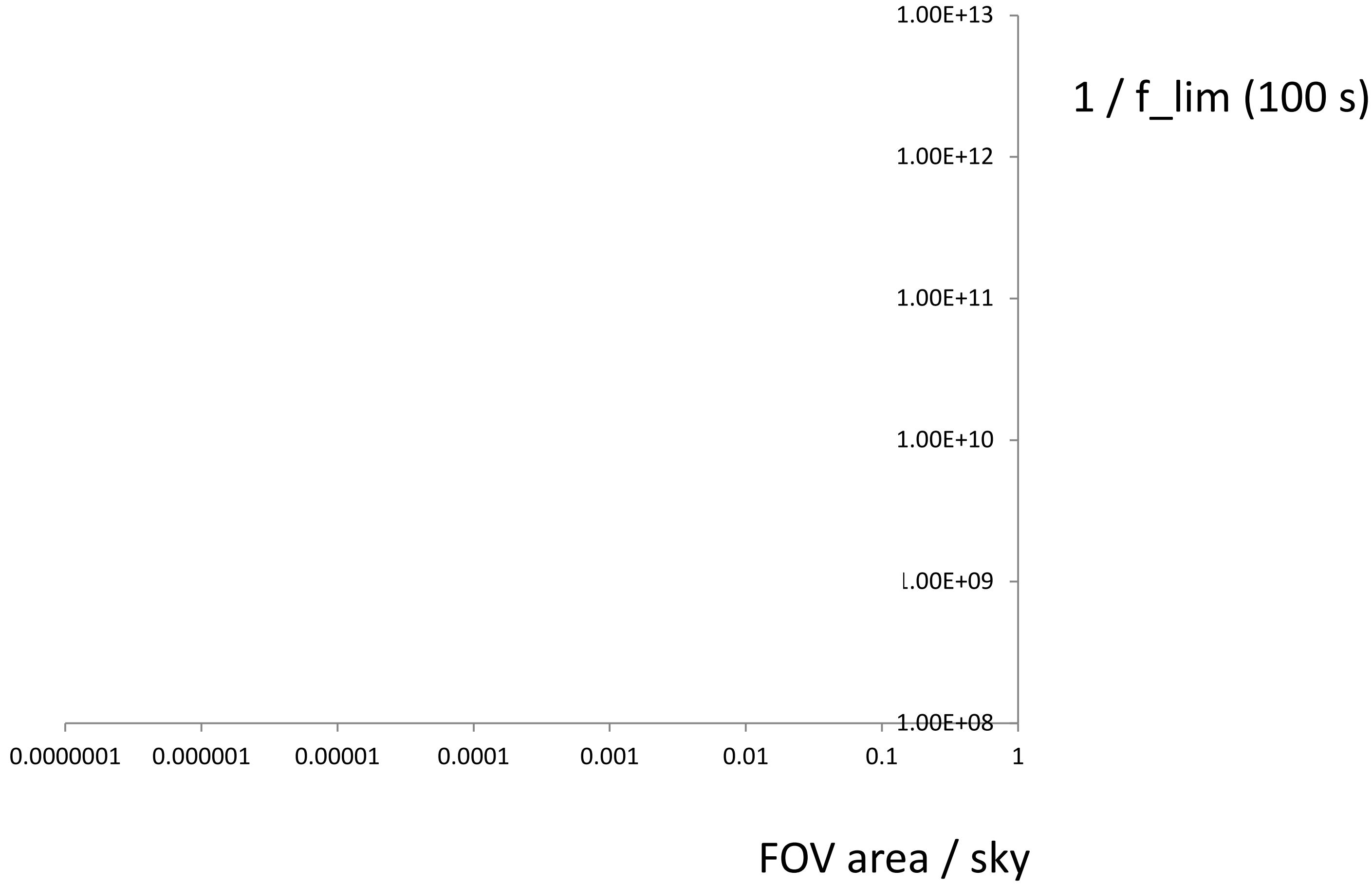
University of Leicester

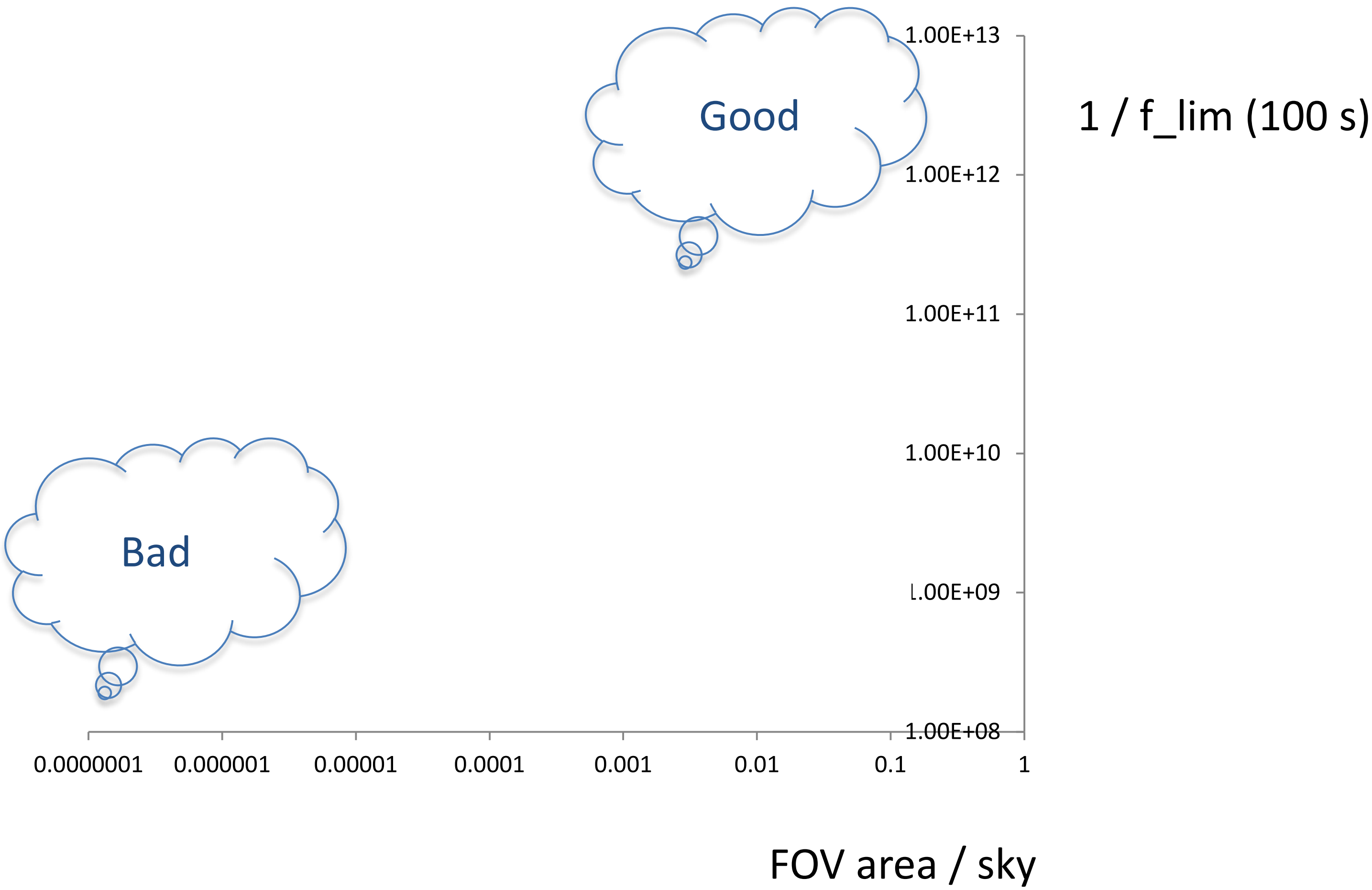
Lobster X-ray Telescope Science

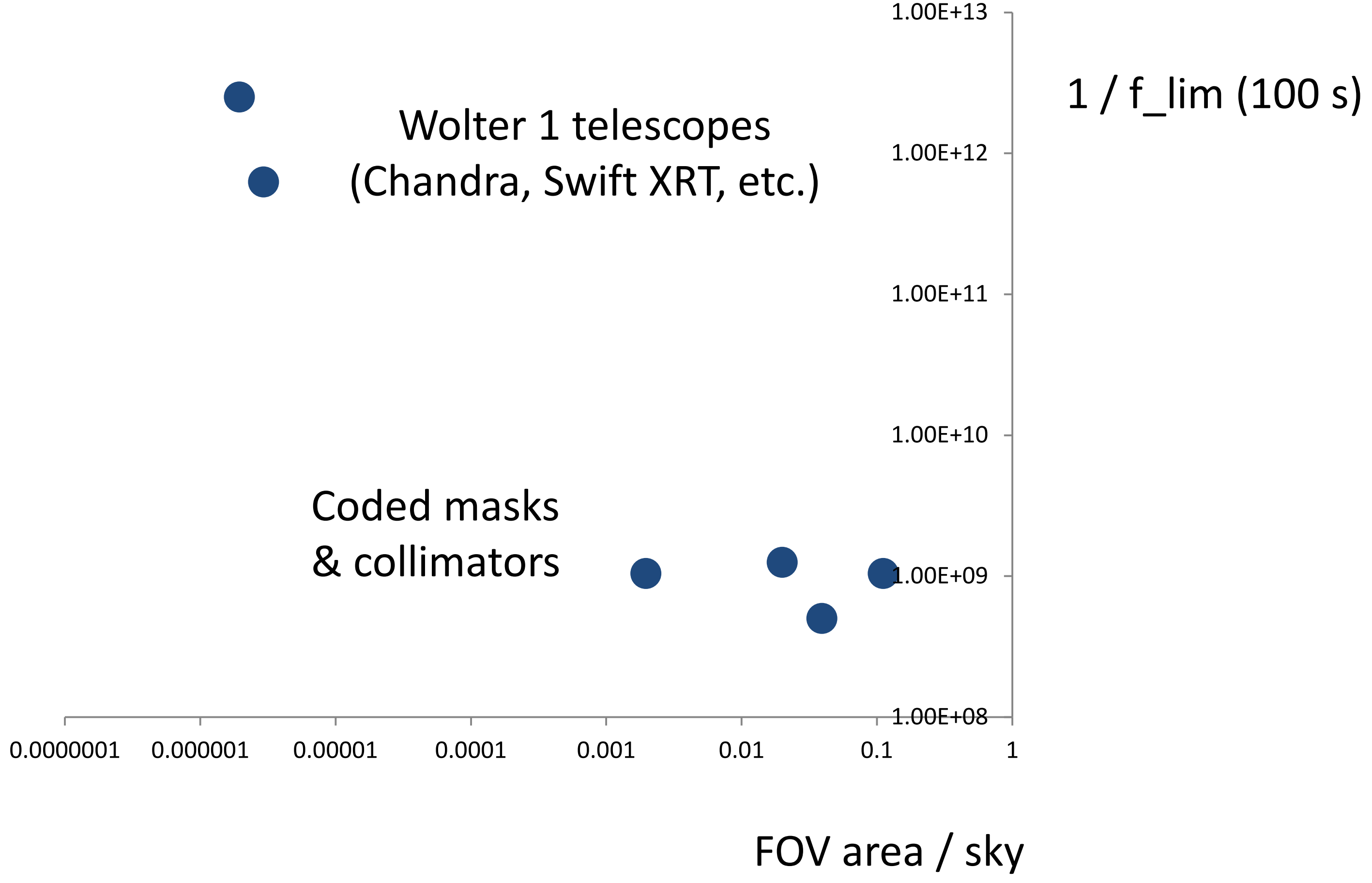
Julian Osborne

What we want – The whole high-energy sky right now

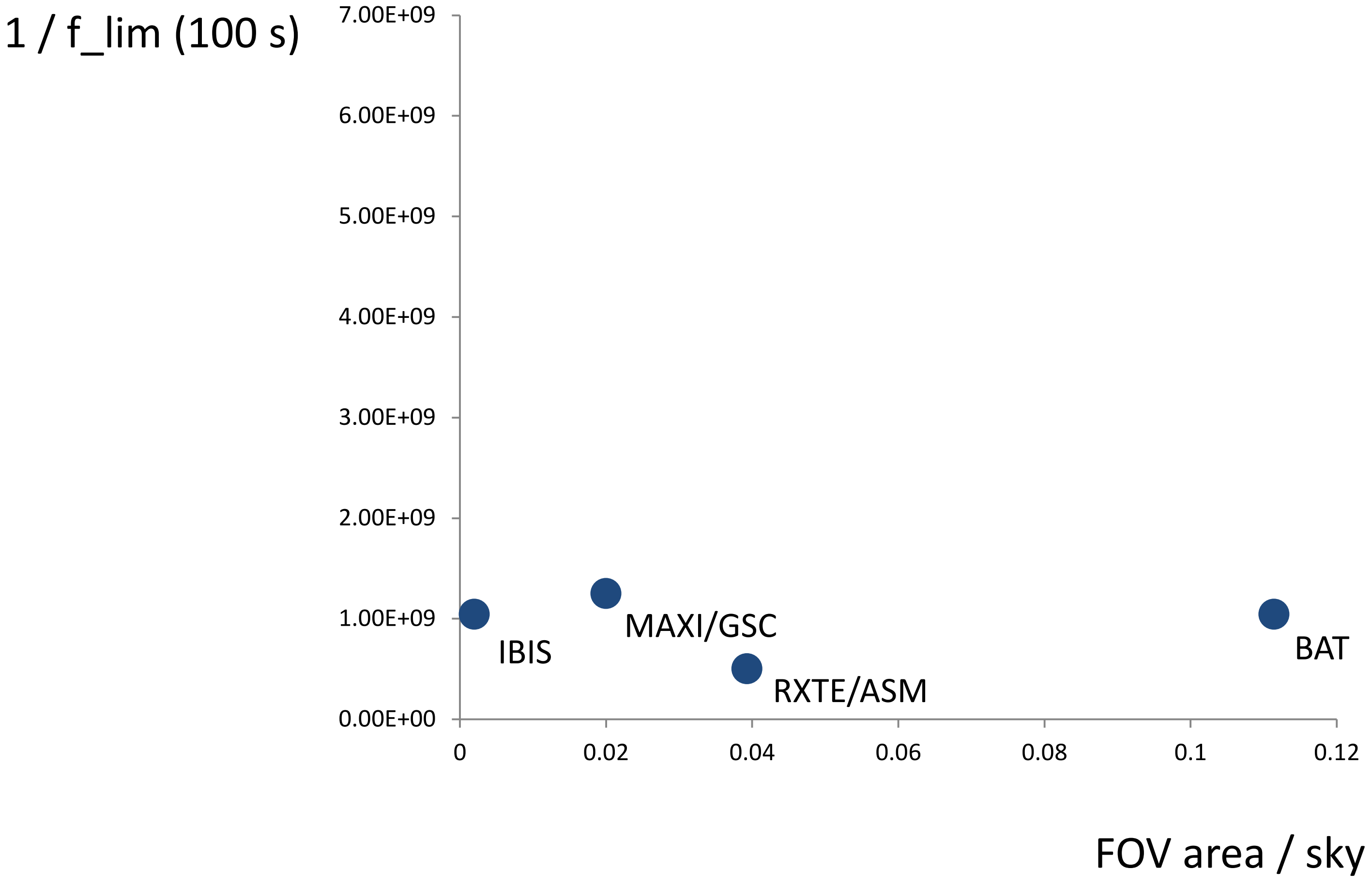


What we want – The whole high-energy sky right now





1.00E+13
1.00E+12
1.00E+11
1.00E+10
1.00E+09
1.00E+08
1 / f_lim (100 s)
Wolter 1 telescopes
