Problem with MODS data in the blue channel

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1. Introduction

During the 2013 June Italian run, a MODS blue proposal (MOS) has been observed (ID 31) and reduced. The PI is interested in measuring absorption features of high redshift objects. These feature are expected to be observed in the bluest region of the spectra.

The PI contact us because no features appear in the reduced data. Event if the open shutter time is only a fraction (~85%) of proposal request time, in her opinion the amount of combined exposures should be enough to point out these features.

A further analysis on data, showed a shift (along the dispersion direction) the spectra features in the frame with one other. Stacking frames with no well matching features, generate stacked data with missing or very weak features.

2. Problem description and tests

We focus our attention on 9 consecutive scientific frames: file from mods1b.20130613.0008.fits to mods1b.20130613.0016.fits (briefly from 0008.fits to 0016.fits), obtained in the June 13th observing night.

High redshift targets are very faint in the individual blue frame, and no reliable measures can be performed on these frames. For this reason, to better investigate the problem, we use an alignment star, which has a very high S/N ratio, but not the same resolution of the scientific target (slit of 4” instead of 1”).

We slightly hacked to pipeline to extract alignment star, and we overplot nine the consecutive spectra of star, to measure if a this shift exists. Zooming around calcium absorptions area, we can highlight the spectra shift along the dispersion direction.

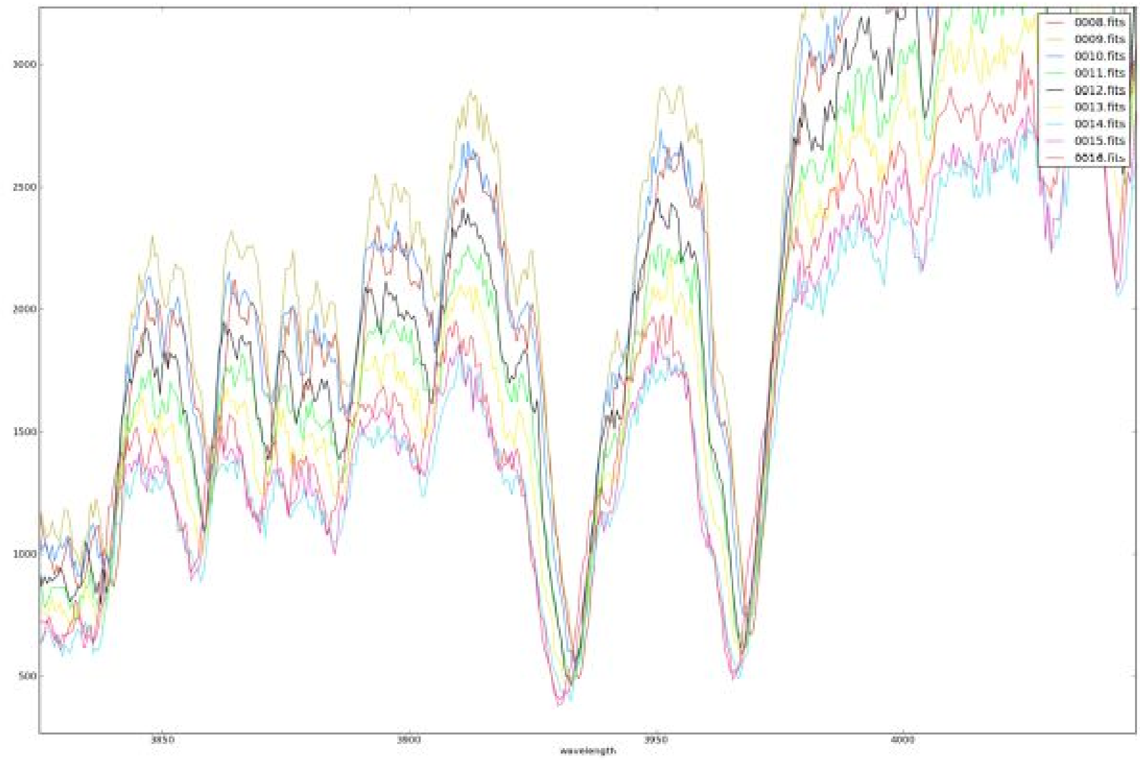


figure 1: Alignment star spectra: zoom in a blue zone

On the other hand, checking spectra in another wavelength region, we observed another amount of shift (the shift direction didn't change).

