OBSERVATIONAL UPDATES ON ACCRETING MILLISECOND X-RAY PULSARS

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in collaboration with
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ACCRETING MILLISECOND X-RAY PULSARS

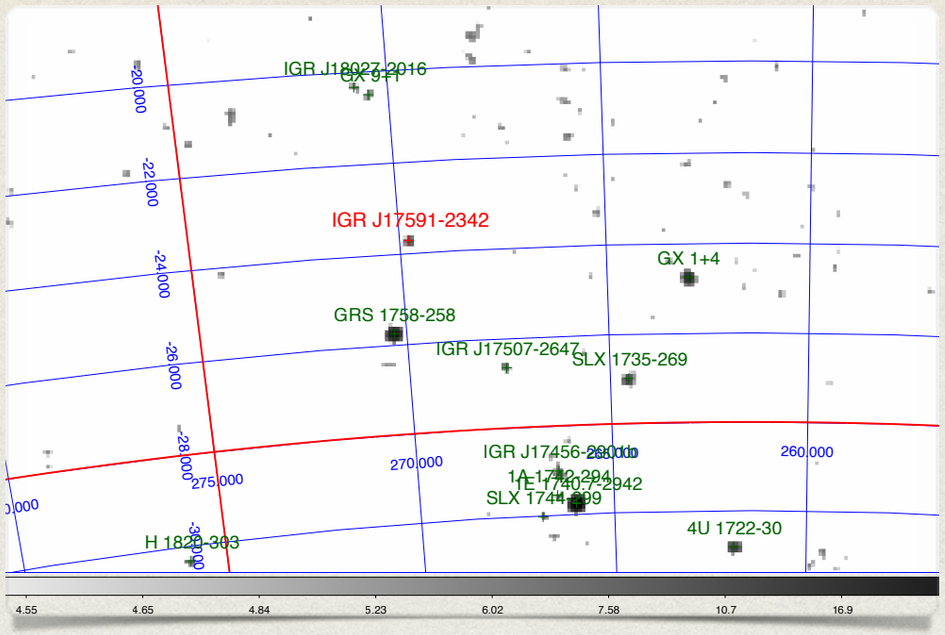
Name	P_spin (ms)	P_orb (h)	Ref
SAX J1808.4-3658	2.5	2.0	Wijnands & van der Klis 1998
XTE J0929-314	5.4	0.73	Galloway et al. 2002
XTE J1751-305	2.3	0.7	Markwardt et al. 2002
XTE J1814-338	3.2	4.0	Markwardt et al. 2003
XTE J1807-294	5.3	0.67	Markwardt et al. 2003
IGR J00291+5934	1.7	2.5	Galloway et al. 2005
HETE J1900.1-2455	2.7	1.4	Kaaret et al. 2005
SWIFT J1756.9-2508	5.5	0.9	Markwardt et al. 2007
Aql X-1	1.8	19	Casella et al. 2007
SAX J1748.9-2021	2.3	8.8	Altamirano et al. 2007
NGC 6440 X-2	4.8	0.96	Altamirano et al. 2010
IGR J17511-3057	4.1	3.5	Markwardt et al. 2009
SWIFT J1749.4-2807	1.9	8.8	Altamirano et al. 2010
IGR J1749.8-2921	2.5	3.84	Papitto et al. 2011
IGR J18245-2452	3.9	11.03	Papitto et al. 2013
XSS J12270	1.7	6.9	Bassa et al. 2014
PSR J1023+0038	1.7	4.75	Archibald et al. 2015
MAXI J0911-655	2.9	0.74	Sanna et al. 2017
IGR J17062-6143	6.1	0.63	Strohmayer & Keek 2017
IGR J16597-3704	9.5	0.77	Sanna et al. 2017
IGR J17379-3747	2.1	1.9	Strohmayer 2018 - Sanna et al. 2018
IGR J17591-2342	1.9	8.8	Sanna et al. 2018

IGR J17591-2342

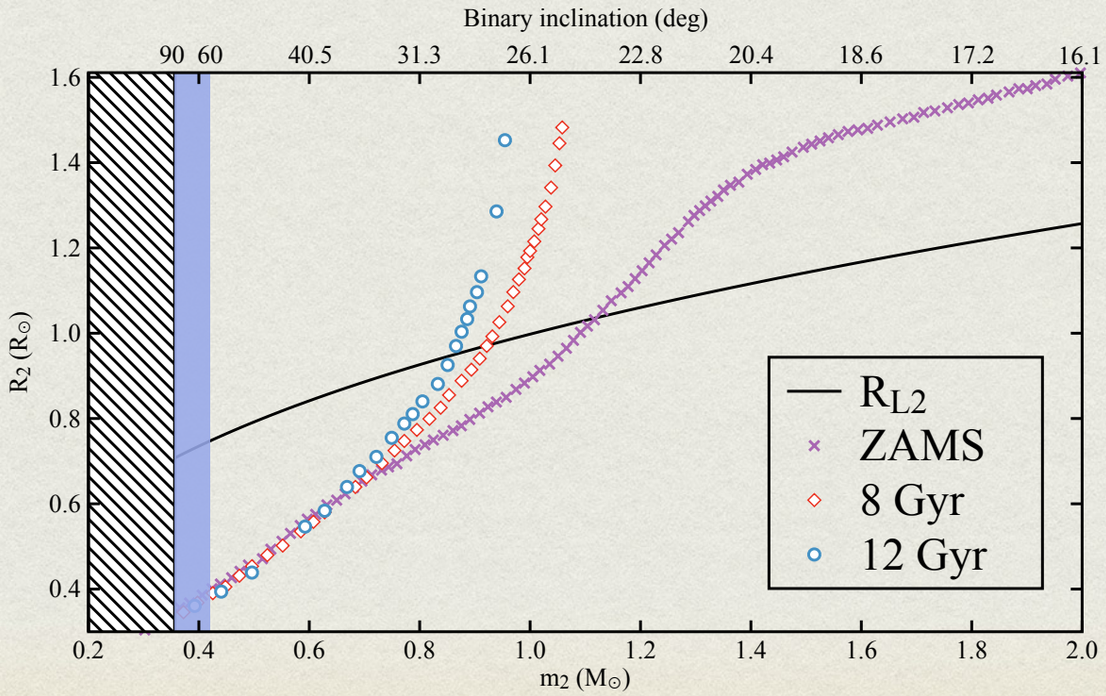
- Discovered on 2018 Aug 10 by INTEGRAL IBIS/ISGRI
- 12th of Aug 2018 Swift/XRT starts monitoring the source
- 14th/15th of Aug 2018 NuSTAR and NICER detect coherent X-ray pulsation