(Chandra, Swift XRT, etc.)
Coded masks
& collimators
0.0000001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
FOV area / sky


1 / f_lim (100 s)
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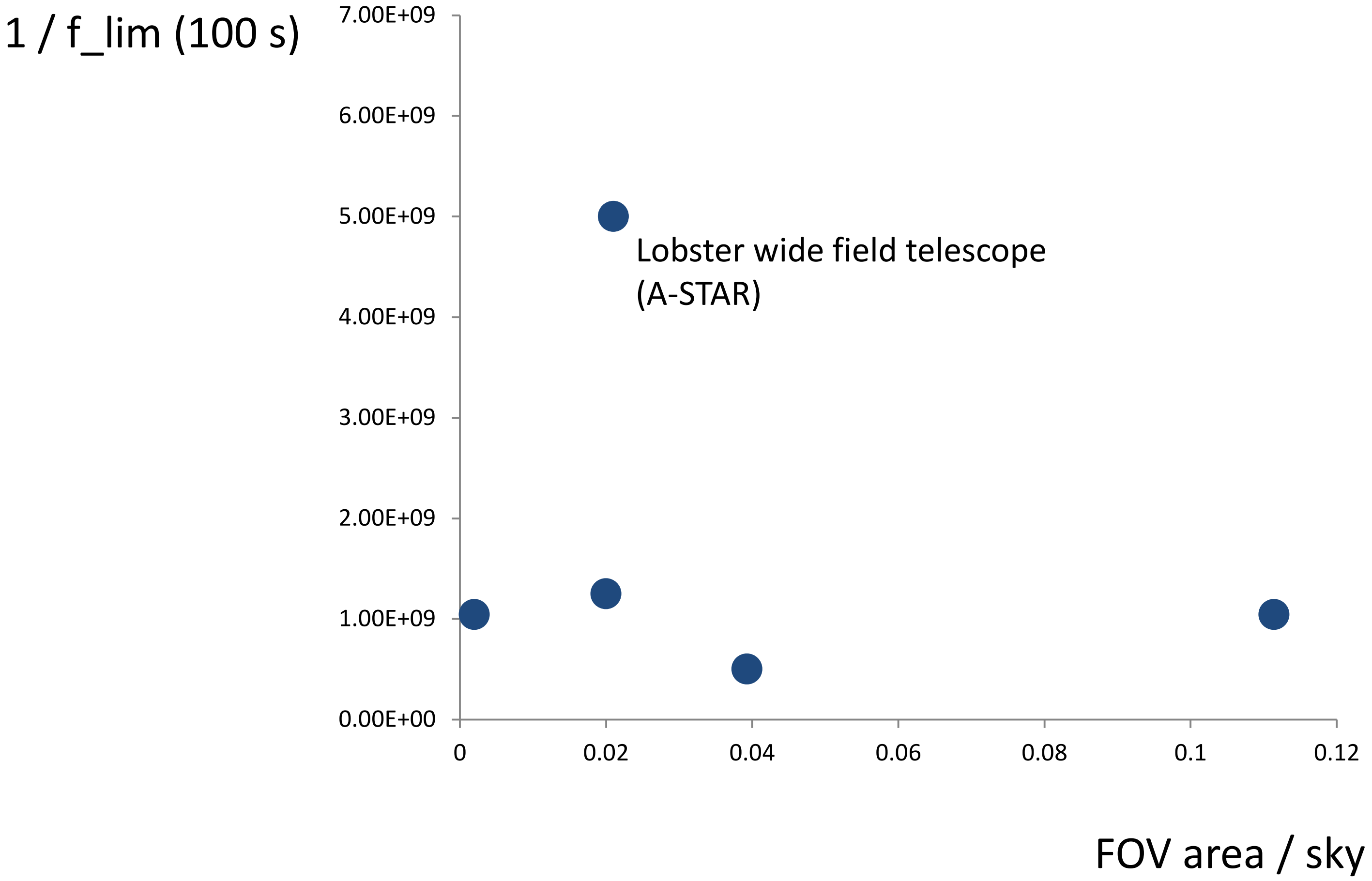
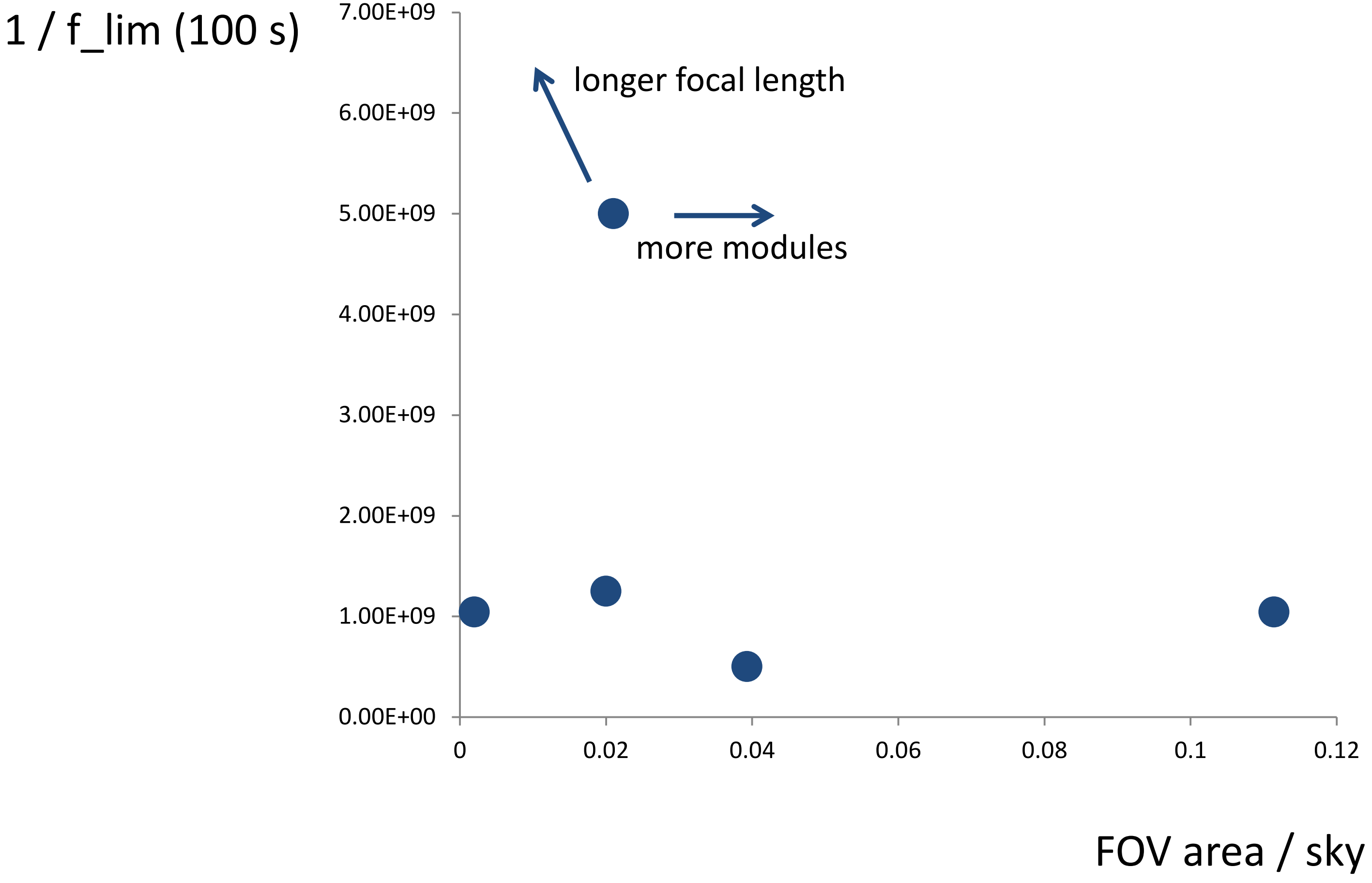
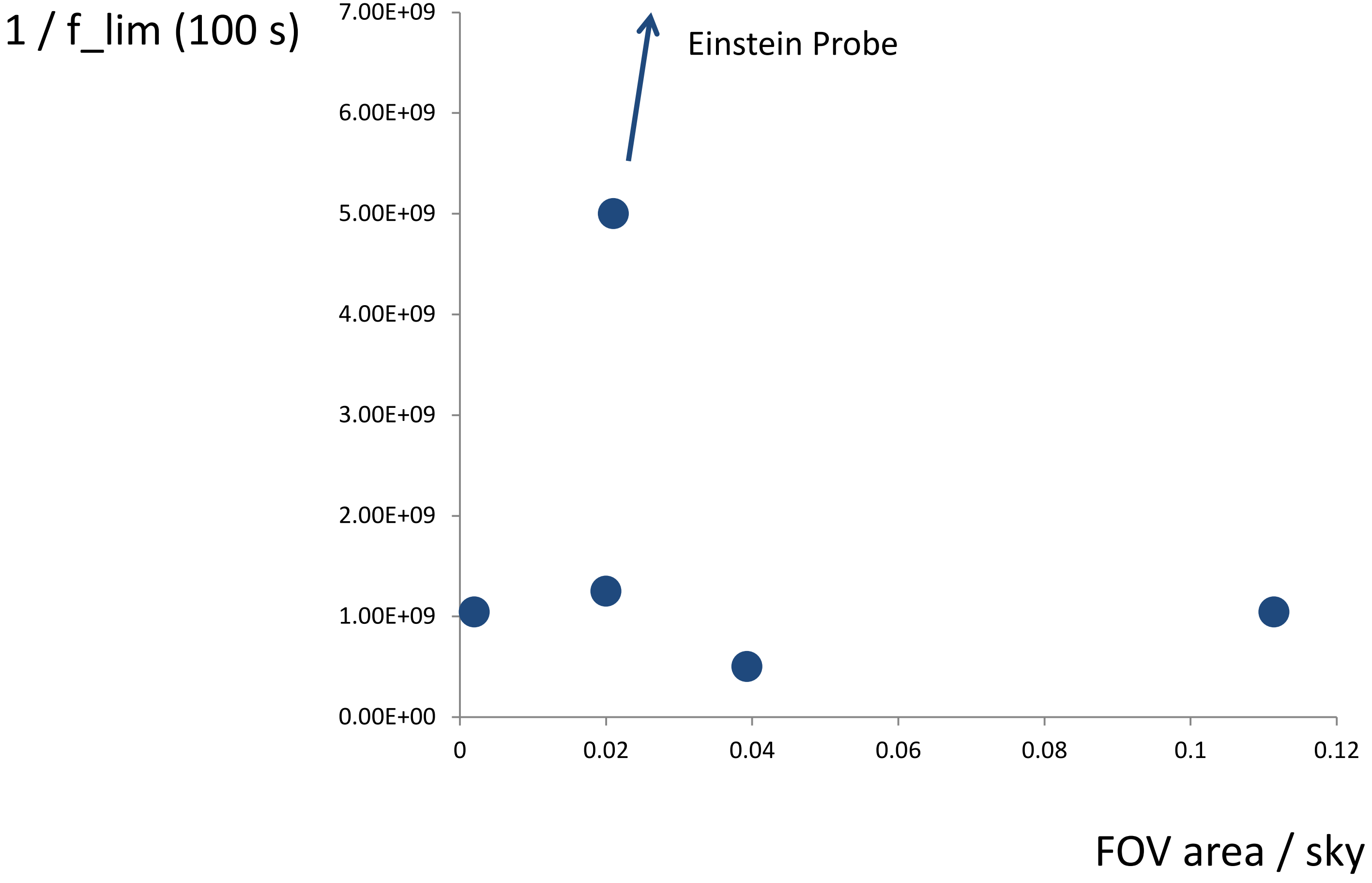
6.00E+09
5.00E+09
4.00E+09
3.00E+09
2.00E+09
1.00E+09
0.00E+00
IBIS
MAXI/GSC
RXTE/ASM
BAT
0
0.02
0.04
0.06
0.08
0.1
0.12
FOV area / sky



