The *Swift* view of Supergiant Fast X-ray Transients

Lara SIDOLI
(INAF-IASF, Milano, Italy)

Pat ROMANO
(INAF-IASF, Palermo, Italy)

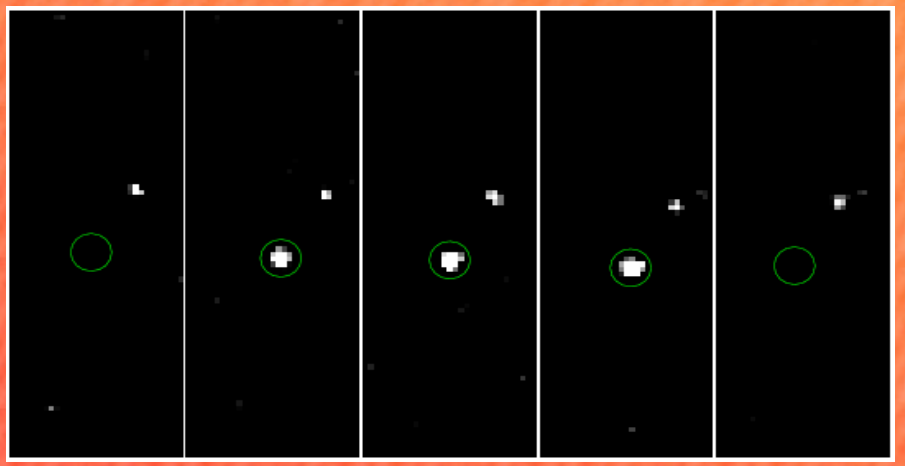
L. Ducci, A. Paizis (INAF-IASF Mi),
S. Vercellone, G. Cusumano,
V. La Parola, V. Mangano (INAF-IASF Pa)
D. Burrows, J.A. Kennea (PSU),
H.A. Krimm, N. Gehrels (NASA/GSFC)

***X-ray Astronomy 2009**, Bologna, 7-11 September 2009*

Supergiant Fast X-ray Transients

Supergiant **Fast X-ray Transients**

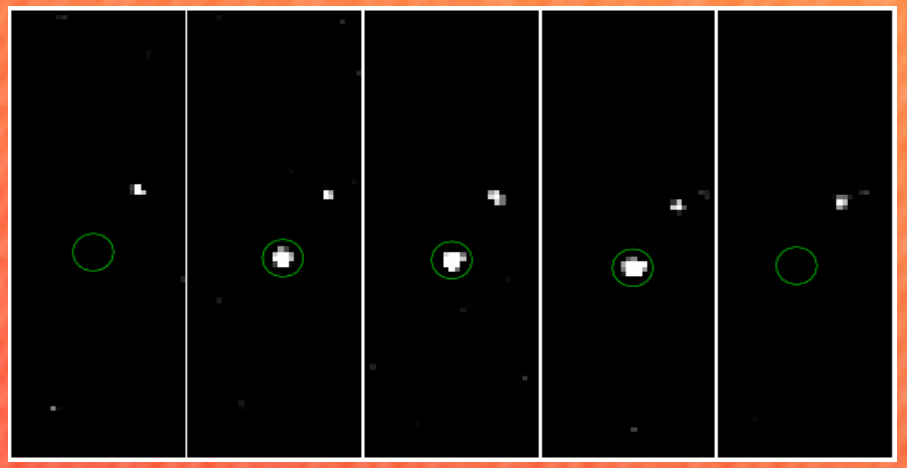
sporadic bright and short (hours) flares
during the survey of the Gal Plane
with IBIS onboard INTEGRAL



Sguera et al. 2005, 2006

Supergiant **Fast X-ray Transients**

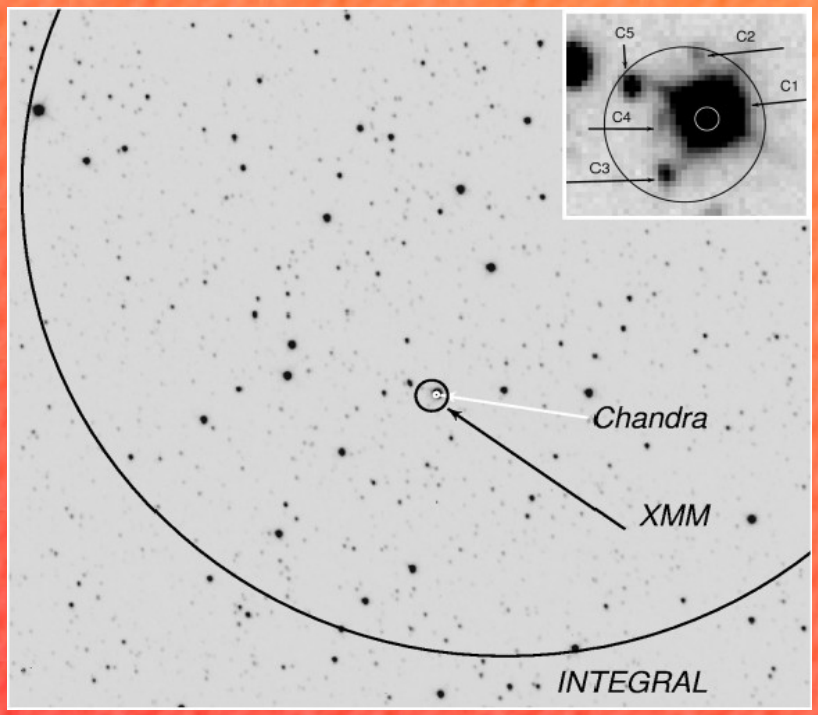
sporadic bright and short (hours) flares
during the survey of the Gal Plane
with IBIS onboard INTEGRAL



IBIS sensitivity allowed to
catch **only bright flares**
(peaking at 1E36-1E37 erg/s)
without persistent
or quiescent emission

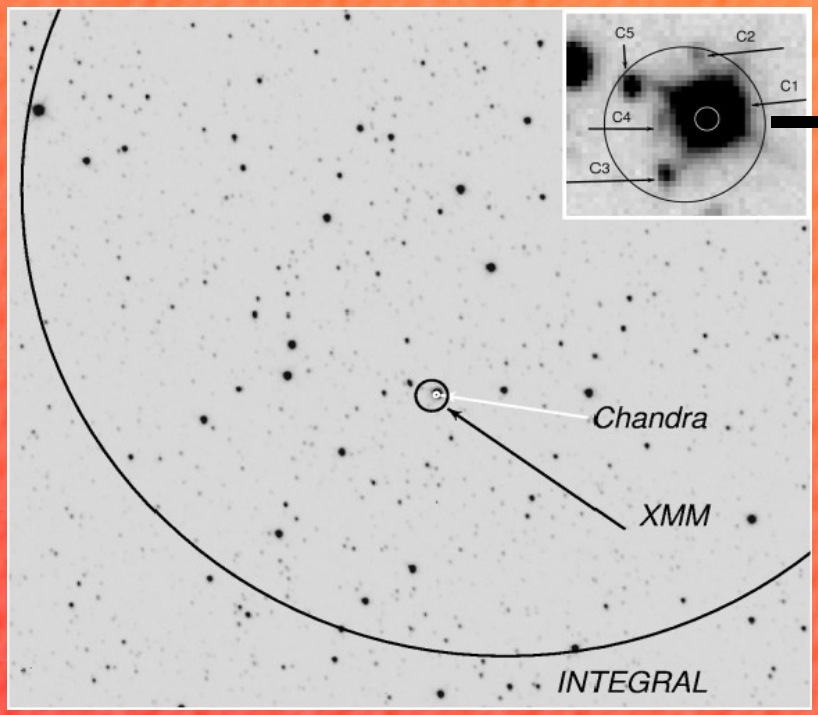
Sguera et al. 2005, 2006

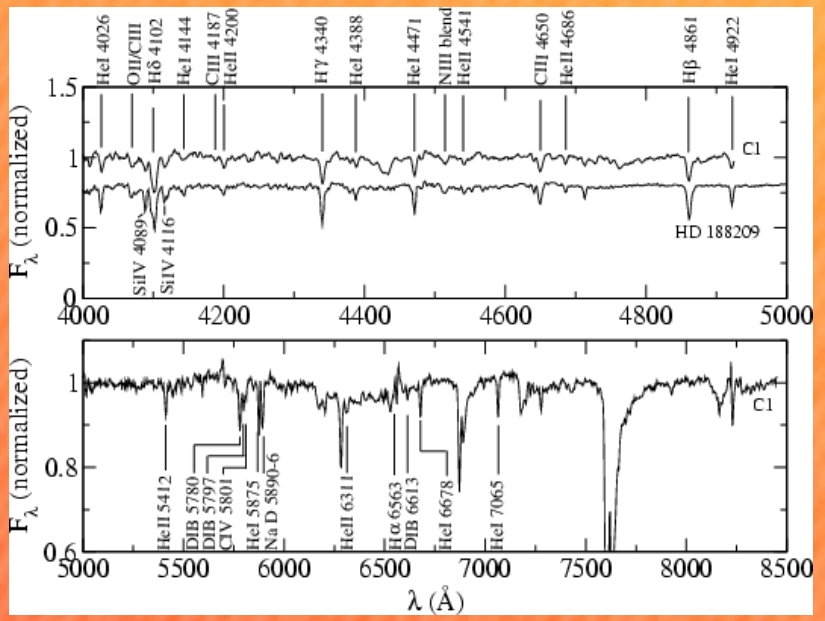
Supergiant Fast X-ray Transients



Supergiant Fast X-ray Transients

OB SUPERGIANT COMPANIONS





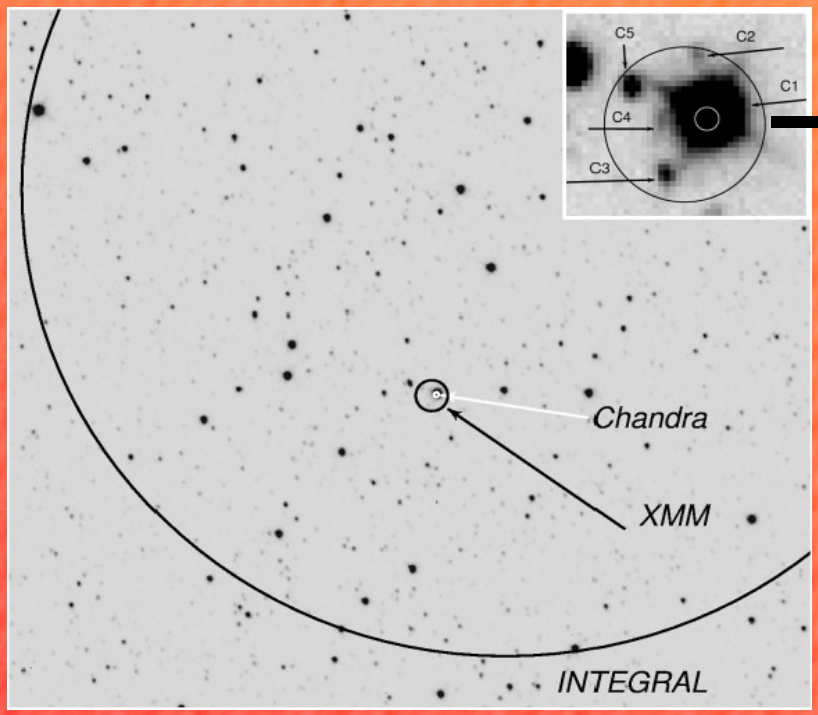
IGR J17544-2619

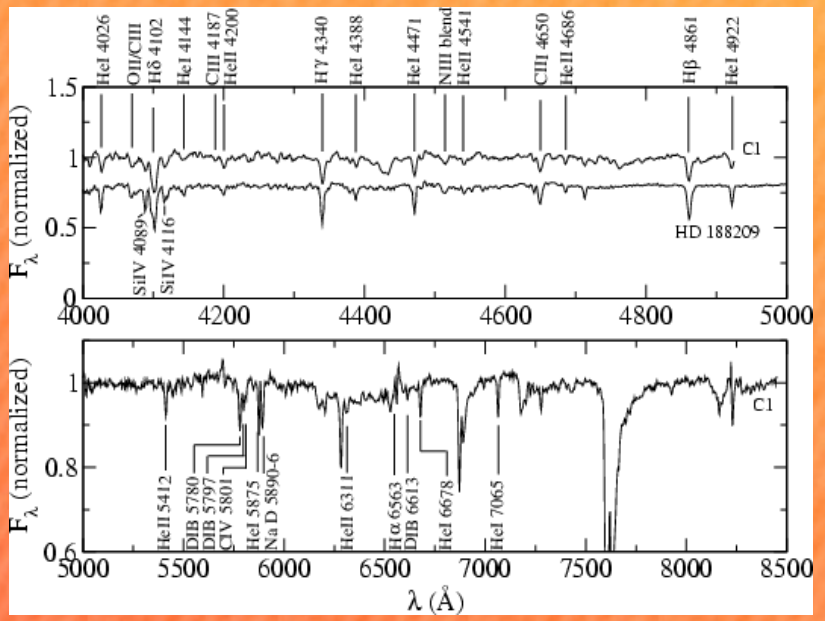
O9Ib optical counterpart

(Pellizza et al. 2005)