$\nu \simeq 527$ Hz

$m_2 \geq 0.42\ M_\odot$

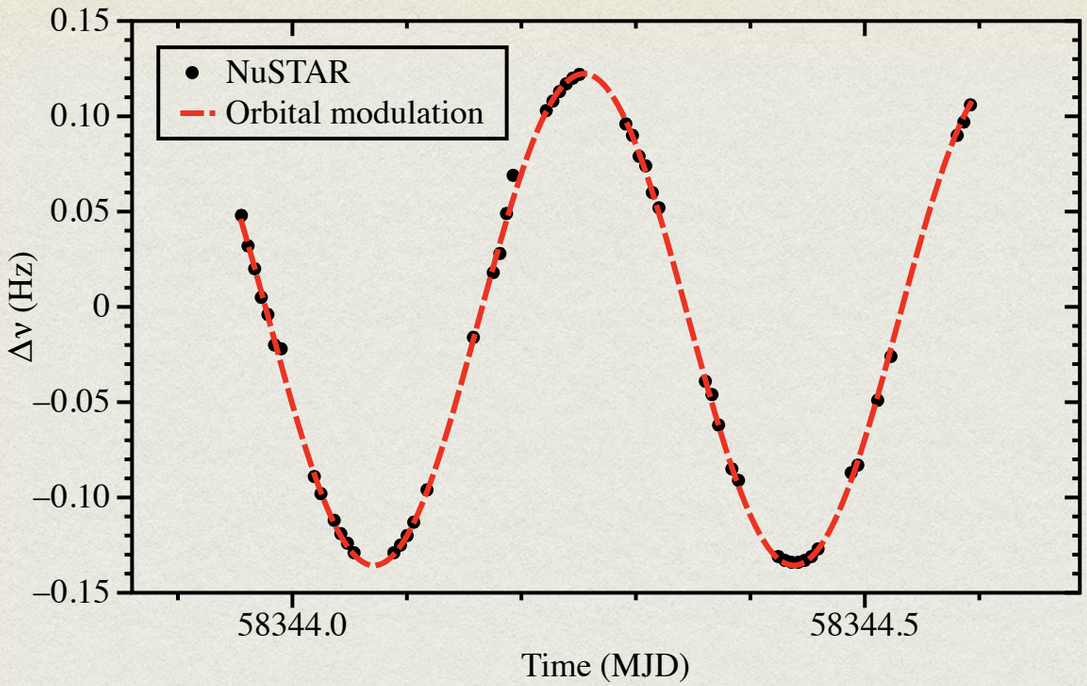


INTEGRAL/IBIS-ISGRI

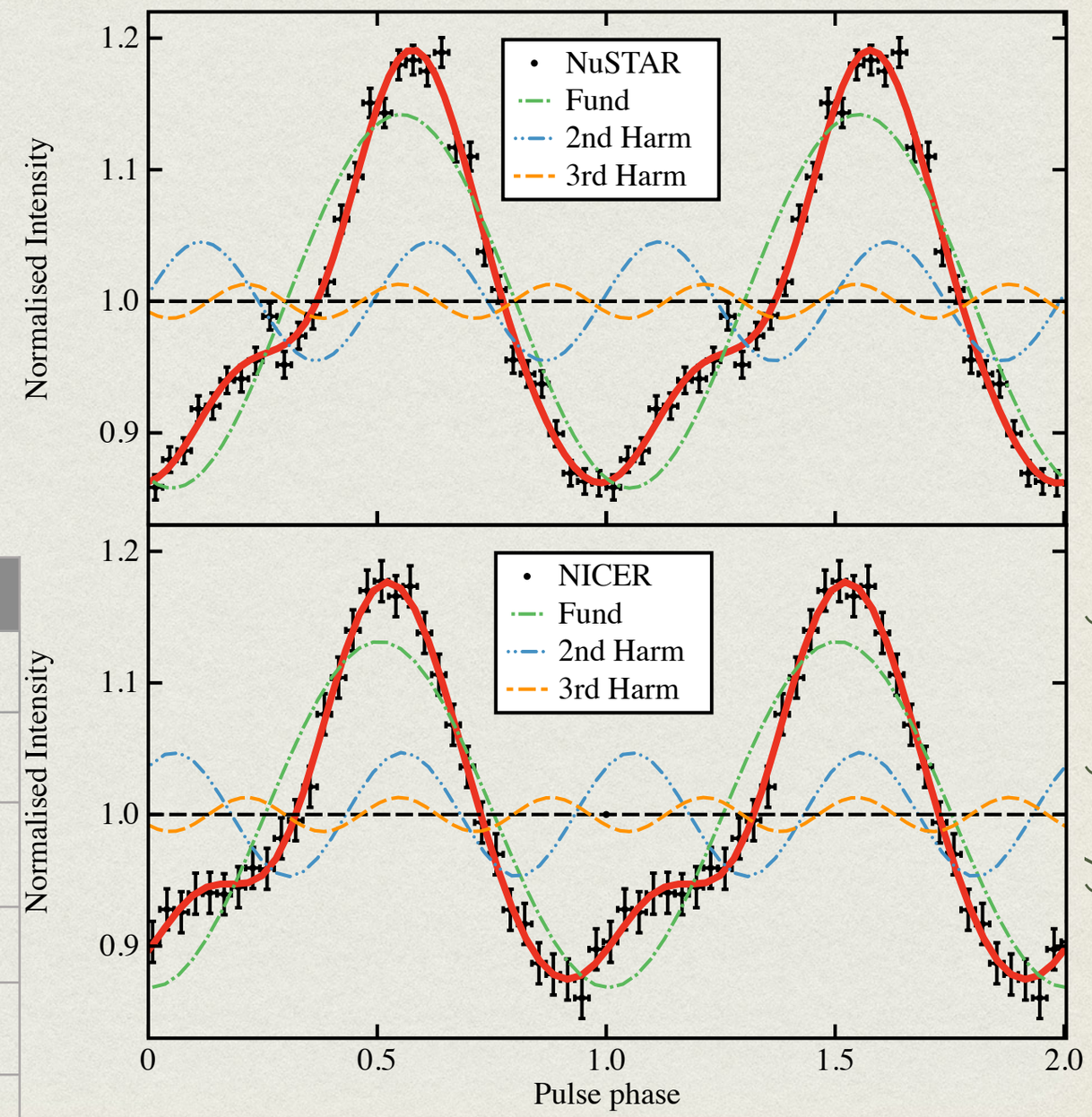


Sanna et al. 2018, A&A, 617, L8

IGR J17591-2342



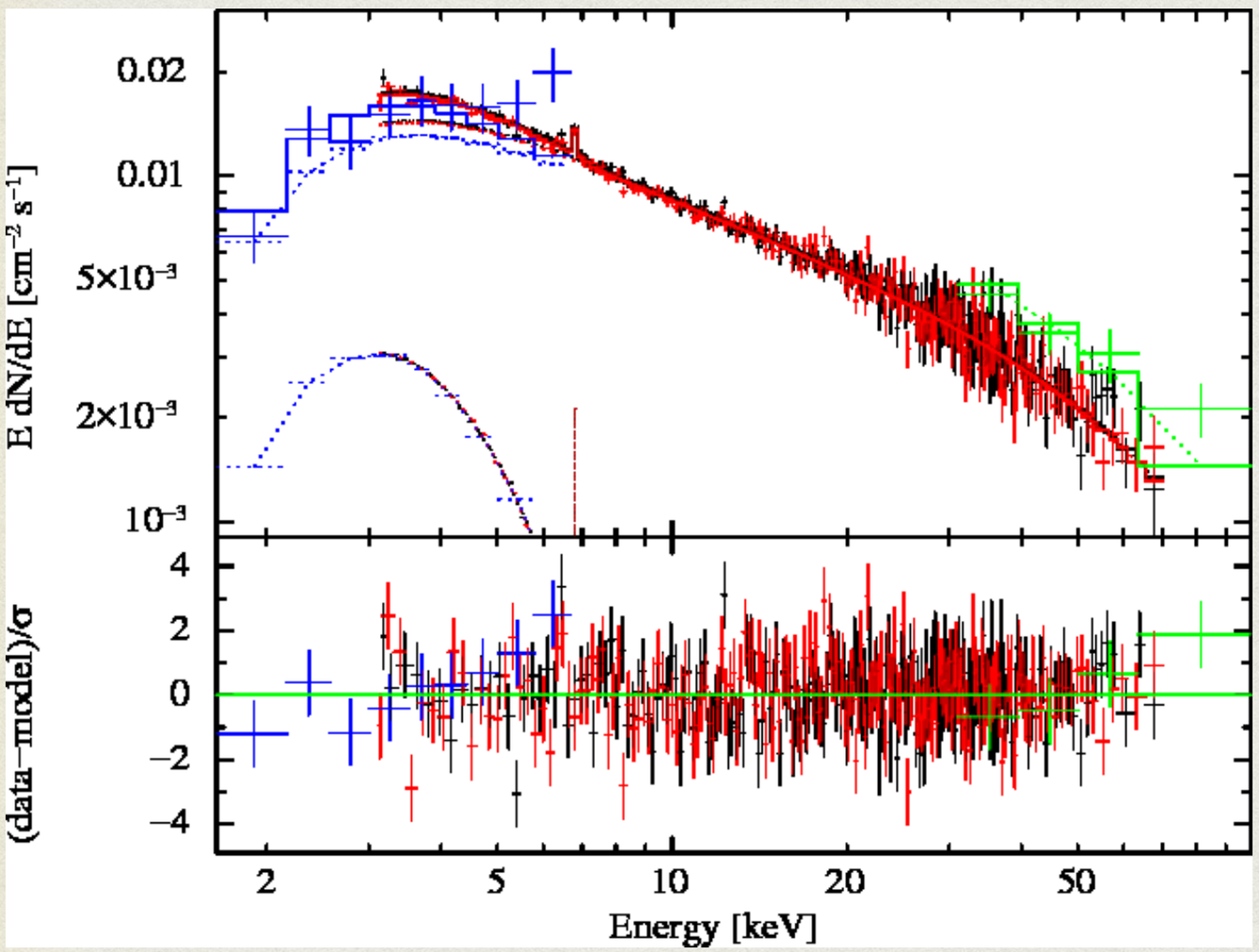
Parameter	Value
ν (Hz)	527.42570042(8)
dν/dt (Hz/s)	<1 x 10^{-13}
asin(i)/c (lt/s)	1.227716(8)
T_{NOD} (MJD)	58345.1719787(16)
P_{ORB} (s)	31684.743(3)
Eccentricity	< 6 x 10^{-5}



