The X-ray outburst of the Galactic Centre magnetar SGR J1745-2900

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Coti Zelati et al., 2015, MNRAS, 449, 2685

XMM-NEWTON: THE NEXT DECADE, May 9th, 2016

The discovery

Large Flare from Sgr A* Detected by Swift

ATel #5006; *N. Degenaar, M. T. Reynolds, J. M. Miller (Michigan), J. A. Kennea (Penn State), R Wijnands (Amsterdam)*
on 25 Apr 2013; 00:54 UT

Swift/BAT detection of an SGR-like flare from near Sgr A*

ATel #5009; *J. A. Kennea (PSU), H. Krimm, S. Barthelmy, N. Gehrels, C. Markwardt, J. Cummings, F. Marshall (GSFC), T. Sakamoto (AGU), N. Degenaar, M. T. Reynolds, J. M. Miller (Michigan), C. Kouveliotou (MSFC)*
on 26 Apr 2013; 02:48 UT

NuSTAR discovery of a 3.76 second pulsar in the Sgr A* region

ATel #5020; *Kaya Mori, Eric V. Gotthelf (Columbia University), Nicolas M. Barriere (UC Berkeley), Charles J. Hailey (Columbia Univerity) , Fiona A. Harrison (Caltech), Victoria M. Kaspi (McGill University), John A. Tomsick (UC Berkeley), Shuo Zhang (Columbia University)*
on 27 Apr 2013; 05:40 UT

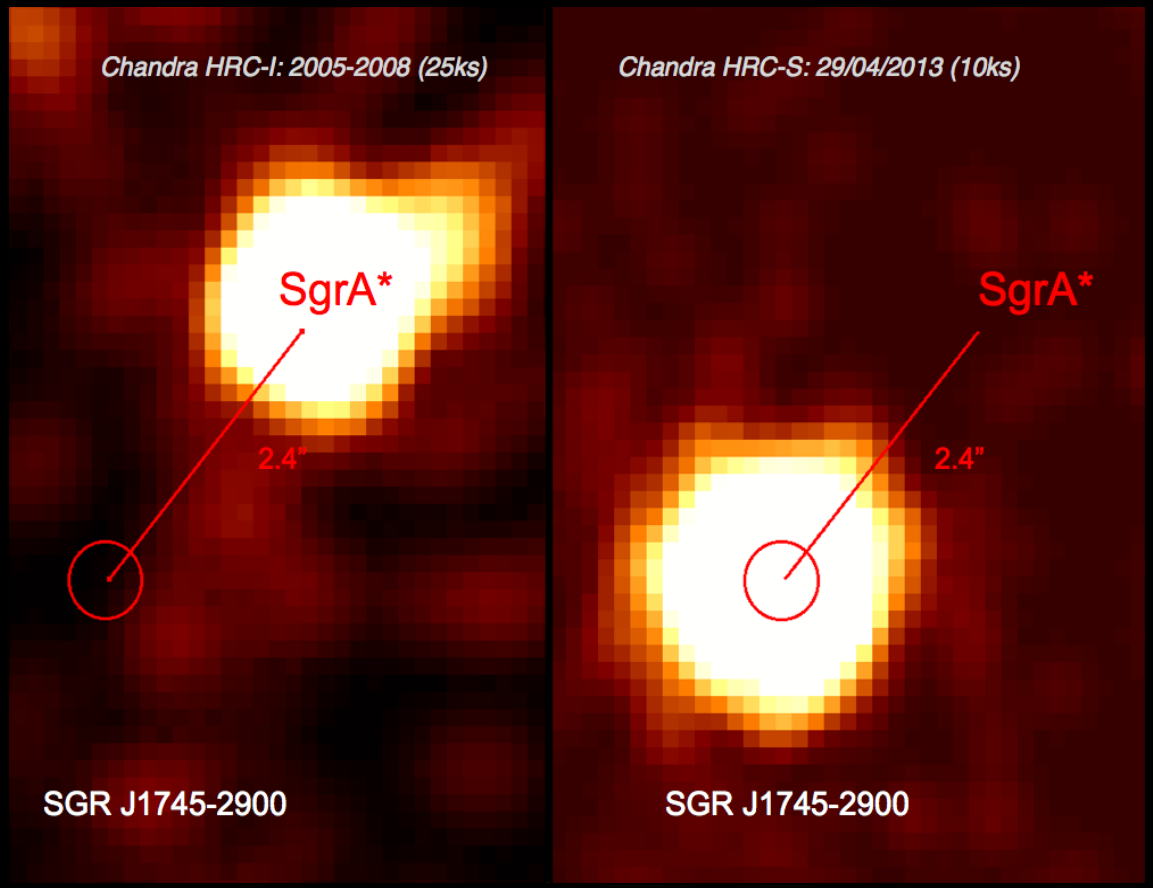
Chandra localization of the soft gamma repeater in the Galactic Center region

ATel #5032; *N. Rea (CSIC-IEEC), P. Esposito, G. L. Israel (INAF), A. Papitto (CSIC-IEEC), A. Tiengo (IUSS/INAF), F. Baganoff (MIT), D. Haggard (Northwestern/CIERA), S. Mereghetti, M. Burgay, A. Possenti (INAF), S. Zane (MSSL), on behalf of a larger collaboration*
on 30 Apr 2013; 21:53 UT

Detection of radio pulsations from the direction of the NuSTAR 3.76 second X-ray pulsar at 8.35 GHz

ATel #5040; *Ralph Eatough (Max-Planck-Institut fuer Radioastronomie: MPIfR), Ramesh Karuppusamy (MPIfR), Michael Kramer (MPIfR), Bernd Klein (MPIfR), David Champion (MPIfR), Alex Kraus (MPIfR), Evan Keane (Jodrell Bank Centre for Astrophysics: JBCA), Cees Bassa (JBCA), Andrew Lyne (JBCA), Patrick Lazarus (MPIfR), Joris Verbiest (MPIfR), Paulo Freire (MPIfR), Andreas Brunthaler (MPIfR), Heino Falcke (ASTRON, Nijmegen)*
on 2 May 2013; 21:48 UT

