Three candidate magnetar-powered fast X-ray transients from Chandra archival data

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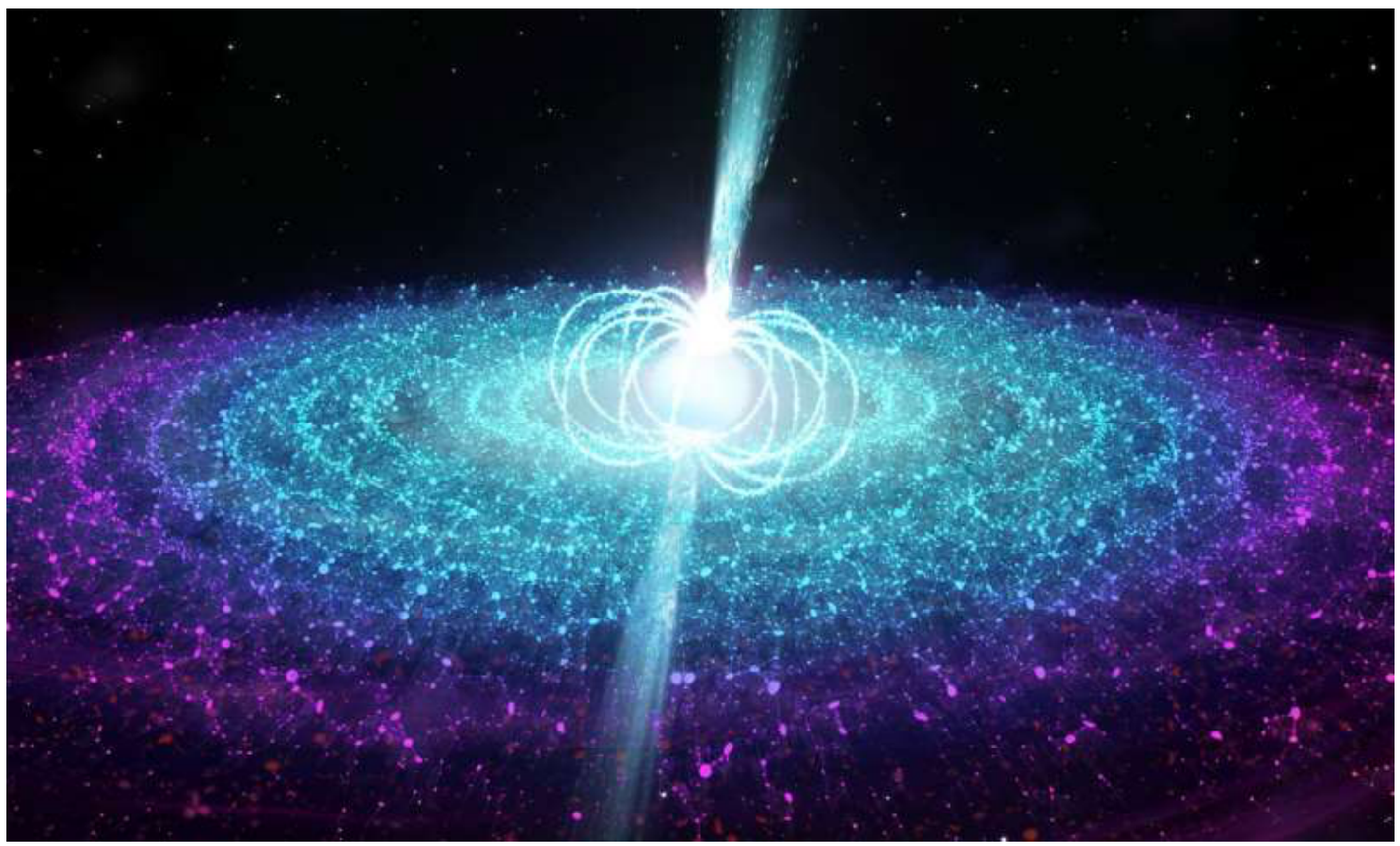
20 Years of Chandra Symposium, Dec 6th 2019

Collaborators: Jimmy Irwin, Edo Berger



Credit: NASA

Outline

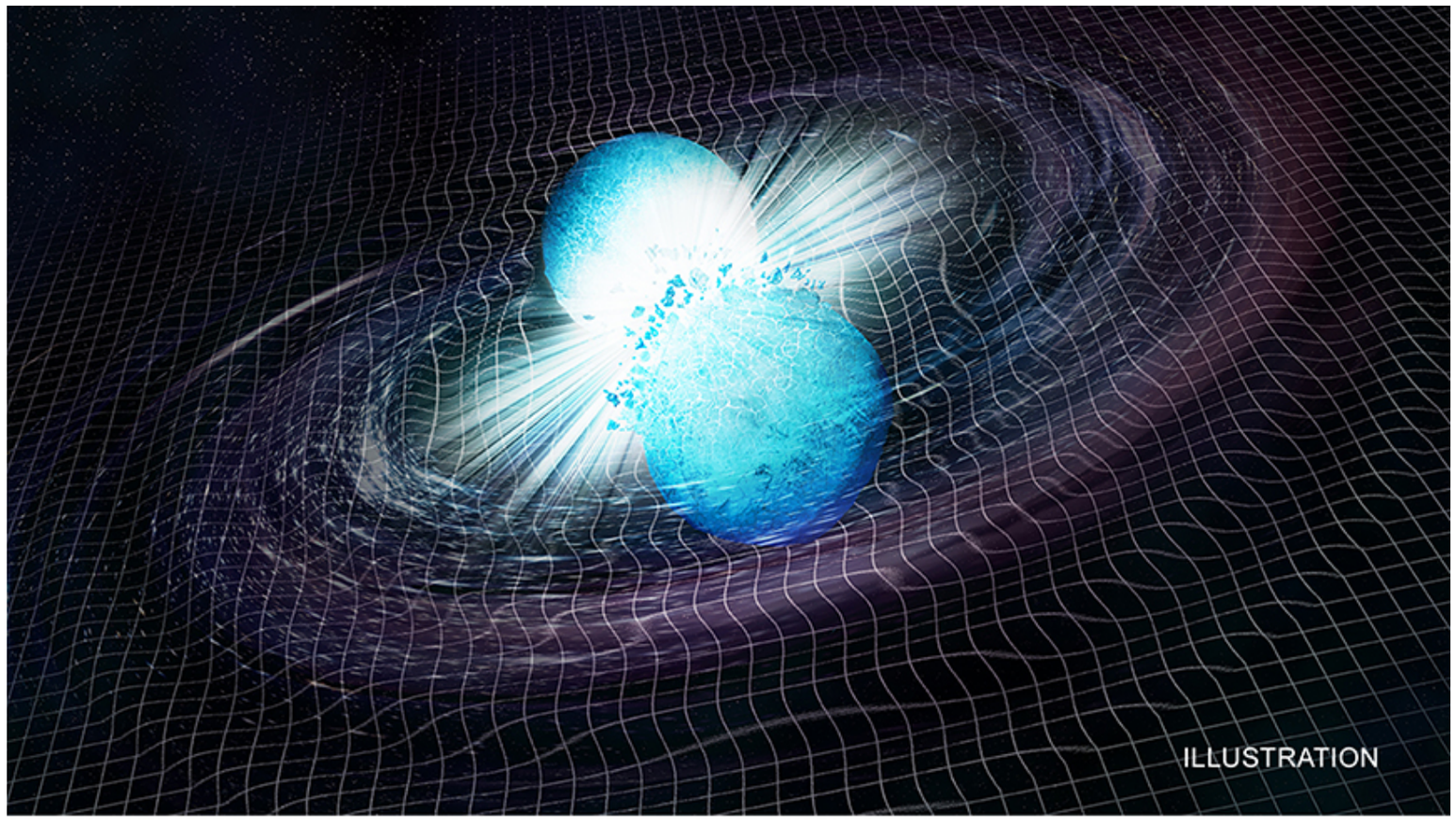
- Highly magnetized supramassive millisecond pulsars (magnetars) formed in binary neutron-star (BNS) mergers

- CDF-S XT2: a fast X-ray transient (FXT) powered by a protomagnetar?

- Three new FXTs from Chandra archival data.

