The legacy of the *Swift* Supergiant Fast X-ray Transients Project

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Supergiant Fast X-ray Transients: basics

- HMXBs with OB SG companions
- Hard X-ray outbursts

(Smith+ 2004, Sguera+ 2005, Negueruela+ 2006)

-lasting 0.5-few hours
-luminosity increases by 3-6 orders of mag (up to ~ 10^{38} erg s^{-1}) cfr. classical 10-50
- spectra ~ NS HMXBs (Abs PL+ expo cutoffs)

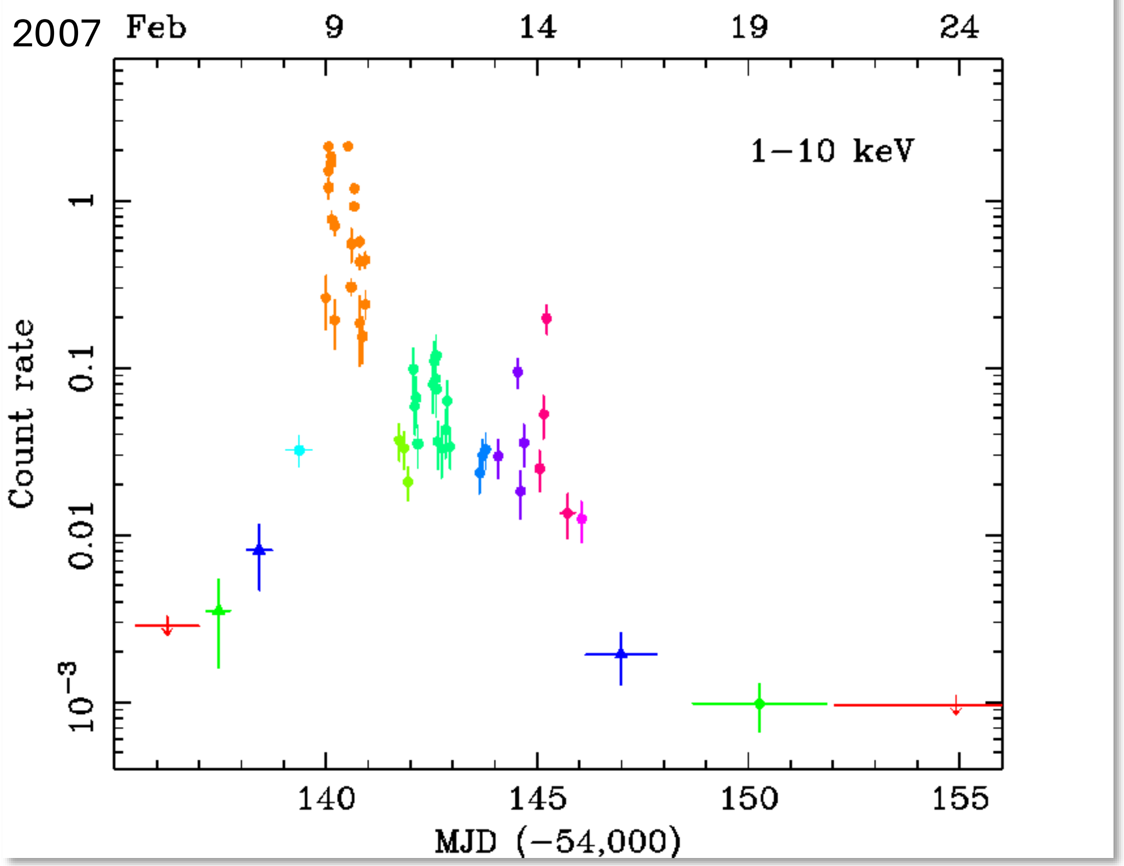
- Some pulsars ($P_{spin} < 10^3$ s), prob. NSs;
- P_{orb}~ 3-50d
- Most X-ray emission from wind accretion

1. Outburst mechanism?
2. Why/How do SFXTs differ from classical HMXBs?

- Wind properties (clumps) (In't Zand 2005; Negueruela+ 2008; Walter & Zurita Heras 2007; Sidoli+ 2007; Chaty 2013)
- Centrifugal/magnetic gating (Grebenev+2007; Bozzo+2008; Ducci+ 2010; Lutovinov+ 2013)
- Quasi-Spherical accretion/subsonic settling accretion (Shakura+ 2012; 14...)

