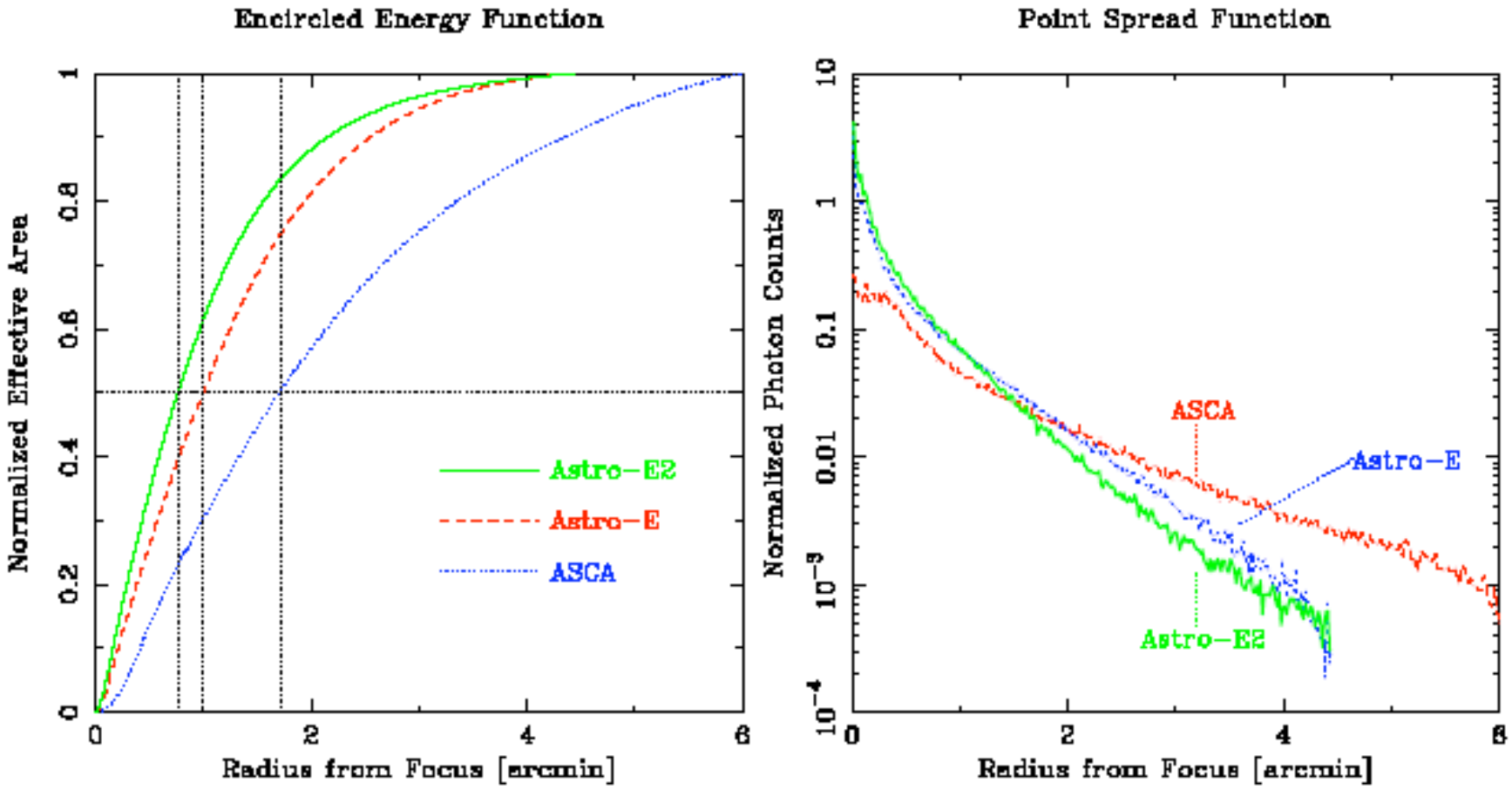


Effective Areas

- Rough numbers, for each XRT
  - ~ 450 cm^2 at 1.5 keV
  - ~ 335 cm^2 at 4.5 keV
  - ~ 245 cm^2 at 8.0 keV (smaller ~ 90% for XRT-S at higher E)
  - ~ 175 cm^2 at 9.4 keV
- Au M edge at ~ 2 keV
- Efficiency slight improved (a few %) from Astro-E1
- For XRT-S, difference is mainly due to Pt → Au
  - Especially at higher energy due to larger critical angle of Pt

Angular Resolution

Point Spread and Encircled Energy Functions



Angular Resolution: HPD

Table 5: HPD of the images of the Quadrants and XRTs at 4.51 keV (W-side).

