In principle, MIDI should always measure the same calibrated total flux spectrum for a specific source, independent of the instrument settings and the baseline geometry. In the data on the Circinus galaxy, however, there is (a) a general offset of the flux values for 2009 and (b) a slow drift of the total fluxes at short wavelengths during two nights (2008-04-17 and 2009-04-14). The latter seems to depend on the hour angle of the observation. The two distinct variations will be referred to as “offset” and “drift” in the following. In this document, a more detailed analysis of these two effects is carried out and summarised. The goal is to find an explanation for these variations in the photometry.

For the analysis, I mainly used four data sets obtained on four different nights, all using different baselines. I looked at both the unmasked total flux spectra (unmasked photometry, \(F_{\text{tot}}\)) and at the masked total flux spectra (masked photometry, \(F_{\text{msk}}\)), hereafter “total flux” and “masked flux”. The masked and total fluxes at two wavelengths, 8 and 13 \(\mu\)m, are shown in Figure 1. For 2008-04-17 and 2009-04-14, the ambient conditions (airmass, DIMM seeing and coherence time) and the timing of the observations are shown in Figure 2. A list of the data sets and the corresponding apertures (at 10 \(\mu\)m) within which the spectra were extracted are given in Table 1.

![Figure 1: Masked (top row) and total (bottom row) flux at 8 and 10 \(\mu\)m as a function of the hour angle, HA, for four different baselines and dates. The average flux values in 2008-04-17 (U2-U4) and 2009-04-14 (U1-U3) are indicated by the dashed lines.](image-url)
Figure 2: Ambient conditions for the measurements on 2008-04-17 (left column) and on 2009-04-14 (right column) as stored in the FITS headers of the interferometric data files: airmass (first row), DIMM seeing (second row) and coherence time (bottom row).
The most obvious difference in the measurements is that the flux values obtained on 2009-04-14 are in general significantly higher (by 3 to 5 Jy, that is by 25 to 50%, see dashed lines in Figure 1) than the values on the other dates, both for the total and the masked fluxes. This offset is present at all wavelengths, but it is stronger at short wavelengths relative to the absolute flux values. The fluxes on the other dates are all consistent with each other.

Although mainly focussed on the correlated fluxes, the higher flux values measured on 2009-04-14 were already discussed in §2 of my memo from 2009/06/09. There it turned out, that not only the masked and total fluxes but also the correlated fluxes measured on 2009-04-14 were higher than those measured on 2008-04-17 (although by far not as much as the total fluxes). The raw correlated fluxes on 2008-04-17 and 2009-04-14 actually agree very well and it was concluded that the calibration of the data may be part of the problem. For the masked and the total fluxes, on the other hand, there are considerable differences in the raw counts (see §2 in the memo from 2009/06/09), indicating that the calibration is not the main reason for the increase of the masked and total flux. In §4 of the same memo, measurements obtained on 2005-02-28 (yellow point at HA = 1:00 in Figure 1) and 2009-04-17 (brown points at HA ~ 4:30 in Figure 1) were compared: both the total and the correlated fluxes agree well, only the differential phases differ.

The second dependence is the drift of the total flux at short wavelengths with the hour angle on 2008-04-17 and 2009-04-14. At 8 μm, both the masked and the total flux decrease by almost a factor 2 over the course of the night. Both the total and masked fluxes seem to have a maximum at HA ~ −2.5 h and a minimum at HA ~ +4.5 h (as far as this can be judged from the limited range of hour angles covered, −4.0 h < HA < +5 h). This drift is only present for 8 μm < λ < 9 μm; there is no apparent variation of the fluxes at long wavelengths, that is, the spectral shape of the source varies changes during the night.

In the remainder of this document, different possible explanations for these variations are discussed.

1 Instrument settings (drift and offset)

For the observations all instrument settings (except the number of frames, NDIT) were generally kept the same between the respective calibrator and the science data, so that all influences by these settings should be calibrated away. None of the parameters varied continuously during an observation epoch, so the drift at short wavelengths must have been caused by something else. There are, however, a few changes between the epochs concerning the detector integration times (DET DIT) and the chopping frequencies (CHOP FREQ). For a detailed listing of these two parameters, see Table 1. In principle, this could have led to the offset of the flux in 2009. But because the respective settings were applied equally to the calibrators and the Circinus nucleus and it is not explainable why only the raw count rates of Circinus changed and not those of the calibrators (see Figure 7 in Section 5). I therefore see no obvious connection between the changed integration time or chopping frequency and the drift or offset in the fluxes.