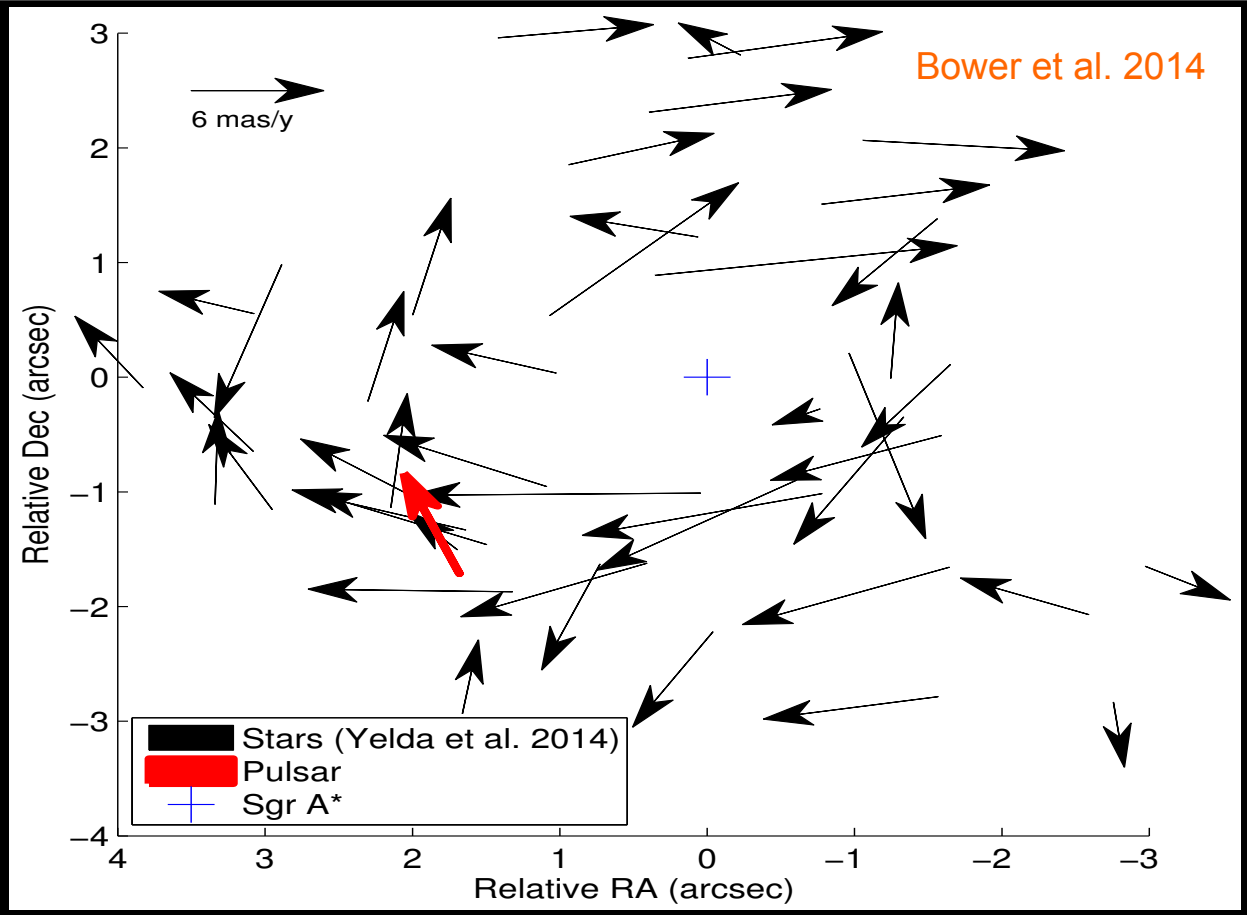
The closest pulsar to a black hole



Chandra/HRC images of the field of Sgr A* (Rea et al. 2013)

a 2.4" projected distance translates in a minimum physical separation
d = 0.09+/-0.02 pc (90% CL) for D=8.3 kpc

Likely bounded to Sgr A*



Proper motion from *VLBA* observations

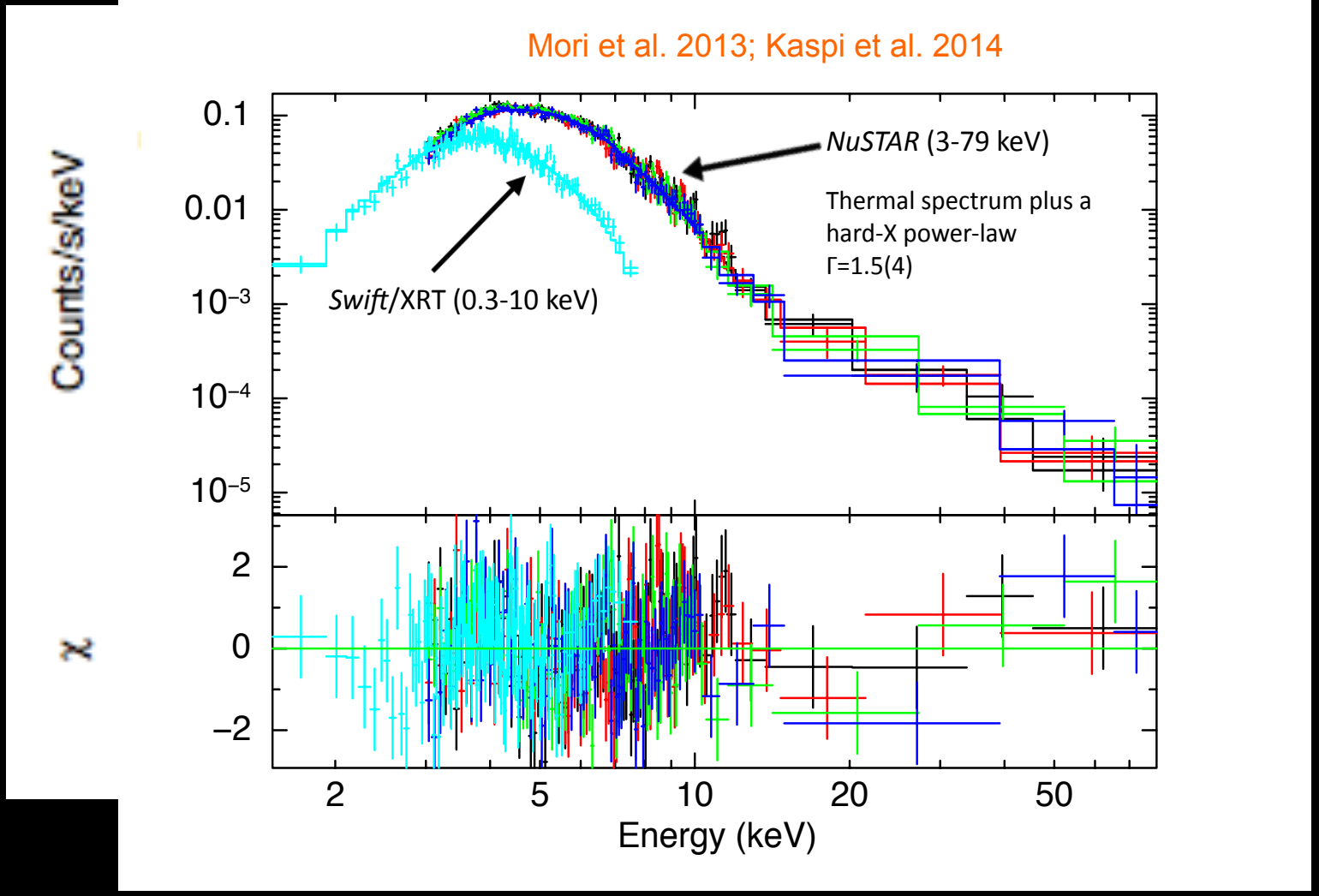
Transverse velocity of 236+/-11 km/s at a position angle 22+/-2 deg East-of-North

90% probability on average of being bound to the SMBH if born within 1 pc.

