HiZ-GUNDAM

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

arXiv: 1406.4202

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HiZ-GUNDAM working group

Gamma-Ray Burst Meeting @ RIKEN (2015/08/31 – 09/02)

■ X-ray & gamma-ray part

米徳大輔（金沢大）、三原建弘（理研）、澤野達哉（金沢大）、河合誠之（東工大）、
有元誠（東工大）、池田博一（ISAS/JAXA）、榎戸輝揚（理研）、大野雅功（広島大）、
黒澤俊介（東北大）、郡司修一（山形大）、坂本貴紀（青山学院大）、芹野素子（理研）、
田代信（埼玉大）、谷森達（京都大）、中川友進（ISAS/JAXA）、村上敏夫（金沢大）、
谷津陽一（東工大）、山岡和貴（青山学院大）、湯浅孝行（理研）、吉田篤正（青山学院大）、
Neil Gherels (NASA/GSFC)

20＋1名

■ Near Infrared part

川端弘治、吉田道利（広島大）、松浦周二（ISAS/JAXA）、津村耕司（東北大）、
松本敏雄（台湾中央研究院）、白籏麻衣、柳澤顕史、沖田博文、田中雅臣（天文台）、
浦田裕次（台湾国立中央大学）、本原顕太郎（東京大）
アドバイザ：金田英宏（名古屋大）、和田武彦（ISAS/JAXA）

11＋2名

■ Theoretical part

浅野勝晃（宇宙線研）、井岡邦仁（高エネ研）、伊藤裕貴（理研）、井上進（宇宙線研）、
川中宣太（東京大）、諏訪雄大（京都大）、高橋慶太郎（熊本大）、寺木悠人（理研）、
當真賢二（東北大）、戸谷友則（東京大）、長倉洋樹（京都大）、長滝重博（理研）、
中村卓史（京都大）、新納悠（国立天文台）、松本仁（理研）、水田晃（理研）、
村瀬孔大（ペンシルバニア州立大）、山崎了（青山学院大）、横山順一（東京大）、
Maria Giovanna Dainotti (Stanford Univ.), Maxim Barkov (RIKEN),
Jirong Mao (Kyushu Univ.), Alexey Tolstov (Kavli IPMU)

19＋4名

59名／22機関

■ Satellite system

坂井真一郎、山田和彦（ISAS/JAXA）

2名

3 key issues for X-ray transient observations

(1) Counterpart of gravitational wave source

・Tests of the theory of general relativity in strong gravitational field

(2) Probing the early universe with high-z gamma-ray bursts

・First stars and First black hole formation in the universe

・History of cosmic reionization and its origin

・Chemical evolution of heavy elements

(3) Multi-wavelength/messenger astronomy

・From radio to TeV gamma-ray, and neutrino, cosmic ray, and GW

・Understanding the extreme universe with transient phenomena

Main purpose of HiZ-GUNDAM is (2) to probe the early universe with GRBs, but also strongly contribute to (1) and (3).

NASA's Decadal Survey 2010 (Science Frontier Discovery)

