# LYRA Noise Distribution: Report

IED, 14 May 2007

Three data sets were analyzed to study the effects of different integration times on LYRA response. There are additional tests from the BESSY NI campaign in March 2006, but the following appeared most suitable:

`20060317_134432_H2C3_SignalvsIntegTime.txt` was observed during the BESSY GI campaign in March 2006. It contains signals from head 2, with a beam signal applied to channel 2-3. The integration time was stepped down through all possible LYRA values: 10 s, 5 s, 2 s, 1 s, 0.5 s, 0.2 s, 0.1 s, 0.05 s, 0.02 s, 0.01 s. The general behaviour is demonstrated in Figure 1.

`20060317_173337_H3C3_SIGNALvsIntegTime.txt` was observed during the same campaign. It contains signals from head 3 and head 2 in parallel, with a beam signal applied to channel 3-3. The integration time was stepped as above, see Figure 2.

`20061213_084925_test_IT.txt` was observed in Davos in December 2006. It contains dark-current signals from head 1. The integration time was stepped from long to short and back to long, 10 s,..., 0.01 s,..., 10 s, see Figure 3.

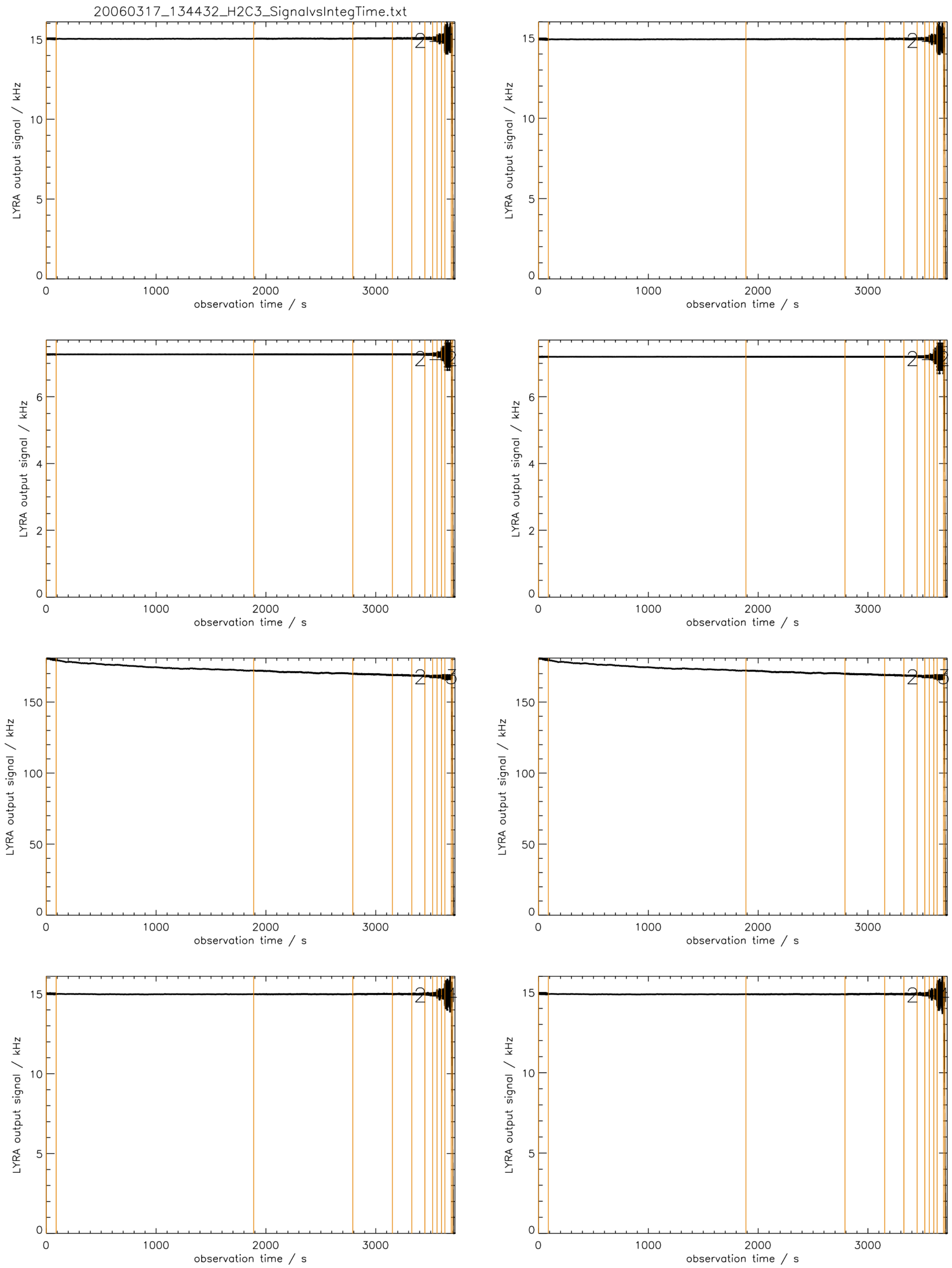


**Figure 1:** Signal vs. integration time for head 2; BESSY beam on channel 2-3, dark currents otherwise. Red lines mark changes of integration time, which is stepped down from 10 s to 0.01 s.

