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┌ Science Operations ┐

—
2nd order contamination in EFOSC2's grisms
Report

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1 Introduction

The efficiency of the system EFOSC2 + 3.6m telescope was re-measured for the spectroscopic observing mode. These efficiency curves have been sent to DMD in Garching to create an Exposure Time Calculator for EFOSC2. While measuring the efficiencies, strong variations in the efficiency values showed up, depending on the standard star used. Since the detector in EFOSC2 is very sensitive in the blue, it was immediately assumed that these differences might have to do with 2nd order contamination, which leads to an overestimation of the efficiency in case blue standard stars are used.

I here report on a thorough analysis of this problem using red and blue standard stars as well as flatfields with and without order sorting filter.

1.1 Applicable documents

The following documents, of the exact issue shown, form a part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this document, the contents of this document shall be considered as a superseding requirement:

1.2 Reference documents

The following documents are referenced in this document:

[3] LSO-MAN-ESO-36100-0004 EFOSC2 Users' Manual

1.3 Abbreviations and acronyms

The following abbreviations and acronyms are used in this document:

SciOp	Science Operations
LSO	La Silla Observatory
ESO	European Southern Observatory
EFOSC	ESO Faint Object Spectrograph and Camera
IRAF	Image Reduction and Analysis Facility
MIDAS	Munich Image Data Analysis Software
CTIO	Cerro Tololo Interamerican Observatory

1.4 Glossary

1.5 Stylistic conventions

The following styles are used:

bold	in the text, for commands, filenames, etc., as they have to be typed.
<i>italic</i>	for parts that have to be substituted with real content.
teletype	for examples.

Bold and *italic* are also used to highlight words.

2 Overview

To quantify the effect of second order contamination, we have observed standard stars with various colour terms, i.e. very blue and very red stars. A presence of second order contamination is supposed to result in a rise in the efficiency curve derived from the blue standards. Due to the atmospheric cutoff at 340 nm, this rise should start beyond 680 nm (2×340 nm). The efficiency curve derived from a red star should show no such effect or at least not in the same magnitude.

We therefore use the quotient of the "blue" efficiency over the "red" efficiency as a measure for the second order contamination in dependency of the wavelength.

For some grisms, we have also analysed flatfields taken with and without an order sorting filter, and compared the results to those derived from the standard star measurements.

At the end, we give recommendations, which grisms should rather be used together with an order sorting filter, and which kind of filters are needed for this purpose.

3 Observations and data reduction

Optical spectroscopy of spectrophotometric standard stars was obtained in three different nights to get data for all available EFOSC grisms. We took care to only use data taken in photometric conditions. The slit-width used was 5 arcsec in all cases. Table 1 gives the details of the observations and also lists the colour terms of the observed standard stars.

Standard reduction of the data has been done using IRAF. The BIAS has been subtracted and the data have been divided by a flat field, which was normalised by fitting Chebyshev functions of high order to remove the detector specific spectral response. The spectra have been optimally extracted (Horne 1986, PASP 98, 609). Wavelength-calibrations was done using He-Ar lamp spectra taken at the beginning of each night. The standard stars have been observed close to zenith to be at low airmass. Nevertheless, extinction correction has been performed using average values derived from CTIO as implemented in IRAF. All later handling of the data has been done using MIDAS.

4 Analysis

4.1 The second order effect derived from standard stars

To evaluate the amount of second order contamination we have determined the system efficiency (EFOSC2 + 3.6m telescope) for each spectrophotometric standard star. The script **efficiency.prg** written by E. Pompei and archived under cmm module nttplemmi, v.2.5 has been used for this purpose. It compares the one-dimensional, wavelength-calibrated, and extinction corrected standard star spectrum with the tabulated spectrum given in MIDAS (Hamuy et al. 1992, PASP 104, 533; Hamuy et al. 1994, PASP 106, 566). The result are tables for each star which give the efficiency in dependency of the wavelength. The standard stars have been divided in blue ones ($B - V < 0.5$) and red ones ($B - V > 0.4$). The efficiencies of the blue stars and the efficiencies of the red stars have been averaged and the quotient Eff_{blue}/Eff_{red} has been computed for each grism. The results are shown in Figure 1. Note that only the data for the red grisms have been plotted as the blue grisms do not show any second order contamination nor are they expected to do so.