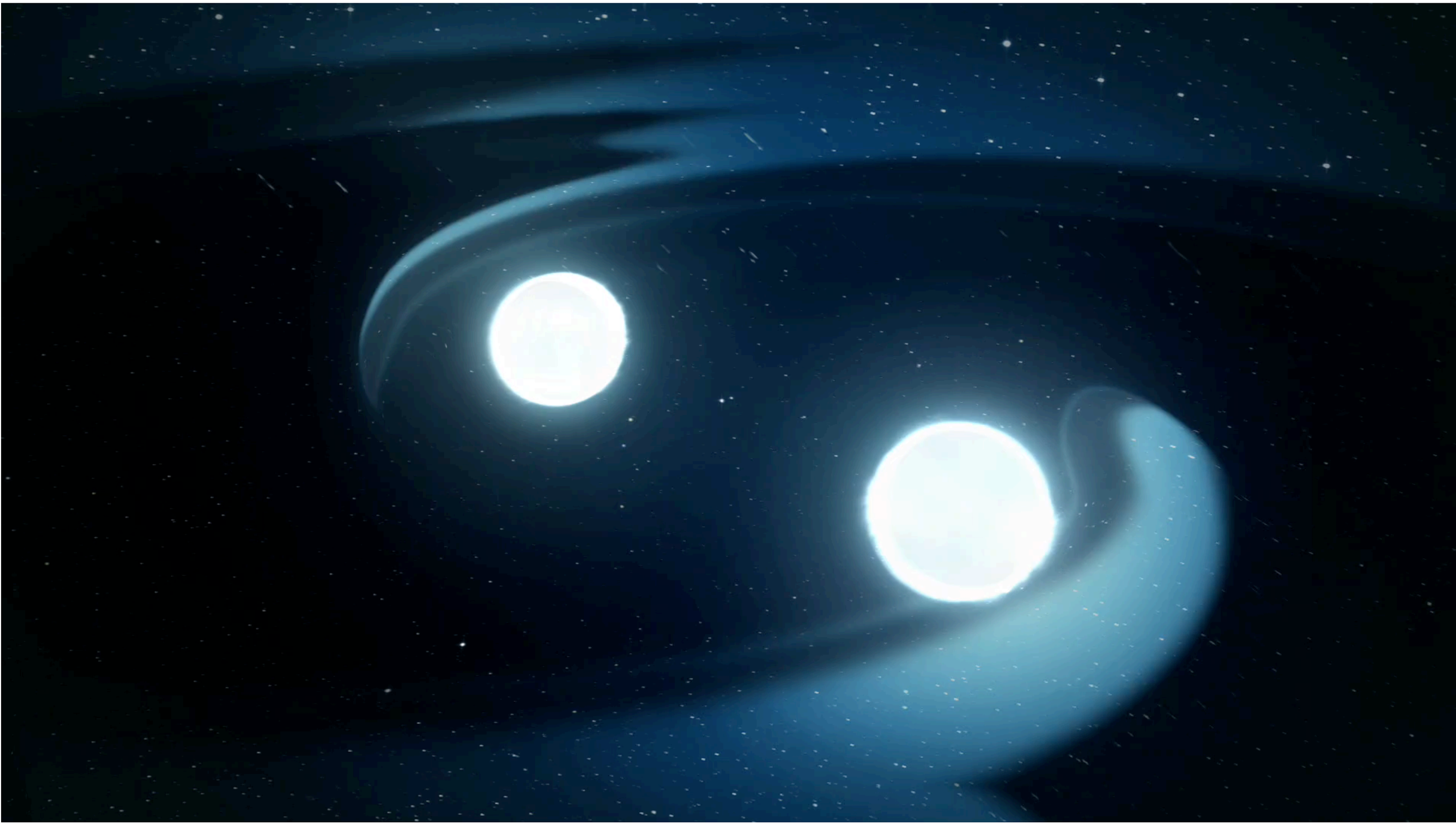
Multi-messenger era

GW 170817



Credit: NASA/CXC/Trinity/Pooley

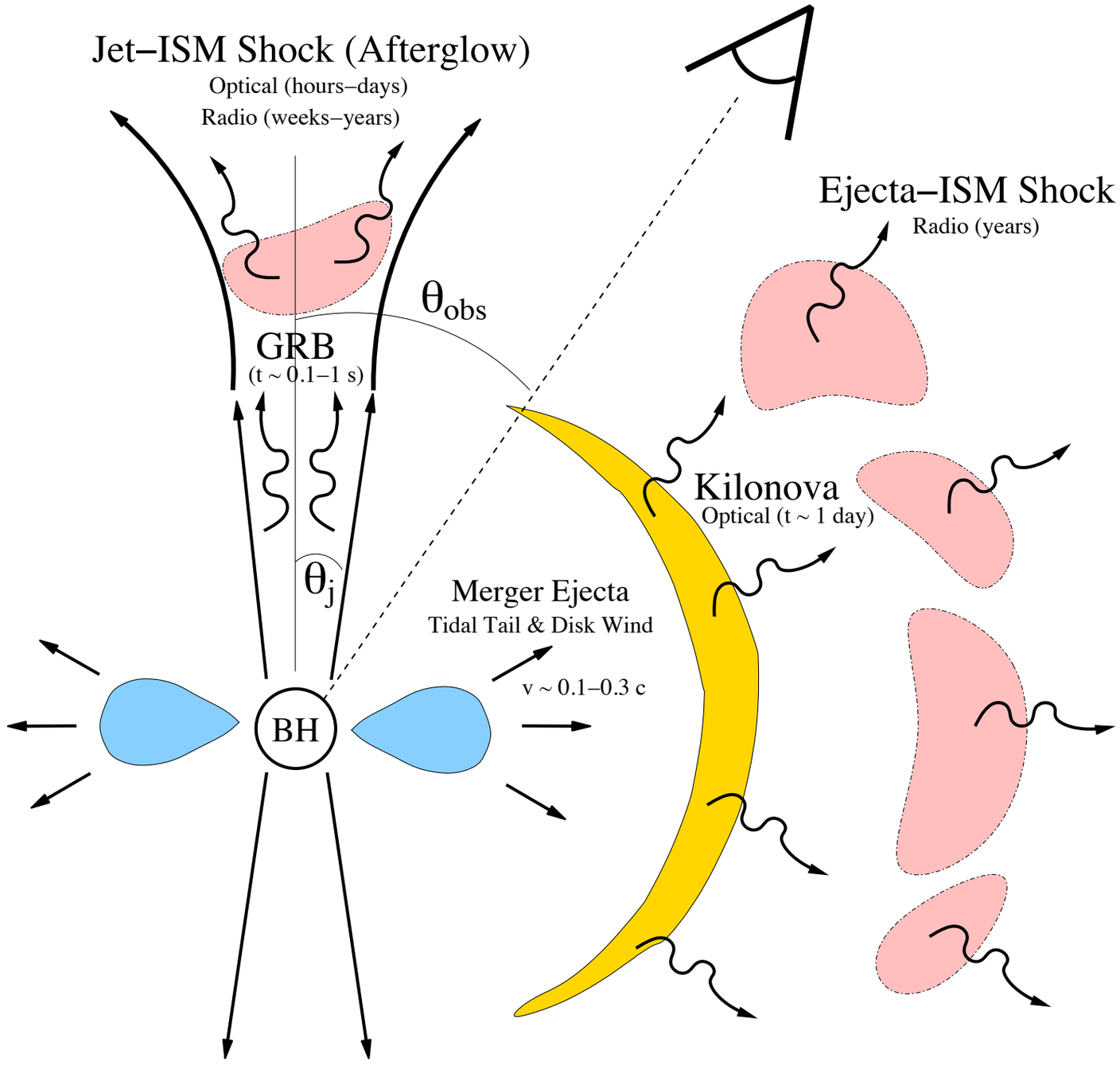
Association of short GRBs with BNS mergers



Credit: NASA/GSFC

EM signal highly depends on the viewing angle

Narrowly collimated jets



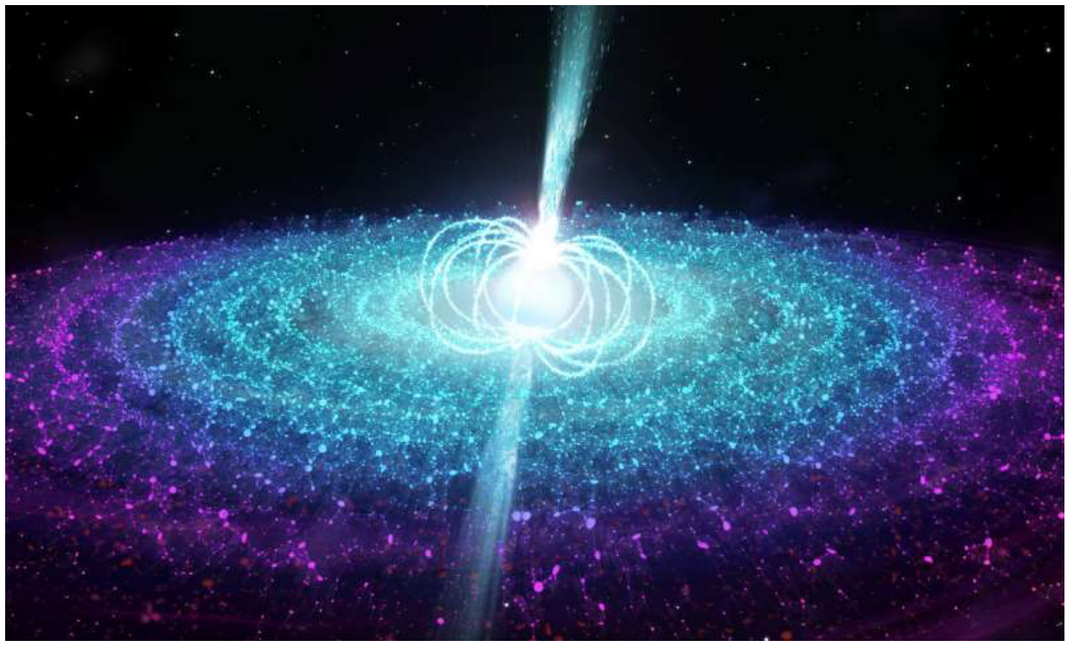
Metzger & Berger 2012

Big question: Most GW events have large positional error and should be GRB-less, how to search for their EM counterparts

Search for strong EM signal of GRB-less GW events

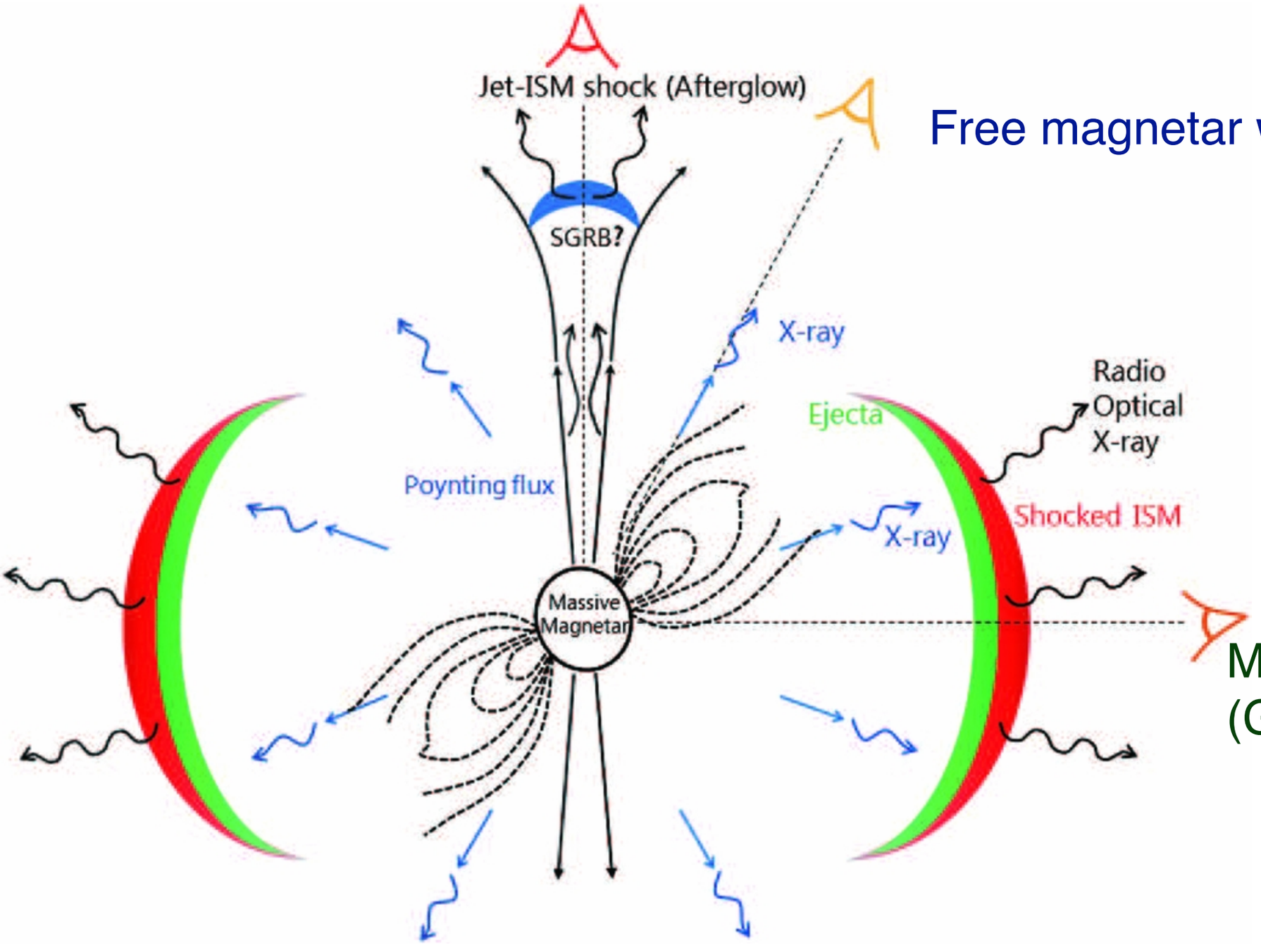
- Highly magnetized supramassive millisecond pulsars (magnetars) formed in BNS mergers

Credit: NASA/Swift/Dana Berry



Credit: NASA

A proto-magnetar from a BNS merger?



