Secular shift of the source spectra in MIDI

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Introduction: During the analysis of AGN data obtained with MIDI in HIGH_SENSE/PRISM mode in November 2007 I noticed that the position of the spectra in the photometric observations had shifted significantly with respect to data obtained at earlier epochs. In fact, the shift was so large that the signal started to move outside the area masked by the standard EWS mask for PRISM data (`minrtsMask_FIELD_PRISM_HIGH_SENS_SLIT.fits`). This prompted me to start a more detailed analysis of the position of the spectra as well as of the source in the acquisition images in MIDI. To this end I used all HIGH_SENSE/PRISM data which were observed since beginning of 2004 and where I could easily lay my hands on. I only selected those data sets, where the exact sequence of first an acquisition, second a fringe search, third a fringe track and finally the two photometries A and B was fulfilled. No distinction between UT and AT data was made. Data from 2003 were excluded from the analysis, because the read-out windows in MIDI were differently before 2004. The positions and widths of the spectra were then determined by fitting a Gaussian distribution to the profile of the spectra. For the acquisition images, two-dimensional Gaussian distributions were fitted. After rejecting extreme outliers and fits that did not converge, 1026 data sets remained. 692 of these are calibrators and 334 are science targets.

The results of this analysis are presented in the following figures.

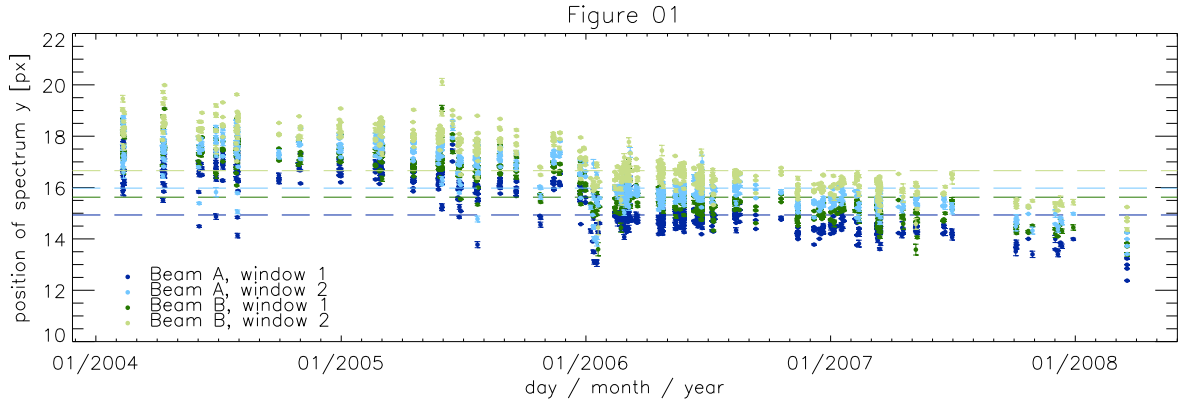


Figure 1: This plot shows the y position of PRISM dispersed spectra in HIGH_SENSE mode versus the observation time. Only the positions of calibrators are shown. There are four different positions, one for each beam, that is for each telescope, and one for each detector window. Clearly a drift of the position of the spectra can be observed with time. Until mid 2005 the position was relatively stable, then the y position began to decrease almost linearly with time. Additionally there are several kinks from individual observing runs, e.g. in January 2006, and from December 2006 until January 2007 the y position moved upward on the detector. In total, the shift in position since early 2004 is almost 3 pixels.

