AMBER data reduction in practice

1 Simple Medium Resolution Observation on Alpha Arae

Here we have a simple case with only a subset of the K band at resolution 1500, on a Be star with Brackett Gamma emission.

Data is in `$HOME/data/Data_Reduction_AMBER/alfara`

use '`gasgano`' to see files organisation. Notice that:

(1) the files are listed in time order
(2) the calibration files for the so-called P2VM are not necessary observed for the same project, but they must have the same spectral resolution, are observed before the science data.
(3) there is at least a series of obervations on the science target and one on a calibrator (star with known visibility).

exit `gasgano`.

Now, call '`amdlib`' which is a `Yorick` interpreter wrapping the compiled amdlib library.⋆ The interpreter has the memory of previous commands that can be recalled with the up/down arrows. There is a number of commands available, which can be seen if you type '`amdlib`'. Each command has an extensive help, such as '`help, amdlibSetPreference`' to look at the documentation of the command '`amdlibSetPreference`'.

Use the *documentation of amdlib* ($HOME/data/JMMC-MAN-2720-0001.pdf), at pages 18-19 (Cookbook). We'll perform the quick data reduction of historical Alpha Arae data described there to get acquainted with a typical data reduction layout and the significance of the plots. Let's stop after all commands to plot results:

`amdlibComputeAllP2vm`

(follow instructions of documentation for the auxiliary bad pixel and flat field maps). will be followed by `amdlibShowP2vm`

`amdlibComputeAllOiData`

will be followed by `amdlibShowOiData` (on Raw Data)

`amdlibPerformAllFrameSelection`

will be followed by `amdlibShowOiData` (on time-averaged Data)

Notice the spectral position of the feature associated with the Brγ line ($\lambda = 2.166$ microns)... Accurate spectral calibration is impossible with AMBER's hardware. There are several ways to solve this:

(1) measure the offset and redo the whole calibration after displacing the P2VM spectral information by the correct shift, using the "`shiftSpectralAxis`" option of `amdlibComputeP2vm`

⋆ to exit from Yorick interpreter, the command is 'quit'.

(2) on MR or HR observations, use the "`amdlibCheckAllWavelengthTable,interactive=1`" command.

2 Medium Resolution Excellent data without Finito

We'll reduce 4 observations of Sirius obtained in the half-hour when the longest baseline of AMBER crosses the first zero of this textbook example of a stellar disk. The first file is before the crossing, the second has the zero exactly in the middle of the K band observed, the 3rd is entirely after the first zero of visibility. The last file, obtained a few minutes after, suffers from terrible seeing. We'll fit an uniform disk in the calibrated data using LITpro.

First, exit from amdlib and call it again (since the BPM and FFM of 'alfara' was for an older detector, we start anew).

Data is in `$HOME/data/Data_Reduction_AMBER/MedResOnSirius/`

Perform the standard reduction.

This time we will calibrate the Science observations using the calibrators observations:

```
amdlibSearchAllStarDiameters
```

and point to the `_AVG` directory.

let's have a look at the value obtained:

```
$cat /home/linux/amdlibCalibDataBase.txt
Star_name    OB_name  RA(deg)     DEC(deg)    diam(mas)  diamErr(mas)  dist(")  Catalog
 CAL-Gam_Mon  --       93.7139750  -6.2748300  3.042      0.217         0.4      II_300_jsdc
```

This file can be edited if you have a better estimate for the calibrator's apparent diameter in the K band...

```
amdlibCalibrateAllOiData, inputDir="./", checkPlot=1,writeOutputFiles=1
```

We can now use the calibrated OI-FITS files to fit, e.g., a stellar diameter. We'll use LITpro:

```
$ litpro
```

create "new settings", load only the first calibrated OIFits file, define the target (`SCI-HIP_32349_SB`), add a model 'disk', uncheck (= do not use) the VISamp, VISphi and T3amp data. Run fit. Plot results. Do the same (separate fit) with the 2nd and 3rd files. Comment, knowing that the diameter of Sirius is 6 milliarcsec with a precision of a few microarcseconds.

3 Tricky data: Low resolution, with fringe tracker.

The low resolution mode covers J H and K bands and is the most sensitive mode of AMBER. However, even in presence of the FINITO fringe tracker (that tracks in the H band) the calibration of the squared visibilities is touchy at best.

Data is in `$HOME/data/Data_Reduction_AMBER/LowRes/`

3.1 Issues with LR P2VMs

`amdlibComputeP2vm`

Enter BAD PIXEL FILE (only once, first time): `BPM.fits`
Idem for Flat Field: `FFM.fits` or `VraimentFlat.fits` (needed, but has very minor importance unless FFM is very wrong!). Use '`VraimentFlat.fits`' for this time.
enter 5 or 10 (here we are with 3T AMBER so it is 10) P2VM calibration files: use button 'Compute Log', which reads the fits files and colors them according to their nature. P2VM's are RED.

In the output, the program says:

```
 The spectral resolution is 3Tstd_Low_JHK
 The used spectral shifts are (pixels): [4,4,-1]
(...)
 Special Pass for autocentering wavelengths...
 Performed shift of -132.448000 nm to align wavelength table on H-K discontinuity.
```

plot p2vm (we'll discuss the contents of the plots) (amdlibShowP2vm).
In the corresponding subdirectory choose:

`LowRes_3.0.7_P2VM/AMBER.2010-10-05T01:06:27.616_P2VM.fits.gz`

and have a look at it.