	XRT-I0(T1)	XRT-I1(T3)	XRT-I2(T2)	XRT-I3(T4)	XRT-S(T5)
Q1	1.91	1.88	1.95	1.70	1.91
Q2	1.70	2.05	1.98	1.77	1.69
Q3	1.91	1.56	1.60	1.91	1.83
Q4	1.81	1.67	2.05	2.15	1.79
Average	1.83	1.79	1.90	1.88	1.81

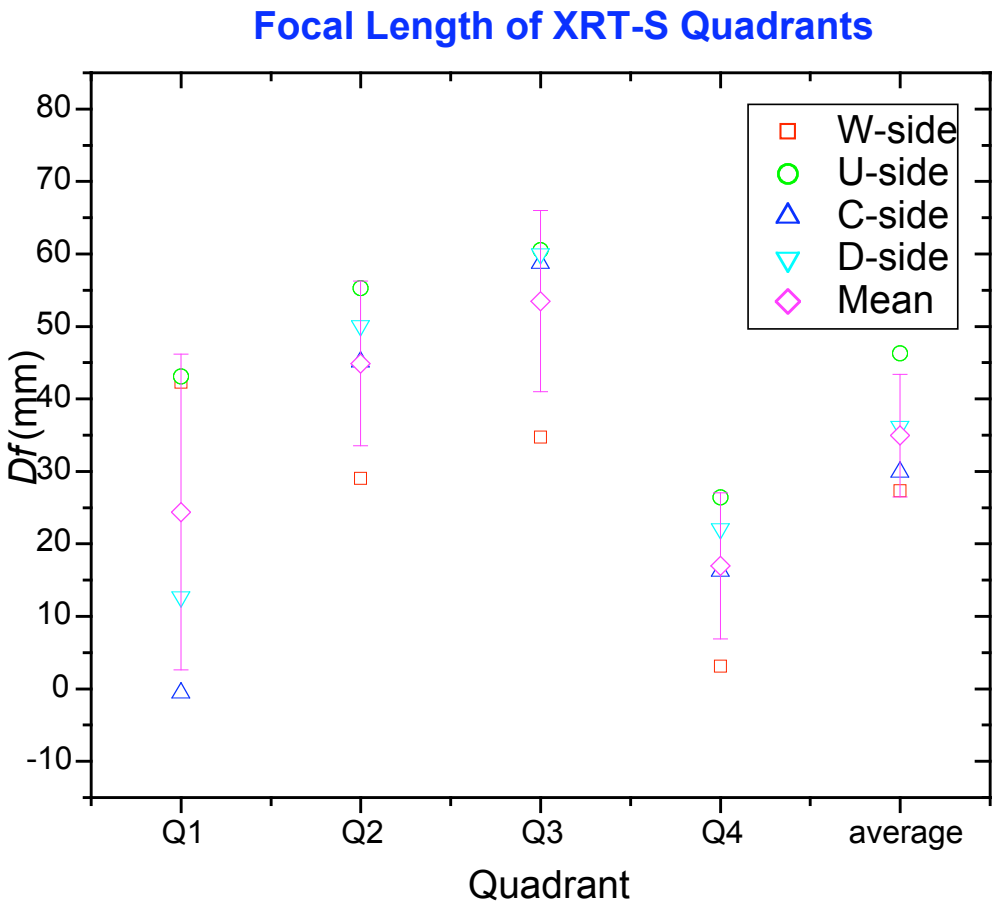
Angular Resolution

- Measured with Half-Power Diameter from Encircled Energy Function
- No dependence of angular resolution on energy
  - Indirect energy dependence on radial position of responsible reflectors
  - Errors in angular resolution (axial figure errors, positioning errors, etc.) are largely radius independent
- HPD ~1.8’
  - Focal length errors absorbed
- Sharp core: inner $r \sim 0.1$’: sharply rising (~ linear) EEF ; no flat PSD (c.f. ASCA mirrors)
- 90% encircled power within 4’ diameter