P_{orb} ~ 500 yr - several kyrs (Rea et al. 2013).

X-ray properties at early stages

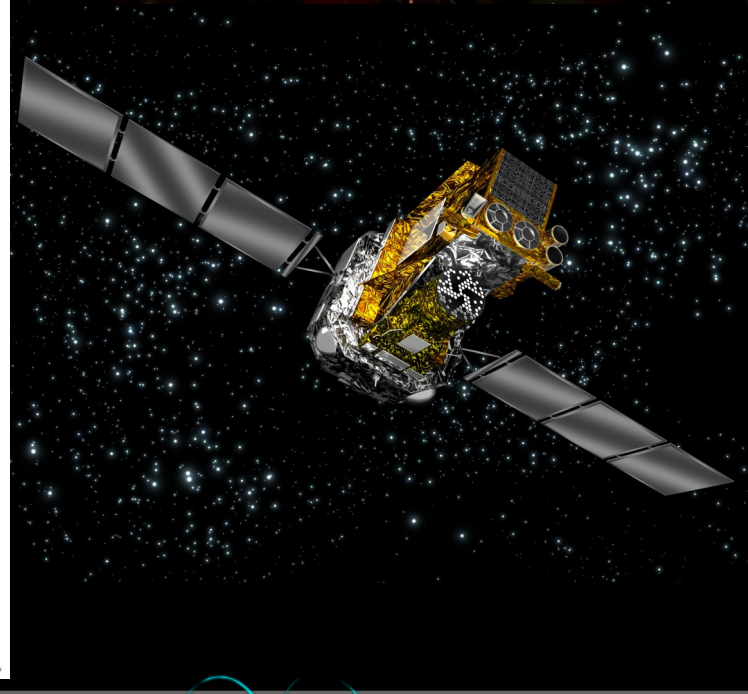
Mori et al. 2013; Kaspi et al. 2014



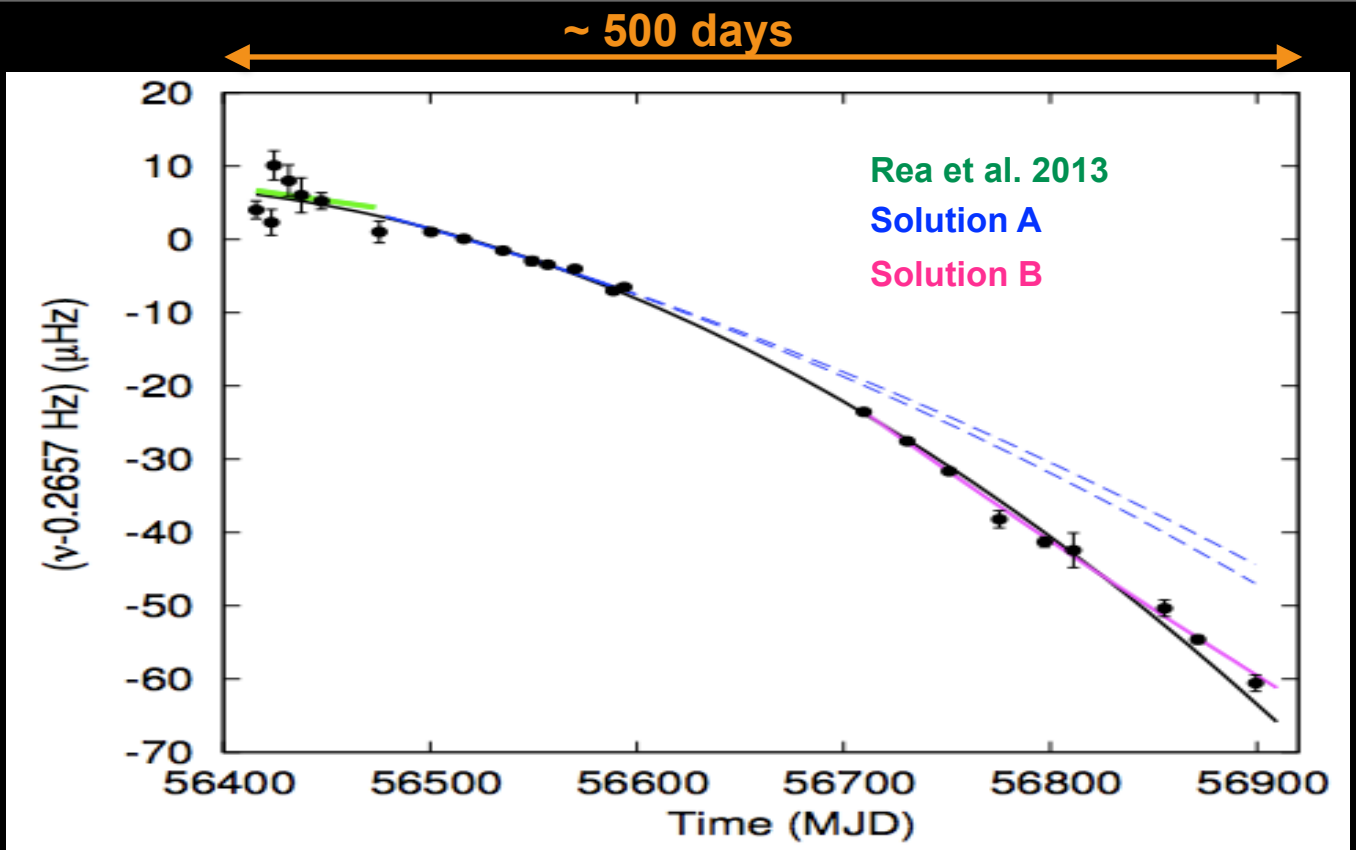
P = 3.76 s Pdot ~ 0.4 - 6.6x10^{-12} s/s B_{dip} ~ 2x10^{14} G L_{sd} = 5x10^{33} erg/s τ_c ~ 9 kyr

