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59

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THE SOFT X-RAY TELESCOPE FOR SOLAR-A

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ABSTRACT

The *Solar-A* satellite being prepared by the Institute for Space and Astronautical Sciences (ISAS) in Japan is dedicated to high energy observations of solar flares. In collaboration with investigators at the National Astronomical Observatory of Japan (NAOJ) and the Institute for Astronomy of the University of Tokyo, we are preparing the Soft X-Ray Telescope (SXT) to provide filtered images in the 2 to 60Å interval. Prof. T. Hirayama of NAOJ is the SXT principal investigator.

The flight model is now undergoing tests in the 1000 foot tunnel at MSFC. Launch will be in September 1991. Earlier resolution and efficiency tests on the grazing incidence mirror have established its performance in soft x-rays. The unique one-piece, two mirror grazing incidence telescope is supported in a strain free mount separated from the focal plane assembly by a carbon-epoxy metering tube whose windings and filler are chosen to minimize thermal and hygroscopic effects. The CCD detector images both the x-ray and the concentric visible light aspect telescope. Optical filters provide images at 4308(fwhm30)Å and 4700(fwhm200)Å.

The SXT will be capable of producing over 8000 of the smallest partial frame images per day (64×64 pixels or 2.5×2.5 arcmin), or fewer but larger images, up to 1024×1024 pixel images. Image sequences with two or more of the five x-ray analysis filters, with automatic exposure compensation to optimize the charge collection by the CCD detector, will be used to provide plasma diagnostics. Calculations using a differential emission measure code were used to optimize filter selection over the range of emission measure variations and to avoid redundancy, but the filters were chosen primarily to give ratios that are monotonic in plasma temperature. Practical exposure times and counting statistics were included in the selection process.

Science planning in collaboration with NOAJ, U.Tokyo, ISAS,and US co-investigators at UC Berkeley, Stanford, and U of Hawaii has been underway for two years, and detailed plans for organization of data acquisition and eventual archiving are being developed. The LPARL work is supported by NASA under contract NAS8-37334.

Objectives of SXT Science

- Magnetic Structures and energy release
- Location of Particle acceleration and precipitation regions
- Electron Beams and heating of low atmosphere by energetic particles
- Superhot thermal plasma
- Plasma and magnetic parameters during flare energy build up
- Waves and moving fronts in the corona
- Flare periodicity and hot spots
- Electrical current systems and flaring
- Explosive chromospheric evaporation
- Coronal holes, x-ray bright points and global magnetic evolution
- Helioseismology

INSTITUTIONS AND NAMES OF SXT AND SOLAR-A PARTICIPANTS

INSTRUMENT	ACRONYM	PRINCIPAL INVESTIGATOR
Hard X-Ray Imager	HXT	K. Kai NOAJ
Soft X-Ray Telescope	SXT	T. Hirayama, NOAJ L. Acton , LPARL
Wide Band Spectrometer	WBS	J. Nishimura NOAJ
Bragg x-tal Spectrometer	BCS	E. Hiei NOAJ L. Culhane, MSSL

SOFT X-RAY TELESCOPE TEAM

T. Hirayama, T. Sakurai, T. Watanabe, NAOJ, S. Tsuneta, U. of Tokyo
Y. Ogawara, ISAS

L.W. Acton, US Principal Investigator, Lockheed Palo Alto Research Lab.

M.E. Bruner, J.W.Lemen LPARL Coinvestigators

R. Canfield, U.Haw., P. Sturrock, Stanford, S. Kane, UC, Coinvestigators

Relation of Solar-A to Max-91

The Solar-A spacecraft will be operated by scientists at the Institute of Space and Astronautical Science at Sagamihara, near Tokyo, Japan. As a mission primarily devoted to the the study of high energy solar physics it is expected that the Solar-A team will choose to participate in most Max '91 and FLARES 22 campaigns. A scientist at ISAS will be designated to facilitate this coordination and it is anticipated that Solar-A x-ray images will be made available to the Boulder forecast center in support of coordinated observing.

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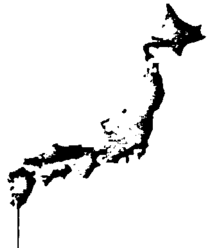
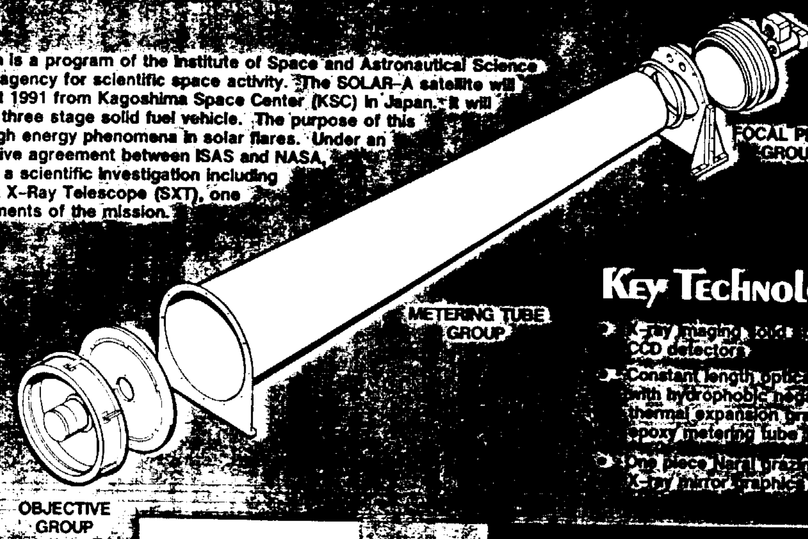
The Solar-A Soft X-Ray Telescope Program (SXT)

