INTEGRAL view of the HMXRB Pulsar SAX J2103.5+4545

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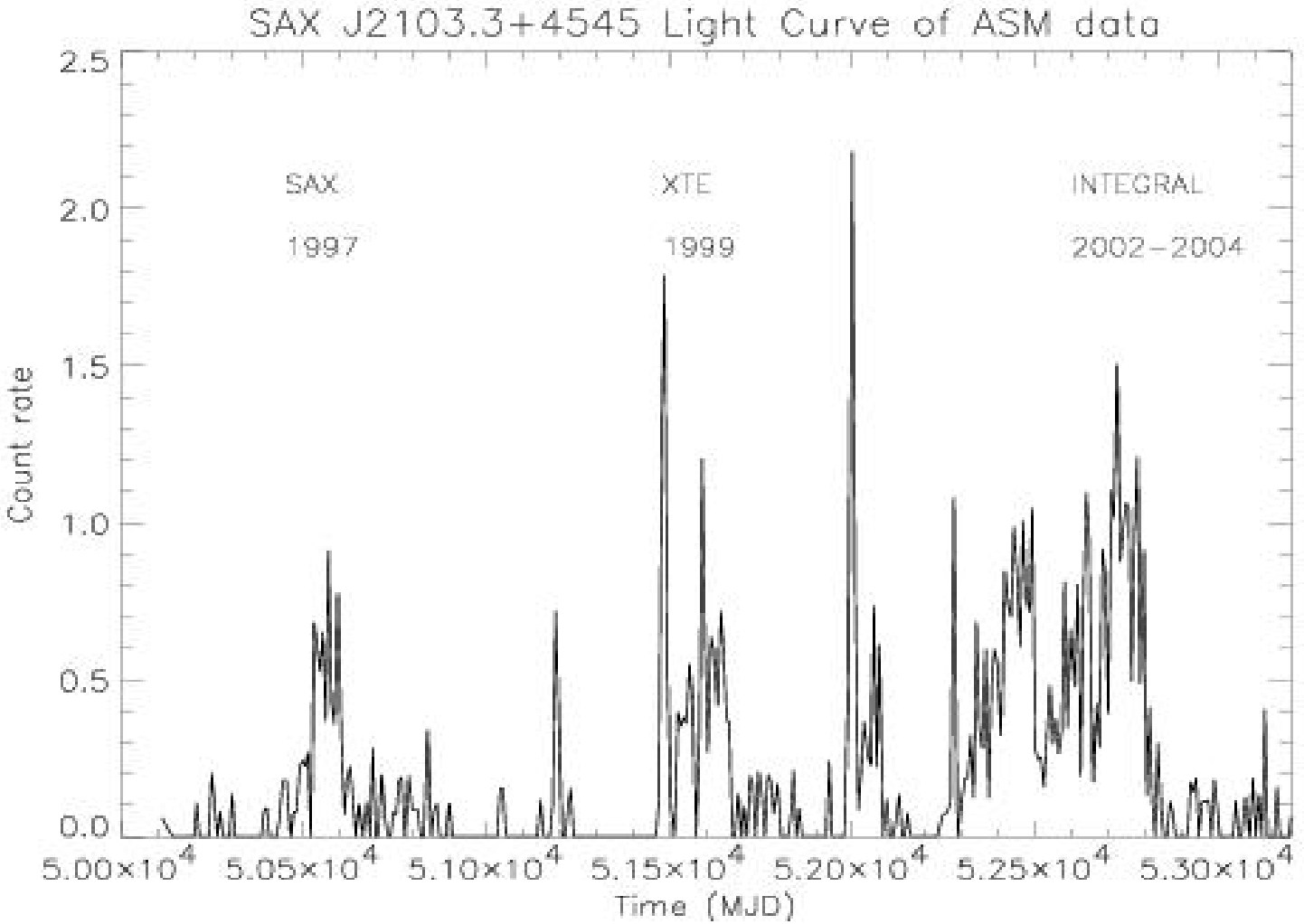
SAX J2103.5+4545

- **Transient** High Mass X-ray Binary
- **Pulsar** (P~358 s; BSAX/WFC Hulleman et al. 1998)
- P orb = 12.68 d; e~0.4 (RXTE; Baykal et al., 2000)
- **Be**/X-ray binary (V=14; B0Ve star; d~6.5 kpc; Reig et al. 2004)
  - **Note that** if this is the correct association, the source has the **shortest orbital period known** among the **Be-systems** and it **does NOT follow the Corbet (1986) correlation** between the ORBITAL and the SPIN PERIODS in Be/X-ray binaries (this would imply a Porb~190 days)

