"Advanced" data reduction for the AMBER/VLTI instrument

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Goals

- Ease the use and handling of AMBER raw data and products
- Provide tools to accurately calibrate the AMBER data
- Improve the AMBER data calibration

Data handling tools

We have developed several tools to easily handle the AMBER data. These are:

- File handling tools
  - to recognize and sort files by types, exposure times, etc.
  - to correct tags in files that were mis-tagged
  - to handle files in night directories instead of individually
- "Global" tools, which give an overview of a whole dataset
  - UV coverage for several nights and data points (Fig. 1)
  - transfer functions: see next panel

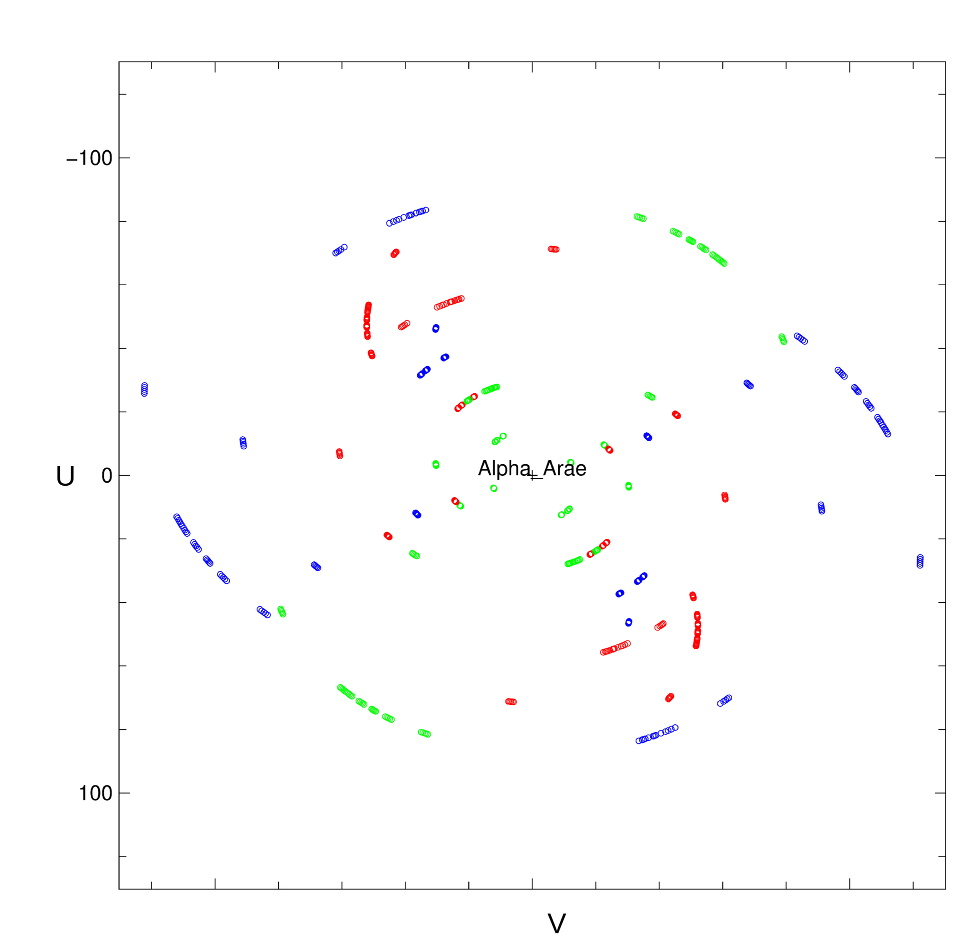

Figure 1: UV plane plot obtained on the star α Arae during a full ESO observing period (6 months).

Transfer function and data calibration

The transfer function is the « ultimate » data quality test before getting calibrated data. This step is the most important as it allow one to validate or discard in a global view the whole data processing made in the previous steps. It allow also to evaluate the impact of the night conditions (Seeing, weather, ...) to the dataset and to compute realistic errors. For that, we developed specific tools to obtain calibrators diameters from the available catalogs and to plot and evaluate AMBER transfer functions (Fig. 2).

