MSC data memo

Applying clock correction factors in KI data reduction

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Summary

In all Keck Interferometer data taken up to June, 2003, there are hardware and software issues which affect the measured visibilities. These issues are:

1. The timing controlling the stroke of the delay line and the read out of the detector were mis-aligned

2. The group delay calculation had an error causing it to be non-linear

3. The stroke of the delay line was non-linear

The first and second items were corrected in data collected after June, 2003. The effects of just the third issue on data taken in July, 2003 and later are discussed in a separate memo.

These problems resulted in a phase dependent error in the measured visibility. This document describes the results of applying a correction algorithm to KI calibration test data. As discussed below, the correction does not significantly improve the data and the MSC therefore recommends that it is not applied to science data.

1. Correction algorithm

The clocking problem was first noticed during a continuous 45-minute segment of data on one source at the end of night 2003107. In this long segment, the visibility is clearly bimodal. If there were a phase dependent error, the visibility would be a function of time as the central fringe cycles through the fringe envelope due to changing atmospheric dispersion. It was later confirmed that a software error caused the shift of 1 bin between the stroke of the delay line and the reading of the detector. The steep transition between the visibility levels was due to non-linearities in the group delay calculation.

Given the phase dependent nature of the error, it may be possible to correct the data. An algorithm was studied in which corrections are applied to the quadratures X and Y, the photon count N, and the energy measure NUM (see M. Colavita, PASP, 111, 111) before the visibility is calculated. Correction coefficients were derived by M. Colavita (reference memo) using an 80 second piece of 45-minute on-sky data segment, during which the visibility goes through a sharp increase. The coefficients were set to minimize the long term variations in the visibility. These corrections include the dewarping correction for mismatch of the stroke and observed wavelength. This correction will be called a clock correction in this document.

Starting from ABCD (derived as usual from zabcd)

$$
\begin{aligned}
X &= C - A \\
Y &= D - B \\
N &= A + B + C + D \\
NUM &= X^2 + Y^2,
\end{aligned}
$$

the phase is given by $\tan^{-1}(Y/X)$. The corrected values are:

$$\begin{aligned} X_c &= X \\ Y_c &= pY \\ N_c &= N + q(X - Y) \\ NUM_c &= NUM - 0.5(1 + p^2)kN_c \end{aligned}$$

The derived coefficients for each channel are given in Table 1. Note that these coefficients do not agree with coefficients derived from internal fringe data on night 2003130. This disagreement is not understood.

	WL	2.3	2.2	2.1	2.0
p	1.22	1.22	1.19	1.09	1.04
q	0.1	0.18	0.18	0.19	0.18

Table 1: Coefficients derived from night 2003107 and applied here. 2.3 etc refers to the spectrometer channels.

2. Implementation in Kvis

To test this correction algorithm, modifications were made to Kvis, the data processing program. As this correction includes the dewarping corrections, it was included as an alternate method in the dewarping section. The correction is applied to all data, including the calibrations. The bias corrections are applied in the same way to both sets of data. The data without the clock corrections were dewarped in the usual way.

3. Tests on visibility data

2003107

The correction was applied to the entire sequence of data on night 2003107 (Figure 1). The fringe tracker rate is 500 Hz and the jitter was 0.3 to 0.4 radians. The bimodality can clearly be seen in the non-corrected data and the sign of the visibility change is opposite for the WL and summed spectrometer visibility. With the correction, the visibility is considerably more flat, and the average visibility has increased but a small residual signature remains.

2003106

A similarly long integration on one source was taken on the previous night with the fringe tracker operating at 200 Hz. As shown in Figure 2, this segment of data has considerable visibility variation, but without the distinct pattern of night 2003107. Although the clock correction increases the visibility, it does not reduce the variations, which may be due to unmeasured ratio changes. Similar results are seen for the summed spectrometer channel (not plotted).

