HiZ-GUNDAM

High-z Gamma-ray bursts for Unraveling the Dark Ages and Extreme Space Time Mission

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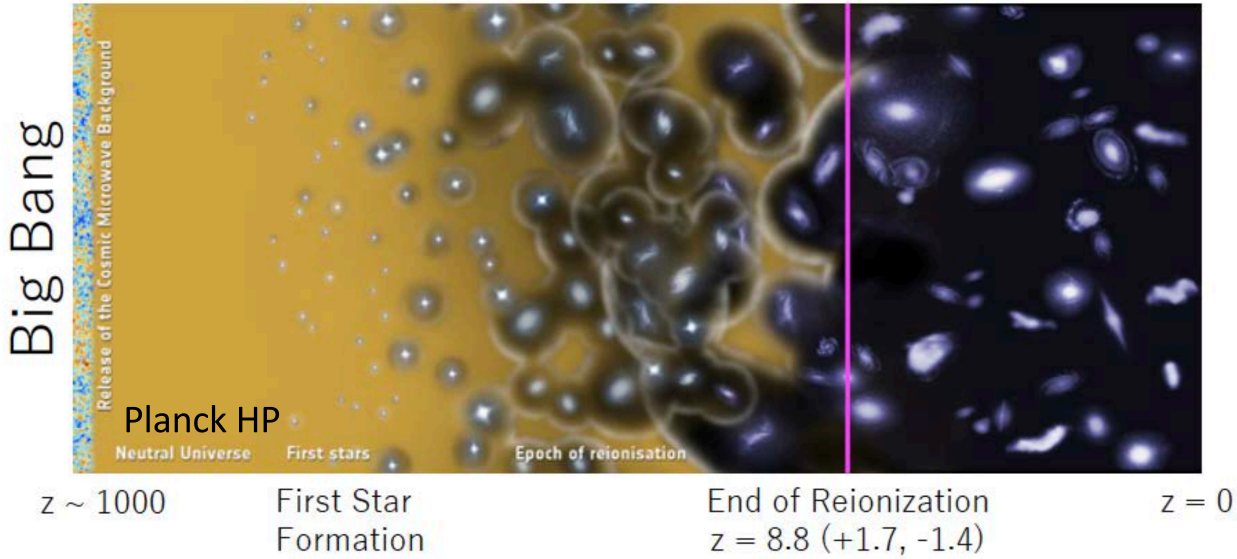
HiZ-GUNDAM working group

- **Mission Concept has been approved by ISAS/JAXA**
- Working group is in Pre-Phase-A
- Target Launch is the late of 2020s

HiZ-GUNDAM：Promotion of Time Domain/Multi-messenger Astronomy

Key Science 1: Exploration of early universe with GRB



Selection of High-z GRBs, Rapid spectroscopic obs. with large area telescopes

(1) GRB rate at z > 7
(2) Cosmic reionization history
(3) First heavy metals
(4) Survey of Pop-III GRBs

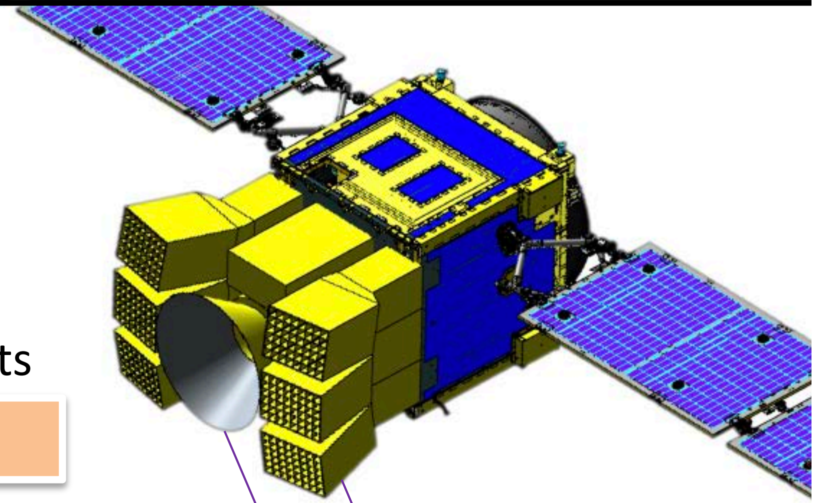
Key Science 2: Multi-Messenger Astronomy

We timely contribute MM-Astronomy after achieving design sensitivity of GW facilities.

(1) High energy phenomena associated with GW
(2) Confirmation of existence of relativistic jet, and statistical studies
(3) Energy transition from
Jet → Cocoon → Kilonova/Macronova
from X-ray to optical/NIR observation
(4) Diversities of kilonova/macronova

High-z Gamma-ray bursts for Unraveling the Dark Ages Mission

Mission Aim: Strong Promotion of
"**Time Domain**" & "**Multi-Messenger Astronomy**".



Wide Field X-ray Monitor
- Lobster Eye Optics
- CMOS imaging sensor

Near Infrared Telescope
- Offset Gregorian Optics
- simultaneous 4-band photometry

Key Science1: Probing the Early Universe

- Detection of high-redshift GRBs (9 < z < 12)
- Probing the reionization history and first metal elements

Key Science2: Progress of Gravitational Wave Astronomy

- Localization of X-ray transient and macronova associated with GW
- Energy transition from jet – cocoon – macronova

Observation Strategy

(1) Discovery of high-energy transient with Wide Field X-ray Monitor
(2) Automatic/Comprehensive follow-up with Near Infrared Telescope
(3) Sending Quasi-Realtime Alert Messages
(4) Spectroscopy with Large Area Telescopes for selected events

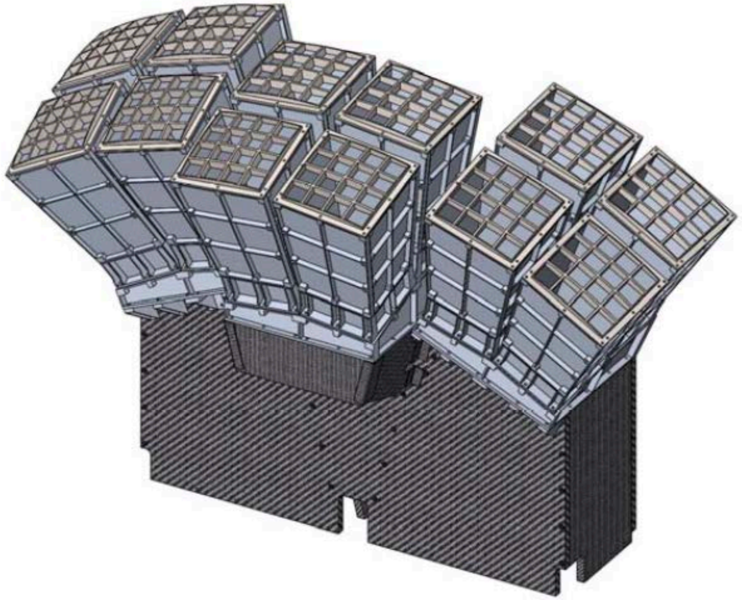
Wide Field X-ray Monitor

Items	Parameters
Energy band (keV)	0.4 – 4 keV
Field of View	~ 1.2 str (6 units)
Sensitivity	1e-10 (erg/cm2/s) For 100 sec exposure
Point Spread Function	3 arcmin
Angular accuracy	~ 60 arcsec