The median position in 2004 is:

Beam A, window 1:	$y_{A1} = 16.647 \pm 0.608$
Beam B, window 1:	$y_{B1} = 17.383 \pm 0.500$
Beam A, window 2:	$y_{A2} = 17.593 \pm 0.614$
Beam B, window 2:	$y_{B2} = 18.335 \pm 0.491$

The median position since July 2007 is:

Beam A, window 1:	$y_{A1} = 13.733 \pm 0.455$
Beam B, window 1:	$y_{B1} = 14.339 \pm 0.444$
Beam A, window 2:	$y_{A2} = 14.691 \pm 0.460$
Beam B, window 2:	$y_{B2} = 15.344 \pm 0.447$

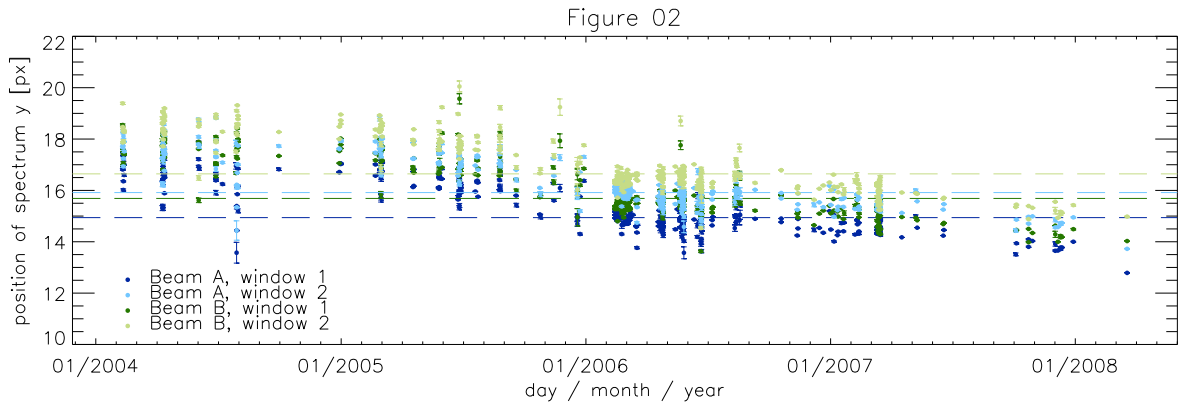


Figure 2: This is the same plot for all science objects. It looks essentially the same as for the calibrators, except that there are more outliers and that there are less than half the number of objects plotted. In general the same statements as for the calibrators are true for the science targets. The error bars for the y position are larger, due to the less certain fits for weaker sources and slightly extended sources (see below). In this plot, one can also see that the shift in the position is not entirely smooth. There are stable periods, for example from April until July 2006 and in the last three months of 2007.

