# X-ray Loading, Gainshift & (Modified) Timing Mode of XMM-Newton's EPIC-pn


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## Abstract

Knowing the instrument's behaviour is highly important when analyzing the collected observational data. Here we investigate the issue of the energy gainshift associated with the EPIC-pn instrument on-board *XMM-Newton*, when it is operated in Timing mode. The gainshift arises as a result of CTI effects or X-ray loading. This depends on the source brightness and the effectiveness of the noise correction. X-ray loading has clearly been detected in Imaging mode, while the importance of its impact on the Timing mode observations is still under investigation. The consequences of X-ray loading in general are pattern migration from higher to lower pattern types and a shift to lower energies for all events associated with the affected CCD column. Current results show a clear correlation between X-ray loading and X-ray flux of the source, but other correlations may also reveal ways to understand and correct for the energy gainshift in the data. A pequliar case of Timing mode is the Modified Timing mode, and here we also explain its properties and its potential impact on the scientific results dealing with bright X-ray sources.


## X-ray loading

### Definition and the cause

Measurements with the EPIC-pn camera of the *XMM-Newton* satellite may be contaminated by IR, visible and UV photons. In order to prevent the contamination thin, medium or thick blocking filters are used. In addition an offset map is calculated which is used for subtracting the constant, measured level of produced charge from the detected source events.
Very bright X-ray source may contaminate the pn offset map, giving rise to X-ray loading. This leads to the loss of the source signal resulting in:

- pattern migration from higher to lower pattern types
- shift to lower energy for all subsequent events associated with the affected pixel

### Affected observations

Here we analyse archival Timing mode observations where we look for the amount of X-ray loading in individual columns of offset maps. X-ray loading occurs most often in the innermost columns as most of the flux comes from the source position, as is evident from the **Fig. 2**. Thus, excluding them would often remove most severe effects of X-ray loading. These columns are usually removed because of the pile-up. It should be noted, however, that the loading may occure even for cases where the source count rate is <pile-up limit (see XMM-SOC-CAL-TN-0050 for a study on imaging mode data).
In **Fig. 3** a correlation between the X-ray count rate and the maximal X-ray loading seen for different sources observed in Timing mode is evident.

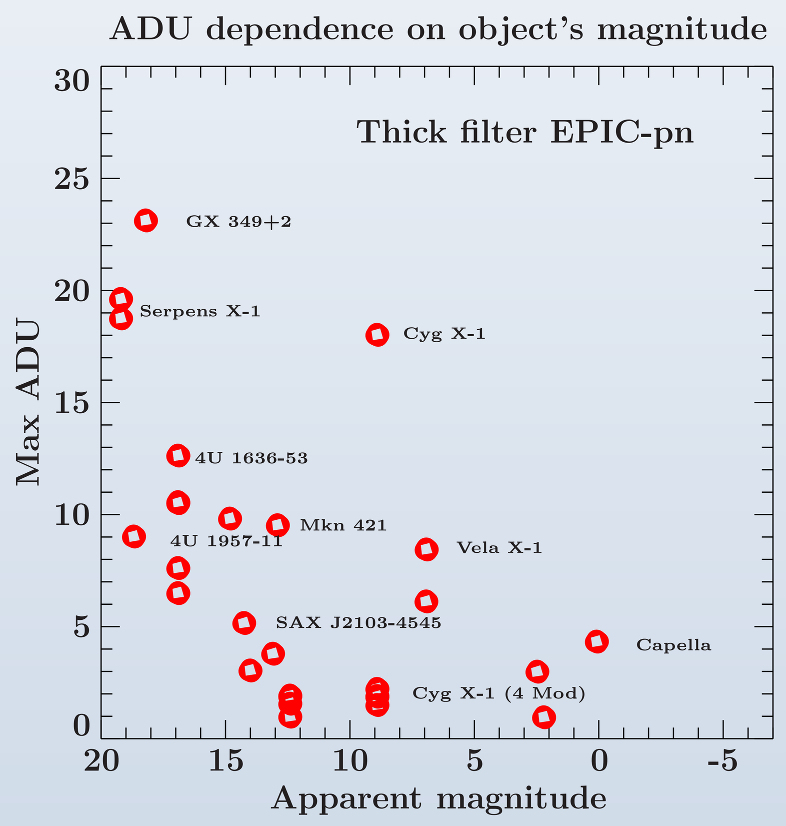


**Figure 1**: Amount of X-ray loading in comparison with objects' apparent magnitudes taken from Simbad show no clear correlation.

