HiZ-GUNDAM: The Ultimate On-Board Mission for Multimessenger Astronomy

Hatsune Goto | RIKEN / HiZ-GUNDAM Working Group

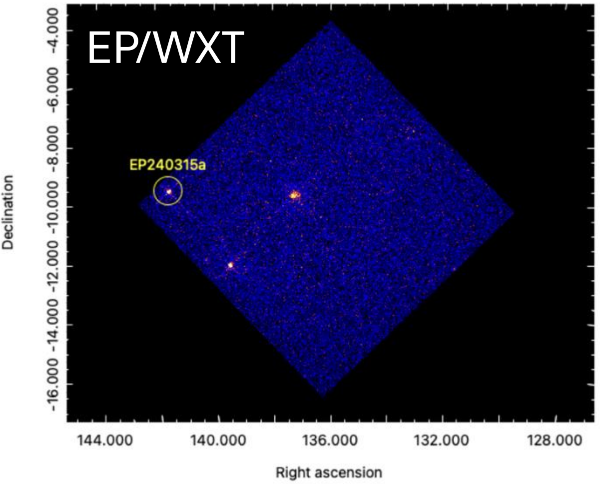
TeVPA 2026 Pre-conference Workshop

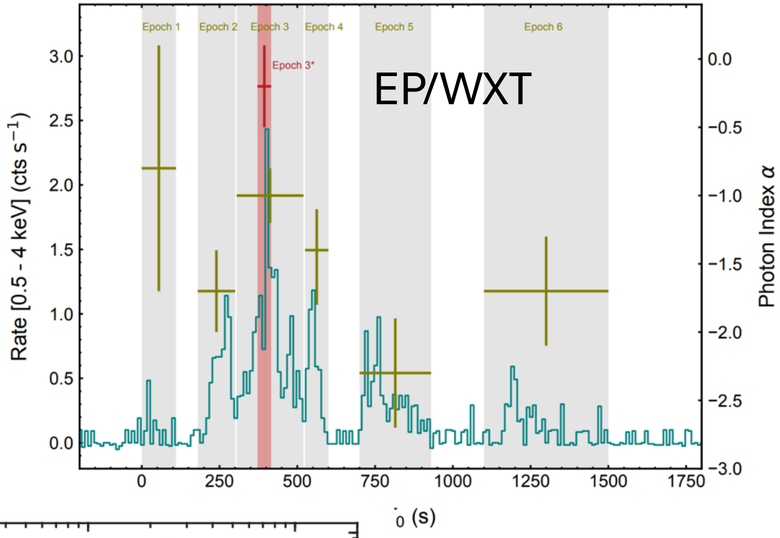
2028/08/30

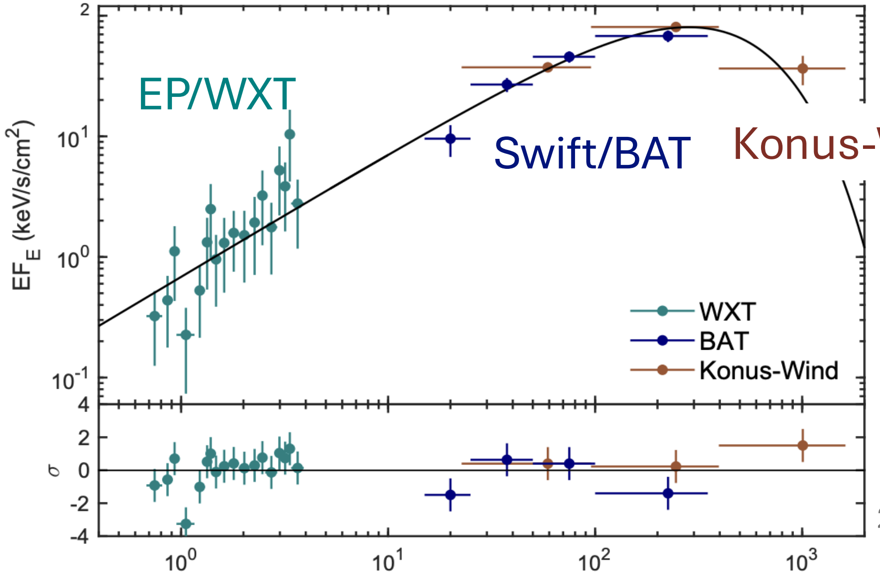
The soft X-ray transient sky

EP240315a Liu et al. 2024

7 minutes early precursor of GRB 240315C







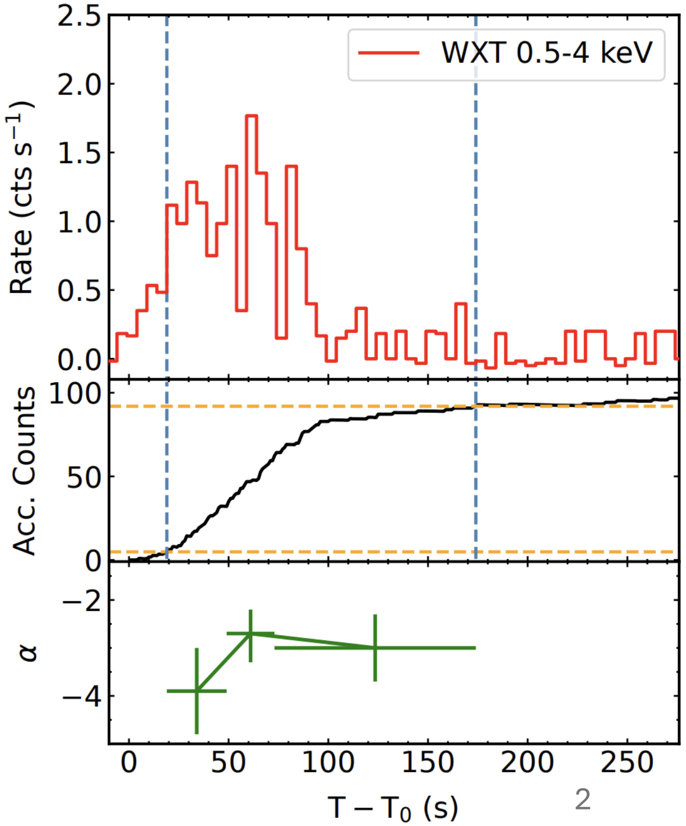
Wide-field soft-X-ray focusing

Expands the selection to softer & fainter transients / reveals earlier or extended emission phases

EP240414a

Dalen et al. 2025

Failed jet before SN 2024gsa



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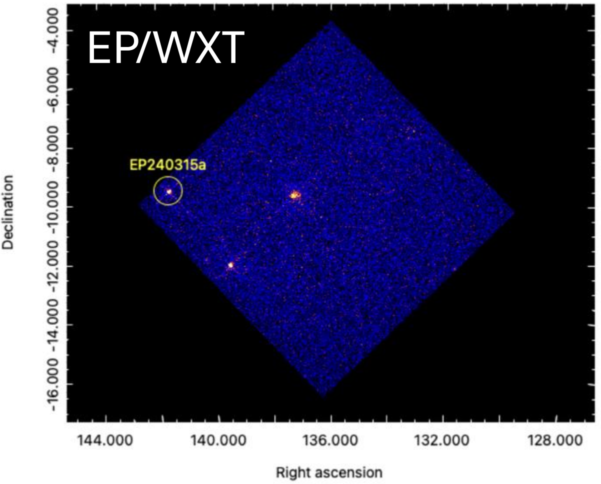

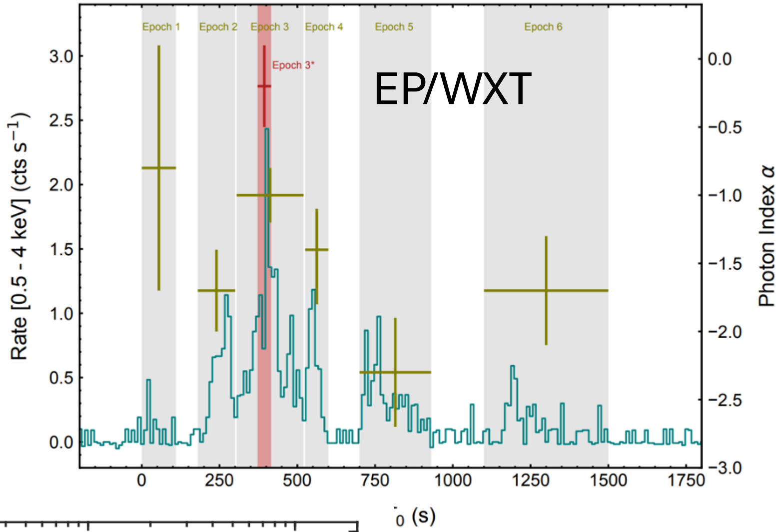

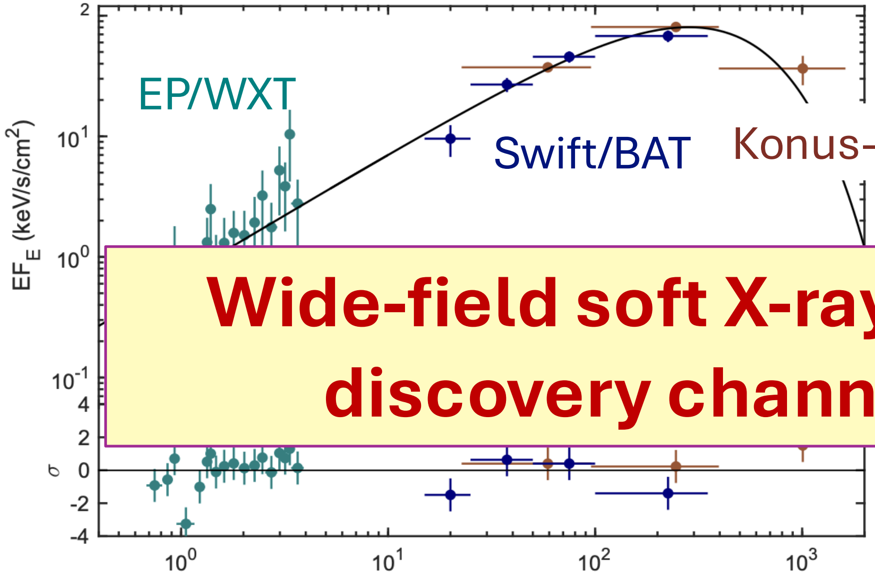

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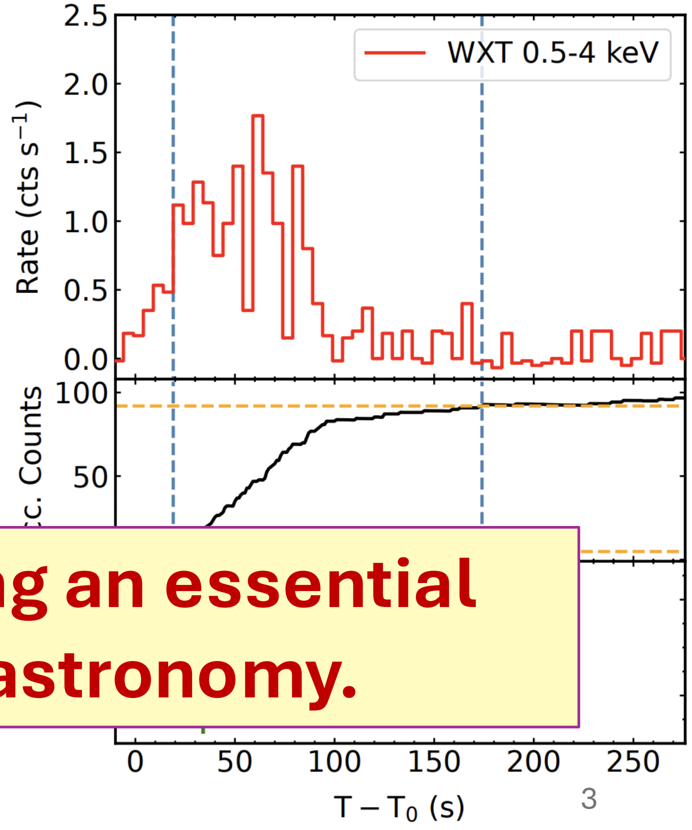


Wide-field soft X-ray monitoring is becoming an essential discovery channel for multimessenger astronomy.

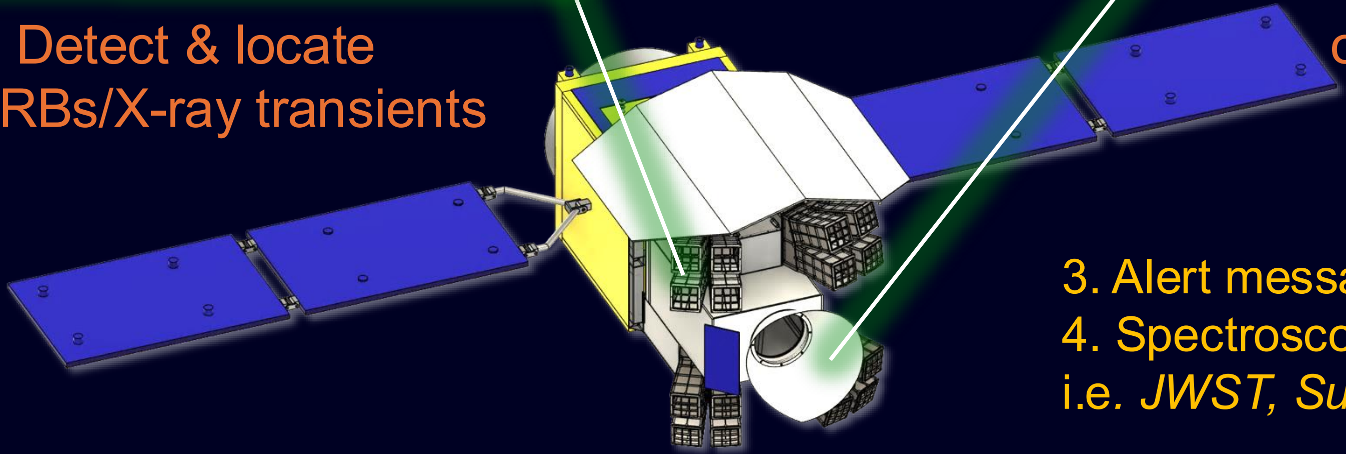
HiZ-GUNDAM (2034~, 3 year)

Wide Field soft X-ray Monitor
EAGLE

1. Detect & locate GRBs/X-ray transients

Optical and Near Infrared Telescope
MONSTER

2. Identify and measure the redshift of counterpart

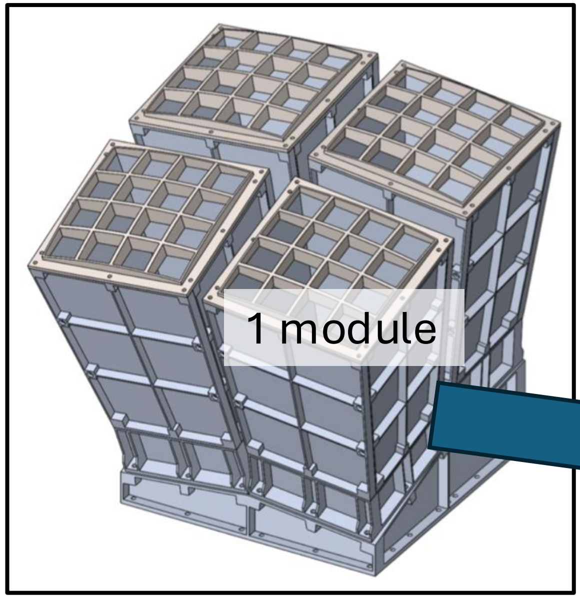


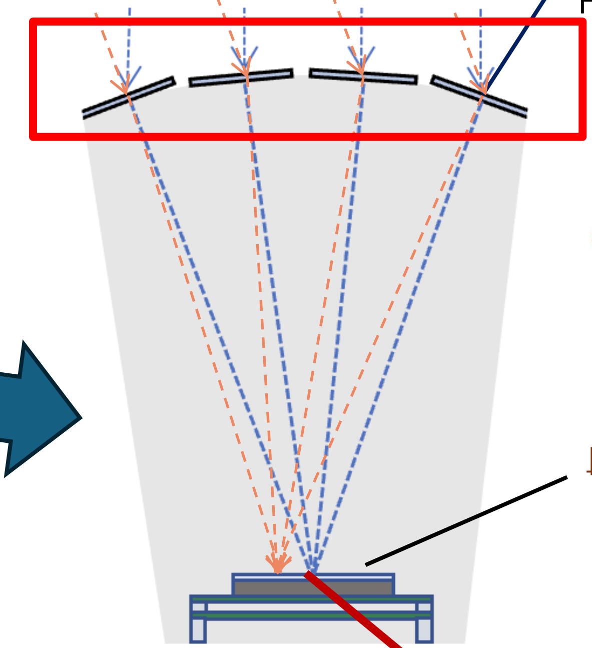
3. Alert message (T << 1 hour)
4. Spectroscopic observation with large area telescopes i.e. *JWST, Subaru* (T ~ 1.5 hr)

