

Probing the dynamic universe with the GRINTA hard X-ray mission



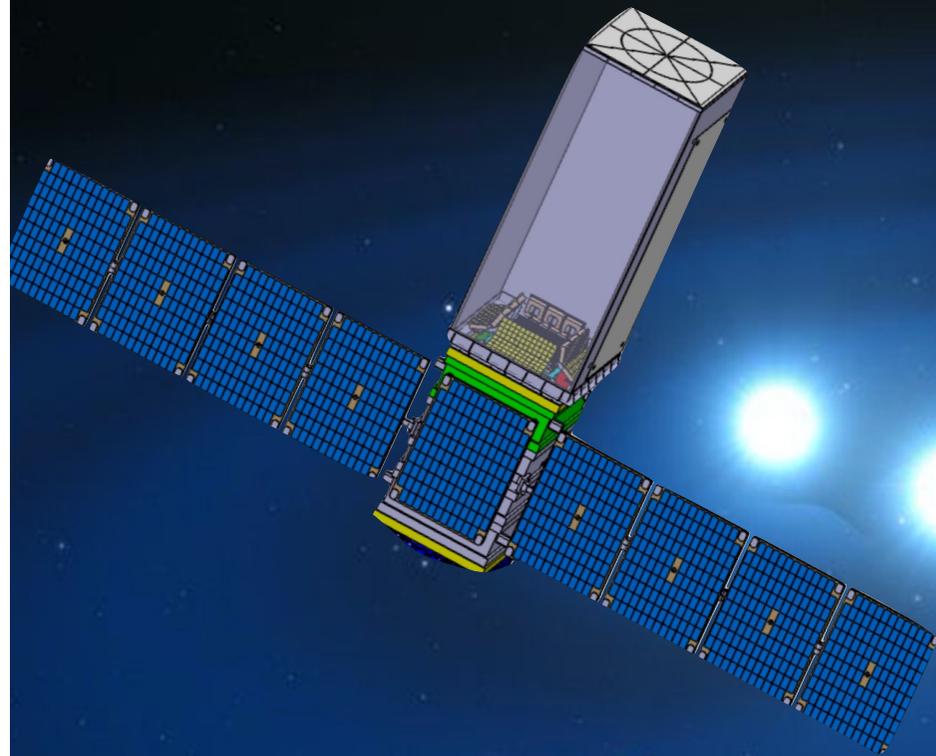
Lorenzo Natalucci
On behalf of the GRINTA Consortium

RSN4 Meeting, Naples 28-30 December 2026



The GRINTA mission

- Main goals: TDA & multimessenger, Surveys
- Launch: ~2034
- Orbit: LEO equatorial (<5deg)
- Rapid repointing, light S/C
- GRB detection (TED):
 - Coverage ~8 sr FoV (0.02-10 MeV)
- Followup (HXI):
 - Coverage 400deg² FoV (5-200 keV)
- #GRBs: ~380/yr (of which 65 SGRBs/yr)
- Localization:
 - <10 deg @90% confidence at first detection,
 - 40" after followup (SNR=8)
- The autonomous re-pointing and the fine localisation capability form the basis of the scientific return of the mission



The Consortium

19 European research laboratories, >50 researchers, 9 countries



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Science objectives

Find and monitor EM counterparts of GW and high-E neutrino events	<ul style="list-style-type: none">• Probe the nature of remnants in BNS mergers• Investigate cosmology using luminosity and distance from GW and EM signals; tests of modified gravity• Understand the physics of mergers responsible for GW emission• Evaluate the fraction of BNS able to produce a jet• Understand the role of NS-BH mergers as short GRB progenitor• Monitor AGN associated with HE neutrinos
Improve knowledge of GRB physics	<ul style="list-style-type: none">• Investigate jet structure by detecting off-axis GRBs• Achieve a complete picture of the relativistic jet and its interaction with the environment
Detect and study new transient phenomena and understand the underlying physical processes	<ul style="list-style-type: none">• Probe the sources and acceleration sites of UHECR and Investigate the link between HE neutrino and UHECR production at emission sites• Investigate what powers the activity in magnetar sources and how is this triggered• Probe the relation between magnetars and other multi-wavelength/multimessenger sources
Understand the Physics of Compact Objects and characterize their populations	<ul style="list-style-type: none">• Extend the known AGN population and probe their evolution• Characterise the nature of 1000's of unidentified sources in the Swift, Fermi and INTEGRAL catalogs• Improve the knowledge of accretion physics in XRB• Investigate jet properties in TDEs

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F3 mission schedule

Event F	Date or duration	Note
Start of Study Phase 0	Q4 2026	Typically one candidate and a one backup (for a short time), with the intention to rapidly focus the effort on the selected mission
Mission Adoption	Q2 2030	At the end of Phase B
F Launch	~2034	Approximate date, mission dependent
Nominal in-orbit operations	Typically 2 years	Must be compatible with ESA CaC

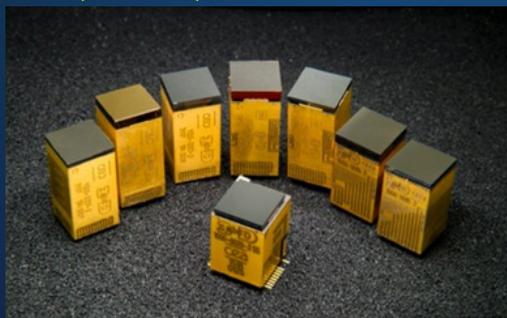
Table 22: Reference schedule for the F-mission

Credit:ESA

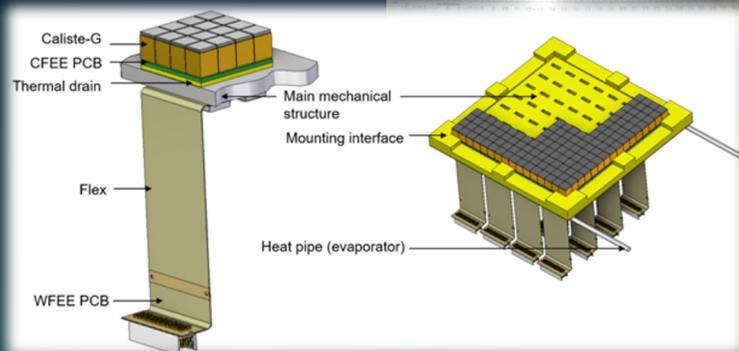
The GRINTA payload

Hard X-ray Imager (HXI)

- Coded mask instrument (400 deg² FoV)
- Detection units based on Caliste modules (CdTe Schottky, already flight proven)
- Focal plane assembly has 16x16 modules, 900cm² detection area. Imaging pixel size = 1mm.



A set of Caliste modules. A version of them has been launched on Solar-Orbiter (TRL ~5-6)



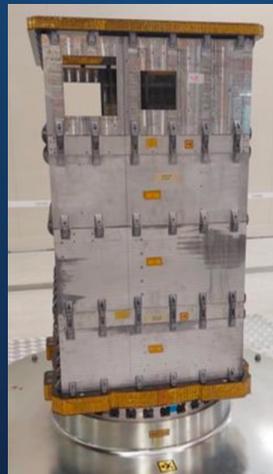
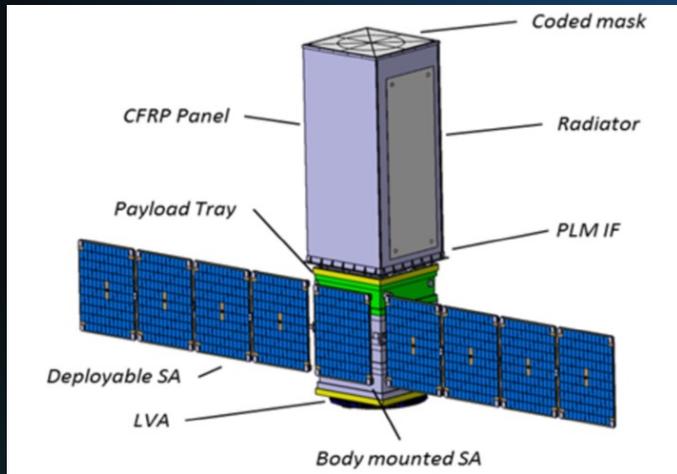
Transient Event detector (TED)

- GAGG scintillator arrays, total detecting area: 2400 cm², SIPM readout
- They are used on board to detect GRBs and other transients and send alerts to the DPU
- Technology already flight proven, mainly on small-sats (e.g. GECAM, GRID, GRBalpha, ...)