25 *Chandra* and 8 *XMM-Newton* observations: an unprecedented dataset

Obs. ID	MJD	Start time (TT) (yyyy/mm/dd hh:mm:ss)	End time (TT) (yyyy/mm/dd hh:mm:ss)	Exposure time (ks)	Source net counts ($\times 10^3$)
14702[a]	56424.55	2013/05/12 10:38:50	2013/05/12 15:35:56	13.7	7.4
15040[b]	56437.63	2013/05/25 11:38:37	2013/05/25 18:50:50	23.8	3.5
14703[a]	56447.48	2013/06/04 08:45:16	2013/06/04 14:29:15	16.8	7.6
15651[b]	56448.99	2013/06/05 21:32:38	2013/06/06 01:50:11	13.8	1.9
15654[b]	56452.25	2013/06/09 04:26:16	2013/06/09 07:38:28	9.0	1.2
14946[a]	56475.41	2013/07/02 06:57:56	2013/07/02 12:46:18	18.2	7.1
15041	56500.36	2013/07/27 01:27:17	2013/07/27 15:53:25	45.4	15.7
15042	56516.25	2013/08/11 22:57:58	2013/08/12 13:07:47	45.7	14.4
0724210201[c]	56535.19	2013/08/30 20:30:39	2013/08/31 12:28:26	55.6/57.2/57.2	39.7
14945	56535.55	2013/08/31 10:12:46	2013/08/31 16:28:32	18.2	5.3
0700980101[c]	56545.37	2013/09/10 03:18:13	2013/09/10 14:15:07	35.7/37.3/37.3	24.9
15043	56549.30	2013/09/14 00:04:52	2013/09/14 14:19:20	45.4	12.5
14944	56555.42	2013/09/20 07:02:56	2013/09/20 13:18:10	18.2	5.0
0724210501[c]	56558.15	2013/09/22 21:33:13	2013/09/23 09:26:52	41.0/42.6/42.5	26.5
15044	56570.01	2013/10/04 17:24:48	2013/10/05 07:01:03	42.7	10.9
14943	56582.78	2013/10/17 15:41:05	2013/10/17 21:43:58	18.2	4.5
14704	56588.62	2013/10/23 08:54:30	2013/10/23 20:43:44	36.3	8.7
15045	56593.91	2013/10/28 14:31:14	2013/10/29 05:01:24	45.4	10.6
16508	56709.77	2014/02/21 11:37:48	2014/02/22 01:25:55	43.4	6.8
16211	56730.71	2014/03/14 10:18:27	2014/03/14 23:45:34	41.8	6.2
0690441801[c]	56750.72	2014/04/03 05:23:24	2014/04/04 05:07:01	83.5/85.2/85.1	34.3
16212	56751.40	2014/04/04 02:26:27	2014/04/04 16:49:26	45.4	6.2
16213	56775.41	2014/04/28 02:45:05	2014/04/28 17:13:57	45.0	5.8
16214	56797.31	2014/05/20 00:19:11	2014/05/20 14:49:18	45.4	5.4
16210	56811.24	2014/06/03 02:59:23	2014/06/03 08:40:34	17.0	1.9
16597	56842.98	2014/07/04 20:48:12	2014/07/05 02:21:32	16.5	1.6
16215	56855.22	2014/07/16 22:43:52	2014/07/17 11:49:38	41.5	3.8
16216	56871.43	2014/08/02 03:31:41	2014/08/02 17:09:53	42.7	3.6
16217	56899.43	2014/08/30 04:50:12	2014/08/30 15:45:44	34.5	2.8
0743630201[c]	56900.02	2014/08/30 19:37:28	2014/08/31 05:02:43	32.0/33.6/33.6	9.2
0743630301[c]	56901.02	2014/08/31 20:40:57	2014/09/01 04:09:34	25.0/26.6/26.6	7.8
0743630401[c]	56927.94	2014/09/27 17:47:50	2014/09/28 03:05:37	25.7/32.8/32.8	7.7
0743630501[c]	56929.12	2014/09/28 21:19:11	2014/09/29 08:21:11	37.8/39.4/39.4	11.7