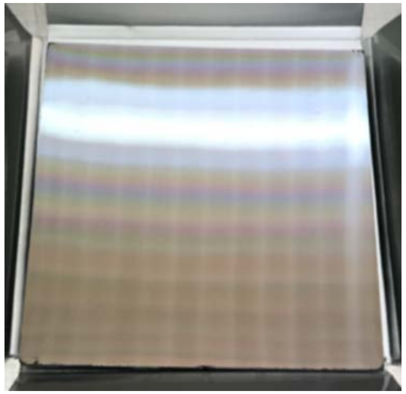
Near Infrared Telescope

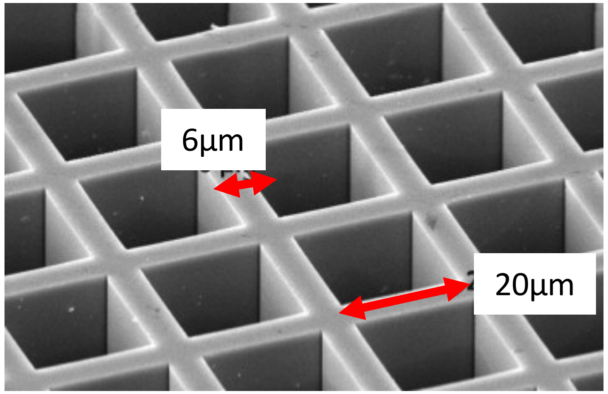
Items	Parameters			
Aperture size	30 cm			
Field of view	34 arcmin ×34 arcmin			
Integration time	10 minutes (2 minutes x 5 frames)			
Observation Band (μm)	0.5–0.9	0.9–1.5	1.5–2.0	2.0–2.5
Limiting Magnitude (AB) 10 min exposure, S/N=10	21.4	21.3	20.9	20.7

Wide Field X-ray Monitor



Lobster Eye Optics (Micro Pore Optics)

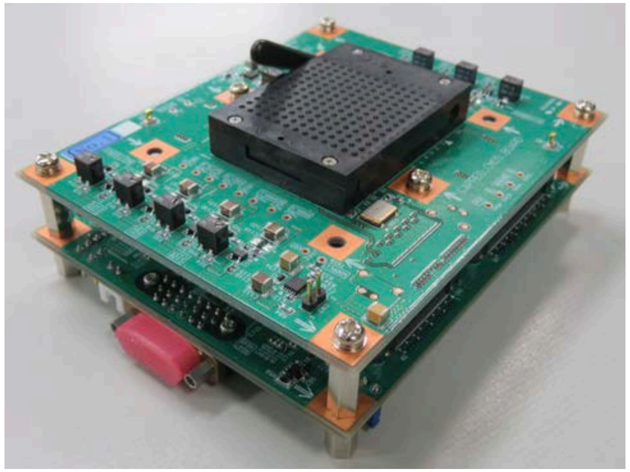


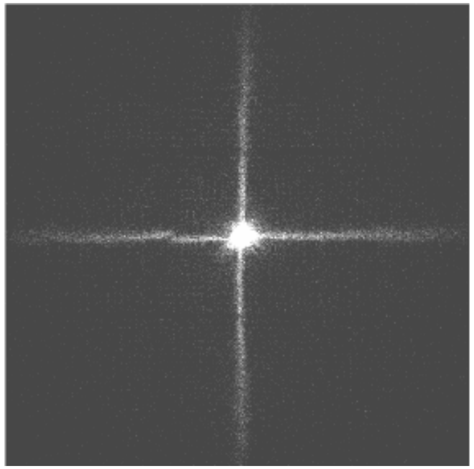


Items	Parameters
Energy band (keV)	**0.5 – 4 keV**
Telescope type:	Lobster Eye Optics
Module aperture size	192 x 192 mm^2
Number of module	24
Field of View	**1.0 str (in total)**
Focal length	300 mm
Focal plane detectors	CMOS array
Number of CMOS	24
Sensitivity	**~ 1e-10 (erg/cm2/s) For 100 sec**
Point Spread Function	~ 3 arcmin

Digital Electronics Board
CMOS or pnCCD

Image performance
with X-ray beamline

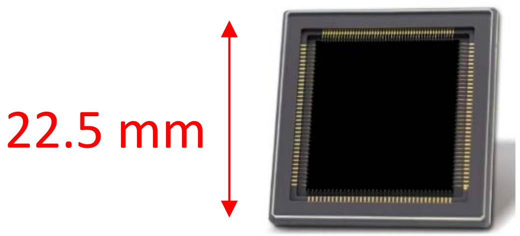


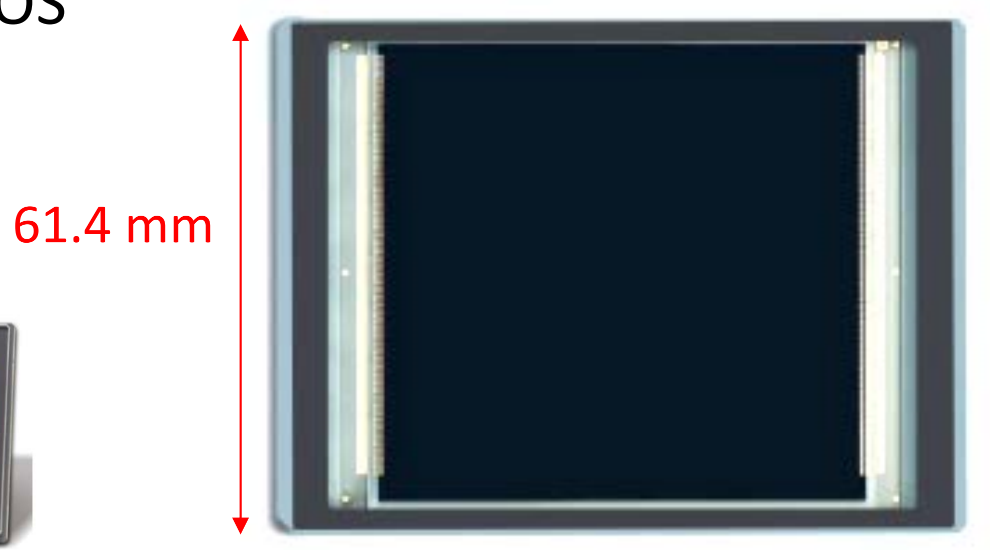


(Left) Digital Electronics Board (BBM)
for smaller CMOS (GSENSE 400)
(Right) Focal Image Obtained at 30m X-ray beamline

GPIXEL CMOSs (One of the candidates)

- Back Side Illuminated type CMOS
- Performance Evaluation Tests
- Radiation Tolerance Tests