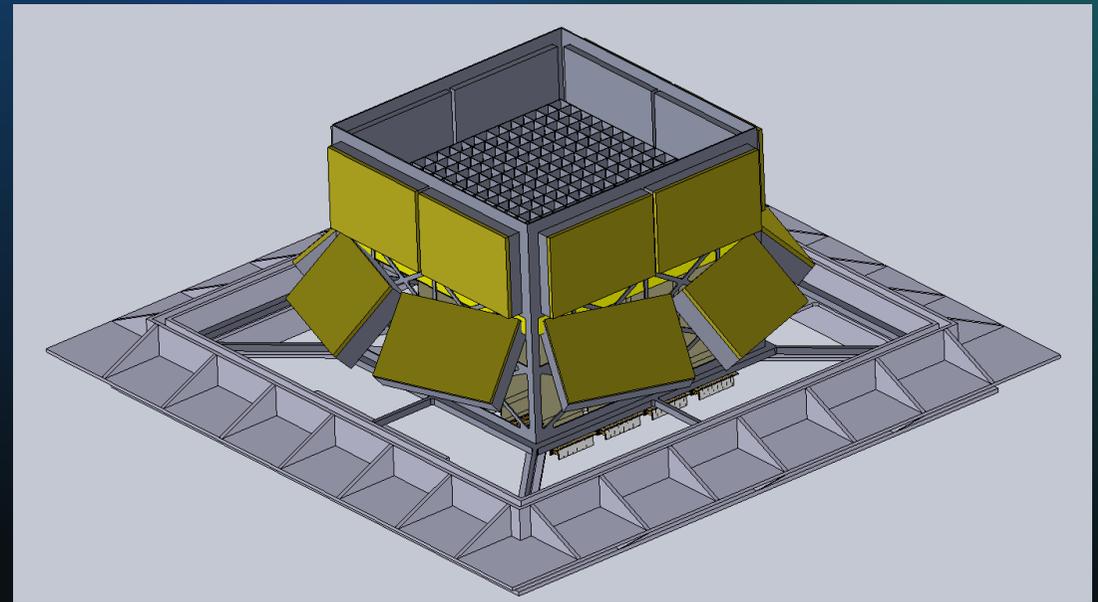
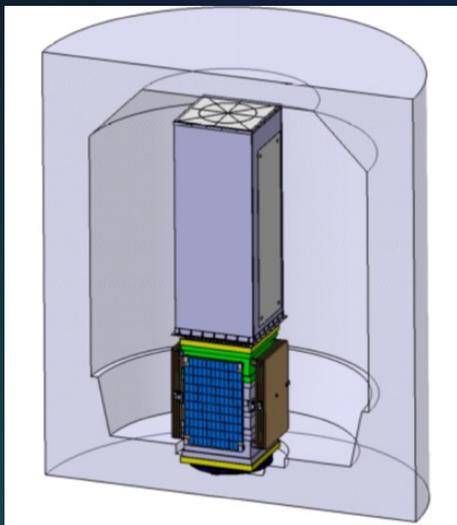


A TED detector (25 cm² area) based on a 2x2 array of GAGG scintillators. ROSSPAD-like design (IDEAS) (TRL~5-6)

The S/C and the Payload Module



S/C platform study based on TAS-I Nimbus model

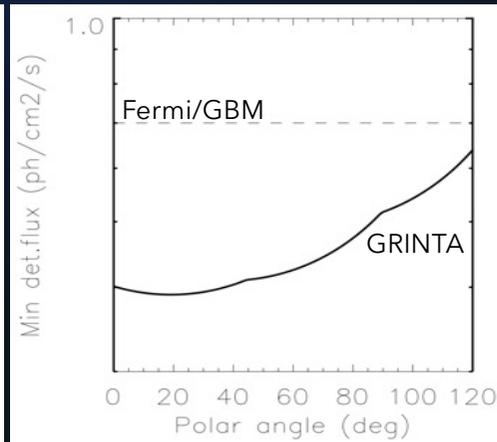
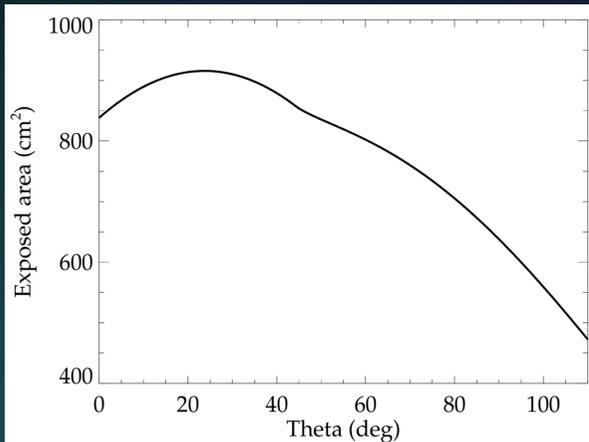
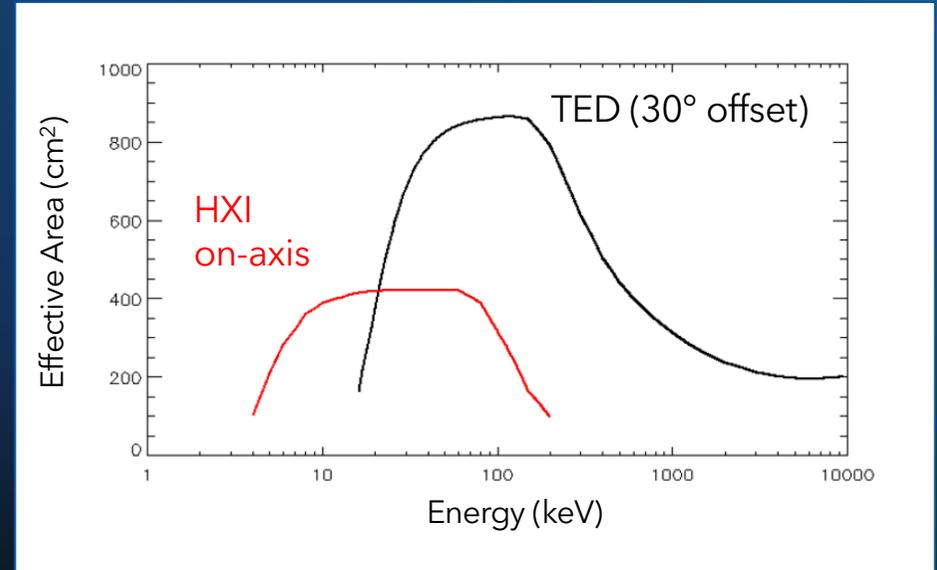


Schematic of the GRINTA Payload Module

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GRINTA performance summary

Characteristics	HXI Performance	TED performance
Energy range	5-200 keV	20 keV – 10 MeV
Effective area	390 cm ² (10-80 keV)	850 cm ² (40-150 keV)
Spectral resolution (FWHM)	1 keV@60 keV	~25% @60 keV, ~10%@500 keV
Field of View	400 sq. deg (>50% coding)	~8 sr
Angular resolution	3.8'	N/A
Source location accuracy (SNR=8)	30"	<5°
Sensitivity (SNR=3, 10 ⁴ s) ph/cm ² /s [mCrab]	Energy range (keV)	ph cm ⁻² s ⁻¹ [mCrab]
	5-30	1.2x10 ⁻³ [0.9]
	30-60	6.9x10 ⁻⁴ [6.0]
	60-120	5.1x10 ⁻⁴ [9.5]
		< 0.5 ph cm ⁻² s ⁻¹ in 50-300 keV

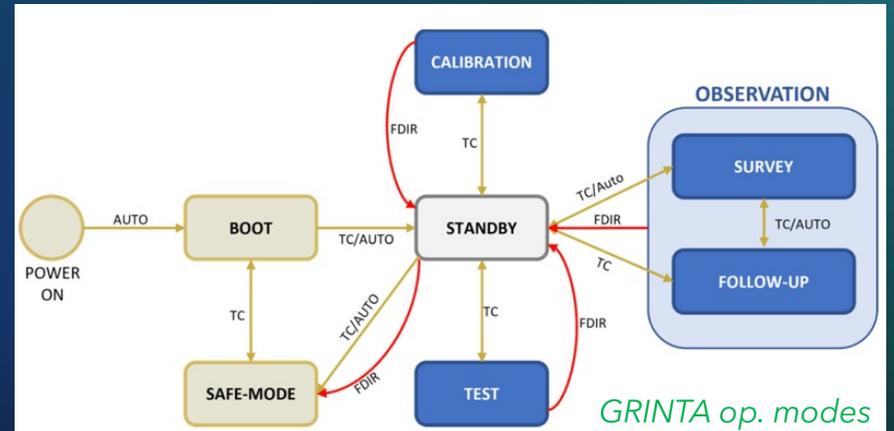


Source Type	Detections/Year
Short GRBs	65
Long GRBs	320

TED exposed area and sensitivity as a function of polar angle

GRINTA Operational Baseline

- Orbit: 600KM LEO, $\sim 5^\circ$ inclination
- Basic operational modes:
 - (a) Safe mode (b) Survey (c) Follow-up
- S/C with re-orientable solar panels
- Follow-up with HXI triggered by TED localisation of an event or by external alert (option under study)



