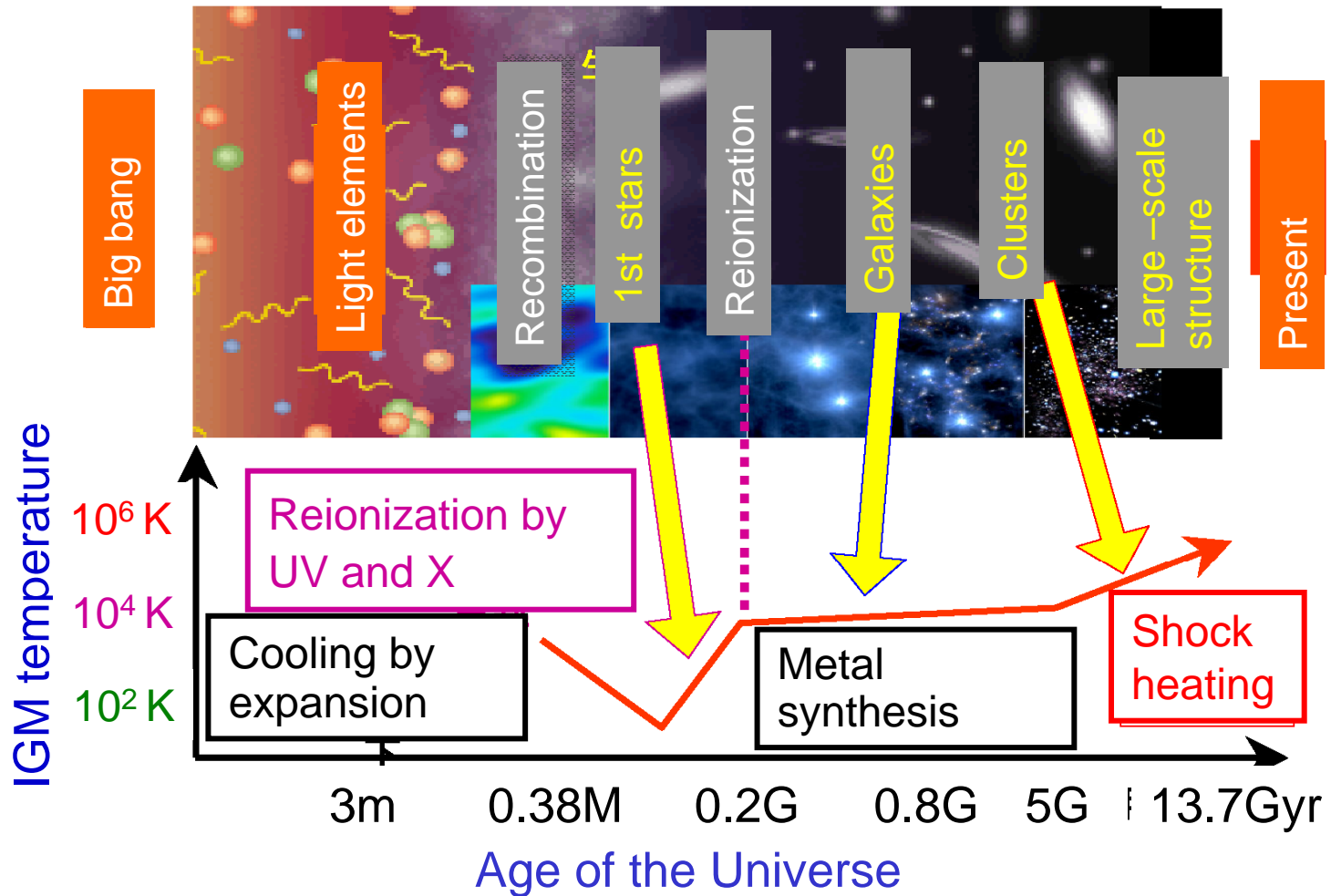


# DIOS: An X-ray mission to survey missing baryons

T. Ohashi, Y. Tawara, K. Mitsuda,  
N. Yamasaki and DIOS team

1. Dark baryons
2. DIOS satellite
3. Development and Schedule

# Thermal history of the universe



WHIM (warm-hot intergalactic medium) will tell us the evolution of the hot-phase material in the universe

# Cosmic structure

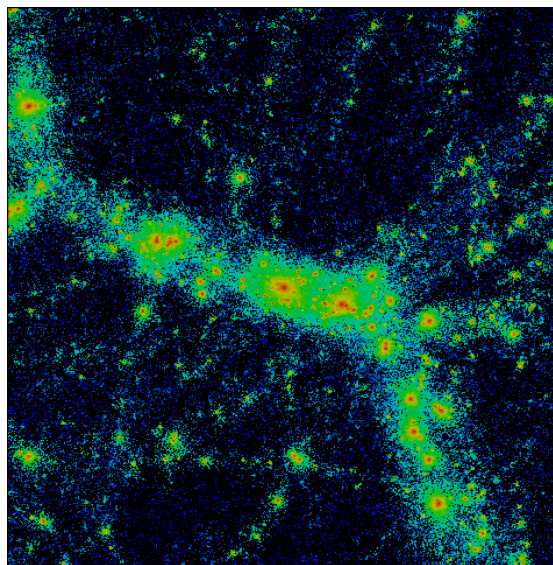
WHIM ( $10^5$ - $10^7$  K)  
traces the cosmic  
large-scale structure  
= “Missing baryon”