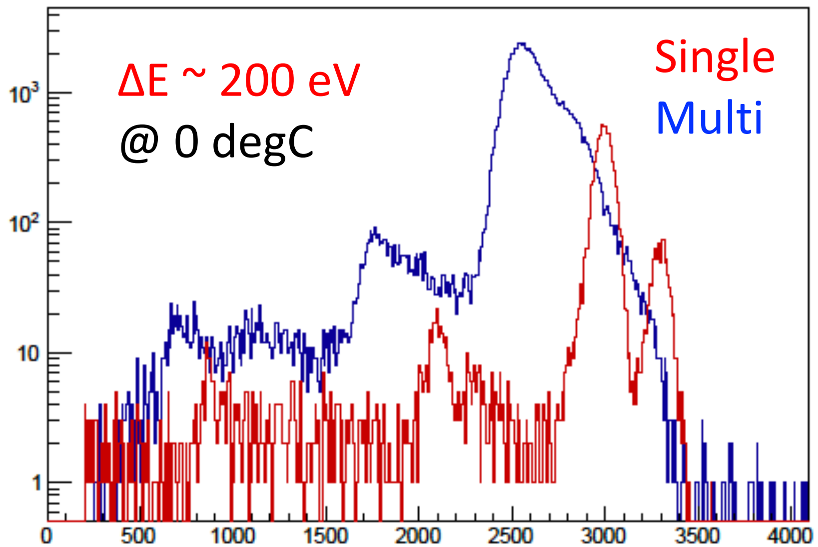


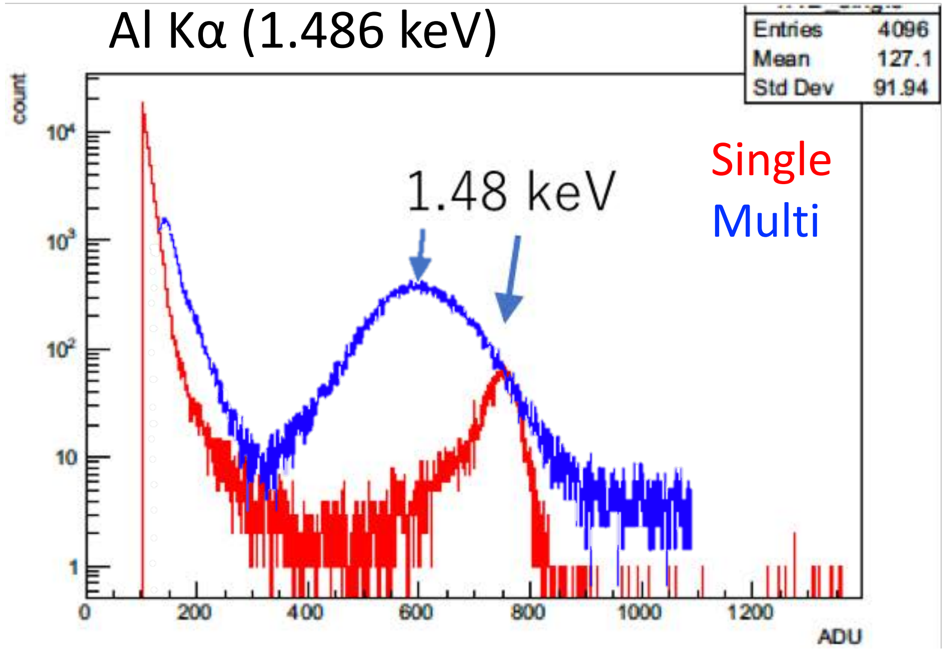
	GSENSE 400BSI	GSENSE 6060BSI
Active image size	22.5 x 22.5 mm^2	61.4 x 61.4 mm^2
Pixel size	11 x 11 um^2	10 x 10 um^2
# of pixels	2048 x 2048	6144 x 6144
Shutter	Rolling	Rolling
Frame rate (STD)	48 fps	26.4 fps
Power	<0.650 W	5.4 W (full speed)
# of LVDS pairs	8	50

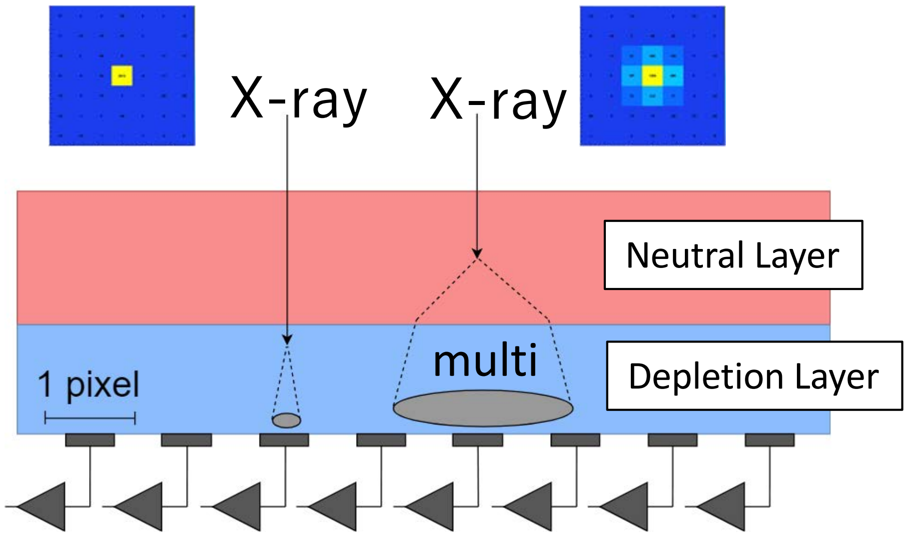
@ 0 degC, 0.1sec exposure

X-ray Performance (400BSI)

Mn Kα/Kβ (5.90 & 6.49 keV)







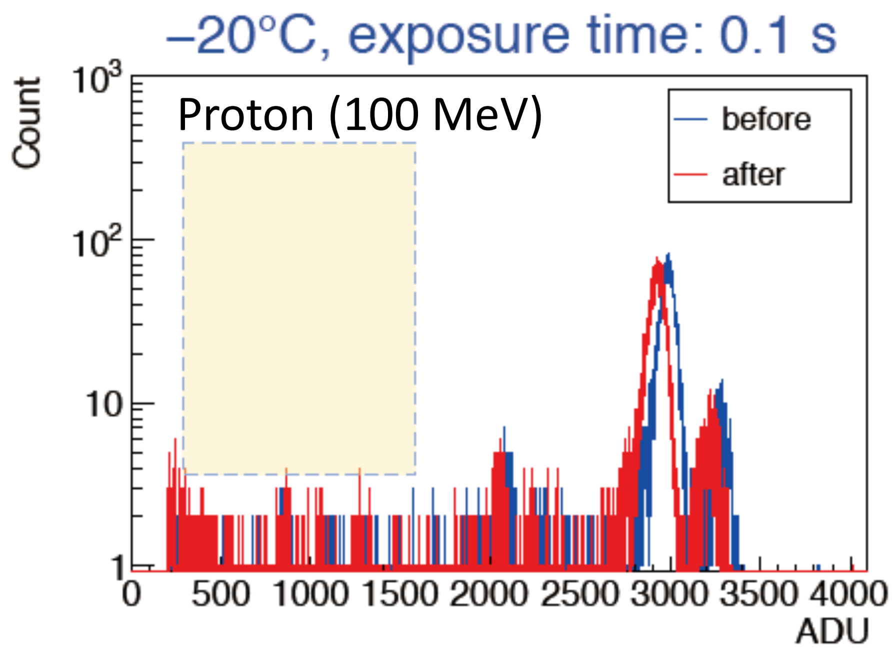
- Successfully measured 1.48 keV line
- Single pixel event : depletion layer
  Multiple pixel event : neutral layer
- Single/Multi ratio depends on the resistivity of epitaxial wafer.

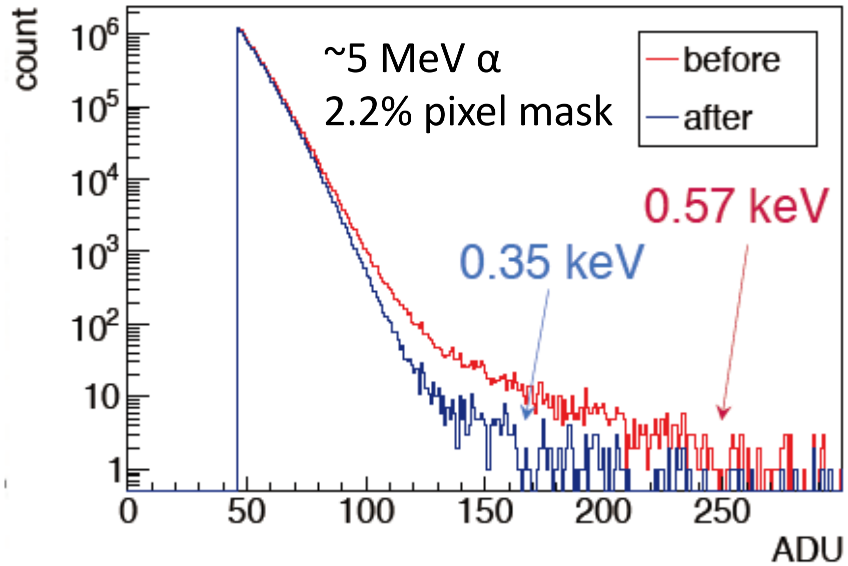
Radiation Tolerance Test for CMOS (400BSI)

Total Irradiation Dose (2018/08/01 – 02)
Almost No Damage up to 30 krad

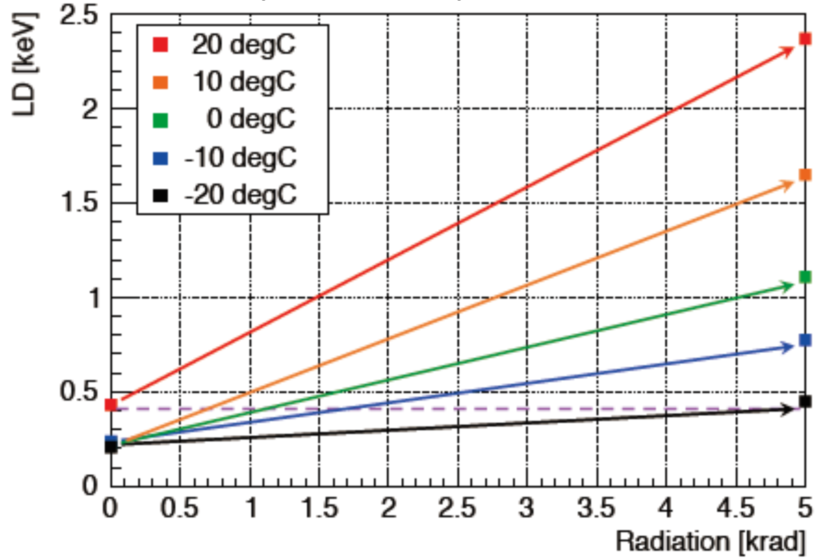
Particle irradiation (2019/05/23 – 24)
Proton : 100 MeV, 5 krad (~6 yrs in orbit)
・Increase of leakage current
→ operation at -20 degC

