

ガンマ線バーストを用いた 初期宇宙・極限時空探査計画 HiZ-GUNDAM

High-**z** Gamma-ray bursts for **Un**raveling the **D**ark **A**ges **M**ission

米徳 大輔 (金沢大学)

HiZ-GUNDAM プリプロジェクト候補チーム

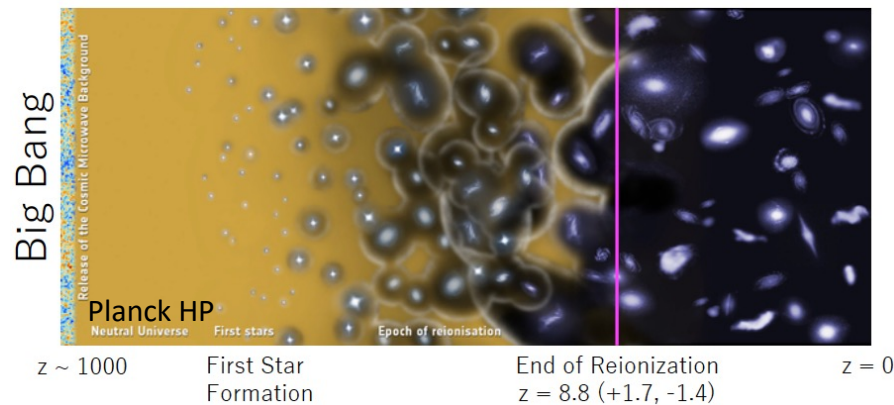
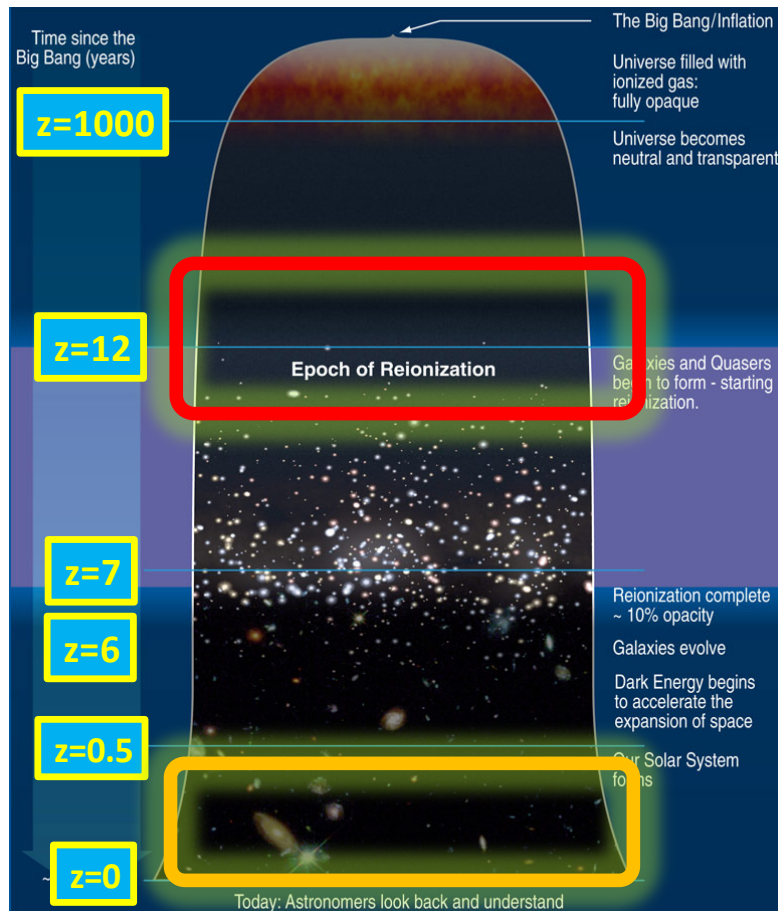
2024/03/01 : ダウンセクション前審査再審査説明会、2024/03/25 本審査 → ステータスは**保留**

Exploring Extreme Transients: Frontiers in the Early Universe and Time-Domain Astronomy

2025/08/05 – 08 @ YITP

HiZ-GUNDAM: Promotion of Time Domain Astronomy

Key Science 1: Exploration of early universe with GRB



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

Key Science 2: Multi-Messenger Astronomy



- (1) High energy phenomena associated with GW and neutrino
- (2) Confirmation and Localization of E-M counterparts
- (3) Transition from gravitational energy to jet / cocoon / kilonova / particle acc.
- (4) Diversities of multi messenger sources from X-ray to optical/NIR observation

These observations require both “wide field monitor” and “near-infrared follow-up” 2

GROND

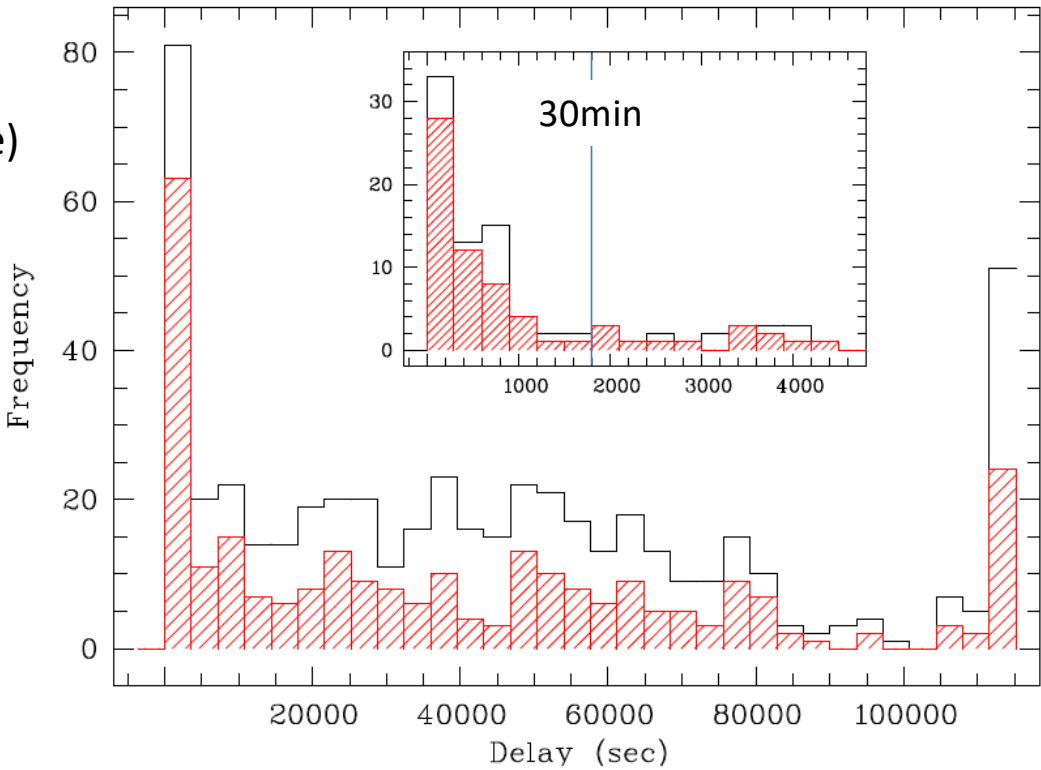
2.2m MPI/ESO Telescope @ La Silla Observatory (Chile)
0.4 – 2.4 μm (7-band)