Science Goals

1. Exploration of the early Universe with GRB
2. **Timely contribution to Multi-messenger astronomy**

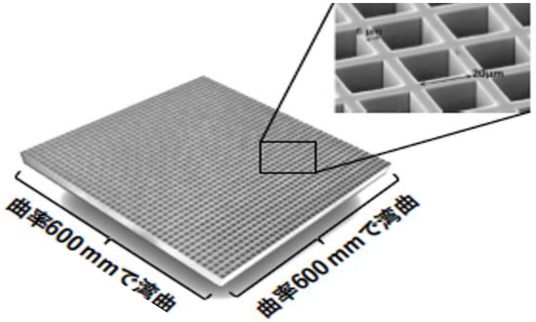
EAGLE finds faint and soft transients



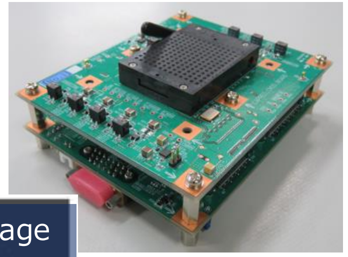


Lobster Eye Optics (MPO)

Focusing X-ray from transients



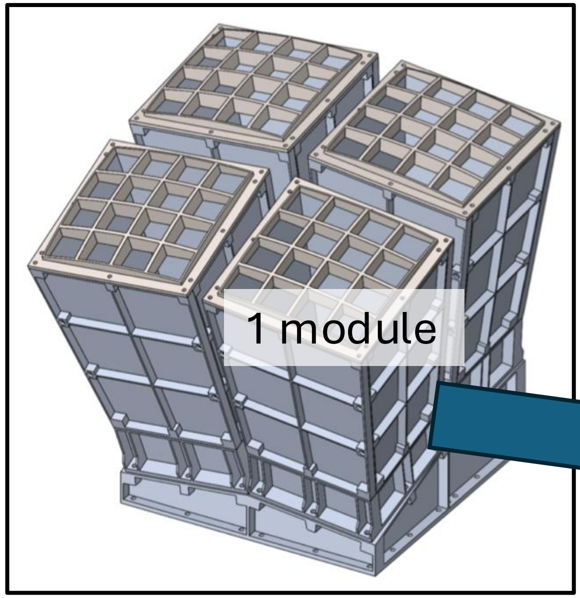
pnCCD image sensor

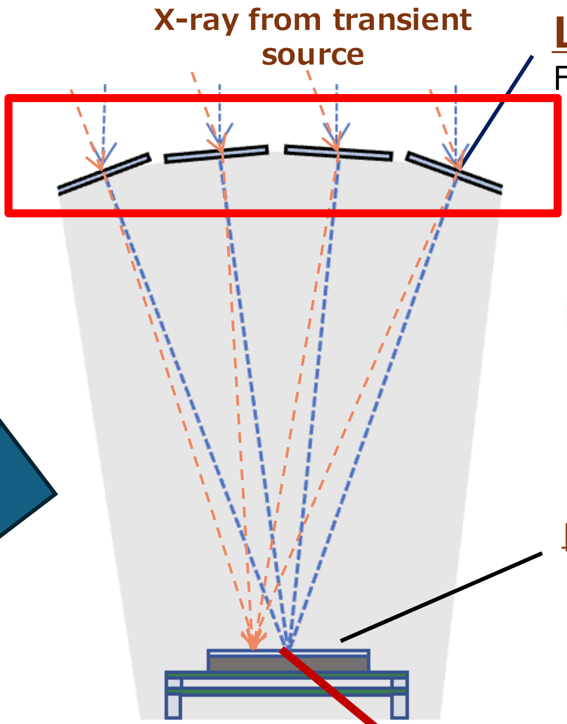


Performance

Observation energy band	**0.4-4 keV**
Field of View	**~0.53 str**
Detection sensitivity	**7×10^{-10} erg/cm^2/s (100s exposure)**
Positioning accuracy	**3 arcmin with 1 σ (for follow up observation)**

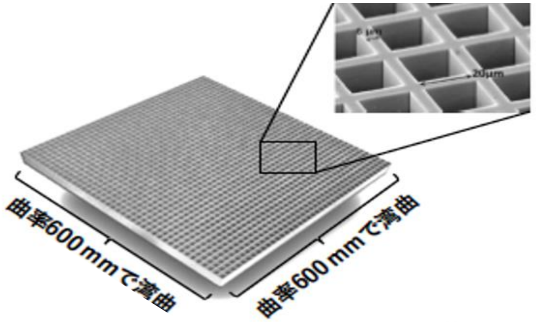
EAGLE finds faint and soft transients





Lobster Eye Optics (LEO)

Focusing X-ray from transients



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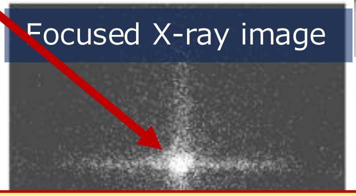


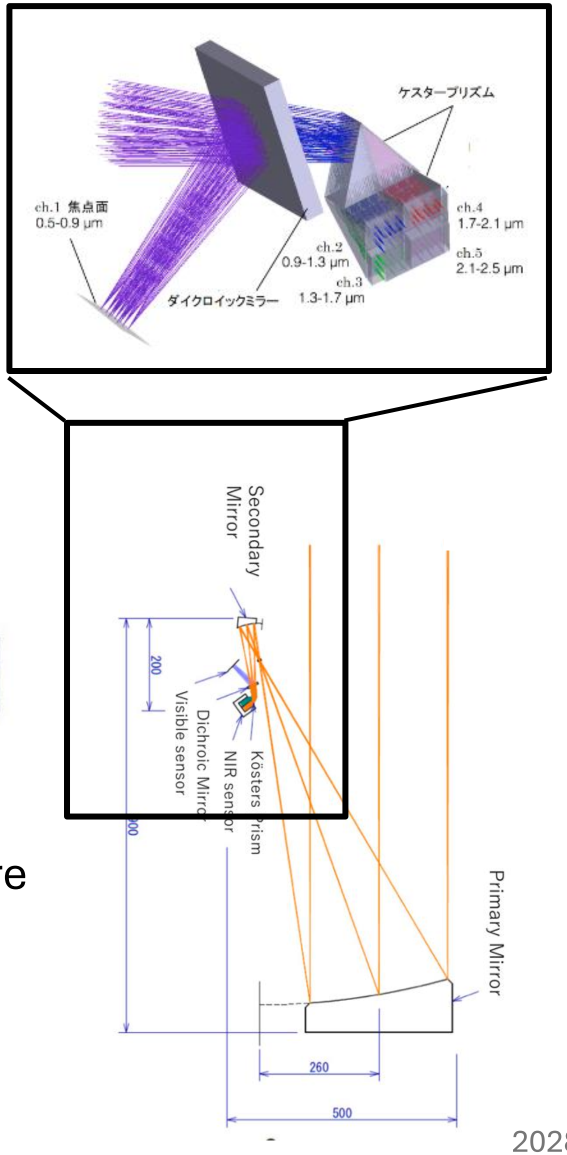
Performance

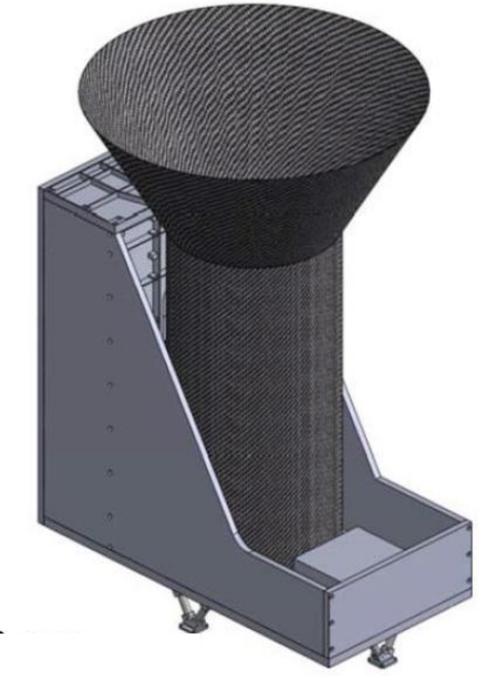
Observation energy band	**0.4-4 keV**
Field of View	**~0.53 str**
Detection sensitivity	**7×1** **(100**
Positioning accuracy	**3 ar** **(for follow up observation)**

EAGLE detects transient and provide arcmin localization in ~100 seconds

MONSTER enables rapid optical/NIR identification

Köster prism





ϕ300 mm aperture telescope

Items	Parameters				
Telescope type	Offset Optics				
Aperture size	30 cm				
Focal length	83.5 cm				
F number	6.1				
Field of view	15 arcmin × 15 arcmin				
FoV per pixel	2 acsec × 2 arcsec				
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 AB mag (@10 min)	21.3	20.9	20.6	20.5	20.4
Focal detector	HyViSi	HgCdTe (H1RG)			

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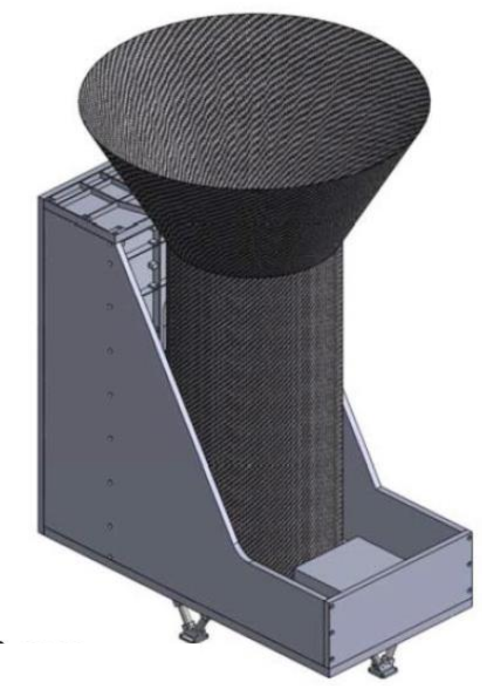

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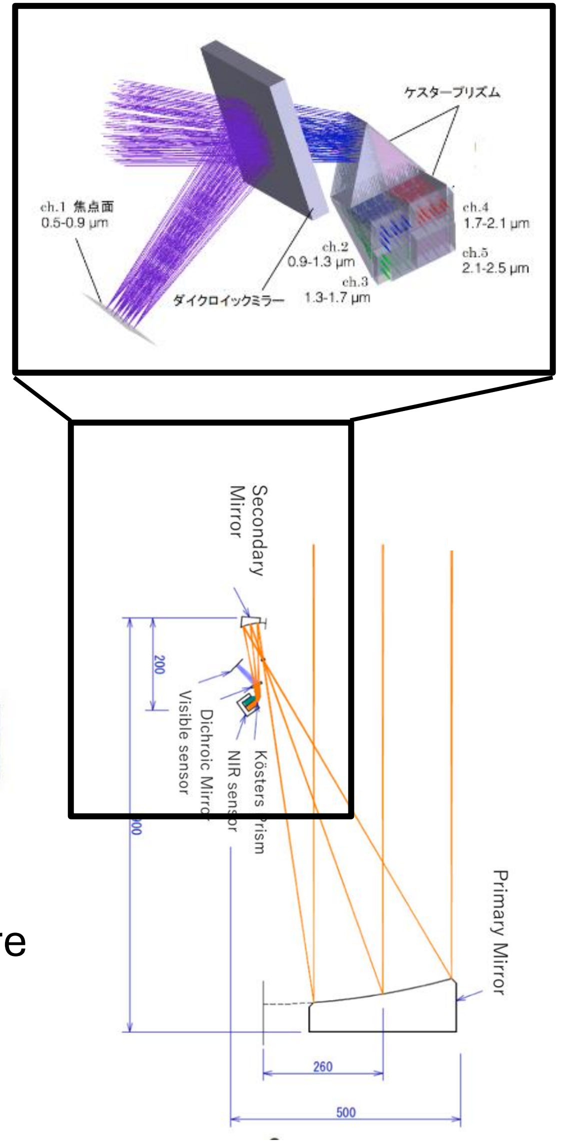

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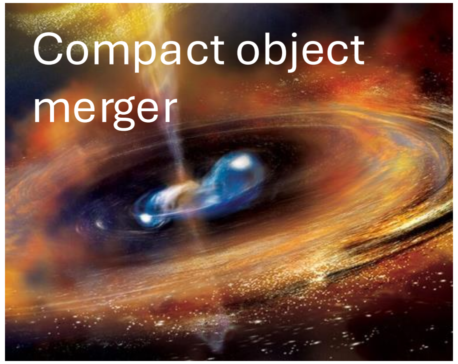
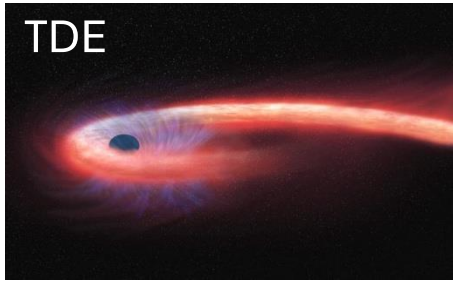
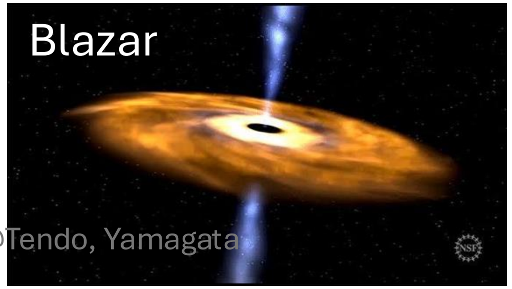
MONSTER obtains an arcsecond localization, and photometric redshift within 10 minutes.

MM source detectable in soft X-ray

Source class	Messenger	Possible EAGLE signal	Characteristic timescale of the EAGLE signal
Compact-object merger	GW	Short-GRB prompt or extended soft X-ray emission	~0.01–10^2 s
Core-collapse SN	MeV neutrinos + GW	X-ray shock breakout or associated GRB	seconds–hours
TDE	HE neutrinos	Bright jetted TDE or X-ray rebrightening	hours–months
Blazar	HE neutrinos	Exceptionally bright X-ray jet flare	days–months







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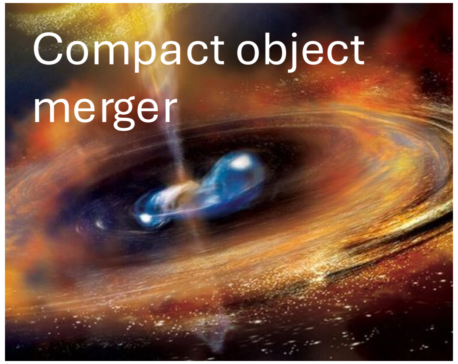
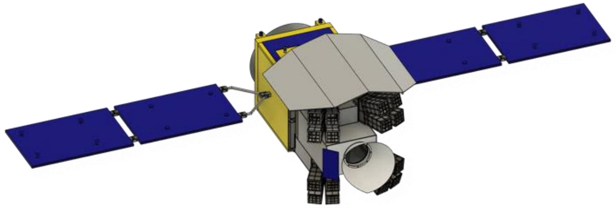


Joint soft X-ray and messenger detections would provide unique laboratories **-stellar explosions, relativistic jets, extreme accretion, and high-energy particle acceleration.**

Paths to multimessenger discovery

HiZ-GUNDAM can independently detect, localize, and characterize in “onset phase” of multimessenger events