A-STAR: ArXiv:1302.2542


1 / f_lim (100 s)
7.00E+09
6.00E+09
5.00E+09
4.00E+09
3.00E+09
2.00E+09
1.00E+09
0.00E+00
longer focal length
more modules
0
0.02
0.04
0.06
0.08
0.1
0.12
FOV area / sky


1 / f_lim (100 s)
7.00E+09
6.00E+09
5.00E+09
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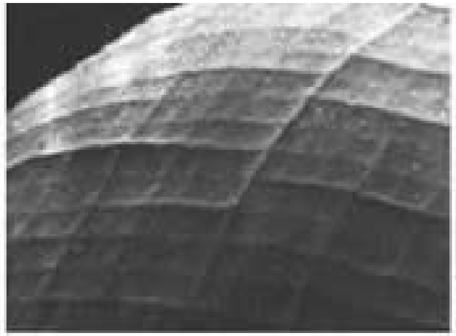
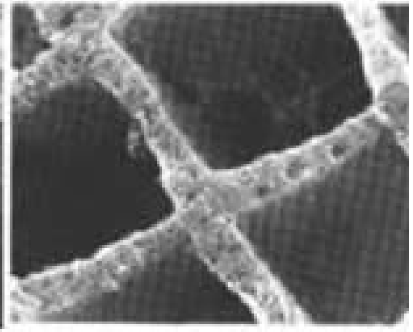
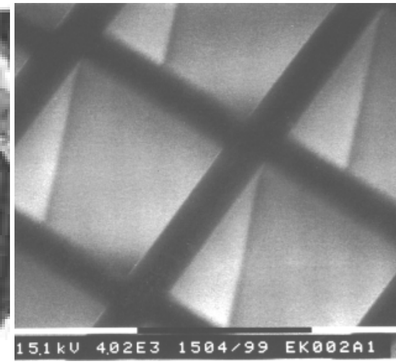
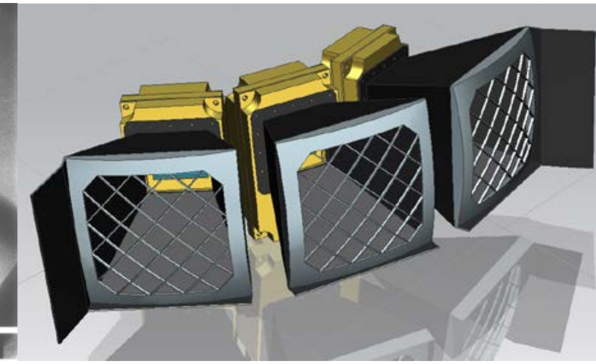
3.00E+09
2.00E+09
1.00E+09
0.00E+00
0
0.02
0.04
0.06
0.08
0.1
0.12
Einstein Probe
FOV area / sky

Lobster X-ray optics

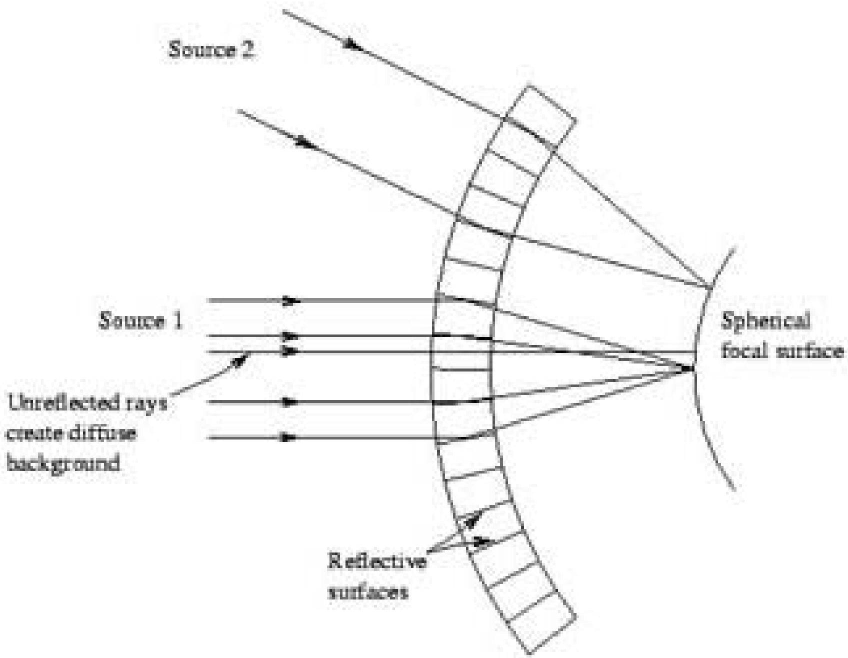




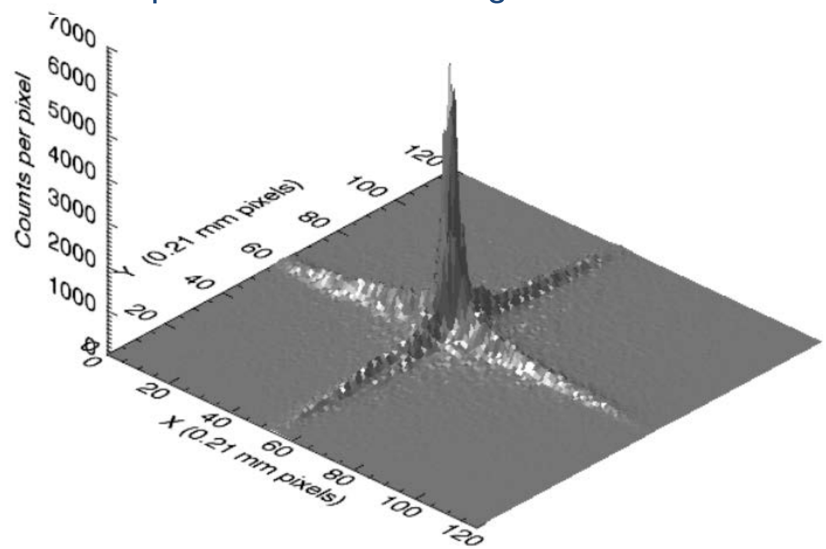




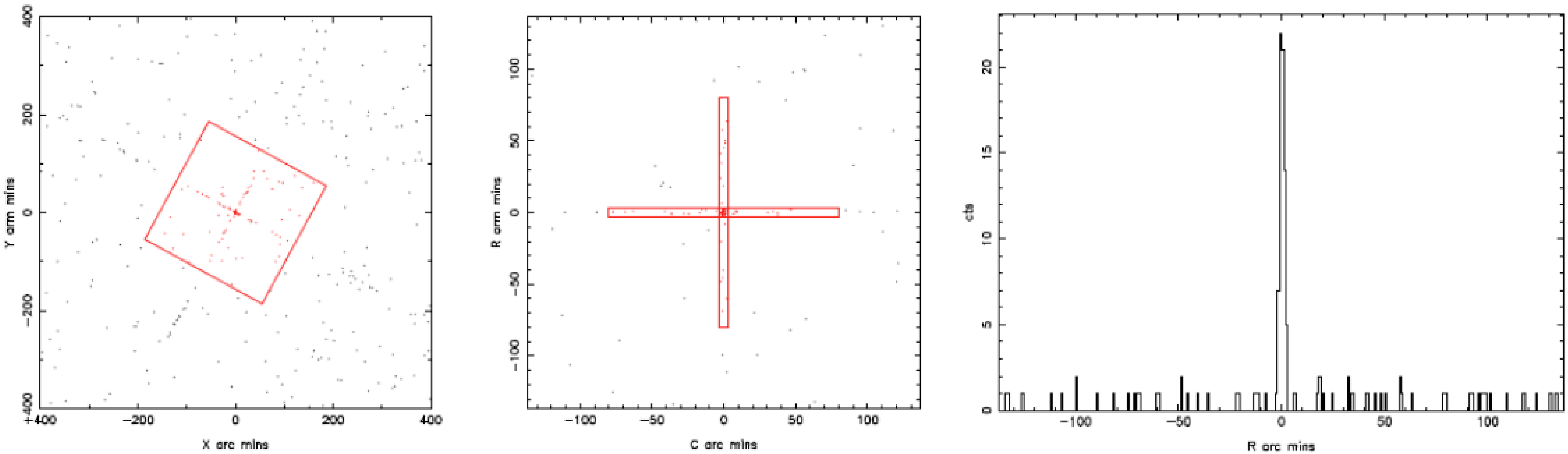
A-STAR Lobster



FOV	17x52°
Energy band	0.15-5.0 keV
Positions	50% <30”
Sensitivity	$4x10^{-11}$ erg.cm^{-2}.s in 10^3 s
Optic & frame	1.8 kg