Low-energy α–particle from ^{241}Am
~5 MeV, 24 krad (Over dose test)
Less damage in circuit layer
Significant damage in depletion layer
→ Masking 2.2% of high noise pixels

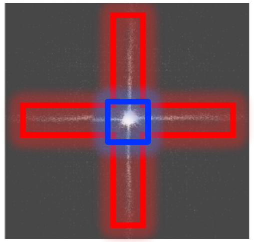


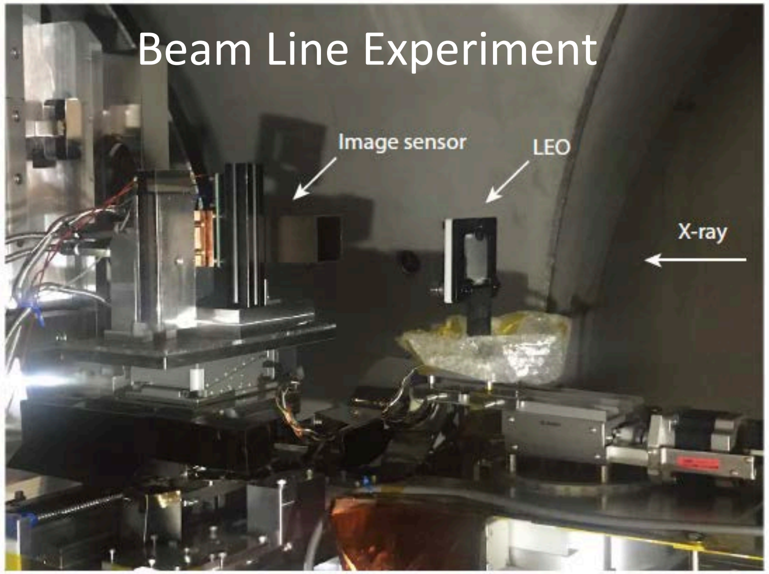


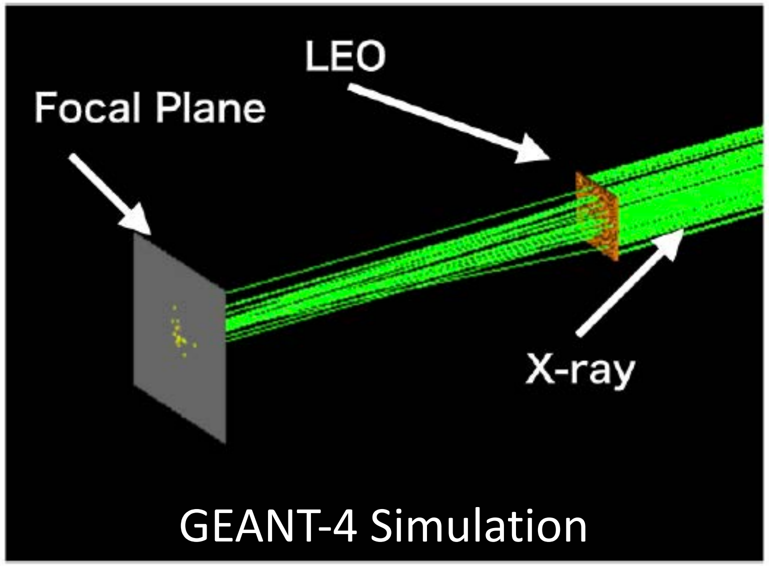
Proton (100 MeV)