The main results of this analysis can be summarised as follows:

- grism # 1 shows second order contamination starting at 9200Å

Table 1: Summary of the observational details.

Grism	Date	Object	$B - V$	Grism	Date	Object	$B - V$
# 1	2004-08-27	LTT 7379	+0.61	# 11	2004-08-28	LTT 1020	+0.56
	2004-08-27	LTT 7987	+0.05		2004-08-28	LTT 7987	+0.05
# 2	2004-08-27	LTT 7379	+0.61		2004-08-28	LTT 9239	+0.61
	2004-08-27	LTT 7987	+0.05	# 13	2004-08-27	LTT 7379	+0.61
# 3	2004-08-28	LTT 1020	+0.56		2004-08-27	LTT 7987	+0.05
	2004-08-28	LTT 7987	+0.05	# 14	2004-08-28	LTT 1020	+0.56
	2004-08-28	LTT 9239	+0.61		2004-08-28	LTT 7987	+0.05
	2004-08-28	LTT 9491	+0.03		2004-08-28	LTT 9239	+0.61
# 4	2004-08-28	LTT 1020	+0.56	# 16	2004-08-27	LTT 7379	+0.61
	2004-08-28	LTT 7987	+0.05		2004-08-27	LTT 7987	+0.05
	2004-08-28	LTT 9239	+0.61		2004-08-28	LTT 7987	+0.05
	2004-08-28	LTT 9491	+0.03		2004-08-28	LTT 1020	+0.56
# 5	2004-08-27	LTT 7379	+0.61		2004-08-28	LTT 9239	+0.61
	2004-08-27	LTT 7987	+0.05	# 17	2004-11-17	EG 21	+0.04
# 6	2004-08-27	LTT 7379	+0.61		2004-11-17	Feige 110	-0.30
	2004-08-27	LTT 7987	+0.05		2004-11-17	LTT 1020	+0.56
# 7	2004-08-27	LTT 7379	+0.61		2004-11-17	LTT 1788	+0.47
	2004-08-27	LTT 7987	+0.05	2004-11-17	LTT 9239	+0.61	
# 8	2004-08-28	LTT 1020	+0.56	# 18	2004-08-27	LTT 7379	+0.61
	2004-08-28	LTT 7987	+0.05		2004-08-27	LTT 7987	+0.05
	2004-08-28	LTT 9239	+0.61		2004-08-28	LTT 7987	+0.05
	2004-08-28	LTT 9491	+0.03		2004-08-28	LTT 1020	+0.56
# 10	2004-08-28	LTT 1020	+0.56		2004-08-28	LTT 9239	+0.61
	2004-08-28	LTT 7987	+0.05	2004-08-28	LTT 9491	+0.03	
	2004-08-28	LTT 9239	+0.61				