(1) Habitable Exoplanet

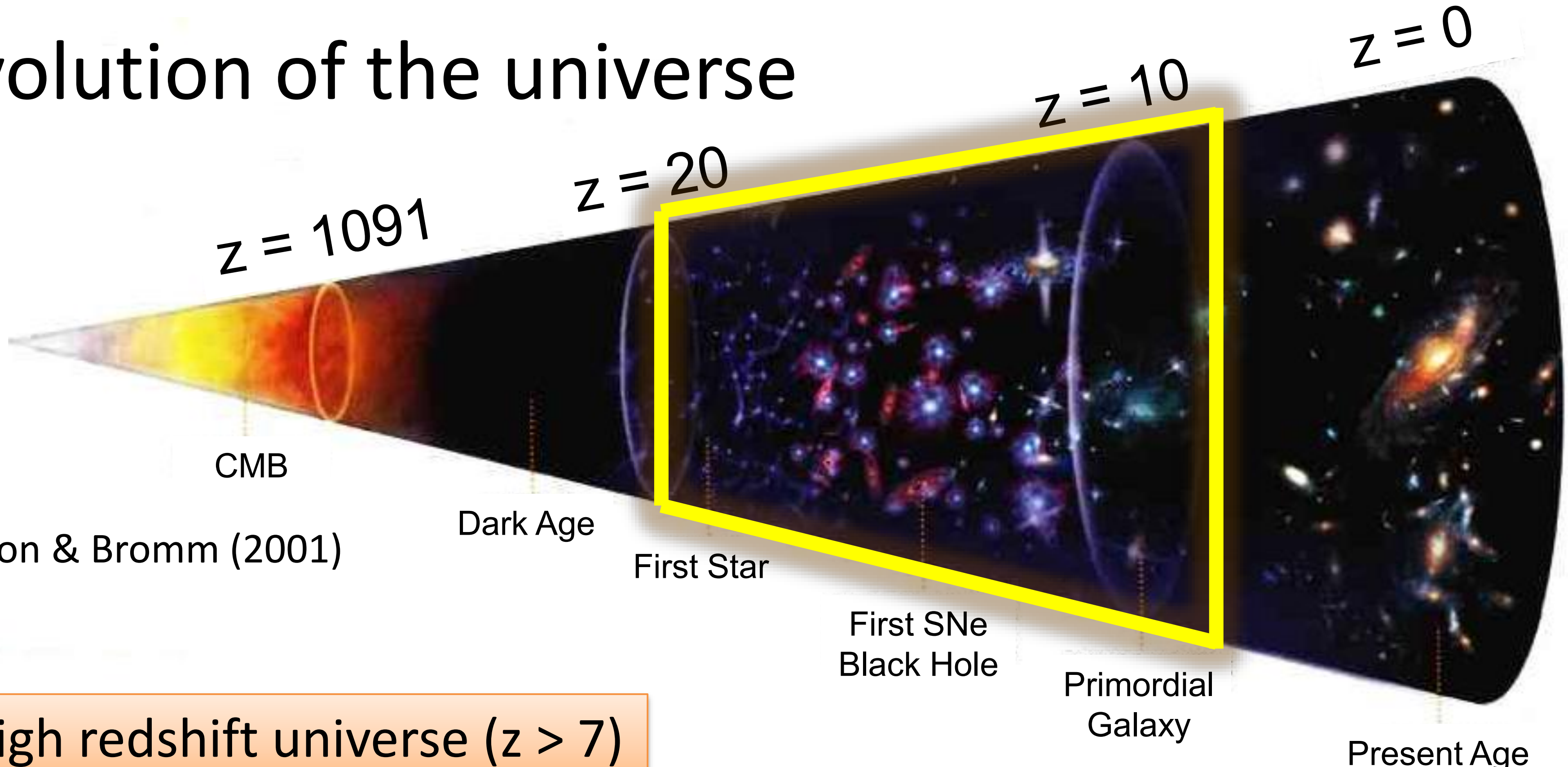
(2) Gravitational wave astronomy

(3) Time Domain Astronomy

(4) Astrometry

(5) Epoch of cosmic reionization

Evolution of the universe



Larson & Bromm (2001)

High redshift universe (z > 7)

- Formation of first stars (Pop-III stars) → Massive stars → GRBs
- Cosmic reionization ← UV radiation (Massive stars)
- First metal production ← Nucleosynthesis (Massive stars)
- First black hole formation ← explosion (GRBs)

↓

Evolution to super massive BH?

GRBs as a cosmological probing tool.

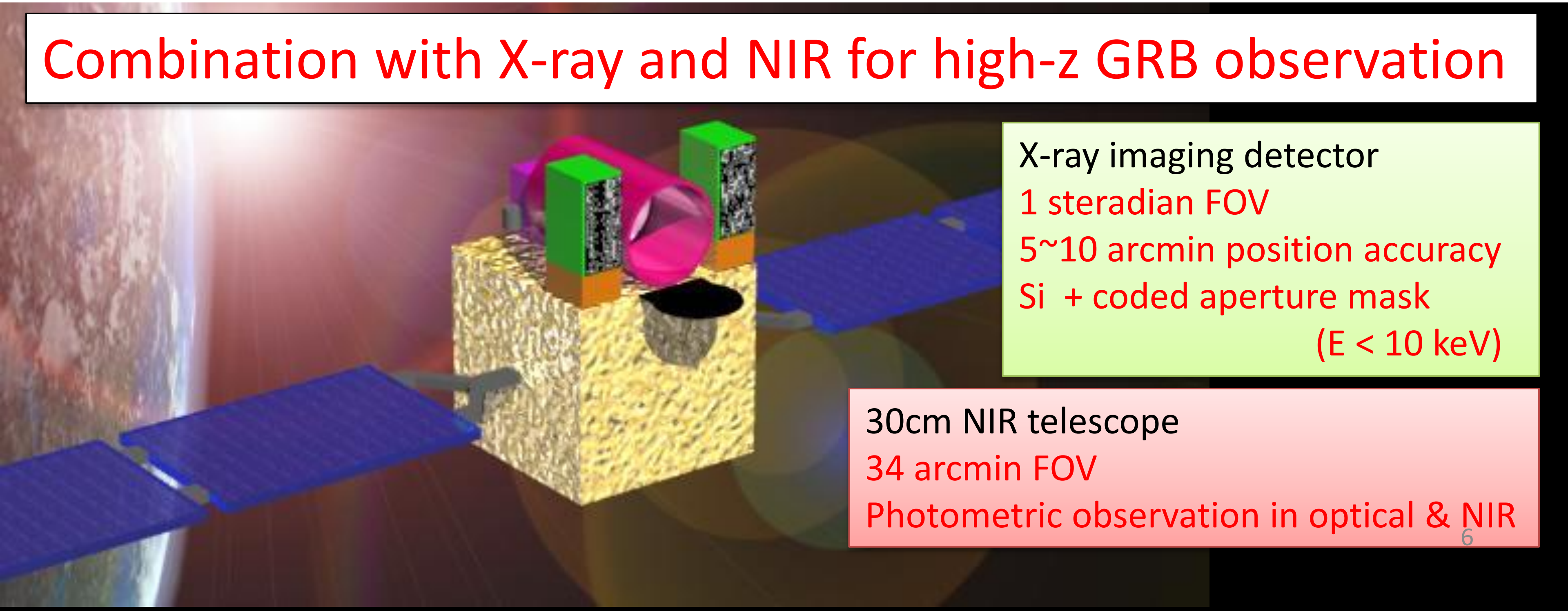

Focus of Large Projects in late 2010's and 2020's
TMT
Primordial galaxies(z > 10)
Reionization (z～10)
Gamma-Ray Bursts
ALMA
Galaxy formation(z～10)
Massive BH evol.(2<z<10)
SKA
High-z HI 21cm-line
Astro-H
Cluster of gal. (z～0.3)
Obscured AGN(z＜1)
Cosmic web, CXB
Time since the Big Bang (years)
The Big Bang/Inflation
Universe filled with ionized gas: fully opaque
Universe becomes neutral and transparent
z=1000
Gamma-Ray Bursts
z=12
Epoch of Reionization
Galaxies and Quasars begin to form - starting reionization.
Optical/NIR/Sub-mm Obs.
z=7
Reionization complete
z=6
z=0.5
2028～
Our Solar System forms
High energy Obs.
2015～
z=0
X-ray and Gamma-Ray
Today: Astronomers look back and understand
NASA/WMAP Science Team
SPICA
Pop-III stars:
H2 molecular (z<7)
H2 excitation (z～20)
Obscured AGN (z<1)
Evolution of dust
JWST
Athena
Evolution of cosmic web
WHIM (z<2)
Massive BH (z<6)
Cluster of gal. (z<2)
Accretion disk
Iron emission line

HiZ-GUNDAM observation strategy

(1) GRB discovery in X-ray band, and send 1st alert of the localization.
(2) Automatically start follow-up obs. with near infrared telescope.
(3) 2nd alert of fine localization (~ 1”) and rough redshift (z>5 or z>7).

after that,

(4) Spectroscopic observation with large area telescopes.

