Southern African Large Telescope

Title: **Analysis of some SLOTMODE data**

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Signature:________________ Date:____________

ABSTRACT

In this document I show results of SLOTMODE data reduction for science program 2008-1-RSA-001 where bright stars were observed.

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1 Introduction

SLOTMODE is the SALTICAM mode for the fastest time resolution observations. Surely SLOTMODE observations and possibly SLOTMODE reduction need a lot of tricks to get correct result and I am not sure that we know all of them yet. On the other hand we (SALT astronomers) observed last two years mainly in SLOTMODE.

Personally, I think it should be extremely useful for all of us to see results for as many observational programs as possibly to realize where we are and how to proceed with SLOTMODE in the future and which kinds of limitations we have. To start such a process I will show below current results of our observations in SLOTMODE for our proposal 2008-1-RSA-001: "Measurement of parameters of magnetic viscosity studying of accreting white dwarf binaries".

Table 1: Log of Observations

Object Name	Date	Bin	Filter	Gain,Speed	Exp.time (sec)	Files
(1)	(2)	(3)	(4)	(5)	(6)	(7)
V1223 Sgr	20080513	6×6	*CLR*	f,f	0.1	1053–1410
V1223 Sgr	20080612	6×6	*B*	f,f	0.1	1642–1822
IX Vel	20080513	8×8	*U*	b,f	0.1	0002–0357
IX Vel	20080516	8×8	*U*	b,f	0.1	0004–0387
IX Vel	20080517	8×8	*U*	b,f	0.1	0152–0512
V3885 Sgr	20080513	6×6	*B*	f,f	0.1	1415–1635
V3885 Sgr	20080528	8×8	*B*	b,f	0.1	0058–0473
V3885 Sgr	20080604	6×6	*B*	f,f	0.1	0089–0499
V3885 Sgr	20080629	6×6	*B*	f,f	0.1	1409–1698

2 Science Program

Our science program was designed to observe a small sample of accreting white dwarf binaries (including dwarf novae and intermediate polars, which have different values of the innermost radii of their accretion disks) with SALT in order to construct the best available power spectra of flickering processes to date on the smallest time scales and measure important parameters of the magneto-rotational instability in accretion disks.

We included in the proposal three very bright targets: Cataclysmic Variable **V1223 Sgr** (m_V = 13.2 mag), White Dwarf **V3885 Sgr** (m_V = 10.4 mag) and Classical Nova **IX Vel** (m_V = 9.5 mag). The plan was to observe them with SLOTMODE with exposure times 0.1s, with binning 6×6 or 8×8 in U or B filter to get enough signal but not saturate CCDs.

Table 2: Parameters of Reduction

Object Name (1)	Date (2)	Bin (3)	Amplifier (3)	Aperture pixel (4)
V1223 Sgr	20080513	6×6 – 24	Same	8,9–10
V1223 Sgr	20080612	6×6 – 24	Same	8,9–10
IX Vel	20080513	8×8 – 16	Different	6,8–9
IX Vel	20080516	8×8 – 16	Different	7,8–9
IX Vel	20080517	8×8 – 16	Different	7,8–9
V3885 Sgr	20080513	6×6 – 24	Same	8,9–11
V3885 Sgr	20080528	8×8 – 16	Same	6,8–9
V3885 Sgr	20080604	6×6 – 24	Same	8,9–11
V3885 Sgr	20080629	6×6 – 24	Different	8,9–11

3 Observations

Altogether 14 observations were done for these three targets during May–July 2008. Five observations had to be rejected, because data were taken not under requested specifications.

All accepted observations are summarized in Table 1.

4 Standard SLOTMODE reduction

All data were reduced first with standard `slottools` package working in `pyraf` environment. The reduction scheme was standard: background was subtracted first and then fluxes were calculated in circular apertures. In all cases background was subtracted in a row-by-row mode. Different sizes of apertures were checked for each observations and those were finally selected that produced the best SNR ratio for the detected flux ratio.

In the current version of `saltred` package I did not find a stable range of parameters for any algorithm to correct our data for cosmic rays, and no cosmic cleaning was applied for this reason. Altogether with that all final ratios were cleaned for spikes of signal above of 3σ of the dispersion to exclude frames with obvious cosmic events. In this case 'slow component' of the signal was subtracted after median filtering. An example of such cleaning is shown in Figure 1.

Results for reduction are shown in the next pages. For each reduced observation, six panels are shown from top to bottom: (1) the flux ratio; (2) the flux ratio error; (3) the target X-position; (4) the target Y-position; (5) the target flux; (6) the comparison flux.

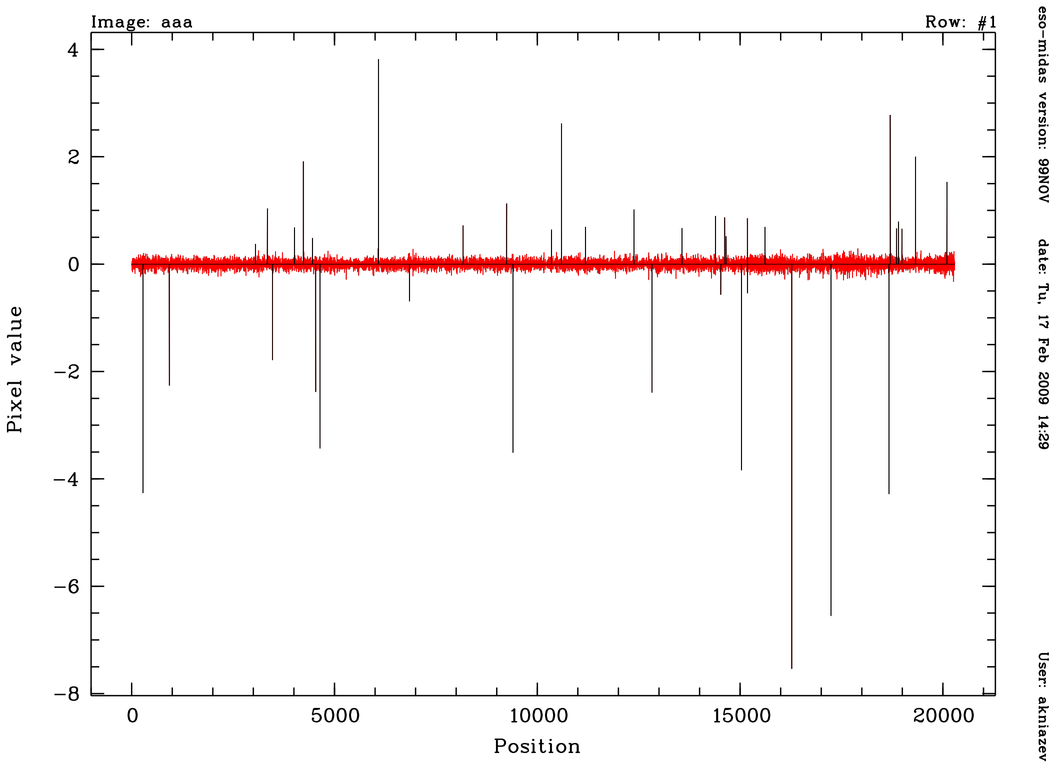

Figure 1: Cleaning for cosmic rays for the **V3885 Sgr** data that were taken on 20080604. The difference between the signal and the 'slow component' (long-term trend) of the signal is shown with red. All detected spikes above of 3σ of dispersion of signal are shown in black. The X-axis just shows the number of the frame.

