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CONSTRAINING LONG-TERM AND SPATIAL VARIABILITY OF THE PN LOW ENERGY RESPONSE WITH RXJ1856

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RX J1856.5-3754 (RXJ1856)

- Brightest of the “Magnificent Seven”, or X-ray Dim Isolated Neutron Stars (XDINSs)

  (e.g. Turolla 2009 for a review)

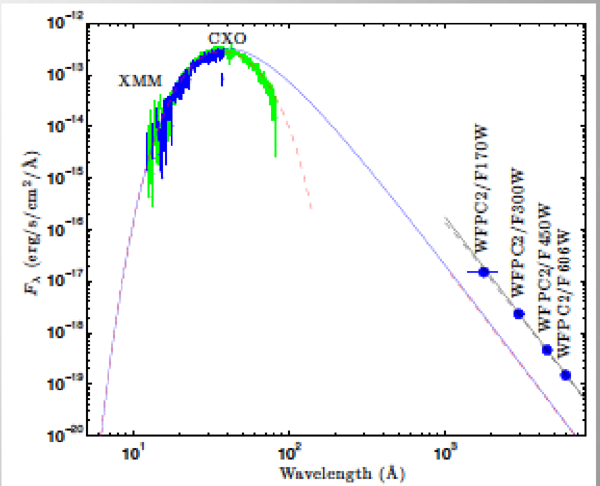
- The closest known neutron star: d ~120 pc

  (Walter et al. 2010)

- No (detected) radio emission

  (Kondriatev et al. 2010)

- Flux ~1.5 x 10^{-11} erg s^{-1} cm^{-2} [0.2 – 10 keV]



- BB spectrum, kT ~61 eV, no features

  (e.g. Burwitz et al. 2003)

- P ~7.055 s, low PF (~ 1.2%)

  (Tiengo & Mereghetti 2007)

- P_{dot} ~10^{-13} – 10^{-14} s s^{-1}

  (van Kerkwijk & Kaplan 2008)

B ~1.5 x 10^{13} G

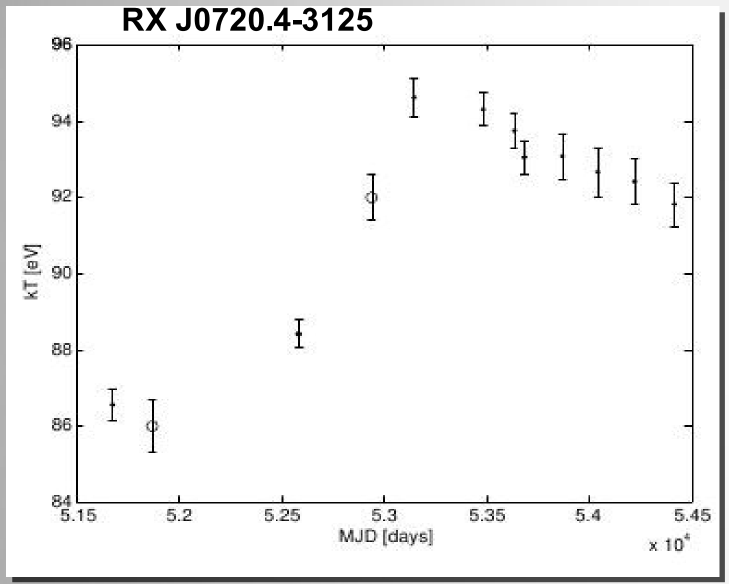
- Optical/UV counterpart (m_V ~26): optical excess ~7x RJ tail of X-ray BB

  (Kaplan et al. 2011)

Why studying RXJ1856 variability?

