

The Enigma of Supergiant Fast X-ray Transients: *Swift* broad-band results

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- HMXB (re)discovered by INTEGRAL:

TRANSIENTS: flares peaking at 10^{36} – 10^{37} erg s⁻¹ lasting hours as observed with IBIS/ISGRI (Sguera+ 2005, 2006)

- flare X-ray spectrum $\sim$ accreting NS

flat power-law below ~ 10 keV + exponential cutoff at 15–30 keV

- a few SFXTs are X-ray pulsars

- large X-ray dynamic range (3–5 oom)

- association with OB supergiant companions

Transient X-ray emission (outbursts shorter than in Be/X-ray binaries) + OB supergiant companion (HMXBs with supergiant were known to be persistent X-ray sources!) make these sources a NEW CLASS of HMXBs

Sidoli 2009 (AdSpR, 43, 1464)

Fast & Panchromatic (~100s):

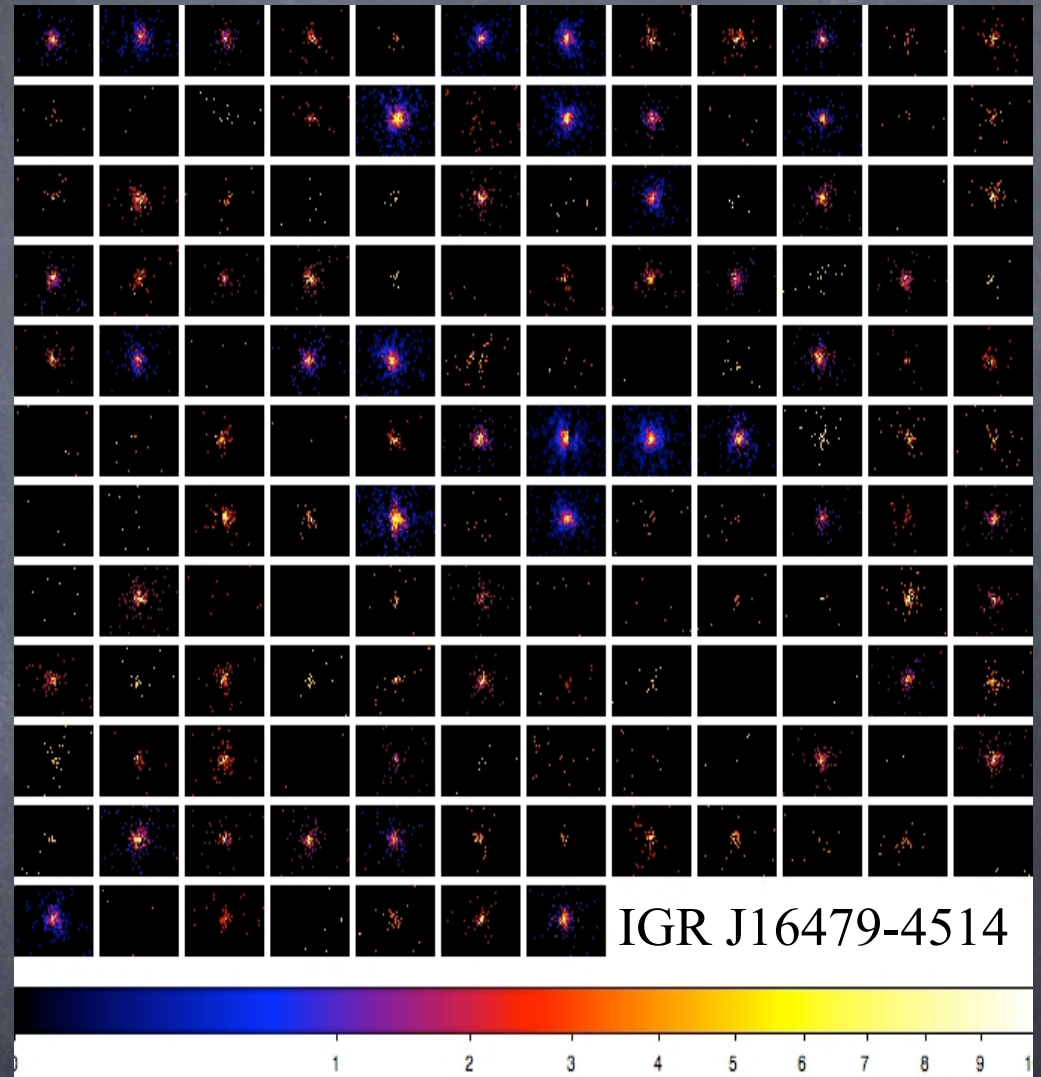
- ✓ true outburst length
- ✓ broad-band spectroscopy

Monitoring program:

non-serendipitous study
in $\neq$ intensity states

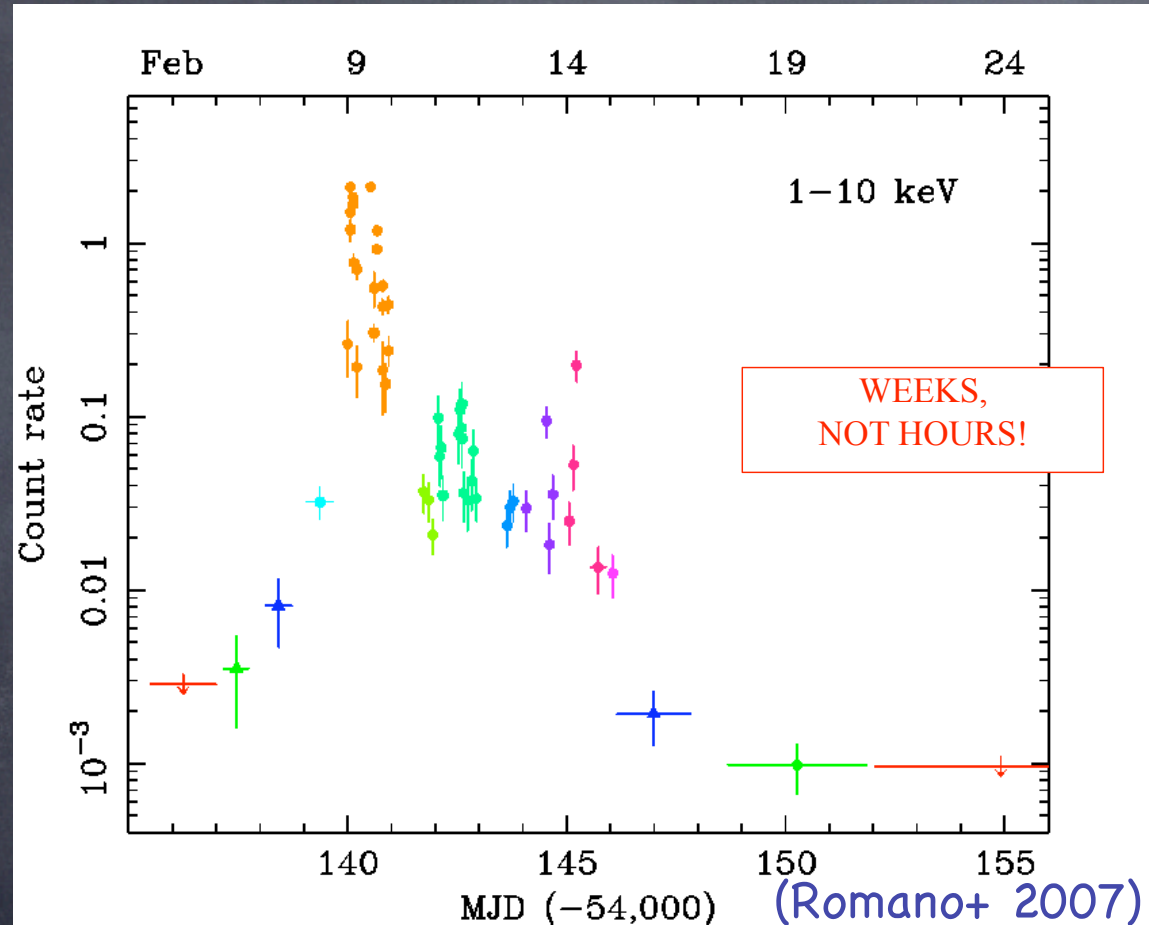
- ✓ different kinds of outbursts
- ✓ assessment of phases
- ✓ intensity-based spectroscopy
- ✓ inactivity duty cycle

(Romano+2011c, arXiv:1103.6036)



<http://www.ifc.inaf.it/sfxt/>

True outburst length: IGR J11215-5952



-Below detectability
 $L(1-10) = 3.7 \times 10^{33} \text{ erg s}^{-1}$

-Slow rise

-Outburst (1day)
Feb 09: CR increase
by ~ 10 in $< 1.5 \text{ h}$
by ~ 65 in 17 h
 $L(1-10) = 1.1 \times 10^{36} \text{ erg s}^{-1}$

$\Gamma \sim 1$, $N_H \sim 10^{22} \text{ cm}^{-2}$

-decline phase (5d)

-down to (15 d)
 $L(1-10) = 1.2 \times 10^{33} \text{ erg s}^{-1}$

✓ SFXT $L_x \sim 10^{36} \text{ erg s}^{-1}$
dynamic range $\sim 10^3$

P_{orb} from Swift/XRT! The spectral and timing properties of all the observed outbursts are similar; the true orbital period is $P_{\text{orb}} = 164.6 \text{ d}$ (Romano+ 2009b, Romano+2011c)

The *Swift* campaign



Sample: of 4 confirmed SFXTs

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

Sidoli+ 2008 (ApJ, 687, 1230)

Romano+ 2009c
(MNRAS, 399, 2021)

Romano+ 2011a
(MNRAS, 410, 1825)

2 or 3 obs /source/week, 1 ks each (Oc 2007–Nov 2009)

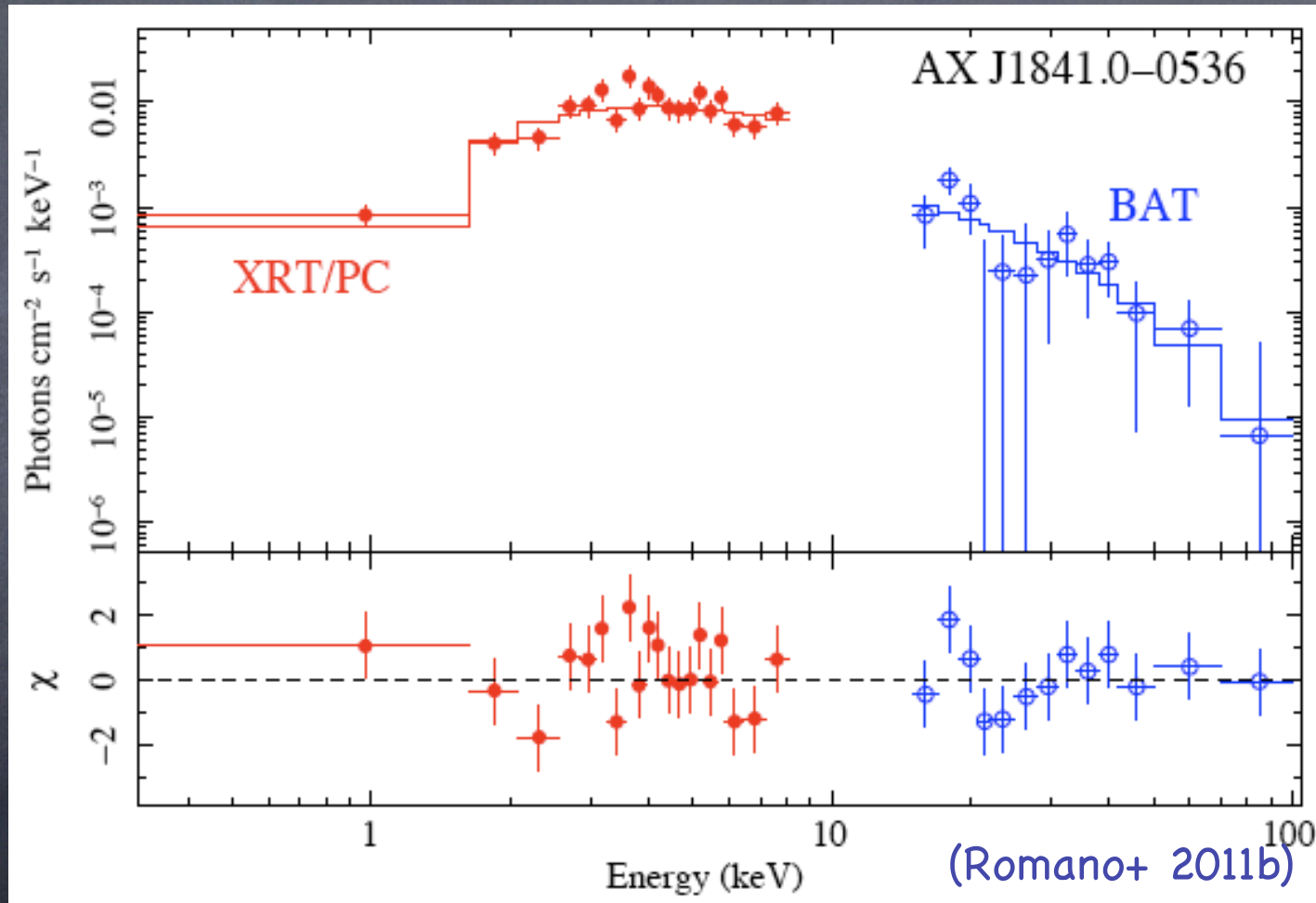
✓ BAT Special Functions (for ALL known SFXTs and candidates)