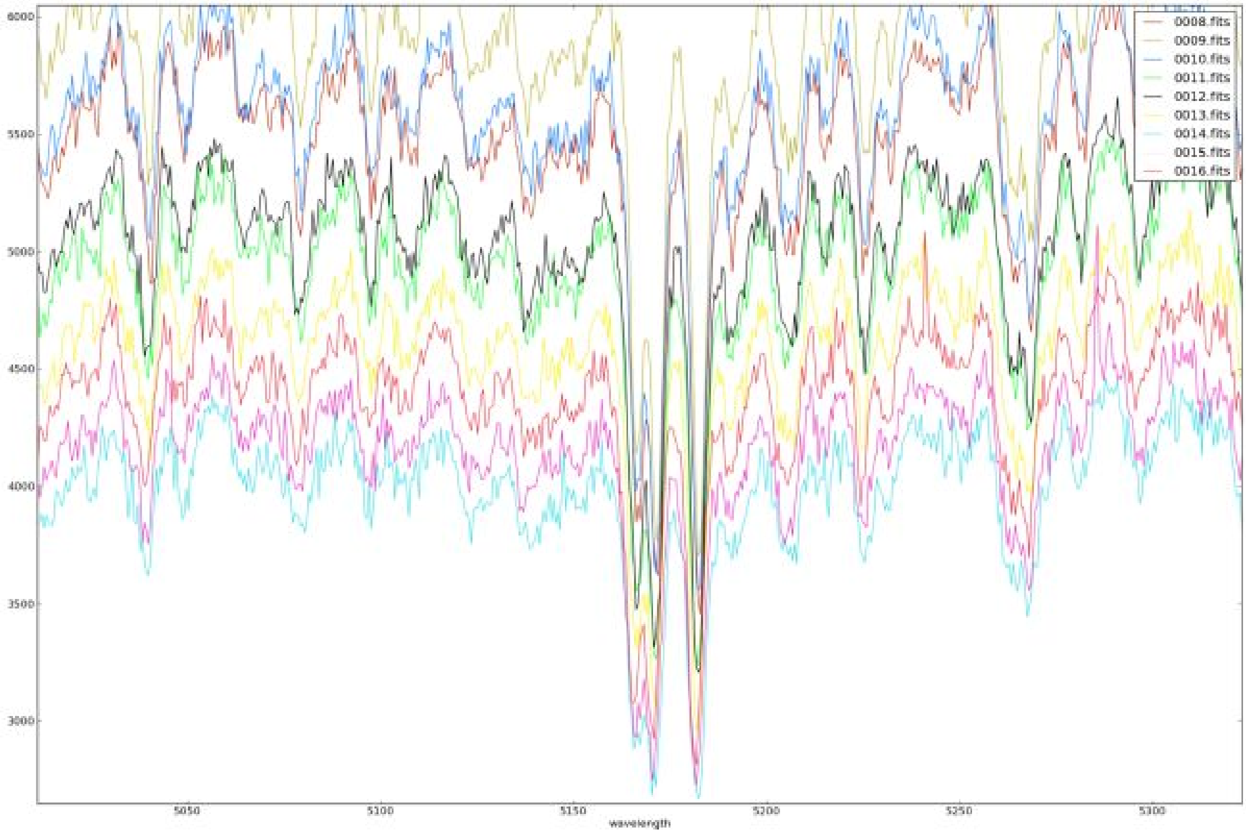


figure 2: Alignment star spectra: zoom in the red zone

The following table shows how performing a Gaussian fit on different spectra feature, we measured different shifts

