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Analysis of the IBIS-ISGRI systematic source location offsets

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Abstract. In this paper we investigate the residual bias in the source positions provided by the standard software of the INTEGRAL IBIS-ISGRI data by analyzing a large number of observations covering more than ten years of the mission. We found a clear dependence of the bias on the satellite roll angle that can be reduced by independent modeling of the IBIS mask quarter displacements and of the photon penetration effect in the ISGRI detector pixels. Preliminary results of this study are presented for strong sources.

Key words. Coded Masks; Gamma-Ray Astronomy

1. Introduction

Source positions provided by the standard OSA 10 software (Goldwurm et al. 2003; Gros et al. 2003) applied to the INTEGRAL (Winkler et al. 2003) IBIS-ISGRI (Ubertini et al. 2003; Lebrun et al. 2003) data are corrected for bias, due to thermoplastic deformations, by using a model based on measures of the IBIS mask temperature (Scaringi et al. 2010). While an improvement is obtained with this correction, residual effects are still visible on data of strong sources. Here we investigate the problem using a much larger data set than available during previous studies.

2. Residual offsets in the field of view

Fig. 1 shows the scaled positioning offsets in instrumental coordinates (Y,Z) for Cyg X-1 observations in the energy range 20-300 keV and over the entire Field of View (FoV). We selected science windows (ScW) between 2003 and 2014.

3. Roll angle dependency

Fig. 2 shows the weighted average residual offsets in celestial coordinates using results of OSA 10 for two strong sources, covering the same time interval. We selected science windows for which the source was at a distance smaller than 13 degrees from the telescope axis and the Signal-to-Noise Ratio (SNR) was larger than 10. We note that while on average the mask temperature correction provide satisfying results, a dependence of the source offset on the roll angle is still present.

4. Photon penetration effect and mask quarter model

We investigated the influence of the photon penetration effect (PPE) on the source position-

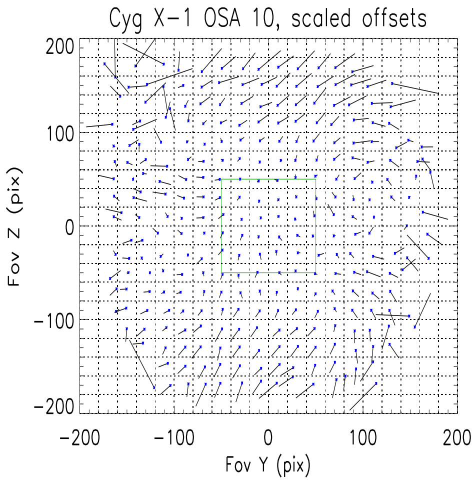

Fig. 1. Positioning offsets in instrumental coordinates (Y,Z) over the FoV for Cyg X-1 observations in the energy range 20-300 keV.

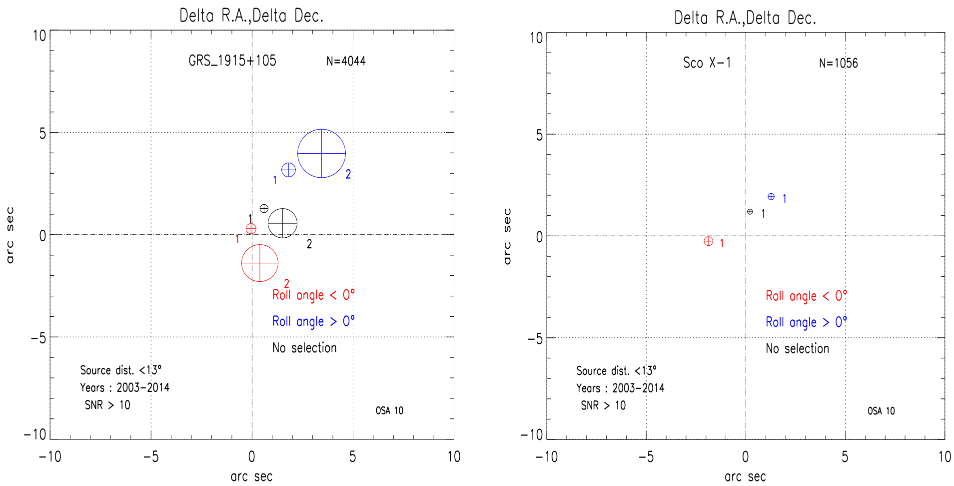

Fig. 2. Weighted average residual offsets in celestial coordinates using results of OSA10 for two strong sources, covering the time interval 2003–2014. Numbers in the figures indicate the different energy ranges used in the analysis (1: 20-40 keV; 2: 40-80 keV; 3: 80-150 keV). Circles indicate the errors on the average residual offsets. The total number of measures is also reported.