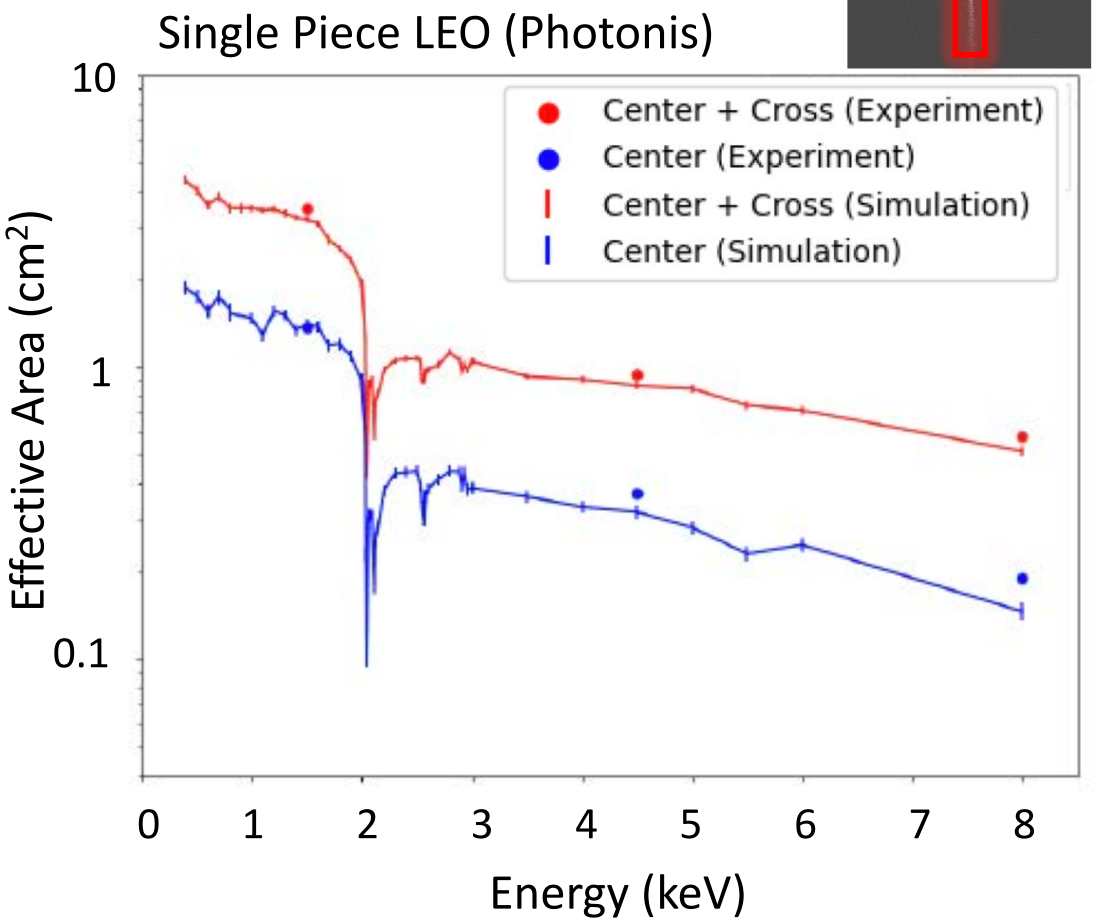


X-ray Beam Line Experiment for Lobster Eye Optics





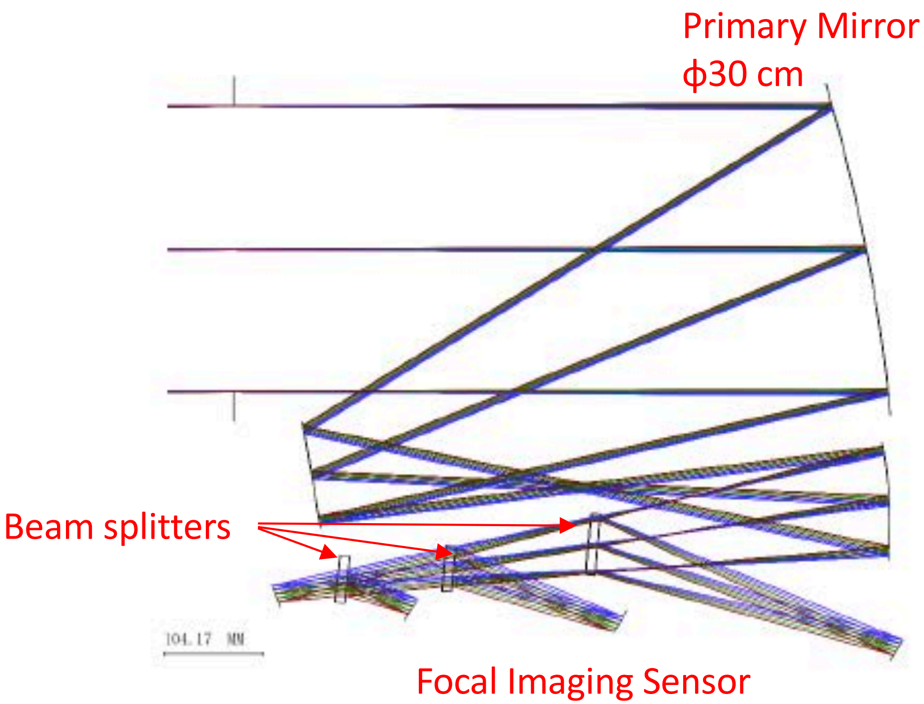


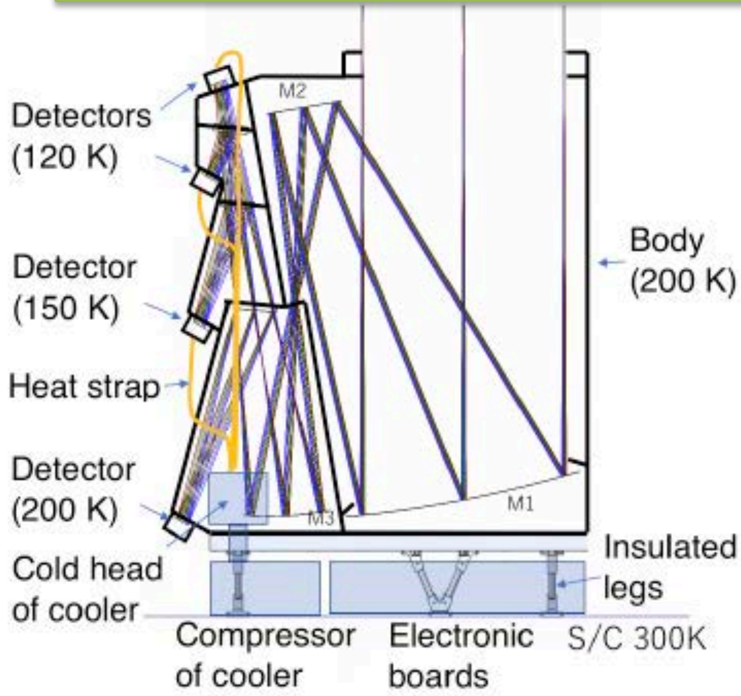


X-ray test at 30 m X-ray beam line
Consistency check with GEANT-4 simulation
Effective area (Photonis LEO)
Center Only : 1.37 cm^2 @ 1.5 keV
Cross + Center: 3.49 cm^2 @ 1.5 keV

Near Infrared Telescope

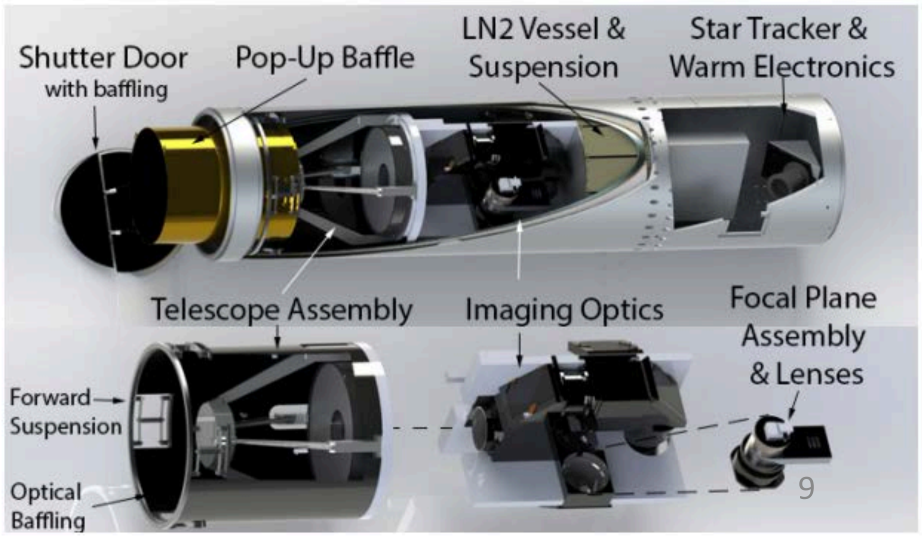
4-band simultaneous photometry





Items	Parameters			
Telescope type	Three-mirror anastigmat			
Aperture size	**30 cm**			
Field of view	34 arcmin ×34 arcmin			
FoV per pixel	2 arcsec × 2 arcsec			
Image size	3 pixel × 3 pixel			
Integration time	10 minutes (2 minutes x 5 frames)			
Wavelength Band (μm)	**0.5**–0.9	0.9–1.5	1.5–2.0	2.0–**2.5**
Band width	0.4 μm	0.6 μm	0.5 μm	0.5 μm
Limiting Magnitude AB, 10min, S/N=10	**21.4**	**21.3**	**20.9**	**20.7**
Focal detector	HyViSi	HgCdTe	HgCdTe	HgCdTe