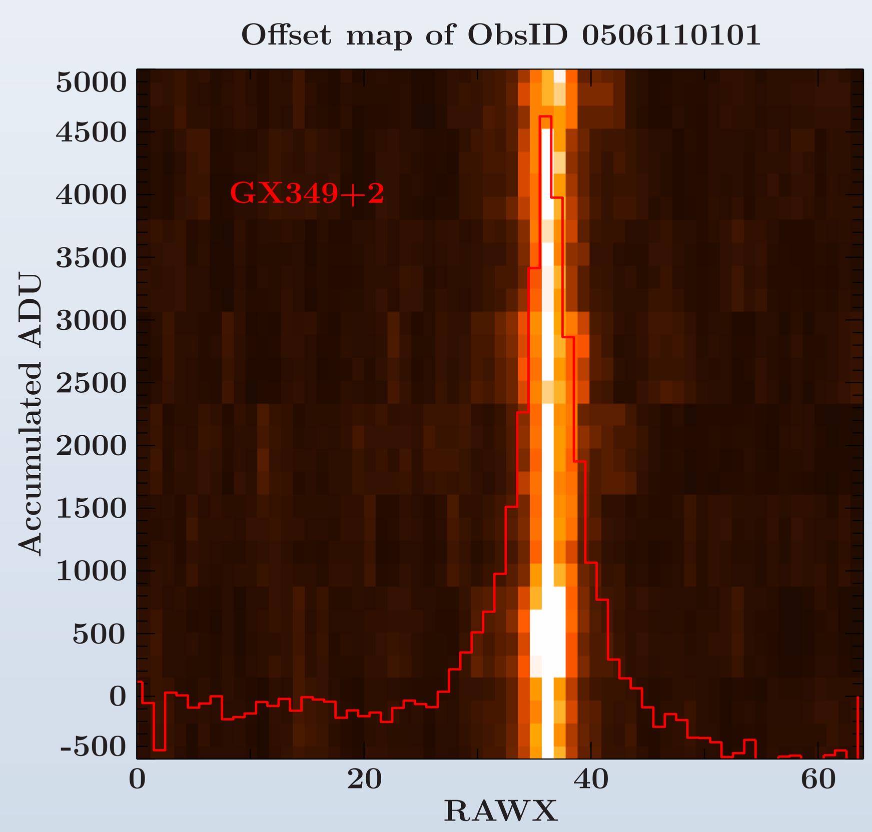


**Figure 2**: Offset maps are calculated before each observation while pointing at the source. As this one shows, they can be used in estimating X-ray loading.