2 Airmass (drift)

The drift in the flux values during one night could be an effect of the airmass, as the airmass through which Circinus is being observed changes during the night. However, the minimum airmass during culmination of the object is reached at HA = 0 h. Any variation of the measured flux should be symmetric to this angle. But this is not the case in a convincing way. Especially the measurements from 2008 show a continuously decreasing flux from HA ~ −2 h to HA ~ 3 h without any symmetry with respect to HA = 0 h. Unfortunately, not many observations were carried out with HA < 0 h on 2009-04-14 due to technical problems.

Also, any such variation in the measured fluxes should have been removed by the calibration, because always a calibrator at a similar airmass was used. Finally, the calibrators don’t show any significant dependence on the airmass themselves (see Section 5 and Figure 6). So this should be also true for the Circinus galaxy, especially because the flux levels are on the order of ~ 10 Jy for both the calibrators and the galaxy.

| date       | baseline | aperture total flux | aperture masked flux | DET DIT | CHOP FREQ |
|------------|----------|---------------------|----------------------|---------|-----------|
| 2005-02-28 | U3-U4    | 0.52 × 1.38 arcsec² | 0.52 × 0.65 arcsec² | 12 ms   | 2.0 Hz    |
| 2005-05-26 | U2-U3    | 0.52 × 1.38 arcsec² | 0.52 × 0.57 arcsec² | 18 ms   | 2.0 Hz    |
| 2008-04-17 | U2-U4    | 0.52 × 1.29 arcsec² | 0.52 × 0.60 arcsec² | 18 ms   | 1.3 Hz²   |
| 2009-04-14 | U1-U3    | 0.52 × 1.29 arcsec² | 0.52 × 0.56 arcsec² | 20 ms   | 0.5 Hz    |

Table 1: Properties of the photometry data used for the analysis.

a The first calibrator and Circinus combination uses 12 ms integration times.

b One observation of the Circinus nucleus has 0.5 Hz chopping.
I conclude that the airmass is probably not the main reason for the variation of the masked and the total flux.

3 Atmospheric conditions and AO correction (offset and drift)

The atmospheric conditions and the quality of the AO correction could lead to both the offset as well as the drift in the total flux, because the PSF size is wavelength dependent and because the atmospheric conditions could have changed smoothly in each night and varied strongly between observing epochs. Figure 2 shows that on 2008-04-17 the DIMM seeing varied between 0.6″ and 1.3″ with no general trend over the night (except for an increase at the end of the night). On 2009-04-14 however, the seeing steadily improved from 1.5″ to 0.4″ over the course of the night, while the measured flux values decreased. The seeing (as measured by the DIMM) is thus not the reason for the decrease of the flux over the night. The average seeing values and their standard deviation for the two nights are 0.90″ ± 0.23″ and 0.75″ ± 0.26″ for 2008-04-17 and 2009-04-14 respectively.

Whether the seeing is causing the variations can be more directly tested by plotting the measured fluxes as a function of the seeing, see Figure 3. For worse seeing conditions, one would expect a worse AO correction and hence a broader PSF which in turn could lead to a decrease of the measured fluxes. This is however not the case. The data from 2009-04-14 actually suggests the opposite trend, higher flux values for worse seeing conditions. The seeing conditions are hence not the reason for the change of the measured fluxes in Circinus. The values of the coherence time, $\tau_0$, show more or less the inverse behaviour than the seeing trends and hence are not responsible for the changes in the measured fluxes either.

Several parameters of the AO systems (e.g. “encircled energy”, “delivered FWHM” or “strehl”) roughly correlate with the seeing or the coherence time. The measured fluxes do not show any clear dependency on these parameters either as can be seen exemplarily for the strehl ratio in Figure 4. However, the values stored in the AO related FITS header keywords should not be taken too serious anyway, as far as I have been told.

4 PSF size (drift and offset)

The size of the PSF can have an influence on the measured flux values, e.g. by changes in the losses induced by the slit and the mask. To analyse the PSF quality, I fitted the spatial profiles of all total flux spectra observed on 2008-04-17 and 2009-04-14 by a Gaussian distribution. The fit was carried out at two wavelengths: at 8 and at 13 µm. The FWHM of these Gaussians as a function of the observing time are shown in Figure 5. Except for a few slightly broader spectra at 8 µm on 2008-04-17 all spectra have very similar FWHM. Above all, no continuous drifts in a single night nor significant offsets between the two different epochs are visible. I therefore conclude that the PSF size did not change much during the observations and that it cannot be responsible for the observed drift and offset in the fluxes.