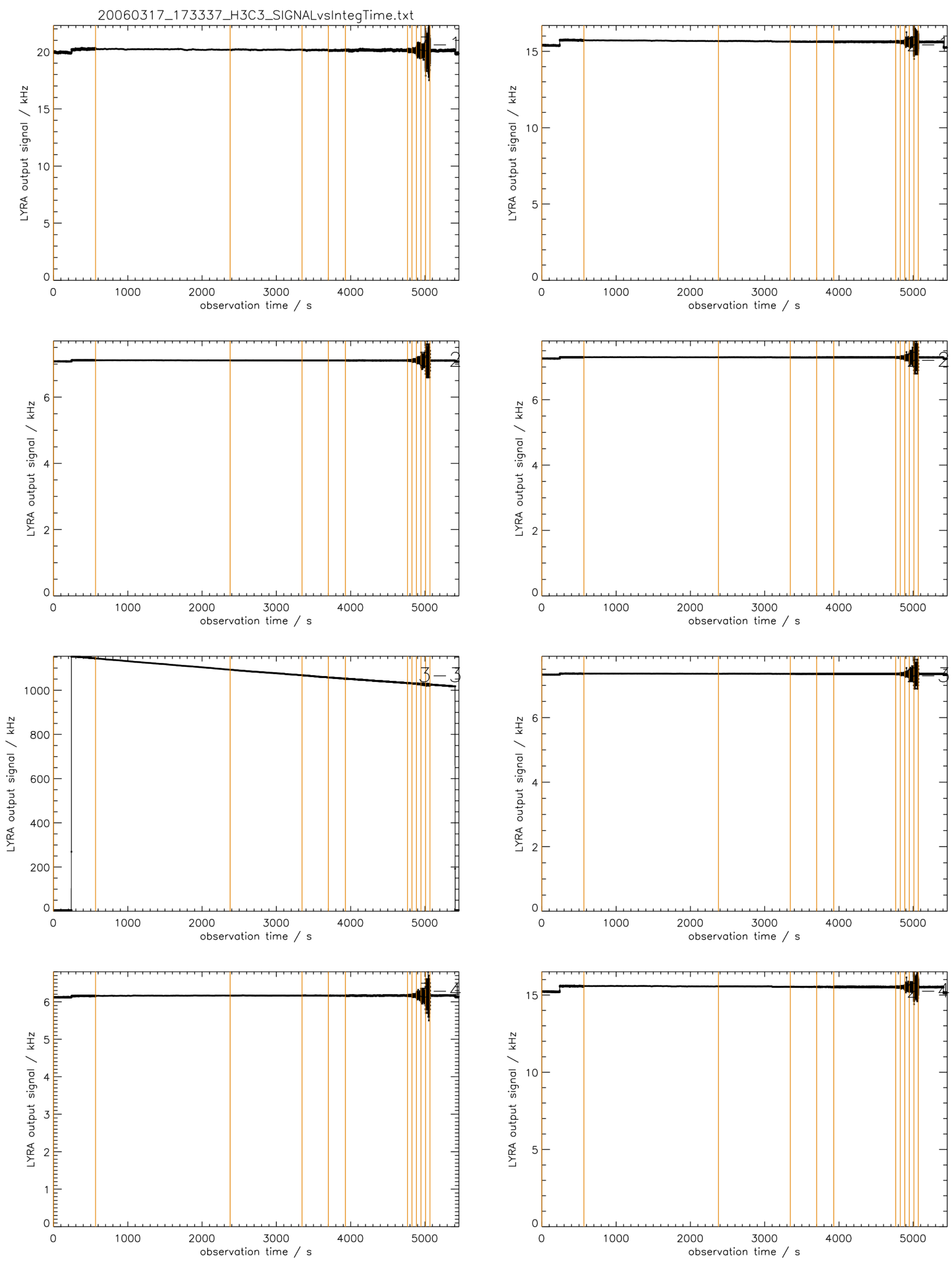


**Figure 2:** Signal vs. integration time for heads 3 and 2; BESSY beam on channel 3-3, dark currents otherwise. Red lines mark changes of integration time, which is stepped down from 10 s to 0.01 s.