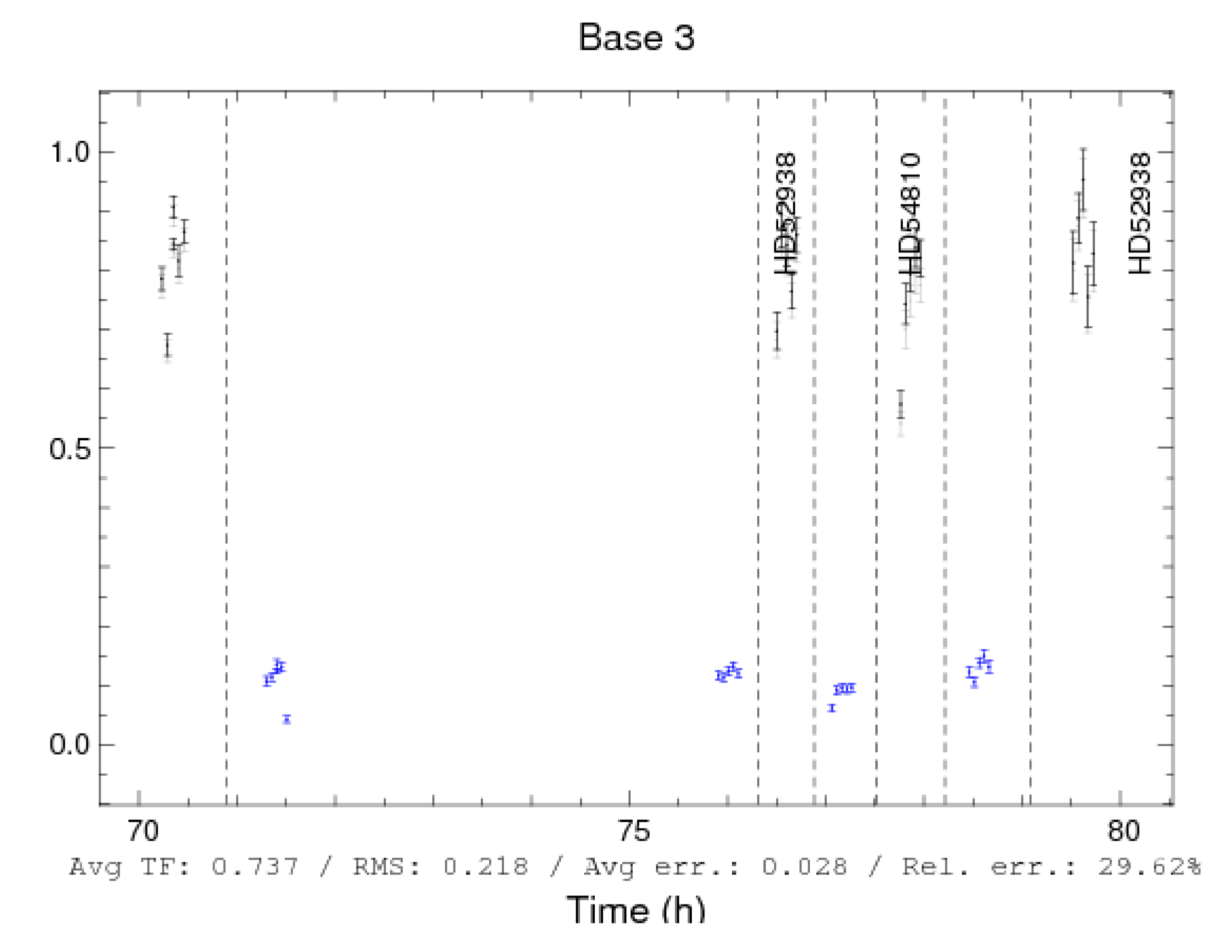

Figure 2: Example transfer function during a good AMBER observing night. The grey data points show the raw calibration stars visibilities, the black points show the transfer function and the blue points show the « science » data.

