XMM-Newton Calibration Technical Note

Status of the EPIC-pn absolute timing capabilities using the Crab pulsar

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May 28, 2020

1 Introduction

This document summarizes the current status of the XMM-Newton EPIC-pn absolute timing capabilities. This document will be updated whenever new calibration observations of the Crab are processed.

2 Calibration observations of the Crab

The Crab pulsar is observed twice yearly with EPIC-pn in both Timing (TI) and Burst (BU) modes as part of the routine observations to calibrate the XMM-Newton relative and absolute timing capabilities. These observations are typically performed ∼6 months apart around February-March, and August-September. Additionally, the Crab has been subject to a number of non-routine calibration observations in both modes. All of these observations are used for the monitoring of the timing capabilities of the EPIC-pn camera. The previous update was reported in CAL-TN-0220-1-3.pdf

The latest observations from XMM-Newton revolution 3703 (2020 Feb 27) have been processed using the most up-to-date version of SAS (currently SAS v18.0) and analysed as described in:

`http://xmmweb.esac.esa.int/docs/documents/CAL-TN-0211-1-1.pdf`.

3 Current status of the absolute timing capabilities of EPIC-pn

The absolute timing performance of EPIC-pn is calculated by measuring the delay between the X-ray and the radio pulse. The radio ephemeris is provided by the Jodrell Bank radio telescope, which observes the Crab regularly. We show, in Fig. 1, the pulse delays over the lifetime of the mission. The mean pulse delay values for TI and BU modes, as well as the total, are also reported in Table 1. The 1σ confidence interval (the standard deviation (SD) of the distribution of offsets) can be used as a proxy for the absolute timing accuracy of EPIC-pn.

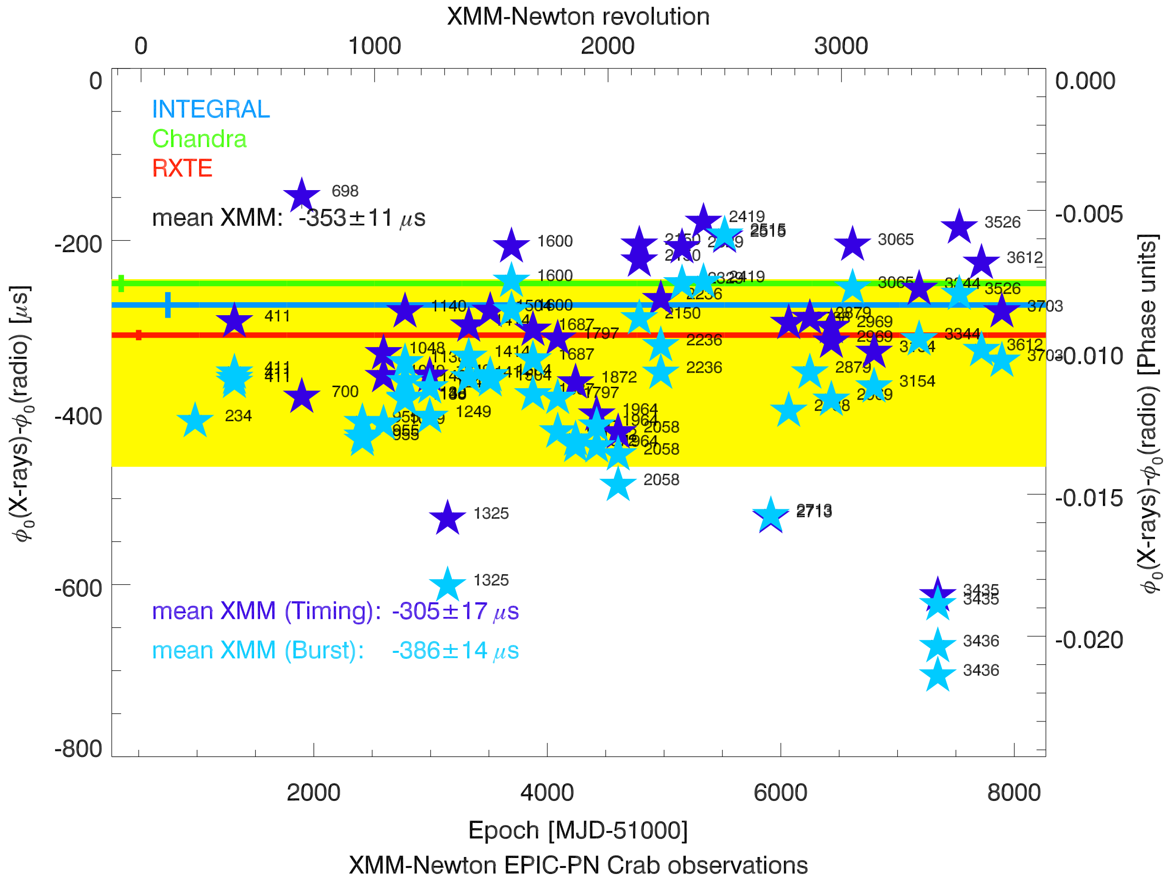

Figure 1: Absolute timing delay measurements of the primary pulses of the Crab pulsar, obtained with the XMM-Newton pn, measured with respect to the Jodrell Bank radio ephemeris. The yellow band indicates the confidence interval of the XMM-Newton measurements in units of $\pm 1\sigma$ (SD) from the mean. The blue, red and green horizontal lines indicate the INTEGRAL, RXTE (Molkov, Jourdain & Roques, 2010, ApJ, 708, 403) and Chandra (see https://cxc.harvard.edu/ccr/proceedings/03_proc/presentations/rots/) measurements, respectively - the small coloured vertical bars in each case indicate their 1σ statistical error. The errors given for the XMM TI, BU and mean XMM offset values, are the formal errors on the mean.

Table 1: Absolute timing accuracy of EPIC-pn.

Mode	Pulse delay (μs)
Timing	-305 $\pm$ 103
Burst	-386 $\pm$ 100
Total	-353 $\pm$ 108

3.1 Comments on the current results

The most recent Crab observations, from revolution 3703, included in this update, yield pulse delays relative to the radio ephemeris that lie well within the distribution of previous delay values. The four Crab measurements in revolutions 3435 and 3436 show significantly discrepant values that contribute to a degradation of the overall absolute timing accuracy of EPIC-pn. The cause of this discrepancy currently remains unresolved. If these 4 points are excluded from the analysis, the mean XMM-Newton pn timing offset from the radio ephemeris is -339 $\pm$ 87 μs, the error being the SD value of the delay distribution.