✓ catch outbursts & follow them until source undetected

✓ monitor long term properties (1st time) and towards quiescent level

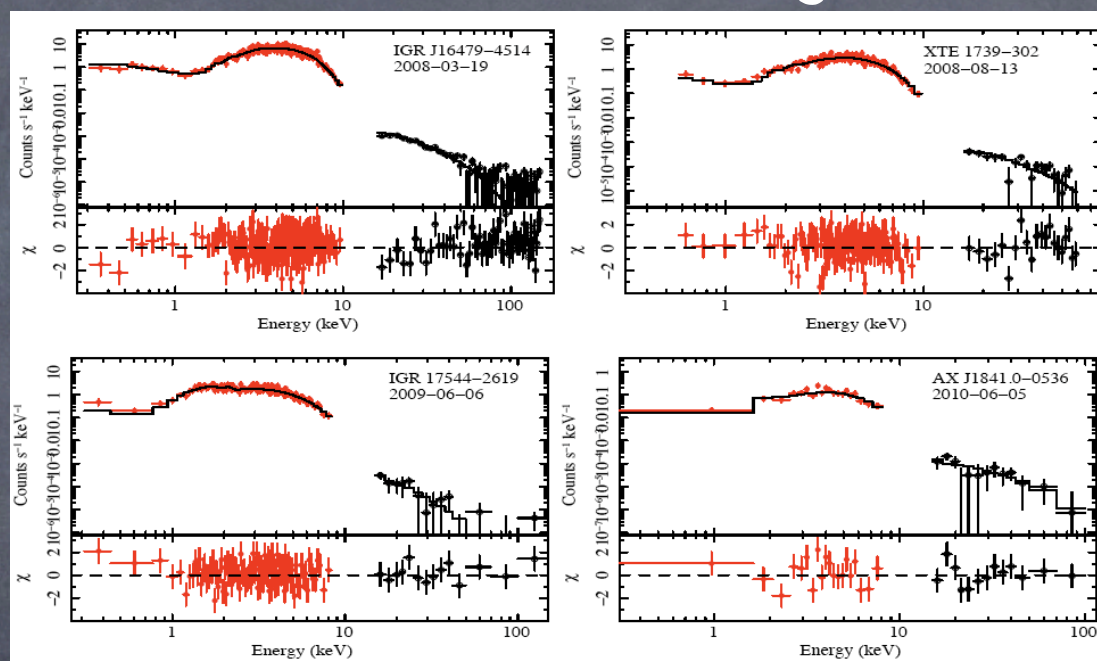
Outburst emission spectroscopy

Broad-band spectroscopy 0.3–10 keV + 15–150 keV



Outburst emission spectroscopy

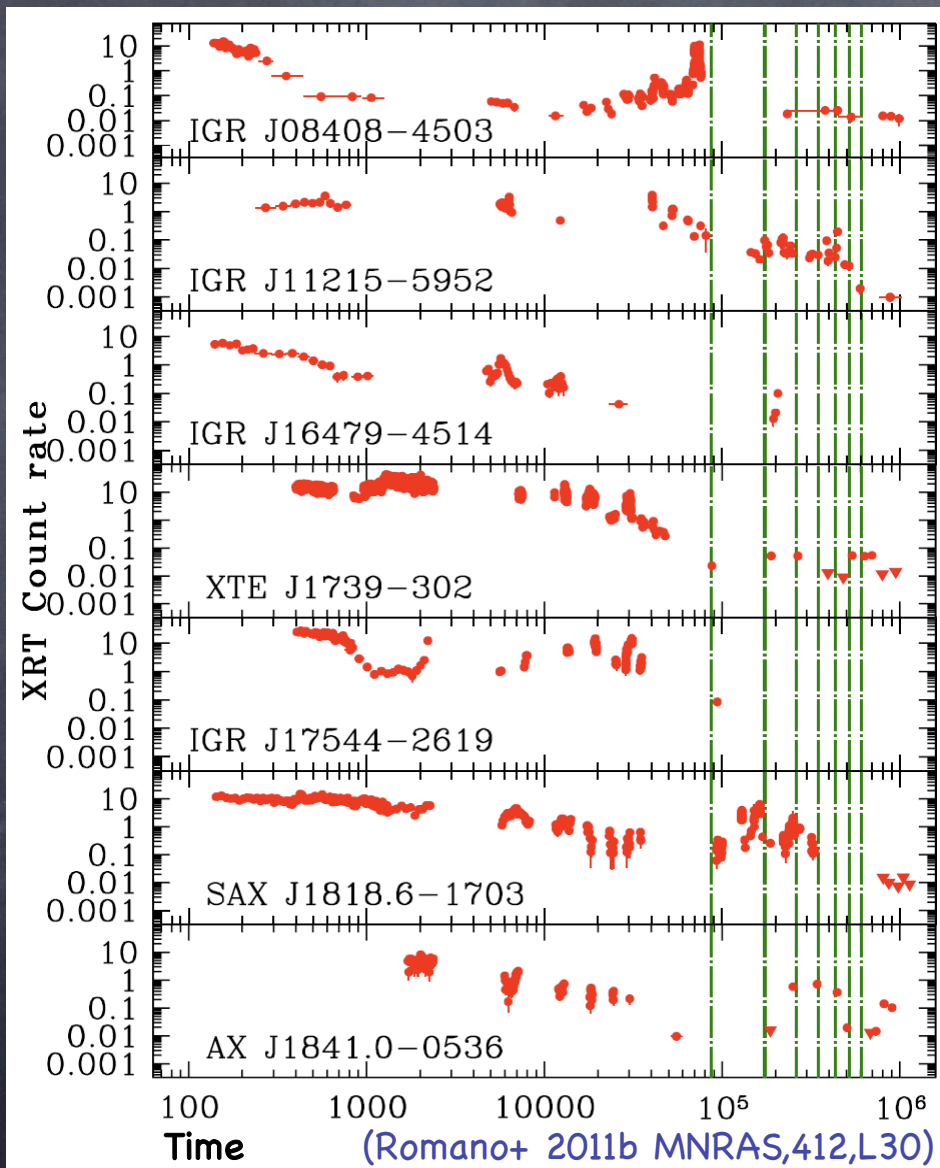
- ✓ absorption & spectral cut-off
- ✓ comparison with models for accreting NS