Launch Date August 1991



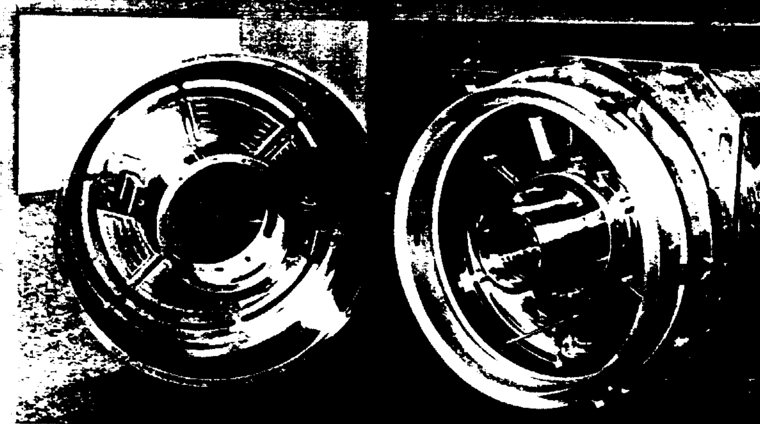
Overview

The SOLAR-A Mission is a program of the Institute of Space and Astronautical Science (ISAS), the Japanese agency for scientific space activity. The SOLAR-A satellite will be launched in August 1991 from Kagoshima Space Center (KSC) in Japan. It will be on board an M-3S three stage solid fuel vehicle. The purpose of this mission is to study high energy phenomena in solar flares. Under an international cooperative agreement between ISAS and NASA, Lockheed will provide a scientific investigation including manufacture of a Soft X-Ray Telescope (SXT), one of the primary experiments of the mission.



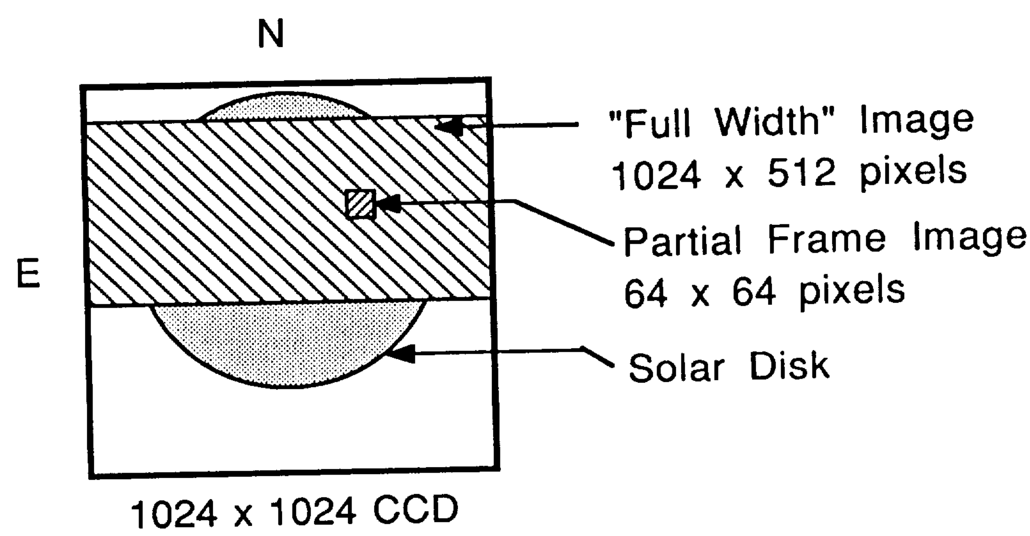
Key Technologies

- X-ray imaging [illegible] CCD detectors
- Constant length optical bench with hydrophobic negative thermal expansion graphite epoxy metering tube
- One piece [illegible] grazing X-ray mirror [illegible]



NASA — Lockheed Research & Development Divisions — SXT — National Astronomical Observatory of Japan — ISAS

SOLAR IMAGE ON SXT CCD



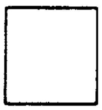
Arrangement of the solar image on the CCD. The partial frame image (64 x 64) pixels may be taken anywhere in the 1024 x 1024 pixel area while the full width image (1024 x 512 pixels) may be placed anywhere in the N-S direction.

SXT Image Parameters

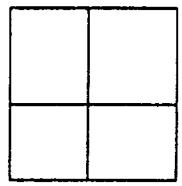
Type	No. Pixels	Pixel Sum	Field-of-View	Time resol.
FWI	1024 x 512	1 x 1	41.6' x 20.8'	256 s
	512 x 512	2 x 2	41.6' x 41.6'	128 s
	256 x 256	4 x 4	41.6' x 41.6'	32 s
PFI	64 x 64	1 x 1	2.6' x 2.6'	2 s
	64 x 64	2 x 2	5.2' x 5.2'	2 s
	64 x 64	4 x 4	10.4 ' x 10.4'	2 s

SXT IMAGE CADENCE

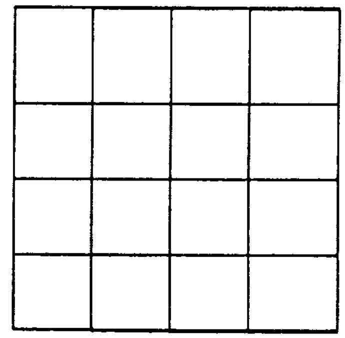
Valid Partial Frame Image Mosiacs:



64 × 64 pixels



128 × 128 pixels



256 × 256 pixels

Time (secs) to complete Partial Frame Images (64 × 64) and Mosaics

Image Size (arcmin)	Pixel Size (arcsec) 2.5	5	10
2.5 × 2.5	2/ 8/16	–	–
5 × 5	8/32/64	2/ 8/16	–
10 × 10	32/128/256	8/32/64	2/ 8/16

Time (secs) to complete Full Width Images (1024 × 512)

Image Size (arcmin)	Pixel Size (arcsec) 2.5	5	10
40 × 20	256/1024/2048	–	–
40 × 40	–	128/512/1024	32/128/256

(3 TELEMETRY RATES: 2048/512/256 PIXELS/SEC)

SOLAR–A TELEMETRY AND DATA RATES

Telemetary Data Rate	32 Kbytes/s
Orbits per day	5*
Recorder Data Capacity	10.5 Mbytes
Total Daily Accumulated Data	52.5 Mbytes*
SXT partial frame images per day (64 × 64 pixels)	≥ 8000*
SXT full width images per day (1028 × 512 pixels)	≥ 5*