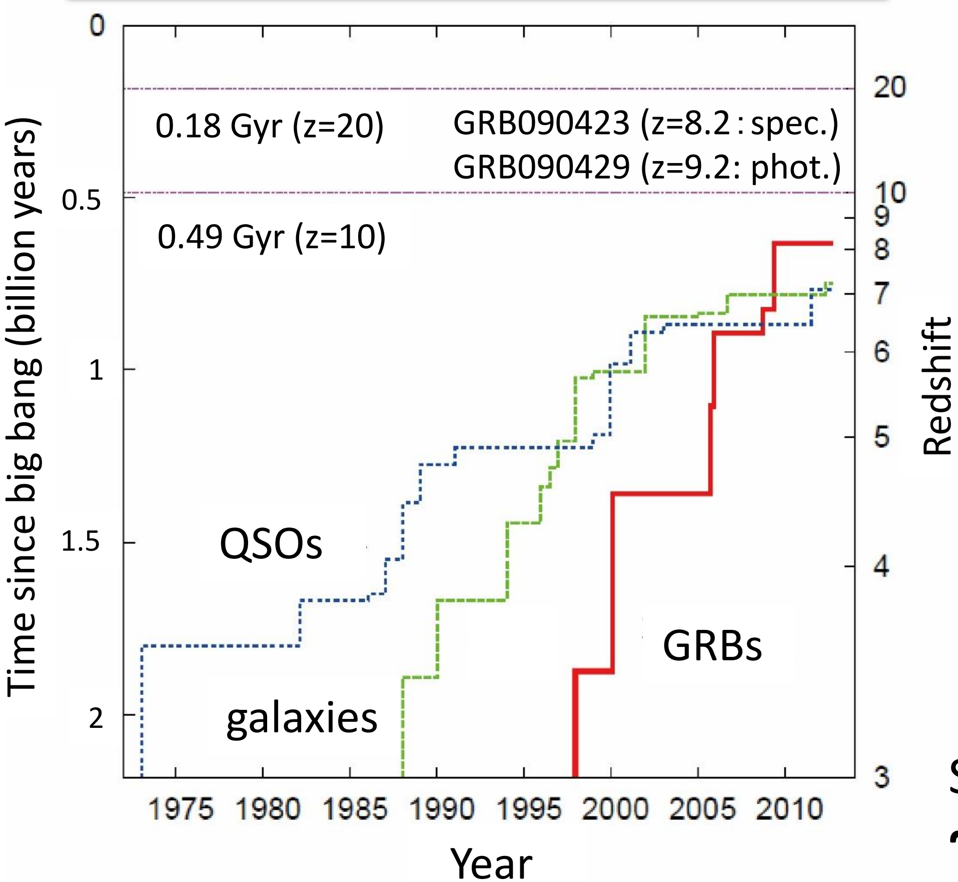


Combination with X-ray and NIR for high-z GRB observation

X-ray imaging detector
1 steradian FOV
5~10 arcmin position accuracy
Si + coded aperture mask
(E < 10 keV)

30cm NIR telescope
34 arcmin FOV
Photometric observation in optical & NIR

Transition of the highest redshift record



(1) Estimation from lumi-func. (Niino 2012)
2.5 ～50 event/yr/str for **z > 7**

(2) Evolution from Dark matter halo (Mao 2012)
~ **16** events/yr/str for **z > 7**

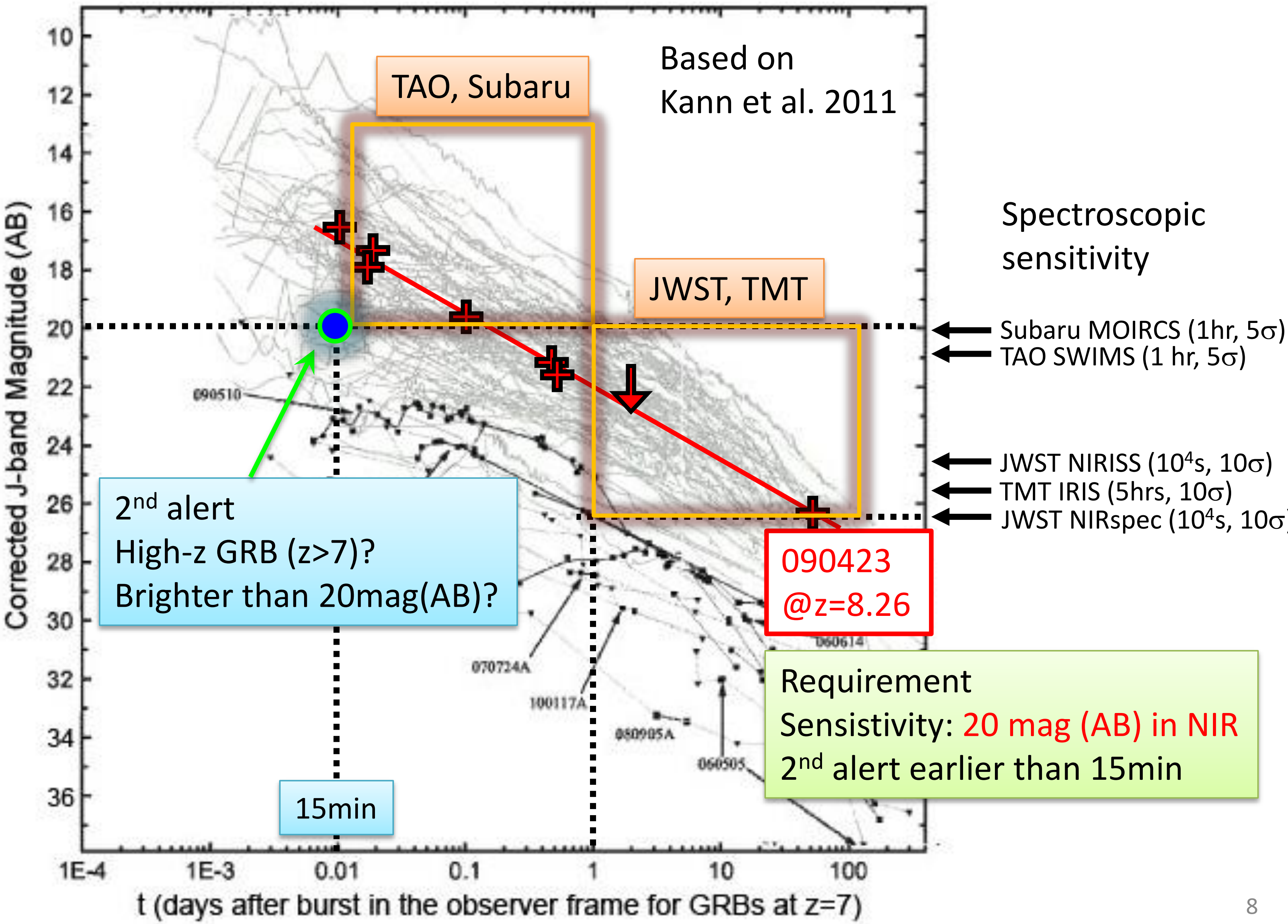
(3) Star Formation Rate (Wanderman & Piran 2010)
~ 10 events/yr/str for **z > 7**
~ **3** events/yr/str for **z > 10**