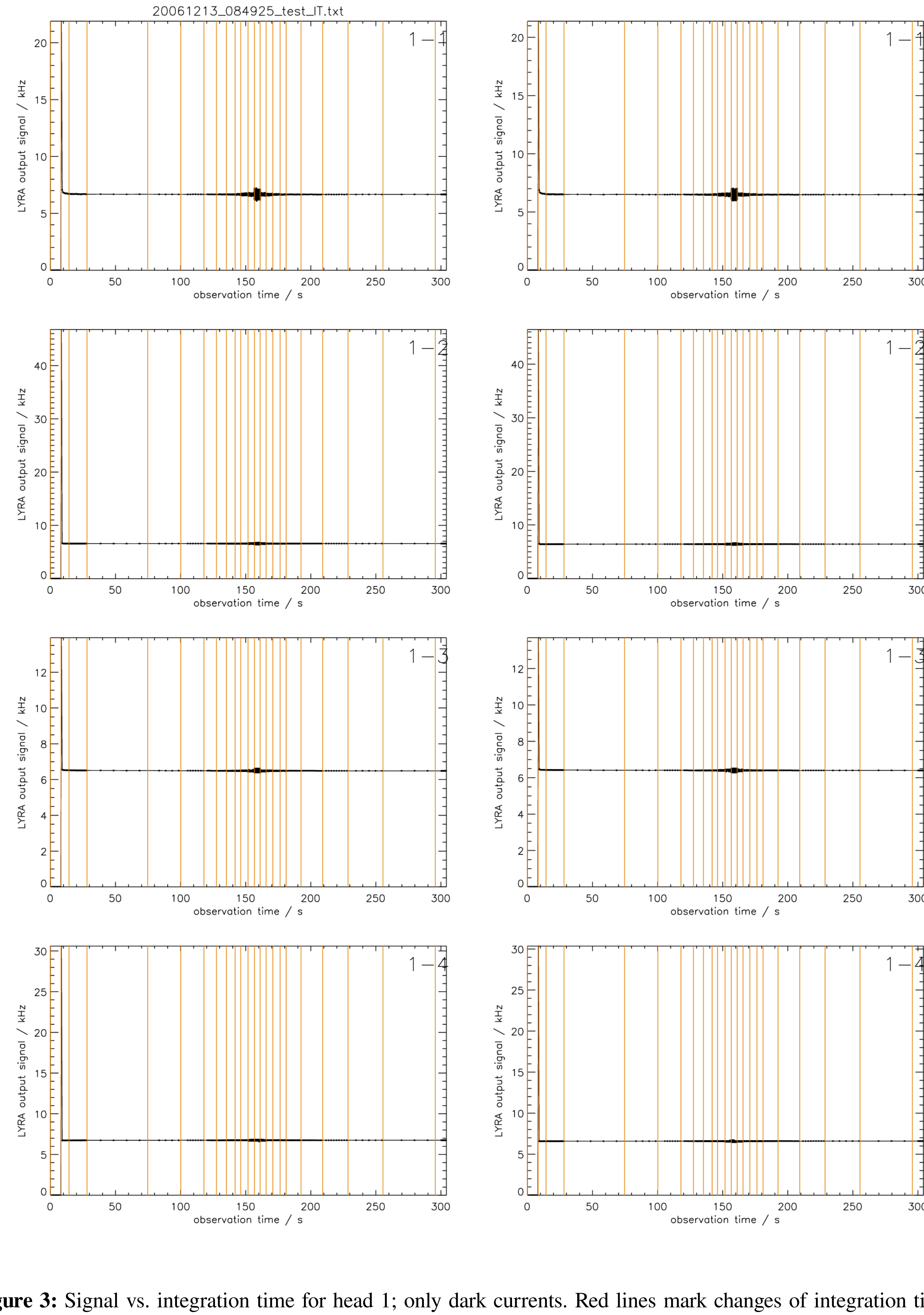


**Figure 3:** Signal vs. integration time for head 1; only dark currents. Red lines mark changes of integration time, which is stepped down from 10 s to 0.01 s, and up to 10 s again.

First, the beam signals in channels 2-3 and 3-3 were analyzed. Their properties are demonstrated in Figure 4. There is clearly a downward drift in both cases, which is known to be caused by the drift in the beam current, so it says nothing about possible drifts in the LYRA detectors; for this problem, see another document: *LYRA Signal Stability: Report (rev. 04 Dec 2006).*

Channel 3-3 (Al filter + AXUV detector) shows a higher output level than channel 2-3 (Al filter + MSM detector). This is confirmed by other tests. Channel 3-3 shows irregular fluctuations with a deviation of approx. +/- 0.05 % around the trend, and some degree of noise. Channel 2-3 shows a sinus curve of approx. 20 s period and 0.1 % amplitude around the trend, and also some degree of noise. This sinus type of fluctuation can also be observed in other beam tests taken with channel 2-3, but it can *not* be observed in tests taken with the same beam, on the same day, with channel 3-3, or – so far – in any other channel (more detailed analysis TBD). So it is probably not a fluctuation in the beam signal.

On the other hand, the sinus curve can *not* be observed in the dark current of channel 2-3, or in its reaction to LED signals, nor can it be observed in the reaction to a longer-wavelength beam (BESSY NI campaign). The latter leads to a much lower signal, caused by a much lower responsivity for longer wavelengths. Therefore, it may be concluded that the sinus fluctuation is a property of the MSM detector of channel 2-3 in the presence of a strong signal.

As visible in Figure 4, at integration times shorter than 0.2 s, a different kind of noise takes over. To analyze this type of noise, the values for the shortest integration time, 0.01 s, were adjusted by the trend and fitted to a Gaussian. The results for channels 2-3 and 3-3 are demonstrated in Figures 5 and 6. It can be concluded that the signal values with short integration times roughly follow a Gaussian - or, to be exact, since they are counts, i.e. integer values, a Poisson distribution. The width depends on the count level.

But these findings only hold for sufficiently high count rates and cannot be extended, e.g., to dark currents with just three different output values (see below).