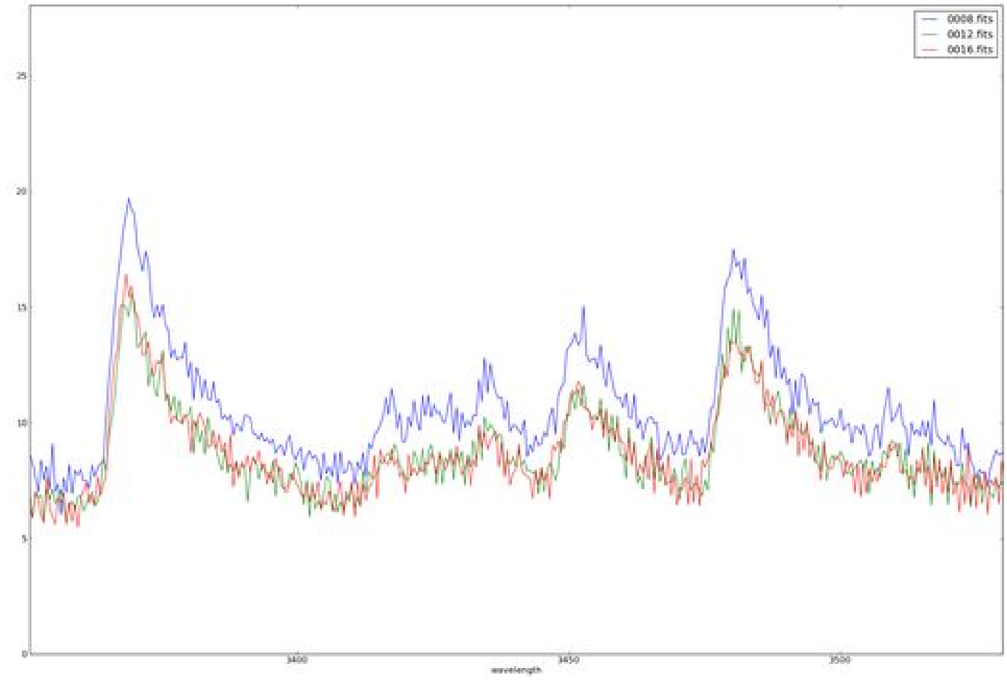
0008.fits	3934.48	4272.80	4860.61	5182.48
0009.fits	3934.13	4272.55	4860.52	5182.52
0010.fits	3933.59	4272.26	4860.29	5182.34
0011.fits	3933.13	4271.79	4860.11	5182.12
0012.fits	3932.94	4271.60	4860.02	5182.13
0013.fits	3932.38	4271.10	4859.79	5181.96
0014.fits	3932.09	4270.81	4859.61	5182.02
0015.fits	3931.49	4270.25	4859.30	5181.67
0016.fits	3930.94	4269.83	4859.00	5181.45