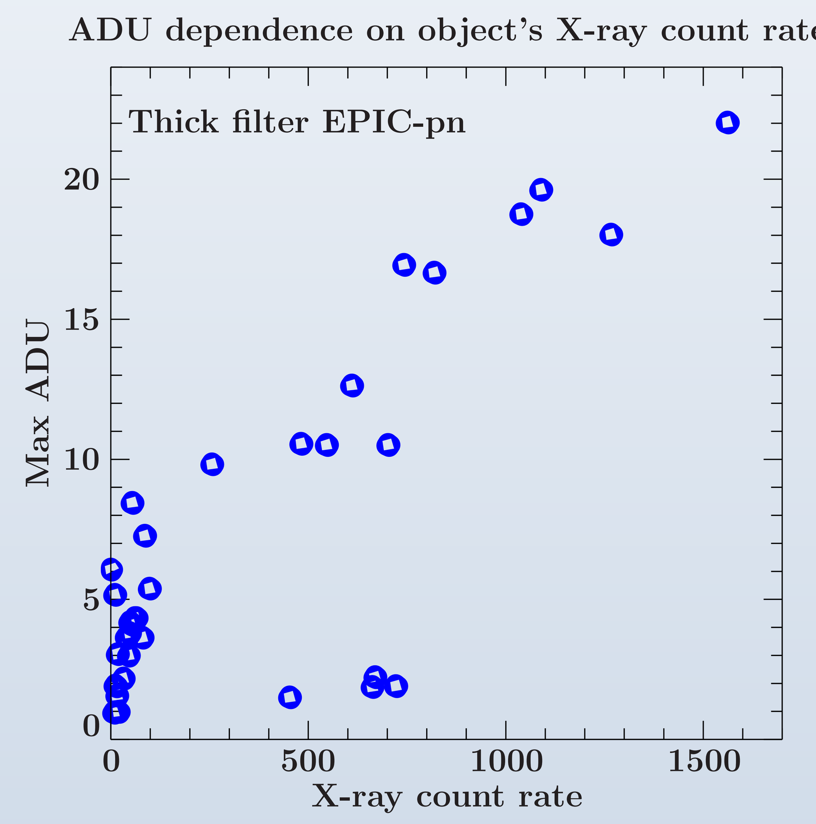


**Figure 3**: Thick filter Timing mode observations show that X-ray loading is increasing with increasing rate. Note four Modified Timing mode observations at the bottom.

## Gainshift

Traps caused by contamination of the silicon with titanium are causing loss of charge upon read-out (Charge Transfer Inefficiency), For bright sources these traps are filled fast, and any correction of CTI causes an over-correction. This means that we end up with a shift of events towards higher energies. In addition, X-ray loading shifts the events in the opposite direction. To correct for such energy shifts one can apply a gainshift correction to the EPIC-pn data when fitting it together with simultaneous data from other X-ray missions (Duro et al. 2011).

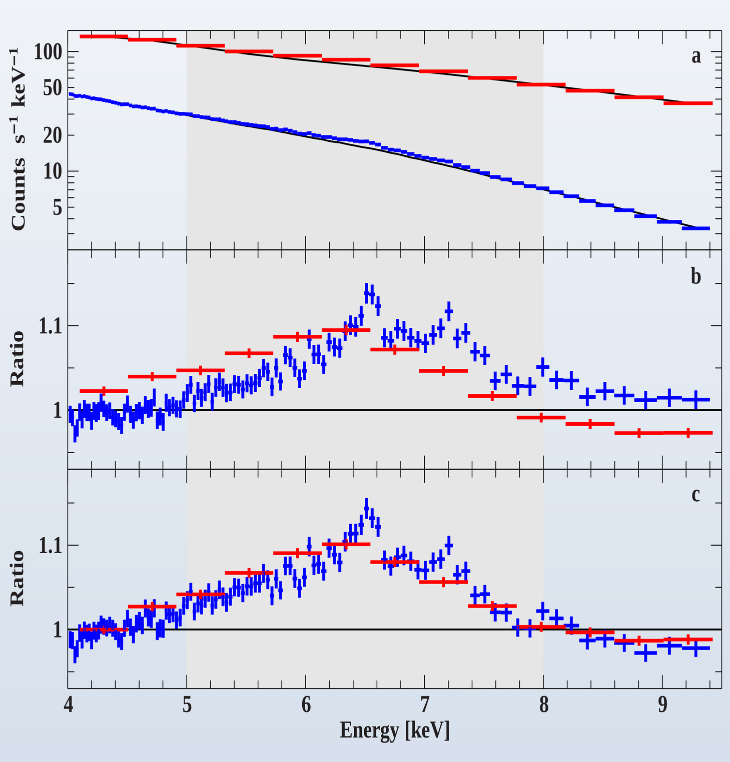


**Figure 4:** The effect of the gainshift correction, when applied on EPIC-pn data here fitted simultaneously with PCA data. Panel **b** represents the fit without the correction and with clear disagreement of the data, while panel **c** shows the improvement when corrected for gainshift of $\sim 2\%$ (see **poster B05** for more details on the spectral analysis of these datasets of Cygnus X-1).