Highlights: outburst length, orbital period

IGR J11215-5952



(Romano+ 2007, A&A, 469, L5)

(Sidoli+ 2007, A&A, 476, 1307)

(Romano+ 2009, ApJ, 696, 2068)

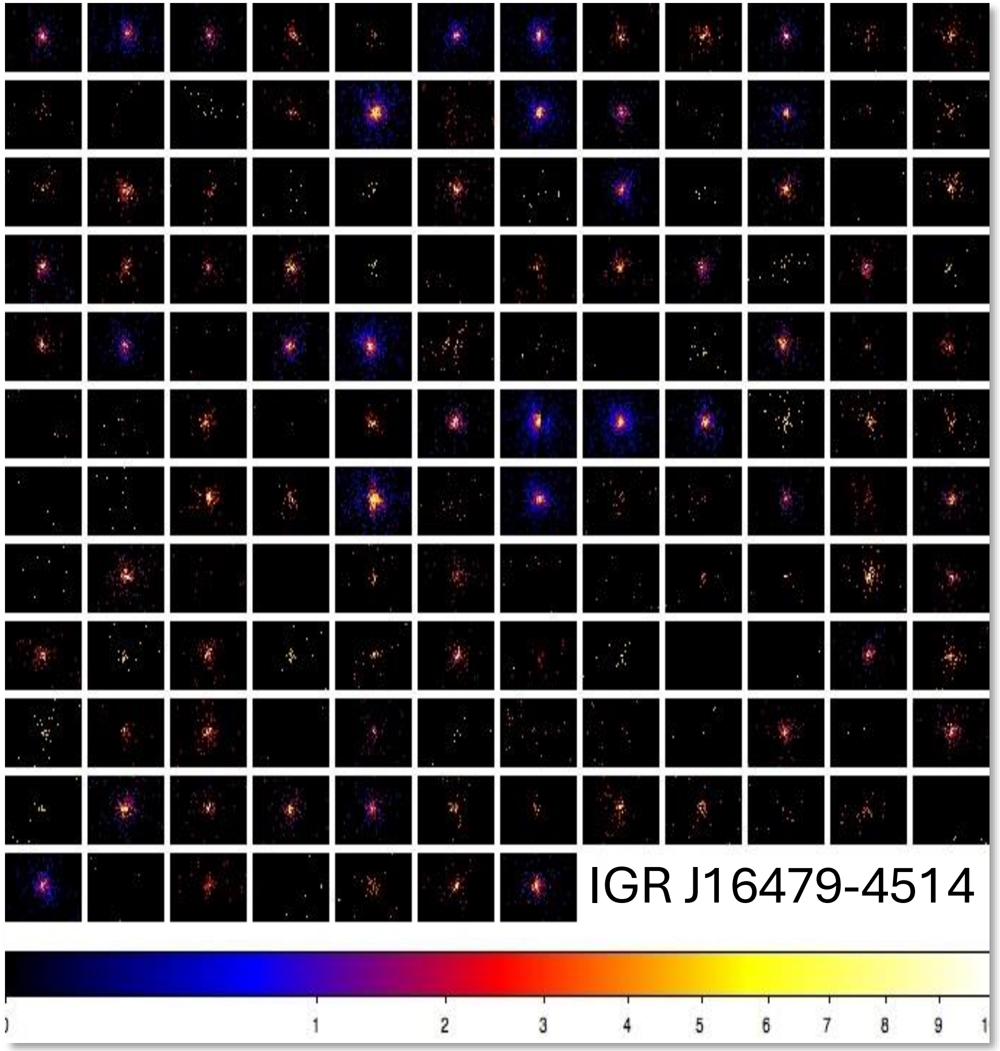
- Below detectability L(1-10)= 3.7×10^{33} erg s^{-1}
- Slow rise
- Outburst (1day)
  CR increase by ~10 in <1.5 h
  by ~65 in 17 h
  L(1-10)= 1.1×10^{36} erg s^{-1}
- decline phase (5d)
- down to (15 d) L(1-10)= 1.2×10^{33} erg s^{-1}

SFXT Lx~10^{36} erg s^{-1}
dynamic range ~10^3 + hard spectrum

3 WEEKS, NOT 3 HOURS!

P_{orb} = 164.6d from *Swift*/XRT!

Highlights: the *Swift* monitoring campaigns



First sample: **4 confirmed SFXTs** (/8 known)

IGR J16479-4514	144 obs/161 ks
XTE J1739-302	184 obs/206 ks
IGR J17544-2619	142 obs/143 ks
AX J1841.0-0536	88 obs/96 ks (2008)