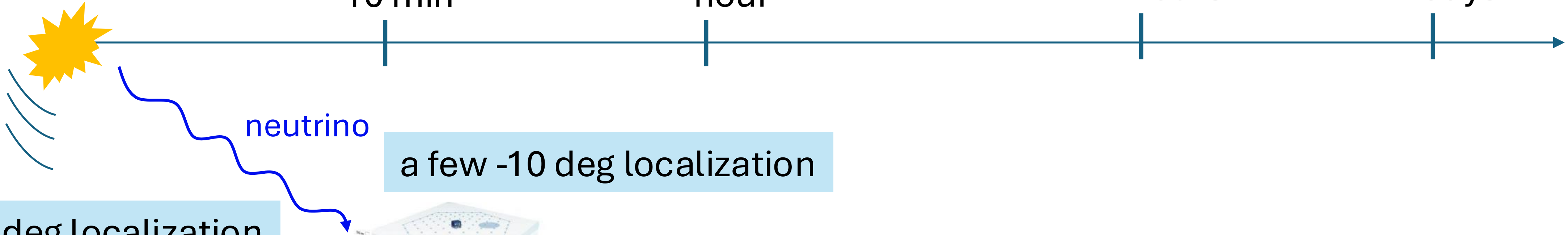
Detection in soft X-ray

~10 min

~hour

~hours

~days



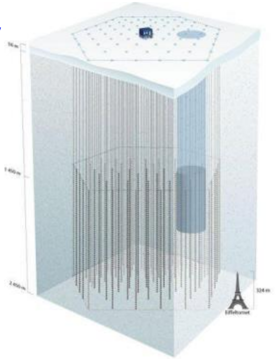
GW

neutrino

a few -10 deg localization

10-1000^2 deg localization

LIGO



IceCube

Paths to multimessenger discovery

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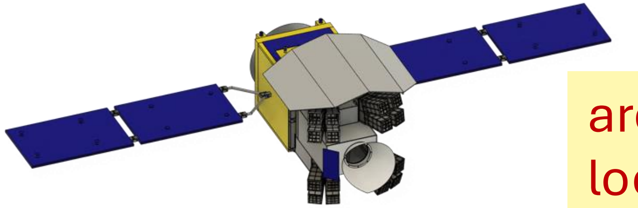


Detection in soft X-ray

arcmin-arcsec localization, redshift

MM event coincidence confirmed in GCN

~10 min

~hour

~hours

~days

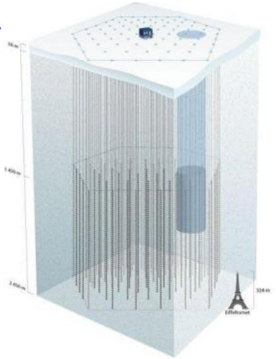
GW

neutrino

a few -10 deg localization

10-1000^2 deg localization

LIGO



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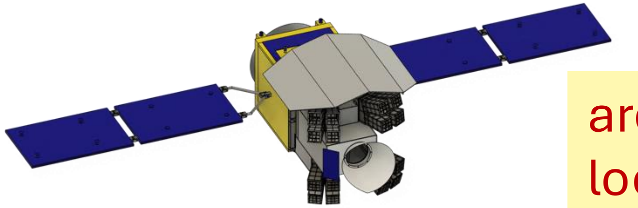
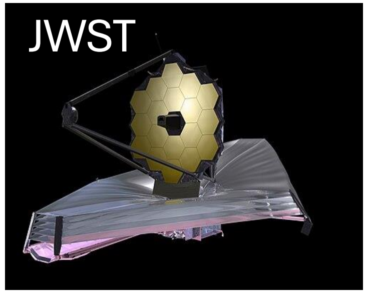




Detection in soft X-ray

arcmin-arcsec localization, redshift

MM event coincidence confirmed in GCN

~10 min

~hour

~hours

~days

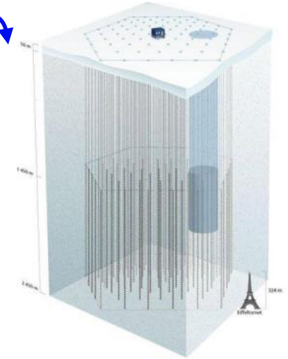
GW

neutrino

a few -10 deg localization

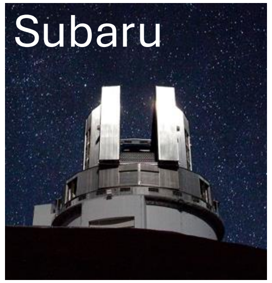
< 1000^2 deg localization

LIGO



IceCube

Large Area Telescope

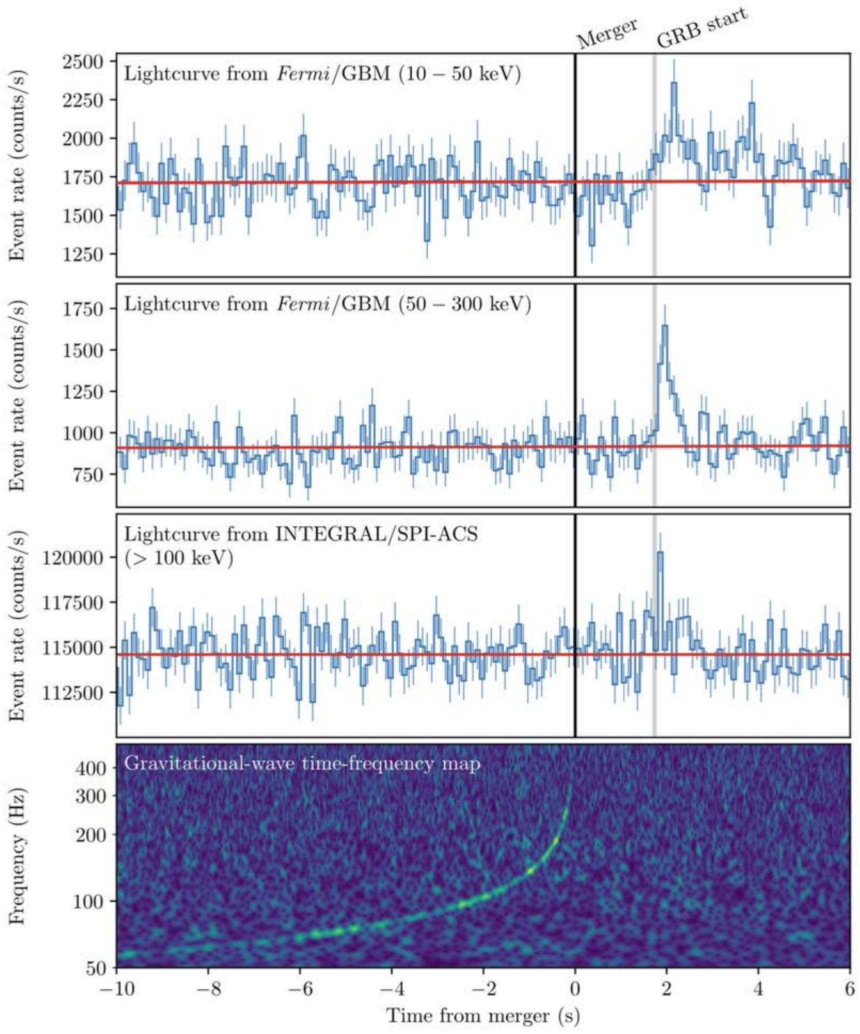


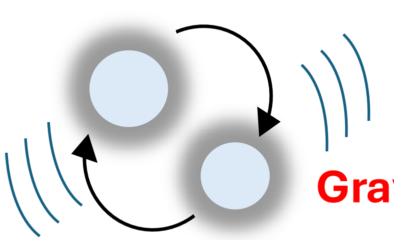
8m

future 30m class

Compact-object merger (BNS / NS–BH)

GW170817 /
AT 2017gfo





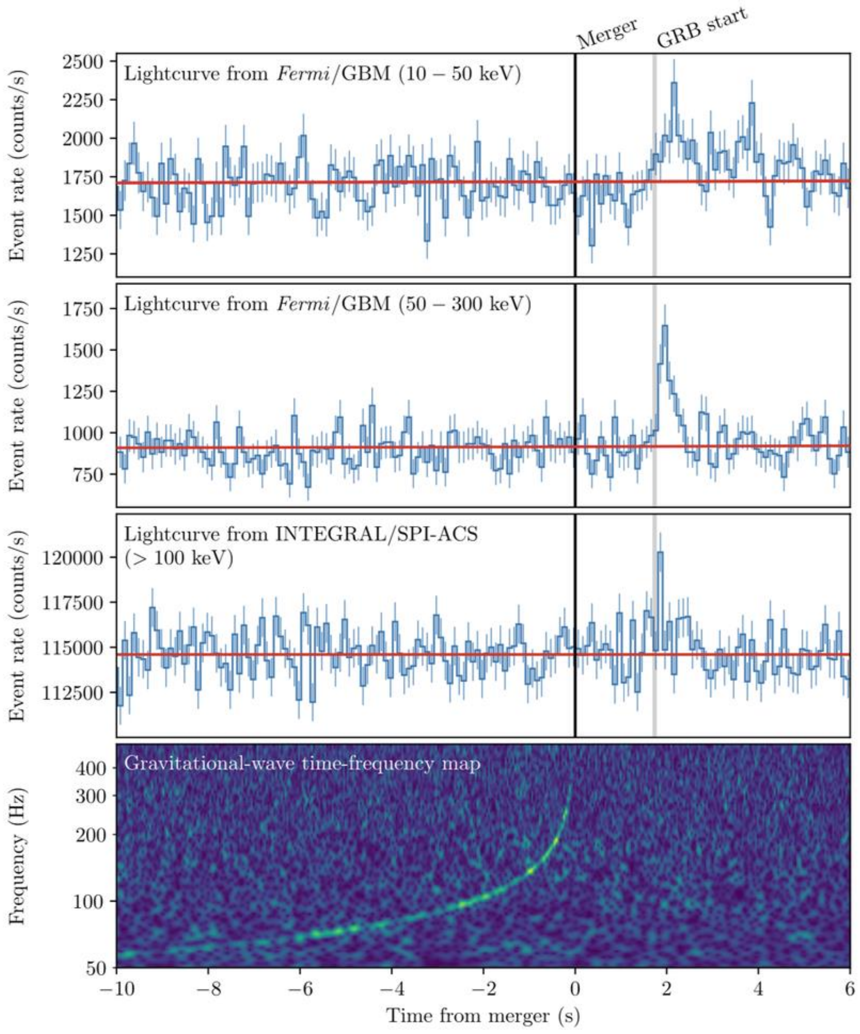
T0

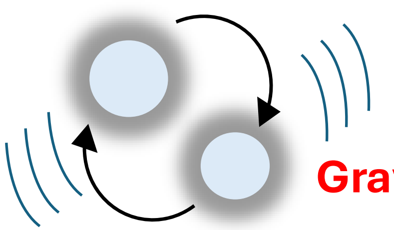
BNS / NS–BH coalescence

Gravitational waves

Compact-object merger (BNS / NS–BH)

GW170817 /
AT 2017gfo





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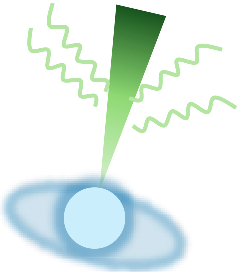


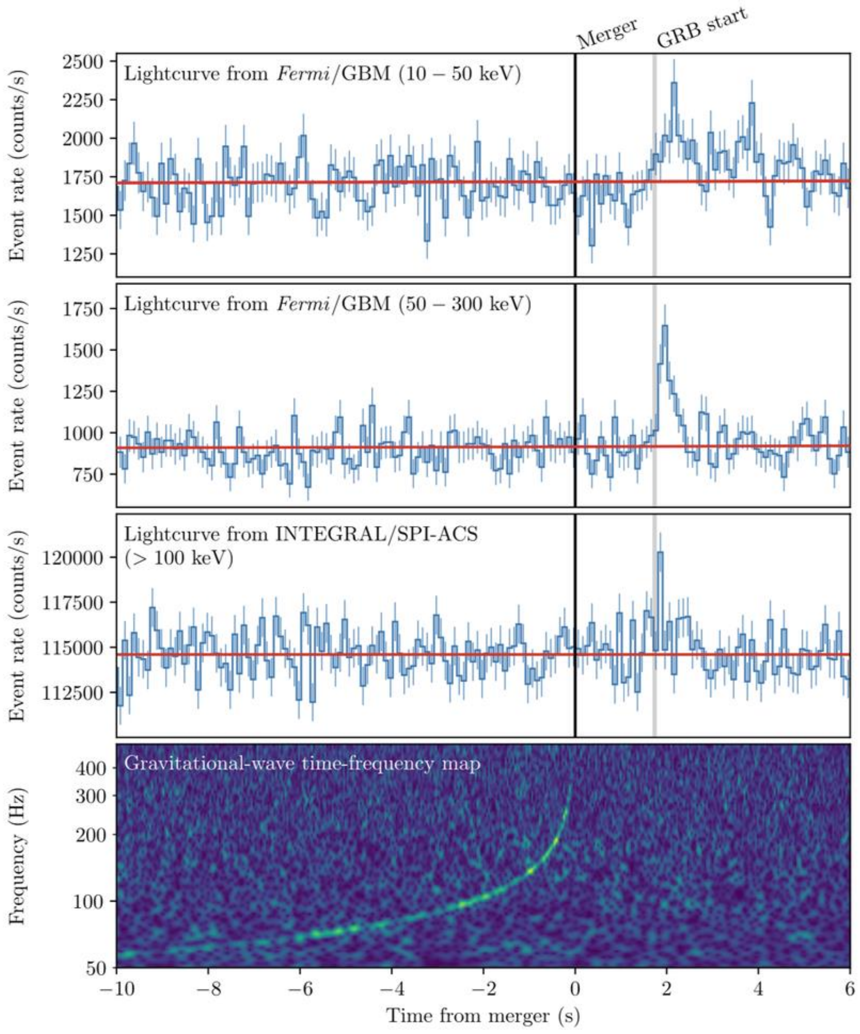
T0 + 0–10 seconds

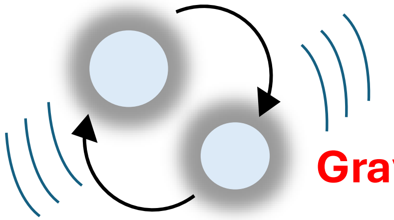
Short GRB + soft X-ray emission

Gamma / X-ray

Compact-object merger (BNS / NS–BH)

GW170817 /
AT 2017gfo





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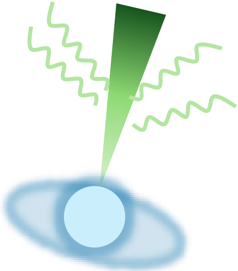

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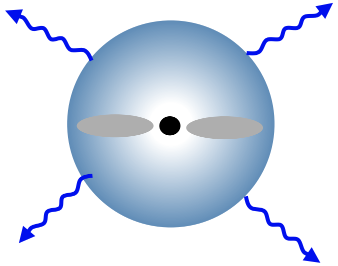
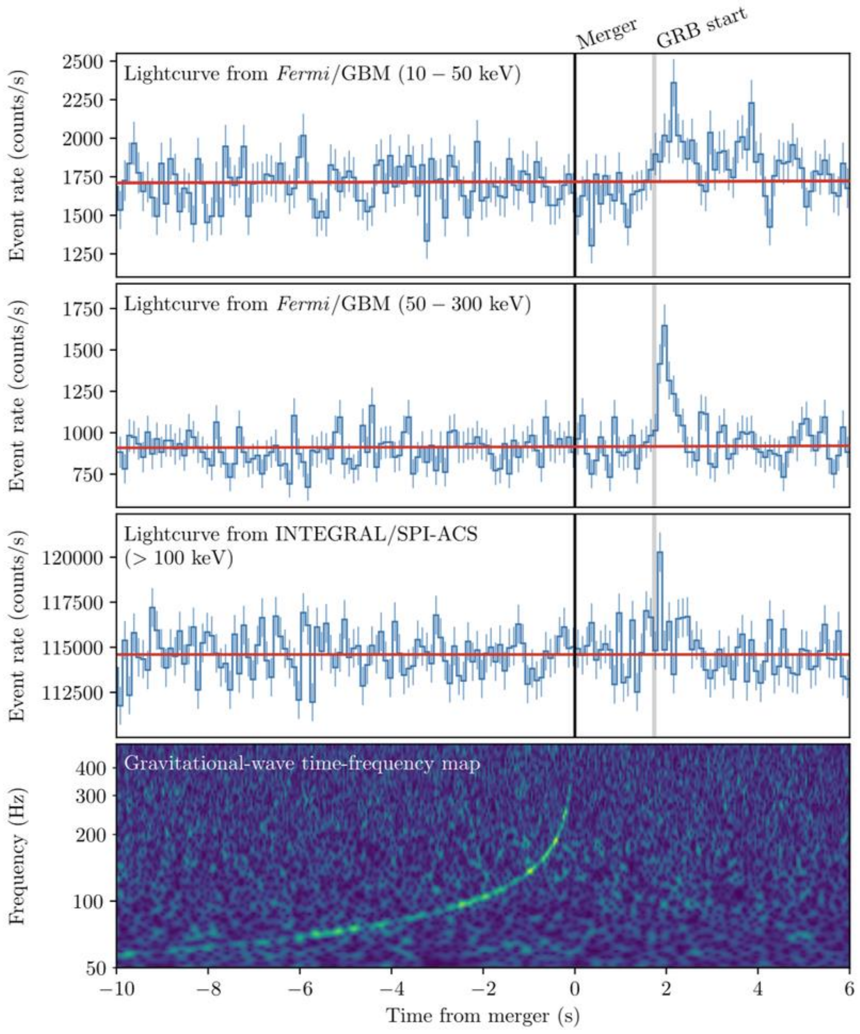