Statistics (2007 – 2016) Greiner et al. (2024)

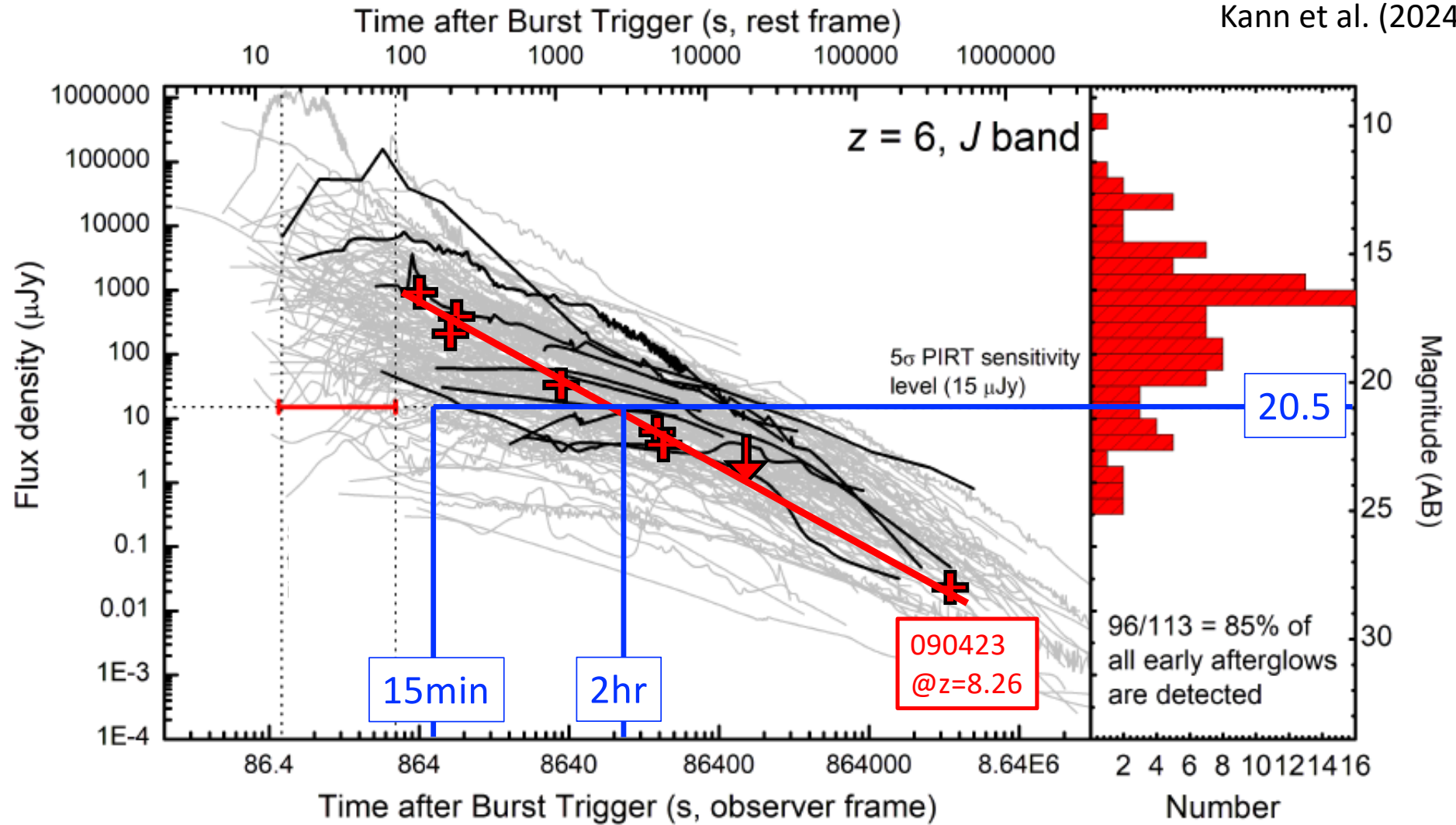
GRB trigger	1018
GROND Obs. (Total)	514 (50.5%)
GROND Obs. (< 0.5 hrs)	69 (6.8%)

(3-sigma)

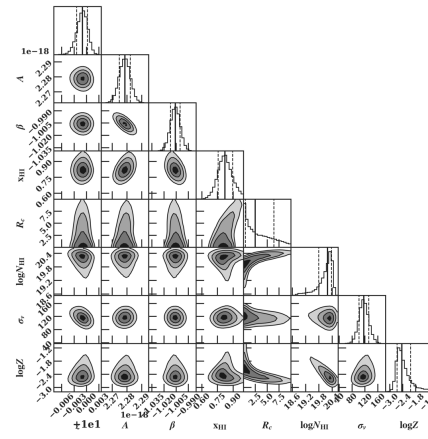
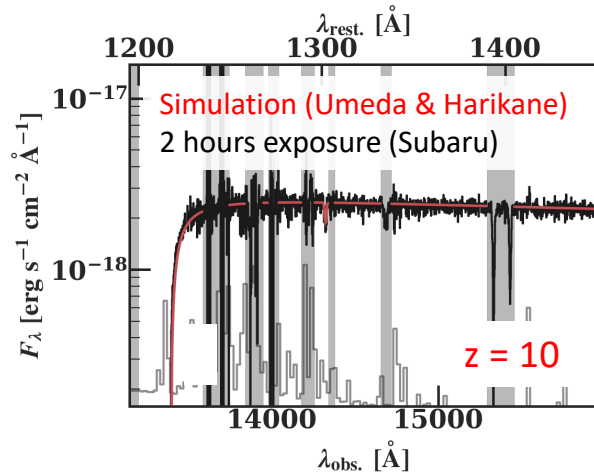
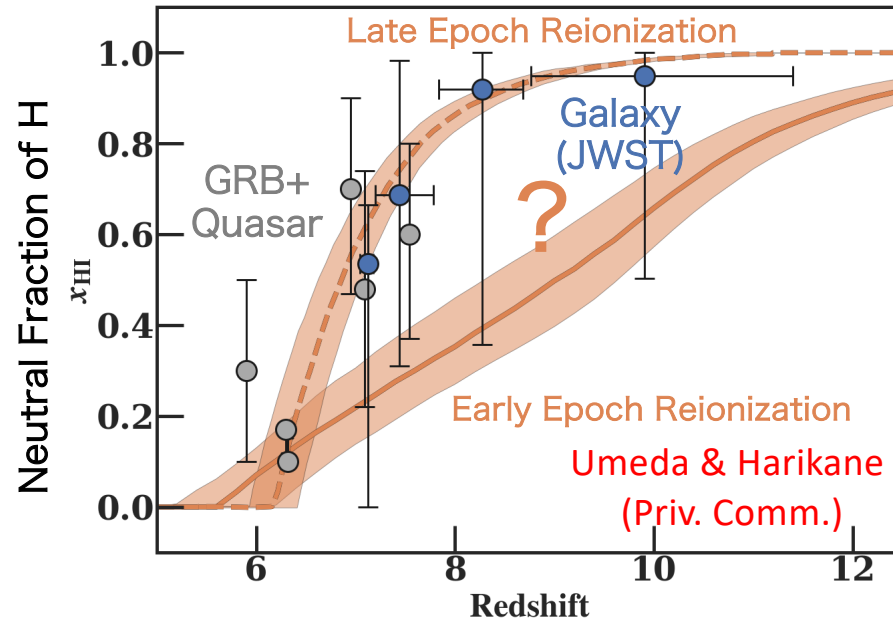
GROND channel	zeropoints (mag)		lim. magnitude in 8 min OB
	Vega	AB	
g'	25.61	25.62	24.2
r'	25.63	25.78	24.2
i'	24.57	24.96	23.7
z'	24.50	25.01	23.5
J	22.97	23.88	21.4
H	22.22	23.60	20.4
K	21.51	23.30	19.0