Supergiant Fast X-ray Transients

OB SUPERGIANT COMPANIONS





IGR J17544-2619

O9Ib optical counterpart

(Pellizza et al. 2005)

→ thus they are a **new subclass** of High Mass X-ray Binaries

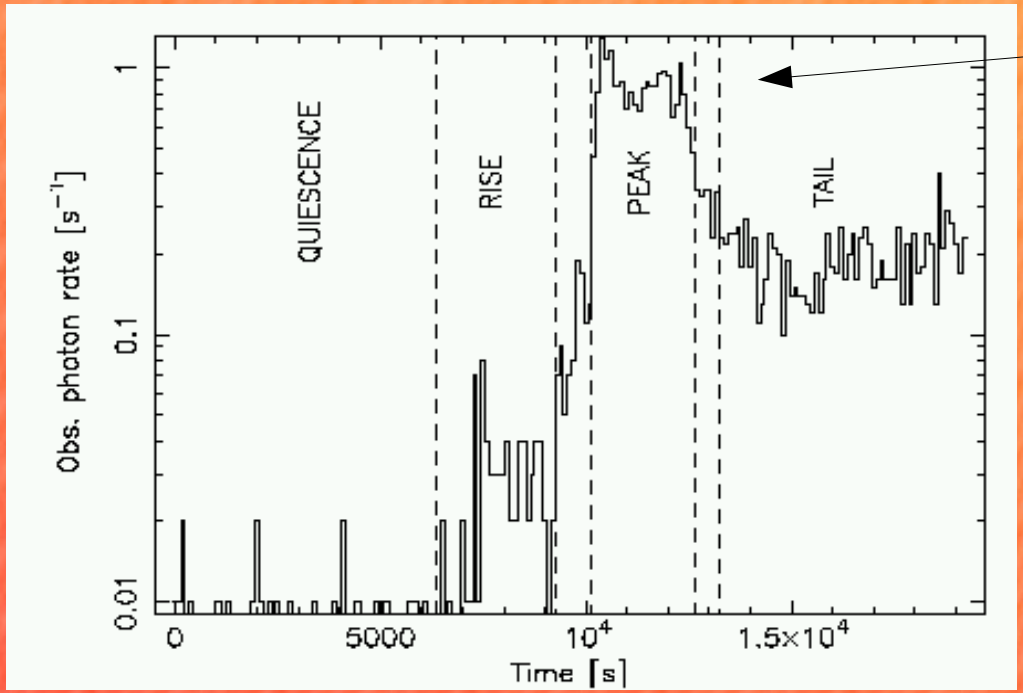
SFXTs properties:

high dynamic range

(Lmax/Lmin=1E4-1E5)

Sporadic observations with **more sensitive instruments** allowed to catch the **quiescent level at 1E32 erg/s in a couple of SFXTs**, with a thermal very soft X-ray spectrum

piled-up
Fmax is
100 times higher



Time (s)

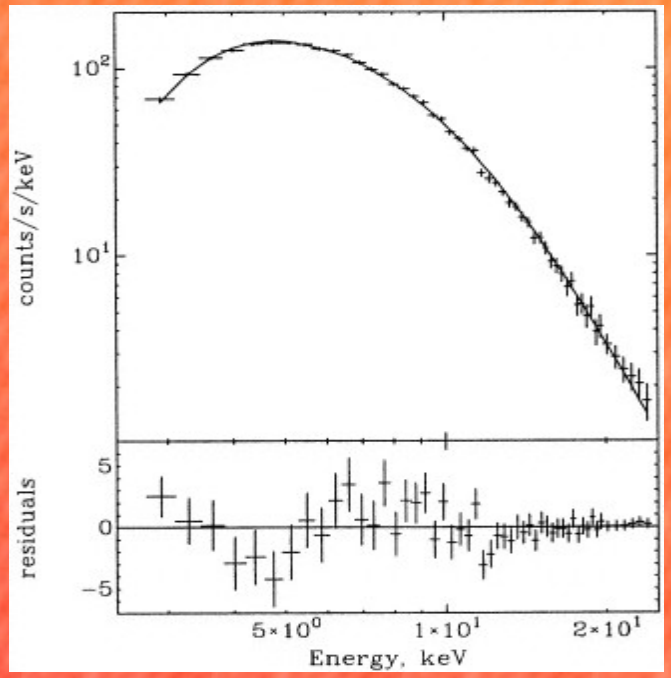
Lmax = 1e36-1e37 erg/s

Lmin = Lquiescence = 1e32 erg/s

Chandra
(in't Zand 2005)
IGR J175442619

SFXTs properties:

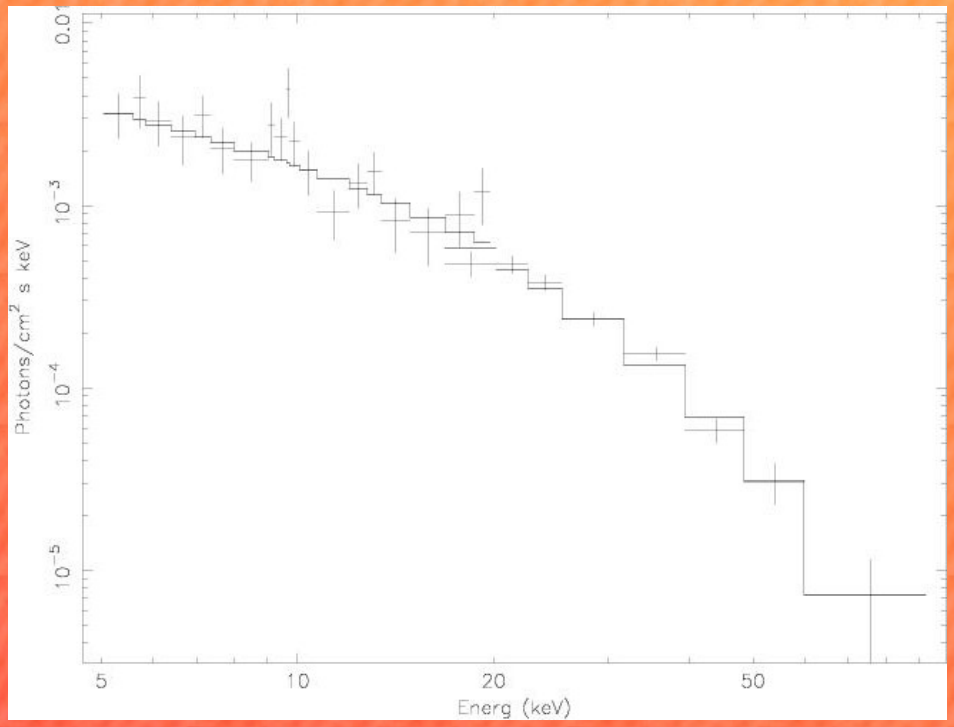
*X-ray **spectrum** during the peak of their flaring activity*
*is **similar** to that of*
accreting X-ray pulsars



XTE J1739-302 ***(Smith et al. 1998)***

brems kT ~ 20 keV

IGRJ11215-5952
JEMX+ISGRI ***(Sidoli et al. 2006)***

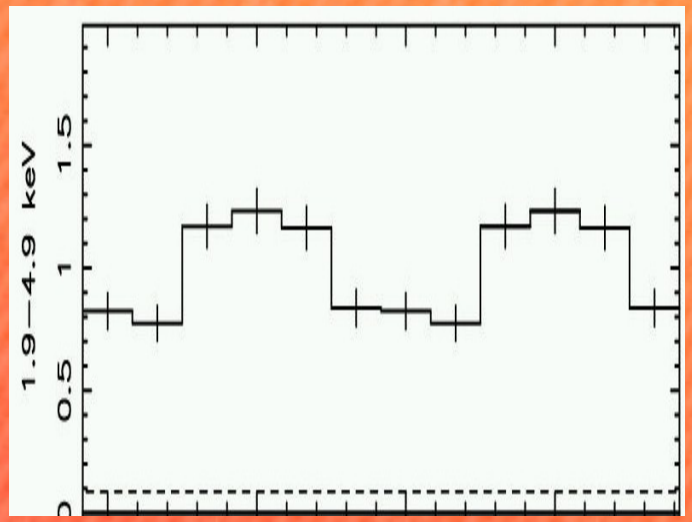


SFXTs properties

Not clear if *all* SFXTs are Neutron stars

BUT at least

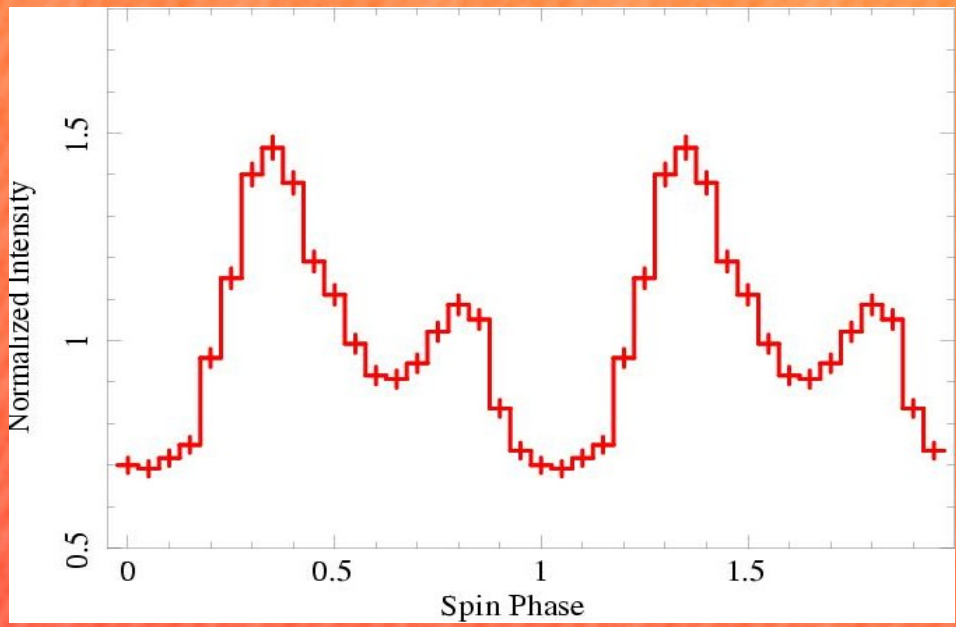
a few *SFXTs are* X-ray pulsars



IGRJ11215-5952

***Pspin ~ 187 s** (RXTE; Swank et al 2007)*

XMM-Newton *folded 0.3-12 keV lightcurve (Sidoli et al. 2007)*



AX1841.0-0536

***Pspin ~ 4.7 s** (ASCA; Bamba et al. 2001)*

IGR J18483-0311

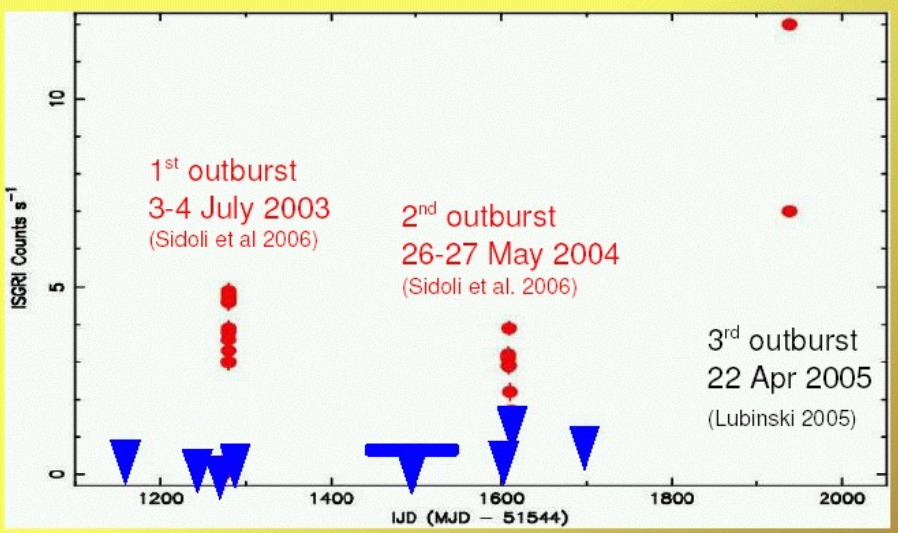
Pspin ~ 21 s

(INTEGRAL; Sguera et al. 2007)

SFXTs properties

Orbital Periods

The **first** orbital period discovered with INTEGRAL *(Sidoli et al. 2006)* from the periodic outbursts in **IGR J11215-5952**