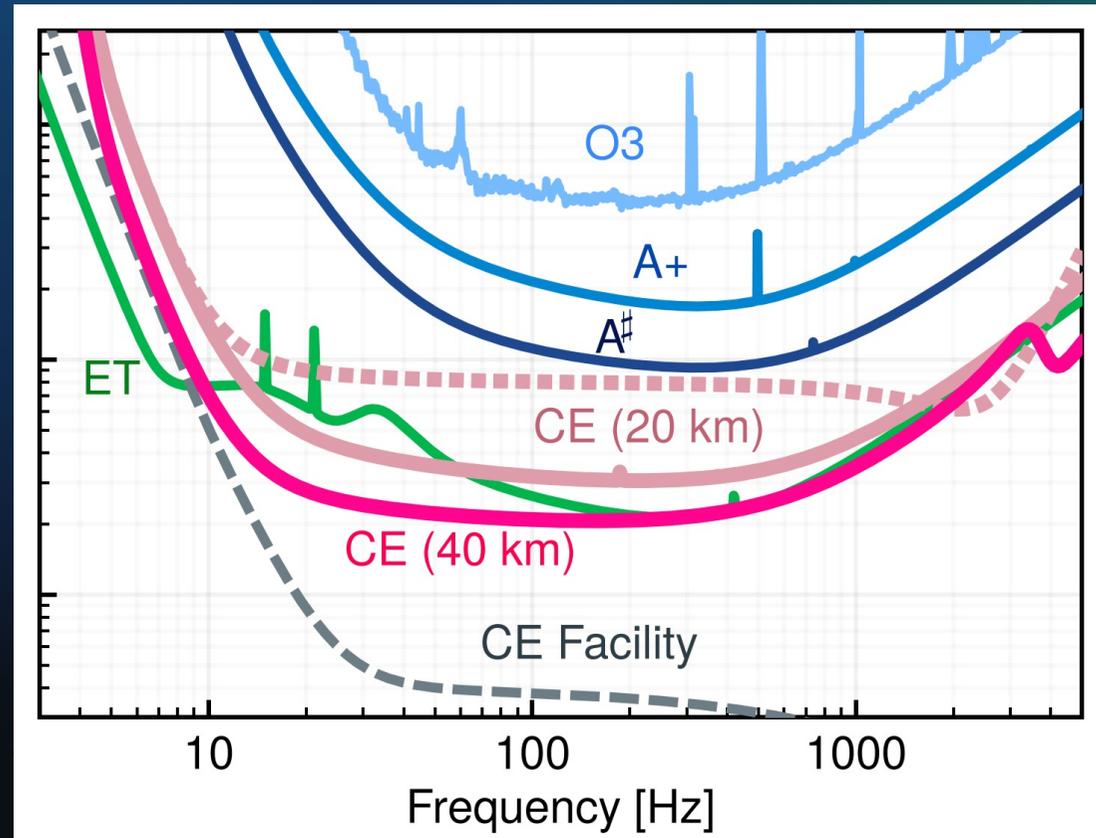
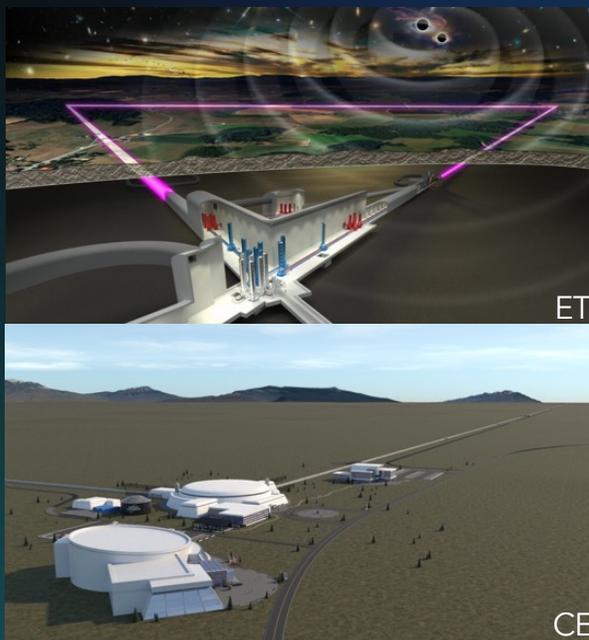
Fast slew towards the target (50° in $< 60''$)

- Capability for bi-directional alert messaging to/from ground
 - S/C communication via both GS and satellite constellations (baseline: Iridium-NEXT)
- Goal: alert messages are transmitted from GRINTA to Iridium ground stations and arrive at GRINTA Alert Centre within < 1 min
- Ensuring instantaneous coverage of the orbit: 65% on average for Iridium



Predicted scenario for GW

- **Post O5:** A# upgrades to Adv.LIGO (~2030) + Virgo nEXT
- **Einstein Telescope (~2040)**
- **ET + CE network?**



Gupta+24

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Yearly joint detections TED/GW

- Current rate estimations for TED/GW yield:

~2-3/year for post-O5/A# configuration
with 3 detectors

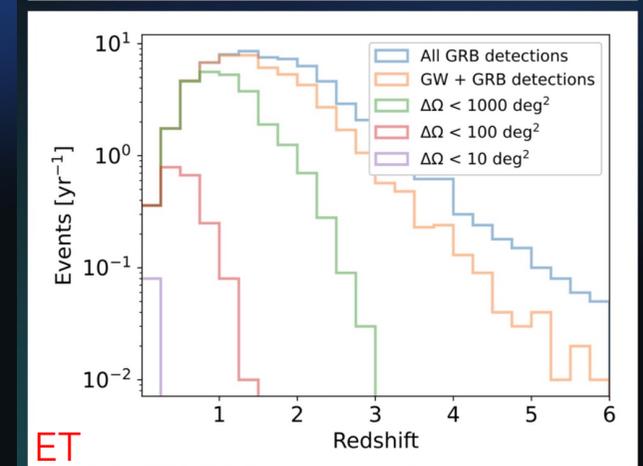
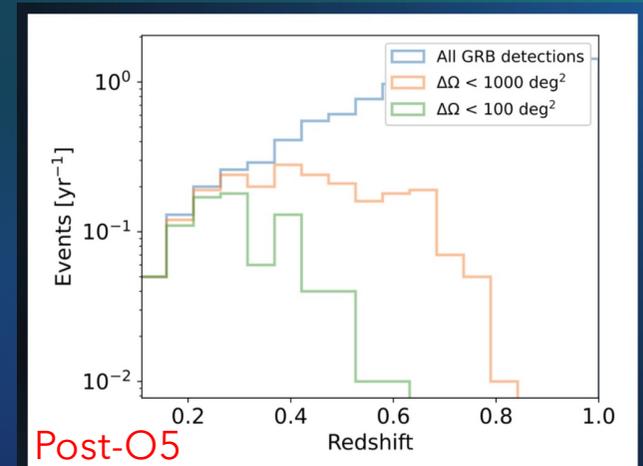
A# event rate for BNS is expected as $\sim O(100)$ /year

~50/year for ET configuration with 2 L-shaped detectors in
Europe

- Localization by TED to $< \sim 10$ deg
- ~50% of TED detected bursts could be localised with HXI
with sub-arcmin accuracy

Potentiality of HXI to directly respond to GW triggers from ground

- The opportunity of GRINTA to be repointed after receiving a GW alert
from ground is being considered (*work in progress*)



Predicted sky localisation error for BNS
mergers (90% c.l.) for two scenarios of GW
detector network

Credit: De Santis & Ronchini (GSSI)

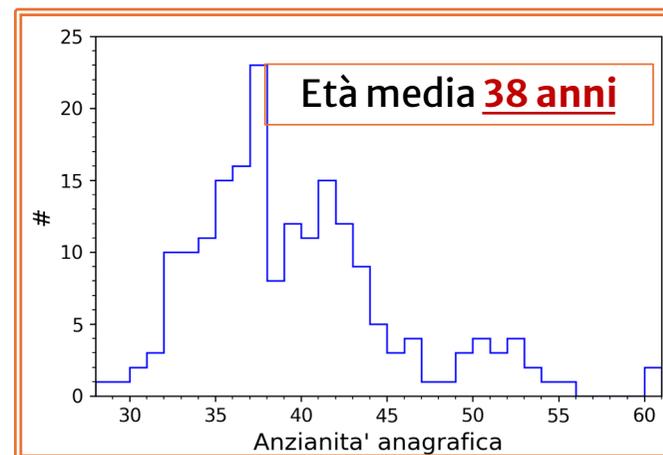
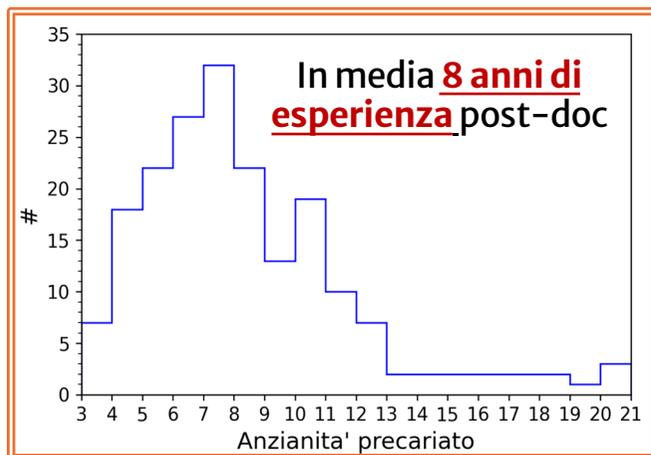
Summary