Sanna et al. 2018, A&A, 617, L8

IGR J17591-2342

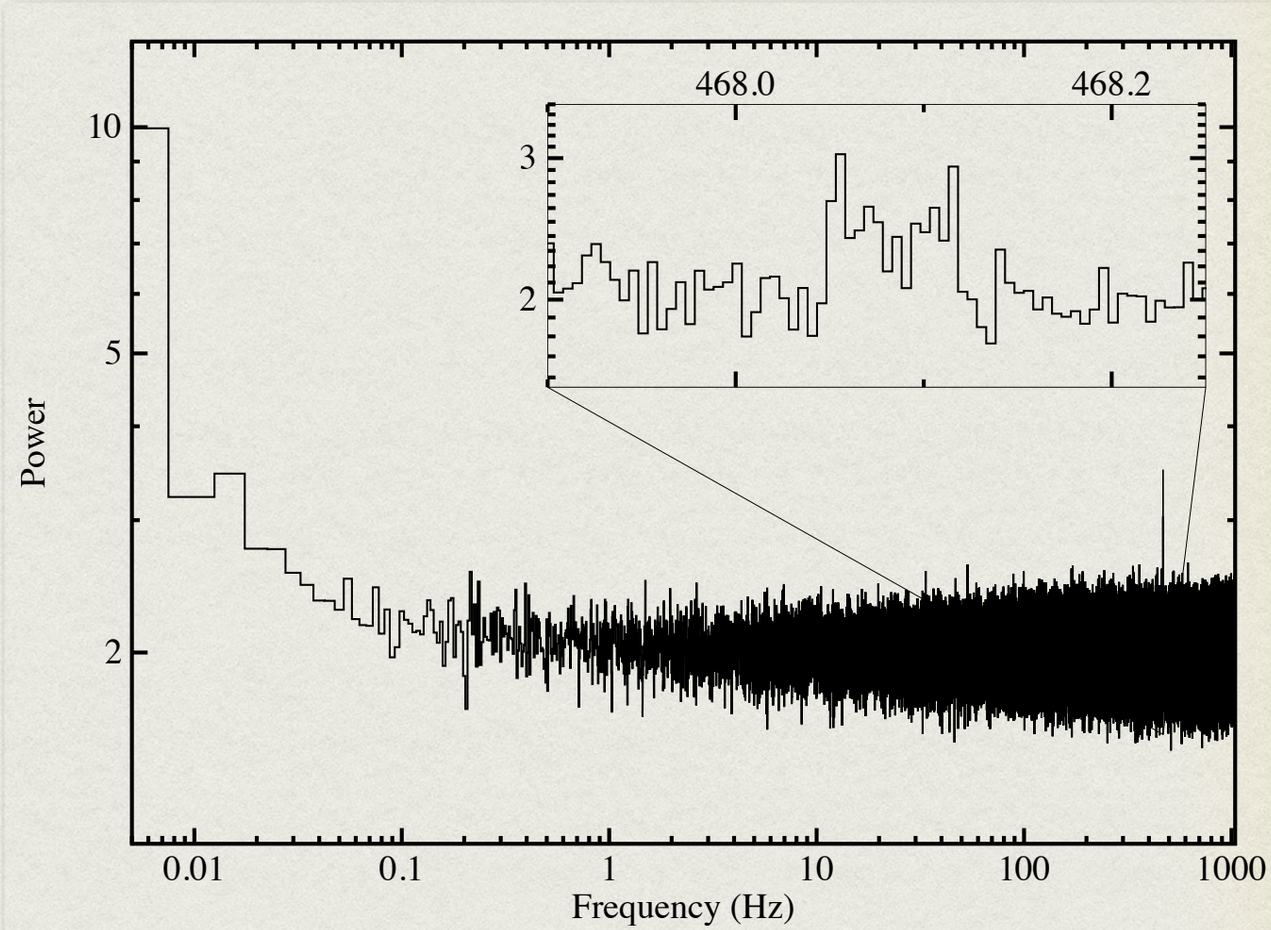
tbabs[bbodyrad+nthcomp+gauss]



Parameter	Value
N_H (cm^{-2})	$(3.6\pm1.1)\ 10^{22}$
Γ	1.76 ± 0.02
kT_{bb} (keV)	0.79 ± 0.09
kT_e (keV)	22 ± 4
E_{Fe} (keV)	6.8 ± 0.3
N_{Fe} (10^{-5} ph/s/cm2)	5.2 ± 1.8
χ^2/dof	515.67/413
$L_{0.1-100}$ (erg/s/cm2)	$9.9\ 10^{-10}$

IGR J17379-3747

- Known as X-ray Burster since 2004 (RXTE)
- Observed 3 times in outburst, the latest one in March 2018
- NICER discovers X-ray pulsations at ~468 Hz (Strohmayer et al. 2018, #Atel 11507)
- Almost simultaneously XMM-Newton DDT ToO detects the same coherent signal



Sanna et al. 2018, A&A, 616, L17

IGR J17379-3747

Parameter	2004	2008	2018
ν (Hz)	468.08338(13)	468.0831(2)	468.0832666(3)
To (MJD)	53056.0	54721.0	58209.0
asin(i)/c (lt-s)	—[a]	—[a]	0.07699(1)
TNOD (MJD)	53056.03926(12)	54721.032403(35)	58208.966437(9)
PORB (s)	—[a]	—[a]	6765.6(1)
Ecc	—[a]	—[a]	$<1 \times 10^{-3}$
$\chi 2$/dof	-	-	60.4/61