Free magnetar wind (Zhang 2013)

Magnetar-powered ejecta
(Gao et al. 2013)

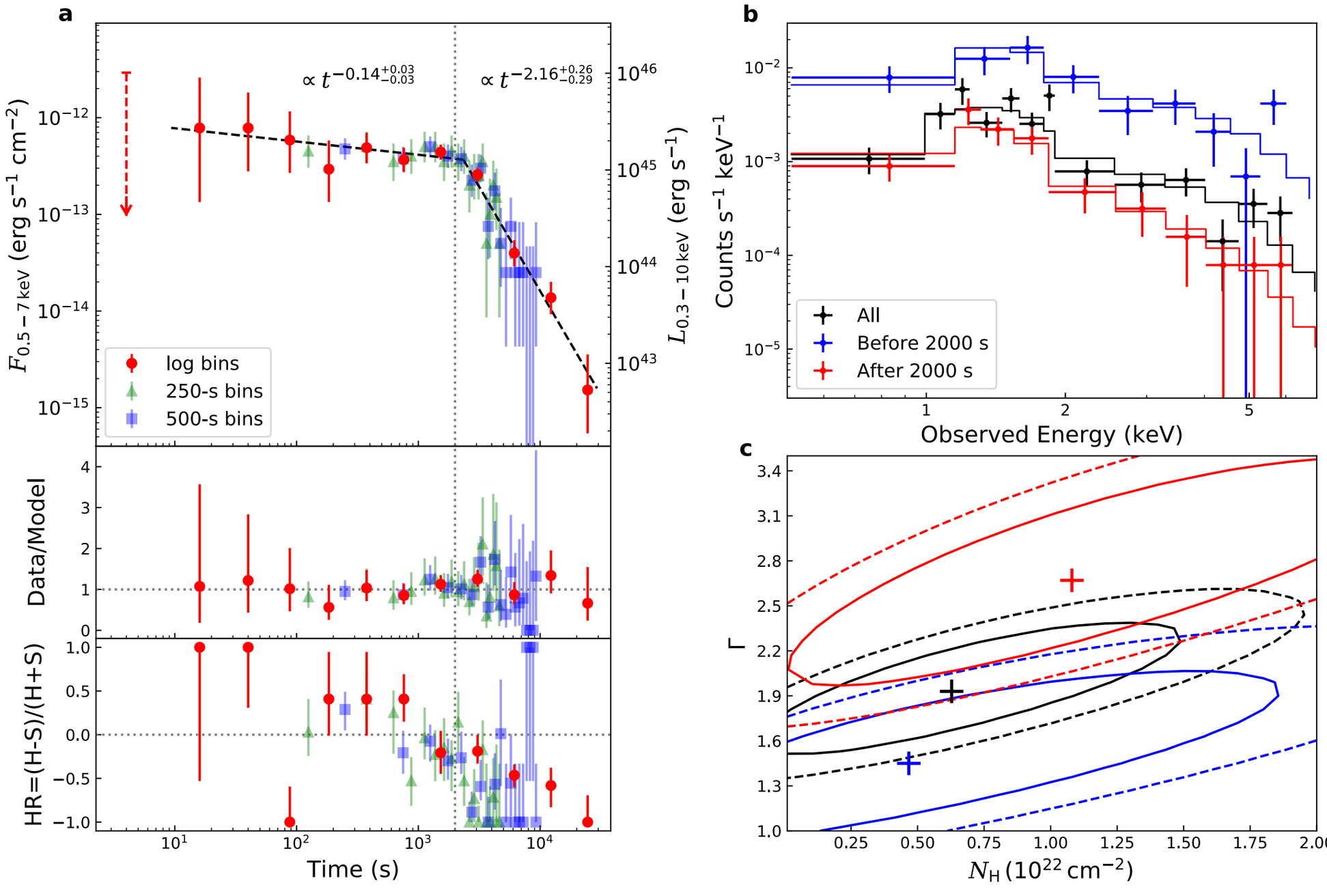
⇒bright X-ray transients lasting for order of thousand seconds

Important: (1) EM counterparts to GW events; (2) EoS of dense matter

CDF-S XT2

❖ Special light curve: a plateau of 2 ks followed by a steep decay of index ~ -2.0