- GRINTA is a natural evolution of the successful missions: Fermi, Swift, INTEGRAL with an **innovative operational approach**
- It represents an **outstanding opportunity to cover the post-O5 (and possibly, the 3rd generation) era of GW observatories and neutrino 2nd generation detectors starting ~2034.**
- It will provide **wide sky coverage in hard X-rays**, currently the most effective choice for the detection and prompt localization of short GRBs from binary mergers at large distances
- The detection of joint EM/GW events will provide **breakthrough discoveries in fundamental physics, cosmology, relativistic jet formation and structure, gravity theories, etc.**
- GRINTA will detect a very large sample (~300/year) of long GRBs to provide deeper **insights into the progenitors, central engines and jet structures associated with massive stellar collapses**
- It will provide **broad band coverage to study accretion and ejection phenomena** in compact sources, covering an important gap in the decade
- It will work in **synergy with other ground and space facilities**, spanning from radio to UHE gamma-rays to study the most energetic phenomena

AXRO 2025 workshop, Prague 1-5 December 2025

La situazione del personale precario in INAF è **INSOSTENIBILE!**

1.200 TI Vs **650** precari: più di 1 precario ogni 2 persone di ruolo



Plot di un campione rappresentativo dei precari INAF al 31/12/2024

Entro l'anno, l'attuale situazione determinerà l'esodo di > 100 lavoratori altamente qualificati

È URGENTE che INAF RIVENDICHI con fermezza, presso il MUR, finanziamenti svincolati dal turnover ed etichettati per le STABILIZZAZIONI MADIA: unica soluzione per questa emergenza

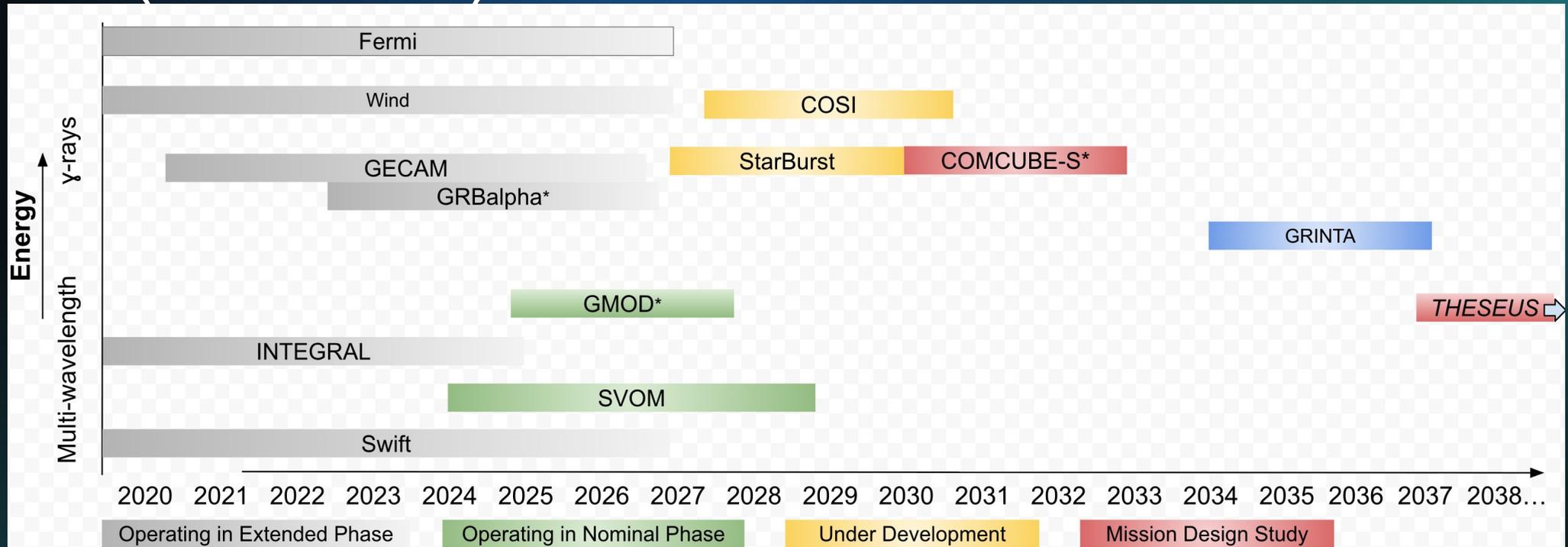


Per sostenerci, inquadra il QRcode e firma



Backup slides

HE (≥ 100 keV) missions scenario



No currently approved hard X-ray missions with spectro-imaging capabilities like *Swift*, *Fermi* and *INTEGRAL* in the 2030's

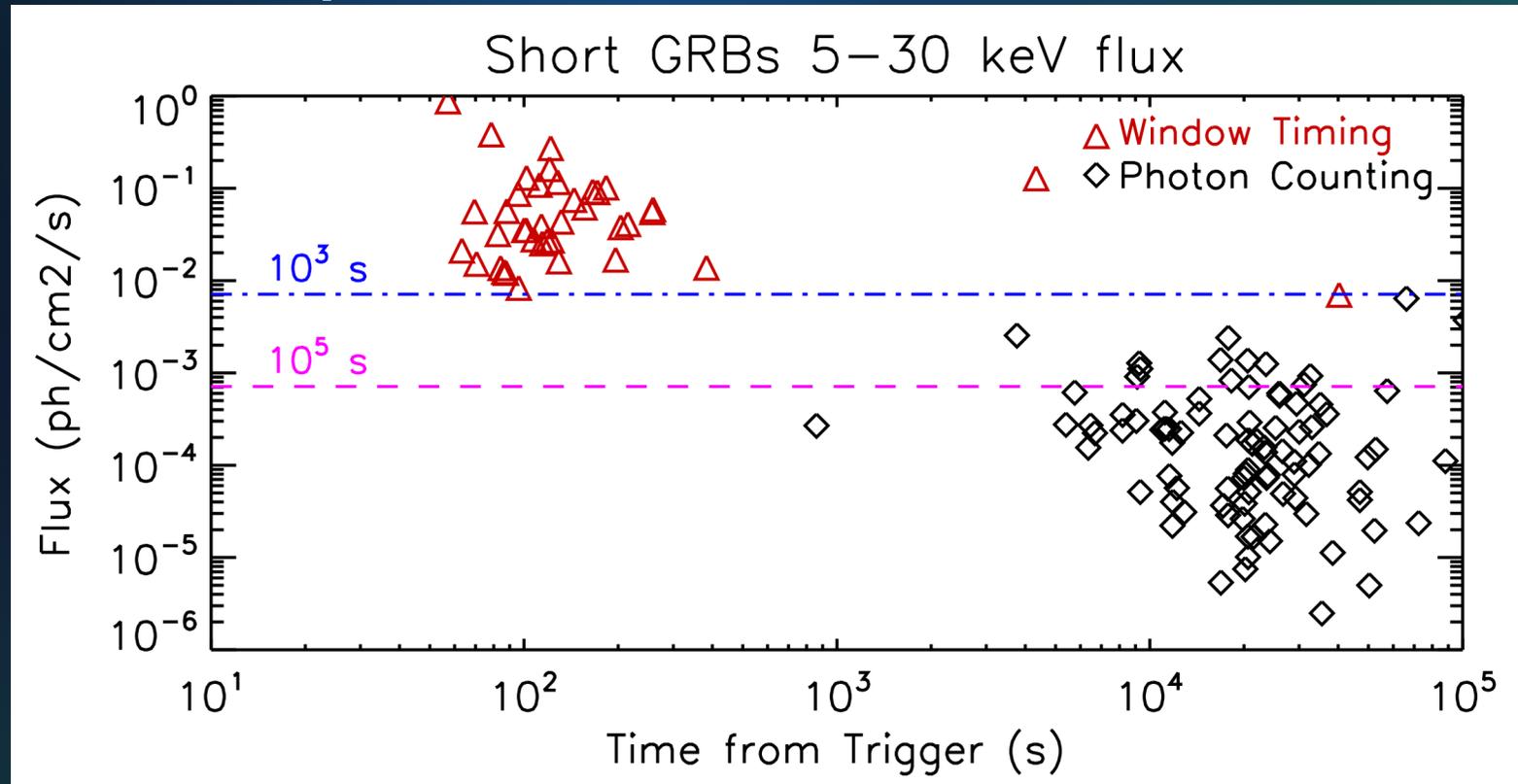
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Synergy with other facilities

