# DOCUMENT

# Update of the Correction for the Time Dependent Sensitivity Degradation of the Optical Monitor grisms.

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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. A correction for this instrumental degradation, which affects data obtained with the OM UV (Grism 1) and Visible (Grism 2) grisms, as well as the narrow band OM filters, was incorporated into the OM_GRISMCAL_0005 CCF file in 2018 and applied to the OM grism data for the first time via the SAS task, *omgrism* (v1.27). The calibration analysis on which the correction was based, was described in XMM-SOC-CAL-TN-0218 while the CCF was described in XMM-CCF-REL-359.

In this technical note, we outline a new update to the time degradation correction for the grism data, which includes some changes to the analysis methodology employed. In addition, the impact, on grism data, of the spatially localised degradation associated with the detector area damaged during an accidental observation of Jupiter in revolution 3224, is also discussed.

# 2 MEASURING THE TIME DEPENDENT SENSITIVITY DEGRADATION IN OM GRISMS

We have used spectra of the white dwarf spectrophotometric standard stars, GD 153, Hz 2 and BPM 16274. These stars have also been used, in the past, to measure the time dependent sensitivity degradation (TDS) and to derive the correction for observations obtained with the colour filters, though recent updates of the photometric TDS have been based on the Serendipitous Ultraviolet Source Survey (SUSS) catalogues. The first two stars are observed once per year and the third one twice. They are observed with all OM filters, including both grisms. In the current analysis, all the OM grism data used stem from the pipeline bulk reprocessing of all XMM data performed in 2019 using SAS 18.0.

As done previously, to increase the S/N of the extracted spectra, we have binned the wavelength dependent count rates into 250Å and 300Å bands for the UV grism and Visible grism, respectively. These bands are defined in Table 1.

| | | | | | | |
|---|---|---|---|---|---|---|
| UV grism | 2000 | 2400 | 2800 | 3200 | 3600 | 4000 |
| Visible grism | 3500 | 4000 | 4500 | 5000 | 5500 | 6000 |

**Table 1. Wavelength bin centroids (in Å) used to measure time dependent sensitivity loss in the OM grisms.**

A significant number of these measurements from the spectra of each star are affected by quality issues, such as contamination of the spectrum itself, or the background region, by zeroth order features or spectra of other objects in the field-of-view (FoV), or by other image features and artefacts, such as scattered light or the localised, degraded sensitivity patch caused by the accidental OM observation of Jupiter in revolution 3224 (hereafter referred to the JDP). The JDP principally affects data obtained in the 2400Å (and to a much lesser extent, the 2000Å) bands in the UV grism and the 4000Å (and less so, the 3500 Å) bands in the Visible grism data. We discuss this JDP feature further in section 4. The impact of contaminating features on the standard star spectrum varies depending on the exact location of the target object in the FoV and the roll angle of the observation. Count rate measurements from bands where contamination/artefacts were clearly present, were excluded from the analysis.

With the available temporal measurements (time-series) in each band, of each star, we determine the degradation as a simple linear function. As previously (XMM-SOC-CAL-TN-0218), due to the level of noise/scatter in the measurements, we consider the degradation to be the same for all wavelength bands for a given grism, thus obtaining one decline function for each grism. However, the approach used for this update is slightly different. Previously, for each grism, the timeseries measurements in each band, from each star, were normalised by an estimate of the rate at epoch t=2000.0 derived from those data, and then all the normalised measurements were fitted with a linear polynomial. Instead, we now fit all the measured time-series from each band and each star simultaneously with a linear function that has a common slope but band and star -dependent normalisations, i.e. we fit a function of the form $R_{s,b}(t) = A_{s,b}$ (1 + B.t), to all the data, where $R_{s,b}(t)$ is the measured rate in band, b, for star, s, at time t (measured relative to epoch 2000.0), $A_{s,b}$ is the normalisation at t=2000.0 (3 weeks after the launch of XMM) for the star and band, and B is the common slope.