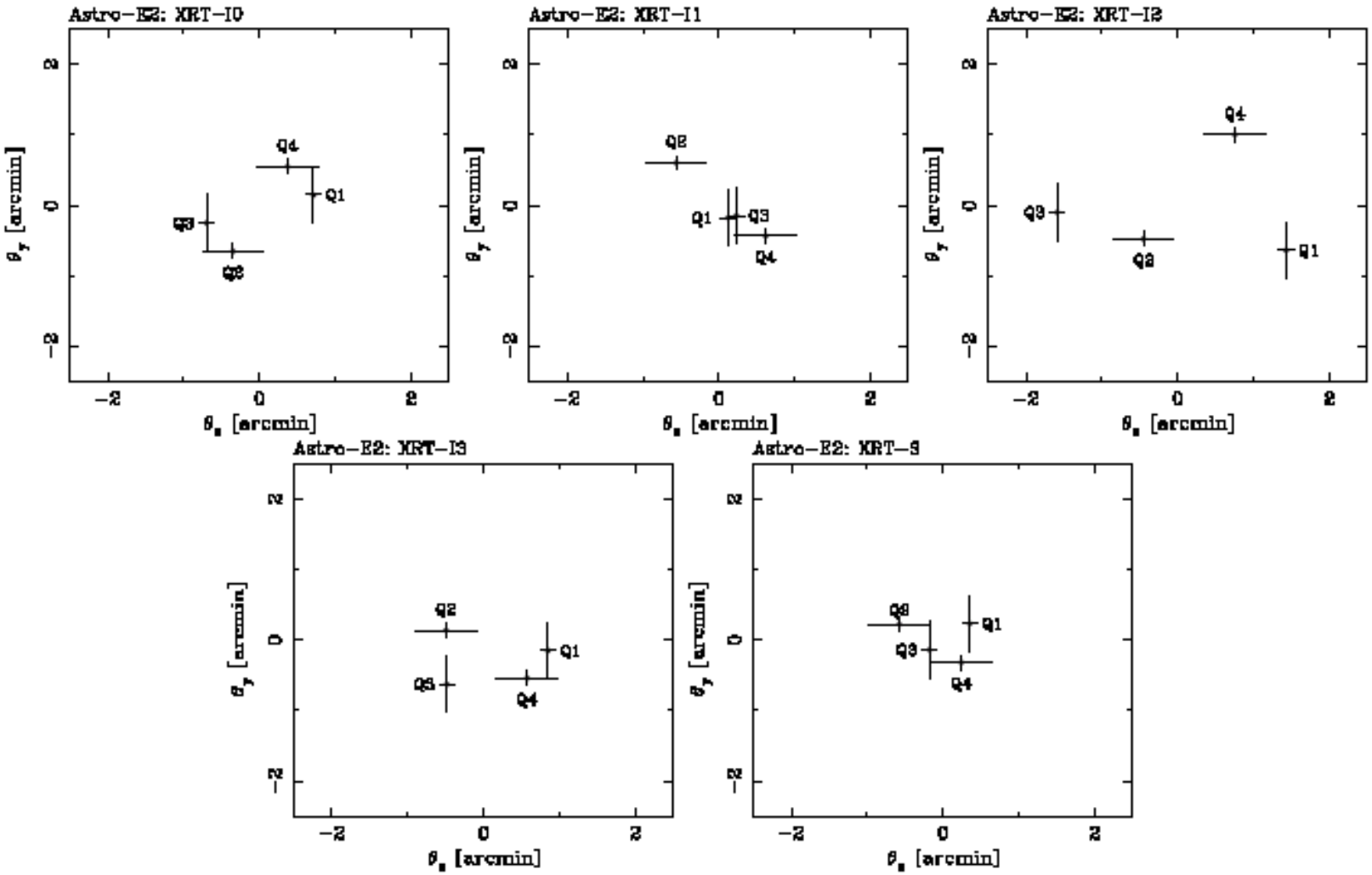
Focal Lengths & Orientation Dependence

- Focal Length variation
  - – as large as 50 mm
  - – all errors due to focal length deviation are absorbed (measurement done at nominal *f*)
- Dependence on orientation