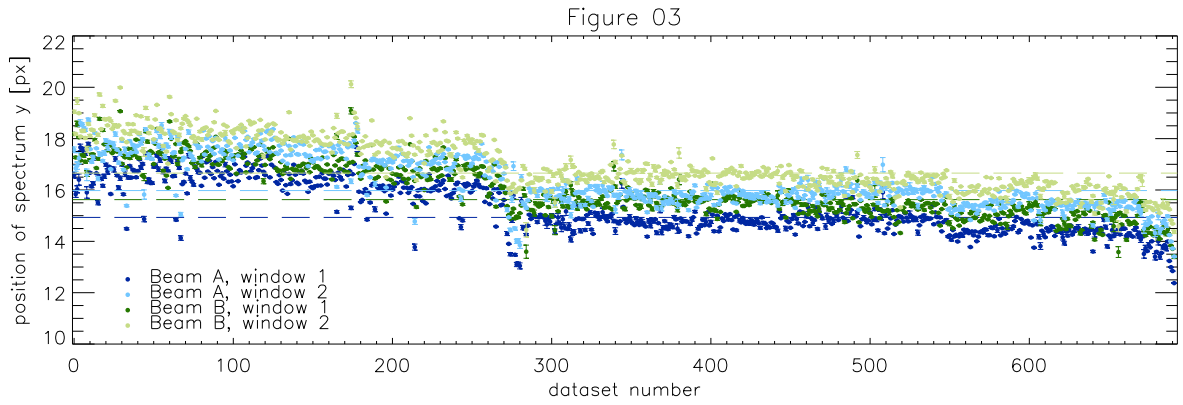


Figure 3: In this plot, the positions of the calibrator spectra are shown evenly spaced, after sorting them by observation time. The plot shows that the change in the position seems to occur in small steps. There are two possible explanations: A) because measurements with MIDI are only done irregularly (or at least the data I had at hand is from a temporally irregular distribution of measurements) a larger amount of time has passed so that a "step" appears. B) instrument changes are applied at a certain date and affect the position of the spectra in all following measurements. The latter is the case for the large jump at dataset 270, which corresponds to the beginning of 2006: on this date, the reference pixels were changed (see figure 6).
Furthermore it also becomes clear, that the four independent measurements of the position behave regularly: the position of the spectrum in window 2 is always higher than that in window 1 and in general the positions of the two windows in beam B are higher than those in beam A. This is quantified by the next figure.

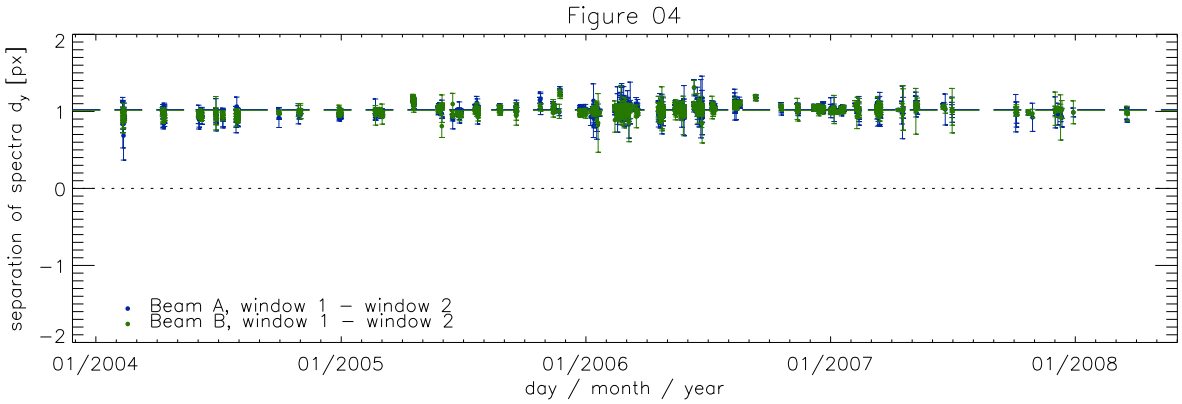


Figure 4: This plot shows the difference between the position in window 1 and in window 2 for each of the two beams. The beamsplitter leads to an offset in the pixel position of pretty much 1 pixel in both beams. Precisely spoken, the spectrum in window 2 is 1 pixel higher than that in window 1. The offset is very accurate with a scatter of only 0.06 pixels and almost all measurements are consistent with the median (dashed lines) when taking the errors in the position into account. The offset also is more or less constant in time, except for a slight drift apart of about 0.1 pixels for a few measurement campaigns (e.g. in April 2005 or on 11/09/2006). The deviation of about 0.1 pixels from the median is clearer when plotting the offset evenly spaced (not shown here). From the high accuracy it follows that the offset is a purely internal effect which is caused by the beamsplitter and applies to all data in the same way. The exact offsets are:

Beam A, window 1 - window 2: $y_{A1} - y_{A2} = 1.0234 \pm 0.0590$
Beam B, window 1 - window 2: $y_{B1} - y_{B2} = 1.0127 \pm 0.0533$