The fitted polynomial function, (1 + B.t), relevant to the data for the UV and Visible grisms, are shown in figure 1, overlaid on the data of each star and each band, which have been normalised by the relevant, fitted, normalisation factors. The fitted slope values are provided in table 2.

| ***Grism*** | ***B*** |
|---|---|
| *UV_grism* | -0.005803 |
| *V_grism* | -0.004126 |

**Table 2. Slope values for the linear fits of the time dependent sensitivity degradation of OM grism spectra. The constant of the linear function is 1.0 in both cases.**

It can be seen in the UV grism panel of figure 1 that there is, apparently, larger scatter in the data obtained from BPM16274 in 2017, 2018 and 2019 than in earlier data. This is probably due to contamination of the background region from an adjacent, serendipitous spectrum in the 4000Å band and possibly, unrecognised contamination of the source spectrum in the 2000 Å band. The 3 or 4 largest high outliers in these observations are associated with the 2000Å band while the 4 lowest outliers are from the 4000Å band. We have not, however, excluded the outliers from the fit as the contamination is not clear, and in any case, their inclusion makes less than 1% difference to the derived slope.

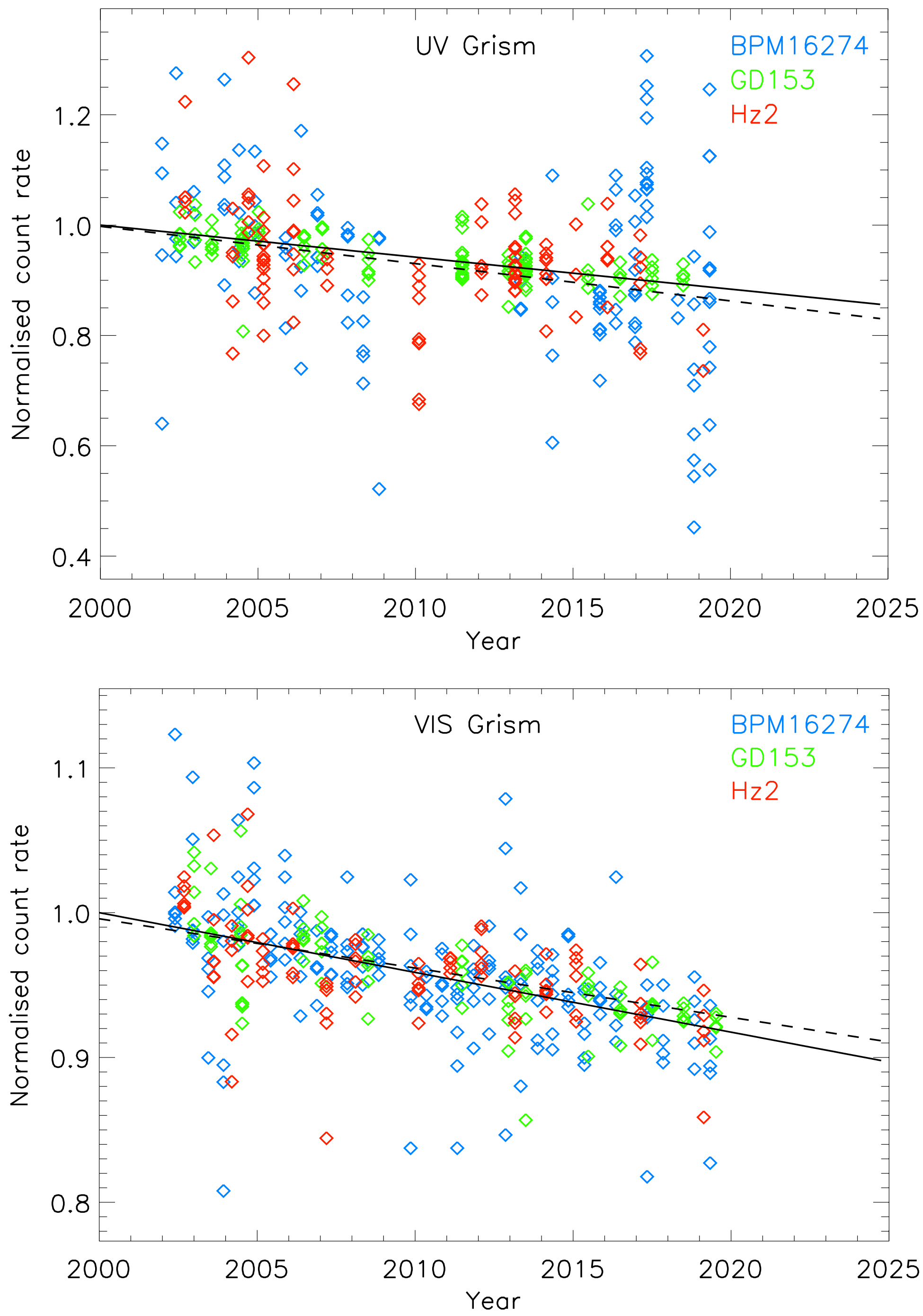


**Figure 1:** OM time-dependent sensitivity degradation for the UV grism (upper panel) and Visible grism (lower panel). The solid black line in each panel is the current fit while the dashed line is the previous fit from OM_GRISMCAL_0005.

# 3 CORRECTION FOR THE TIME DEPENDENT SENSITIVITY DEGRADATION IN OM GRISMS

The linear fits shown in Figures 1 and 2 give us an approximate value of the degradation affecting OM grism spectra. We reiterate the point made in XMM-SOC-CAL-TN-0218 that the level of scatter in grism data prevents us from deriving an accurate value. As such, we cannot offer an accurate correction for this effect but the analysis permits users to make an approximate correction for degradation that enables them to compare OM spectra of the same source obtained at very different epochs, given the longevity of the OM instrument and XMM-Newton mission.

The fitted function defined in section 2, is used to obtain the residual throughput at a set of uniformly spaced (2 years) epochs between 2000 and 2022, according to