Quiet Mode Telemetry (60% SXT)

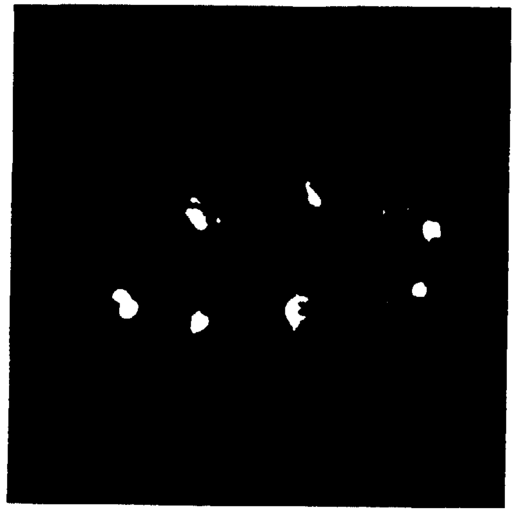
Basic Data	WBS	BCS	SXT 1	SXT 2

Flare Mode Telemetry (50% SXT)

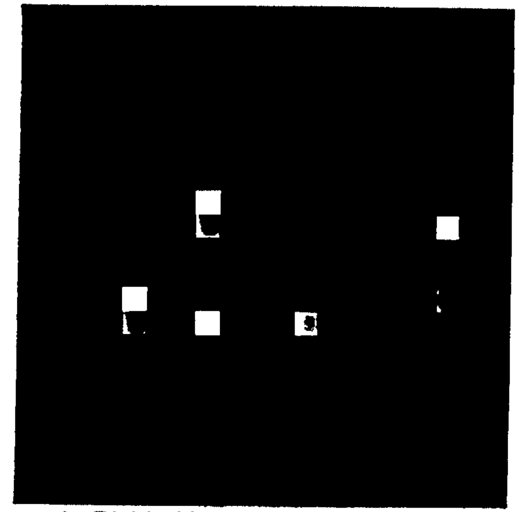
Basic Data	WBS	BCS	HXT	SXT

* If Deep Space Network available increase by factor of about 2

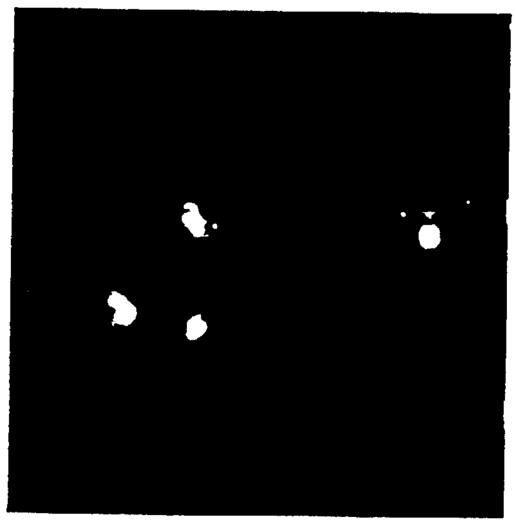
ILLUSTRATION OF SXT SELECTION OF A REGION OF INTEREST (ROI)



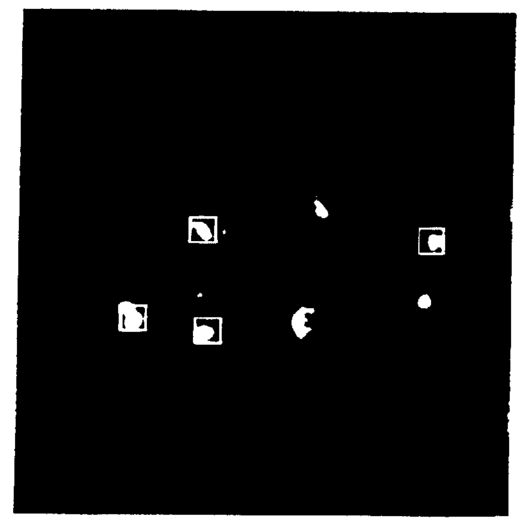
a. Original Image. Skylab x-ray image from S056 telescope.



b. Divided into zones representing 64x64 SXT pixels



c. Automatic selection algorithm chooses 4 brightest locations.