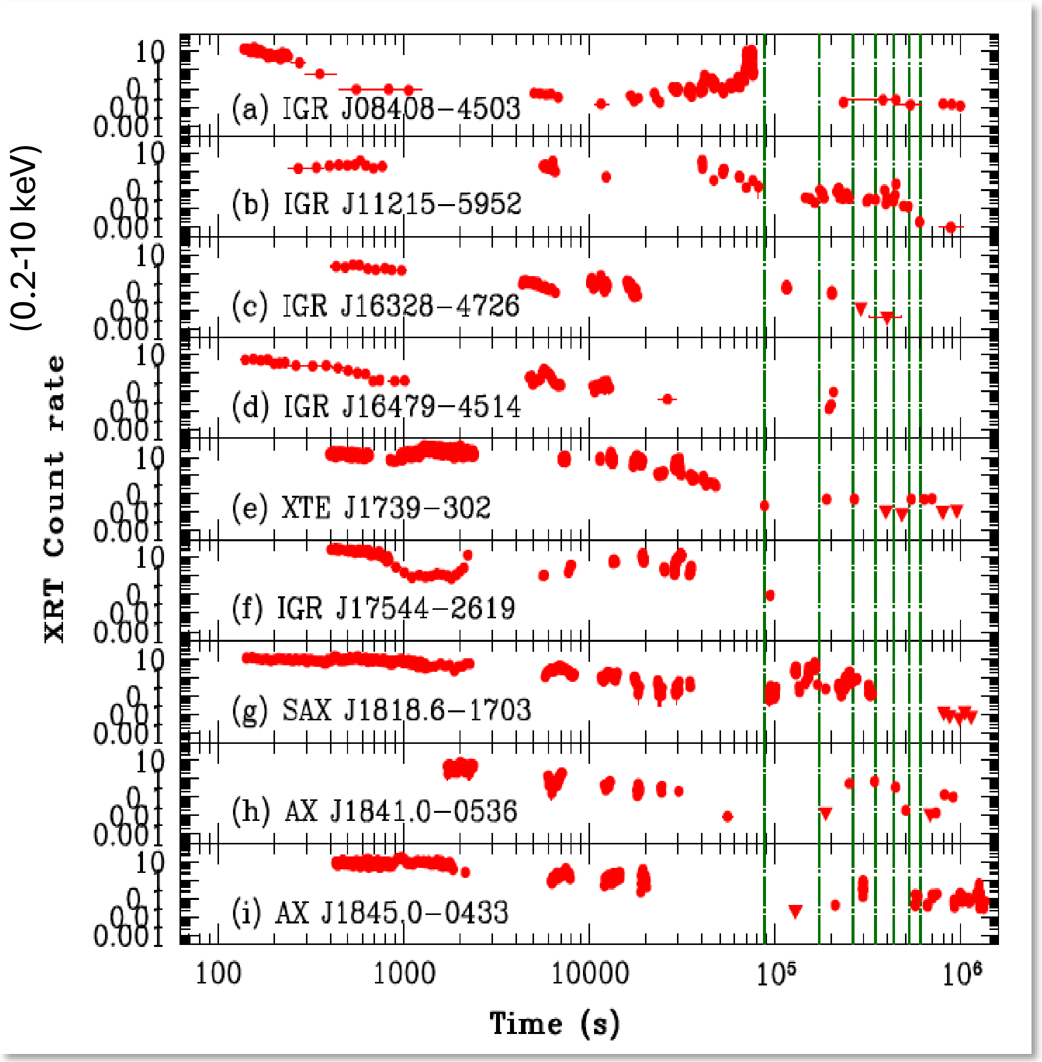
Total Exposure 606 ks / 558 observations

2 or 3 obs /source/week, 1 ks each (Oct 2007 – Nov 2009)
BAT Special Functions

- **catch outbursts** & follow them until source undetected
- **monitor long term properties** (1st time) and quiescence

(Romano+2008, ApJ, 680, L137)
(Sidoli+2008, ApJ, 687, 1230)
(Romano+2009, MNRAS, 399, 2021)
(Romano+2011, MNRAS, 410, 1825)
(Romano+2014, A&A, 568, A55)