Typical matter density:  
 $\delta (=n/\langle n_B \rangle) = 10 - 100$

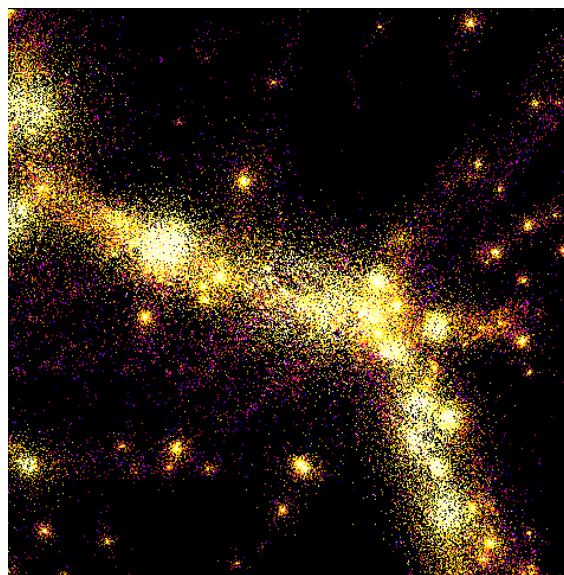
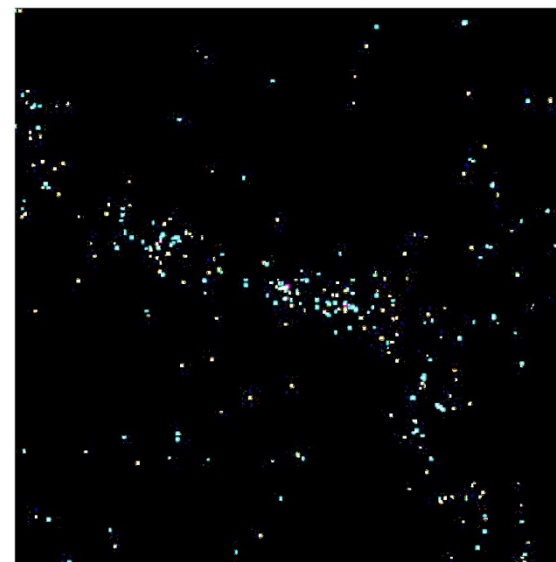
Yoshikawa et al. 2001,  
ApJ, 558, 520

size =  $30 h^{-1}$  Mpc  
 $\approx 5$  deg at  $z=0.1$

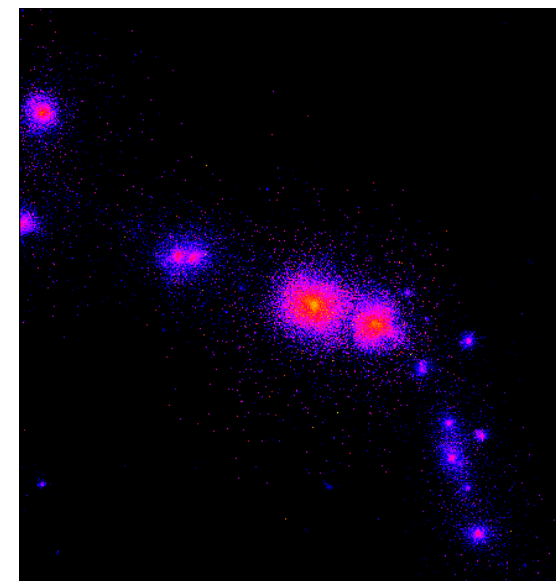
Dark matter



Galaxies ( $\sim 10^4$ K)



IGM ( $10^5$ - $10^7$ K)