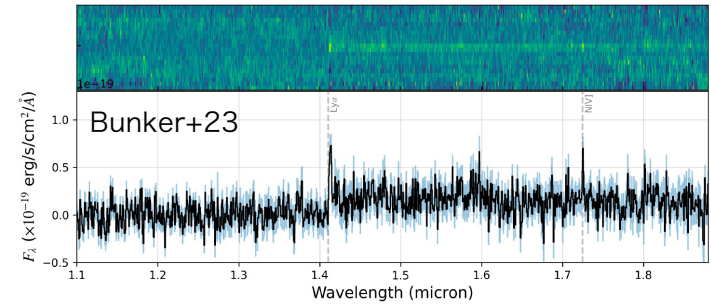
Delay (hr)	Detected vs. observed		Fraction of total observed	
	Long	Short	Long	Short
<0.5	50/ 62 (81%)	4/ 7 (57%)	13%	14%
0.5–4	38/ 60 (63%)	4/ 8 (50%)	13%	16%
4–8	33/ 61 (54%)	3/12 (25%)	13%	24%
8–12	28/ 61 (46%)	0/ 5 (0%)	13%	10%
12–24	76/151 (50%)	4/14 (29%)	32%	29%
>24	32/ 70 (46%)	0/ 3 (0%)	15%	6%



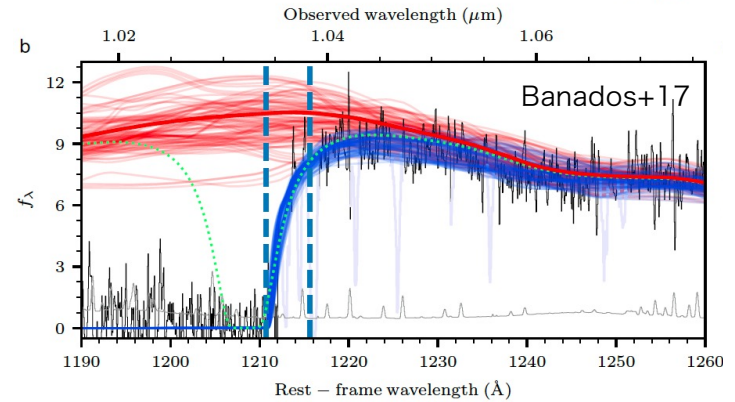
Cosmic Reionization – Future Prospect



Brightest galaxy GN-z11, $z=10.60$
6 hours exposure (JWST)



Quasar $z=7.5$ (8 hours exposure)



High-redshift GRBs are

- Enough bright
- Simple power-law spectrum
- redshift, x_{HI} , galactic neutral gas, metallicity, ionization bubble size, etc.

HiZ-GUNDAM (High-z Gamma-ray bursts for Unraveling the Dark Ages Mission)

Mission: Time Domain Astronomy

“Multi-messenger astronomy” and “Exploration of the early universe”

Observation strategy

- (1) Discovery of GRBs/transients with the wide field X-ray monitor ($t = 0$ sec)
- (2) Automatic repointing ($t < 300$ sec)
- (3) Identification of counterpart with the near infrared telescope ($t \sim 1000$ sec)
- (4) Alert message ($t \sim 0$ sec, ~ 1800 sec)
- (5) Spectroscopic observation with large area telescopes ($t \sim 1.5$ hour)

We will discover treasured targets from a large amount of transient sources, and provide important observation targets to large area telescopes.

We will promote "early space exploration" and "MM astronomy" with all the power of astronomy.

EAGLE: Exploration of Ancient GRBs with Lobster Eye

- Lobster Eye Optics
- pnCCD Imaging Sensor

MONSTER:

Multiband Optical and Near-infrared Simultaneous Telescope for Efficient Response