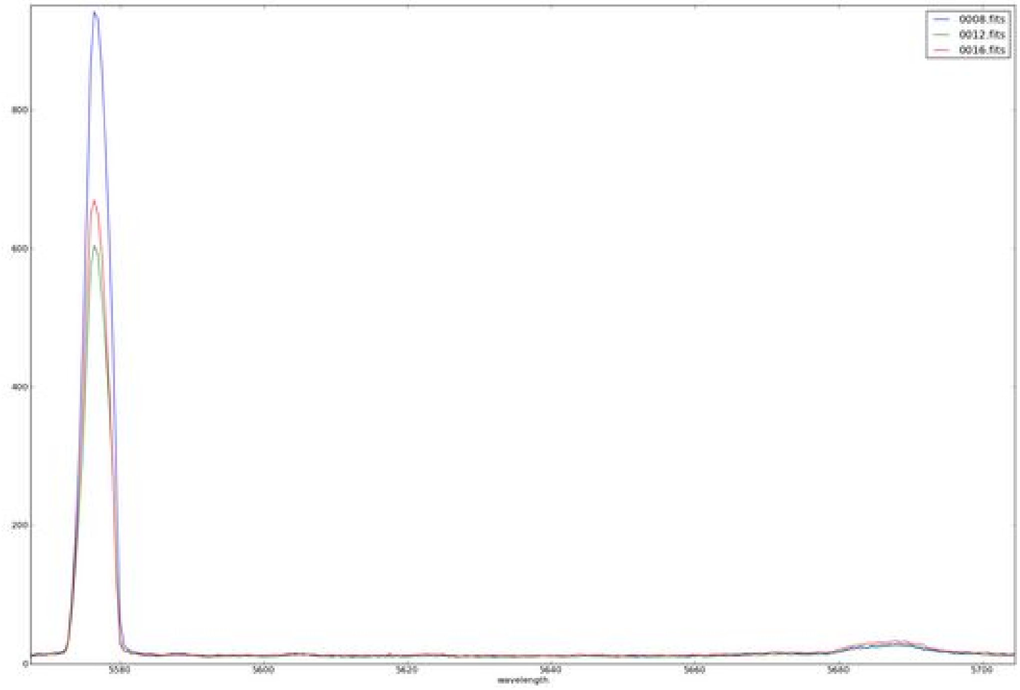
This first tests focused the problem: **data are not affected by a shift, but the are stretched along the dispersion direction.**

Moreover this difference, lead us to **exclude a guiding/tracking problem**. So we had to perform further tests to discover the origin of the problem.

A such kind of stretch could be explained by a tilt of the grism. A tilt should stretch the dispersed light along one direction, and the amount of stretch is greater on the border than in the middle of the frame. Whether the stretch it is due to a tilt problem, the same stretch must be measured as much on the scientific target as on the sky lines position.

Since one step of the data reduction is the background removal (usually called sky subtraction), we used these background subtracted as sky spectra. We selected a slit and extracted a sky spectra from the first, the 5th and the last exposure (frames 0008, 0012 and 0016) and overplot them.





The figure shows a zoom of this plot in a blue and in a red area, but in this case spectra feature appear perfectly aligned. **For this reason we can exclude a tilt problem.**

In order to check whether problem is introduced by our reduction pipeline, we executed a trivial spectra extraction on the raw data: we detect manually a blue region (X pixel ~2900) and a red region (X pixel ~6200), then sum columns in these regions to obtain respectively blue and red spectra features for the usual alignment star.

Obviously no lambda calibration and distortion corrections are applied, we just focus our attention on spectra counts. As before, we select 3 frames of the entire list: the first, the 5^{th} and the last one (0008, 0012, 0016 frames) and performed this trivial extraction.