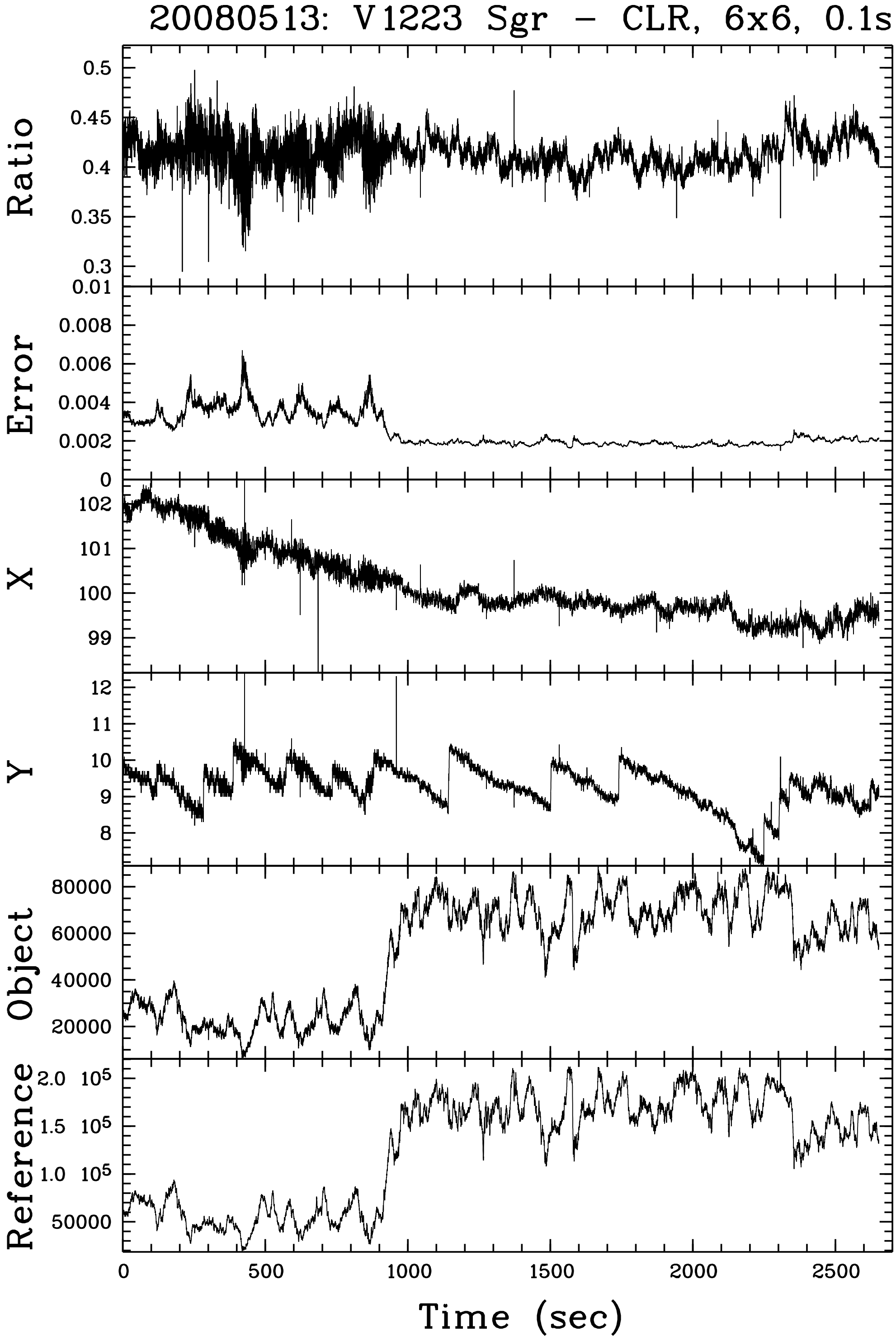

Figure 2: Results of observations of **V1223 Sgr** on 20080513.

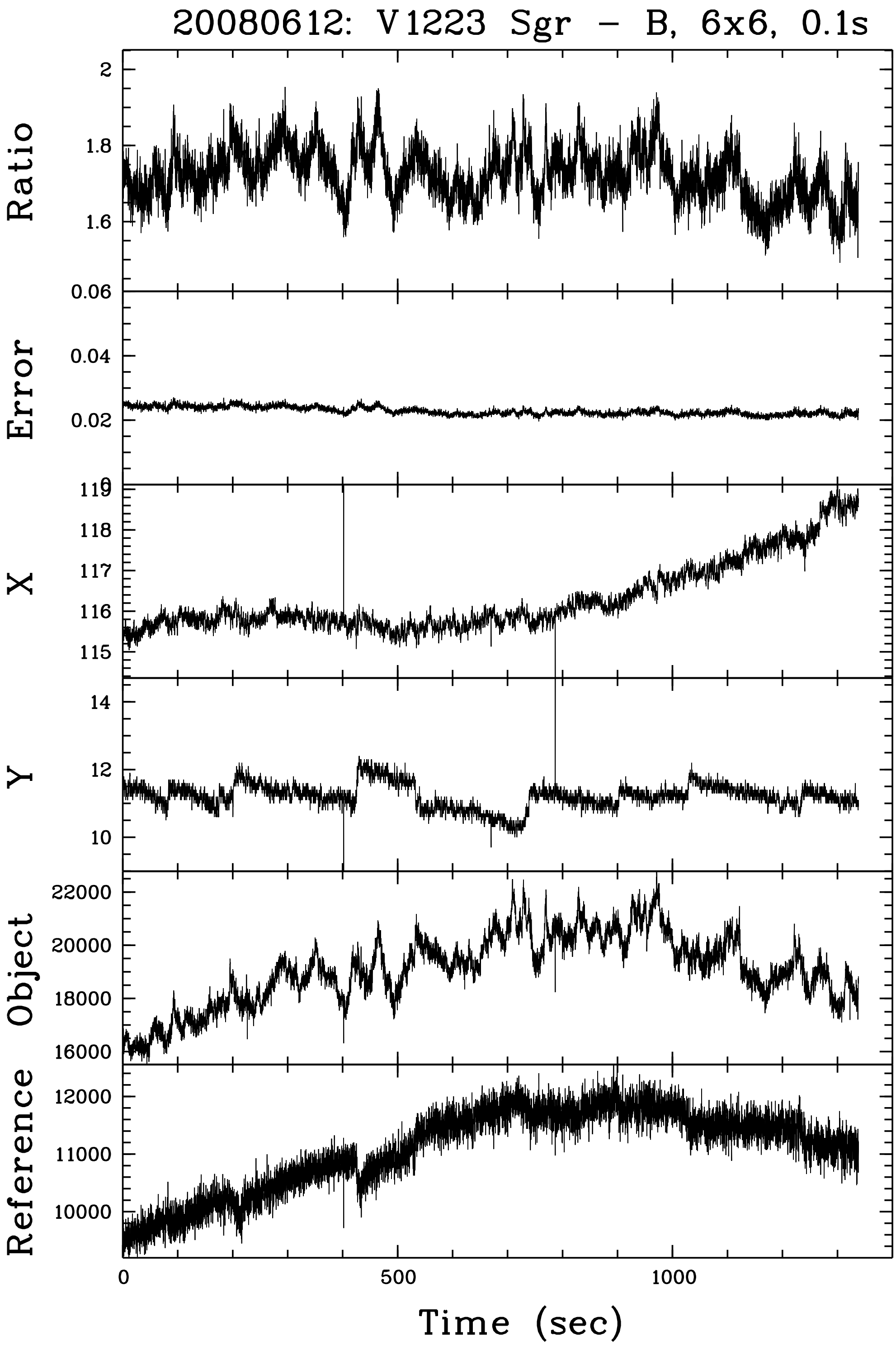

Figure 3: Results of observations of **V1223 Sgr** on 20080612.

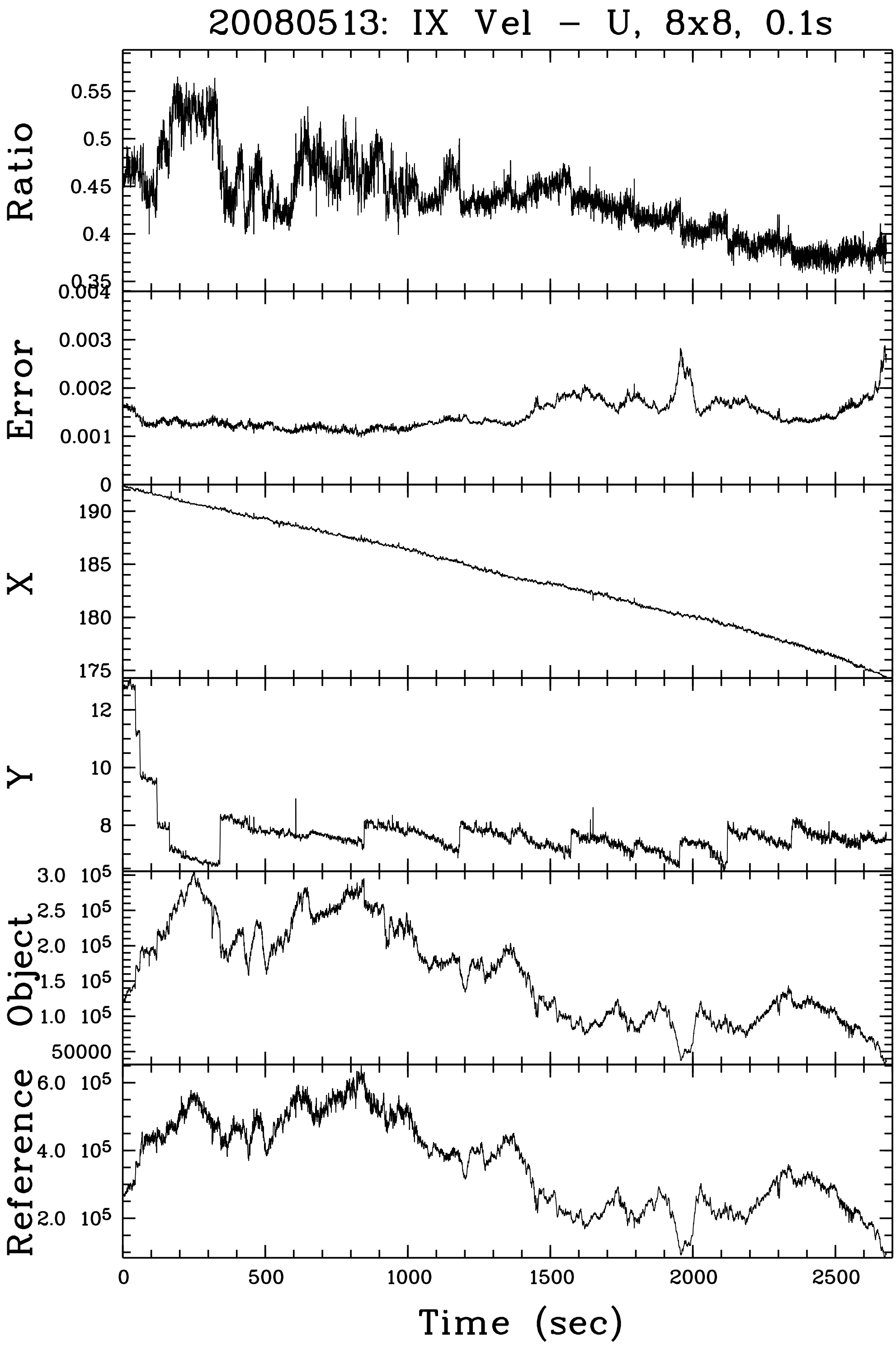

Figure 4: Results of observations of **IX Vel** on 20080513.