- 5-band simultaneous photometry



JWST

Space telescope

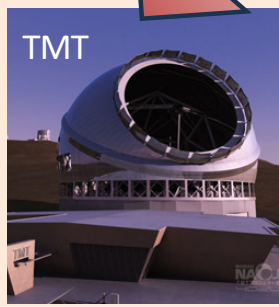


TAO

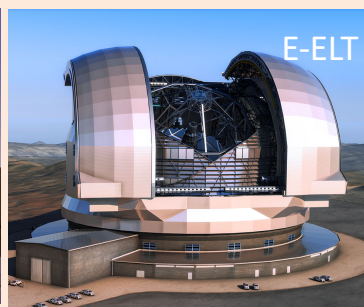


Subaru

8m-class



TMT



E-ELT

Future 30m-class

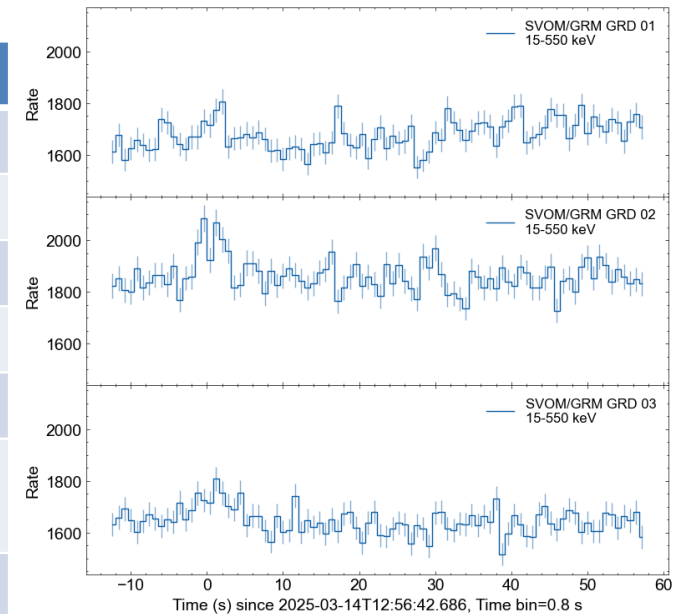


GMT

GRB 250314A @ $z=7.3$

GCN Circular Time	Delay	Observation
		25/03/14 12:56:42 SVOM ECRAIRS trigger
		25/03/14 13:01:28 SVOM VT start follow-up (285 sec)
25/03/14 14:12:08	1.26 hr	SVOM ECRAIRS trigger report
25/03/14 16:16:43	3.33 hr	SVOM VT Upper Limit ($R > 20$)
25/03/15 04:30:21	15.6 hr	NOT: $J = 20.85 \pm 0.15$ (Vega) (12.3 hr)
25/03/15 07:13:31	18.3 hr	SVOM MXT: $F < 5.5e-11$ ergs/cm ² /s This upper limit likely a high-z scenario
25/03/15 12:45:58	23.8 hr	VLT HAWK-I: (16.5 hr) $photo-z = 7.21 (+0.18, -0.38)$ $Y = 23.2 \pm 0.15, J = 22.4 \pm 0.1, H = 22.5 \pm 0.1$
		VLT X-shooter: $z \sim 7.3$ (17.4 hr)
25/03/15 14:08:48	25.2 hr	GCN Circular Swift XRT: $2.2e-12$ erg/s/cm ²
25/03/15 14:40:53	25.7 hr	Swift UVOT Upper Limit ($u > 20.94$) (1.58 hr)
25/03/15 16:32:44	27.6 hr	21:48:20 EP-FXT afterglow detection (8.9 hr) $5.2 (-/+1.6) e-13$ erg/s/cm ²

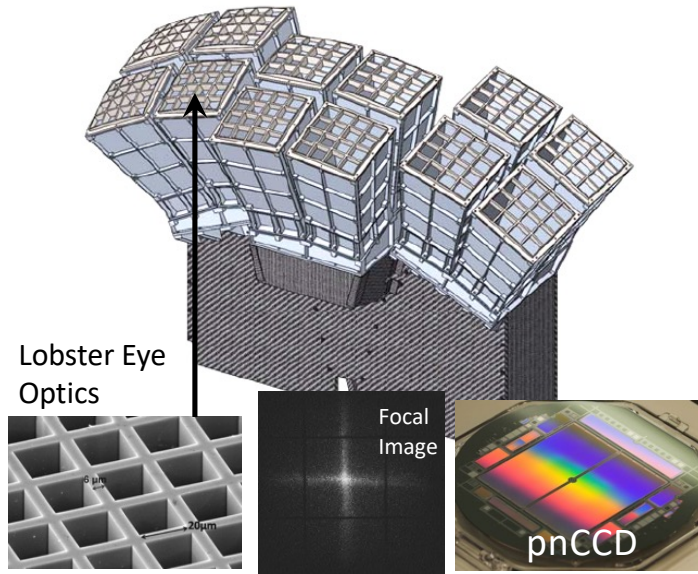
SVOM GRM Lightcurve



HZG はここまでを自動で行う

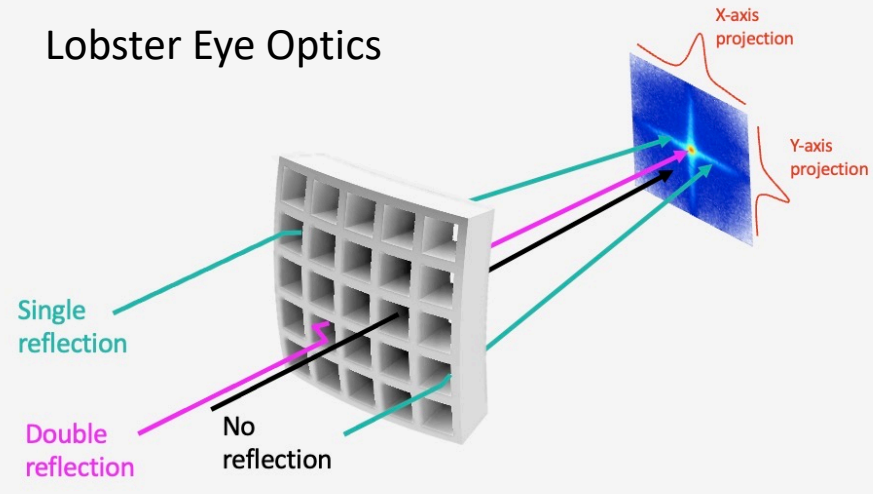
- MONSTER (NIRT) で検出し
オンボードデータ処理
- 30min ~ 1 hr 以内に
redshift の情報を含めて
Notice として通報する
(人を介さないレポート)

EAGLE : Wide Field X-ray Monitor

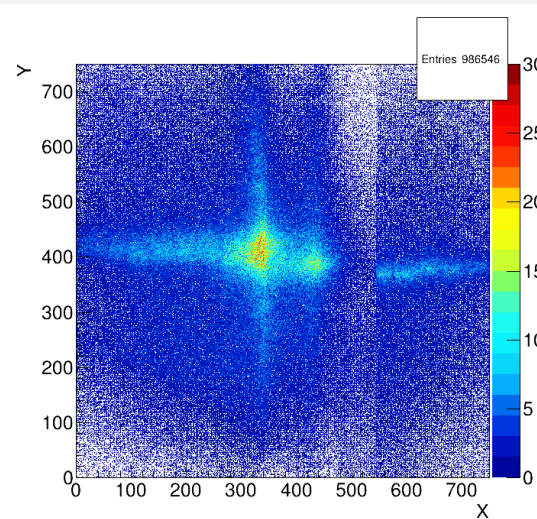
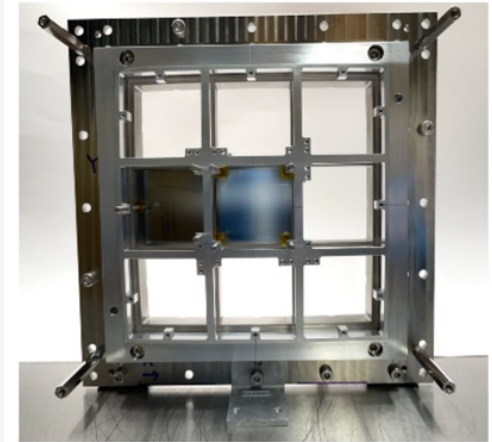


Items	Parameters
Energy band (keV)	0.4 – 4 keV
Telescope type:	Lobster Eye Optics
Optics aperture	240 x 320 mm ²
Number of Modules	16
Field of View	0.53 str (16 modules)
Focal length	300 mm
Focal plane detectors	pnCCD array
Time resolution	< 100 msec
Sensitivity	~ 1e-10 (erg/cm2/s) For 100 sec
Position accuracy	3 arcmin