The values of the FWHM are nevertheless interesting in themselves. At 8 µm, the PSF of Circinus is slightly larger than that of the calibrator star, while at 13 µm both PSF have comparable sizes (see Table 2). This means that, in the MIR at 8 µm, Circinus is already slightly resolved by an AO assisted 8m-class telescope. In both nights the FWHM of the PSF of the Circinus nucleus seems to have been slightly broader.
Figure 4: Masked flux as a function of the strehl ratio from the MACAO unit in beam 2. Note that for all our measurements before 2006, all AO related values in the FITS headers are 0 - probably these were not stored correctly.

Figure 5: FWHM of the spectrum at 8\,\mu m (top row) and at 10\,\mu m (bottom row) for the photometries observed on 2008-04-17 (left column) and 2009-04-14 (right column). The FWHM are plotted for both the Circinus galaxy ("Science") and the calibrators ("Calibrator") with different colours for the different beams (i.e. telescopes) and different symbols for the the different windows in MIDI.
2008-04-17

| object  | FWHM(8 µm) | FWHM(13 µm) |
|---------|------------|-------------|
| Circinus | 317 ± 55 mas | 404 ± 30 mas |
| Calibrators | 238 ± 17 mas | 375 ± 34 mas |

2009-04-14

| object  | FWHM(8 µm) | FWHM(13 µm) |
|---------|------------|-------------|
| Circinus | 265 ± 20 mas | 384 ± 32 mas |
| Calibrators | 235 ± 16 mas | 376 ± 35 mas |

Table 2: Average FWHM and standard deviations of the FWHM of the spectra measured on 2008-04-17 and 2009-04-14. The FWHM of the diffraction limited PSFs of an 8.2 m telescope at 8 and 13 µm are ∼ 210 and ∼ 340 mas, respectively.

Figure 6: Transfer functions for the masked flux on 2008-04-17 and 2009-04-14.

at the beginning and at the end of the night, where observations were carried out at higher airmasses (c.f. Figure 2). In 2009 the effect is only visible for the end of the night because observations of Circinus only started only in the middle of the night due to technical problems earlier. On 2009-04-14 the atmospheric conditions improved significantly over the course of the night (see Figure 2), the PSF size in the MIR did, on the other hand, not change much. This indicates that the AO correction provided a relatively stable PSF in the MIR, irrespective of the atmospheric conditions (see also Figure 10 in my memo from 2008/05/29).

5 Variations in the calibrator data (drift and offset)

Actually, any atmospheric and instrumental influences on the measured data should be removed by the calibration process. The data on 2008-04-17 and on 2009-04-14 were calibrated using calibrator stars, which were observed interleaved with the science data (see Figure 2, calibrators marked in green). With a few exceptions, the calibrator observed closest in time and airmass was used to calibrate the Circinus data. In Figure 6, the transfer functions for the masked flux on 2008-04-17 and 2009-04-14, calculated from the calibrator observations, are plotted. Both nights seem to have been stable nights and the scatter in the transfer functions (dotted lines in Figure 6) is less than 10%. This is despite the individual calibrators having been observed with airmasses between 1.4 and 2.2. It is also worth mentioning that the largest deviations from the mean transfer function (black dashed lines in Figure 6) are observations of stars other than HD 120404, which is the standard calibrator used for the Circinus galaxy. This probably means that some of the variations in the transfer function are due to the uncertainty of the stellar spectra (taken from the data base by Roy van Boekel) and not so much due to variations of the atmospheric transparency. On 2009-04-14 only the three observations of HD 120404 were used for the calibration because HD 115211 was observed at a very high airmass (c.f. Figure 2) and a few hours before the first observations of the Circinus nucleus succeeded.

The stability of the calibrator transfer functions argue against the drift at short wavelengths being simply explained by calibration errors: the drift is not seen in the raw calibrator data, it comes from the raw data of the Circinus galaxy alone. The general offset in flux values in 2009 could, however, be caused by a variation of the flux of the calibrator, which would have had to decrease from 2008-04-17 to 2009-04-14. However, HD 120404 is not listed as a variable star.