9 hr < 1st outburst duration < 7 days

3rd outburst duration ~ 4000 s

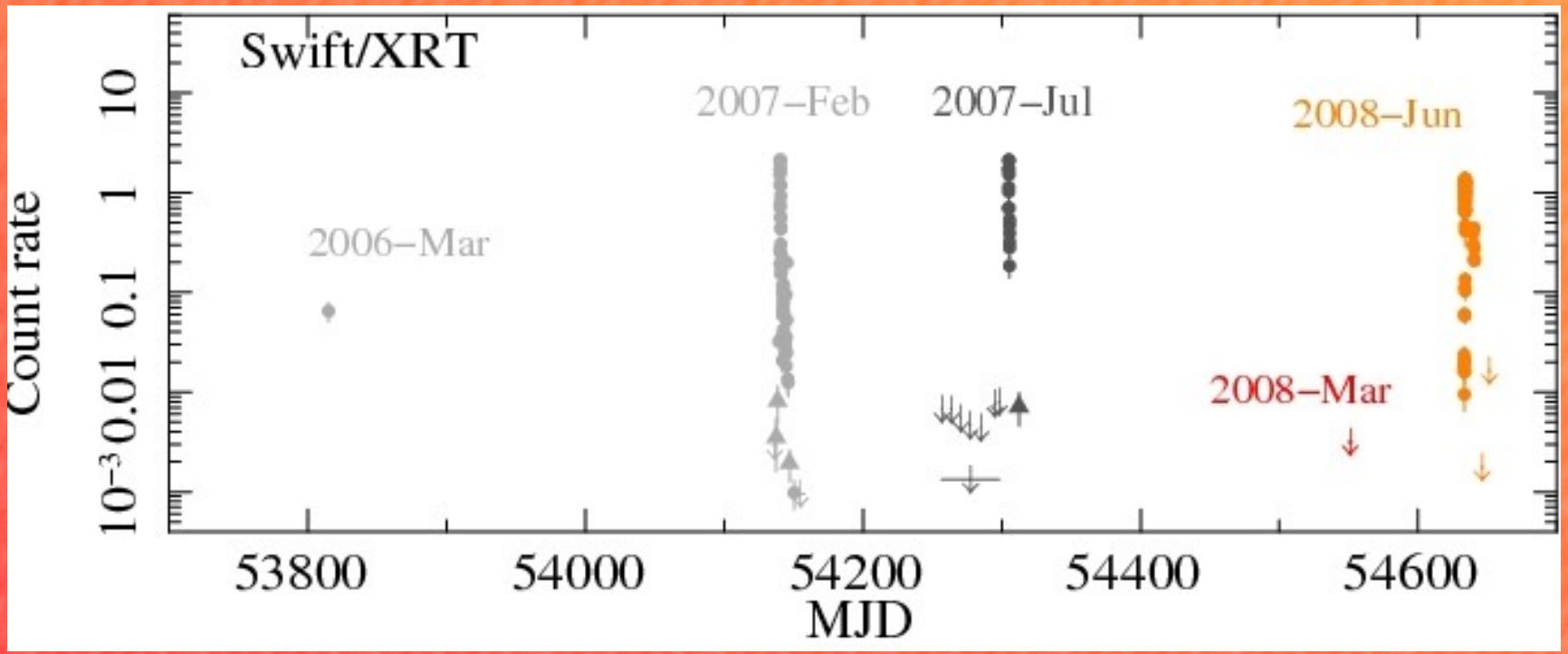
2 days < 2nd outburst duration < 7 days

SFXTs properties

Orbital Periods

The **first** orbital period discovered with INTEGRAL *(Sidoli et al. 2006)* from the periodic outbursts in **IGR J11215-5952**

Romano et al. 2009
Porb = 165 days

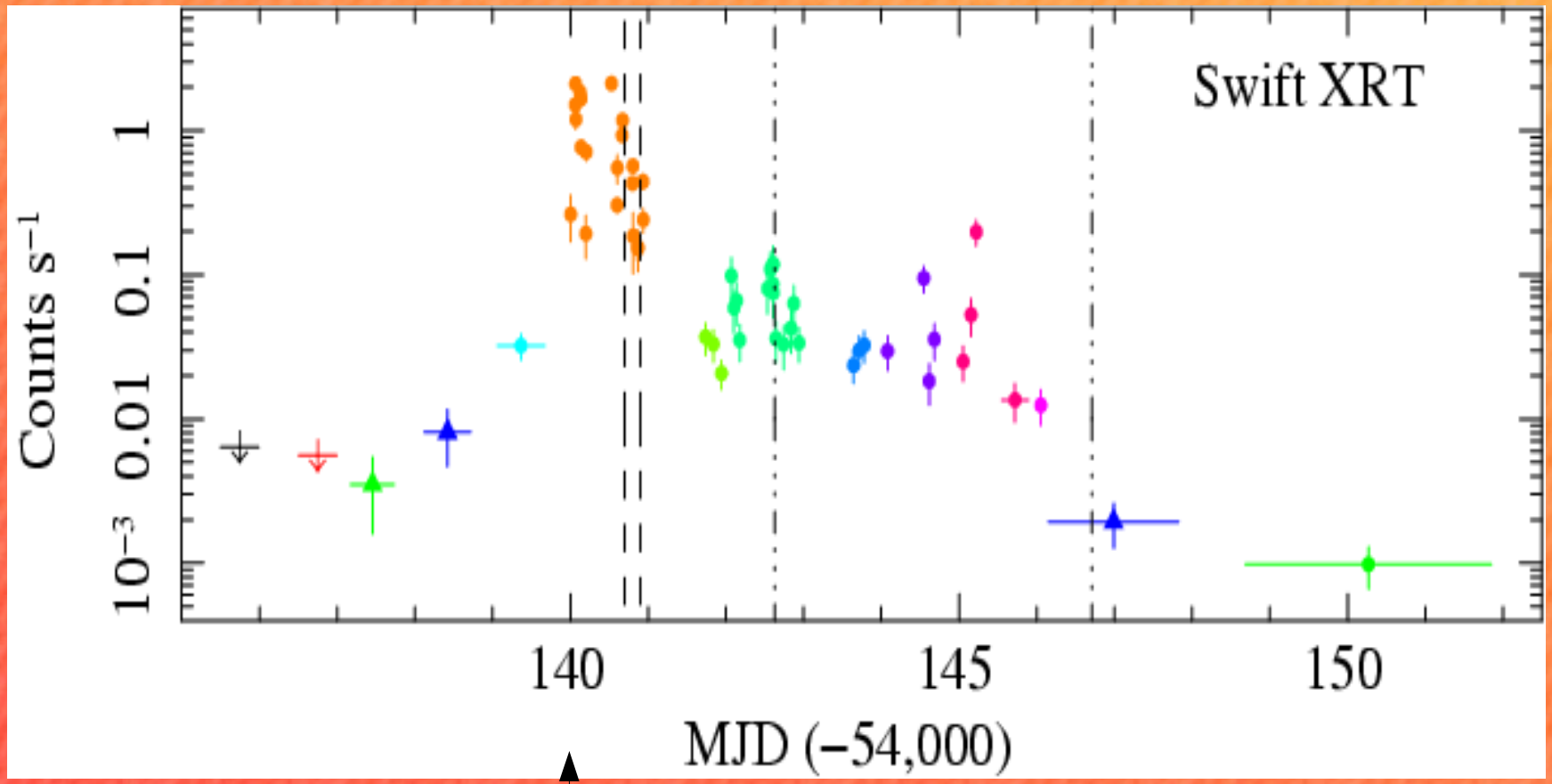


SFXTs properties

Besides IGRJ11215-5952 (which has the longest Porb!), other periodicities, likely orbital, have been discovered in these SFXTs:

3.3 days	IGRJ16479-4514	*(Jain et al. 2009)*
4.9 days	IGRJ17544-2619	*(Clark et a. 2009)*
18.5 days	IGRJ18483-0311	*(Levine & Corbet 2006)*
30 days	SAXJ1818.6-1703	*(Bird et al. 2009, Zurita Heras & Chaty 2009)*

IGRJ11215-5952
the first *Swift* discoveries:
observing the fifth expected outburst: Feb 2007



9th February 2007

Romano et al. 2007

Supergiant Fast X-ray Transients

Subclass of High Mass X-ray Binaries
with Blue Supergiant companions
WIND ACCRETORS

Fast Transient X-ray Flaring Activity with a high dynamic range,
vs classical HMXBs with supergiants which are persistent X-ray sources

Broad band truly simultaneous **spectra**: really similar to X-ray pulsars?

Duration of the outbursts ?

Long term properties ? how much time spent in outbursts vs quiescence?

Are they still in **accretion** when they are not in bright flaring activity?

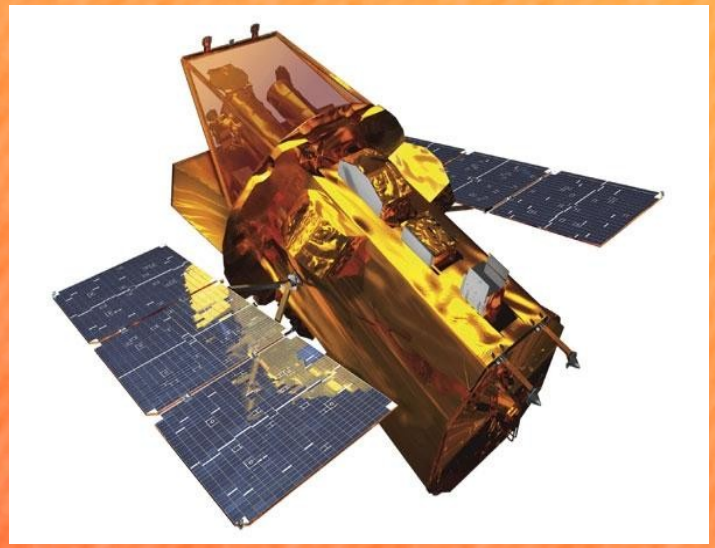
Orbital and spin periods? neutron star magnetic field?

Swift: the 1st wide-band and long-term monitoring campaign of SFXTs

(started in Oct 2007, still on-going)

Sample of 4 confirmed SFXTs:

XTE J1739-302 (prototype)
IGRJ 17544-2619 (prototype)
IGR J16479-4514 (triggered BAT in 2005)
AX J1841.0-0536/IGR J18410-0535



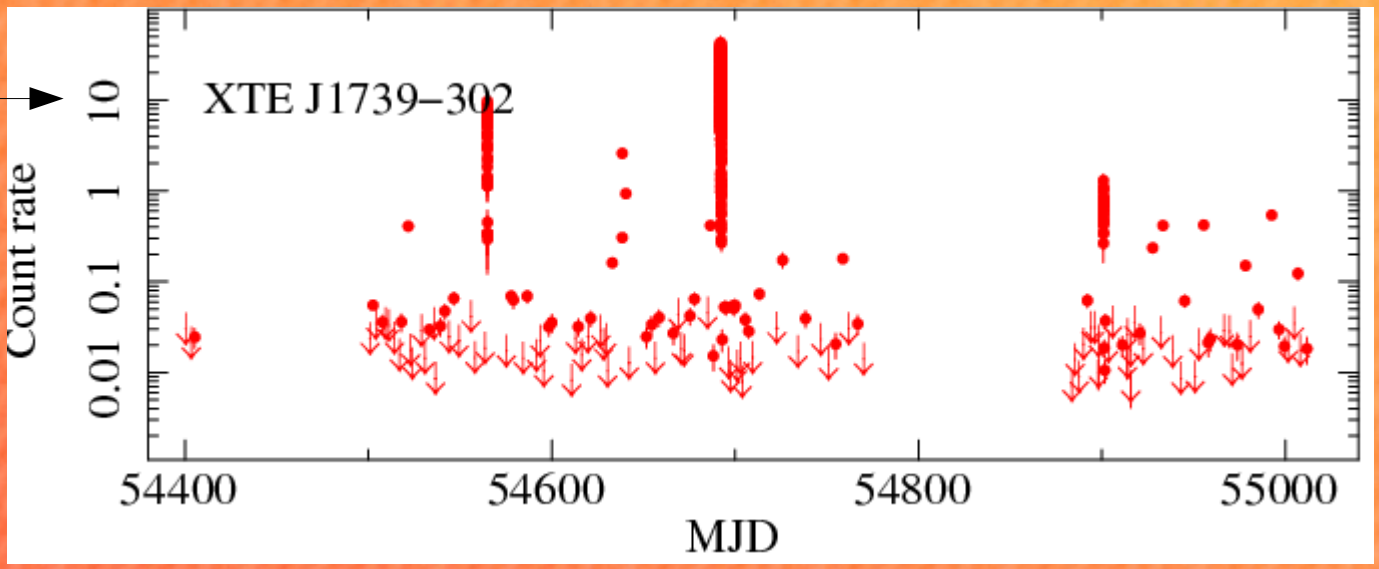
2 or 3 obs /source/week, 1 ks each

- catch "almost" every outbursts,
- monitor the onset of a new outburst to follow the whole ***outburst duration***
- monitor the **long term** properties *(completely **UNKNOWN** before this monitoring)* and the quiescent level

Results from Swift monitoring
(October 2007 – August 2009)

XRT (0.2-10 keV)