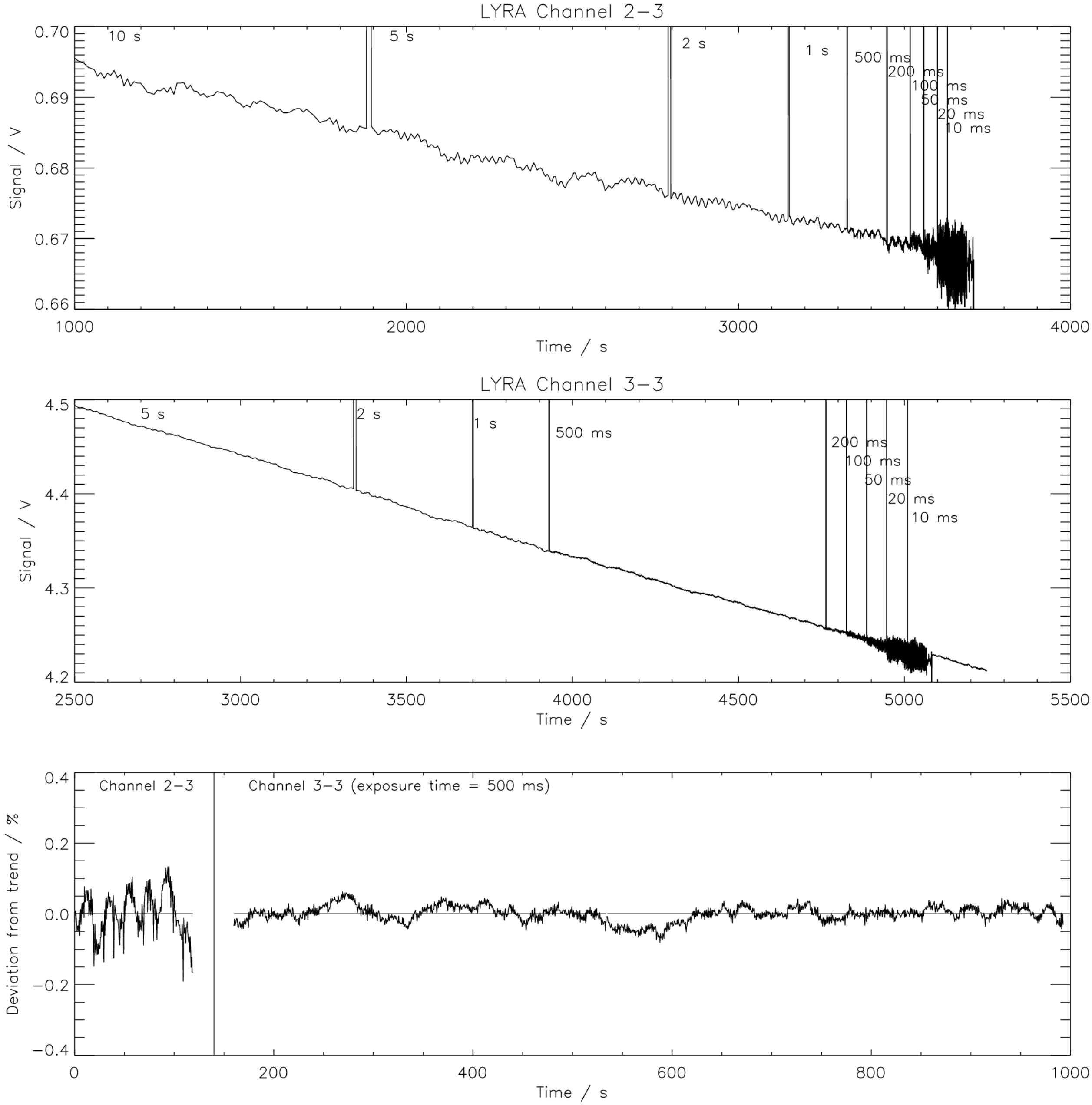


**Figure 4:** The upper images demonstrate the lower parts of the test data generated with a BESSY beam on channels 2-3 and 3-3. Integration times are marked at the begin of their intervals. - The lower image shows the resp. intervals with 0.5 s integration time, the trend being removed.

