Introduction to HiZ-GUNDAM mission: Cooperative Observations with Subaru in 2030s

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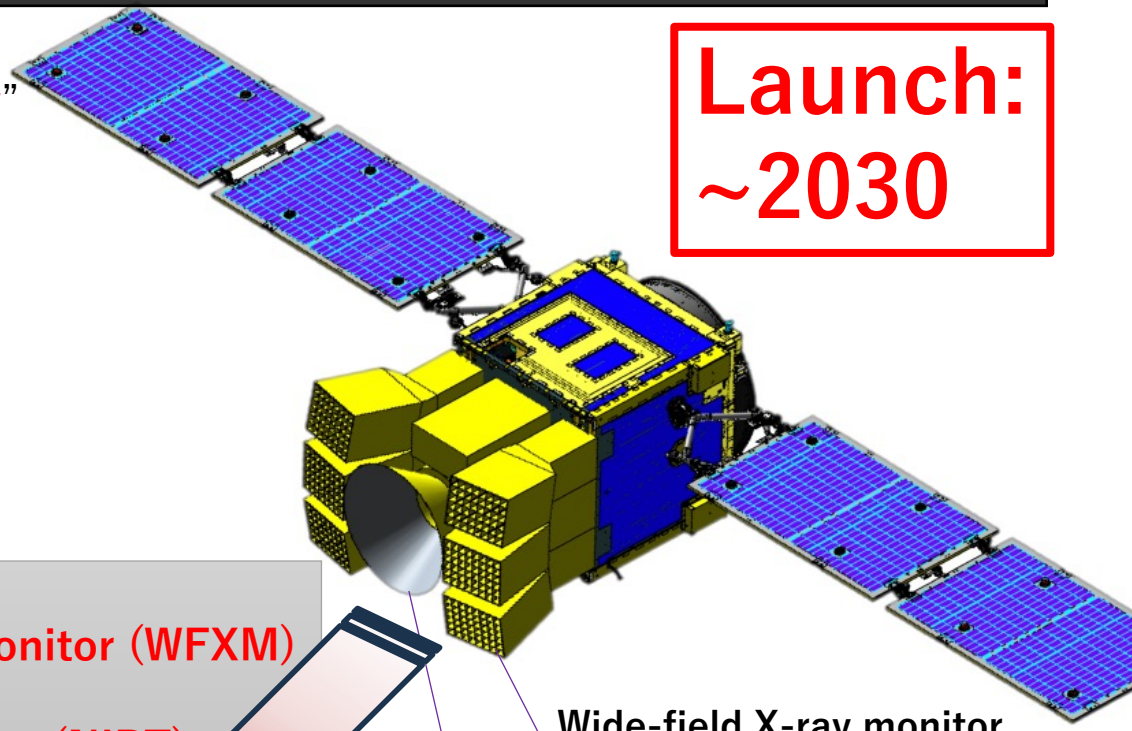
and HiZ-GUNDAM collaboration

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

Main themes：
"**Exploration of the early universe**" & "**Multi-messenger astronomy**"

Launch: ~2030



Mission 1 ： **Exploration of the early universe**

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

Mission 2： **Multi-messenger astronomy**

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

Observation Strategy
(1) Discovery of GRBs or X-ray transients by the **Wide-field X-ray monitor (WFXM)**
(2) Satellite attitude change by autonomous control
(3) Identification of GRBs or kilonovae by the **Near-infrared telescope (NIRT)**
(4) Transmission of alerts including location and photo-z.
(5) **Spectroscopic follow-up observations with large telescopes.**

Wide-field X-ray monitor
- Lobster-eye optics
- pnCCD

Near-infrared telescope
- Off-axis 30-cm telescope
- 5-band simultaneous observation

