GAME: GRB and All-Sky Monitor Experiment

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for

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on behalf of the GAME collaboration

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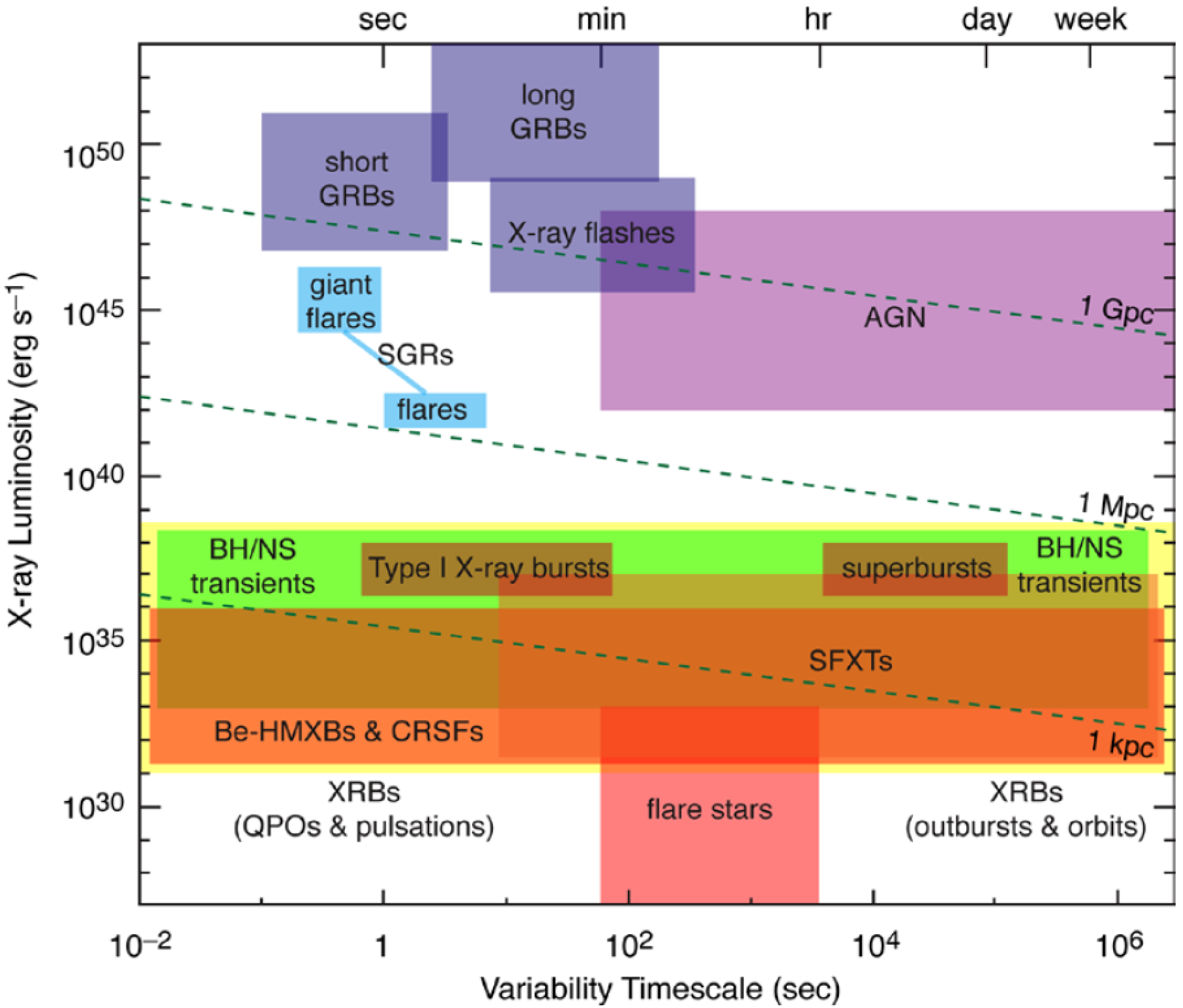
Science Drivers

- **The transient and variable X-ray sky:**
  simultaneous monitoring in 1-50 keV, over a large fraction of the sky, with ~1 arcmin imaging accuracy and all-sky coverage

- **Gamma-Ray Bursts:**
  detection, ~arcmin localization and spectroscopy of the prompt emission, down to 1 keV