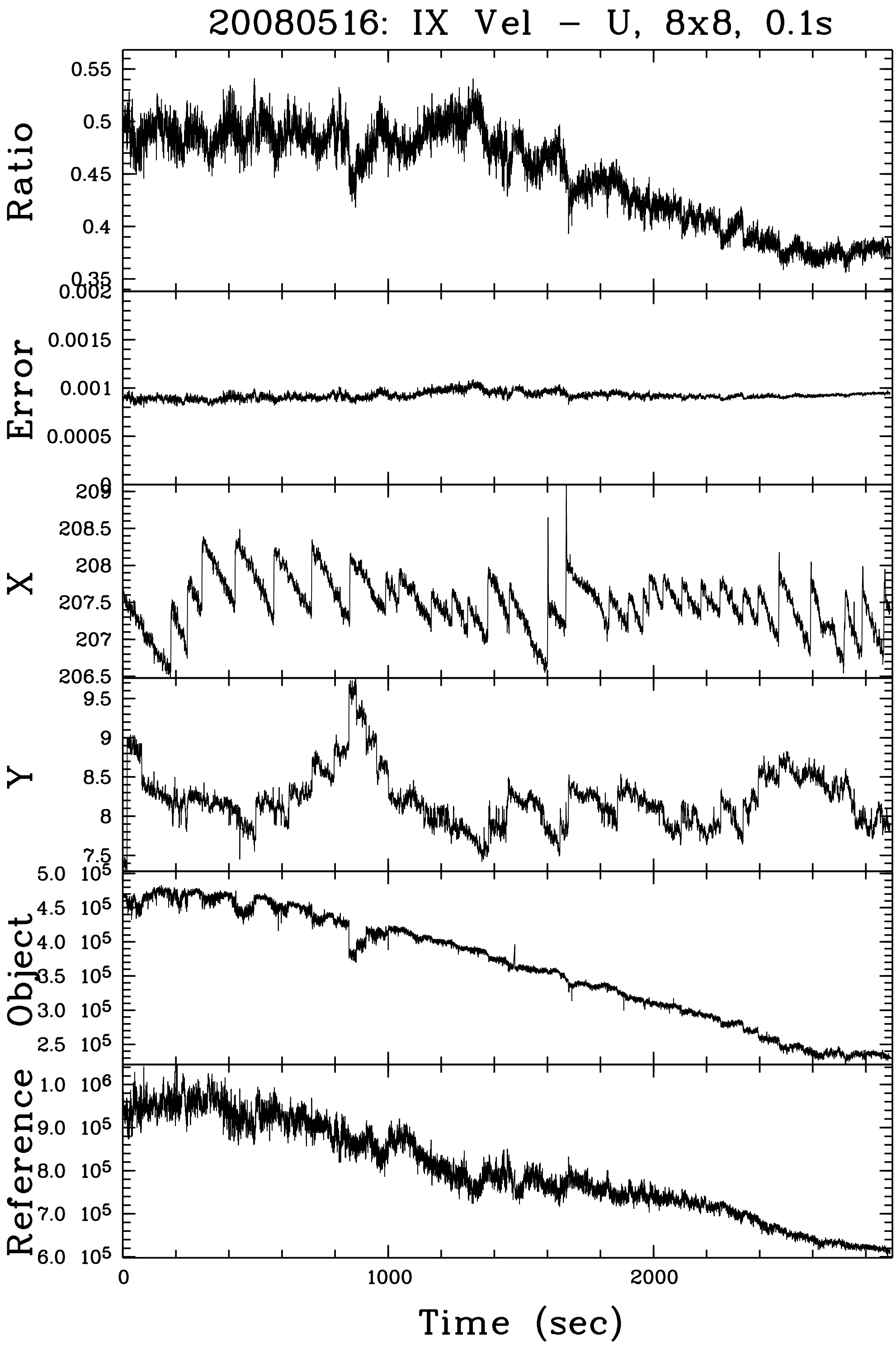

Figure 5: Results of observations of **IX Vel** on 20080516.

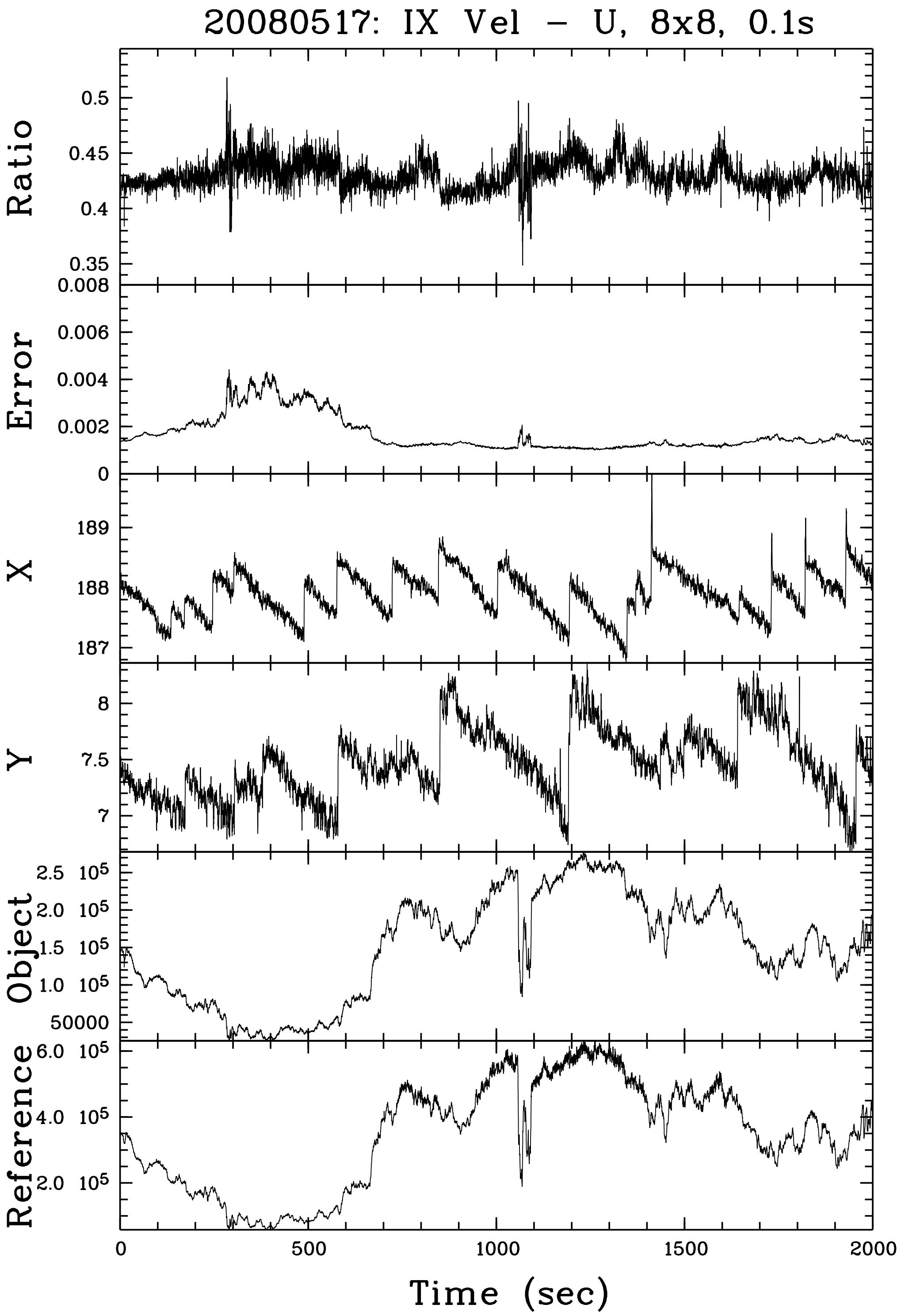

Figure 6: Results of observations of **IX Vel** on 20080517.