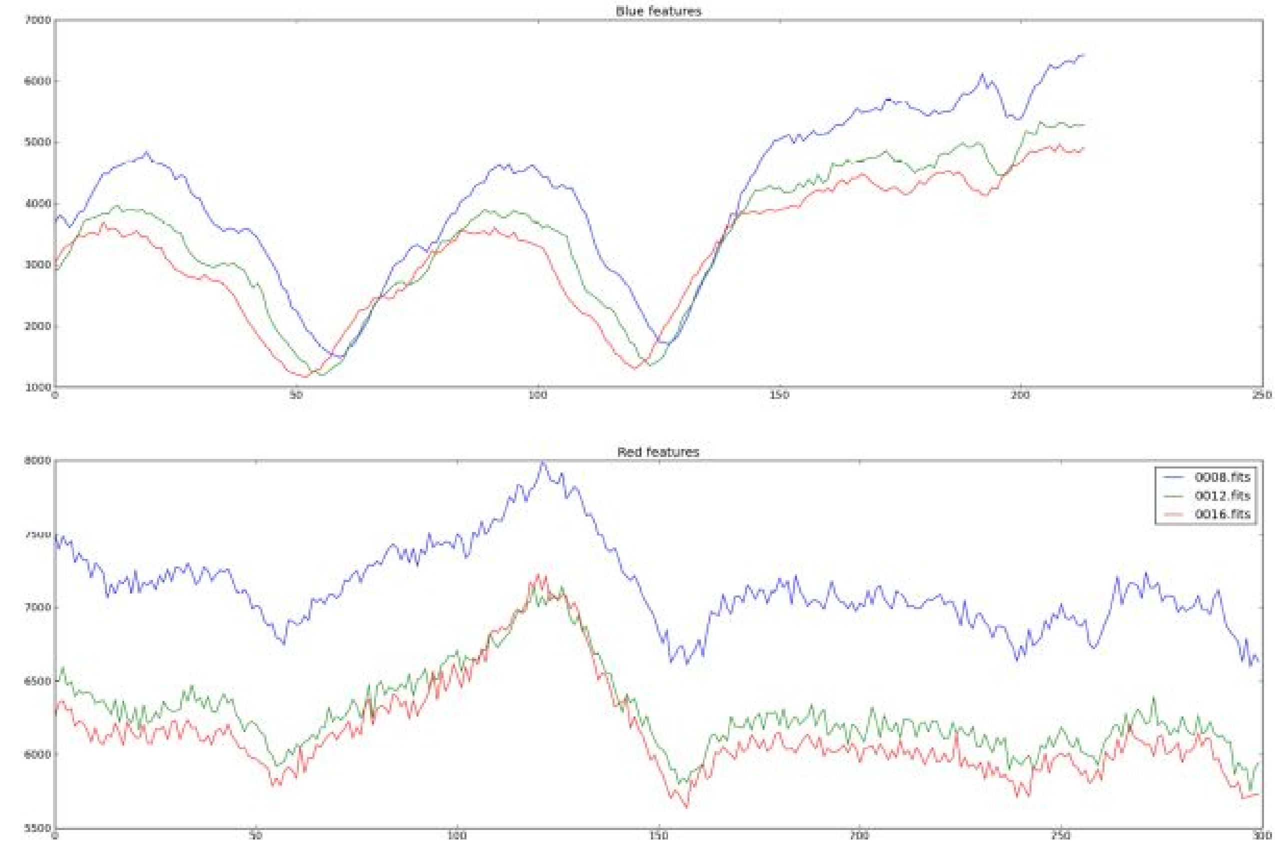


figure 3: Trivial extraction on raw data: blue and red region on the alignment star

The figure shows as the problem already affects the raw frames: in the blue side we can measure a shift (figure 3, upper side). This shift almost disappears for the red features. **The pipeline is not the origin of this effect.**

At this point we check if it could related to a differential atmospheric diffraction effect.

The mask of the proposal are been created with a small position angle (POSANGLE=-0.1138), and observations in the 13th night, start 2h before meridian and end 2h after meridian transit.

Using the DAR tool on the MODS web page:

http://www.astronomy.ohio-state.edu/MODS/ObsTools/obstools.html#DAR

we obtain the picture, which shows how features at different wavelength move on the focal plane.

This picture also shows us 2 fundamental effects:

- the feature relative distance, changes at different airmass values

- features are affected by a shift along the X direction (dispersion direction) and this shift is bigger for the blue features.