The variable X-ray sky, at all scales



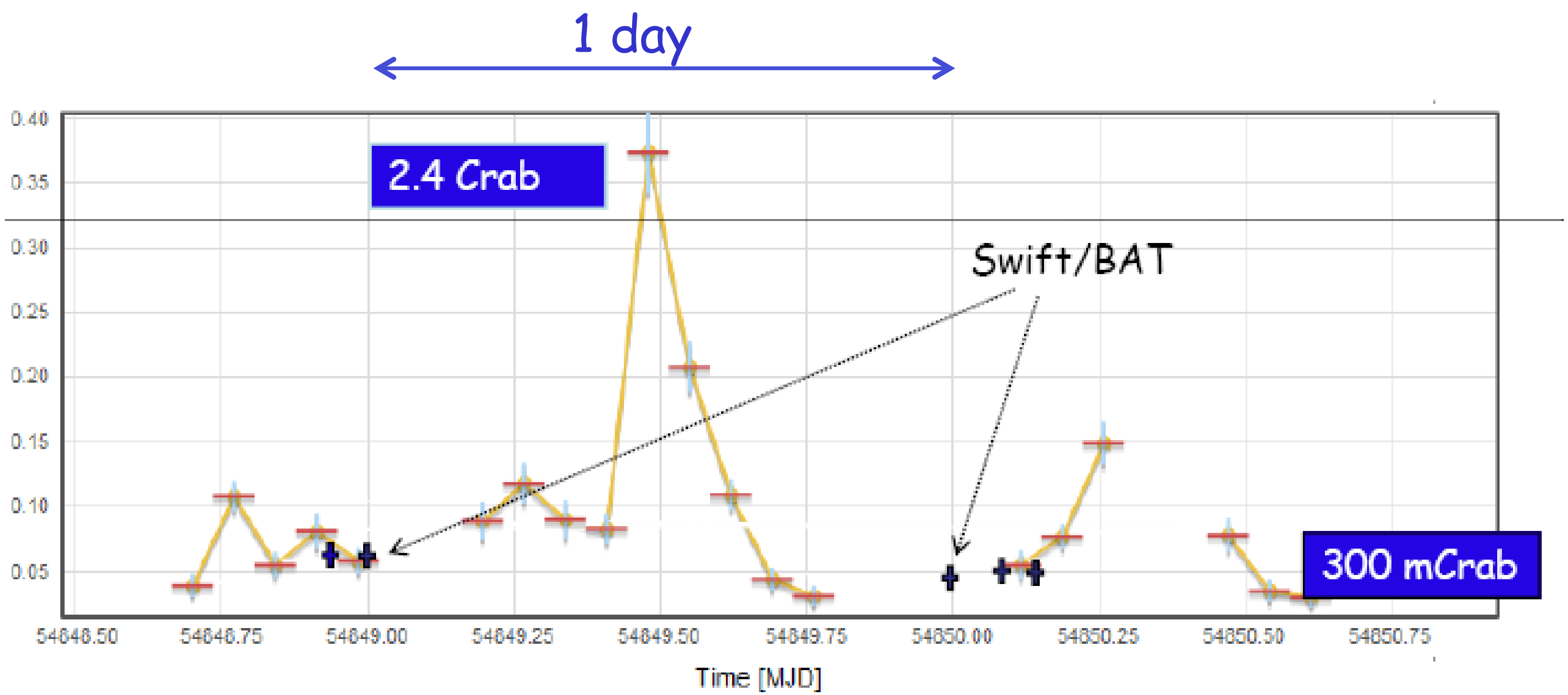
X-ray All-Sky Monitoring

- The X-ray sky is highly variable and transient. Discovery of new classes of sources is made possible by All Sky Monitoring in the most suitable energy range, soft X-rays. Example also from the recent past are outstanding, e.g.: magnetars, jetted tidal disruption events, ..

- Long-term, continuous monitoring of Galactic sources allows the study of source/class properties unaccessible to narrow field instruments: state changes in black hole candidates, bursting and super-bursting behaviour, orbital and superorbital periods, period derivatives, low frequency QPOs, ….

- Multi-messenger (photons, gravitational waves, neutrinos),Time-domain Astronomy in the 2020's, when large facilities like SKA, LSST, E-ELT, CTA, A-LIGO/Virgo, … will become operational, require an all sky monitor in the X-ray domain.

Continuous vs multiplexed monitoring

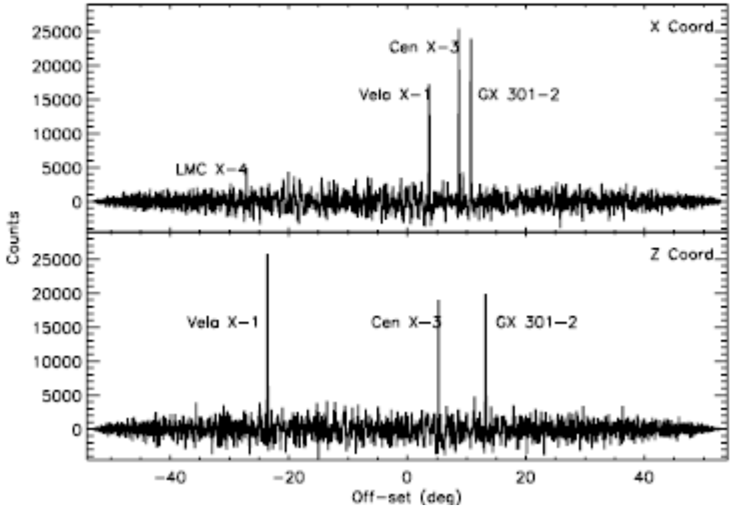


Flux data from Vela X-1, as observed from Swift/BAT (black points) and AGILE/SuperAGILE (red points):

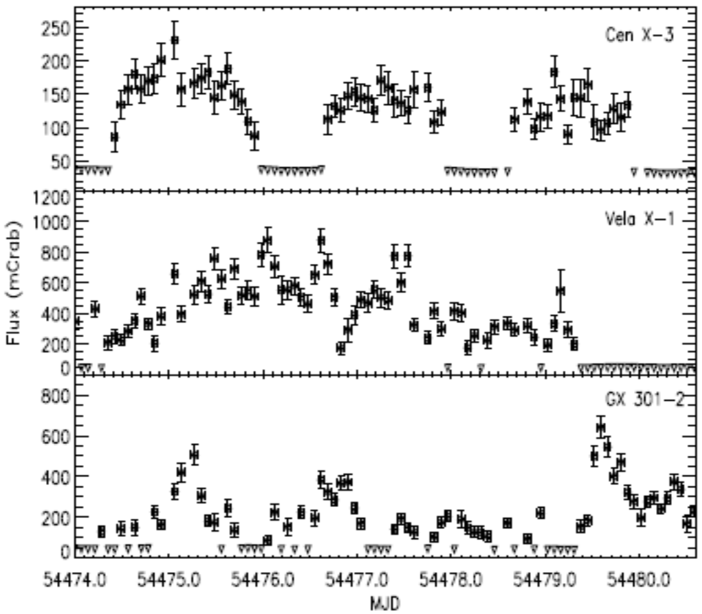
sparse monitoring can miss the most extreme and interesting states of sources