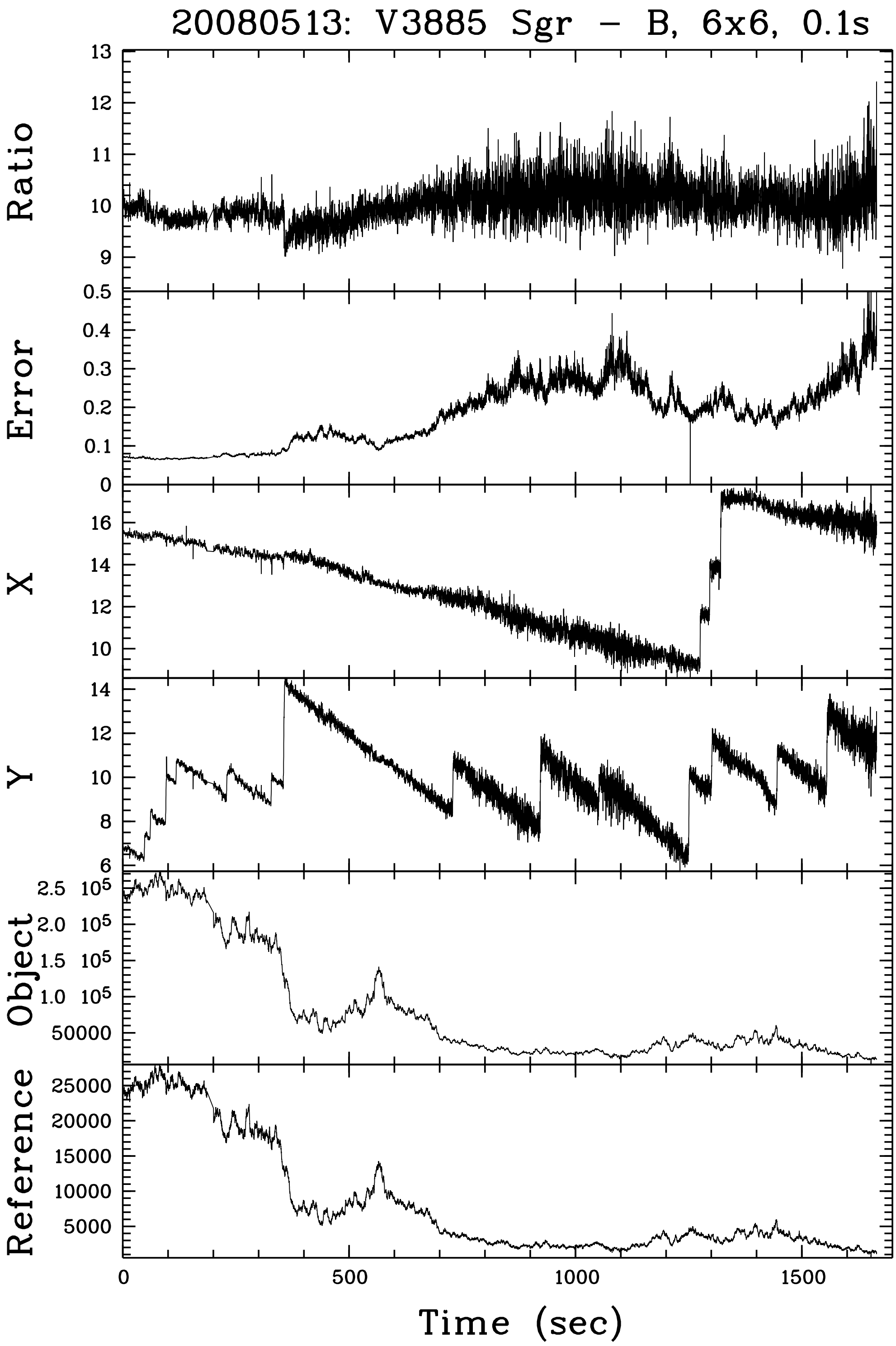

Figure 7: Results of observations of **V3885 Sgr** on 20080513.

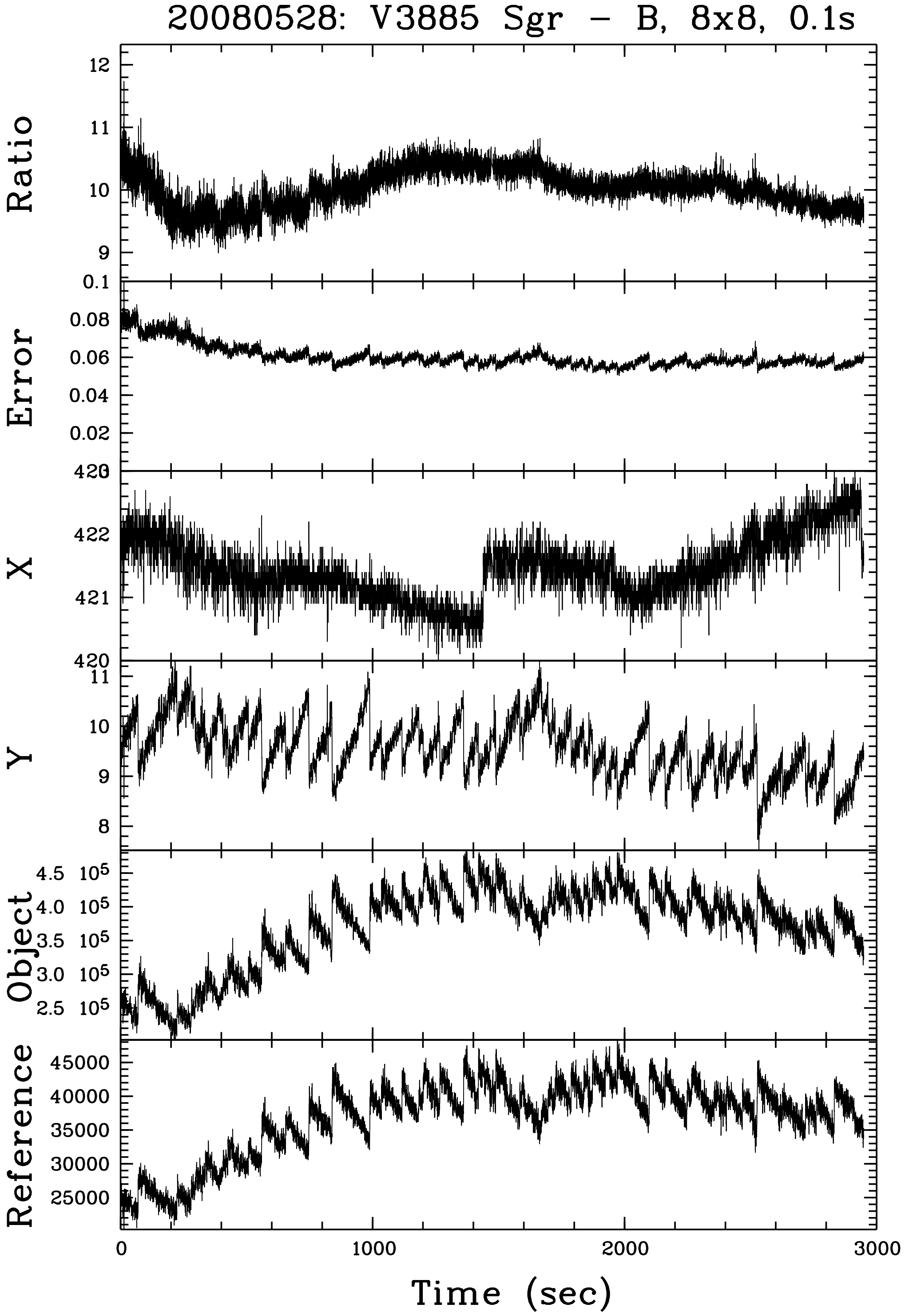

Figure 8: Results of observations of **V3885 Sgr** on 20080528.