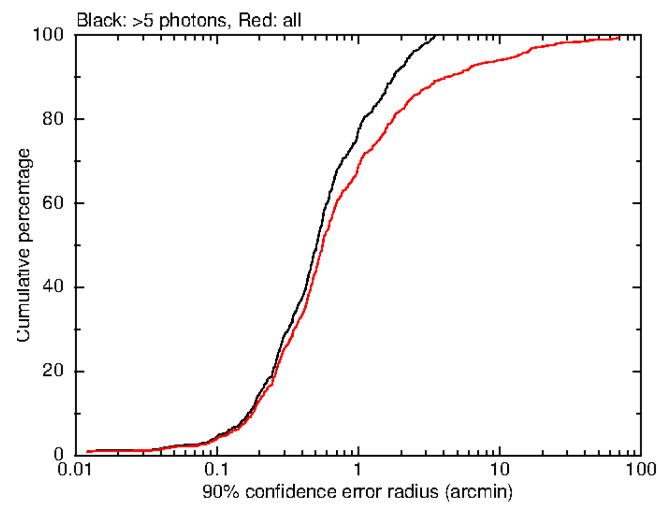


Lobster transient triggering:



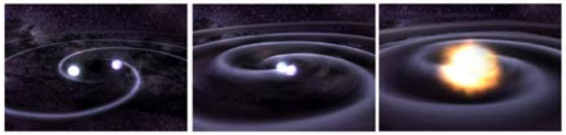
A-STAR location precision (R_{90} from Monte Carlo simulations of Swift bursts):

- 90% < 1.8'
- 50% < 30"
- 10% <10"



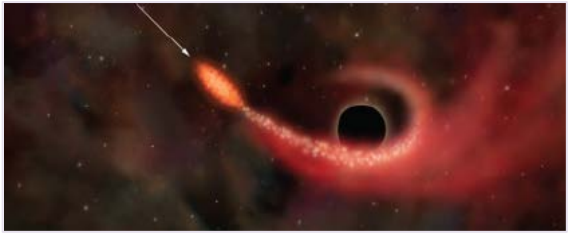
Why do we want it?

1. Precisely locate the high-energy photon sources of gravitational-wave and neutrino transients and transients located by the new generation of astronomical facilities

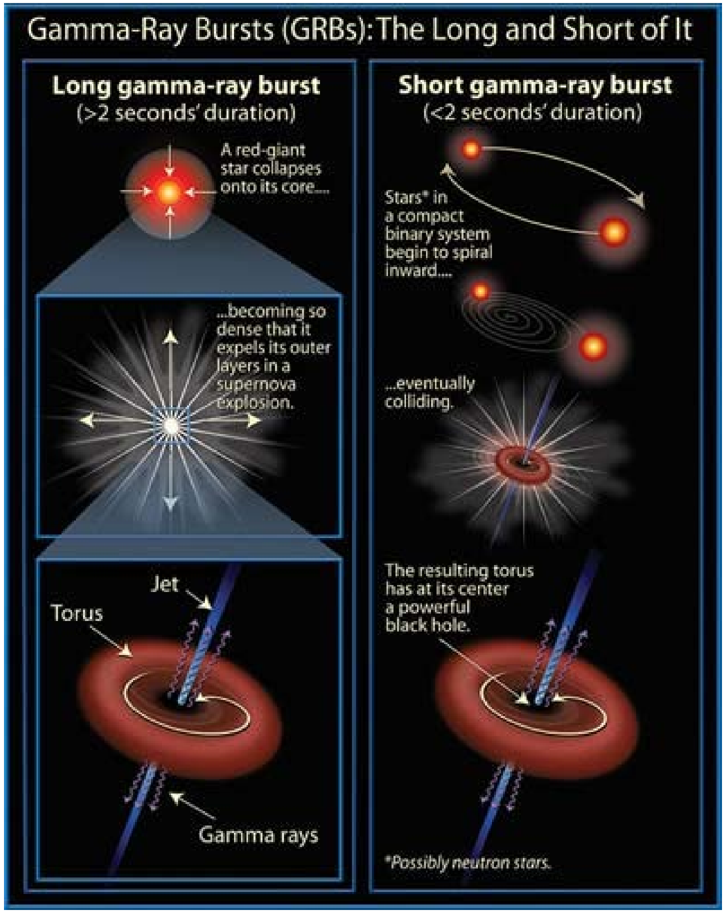


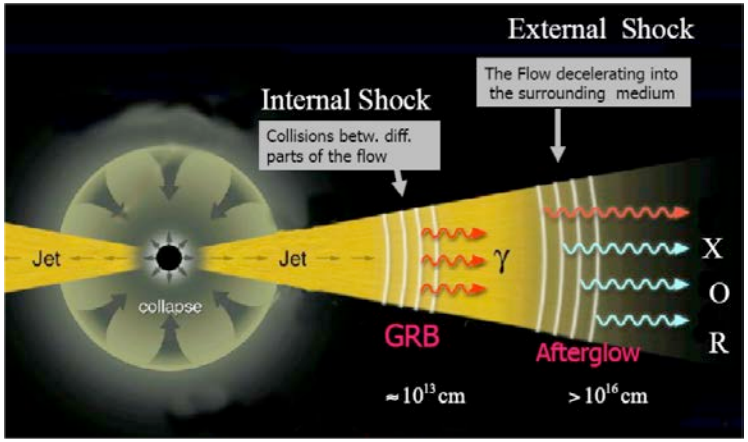
1. Reveal the physics underlying the variety in the population of gamma-ray bursts, including high-luminosity high-redshift bursts, low-luminosity bursts and short bursts

1. Discover new high-energy transient sources over the whole sky, including supernova shock break-outs, black hole tidal disruption events, magnetar flares, and monitor known X-ray sources with daily observations

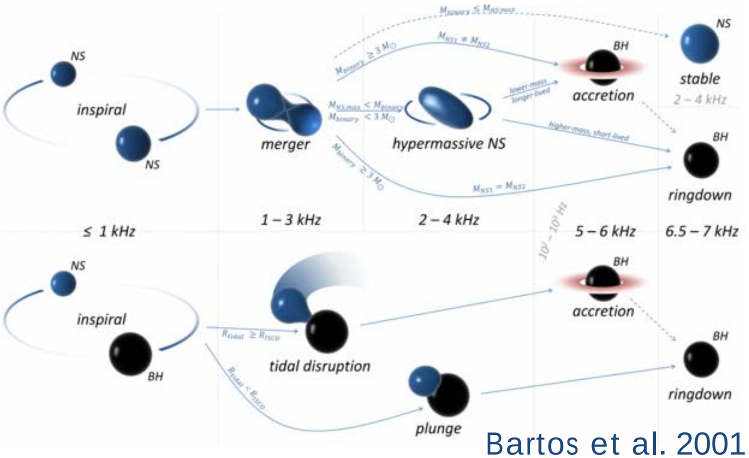


Gamma-Ray Bursts





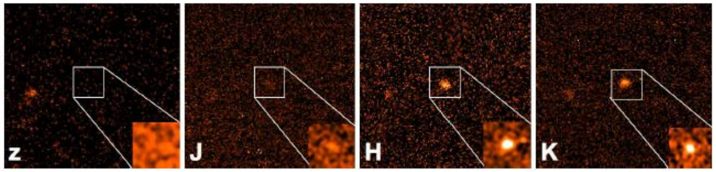
Meszaros 2001

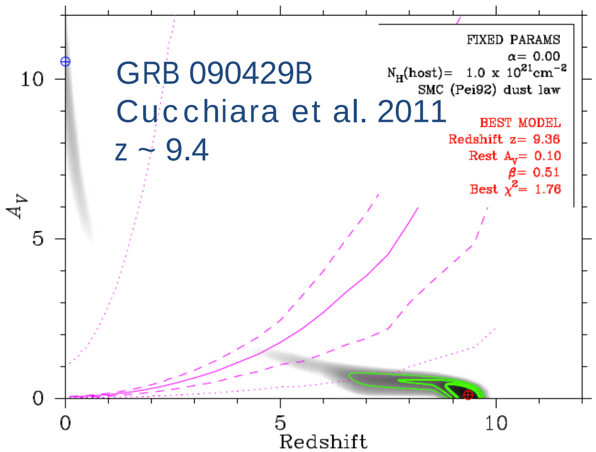


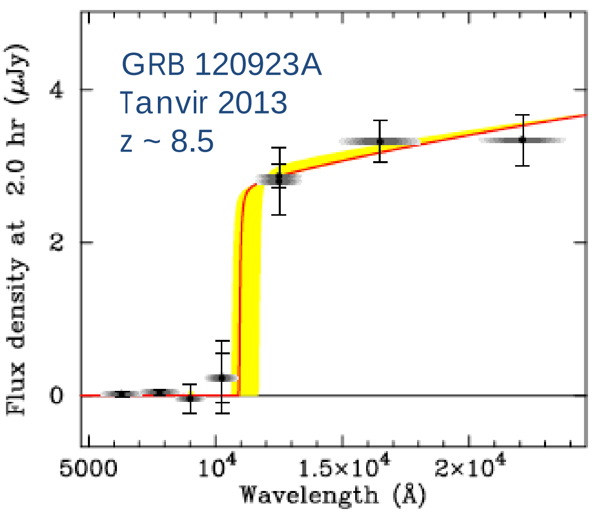
Bartos et al. 2001

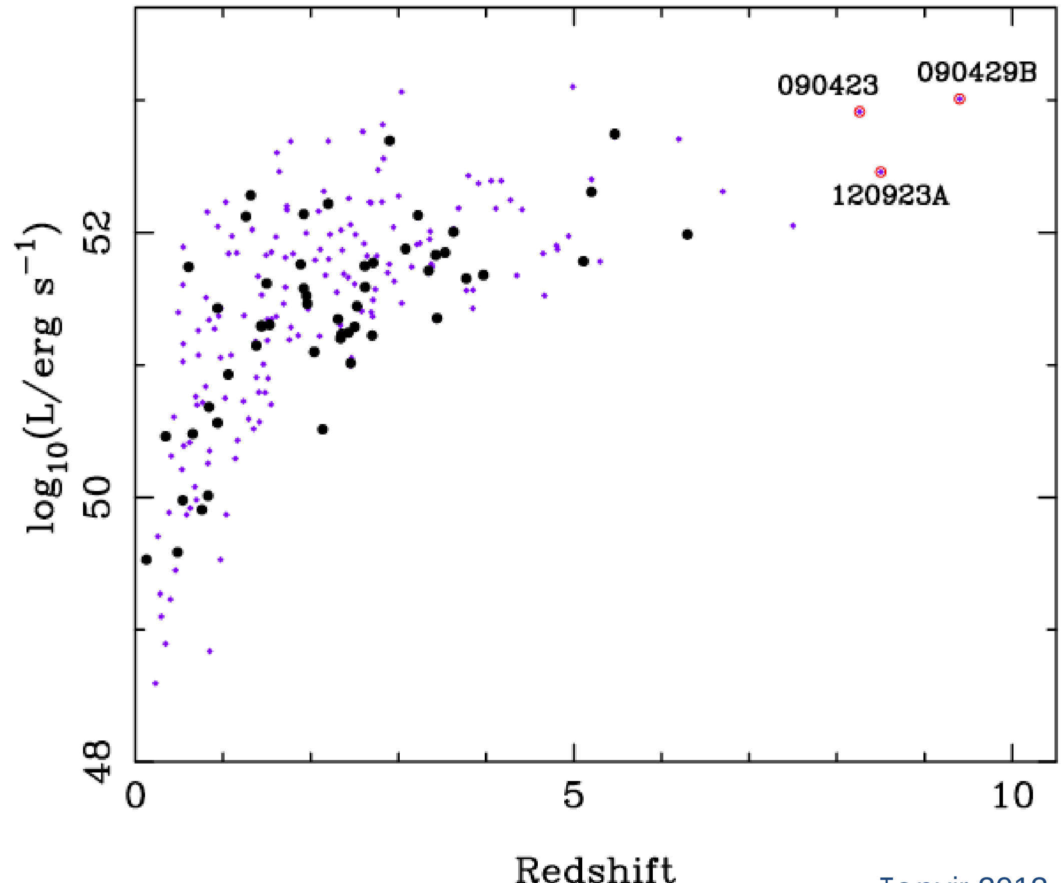
- Long GRBs are found out to the highest redshifts because of their huge luminosities
- Short GRBs will provide strong gravitational wave signals