Outbursts History



INTEGRAL Observations

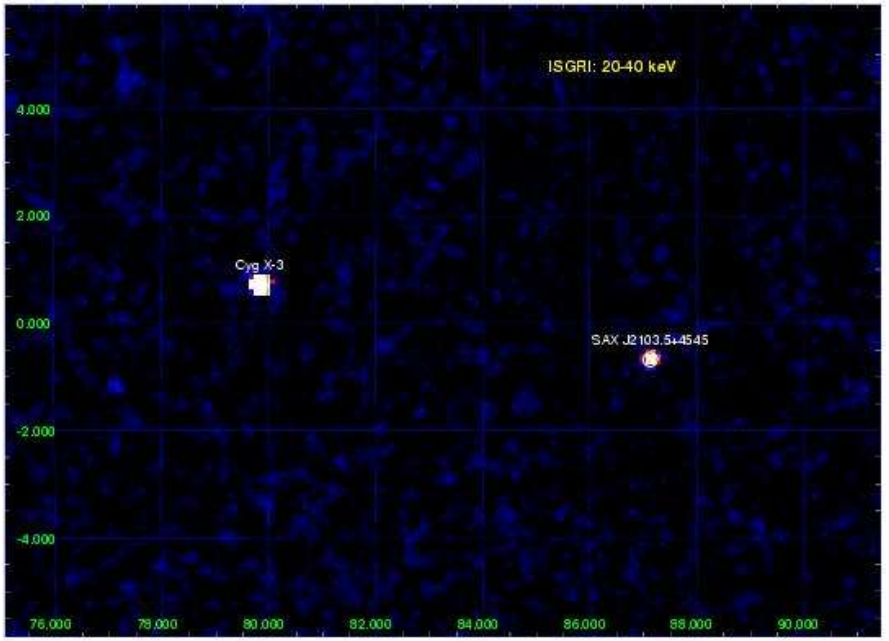
SAX J2103.5+4545 was **observed several times** during the **last outburst with INTEGRAL**, during the PV phase, the Galactic Plane Scan, AO observations of the Cygnus field.

Analysis of part of these obs. has been reported by Lutovinov et al. 2003, Sidoli et al. 2004, Blay et al. 2004, Filippova et al. 2004, Falanga et al. 2004.

We report here a comprehensive study of all INTEGRAL observations, from Dec 2002 to July 2004

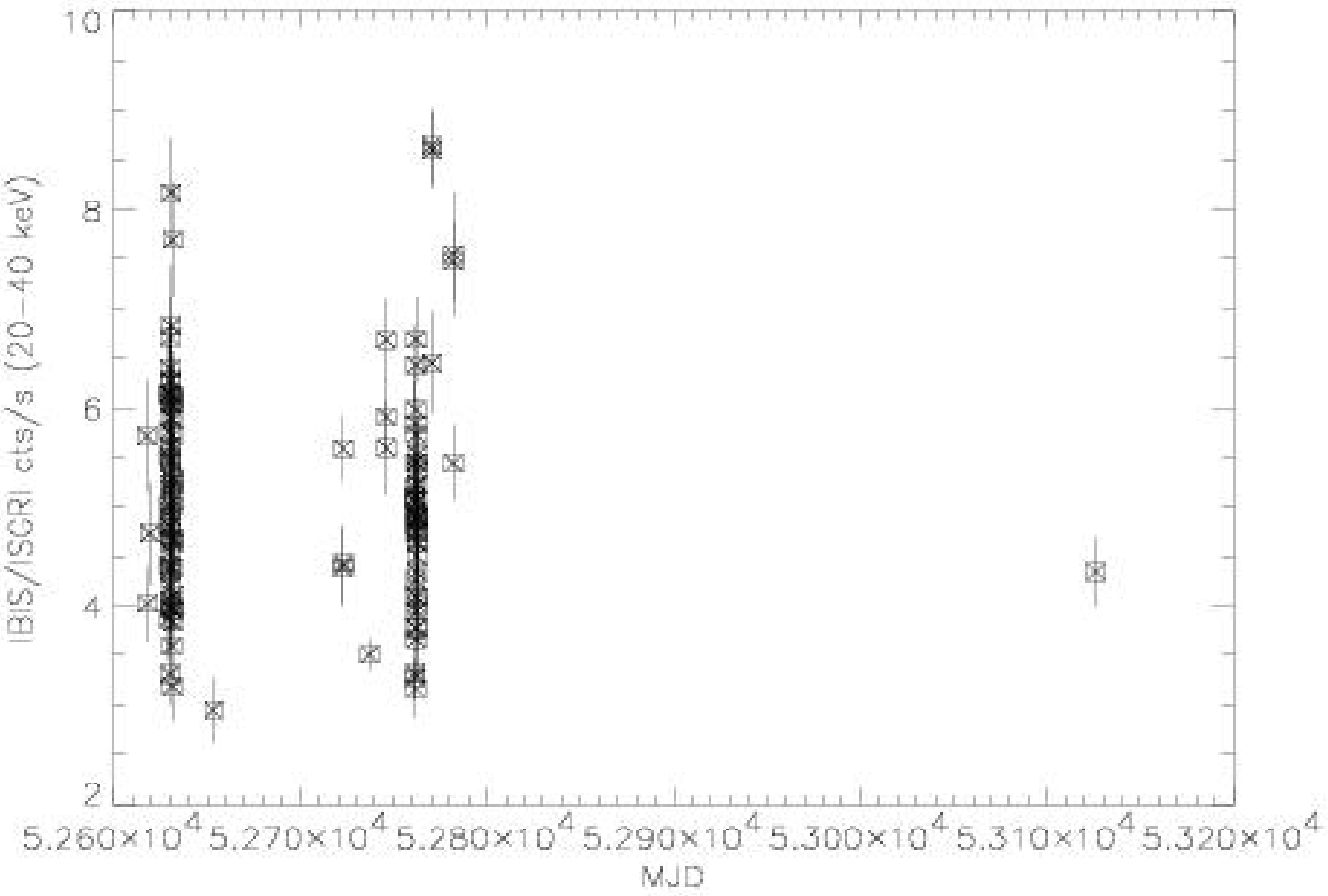
~170 IBIS/ISGRI pointings contain the source position (within 9deg), in ~100 observations the source has been detected in the 20-40 keV range with IBIS/ISGRI