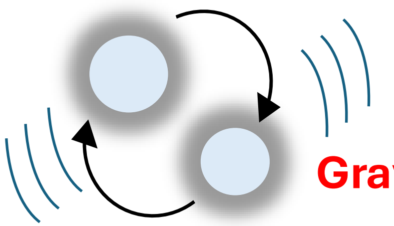
T0 + minutes to hours

Blue kilonova:
lanthanide-poor r-process ejecta

Compact-object merger (BNS / NS–BH)

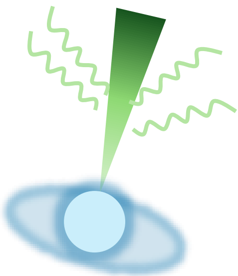
GW170817 /
AT 2017gfo





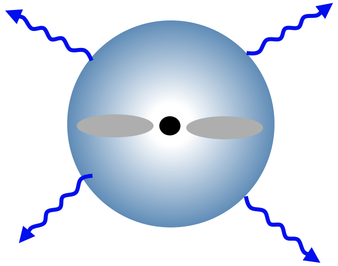
T0

BNS / NS–BH coalescence



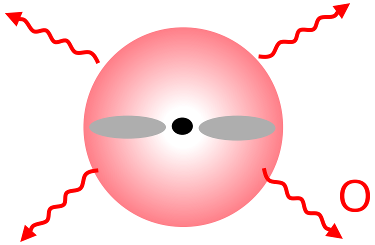
T0 + 0–10 seconds

Short GRB + soft X-ray emission



T0 + minutes to hours

Blue kilonova:
lanthanide-poor r-process ejecta

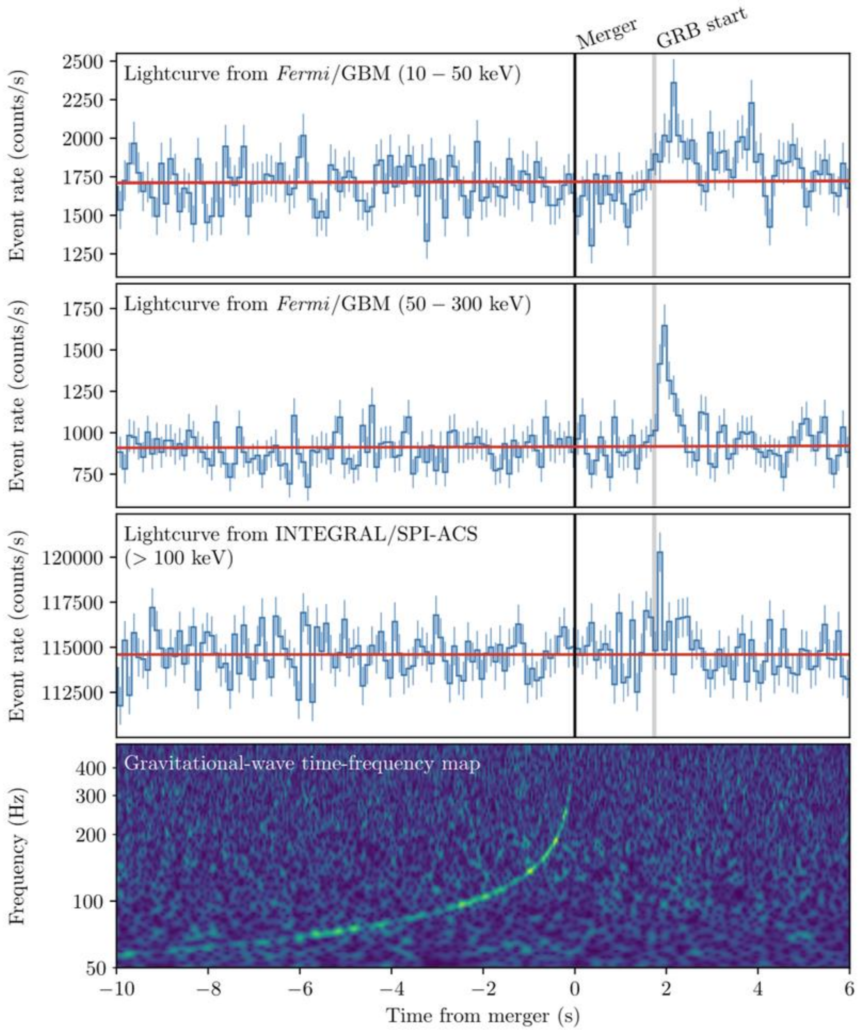


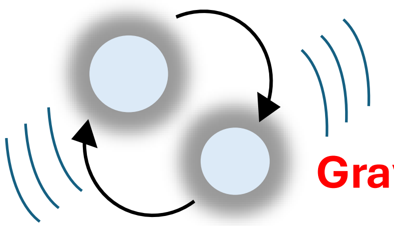
T0 + hours to days

Red kilonova:
lanthanide-rich r-process ejecta

Compact-object merger (BNS / NS–BH)

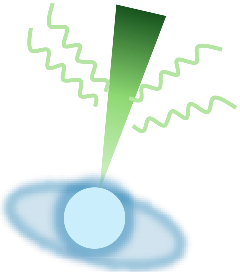
GW170817 /
AT 2017gfo





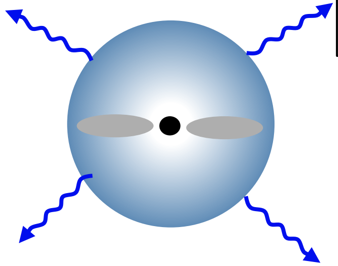
T0

Gravitational waves



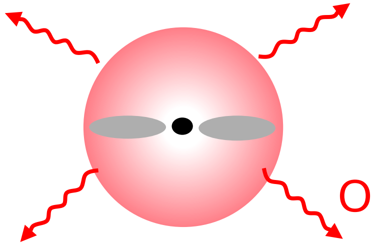
T0 + 0–10 seconds

Gamma / X-ray



T0 + minutes to hours

Optical(blue)



T0 + hours to days

Optical / NIR

Detection by GW facility

≤ minutes

EAGLE
short / soft X-ray
uncatalogued transient
arcminute position

MONSTER
new optical/NIR source
arcsecond position + host

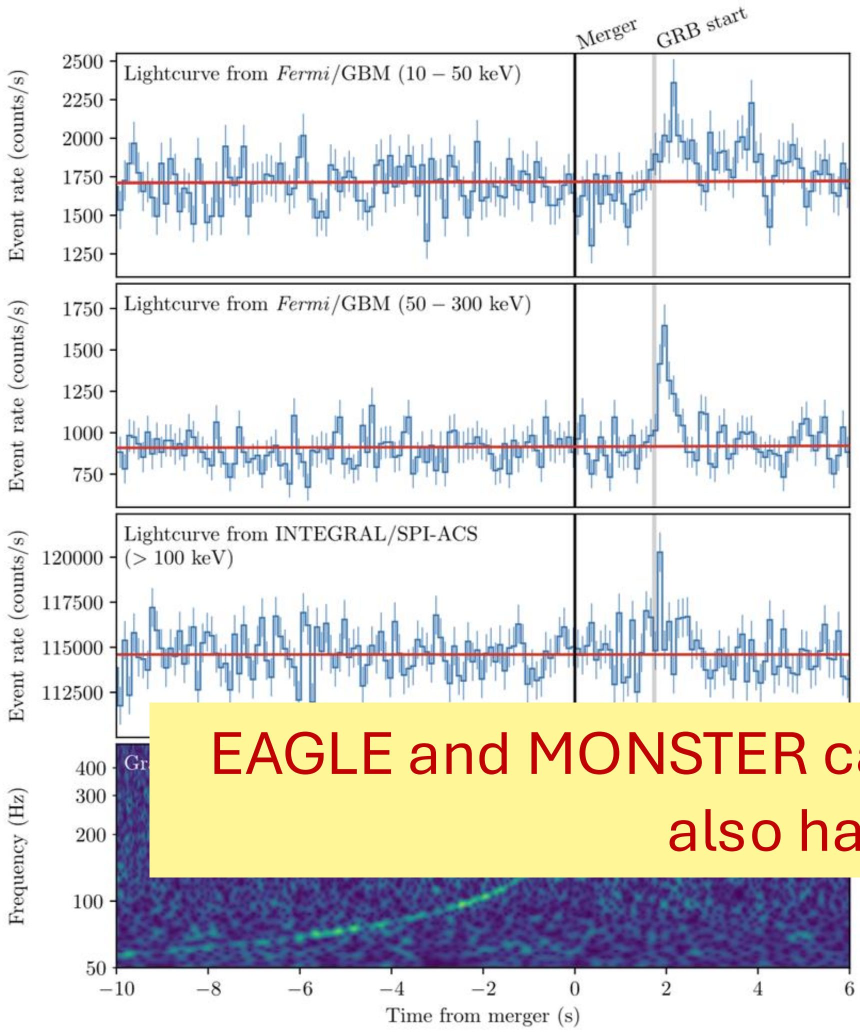
counterpart
candidate

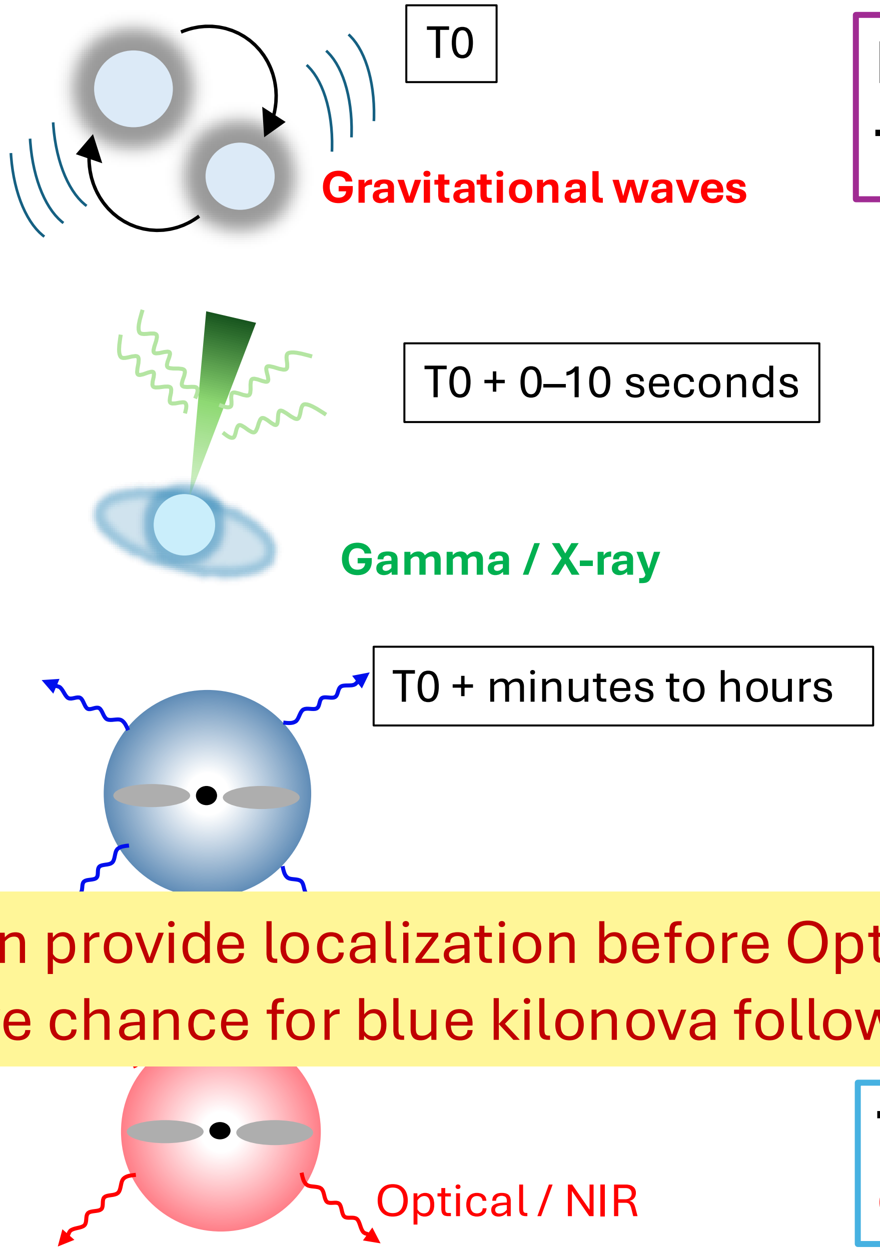
1st GCN minutes
2nd GCN ~1hour

Targeted follow-up
Optical / NIR

Compact-object merger (BNS / NS–BH)

GW170817 /
AT 2017gfo





Detection by GW facility

≤ minutes

EAGLE
short / soft X-ray
uncatalogued transient
arcminute position

MONSTER
new optical/NIR source
arcsecond position + host

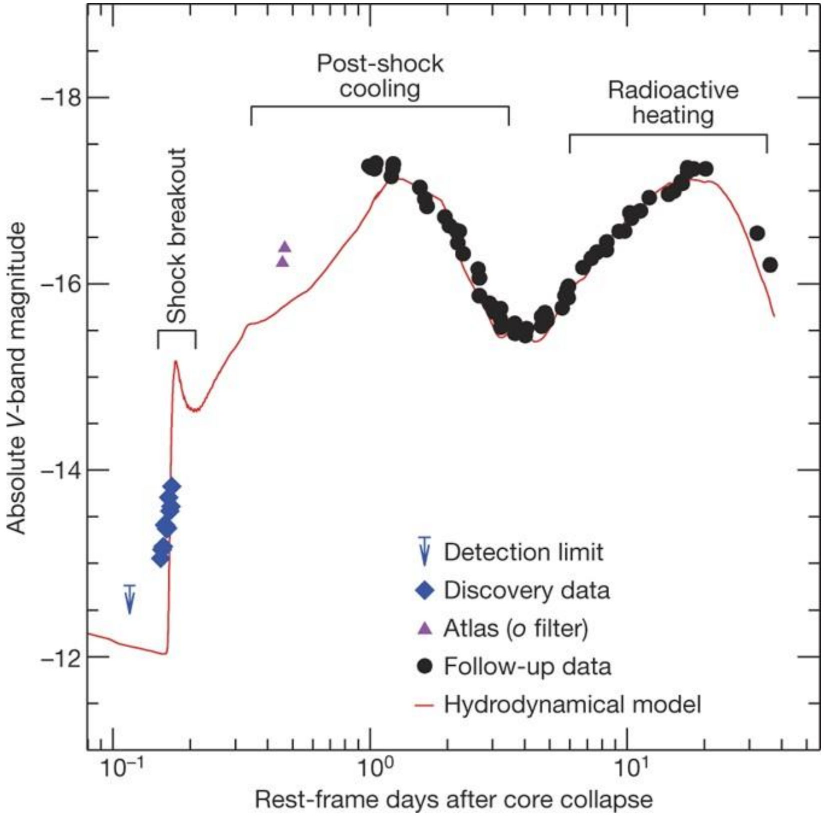
inutes
1 hour

Targeted follow-up
Optical / NIR

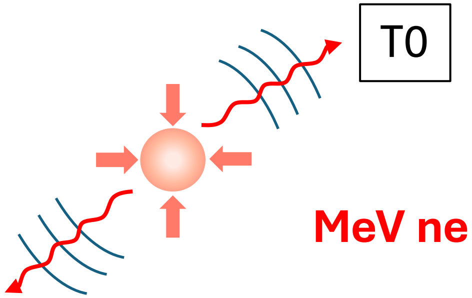
EAGLE and MONSTER can provide localization before Optical/NIR brightening,
also have chance for blue kilonova follow-up