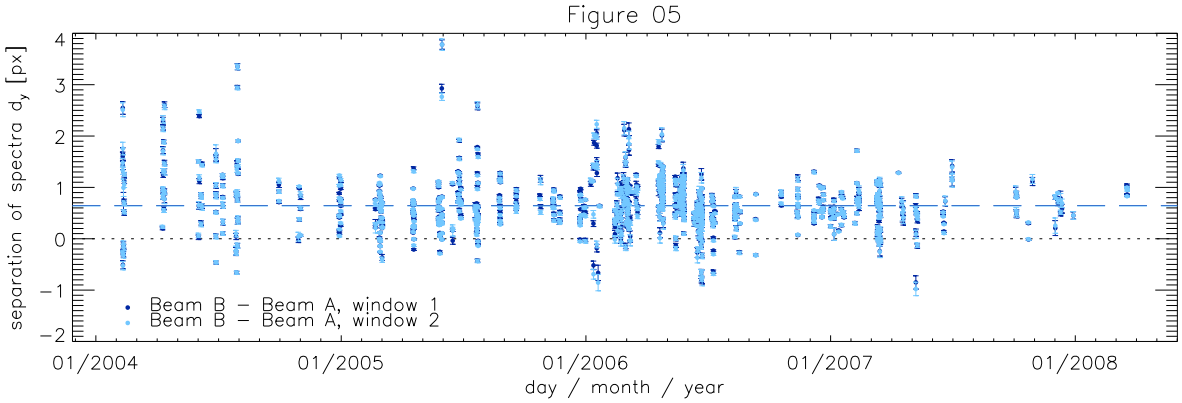


Figure 5: This plot now shows the offset in position between the two beams. Because the offset between the windows is 1 pixel, there is no significant difference between the offsets of the beams for the two windows, i.e. the light and dark blue points lie more or less on top of each other. The offset between the beams is important for the beam overlap: if the offset is too large, the beams will not interfere. From the plot, one can see, that the mean offset between the two beams is non-zero. Beam B is on average located 0.64 pixels higher than beam A. The plot also shows, that the scatter in the positioning of the two beams is relatively large with offsets of more than 1.5 pixel not that uncommon. The positioning accuracy might show a slight trend to have become better (especially at the start of 2005 and in mid 2006), however this indication is very tentative only. A possible explanation could be that MACAO became available at the start of 2005 and IRIS in 2006. However, in general no great improvement in the positioning accuracy can be seen here. Because the relative offsets between the beams do not depend on time, the entire position of the source (as shown in figures 1 to 3), for both telescopes and both beams, has moved on the detector in the same way. The mean and the scatter of the offsets in the two windows are:

Beam B - Beam A, window 1: $y_{B1} - y_{A1} = 0.6471 \pm 0.5908$
Beam B - Beam A, window 2: $y_{B2} - y_{A2} = 0.6370 \pm 0.5968$

Note: This offset was previously measured during alignment of MIDI on Paranal on 07/11/2002 (Chr. Leinert, private comm.). The offset was corrected for by adjusting the reference pixels in the acquisition: on 18/04/2008 Sébastien Morel changed the reference pixels to $\tilde{y}_B = 78.7$ and $\tilde{y}_B = 164.0$ on the detector, which corresponds to $y_B = 31.7$ and $y_B = 32.0$ in the read-out windows (compare also to the next figure).

