USA Offset estimations, September 1999

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In this note we estimate the offsets for USA's pointing from Epoch 1 - 4 drift scan data, and the systematics of pointing using observations from Epoch 1 and 4.

We find a significant correlation between the pitch offset (P_{off} hereafter) and the value of Pitch and Yaw. A plane fits the data well over all Epochs.

We find a less significant correlation between the yaw offset (Y_{off} hereafter) but the estimation of Y_{off} has a large error at most equal to the step in the drift scan. Drift scans in Yaw may prove to give a better correlation.

The important question has been raised if this effect has existed unchanged from the time that USA became operational. Observations at large values of Pitch and/or Yaw would then place the observed sources in a bad position in the field of view for all epochs. We check for this effect using sources that we believe have relatively constant intrinsic counting rate. We test for a non-constant constant counting rate as a function of Pitch and Yaw.

0.1 Data used

We used for our estimations drifts scan data given at the end of P. Ray's note (dated September 20, Note1 hereafter) , but we removed observations where the selected peak is the first one of the drift scan. We also used the following drift scans that arrived later in the XEUS repository:

DOY	End Obs	Pitch at max (deg)	Yaw at max (deg)	P_{off} (deg)	$Y_{off}(deg)$
258	0600	78	-33	-0.16	-0.06
258	2356	58	-56.2	-0.37	0.54
258	2356	60.85	-6.3	0.2	0.5
258	2356	25.2	-49.9	0.2	0.5
260	0103	38.5	-50.5	-0.02	0.5
260	0103	25	-50.9	0.2	1
263	1453	78.5	-60	-0.64	0.54
266	0000	64.8	-3.8	0.36	0.51

Table 1: Data added to those present in P. Ray's note.

Thus the population of Epoch 4[1] has increased.

[1]Epochs are defined in Note1.

0.2 Correlations in Pitch and Yaw

A plane of the form

$$P_{off} = a \times Pitch + b \times Yaw + c \tag{1}$$

is used for a least squares fit of P_{off} as a function of Pitch and Yaw. The fit made by Berrie yields

$$a = -0.0124, b = 0.0164, c = 1.27$$

and the residuals are shown in Fig(1). Since the data of epoch 1 also fit this

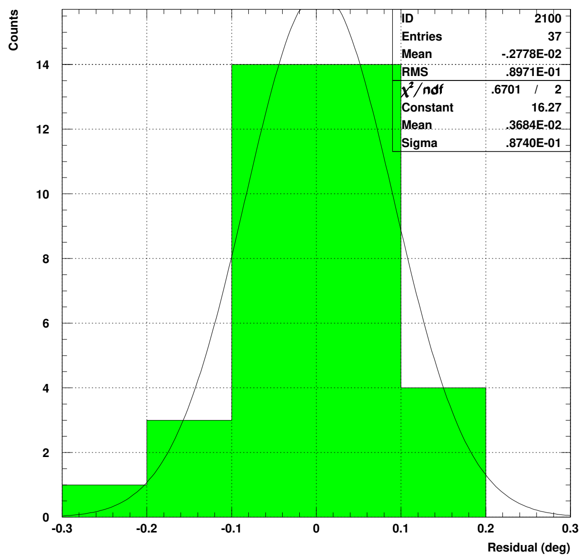

Figure 1: Residuals of the fit of eq.(1) to the data. The distribution is fitted by a gaussian of mean 0.0037° and σ=0.87°.

distribution this is evidence that nothing actually changed in the spacecraft over the different epochs. Figure 2 shows the residuals for each epoch. Gary's estimation of the plane coordinates, done independently of Berrie's, are

$$a = -0.011, b = 0.017, c = 1.2$$

and are very close to Berrie's.