Name	Date	N_{H} (10^{22} cm^{-2})	Γ	E_{cut} (keV)	E_{fold} (keV)
IGR J16479-4514	2008-03-19	$6.2^{+0.6}_{-0.5}$	$1.2^{+0.2}_{-0.1}$	6^{+1}_{-1}	15^{+3}_{-2}
XTE J1739-302	2008-08-13	$4.8^{+1.3}_{-0.6}$	$0.8^{+0.4}_{-0.2}$	5^{+2}_{-1}	12^{+8}_{-3}
IGR J17544-2619	2009-06-06	$1.0^{+0.2}_{-0.3}$	$0.6^{+0.2}_{-0.4}$	3^{+1}_{-1}	8^{+4}_{-3}
AX J1841.0-0536	2010-06-05	$1.9^{+1.7}_{-1.0}$	$0.2^{+0.4}_{-0.5}$	4^{+12}_{-4}	16^{+10}_{-9}

Romano+2011,
POS(Texas2010), 117

Outburst light curves

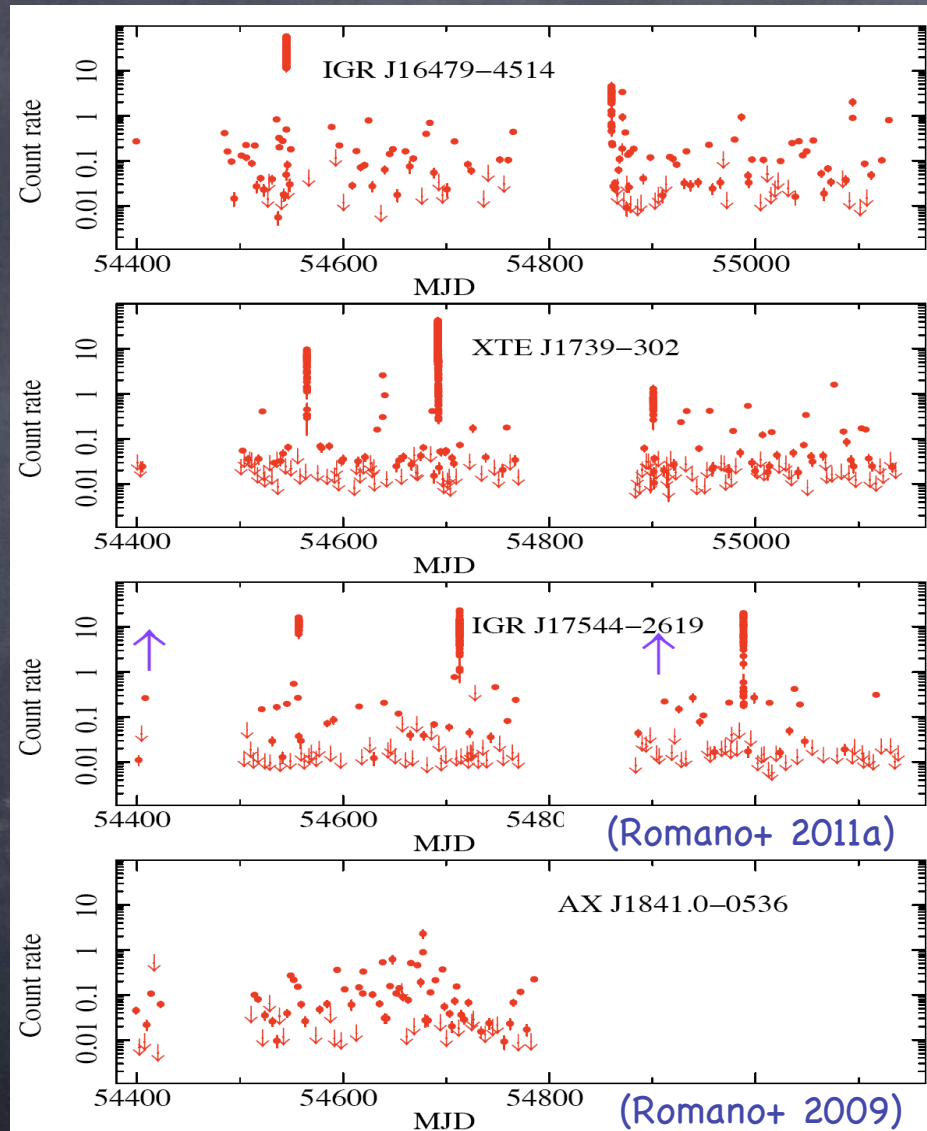


(highest timing resolution)