In 2008, HD 115211 had a higher transfer function than HD 120404, while in 2009 it had a lower transfer function (see Figure 6). This also argues against a decrease of the flux of HD 120404 from 2008 to 2009,
unless HD 115211 underwent an even larger decrease. The strong relative change in the transfer function of HD 115211 with respect to that of HD 120404 is best explained by the high airmass (∼2.05, see Figure 2) in conjunction with a lower atmospheric transparency (see Section 6) in 2009.

From Figure 6 it appears that the absolute count rates for HD 120404 on 2009-04-14 are lower than those on 2008-04-17 especially at short wavelengths. A more accurate measure of the difference in raw count rates is obtained when dividing the (averaged) raw counts on 2009-04-14 by those on 2008-04-17. This is shown for the masked flux in Figure 7 for both HD 120404 and the Circinus nucleus. It becomes clear that the raw count rates of the calibrator only decreased shortward of 9.5 µm; between 9.5 and 13.0 µm the ratio of the count rates is consistent with 1, i.e. no change in the absolute flux of the calibrator. Figure 7 also shows that it is the raw counts of the Circinus nucleus that actually increased by roughly 30%. I therefore conclude that the count rates of the calibrators are consistent with each other in the two epochs, taking into account variations the atmospheric transparency (see Section 6). The offset in the masked and total flux in Circinus in 2009 is thus not caused by variability of the calibrator.

### 6 Change in the atmospheric transparency (drift)

While the count rates of HD 120404 have remained constant between 2008 and 2009 for 9.5 µm < λ < 13.0 µm, there is a 10 to 15% decrease of the count rates of the calibrator between 8.0 and 9.5 µm and possibly for λ > 13.0 µm. Between 7.0 and 8.0 µm the count rates in 2009 are only a small fraction of those in 2008. For example the “spike” at 7.5 µm, visible in the transfer functions in 2008, is not present in the transfer functions in 2009 (c.f. Figure 6). This effect is most likely caused by a different atmospheric transmission during the two nights. The short wavelength cut-off of the N-band is caused mainly by absorption by water with some additional absorption by methane and N2O between 7.7 and 8.0 µm. By comparing the optical thickness of the different species\(^1\) it is not entirely clear which one of them causes the “spike” at 7.5 µm, it could be either methane or water.

According to the ESO Ambient Conditions Database\(^2\), the humidity on 2008-04-17 was higher (20 – 35%) than on 2009-04-14 (10 – 15%), exactly the opposite than to be expected from the count rates, which suggest a higher water column in 2009. According to satellite data\(^3\), however, the precipitable water vapour in the atmospheric column above the observatory was (2.7 ± 0.7) mm in 2008 and (3.3 ± 0.7) mm in 2009. Although not significant, this could indicate that indeed a higher water column could be the reason for the lower count rates at the short wavelength end of the N band in 2009. Note however that the transfer functions of the calibrator remained very stable during each night, indicating that the atmospheric transparency did not change a lot in a single night. The atmospheric transmission is hence not the cause of the nightly drifts in the fluxes.

The wavelength dependent shape of the ratio of the count rates of the science source (ignoring the general offset) in Figure 7 are similar to that of the calibrator. This means that the atmospheric conditions for the science source and the calibrators were similar and that the wavelength dependent changes should calibrate

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\(^1\) I could only do a visible comparison as the only site where I could find the individual species involved in the atmospheric absorption broken down is at [http://www-atm.physics.ox.ac.uk/group/mipas/atlas/](http://www-atm.physics.ox.ac.uk/group/mipas/atlas/).

\(^2\) [http://archive.eso.org/asm/ambient-server](http://archive.eso.org/asm/ambient-server)

\(^3\) [http://www.eso.org/gen-fac/pubs/astclim/forecast/meteo/ERASMUS/par_fapp.txt](http://www.eso.org/gen-fac/pubs/astclim/forecast/meteo/ERASMUS/par_fapp.txt)
Figure 8: Masked flux at 8 and 10 µm as a function of the orientation of the slit on the sky for four different baselines and dates. The average flux values in 2008-04-17 (U2-U4) and 2009-04-14 (U1-U3) are indicated by dashed lines.

away. What remains is the directly visible increase in count rates for the Circinus nucleus in 2009. This is further discussed in Sections 9 and 10.