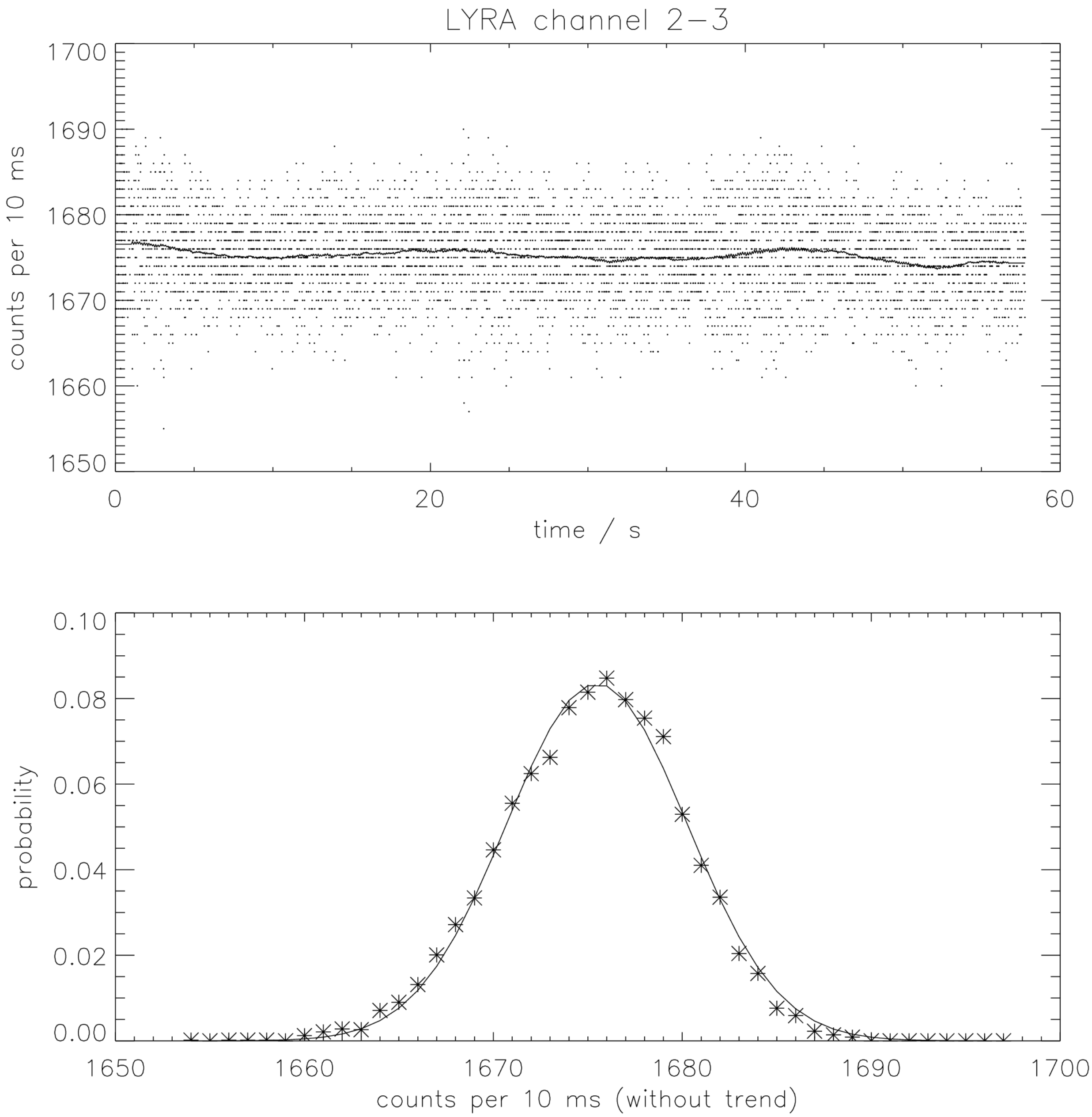


**Figure 5:** The upper image shows the result of approx. one minute observation of the beam on channel 2-3, with 0.01 s integration time (dots are raw data, the line denotes the trend). - In the lower image, the asterisks denote the histogram of realized counts (trend removed), while the line is a Gaussian fit. The mean of the raw data is 1675.23, the mean of the Gaussian is 1675.48, and the standard deviation is 4.79.

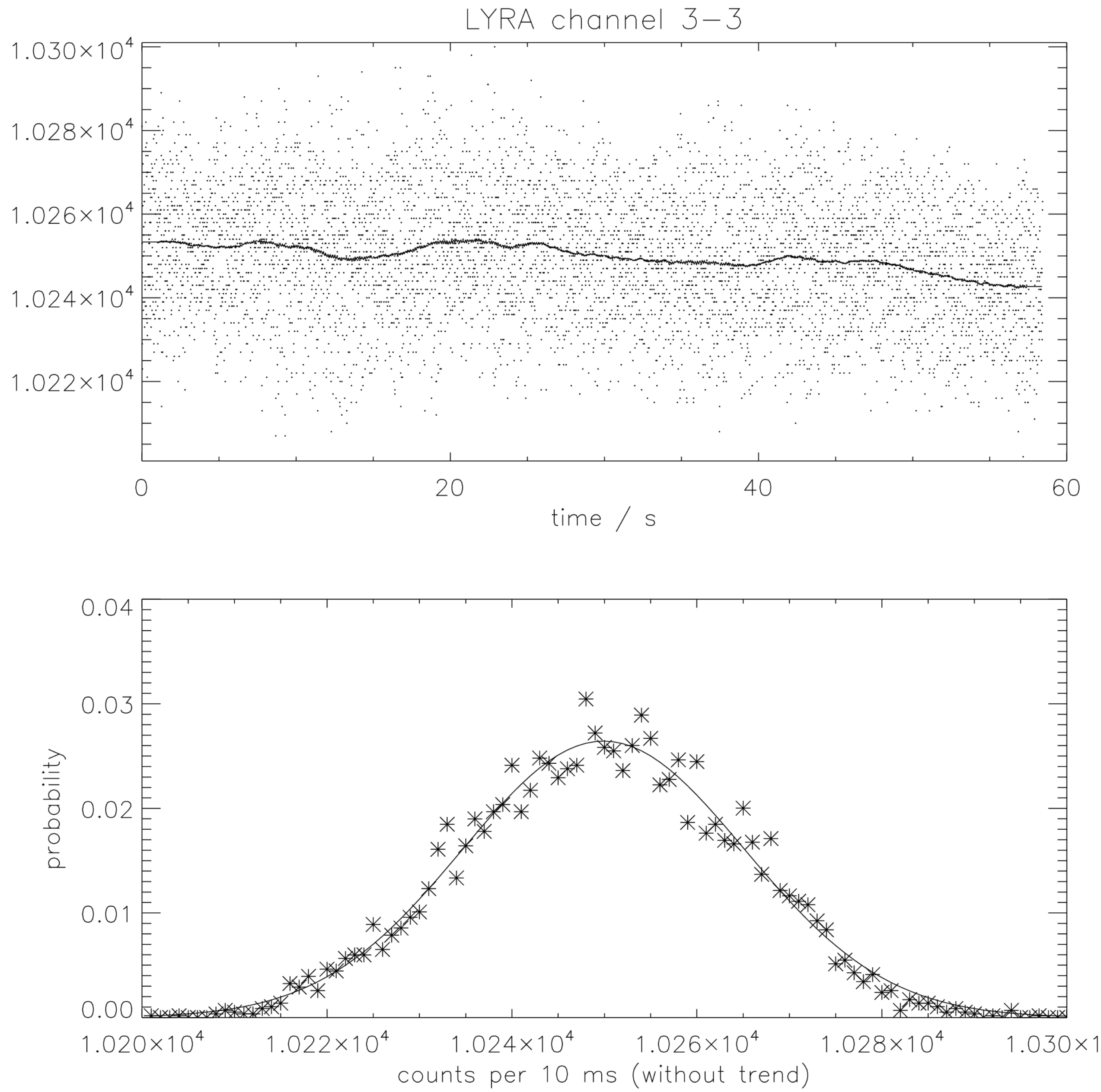


**Figure 6:** The upper image shows the result of approx. one minute observation of the beam on channel 3-3, with 0.01 s integration time (dots are raw data, the line denotes the trend). - In the lower image, the asterisks denote the histogram of realized counts (trend removed), while the line is a Gaussian fit. The mean of the raw data is 10249.7, the mean of the Gaussian is 10249.9, and the standard deviation is 15.29.