High-z GRBs: **~10** events/yr/str

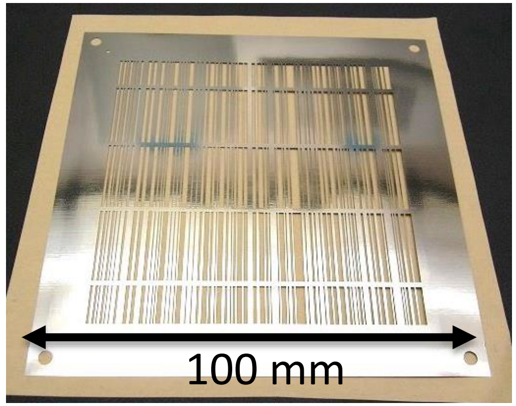
Swift observation:
~ 0.5 event/yr/str for **z > 6** (lower limit)

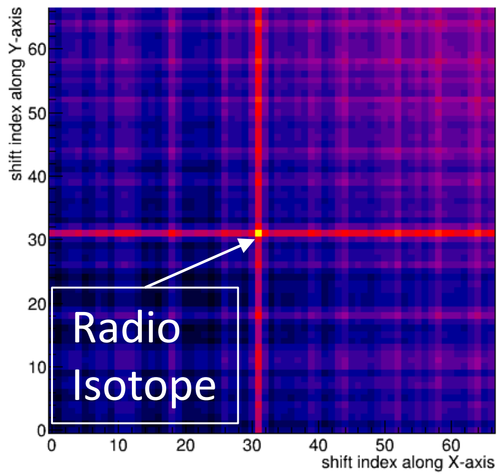
Expected high-z GRB rate is **~ 5** event/yr/str
if we realize one order of better sensitivity than Swift-BAT in soft X-ray band

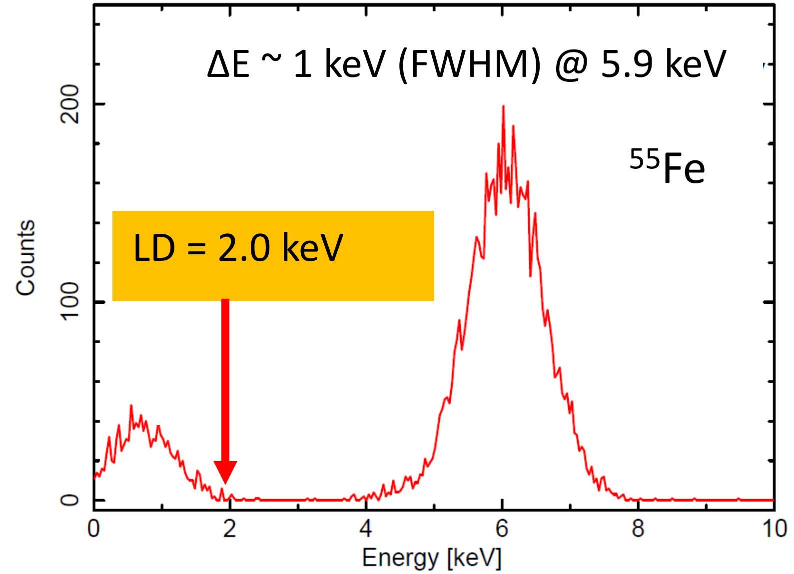
Expected lightcurve of GRB afterglow @ z=7