[a] parameter fixed to the value obtained from the 2018 outburst

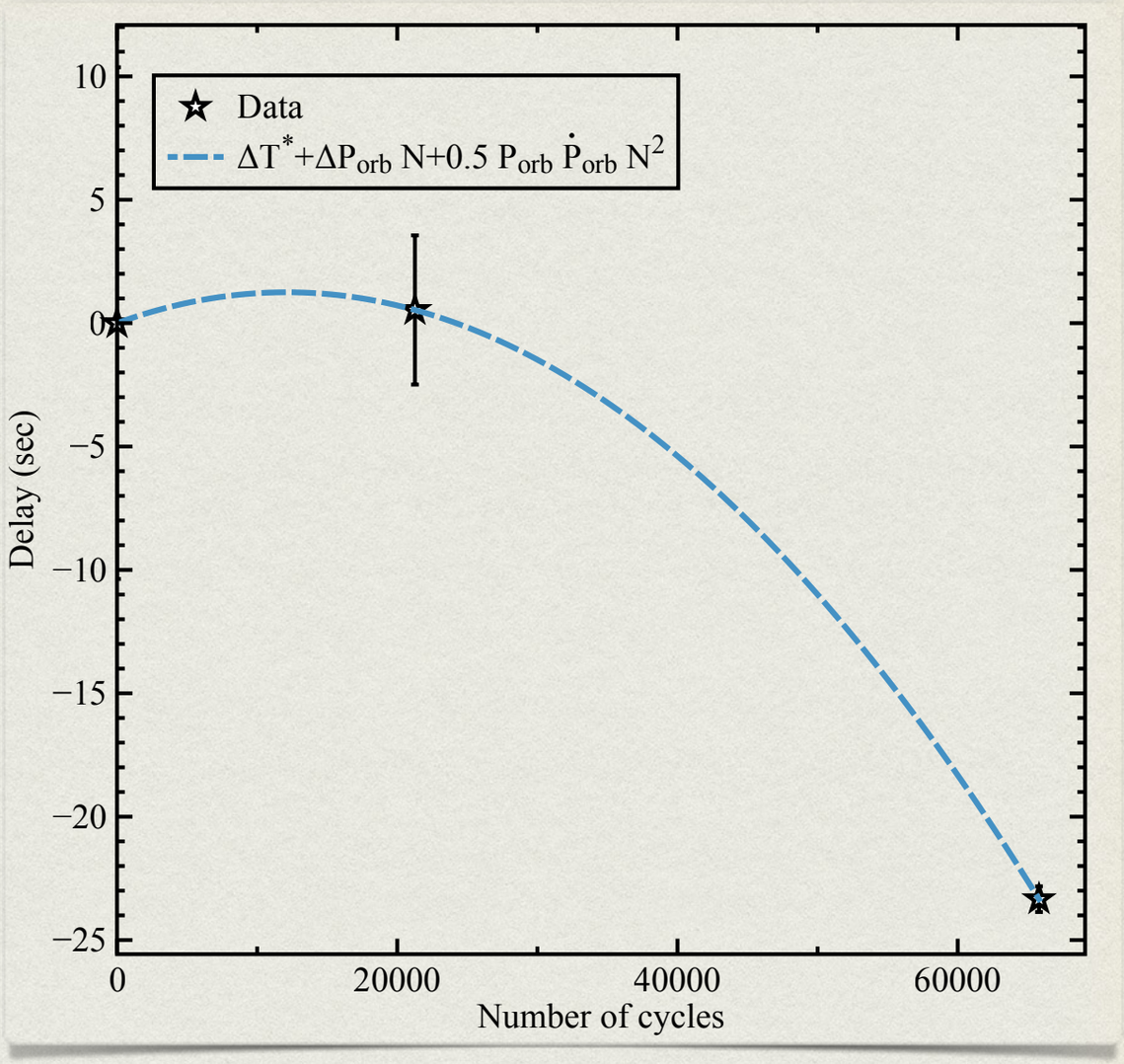
IGR J17379-3747

- **Reference: outburst 2018**
- **Each outburst we get:**

$$T_{NOD,PRE} = T_{NOD,18} + N * P_{ORB,18}$$

$$\Delta T_{NOD} = T_{NOD,OBS} - T_{NOD,PRE}$$

$$f(N) = \Delta T_{NOD,18} + N * \Delta P_{ORB,18} + 0.5\, N^2 * P_{ORB,18} * \dot{P}_{ORB}$$

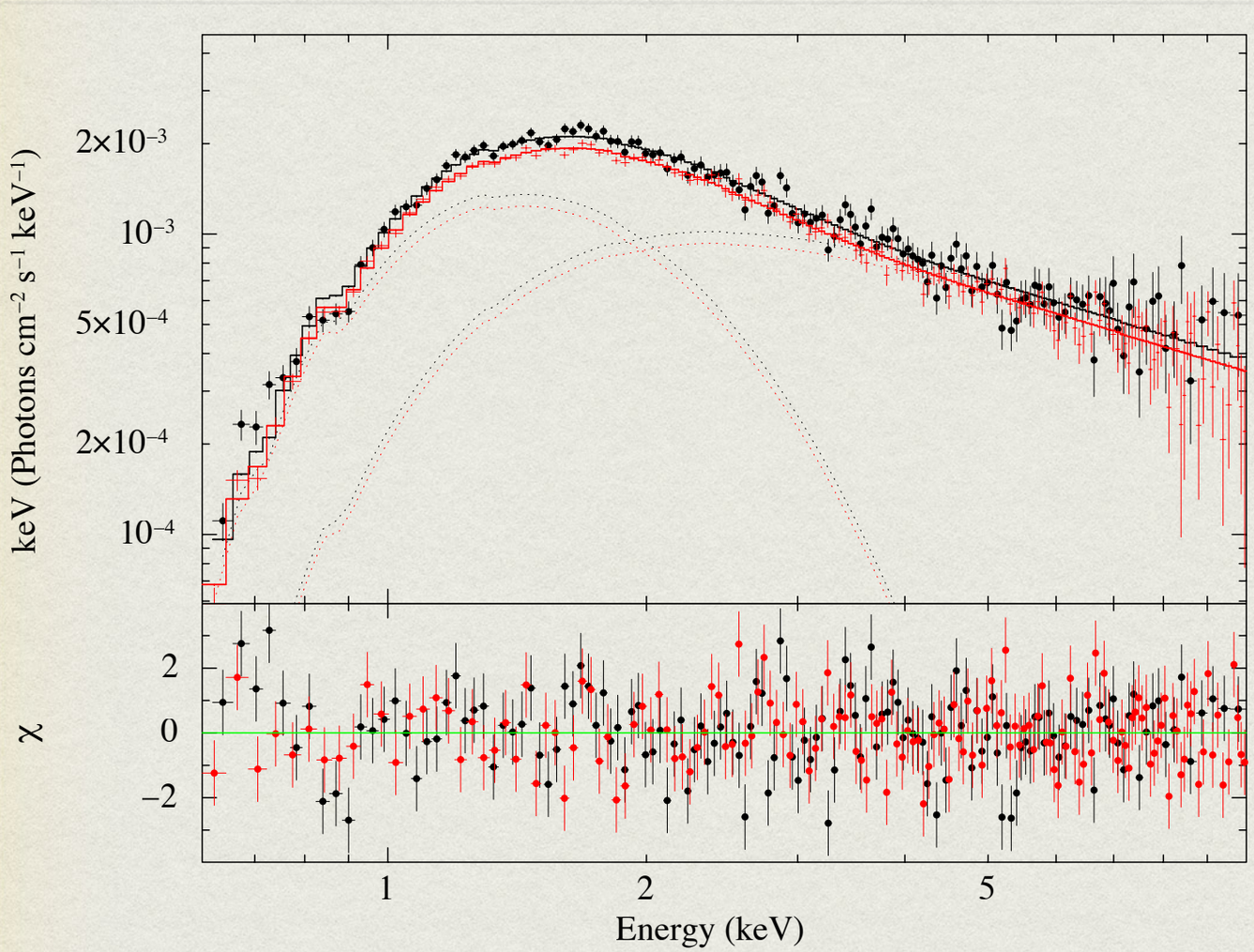


P_{ORB} =6765.85521(3) s

$\dot{P}_{ORB}$ = (2.5±2.3) x 10^{-12} s/s

IGR J17379-3747

tbabs[diskbb+nthcomp]



Parameter	Value
NH (cm^{-2})	(0.90±0.03) 10^{22}
kT_{disk} (keV)	0.45±0.03
Γ	1.88±0.08
kT_{bb} (keV)	0.45*
kT_e (keV)	30 (fixed)
χ^2/dof	318.66/282
$L_{0.5-10}$ (erg/s)	4.3 10^{35}