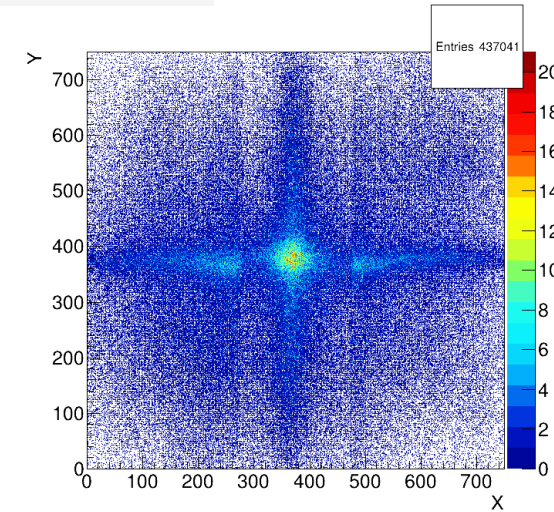
Lobster Eye Optics



Bread Board Model

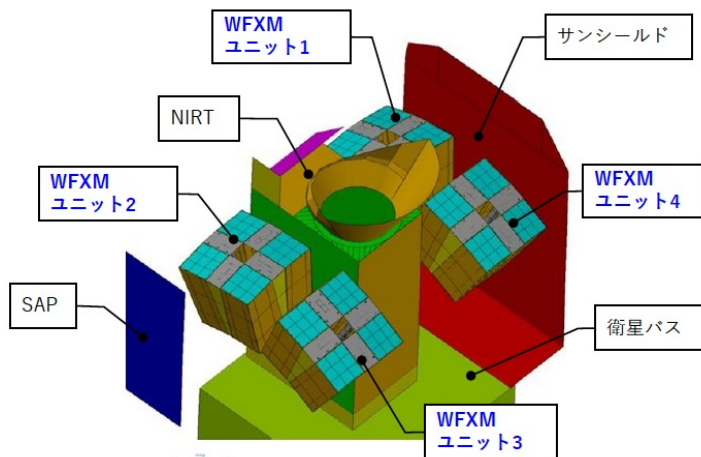
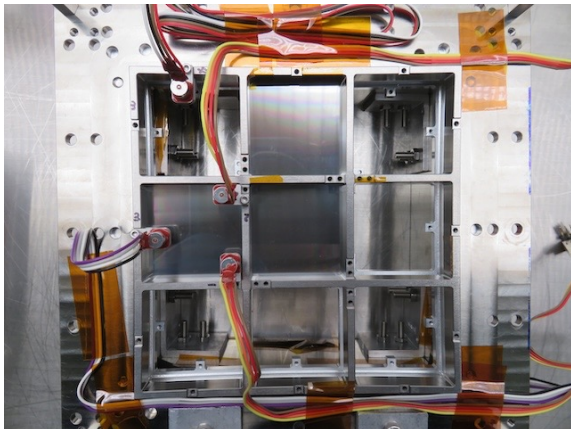


アラインメント調整前

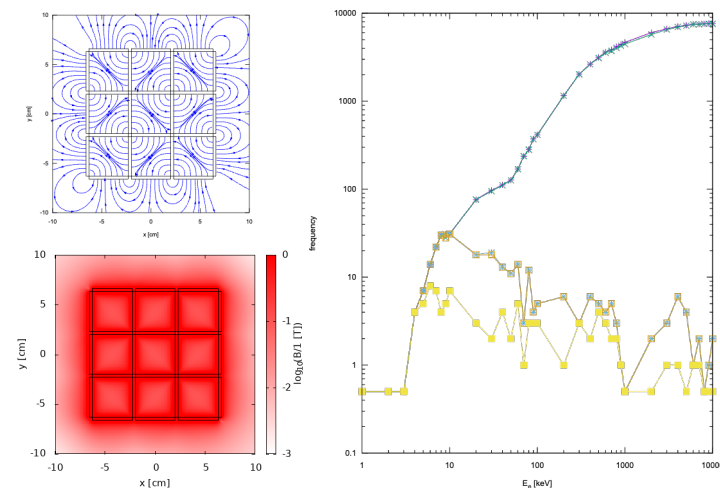


アラインメント調整後

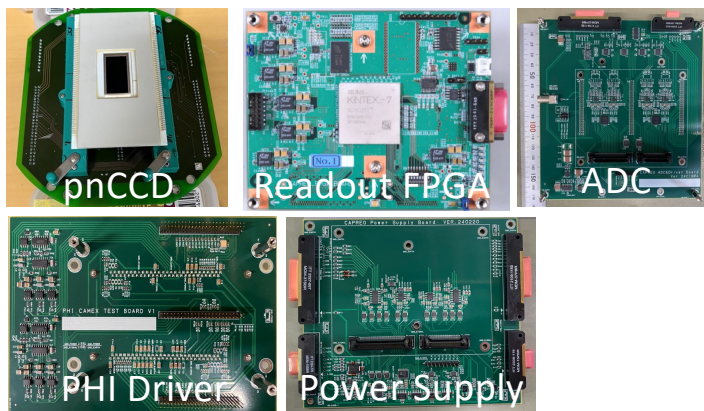
LEO アライメント調整(長高ポスター) EAGLE の主な進捗



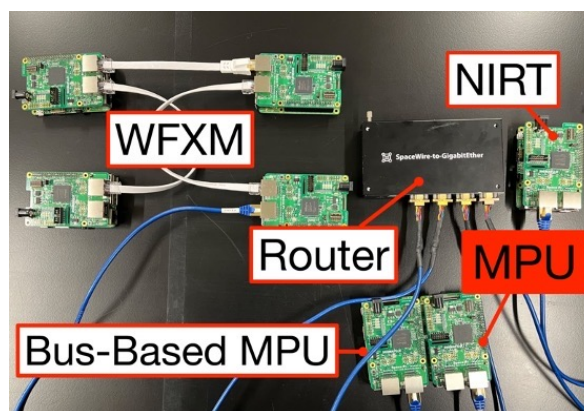
バックグラウンドシミュレーション (電子)



pnCCD + CAMEX(ASIC) + Electronics

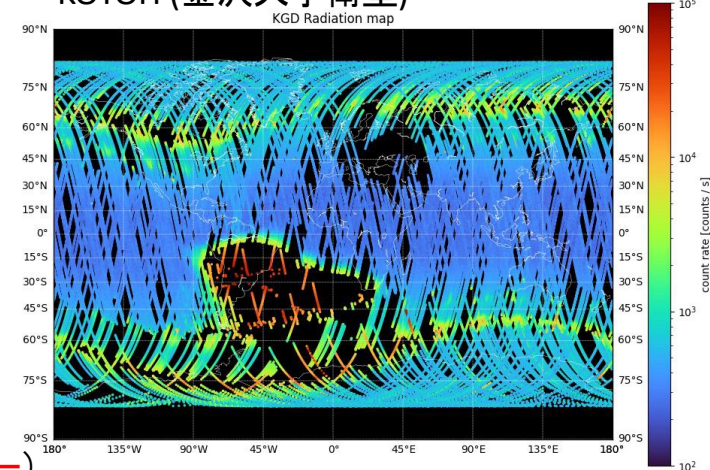


MPU (澤野ポスター)



(久津見ポスター)