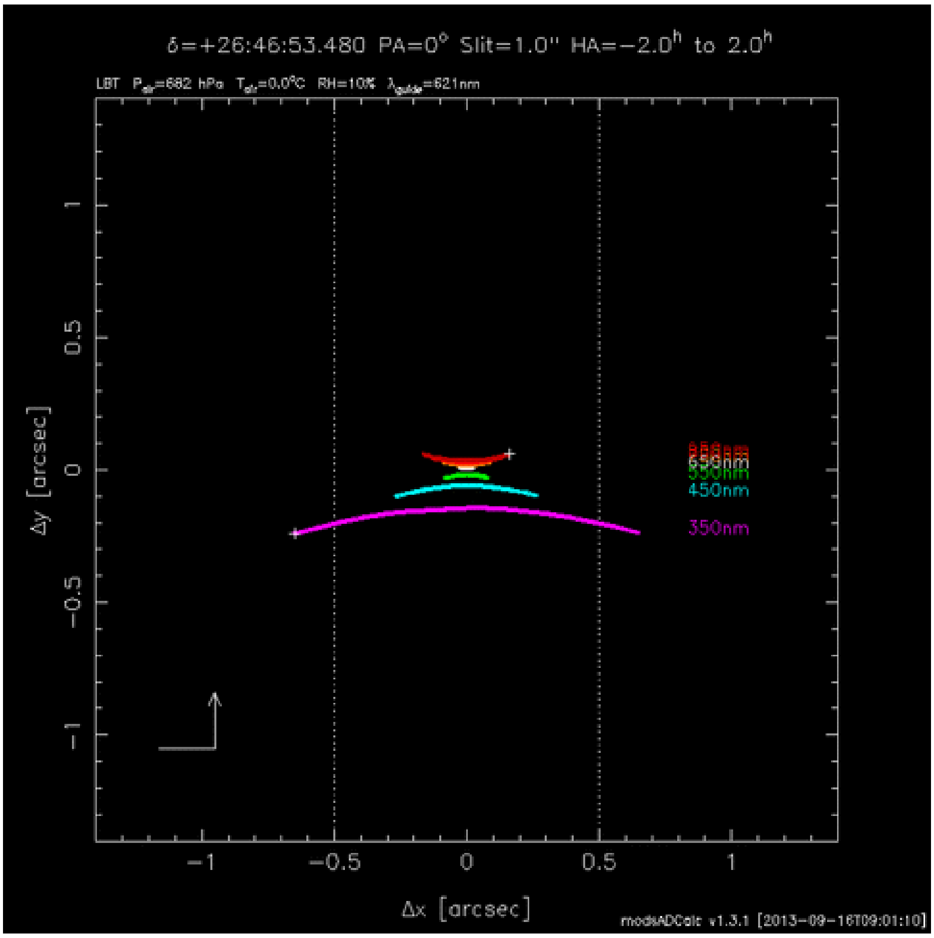


figure 4: Differential Atmospheric Refraction with position angle around 0

This figure reveal that features around ~4000 A are affected by an X shift greater than 1”, i.e. **these feature falls out of the slit during the exposures!**

This qualitative estimation is in agreement with the previous figure 2. Measuring X position of the calcium feature, we have: ~59 pixels (frame 0008), ~55 pixels (frame 0012) and ~51.5 pixels(frame 0016). Considering a pixel scale of 0.12”/px, we roughly obtain an offset of 0.5” from each frame, according with the figure produced by the DAR tool.

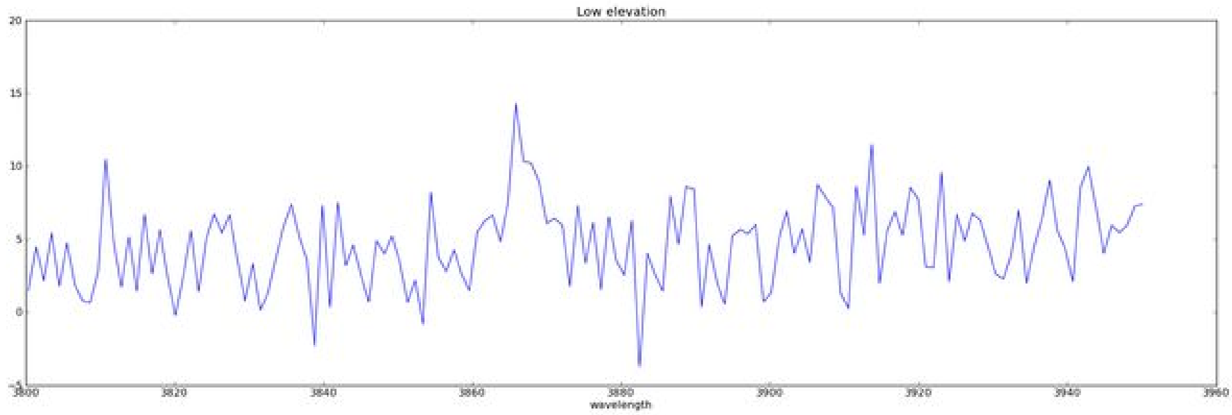
Differential atmospheric refraction seems to be a good explanation for the problem which affects our data!