No Fe line nor Compton Hump

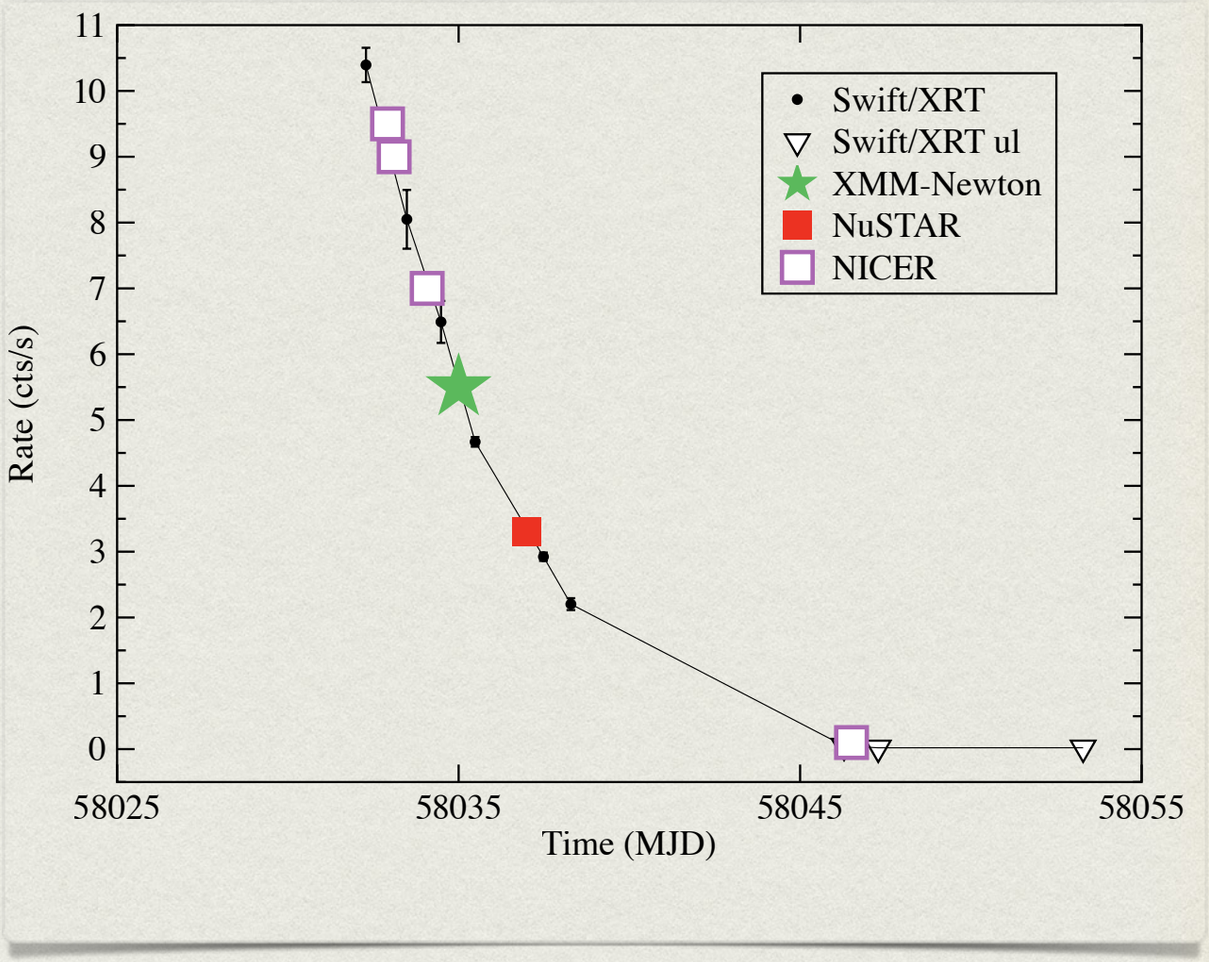
SAX J1748.9-2021

- Discovered in 1998 in the GC NGC 6440
- 6 outbursts in the last 20 years
- **Intermittent** X-ray pulsation detected in 2001/05/10/15/17

$$\nu \simeq 442.3\,\mathrm{Hz}$$

$$B \geq 1.3 \times 10^{8}\,\mathrm{G}$$

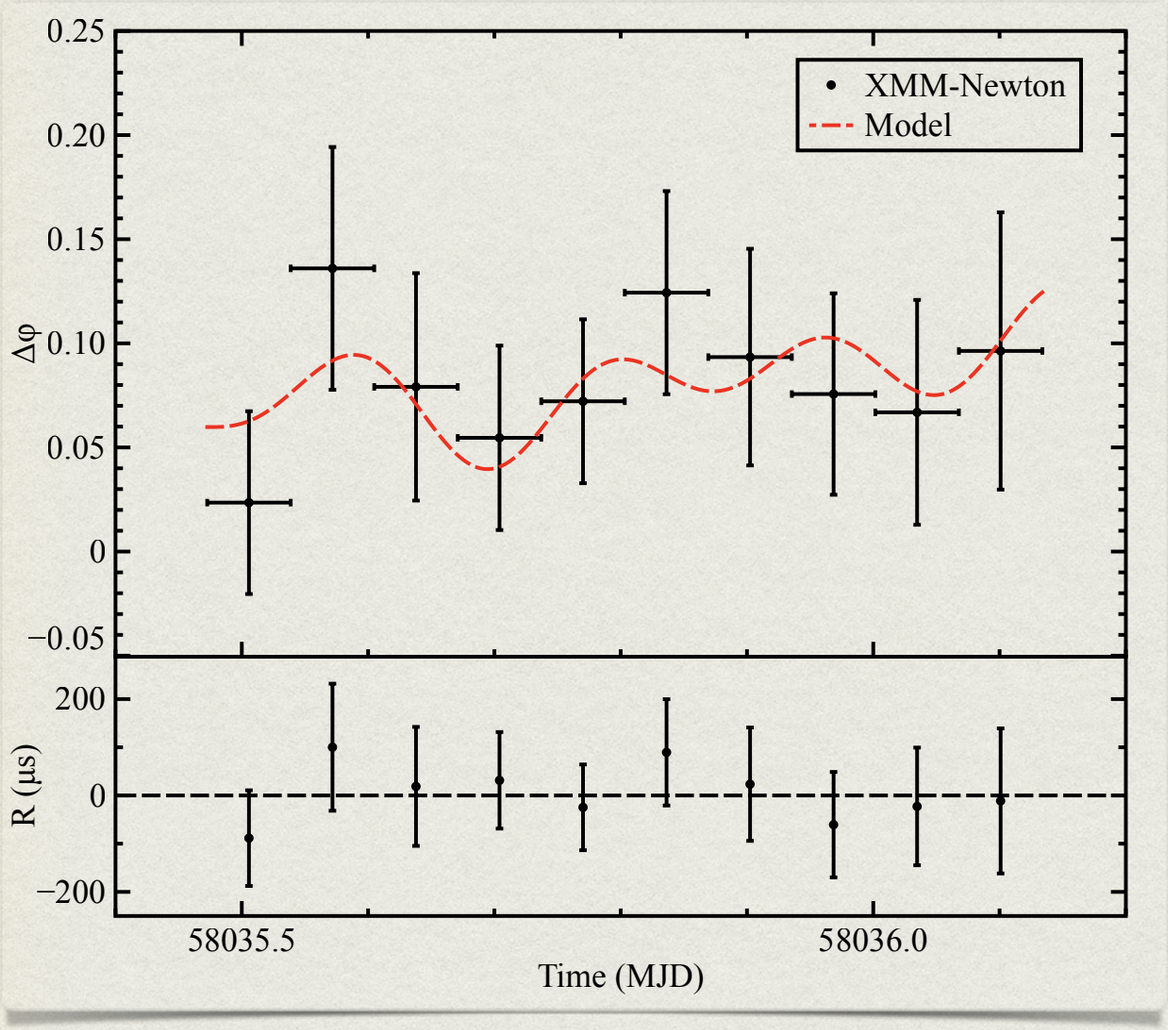
$$d = (8.5 \pm 0.4)\mathrm{kpc}$$



Sanna et al. 2018 in prep.