GRBs: high redshifts and high luminosities



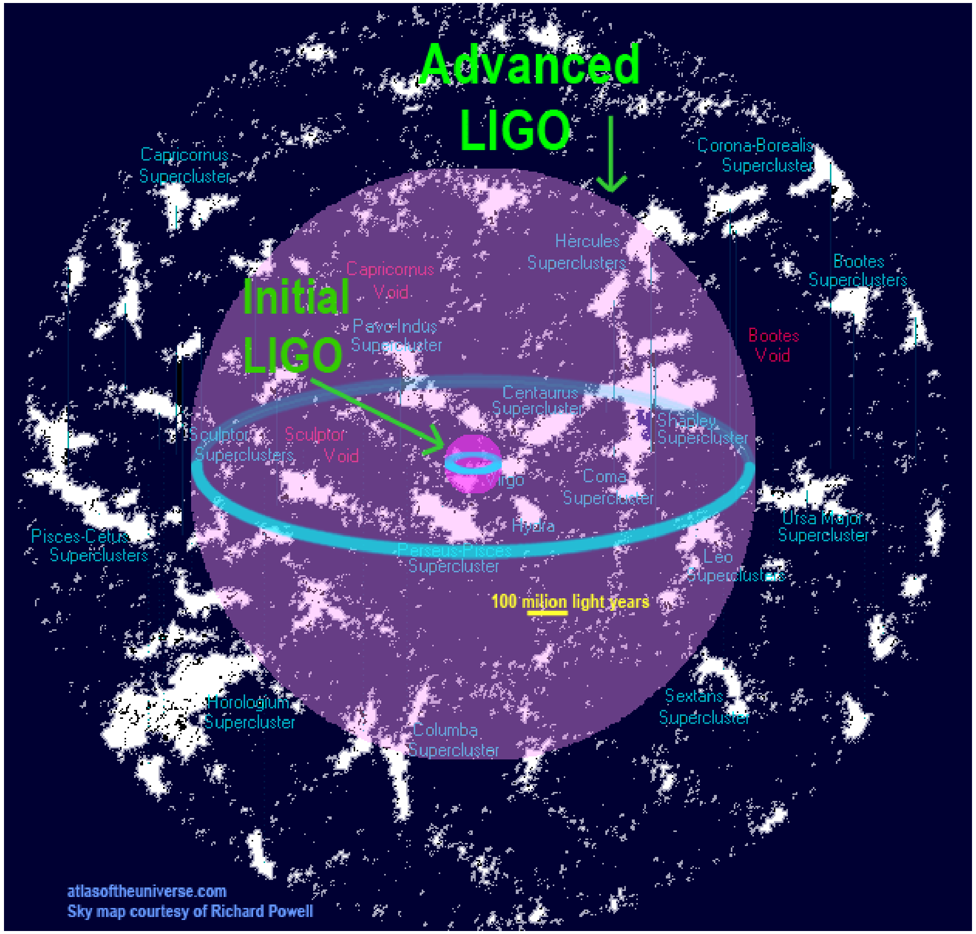


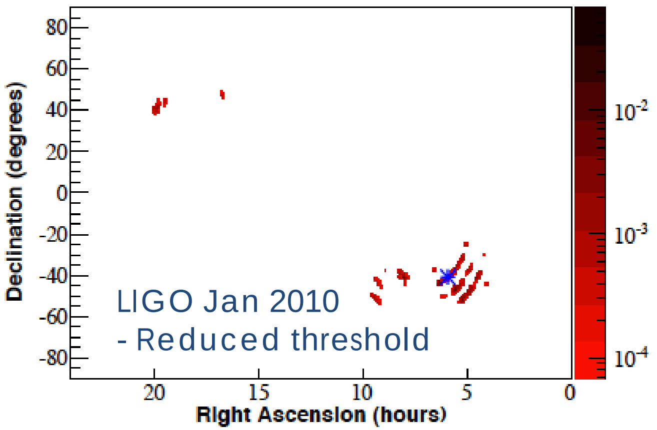


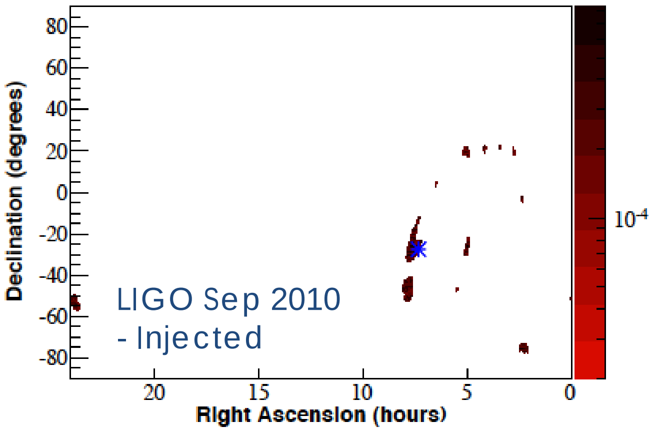


Tanvir 2013

1. Precisely locate the high-energy photon sources of gravitational-wave and neutrino transients and transients located by the new generation of astronomical facilities

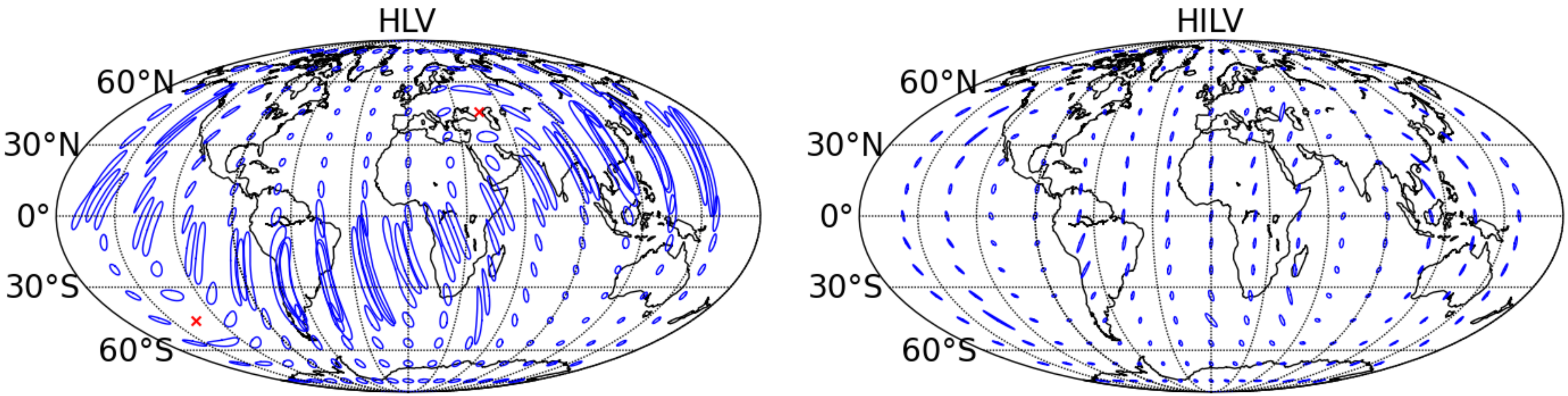






Evans et al 2012

Advanced LIGO/Virgo GW transient location



Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_{\odot} c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections	% BNS Localized within	
		LIGO	Virgo	LIGO	Virgo		5 deg^2	20 deg^2
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

Aasi+ ArXiv:1304.0670

Scientific importance of joint EM and non-EM GRB detection hard to overstate

ALIGO: ~50 NS+NS & NS+BH /yr to 900 Mpc (Abadie+ 2010)

IceCube and Km3NET neutrino observatories also operational

- Photon detection leads to redshift, astrophysical context of source, and allows strong source geometry constraints to be tied to the rich knowledge of GRB electromagnetic behaviour – neutrino-long GRB detection vital for collapsar model

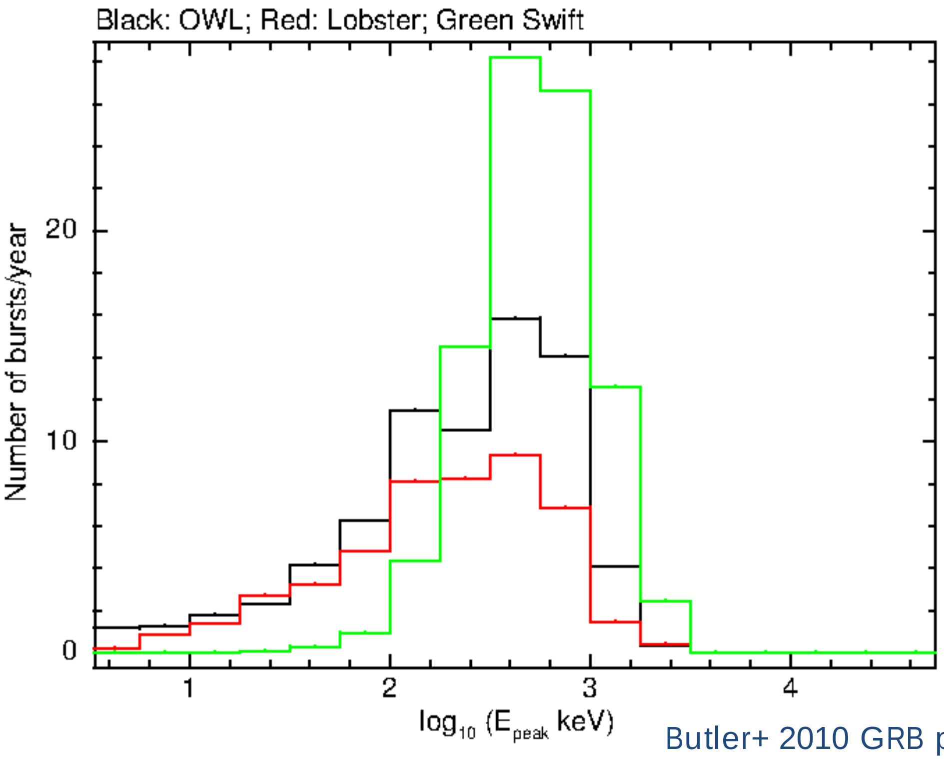
- GW detection validates the short GRB binary model