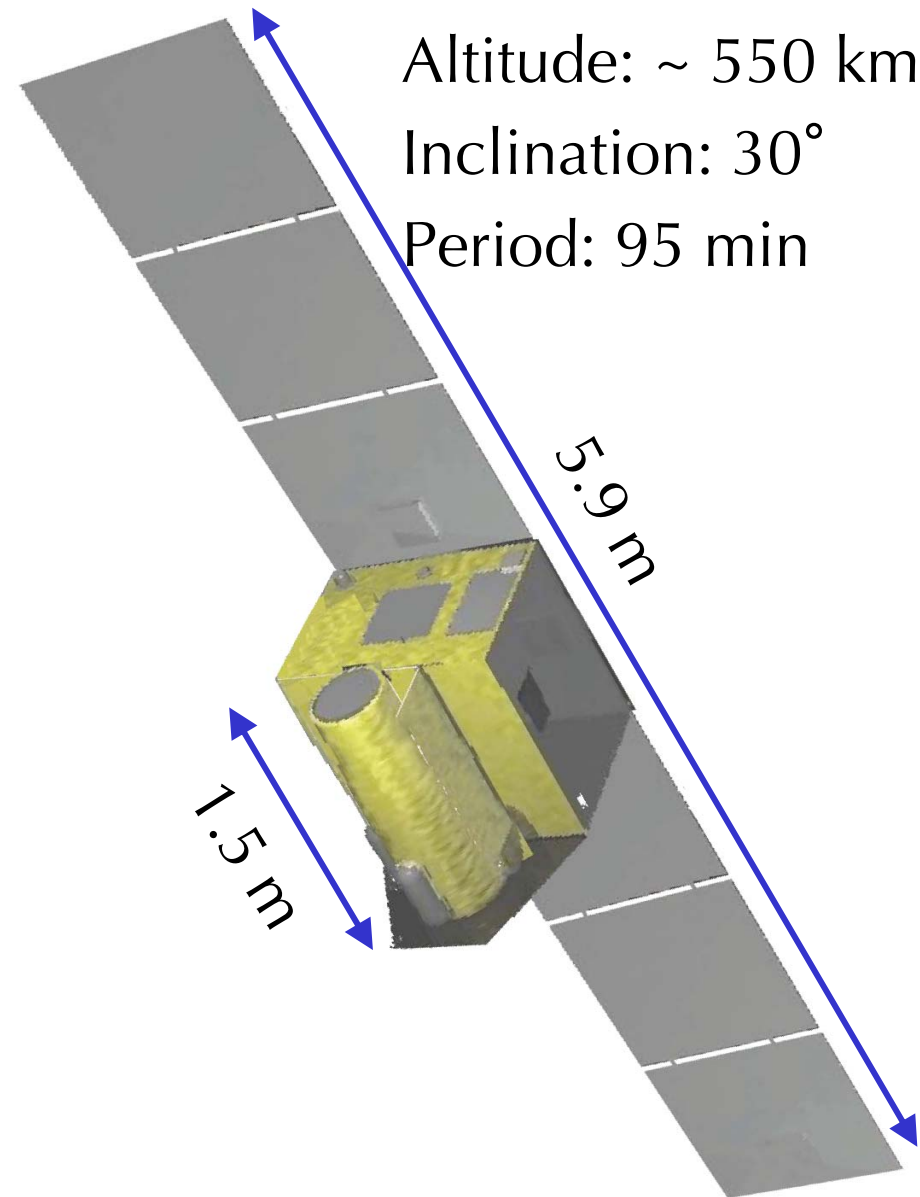


Cluster gas ( $10^7$ K)

# DIOS Spacecraft

- Launch Target ~2015  
(after Astro-H in 2013)
- Launch Vehicle  
JAXA's new solid rocket (2011~)

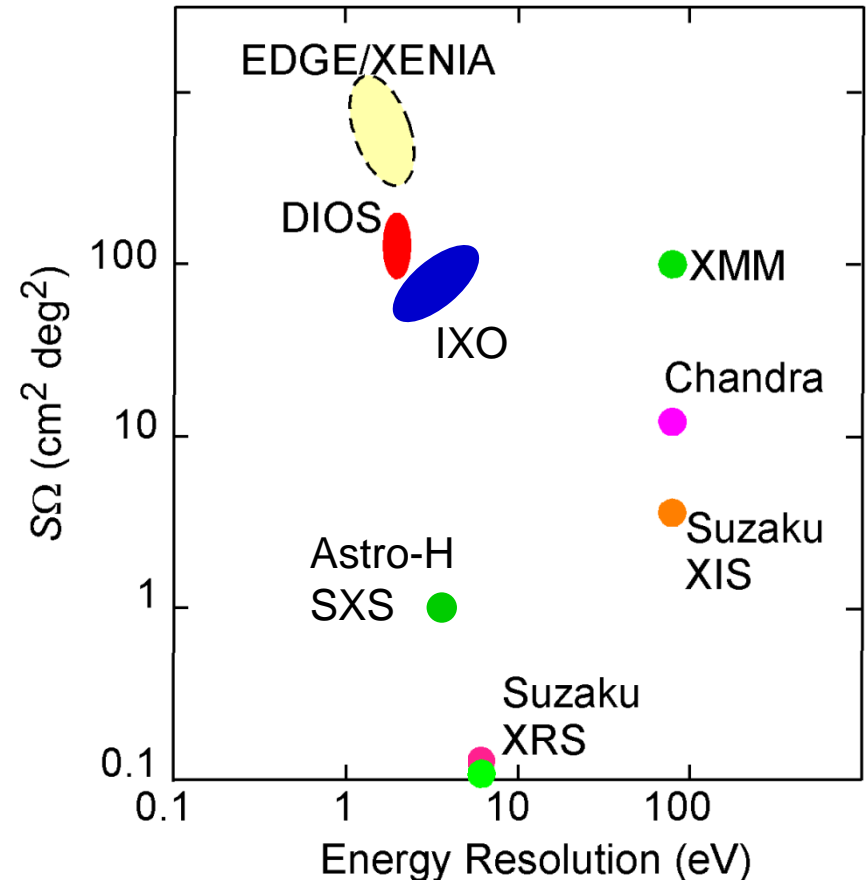
Weight	Total	~ 400 kg
	Payload	~ 200 kg
Size	Launch	1.2 × 1.45 × 1.4 m
	In orbit	5.9 × 1.45 × 1.4 m
Attitude	Control	3-axis
	Accuracy	≤ 30 arcsec
Power	Total	500 W
	Payload	300 W