Common features:

- ✓ outburst length > hours
- ✓ multiple peaked structure with lots of flares
- ✓ dynamic range: 3 orders of magnitude

Long term monitoring

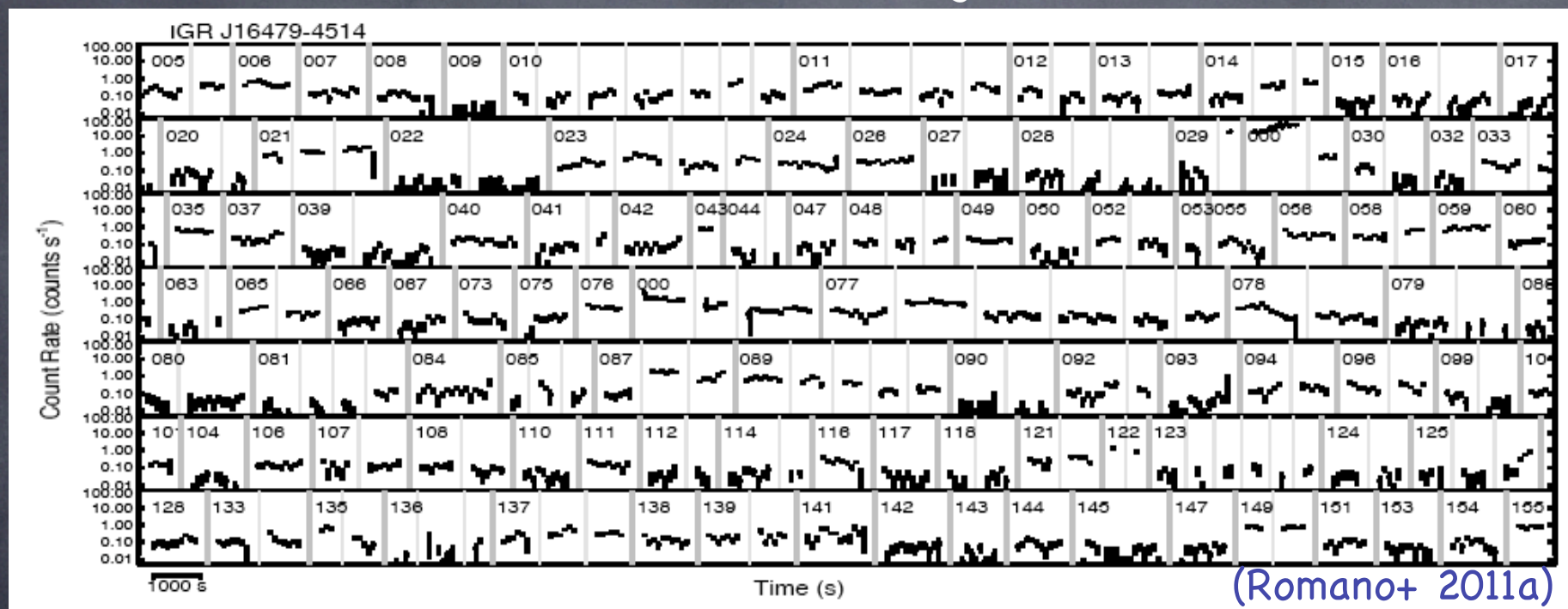


2007-10-26
to
2009-11-03
(daily resolution)

- ✓ dynamical range:
4 orders of magnitude
- ✓ 8 outbursts (+2!!!)
- ✓ Emission outside of
outbursts
- ✓ variability:
days to months

Variability in *Swift*/XRT light curves

highest resolution: PC: 100s, WT 20s

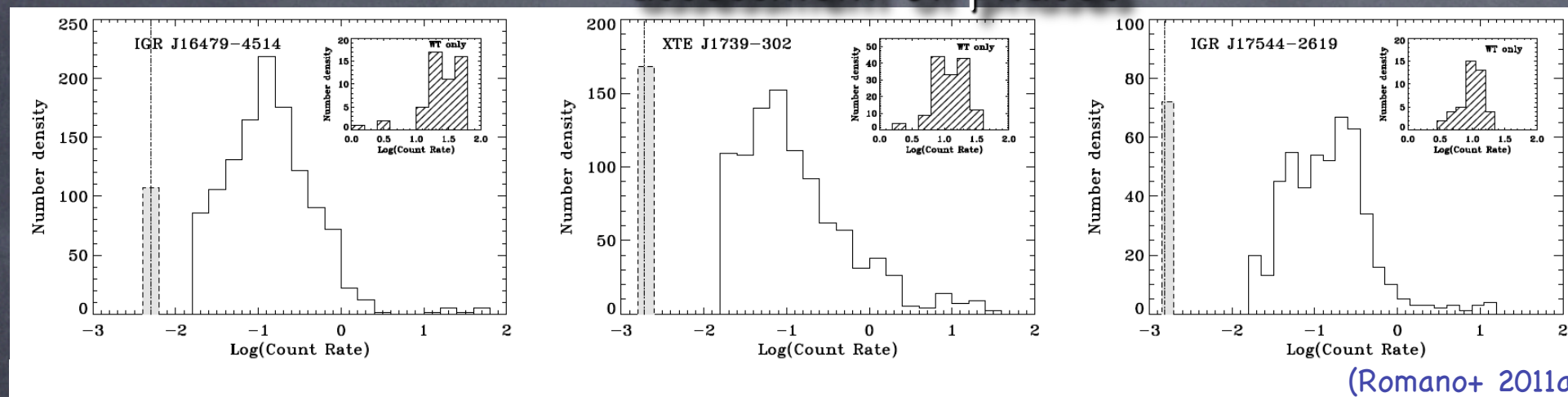


- ✓ variability observed on all timescales and intensity levels →
- ✓ short timescales 1 order of magnitude (1 ks, down to 0.1 counts s⁻¹) using Walter+(2007)