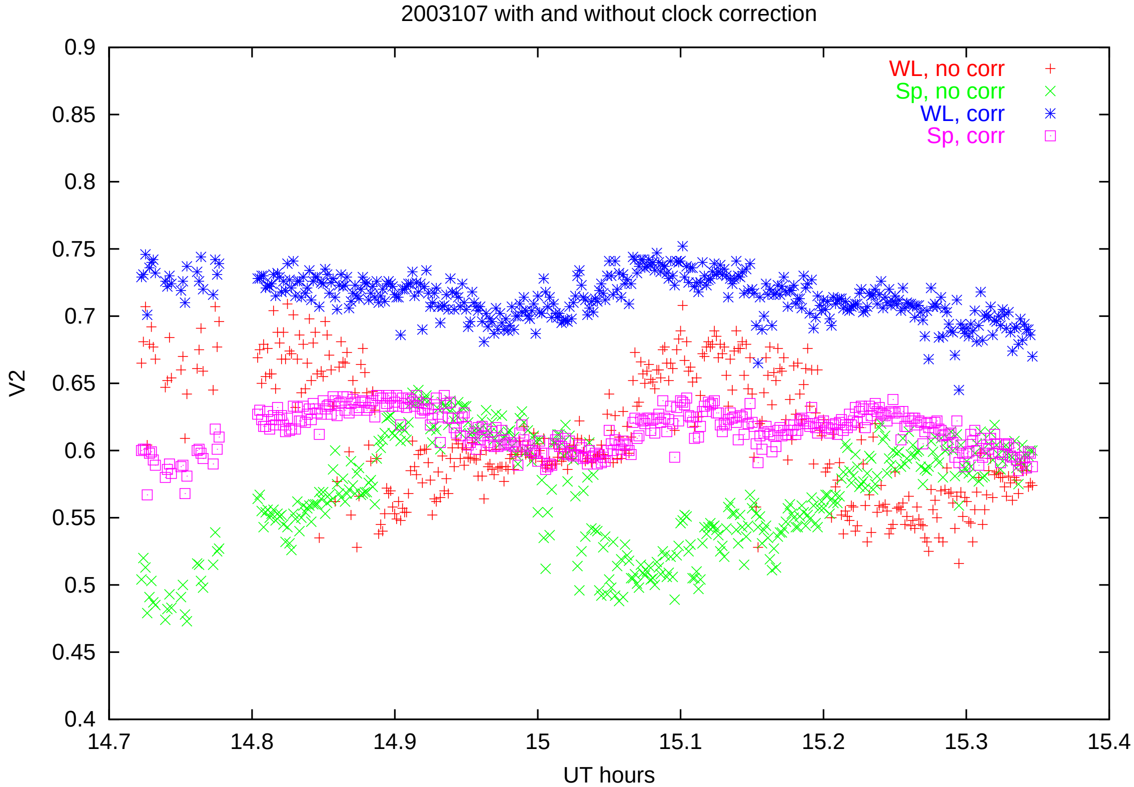

Figure 1: The long integration from night 2003107 with and without the clock correction applied. WL is the white light channel and Sp is the summed spectrometer visibility.

Binary observations

To test the clock correction on data taken in the normal pattern of interleaved calibrators and targets, observations of known binaries were used. Both binaries used here have good orbital solution from interferometry data taken at the Palomar Testbed Interferometer and radial velocity measurements. The KI predicts were kindly supplied by A. Boden. The binaries and nights used are:

- 2003018: Binary HD 78418, fringe tracker at 500 Hz, jitter 0.5 to 0.8 radians.
- 2003106: Binary HD144208, fringe tracker at 200 Hz, very high scatter in visibilities, jitter 0.8 to 1 radian.
- 2003141: Binary HD144208, fringe tracker at 200 Hz, jitter 0.7 to 1.1 radians.

For each night, the data were reduced in Kvis both with and without the clock correction, using the standard bias correction method. The binary was then calibrated for the system visibility using wbCalib and nbCalib. The ratio correction was applied, but the jitter correction was not as for all three nights the binary and its calibrators had the same jitter.