Collapsar SN and shock breakout

SN 2016gkg



Bersten et al. 2025

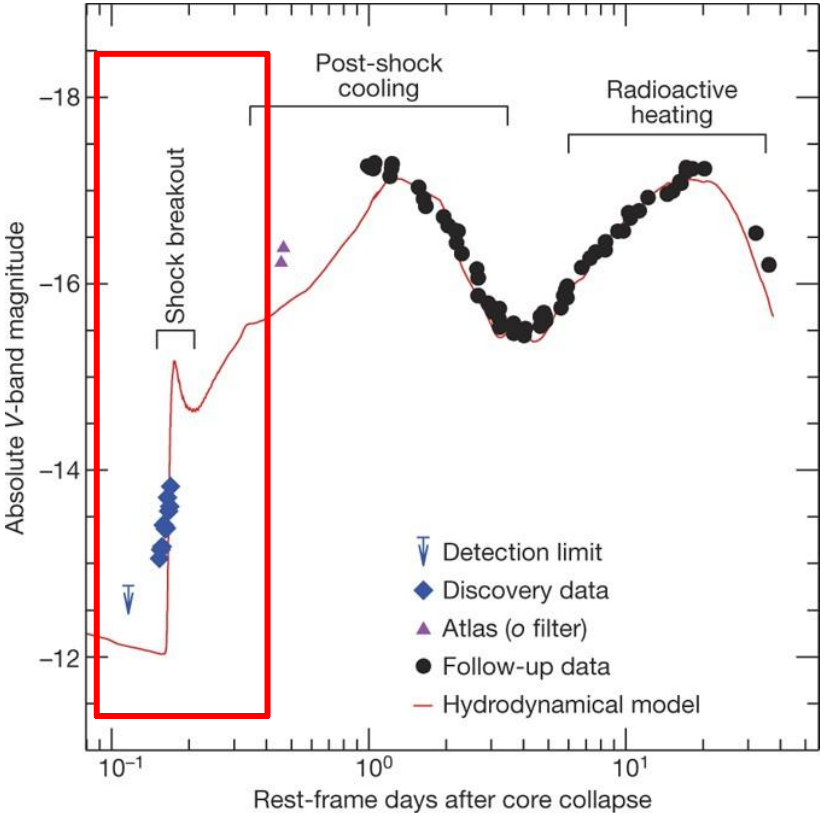


Core collapse and compact-object formation

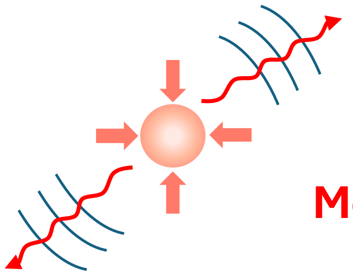
MeV neutrinos + GW

Collapsar SN and shock breakout

SN 2016gkg



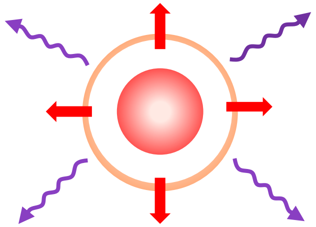
Bersten et al. 2025



T0

Core collapse and compact-object formation

MeV neutrinos + GW



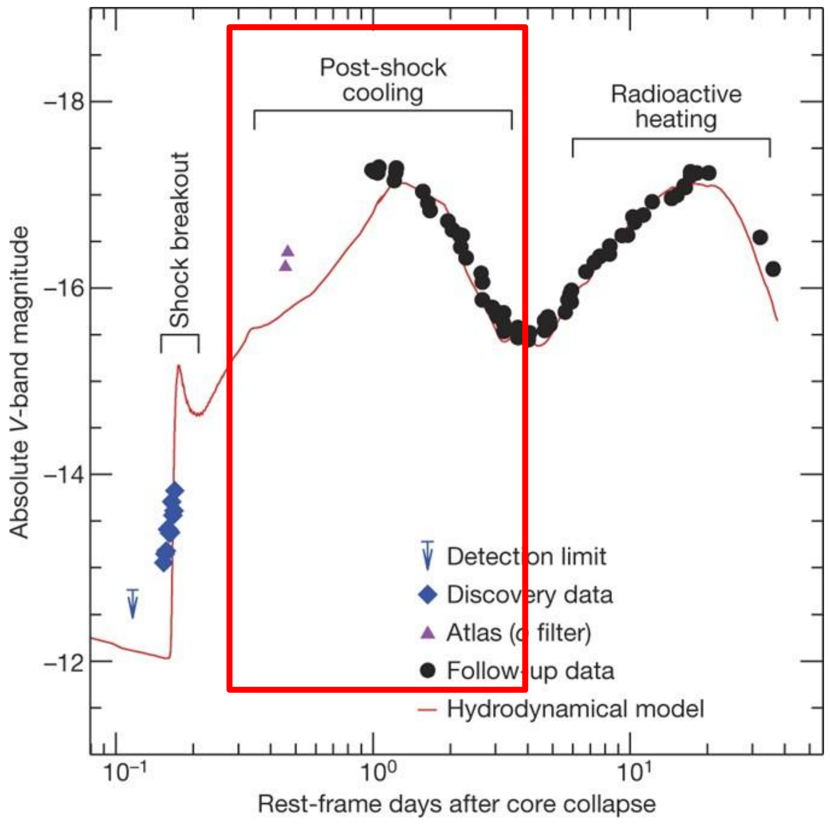
T0+seconds to hours

Shock breakout ~100-1000 seconds

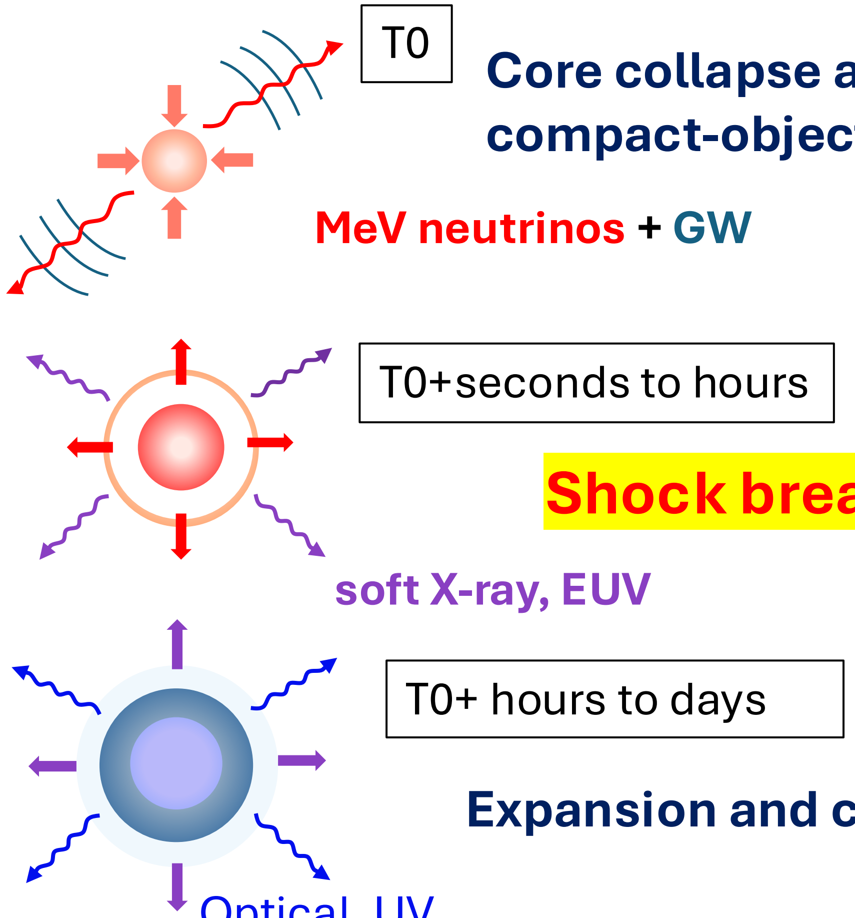
soft X-ray, EUV

Collapsar SN and shock breakout

SN 2016gkg



Bersten et al. 2025



Core collapse and compact-object formation

MeV neutrinos + GW

Shock breakout ~100-1000 seconds

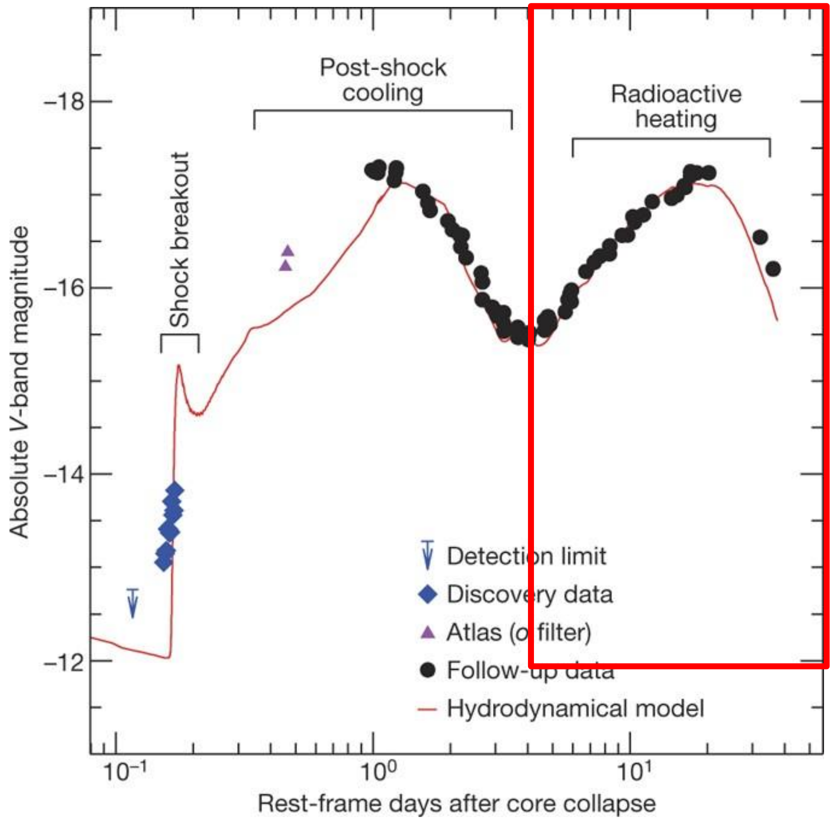
soft X-ray, EUV

Expansion and cooling of shock heated ejecta

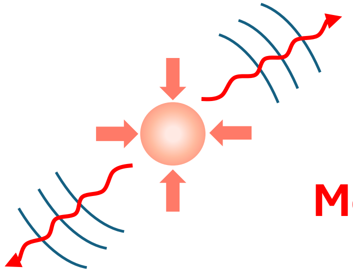
Optical, UV

Collapsar SN and shock breakout

SN 2016gkg



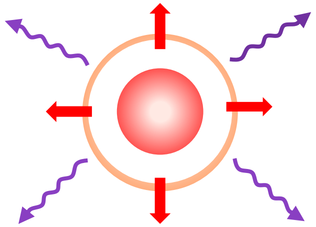
Bersten et al. 2025



T0

Core collapse and compact-object formation

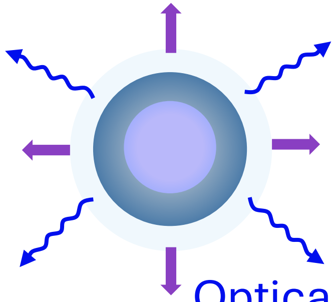
MeV neutrinos + GW



T0+seconds to hours

Shock breakout ~100-1000 seconds

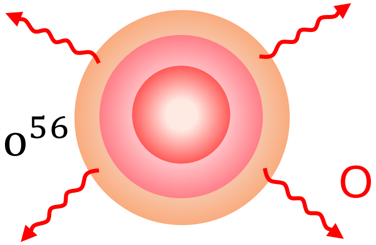
soft X-ray, EUV



T0+ hours to days

Expansion and cooling of shock heated ejecta

Optical, UV



T0+10 to 30 days

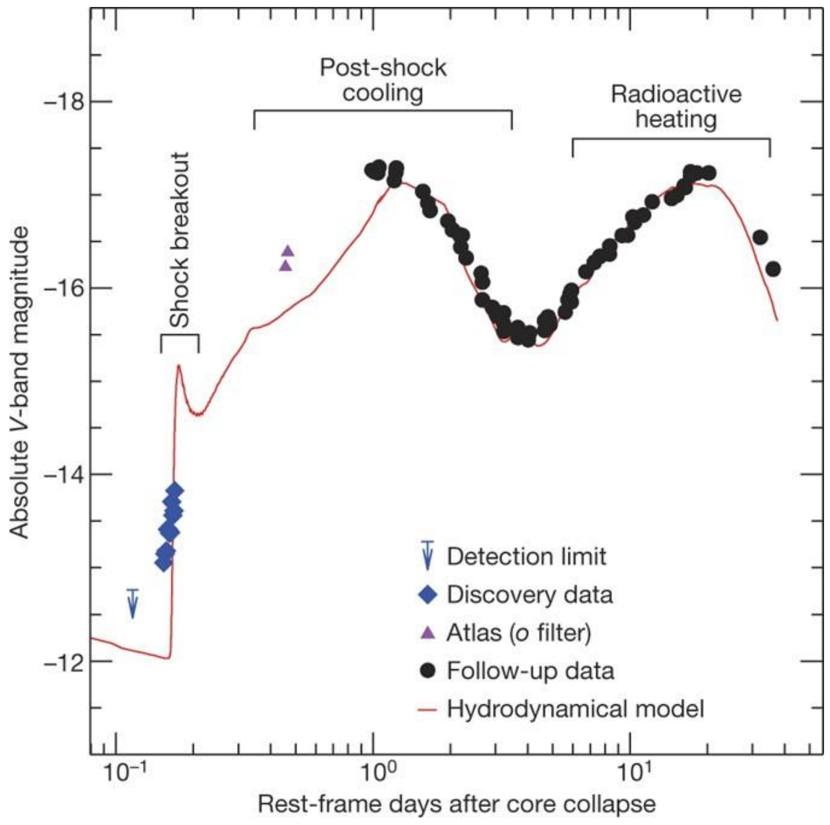
Radioactive heating

Ni^{56} and Co^{56}

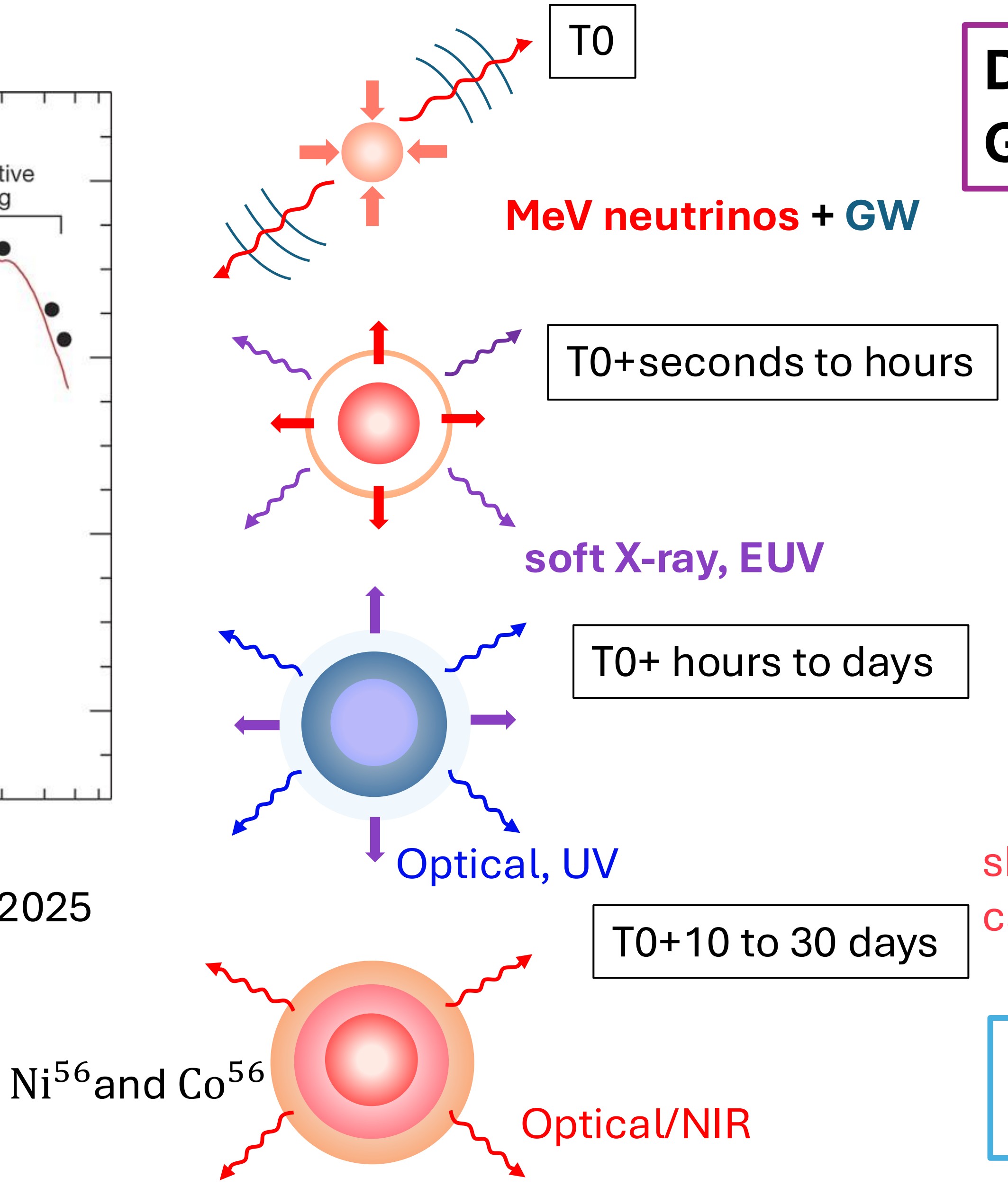
Optical/NIR

Collapsar SN and shock breakout

SN 2016gkg



Bersten et al. 2025



Detection by neutrino & GW facility

seconds-hours

EAGLE
single soft-long flare
from uncatalogued source

MONSTER
a rapidly cooling and evolving
optical/NIR SED

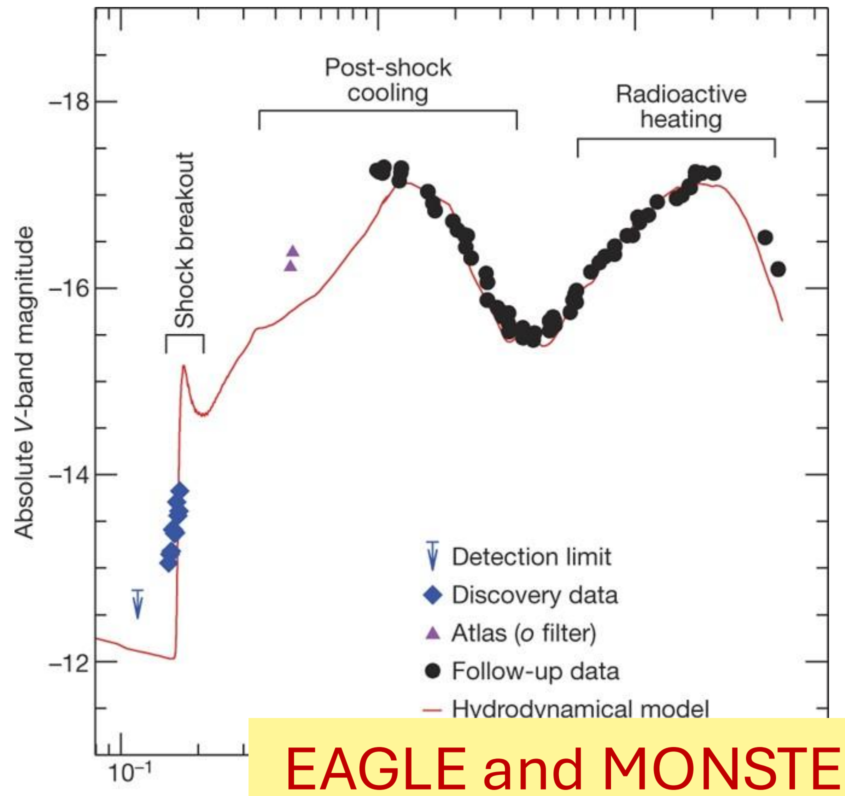
shock breakout candidate