ing. This effect depends strongly on the source off-axis angle and the energy range. It was modeled as an apparent modification of the detector pixels centers and sizes. We developed an alternative method to reduce positional offsets of the IBIS/ISGRI telescope. It includes the photon penetration effect correction (PPE) and a mask model (MM) which allows its quarters to move as a function of the mask temperature. The model was calibrated using observa-

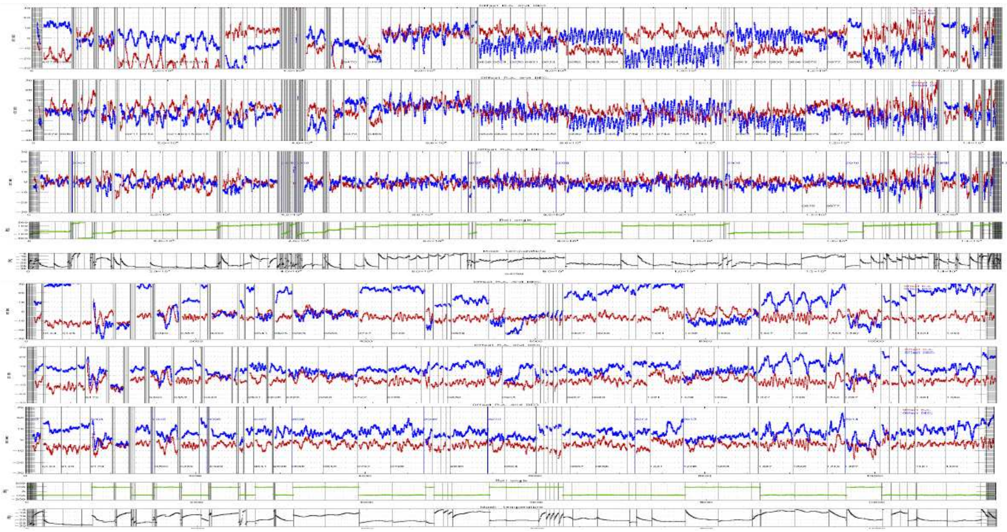

Fig. 3. Top: Temporal evolution of the Cyg X-1 position shifts in RA (red) and in Dec (blue) as a function of Scw number. Upper graph: offsets in absence of mask temperature correction. Middle graph: offsets from the standard OSA10. Bottom graph: offsets obtained with our alternative model PPE+MM. Two additional graphs indicate the current roll angle (green) and the mask temperature (black). Bottom: Temporal evolution of the Crab position shifts as for Cyg X-1.

Table 1. Number of measures per source

Source	No. of Measures
Cyg X−1	14819
Cyg X−3	6126
GRS 1915 + 105	5527
Ginga 1826 − 2	2397
Sco X−1	1281
4U 1700 − 377	952
GX 1 + 4	946
GX 17 + 2	875
1A 0535 + 262	531
Her X−1	165

tions of several well known strong sources covering a large fraction of the mission life time. The number of measurements for each source is reported in table 1.

5. Off-axis temporal evolutions

In Fig. 3 we present the temporal evolution of the Cyg X-1 and Crab position shifts in R.A. and Dec. as a function of individual observations over time. The Cyg X-1 dependence of ΔRA and ΔDec shifts to the roll angle is clearly seen in absence of mask temperature correction and still present in the standard OSA results. Our alternative analysis, applied on the data not corrected for temperature, clearly improves the Cyg X-1 positioning accuracy. In the Crab case, the residual offsets are still present even when PPE+MM model is applied. This may indicate the possibility of a temporal evolution of the Crab emission location (Eckert et al. 2010).

6. Conclusions

Using a large number of observations covering more than ten years of the mission we investigated the residual bias (Gros et al. 2013) still present for strong sources by analyzing the offsets between the derived locations and known source positions. We found a clear dependence of the bias on the satellite roll angle but we found that they can be reduced by independent modeling of the IBIS mask quarter displacements and by properly taking into account the photon penetration effect in the ISGRI detector pixels. Preliminary results are presented for strong sources. Further work is needed to improve the telescope modeling and refine the source location.

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