There remains one more problem to be analyzed. Does frequency depend on integration time, or in other words, can LYRA signals be recorded in an arbitrary cadence, and afterwards, for example, can 100 values taken at 0.01 s just be added up to receive the appropriate value for 1 s?

To answer this question, the signal values were averaged within their integration-time bins. As a result, the averages of low integration times (i.e. below 0.2 s) can be observed to drop. This can be explained and corrected with the dead-time value, i.e. the amount of time within the integration interval which is needed to read out the integrated data value. According to PMOD, where LYRA was built, a dead time of 10.5807 microseconds must be removed from the integration times; this dead time is the same for all integration times.

Therefore, it is possible to correct for the dead-time effect in given LYRA frequency values as follows (implying that frequencies are currently calculated as counts per nominal integration time):

*[corrected LYRA signal / (count/s)] = [LYRA signal / (count/s)] * [int.time / s] / ([int.time / s] – 0.0000105807)*

where *int.time* can be any possible nominal integration time between 10 s,...,0.01 s. Thus, the highest possible correction – at 0.01 s integration time – is approx. +0.1%.

One example is shown in Figure 7. Other examples appear less smooth, because at the rather low dark-current levels, the output sometimes oscillates between just three or four integer values (counts per integration interval). On the other hand it is also possible that the output oscillates between two clusters of three or four output values each; this was observed for MSM channels 1-1, 2-2, and 2-4.

The general behaviour of the averages – raw and corrected - within their integration-time bins is demonstrated in Figures 8, 9, and 10, for the three test sets. Values of dark currents roughly agree with values found in another report, see *LYRA Pulsed LED Tests: Data Analysis (rev. 06 Mar 2007)*. - One should also note that the second multiplexer, while reading the same channel (see right sides of Figures 8 and 10), records around 0.1 kHz less than the first one.

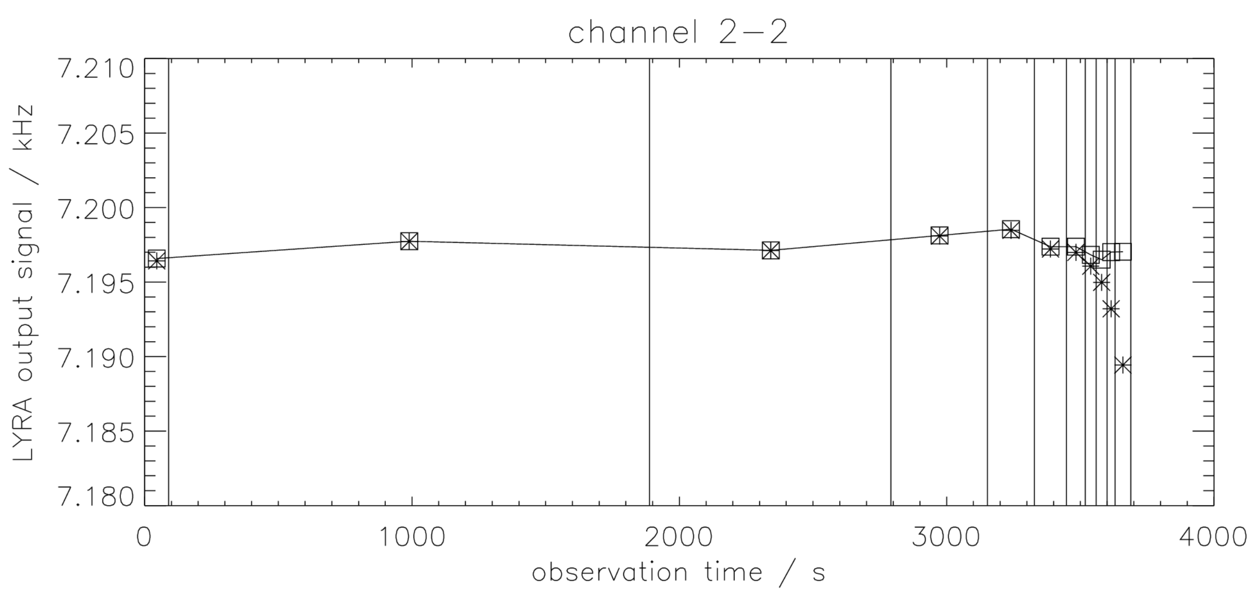


**Figure 7:** Signal averages in bins of integration time, as calculated for channel 2-2; from left to right, beginning with a short set of 0.5 s, integration times are stepped from 10 s down to 0.01 s. Asterisks mark raw frequency values, squares are corrected for dead time.