Wide-field simultaneous monitoring

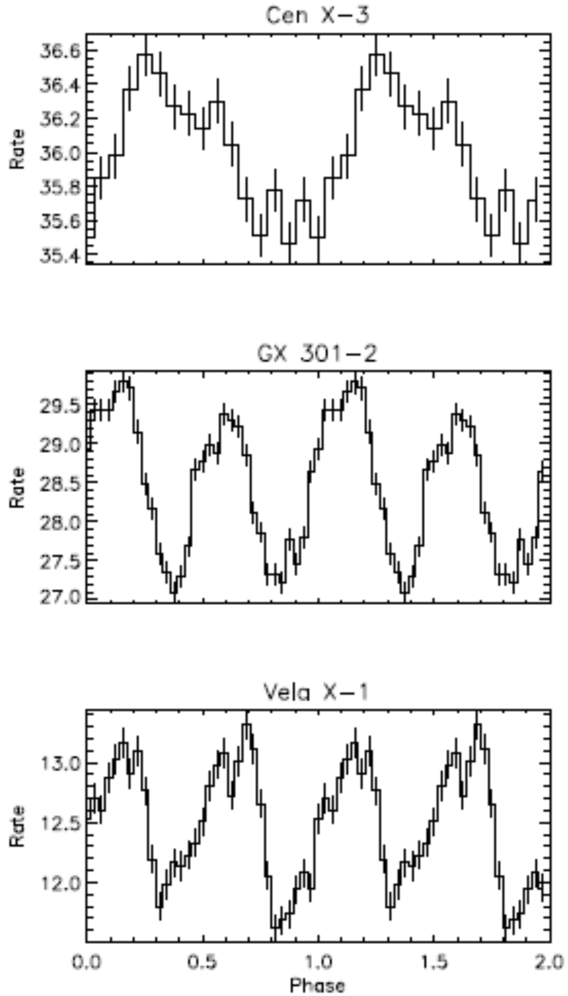
2 x 1D images



lightcurves



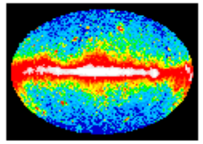
Folded Pulse Shapes

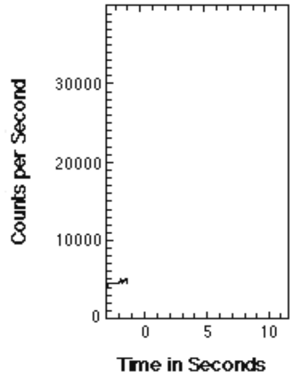


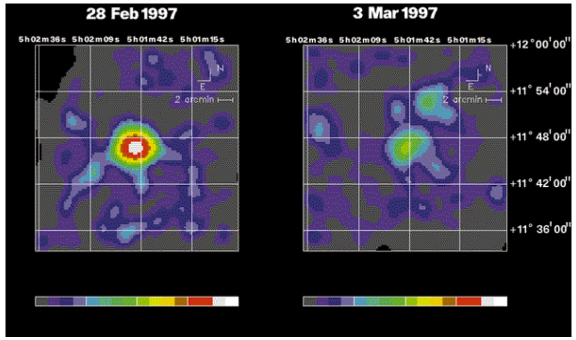
SuperAGILE data (Feroci et al. 2010)

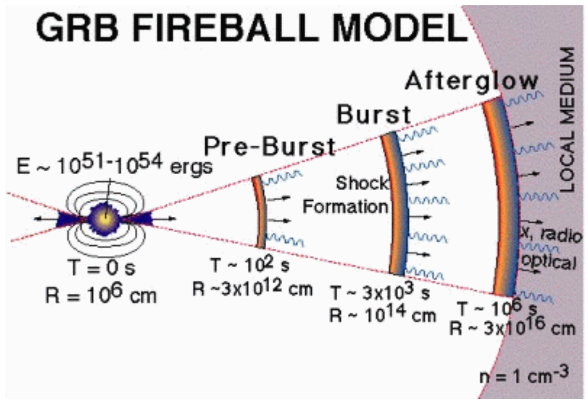
Gamma Ray Bursts: prompt emission in X-rays

- Despite the huge advances occurred in the latest years, the GRB phenomenon is still far from understood: going back to the study of the *Prompt Emission is needed.*
- **An energy band extending down to soft X-rays is needed.**
- Measurements down to a few keV were provided in the past by BeppoSAX, but a larger sample with higher sensitivity and energy resolution is urgently needed.
- Current GRB experiments are limited to prompt emission > ~10 keV; future (SVOM, CALET/GBM, UFFO) > ~ 5-8 keV

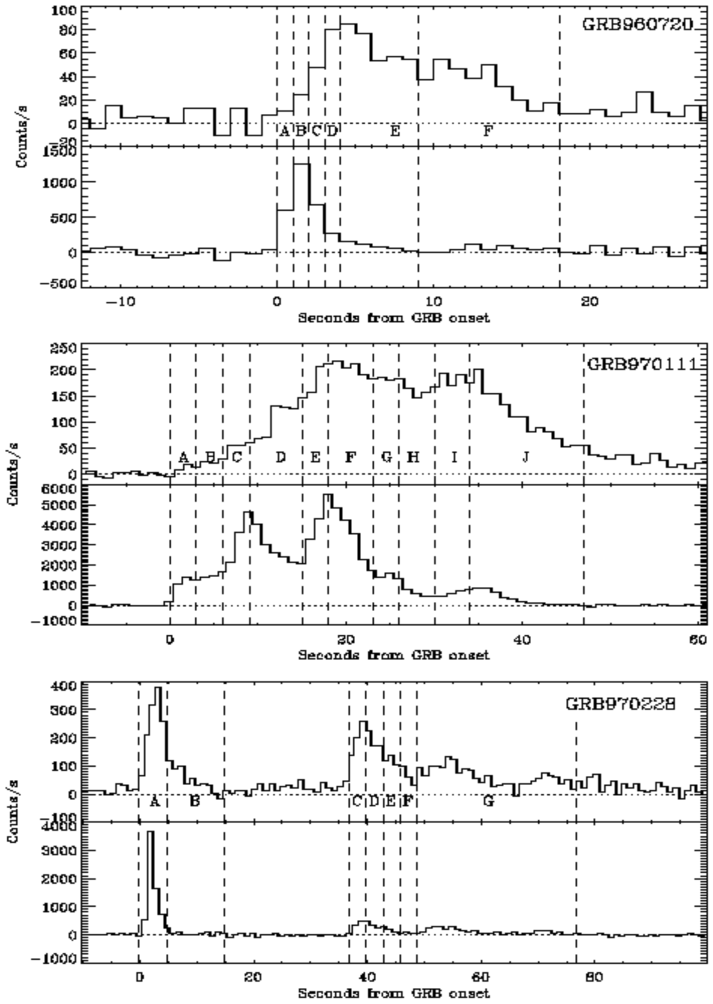




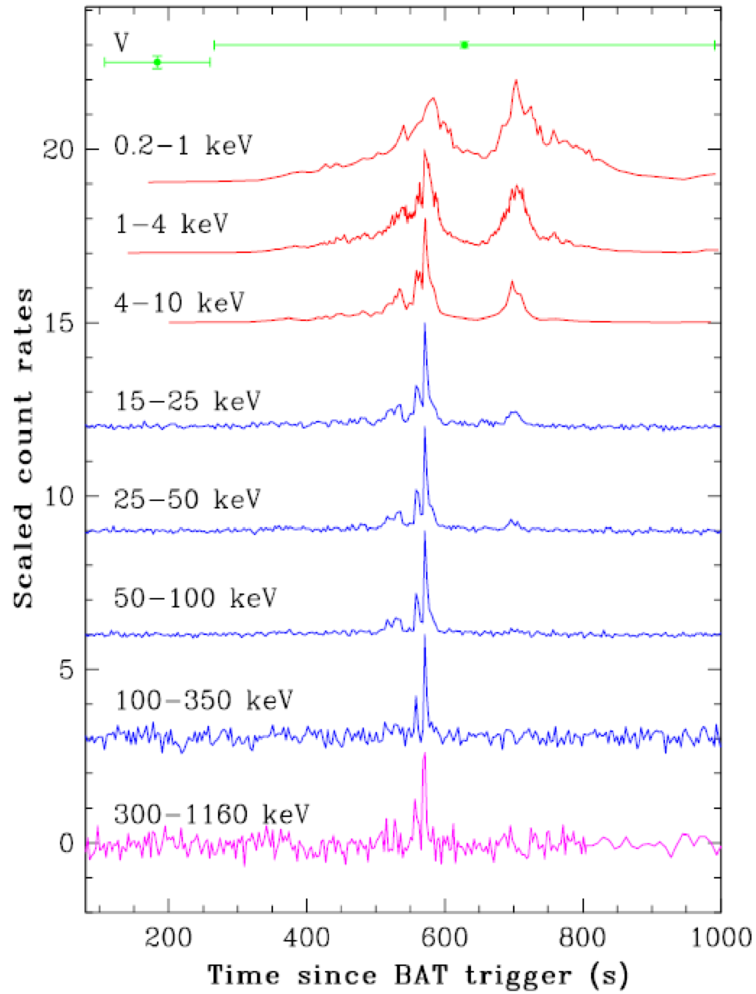




Why prompt emission at soft X-rays?