7 Rotation of the slit on an extended source (drift)

An explanation for the drift of the fluxes might be that the slit in MIDI rotates on the extended MIR emission of Circinus. The masked flux as a function of the orientation of the slit, φ, is shown in Figure 8. The figure is very similar to Figure 1, because there is almost a linear relationship between the hour angle and the slit orientation.

As can be seen from the VISIR image of Circinus at 10.8 µm in Figure 9, the nucleus is significantly extended, when deep images are taken. The VISIR image is seeing limited with FWHM_{nucleus}(10.8 µm) = 400 mas (i.e. it is larger than the corresponding diffraction limit λ/D = 10.8 µm/8.2 m = 270 mas and the

Figure 9: VISIR image of the nucleus of the Circinus galaxy at 10.8 µm (logarithmic colour scaling). Overplotted in green are the apertures for the total (hatched) and masked (cross-hatched) flux for a slit orientation of φ = 0° (North-South).
calibrator PSF, FWHM\text{calib}(10.8 \mu m) = 320 \text{ mas}). From the MIDI observations with the ATs it is also clear, that the source is elongated along PA $\sim 100^\circ$ down to spacial scales of about 100 mas. The average apertures of the total and masked fluxes as specified in Table 1 are shown in Figure 9 in green. In contrast to the rectangular aperture of the total flux, the aperture of the masked flux is almost quadratic and hence it should be much less affected by the elongation of the source. In the measured data, this is however not the case: the dependence of the masked flux on the hour angle (and similarly on the position angle of the slit) is as large as that of the total flux (c.f. Figures 1 and 8). Also, the source is similarly extended at $\lambda > 9 \mu m$ and the lack of any angle dependence of the flux at long wavelengths cannot be simply explained by the larger size of the diffraction limit with respect to $8 \mu m$: there should be still be some slit angle dependence also at the longest wavelengths.

To test this further, I extracted the fluxes at $10.8 \mu m$ from the VISIR image using the two apertures from 2005-05-26 (considering them as some sort of median of the apertures) and for varying position angles of the slit. Losses due to the relatively small apertures with respect to the larger PSF size in VISIR (no AO correction) were corrected. The result is shown in Figure 10. As expected, the flux is much less dependent on the slit position for the masked flux than for the total flux. In addition, even for the total flux, the dependency is much weaker than in the measured data. This may be partially explained by the larger PSF in the VISIR data with respect to the AO corrected PSF in MIDI (400 mas versus 350 mas). But even when increasing the aperture sizes for the extraction, so that PSF effects are less relevant, the dependency on the slit angle remains less than 20%. On 2008-04-17 the flux at $8.0 \mu m$ changed by more than a factor of 2 between $\phi = -85^\circ$ and $\phi = -15^\circ$. Therefore I conclude that also the slit orientation cannot be the main reason for the continuous change in the masked and the total flux.

In this context it is interesting to note that in the MIDI acquisition images in 2008 and 2009 FWHM $\sim (250 \pm 20) \text{ mas}$ ($\lambda/D = 8.8 \mu m/8.2 \text{ m} = 220 \text{ mas}$) for the calibrator with the N8.7 filter and FWHM $\sim (350 \pm 30) \text{ mas}$ ($\lambda/D = 11.8 \mu m/8.2 \text{ m} = 300 \text{ mas}$) for the Circinus nucleus and the SiV filter. This is consistent with the sizes of the PSF derived from the spectra in Section 4. As far as can be judged from the acquisition images, the PSF for the Circinus galaxy is not much more elongated than that of the calibrator stars. Due to the different filters used, it is impossible to estimate from these numbers to what degree the emission in Circinus is extended with respect to the PSF of the calibrators like it was done for the spectra in Section 4.

8 Polarisation (drift)

If the light of Circinus or the calibrator were polarised to a certain degree, the rotation of the field of view together with the MIDI and VLTI optics may lead to a smooth change of the flux with position angle. However, the degree of polarisation would have to be up to 50% to lead to a change of the flux of up to a factor of 2 (masked flux on baseline U2-U4 on 2008-04-17 between HA = $-2:30$ and HA = $+3:00$). I assume the emission of the calibrator stars are essentially unpolarised, which is corroborated by the fact that the transfer functions only show a small scatter and that there is no continuous change in the transfer function over the night (see Figure 6). By consequence, the effect would have to come from the Circinus nucleus alone. There are no MIR polarisation measurements for the Circinus galaxy; in the K band the nucleus of the Circinus galaxy has a polarisation on the order of 3 to 4% (Alexander et al., 2000). The degree of polarisation of NGC 1068 in the MIR is less than 3% (Smith et al., 2000; Packham et al., 2007), that of
Mrk 231, a Seyfert 1 galaxy, 8% (Siebenmorgen & Efstathiou, 2001). It thus seems unlikely that the MIR emission of the Circinus nucleus is much higher polarised and that the position angle dependent change of the flux is due to polarisation. Furthermore, the effect should be equally strong at 8 and 13 µm, unless Circinus is only polarised at the short wavelength end of the N band. I therefore conclude that it is very unlikely that polarisation is the reason for the drift. Nevertheless it remains to be answered, how the VLTI and MIDI optics react to a polarised source for a rotating field of view.