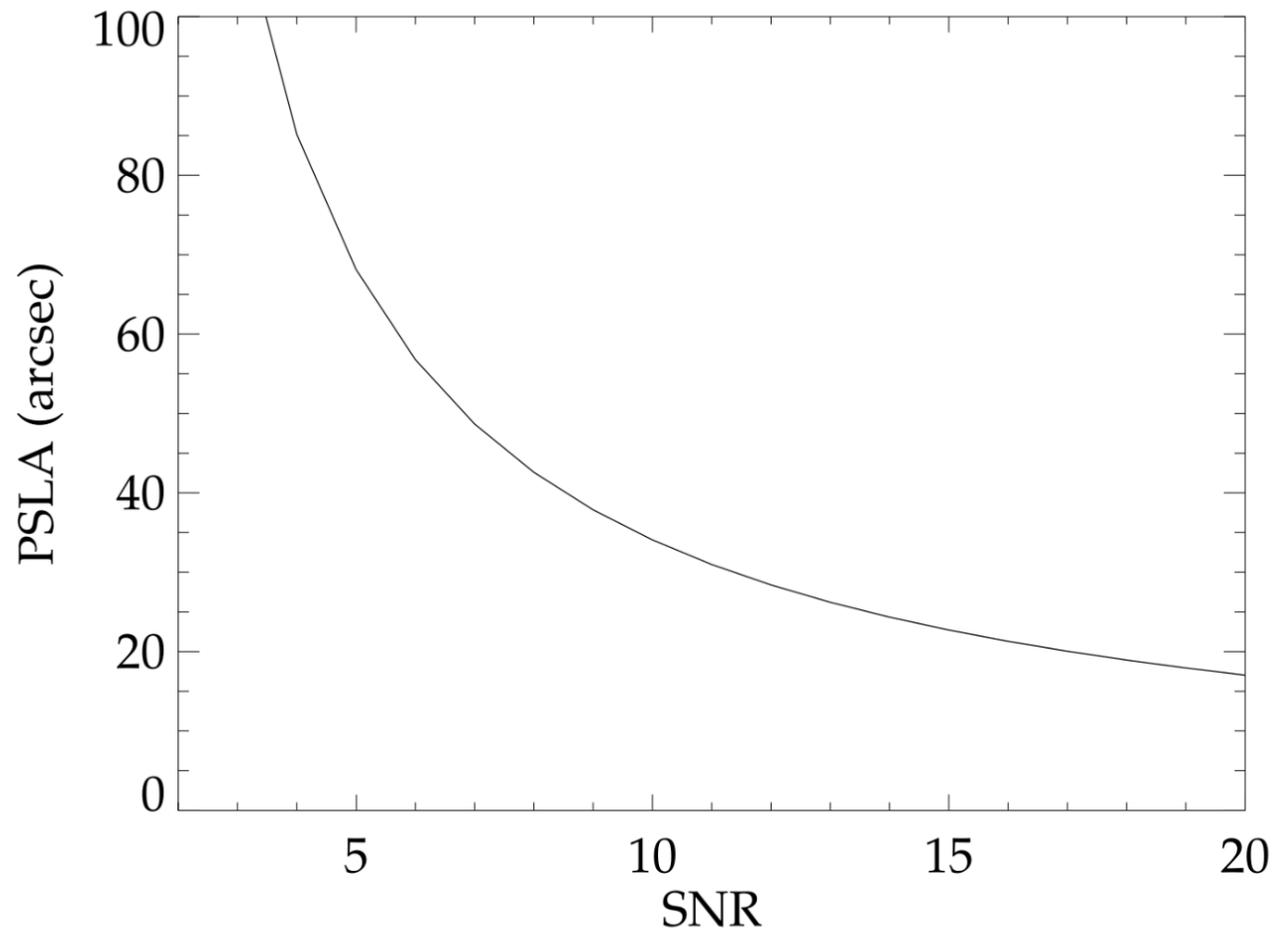
- Provide accurate locations of the events to follow-up with IR/optical/UV telescopes. Measurements of redshifts by IR/optical followup of SGRBs will have impact on cosmology (H_0 measurements) and fundamental physics (e.g. theories of modified gravity)
- Followup with optical/UV to investigate the relative contribution of mergers and core-collapse SNe to the r-process (connection to cosmic-ray science, origin of heavy elements).
- Investigation of alerts generated by radio, optical and VHE (e.g. SKA, Vera Rubin, CTA), including subthreshold searches. Events from GRBs, TDEs, FRBs,...
- Search for HE neutrino counterparts in the error regions of neutrino telescopes: IceCube Gen2, KM3NET...
- Perform joint studies of the hard X-ray and TeV emission (e.g. blazar flares) with GRINIA and CTAO
- Follow-up and localization of many astrophysical transients
- Investigation of HE unidentified sources for thousands of objects (e.g. sources already detected by INTEGRAL, Swift, Fermi, eRosita, ...)