*Degradation = 1.0 + B x Year_of_Observation*

Where the year of observation is measured from 2000.0.

| ***Year*** | ***UV_Grism*** | ***V_Grism*** |
|---|---|---|
| 2000 | 1.000 | 1.000 |
| 2002 | 1.012 | 1.008 |
| 2004 | 1.024 | 1.017 |
| 2006 | 1.036 | 1.025 |
| 2008 | 1.049 | 1.034 |
| 2010 | 1.062 | 1.043 |
| 2012 | 1.075 | 1.052 |
| 2014 | 1.088 | 1.061 |
| 2016 | 1.102 | 1.071 |
| 2018 | 1.117 | 1.080 |
| 2020 | 1.131 | 1.090 |
| 2020 | 1.146 | 1.100 |

**Table 3: Correction factors for the time dependent sensitivity loss in OM grisms.**

To obtain the corrections, in another change to the method, rather than fitting a linear function to the inverse of the data, we take the inverse of the decline function – specifically, the correction values, which are presented in table 3 and stored in the OM_GRISMCAL_006 CCF update, are simply the inverses of the throughput values at the grid points. Users can obtain the appropriate correction estimate by interpolation of the tabulated values, for any epoch in the range. Note, however, that this is generally unnecessary as, since SAS 18, the correction is automatically applied by the SAS tasks used to process OM grism data; the correction value is also written, as a header keyword, TDS_CORR, in the grism spectra FITS files. It is applied only to the fluxed spectrum, not to the count rates in the grism spectra files.

As the error bars on the data points are quite large, yielding reduced $\chi^2$ values substantially less than 1, we have estimated statistical uncertainties through simulations. For each grism, the best fit to the normalized data was used to simulate 100,000 sets of the data used in the analysis. In each simulation, each data point was deviated from the model fit by a random Gaussian deviation with the Gaussian sigma defined by the real data point error bar. Each simulated data set was then fit by a polynomial and the parameters, including the predicted residual throughput at 2020.0, were recorded and then used to generate distributions of the parameters, from which the uncertainties were determined. We estimate 1-$\sigma$ errors of 1.7% and 1.4% on the UV and Visible grism degradation (and correction), respectively, at 2020. These estimates are statistical and do not include systematic effects.