d. Original image with selected ROI's superimposed

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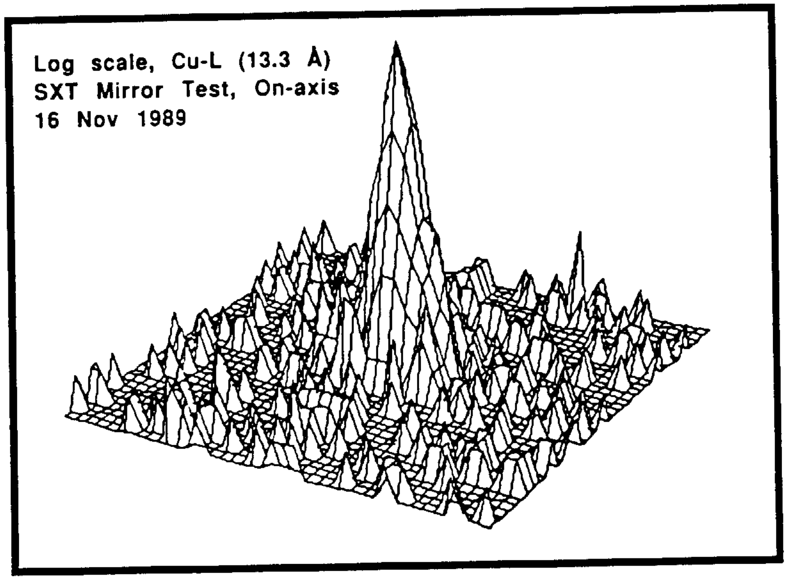
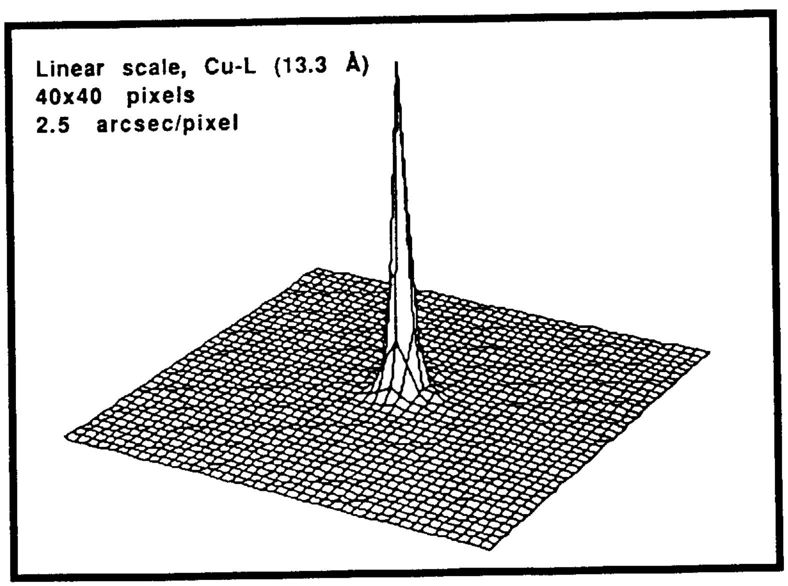
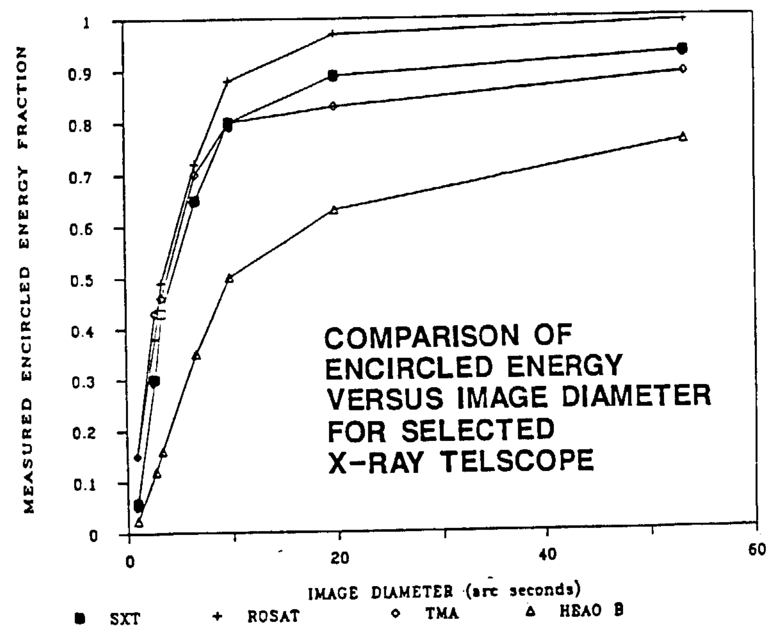
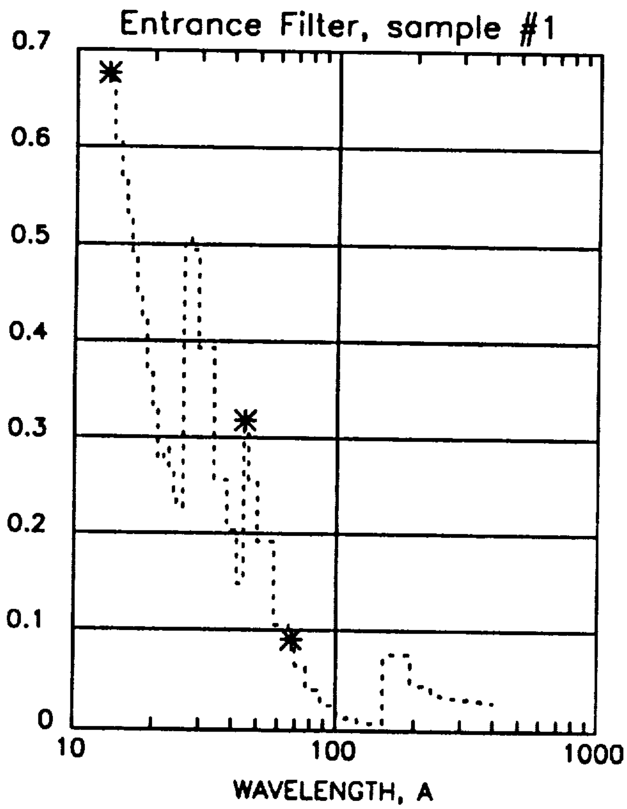
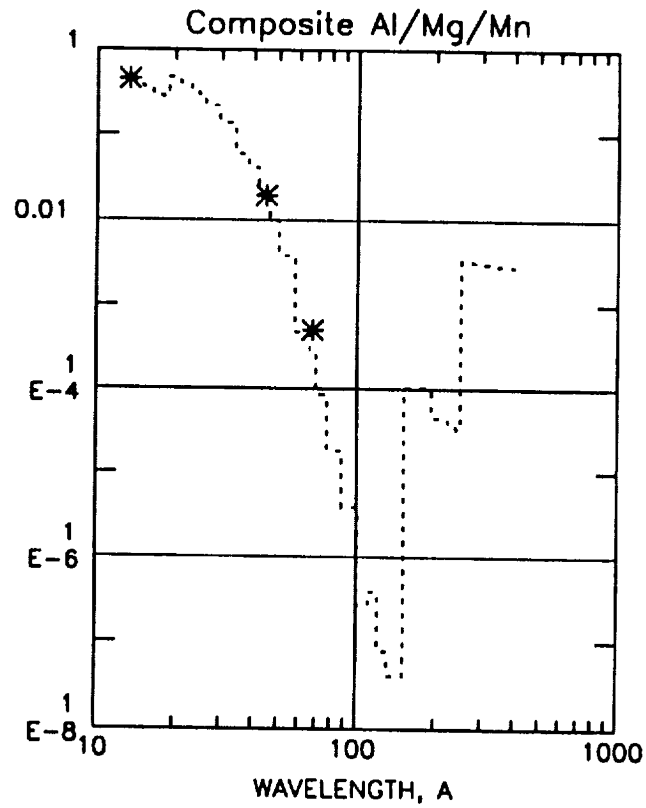