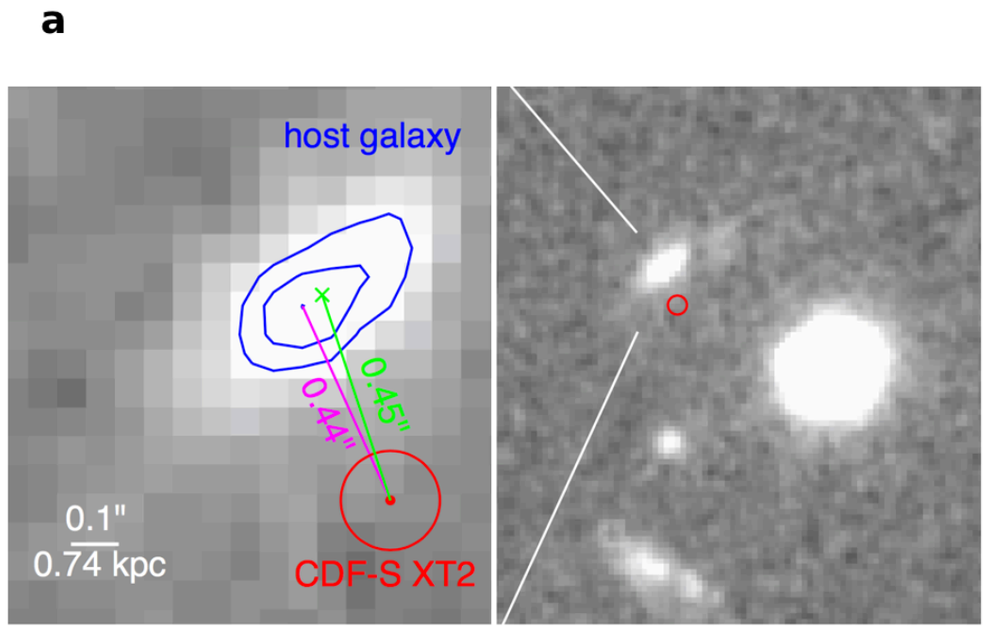
Xue et al. 2019, Nature

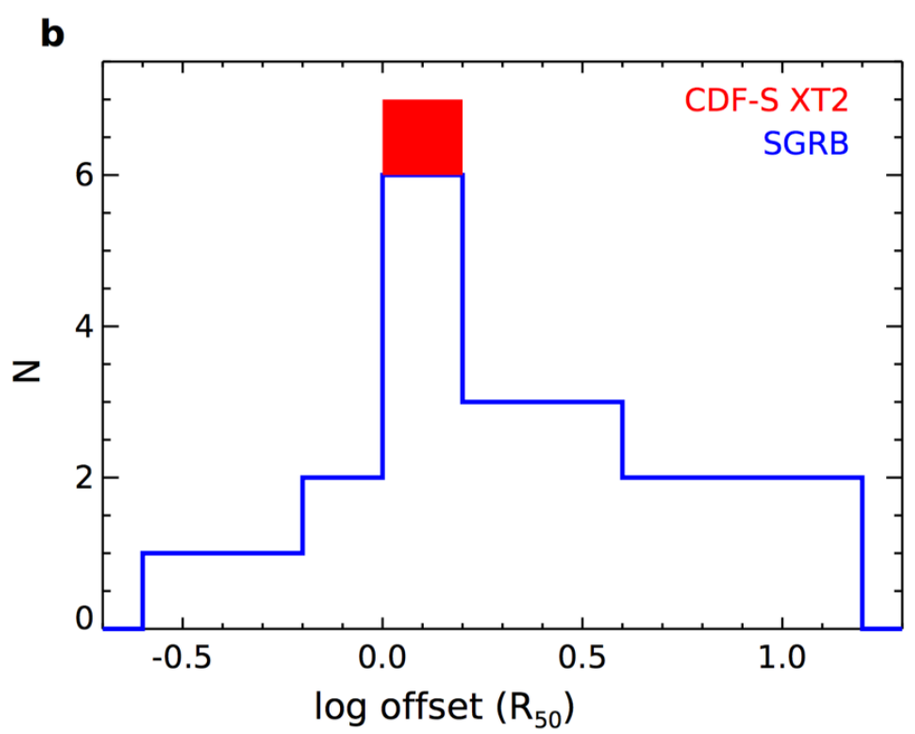


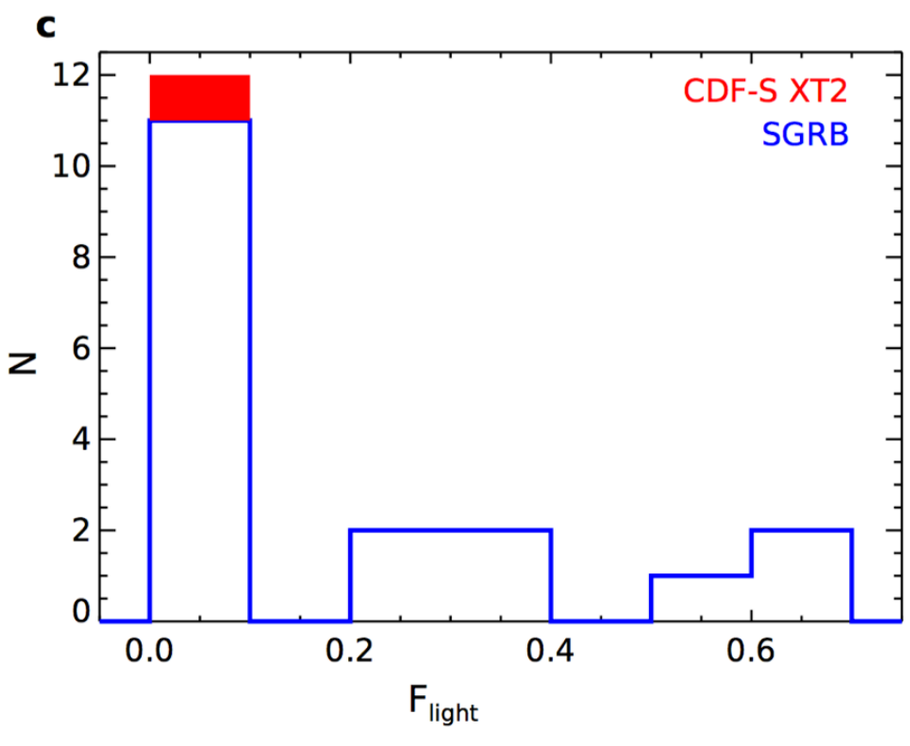
CDF-S XT2

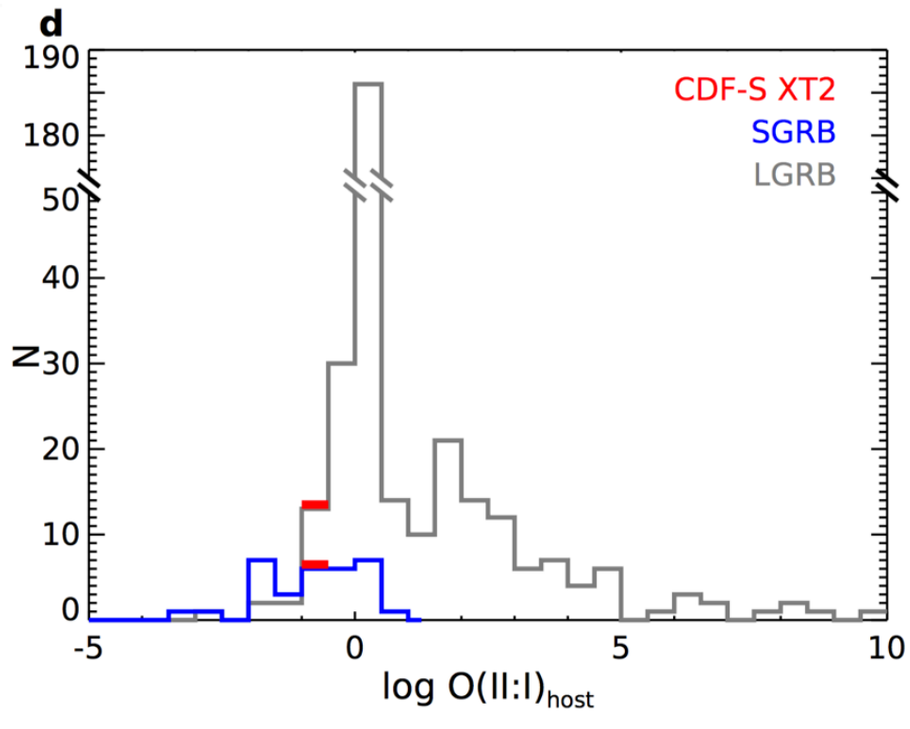
Host-galaxy related properties similar to most short GRBs

Redshift at 0.738

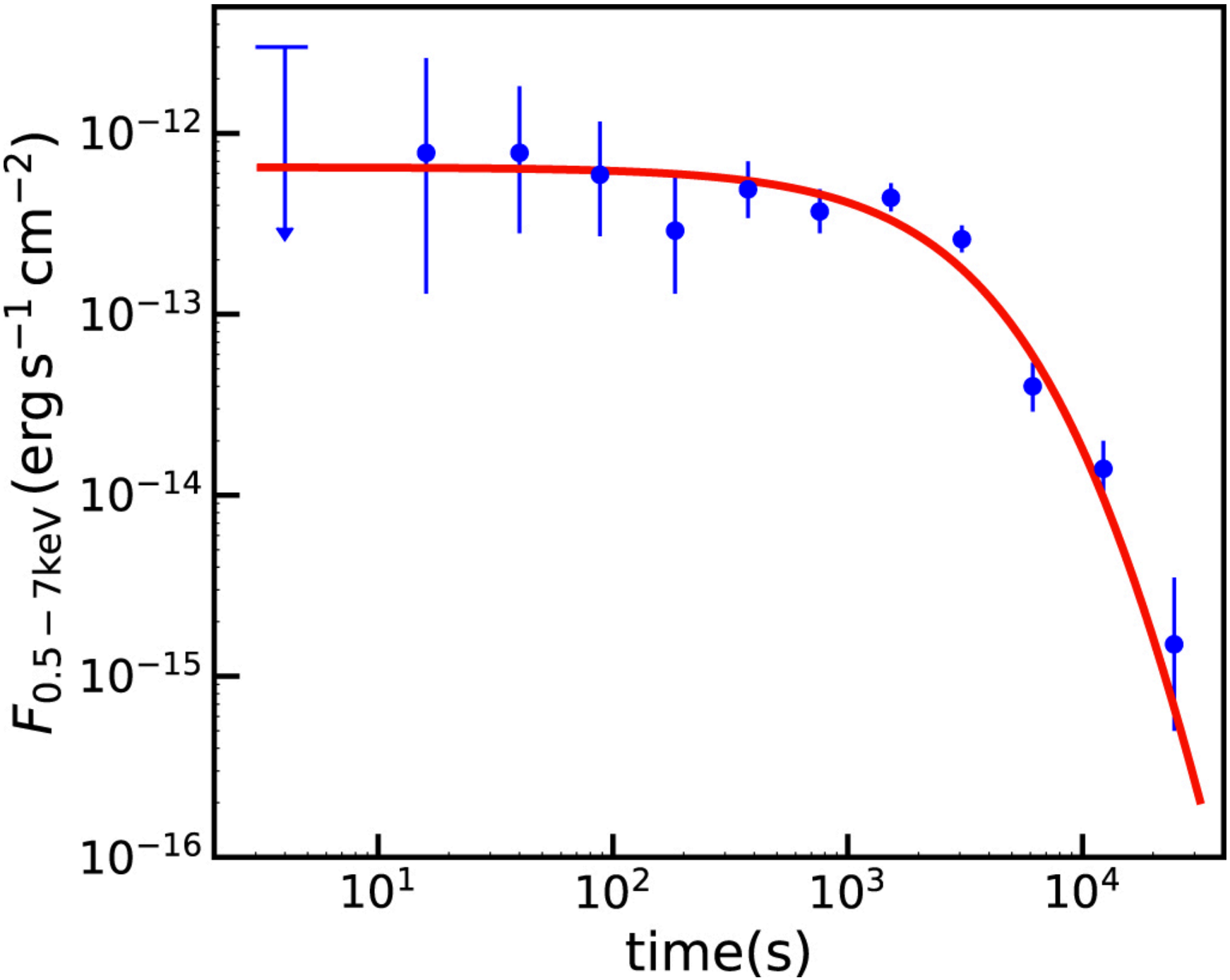








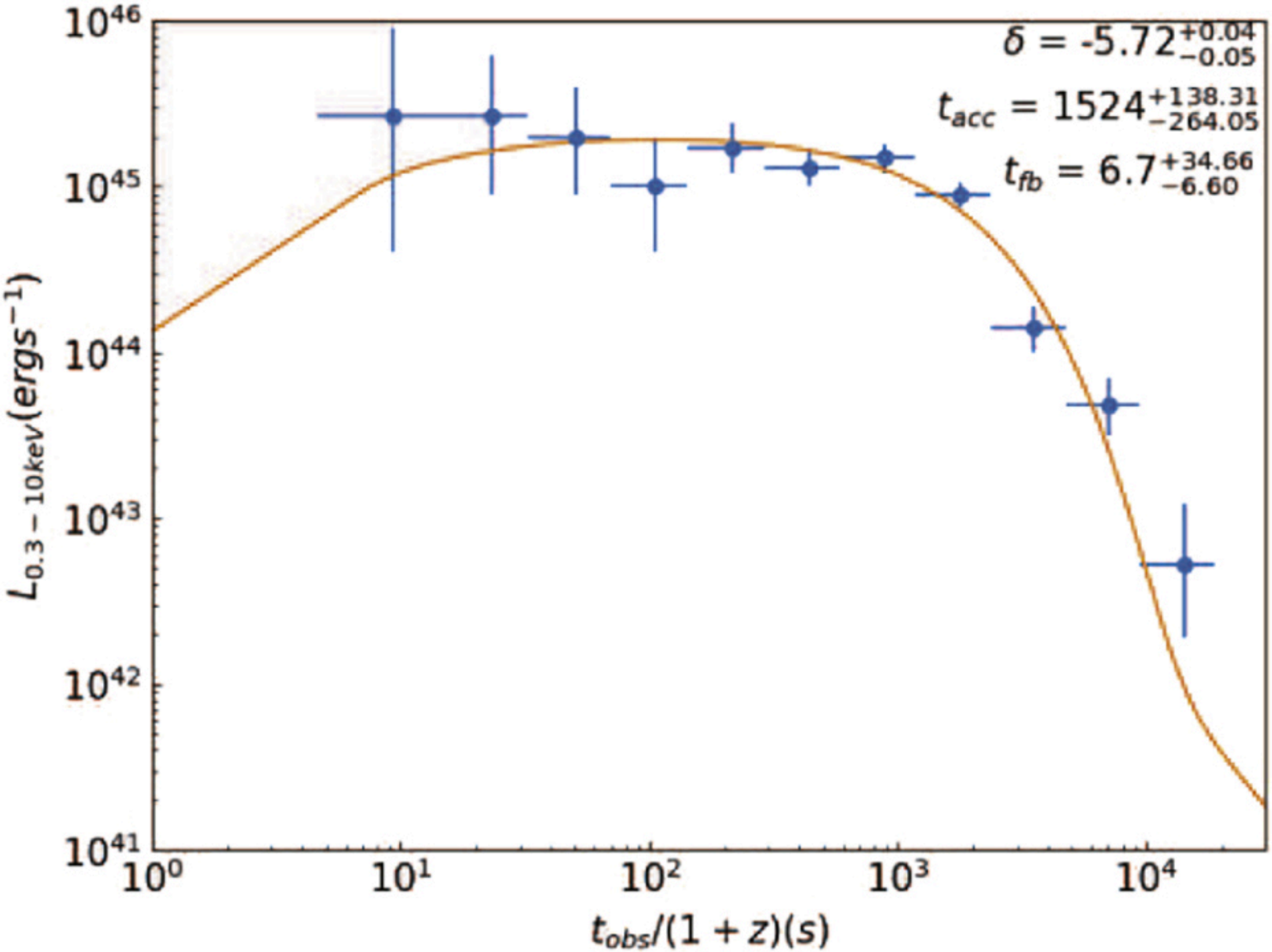
Explanations: proto-magnetar from BNS merger