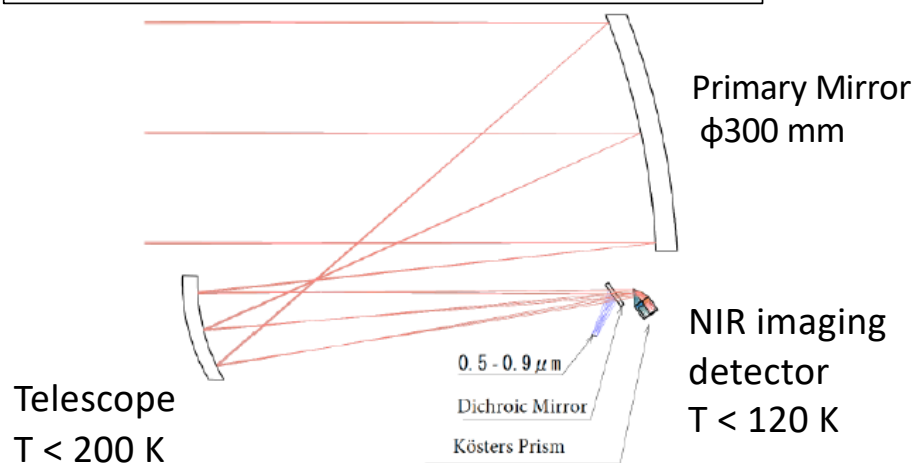
KOYOH (金沢大学衛星)



- 小型 pnCCD を駆動するためのエレキ開発 (今度ポスター、八木ポスター)
- FPGA に突発天体発見機能の実装

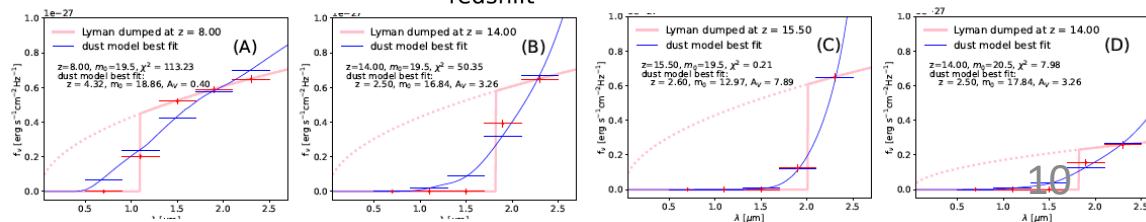
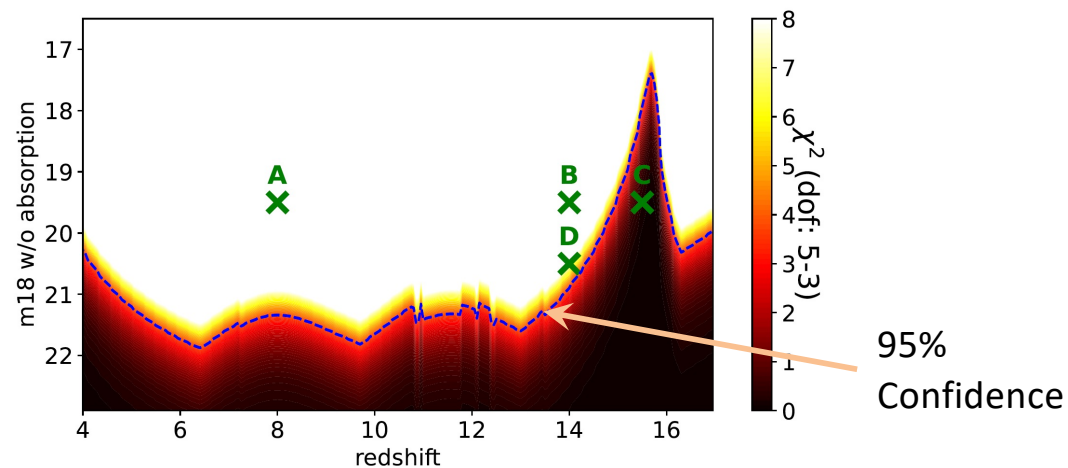
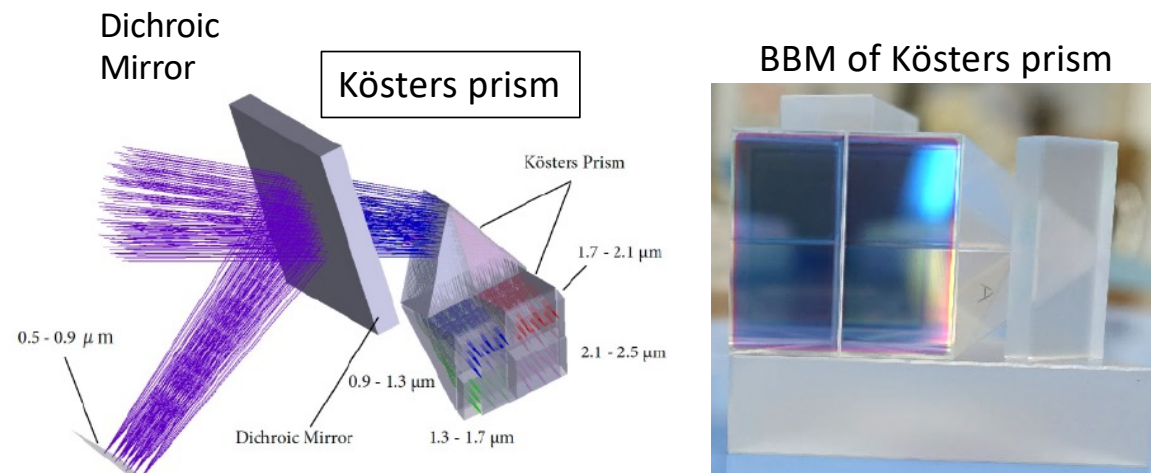
- 複数機器からの信号を模擬した SpW ダミーネットワーク
- オンボード解析ソフトの開発(富樫ポスター)

MONSTER: Near Infrared Telescope



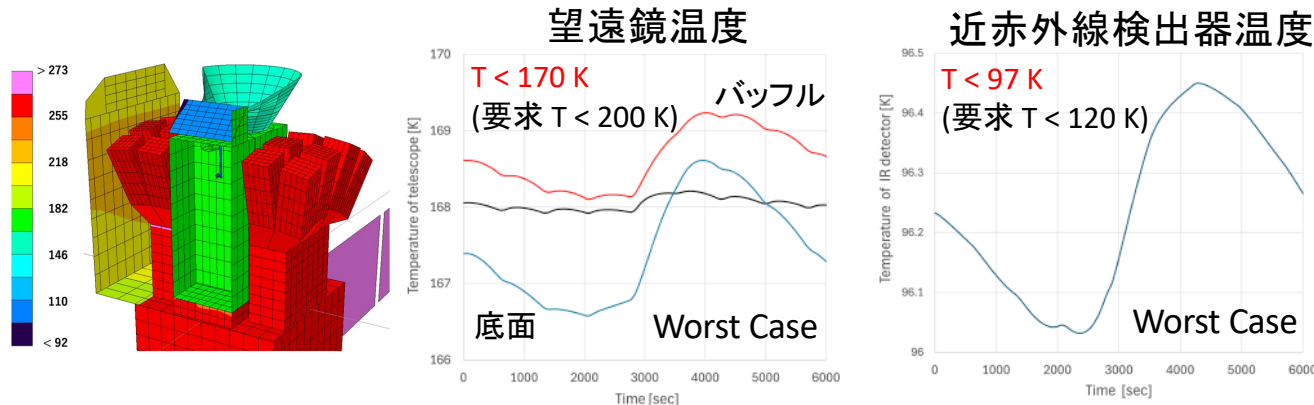
5-band simultaneous photometry

Items	Parameters				
Telescope type	Offset Optics				
Aperture size	30 cm				
Focal length	183.5 cm				
F number	F6.1				
Field of view	15 arcmin $\times$ 15 arcmin				
FoV per pixel	2 acsec $\times$ 2 arcsec				
Image size	3 pixel $\times$ 3 pixel				
Integration time	10 minutes (2 minutes $\times$ 5 frames)				
Observation Band (μ m)	0.5-0.9	0.9-1.3	1.3-1.7	1.7-2.1	2.1-2.5
Limiting Magnitude mag (AB) 10min, 10 σ	21.4	21.3	21.4	20.8	20.7
Focal detector	HyViSi		HgCdTe (H1RG)		