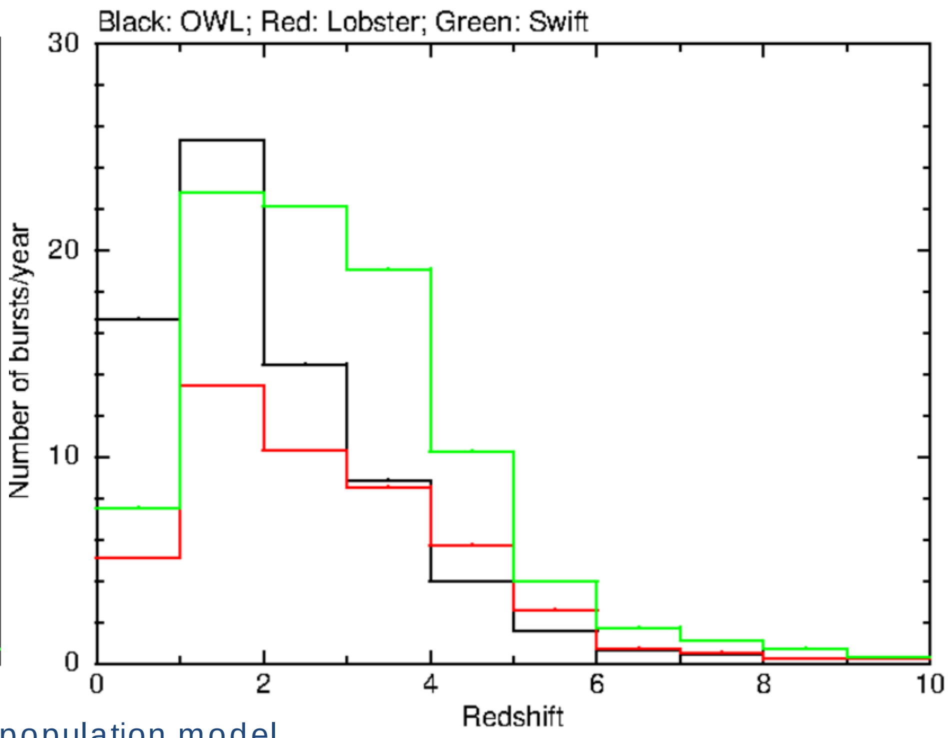
- Simultaneous EM redshift and GW luminosity distance determination – breaks cosmology determination degeneracies

- Joint detection increases sensitivity

Fairhurst 2012

2. Reveal the physics underlying the variety in the population of gamma-ray bursts, including high-luminosity high-redshift bursts, low-luminosity bursts and short bursts



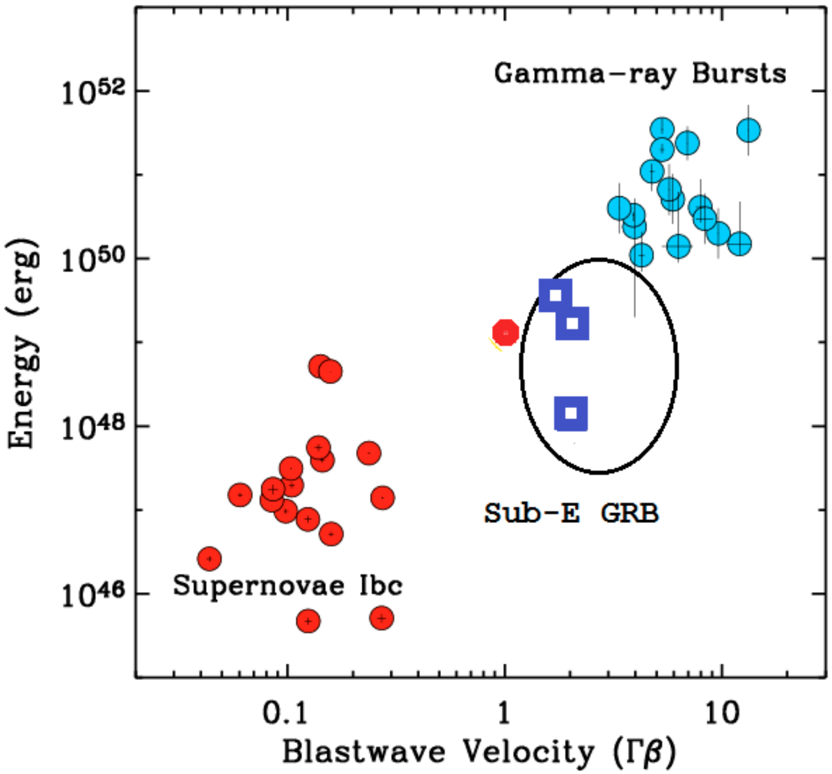


Butler+ 2010 GRB population model

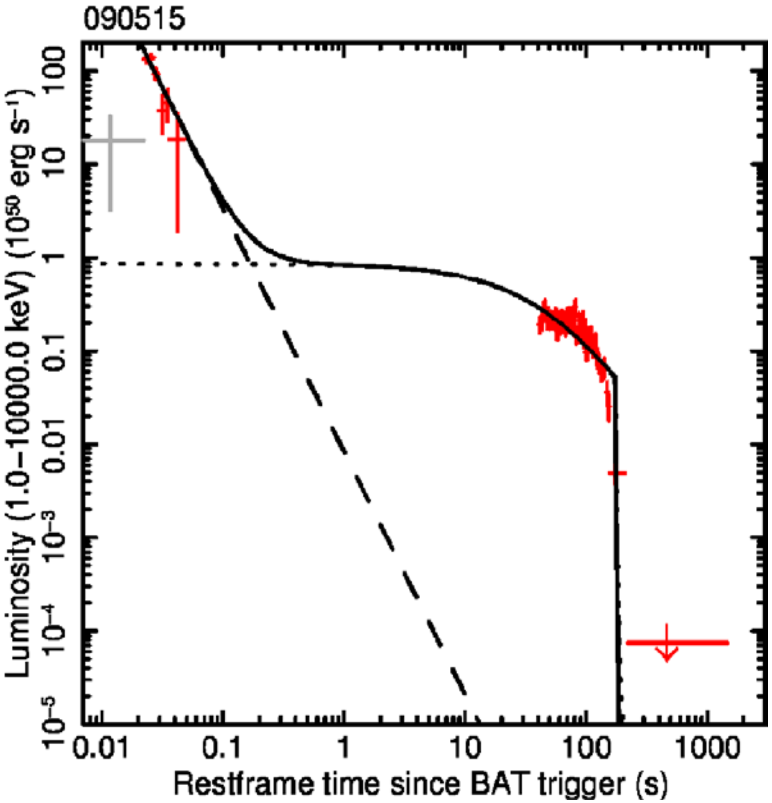
Find low-luminosity nearby GRB population, and high redshift bursts

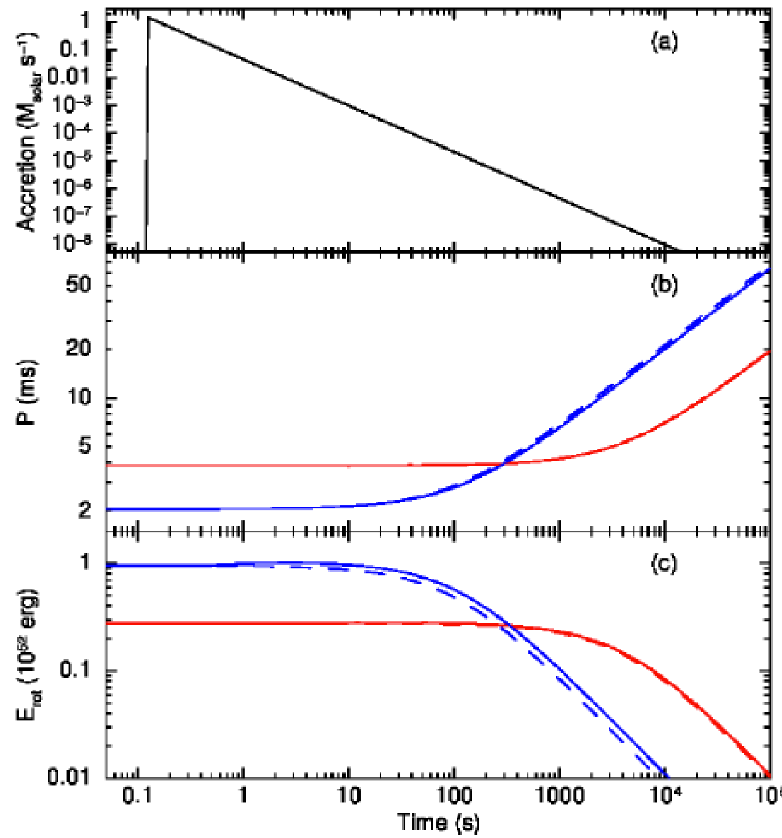
Despite recent progress, and their importance as gateways to the early universe, much remains to be learnt about GRBs

- What is the true relationship between SNe and GRBs?
- What is the origin of the low-luminosity XRFs?
    - Population density is likely large
    - Current instruments have poor sensitivity
- Are magnetars a key component of GRBs?
- What is the nature of the first stars?
- Basic physics of GRB explosion?
- New facilities need triggers: CTA, HAWK, SKA, JWST, ALMA, ELT