Xiao et al. 2019

Explanations: white dwarf TDE by IMBH

White dwarf tidal disruption event by intermediate-mass black hole

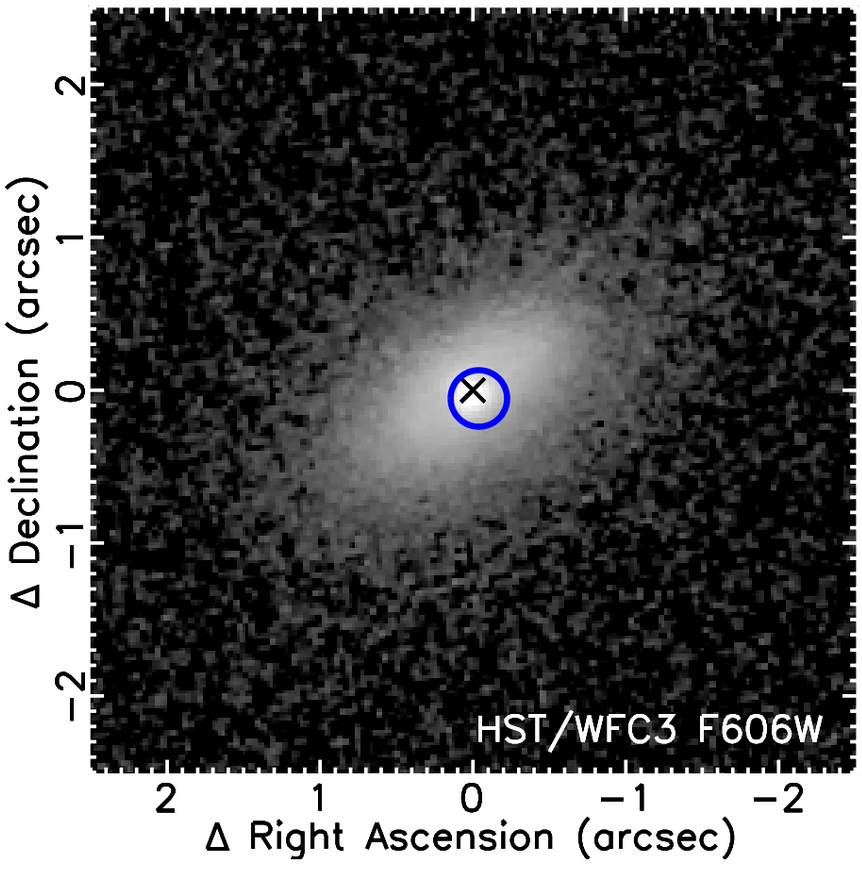


Xiao et al. 2019

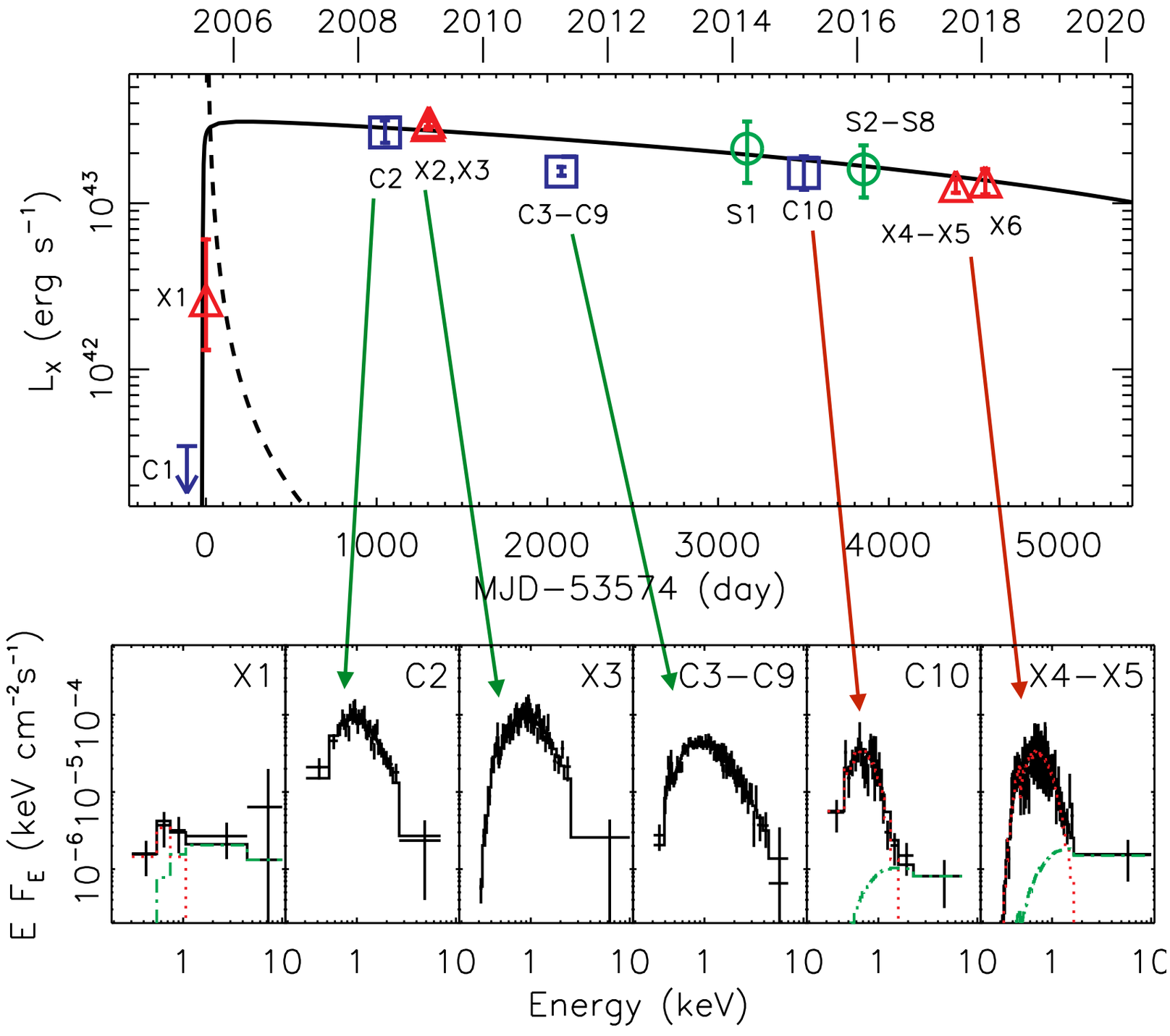
Mining Chandra archival data

Mining Chandra Archival Data

A decade-long super-Eddington accreting tidal disruption event



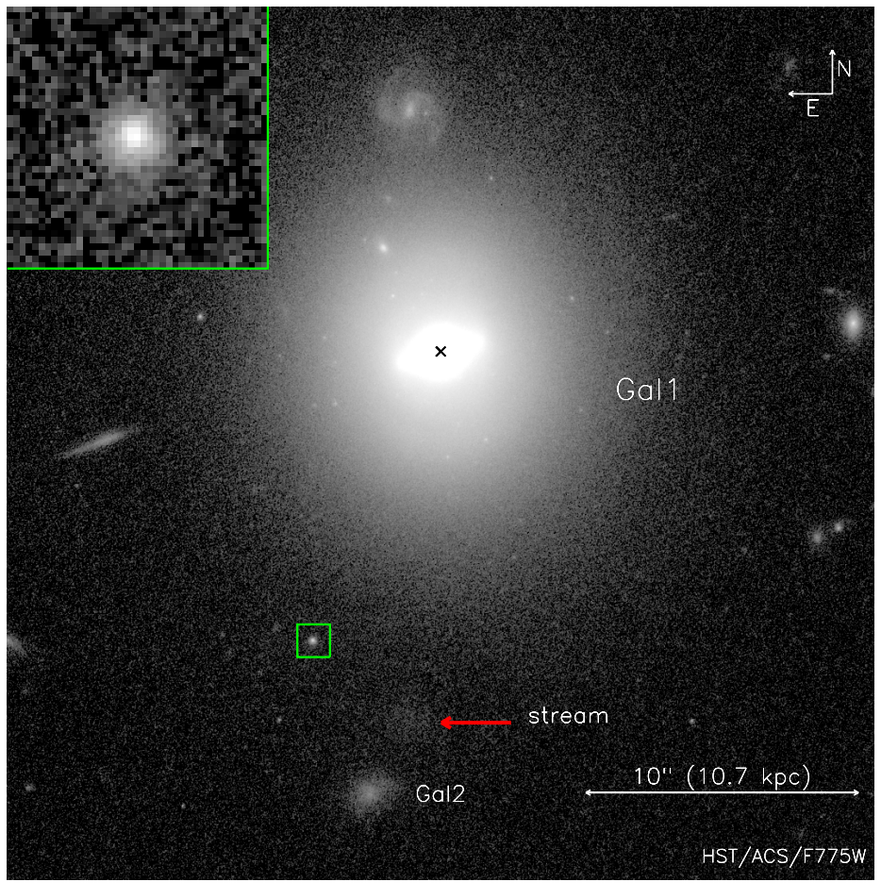
circle: Chandra X-ray 95% positional error, radius 0.18″ or 0.5 kpc)