Hope (optimistic) that resolution will be better in space:
– no displacement
– no gravity sag

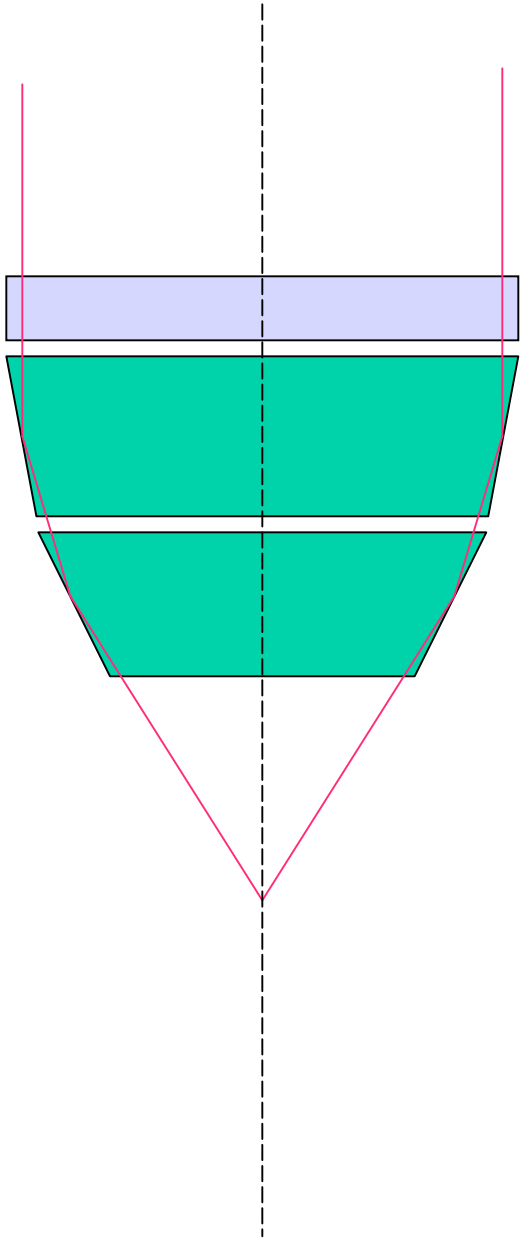


Optical Axes

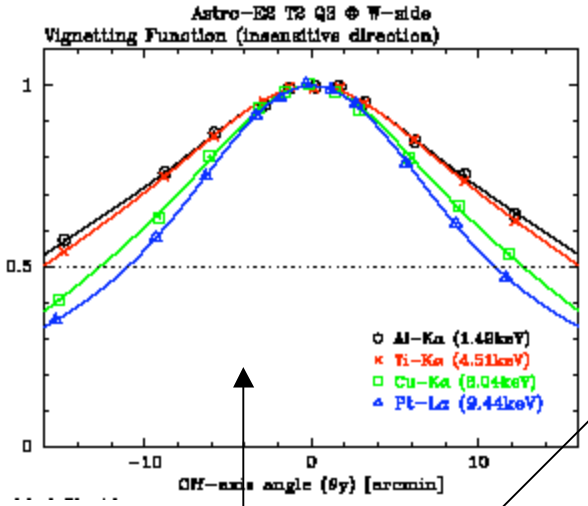


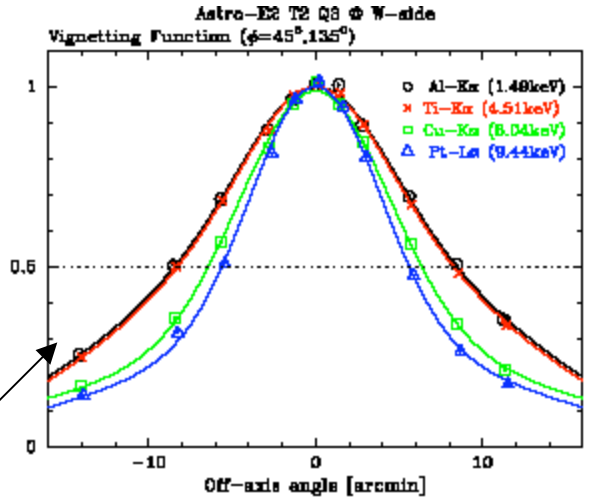
Optical Axis

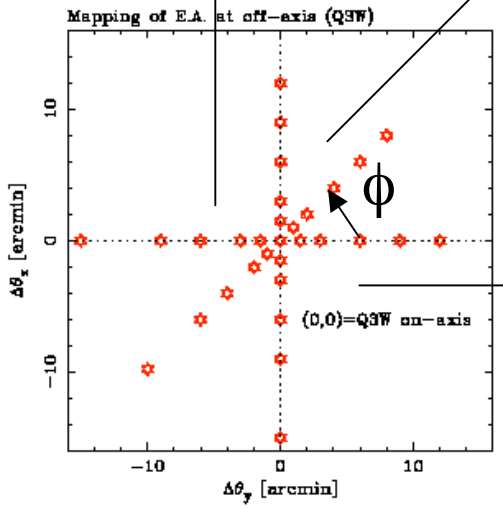
- Optical axes defined as the direction of maximum output
  - Not the bore sites (which are well sub-arc-minutes)
- Optical axes of quadrants are located within +/-1 arcmin from the nominal telescope axes
- Do not contribute to angular resolution (double reflection)
- Lower throughput by <~5% at 1 arc minute

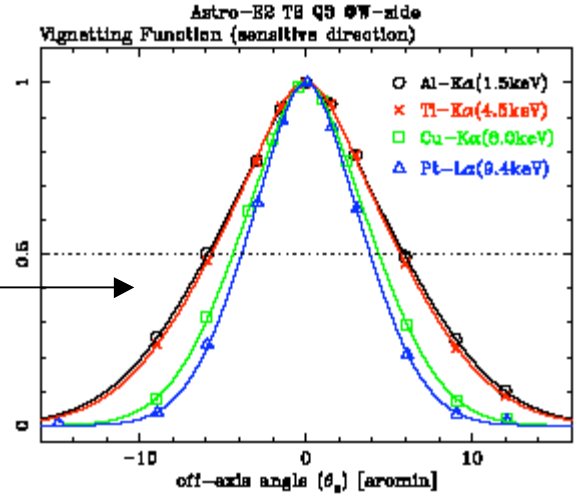


Field of View

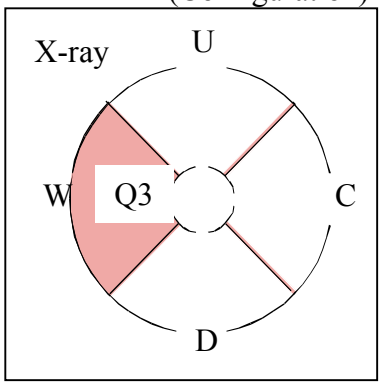








(Configuration)



F.O.V. (FWHM)
(XRT-I)

	0’	45’	90’
Al-K	12	17	36
Ti-K	12	17	32
Cu-K	9	13	26
Pt-L	8	12	22

(arcmin.)

FOV of full XRT at 4.51 keV

XRT	I0(T1)	I1(T3)	I2(T2)	I3(T4)	S(T5)
FWHM(arcmin)	19.7	19.6	19.8	19.6	18.0

Field of View

- Collimator limits stray light, but not significantly restricts the aperture
- Full XRT Field of View ~ 20’ at 4.5 keV
- Energy dependence via radial dependence of responsible reflectors
  - Smaller FOV for higher energy x-ray (smaller critical angle of reflection)

Parameters for the Pre-collimator

	XRT-I	**XRT-S**
Number of Collimators	4	1
Height	32 mm	32 mm
Blade substrate	Aluminum	Aluminum
Blade Thickness	120 μm	120 μm
Blade Height	22 mm	22 mm
Height from Blade Top to Reflector Top	30 mm	30 mm
Number of nested shells	175	168
Blade/Telescope	700	672
Mass/Collimator	2.7 kg	2.7 kg