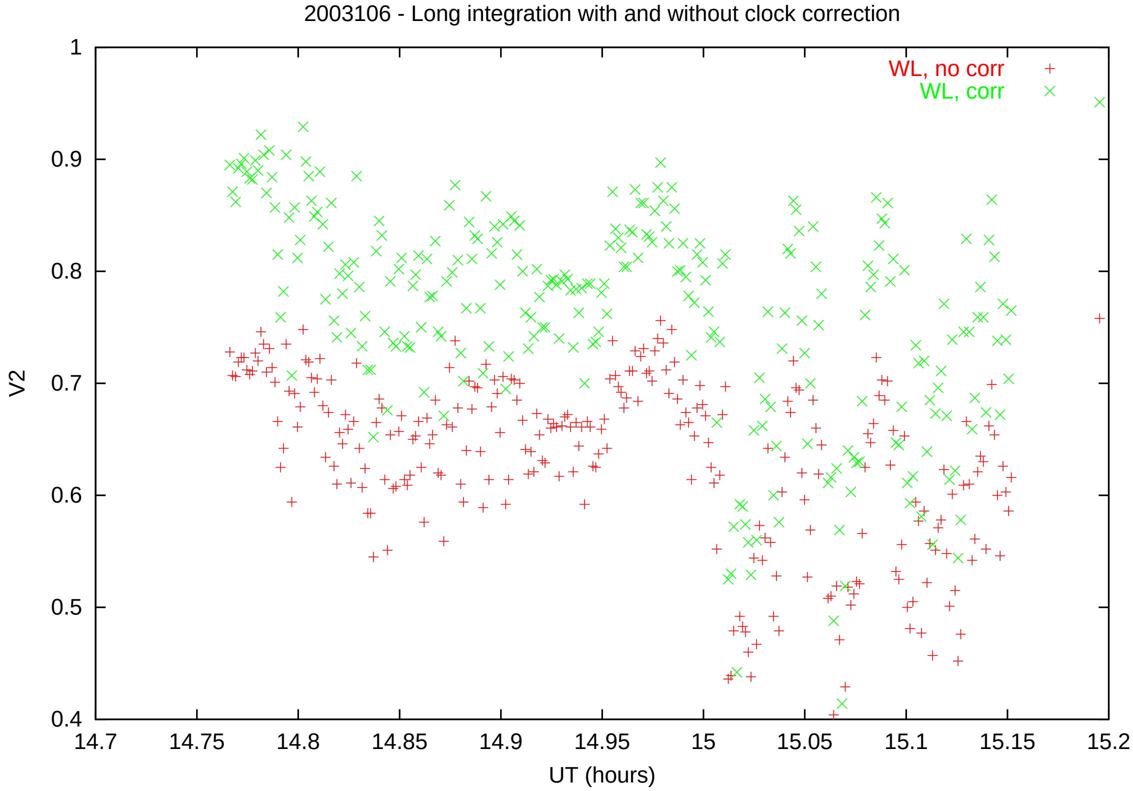

Figure 2: The long integration from night 2003106 with and without the clock correction applied.

After calibration, the visibility estimates for the white light channel (WL), the summed spectrometer channels and the individual spectrometer channels were compared to the visibility predicted by the binary model (using the appropriate wavelength). Table 2 gives the rms and χ^2 for each night by channel. Figures 3–5 plot the calibrated visibility for each channel and the predicted visibility from the binary model with errors.

For night 2003018, the clock correction changes are less than 1 σ for all points. For the WL data, the correction slightly decreases the agreement with the model and for the spectrometer data the agreement slightly increases.

For night 2003106, the clock correction does not make a significant difference, although the errors are so large for this data, only large correction would be statistically significant.

For night 2003141, the clock correction brings some points closer to the model and other points further away, but in general (Table 2) does not improve the overall agreement.

For both nights with data taken at 200 Hz (2003106 binary and long segment, 2003141 binary) the clock correction does not improve the data. This may be due to the high jitter at this fringe tracker rate acting to average over the phase dependent effects of the clock error for each integration.

	No correction		With correction	
	rms	χ^2	rms	χ^2
		2003018		
WL	0.019	2.3	0.025	3.7
Σ sp	0.041	6.4	0.035	5.1
2.0 μm	0.041	3.4	0.040	3.2
2.1 μm	0.041	5.7	0.036	4.7
2.2 μm	0.045	8.5	0.036	6.1
2.3 μm	0.047	10.3	0.036	7.2
		2003106		
WL	0.072	0.82	0.091	1.5
Σ sp	0.103	3.5	0.091	3.3
2.0 μm	0.123	4.8	0.119	4.8
2.1 μm	0.121	5.4	0.12	5.1
2.2 μm	0.093	2.7	0.083	2.8
2.3 μm	0.071	1.1	0.058	1.2
		2003141		
WL	0.016	1.3	0.019	1.3
Σ sp	0.040	4.3	0.037	3.3
2.0 μm	0.036	2.2	0.033	1.9
2.1 μm	0.037	3.0	0.034	2.3
2.2 μm	0.041	5.0	0.042	4.2
2.3 μm	0.038	4.0	0.035	3.5

Table 2: Comparison of rms and χ^2 for binaries with and without the clock correction applied.