SAX J1748.9-2021

XMM-NEWTON



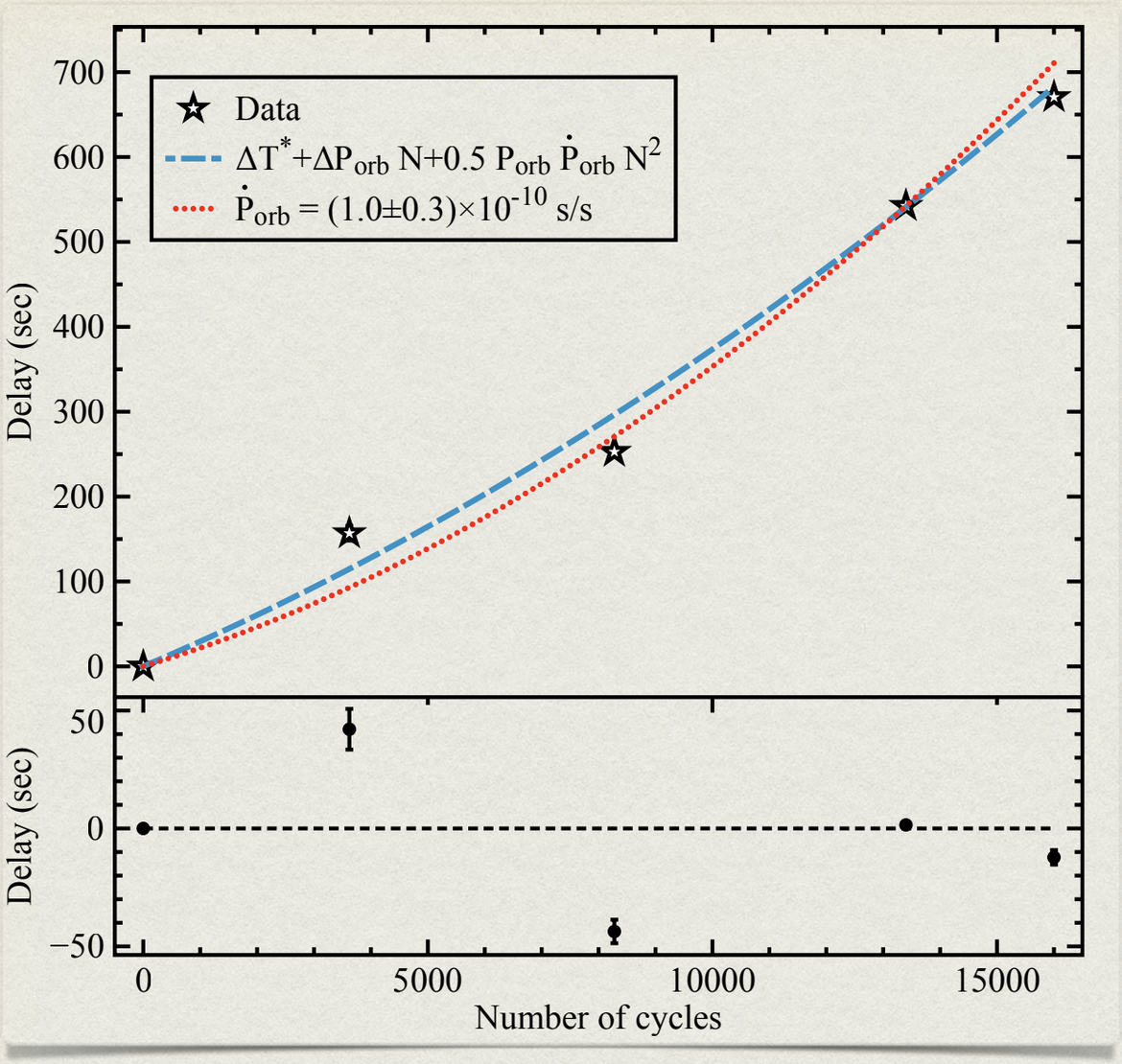
Parameter	Value
ν (Hz)	442.361097(1)
asin(i)/c (lt/s)	0.38758(5)
T_{NOD} (MJD)	58035.38017(4)
P_{ORB} (s)	31554.7(13)
Eccentricity	$< 1 \times 10^{-3}$
T_0 (MJD)	58035.4
χ^2/dof	2.6/3

SAX J1748.9-2021

Parameter	2001	2005	2010	2015	2017
ν (Hz)	442.36108118(5)	442.36108(4)	442.36111(2)	442.3610957(2)	442.361097(1)
asin(i)/c (lt/s)	0.38760(4)	—[a]	—[a]	0.38757(2)	0.38758(5)
TNOD (MJD)	52191.507190(4)	53513.9661(1)	55214.42571(3)	57085.444718(9)	58035.38017(4)
PORB (s)	315 54.9(1)	—[a]	—[a]	315 55.3(3)	31554.7(13)
Ecc	$<2.3 \times 10^{-4}$	—[a]	—[a]	$<8 \times 10^{-5}$	$< 1 \times 10^{-3}$
To (MJD)	52190.0	53535.4	55214.7	57085.7	58035.4
$\chi 2$/dof	-	-	4 . 6 / 3	1 0 . 9 / 1 1	2.6/3

[a] parameter fixed to the value obtained from the 2001 outburst

SAX J1748.9-2021



- **Reference: outburst 2001**
- **Each outburst we get:**

$$T_{NOD,PRE} = T_{NOD,01} + N * P_{ORB,01}$$

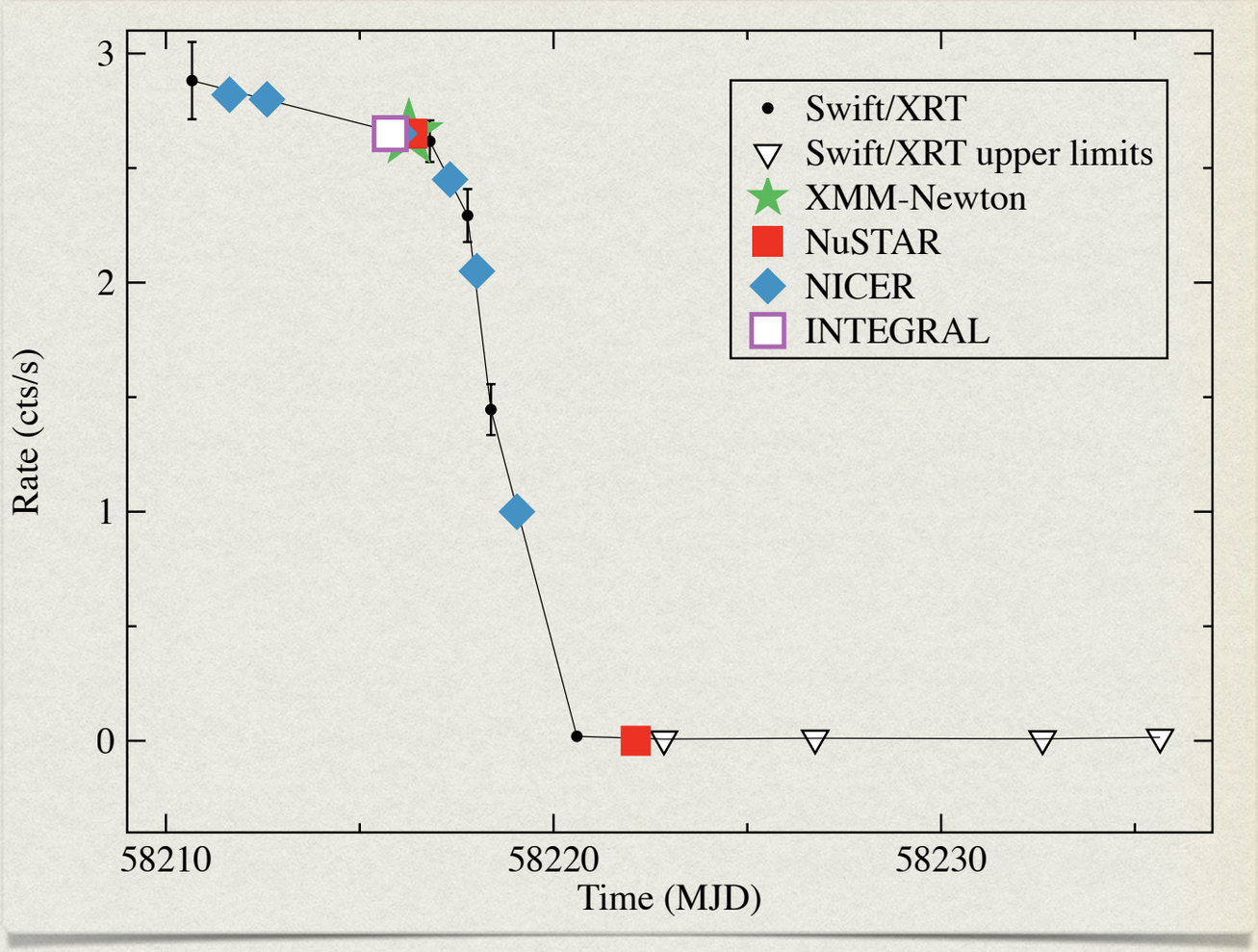
$$\Delta T_{NOD} = T_{NOD,OBS} - T_{NOD,PRE}$$

$$f(N) = \Delta T_{NOD,01} + N * \Delta P_{ORB,01} + 0.5\, N^2 * P_{ORB,01} * \dot{P}_{ORB}$$