OSA 4 software has been used for the data reduction



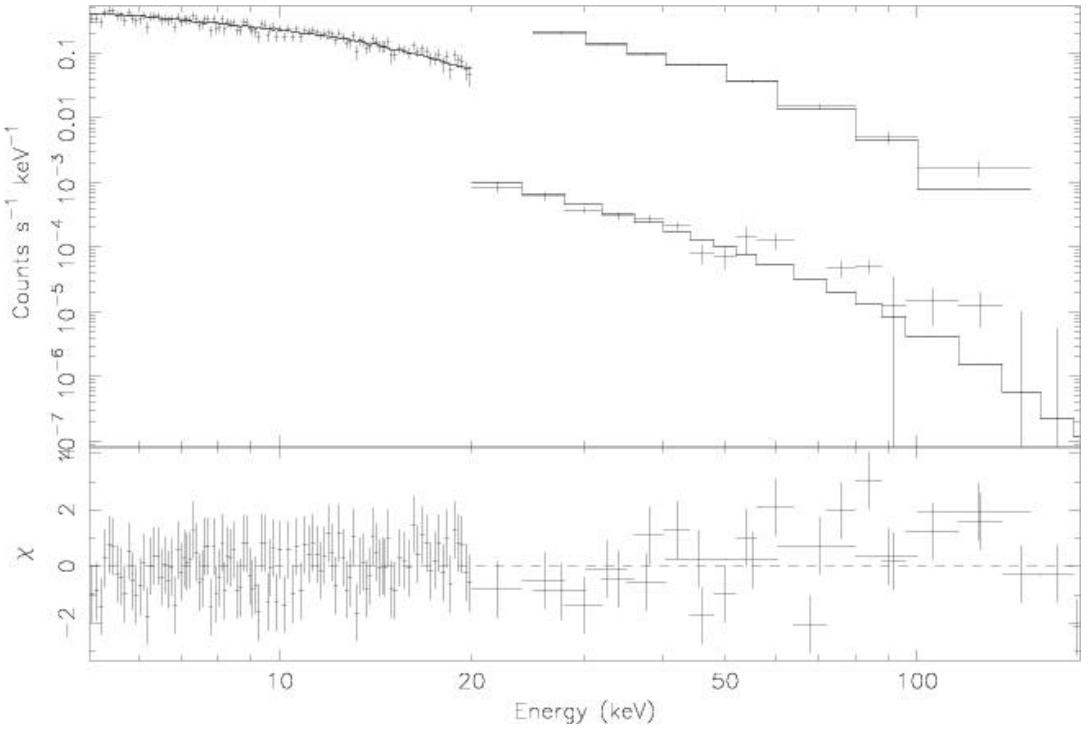
IBIS/ISGRI 20-40 keV light curve

ct/s



Time (MJD)

Spectral Analysis



- 5-200 keV spectrum (JEM-X + ISGRI + SPI)
- Best-fit: **power-law with high energy cutoff**, Nh fixed at 3e22cm-2
- Ph Ind=1.5; Ec=20 keV; Ef=32 keV
- Flux (5-200 keV) =**1e-9 erg/cm2/s**

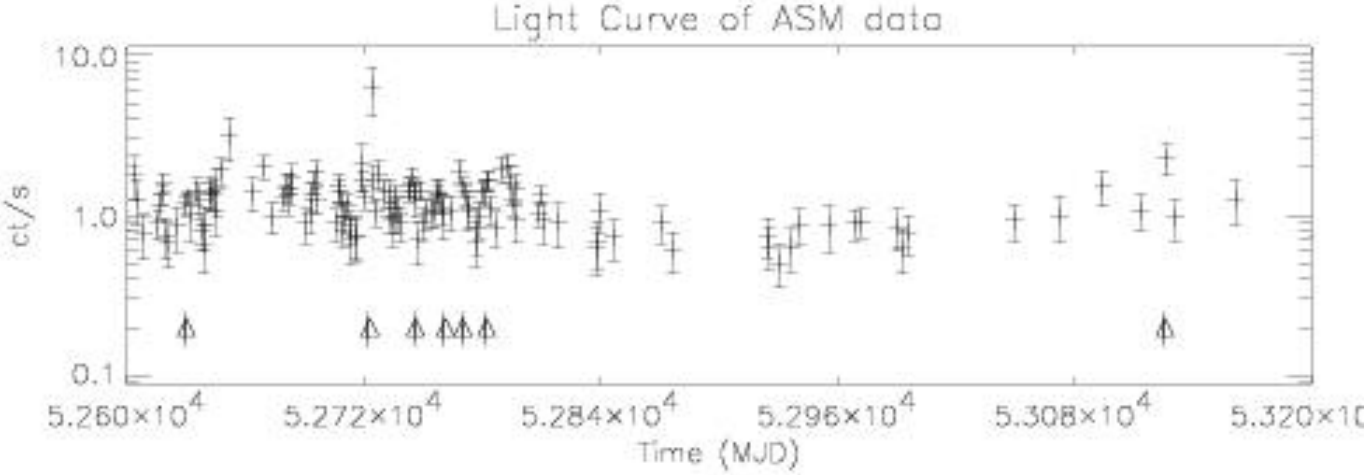
Timing Analysis

- Our analysis is focussed on the measurement of the source **Pulse Period** and **Period Derivative**
- We selected events with a Pixel Illumination Function PIF>0.5 with ISGRI (20-40 keV) and JEM-X (3-30 keV; where available)
- Events were both **corrected** for the Solar System barycenter and for the Doppler delay due to the motion in the binary system
- A single obs has a ~2 ks duration -> large uncertainty in the Period determination

  --> thus ***we grouped*** INTEGRAL observations in ***7 data-sets***, each data-set composed by pointings performed in the **same satellite Revolution** (good data have been collected from Rev.23,54,62,67,70,74,189)