Recommendation

Based on the empirical nature of the correction, the disagreement between the correction coefficients derived from external and internal data and the limited improvement seen in the binary data discussed above, we do not recommend using the correction for any science data. However, for 500 Hz data only we will make corrected data available on request.

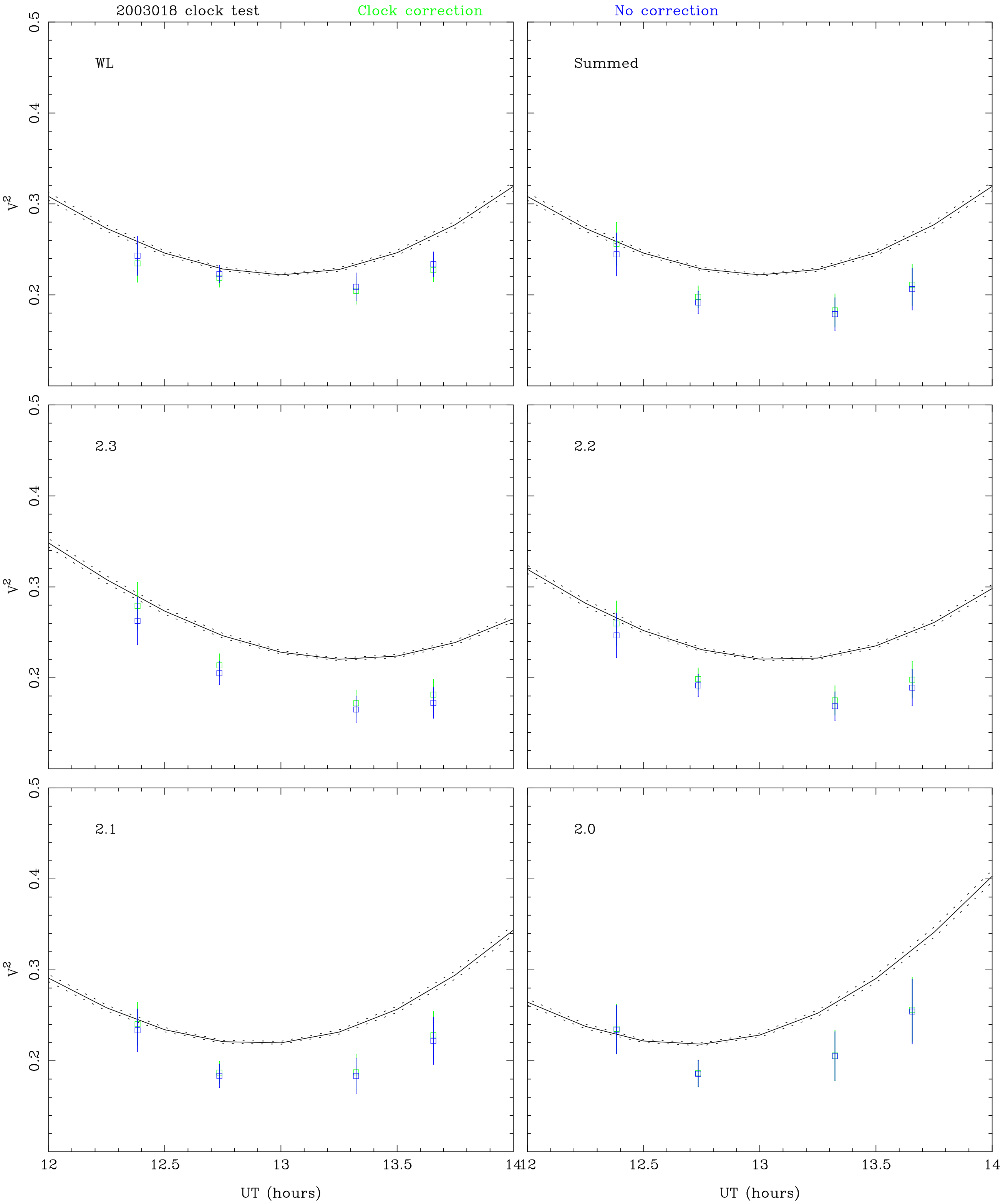

Figure 3: Night 2003018 - Comparison of calibrated visibilities with and without the clock correction to the binary model. The dashed lines represent the 1 σ error on the model.