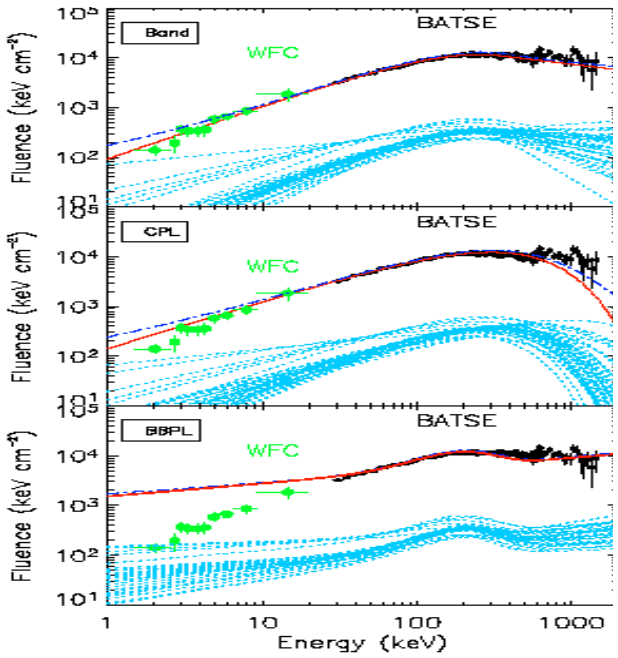
BeppoSAX (top: 2-28 keV, bottom: 40-700 keV)

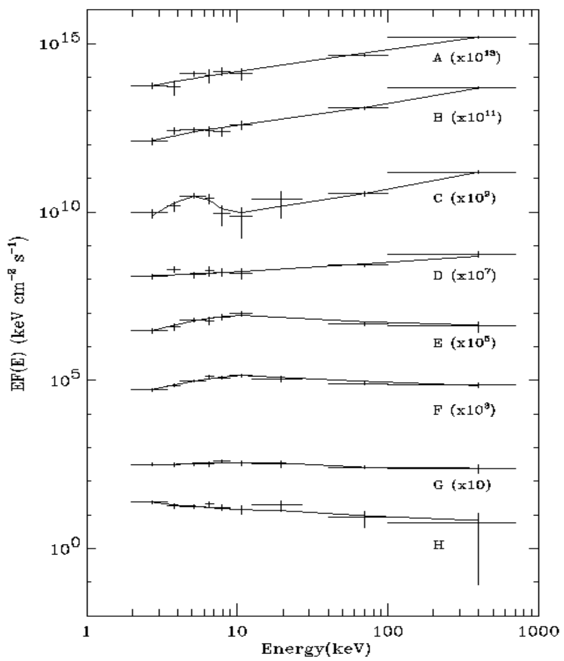


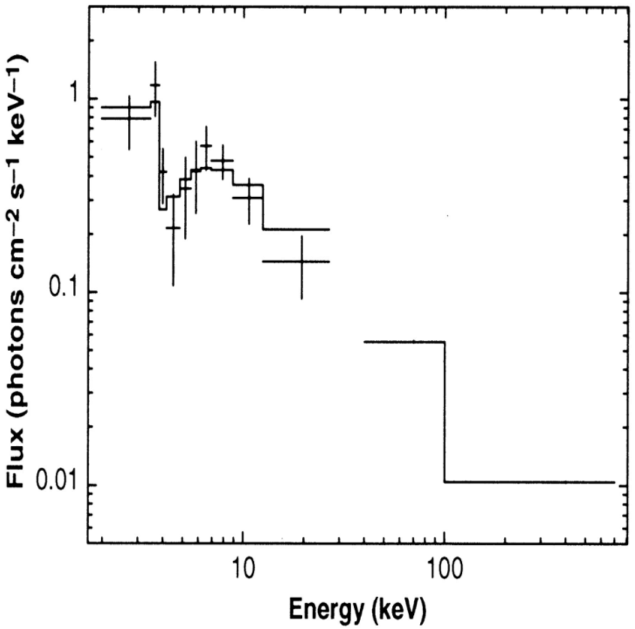
Swift XRT (rare / unique case) + Swift/BAT + konus/WIND

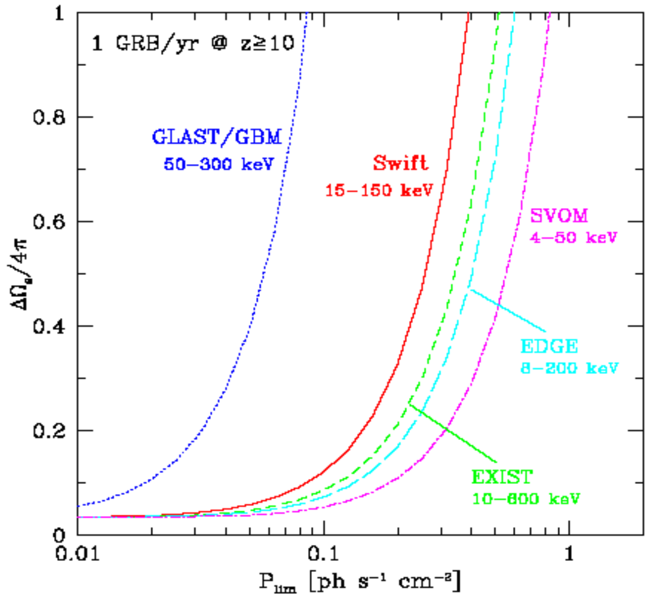
GRB Physics at soft X-rays:

- emission models and thermal components
- absorption features (redshift, circumburst matter)
- high redshift GRBs
- X-ray flashes
- localization and trigger to multi-messenger observatories (e.g., GWs)