Heritages: CIBER-2 Rocket Experiment

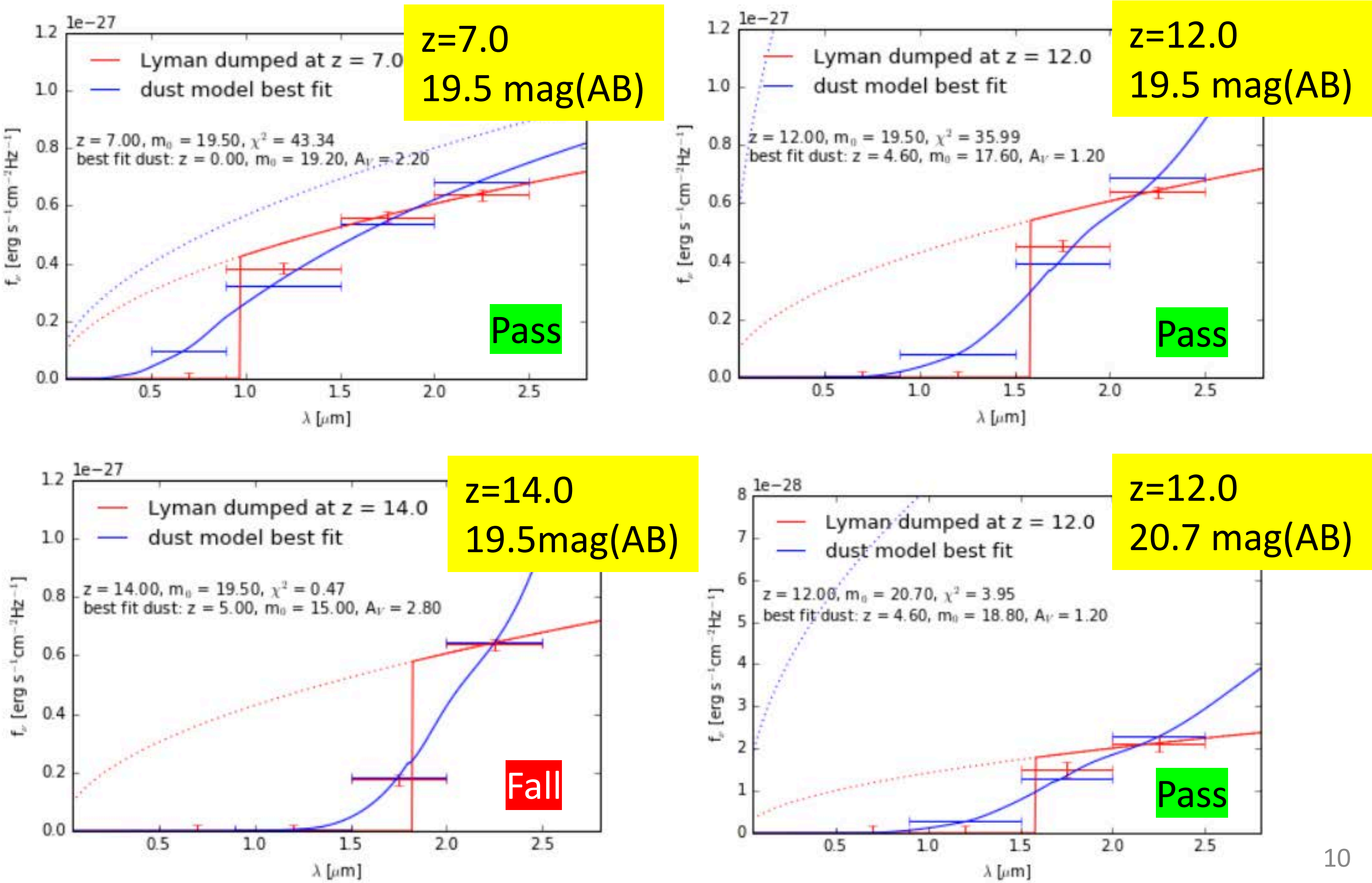


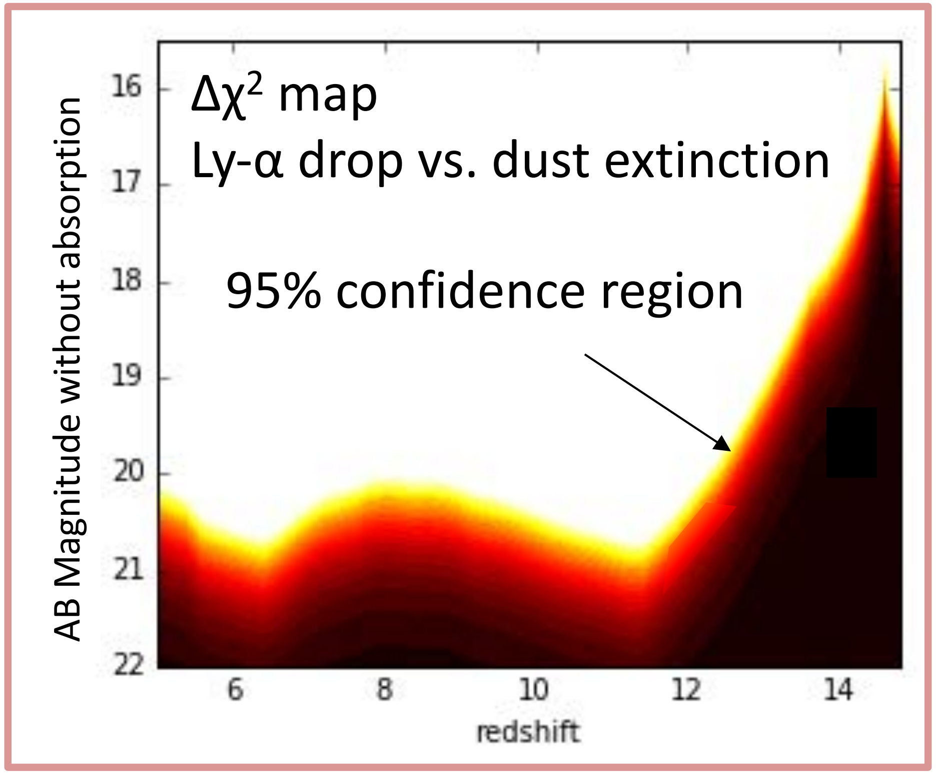
Simulations: Photometric Redshift

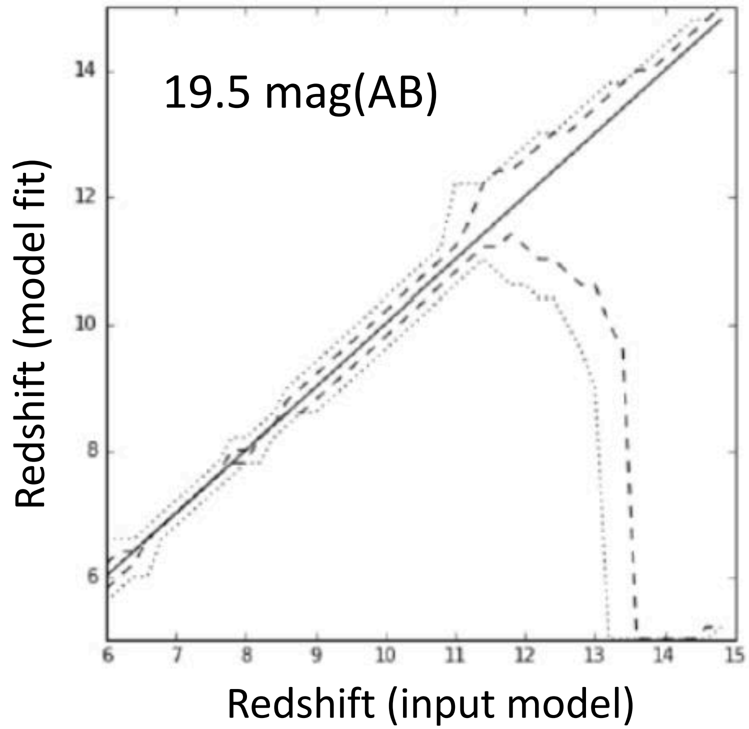
Afterglow spectrum is power-law with 0 < β < 1 (~ 95%), and β = 0.5 is used.

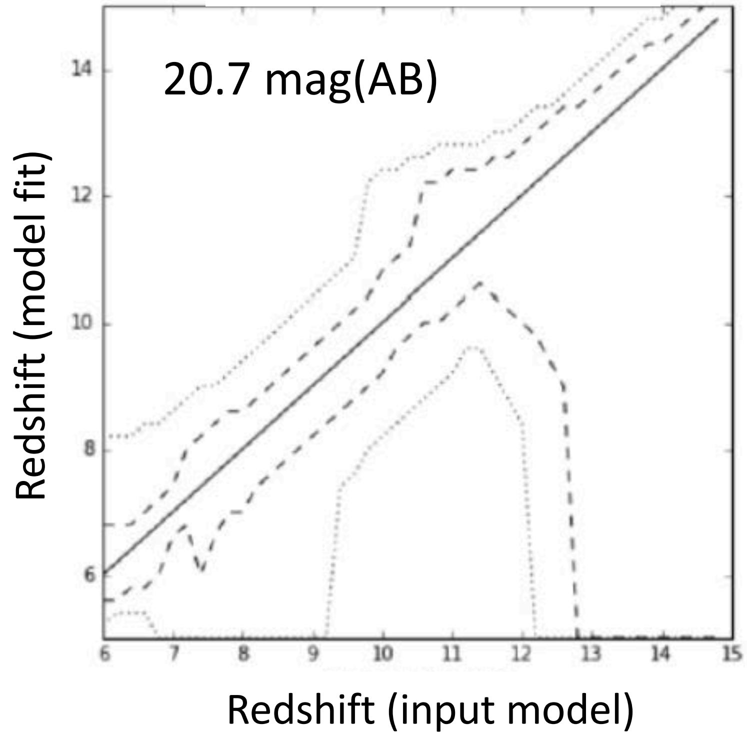
Red: Input model (power-law with Ly-α drop)

Blue: Fitting model (power-law with dust extinction)