Problems in conventional GRB follow-ups

1. Detection of GRBs by a satellite, alerting it to the ground

   ⬇ ~1 hour

2. Afterglow observation with small (30 cm – 1 m) telescopes

   ⬇ a few hours – 1 day

3. Identify the redshift with medium size (2-4 m) telescopes

   ⬇ ~1 day

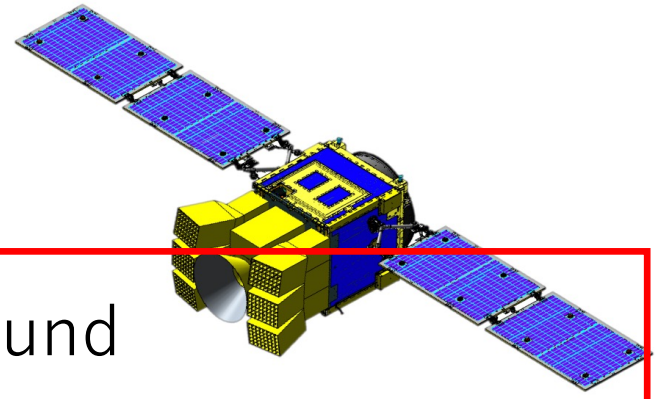
4. Spectroscopic observation of high-z GRBs with large (>8 m) telescopes

GRB afterglow has faded by the time the large telescopes observe.

In the 18 years of SWIFT, there have been only two GRBs with z>6.

Moreover, statistical accuracy of these spectra is low…

Our goal with HiZ-GUNDAM



1. Detection of GRBs by a satellite, alerting it to the ground

   ~~⬇ ~1 hour~~

   Automatic on-board follow-up within 300 sec

2. ~~Afterglow obse ation with small (30 cm – 1 m) telescopes~~

   ~~⬇ a few ho – 1 day~~

3. Identify the redshift ~~with medium size (2-4 m) telescopes~~

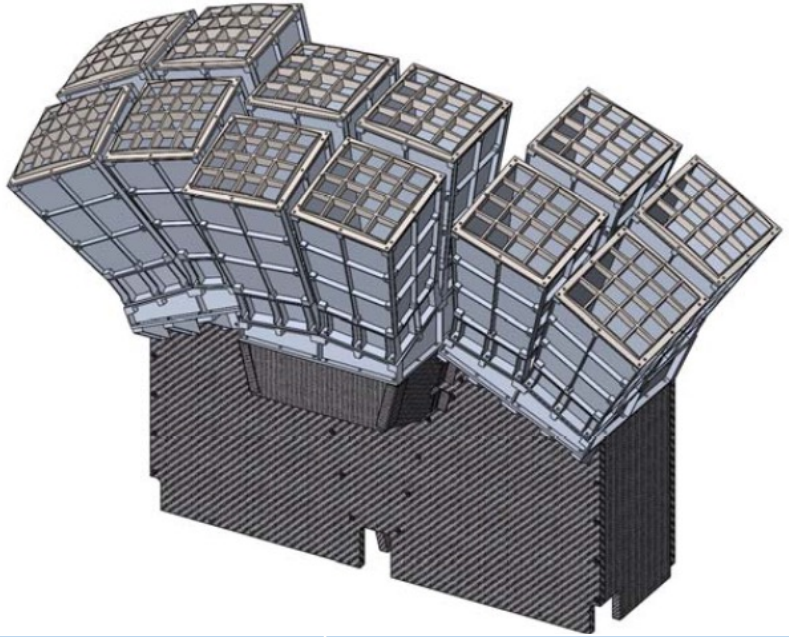
   ~~⬇ ~1 day~~ **Within a half-hour**

4. Spectroscopic observation of high-z GRBs with large (>8 m) telescopes

Accelerates the process from GRB discovery to follow-up observations with large telescopes.

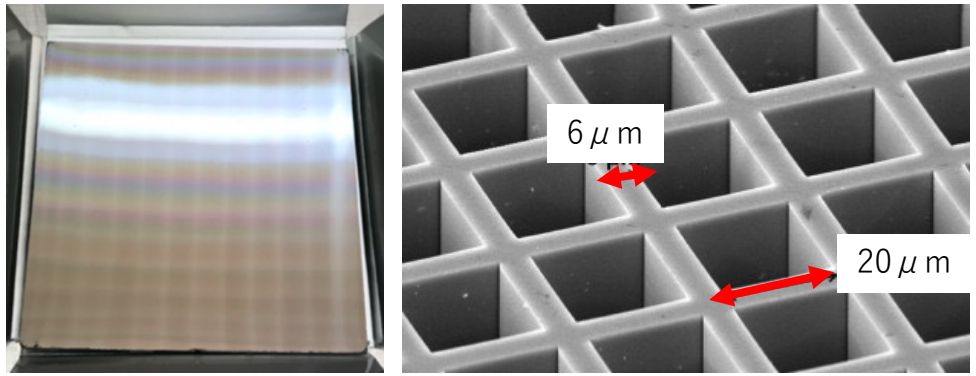
Almost no high redshift GRBs are missed because redshifts are measured for all GRBs discovered by HiZ-GUNDAM.