There are two possible calibration problems in LR mode: the spectral shifts may be wrong, the wavelengths recorded by AMBER may be quite false. In LowRes mode, the wavelength table is adjusted automatically by `amdlib`, but there are cases where this trick does not work. Here $-132.44\,\mathrm{nm}$ is ~ 4 pixels—which could be correct, or not. Similarly, the default spectral shifts (here [4,4,-1]) may change with time. Let's reduce again with option `specCalShifts="MAN"` to play with the shifts (between photometric and interferometric data) and unsetting `autoShiftP2vm` to use only the spectral calibration given by the instrument:

```
raw=[];amdlibFileChooser,,raw;
bias=[];amdlibFileChooser,,bias;
amdlibComputeP2vm,inputRawFile=raw,inputBiasFile=bias,specCalShifts="MAN",autoShiftP2vm =0
```

The best offests are $4, 3, -1$ but the phase transition between H and K is at 1.7μ, which is a clear sign that the wavelength table provided by the instrument is wrong, this shift should be at $\simeq 1.85\mu$. So, the final calibration command should be redone:

```
amdlibComputeP2vm,inputRawFile=raw,inputBiasFile=bias,specCalShifts=[4,3,-1],autoShiftP2vm =1
```

one can check that everything looks OK with `amdlibShowP2vm`.

All the spectral information is now contained in the P2VM file and will be used for all the other files.

3.2 Issues with Piston in Bands and FINITO use

Now, compute once all data:

`amdlibComputeAllOiData`

Let's then look at a few raw data files:

`amdlibShowOiData`

The plots correspond to half-reduced data where all the individual (frame by frame) values have been kept and are not time-averaged. Thus we have access to the histogram of interferometric observables and to the time behaviour of pistons. The plot covers the 3 bands J H and K, and you must use the panel 1 to look at what's going on band-per-band.

Q: what is wrong with piston plot in this mode?

Q: what do you make of the histograms of closure phase and V2?

A: It is quite evident that the piston has weird values, even taking into account that it is a mean of the (independent) J, H and K pistons. And this, when FINITO was in use!

A: J band is totally crap (no significant V2, closure has all values). K is very good, H varies a lot in quality.

Q: why?

So it is necessary to split the data between bands, and quite possibly use only the K data wich is good.

To avoid confusion, remove the `LowRes_SVN_20130905_16210_OIDATA` directory, e.g., by:

```
$rm -rf ../LowRes_SVN_20130905_16210_OIDATA
```

Let's redo, using only the K band:

```
amdlibComputeAllOiData,band="K"
amdlibShowOiData
```

data looks good. However there are some spurious piston excursions left, and perhaps some frames are not very good. So, we'll apply a severe selection on pistons (the spectral coherence length for LR is 70 microns) and a mild selection on frame quality:

```
amdlibPerformAllFrameSelection,selCriterion=["piston","snr"],selType=["threshold","percent"], selValue=[15,80]
```

the amdlibShowOiData plots are different, since these are now time-averaged data: amdlibShowOiData (the last files are *_AVG_K.fits.gz, the *_AVG_K_AVG1.fits.gz are intermediate products that we could remove) at this stage, individual OIFITS files can be explored also with OIFITS-Explorer.

3.3 calibration

Now we'll calibrate the science data with the calibrator. First we need to find the calibrator's diameter:

amdlibSearchAllStarDiameters, inputDir="./"

let's have a look at the values:

```
$cat /home/linux/amdlibCalibDataBase.txt
 Star_name  OB_name  RA(deg)       DEC(deg)   diam(mas)  diamErr(mas)  dist(")  Catalog
 HR8090     --       317.1166920  6.9889900  2.29       0.031         2.4      J_AA_393_18
```

```
amdlibCalibrateAllOiData, inputDir="./", checkPlot=1,groupOiData=1,vis2TfMode=0,t3TfMode=0
```

which interpolates linearly the apparent change of transfer function between the 2 observations of the calibrator, or

```
amdlibCalibrateAllOiData, inputDir="./", checkPlot=1,groupOiData=1
```

which does not.

After discussion, we write the calibrated data:

```
amdlibCalibrateAllOiData, inputDir="./", checkPlot=1,groupOiData=1,vis2TfMode=0,t3TfMode=0,visTfMode=0,writeOutputFiles=1
```

The files can then be used to, e.g., fit a model. For example in LITpro (see dedicated practice session)

For those interested, one can split bands and reduce all bands separately:

```
amdlibComputeAllOiData,splitBands=1
```

then have a look at, e.g., `AMBER.2010-10-05T02:22:04.145_OIDATA_RAW_J.fits` and the corresponding H and K file. This confirms the J and H piston behaviour which is terrible: those 2 bands are not to be used.

One can try to redo the calibration and disk fit with LITPro adding H, then J data to the input files. The V2 of J being essentially zero (not because of the true visibility but because of the piston jitter) corrupts the diameter measurement.

4 Spectral dispersion calibration

If time permits, we'll use an undocumented utility of amdlib (written by J.B. Le Bouquin) on a set of HR observations to get accurate wavelength calibration.

Reduce quickly data in `$HOME/data/Data_Reduction_AMBER/HiRes/` up to the obtention of AVG data. use

```
\amdlibCheckAllWavelengthTable,interactive=1
```

on the AVG data. The display show the correlation between each spectra and the spectrum of the telluric absorption lines. One can select the file with the best fit (depends on S/N of observations) and apply to all data. There may be several setups, based on the 'magic number' of the various P2VMs present in the directory (since each P2VM is by definition a new spectral setup—AMBER's grating was moved).

In the present case, the offset is negligible, but can go up to tens of pixels in the worst cases.