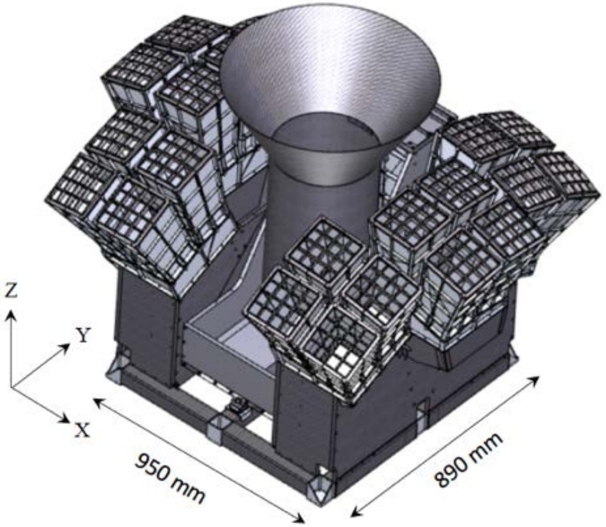


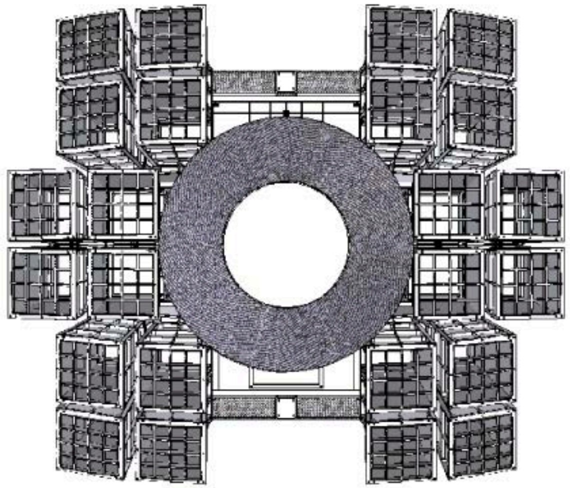


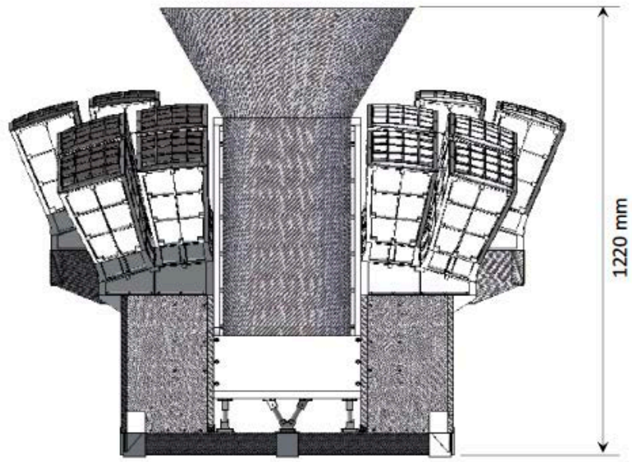


- Photo-z coverage:
  5 < z < 12 for m < 20.5 mag(AB)
- Accuracy of photo-z:
  Δz ~ +/- 0.1 for 19.5 mag (AB)
  Δz ~ +/- 1 for 20.7 mag (AB)
- We can observe high-z afterglow candidate up to z < 19.5 even if we can not distinguish between real high-z or dusty GRB.

Overview of Mission Payloads





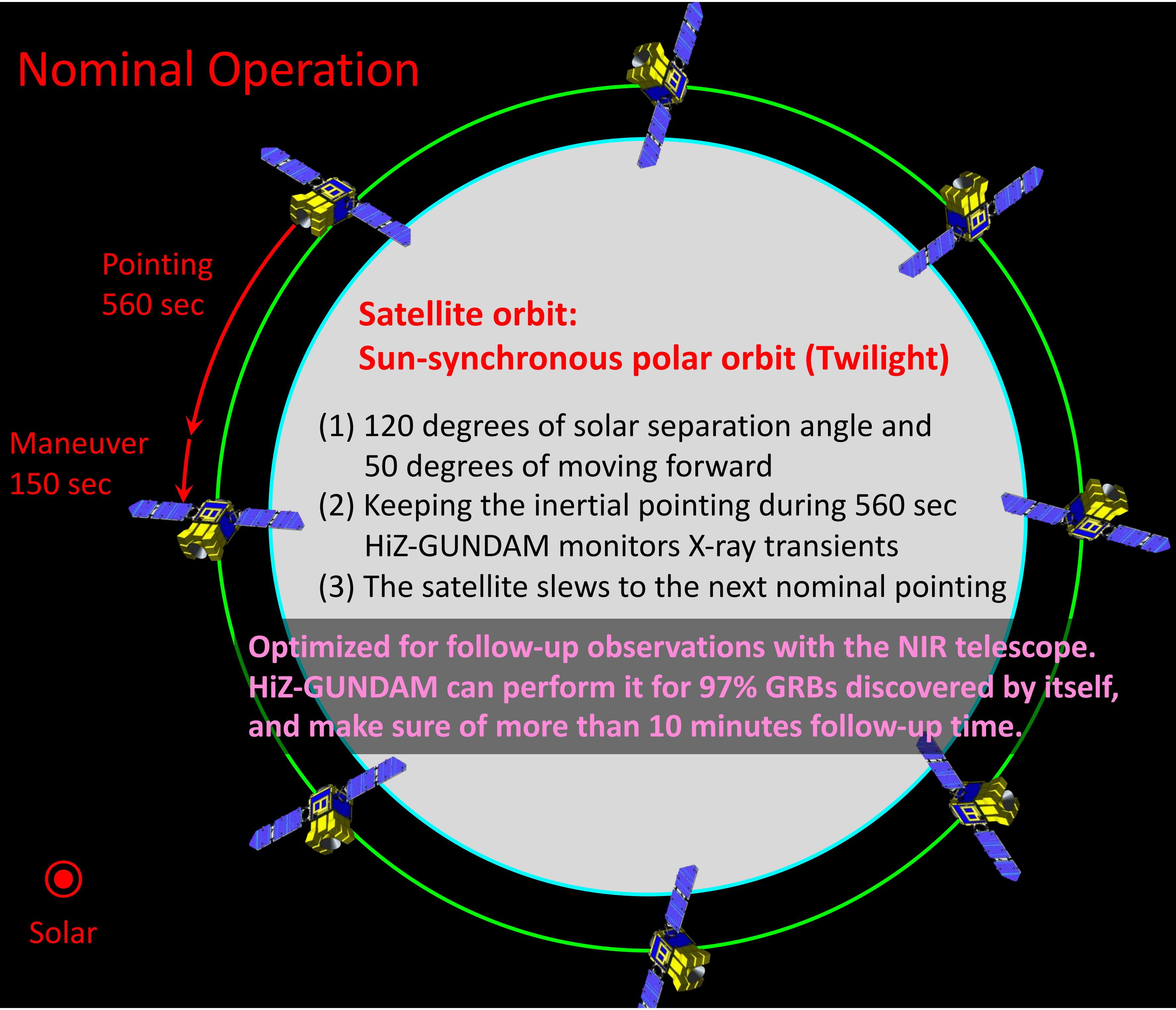


The size of mission payload: 890 mm x 950 mm (base frame) x 1,220 mm (height)
The total mass is ~200 kg.

Structural analysis using the finite element method
The number of contacts : 331,043
The number of elements: 345,618
The natural frequency of primary mode:
45.23 Hz (X-axis), 65.45 Hz (Y-axis), and 108.96 Hz (Z-axis).

We confirmed that vibration tolerance was sufficient at all points.