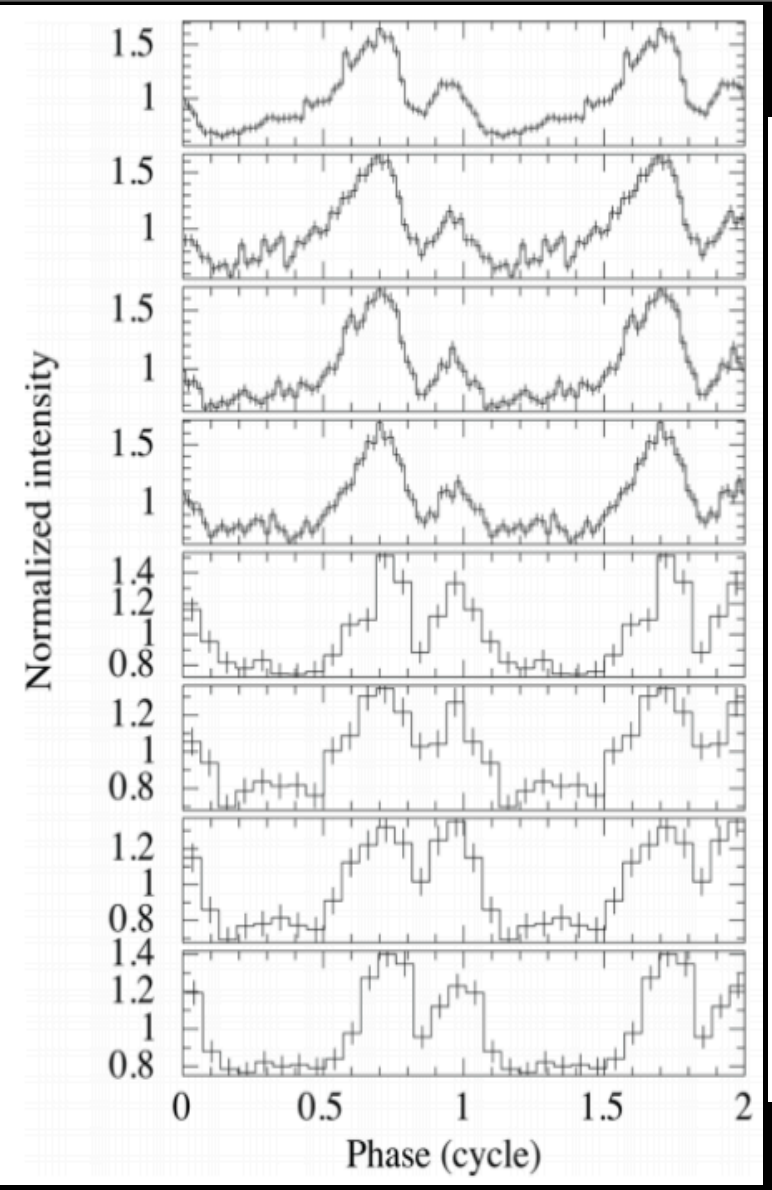


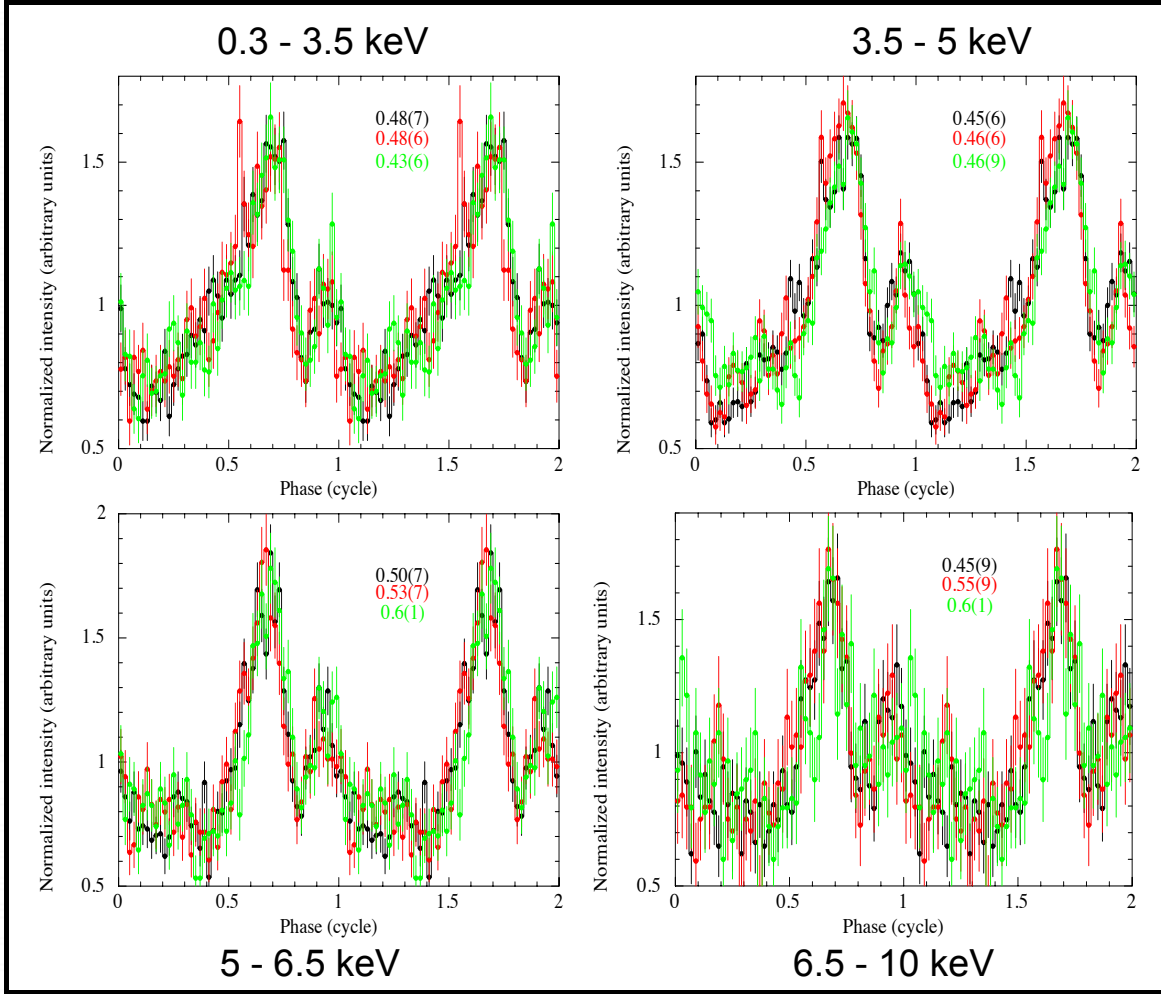
Timing properties



Solution	Rea et al. (2013b)	Kaspi et al. (2014)	This work (solution A)	This work (solution B)
Epoch T_0 (MJD)	56424.5509871	56513.0	56513.0	56710.0
Validity range (MJD)	56411.6–56475.3	56457–56519	56500.1–56594.1	56709.5–56929
$P(T_0)$ (s)	3.7635537(2)	3.76363824(13)	3.76363799(7)	3.7639772(12)
$\dot{P}(T_0)$	$6.61(4) \times 10^{-12}$	$1.385(15) \times 10^{-11}$	$1.360(6) \times 10^{-11}$	$3.27(7) \times 10^{-11}$
$\ddot{P}$ (s^{-1})	$4(3) \times 10^{-19}$	$3.9(6) \times 10^{-19}$	$3.7(2) \times 10^{-19}$	$(-1.8 \pm 0.8) \times 10^{-19}$
$\nu(T_0)$ (Hz)	0.265706368(14)	0.265700350(9)	0.26570037(5)	0.26567642(9)
$\dot{\nu}(T_0)$ (Hz s^{-1})	$-4.67(3) \times 10^{-13}$	$-9.77(10) \times 10^{-13}$	$-9.60(4) \times 10^{-13}$	$-2.31(5) \times 10^{-12}$
$\ddot{\nu}$ (Hz s^{-2})	$-3(2) \times 10^{-20}$	$-2.7(4) \times 10^{-20}$	$-2.6(1) \times 10^{-20}$	$(1.3 \pm 0.6) \times 10^{-20}$
rms residual	0.15 s	51 ms	0.396 s	1.0 μHz
χ^2_ν (d.o.f.)	0.85 (5)	1.27 (41)	6.14 (44)	0.66 (10)