Adapted from Soderberg et al 2010

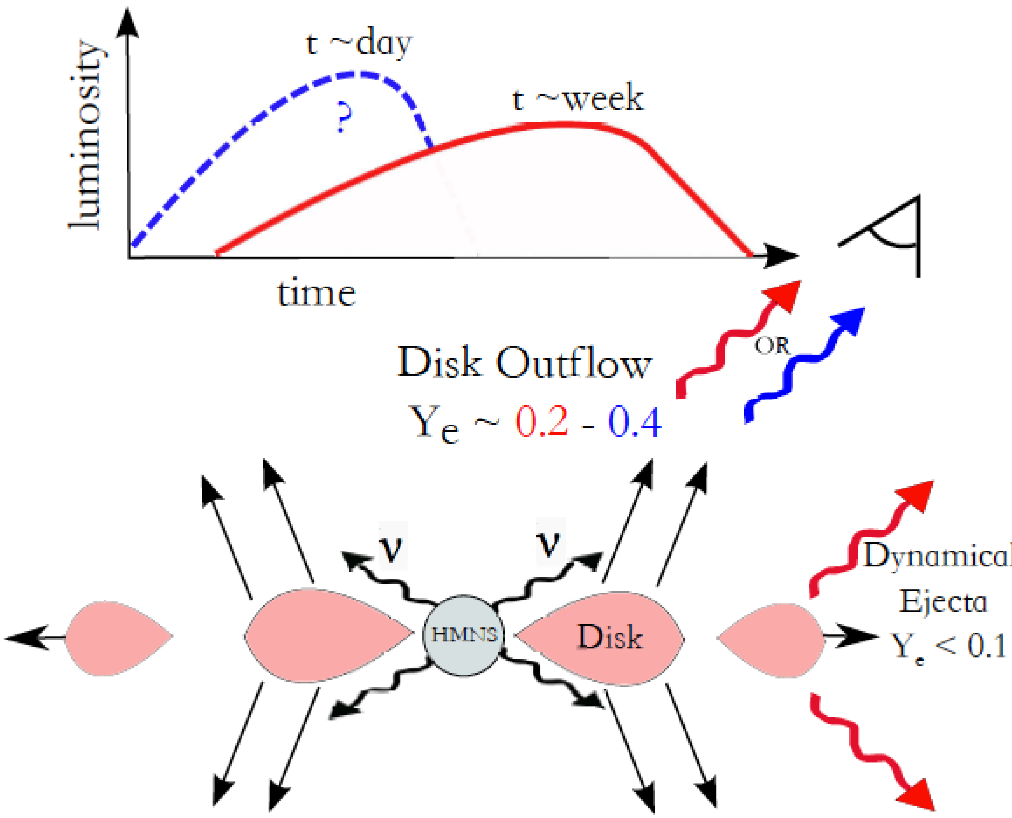




Rowlinson et al. 2013

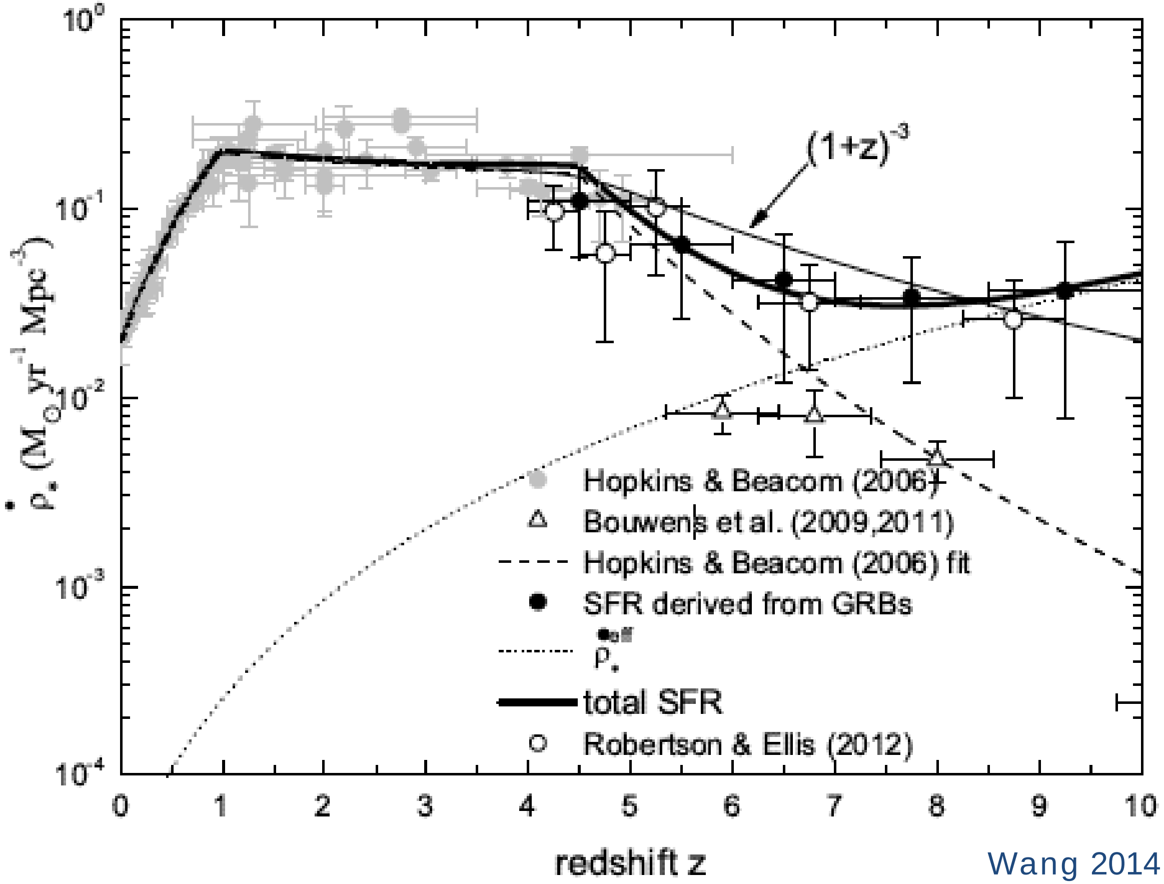
Are the plateaux and steep drops in X-ray afterglow light curves due to energy injection from magnetar spin down?

Half of short GRBs are well fit by a spin down model. B & P consistent with prior constraints: log B = 15-17, P = 1-10 ms



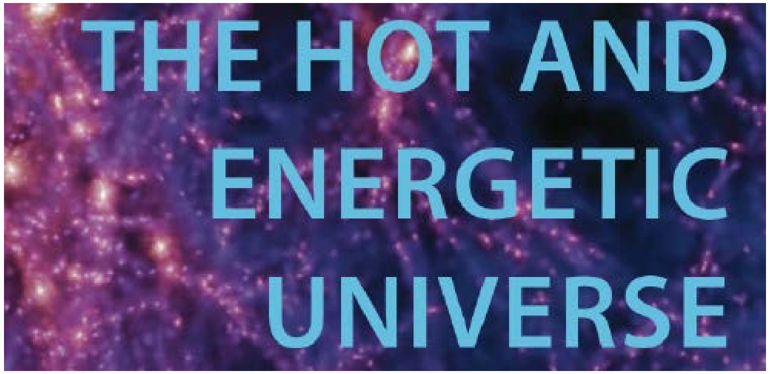
Can we constrain the collapse timescale of a hyper-massive NS-NS merger product to a BH in a short GRB?

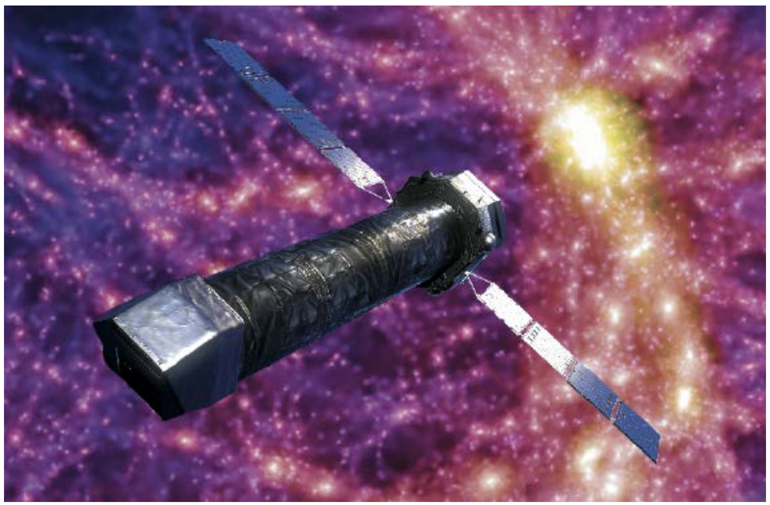
Metzger & Fernández predict an early blue bump from late collapses (ArXiv:1402.4803)

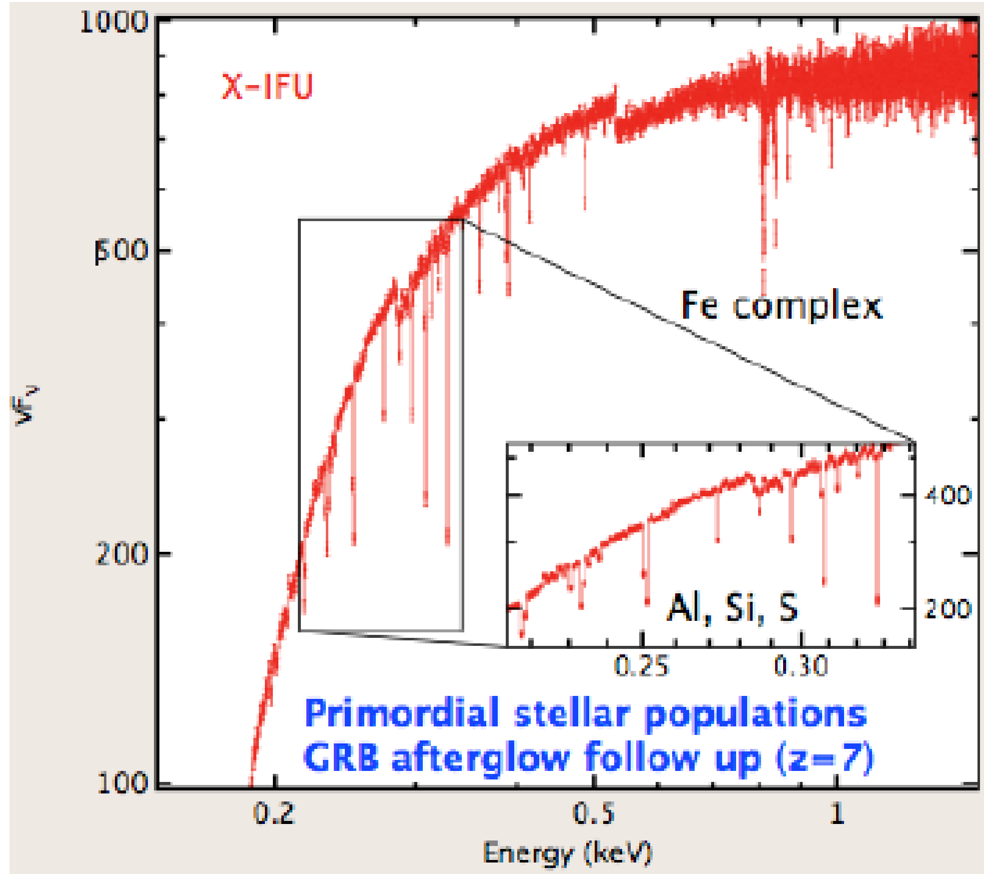


Wang 2014

The cosmic star formation rate derived from GRBs is reconciled with other measures if they occur in rapidly rotating metal-poor massive stars (Wang, ArXiv:1401.5864), and if they occur in low metallicity dwarf galaxies (Jimenez & Piran, ArXiv:133.4809). GRBs were more common w.r.t. SNe in the early Universe.

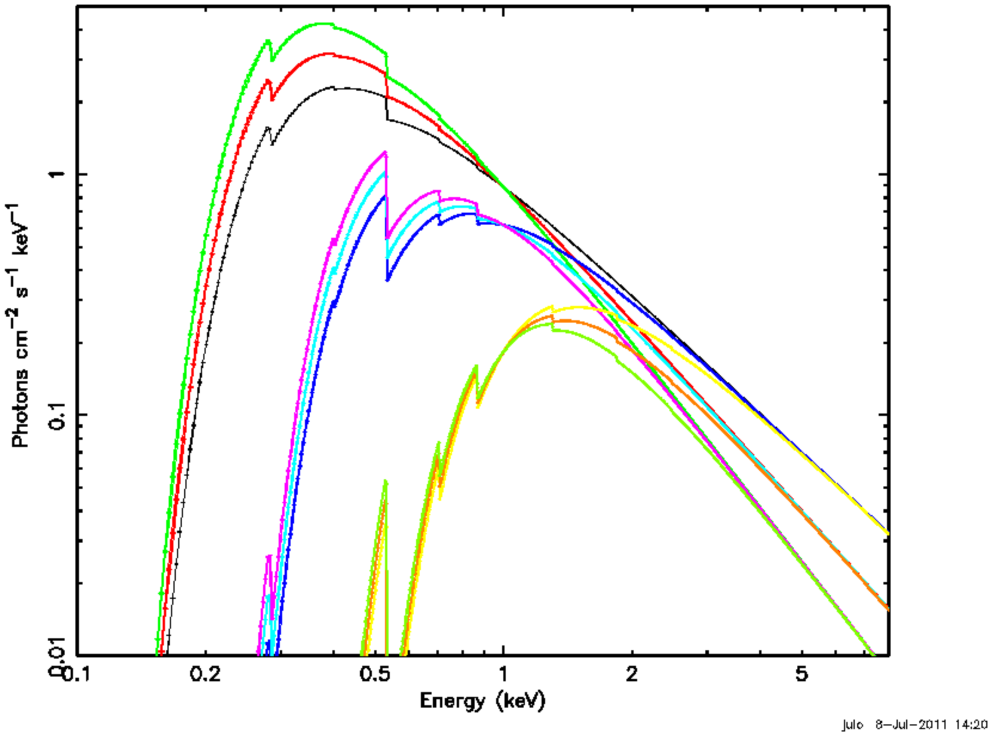






Athena simulated spectrum of the Warm-Hot Intergalactic Medium in absorption in front of a bright GRB (Nandra et al. ‘The Hot and Energetic Universe’)