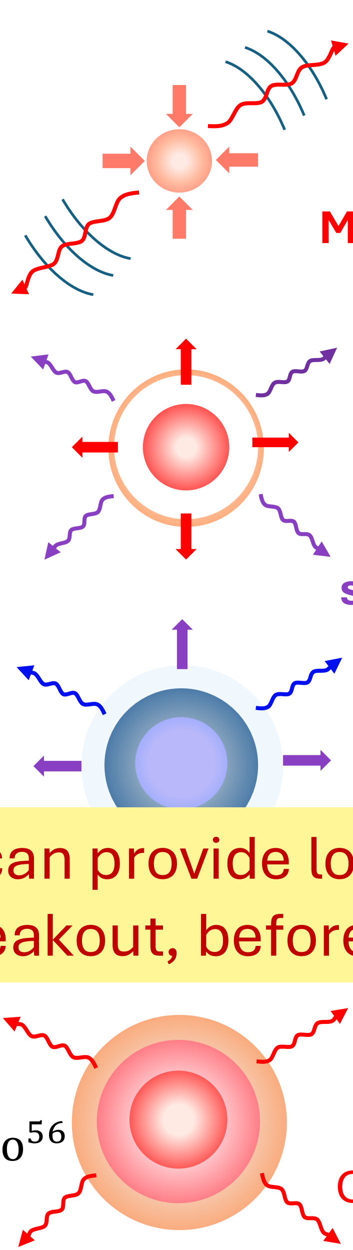
GCN ~hours

Follow-up by UV/Optical/NIR telescope

Collapsar SN and shock breakout

SN 2016gkg





Detection by neutrino & GW facility

seconds-hours

EAGLE
single soft-long flare
from uncatalogued source

MONSTER
a rapidly cooling and evolving
optical/NIR SED

EAGLE and MONSTER can provide localization and characterization of SN shock breakout, before it has UV/Optical peak

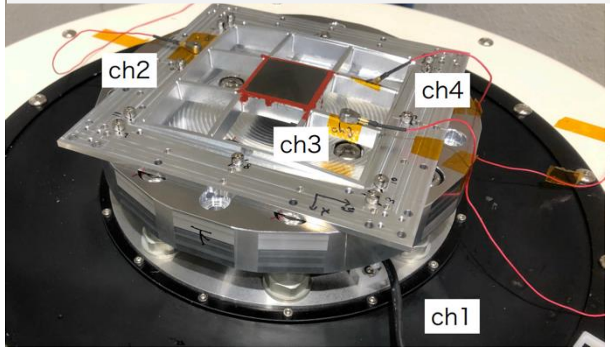
CN ~hours

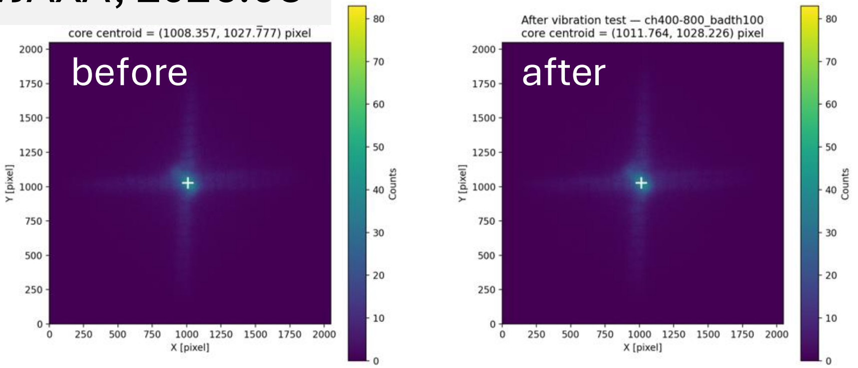
Follow-up by UV/Optical/NIR telescope

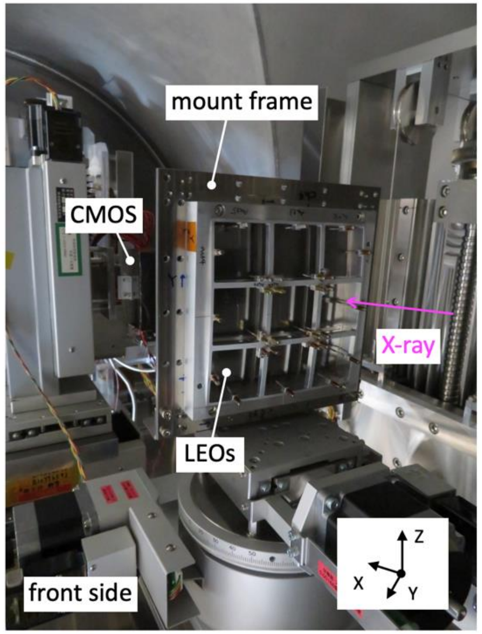
key technology: EAGLE Prototype

Optics System

AT level vibration test @ISAS/JAXA, 2026.08



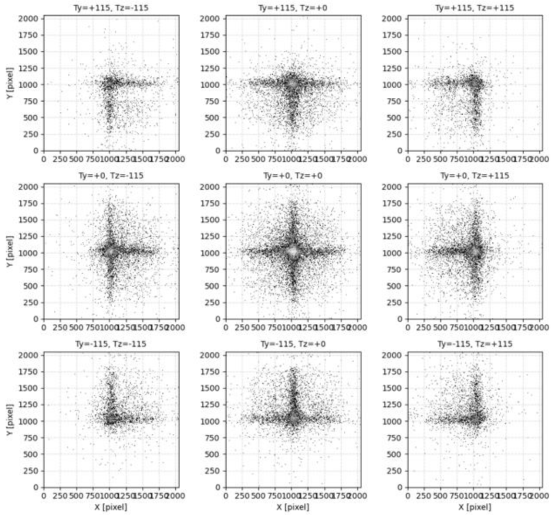




@ISAS/JAXA, 2026.06

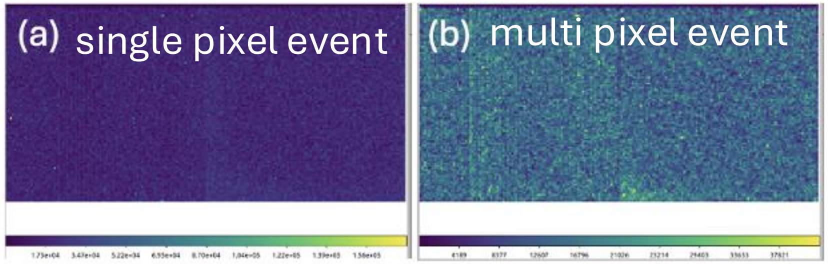
Validation of optics selection criteria

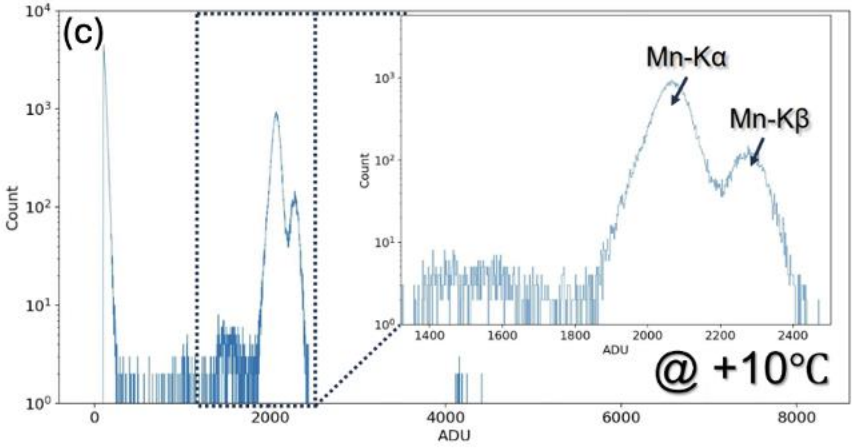
e.g. measurement of angular response



pnCCD detector

- Functional demonstration of the drive and readout system
- X-ray tests with a Fe-55 source confirmed the detection of Mn-Kα and Mn-Kβ line



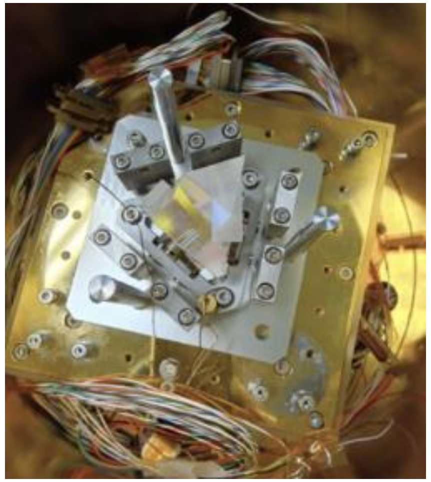


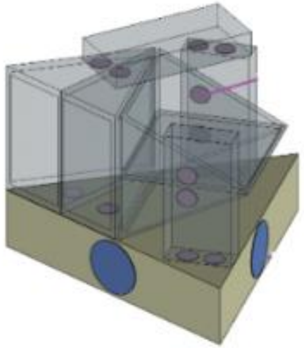
Spectra obtained from Fe-55 source

key technology: MONSTER

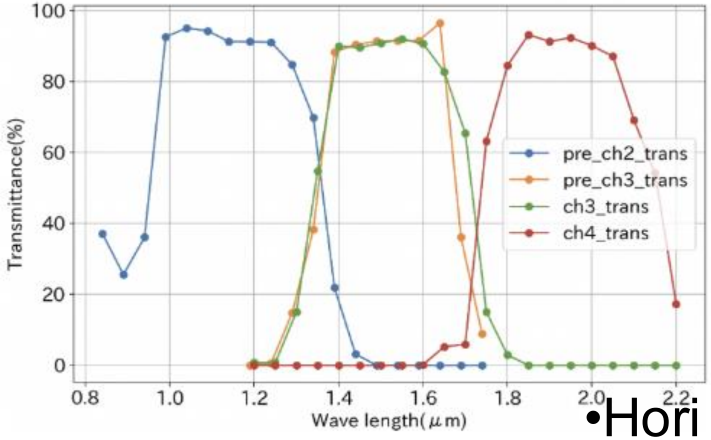
Köster prism

Design and testing of holders, selection of adhesives





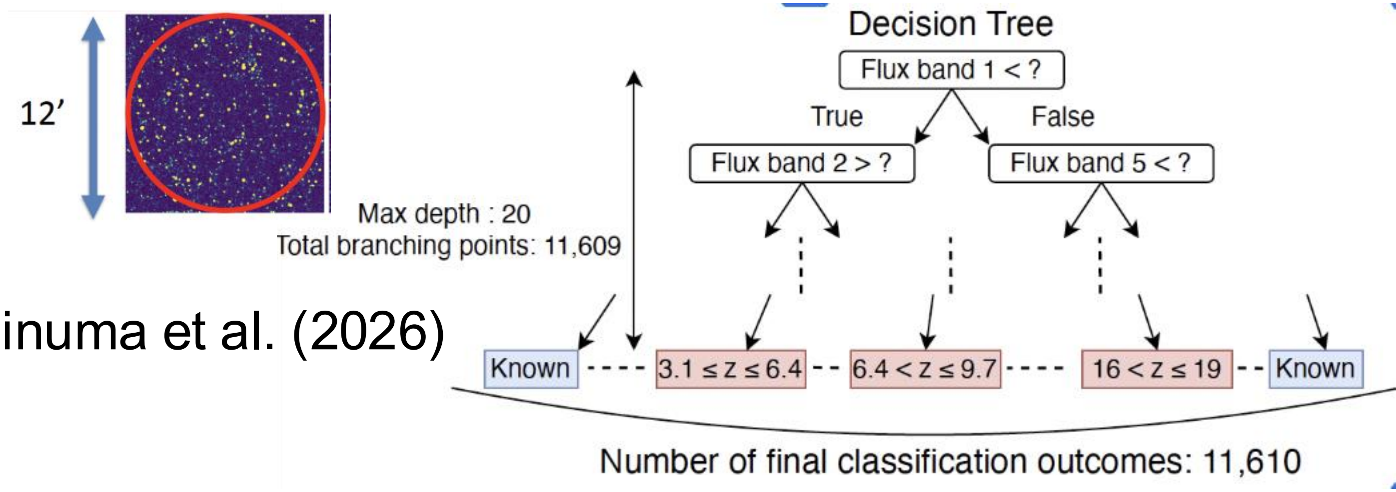
Measurement of spectral transmittance



•Hori et al. (2026)

Data processing

A machine-learning-trained decision tree reduces ~1,000 sources in the MONSTER field to < 100 GRB candidates.

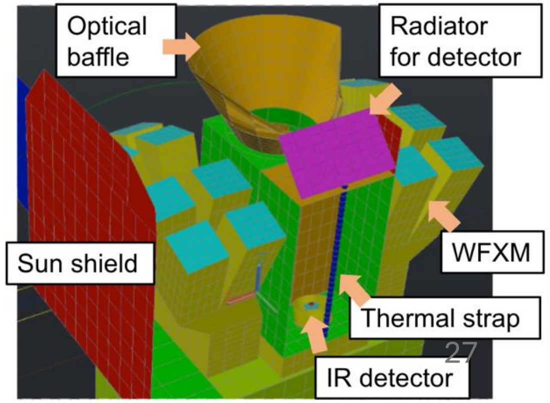


Niinuma et al. (2026)

Thermal model

Build an inhouse-model of EAGLE and MONSTER:
with improved thermal design, thermal feasibility has been confirmed.