Nominal Operation

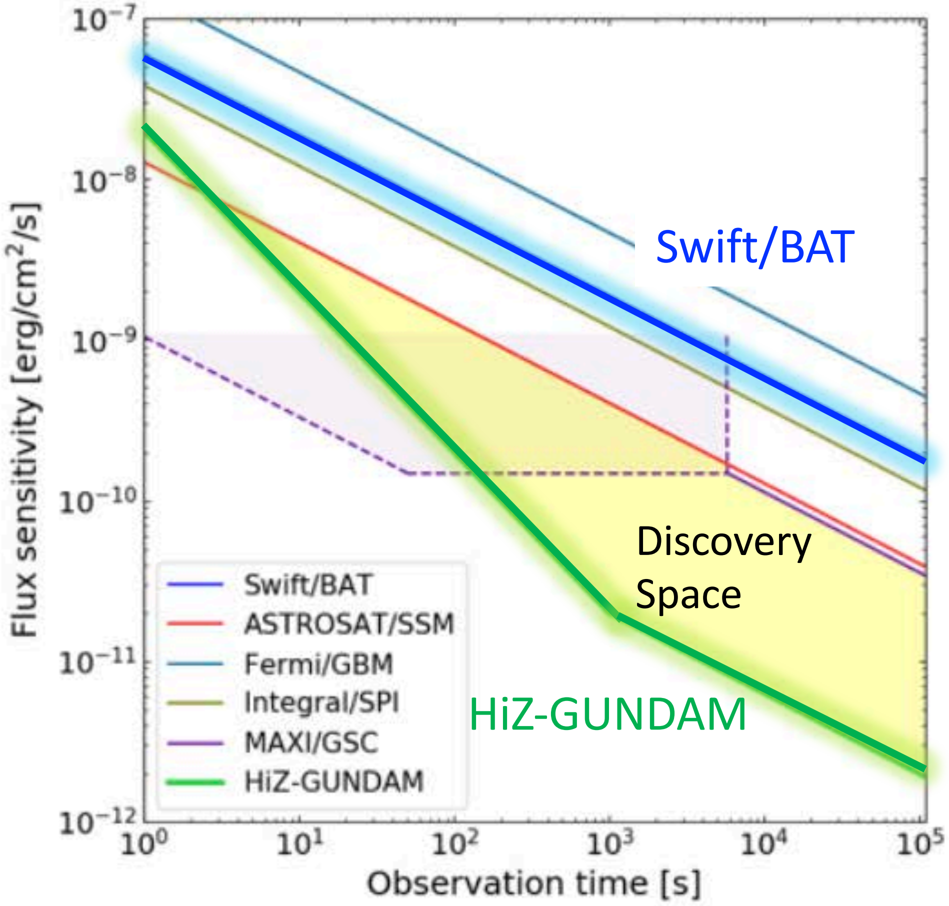


Satellite orbit:
Sun-synchronous polar orbit (Twilight)

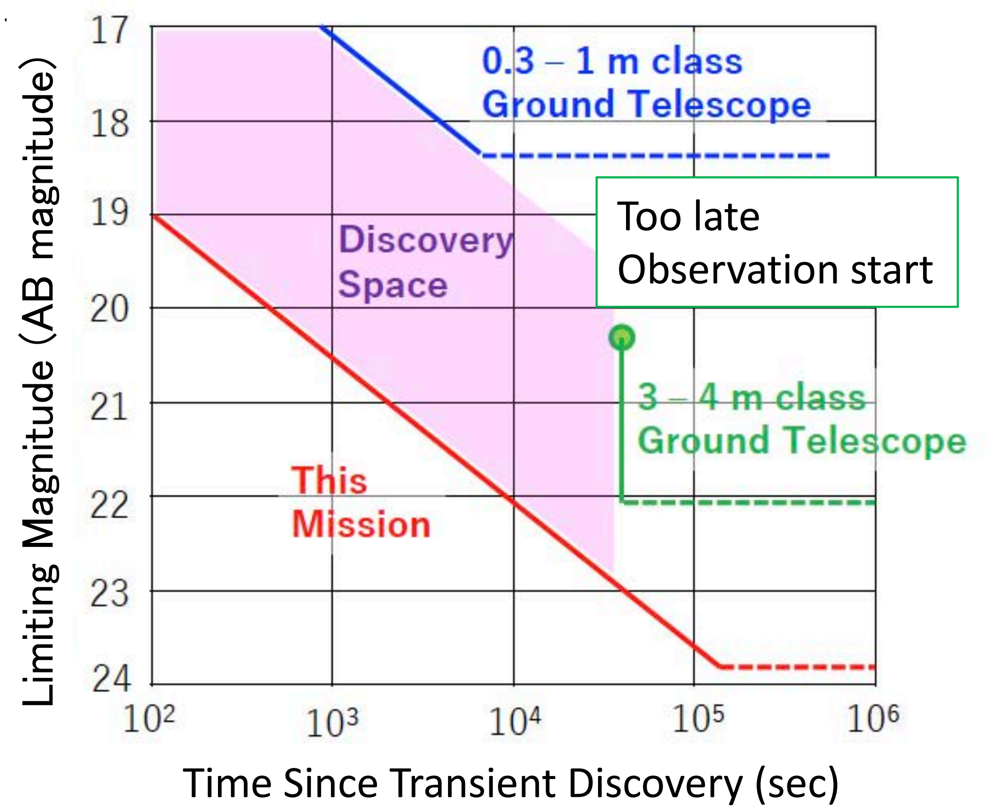
(1) 120 degrees of solar separation angle and
50 degrees of moving forward
(2) Keeping the inertial pointing during 560 sec
HiZ-GUNDAM monitors X-ray transients
(3) The satellite slews to the next nominal pointing

Optimized for follow-up observations with the NIR telescope.
HiZ-GUNDAM can perform it for 97% GRBs discovered by itself,
and make sure of more than 10 minutes follow-up time.

Detection Sensitivity and Expected Event Rate



Sensitivity of Follow-up Obs.

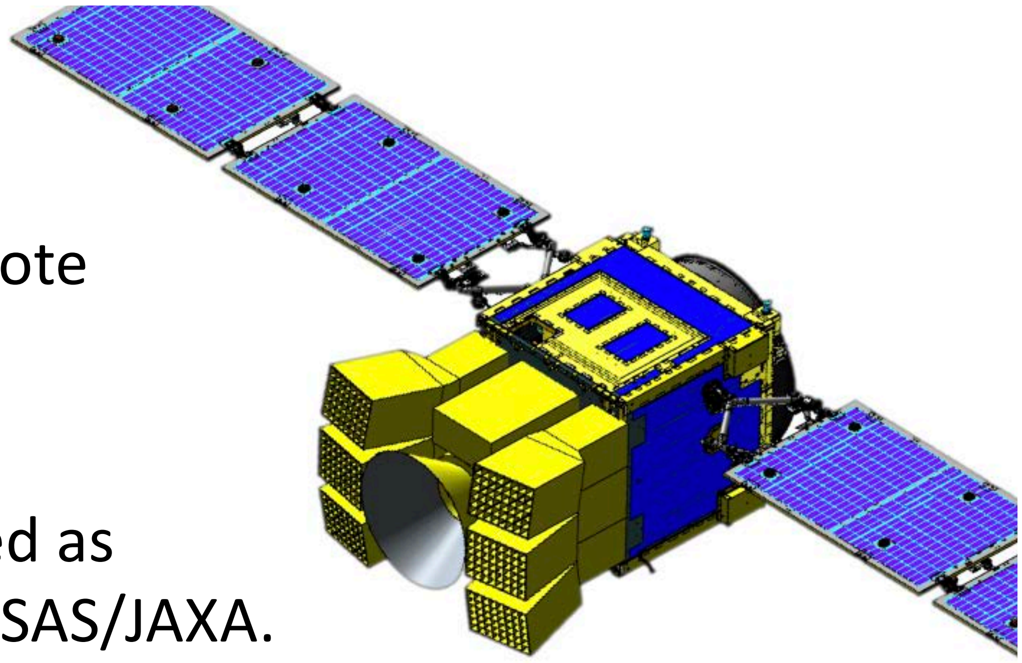


X-ray	event/yr
GRB (z>9) best model	33
GRB (z>9) lower limit	> 10
GW/SGRB prompt	~8
GW/SGRB E.E.	~8
GRB/SGRB	~700
Low-Luminosity GRB	> 5
X-Ray Flash	50

X-ray	event/yr
Tidal Disruption	60
SN Shock Breakout	> 5
Stellar Flare	many
Direct collapse BH	a few
Accretion induced collapse	~10

Near Infrared	event/yr
afterglow (z>9) best model	28
afterglow (z>9) lower limit	> 10
macronova	~8 + α
Supernovae	40
afterglow of GRB/SGRB/XRF	many
Variable stars	many

Summary



- HiZ-GUNDAM will strongly promote
  (1) exploration of early universe
  (2) multi-messenger astronomy
- The mission concept was selected as a candidate of future project of ISAS/JAXA.
- The launch target is the late of 2020s.

- We will have two kinds of mission payloads
  (1) The wide field X-ray monitor with LEO and focal imaging sensor
  (2) The near infrared telescope with aperture size of 30 cm
- Satellite orbit is selected as the twilight line of the sun synchronous polar orbit.
- We may also contribute to the follow-up observation in 2.0 – 2.5 um for GRBs found by THESEUS.