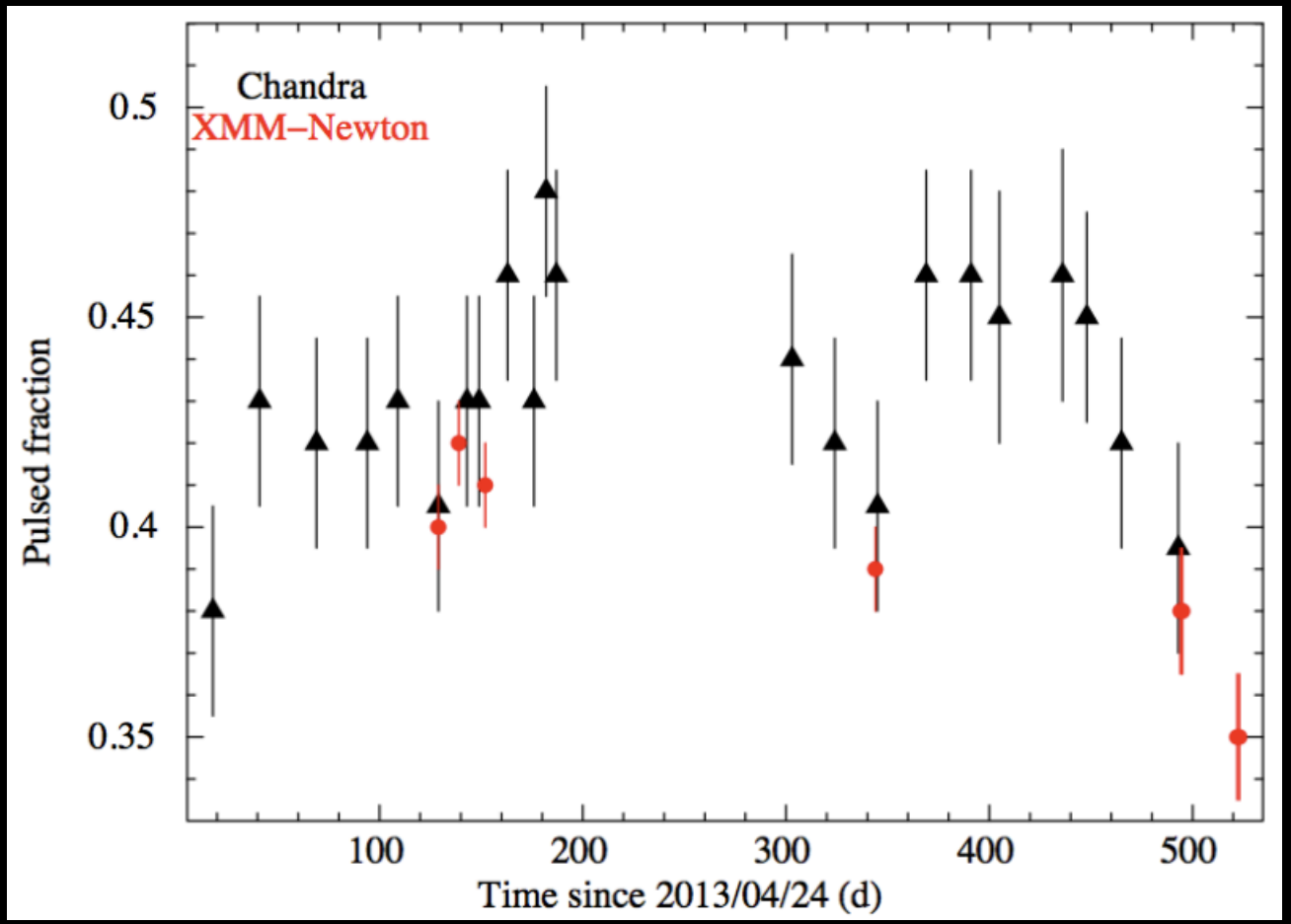
Pulse profiles





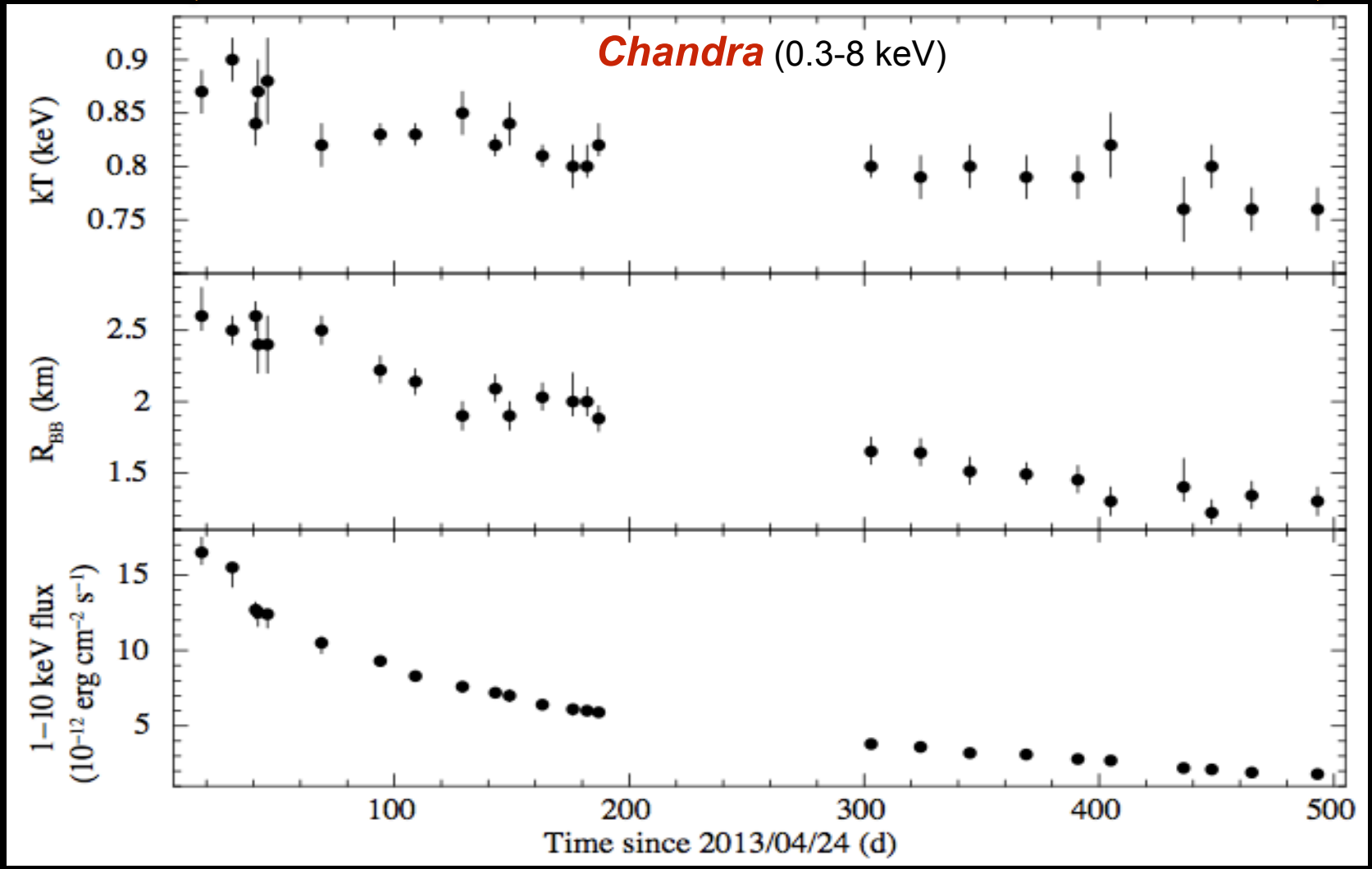
XMM-Newton observations (0.3-10 keV)