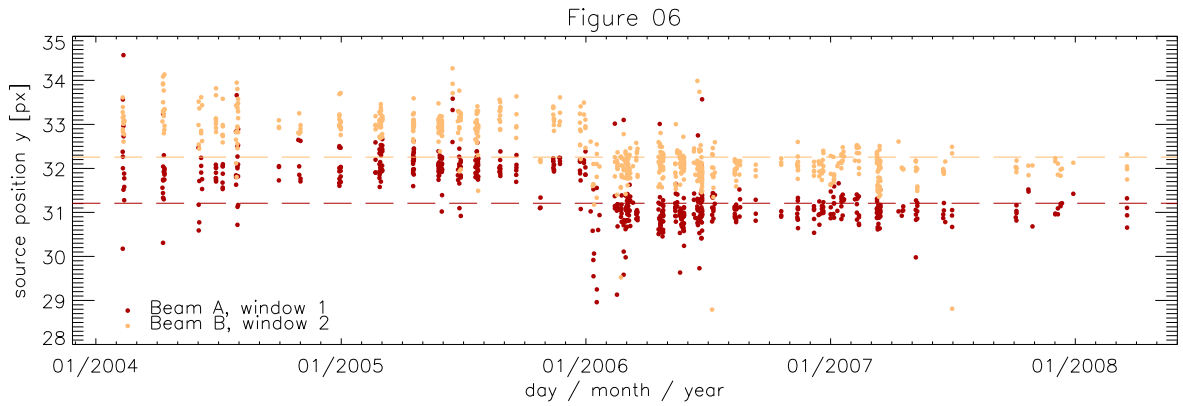


Figure 6: Essentially the acquisition process is responsible for the positioning of the source. To check if the movement of the spectra is due to different reference pixels in the acquisition, the y position of the source in the last acquisition frame, which was taken before the photometry, is plotted in this figure. The two beams are centred about 1 pixel apart in y position. The position, where the two beams were centred changed at the start of 2006: before this date the positions where 1 pixel higher (and in fact also 1 pixel less in x direction, see also figure 8). Otherwise the positioning remained constant. The overall scatter of in the positioning is about 0.4 pixels and does not seem to depend much on time. The median positions, where the object is centred are:

Before 01/01/2006:		**After 01/01/2006:**	
Beam A, window 1:	$y_{A1} = 32.017 \pm 0.460$	Beam A, window 1:	$y_{A1} = 31.017 \pm 0.396$
Beam B, window 2:	$y_{B2} = 33.014 \pm 0.366$	Beam B, window 2:	$y_{B2} = 32.064 \pm 0.370$

The offset in the positioning should theoretically compensate for the offset between the two windows, which is generated in the beam combiner (see figure 4). This is not entirely achieved by positioning the source 1 pixel apart during the acquisition. It seems that an additional offset is introduced by the prism, leading to the remaining offset of 0.6 pixels between the two beams (see figure 5).
Because there is no general drift in the position of the acquisition, only the jump in the position of the spectra at the start of 2006 can be explained by movements of the reference pixels. The remaining drift, especially since 2006 must be internal to the instrument and most likely depends on the prism.

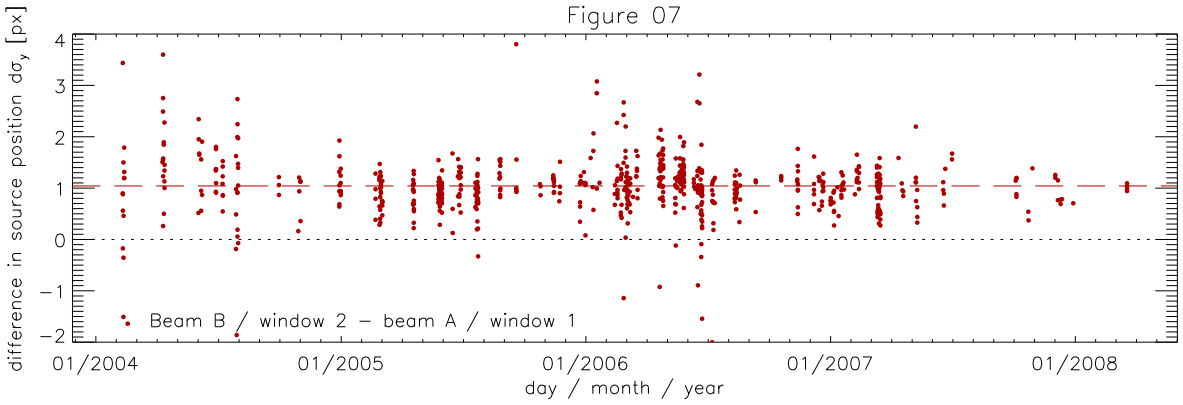


Figure 7: This plot shows the difference between the position in beam A / window 1 and beam B / window 2 and can be compared to the plots 4 and 5. Clearly the offset of 1 pixel which is aimed for can be seen. The remaining scatter is due to inaccuracies in the positioning or errors in the fit of the source (e.g. a bright sky region fitted instead of the true source). In fact the scatter is very similar to the one in figure 5, showing that the scatter in the position of the spectra comes from the inaccuracies of the positioning. It also shows, that the position of the source remains relatively constant between the acquisition and the photometry. The offset and the scatter in the difference of the y position is:

Beam B / window 2 - beam A / window 1: $y_{B2} - y_{A1} = 1.043 \pm 0.545$

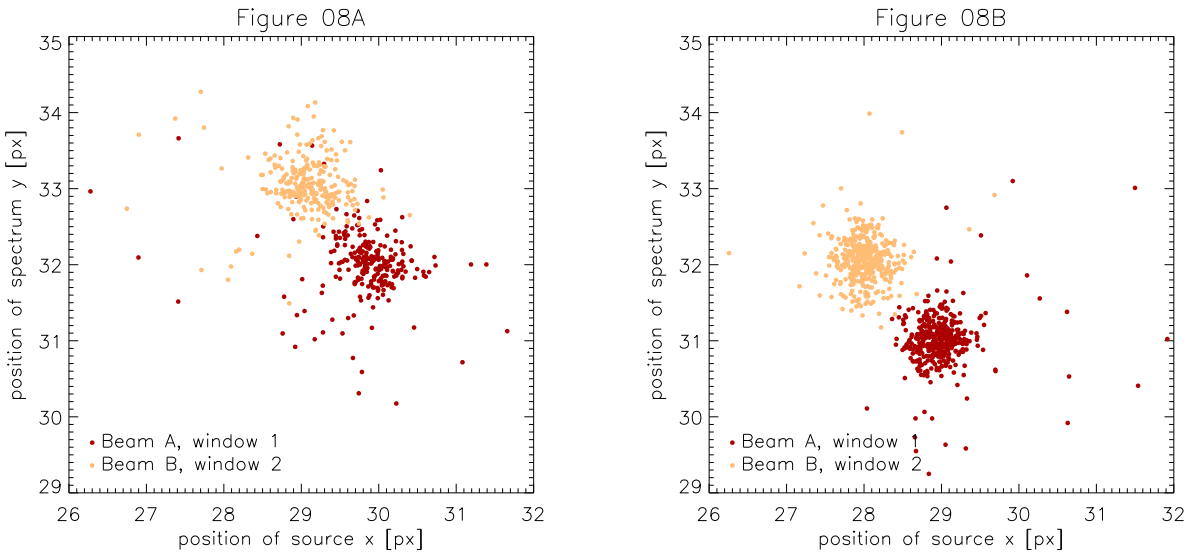


Figure 8: In this plot the positions of the source in the acquisition images are plotted. Clearly the two different positions where the source is centred on the detector can be seen. The two sets are plotted for the time before 01/01/2006 (left plot) and after 01/01/2006 (right plot). It is interesting, that also the x-position is different in the two beams / windows. The exact positions of the source on the detector are:

	Before 01/01/2006:	**After 01/01/2006:**
Beam A, window 1, x position:	$x_{A1} = 29.887 \pm 0.589$	$x_{A1} = 28.963 \pm 0.525$
Beam A, window 1, y position:	$y_{A1} = 32.017 \pm 0.460$	$y_{A1} = 31.017 \pm 0.396$
Beam B, window 2, x position:	$x_{B2} = 29.080 \pm 0.430$	$x_{B2} = 28.006 \pm 0.613$
Beam B, window 2, y position:	$y_{B2} = 33.014 \pm 0.366$	$y_{B2} = 32.064 \pm 0.370$

Note: As already noted in figure 5, the position of the reference pixel was changed again on 18/04/2008 and now lies at $x_A = 29.0$, $y_A = 31.7$ and $x_B = 28.0$, $y_B = 32.0$.