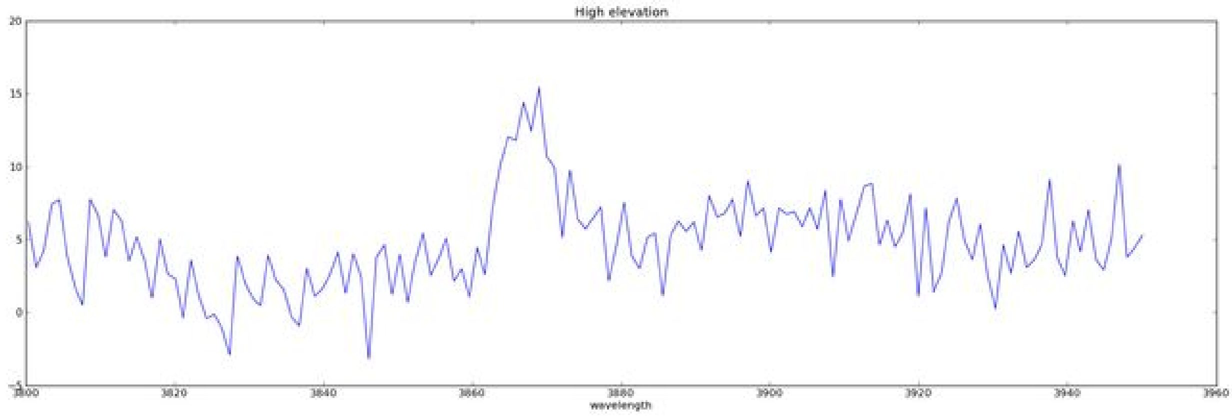
Finally we try to verify this hypothesis, on the faint scientific targets. So we selected the object in the first slit, which shows (in the combined data) a weak emission line around ~3866A.

Then we combined together frames far from meridian, at high airmass (1.1<=airmass<=1.2) obtaining a first spectrum. We also combined frames acquired around meridian (low airmass ~1) to obtain a second spectra.

In case our guess is exact, the first spectra is obtained using “bad” frame, frame with the blue feature at least partially out of the slit and the second spectra is obtained combing “good” frames where the blue feature is into the slit.

Last we rebinned these spectra in order to increase their S/N ratio.





The quality of these spectra is not superb, because not many frames are stacked to obtain these spectra, but the spectra comparison but the emission arising from the second spectra, is stronger compared with the first spectra.

For completeness we spend fee word to illustrated why this problem doesn't affect other data acquired in the blue channel. For example we investigate the data of the proposal (ID ??): mos dual grating.

In this case the mask was created using a position angle around 90 (POSANGLE= 89.8487), and the corresponding DAR plot show looking better.