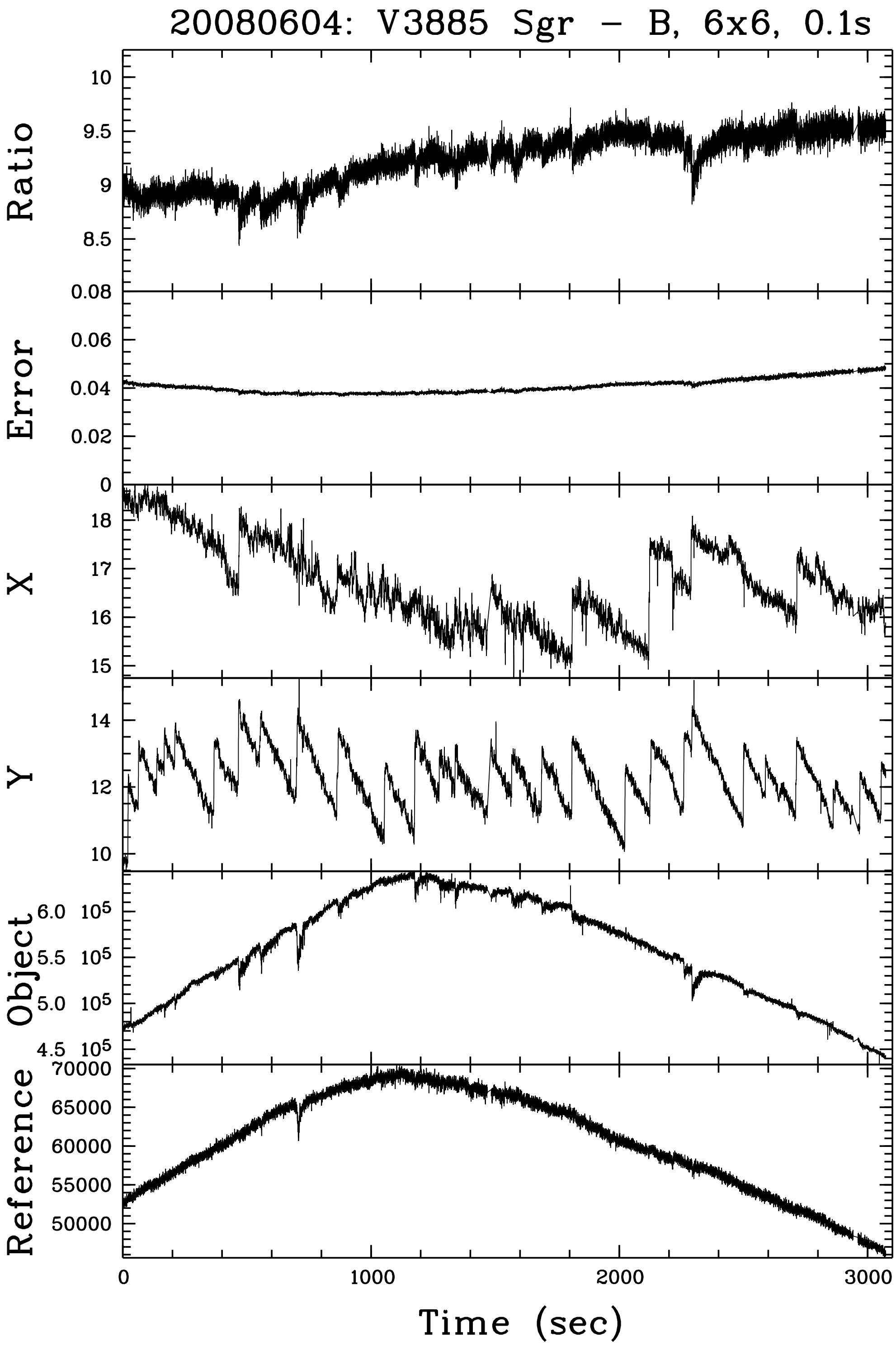

Figure 9: Results of observations of **V3885 Sgr** on 20080604.

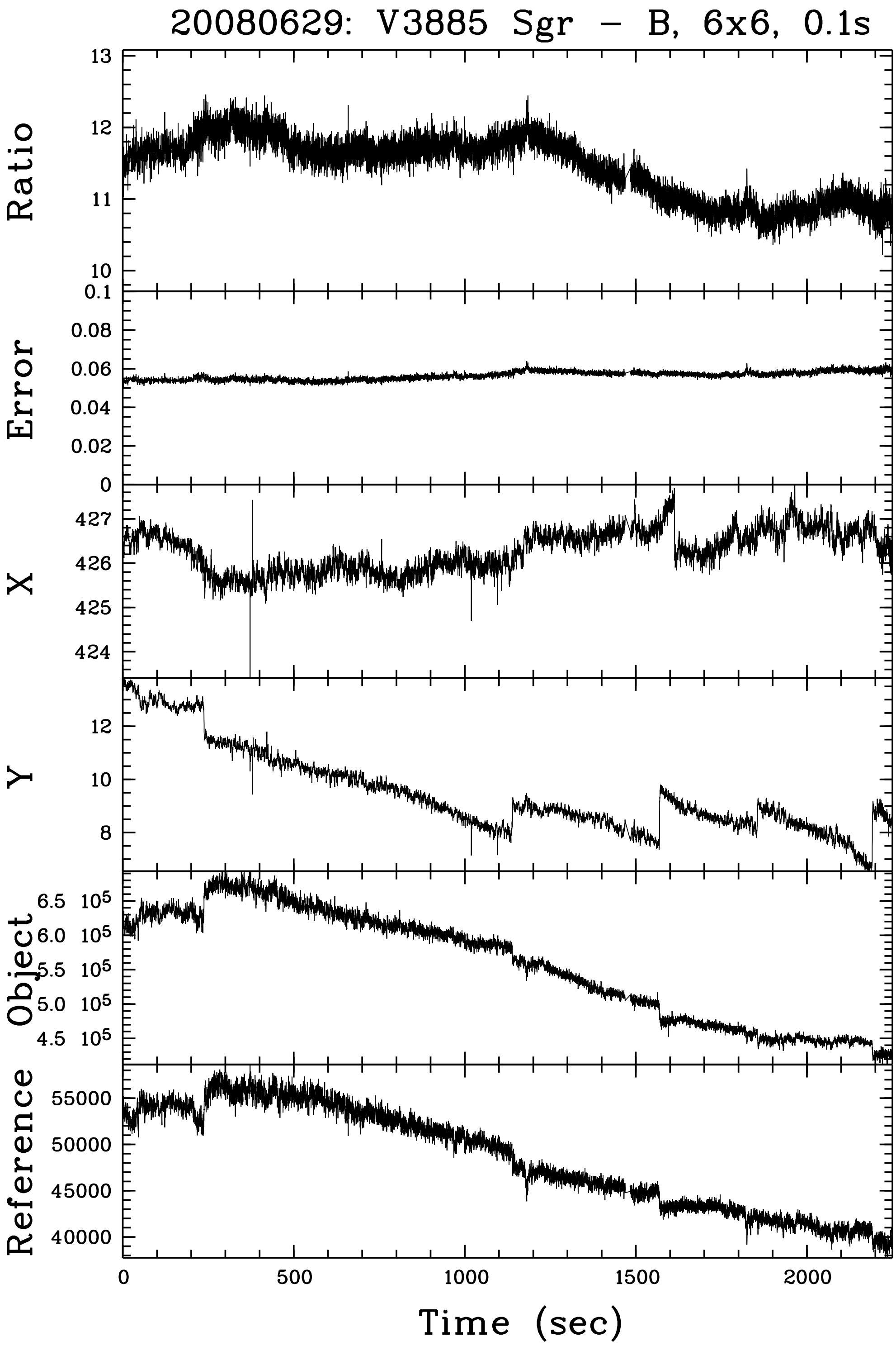

Figure 10: Results of observations of **V3885 Sgr** on 20080629.

4.1 Some preliminary conclusions

There are some remarks I summarize as the result of these data reductions:

1. Only two of the used nights were definitely non-photometric, where total detected flux changed by a factor up to 5 during the track (see nights 20080513 and 20080517). At least in two such cases (V1223 Sgr 20080513 and IX Vel 20080517) the increase of scatter of the flux ratio is hard to explain in terms of the calculated and shown error. The error shown is very small even if it is inversely proportional to the decreasing of the signal.

2. I do not see any difference when object and reference are located on the same amplifier or on different amplifiers.

3. Practically all reduced brightness curves contain obvious jumps of the detected flux ratio that clearly correlate with jumps in Y-coordinate of the center of the object.

4. Jumps of the object center in Y-coordinate are the result of guiding (or the lack of it). But not all jumps in Y-coordinate result in jumps of the detected flux ratio.

5. Jumps in X-coordinate do not result in jumps of the detected flux ratio.

5 Additional Analysis

Jumps of the detected flux ratio is the most non-understandable result for me. Please, look at Figure 11, where three of such jumps are shown in detail. First, I have to point out that the centers of the object (black) and reference (red) are misaligned by about one pixel and, as a first guess, this could explain the difference of the flux in case of Y-shifts. But why are these detections different in the three different cases even when the Y-shifts are about the same (just look at the first and the last jumps shown in this Figure)?

If I will forget about this difference in the flux detection for similar Y-shifts, and take into account the fact that SLOTMODE data have a profile in Y-direction, it is possible to suggest that we have not additive, but multiplicative background. In this case we have to divide SLOTMODE data with the background, but not subtract it.

To compare our standard SLOTMODE reductions with and independent reductions, and as well to the test the idea about the multiplicative background, I wrote my own SLOTMODE data reduction programs in MIDAS. These programs are very simple and consist of standard MIDAS tasks. They do not contain total SLOTMODE reduction, but I used background and/or background subtracted data after standard task `slotback`. I also have found during these games that `slotback` does not work correct when output parameter ”background” is specified. One example of results of these programs is shown in Figure 12, where the same SLOTMODE data after background subtraction were used as was shown in Figure 11. The whole sample of reduced data for this night are shown in Figure 13 and it can be compared with those shown in Figure 9.