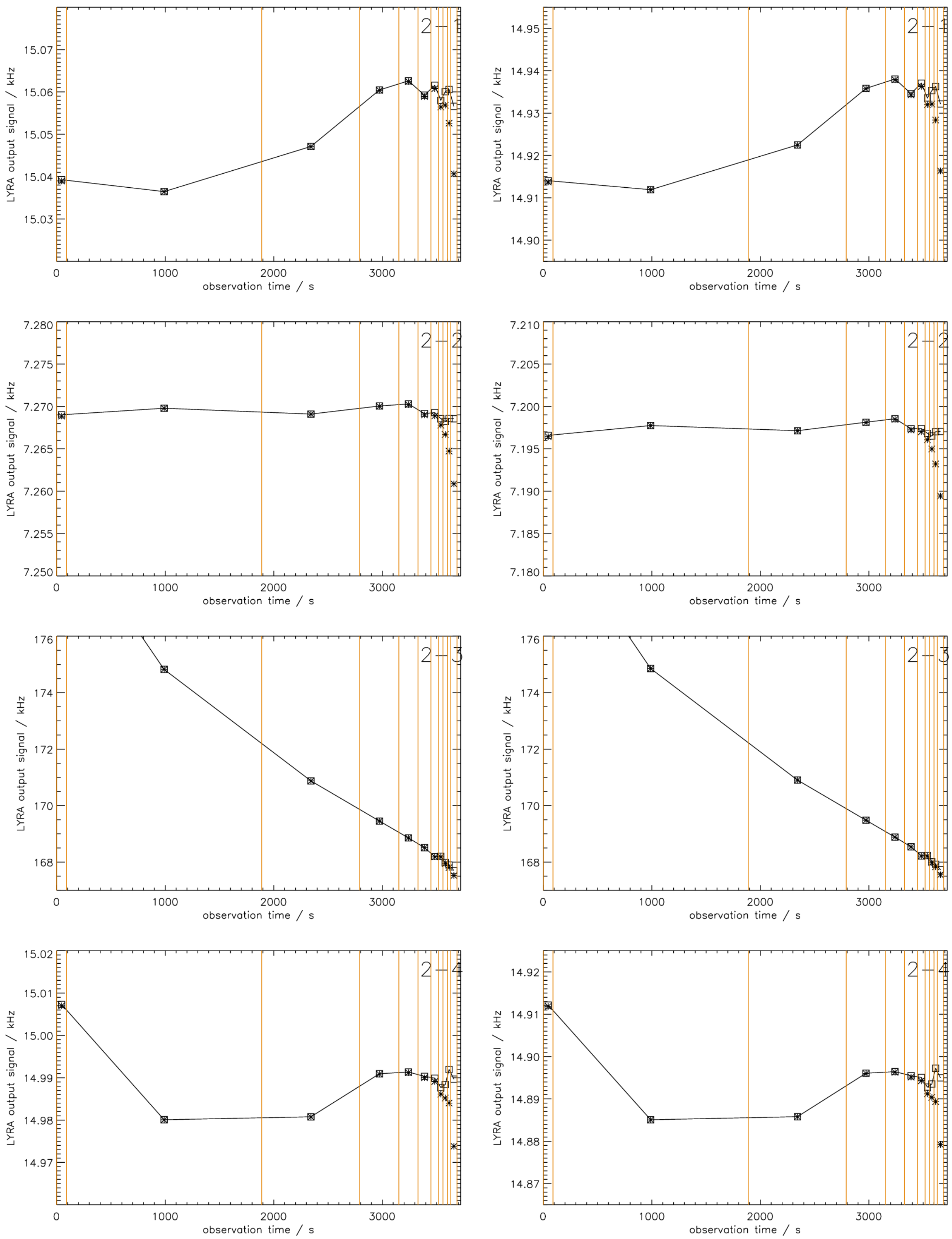


**Figure 8:** Signal averages in bins of integration time, for head 2; BESSY beam on channel 2-3, dark currents otherwise. Red lines mark changes of integration time, which is stepped down from 10 s to 0.01 s.

