DOCUMENT

Time Dependent Sensitivity Degradation Correction for the Optical Monitor (OM)

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APPROVAL

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CHANGE LOG

Reason for change	Issue	Revision	Date
Errata: sign in Table 3	2	1	21 January 2017
Errata: coefficient in Table 3	2	2	27 January 2017

CHANGE RECORD

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Reason for change	**Date**	**Pages**	**Paragraph(s)**
Different methodology applied	17 January 2017	All	
Issue 2	**Revision 1**		
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Correcting errata: sign in Table 3	21 March 2017	10	Table 3 . Coeff. C for filter B: -2.18...
Issue 2	**Revision 2**		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Correcting errata: coefficient in table 3	27 March 2017	10	Table 3 . Coeff. A for filter UVM2: -8.235

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1 INTRODUCTION

The sensitivity of the Optical Monitor (OM) on board XMM-Newton is affected by a time dependent degradation. This is due to two main effects: the degradation of the S-20 photocathode and the aging of the MCP. The first of these effects is known to be wavelength dependent.

Observing periodically a set of photometric standard stars has allowed us to derive a correction for this degradation. The correction is implemented in SAS as

$$Corrected\_Rate = Measured\_Rate \times Correction\_factor$$

with

$$Correction\_Factor = A + B \times MJD$$

where MJD is the Modified Julian Date of the observation and A and B the coefficients of a linear fit to the degradation which depends on the filter.

The coefficients A and B are contained in the calibration file OM_PHOTTONAT_0005.CCF. The structure of the CCF allows us to use a polynomial correction

$$Correction\_Factor = A + B \times MJD + C \times MJD^2 + \ldots$$

2 MEASURING THE TIME DEPENDENT SENSITIVITY DEGRADATION

The white dwarfs GD 153, Hz 2 and BPM 16274 are used to measure the time dependent sensitivity degradation and to derive the correction. The first two stars are observed once per year and the third one twice. The data are processed with SAS to obtain the count rates of the stars in all the OM filters.

The count rate (corrected) and the time dependent correction applied by SAS are obtained from the SWSRLI sources files produced by SAS. Corrected Rates are divided by the applied correction and by their mean value to obtain normalized un-corrected rates. We can display these values as a function of time to see the degradation. The inverse of these uncorrected rates gives us the correction.

Fitting of the inverse of the normalized uncorrected rates to the observation date (MJD) gives us the coefficients A and B.

The current values of A and B implemented in SAS are given in Table 1.

Filter	*A*	*B*
UVW2	-1.144806	4.202973e-5
UVM2	-1.170174	4.260755e-5
UVW1	-0.303296	2.546142e-5
U	0.197939	1.567036e-5
B	0.146992	1.671589e-5
V	-0.641417	3.182019e-5

Table 1. Time dependent sensitivity degradation correction implemented in SAS: OM_PHOTTONAT_0005.CCF

3 MONITORING THE TIME DEPENDENT SENSITIVITY DEGRADATION

Adding new observations of our standard stars allows us to monitor the validity of the applied correction.

Figure 1 shows the uncorrected count rates for all stars as of January 2017. The current SAS degradation correction (blue dashes) can be compared with the new linear fit to all data available (green line). A quadratic fit is displayed in red. This one seems to better reproduce the observed variation; however for the UVW2 and V filters the degradation represented by the quadratic fit shows a reversal which has no physical sense. The light blue line represents the degradation obtained from many stars, described in Section 4.

We can see in Figure 2 a comparison of the corrected count rates using SAS (current fit) and the new linear fit for UVW1, U, and B filters and a quadratic fit for UVW2, UVM2 and V filters in all stars. The new fits reproduce very well the observed deviation, with the drawback of the reversal mentioned before for UVW2 and V filters.

It should be noted that the abscissae in all our figures is given in Years for a better understanding. However, the parameters of the correction are based on Modified Julian Date as defined above.