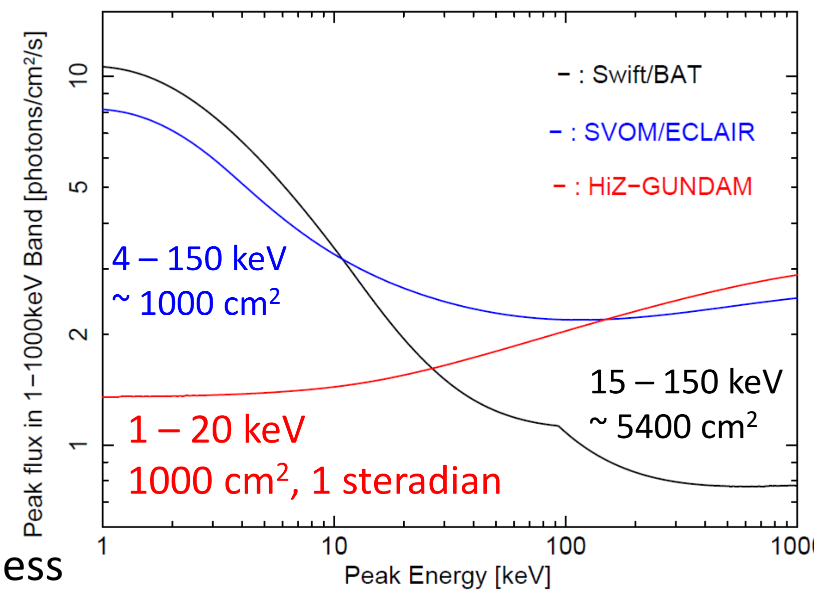
Wide Field X-ray Imaging Detector





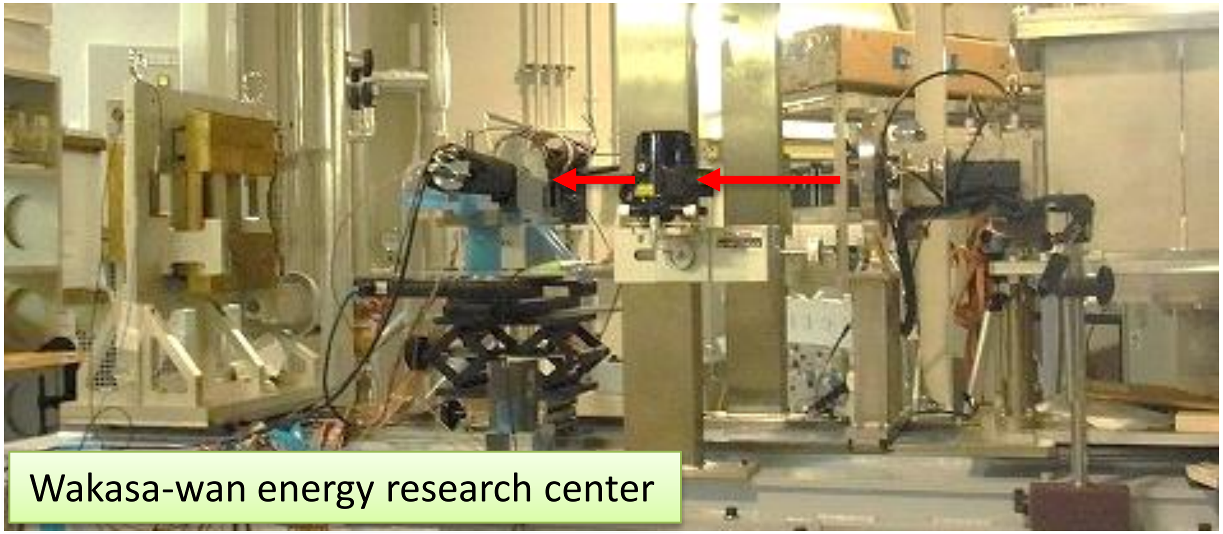


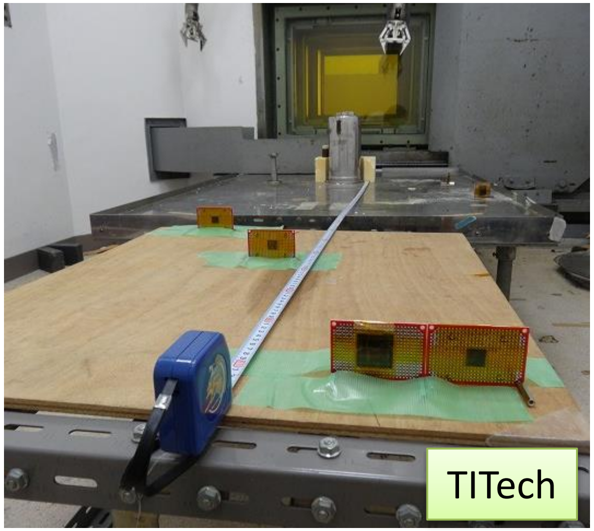
8σ detection sensitivity



- Silicon Strip Detector with Coded Aperture Mask
- X-ray Spectroscopy from 2 keV (Goal 1 keV)
- Tungsten Coded Aperture Mask with 0.5 mm thickness
- Verification of X-ray Imaging
- Final sensitivity will be ~ one order of magnitude higher than Swift/BAT and SVOM/ÉCLAIR for soft X-ray transients & high-z GRBs.

Radiation tolerance Test





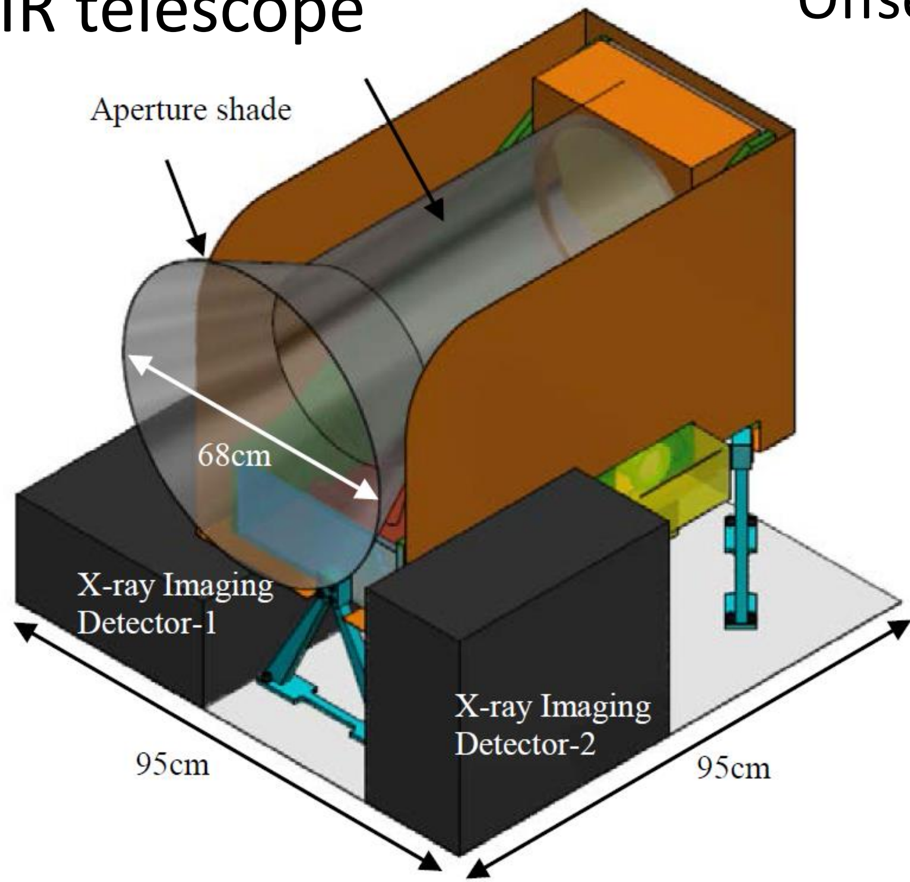
2013/10/03 – 04 : Proton irradiation test for SSD (200 MeV monochromatic)
No change of breakdown voltage for the proton for 10 yrs fluence in orbit
Leakage current increased by factor of 4