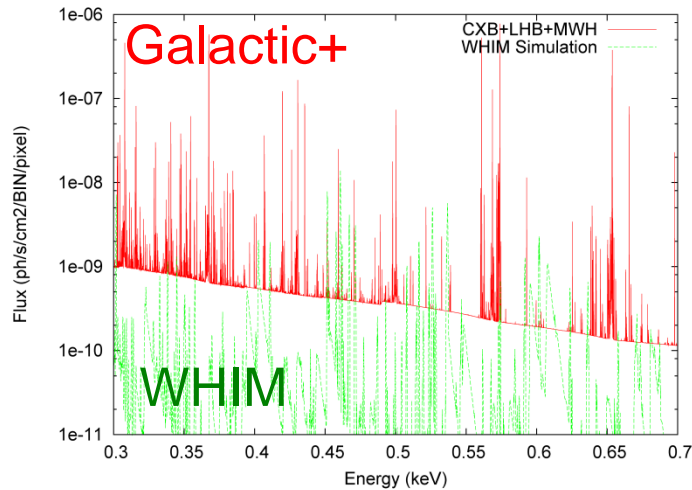
Incl. 20% contingency

# DIOS Performance

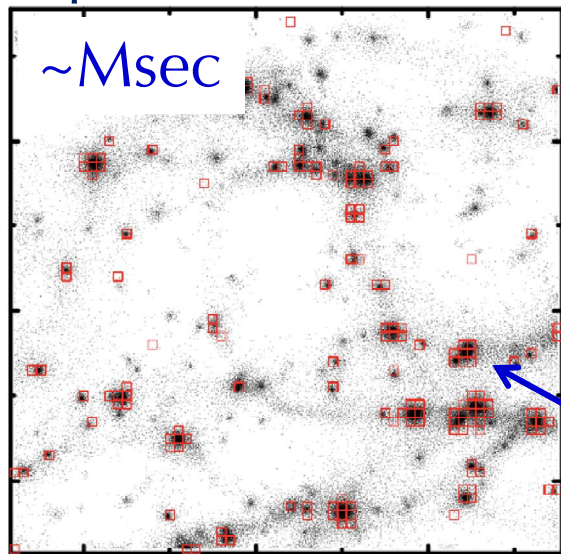
Effective area	$> 100 \text{ cm}^2$
Field of view	50' diameter
$S\Omega$	$> 100 \text{ cm}^2\text{deg}^2$
Angular resolution	3' (16 x 16 pix)
Energy resolution	2 eV (FWHM)
Energy range	0.3 – 1.5 keV
Mission life	$> 5 \text{ yr}$



## Incident spectrum



5 deg x 5 deg at  $z = 0.2$   
(60 Mpc)



# Expected results

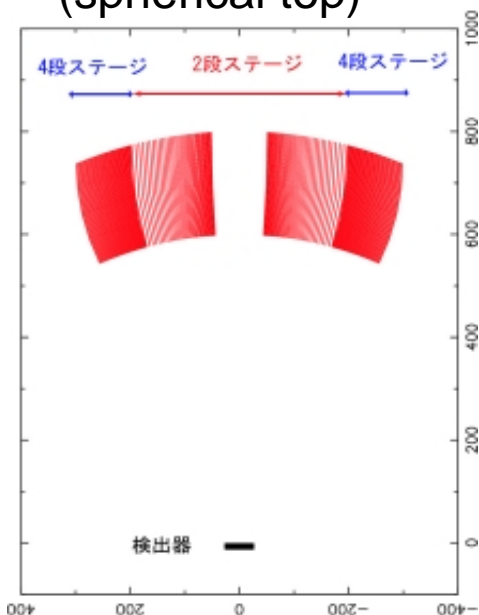
- $\geq$  Msec exposure with DIOS ( $S\Omega > 100 \text{ cm}^2 \text{ deg}^2$ ) gives significant detection of WHIM filaments
- Combined detection of OVII and OVIII lines suppresses spurious features
- Filaments tracing the large-scale structure can be detected