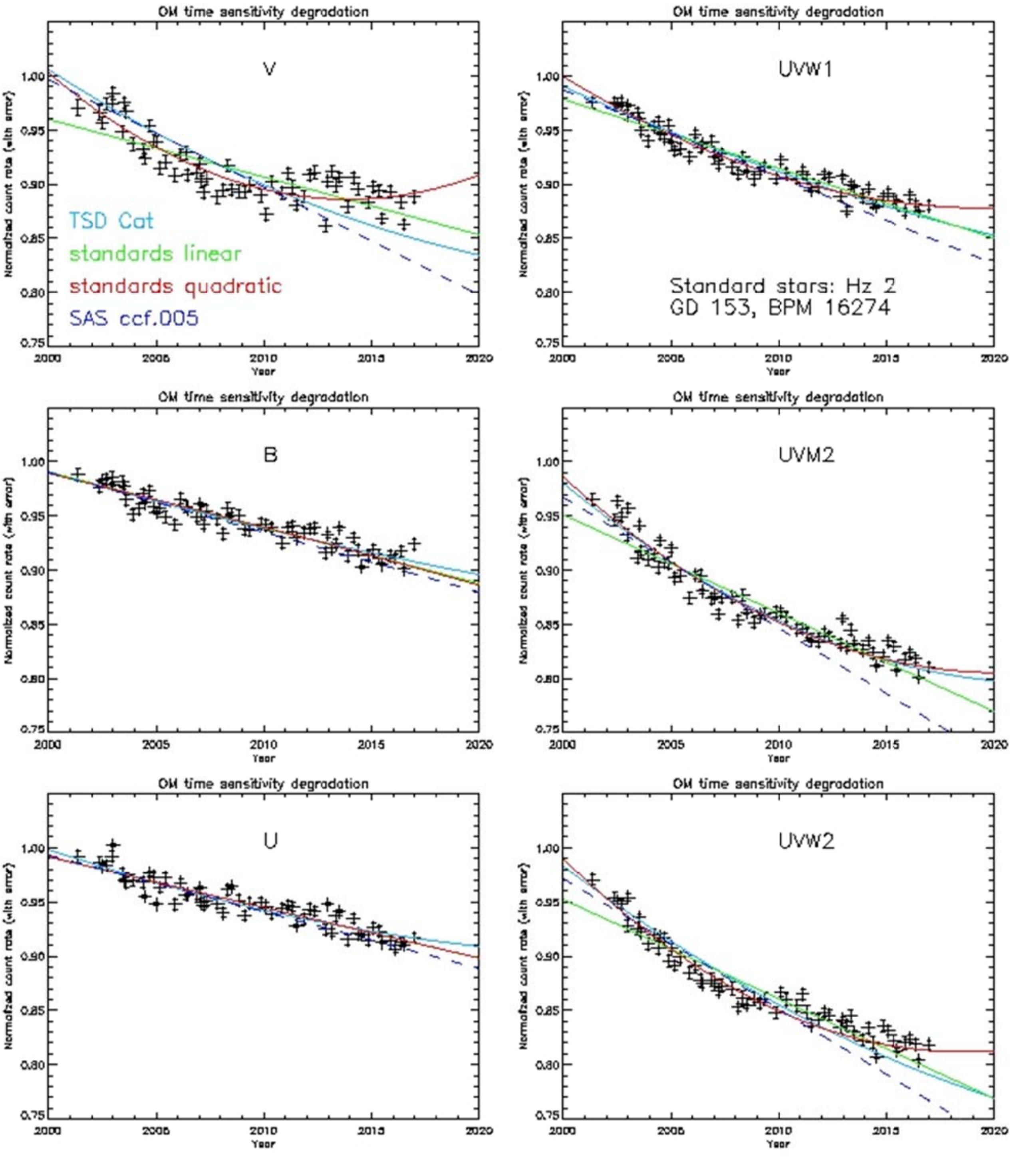

Figure 1. OM time dependent sensitivity degradation: normalized, uncorrected rates of standard stars. Different fits to the data are explained in the text.