1E36 erg/s

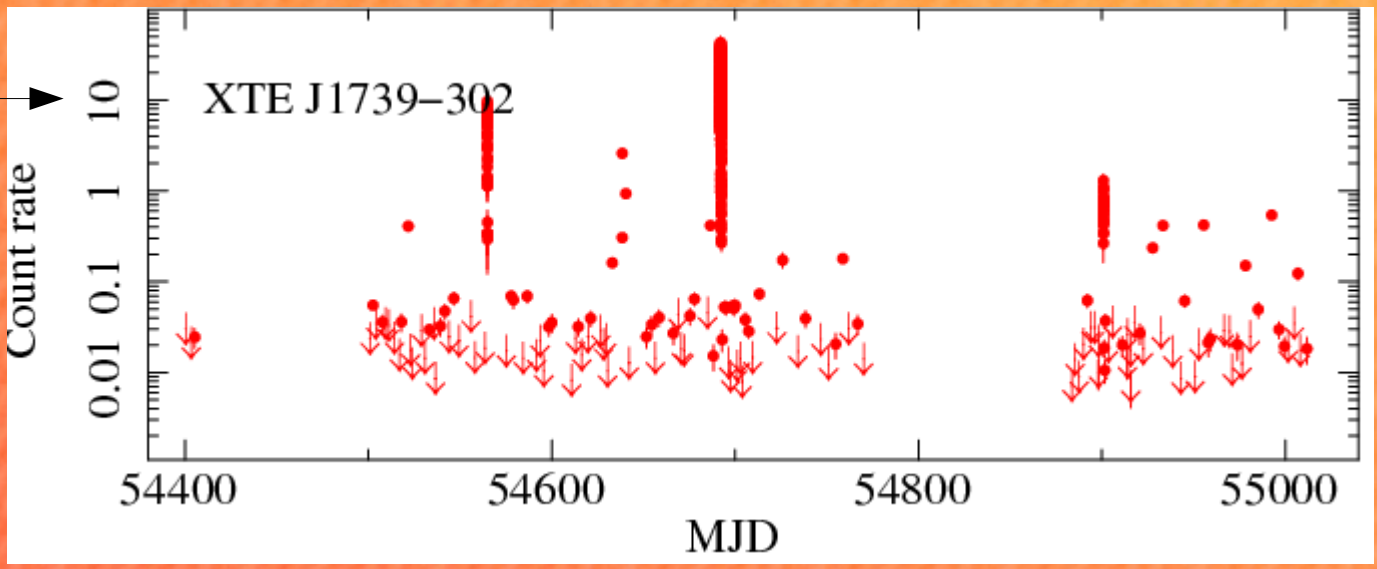


3 flares
4 orders
of magnitude

Results from Swift monitoring
(October 2007 – August 2009)

XRT (0.2-10 keV)

1E36 erg/s →



3 flares
4 orders
of magnitude

3-sigma UL "non detection" state
(source faint or exp too short to be detected,
obs interrupted by GRB). To create a uniform subsample, only Texp > 900 s
Texp= 900 s corresponds to **2-10 keV flux limits** from
1 to 3 E-12 erg/cm2/s, depending on the local bg and source spectrum

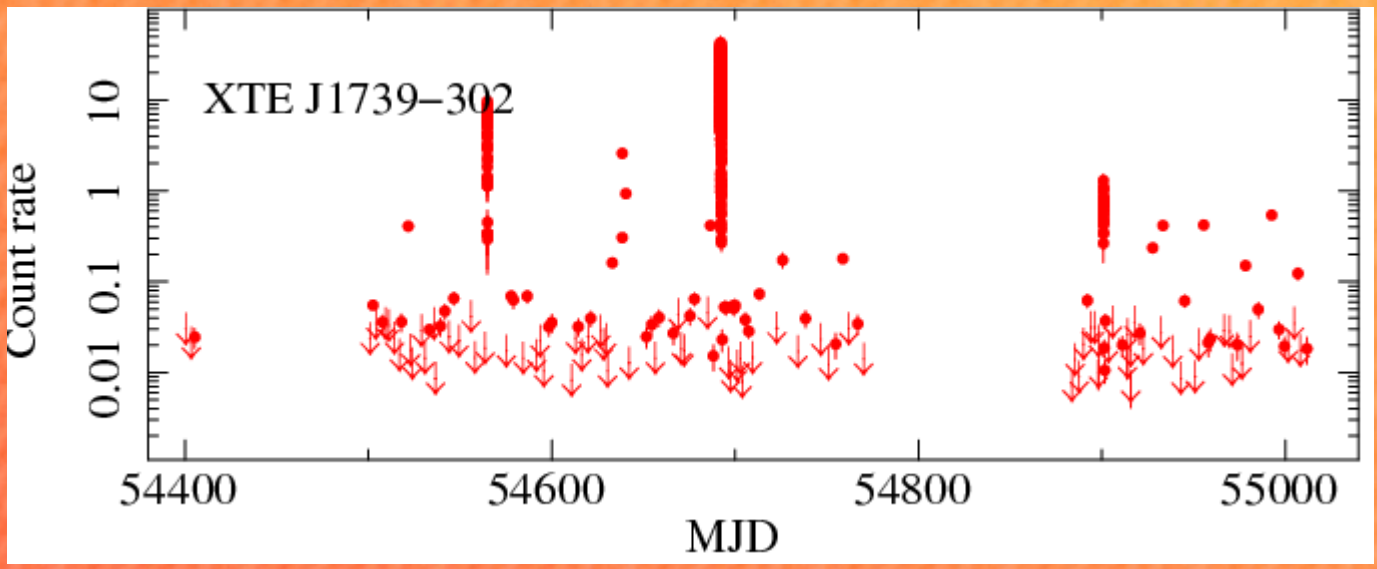
Duty cycle of inactivity IDC

% of time each source spends undetected
down to this limiting flux (time spent in inactivity,
which is not necessarily quiescence)

Results from Swift monitoring
(October 2007 – August 2009)

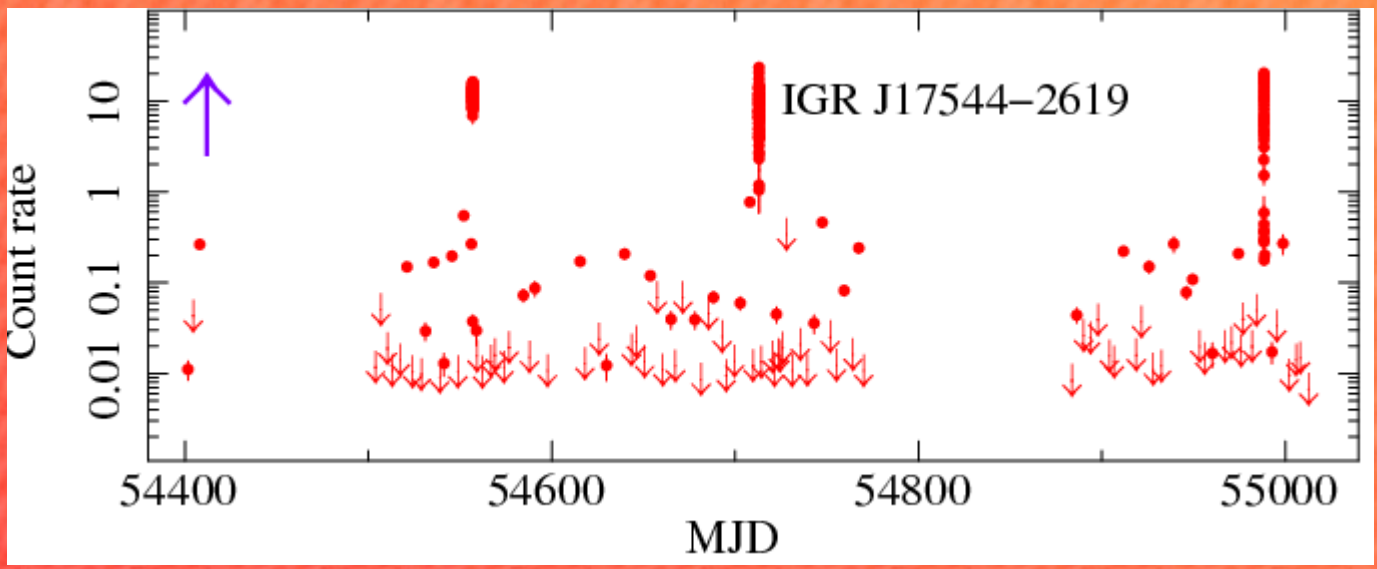
XRT (0.2-10 keV)

IDC=39%



3 flares
4 orders
of magnitude

IDC=55%

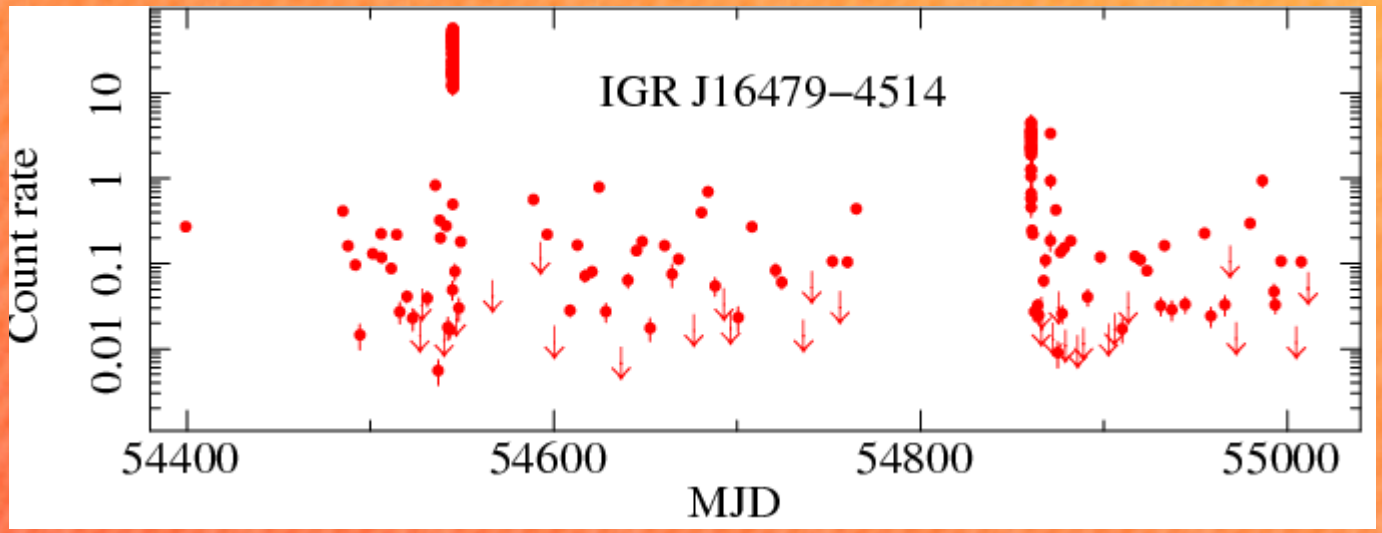


4 flares
4 orders
of magnitude

Results from Swift monitoring
(October 2007 – August 2009)

XRT (0.2-10 keV)

IDC=17%

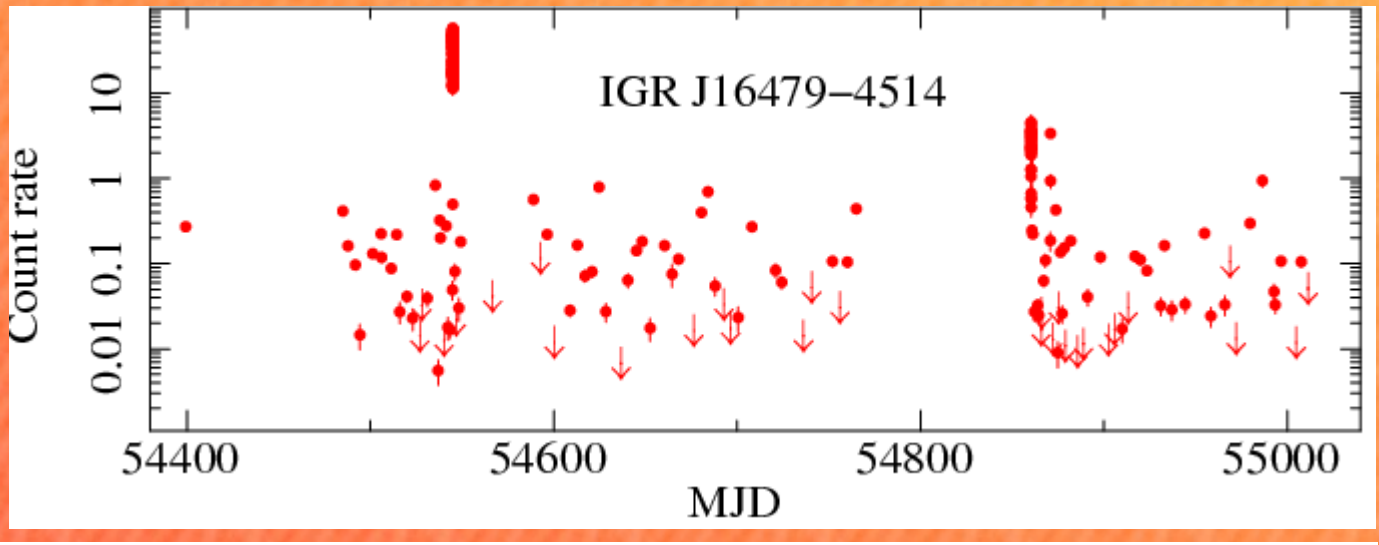


2 flares
4 orders
of magnitudes

Results from Swift monitoring
(October 2007 – August 2009)