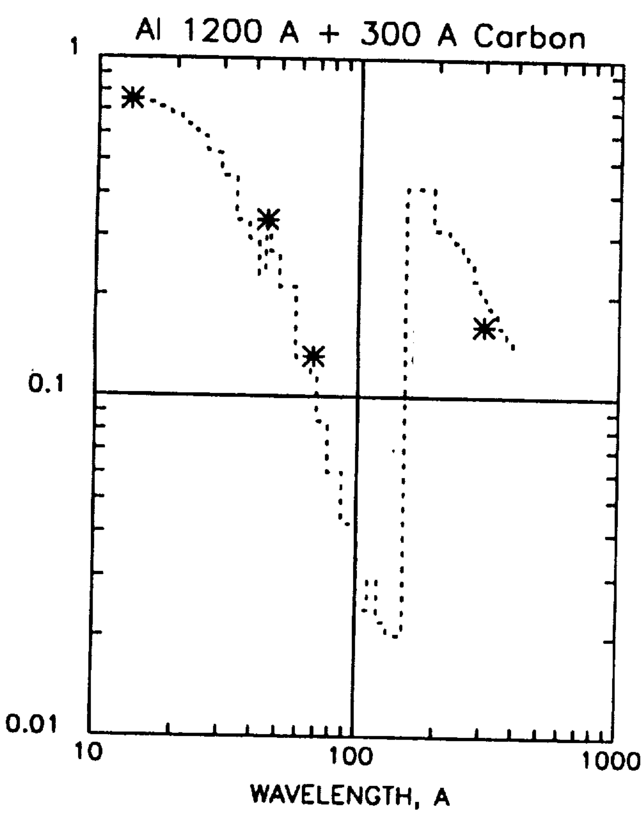




TEST OF POINT SPREAD FUNCTION OF THE X-RAY TELESCOPE. THE PLOTS SHOW LOG AND LINEAR SIGNALS COLLECTED ON THE CCD PIXEL ARRAY AND THE ENCIRCLED ENERGY. THIS DATA TAKEN AT THE BEST FOCUS OBTAINED IN MSFC TUNNEL.







OBSERVED AND CALCULATED TRANSMISSIONS OF 3 SXT FILTERS

SXT Characteristics

X-RAY TELESCOPE:

Mirror Nariai-Werner Double Hyperboloid, Gold on Fused Quartz
Focal Length 154 cm
Thermal Filter 1800 A Lexan + 800 A Al + 900 A Titanium (Doubled)
Metering Tube Tapered epoxy-carbon fiber
Filter Wheels Two 6 position wheels in tandem
X-Ray Analysis Filters
1200 Angstrom Aluminum (2 each, one in each wheel)
3 micron Magnesium
Al/Mg/Mn 3000/2000/600 Angstrom DS
12 micron Aluminum
100 micron Beryllium

Detector CCD 1024x1024 18.3 micron pixels
Front illuminated virtual phase
Resolution< 4 arcseconds over sun's diameter
from geometric,diffraction, and mirror surface

ASPECT TELESCOPE:

Lens achromatic doublet with .008" spacing, consisting of radiation-resistant crown and flint spherical elements
Clear Aperture 50 mm
Focal Length Matched to X-ray mirror effec foc len to 0.2%
Filters
Entrance filter 4250-4800 A fwhm
Al attenuator layer, IR blocking substrate, dielectric films for out-of-band reflection, + dielectric passband filter 0.001 peak transmission to match X-ray responsivity
Narrow band filter Interference filter
30 A fwhm bandpass centered at 4308 A
CH bandhead, plage and active region sensitive
0.1 +/- 0.05 peak transmission
Wide band filter 200 A fwhm bandpass centered at 4700 A
Opal glass, flat field diffuser for radiometric calibratio