- **Astrophysical goal:**

  - Constrain spectral evolution (as observed in RX J0720.4-3125)



Possible cause:

- Precession
  (e.g. Haberl et al. 2006)

- Glitch episode
  (e.g. Kaplan et al. 2007)

  - If no spectral changes, cumulative spectrum (huge statistics to test NS EOS)

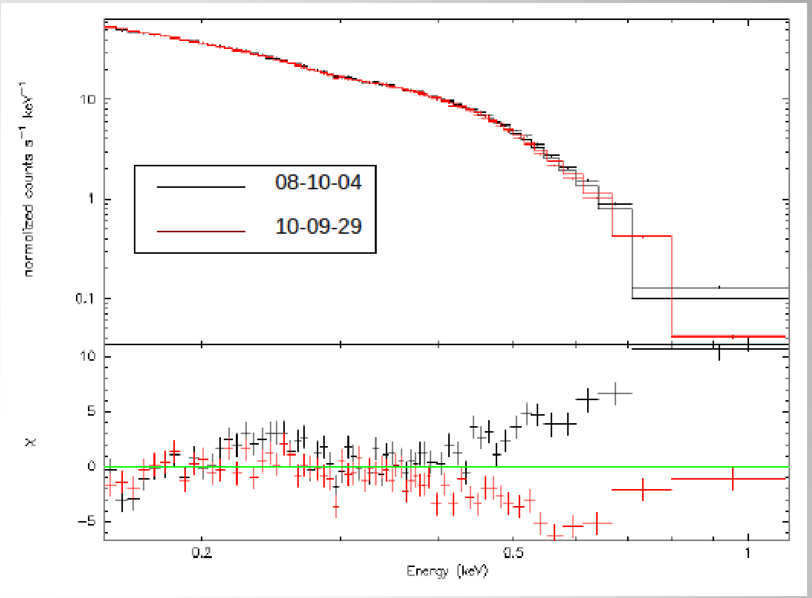
- **Instrumental goal:**

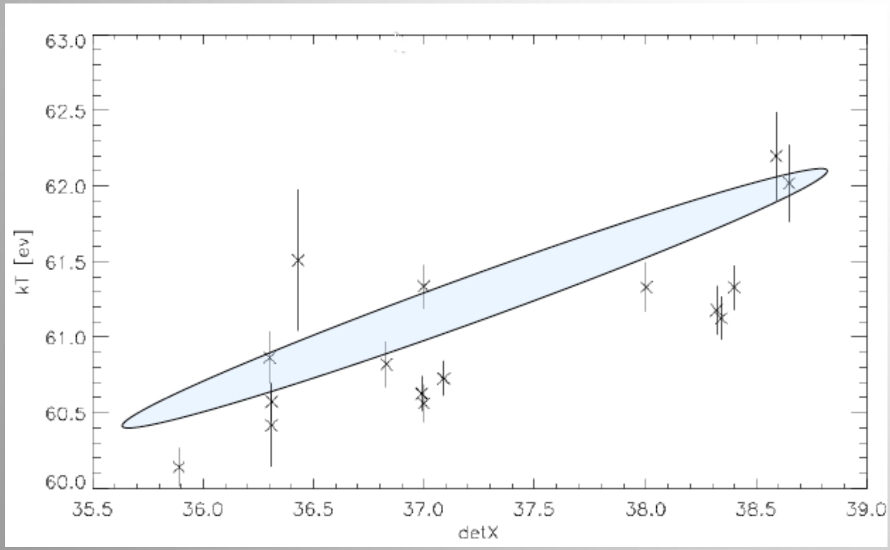
  - Constrain PN response stability at low energies (<1.2 keV)