2014/06/12 – 13 : Proton irradiation test for ASIC (200 MeV)
Maintain the operation function for 10 yrs irradiation
No single event (SEU/SEL)

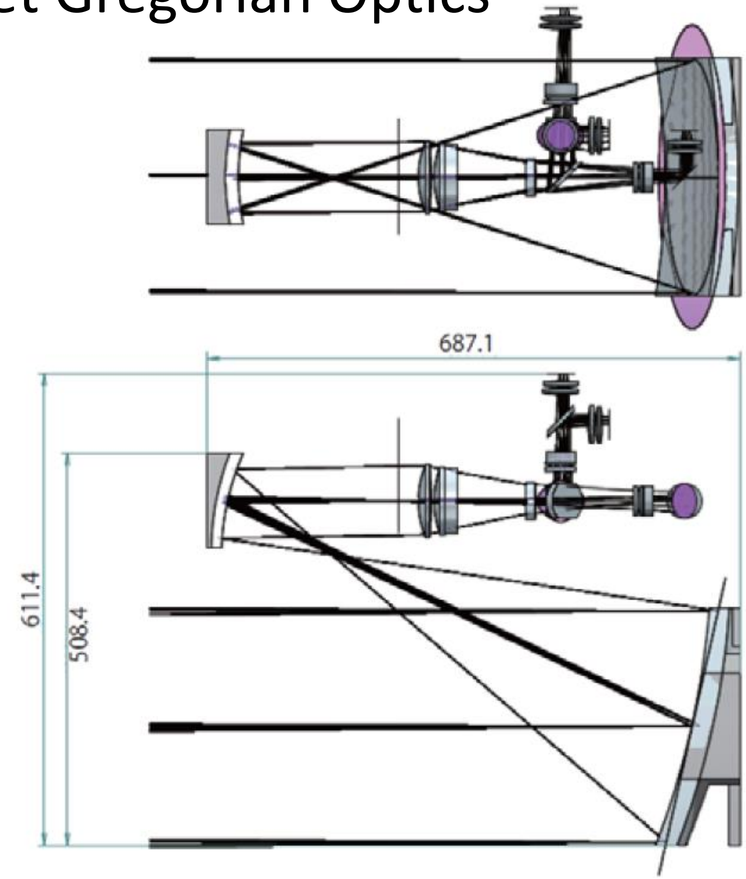
2015/02/04 – 06 : Carbon irradiation for ASIC (~ 10 MeV)
Loss the capability for 10,000 yrs irradiation
SEU occure for 100,000 yrs irradiation
Completely destroyed for 1,000,000 yrs irradiation

2015/07/24 : Gamma-ray irradiation for ASIC（^{60}Co）
Maintain the operation function for 40 krad, 100 krad, 200 krad

NIR telescope



Offset Gregorian Optics



Aperture size	30 cm in diameter			
Optics	Offset Gregorian			
Focal length (F-number)	183.5 cm (F6.1)			
Size of aperture shade	68 cm in diameter, 30 cm in length			
Field of view	34 x 34 arcmin^2			
Sky coverage	30 degree for the solar side, 56 degree for the earth side (depends on the orbital altitude)			
Plate scale	2.0 arcsec/pixel (1 pixel = 18μm)			
Operating temperature	< 230 K (for telescope tube), < 100 K (for detectors)			
Band	0.5 – 0.73 μm	0.73 – 1.00 μm	1.00 – 1.30 μm	1.30 – 1.70 μm
Sensitivity (10σ, 3 min)	20.5 mag(AB)	20.3 mag(AB)	20.1 mag(AB)	20.1 mag(AB)
Detector	HiViSI-Blue	HiViSI-NIR	HgCdTe	HgCdTe

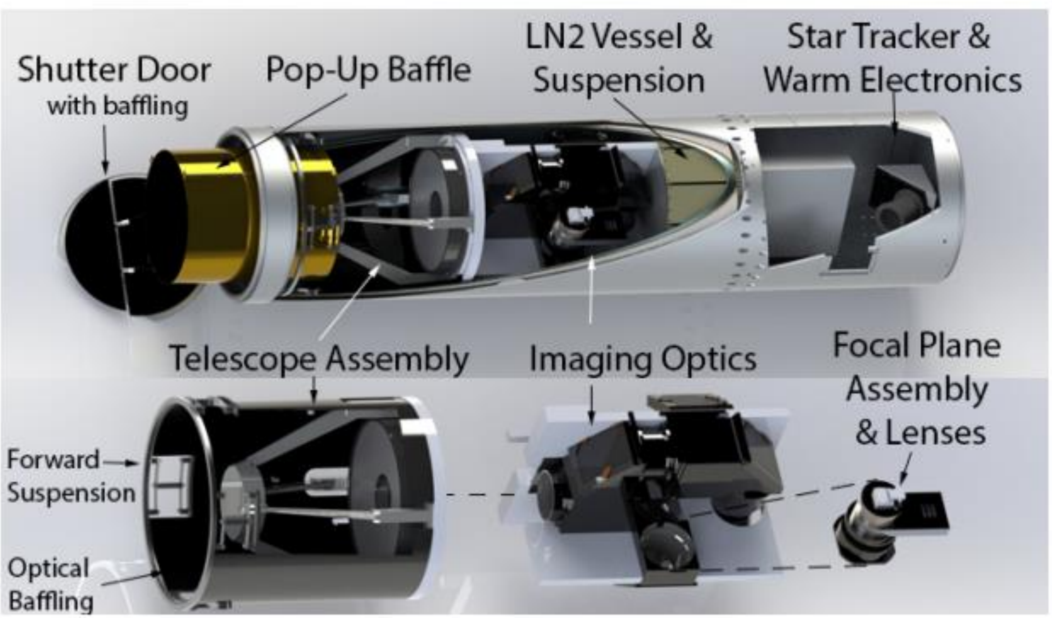
Similar to the optics of CIBER-2 rocket experiment