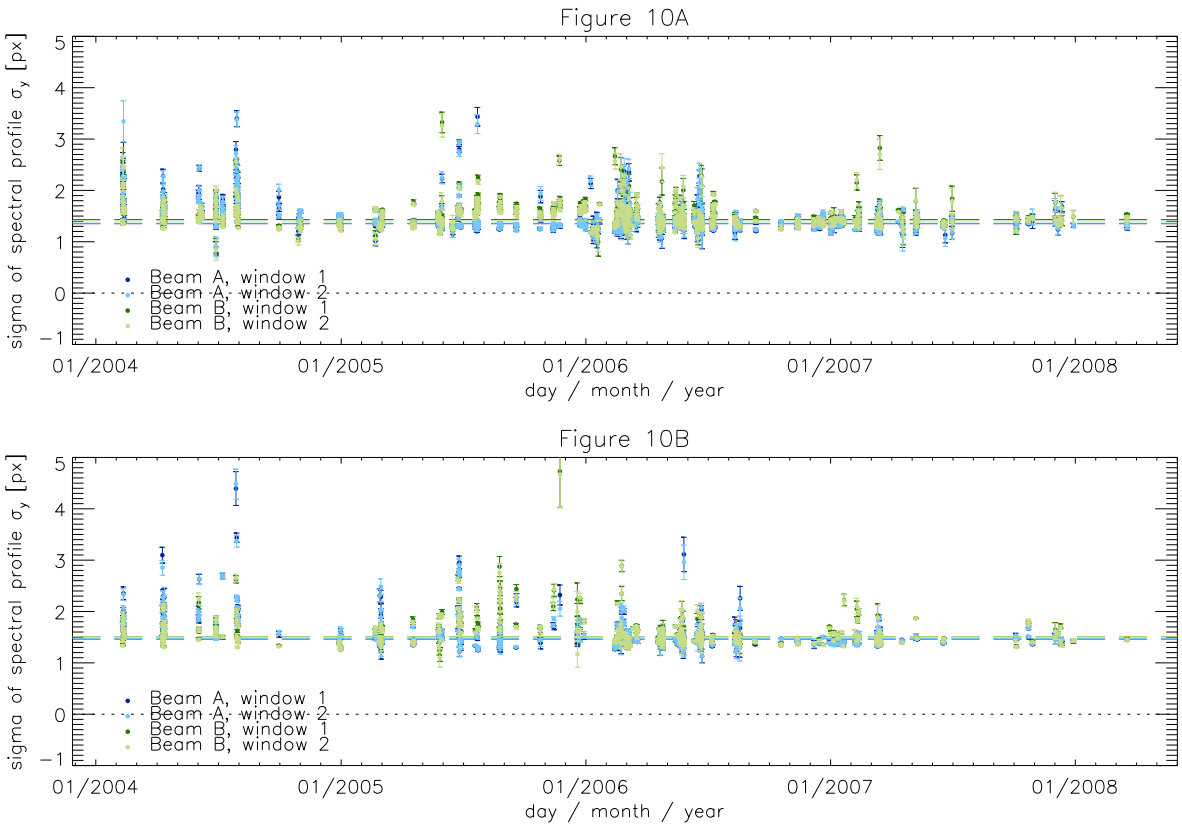


Figure 9: These plots show the sigma of the Gaussian fit to the spectrum profile in y direction, that is in spatial direction. In the upper plot, the sigma is shown for the calibrators, while in the lower panel the science targets are plotted. The sigma is independent of the window, but it slightly depends on the beam: it is in average a bit larger for beam B (more so for ADAPT_OPT_TCCD than for FIELD_STAB_TCCD). In general, the scatter of the sigma is relatively small with only a few outliers. For the science targets, a slightly larger scatter can be observed, especially before beginning of 2006. This means that the sources are either slighly resolved or the AO correction doesn't work as good for the science targets as for the calibrators. For the calibrators, the scatter seems to have been a little larger before 01/01/2005 (probably because no MACAO was available for the UTs). The precise values are:

Calibrators:		**Science targets:**	
Beam A, window 1:	$\sigma_{A1} = 1.352 \pm 0.269$	Beam A, window 1:	$\sigma_{A1} = 1.464 \pm 0.551$
Beam B, window 1:	$\sigma_{B1} = 1.432 \pm 0.223$	Beam B, window 1:	$\sigma_{B1} = 1.510 \pm 0.308$
Beam A, window 2:	$\sigma_{A2} = 1.363 \pm 0.270$	Beam A, window 2:	$\sigma_{A2} = 1.475 \pm 0.532$
Beam B, window 2:	$\sigma_{B2} = 1.408 \pm 0.226$	Beam B, window 2:	$\sigma_{B2} = 1.510 \pm 0.306$