Kageyama et al. (2026)



key technology: MONSTER

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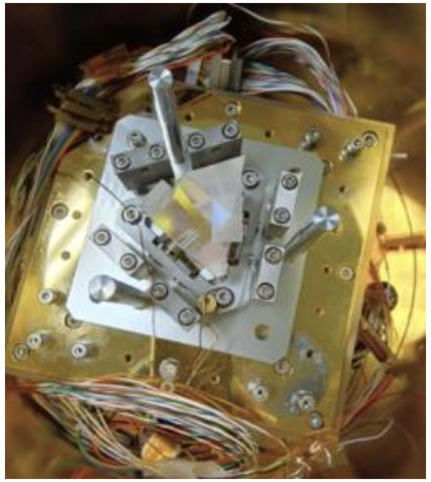

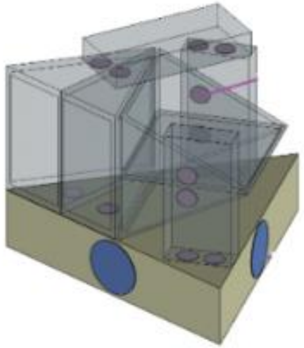

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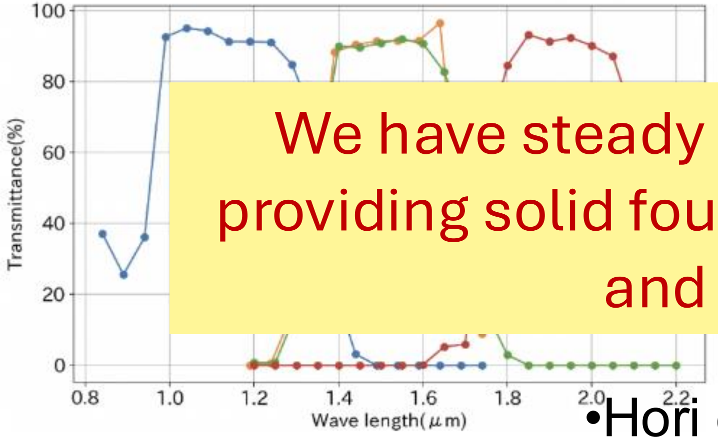

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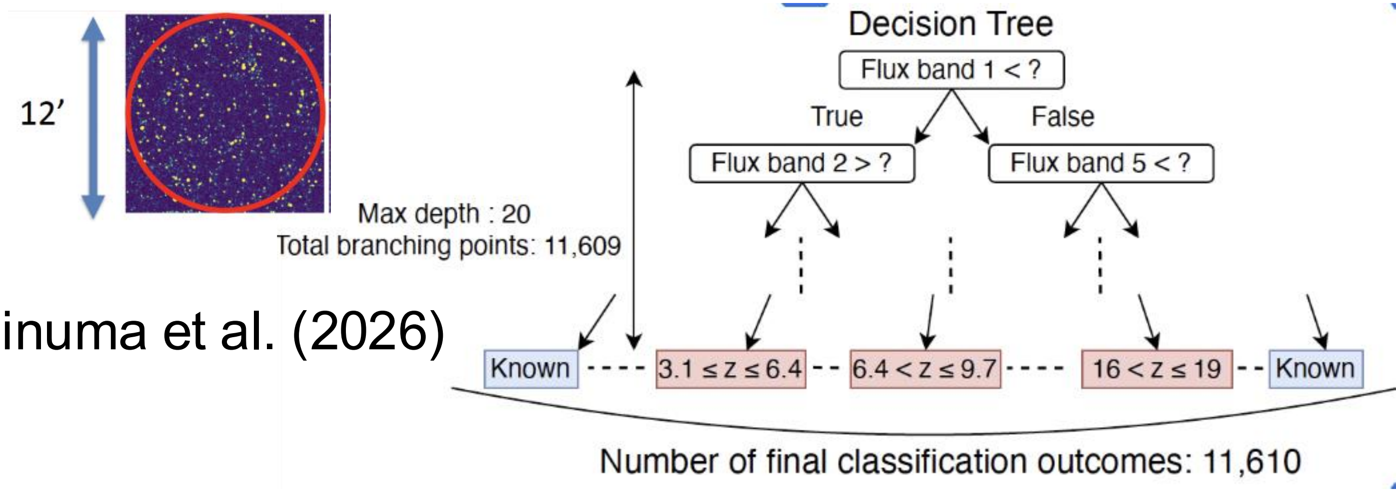
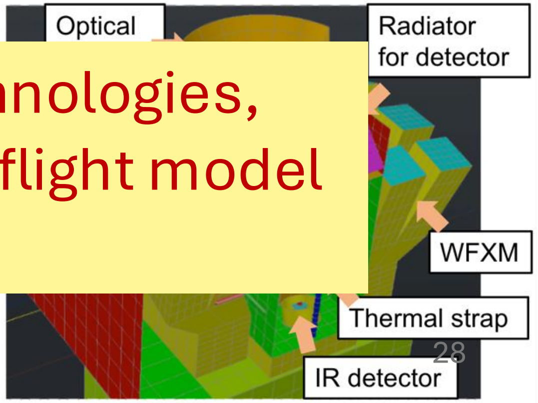


Niinuma et al. (2026)

Thermal model



Kageyama et al. (2026)

We have steady progress in establishing the core technologies, providing solid foundation for the next stage, design for flight model and complete observational work flow.

HiZ-GUNDAM turns soft X-ray triggers into actionable targets

- Wide-field focusing in soft X-rays expands discovery to fainter and softer transients and reveals early or extended emission phases.
- EAGLE detects and localizes X-ray transients, while MONSTER immediately searches for optical/NIR counterparts and provides early multiband information.
- Compact-object mergers and core-collapse supernovae demonstrate the workflow of rapid identification, and follow-up.
  Those workflows are applicable to a broader range of multimessenger transients.
- Key technologies for EAGLE and MONSTER are now being developed and validated through prototype model testing.

HiZ-GUNDAM turns soft X-ray triggers into actionable targets

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Those
trans

- Key te
valida

HiZ-GUNDAM is now open to MM community, to make unique science discoveries together.

We are waiting for specialists from a wide range of transients, to develop new science cases and follow-up strategies with us!!

Discussion: From X-ray Trigger to Multimessenger Action

A growing diversity of transient alerts

- Future wide-field monitors will detect many different classes of transient sources.

- GRB-focused experts and automated systems may have difficulty to recognize unfamiliar events and rapidly connect them with the appropriate communities.

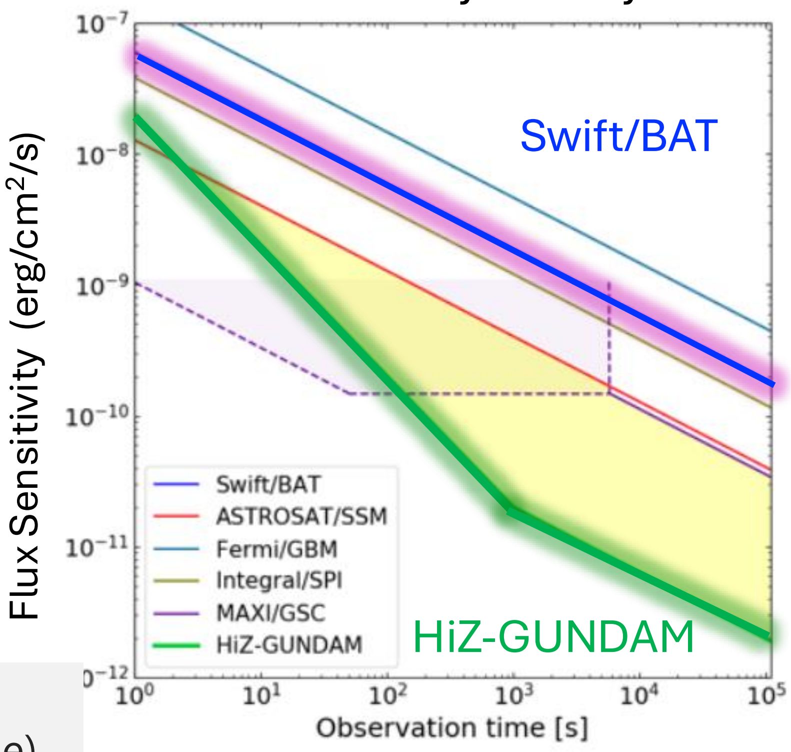
- Alerts may be delivered fast enough technically, while delays in classification and decision-making still create gaps in follow-up coverage.

How can we move rapidly from an X-ray transient trigger to classification and coordinated multimessenger follow-up?

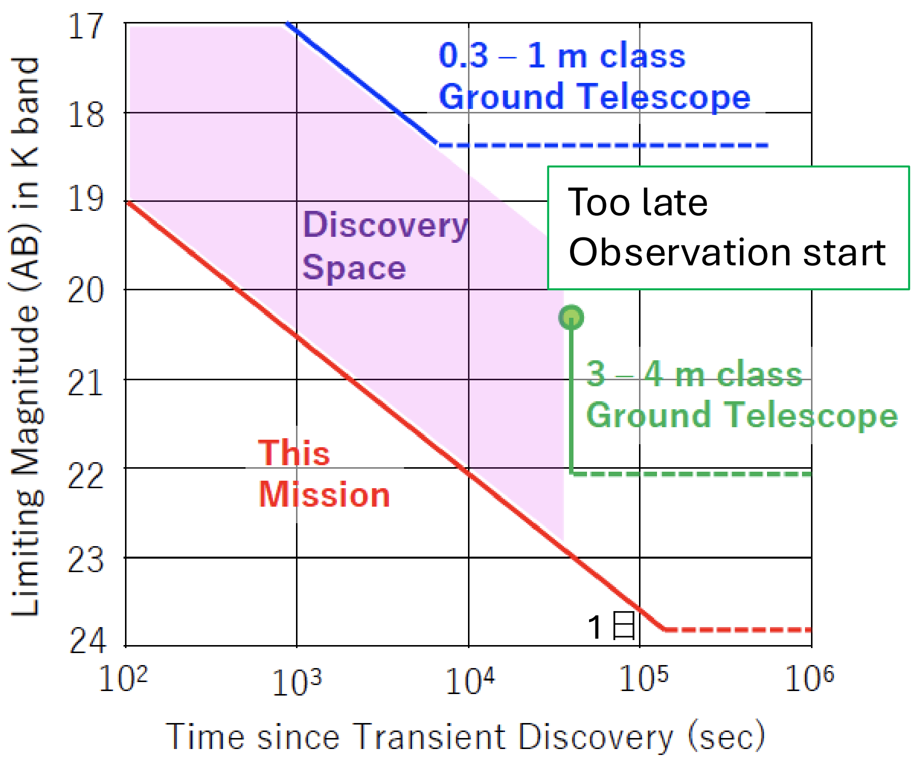
Appendix

Expected detection possibility for various transients

Detection sensitivity of X-ray transient



Detection sensitivity of follow-up



F_lim = 1e-10 erg/cm/s
FoV = 0.53 str (16 module)

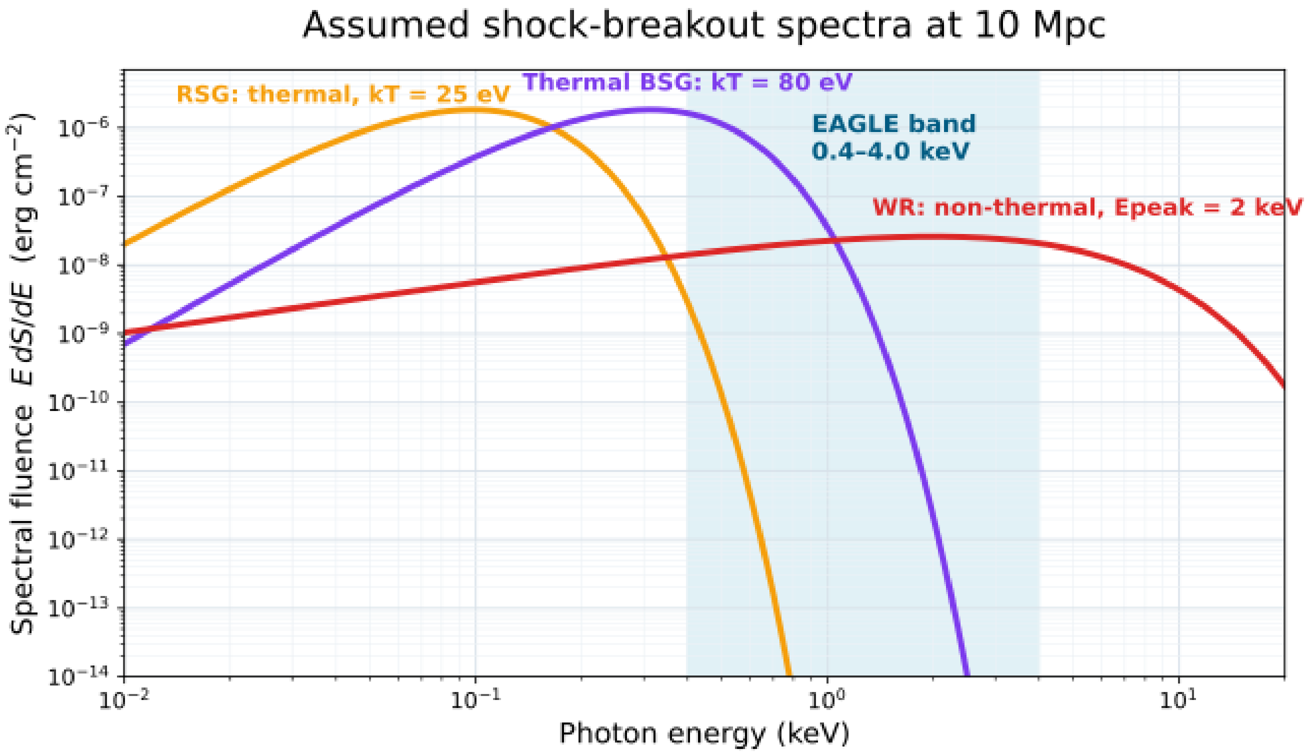
X-ray	event/yr
GRB (6<z<12) best	17
GW/SGRB prompt	~5
GW/SGRB E.E.	~5
GRB/SGRB	~464
Low-Luminosity GRB	> 3
X-Ray Flash	33

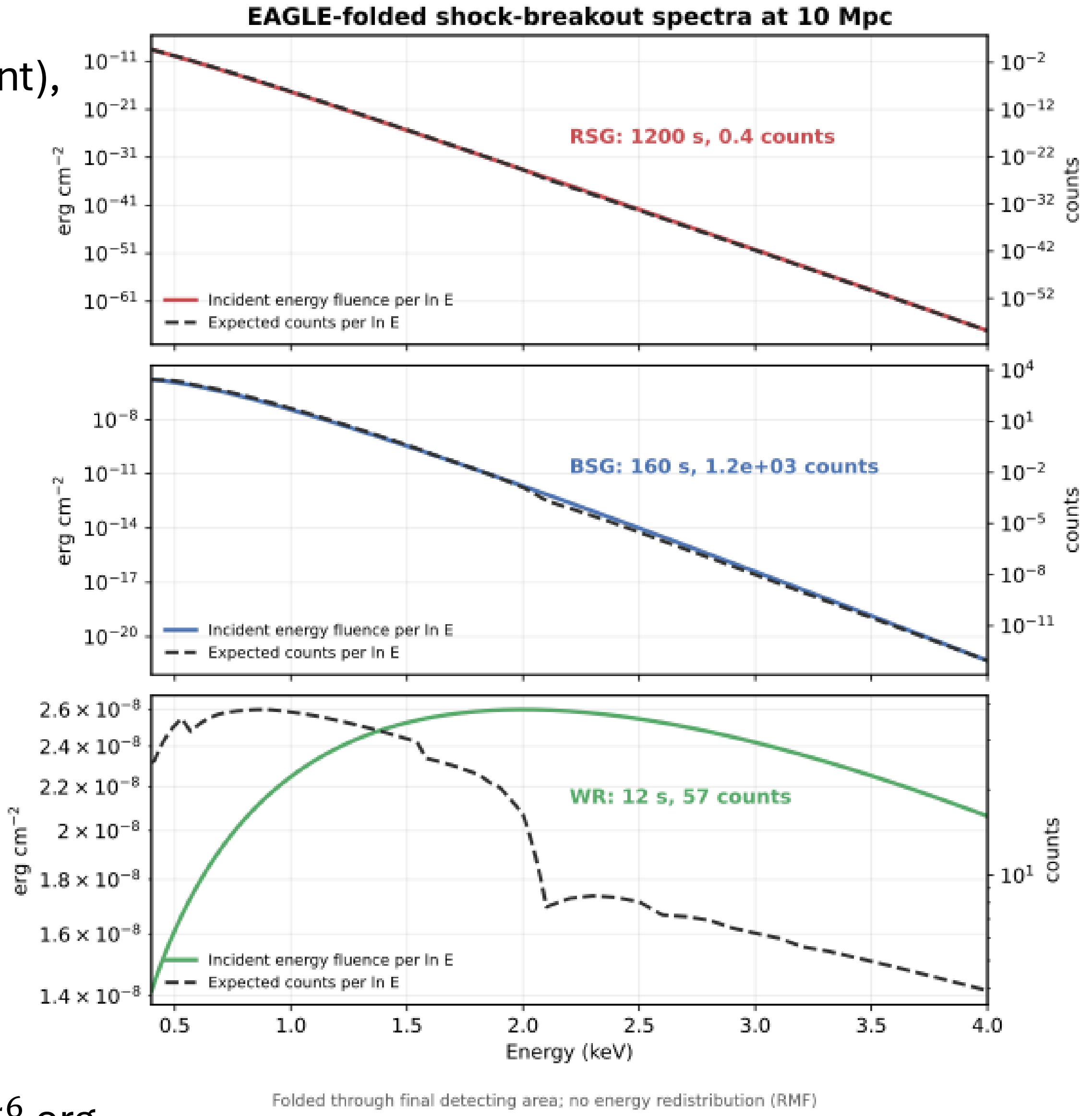
X-ray	event/yr
Tidal Disruption	40
SN Shock Breakout	> 3
Stellar Flare	many
Direct collapse BH	a few
Accretion induced collapse	~7