Wide-field X-ray monitors: context

Mission	Experiment	Energy band (keV)	Field of view (sr)	GRB Location accuracy	Max. eff. area (cm^2)	Energy resolution (keV)	#GRB / year	Nominal operation / launch
CGRO	BATSE	25 - 2000	9	> 3°	2000	15@100 keV	300	1991 - 2000
BeppoSAX	WFC	2 – 28	0.26	3'– 5'	180	1.5@6 keV	15	1996 - 2002
	GRBM	40 - 700	6	> 10°	700	20@100 keV	200	
HETE-2	WXM	2 - 25	0.8	-	70	1.8@6 keV	15	2000 - 2006
	FREGATE	7 - 400	1.74	-	40	15@100 keV	70	
Swift	BAT	15 - 150	1.4	3'	2600	3@60 keV	120	2004 -
WIND	Konus	15 - 10000	4π	-	250	15@100 keV	250	
Fermi	GBM	8 - 30000	9	> 3°	300	15@100 keV	250	2008 -
INTEGRAL	ISGRI	20 - 200	0.1	1.5	1300	3@60keV	10	2003 -
MAXI	GSC	2 - 30	1.5°x160°	0.1°	5350	1@5.9 keV	5	2009-
	SSC	0.5 - 12	1.5°x90°	0.1°	200	0.15@5.9 keV	2	
GAME	**XRM**	**1 - 50**	**~3 (FC)**	**1'**	**550**	**0.2@3 keV**	**200**	**2021-**

The proposed payload for GAME

Science Requirements:

- Arcmin-imaging in the 1-50 keV energy range
- mCrab-level daily sensitivity
- Few-steradian field of view, all sky coverage
- Good spectral resolution (<500 eV @6 keV)
- Prompt localization & transmission of transient coordinates to the ground

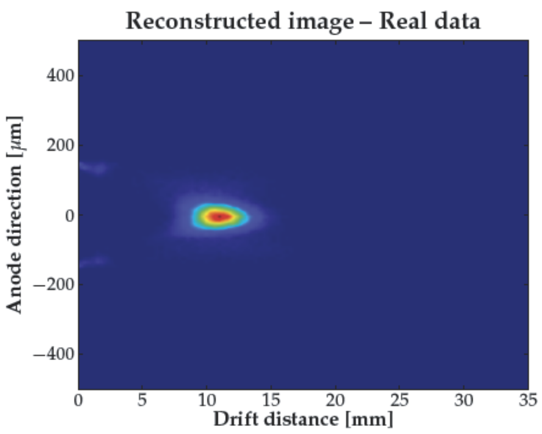
Payload requirements:

- Imaging over a wide field of view in 1-50 keV: coded masks
- Fine position resolution in 1-50 keV: Silicon detectors
- High efficiency in 1-50 keV: Silicon detectors
- Good spectral resolution: Silicon Drift Detectors
- Fast-communication to ground: VHF transmission

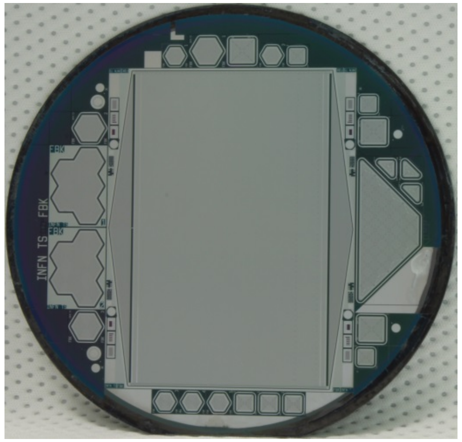
An X-ray Monitor based on Silicon Drift Detectors

Silicon Drift Detectors, heritage of the LHC/Alice experiment at CERN, with high readiness and excellent performance (energy resolution <300 eV, low energy threshold < 2 keV, time resolution < 10μs) can be used to build large area detectors.

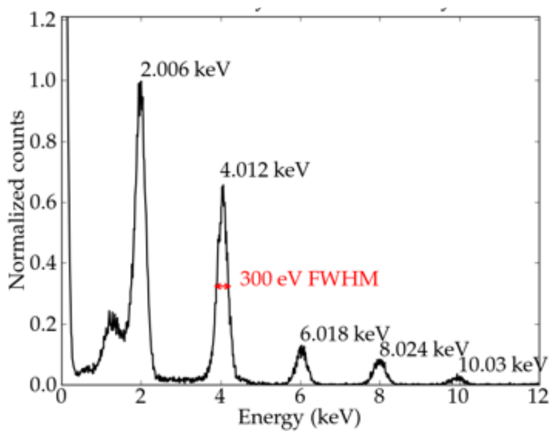
Fine position



Large Area



Good spectroscopy

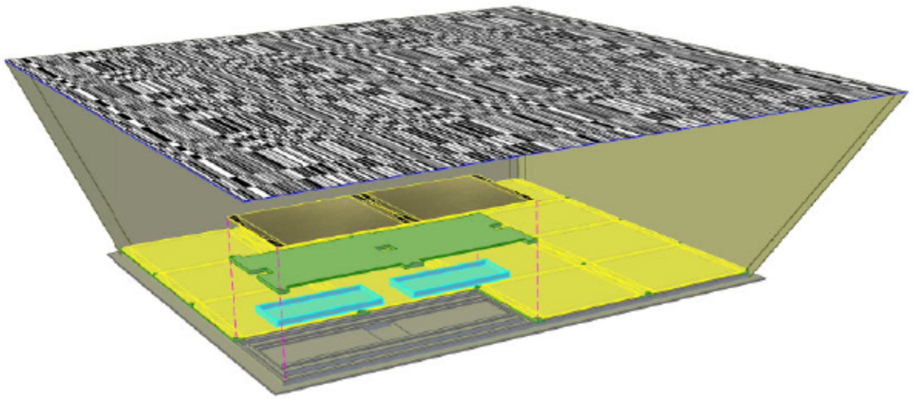


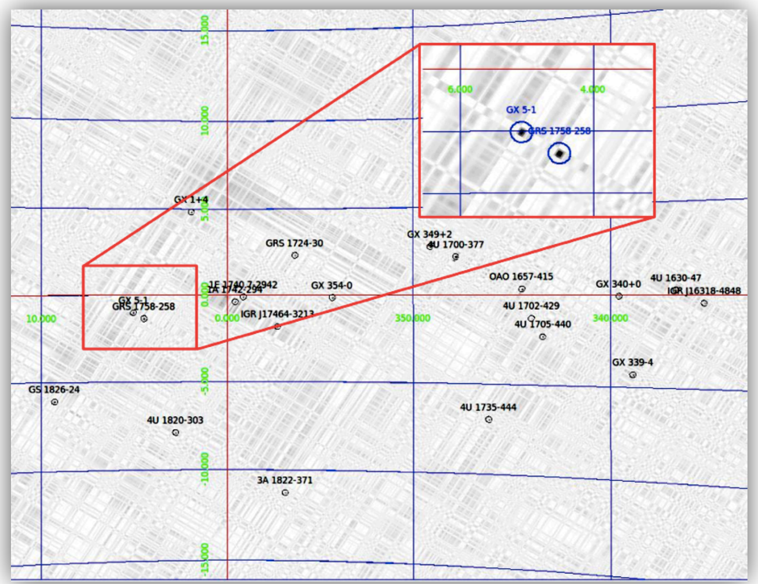
Instrument configuration

The proposed SDD detector has asymmetric position resolution: $\leq 100 \mu m$ in one direction and ~2-3 mm in the orthogonal direction.