OVII & OVIII  $> 3\sigma$

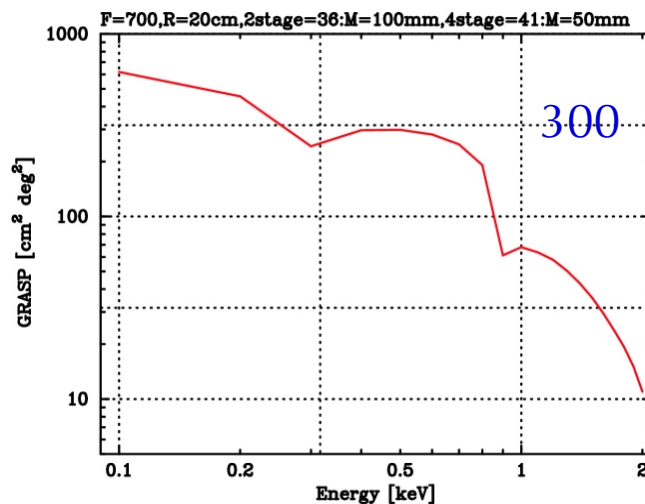
# X-ray optics for DIOS

## Walter I + 4 reflection: 2 and 4 reflection

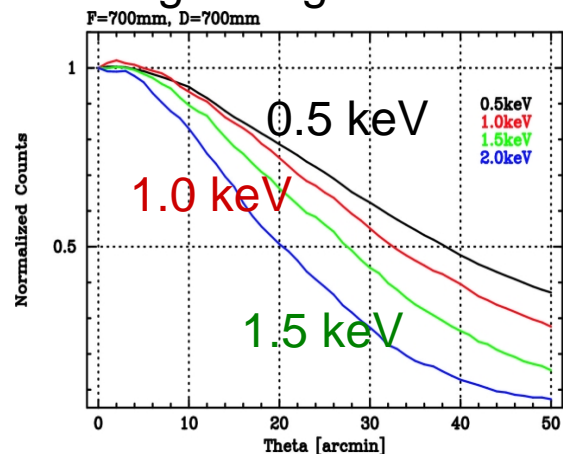
Mirror configuration  
(spherical top)



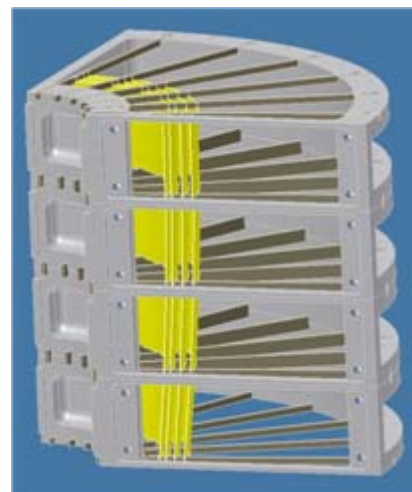
GRASP (cm<sup>2</sup> deg<sup>2</sup>)



Vignetting function



Focal length	70 cm
Diameter	60 cm
2 refl. to 4 refl. change	20 cm
Surface	C 25 Å + Ni 25 Å + Pt 300 Å
# of shells	36 (2 refl) + 41 (4 refl)
Detector size	10 mm × 10 mm