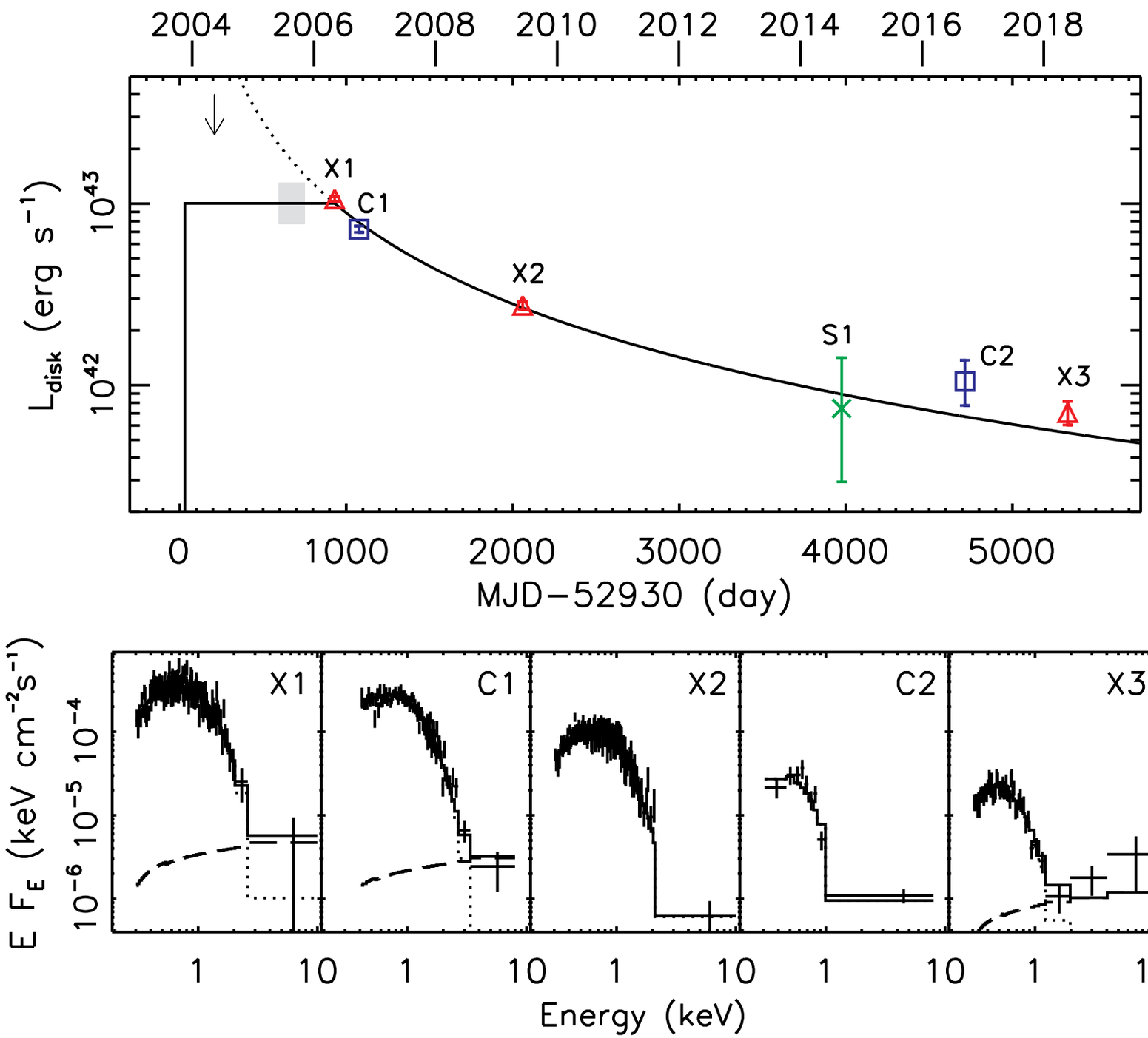


Lin, et al. 2017, Nature Astronomy, 1, 33

Mining Chandra Archival Data

An off-center intermediate-mass black hole tidal disruption event





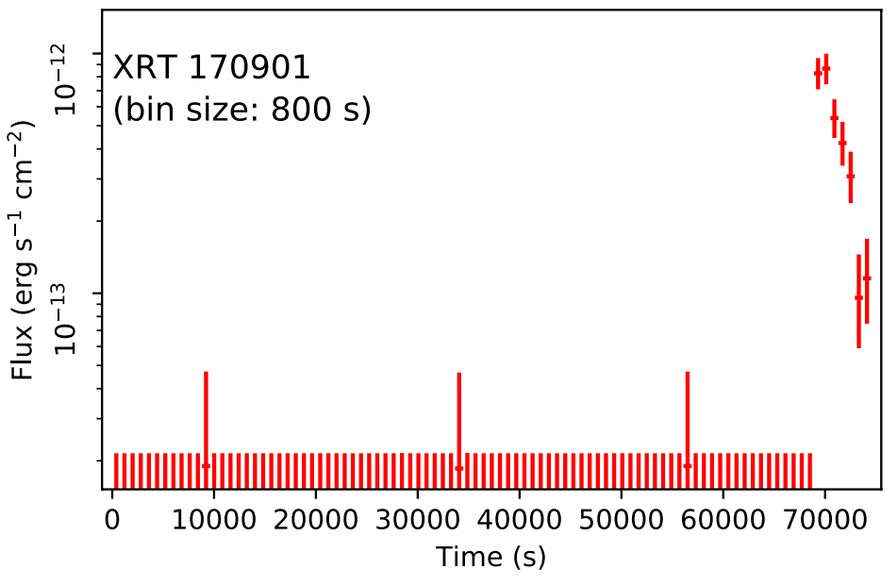
Lin, et al. 2018, Nature Astronomy, 1, 656

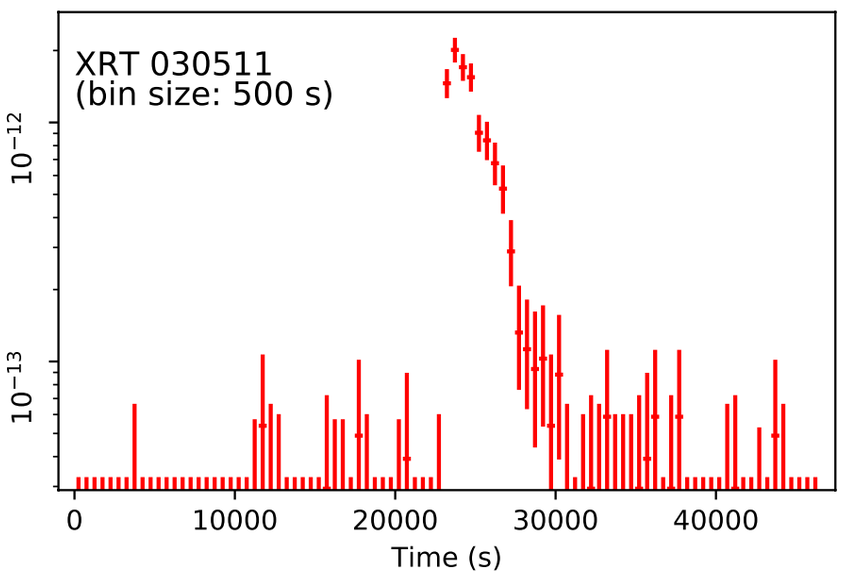
Three new FXTs from Chandra archival data

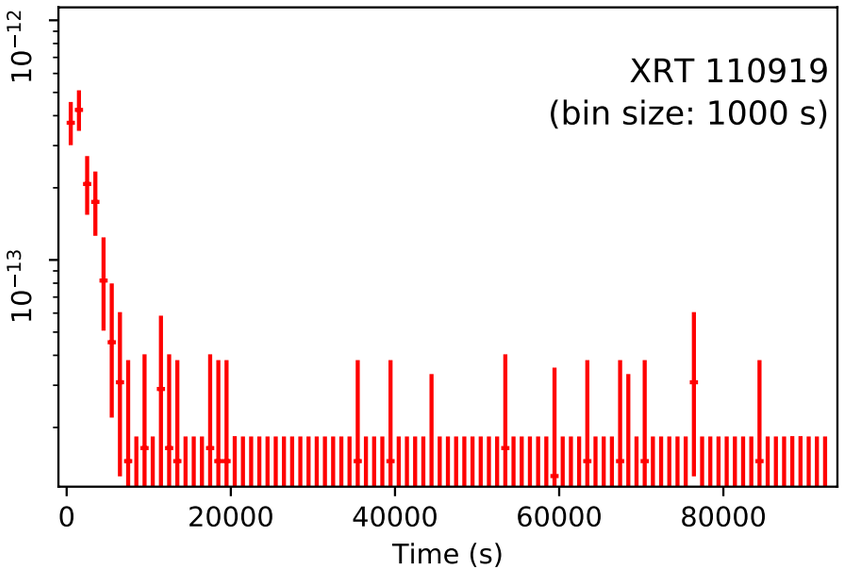
(Lin et al. 2019, in preparation)

Three new FXTs from Chandra archival search

Light curves





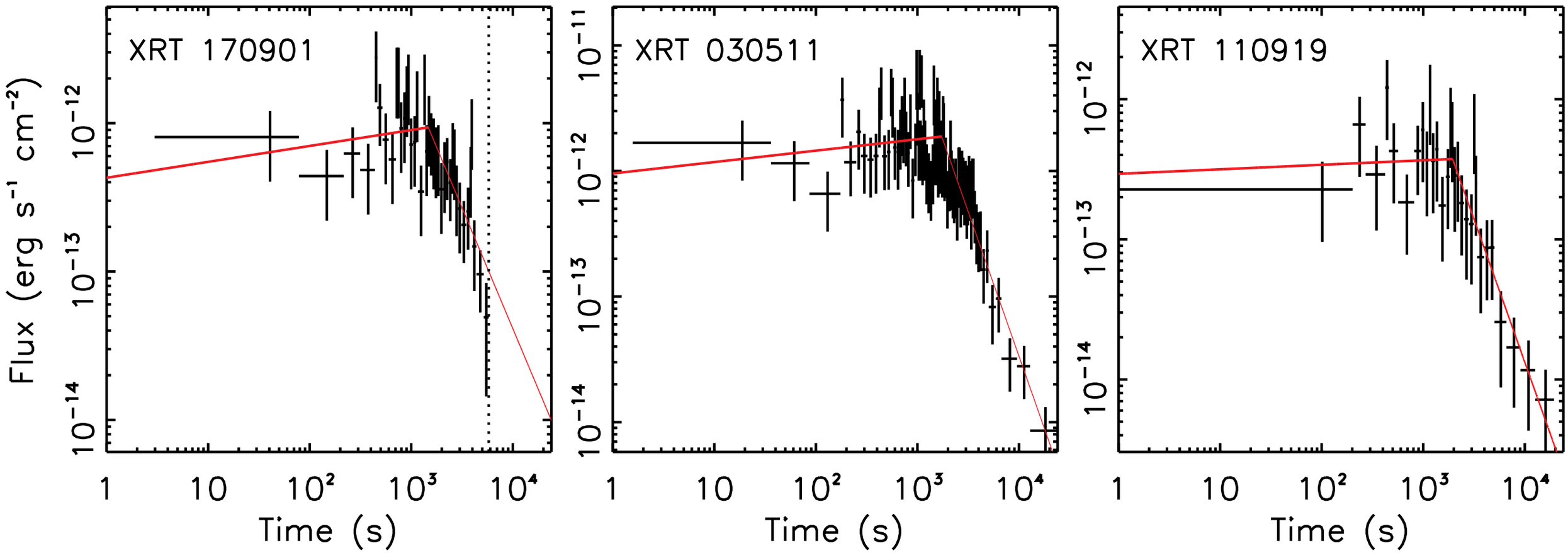


$\frac{\text{peak}}{\text{quiescence}}$	> 400	> 300	> 100

- Large amplitude flare (factor >100)
- Fast rise (<few ten seconds)
- No quiescence emission
- Faint (peak X-ray flux $\sim 10^{-12}$ erg s^{-1} cm^{-2})
- Non-recurrent
- No GRB association