⇒ Asymmetric 2D coded mask

⇒ 2 orthogonal cameras always looking at the same FoV to guarantee arcmin imaging in both coordinates.

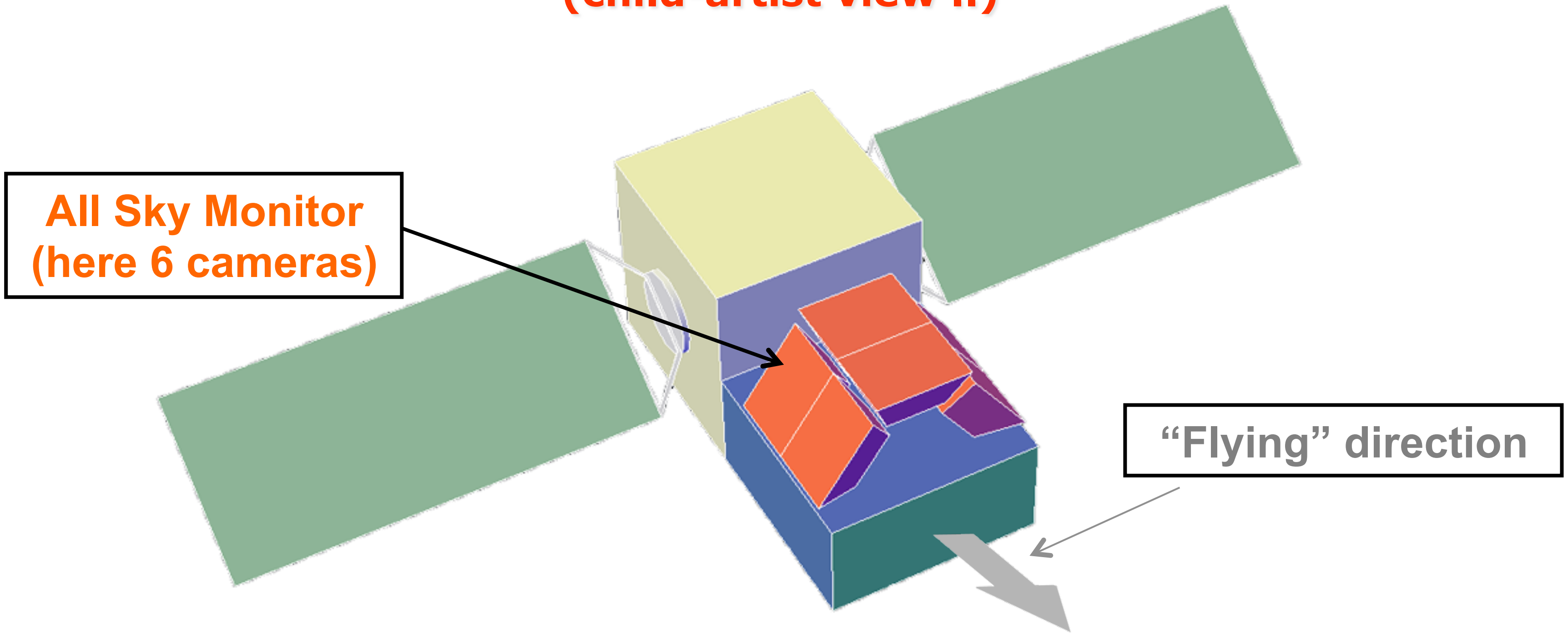




Based on previous studies (e.g., LOFT/WFM) this type of configuration can be realized with ~10 kg per camera.

GAME: Model Payload Concept

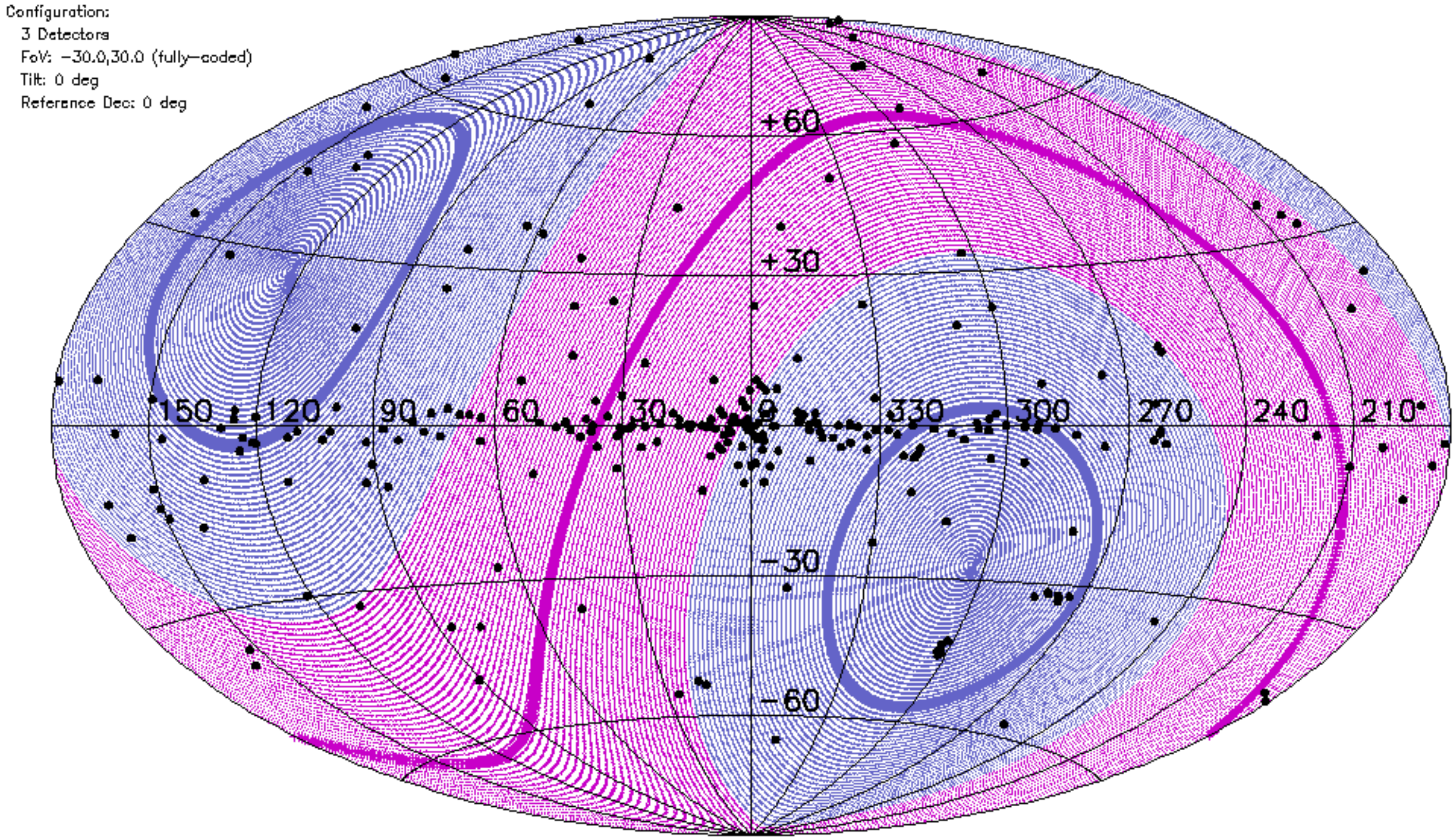
(child-artist view ..)