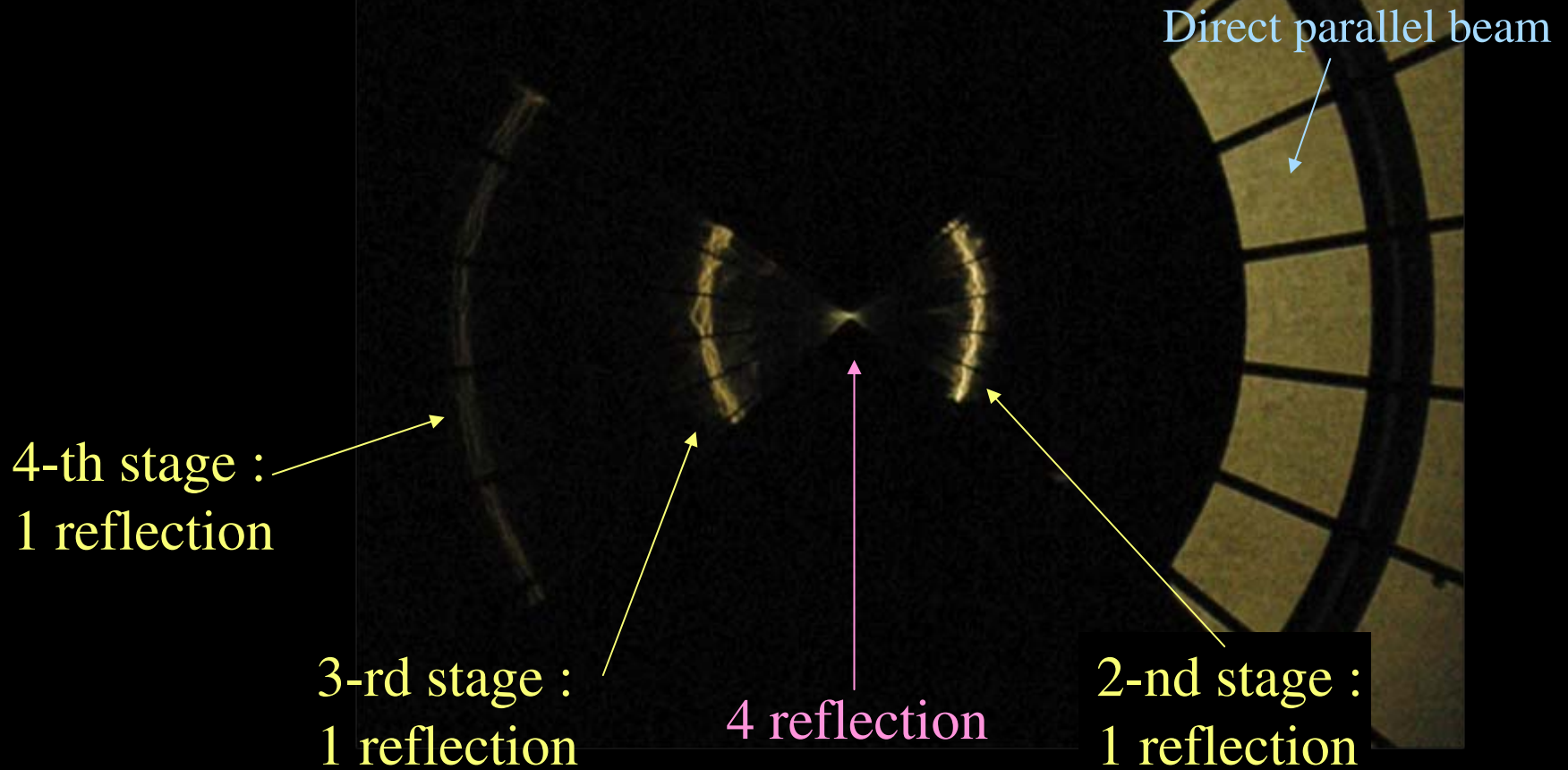


Housing:  
2' accuracy

# Optical images :

180 mm dia mirror 4-stage set (heat formed substrate)

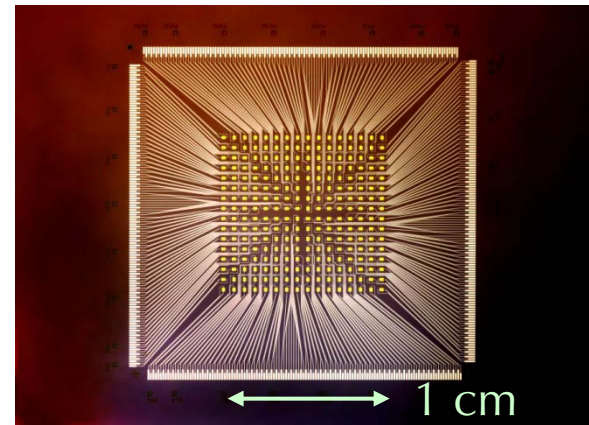
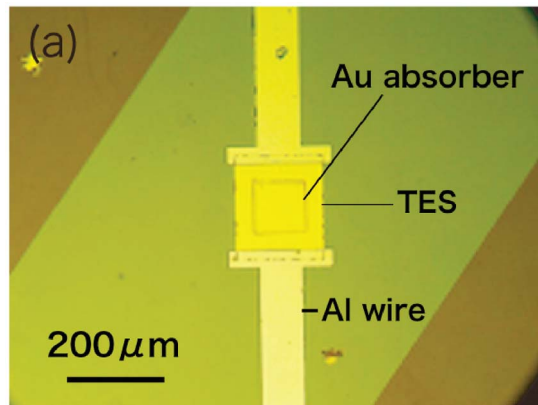
One quadrant



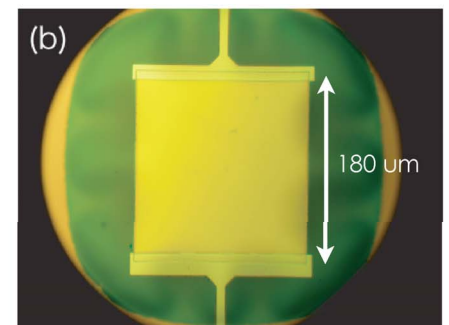
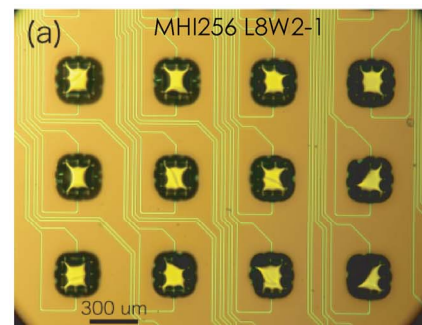
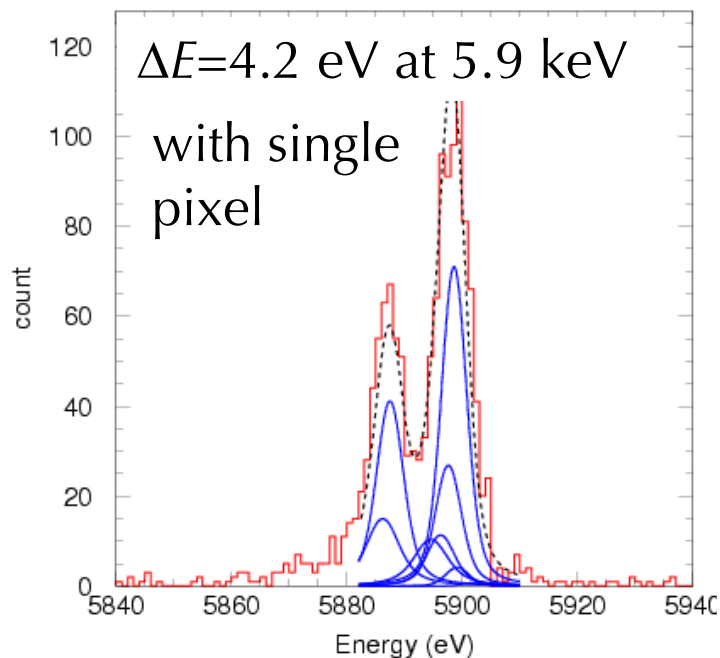
# Development of TES array detector