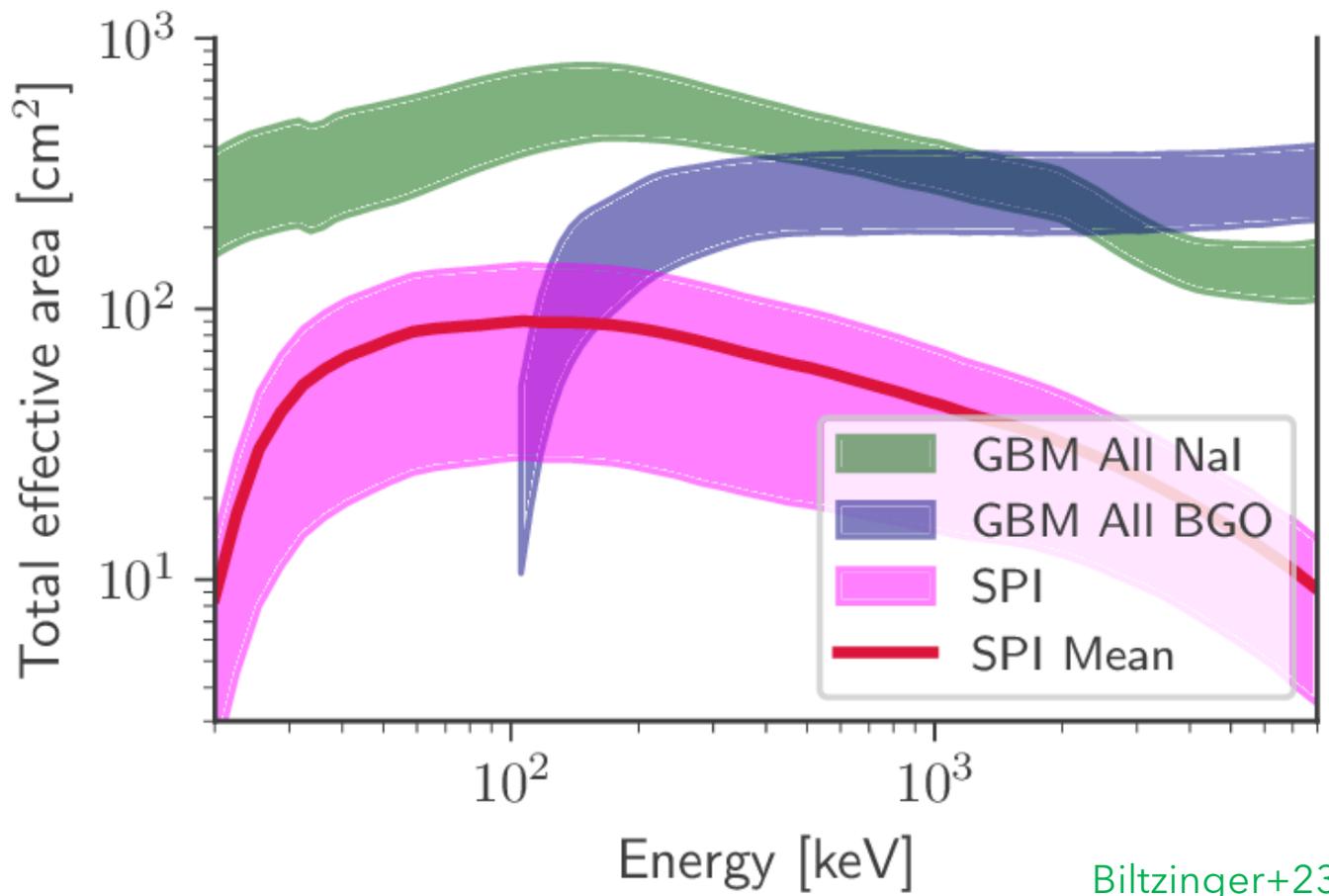
HXI follow-up of Short GRBs



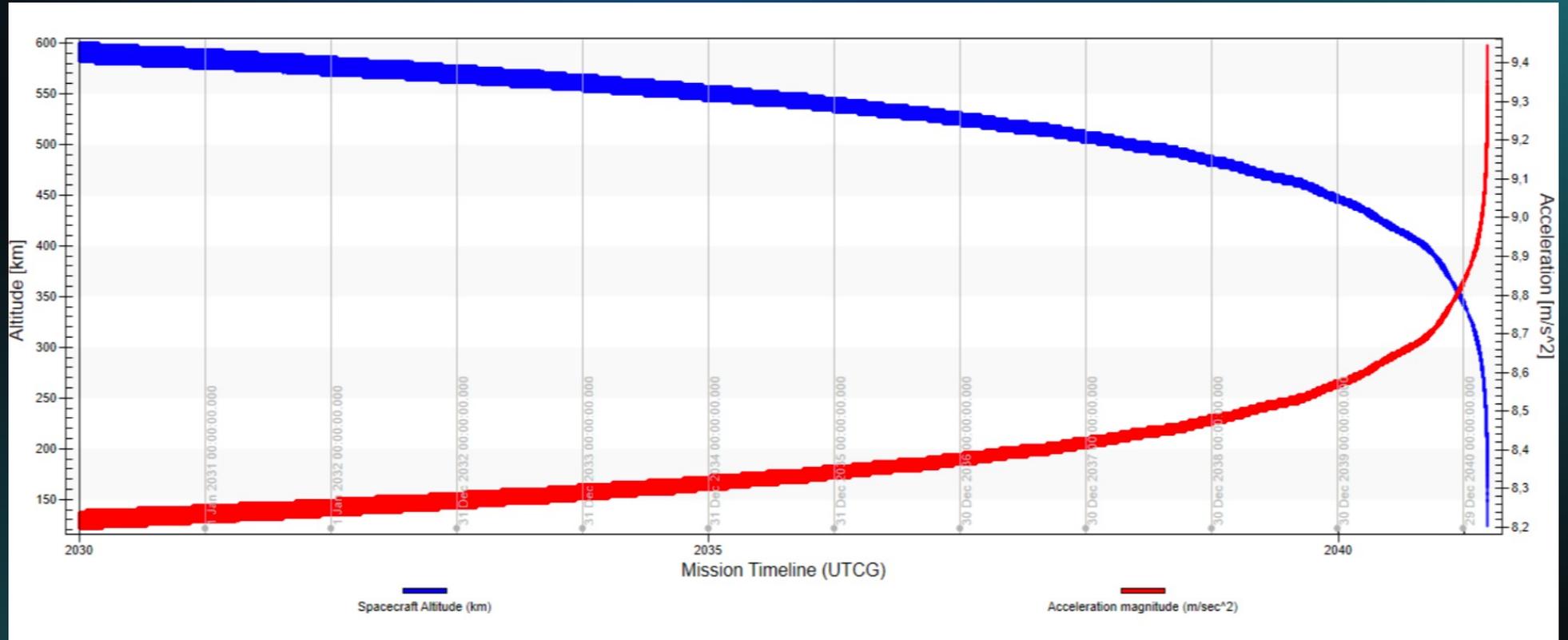
Extrapolated 5–30 keV flux for sGRB afterglows based on Swift/XRT results in Window Timing (red triangles) and Photon Counting (black diamonds) modes.



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Biltzinger+23



List of F3 shortlisted for step-2



Title	Topic	Lead Proposer	Country
GRINTA: Exploring the dynamic universe through bursts, X-rays, and cosmic messengers	Astrophysics	Lorenzo Natalucci, INAF/Istituto di Astrofisica e Planetologia Spaziali	IT
GUEST: Gravitational Universe Exploration with Satellite Tracking	Fundamental Physics	Diego Blas, IFAE/ICREA	ES
Magnetotail Dynamics Explorer	Solar System	Andrew Fazakerley, Mullard Space Science Laboratory, University College London	UK
MESSIER Surveyor - Lifting the veil on the dark universe	Astrophysics	David Valls-Gabaud, Observatoire de Paris	FR
STEIN - Satellite Test of Einstein's gravitation theory	Fundamental Physics	Joel Bergé, ONERA - Paris Saclay University	FR
Proposals submitted as mini-F and moved to F			
Hannes - explore the physics of the small-scale dynamic aurora	Solar System	Mykola Ivchenko, KTH	SE
HYADES - Hydrogen And Deuterium Surveyor for Small Bodies in the Solar System	Solar System	Michal Drahus, Astronomical Observatory of the Jagiellonian University	PL
A Massive stars far-Ultraviolet Spectroscopic mission (MUSTI)	Astrophysics	Hugues Sana, KU Leuven, Institute of Astronomy	BE
ROARS: Research Observatory for Atmospheric Responses to Sun-magnetosphere interactions	Solar System	Ravindra Desai, University of Warwick	UK
SIRIUS - Stellar & ISM Research via In-orbit Ultraviolet Spectroscopy	Astrophysics	Martin Barstow, University of Leicester	UK
Wide-band Atmospheric Laboratory for Transiting Exoplanet Research (WALTzER)	Astrophysics	Luca Fossati, Space Research Institute, Austrian Academy of Sciences	AT

Overall schedule (ESA)

Event	Date	Comments
<i>F3 Call issued</i>	<i>19-Mar-25</i>	<i>Open call for mission proposals</i>
<i>Step 1 proposal deadline</i>	<i>21-May-25</i>	<i>23 proposals submitted</i>
<i>Evaluation of Step 1 proposals</i>	<i>Jun-25 to Sep-25</i>	<i>Technical / programmatic feasibility and scientific merit</i>
Workshop with Step 2 proposers	29-30 Oct-25	Includes ESA one-to-one sessions with proposers
F3 proposal maturation phase	Nov-25 to Jan-26	Consolidation of payload provision scheme
Step 2 proposal deadline	21-Apr-26	> 5 months for elaborating Step 2 proposals
Letters of Endorsement	16-Jun-26	For the Member States and international contributions
Evaluation completed	Oct-26	Technical / programmatic feasibility, and scientific ranking
Selection of F3 (baseline & back-up)	Nov-26	SPC decision following SSC recommendation
F3 Phase 0 CDF study	Nov-26 to Jun-27	With proposing team support for science/payload aspects
F3 Phase A/B	Jul-27 to Jun-30	Parallel industrial contracts; Instruments Phase A/B & pre-developments for securing the implementation schedule
F3 mission adoption	Jun-30	SPC decision, following SSAC recommendation

Provision scheme (current)

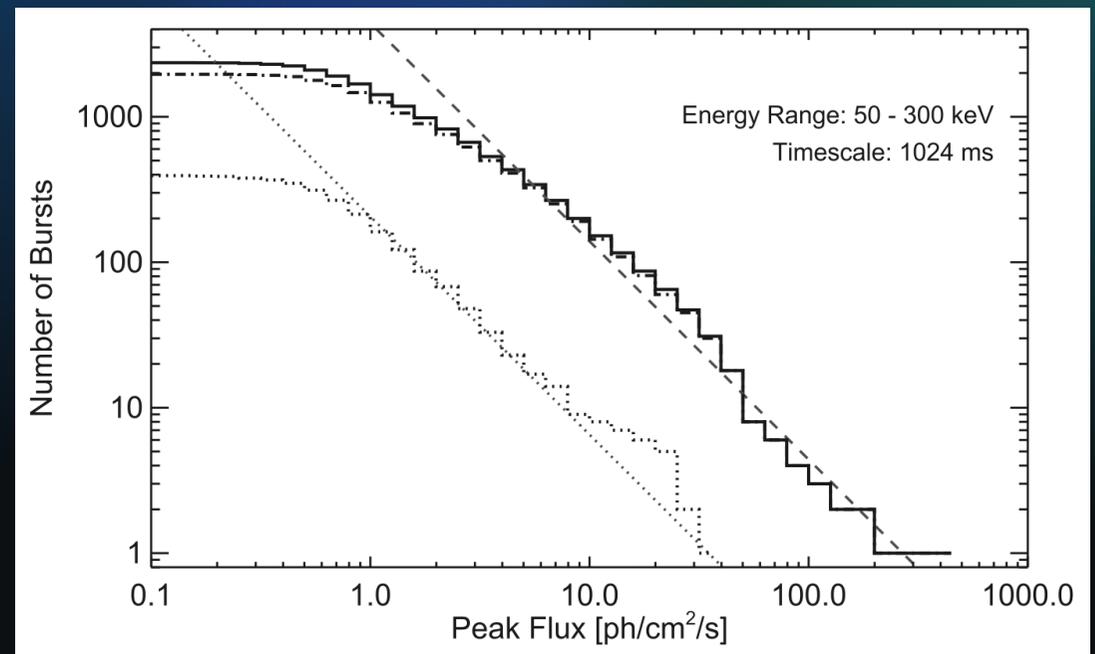
Institute	Subsystem	Contact person (Consortium)	Funding entity
INAF-IAPS/Rome	<ul style="list-style-type: none"> Provision of the integrated TED modules including scintillators, readout & control units, EGSE GRINTA DPU Use of Malindi GS, Instrument (TED) Support Centre 	L. Natalucci (PI)	ASI
CEA-Saclay (+ESA contribution)	<ul style="list-style-type: none"> Provision of the integrated HXI detector including FEE, mechanical parts & heat pipes Instrument (HXI) Support Centre 	P. Laurent, A. Meuris	CNES
CSIC-INTA	<ul style="list-style-type: none"> Coded mask & mask support structure Thermal system units for TED 	M. Mas-Hesse	AEE
MSSL	<ul style="list-style-type: none"> TED BEE units 	S. Zane	UK Space Agency
Space Res. Centre, Polish Academy of Science	<ul style="list-style-type: none"> HXI BEE units 	Konrad R. Skup	Polish Delegation to ESA
UK collaboration (Durham Univ., Soton, Uleic, MSSL)	<ul style="list-style-type: none"> GRINTA Science Data Centre 	S. Scaringi	UK Space Agency
	<ul style="list-style-type: none"> HXI detector modules (Caliste), expected to be available on the market 		ESA (TBC)