By interpolation of the Yaw values, a better correlation between the Yaw offsets as a function of Pitch and Yaw can be obtained. **See the attached MathCad file for this** The points then are less scattered and come close to a

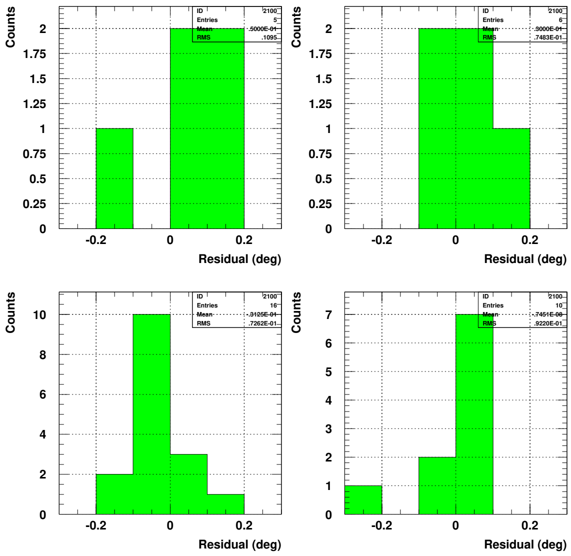

Figure 2: Residuals of the fit of eq.(1) for each epoch.

plane: the Yaw scans should allow a better estimation of this correlation in the future.

Why would a plane fit the data? A model for this could be a bad transformation from calculated Pitch and Yaw angles into encoder steps, but this is just a guess. As we shall see below there seems to be evidence for a spacecraft change from Epoch 1 to 4, and an encoder calibration error does not seem to fit this evidence.

0.3 Flux as a function of Pitch

Given our derived correlation, the effect of the offset must thus be more important at large values of pitch and yaw, or in observations where these values vary widely enough to give a measurable loss in rate. The Yaw value for a given observation remain almost constant, and for a given source, it changes slowly over days making the measurement more sensitive to intrinsic changes of the source. We initially attempted to look for a correlation in Yaw using a series of Epoch 1 observations of Aql X-1 over many days. However, the ASM of RXTE indicated a change in output of this source over this time that tended to match the decrease in rate that we were observing as Yaw increase, thus yielding no change in the ratio within large errors.

Contrary to Yaw, the Pitch value changes significantly within one observation. Such changes in Pitch should also yield a measurable variation in observed counting rate if the Pitch offset indeed varies as equation 1. To check for indications of this effect we used 3 different observations, one of Aql X-1 in epoch 1, one of Cyg X-3 in epoch 4 and a Cas A observation also in epoch 4.

0.3.1 Aql X-1 in epoch 1

A measurement of Aql X-1 in epoch 1 is shown in Figure 3. The Pitch spans a range of 24° (top figure) while the Yaw remains constant (middle figure) within 400 seconds of observation. The counting rate R is fitted by a 1-degree polynomial $R = A0 + A1 \times t$, the result is shown on the bottom plot. The rate loss is 6 counts/sec at the end, or 2.5%, over 24° of Pitch.

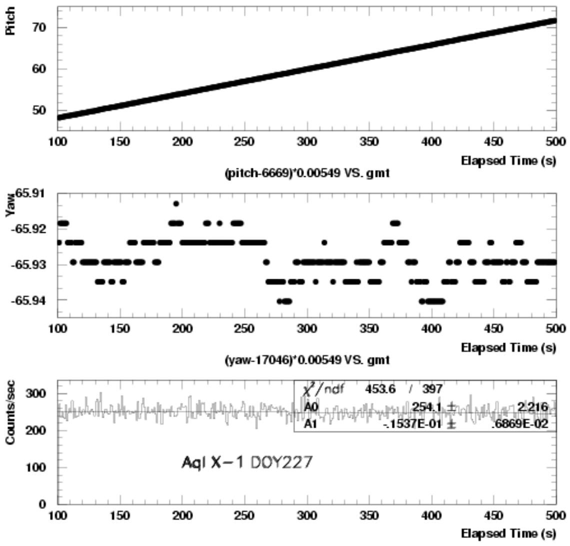

Figure 3: Observation of Aql X-1; Top: Pitch as a function of time. Middle: Yaw as a function of time. Bottom: Rate as a function of time.

Using the result of eq. 1 the expected drift in Pitch offset would be 24 ×

$-0.0124 = 0.3°$. Using Gary's estimation of the efficiency of transmission as a function of angle, which can be approximated to a triangle with a slope of 0.8 degree^{-1}, the expected loss is $0.3deg \times 0.8deg^{-1} = 23\%$ of the signal, which is 10 times more than what we see... Epoch 1 offsets seem to be almost independent of Pitch at this stage of the analysis.