Wide Field X-ray Monitor (WFXM)



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	16
Field of View	0.5 str (in total)
Focal length	300 mm
Focal plane detectors	pnCCD array
Number of pnCCD	16
Sensitivity	~ 1e-10 (erg/cm2/s) For 100 sec
Position Accuracy	~ 3 arcmin

Lobster Eye Optics (Micro Pore Optics)



Digital Electronics Board for pnCCD

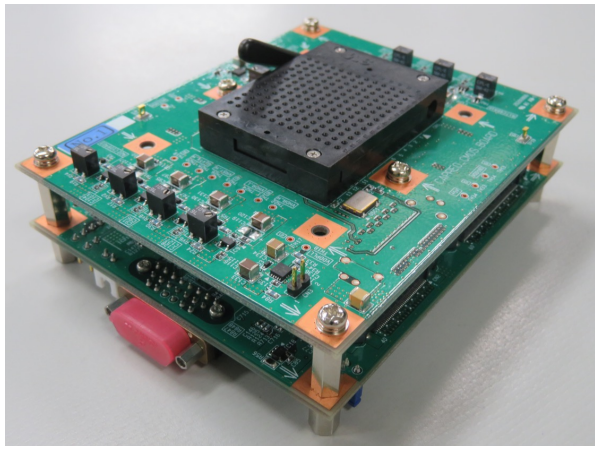
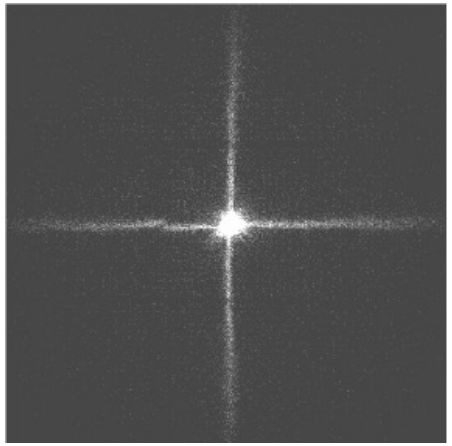