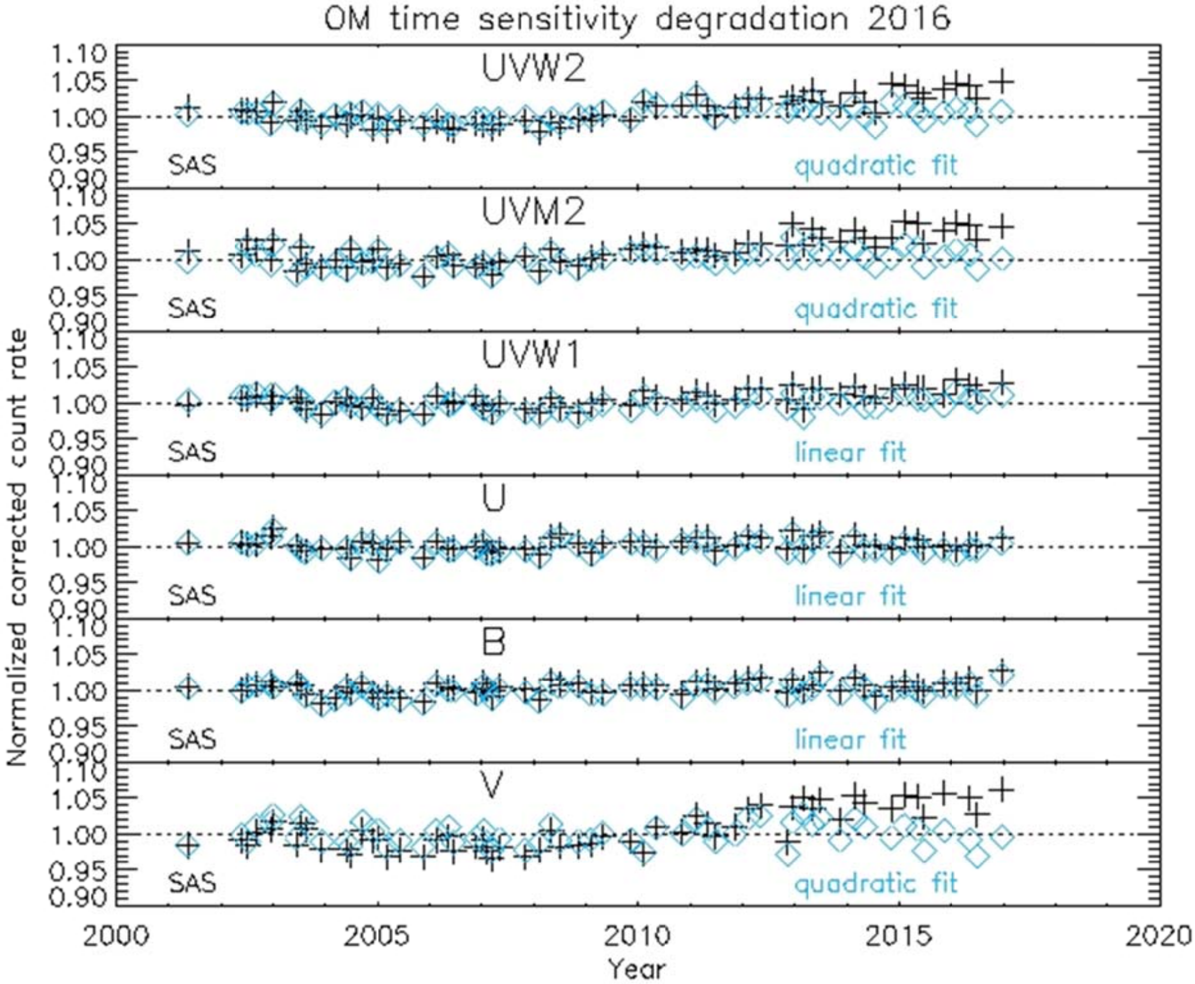

Figure 2. Corrected, normalized count rates of standard stars. Crosses: current SAS correction. Blue diamonds: new linear or quadratic fits to all stars, as of 2016

4 MEASURING THE TIME DEPENDENT SENSITIVITY DEGRADATION USING THE OM SERENDIPITOUS SOURCES CATALOGUE SUSS2.1

The OM Catalogue (SUSS2.1) contains all sources detected in all observations obtained till the end of 2013. A total of 4,246,432 sources with 831,582 of them observed more than once. This gives us a huge database to study the OM Time Dependent Sensitivity Degradation.