# 4 IMPACT OF THE JUPITER DEGRADATION PATCH ON OM GRISM DATA

The small, localized patch of reduced sensitivity in the OM caused by the accidental observation of Jupiter has been discussed in XMM-CCF-REL-353. The image pixels in the patch are recorded in the OM bad pixel CCF (OM_BADPIXEL_0006 and thereafter, see XMM-CCF-REL-353 and XMM-CCF-REL-368) and, for photometric data, sources that are detected within this area (during routine OM data processing), have a 'bad' quality flag set. For grism data, however, no flagging is currently provided.

For target sources that are observed in the default grism window configuration at epochs after revolution 3224, users should thus be aware that a portion of the spectrum of a target source will likely be affected by this patch. In the UV grism, data in the 2120Å - 2600Å range are affected, with a maximum degradation of ≈25% at 2350Å, while for the Visible grism, the 3440Å - 4180Å range is affected, with a maximum impact also of about 25%, at 3860Å. Figure 2 shows part of a UV grism image of GD153, where the Jupiter patch can clearly be seen as a darker elliptical region, while figures 3 and 4 show the extracted count rate spectrum and fluxed spectrum, respectively, of the source, both displaying a clear depression around 2400Å, due to the patch.

The impact of the JDP is not currently corrected in SAS or pipeline processing. It should also be noted that the amount of degradation can depend sensitively on the exact location of the spectrum since the degradation in the patch has a strong spatial dependence.

# 5 CONCLUSIONS

An update for the time-dependent sensitivity degradation of the OM grisms has been presented, which involves both the inclusion of the latest available calibration source spectra, and a modified approach to the analysis. The impact is modest, with a slightly shallower decline estimated for the UV grism and a slightly steeper decline for the Visible grism, than in the previous calibration CCF, by about 2% at 2020 in both cases. The current analysis extends the range of application of the correction to 2022, at which time a new update will be required.

At the current time, at least in part due to the significant scatter in the data, a dependence of the degradation trend with wavelength within a given grism, has not been clearly identified in the data and the analysis derives a single degradation slope for each grism. Nevertheless, we will continue to monitor the data to quantify any such trends, if they become statistically recognizable.

We have also drawn attention, for the first time, to the impact of the 'Jupiter degradation patch', on grism data taken since the event. It was shown that the spectra of targets observed in the default grism observing configuration, for both grisms, cross the patch and consequently suffer from suppressed count rates over limited wavelength ranges, by up to about 25%, depending on the spatial positioning of the source.