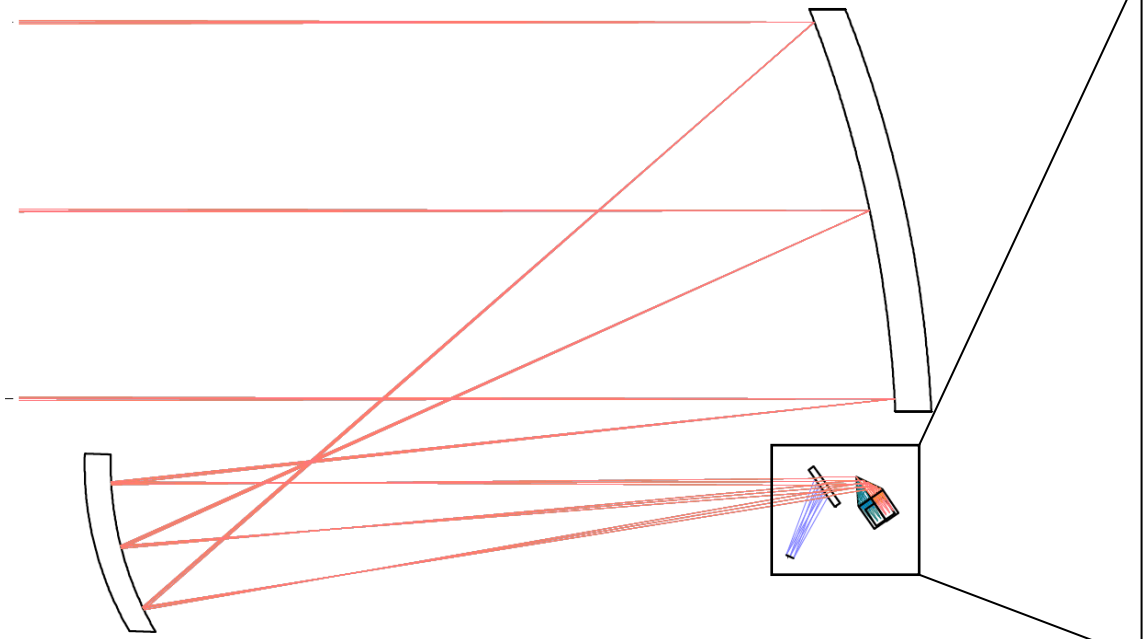
Image performance with X-ray beamline

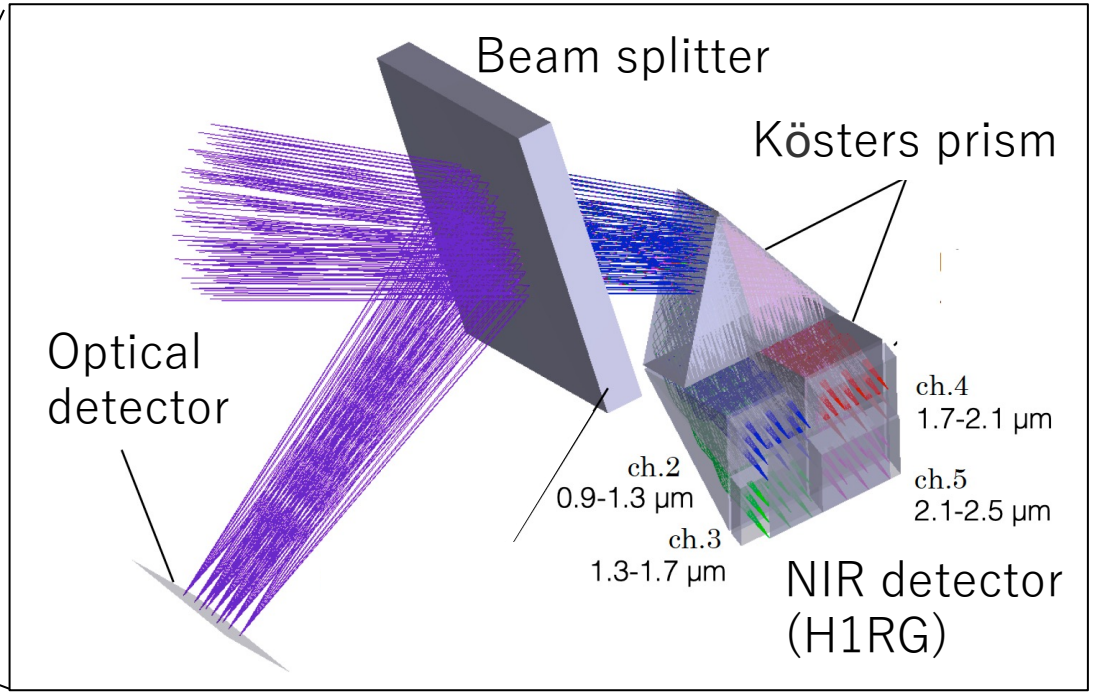


(Left) Digital Electronics Board (BBM) for pnCCD
(Right) Focal Image Obtained at 30m X-ray beamline

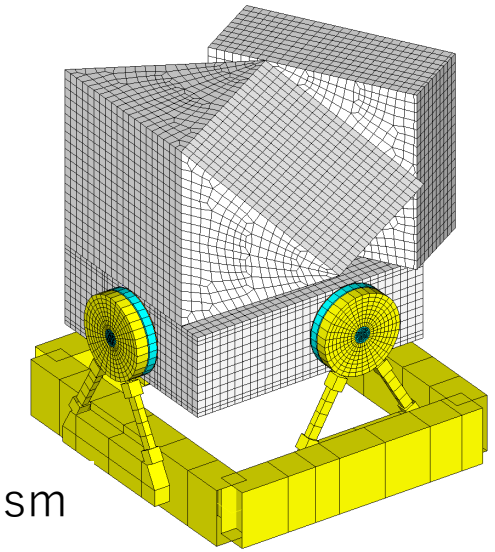
Near Infrared Telescope (NIRT)