In-house product of TES

256 pixel array:  $\Delta E \sim 11$  eV  
without X-ray absorber



Close-up view of array pixels



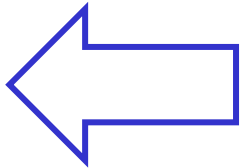
# Cooling system

No expendable cryogen, warm launch

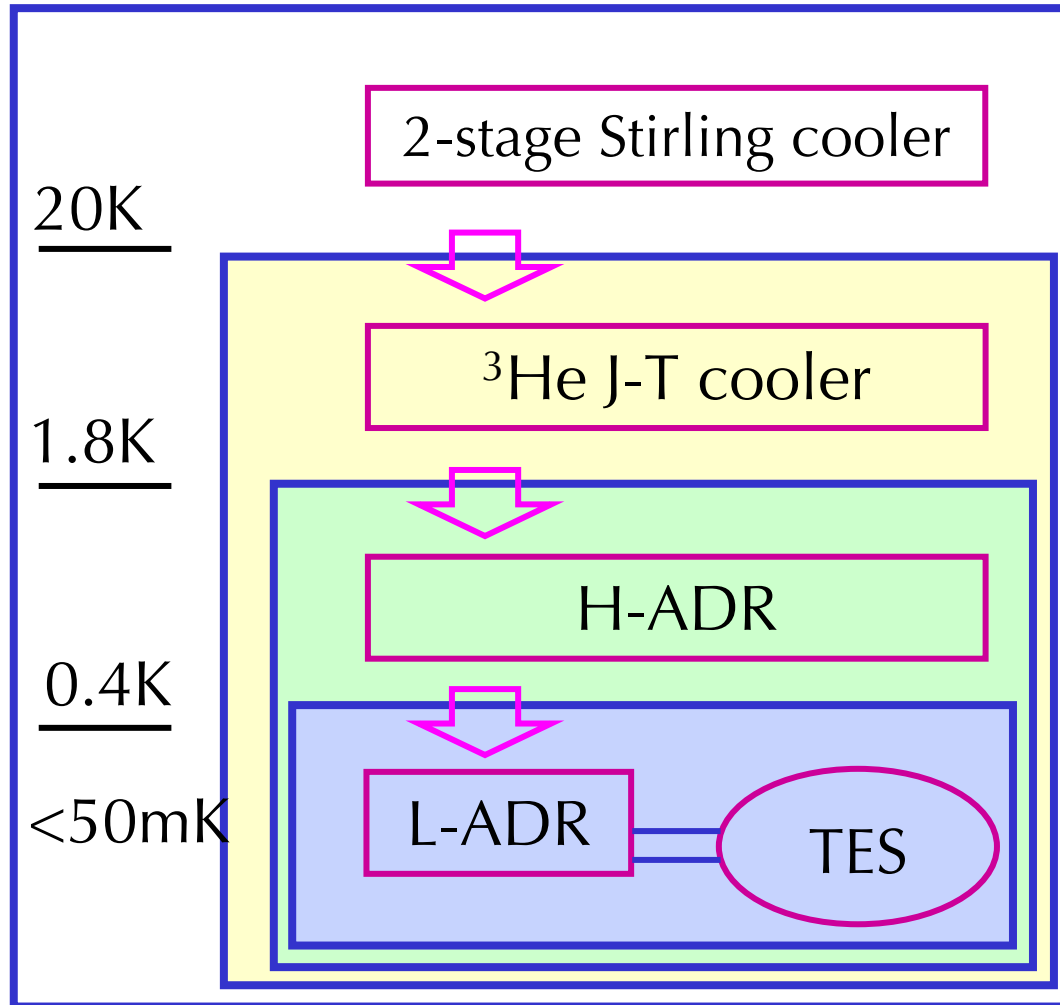
Radiation

225-300 K

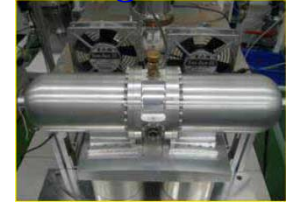
> 1.1 m<sup>2</sup>



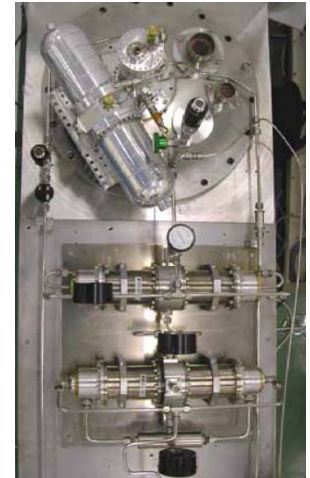
Attitude  