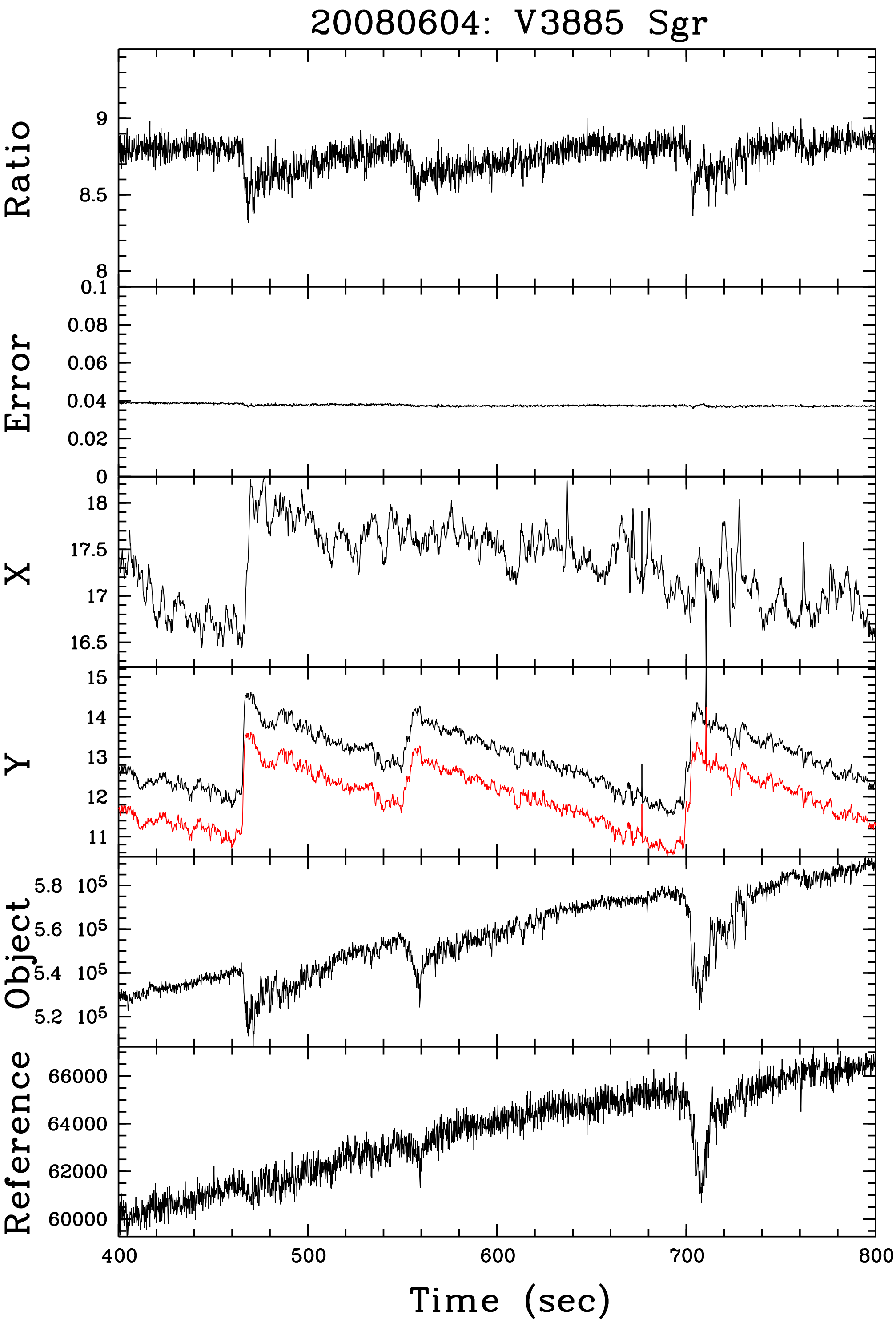

Figure 11: Part of SLOTMODE data reduced with standard `slottools` package for **V3885 Sgr** on 20080604.

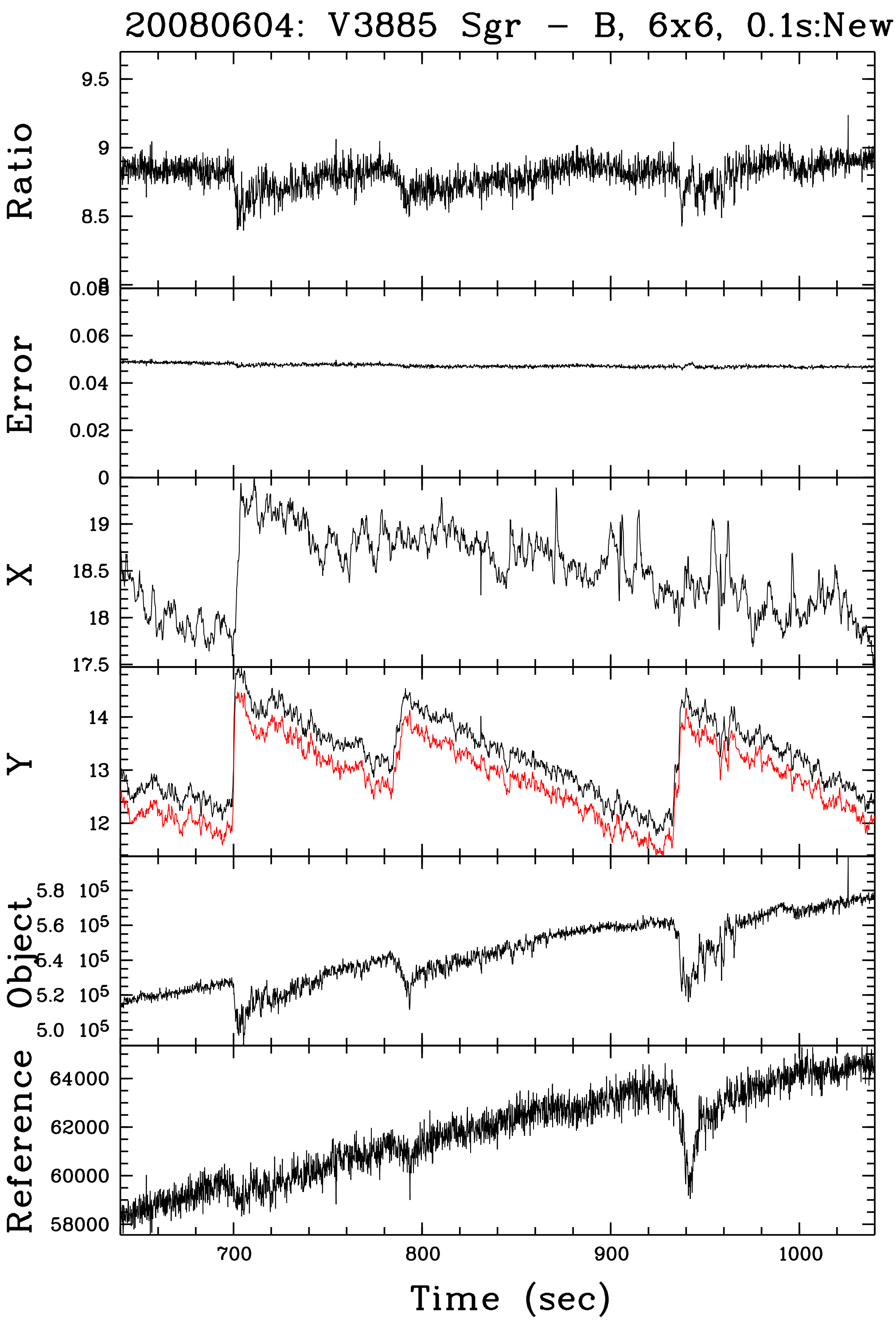

Figure 12: Part of SLOTMODE data reduced with MIDAS programs for **V3885 Sgr** on 20080604.

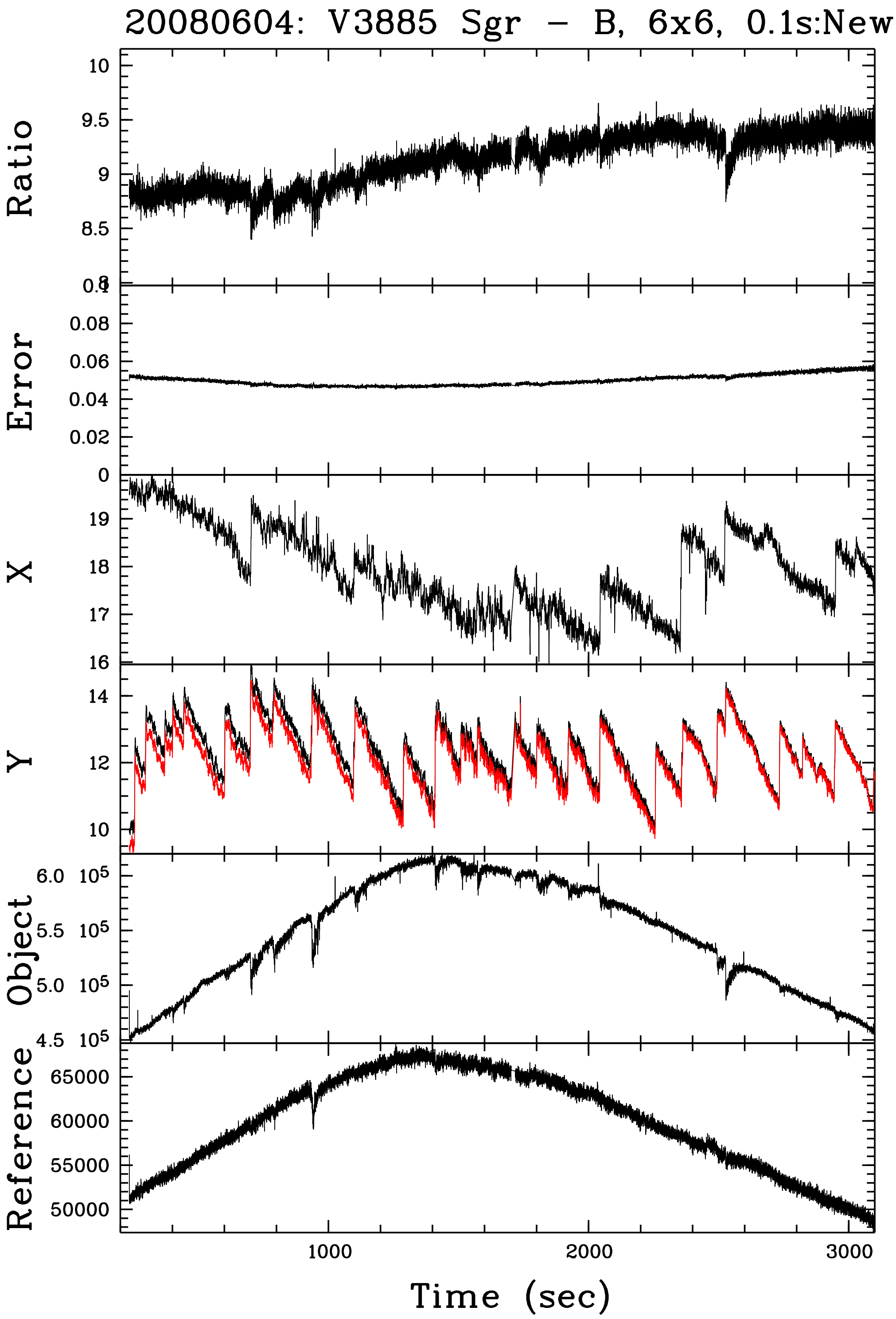

Figure 13: All SLOTMODE data reduced with MIDAS for **V3885 Sgr** on 20080604.