P_{ORB} = 31554.872(6) s $\dot{P}_{ORB} = (5.6\pm3.0)\ 10^{-11}$ s/s

SWIFT J1756.9-2508

- Discovered on 2007 June by Swift/BAT
- RXTE detected X-ray coherent pulsations
- Observed in outburst 3 times: 2007/09/18
- The last one has been covered by XMM-Newton, NuSTAR, INTEGRAL and NICER

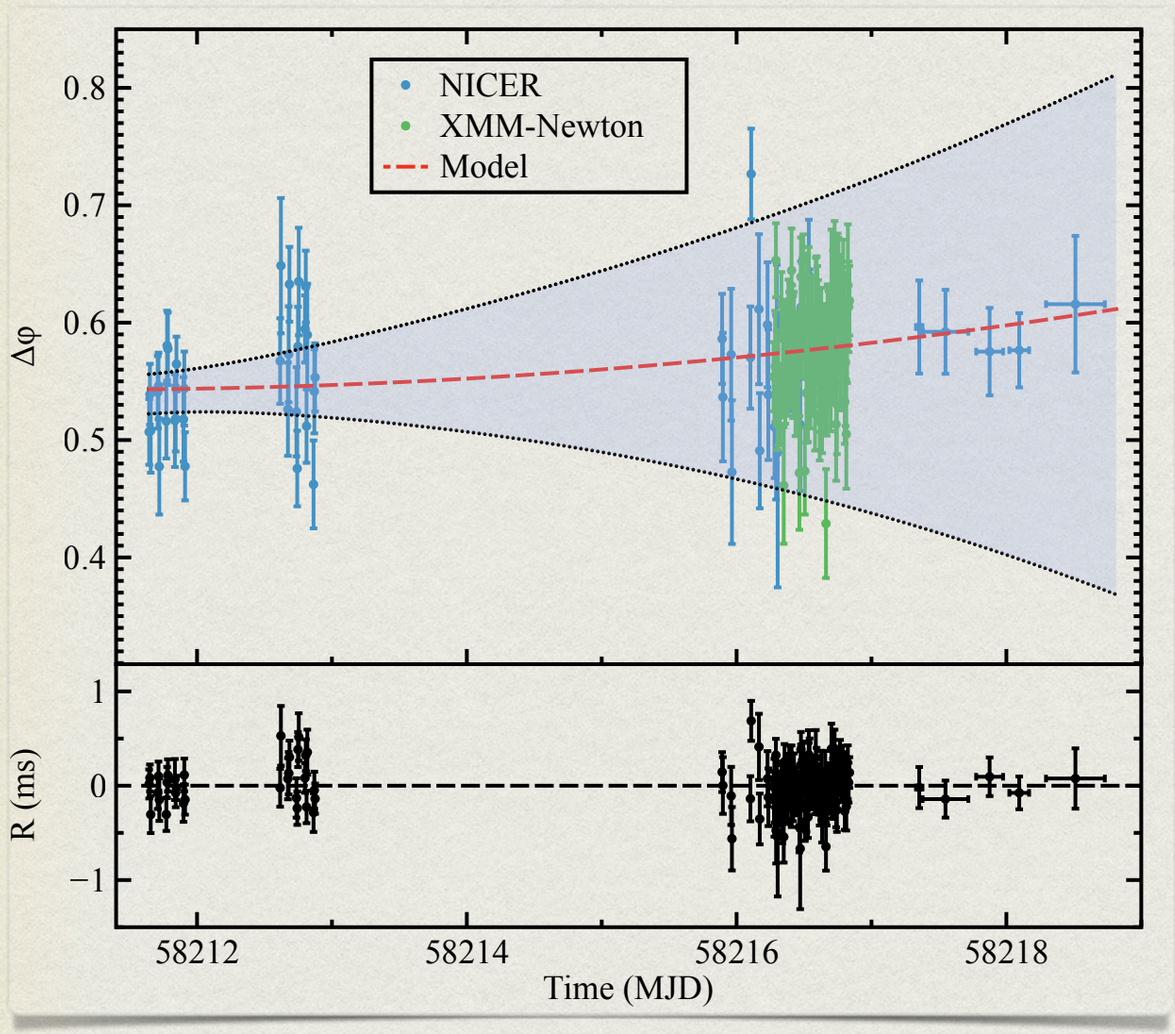


$\nu \simeq 182$ Hz

$0.4\ 10^8$ G $< B < 9\ 10^8$ G

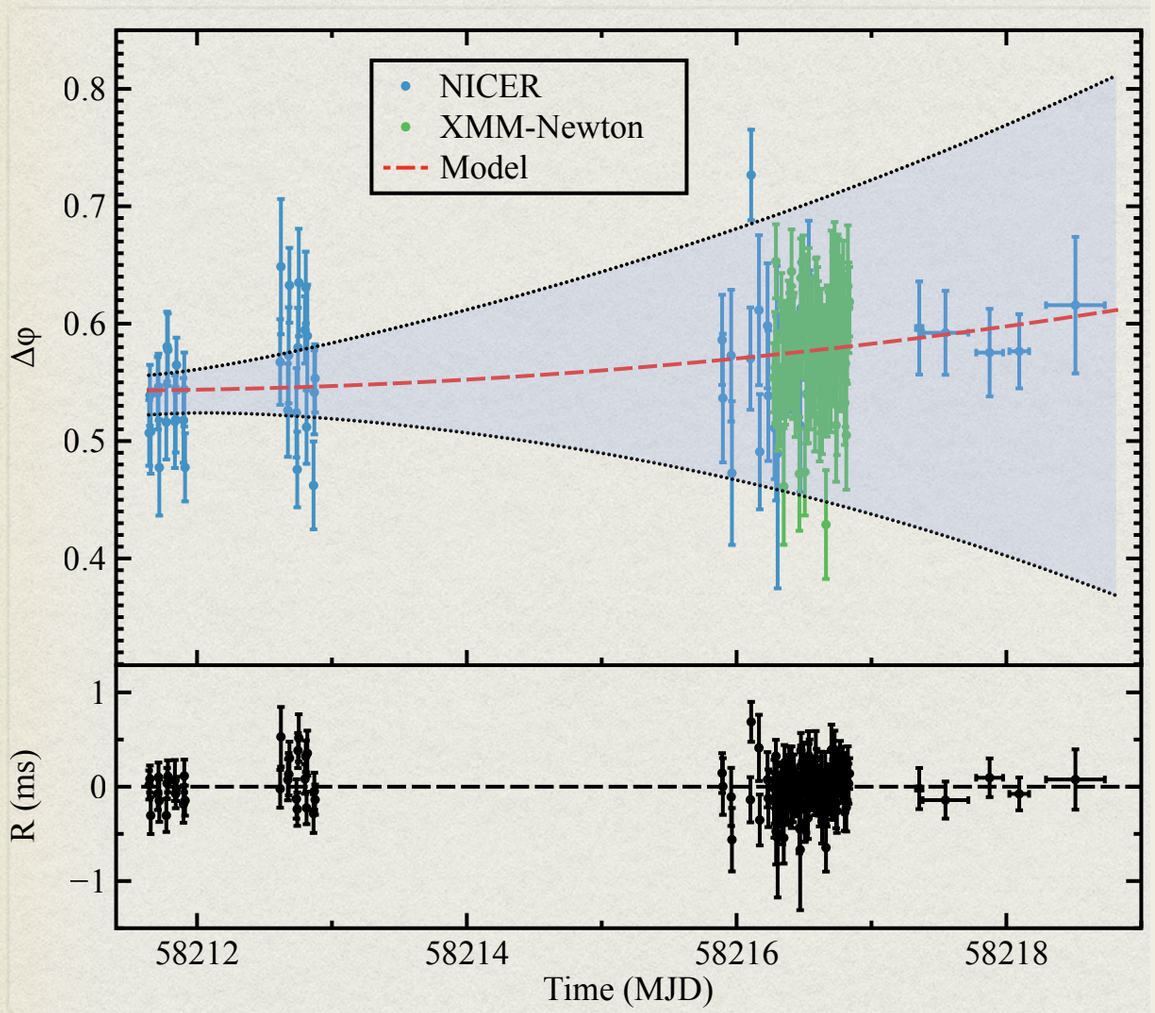
Sanna et al. 2018, MNRAS, 481, 1658-1666