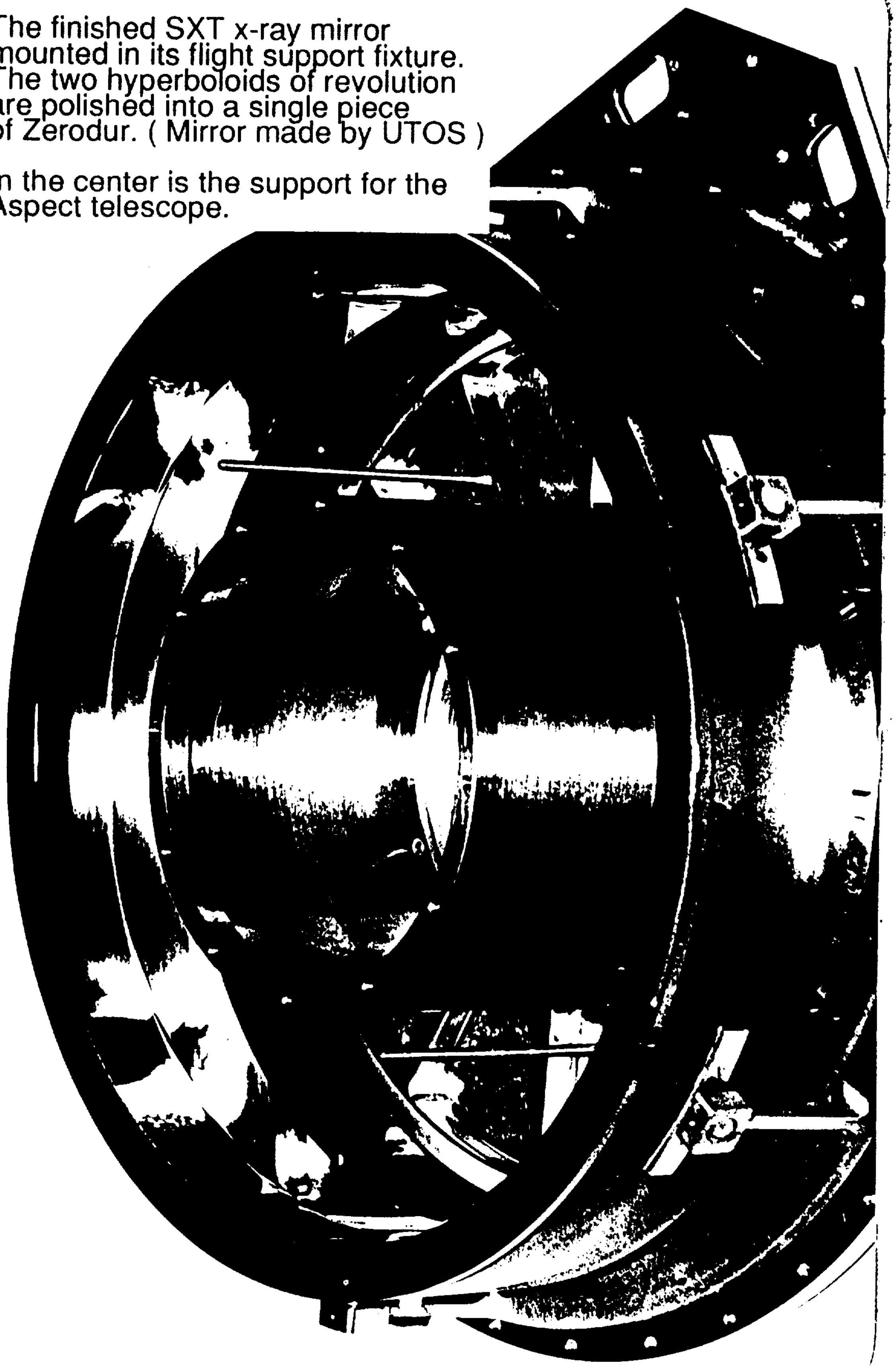
Detector Shares the same CCD as x-ray telescope

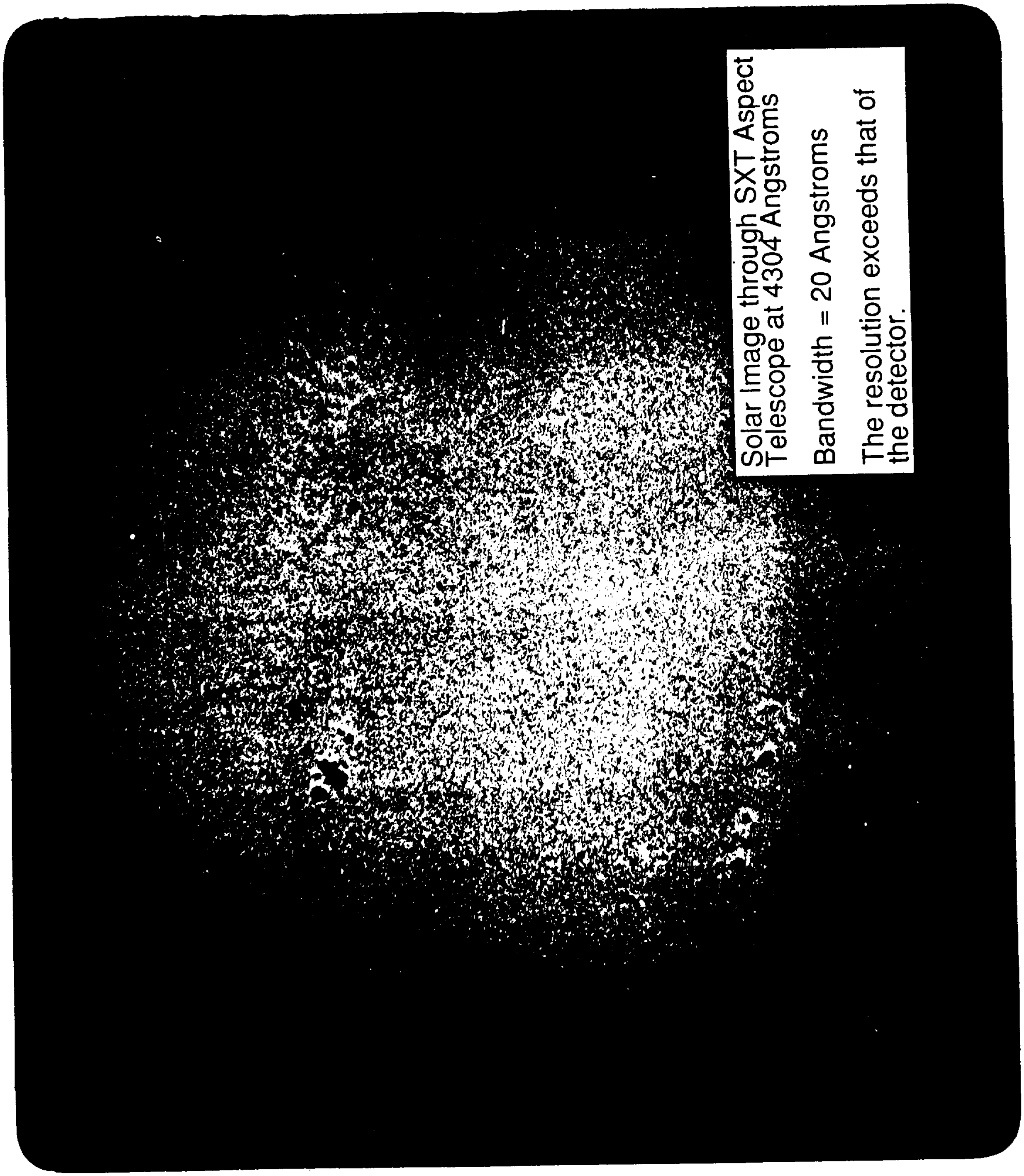
ACCOMODATION:

Weight 29 kg
Power 18 watt average 29 watts peak
Envelope 30 x 30 x 200 cm + Electronics Boxes

The finished SXT x-ray mirror mounted in its flight support fixture. The two hyperboloids of revolution are polished into a single piece of Zerodur. (Mirror made by UTOS)

In the center is the support for the Aspect telescope.