GRB rates & joint detections/localisations

- GRB rates are evaluated using the Fermi/GBM catalog peak flux distribution function
- TED & HXI sensitivity data are used by the GSSI team to estimate rates of joint detections TED+GW
- Possible ~arcmin HXI localisations after fast followup

Source Type	Detections/Year
Short GRBs	65
Long GRBs	320

Expected yearly detections with TED



Von Kienlin et al, ApJ 2020

Mass & Power Budget

MASS BUDGET

- Dry mass of S/C: 240 kg including the payload
(**289 kg** including payload and 20% additional system margin)

POWER BUDGET

- Overall power for S/C is 225W including all subsystems (data, avionics, TT&C EPS, etc.)
- Total GRINTA power budget including payload:
~400W (**490W** with additional system margin)

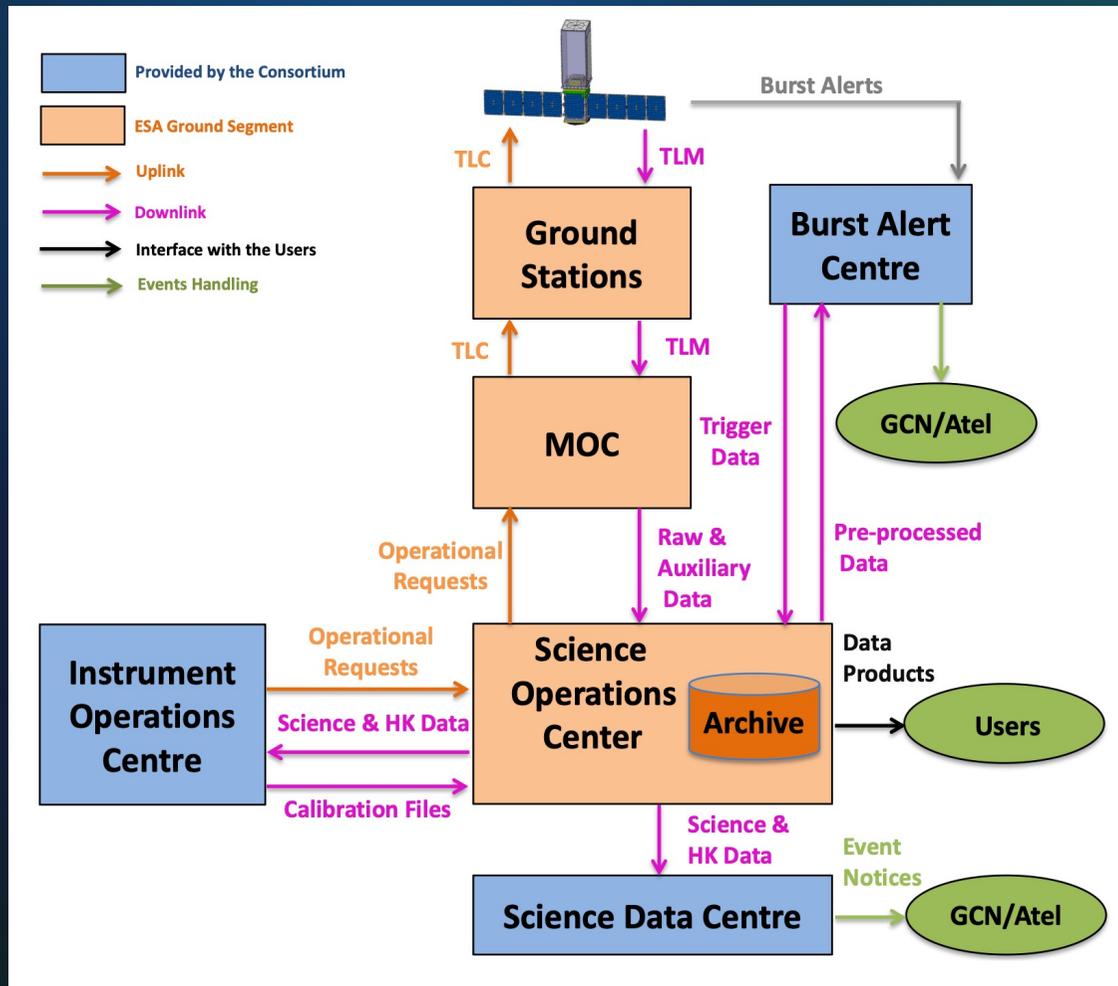
Additional budget should be considered for a **propulsion system** to be installed on GRINTA (to be assessed during Phase-2)

Component	Mass (kg)
Coded mask	5.5
Mask support, adapter & vertical support panels	8.1
Passive shields (collimator & side panels)	4.5
HXI detector (incl. BEE, thermal pipes & shielding)	11.1
HXI/AC system (plastic scint + 2 PMTs)	4.0
TED assembly, 8 modules (incl thermal pipes & FEE, BEE)	22.1
DPU (incl. power supply)	6.5
Radiator (plates + pipes)	12.7
Harness	3.0
MLI blankets	2.6
Platform adapter	7.3
Total	87.4

Component	Power (W)
HXI detector (sensors + el.)	95.0
HXI/AC system	5.0
TED assembly (incl. FEE & BEE)	19.5
DPU	26.0
Total	145.5

Payload mass & power budget
(no margin included)