Mission	
Orbit	Low-Earth, equatorial (90')
Pointing	3-axis stabilized, zenith-pointed
Accuracy	1 arcmin
TM rate	~200 kbps (average)

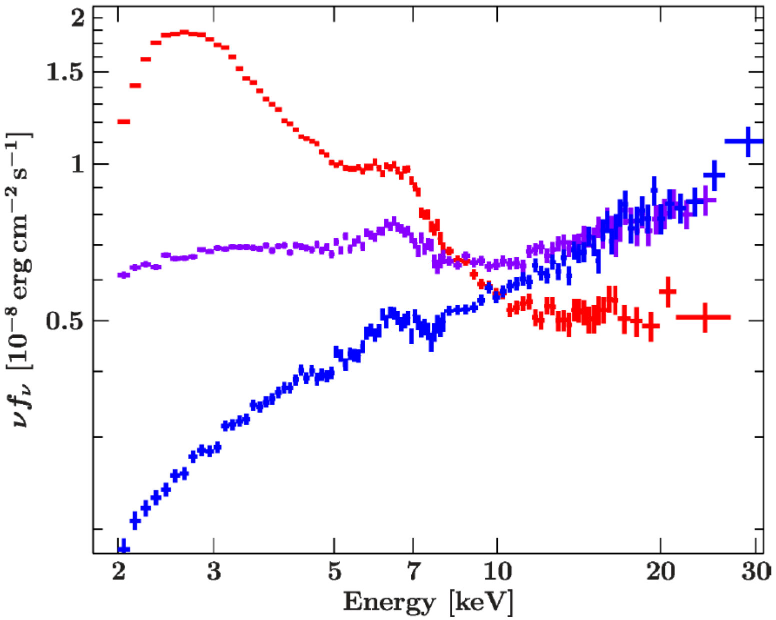
Payload	
XRM Cameras	4-6
Energy range	1-50 keV
Energy res.	300 eV (FWHM, 6keV)
Field of View	~2-4 sr
Source Location	1 arcmin
Mass (CBE)	~40-60 kg
Power (CBE)	~60-90 W

Sky coverage (every orbit)