2nd order contamination from standard stars

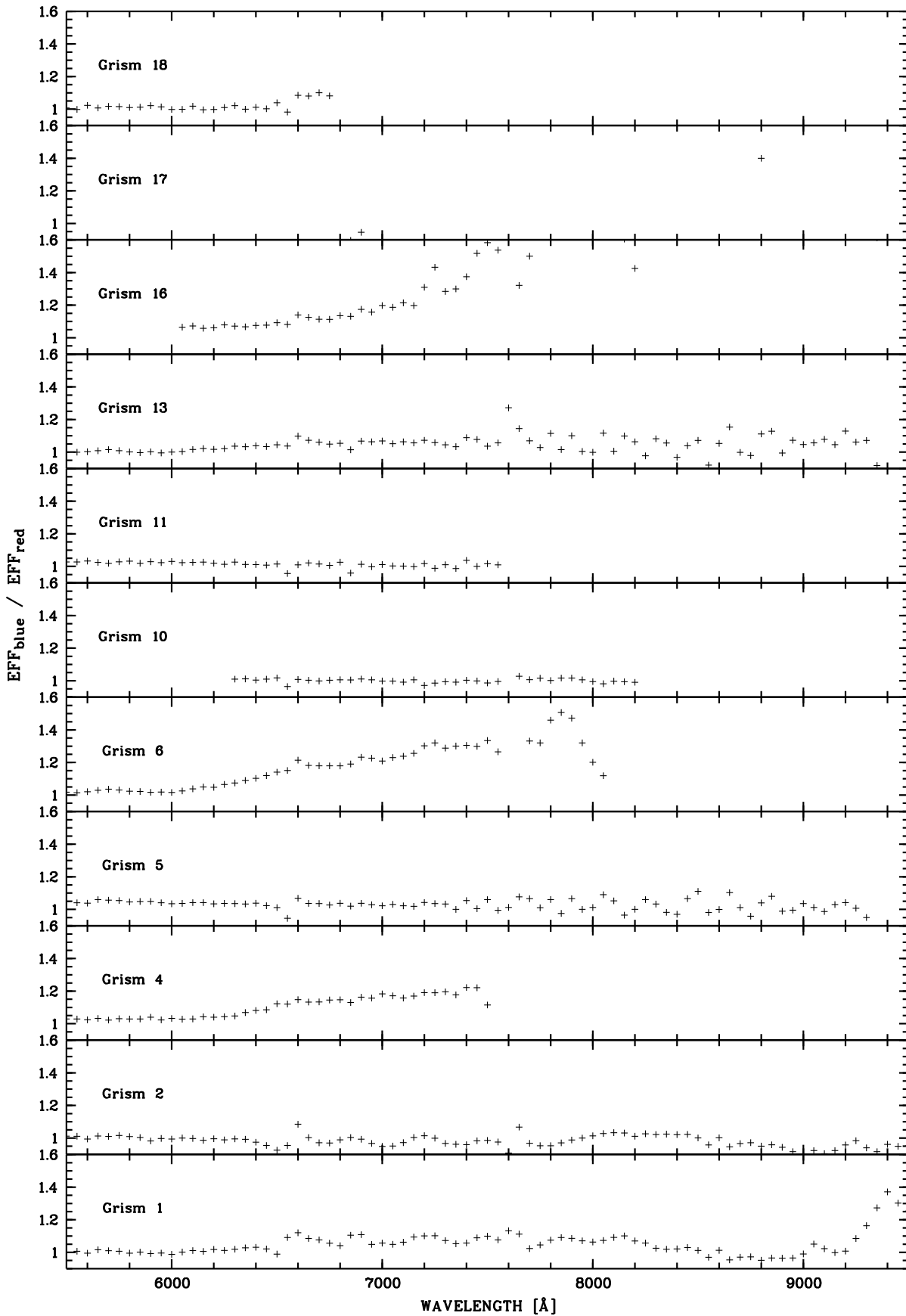


Figure 1: The quotient of "blue" efficiency over "red" efficiency has been plotted against the wavelength for all grisms.