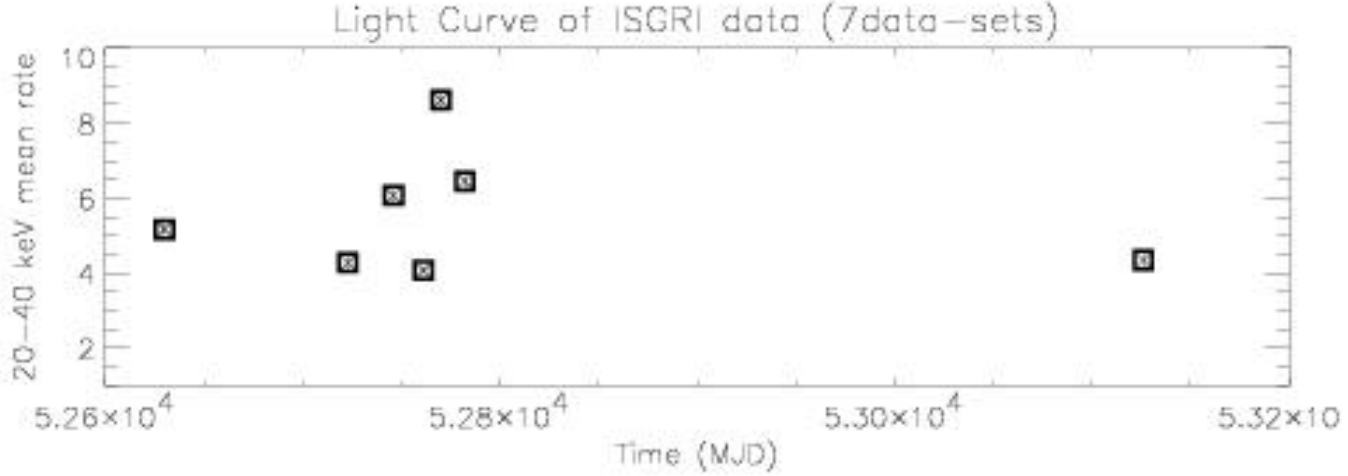
Time distribution of the 7 data-set used for the timing analysis