5.1 The Y-difference trend

Below, in this section, I will call 'Y-difference' the difference of Y-coordinates between the object and reference star.

First, I can immediately see after comparison of Figure 11 and Figure 12 that both Figures are similar and show the same features in the data. Sometimes small details are different, but such a difference is not very large. Except of one detail: the Y-difference between centers of object and reference star is less with MIDAS programs than with standard ones. A quick look at Figure 13 explains this detail: there is a trend of this Y-difference with time of the track. Such a fact is not visible with standard `slottools` package, since the principle `Y-difference=constant` is used there. To show the Y-difference trend in more detail, look at Figure 14. Since the object and reference are located at the same amplifier and observations were done with 6×6 binning we have to conclude that for 2×2 binning the total amplitude of additional field rotation has to be about ±3 pixels (relatively to the center) for the total exposure of ∼3000 s for objects that are located at the opposite edges of the field of view. This trend is very stable for the current object (azimuth) as it is possible to see from Figure 14.

5.2 The FWHM

SLOTMODE data also have information about seeing+telescope-focus that is very useful to know. See in Figure 15 where FWHM in pixels is shown that was calculated with standard MIDAS program CENTER/MOMENT.

5.3 Multiplicative Background

To check the possibility of multiplicative background I wrote a program, where the part of the slot-image that is free of sources was averaged in rows and fitted with a polynomial of second order. Some examples are shown in Figure 16. Unfortunately, the result of using such an algorithm is unacceptable, since there is no improvement in the final flux ratio, but scatter of the detected fluxes in fact increases strongly.

After this I changed the algorithm in a way to work with a 2-D background, that was created using task `slotback` from `slottools` package. A result of using such a program is shown in Figure 17. Comparing this Figure with Figures 11 and 12 gives the possibility to conclude that the final flux ratio looks more correct, but scatter in the detected fluxes increases strongly as well. It looks to me like the idea of a multiplicative background is more correct compared to just an additive background, but the algorithm for its correction is still unacceptable.

5.4 More problems?

To show another problem I have plotted calculated level of background for **V3885 Sgr** on 20080604 in Figure 18. For each exposure I calculated the background as the median value of all counts in the region far away from both target and reference star. All images are

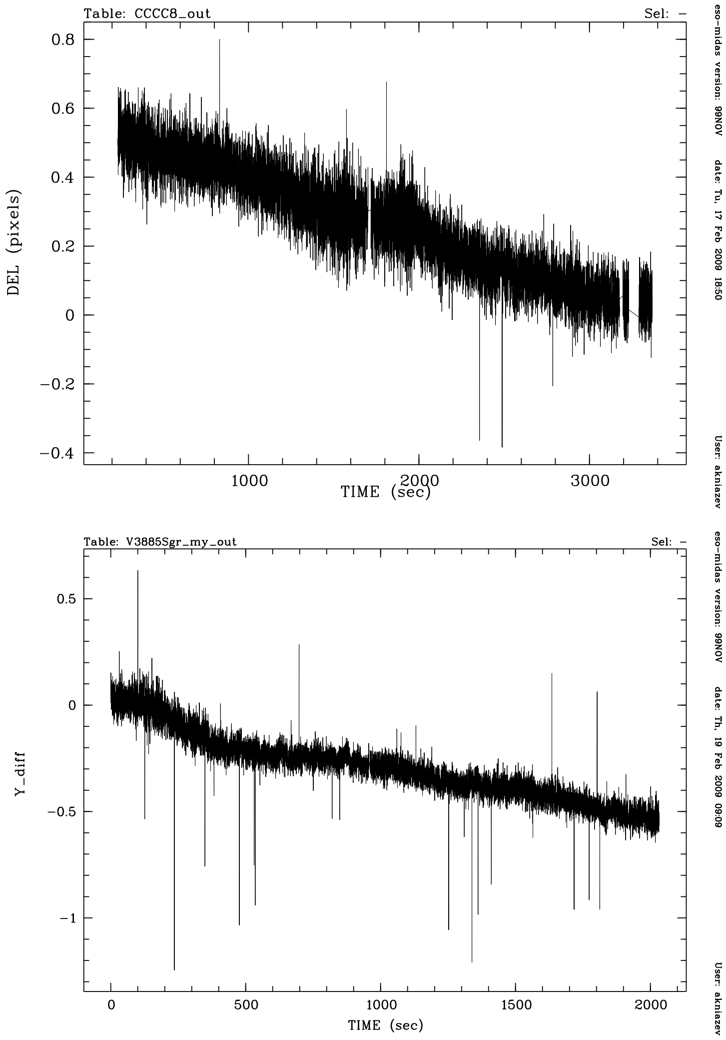

Figure 14: The Y-difference trend for **V3885 Sgr** on dates 20080604 and 20080528.

after `slotback` task that I asked do nothing, but accumulate all useful amplifiers in one big FITS-file. Can someone explain to me why we have quantum levels?

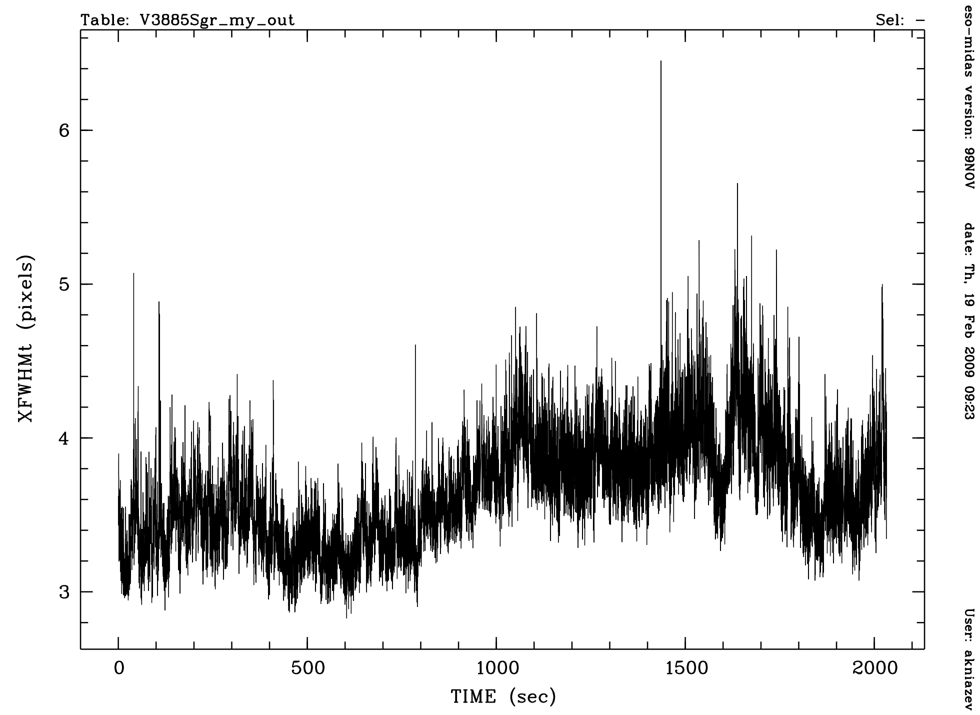

Figure 15: Variations of FWHM (in pixels) in X-direction during track time for **V3885 Sgr** on date 20080528.