5-band simultaneous photometry



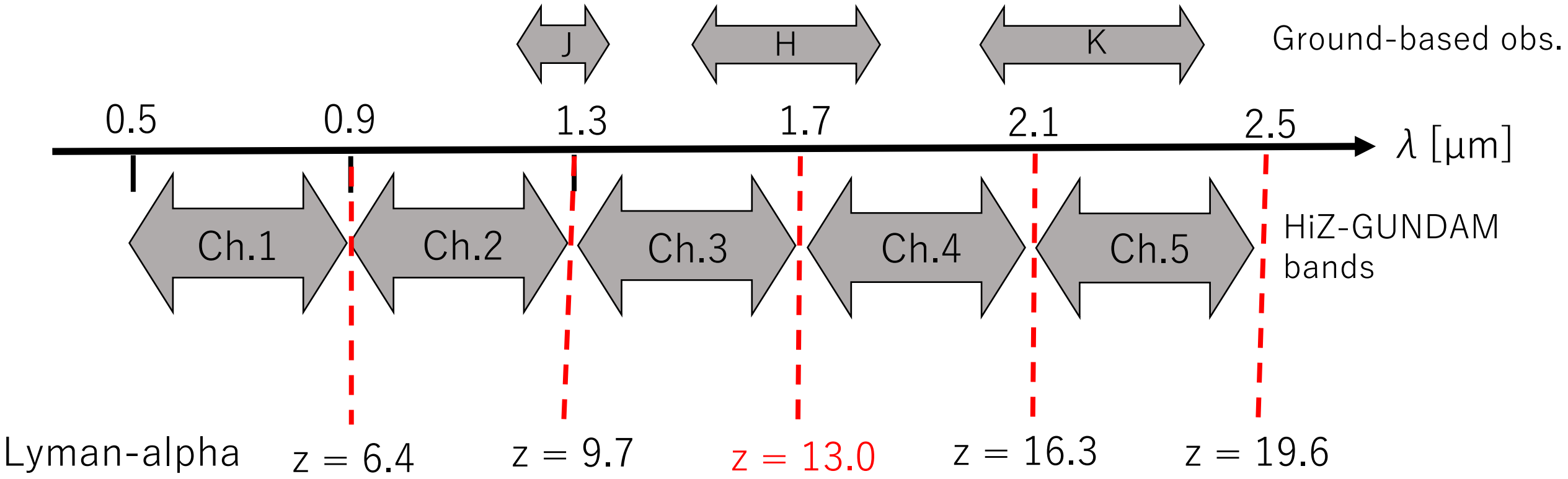


Items	Parameters				
Telescope type	Offset Gregorian				
Aperture size	**30 cm**				
Field of view	15 arcmin × 15 arcmin				
FoV per pixel	2 arcsec × 2 arcsec				
Image size	3 pixel × 3 pixel				
Integration time	10 minutes (2 minutes x 5 frames)				
Wavelength Band (μm)	0.5 – 0.9	0.9 – 1.3	1.3 – 1.7	1.7 – 2.1	2.1-**2.5**
Limiting Magnitude (AB), 10min, S/N=10	21.4	21.3	21.4	20.8	20.7
Focal detector	HyViSi	H1RG (HgCdTe)			



Kösters prism

Wavelength bands and redshift



- >2-band detections on the long wavelength side are required to distinguish the high-z objects from dusty galaxies.
- Photo-z can be determined with good accuracy at $z < 13.0$
- Object at $z<19.6$ can be detected in principle.