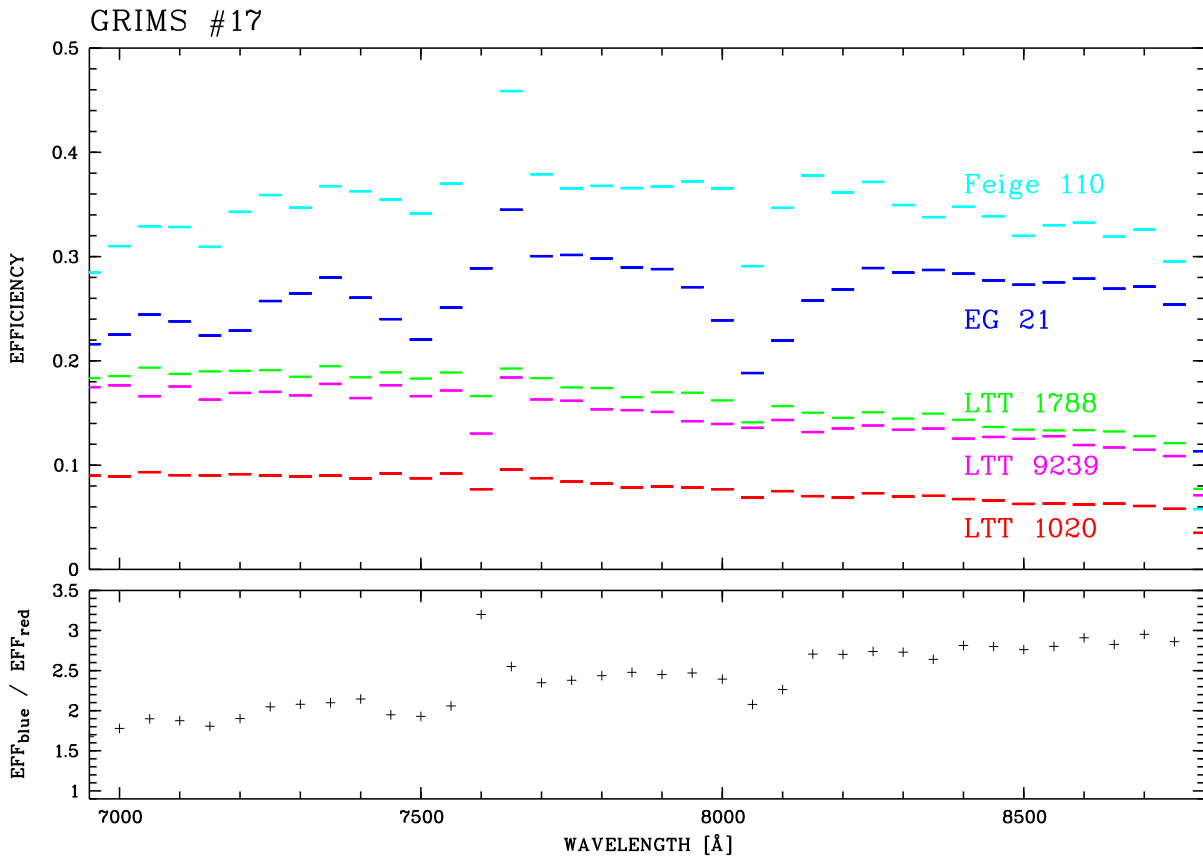


Figure 2: For grism #17, the second order contamination and the efficiencies as derived from the observed standard stars are plotted against the wavelength. The three red stars provide a significant lower "efficiency" than the blue ones.

- grism # 4 and grism # 6 show second order contamination starting around 6300Å
- grism # 16 shows second order contamination starting at 6800Å
- grism # 17 has an extremely high quotient, nearly all points are outside the plotted range; the grism will be analysed in more detail below
- grisms # 2, 5, 10, 11, 13, and 18, show no or only very little second order contamination.

4.1.1 Grism # 17

In Figure 2, the quotient of "blue" over "red" efficiency has been plotted against the wavelength. The quotient reaches values of up to 3 which suggest an extremely high contamination from the second order. To evaluate this contamination, the individual efficiencies have been plotted above. One notices immediately that the efficiencies of both "blue" standard stars (Feige 110 and EG 21) are significantly higher than those derived from the red stars, also the shape of the efficiency curve is different. The blue stars also show the blue Balmer absorption lines in second order: $H\beta$ at $\approx 8050\text{Å}$, $H\gamma$ at $\approx 7500\text{Å}$, and $H\delta$ at $\approx 7150\text{Å}$. We thus conclude that grism # 17 is indeed affected by strong second order contamination.

Grism # 17 had been bought to replace the damaged grism # 15. While we did not find any analysis of second order contamination for this old grism, we still have the HeAr-lamp spectra for the classification of spectral lines (see Figure 3). An analysis of this spectrum reveals several second order