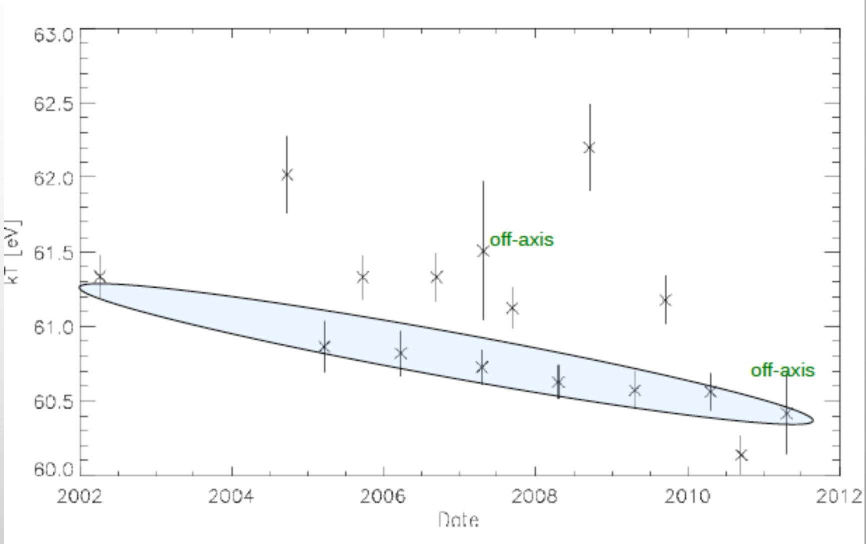
Preliminary results

(presented last year by Nicola Sartore)

Observation	Date	Obs.ID	Net Exposure Time [s]	Counts
A	2002-04-08	0106260101	40030	302601
B	2004-09-24	0165971601	22960	174955
C	2005-03-23	0165971901	14190	106949
D	2005-09-24	0165972001	22700	168609
E	2006-03-26	0165972101	48340	361845
F	2006-10-24	0412600101	49820	374018
G	2007-03-14	0412600201	26940	204513
H	2007-03-25	0415180101	16540	126883
I	2007-10-04	0412600301	23920	179449
J	2008-03-13	0412600401	33080	245923
K	2008-10-04	0412600601	43580	330553
L	2009-03-19	0412600701	47510	353698
M	2009-10-07	0412600801	40780	306449
N	2010-03-22	0412600901	48380	360306
O	2010-09-29	0412601101	47870	356580
P	2011-03-14	0412601301	45210	342204