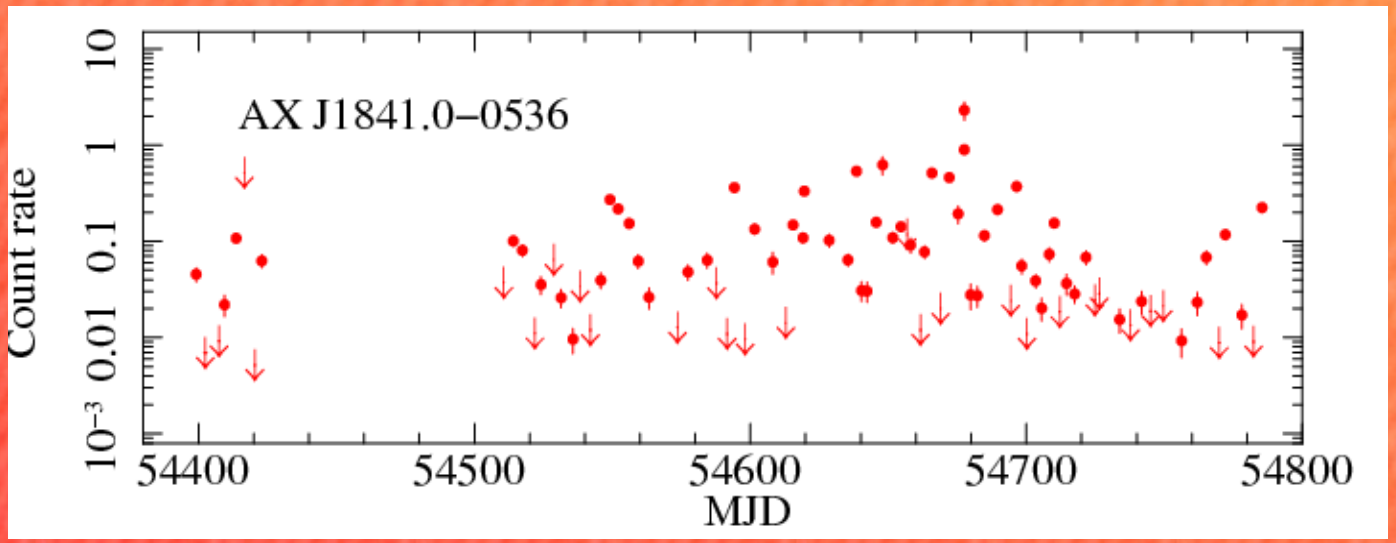
XRT (0.2-10 keV)

IDC=17%



2 flares
4 orders
of magnitudes

IDC=28%

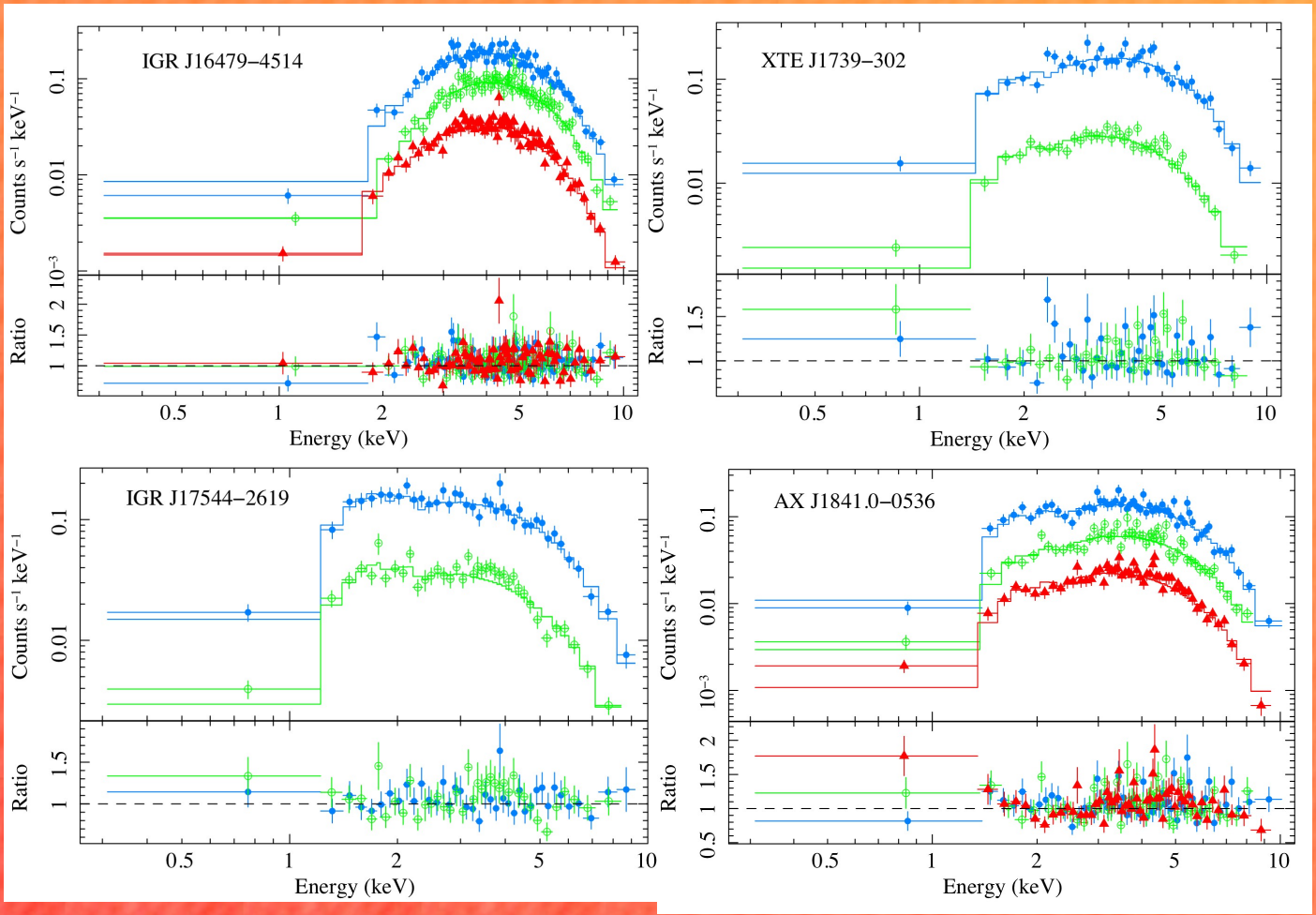


no flares
2 orders
of magnitudes

Results of the on-going Swift monitoring:
spectra of the **out-of-outburst** emission (intensity selected)

Sidoli et al. 2008
Romano et al. 2009

XRT (0.2-10 keV)



hard power-laws (Γ~0.8-2)

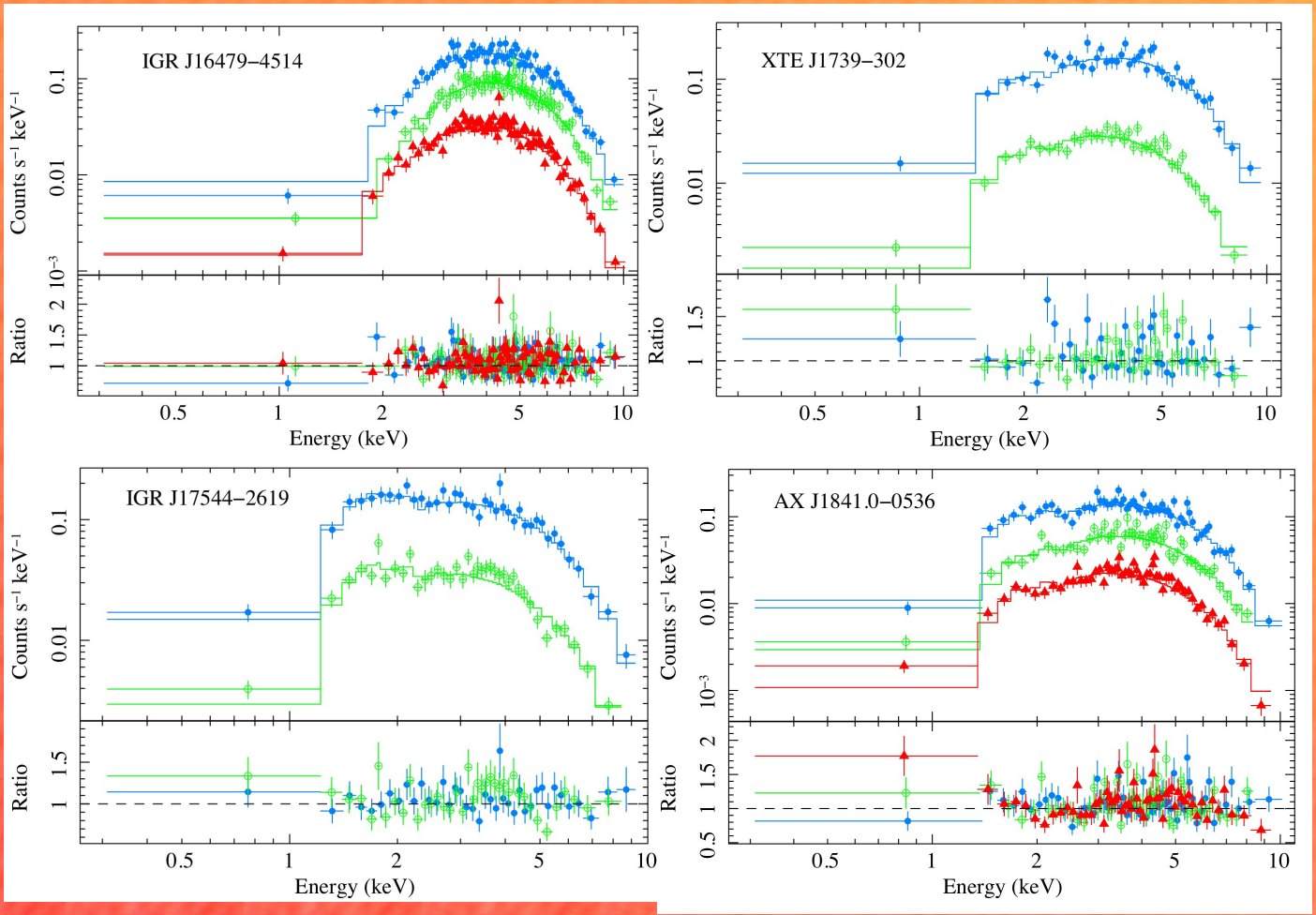
or hot BBs (kT~1-2 keV)

L x = 1e33-1e34 erg/s
@ the following distances:
4.9 kpc (IGR16479)
2.7 kpc (XTE1739)
3.6 kpc (IGR17544)
(Rahoui et al 2008)
5 kpc (IGR18410)

Results of the on-going Swift monitoring:
spectra of the **out-of-outburst** emission (intensity selected)

Sidoli et al. 2008
Romano et al. 2009

XRT (0.2-10 keV)



hard power-laws (Γ~0.8-2)

or hot BBs (kT~1-2 keV)

The lowest luminosity level we could monitor with Swift:
Lx = **6E32 erg/s in XTEJ1739-302** and Lx = **3E32 erg/s in IGRJ17544-2619**

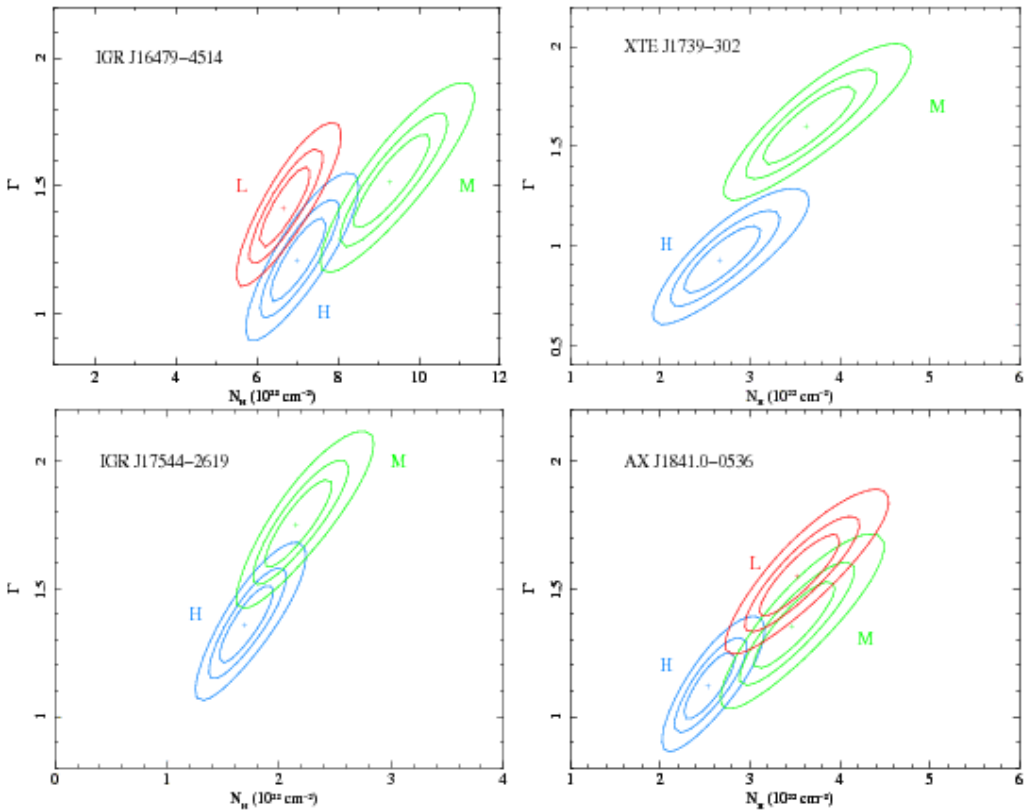
Results of the on-going Swift monitoring:
spectra of the **out-of-outburst** emission (intensity selected)