Highlights: *Swift* lightcurves of outbursts

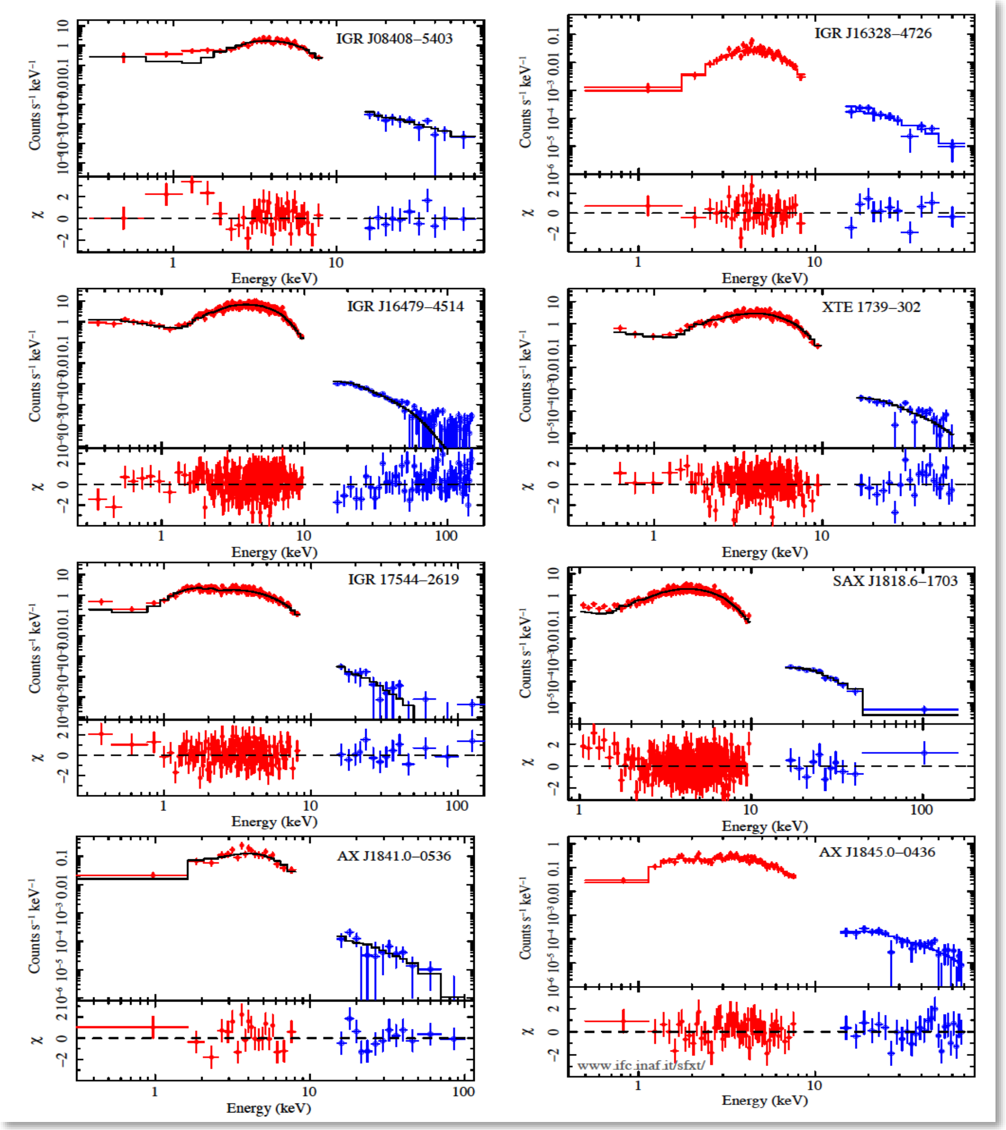


(Romano, 2015, JHEAP, 7,126)

Common features:

- outburst length > hours
- multiple peaked structure
- dynamic range ~ 3 oom

Highlights: *Swift* spectroscopy of outbursts



(Romano, 2015, JHEAP, 7,126)

Simultaneous broad-band spectroscopy during outburst (Romano+2008, ApJ, 680, L137)

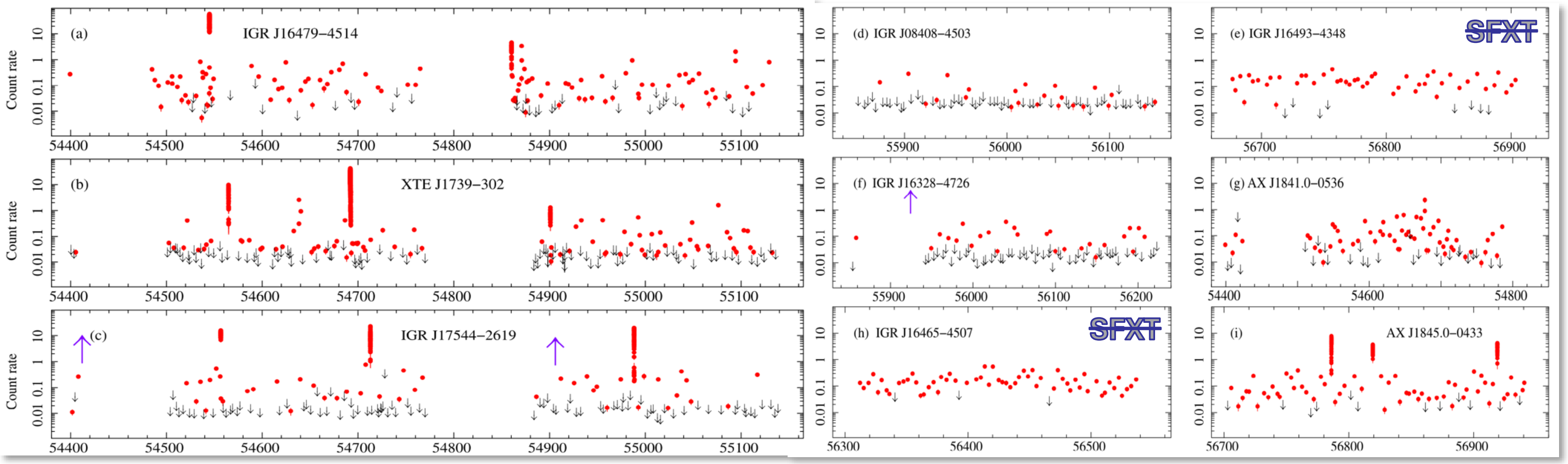
XRT+BAT: **0.3-10** keV + **15-150** keV

- absorption & spectral cut-off
- comparison with models for accreting NS

Motivated physical model, *compmag* in XSPEC which includes thermal and bulk Comptonization for cylindrical accretion onto a magnetized neutron star

(Farinelli+2012, A&A, 538, A67) (Farinelli+2012, MNRAS, 424, 2854) (Ducci+2013, A&A, 631, A135)