0.3.2 Cyg X-3 and Cas A

The same study is done for an observation of Cyg X-3 (DOY266) in Epoch 4, resulting in Figure 4.

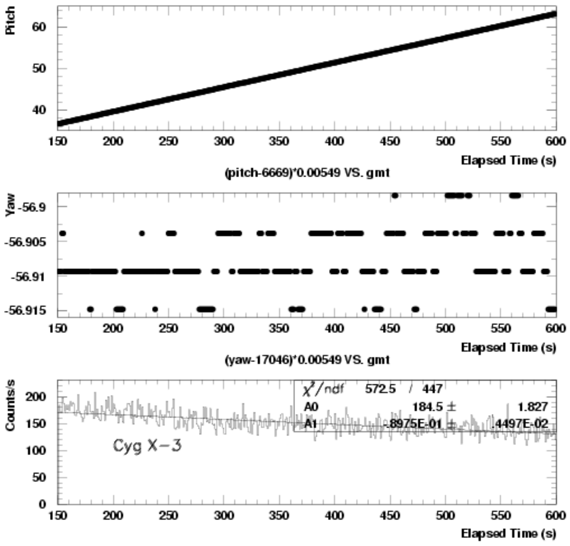

Figure 4: Same as Fig. 3 but for Cyg X-3 in epoch 4 this time.

This time the Pitch spans 26° and we observe a loss of 24% of the initial flux. The expected loss is $26deg \times -0.0124 \times 0.8deg^{-1} = 26\%$, very close to the observation.

A Cas A observation on DOY262 (Figure 5) shows a 24% decrease in counting rate over 21 degrees, where we would expect a 21% loss, once again very close to the observation.

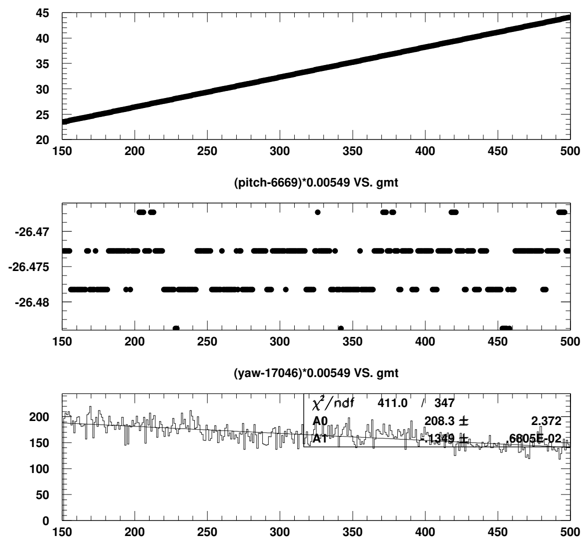

Figure 5: Same as Fig. 4 but for Cas A in epoch 4 this time.

0.4 Conclusions

The results we have obtained are somewhat contradictory. On one hand, the drift scans from Epochs 1 and 4 fit the same correlation plane, 1 within error, including 5 drift scans from Epoch 1. This evidence would suggest that no change has occurred in the spacecraft orientation from Epoch 1 to 4.

On the other hand, Our analysis also shows that source observations as opposed to drift scans in Epoch 1 are simply corrected for offset and do not follow 1. Both a series of observations over a wide range of Yaw, as well as a measurement over a wide range of Pitch show no change of counting rate within error, given that the correct offsets are installed. In addition, a number of Epoch 4 measurements, each with widely varying values of Pitch, show a significant drop in counting rate with increasing Pitch that agrees with the drop predicted by 1 after using our known collimator efficiency vs angle of incidence.

Our source observation based analysis thus implies two things. First, there has been a change in the spacecraft between Epoch 1 to Epoch 4. Second, if the spacecraft is now stable, we can correct for this change using 1(refined as we continue collecting drift scans).

Given the conflicting evidence obtained from our drift scans and source observations analyses, we suggest that the wise course may be to just correct Pitch and Yaw using 1, and try to pin down our understanding of why we are confused rather than wasting weeks by requiring the AF to upload the old ADACs software with all its shortcomings.