Sidoli et al. 2008
Romano et al. 2009

XRT (0.2-10 keV)

Absorbing Column Density

Photon Index



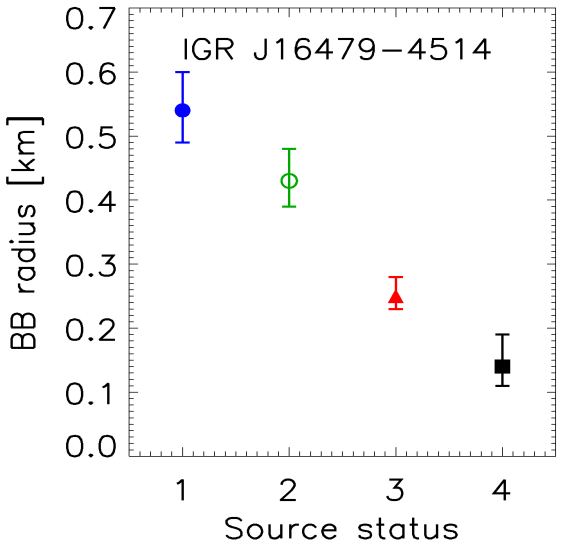
hard power-laws (Γ~0.8-2)

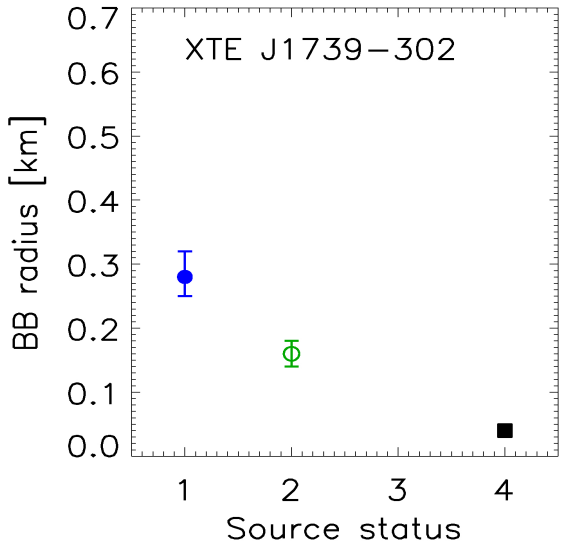
or hot BBs (kT~1-2 keV)

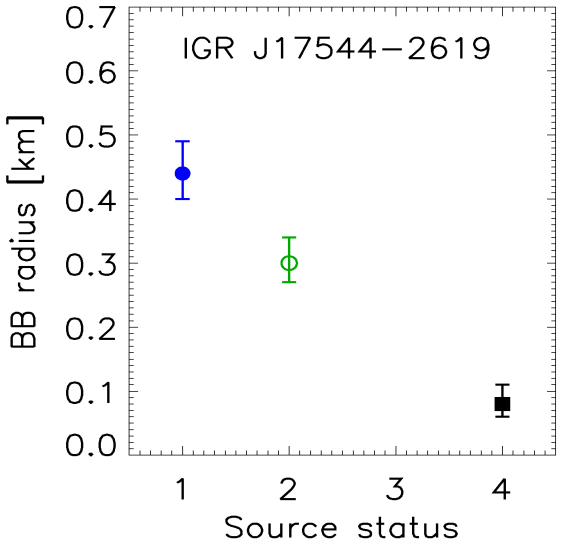
L x = 1e33-1e34 erg/s
@ the following distances:
4.9 kpc (IGR16479)
2.7 kpc (XTE1739)
3.6 kpc (IGR17544)
(Rahoui et al 2008)
5 kpc (IGR18410)

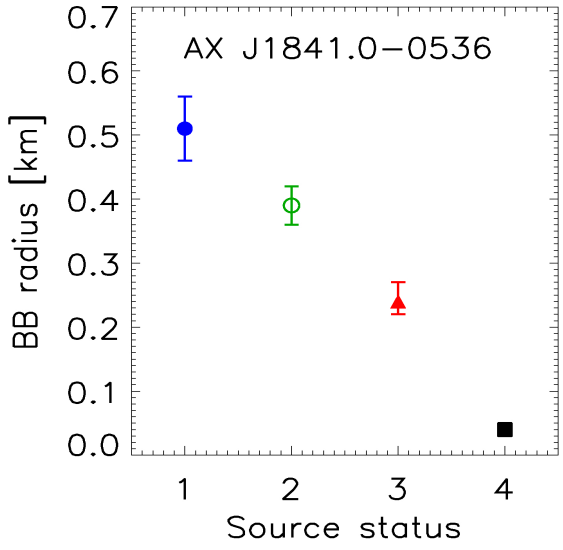
Results of the on-going Swift monitoring:
spectra of the **out-of-outburst** emission (intensity selected)

Sidoli et al. 2008
Romano et al. 2009









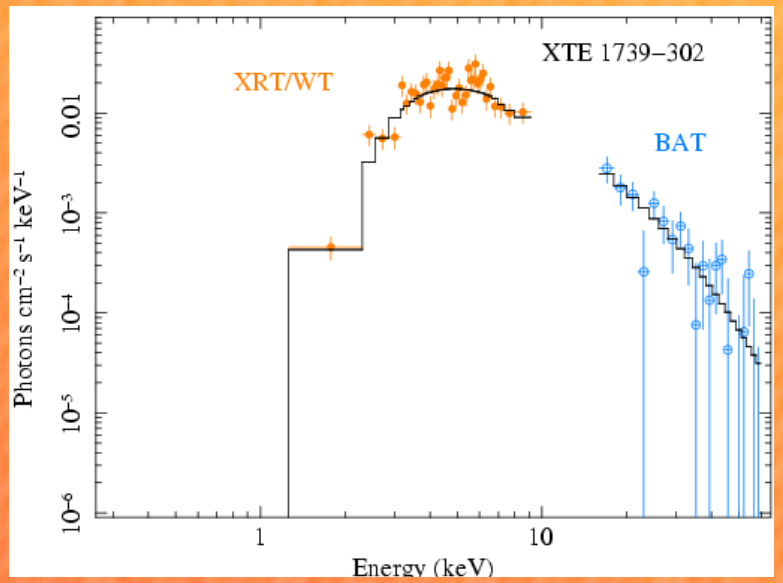
Black-body radii
< 1km!!!
<< R_{NS}

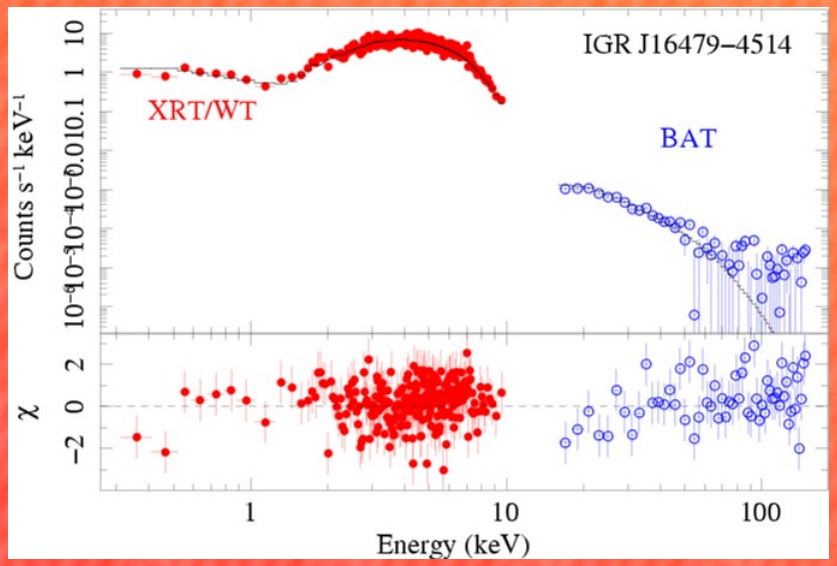
polar cap ?

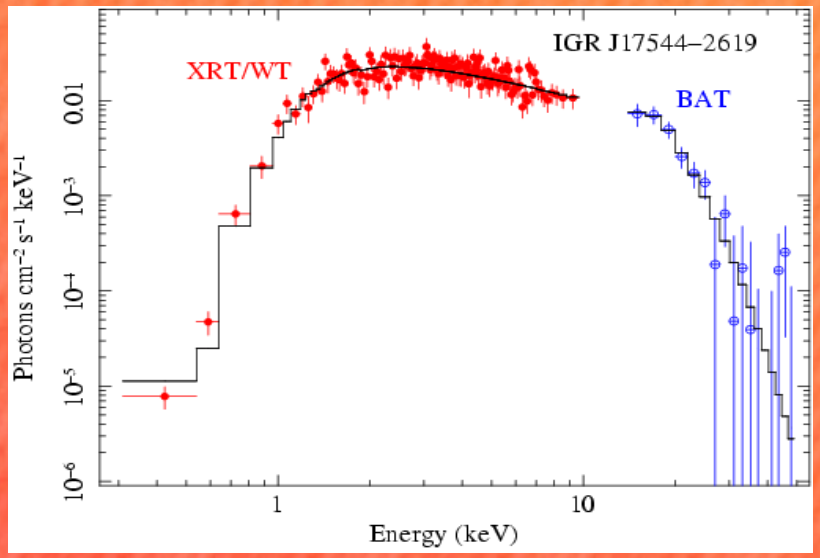
Results of the on-going Swift monitoring:
spectra of the emission during **outbursts**

Sidoli et al. 2009

	IGRJ16479-4514	IGRJ17544-2619	XTEJ1739-302
N_H (10^{22})	6.2±0.5	1.1±0.2	12.5±3
Γ	1.15±0.14	0.75+/-0.1	1.4±0.7
E_{cut} (keV	6.6±0.9	18±2	6±6
E_{fold} (keV)	15.3±2.5	4±2	16±10
L_X (0.5-10 keV)	28.2x10^{36}	1.9x10^{36}	1.9x10^{36}
L_X (0.5-100 keV)	57.3x10^{36}	5 x10^{36}	3x10^{36}