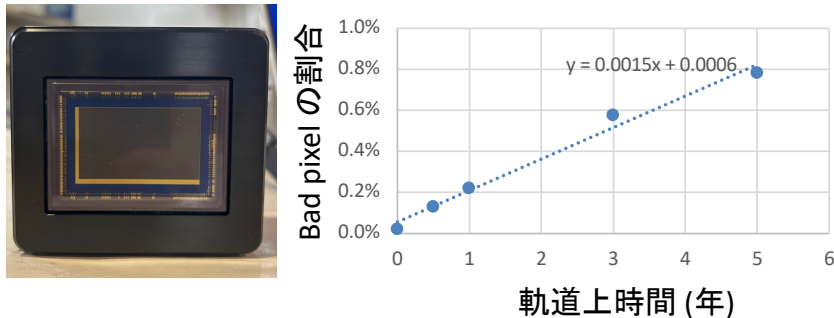
MONSTER の主な進捗 (津村ポスター)

熱設計・解析 (影山ポスター)



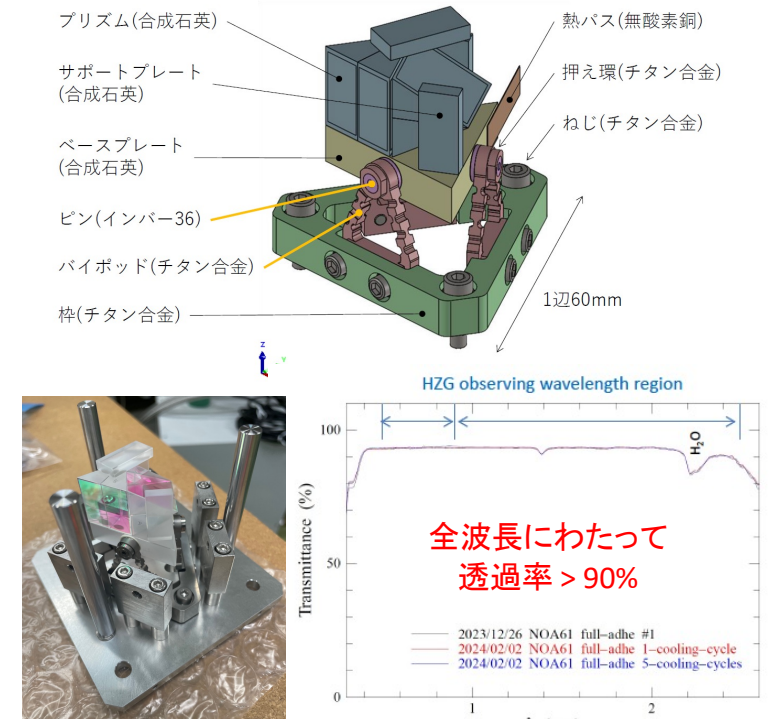
- 熱数学モデルを作成し、機器配置・ラジエータ配置・熱リンク等の検討
- 望遠鏡温度と検出器温度は 20K の温度マージンを持って成立する解を得た

可視光CMOS 放射線耐性



- 100 MeV プロトン照射試験 (若狭湾エネルギー研究センター)
- Bad pixel の増加傾向を把握
5年後に 0.8% 程度

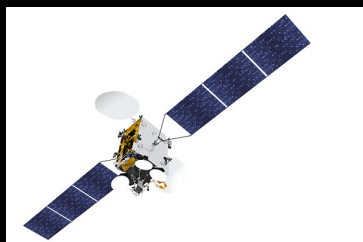
ケスタープリズム BBM の開発 (堀ポスター)



- 接着剤透過率測定、熱サイクル試験
- BBM 構造設計、プリズム製造、静荷重試験
- 透過率特性の把握
- 保持構造を製造中

Nominal Operation Sequence

Inmarsat



geostationary orbit

Inmarsat
Ground Station

HiZ-GUNDAM
Project Server

GCN

Latitude : 600 km
Orbital Period : 5801秒
Pointing : 572.125秒
Maneuver : 153秒

Alert

Coverage : > 90 %
Latency : ~ 0 sec
max delay : 5 min

Alert message

Pointing
572 sec

Maneuver
153 sec

KSAT

**Satellite orbit:
Sun-synchronous polar dawn-dusk orbit**

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

We observe roughly eight different fields of view in every orbit.
This sequence is optimized for follow-up observations with the NIR telescope,
we make sure of more than 10 minutes for 97% GRBs discovered by itself.



KSAT

Current Status Down selection review (2024/03 – 04)