Project Status and Planed Master Schedule

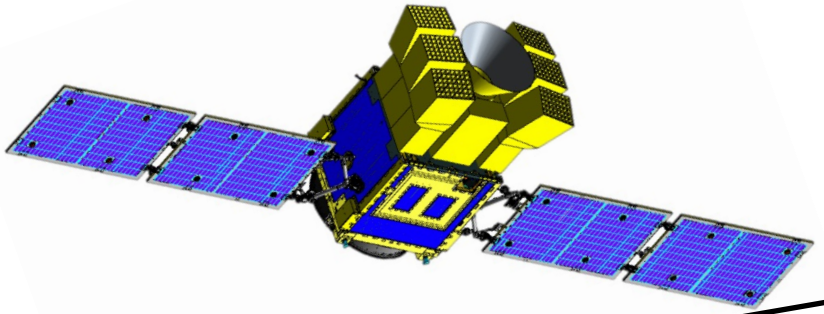
- Mission concept was selected in 2018 as the Competitive M-class Mission of ISAS/JAXA.
- Now in the pre-Phase A study in ISAS/JAXA.

Fiscal Year	Plans and Milestones
FY2023	Concept Study, **Down Selection Review (2023.4-5)** Down Selection Review (**Re-examination, 2024.3**)
FY2024	Development of BBM, Mission Definition Review, Estimated Budget Requirements
FY2025	Establishment of Pre-Project Team
FY2026	Establishment of Project Team
FY2026 – 2027	EM Phase
FY2028 – 2030	FM Phase, Launch in 2030

- **Down selection review** was held in April-May 2023;
  - The ISAS Executives recommended that the mission scope be "to produce Key Science results through coordinated observations with space and ground-based telescopes that have been alerted from HiZ-GUNDAM".

Follow-up team is being constructed

HiZ-GUNDAM plays the role of “commander”,
and promotes GRB observations with the world's large telescopes.



HiZ-GUNDAM team
Led by **Daisuke Yonetoku**

Early Universe
Led by **Yuichi Harikane**

MM (GW)
Led by **Masaomi Tanaka**

MM (Neutrino)
Led by **Shigeo Kimura**

Science D

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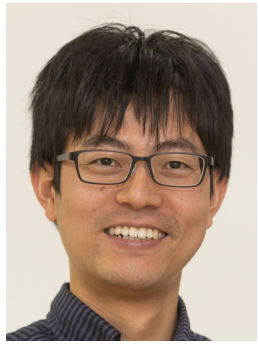
Follow-up obs.

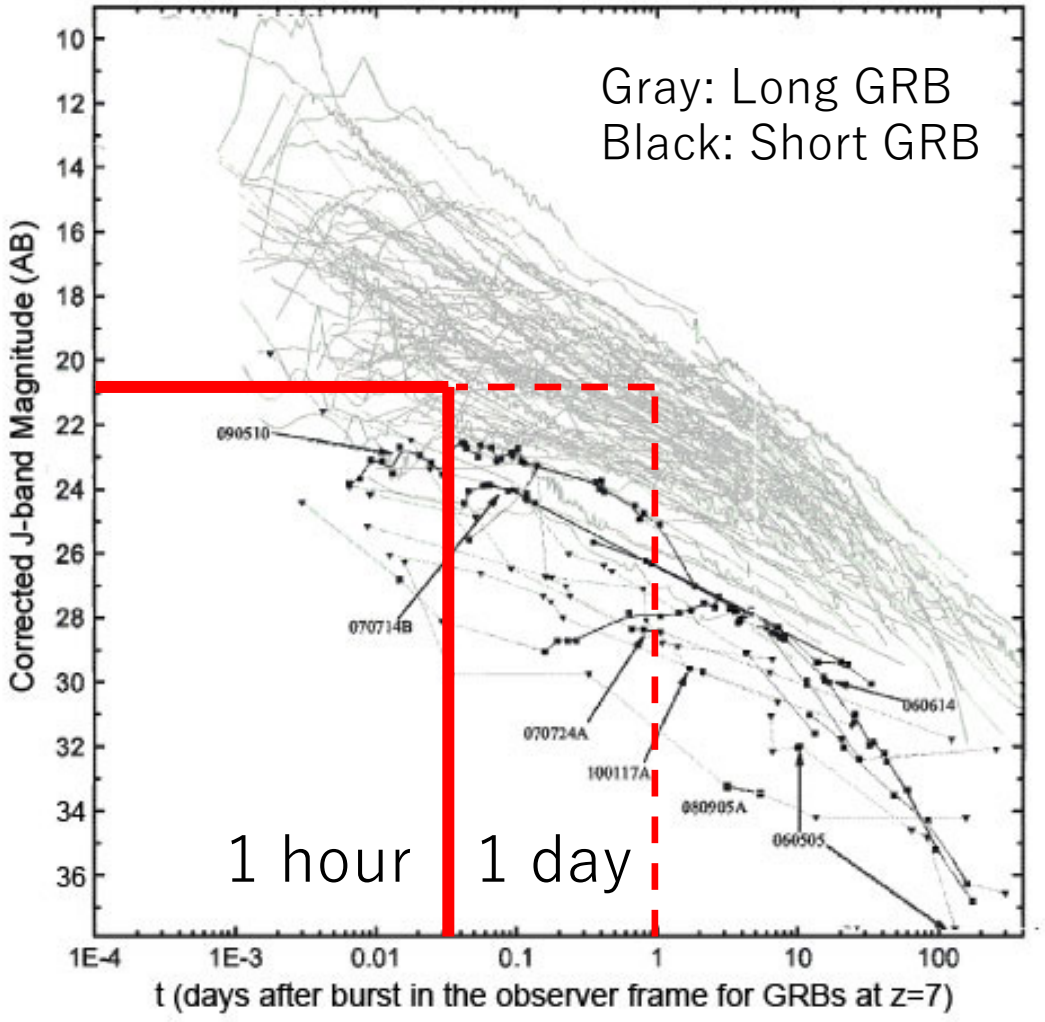
Follow-up obs.