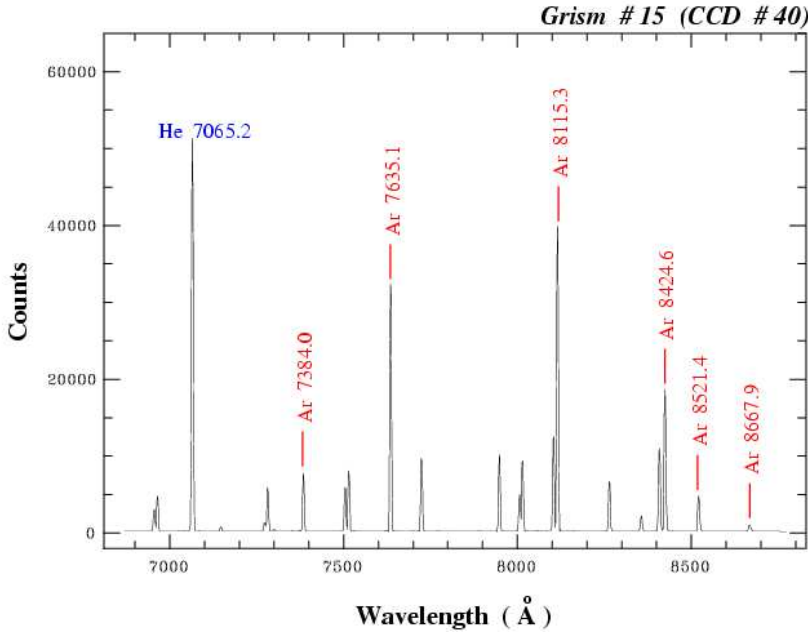


Figure 3: The HeAr-lamp spectra taken with grism # 15, which was replaced by grism # 17. Among the first order lines also strong lines of second order are visible.

lines: Ar 4158 and Ar 4201 around 8400Å, He 3889 around 7950Å, and He 3188 around 7500Å. This shows that also in the original grism # 15 second order contamination was present.

4.2 The second order effect derived from flatfields

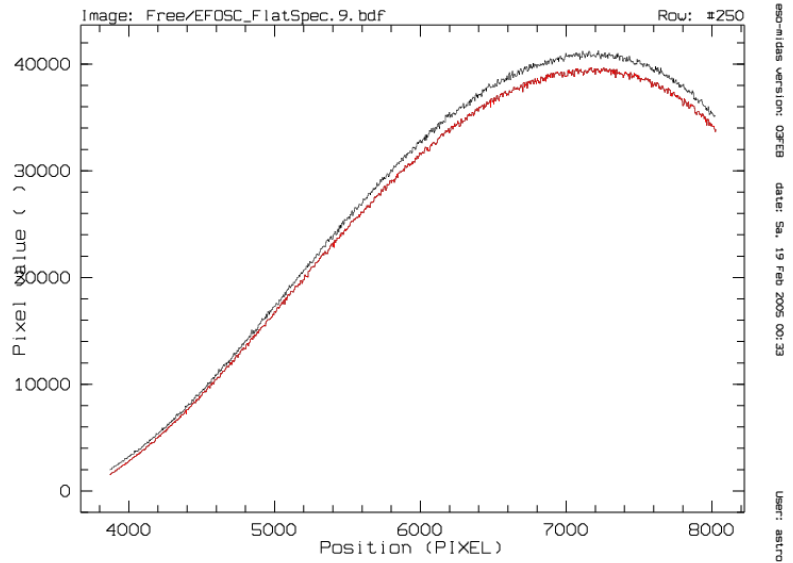
An independent analysis of the second order contamination has been done for grisms # 11, # 13, and # 6. Domeflats have been taken for these grisms with and without an order sorting filter which was mounted in the filter wheel of EFOSC. The filter was chosen to cut at 3600Å. Figure 4 shows a trace through these flatfields, the black one being without, the red one with the order sorting filter. Although the lamps used for taking domeflats are not specially blue, the effect of the filter is clearly seen. Surprisingly, also the grisms # 11 and # 13 show a small second order effect in this analysis.