Highlights: monitoring campaigns

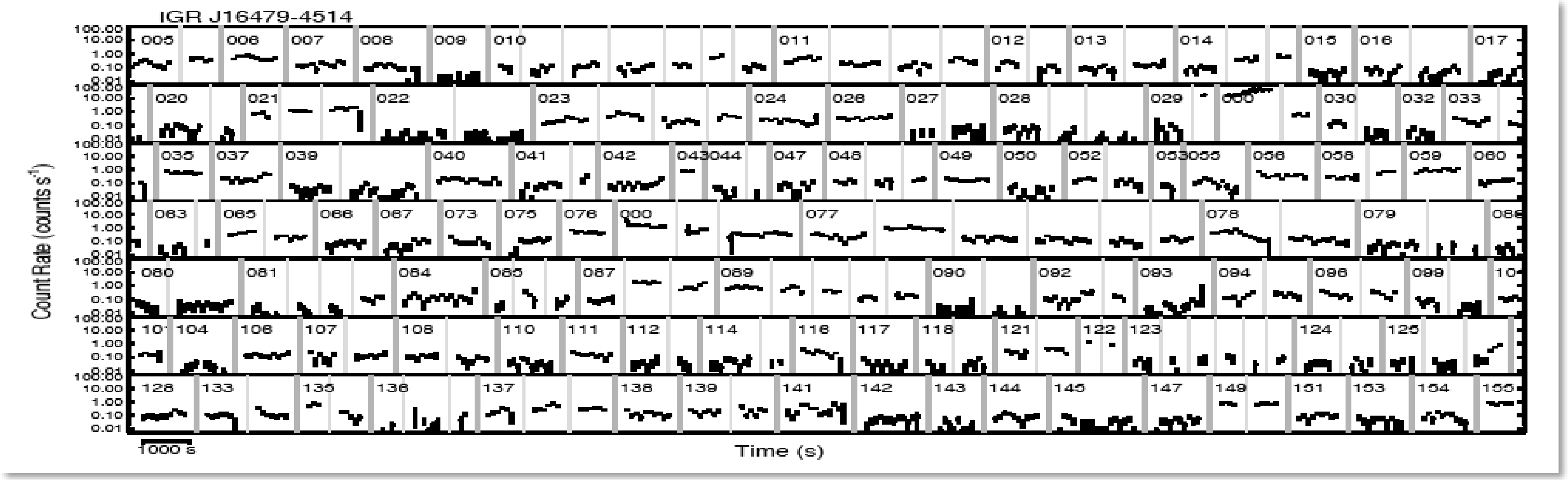


Daily resolution

- Bright outbursts
- DR: 4-5 oom

(excl. 16465 and 16493)

Emission outside of outbursts



high resolution: PC: 100s, WT 20s

Minute resolution

- Variability all timescales and intensity levels
- Short timescales 1 order of mag. (1 ks, down to 0.1cps)
- **Evidence for clumps**

(Romano+2009, MNRAS, 399, 2021)

(Romano+2011, MNRAS, 410, 1825)

(Romano+2014, A&A, 568, A55)

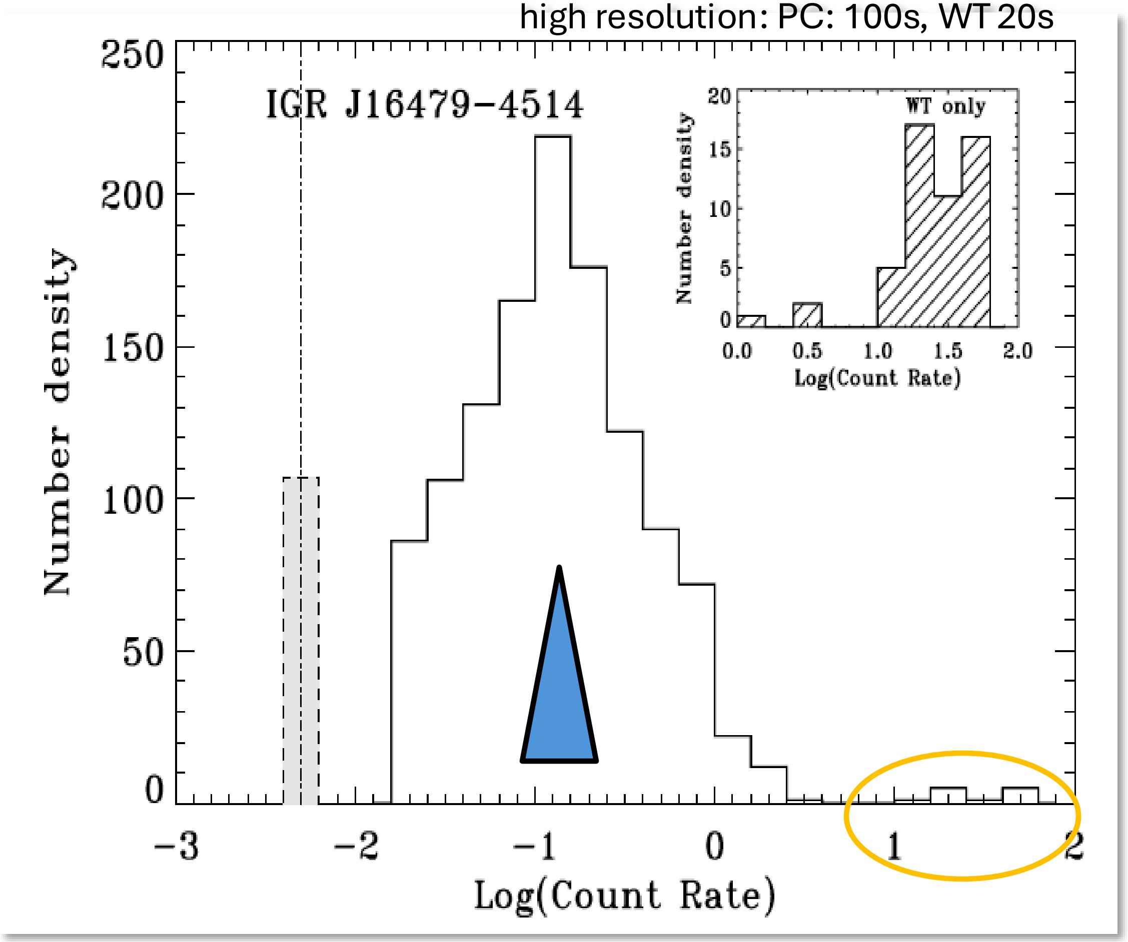
(Romano, 2015, JHEAP, 7,126)