$$M_{cl} = 7.5 \times 10^{21} (L_{X,36})(t_{fl,3ks})^3 \text{ g}$$

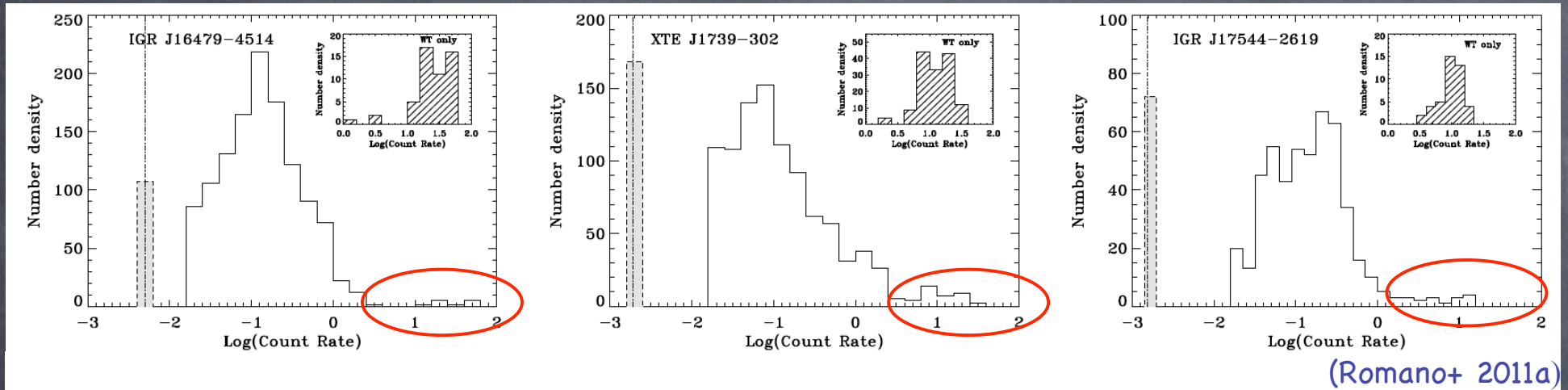
clumpy winds with **clumps of 10^{18-19} g** (Romano+ 2011a)

Swift/XRT Count Rate Distributions assessment of phases



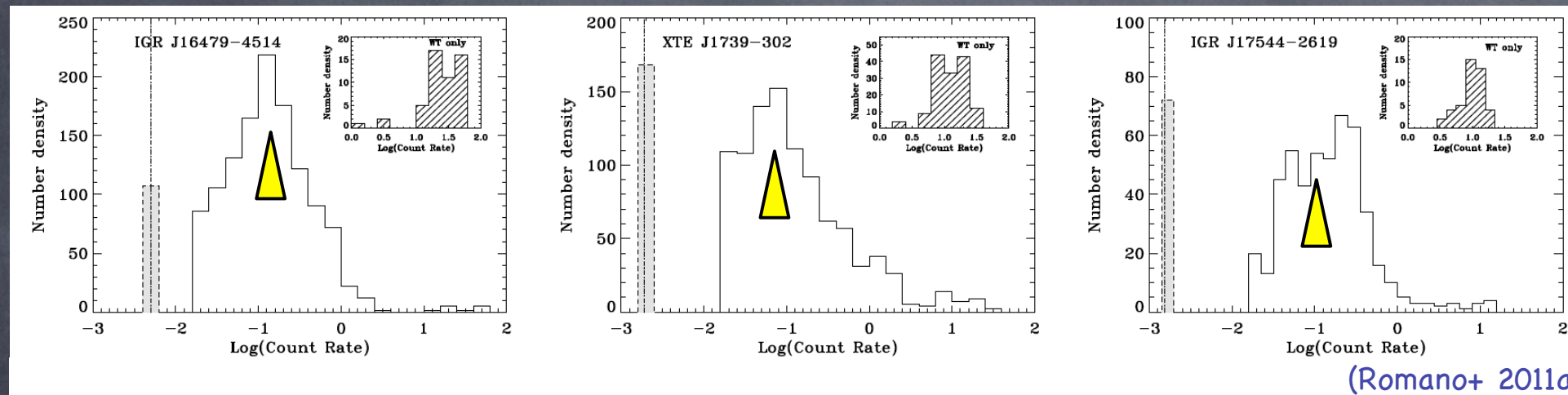
- ✓ 3-5% of time spent in bright outbursts
- ✓ Most probable observed flux: $1-3 \times 10^{-11}$ erg cm⁻² s⁻¹
(2-10 keV, unabsorbed) so that
- ✓ long term behaviour is intermediate state of accretion
 $L \sim 10^{33} - 10^{34}$ erg s⁻¹
- ✓ non detections