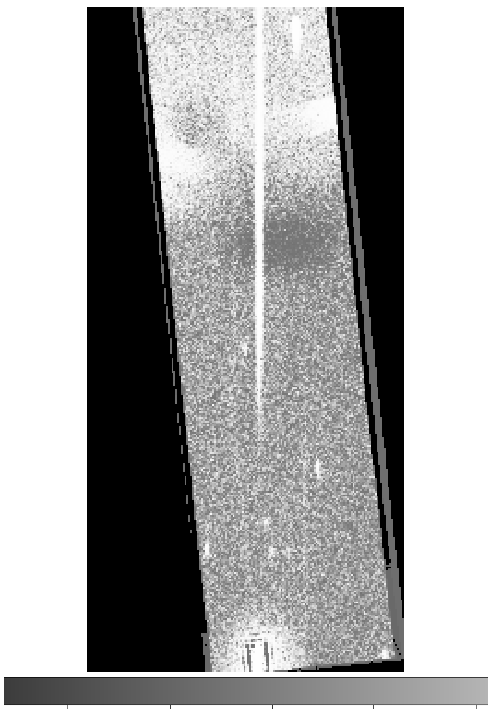

**Figure 2: UV grism image of GD153. The spectrum falls across the dark region of the Jupiter degradation patch.**

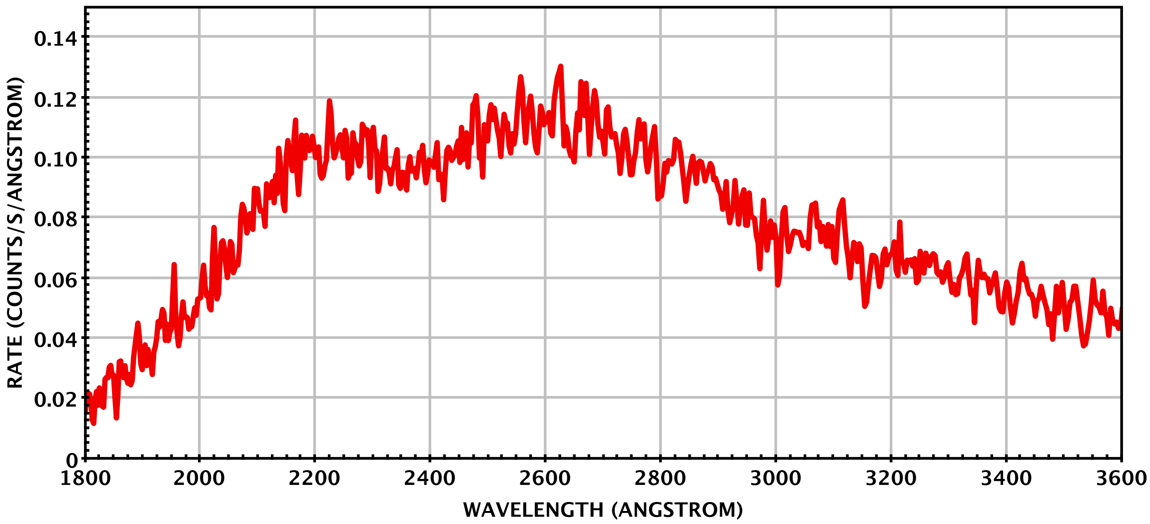


**Figure 3: Extracted (background-subtracted) count rate spectrum of GD153 in the 1800Å - 3600Å range, from the data in figure 2. The effect of the JDP is evident as the prominent depression centred at about 2400Å, where, in these data, the effect is about 20% but note, from figure 2, that the spectrum does not cross the central, deepest part of the patch.**

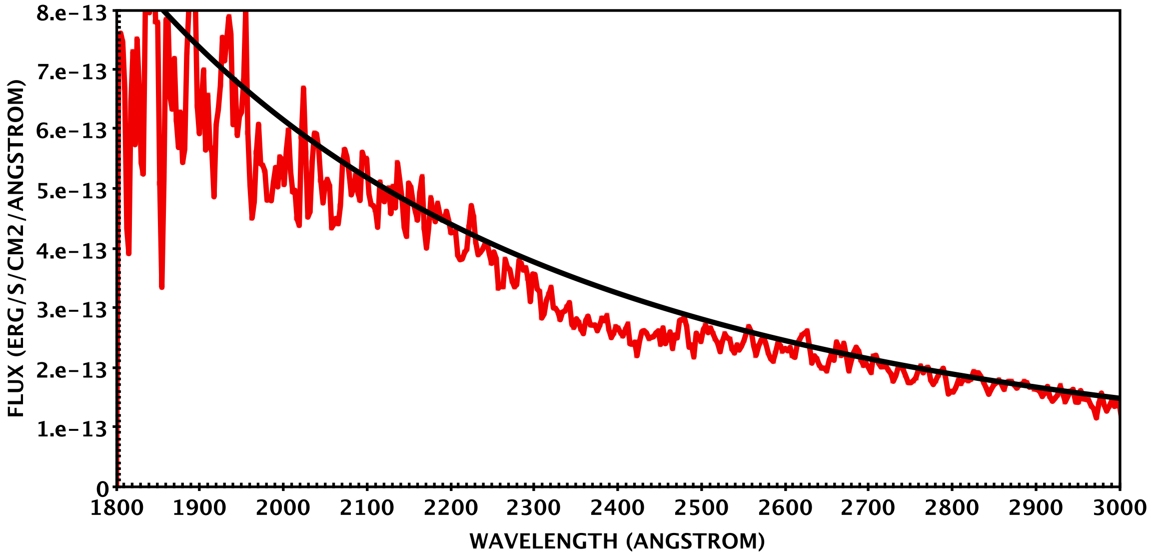


**Figure 4: Fluxed spectrum of GD153 in the 1800Å - 3000Å range, showing the prominent depression centred at about 2400Å. The black line is a power law profile that approximately fits the continuum data either side of the dip.**