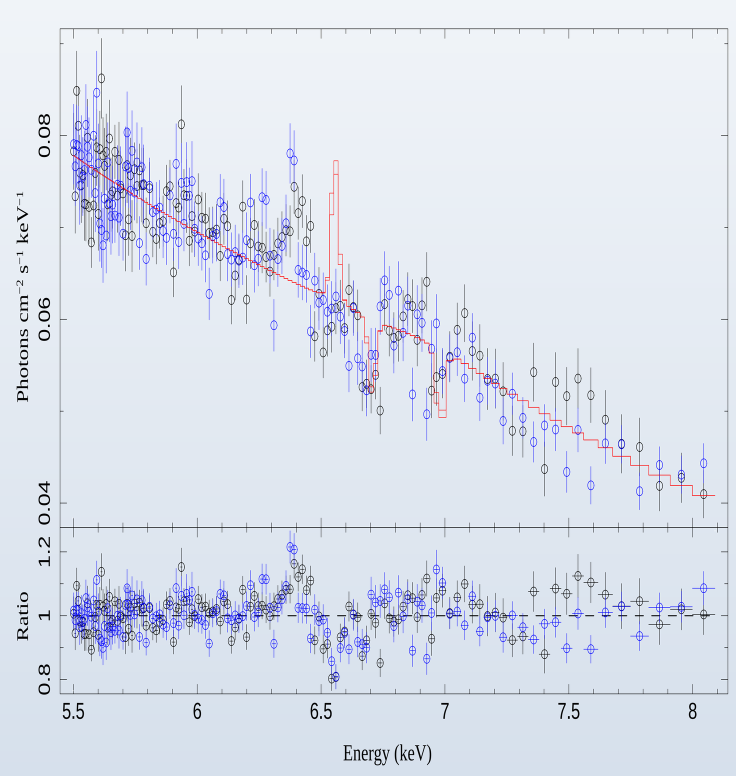


**Figure 5:** The best fit model (shown in red) to the same EPIC-pn data now compared to *Chandra* data (blue) shows clear disagreement in the position of 6.4 keV narrow emission line and resonant iron absorption lines (*Chandra* values by Hanke et al. 2009). Only when applying a gainshift of $\sim 2\%$ to EPIC-pn data (as in the Fig. 3), agreement is reached.

## Modified Timing Mode

To get high S/N data of bright sources, one may observe with EPIC-pn instrument set in Timing mode. Nevertheless, telemetry limit of $\sim$ 100 mCrab makes it difficult to observe sources such as Cygnus X-1 with fluxes $\sim$ 300 mCrab without going into counting mode. To bypass the telemetry limit, two steps are performed onboard the *XMM-Newton* and one on the ground (see below), which results in more telemetry allocated to the EPIC-pn and less data sent (Kendziorra et al. 2004).
Modification implies a re-calibration of the instrument, mainly due to the lost information on the single-to-double ratio of events caused by increased lower energy threshold. A new response matrix is calculated based on the archival Timing mode observations by measuring energy dependent probability distribution of split events. With this combination we can observe objects of few hundreds mCrab.

**Modification:**

- 2 EPIC-MOS instruments switched off
- Increased lower energy threshold limit to 2.8 keV

**Recalibration**

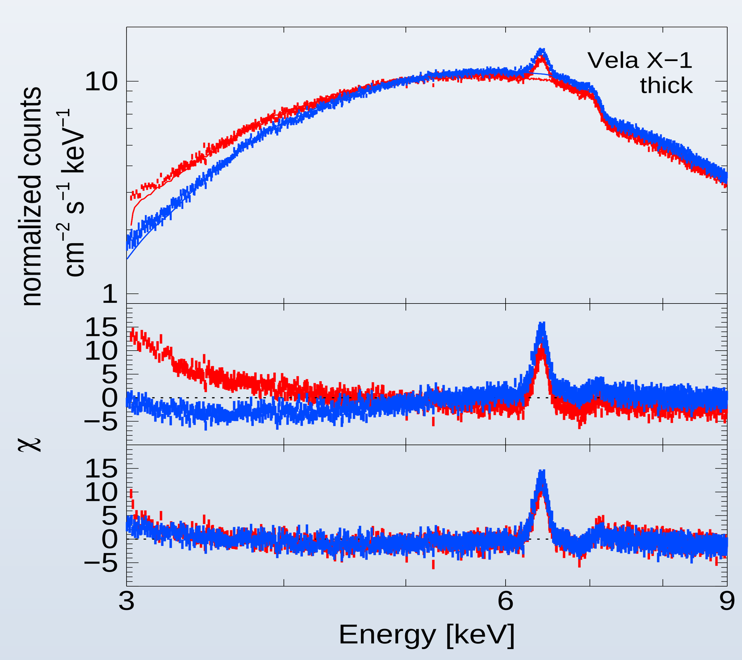


**Figure 6**: *Top*: Measured EPIC-pn Timing mode spectrum (blue) and Modified Timing mode spectrum generated from these data (red), fitted with an absorbed power-law. *Middle*: The redistribution of events in the Modified Timing mode leads to an apparent soft excess. *Bottom*: New response matrix for the Modified Timing mode fully describes the calibration of this mode (Fritz 2008).


### References

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