Pulsed fraction evolution



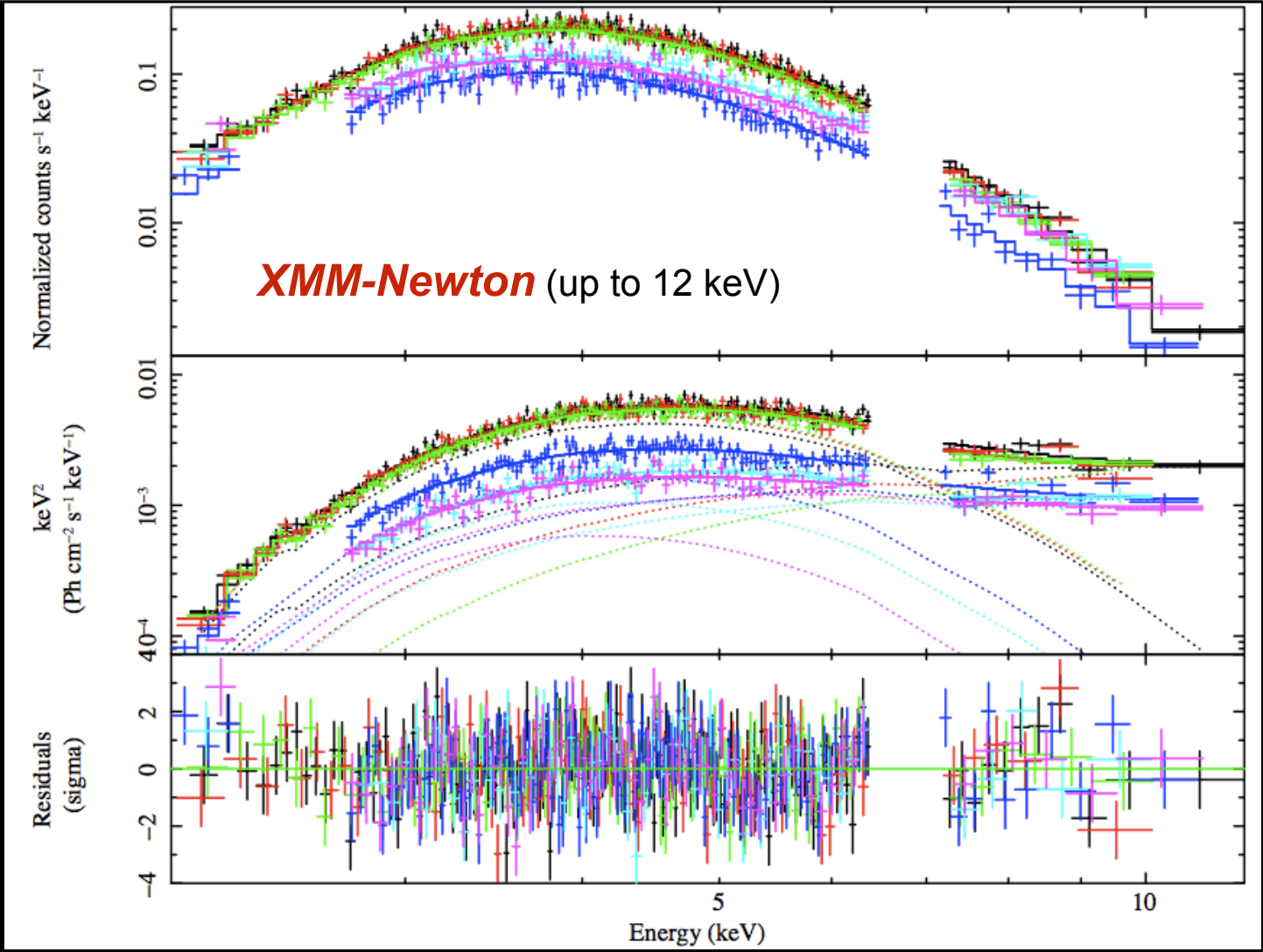
Spectral evolution

~ 500 days



- highly absorbed (N_H = 1.90+/-0.02 x 10^{23} cm^{-2}) thermal spectrum
- very slow spectral decay

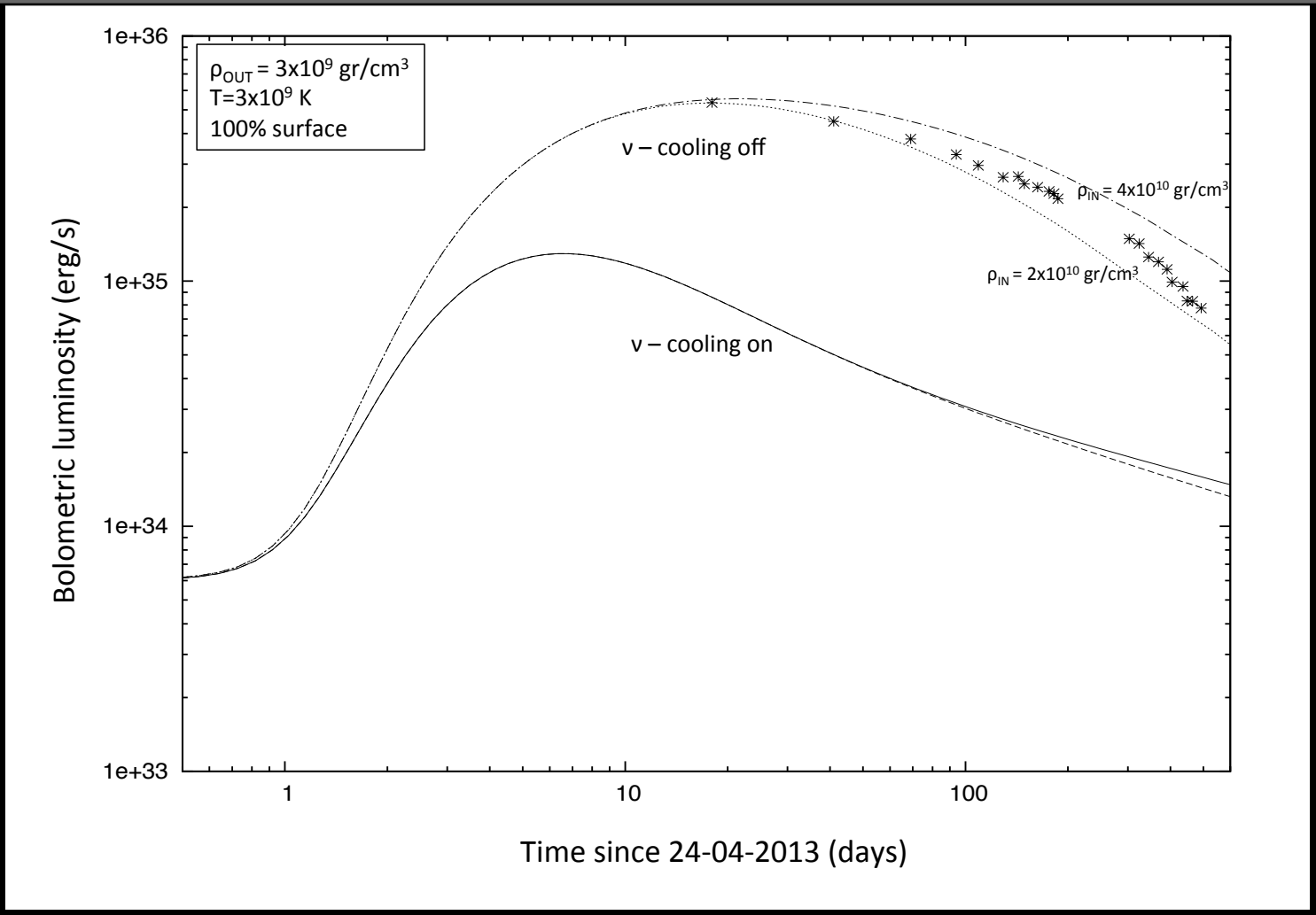
A prolonged, faint non-thermal component