ASM



ISGRI

20-40 keV

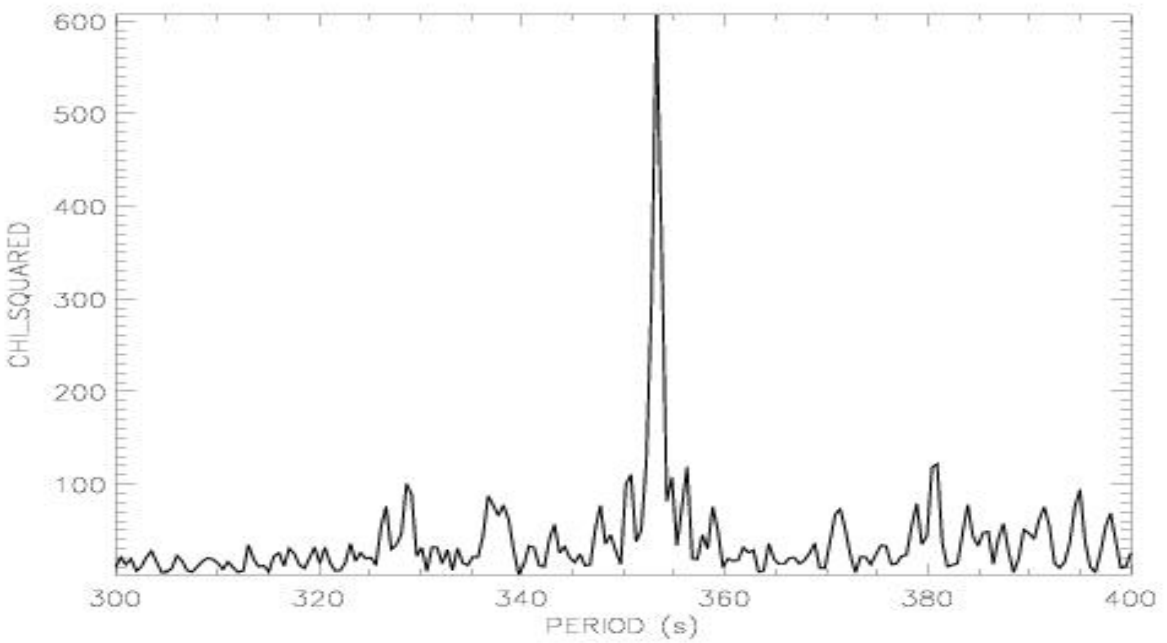


52600

53200

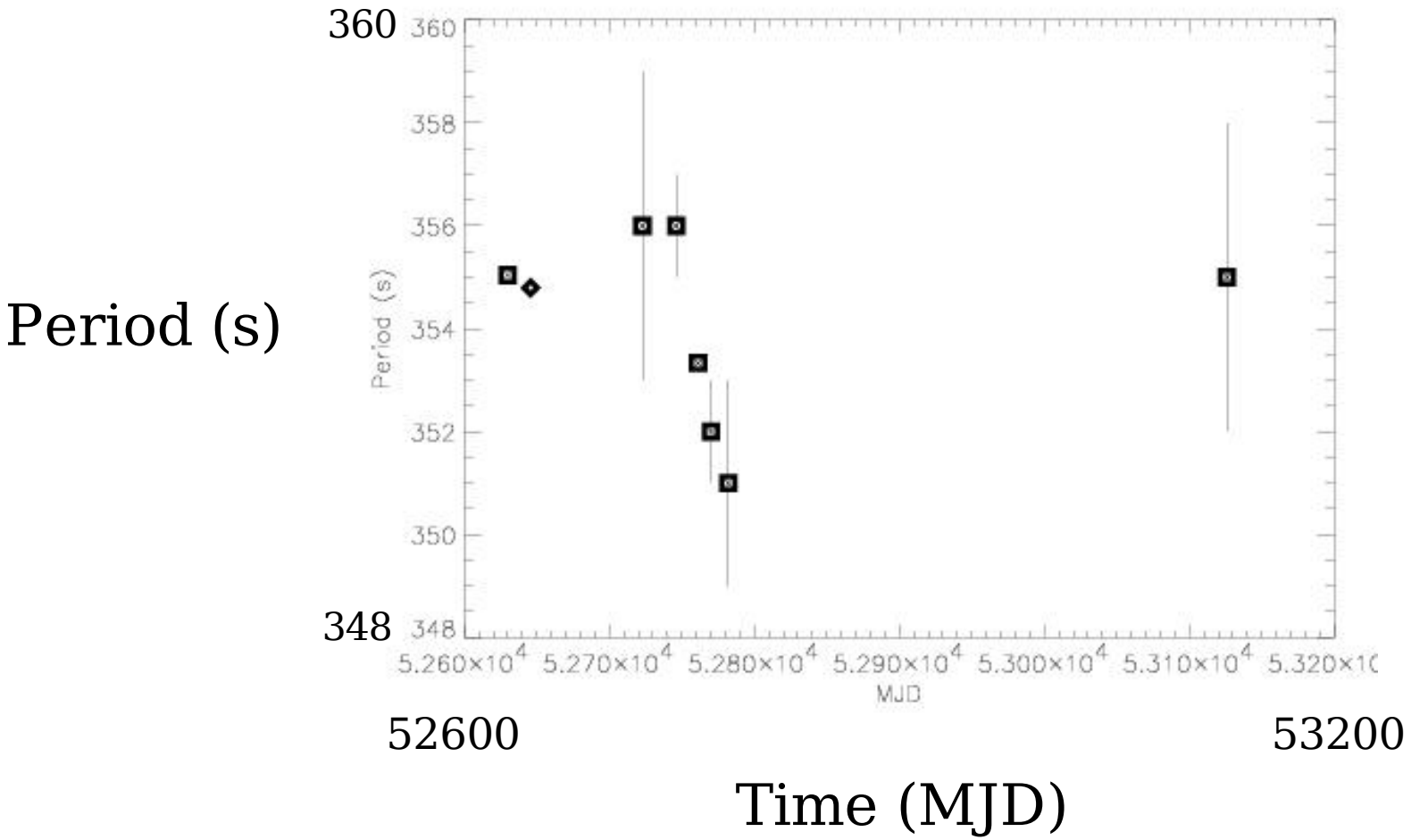
Time (MJD)

Timing Analysis Techniques



- Search for the Pulse Period by using Epoch Folding Techniques (Leahy 1987): we produced periodograms for each data-set, and then we fit them with the Leahy function, to get the best-fit pulse period and its uncertainty

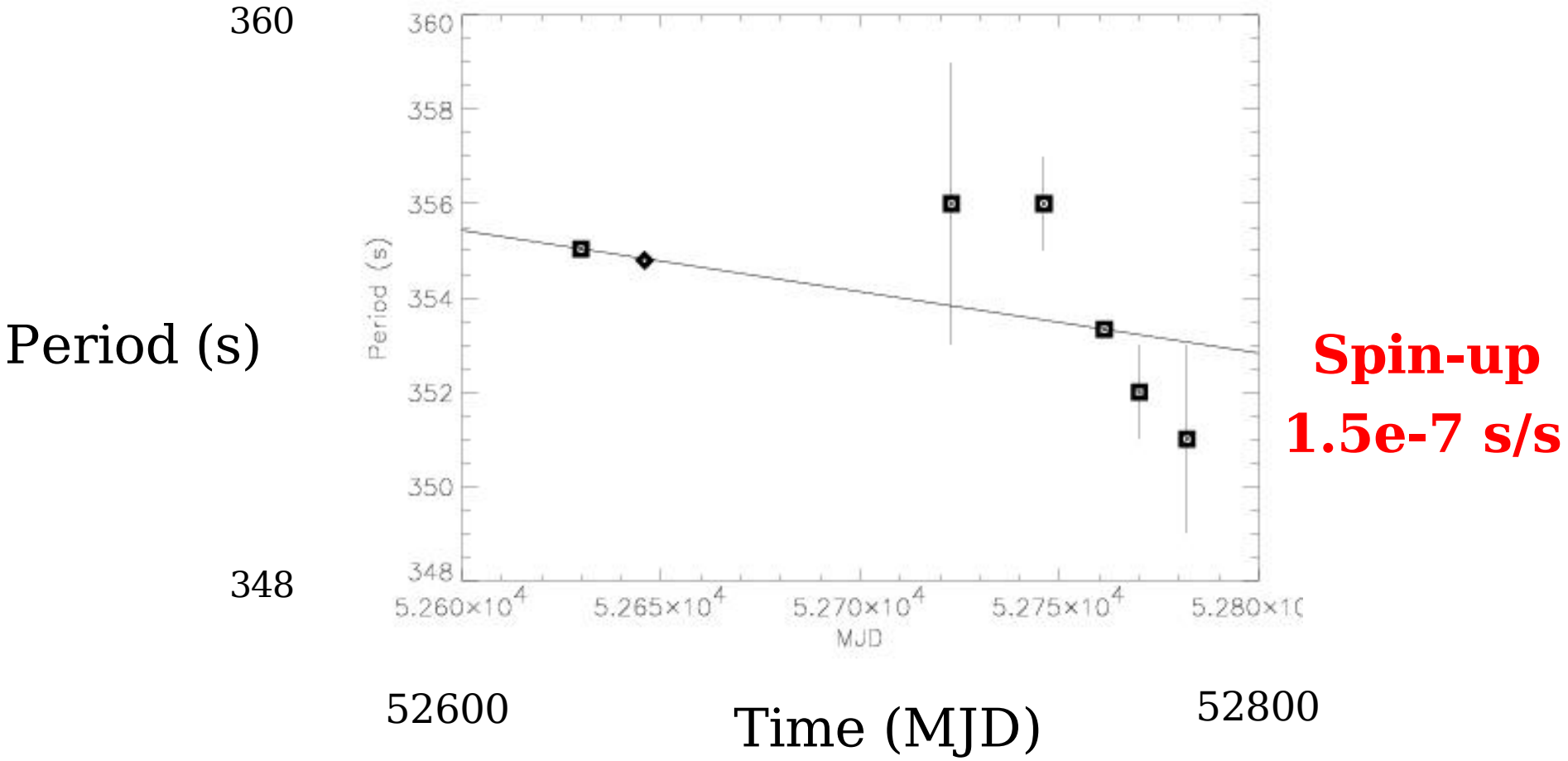
Timing Analysis Results: **Pulse Period** and its evolution