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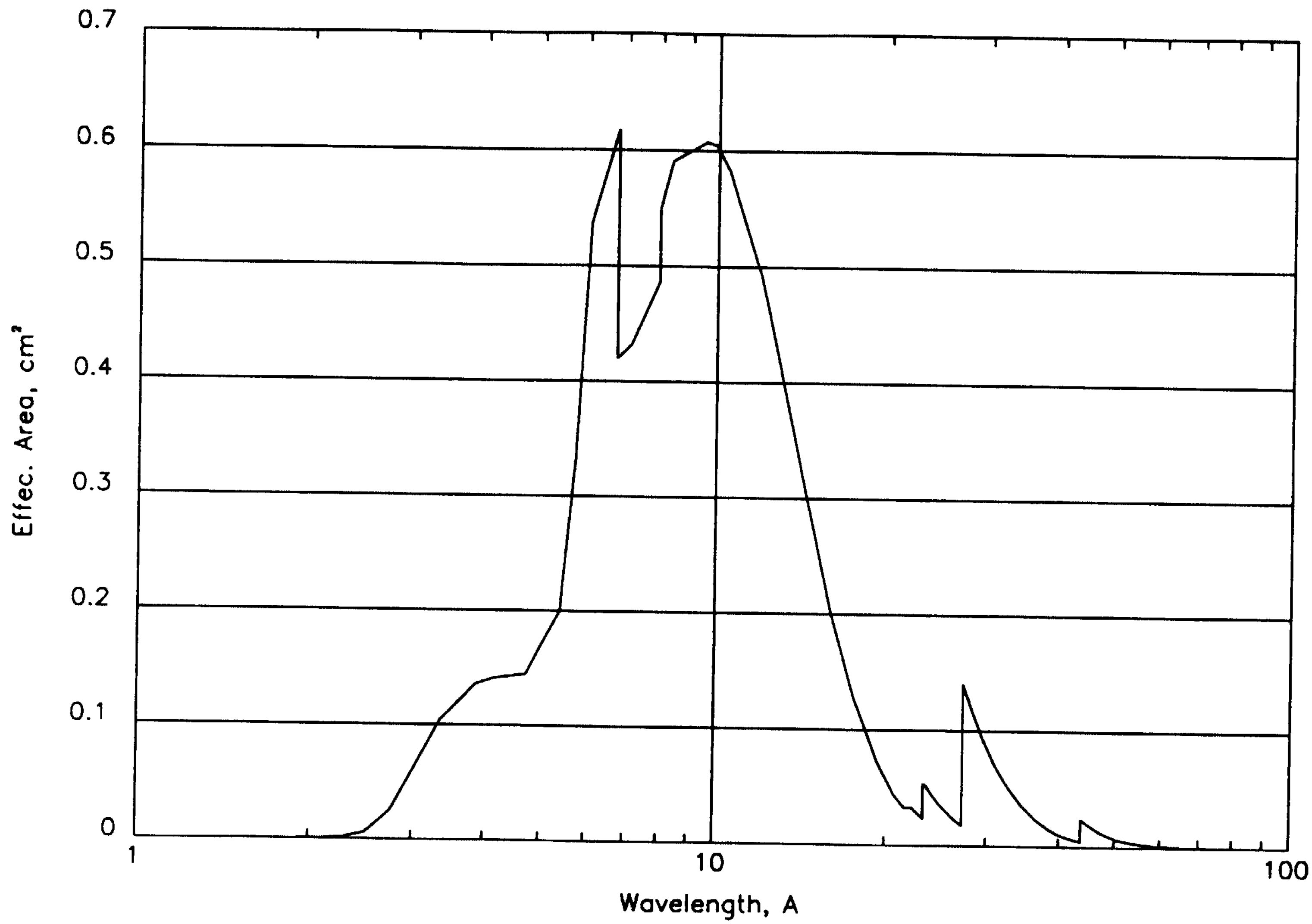
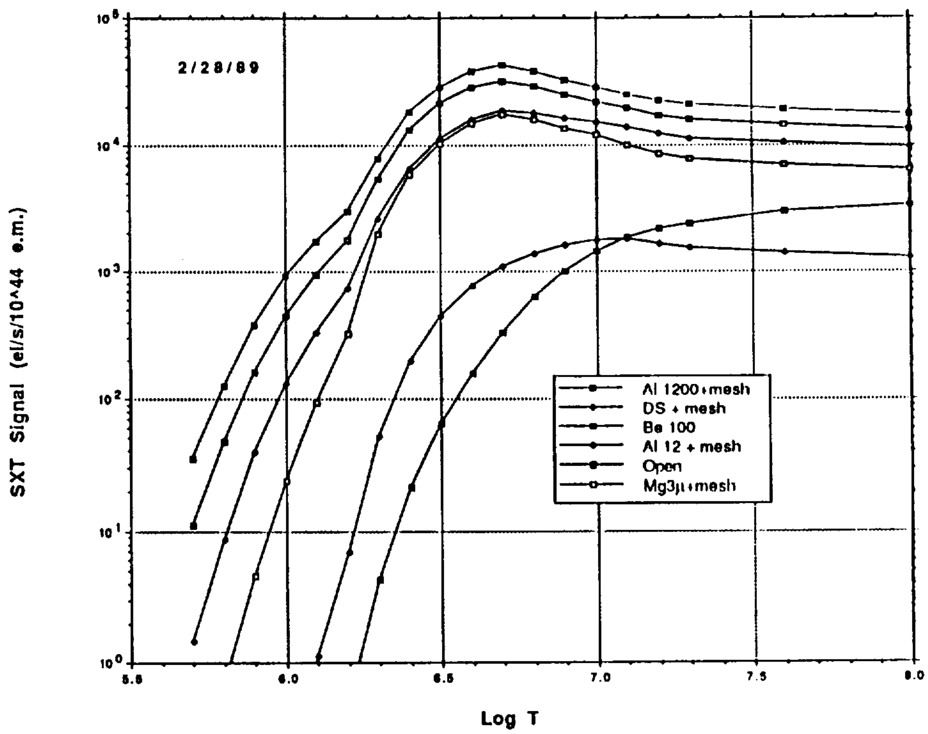
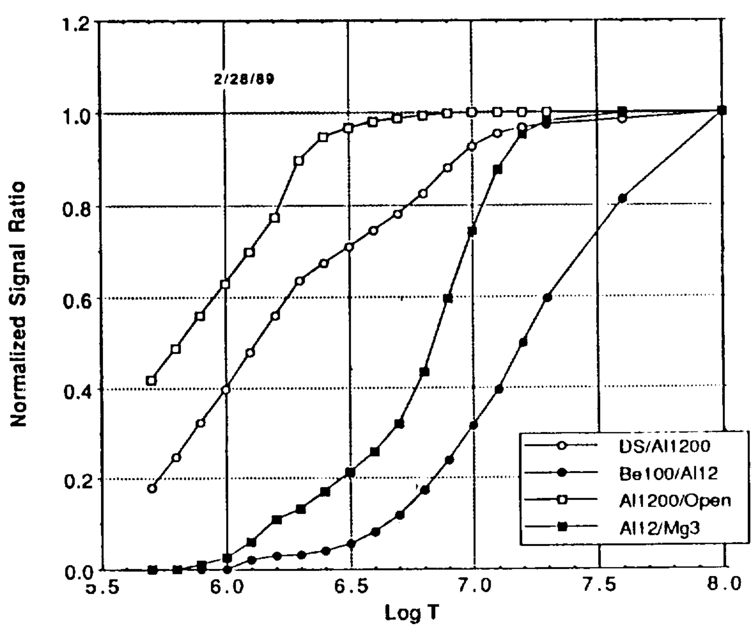