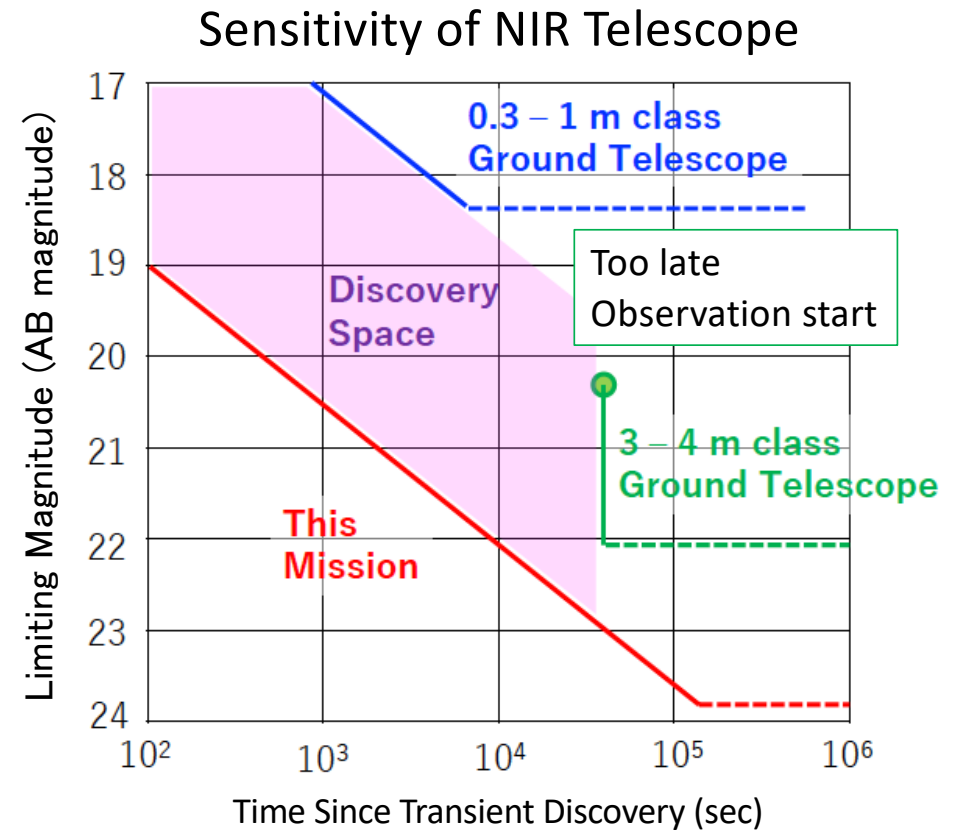
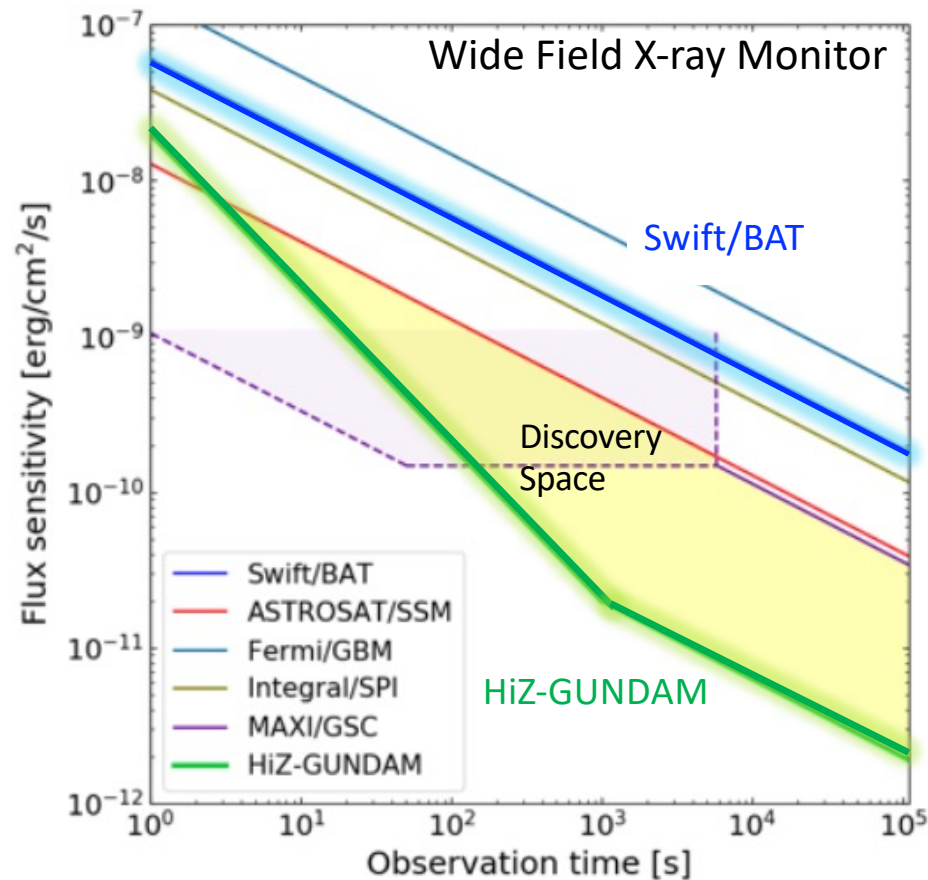
Activity in the concept study phase, the significance and value of the mission, and the feasibility of the system were evaluated as appropriate.

However, **selection status is “pending”**.

Future Schedule

Fiscal Year	Plans and Milestones
Current	Development of BBM (front loading)
FY2026	Down Selection Review for 3 candidates (HiZ-GUNDAM/Silvia/Lapyuta) Establishment of Pre-Project Team
FY2027	Mission Definition Review (the end of FY2024)
FY2029	System Definition Review Establishment of Project Team
FY2029 – 30	EM phase, System Definition Review
FY2030 – 32	FM phase
FY2033 – 34	Launch

Expected Sensitivity



High-**z** Gamma-ray bursts for **U**n unraveling the **D**ark **A**ges **M**ission

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

Key Science1: Probing the Early Universe

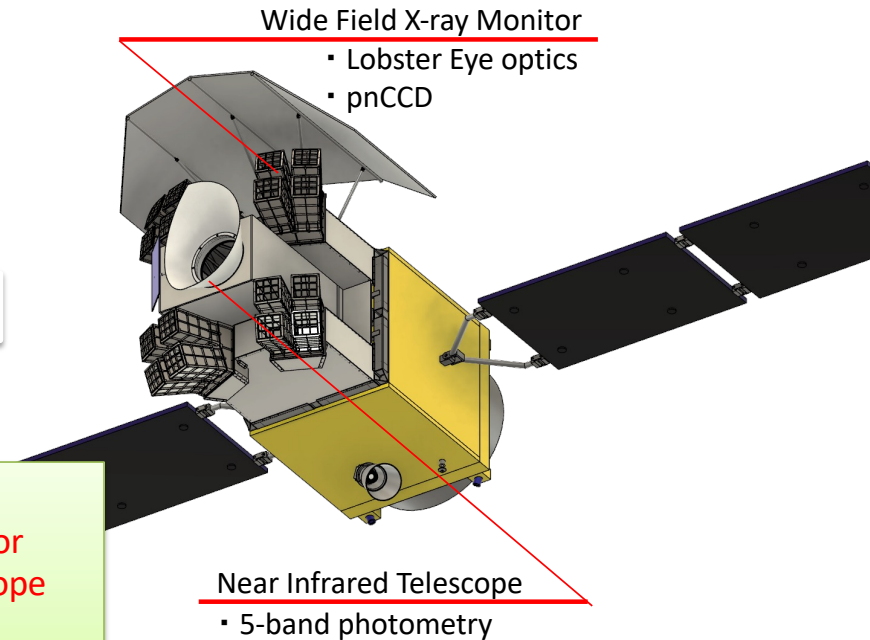
- Detection of high-redshift GRBs ($9 < z < 14$)
- Probing the reionization history and first metal elements

Key Science2: Progress of Multi messenger Astronomy

- Localization of X-ray transients from MM sources
- Energy transition from gravity to particles/elements

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)	0.5 – 4 keV
Field of View	> 1.0 str (6 units)
Sensitivity	1e-10 (erg/cm ² /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	15 arcmin × 15 arcmin				
Integration time	10 minutes (2 minutes x 5 frames)				
Observation Band (μm)	0.5–0.9	0.9–1.3	1.3–1.7	1.7–2.1	2.1– 2.5
Limiting mag (AB)	21.4	21.3	21.4	20.8	20.7