Calibration is made afterwards when all the data has been validated. It produces final data products in the form of OI-FITS files. In a first attempt, we coded a very simple calibration scheme, assuming that the transfer function is constant over the whole night. Other schemes can be coded as the tools are made of independent modules.

Visibility loss effects

AMBER is a fibered monomode instrument. Theoretically the only origins of visibility loss are:
- the fringe motion during an exposure (also called jitter), which blurs the fringes,
- the non zero optical path difference (OPD) combined with the coherence length visibility loss

Once the the visibility loss has been computed, the correction can be done by dividing visibility of each frame by the theoretical visibility loss. Averaging is then done in the standard way, without frame selection or any other processing.

O[ptical] P[ath] D[ifference] correction:

A "basic" correction can be done assuming that only the achromatic OPD is responsible of the visibility loss. The estimation of visibility loss is shown on Fig. 3, compared to the actual measured squared visibility.

"Subtle" additional effects:
- Since the AMBER phase is measured relative to a reference (P2VM), this effect must be corrected.
- The chromatic atmospheric dispersion effect also affects the visibility loss.

These two effects are affecting the visibilities at the few percents level. Corrected V² are much better in this way (Fig. 4), but still not perfect (Fig. 5)

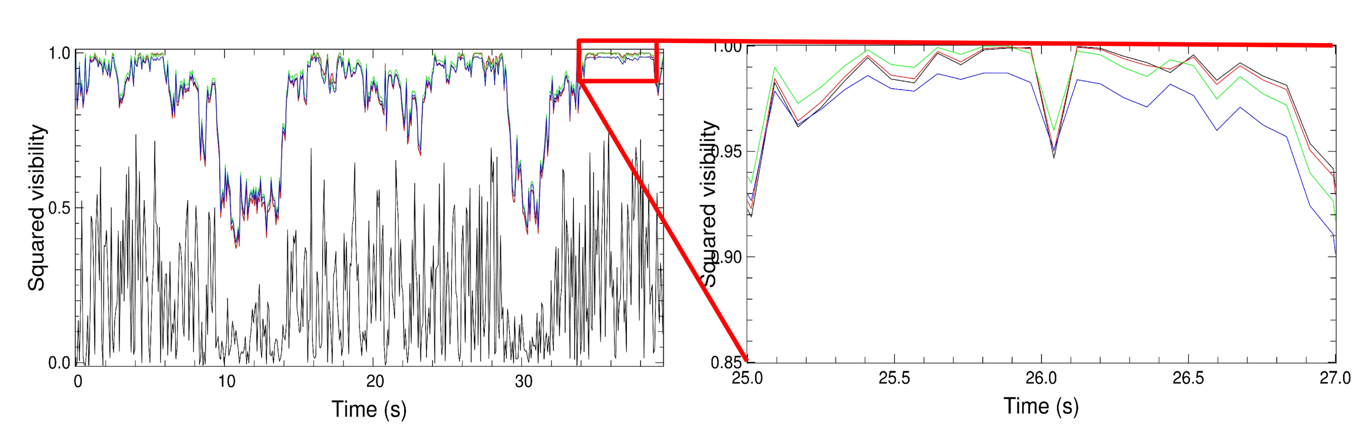

Figure 3: An example of visibility attenuation on a typical AMBER exposure. In black (lower noisy curve) is plotted the raw squared visibility versus time, and also in black (upper curve) is shown the attenuation expected from the amdlib OPD measurement only, in red is the same as before but taking into account the P2VM non-zero OPD, in green is including effects from chromatic dispersion of air and in blue is including all effects. One can see in the right enlargement that the difference is about 1% (this is a best case).