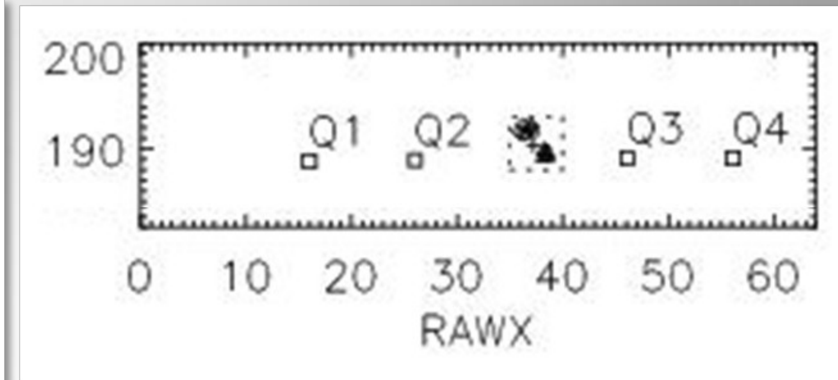


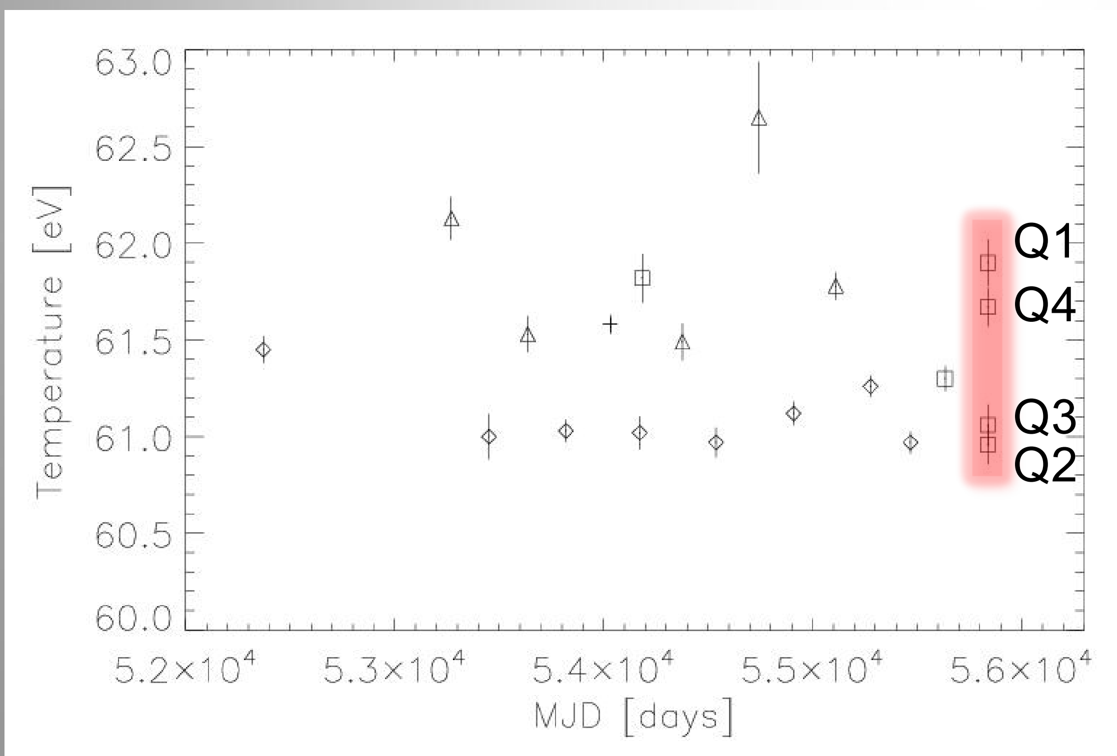
Significant changes, possibly correlated to position on the detector (and time?)

New calibration observation

October 2011 observation divided into 4 pointings to sample different RAWX positions

Observation	Date	Obs.ID	Net Exposure Time [s]	Counts
Q1	2011-10-05*	0412601501	17490	134747
Q2	"	"	16310	124431
Q3	"	"	16800	127176
Q4	"	"	17920	128549