9 Fluxes in the acquisition (offset)

The acquisition images can also be used for aperture photometry. An example of a set of acquisition images is shown in Figure 11. An aperture of 10 pixels, i.e. 860 mas, was used for the aperture photometry and is marked by a green circle in Figure 11. The photometry was obtained not only using the full acquisition images but also a second time, after multiplying the images with the slit transfer function. The slit transfer function was directly determined from acquisition images taken with the slit inserted (c.f. my memo from 2008/12/22).

The raw count rates of the acquisition images obtained with MIDI on 2008-04-17 and 2009-04-14 are plotted in Figures 12 and 13 for the Circinus nucleus and HD 120404 respectively. For Circinus mainly the SiC filter was used, while for HD 120404 the N8.7 filter was used. Due to the different filters it is not possible to calibrate the photometry for Circinus, only the raw count rates can be compared. The average values for each night are indicated by the black dashed line and the black data point at the end of the observing period. They are summarised in Table 3.

In all these plots, no trend of the flux with time of observation within one epoch is discernible. This is consistent with the flux values of Circinus to only change at short wavelengths, because the SiC filter with λc = 11.79 was used for the Circinus acquisition. By consequence the acquisition images give no clue, what may cause the drift of the fluxes at short wavelengths during one night.

On the other hand, higher flux rates for Circinus in 2009 than in 2008 were measured in the acquisition images. The difference is not significant for the individual measurements but it is for the average with an

| object       | slit      | 2008-04-17 (ADU) | 2009-04-14 (ADU) |
|--------------|-----------|-----------------|-----------------|
| Circinus     | no        | 1849 ± 47       | 2180 ± 121      |
| (SiC)        | yes       | 1240 ± 46       | 1643 ± 64       |
| slit losses  | (33 ± 4)% | (25 ± 6)%       |
| HD 120404    | no        | 5058 ± 172      | 4443 ± 140      |
| (N8.7)       | yes       | 3900 ± 248      | 3708 ± 191      |
| slit losses  | (23 ± 6)% | (17 ± 6)%       |

Table 3: Average count rates (left table, in ADU) and PSF sizes (right table) determined from the acquisition images.
increase of the average count rate by $(18 \pm 8)\%$. For HD 120404, the opposite is the case, the average of the count rates in 2009 is lower by $(12 \pm 4)\%$ than in 2008. Considering that the N8.7 filter was used for the calibrator this is consistent with the change of the atmospheric conditions and the 10 to 15\% decrease of the atmospheric transparency at short wavelengths already discussed in Section 6. Note that due to the different filters used for Circinus and the calibrator a direct comparison is not possible. In any case, there seems to have been an increase in the Circinus flux from 2008 to 2009 already in the acquisition images by about 20 to 30\% with respect of that of the calibrator.

The increase in Circinus is even larger when the acquisition image is multiplied by the slit transfer function. Then the increase is $(32 \pm 9)\%$ for the raw counts alone. This enhancement can be explained by reduced slit losses in 2009. Before January 2009, the reference pixel for centring the source was not centred in the MIDI slit (see my memo from 2008/12/22). This can be clearly seen in Figure 11: The blue cross is not centred in the slit. This causes stronger slit losses. In principle, the calibration should corrected for the slit losses, however the slit losses are a bit larger for the Circinus galaxy than for the calibrator because the PSF of the galaxy is slightly more extended. This could have lead to a further apparent increase in the Circinus flux from 2008 to 2009. The values for the slit losses in Table 3 are not directly comparable due to the different filters used: the slit losses should be larger at longer wavelengths than at short wavelengths, due to the wavelength dependent size of the PSF. The increase in flux of Circinus is however not wavelength dependent (apart from an atmospheric contribution, see Section 6 and Figure 7). Thus the adjustment of the reference pixel in January 2009 can only have lead to a minor apparent increase in the Circinus flux. The majority comes from the increase of the raw count rates for Circinus.