Highlights: *Swift*/XRT detailed light curves

(Romano+2009, MNRAS, 399, 2021)
(Romano+2011, MNRAS, 410, 1825)
(Sidoli+2008, ApJ, 687, 1230)

Count rate distribution

high resolution: PC: 100s, WT 20s



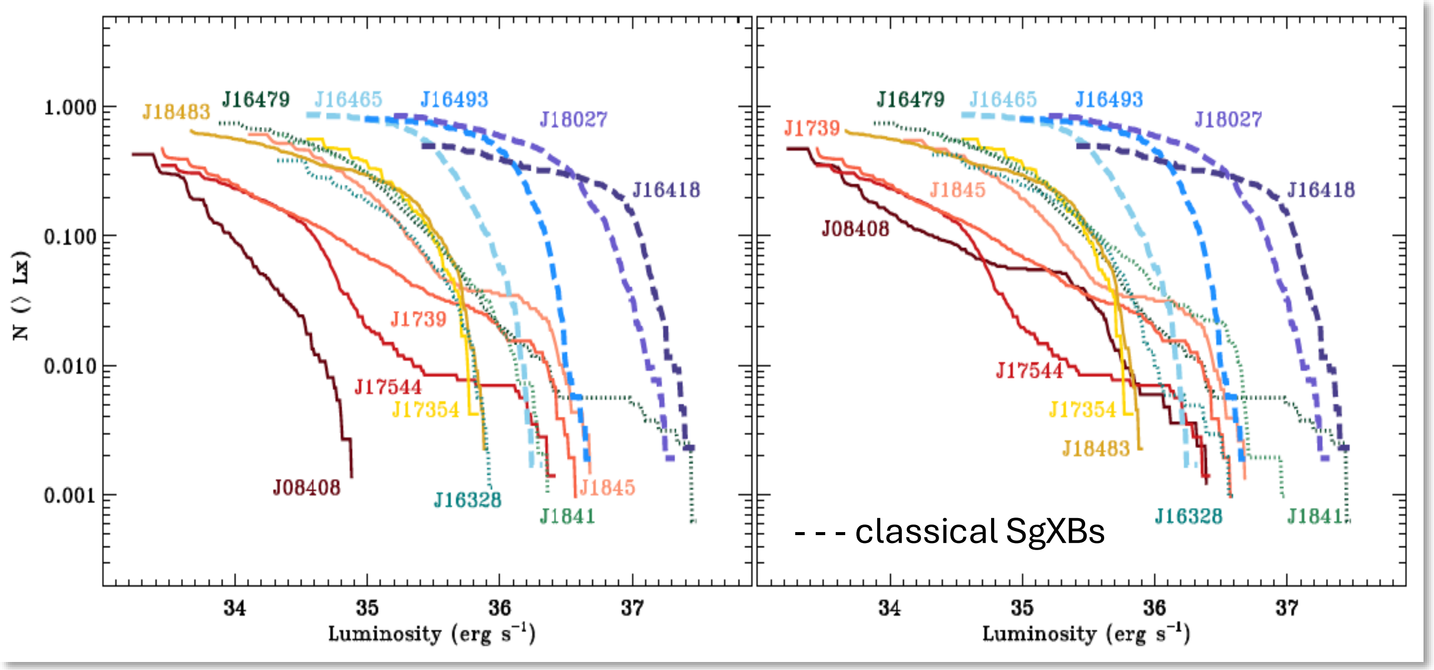
- 3-5% of time spent in bright outbursts
- **Most probable 2-10 keV observed flux: 1-3x10^{-11} erg cm^{-2} s^{-1}**
- **Long term behaviour is not quiescence but intermediate state of accretion** L~10^{33} – 10^{34} erg s^{-1}
- Inactivity Duty Cyle ~19-55 % (vs few% for SgXBs)

SFXTs accrete matter most of the time

Highlights: CLDs

First Cumulative Luminosity Distributions in the soft X-ray

(Bozzo+ 2015, AdSpR, 52, 1593)