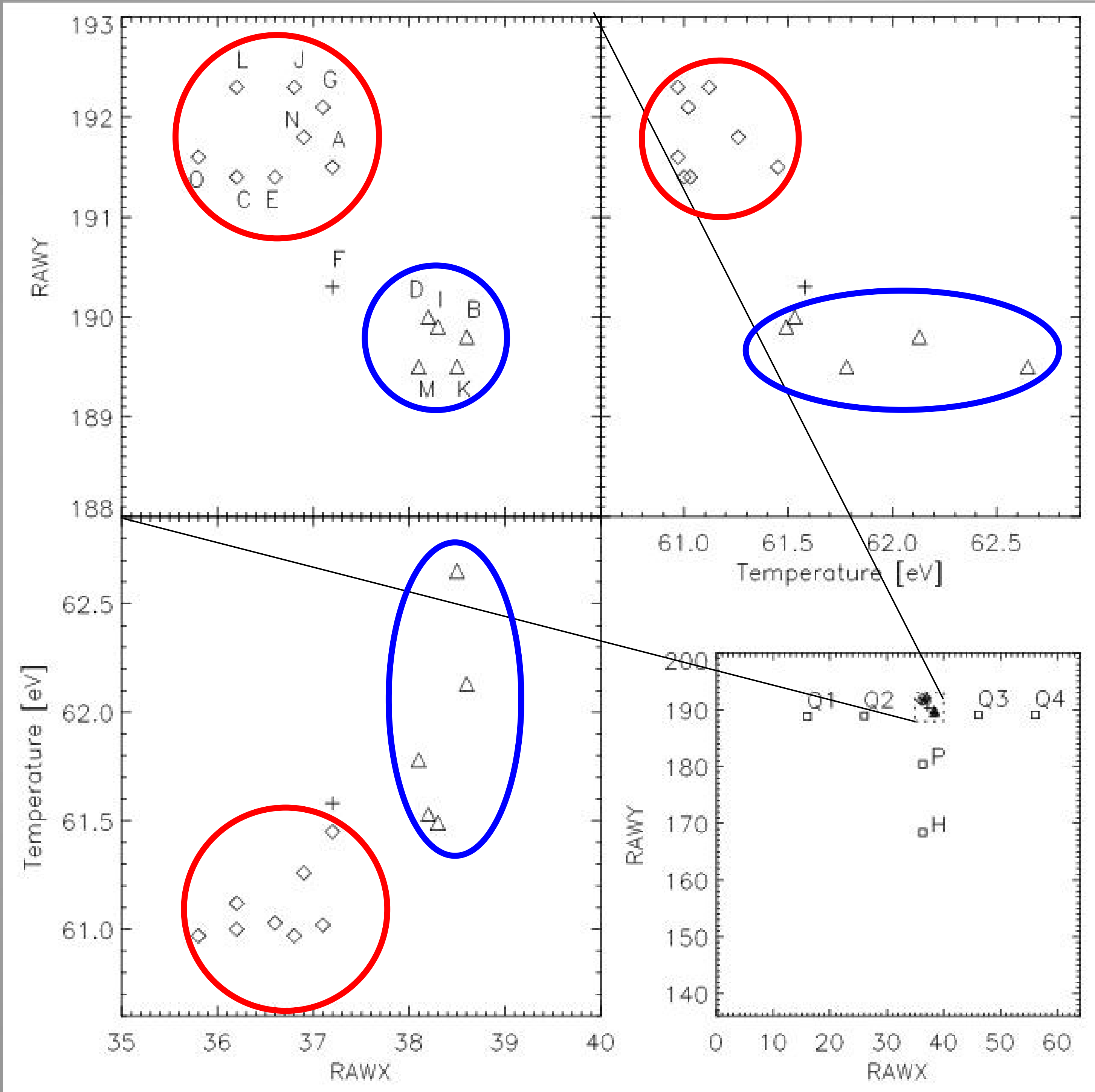


Observations at larger distance have higher temperatures, but in the same range as in previous observations (ΔkT_{BB}~1 eV)

⇒ The effect is present also at different detector positions, but it does not strongly increase with Δ RAXW

Re-analysis of all data

(Sartore et al. 2012, A&A in press, arXiv:1202.2121)



Equally good fit with absorbed BB model by freeing:

- gain slope (~4%) and offset (~15 eV)