flipping in  
every orbit



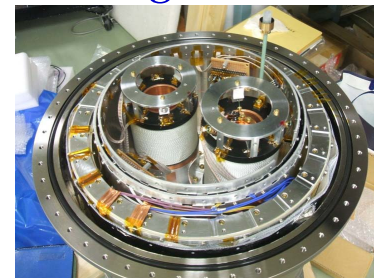
Stirling cooler



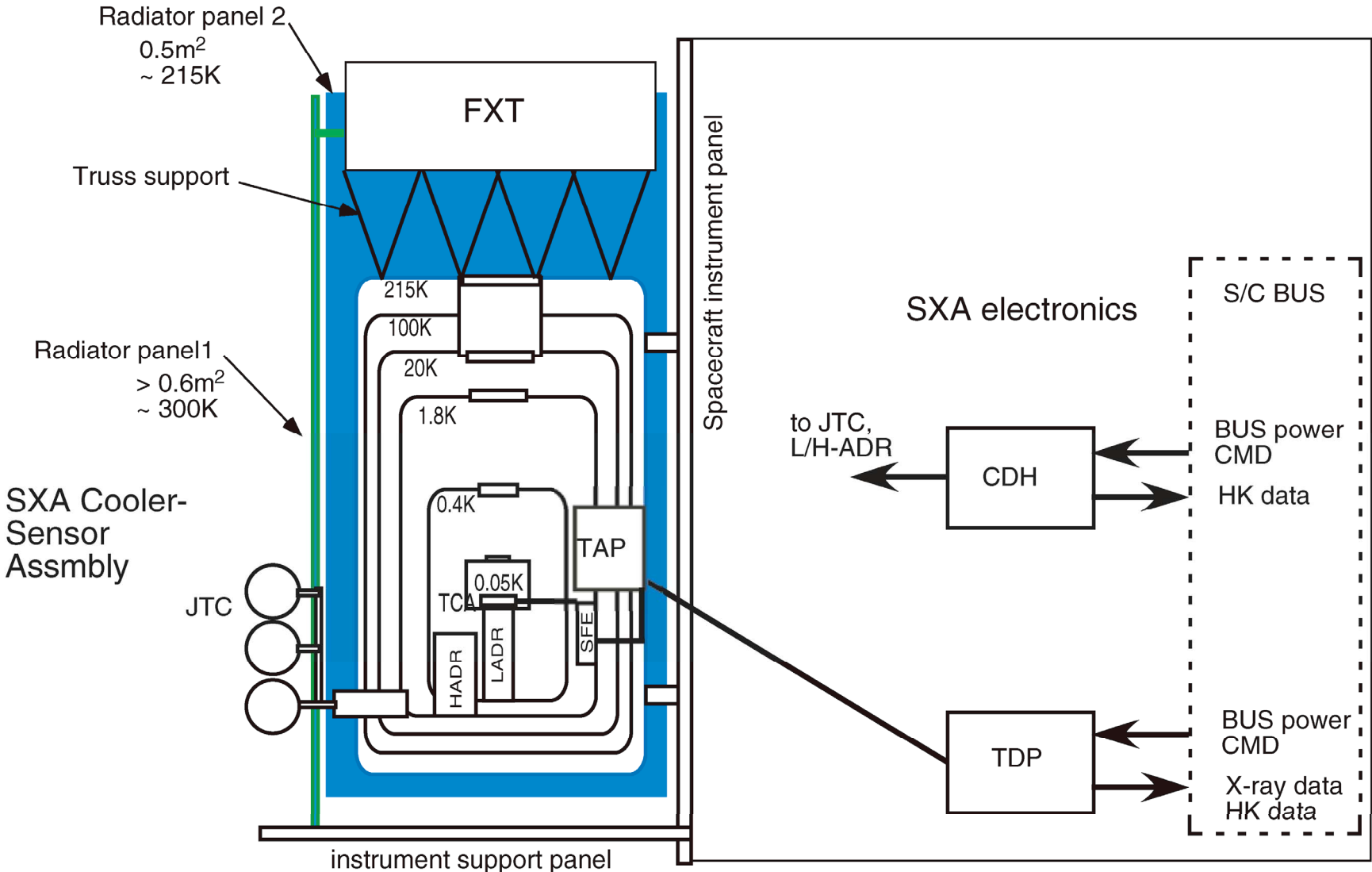
J-T cooler



2-stage ADR



# Instrument and control electronics



# Schedule

- DIOS will come later than Astro-H (2013)
- Proto-type model of the mechanical coolers for Astro-H will be used for DIOS
- International collaboration is important

Astro-H ↓

↓ DIOS