Near Infrared	event/yr
afterglow (6<z<12) best	9
macronova	~5 + α
Supernovae	27
afterglow of GRB/SGRB/XRF	many
Variable stars	many

EAGLE spectral response to SN Shock breakout

SN shock breakout from RSG (red supergiant), BSG (blue supergiant), and WR (Wolf–Rayet star)





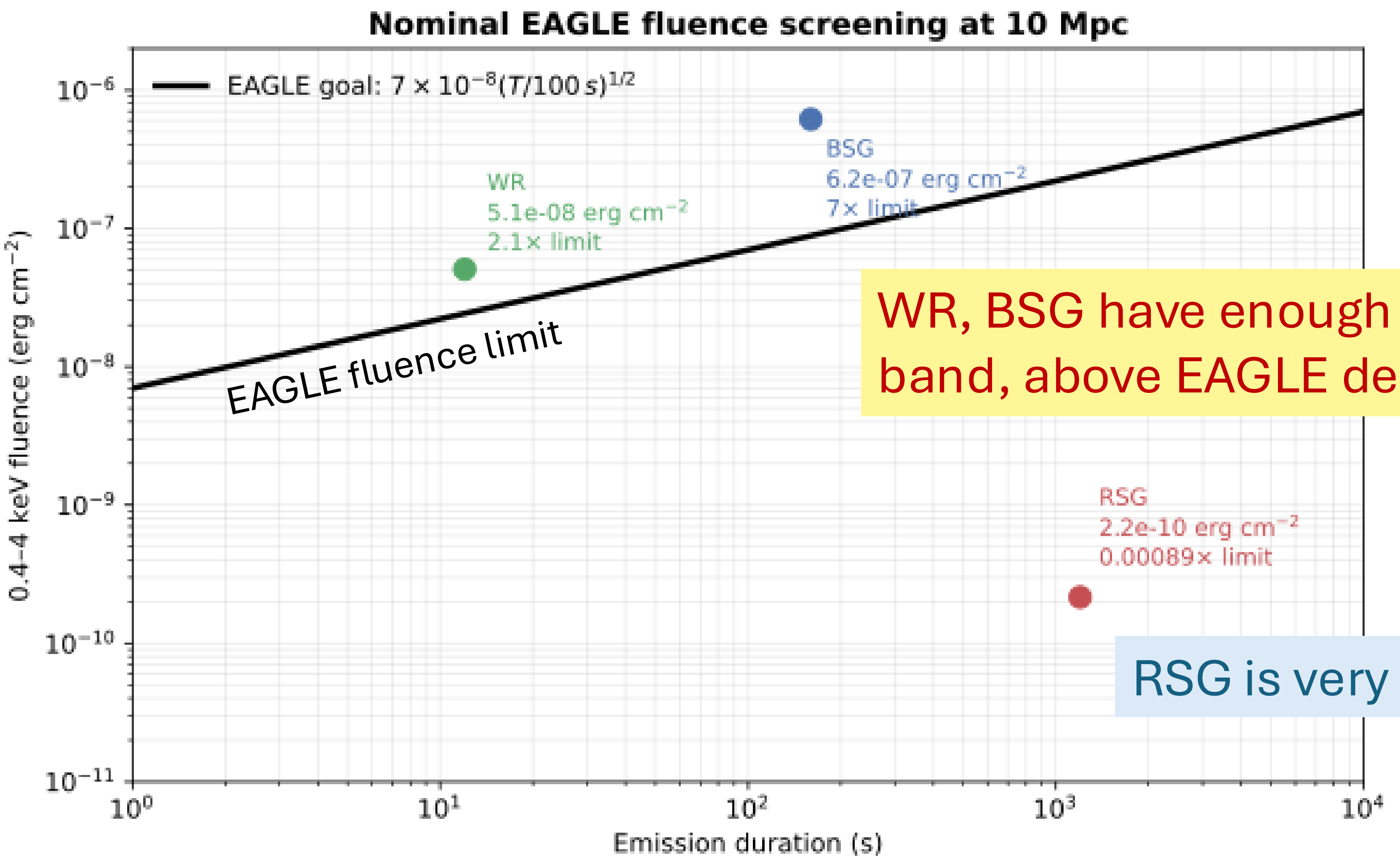
models: Nakar & Sari (2010)

RSG：thermal spectrum、$kT = 25$ eV、$E_{\mathrm{rad}} = 3 \times 10^{46}$ erg

Thermal BSG：thermal spectrum、$kT = 80$ eV、$E_{\mathrm{rad}} = 3 \times 10^{46}$ erg

WR：cutoff power law、$\beta = 0.25$、$E_{\mathrm{peak}} = 2$ keV、$E_{\mathrm{rad}} = 10^{45}$ erg

EAGLE detectability SN Shock breakout



WR, BSG have enough counts in EAGLE energy band, above EAGLE detection fluence limit.

RSG is very faint in EAGLE band

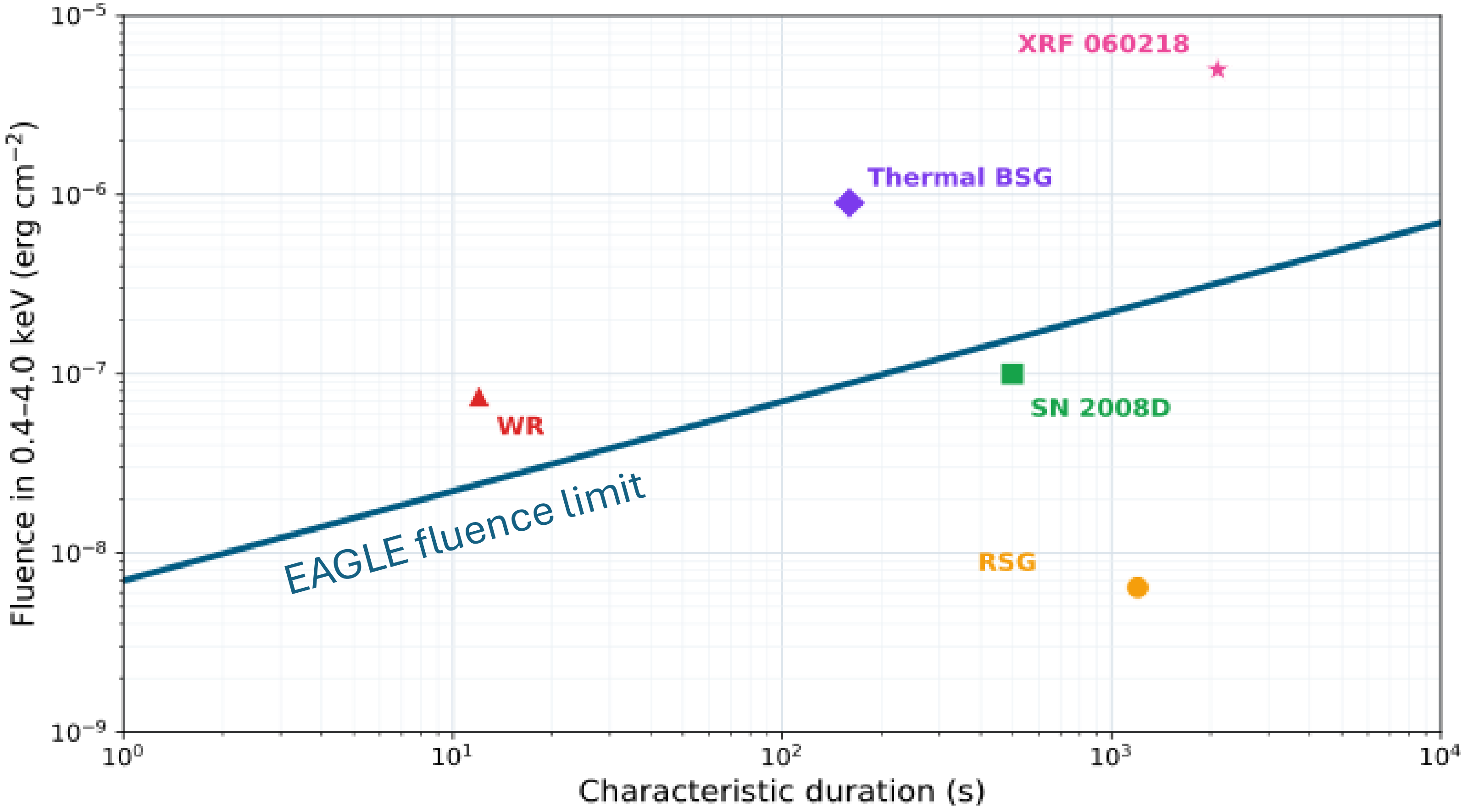
Details of spectral model of SN shock breakout

model details adopted from: Nakar & Sari (2010)

Model	M_*	R_*	E_{exp}	n	κ	R_*/c	$T_{\mathrm{obs},0}$	Plot fluence at 10 Mpc
RSG	$15\ M_\odot$	$500\ R_\odot$	10^{51}erg	1.5	0.34 cm^2 g^{-1}	~1200 s	~25 eV	6.4×10^{-9}erg cm^{-2}
Thermal BSG	$25\ M_\odot$	$70\ R_\odot$	10^{51}erg	3	0.34 cm^2 g^{-1}	~160 s	~80 eV	9.0×10^{-7}erg cm^{-2}
WR	$15\ M_\odot$	$5\ R_\odot$	10^{51}erg	3	0.20 cm^2 g^{-1}	~12 s	~2 keV	7.5×10^{-8}erg cm^{-2}

- We adopt spherical, bare-star shock-breakout models with a canonical explosion energy of 10^{51}erg.
- The characteristic pulse duration is approximated by the stellar light-crossing time, R_*/c.
- The progenitor radius and envelope structure determine the duration, temperature, and spectral hardness of the breakout emission.

Simplest comparison without EAGLE spectral responce



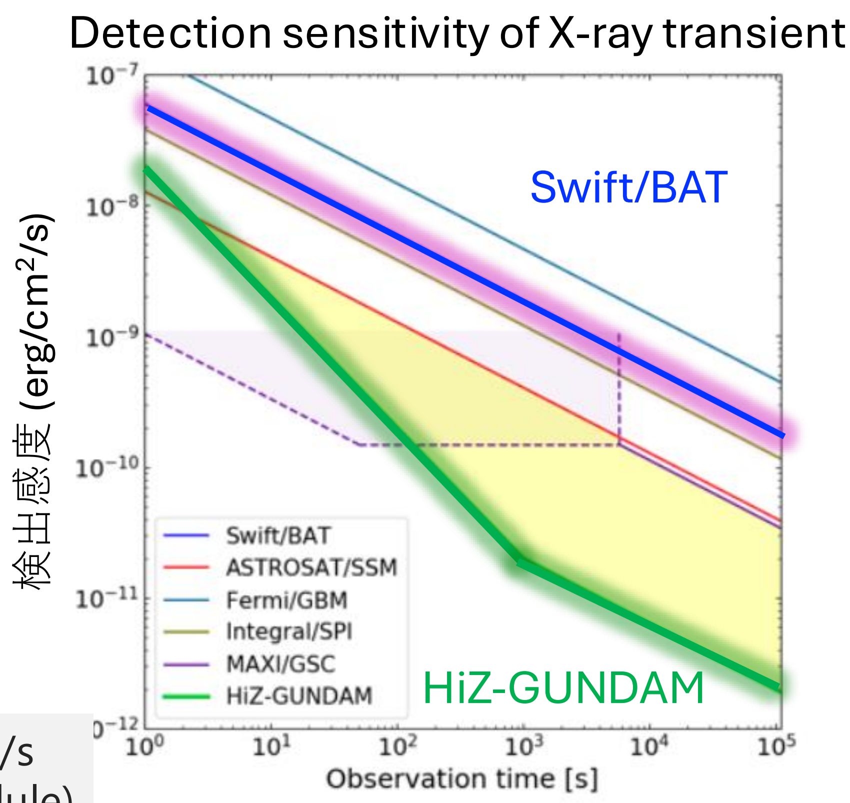
Assumptions for the detectability plot

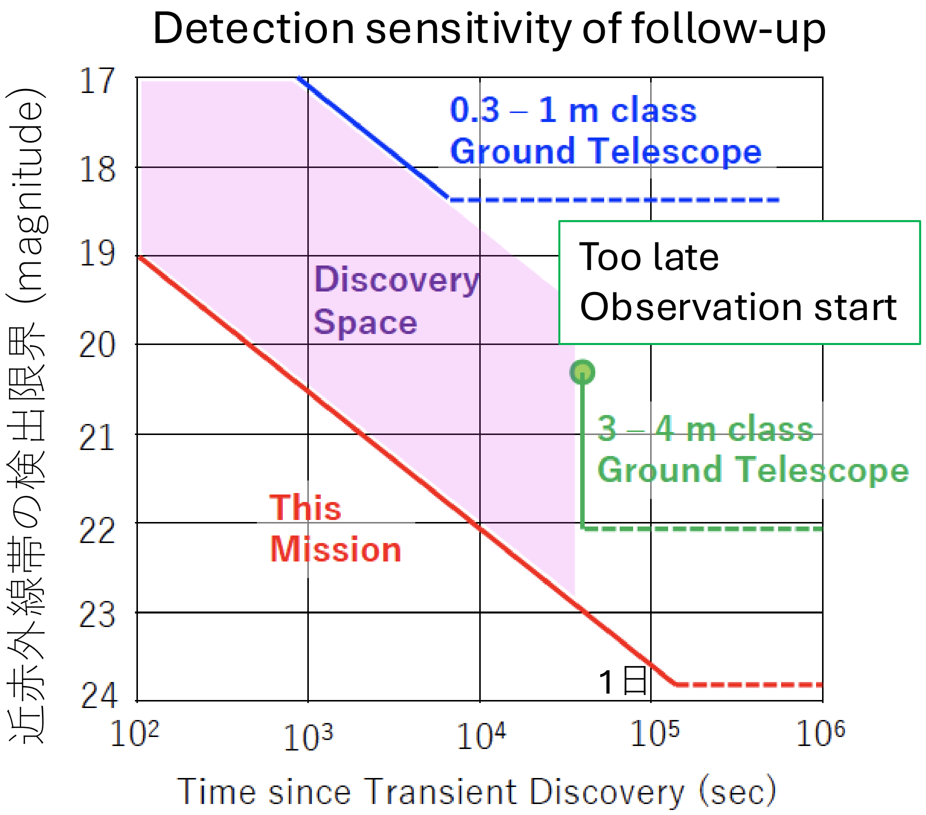
- Distance: 10 Mpc
- Unabsorbed 0.4–4.0 keV fluence
- Simple spectral band-fraction estimates
- No detector-response folding

$$f_{0.4-4} = \frac{\int_{0.4\,\mathrm{keV}}^{4.0\,\mathrm{keV}} \frac{dE_{\mathrm{rad}}}{dE}\, dE}{\int_{0}^{\infty} \frac{dE_{\mathrm{rad}}}{dE}\, dE}$$

Progenitor	Expected spectral model	counts ratio in 0.4–4 keV
RSG	Blackbody, $kT = 0.025$keV	8.6×10^{-5} （0.0086%）
BSG	Blackbody, $kT = 0.080$keV	0.245 （24.5%）
WR	Cutoff power law, $E_{\mathrm{peak}} = 2$keV	0.606 （60.6%）

Expected detection possibility for various transients





F_lim = 1e-10 erg/cm/s
FoV = 0.8 str (24 module)

X-ray	event/yr
GRB (6<z<12) best	26
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
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