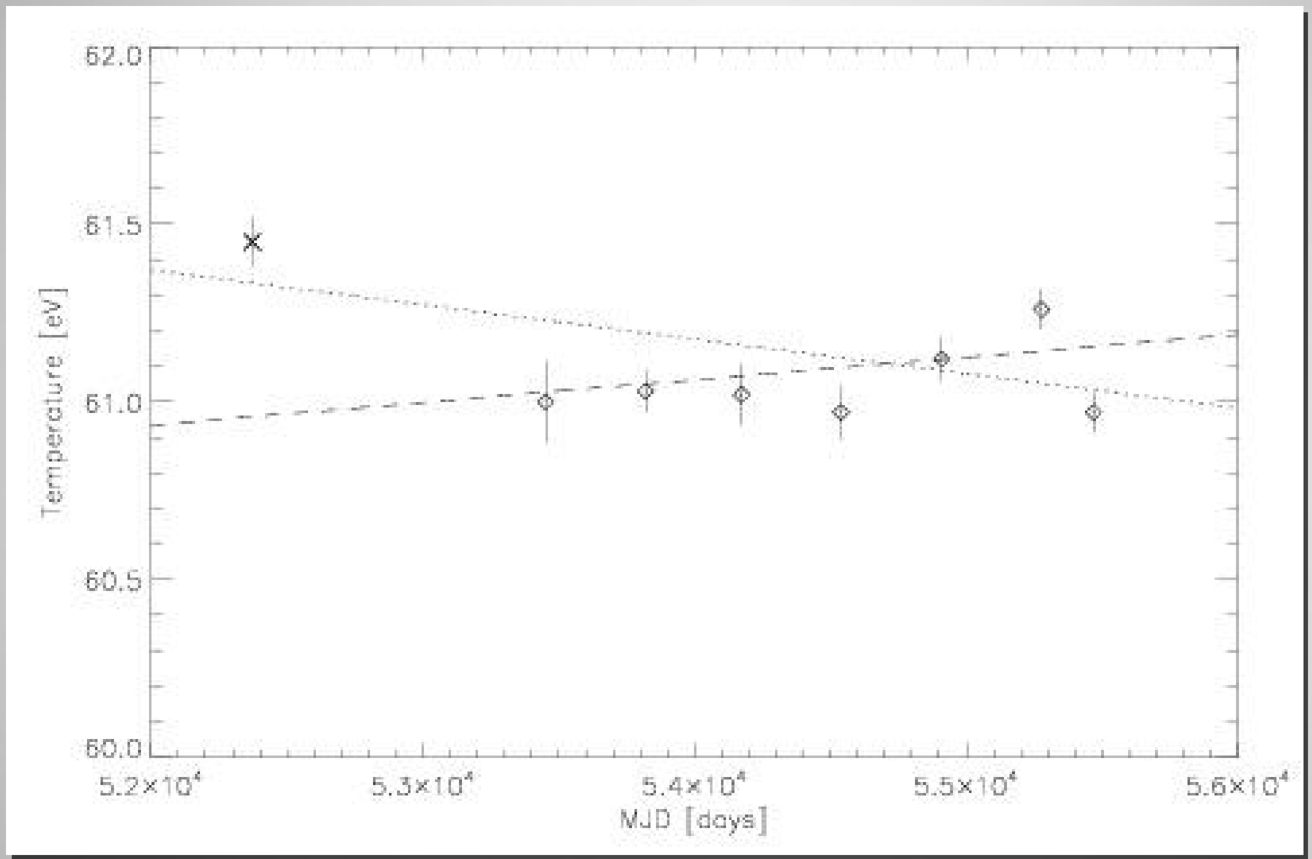
OR

- BB temperature and normalization

Target positions clustered in two regions: **hard** and **soft**

Observations in "soft region" (I)

Include ~50% of all RXJ1856 observations: $\Delta kT \sim 0.5\%$ and $\Delta f_X < \sim 3\%$