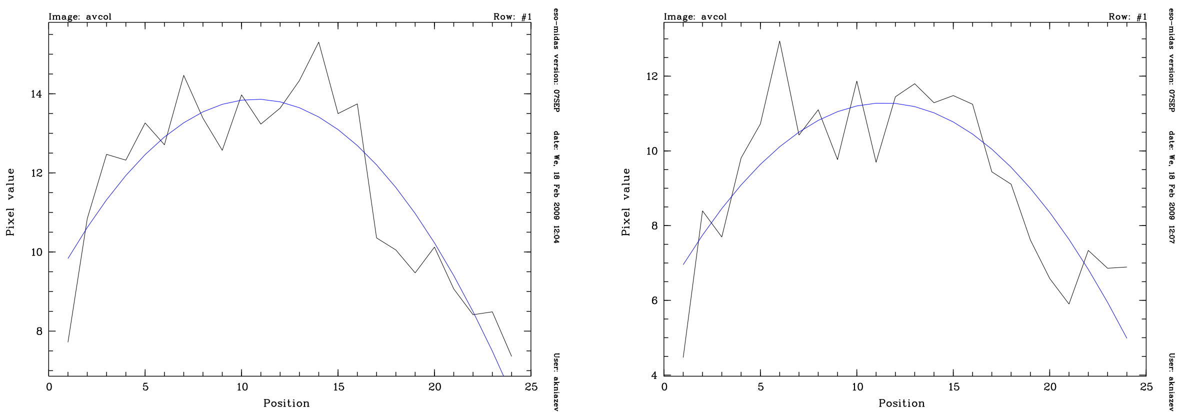

Figure 16: Examples of profiles of SLOTMODE image in Y-direction. The averaged profile is shown in black and the fitted profile is shown with blue.

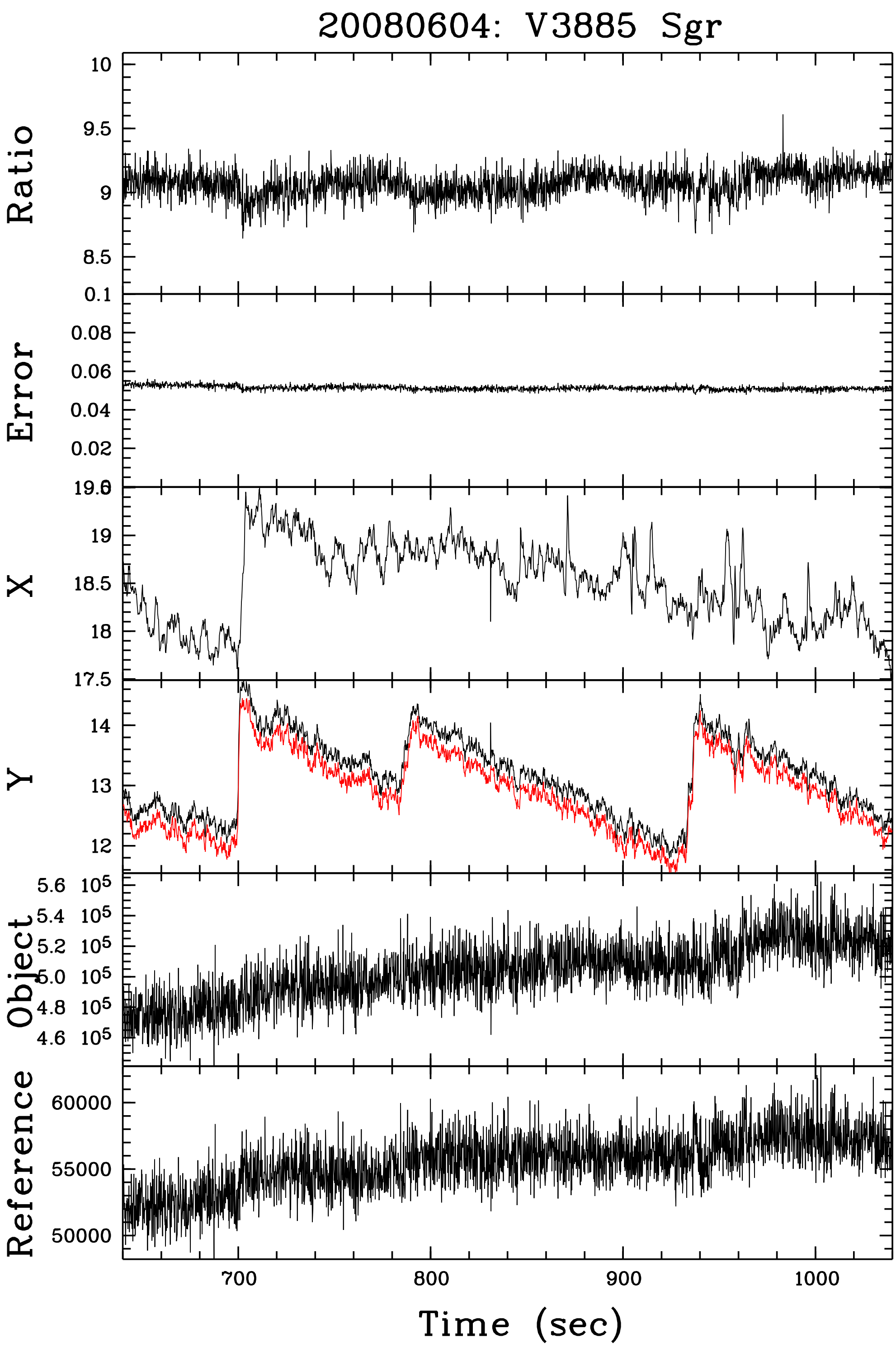

Figure 17: Part of SLOTMODE data reduced with MIDAS programs for **V3885 Sgr** on 20080604.

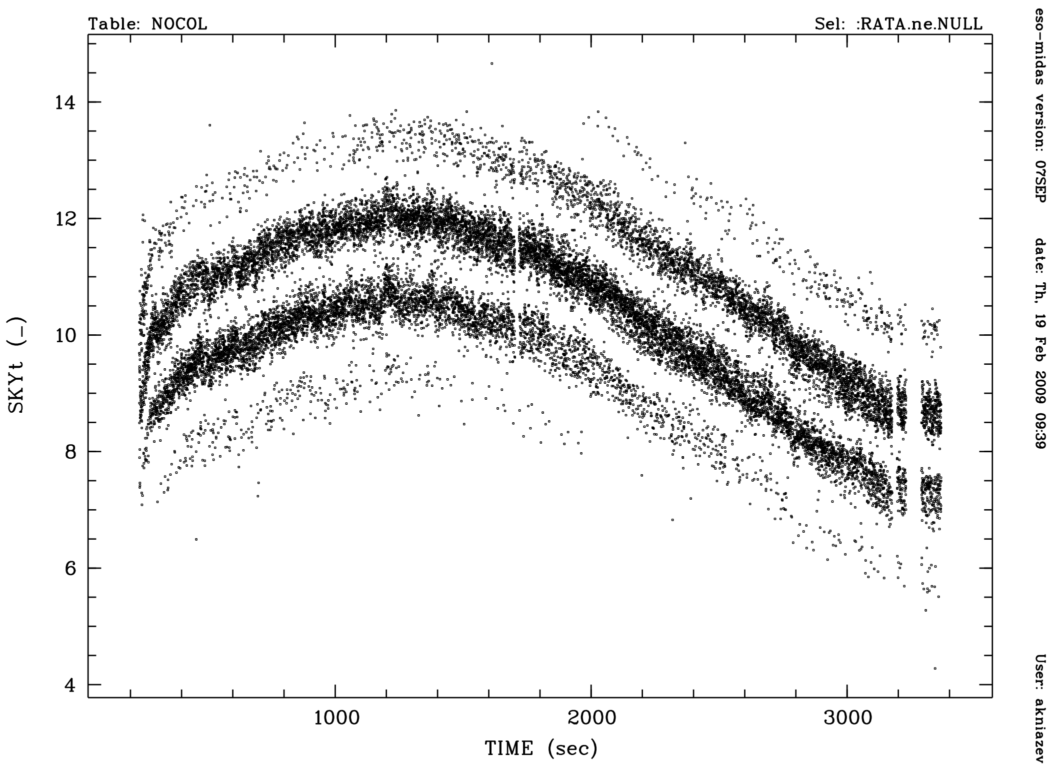

Figure 18: The calculated level of background (median value in counts) for **V3885 Sgr** on 20080604
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6 Final Conclusions

- Without proper guiding, SLOTMODE observations produce a large fraction of un-useful science data. In our particular case this fraction is very close to 100.
- Above statement is even stronger without proper auto focusing of the telescope.
- Rho-drift is a concern. This can be characterized using the multitude of SLOTMODE data obtained in the past.

7 My recommendations for `slottools` package

I also have some amount of recommendations to the current version of `slottools` package:

1. First, I would like to say that big amount of work was done by his author (Steven Crawford), but my current general filling is that `slottools` package is still very raw.
2. I am not sure that proper testing of the current version was done since deeper I am digging more problems/errors I have found.
3. The creation of any package for any standard reduction starts with creation/selection test set of the data that have to be used as a first step.
4. It looks like `slotback` does not work correct when output parameter "background" is specified. Please, check.
5. The package has to be upgraded to have the possibility to detect Y-positions of both target and reference star independently, to calculate FWHM of the studied sources and sky background statistic, and delta time (time between two nearest images). Maybe more output parameters could be also discussed.
6. As the final output of these programs **FITS-table has to be created, but not the ASCII-file**. I am very sorry, but ASCII file is the wrong way. FITS-table compare to ASCII file is the self-described output: all columns are named (described) and have their units are specified as well. FITS-table has standard descriptor "HISTORY" where all information stored about procedure that creates this table with all parameters of this procedure. Only FITS-table can be stored as the standard result of pipeline, but not ASCII. Any FITS-table can be transformed to the ASCII file with loosing of above information.