GRB photon spectra

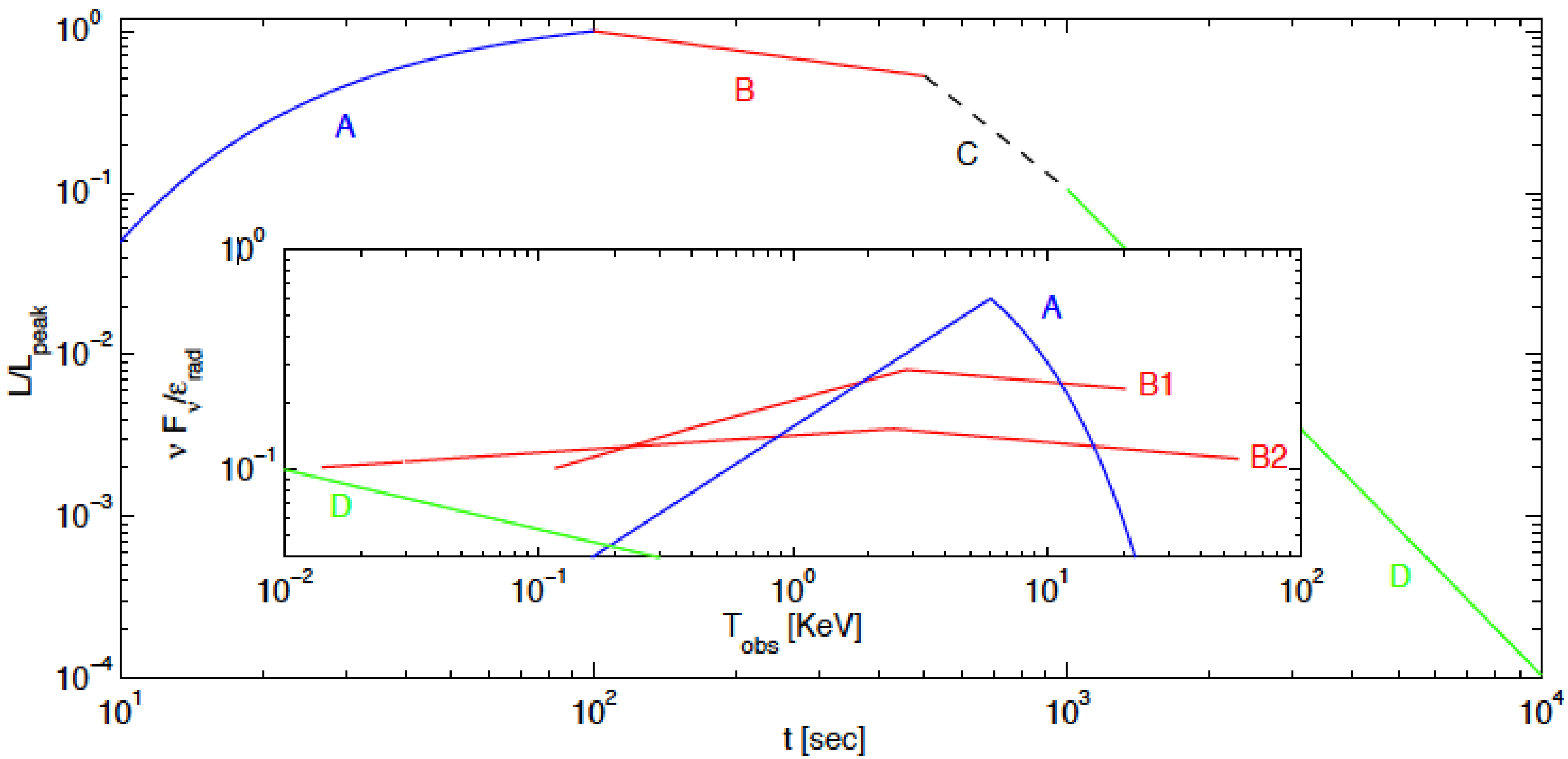


<u>A-STAR Lobster</u>

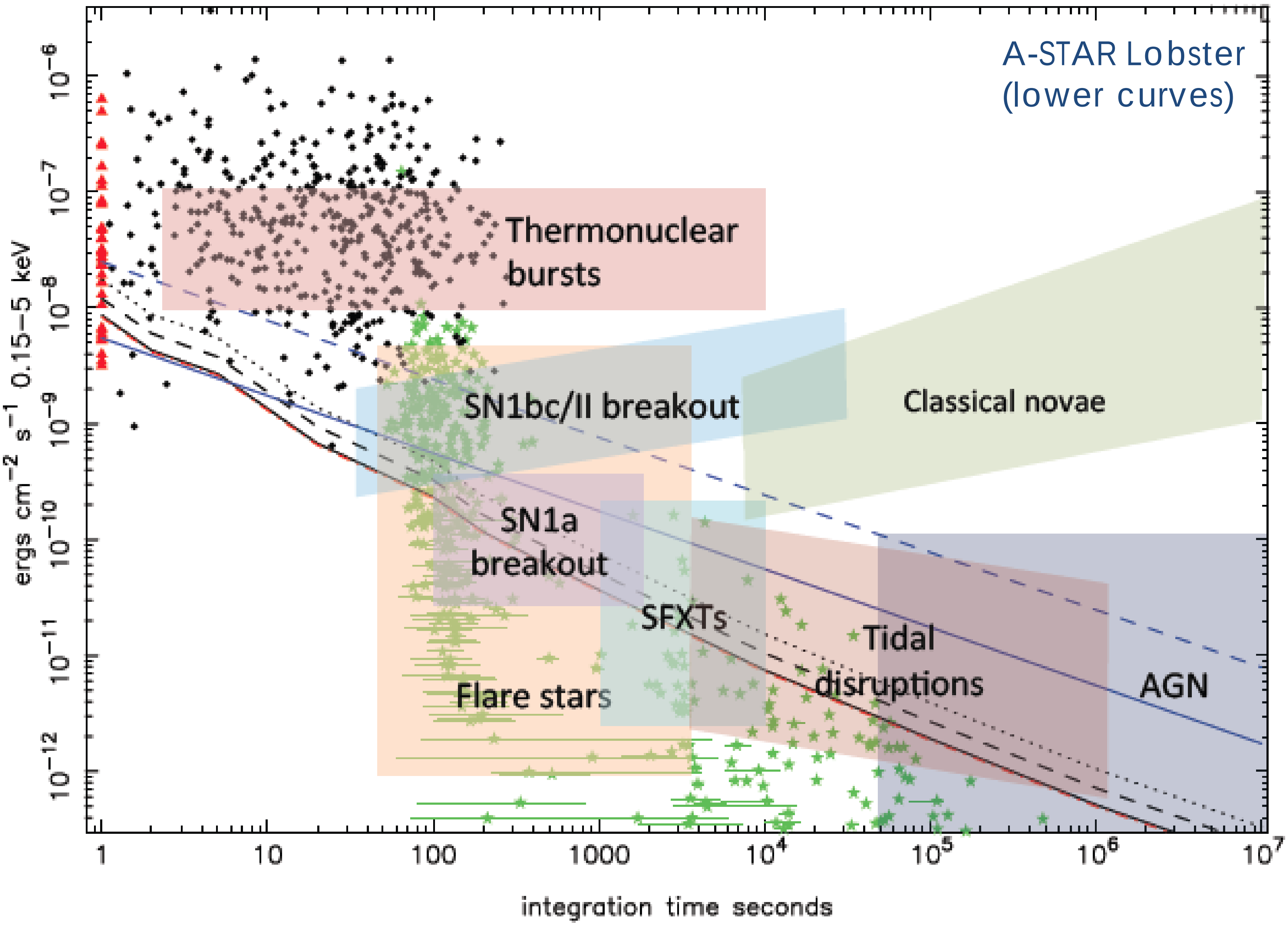
- Novel low mass wide field focussing optics
- FOV 17x52°
- Soft X-ray band: 0.15-5 keV
- Ideal passband for max sensitivity
- Good to explore poorly understood LLGRBs
- Triggers on 45 GRBs/yr (5/yr @ z>5)

3. Discover new high-energy transient sources over the whole sky, including supernova shock break-outs, black hole tidal disruption events, magnetar flares, and monitor known X-ray sources with daily observations

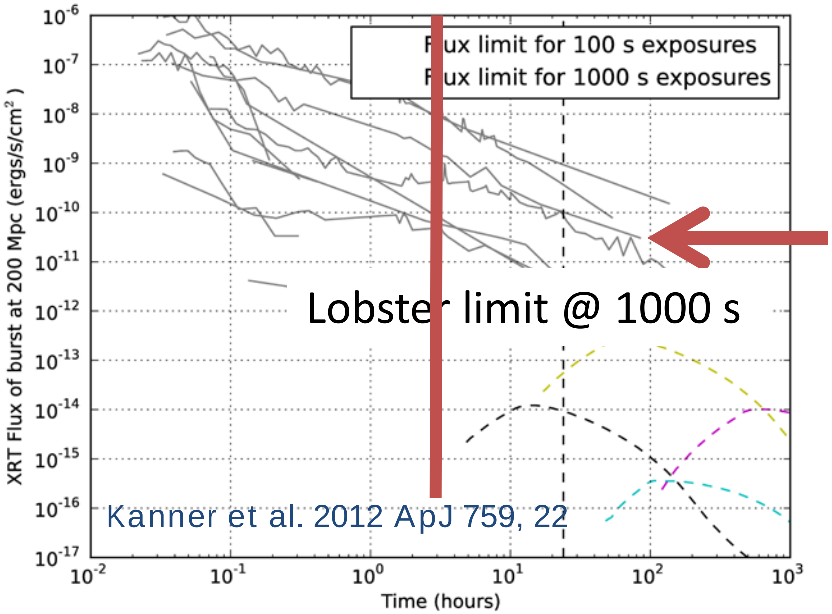
e.g. Transient soft X-ray pulse predicted from a SN shock breakout from a thick WR stellar wind constrains the progenitor characteristics



Svirski & Nakar. ArXiv;1402.4471


A-STAR Lobster
(lower curves)
Thermonuclear
bursts
SN1bc/II breakout
Classical novae
SN1a
breakout
SFXTs
Tidal
disruptions
AGN
Flare stars
ergs cm−2 s−1 0.15–5 keV
integration time seconds
1
10
100
1000
10^4
10^5
10^6
10^7
10^−6
10^−7
10^−8
10^−9
10^−10
10^−11
10^−12

Community desire:



"The high fraction of short GRBs with X-ray band afterglows, and the potentially bright fluxes associated with them, make the Swift X-ray band an attractive wavelength to seek EM counterparts to NS–NS and NS–BH mergers. ***An imaging, wide field, soft X-ray band detector with a fast response to TOO requests is required.****"*

"It is challenging to detect the X-ray afterglow [of a GWB magnetar wind] with the current facilities such as Swift, ***but a wide-field X-ray imager (such as ISS-Lobster) would be ideal to catch this bright X-ray signal.****"* (Zhang, B. 2013 ApJ 763, 22)

Conclusions:

- Low-mass lobster wide-field X-ray telescopes provide a unique capability to perform a high-cadence whole sky survey

- They can be used to locate GRBs and other transients, providing prompt alerts for other facilities in the coming time-domain era (e.g. ESA L2)

- High energy transients are, and will remain, a hugely active area due to their cosmological interest and the new complementary facilities in development