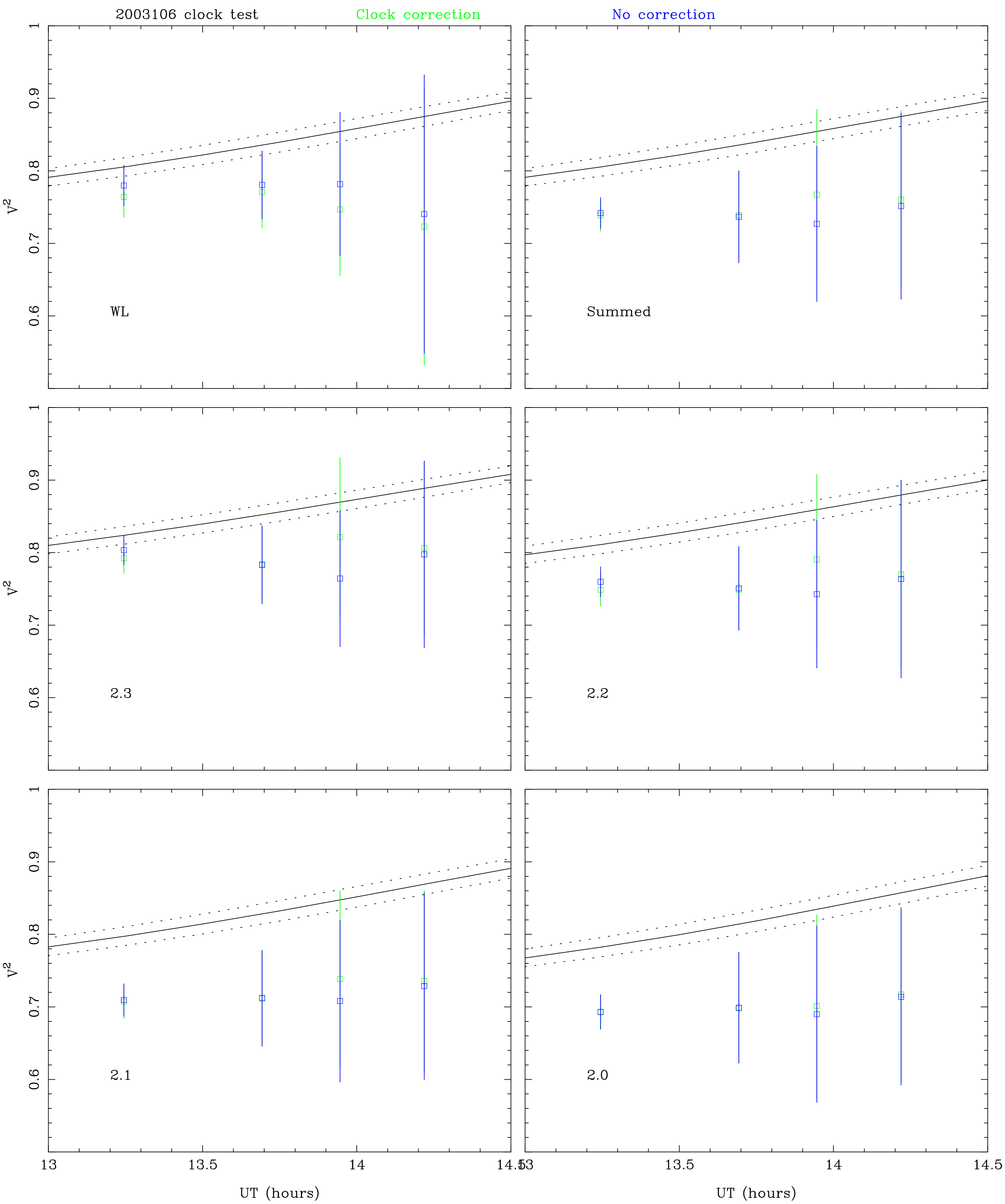

Figure 4: Night 2003106 - Comparison of calibrated visibilities with and without the clock correction to the binary model. The dashed lines represent the 1 σ error on the model.