Three new FXTs from Chandra archival search

Light curve fitted with broken power law

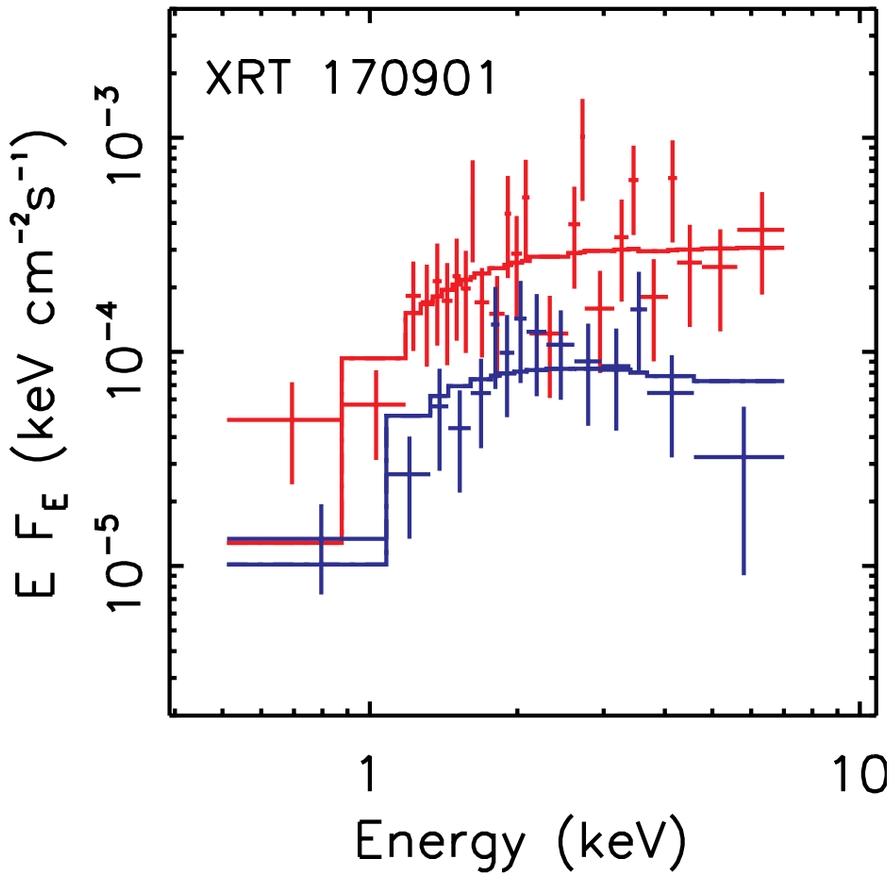


Initial index:	$0.1^{+0.3}_{-0.1}$	0.1 ± 0.1	0.0 ± 0.2
Break (ks):	$1.5^{+0.3}_{-0.6}$	1.7 ± 0.1	1.9 ± 0.3
Second index:	$-1.6^{+0.5}_{-0.4}$	-2.3 ± 0.2	-2.0 ± 0.3

❖ Initial plateau (index ~ 0), break at ~ 1.7 ks, and steep decay (index ~ -2.0)

Three new FXTs from Chandra archival search

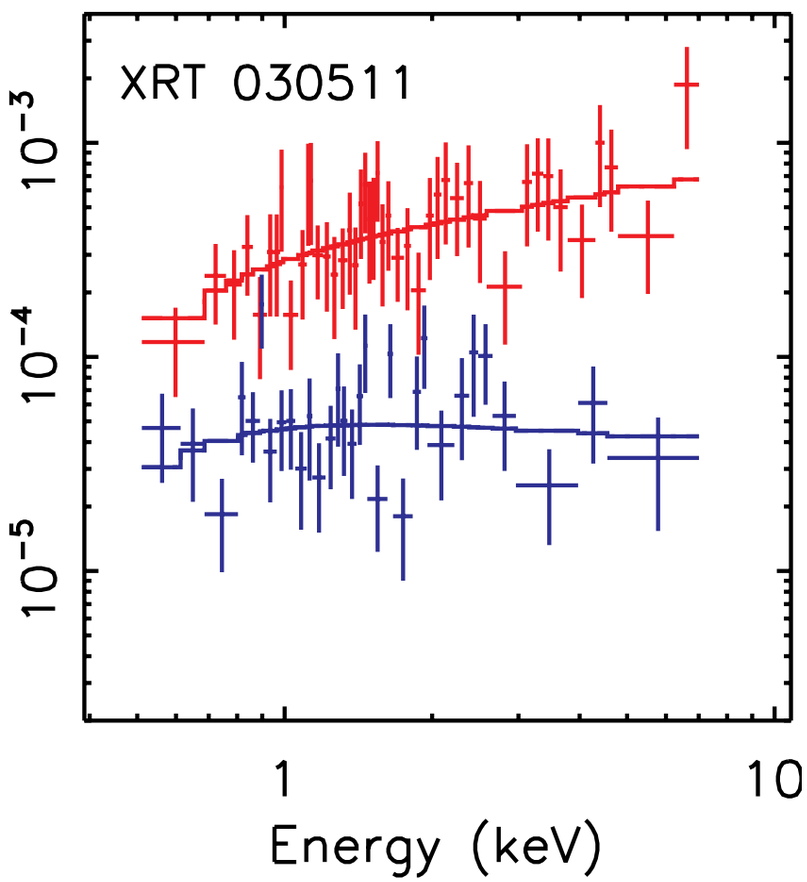
Fits to X-ray spectra in peak and decay



$N_{\rm H,i} = 4.4 \pm 2.0 \times 10^{22}$ cm^{-2}

Plateau $\Gamma = 2.0 \pm 0.2$

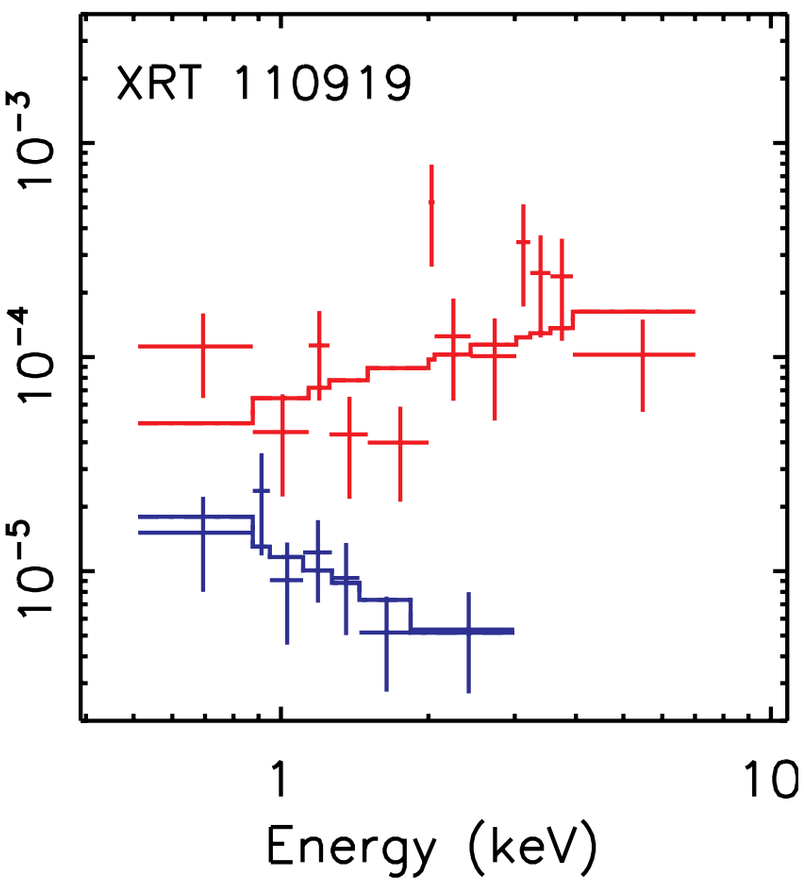
Decay $\Gamma = 2.3 \pm 0.3$



$N_{\rm H,i} = 0.4^{+0.7}_{-0.4} \times 10^{22}$ cm^{-2}

Plateau $\Gamma = 1.6 \pm 0.2$

Decay $\Gamma = 2.1 \pm 0.3$



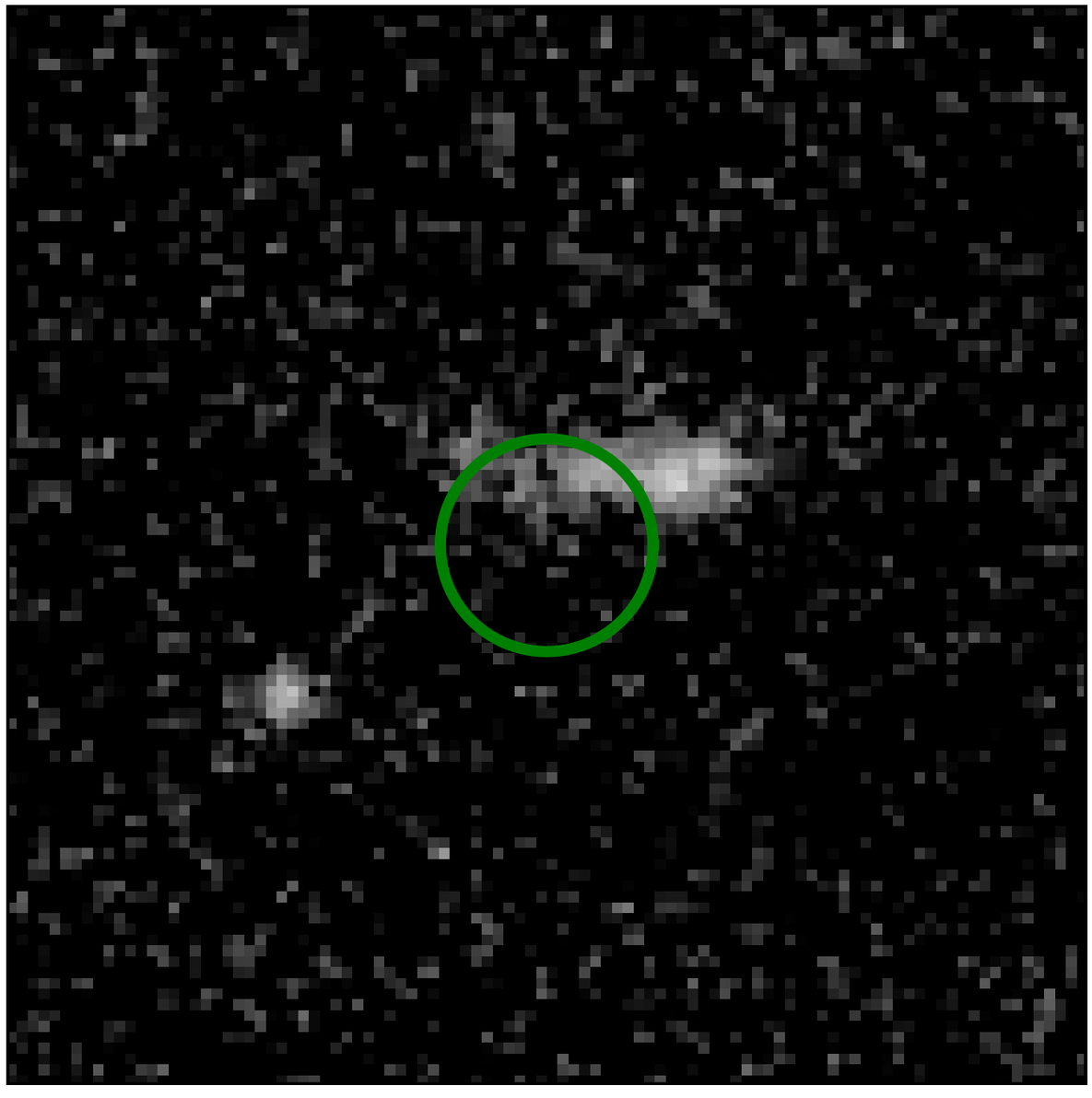
$N_{\rm H,i} = 0.0^{+0.4} \times 10^{22}$ cm^{-2}