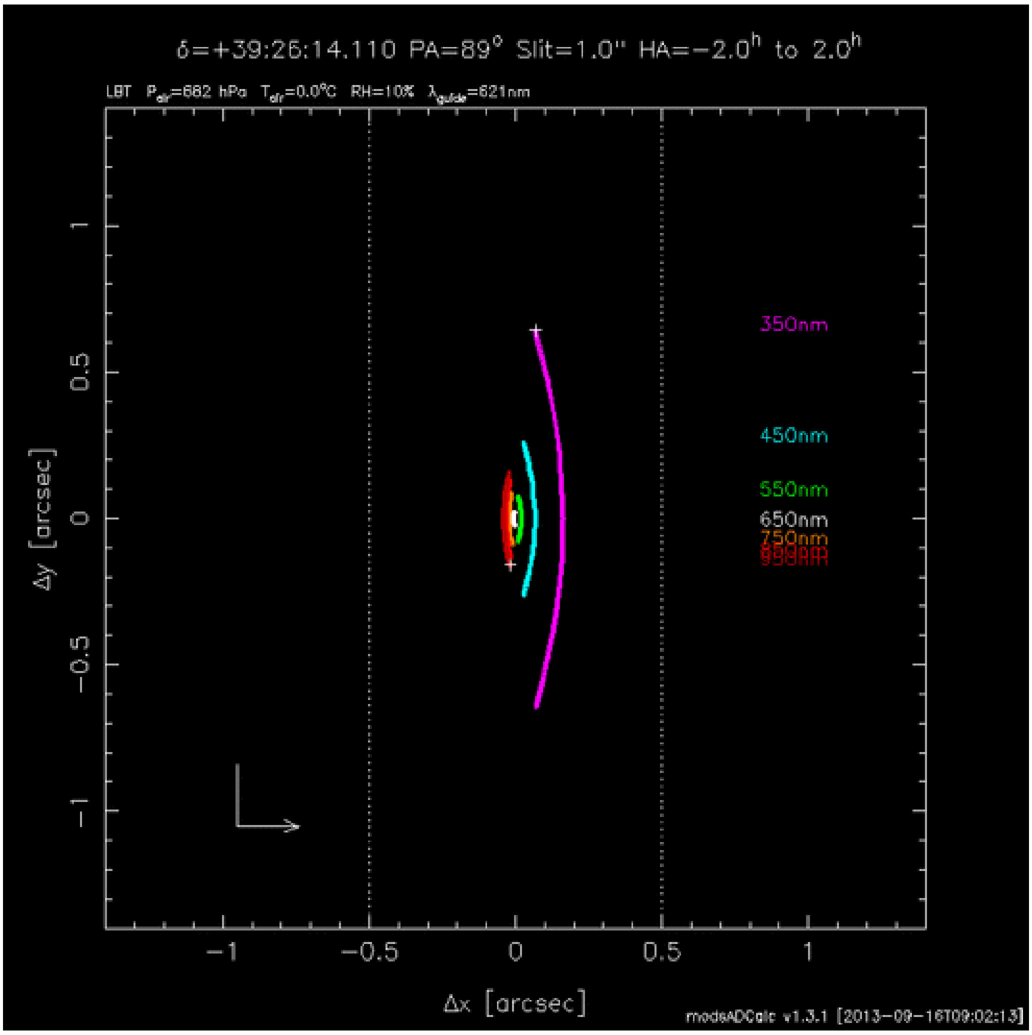


Illustration 5: Differential Atmospheric Refraction with position angle around 90

In this case:

- the features still remains in the slit
- the X shift quite quite small
- the huge shift is along Y direction (spatial direction), and this can be easily compensate by the pipeline, during the stack process.

3. Conclusions

This analysis shows as the atmospheric differential refraction is non-negligible effect, especially in case PI wants to analyze the bluest range of the spectra.

In order to minimize the effect, our suggestion are:

- according with scientific constrains and with field target dislocation, the masks should be created with posangle around 90
- even if proposal airmass constrain are not so strict, observer should not observe too far from meridian
- probably more than one acquisition are required, during long observations
- acquisition should be performed using a blue filter, in order to acquire as near as possible to a blue features
- PI should clearly indicate in the Proposal or in the README file submitted with the OB,