We have created a subset of the Catalogue containing all sources observed at least six times in any filter. In order to avoid "variable" sources we have applied a chi-square probability density function criterion (chi2pdf) to select the appropriate stars: only stars for which the measured rates in a filter give a chi2pdf less than 0.05 (namely a 95 % probability of not varying) have been selected. Table 2 gives the number of stars in each filter that satisfy this criterion.

Filter	UVW2	UVM2	UVW1	U	B	V
Sources	189	269	783	339	288	266

Table 2. Non variable sources from SUSS2.1 with 6 or more observations.

The same method used with the standard stars has been applied to the catalogue sources. The normalized uncorrected rates can be seen in Figure 3. We have depicted there the degradation trend implemented in SAS as well as a quadratic fit. It can be seen that the applied fit is very close to the SAS one (based on the standard stars), showing an increasing variation with time.

This quadratic fit is depicted also in Figure 1 (light blue line), with the standard stars degradation. Note that this new quadratic fit is monotonically decreasing.

The appearance in Figure 3 of several sources with the same observing time (vertical grouping) is due to the fact that the same observation can contain several sources that are used in the fit since they have repeated observations. This means that the sources used in the study are spread across the field of view and not necessarily located at the boresight as it is the case when we use the standard stars only. In other words, we are looking at the sensitivity degradation in the whole detector.

5 NEW CORRECTION

The correction for the OM time dependent sensitivity degradation was implemented in SAS in 2005. An update of the coefficients was made in 2011. The monitoring of the degradation trend has shown a slight deviation from the SAS linear correction, in particular for the UVW2, UVM2 and V filters. This deviation was very small, thus we decided not to make a new update since 2011. This deviation is reaching now 5% in some filters (see Figure 2), thus a new update is justified.

A correction based in many stars located in different positions of the detector seems to be more appropriate. Furthermore, we can see in Figure 4 how this new correction is applicable to the standard stars.