Plateau $\Gamma = 1.5 \pm 0.3$

Decay $\Gamma = 3.1 \pm 0.4$

❖ Hard spectra in plateau and softening in decay

Three new FXTs from Chandra archival search



XRT 170901 HST F606W image

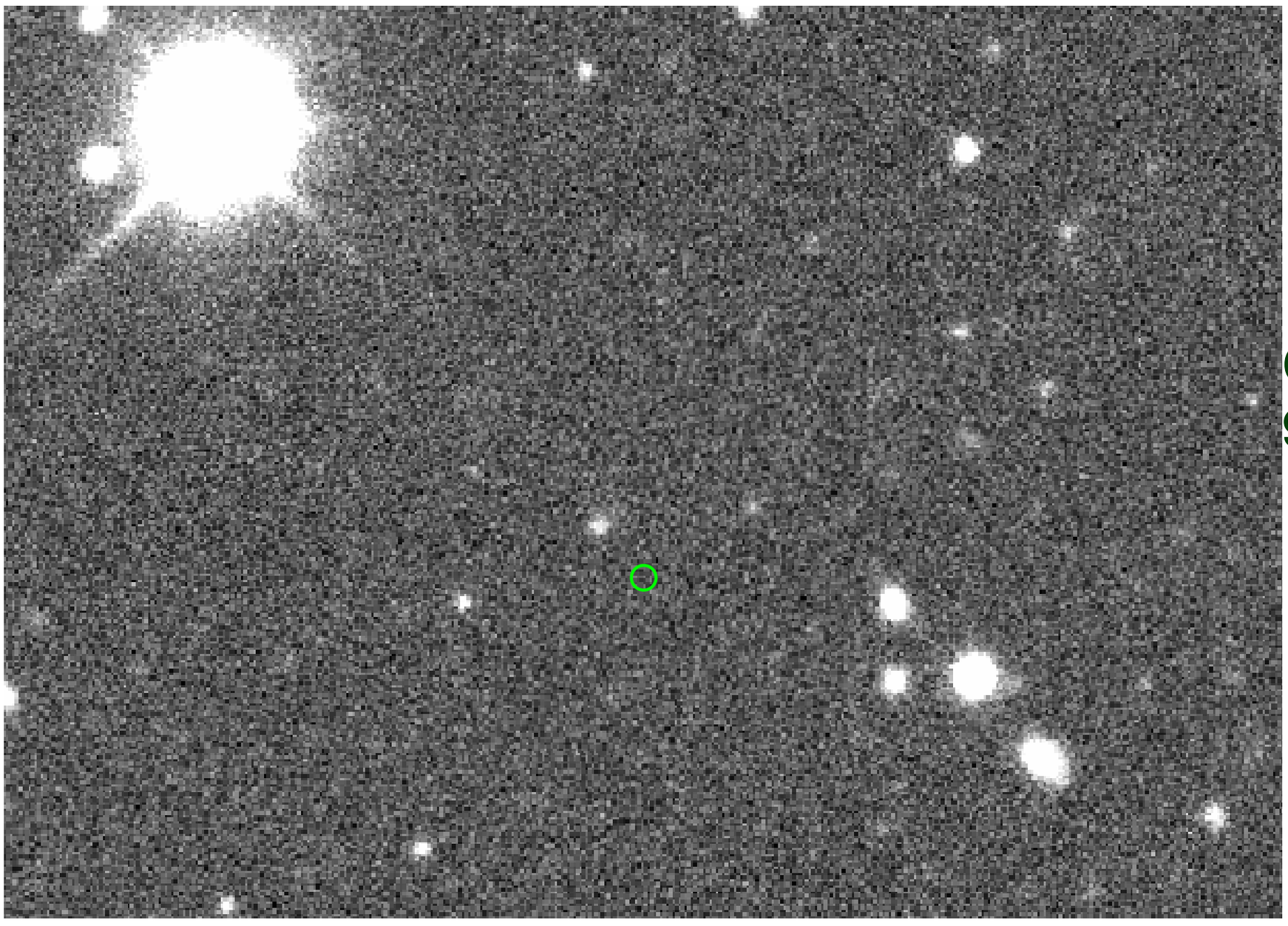
Green circle: Chandra 95% positional uncertainty

❖ A blue irregular host galaxy

F606W: 24.92 AB mag, F160W: 24.69 AB mag

Three new FXTs from Chandra archival search

XRT 030511 DES r image

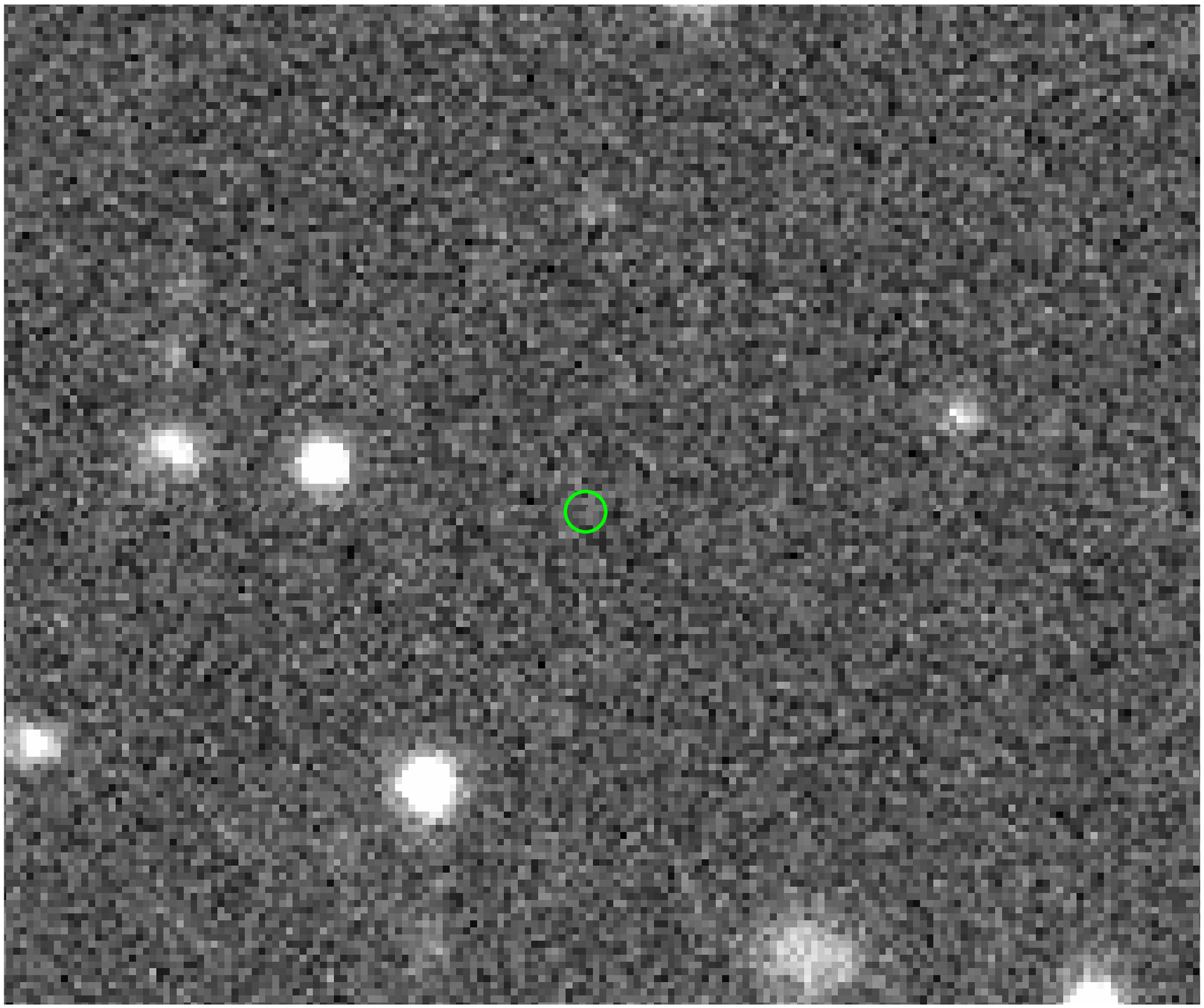


Green circle: Chandra
95% positional uncertainty

❖ No counterpart (r limit: 24.0 AB mag, J limit 20.4 mag)

Three new FXTs from Chandra archival search

XRT 110919 DES r image



Green circle: Chandra
95% positional uncertainty

❖ No counterpart (r limit: 24.0 AB mag, J limit 20.6 mag)

Explanations:

- Magnetar-powered FXTs as aftermath of BNS mergers
- White Dwarf TDEs by IMBHs
- Very distant on-axis GRBs afterglow (very unlikely: no prompt emission)
- Galactic Stellar flares (very unlikely: no counterpart, not recurrent)

Comments? Dacheng.Lin@unh.edu