Squares = INTEGRAL (our 7 measurements)

Diamond = RXTE (Inam et al. 2004)

Timing Analysis Results: **Pulse Period** and its evolution

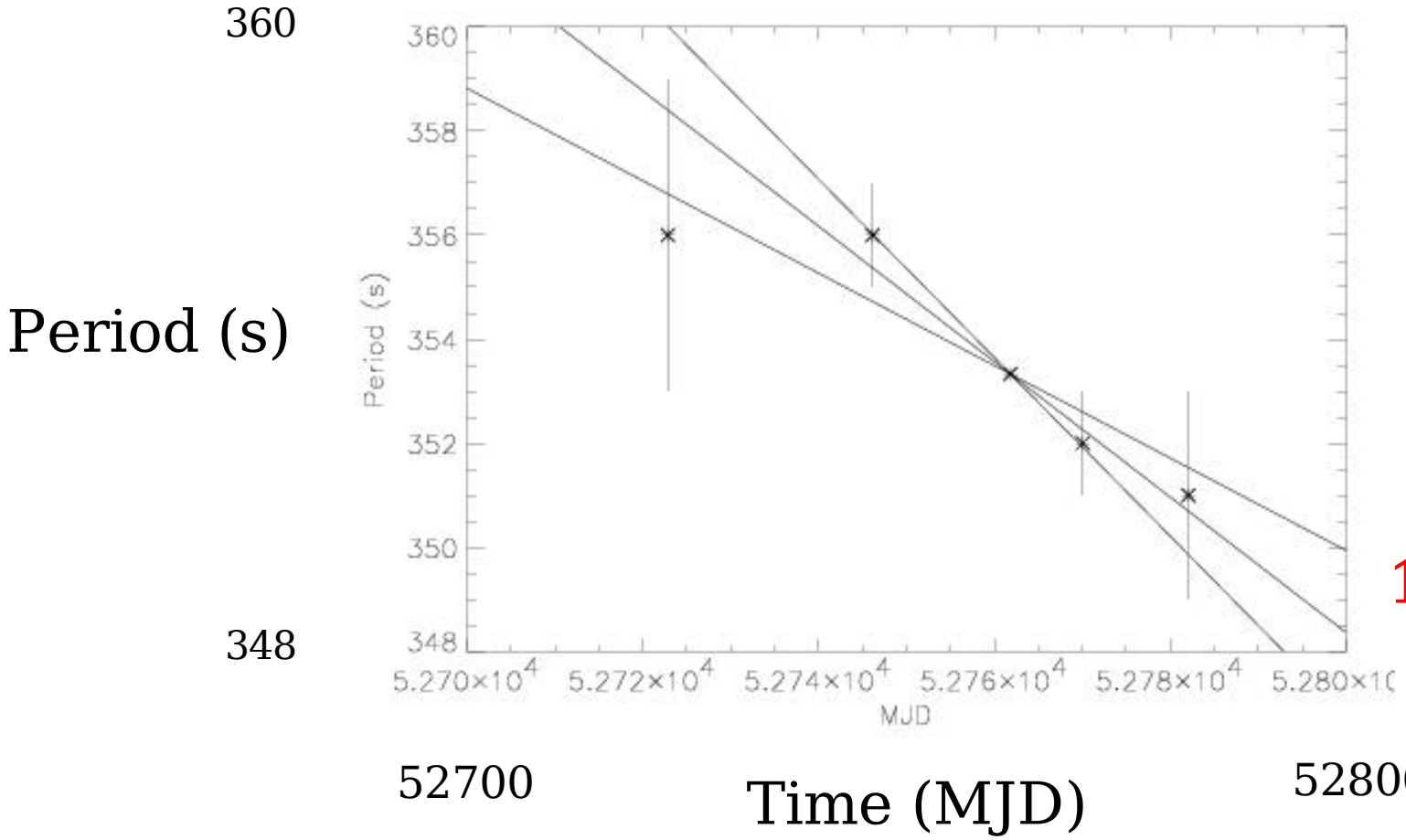


Spin-up
1.5e-7 s/s

Squares = INTEGRAL (zoom on 6 periods)

Diamond = RXTE (Inam et al. 2004)