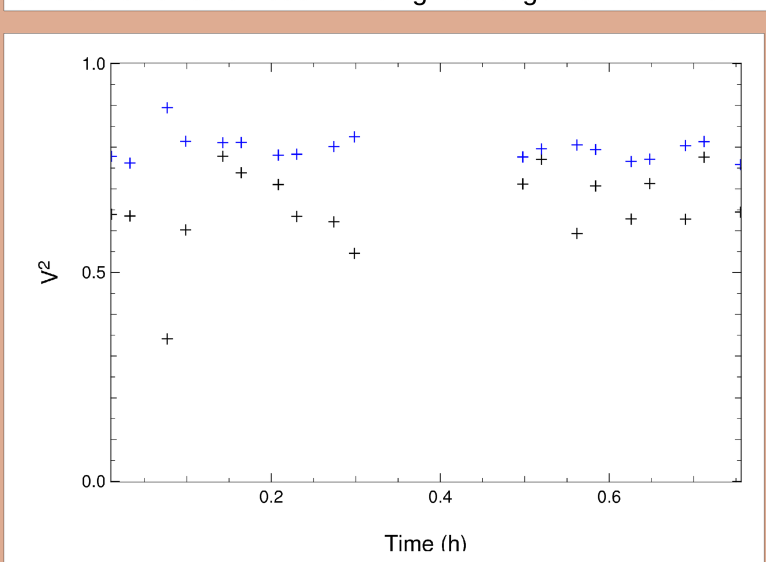

Figure 4: Squared visibilities versus time without (black crosses) and with (blue crosses) coherence loss correction. A huge amelioration (SNR 6.6 without correction, SNR 26.7 with correction) can be seen in the transfer function when correcting for this effect at low spectral resolution (R=35). No data selection has been applied on the data for this example.

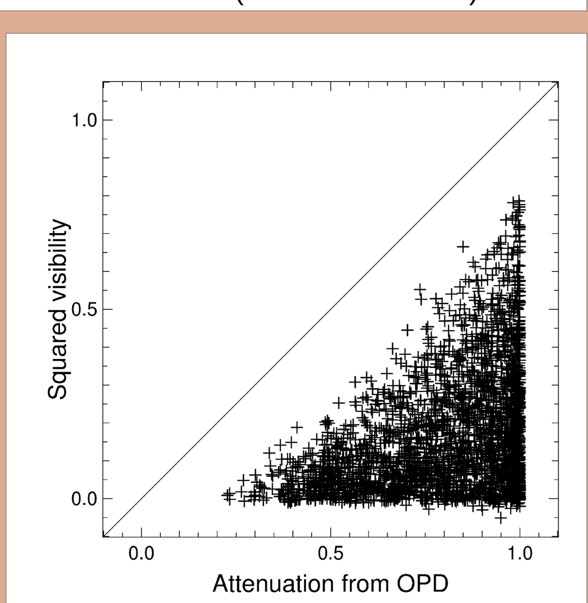

Figure 5: Only a partial correlation between computed attenuation and visibility is obtained as seen in this correlation plot. Thus another effect than the coherence loss is affecting the data.

"Jitter" correction

"Jitter" estimation:

"Jitter" is by definition the OPD variation during one single integration time of the interferometer (responsible of the fringe "blurring"). Unfortunately no direct way to measure or estimate the jitter exists today.

The idea developed here assumes the jitter is only composed by a fringe shift during the frame. We therefore estimate the jitter using the difference between two consecutive frames. Figure 6 shows the correlation between this estimate, OPD and visibility. Visibility decreases as OPD and jitter increases. No correlation between jitter and OPD can be seen, which means they can be treated separately.

Results:

These two main effects on visibility can be corrected in AMBER data processing. Transfer function is typically better by a factor 4 when applying correction and a relative error of 3-4% can be obtained on low spectral resolution data and bright objects (see Figure 4 and 7).