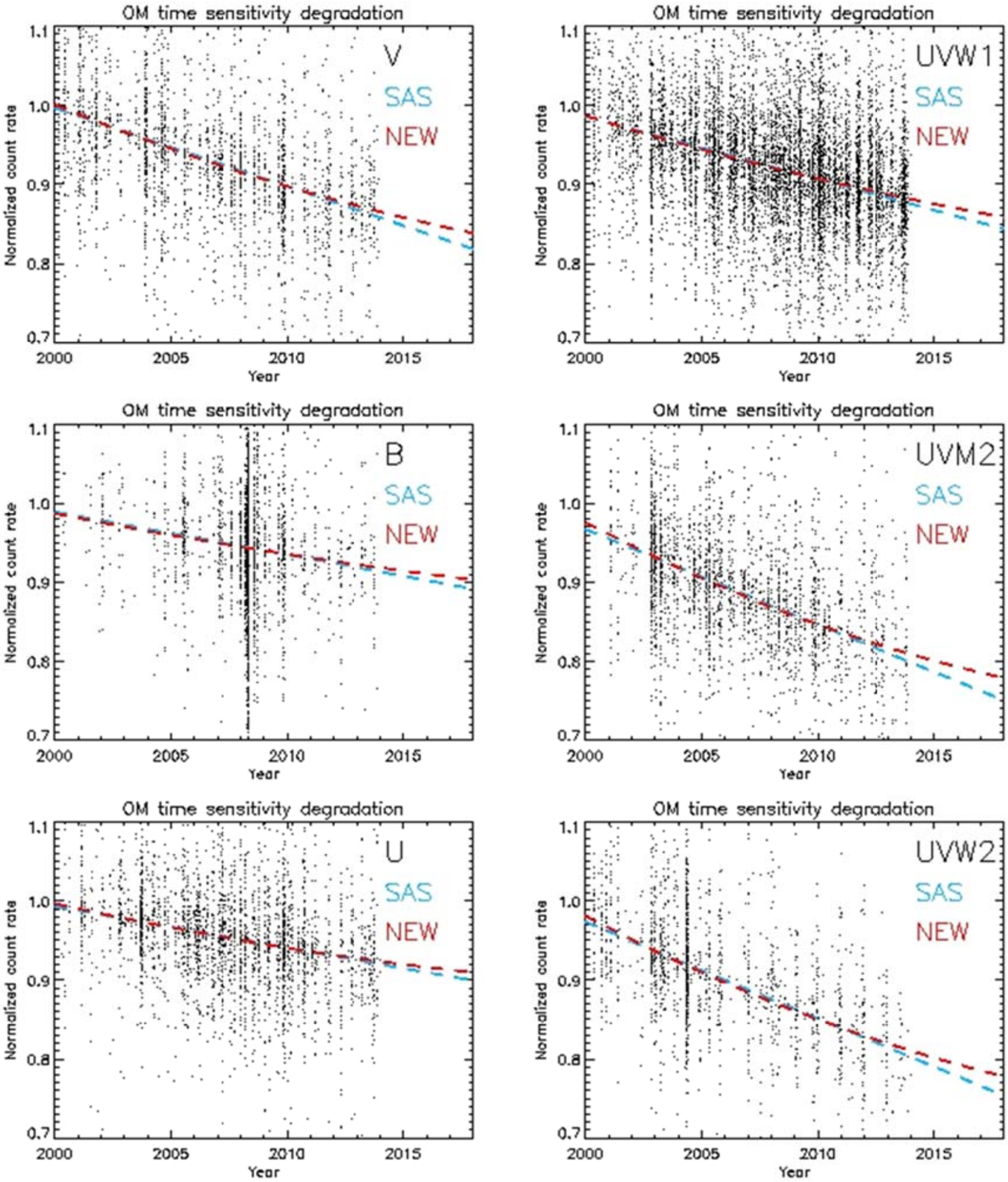

Figure 3. OM time dependent sensitivity degradation: uncorrected rates of many stars from the OM SUSS2.1 catalogue. Dashed blue shows the current SAS degradation. In red a new quadratic fit (see text).

Table 3 gives the coefficients of the proposed new correction based on OM catalogue stars. The proposed quadratic fit corrects better the small deviations we have mentioned before, without reversing the degradation.

Filter	***A***	***B***	***C***
UVW2	-3.2343915	1.1995443e-04	-7.2776106e-10
UVM2	-8.2351192	3.0736395e-04	-2.4809715e-09
UVW1	-1.4112562	6.8321895e-05	-4.1441952e-10
U	-2.0050605	9.7382127e-05	-7.5787927e-10
B	-4.1305610e-01	3.8843047e-05	-2.1839614e-10
V	-3.8775029	1.5212479e-04	-1.1183811e-09

Table 3. Time Sensitivity Degradation Correction coefficients derived from non variable sources extracted from SUSS2.1 (see text).

Figure 4 shows the standard stars, normalized and corrected using the new correction given in Table 3. These results present a standard deviation of less than 1% for all filters, except for UVW2 and V where it is 2%.

6 CONCLUSIONS

The time dependent sensitivity degradation of OM was established by using periodically repeated observations of a set of standard stars. The observed trend has also been monitored using these observations. The derived correction was implemented in SAS, first in 2005 and updated in 2011.

The same method has been used, but applied to a set of several hundreds sources obtained from the OM serendipitous sources catalogue. The results are very similar to those obtained with the standard stars. Although the differences are very small, the new derived correction seems to compensate the deviating trend observed in the last couple of years.

This new correction, given in table 3, will be used in SAS. The new version of the OM catalogue, SUSS3, will make use of the new correction.