Timing Analysis Results: **Pulse Period** and its evolution



Spin-up

1.5e-6 s/s

INTEGRAL (zoom on the central 5 periods)

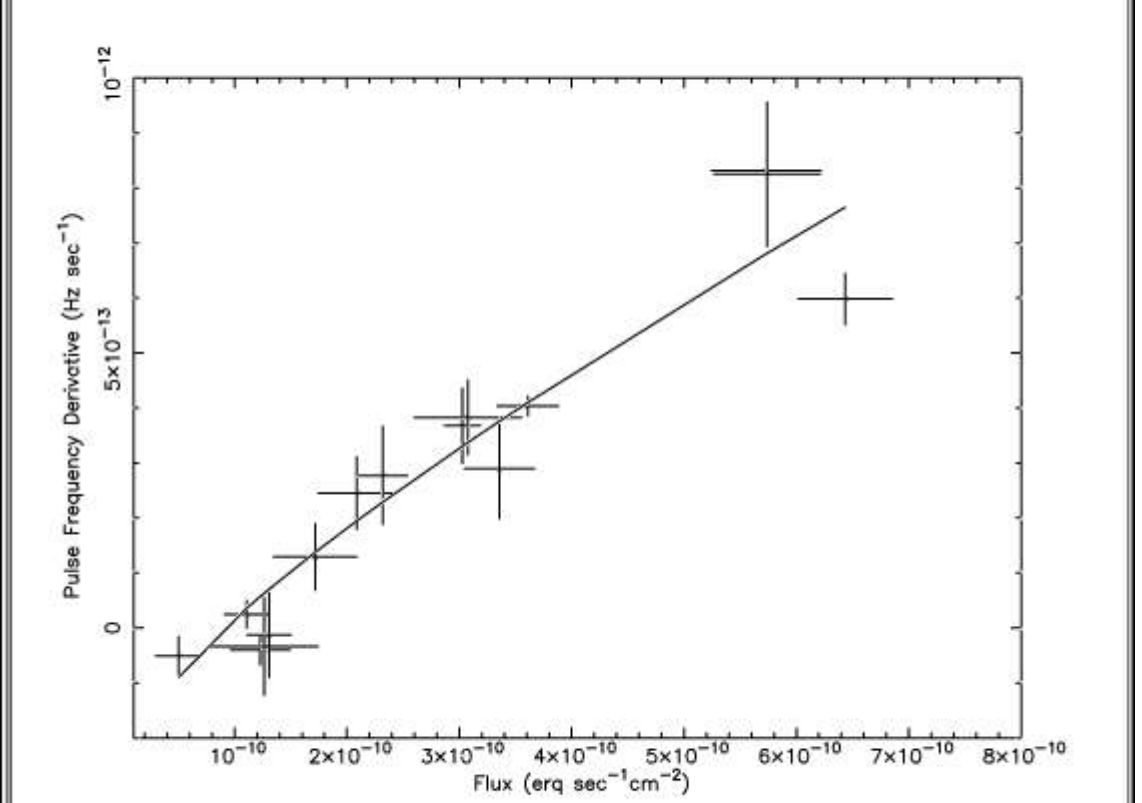


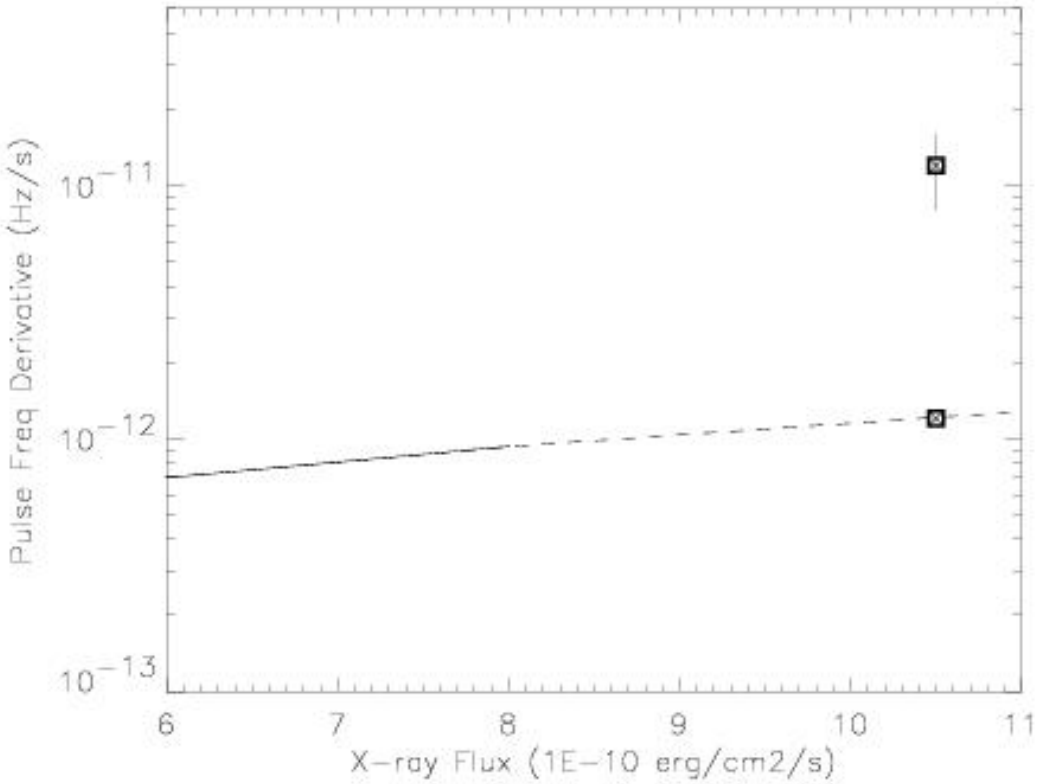
FIG. 7.—Pulse-frequency derivative vs. X-ray flux of SAX J2103.5+4545. The solid line presents the best-fit model to the data.