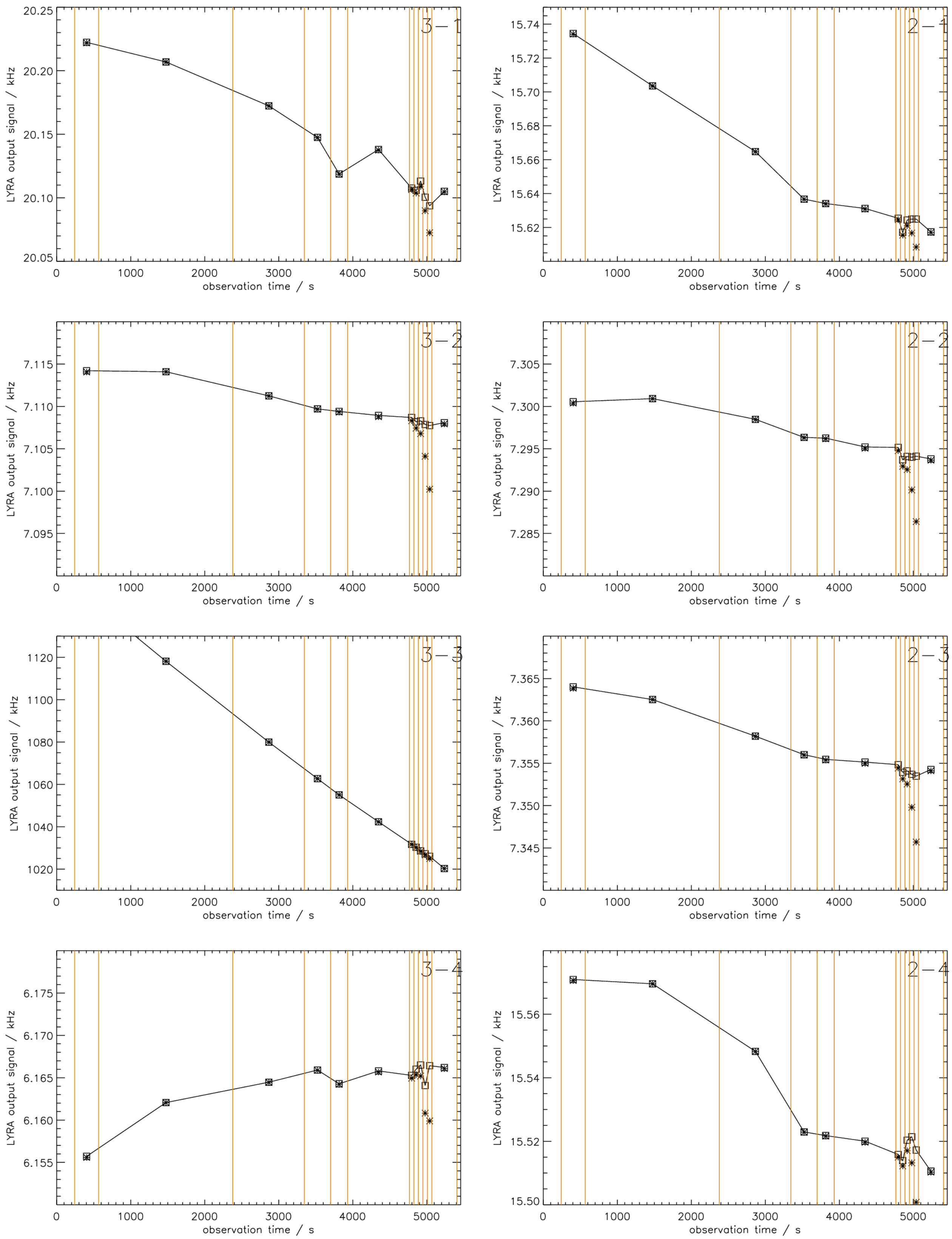


**Figure 9:** Signal averages in bins of integration time, for heads 3 and 2; BESSY beam on channel 3-3, dark currents otherwise. Red lines mark changes of integration time, which is stepped down from 10 s to 0.01 s.

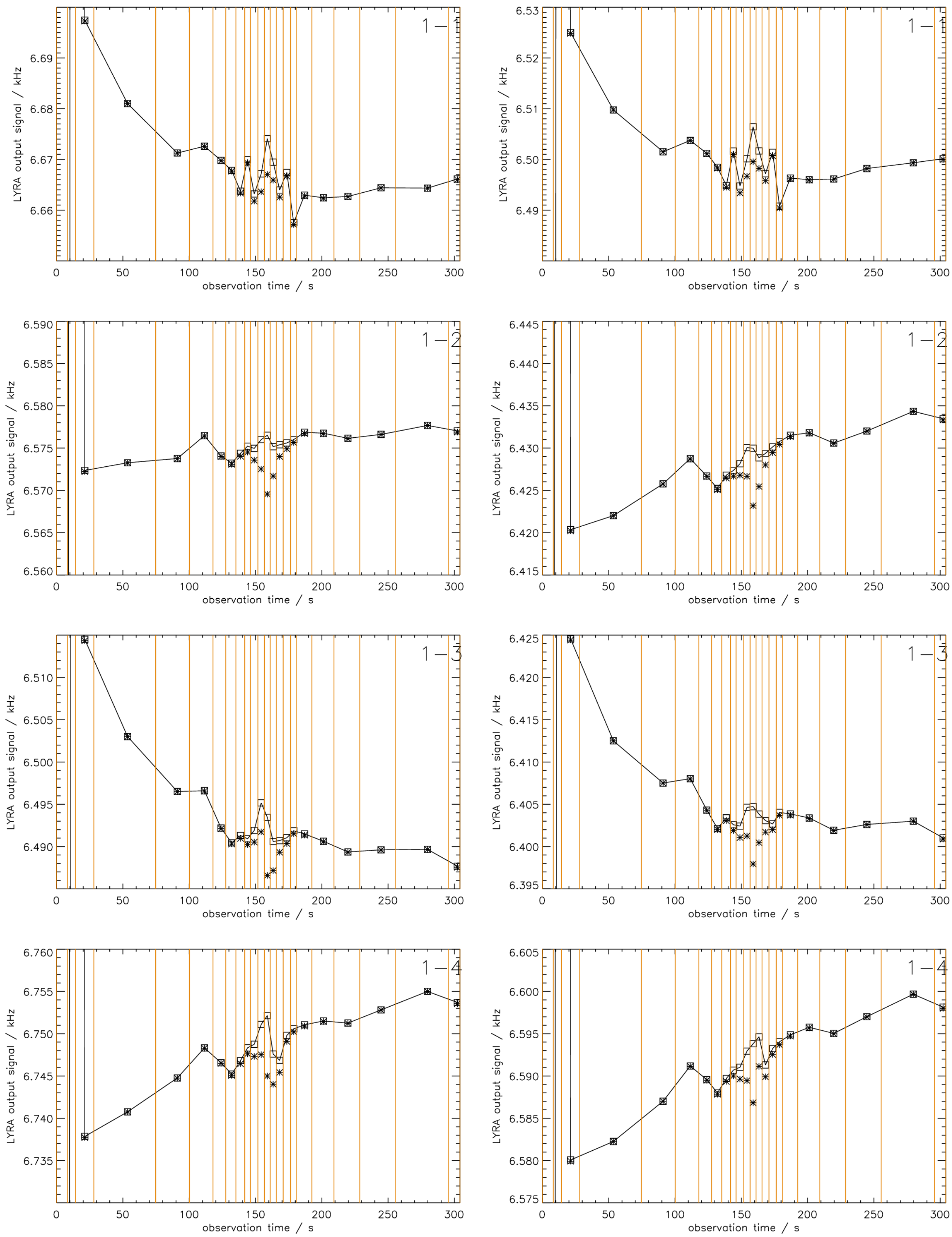


**Figure 10:** Signal averages in bins of integration time, for head 1; only dark currents. Red lines mark changes of integration time, which is stepped down from 10 s to 0.01 s, and up to 10 s again.