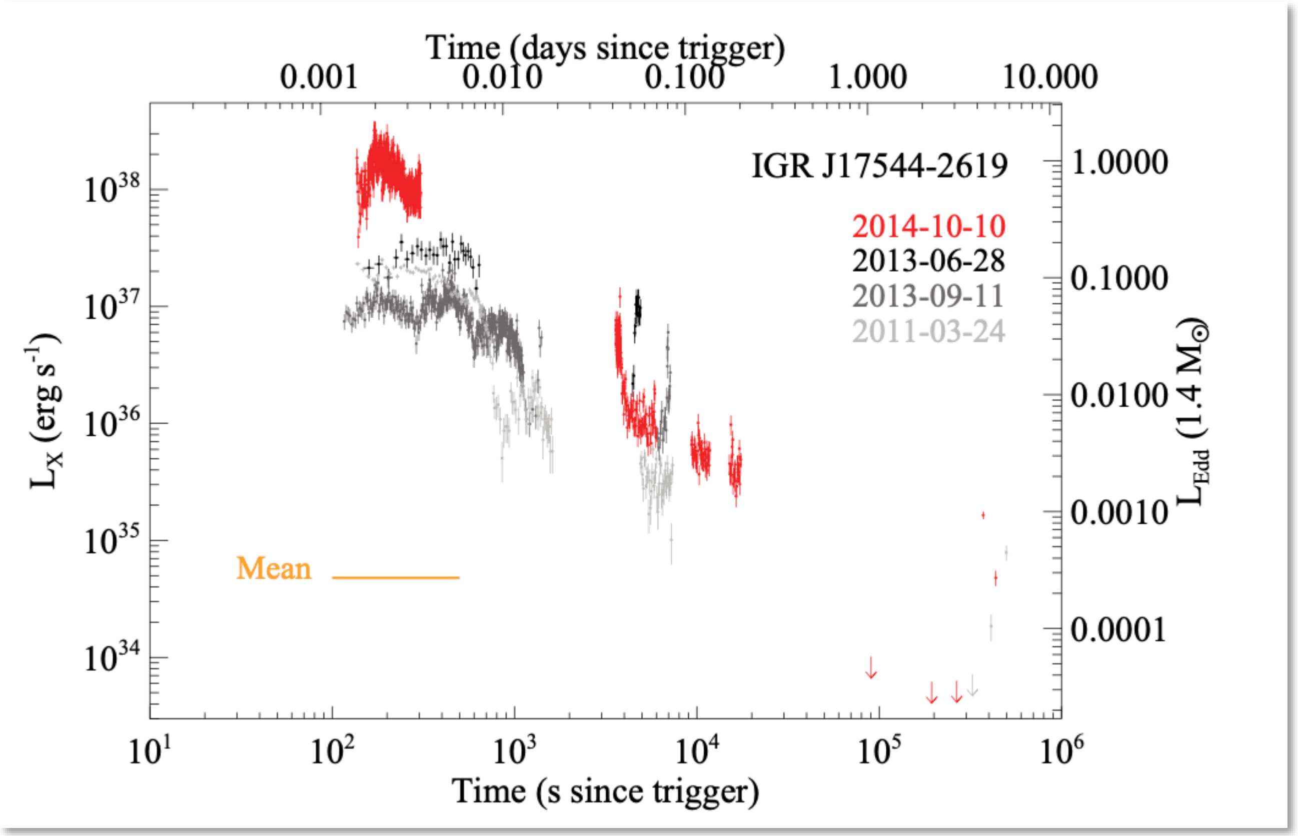
(Romano, 2015, JHEAP, 7,126)

classical SgXBs : single knee around $\sim 10^{36}$-10^{37} erg s^{-1}

SFXTs are systematically sub-luminous
CLDs are shifted at lower luminosities (x ~10-100).

Classical systems: accretion from structured wind
SFXTs: magnetic/centrifugal gates or quasi-spherical settling accretion regimes

Highlights: SFXT Giant Outburst



(Romano+ 2015, A&A, 576, L4)

2014-10-10 **Brightest burst** ever recorded from **IGR J17544-2619**

Peak flux in 0.3–10 keV (668 cps)
~ 10^{-7} erg cm^{-2} s^{-1} ~ 2.1 Crabs
~ 10^{38} erg s^{-1}

Extends dynamic range to 10^6

Formation of a **transient accretion disc** around the compact object

SFXT Cat I

(Romano+2014,A&A, 562, A2)

The 100-month Swift Catalogue of SFXTs - I

- 2005-Feb-12 to 2013-May-31 (MJD 53413– 56443)
- **1117 flare from 11 SFXTs** recorded by BAT
- flux limit 6×10^{-10} erg cm^{-2} s^{-1} (daily) (15-150 keV)
  1.5×10^{-9} erg cm^{-2} s^{-1} (orbital, $\sim$ 800 s)

Results:- Flares short (x100 s), bright (~100 mCrab) events << day length
- Outbursts > day length (clustering in phase)

Applications:

- Estimation of #flares for a given flux
- N(SFXTs) = 37^{+53}_{-22} Where are the rest? (Ducci+ 2014, A&A, 568, A76)