In 2008, one acquisition of Circinus was obtained using the N8.7 filter. Calibration gives a flux of $(4.92 \pm
0.43) Jy for Circinus at $\lambda_c = 8.64 \mu m$. This value fits perfectly to the average of all total flux measurements with MIDI (see Figure 15).

10 Variability of Circinus

The previous section directly leads to the conclusion that the higher values measured in 2009 are due to a variability of the source itself. Figure 14 shows the fluxes measured by MIDI at 12 $\mu$m as a function of the observing date. Clearly the increase in the flux by almost 50% is apparent for the measurements in 2009; all measurements before 2009 seem to be consistent with each other considering the errors. Also several other MIR measurements obtained in the last years all agree to the averaged MIDI spectrum within 30% (most of the differences being probably due to differences in aperture, see Figure 15).

There are no studies of the variability of the Circinus nucleus in the infrared (i.e. for neither the NIR nor the MIR). In the X-ray regime, the nucleus of Circinus “is observed as consistently not variable” over a time span of about 9 years (Winter et al., 2009). Hard X-ray observations show no clear indications for variability of the nucleus either, although the results are inconclusive (Yang et al., 2009). In the X-ray monitoring with RXTE\(^4\), no strong increase of the X-ray flux in 2009 is discernible either (see Figure 16). Because Circinus is Compton thick with $N_H \sim 4 \cdot 10^{24}$, one has to be careful to use X-rays as a tracer for the luminosity of the accretion disk, but for energies above 13 keV the directly transmitted nuclear emission seems to be visible (Yang et al., 2009).

A problem with a possible increase of the intrinsic MIR flux of the Circinus nucleus is however, that because of the time scale of variation, this variable emission should come from a region smaller than about 1 ly $\approx 0.3$ pc, which corresponds to 15 mas. This is just the size of the central disk component probed with MIDI. Therefore the increase in the flux should, to a large degree, also be seen in the correlated fluxes. This is, however, not the case: the absolute increase of the masked flux is on the order of 3 to 5 Jy, all the

\(^4\)http://xte.mit.edu/asmlc/ASM.html
Figure 14: Total flux of the Circinus nucleus at 12 µm as a function of the observing date. The large red points with error bars mark the weighted average of the individual flux measurements for each of the epochs. The individual measurements are indicated by the yellow points. Especially in 2008 and 2009 more than 10 individual spectra were obtained for each epoch. The average of the measurements from 2004 to 2008 is indicated by the red dotted line.

Figure 15: Comparison of various spectra and photometric measurements of the Circinus nucleus in the N band.
correlated fluxes in 2009 on the U1-U3 baseline have $F_{\text{cor}} < 2.0$ Jy with most of them actually on the order of only 0.5 Jy. They simply cannot have increased by a few Jy. Furthermore, AT measurements on the E0-G0 baseline were carried out both on 2008-04-25 and on 2009-04-26, a few days after the UT observations in these two years. In Figure 17, the correlated fluxes of these measurements are plotted as a function of the position angle for two wavelengths, 9 and 12 µm. Both observations agree well (almost within 1σ) even though the night in 2009 (boxes) was less stable than the one in 2008 (circles) and the transfer function in 2009 varied by up to 50% (for a more detailed discussion see also my memo from 09/06/2009). There is hence no indication for variability in this AT data, which probes spacial scales of $\sim 80$ mas. This leaves three explanations:

- the variability comes from regions larger than $\sim 80$ mas
- there was just an “outburst” on 2008-04-14 and the MIR flux reverted to its normal state by 2009-04-26
- there was no intrinsic increase in the MIR emission of Circinus.

The first two explanations are very unlikely. Thus the most likely explanation is that there was no increase in the MIR emission of the Circinus nucleus and that the increased count rates are due to an instrumental effect. Note that no useful photometry could be measured with the ATs.

11 Conclusion

The MIDI photometry data of the nucleus of the Circinus galaxy shows a general offset of the flux values for 2009 and a slow drift of the total flux at short wavelengths. Several possible reasons for these variations were investigated, but no conclusive explanation for either of these variations could be found. The implications of the “unexplainable” variations on the credibility of the data obtained with MIDI remain to be discussed.
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