

XMM-Newton Calibration Technical Note

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

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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-0220-1-9.pdf

The latest observations from XMM-Newton revolution 4351 (2023 Sep 11 and 12) have been processed using the most up-to-date version of SAS (currently SAS v21.0) using the DE200 solar system ephemeris (for consistency with the Jodrell Bank radio ephemeris) 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 ([1]) (see also ¹). We show, in Fig. 1, the pulse delays over

¹<http://www.jb.man.ac.uk/pulsar/crab.html>

Table 1: Absolute timing accuracy of EPIC-pn.

Mode	Pulse delay (μs)
Timing	-304 ± 100
Burst	-384 ± 101
Total	-351 ± 108

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.

3.1 Comments on the current results

The most recent Crab observations, from revolution 4351, included in this update, yield pulse delays relative to the radio ephemeris that are broadly consistent with 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 unidentified. Analysis of data from revolution 4251 showed large offsets ($\sim -4000\mu\text{s}$), more than 10 times larger than the ensemble average, whose origins also remain unclear at present. These data from revolution 4251 are not included in the quoted mean offsets.

4 References

- [1] Lyne, A. G., Pritchard, R. S. & Graham-Smith, F. 1993. MNRAS, 265, 1003

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.