Follow-up obs.



Requirement for follow-up spectroscopy at NIR

Expected Lightcurve for GRBs @ z = 7



Based on Kann et al. (2010)

Expected light curve when the GRB is placed at z=7 for a GRB with a known distance.

If follow-up observations can be carried out within 1 hour after discovery, the expected brightness is brighter than 21 mag (in >90% probability)

~10 GRBs at z>6 is expected (depending on the model)

8-m class telescope with 1-2 hours follow-up latency is required

Candidates of spectrometer on 8m-class telescope

- Simultaneous spectroscopy of wide NIR bands (J,H,K) is important
- Subaru
  - NINJA: J, H (+ K) Simultaneous spectroscopy, 21.5 – 22.0 mag (6 hours, S/N = 10).
    The only spectrometer that can use LTAO.
  - PFS: Not suitable for spectroscopy of a single object.
    It takes >9 hours after receiving the alert to start the observation.
- Keck/NIRES, VLT/X-shooter, Gemini/SCORPIO(2024~) are also candidates, but Subaru/NINJA has better sensitivity (0.5-1.0 mag) thanks to LTAO.
- Keck/MOSFIRE, Gemini/GNIRS are less efficient because multiple observations are required to cover a wide NIR range.

Subaru/NINJA is the best solution !

Comparison of spectrometers on 8m-class telescope

Simultaneous spectroscopy of wide NIR bands (J,H,K) is important

	Wavelength coverage	Resolution $R = R/\Delta R$	Multiplicity	Notes
Subaru/PFS	Optical + J-band simultaneous	2000 (blue) 3000 (red) 4000 (NIR)	2394 fibers	
Subaru/NINJA	Optical to J, H (+K)-band simultaneous	5000	Single object	LTAO => 0.5-1.0 mag deeper than X-shooter
Keck/NIRES	Y, J, H, K simultaneous	2900	Single object	
VLT/X-shooter	Optical to J, H, and K-band simultaneous	5000	Single object	

Topics to be discussed

- How can we achieve ToO follow-up observations **within an hour** from receiving an alert with Subaru telescope in 2030s?
  - Consideration of a scheme for ToO triggering by users when a GRB that meets predefined conditions occurs.
- Preparing a letter from Subaru to ISAS/JAXA stating that GRB science has high value.
  - JAXA is requesting such a letter for re-examination in 2024 March.
  - The content can be a summary of objective facts, such as the past results of GRB follow-up observations by Subaru, in order to demonstrate the follow-up power of Subaru.
  - SAC will show a draft of the letter, and we would like the Subaru user's community to discuss whether this letter is acceptable.