Ghosh & Lamb accretion model

- During 1999 outburst, with RXTE data a **correlation between spin-up rate and X-ray flux** was observed, as predicted by theory (Ghosh & Lamb 1979), indicative of the formation of an accretion disk (Baykal et al. 2002)

- 1999, RXTE observed a spin-up phase where the pulse period decreased by 0.9 s in 150 days
- A transition from the spin-up phase to the spin-downs regime was observed

Comparison of INTEGRAL results with the accretion theory



A problem with the theory...

Pulse Profiles

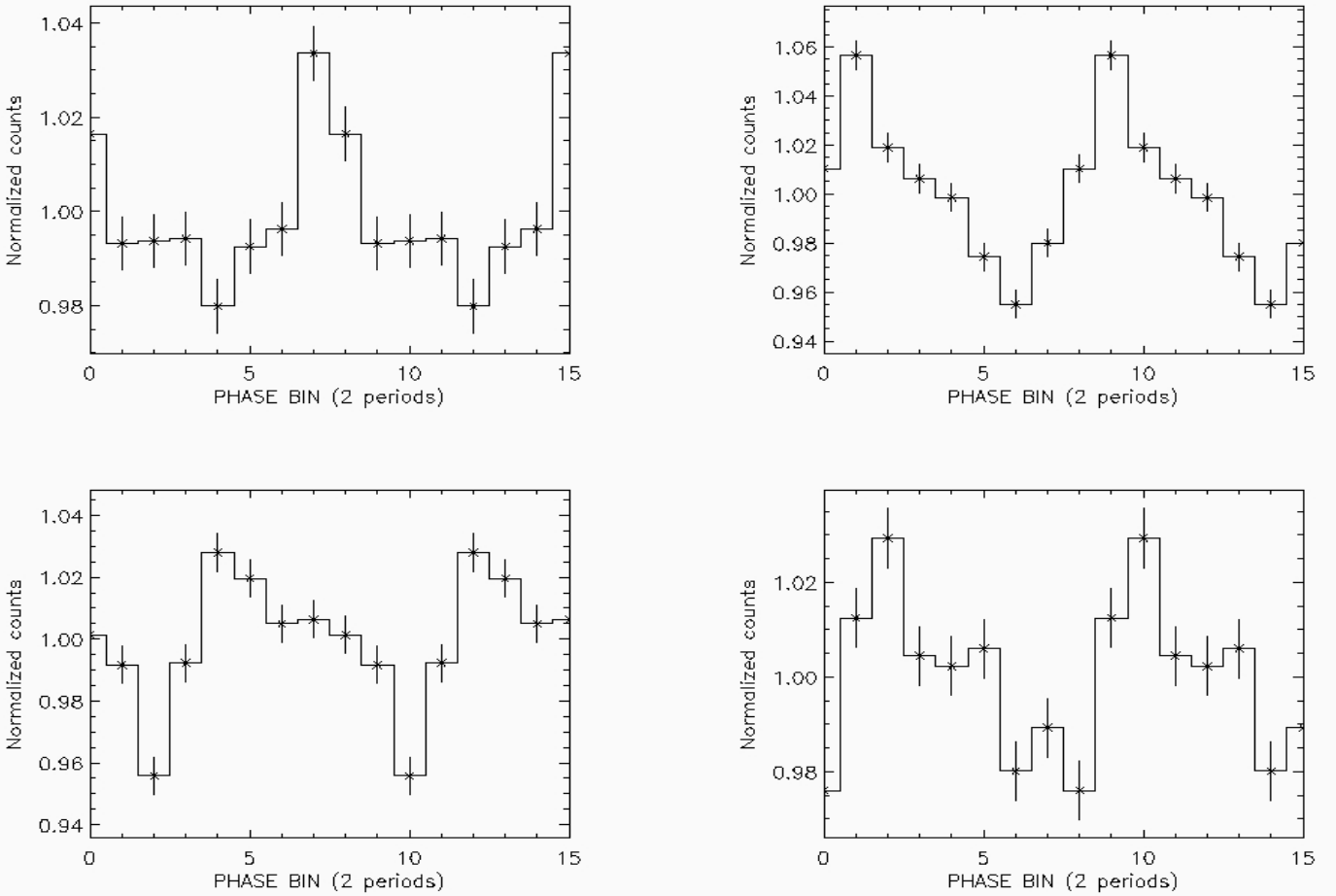


Fig. 4. Few examples of SAX J2103.5+4545 pulse profiles from INTEGRAL observations where a different shape is evident. From top to bottom, from the left to the right, profiles are from data-sets n.2, n.5, n.6 and n.7, all in the energy range 20–40 keV. The zero phase is arbitrary.

Conclusions

- SAX J2103.5+4545 shows a **spin-up** trend both with respect to previous observations with other missions and during the INTEGRAL observations
- From the 3 best periods measured during the latest outburst, a **spin-up** of 1.5e-7 s/s can be measured, which is in agreement with the extrapolation at high X-ray fluxes of the spin-up correlation with flux predicted by Ghosh & Lamb model for the accretion
- Results on the period measured from MJD 52723 to MJD 52782 (60 days) are indicative of a very rapid spin-up episode (1.5e-6 s/s, assuming a steady period derivative).
  Problems with the theory…