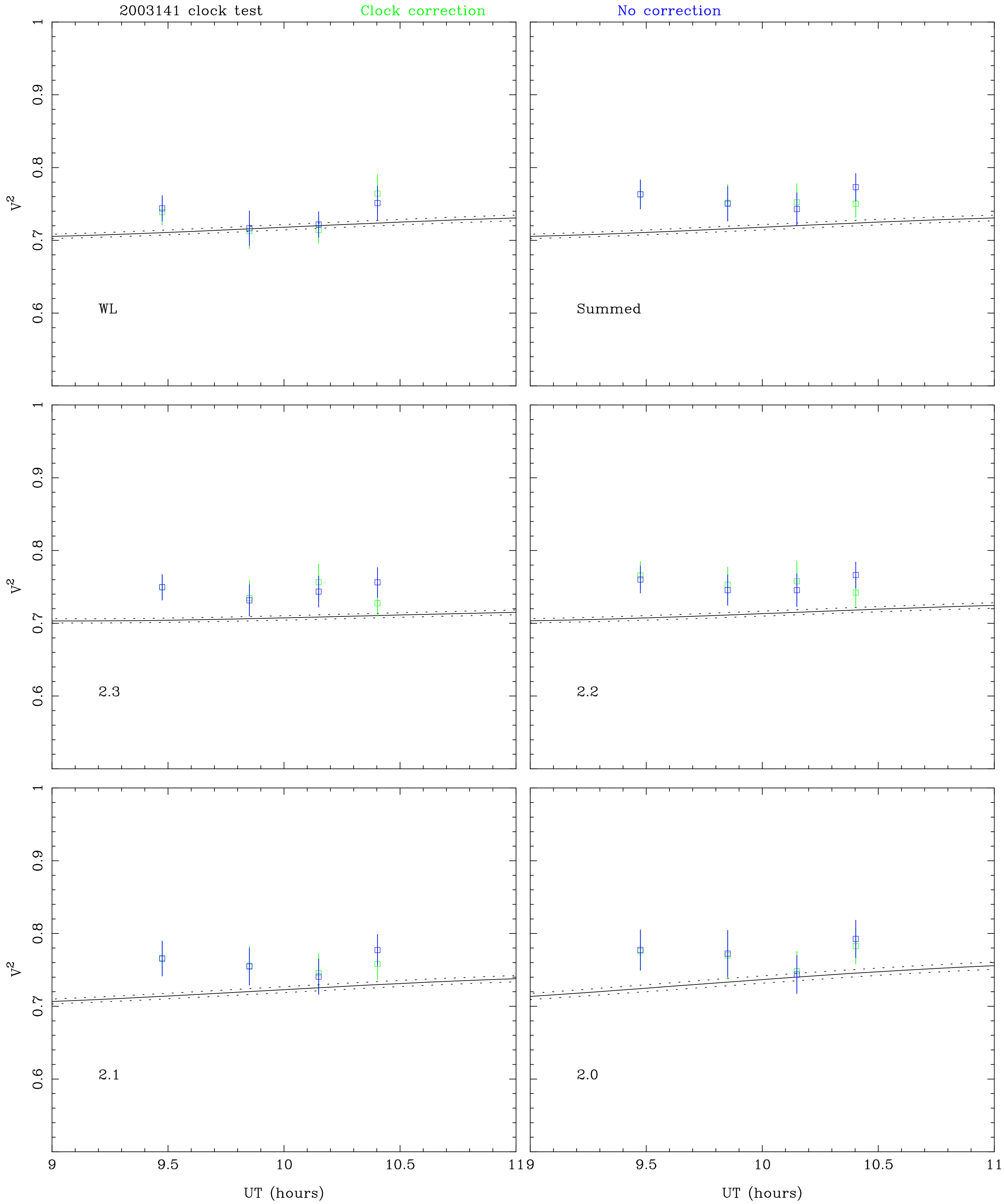

Figure 5: Night 2003141 - Comparison of calibrated visibilities with and without the clock correction to the binary model. The dashed lines represent the 1 σ error on the model.