This means the HWHM of the flux-ridge is less than 1.6 pixels. This is more than double the average offset between the two beams, which in turn means that a sufficient overlap is achieved in most of the cases. However for the not so uncommon case of an offset of 1.5 pixels between the spectra, a significant amount of flux is lost. The HWHM of 1.5 pixels corresponds to a FWHM of 0.3 arcsec on the sky. This is the resolution achieved on average for the UTs with MIDI and corresponds to the diffraction limit of an 8.2 m mirror at 12.0 μm. The quality of the correction seems to not depend much on time and on weather conditions (see also the next figure).

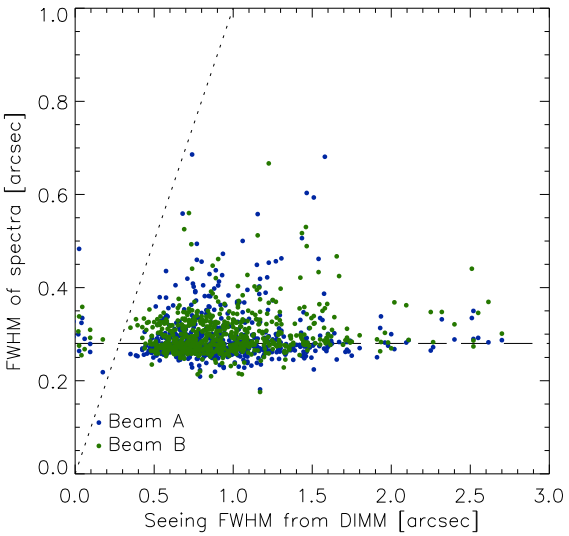


Figure 10: This plot shows the FWHM (in spatial direction) of the spectrum versus the seeing FWHM from the DIMM. When excluding the cases where the DIMM seeing is ~ 0, which are obviously erroneous, the source PSF is always smaller than the seeing in the optical. Most of the measurements were obtained with a seeing between 0.5 and 1.5 arcsec. For this range, no influence of the seeing on the size of the spectra is present. Only for optical seeing values larger than 1.5 arcsec, apparently the source size also seems to increase slightly. However this is most likely only because of the fewer data points and even for these values the source size remains below 0.4 arcsec. This means that the AO systems are doing a good job indeed.

Concluding remarks: Although this analysis was performed on a limited sample of MIDI data, it shows clear trends in the positioning of the source and the spectrally dispersed data on the detector of MIDI. This was the initial aim of the investigation. First, the two beams were found to be misalignment by 0.64 pixels. This misalignment decreases the overlap of the two beams and may have lead to slightly lower correlated fluxes than could have been possible for a perfect alignment. The misalignment has in the meantime been rectified by a shift of the reference pixels. Second, a long term drift of the y position of the spectra is revealed. The reason for the overall drift of the spectra remains unclear and seems to be an effect internal to the instrument. A possible reason could be an increasing tilt of the prism. Because the spectra start to move outside the standard EWS mask, the sensitivity of the instrument is decreased. This is relevant for the fringe track during the observations and for the data reduction. For this reason, the mask used by the real time software on Paranal was shifted down by a few pixels on 18/04/2008 to take into account the new positions of the spectrally dispersed signals. Users with relatively new data will have to adjust the masks for data reduction themselves to obtain optimal results.

In addition, the Gaussian fits to the spectra and the acquisition images allow one to draw conclusions on the AO correction and beam stabilisation.

The analysis presented here is obviously not exhaustive and several further tests can be performed, such as the stability of the positioning between the acquisition and the photometries. Tests in combination with external factors, such as the telescopes used (ATs or UTs) or the airmass of the object, may reveal specific dependencies on these external factors. Finally, a similar analysis should also be performed for GRISM data as well as for SCI_PHOT data.

Measurements on Paranal in technical time should quantify to what degree a misalignment of the beams causes a drop in the measured visibility.

To my knowledge, there is no comparative study in the context of quality control by ESO.