SFXT Cat II

(Romano+2023, A&A, 670, A127)

The 100-month Swift Catalogue of SFXTs – II

Purpose: provide a set of diagnostics to discriminate SFXT candidates from newly discovered X-ray transients

- 2005-Feb-12 to 2014-Dec-31 (MJD 53413– 57022)
- **56 BAT triggers (4 double) from 11 SFXTs**
- **35 with XRT follow-up** (27 due to SFXTs in BAT special list)

1) SFXTs are IMAGE triggers (via GCN)
2) SFXTs are very long transients
3) SFXTs are faint and 'soft' hard-X ray transients
4) Soft X-ray prompt and long-term variability

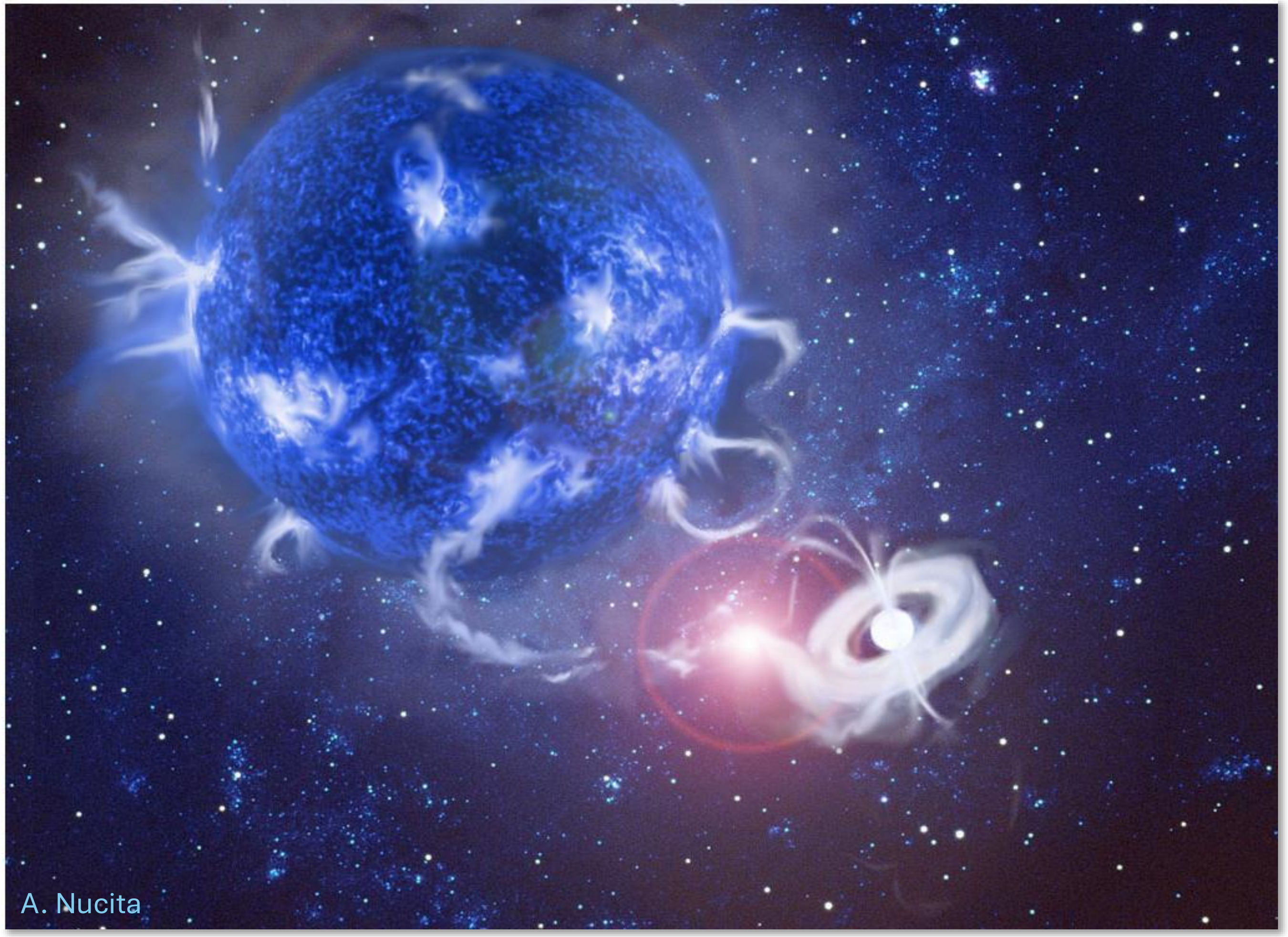
Easy on-board discrimination from GRBs

For other transients one needs BAT ground analysis and XRT data

Summary

- Swift has been a game changer for SFXTs
- First systematic investigation of the long term properties of SFXTs with a sensitive instrument
- The 100-month *Swift* Catalogues
  - I. BAT on-board and transient monitor flares
  - II. SFXT diagnostics from outburst properties
- Coming up: 20yr catalogue!

Thanks!



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Swift SFXT Project
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