GRINTA Ground Segment block diagram



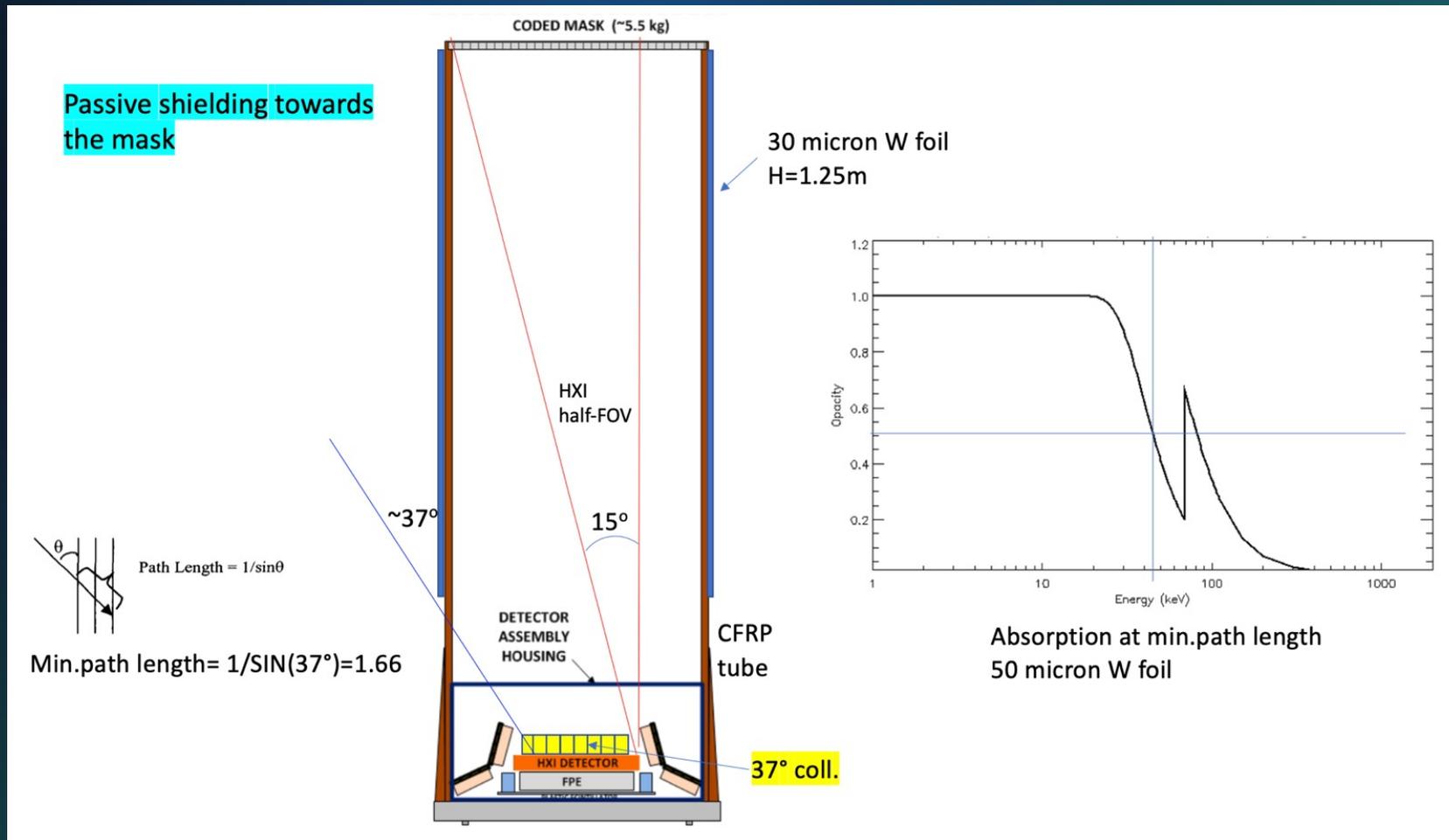
Joint GW/EM signal detection in the Post-O5 scenario

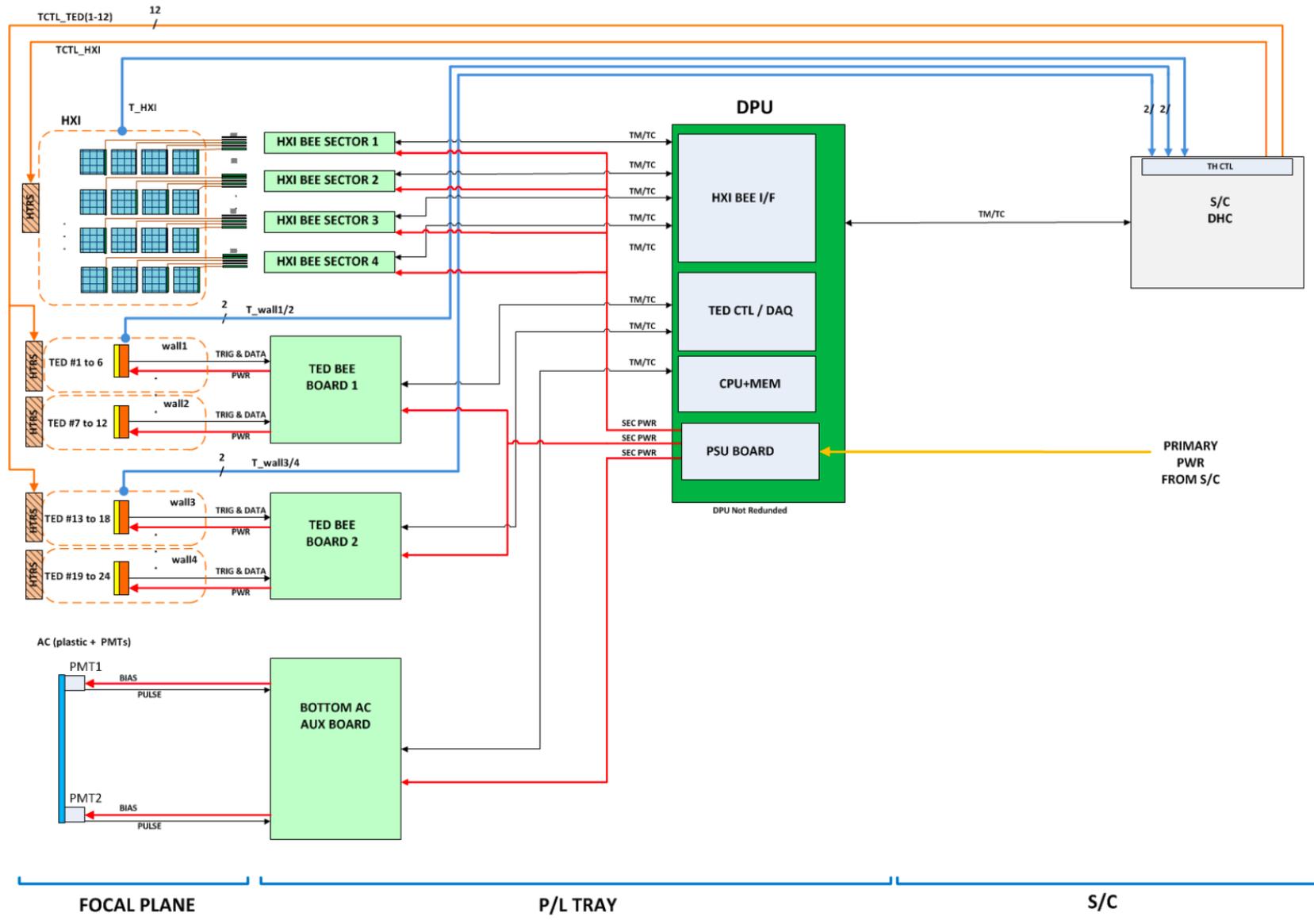
- > ~2030? (post-O5): $O(100s)$ of GW BNS detections per year
- Horizon expected to increase to ~1-1.5 Gpc for BNS
- For many events, prompt follow-up by optical/UV telescopes will not be feasible
- **Hard X-rays are needed! For both detection and localisation**

Configuration	Annual Detections		
	BNS	NSBH	BBH
A+	135^{+172}_{-78}	24^{+34}_{-16}	740^{+940}_{-420}
A [#]	630^{+790}_{-350}	100^{+128}_{-58}	2100^{+2600}_{-1100}
A [#] (A+ coatings)	260^{+320}_{-140}	45^{+60}_{-27}	1150^{+1450}_{-640}
A [#] Wideband (A+ coatings)	200^{+250}_{-110}	40^{+54}_{-25}	970^{+1220}_{-540}

Credit: Post-O5 group report 2024

HXI shielding (basic scheme)





Configuration	Range [Mpc]		t_{early} [min]	z_{max}	Post-Merger	
	BNS	BBH			$\rho_{\text{pm}}^{(10)}$	$\rho_{\text{pm}}^{(\text{max})}$
O3 LLO	130	1200	0.3	1.3	0.4	0.6
July 2022 LLO	120	1200	0.5	1.5	0.3	0.5
A+	350	2600	2.7	3.2	1.4	2.0
A+ Wideband	290	2300	3.7	3.5	2.2	2.6
A [#]	600	3700	6.2	5.4	2.7	3.7
A [#] (A+ coatings)	440	3000	6.1	4.6	2.7	3.4
A [#] Wideband	490	3300	6.8	5.5	4.8	5.6
A [#] Wideband (A+ coatings)	400	2900	6.7	4.7	4.8	5.5
Intermediate Voyager	670	3900	4.8	6.5	2.5	3.7
Voyager Deep	780	4100	9.0	7.9	2.8	4.1
Voyager Wideband	630	3800	9.3	8.4	5.2	5.9
STO	690	4000	10.1	7.6	2.7	3.7
A [#] 655 m SEC	450	3100	6.7	5.3	3.4	5.1
A [#] 12 km folded arms	530	3400	9.9	6.4	8.5	9.7

Network of 2 LIGO
(Hanford+Livingston)

Configuration	Annual Detections		
	BNS	NSBH	BBH
A+	69^{+138}_{-48}	291^{+291}_{-148}	1440^{+572}_{-412}
A [#]	364^{+717}_{-244}	1526^{+1517}_{-762}	6131^{+2132}_{-1739}
A [#] (A+ coatings)	138^{+274}_{-94}	630^{+627}_{-317}	2902^{+1149}_{-826}
A [#] Wideband	177^{+350}_{-120}	909^{+905}_{-455}	3937^{+1557}_{-1118}
Voyager Deep	794^{+1563}_{-529}	3798^{+3771}_{-1894}	11975^{+2932}_{-3392}
Voyager Wideband	404^{+798}_{-270}	2035^{+2021}_{-1016}	7343^{+2901}_{-2082}