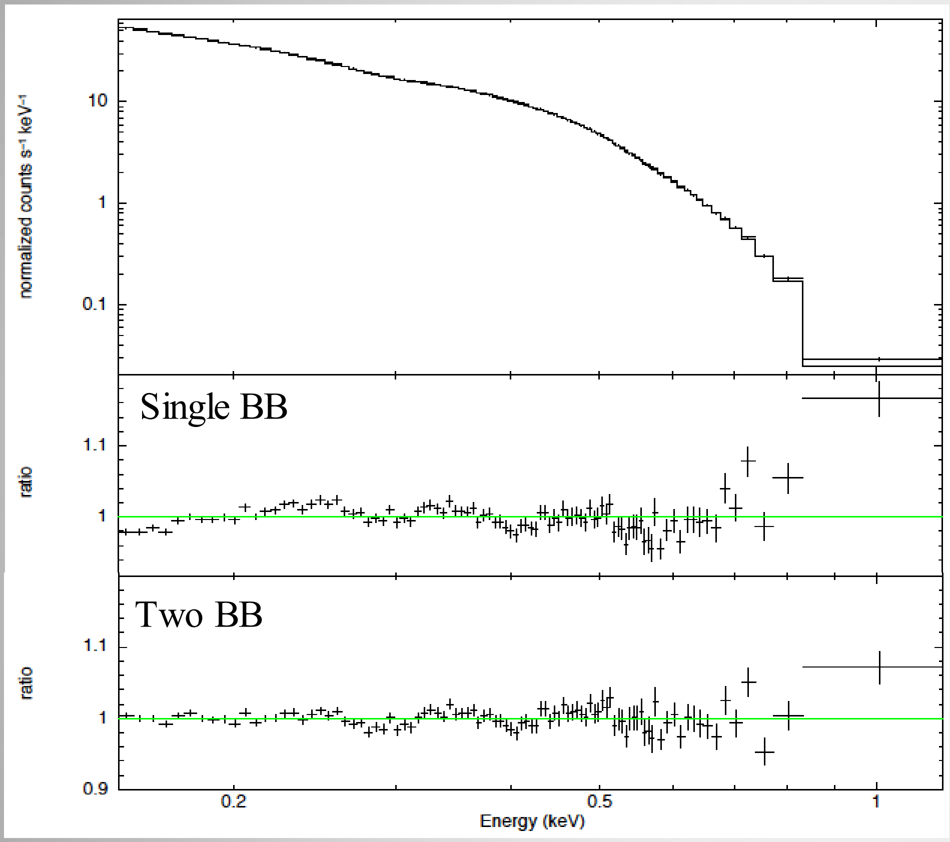


Time evolution:

- ✓No significant variability in 2005-2011 period
- ✓Obs. of April 2002 is "anomalous":
  - fit with a constant profile rejected at 4 σ
  - $\Delta kT \sim 0.5$ eV in < [illegible] years

Observations in “soft region” (II)

Merged spectrum: ~250 kiloseconds; ~2 x 10^6 counts



Parameter	Single BB	Two BB
N_H $[10^{19}\,\mathrm{cm}^{-2}]$	$4.8^{+0.2}_{-0.2}$	$12.9^{+2.2}_{-2.3}$
kT_h^∞ [eV]	$61.5^{+0.1}_{-0.1}$	$62.4^{+0.6}_{-0.4}$
R_h^∞ [km]	$5.0^{+0.1}_{-0.1}$	$4.7^{+0.2}_{-0.3}$
kT_s^∞ [eV]	-	$38.9^{+4.9}_{-2.9}$
R_s^∞ [km]	-	$11.8^{+5.0}_{-0.4}$
σ_{sys}	1.5%	0.6%
χ^2_ν	1.12	1.11

- No spectral features (EW < 6 eV)

- Extrapolation of 2BB model in optical band is 5x higher than single BB
⇒ consistent with optical/UV flux

Conclusions

(Sartore et al. 2012,A&A in press, arXiv:1202.2121)

✓ **Calibration results**

- Small PN gain variations (slope ~4% and offset ~15 eV) related to target position

- PN response in “soft region” is very stable (with possible exception of earliest observation in 2002), slightly more unstable (>2 times larger ΔkT) in “hard region”

✓ **Astrophysical results *(if calibration issues fully understood)***

- RXJ1856 very stable in time ($\Delta kT < 0.5\%$ and $\Delta f_X < 3\%$ from March 2005 to present)

⇒ Still a good standard candle

- April 2002: possible hint of small scale heating episode

- High-statistic cumulative spectrum: 2BB model provides much better fit and its extrapolation is compatible with optical/UV emission

Future prospects

✓ Re-analysis of all RXJ1856 observations with SASv12.0 to check whether position dependent gain is correctly accounted for.

✓Further observations might show instrumental problems or onset of heating episode in RXJ1856

✓ Improvements in calibration of PN low energy response are needed to fully exploit the cumulative spectrum of RXJ1856 (the best ever to study NS thermal emission)