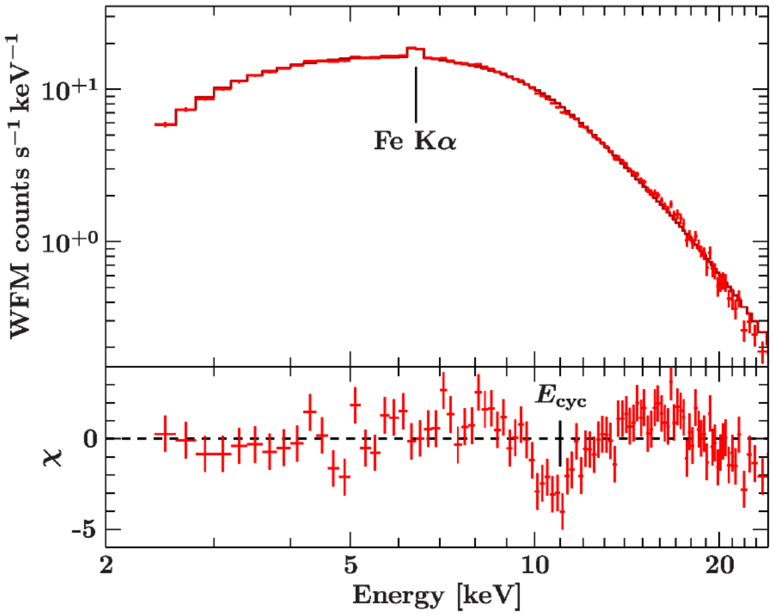
Anticipated performance: ASM

State changes in Black Hole Candidates



15 ks, 300 mCrab

Discover and study the evolution of cyclotron lines in X-ray pulsars

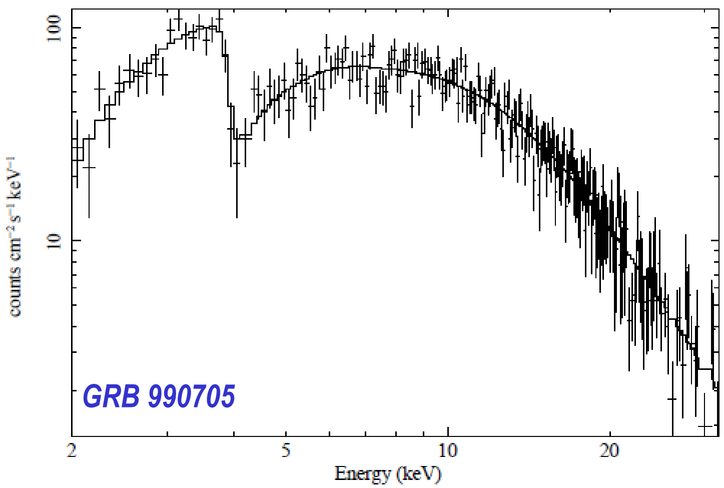


4U 0115+634, 200 mCrab, 20 ks

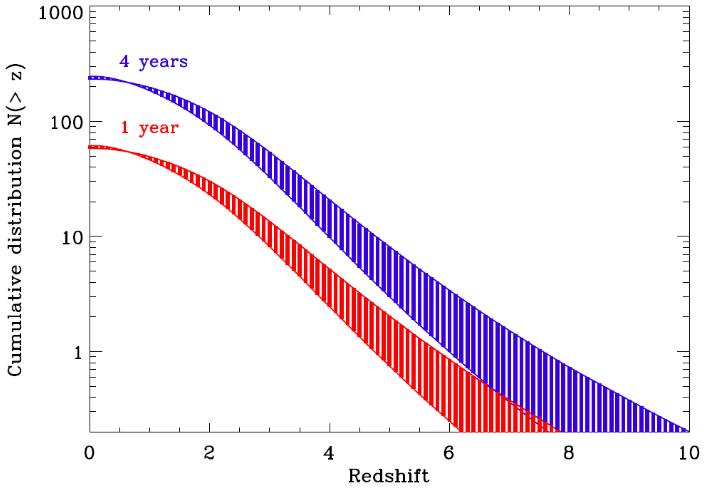
Simulations courtesy of the LOFT Team

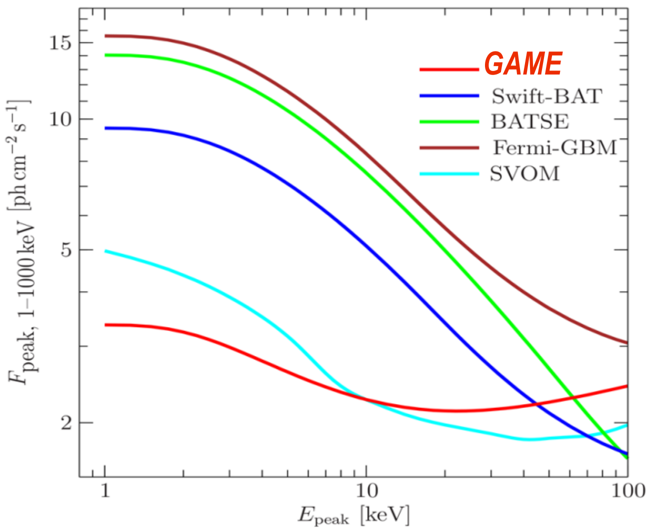
Anticipated performance: GRBs

Independent redshift estimate



Expected redshift distribution





Improved sensitivity for low-E_{peak} GRBs

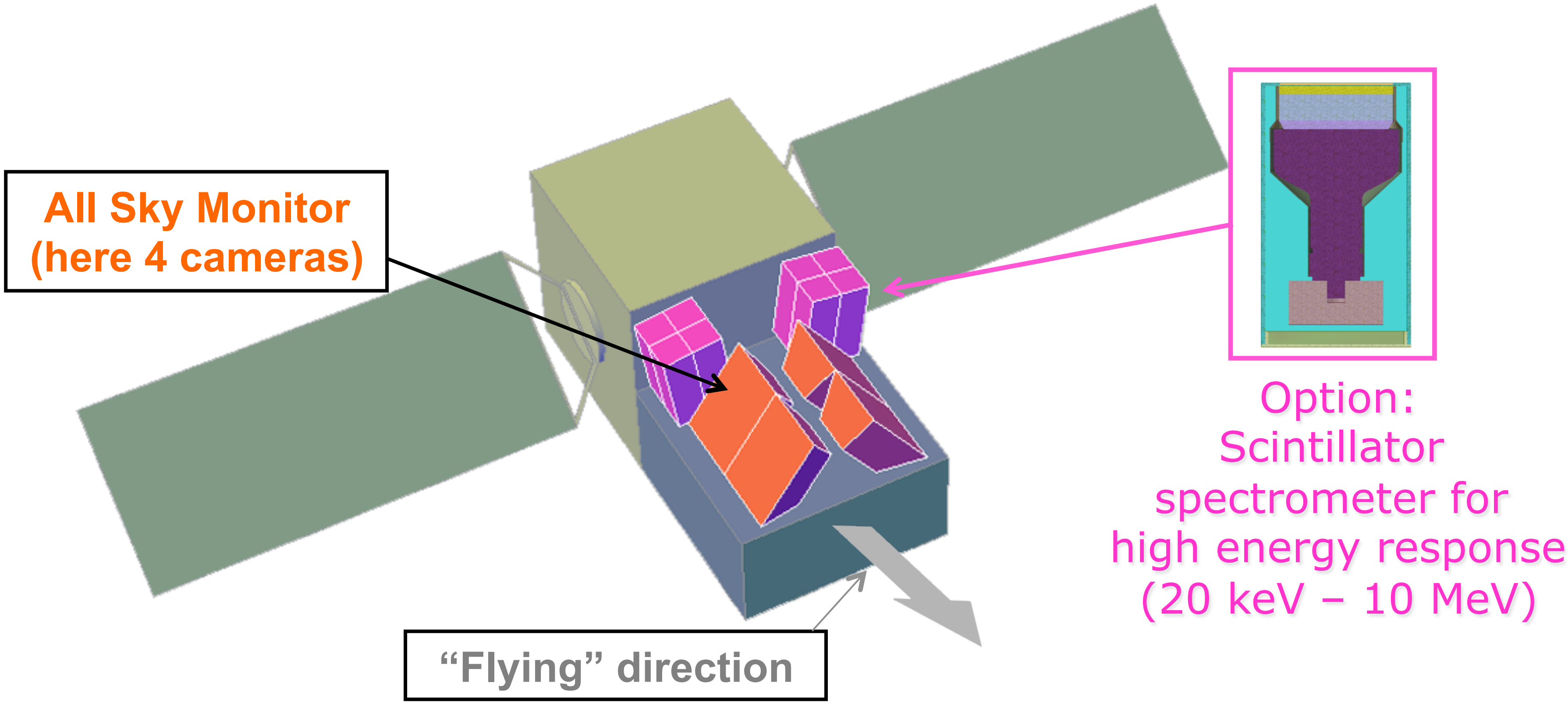
GAME: Enhanced Science

Including a Soft Gamma-ray Spectrometer would extend the energy range up to 10 MeV, offering:

- ✓ Wide-band spectroscopy of the prompt emission of GRBs from ~1 keV up to ~10 MeV + arcmin localization: GRB physics and cosmology (E_{peak}-E_{iso}); higher efficiency for short-hard GRBs (trigger and position for gravitational wave counterparts)

- ✓ Hard tails of Galactic and Extragalactic X-ray sources

GAME: Enhanced Model Payload Concept



Mission	
Orbit	Low-Earth, equatorial
Pointing	3-axis stabilized, zenith-pointed
Accuracy	1 arcmin
Data rate	~200 kbps + ~20-40 kbps

Payload	
XRM Cameras	4-6
Mass (CBE)	~40-60 kg + ~40-80 kg
Power (CBE)	~60-90 W + ~15-30 kg

Conclusions

- ❖ GAME aims at exploiting the unique combination of large area, broad FOV, ~arcmin source location accuracy, 300 eV energy resolution, and energy band (~1-50 keV) of the solid technology of SDD-based coded mask cameras to perform:
- ➢ all-sky monitoring in 1 – 50 keV, providing triggering and accurate location of transient sources and the study of the spectral-timing variability of several classes of X-ray sources on time scales from s to years;
- ➢ address some of the main open issues in the GRB field by means of sensitive measurements of the prompt emission down to 1 keV and arcminute localization

- ❖ The payload for the GAME mission is compatible with the boundary conditions set in the ESA-CAS call for ideas.