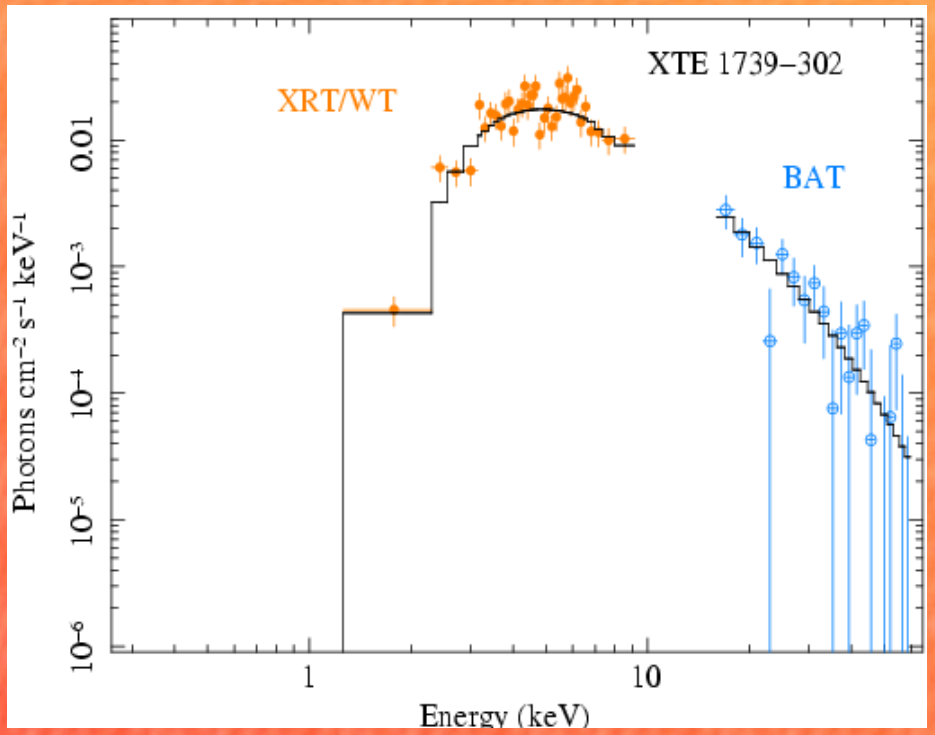




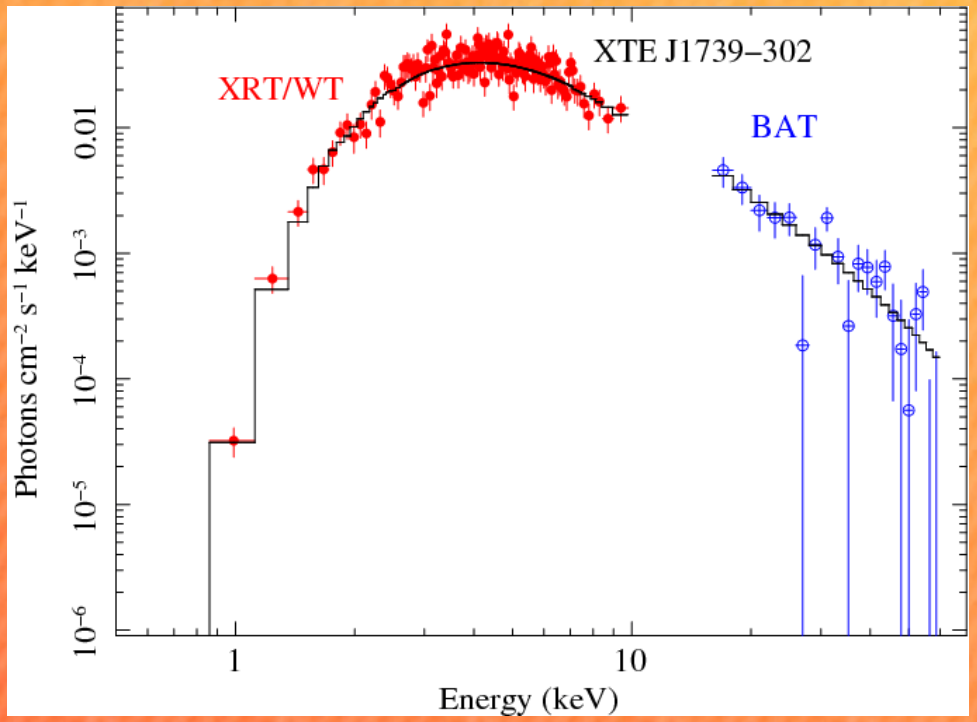


Absobed powerlaws with high energy cutoffs

Results of the on-going Swift monitoring emission during **outbursts: absorption and/or spectral variability?**



1st outburst (Apr 2008)



2nd outburst (Aug 2008)

BMC model is a good fit too

BMC	N_H[a]	kT_{BB}[b,d]	α[d]	log(A)[d]	Flux[c]
	$3.4^{+0.6}_{-0.5}$	$1.6^{+0.2}_{-0.3}$	$1.3^{+0.4}_{-0.4}$	$0.5^{+7.5}_{-0.6}$	4.9

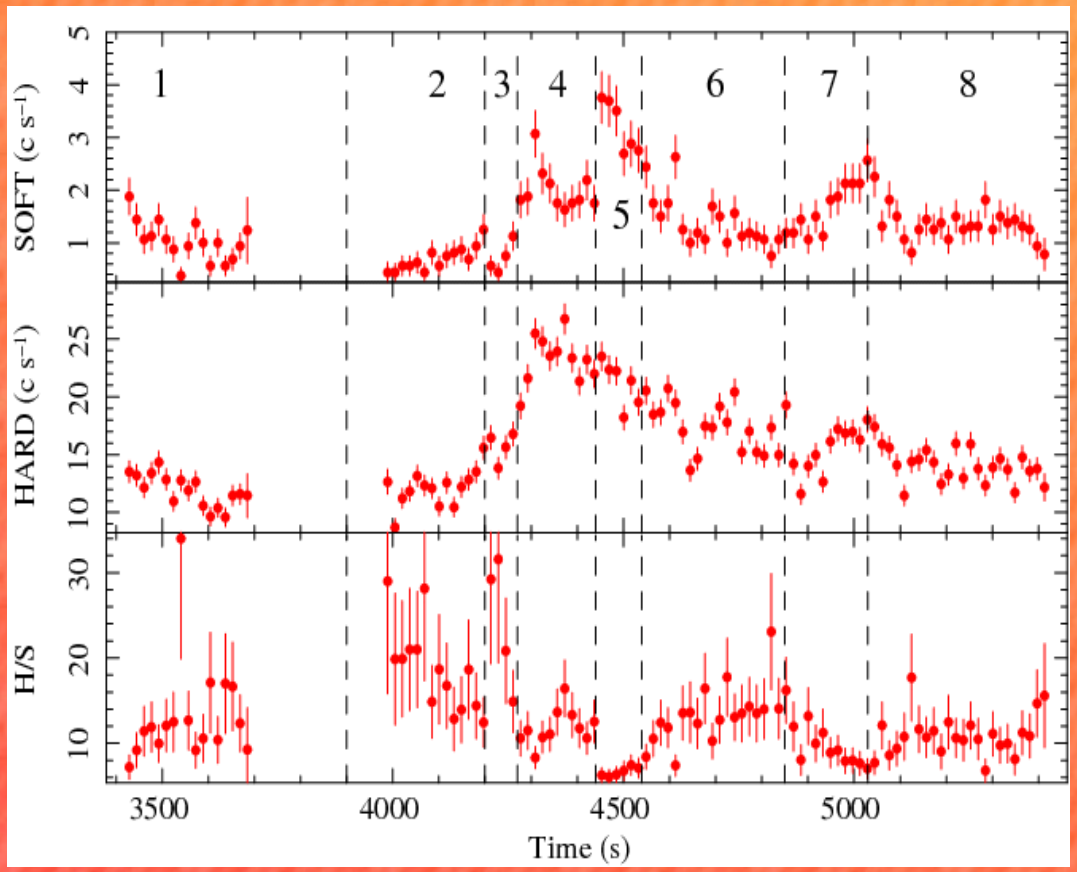
[Nh] = 1E22 cm-2
A = illumination parameter
alpha = spectral index

[Flux] = 1E-9 erg/cm2/s

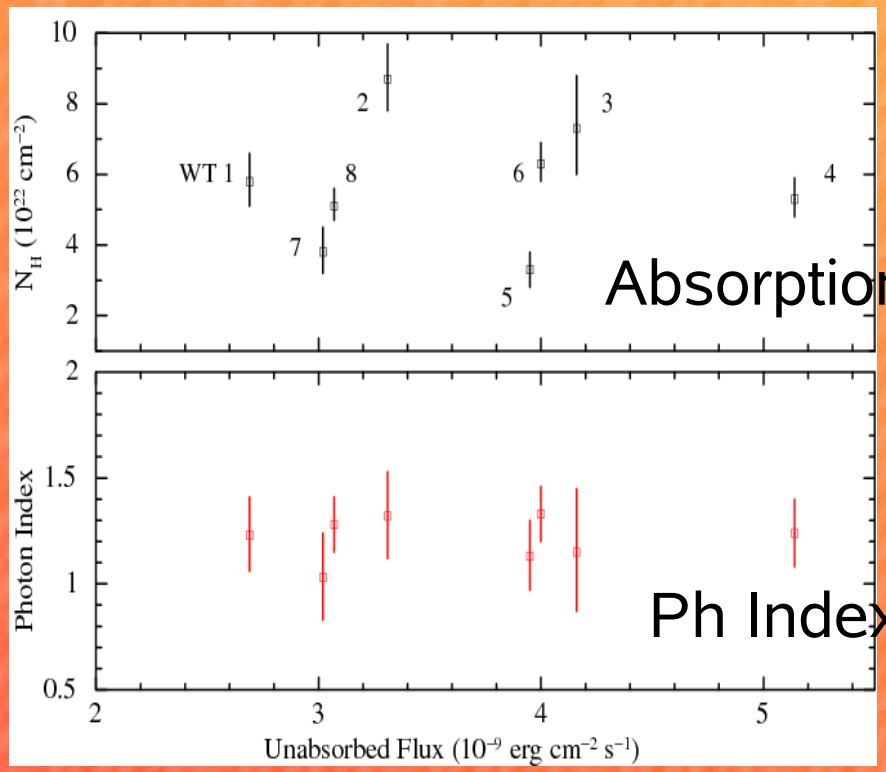
Sidoli et al. 2009

Results of the on-going Swift monitoring emission during **outbursts: absorption and/or spectral variability?**

Sidoli et al. 2009

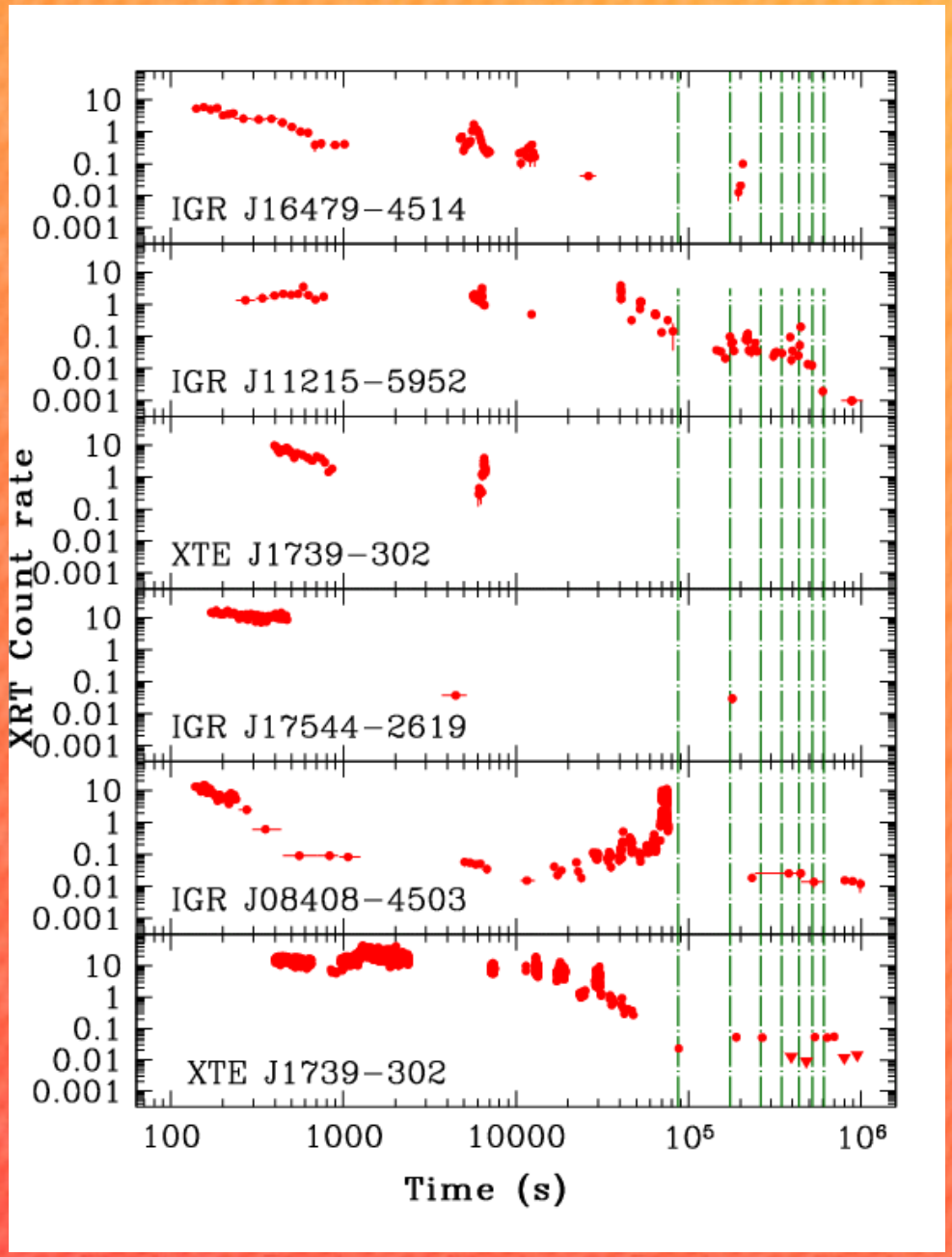


XTE J1739-302
2nd outburst (Aug 2008)



Unabs FLUX

Comparison of 5 SFXTs light curves during bright flares



2005Aug 30
Sidoli et al. 2008

2007 Feb 09
Romano et al. 2007

2008 Apr 08
Sidoli et al. 2009a

2008 Mar 31
Sidoli et al. 2009a

2008 Jul 05
Romano et al. 2009a

2008 Aug 13
Sidoli et al. 2009b

8 days of monitoring with Swift/XRT

Common features:

-outburst length > hours

-multiple peaked structure

-dynamic range ~ 1000

Sidoli et al. 2008b, 2009b

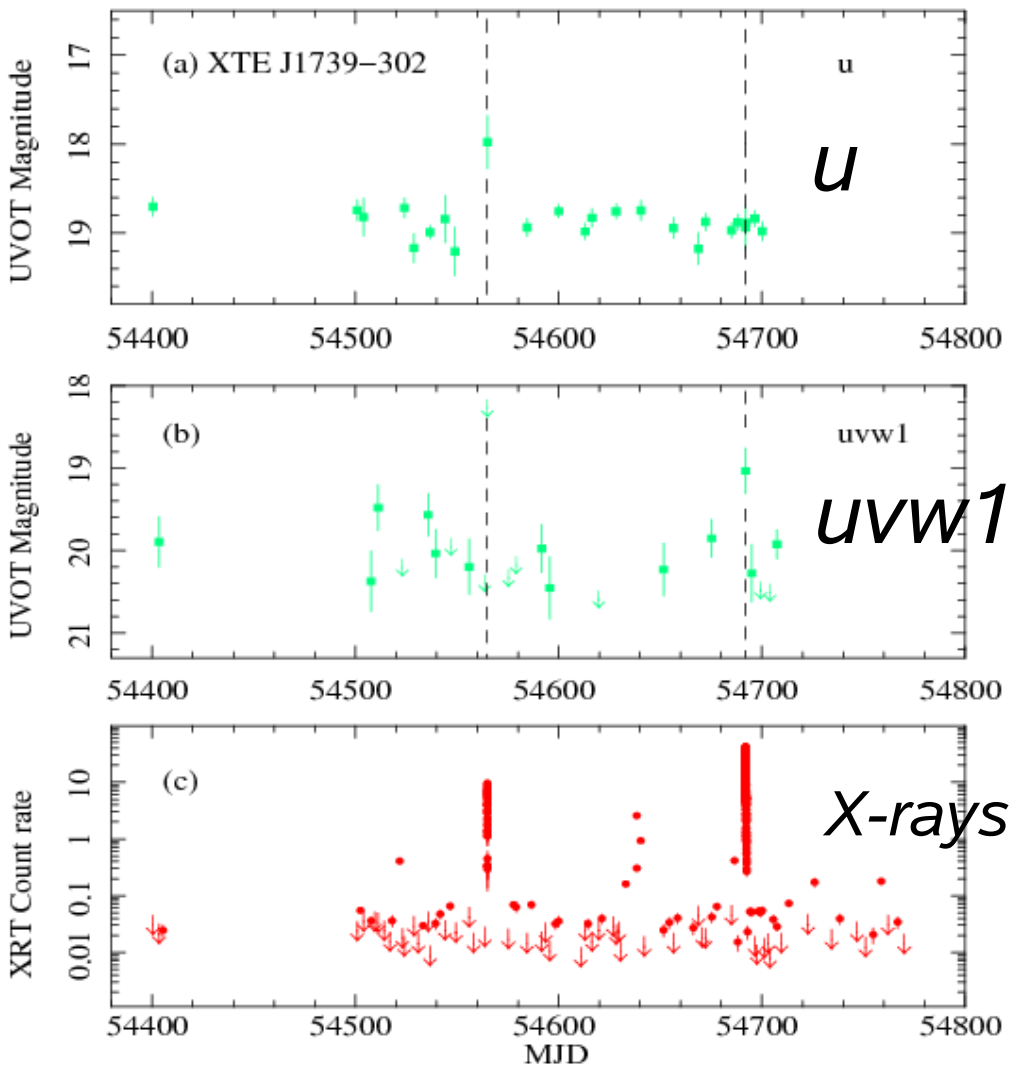
Swift/**UVOT** SFXTs light curves

Optical/UV observations simultaneous to our Swift/XRT monitoring

Swift/**UVOT** SFXTs light curves

Optical/UV observations simultaneous to our Swift/XRT monitoring

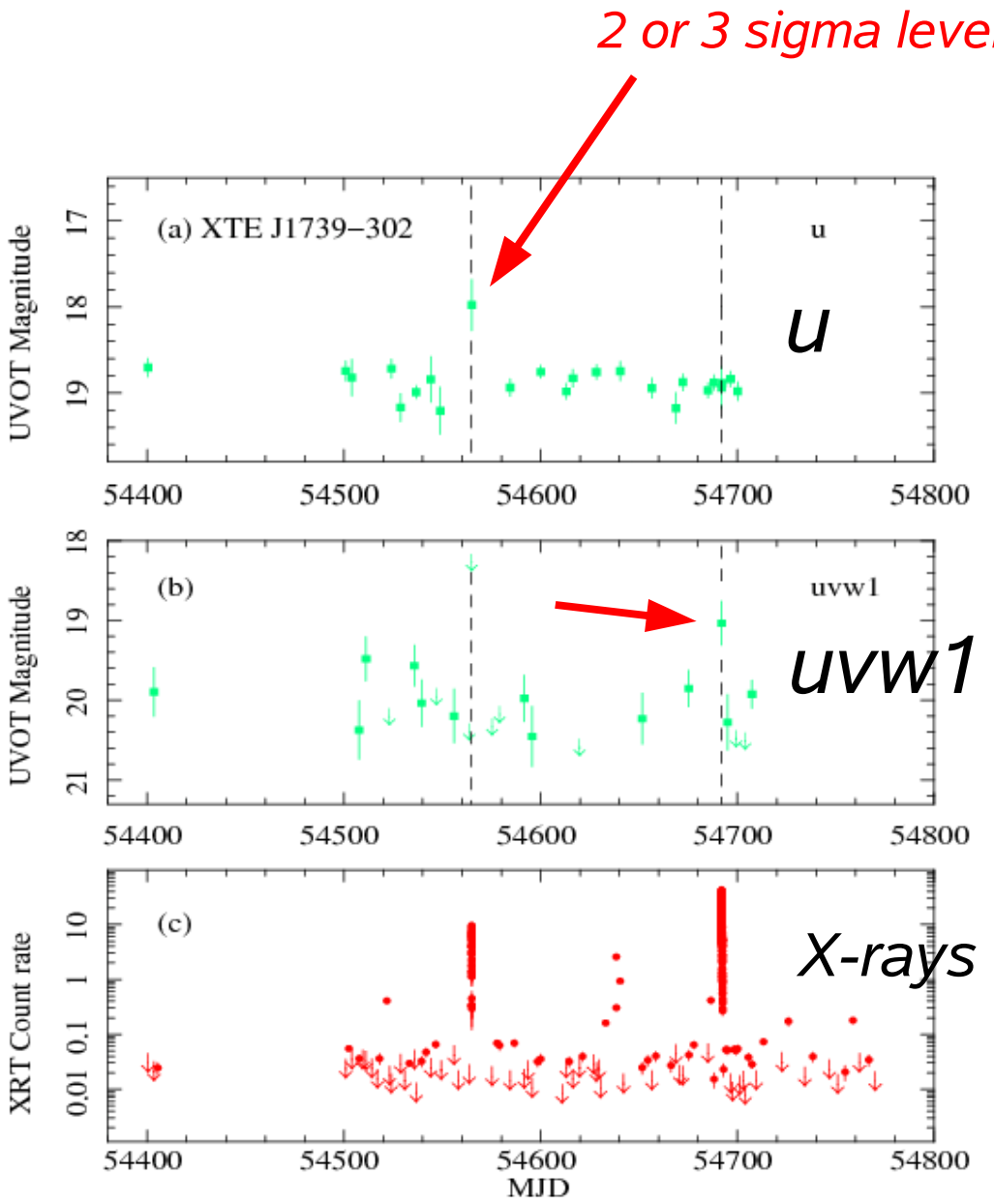
XTE J1739-302



Swift/**UVOT** SFXTs light curves

Optical/UV observations simultaneous to our Swift/XRT monitoring

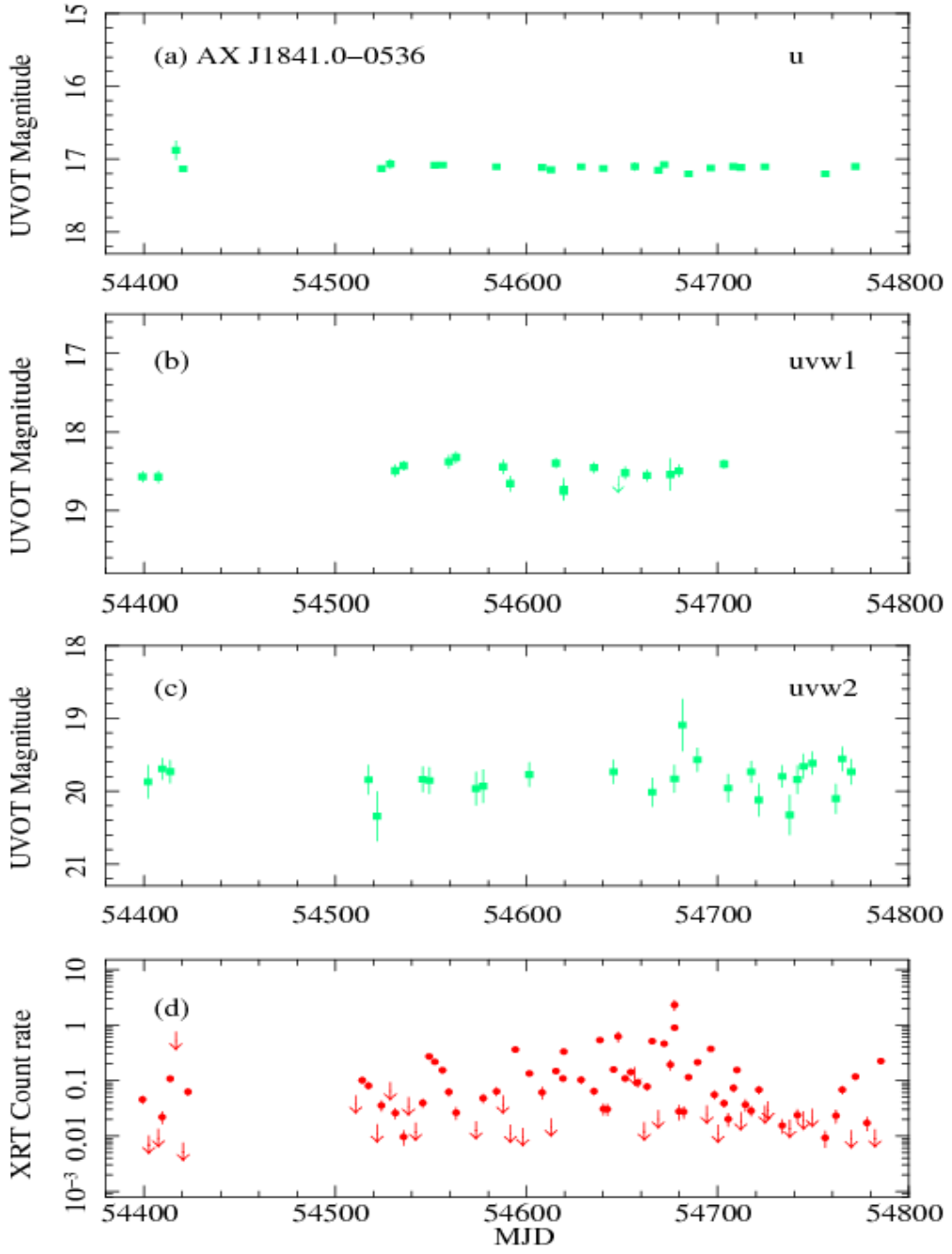
XTE J1739-302



Swift/**UVOT** SFXTs light curves

Optical/UV observations simultaneous to our Swift/XRT monitoring

AX J1841.0-0536



Results of the on-going Swift monitoring: (1) **out-of-outburst emission**

Sidoli et al., 2008
Romano et al. 2009

Our Swift monitoring campaign of a sample of 4 SFXTs demonstrates that:

The **long-term behaviour** of SFXTs **is NOT the true quiescent state**,
characterized by a soft spectrum and an X-ray luminosity of ~ 1E32 erg/s,
BUT an intermediate state of **ACCRETION**
with an average X-ray luminosity of 1**E33 – 1E34 erg/s**,
a **hard spectrum** (power law photon index 1-2) and a **high flux variability**

The calculated inactivity duty cycle (IDC) is only an UPPER LIMIT to the quiescent level.
The lowest luminosity state Swift could monitor is:
Lx = 6E32 erg/s in XTEJ1732-302 (2-10 keV)
Lx = 3E32 erg/s in IGRJ17544-2619 consistent with Chandra obs
BUT with a much harder spectrum
The low intensity level in IGRJ16479-4514 is consistent with eclipses

Results of the on-going Swift monitoring: (2) **outburst emission**

Sidoli et al., 2008
Sidoli et al., 2009
Romano et al. 2009

Our Swift monitoring campaign demonstrates that:

The **wide band spectrum during outburst** is well modelled by models usually adopted to describe **typical accreting X-ray pulsars**

The **duration** of the outburst in 4 cases observed with Swift is **longer than a few hours** (this means that IGR J11215-5952 is NOT a "strange" case)

The **spectra** during outburst shows high energy cut offs compatible with a neutron star **magnetic field** around 1E12 G, although no cyclotron lines have been detected yet.

UVOT monitoring simultaneous with XRT is suggesting a variability too, which needs confirmation.

Status of the SFXT Project:
Swift/XRT exposures

2009 Aug 31

IGRJ16479-4514

133 obs/**152 ks**

XTE J1739-302

162 obs/**165 ks**

IGRJ17544-2619

138 obs/**127 ks**

AX 1841.0-0536

88 obs /**96.5 ks**

Total XRT esposure **540.5 ks**

Posters on SFXTs by our group

P1. 2 Ducci L. et al.
The role of structured OB supergiant winds in producing the X-ray flaring emission from High Mass X-ray Binaries

P4. 31 La Parola V. et al.
The Swift SFXTs monitoring campaign: the IGR J16479-4514 outburst in 2009

P4. 41 Romano P. et al.
Swift Observations of the SFXT SAX J1808.6-1703 in outburst

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