- power law component at $E \geq 8$ keV

- $\Gamma \sim 1.7–2.6$: consistence with *NuSTAR* (Mori et al. 2013; Kaspi et al. 2014)

Outburst modeling

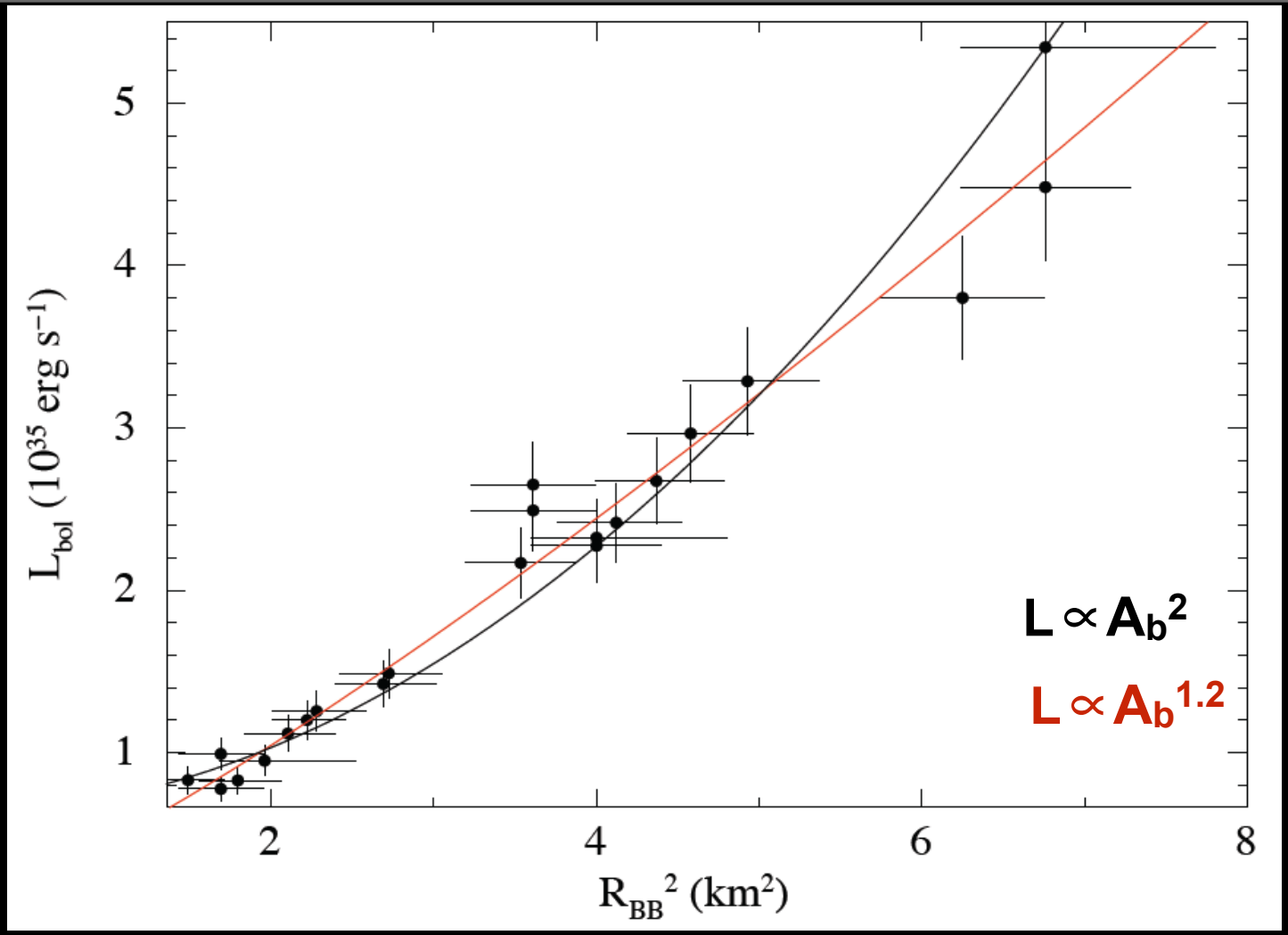


Bad modeling when injecting an energy of 10^{45} erg in the inner crust ($\rho_{IN}<\rho<\rho_{OUT}$)

Better modeling if relevant neutrino emissions are switched off…BUT they should be at work!

Pons & Rea 2012

Bombardment of magnetospheric currents



Currents in a bundle of twisted field lines keep slamming on to the NS surface and form a hot spot

As the bundle untwists, the hot spot cools and shrinks. L should decrease as $L \propto A_b^2$

Beloborodov 2009

Conclusions

- SGR J1745-2900 is the closest pulsar to a BH detected so far (≥0.07 pc from Sgr A*)

- It is likely bound to Sgr A*.

- An unprecedented dataset of X-ray observations
  Study of the outburst properties on a long temporal baseline (500 days)

- A very slow spectral decay.

- The cooling is challenging most of the crustal models.
  Probably a large contribution from bombardment of magnetospheric currents

- the X-ray monitoring campaign of the GC is ongoing.