SXT Response Function including Mirror, Detector, and Entrance Filters

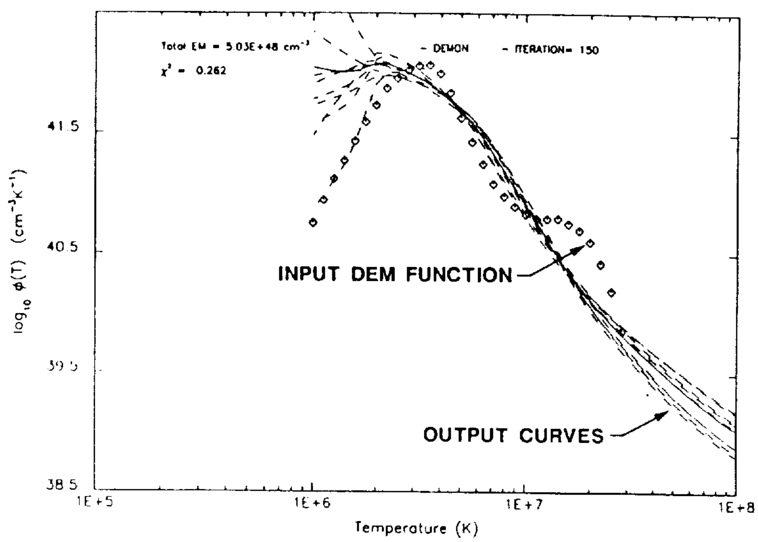
SXT SIGNALS FOR CONSTANT EMISSION MEASURE.



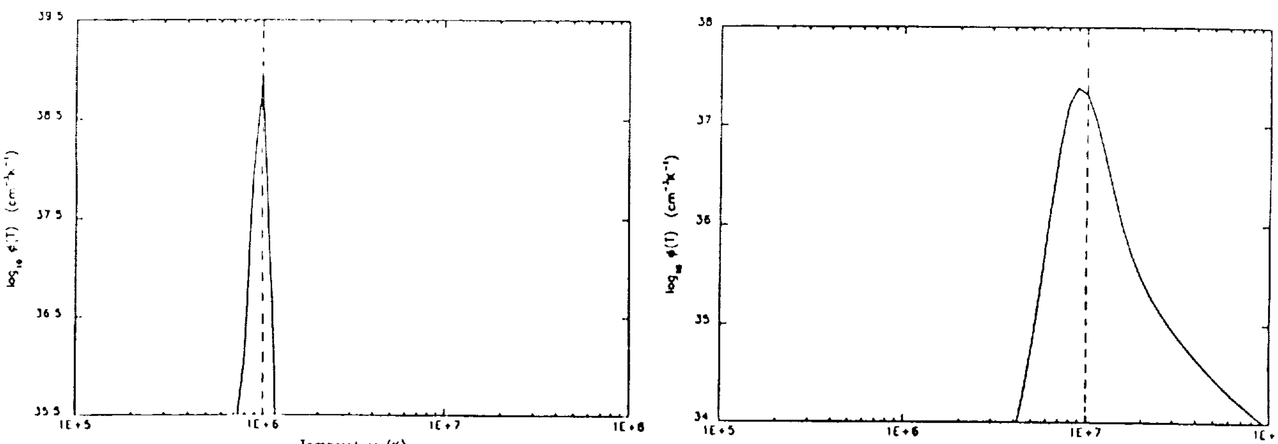
RATIOS OF SIGNALS ILLUSTRATING THE TEMPERATURE SENSITIVITY WITH FOUR PAIRS OF FILTERS



SIMULATIONS OF THE ABILITY OF THE SXT TO REPRODUCE A DIFFERENTIAL EMISSION MEASURE CURVE.



a. INPUT DEM CURVE INFERRED FROM SMM XRP DATA. VARYING PHOTON NOISE ADDED TO EACH DEMON RUN. NOTE THAT IN PRACTICE BCS DATA WILL BE USED TO IMPROVE HIGH ENERGY FIT.



b. INPUT ISOTHERMAL SPECTRA AT 1 AND 10 MILLION DEGREES. NO NOISE ADDED.