5 Conclusions

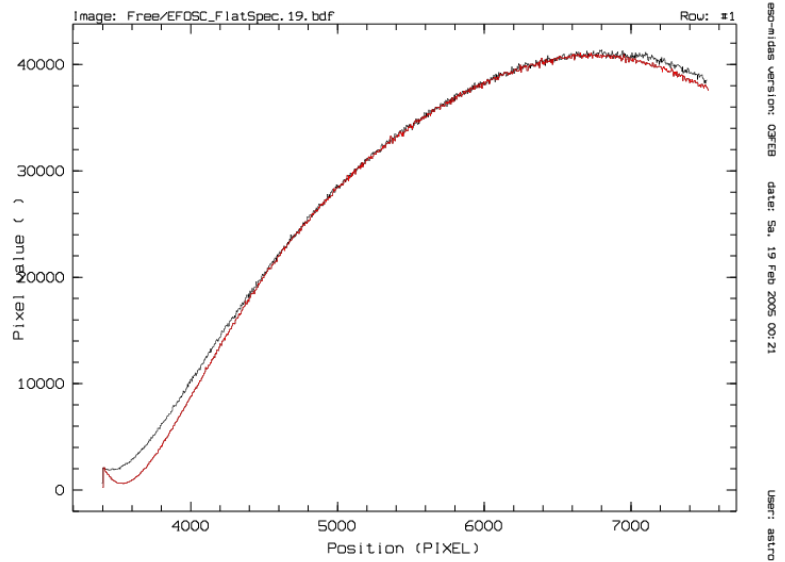
Second order contamination is present in several EFOSC grisms but in most cases (apart from grism#1, which has a too large spectral range) can be subdued by the usage of special second order cutting filters, which open for wavelengths above a cutting edge only:

- grisms # 11 and # 13 show only a small amount of second order contamination; if the red part of the spectra is needed, the usage of a filter is recommended for observations of very blue objects; for grism # 11 it has to cut at 3750Å; note though that this reduces the efficiency in the blue, and reduces the spectral range, as the blue end is at 3380Å without the order sorting filter; for grism # 13 the filter has to cut at 4650Å, again reducing the original spectral range
- grism # 4, grism # 6, and grism # 16 show strong second order contamination which can however easily be corrected with a filter cutting at about 3900Å for #4 and #6 and at about 5000Å for #16. Thus the spectral range is hardly diminished, but the contamination sufficiently suppressed. The usage of such filters is recommended for the observation of any blue objects.

grism # 6:



grism # 11:



grism # 13:

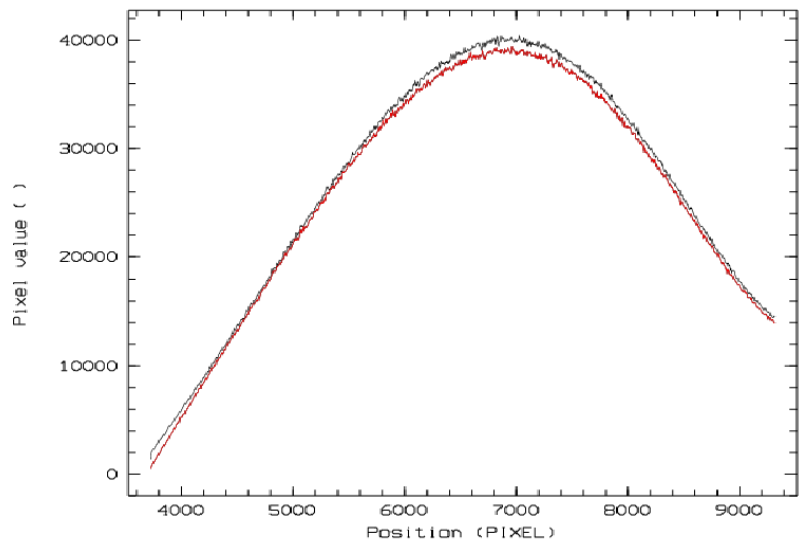


Figure 4: Traces through a flatfield taken with (red) and without (black) an order sorting filter.

- the contamination in grism # 17 is of such a magnitude that its usage without a second order cutting filter is strongly discouraged; the filter has to cut at 4400Å and does thus not influence the the spectral range of this grism

A further analysis of the second order contamination is required. In particular the comparison of observations with and without order sorting filter should be done for all grisms. We also need to test different order sorting filters to establish there suitability with respect to suppressing the second order while least influencing the spectral range of the grisms.

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