Swift/XRT Count Rate Distributions



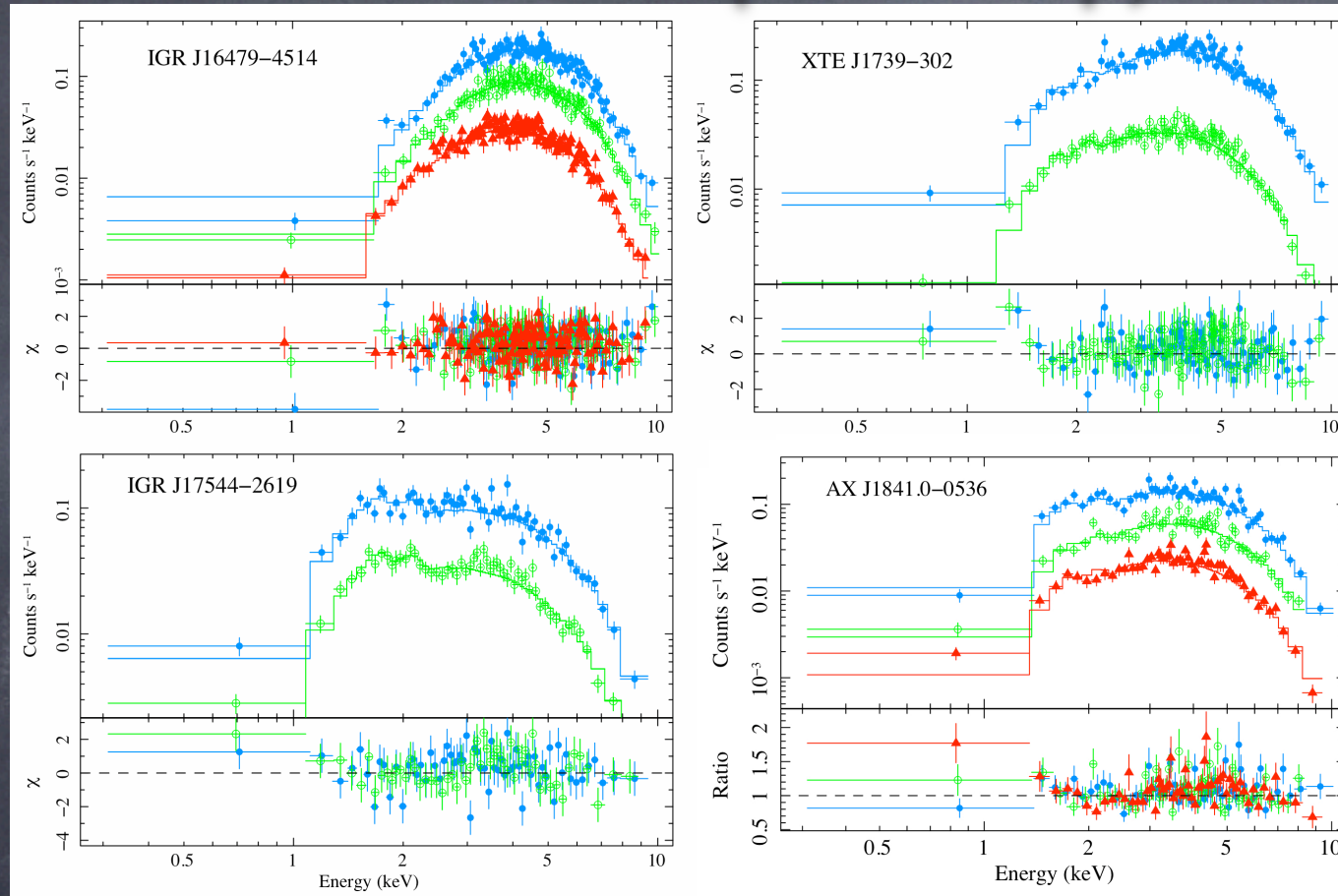
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Out of Outburst spectroscopy



(Romano+ 2009c,
Romano+ 2011a)

hard power-
laws
($\Gamma \sim 0.8-2$)

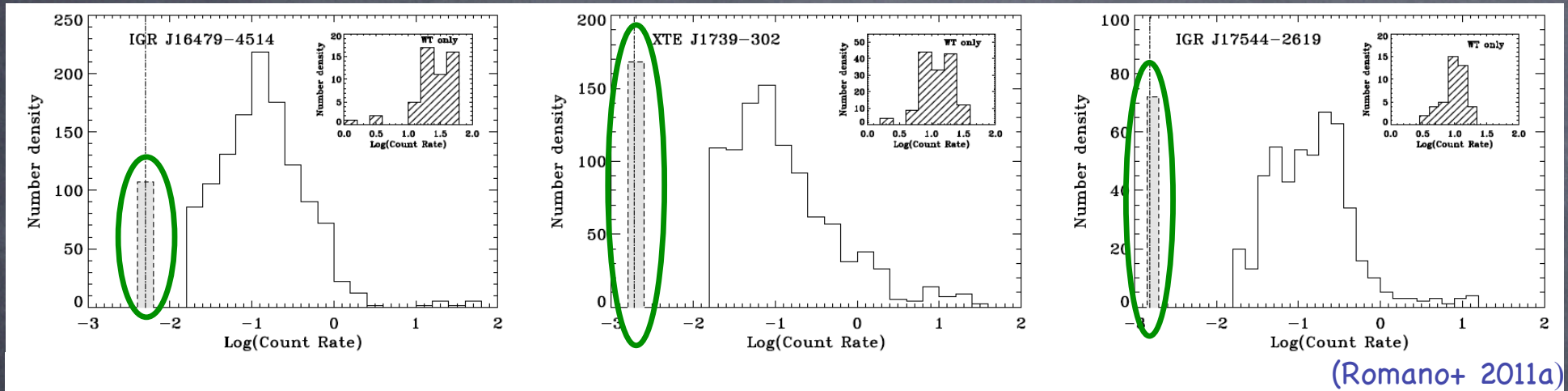
$L_x \sim 10^{33}-10^{34}$
 erg s^{-1}

✓ accretion
over several
oom in
Luminosity

The lowest luminosity level we could reach with *Swift*:

$L_x = 4 \times 10^{32} \text{ erg s}^{-1}$ in XTE J1739-302, $L_x = 3 \times 10^{32} \text{ erg s}^{-1}$ in IGR J17544-2619
incompatible with spherically symmetric steady wind → clumpy wind.

Swift/XRT Count Rate Distributions



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(Romano+ 2009c,2011a)

XRT provides casual sampling of the light curve at a 4d resolution

- BAT-detected outbursts,
- intermediate state (firm detection excluding outbursts),
- non detections (detections with a significance below 3σ).

$$IDC = \Delta T_{\Sigma} / [\Delta T_{\text{tot}} (1 - P_{\text{short}})]$$

IGR J16479-4514	19%
AX J1841.0-0536	28%
XTE J1739-302	39%
IGR J17544-2619	55%

time a source spends
undetected down to a
flux $1-3 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$