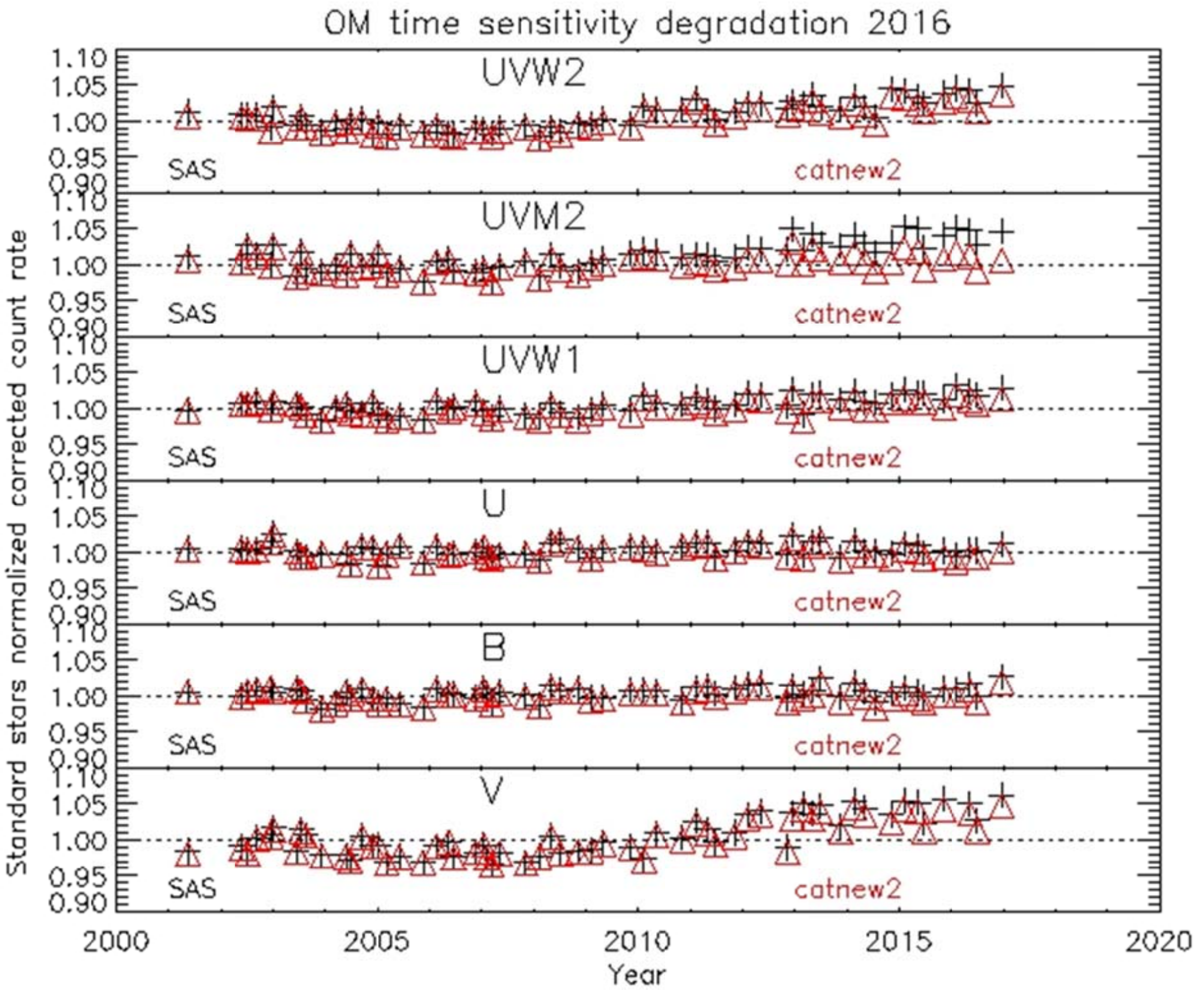

Figure4. Corrected, normalized count rates of standard stars. Crosses: current SAS correction. Red triangles: new quadratic correction derived from catalogue stars.