CIBER-2 Rocket Experiment   Lanz et al. (2014)

- NASA's rocket experiment for the near infrared background light
- Telescope Size : 28.5cm cooled telescope ⇒ 30 cm
- 3 band photometric observation in optical and NIR

  → Verification for the NIR telescope aboard HiZ-GUNDAM

Flight Configuration

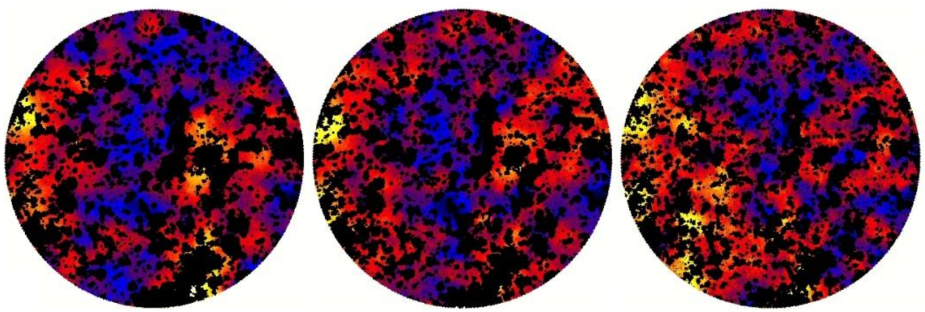


Flight Primary Mirror

Monitoring observations and Transients

NIR telescope

- fluctuation of NIR background



2.4 um 3.2 um 4.1 um

- NIR catalogue
  (deeper than 2MASS catalogue)
- high-z QSO survey
- transit of exoplanet
- monitor of variable objects

Wide field X-ray imaging detector

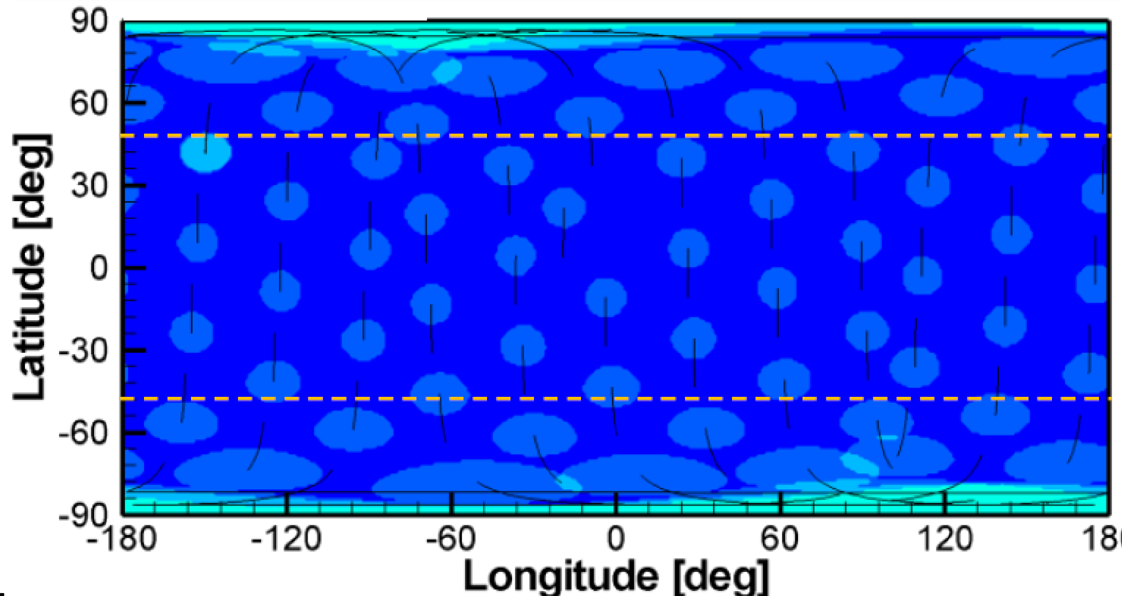
- Normal GRBs (~100 events/yr)
- X-ray flash & X-ray rich GRBs
- short GRB & Gravitational Wave
- optically dark GRBs
- ultra long GRBs, pop-III GRBs
- shock break-out of SN explosion
- Tidal disruption events
- Supergiant fast X-ray transient
  binaries of High-mass + NS
- X-ray monitor for bright sources

Real Time Alert

Iridium Short-Burst-Data
(SBD 9603)

Packet Communication
Send : 340 byte
Receive : 270 byte
Delay : 1～3 min

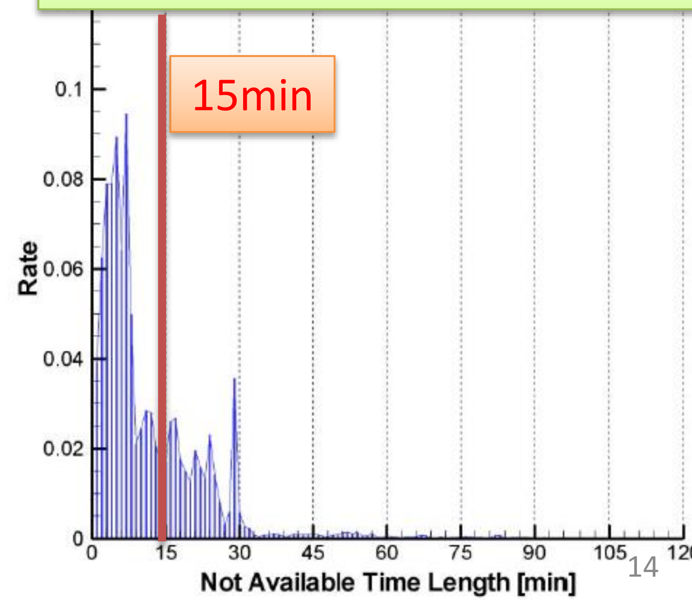
Sendable area fraction of real time alert (400 km otbit)