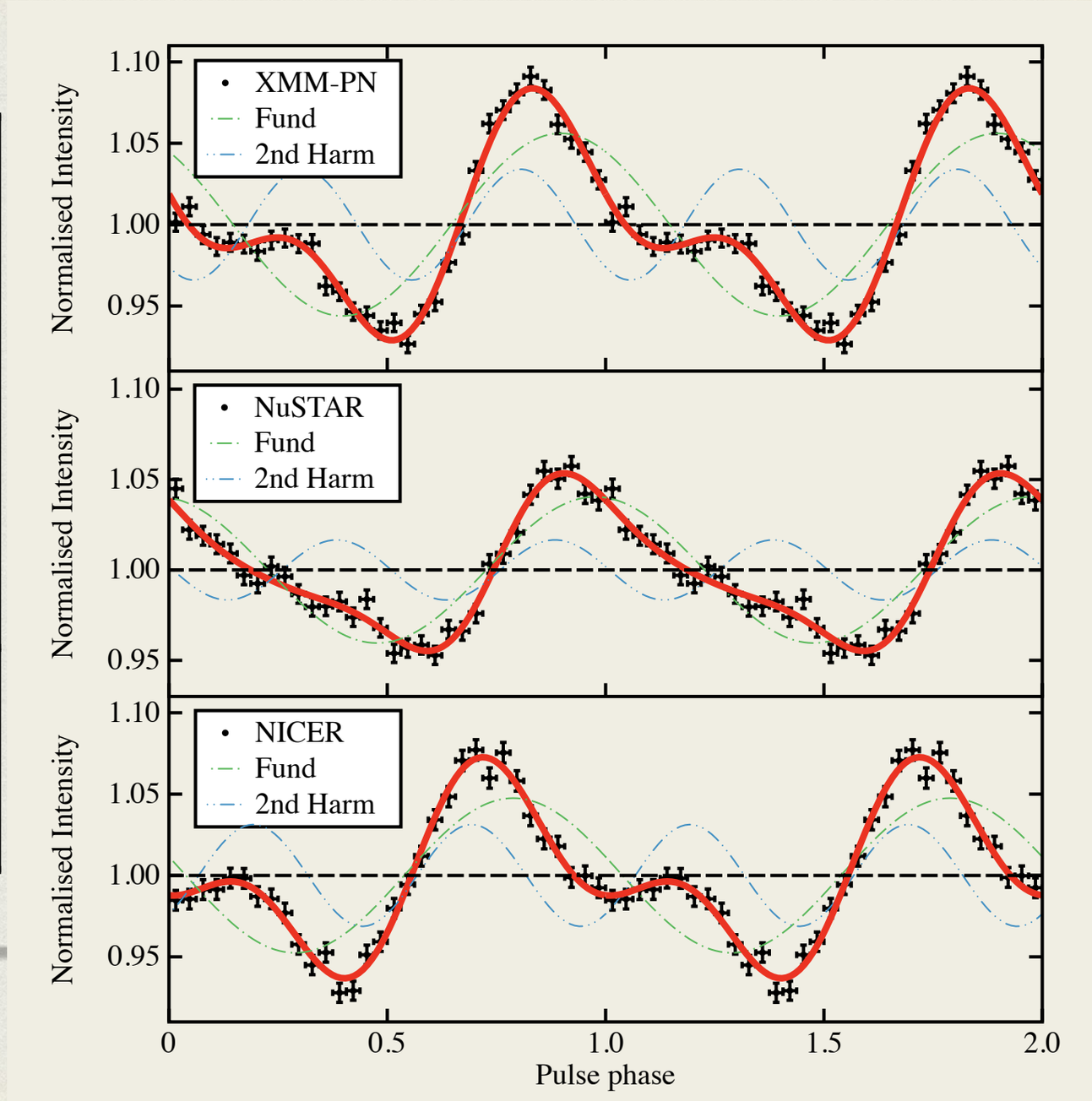
SWIFT J1756.9-2508



Parameter	XMM-NICER	NuSTAR
ν (Hz)	182.06580377(11)	182.065803(1)
dν/dt (Hz/s)	$< \lvert 1.4 \rvert \times 10^{-12}$	$-(4.3 \pm 2.1) \times 10^{-11}$
asin(i)/c (lt/s)	0.00596(2)	0.00598(5)
T_{NOD} (MJD)	58216.18433(10)	58216.1841(2)
P_{ORB} (s)	3282.40(4)	3282.4(6)
Eccentricity	$< 2 \times 10^{-2}$	$< 5 \times 10^{-2}$
T_0 (MJD)	58211.6	58211.6
χ^2/dof	131.2/126	109.1/65

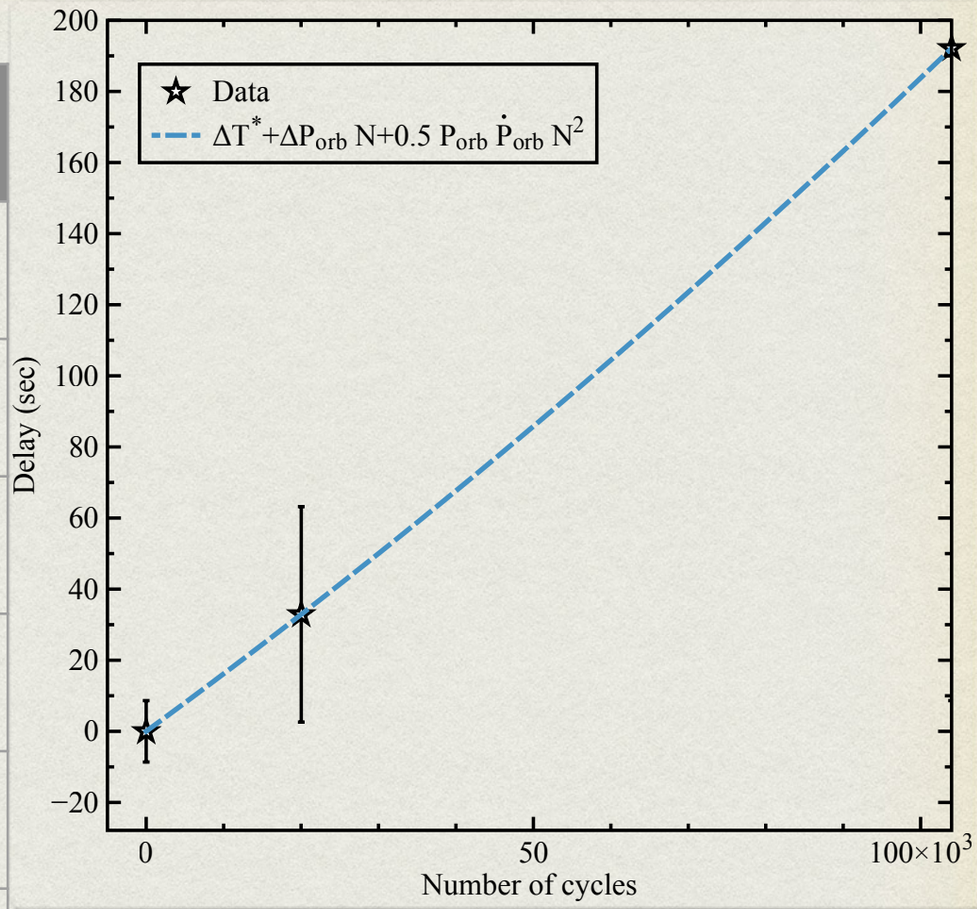
SWIFT J1756.9-2508





SWIFT J1756.9-2508

Parameter	2007	2009	2018
ν (Hz)	182.06580393(7)	182.06580391(2)	182.06580377(11)
To (MJD)	54265.2	55026.0	58211.6
asin(i)/c (lt/s)	0.00595(4)	0.00598(2)	0.00598(5)
TNOD (MJD)	54265.28087(10)	55026.03431(3)	58208.966437(9)
PORB (s)	3282.41(15)	3282.32(3)	3282.4(6)
Ecc	<0.03	<0.01	$< 5 \times 10^{-2}$
$\chi 2$/dof	59.94/63	250.9/251	131.2/126



P_{ORB} =3282.3503(12) s

$\dot{P}_{ORB}$ = (1.5±2.8) x 10^{-12} s/s

Patruno et al. 2010, MNRAS, 403, 1426

Thanks for your attention!