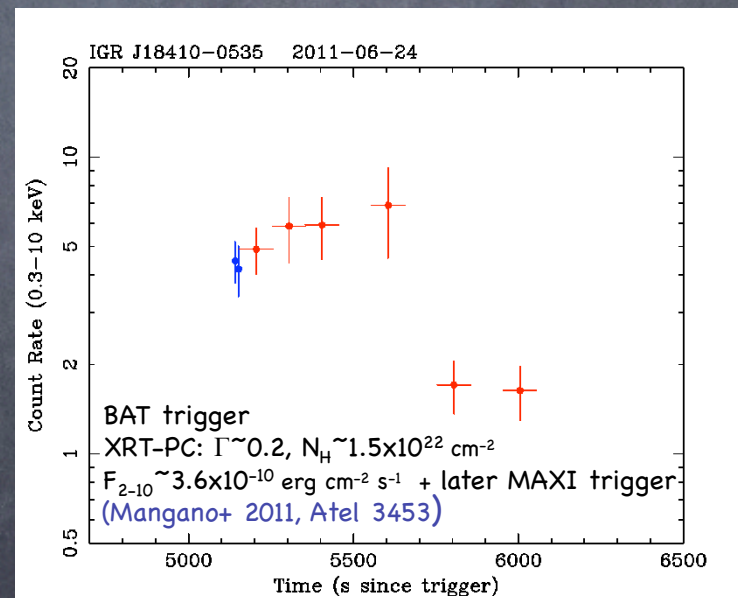
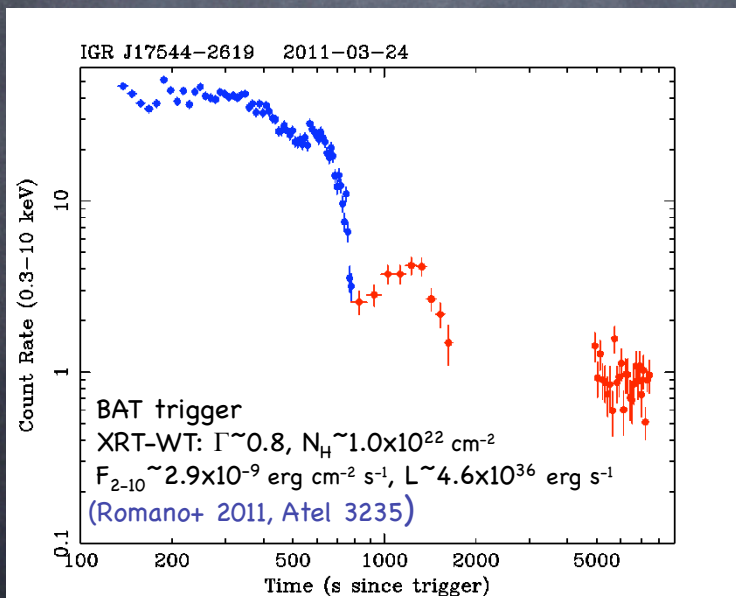
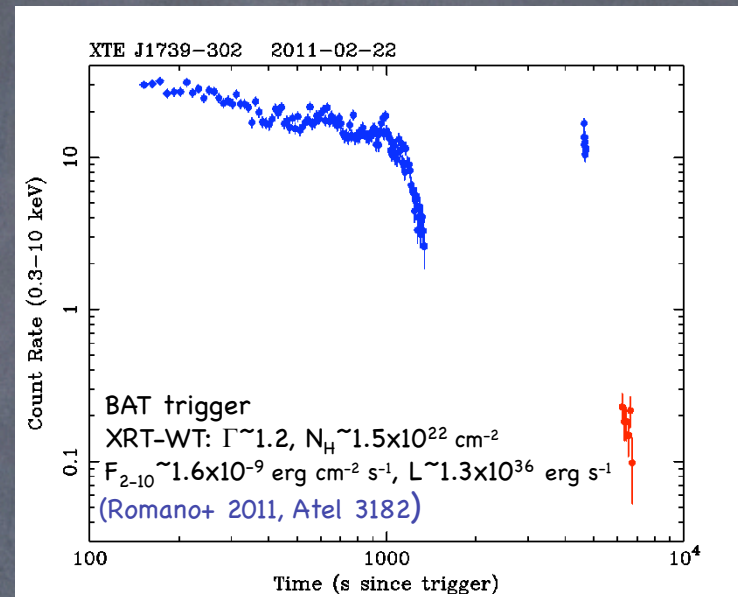
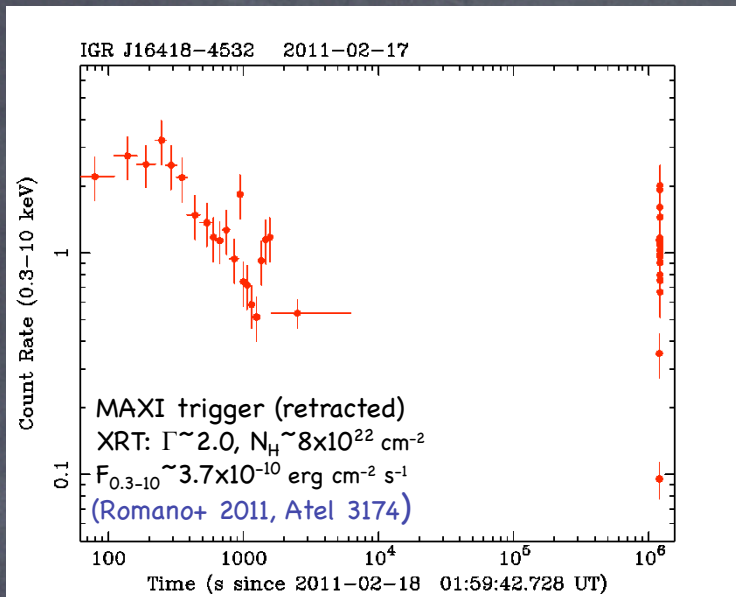
ΔT_{Σ} = total expo(>900s) where
 3σ UL only obtained;

ΔT_{tot} = total expo

P_{short} = %(expo < 900s)

✓ **Accreting matter**
most of the time

Most Recent Outbursts



PRELIMINARY

(Romano+ in prep.)

Catching outbursts

- ✓ true outburst length
- ✓ broad-band spectroscopy

Monitoring programs

- ✓ outbursts
- ✓ assessment of phases
- ✓ intensity-based spectroscopy
- ✓ inactivity duty cycle

Swift SFXT Project

<http://www.ifc.inaf.it/sfxt/>

Contact point:

romano@ifc.inaf.it

X-ray Universe 2011



Thanks!