From
Nagata-san (Okayama U.)
Yamada-san (ISAS/JAXA)

Special thanks
Yamada-san (TMU)

Distribution of non-contact time



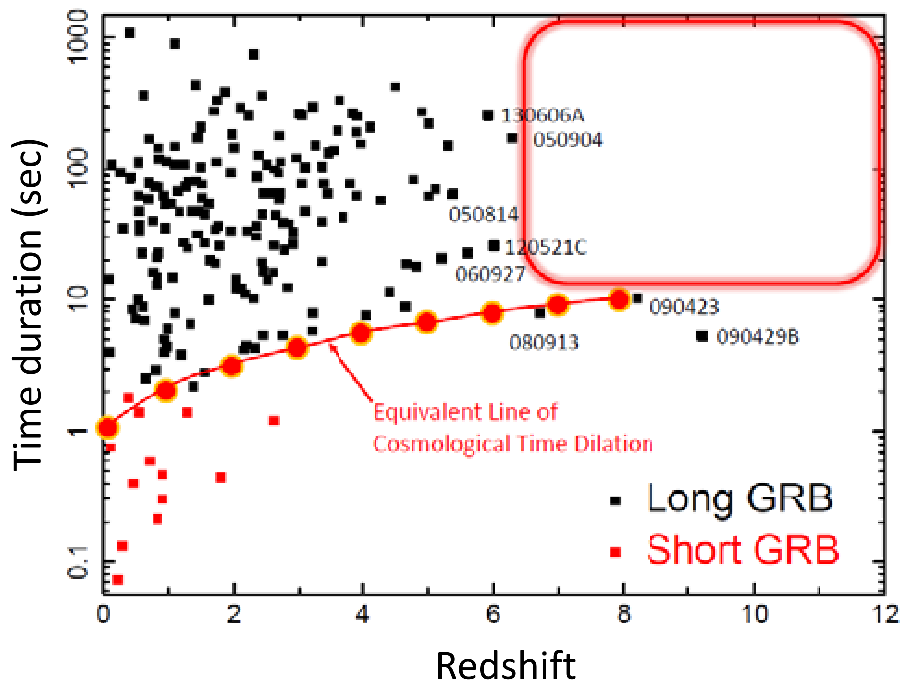
- Duration of non-contact time is less than 15 minutes : 50 ~ 60 %, but the longest case is 5 hours
- Almost perfectly covered around Arctic/Antarctic regions.
- We need an additional UHF antenna.

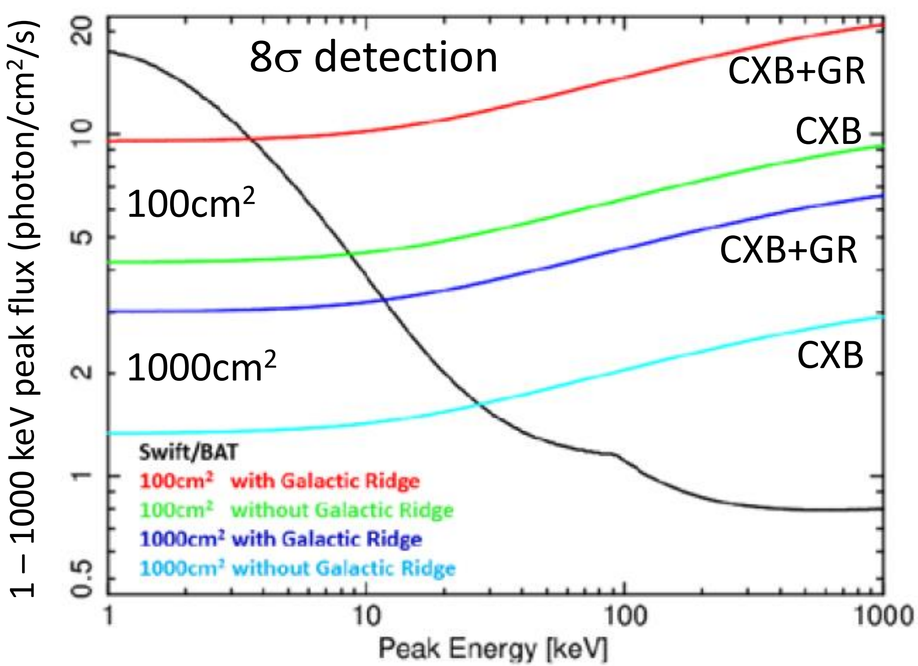
Summaries

- Japanese GRB community considers the future GRB mission “HiZ-GUNDAM”.
- We are developing the 1/10 proto-type model of the X-ray instrument, and the flight model of NIR telescope for CIBER-2 rocket experiment.
- We need a world wide collaboration especially for the satellite operation and trigger system, and also the driving powers of scientific outputs.

Properties of high-z GRBs

GRB	redshift	T_{90} (sec)	E_{peak} (keV)
090429B	9.4	5.5 ± 1.0	42.1 ± 5.6
090423	8.26	10.3 ± 1.1	54 ± 22
080913	6.695	8 ± 1	121 (-39/+232)
140515A	6.32	30	-
050904	6.29	225 ± 10	-
120521C	6.0	26.7 ± 4.4	-
130606A	5.913	276 ± 19.31	-
060927	5.47	22.6 ± 0.3	71.7 ± 17.6





- Time duration of prompt emission is much shorter than expected one.
- Typical energy of high-z GRBs are lower than ones of nearby GRBs (E_{peak} ~ 200 keV).

We must observe E < 10 keV
with better sensitivity in soft X-ray band.
The goal is 1 < E < 20 keV.

Effective area of 1000 cm² @ a few keV
will realize better sensitivity than Swift-BAT.