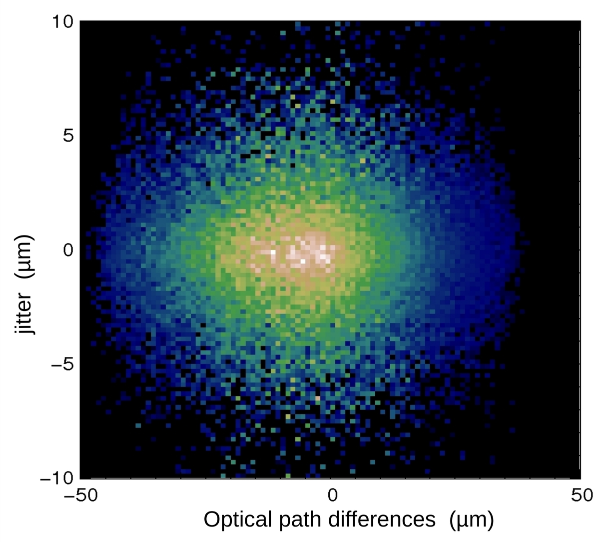

Figure 6: visibility (0=black, white=1) as a function of jitter and OPD on many different data sets. This plot basically shows that there is no correlation between jitter and OPD, and thus that they can be treated separately.

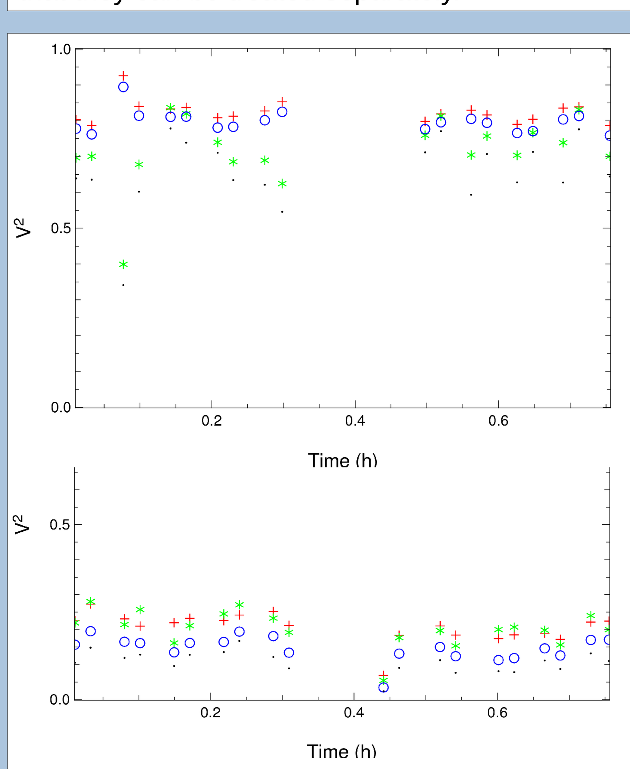

Fig.7: Transfer functions illustrating the strength of the methods described here to enhance the low spectral resolution data calibration:
- Black dots show averaged uncorrected V²,
- Green stars : 20% of the best SNR selection,
- Blue circles : OPD correction only,
- Red crosses show OPD+jitter correction.

Top graph is a good night whereas bottom one is a night with poor conditions. A slight amelioration compared to OPD correction is seen for the good night, whereas jitter appears as a main contributor in the second case.

Results

We presented new tools to handle AMBER data in a more efficient way, with global data evaluation tools. We also demonstrated that it is possible to correct AMBER V² for OPD and jitter effects. We showed that these effects are the major drawback to a proper data calibration at low spectral resolution. The proposed solution has been tested on several cases and show a significant improvement to the data quality after applying the correction and no additional filtering (data selection, etc.).

Conclusions

Data handling tools, transfer function tools and "basic" calibration tools are already provided in a prototype development version through the amdlibPipeline.i script, distributed by the author at the following address:
http://www.mpifr-bonn.mpg.de/staff/fmillour/

Coherence length and jitter correction are being partially implemented also in this script but not yet fully usable as a development phase is still ongoing.