Satellite Alignment

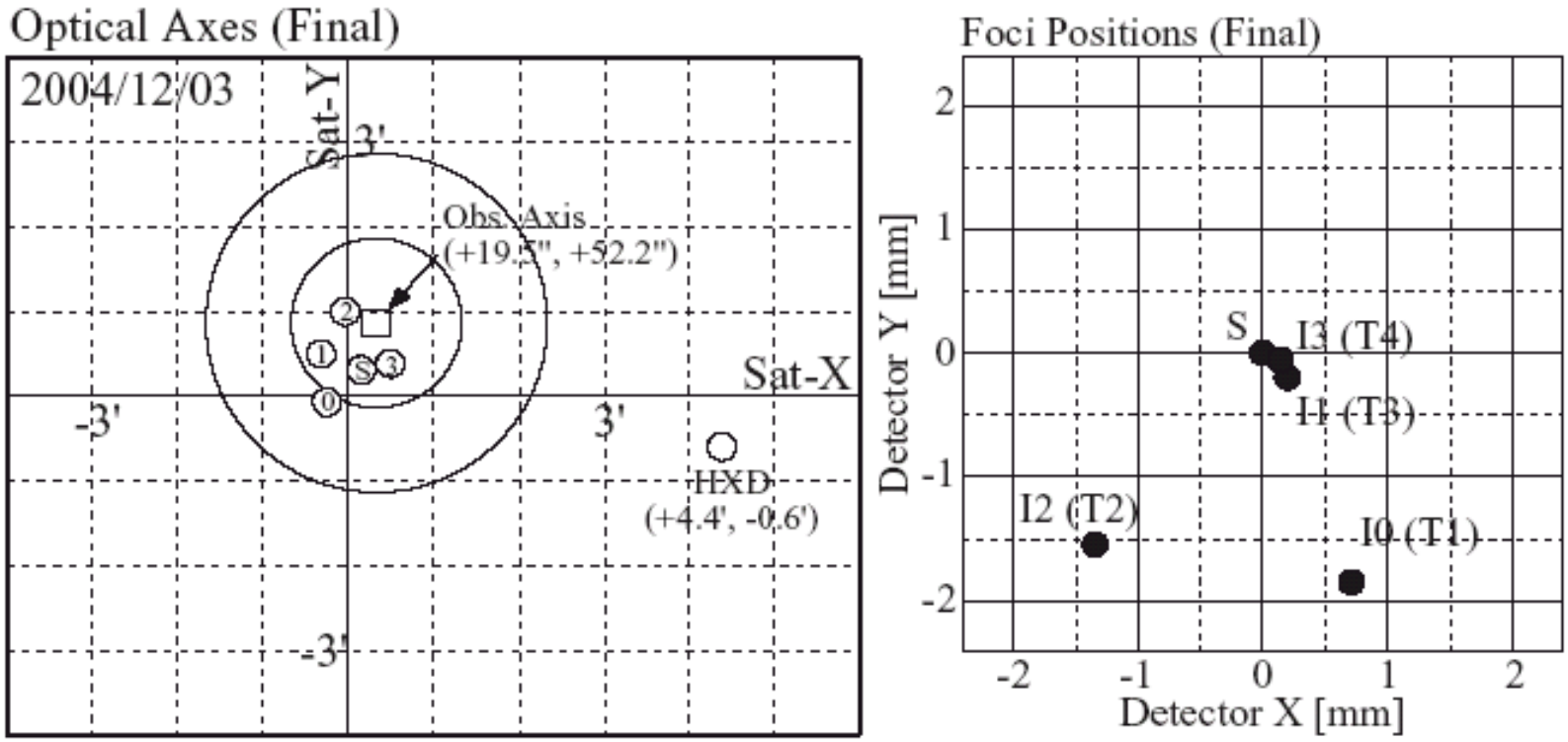


Figure 27: *Left*: The resultant final optical axes of all the XRTs, as well as the observation axis. The angular distance between the observation and optical axes of the XRT-S is 35″, and that of the XRT-Is is in the range 23″– 66″, both of which are well within the alignment requirements (< 2′). Unfortunately, however, the maximum transmission axis of the HXD fine collimator is separated from the observation axis by ∼ 4′. See the HXD chapger for more detail. *Right*: Foci positions of X-rays from the direction of the observation axis, measured from each detector center.