Reduction Project:VLTI measurements of NGC 1068

The project will cover the reduction and simplistic interpretation of MIDI data on the nearby AGN (Seyfert 2 galaxy) NGC 1068.

Description of the MIDI instrument itself will be given in class but is also available at:MIDI home page and also at the ESO instrument pages :ESO MIDI site

The data is in the directory:Data_Reduction_MIDI/HD100546

Despite the directory name, the data contains MIDI measurements of the Seyfert 2 AGN NGC 1068 with the 1.8m Auxiliary Telescopes, plus calibrator measurements.

The goal of the exercise is to convert the raw data to instrumental correlated fluxes and calibrate the fluxes. We want to be able to judge the quality of the individual measurements. At the end we will see what kind of information we can get out of the fluxes.

The reduction will be pursued using the *Expert Workbench System* (EWS) which I wrote for MIDI. This system consists of a number of C-programs to do heavy number crunching, and a large number of IDL-scripts and programs that call the C-programs and display the data, both in a batch mode and interactively.

The EWS system is documented at:EWS manual and at the

Midiwiki:Heidelberg WIKI.

There is a “pipeline” routine, named midiVisPipe that runs all the individual steps to reduce one observation. If you do this for a target observation and a calibrator observation, these can be combined with *midiCalibrate* to produce calibrated fluxes and a number of plots.

Below I describe the individual steps in midiVisPipe, and I will demonstrate these, and examine the intermediate results, so we have some idea of what is really going on.

Here is a very short description of reduction steps; a more complete description is given at the step by step guide to EWS

1. Look at the raw data: You can find a list of the observations by starting up EWS, moving to the directory with the data and typing: *file = midiguis()* I will explain how this gui works. When you have chosen a file, the data can be read into the IDL work area with *data = oirGetData(file)* The data is in the form of an IDL structure, which I will explain in class.

2. Compress the data. A C-program: *oir1dCompressData* uses a data mask to select the important rows on the detector, and sums them along the slit. If you reading the data with data=oirGetData(file) and display it with tvscl,transpose(data.data1) it may look like this:raw compressed data

3. Filter the data to remove sky backgrounds: A C-Program *oirFormFringes* runs a high-pass time filter over the compressed data, and optionally removes the spectrum average from each frame. Then you data may look like this:highpass cleaned spectra

4. Remove the instrumentally modulated OPD variations from the data. *oirRotateInsOpd* reads these variations in the data files, and multiplies each spectrum by exp(-ikD). The data is now complex and should be read in with

cdata=midiComplex('hd10380','insopd'). The real part looks like this:demodulated spectra

5. Estimate the atmospheric contributions to the delay. *oirFGroupDelay* averages data together over a short time interval and determines the group delay of the signal by a fourier transform of the spectral data. For very weak sources (including NGC 1068) we do this in two passes with another program, *oirPowerDelay* in between. See the step by step manual for details. The plots of fringe amplitude vs. delay look like this:group delay plot

6. Remove atmospheric delays, and estimate and remove water vapor phase delay: *oirRotateGroupDelay.* The fringe patterns now look very smooth:ungroupdelay

7. Check for unusual delay variations and flag this data as bad:*oirAutoFlag*

8. Average flagged and hopefully coherent data over time:*oirAverageVis*. The output is the (complex) correlated flux as a function of wavelength. This file has a different output format (OI_VIS) and can be read with *corr=oirGetVis(file, wave=wave).* You can try plot,wave,corr.visamp. The plots may look a little like this:correlated fluxes etc.

9. The above steps must be applied separately for each measurement of the target source, and each nearby calibrator source. The calibrator measurements are used to correct for atmospheric absorption, instrumental sensitivity, and variations of atmospheric decorrelation conditions. The results will be correlated flux for the target in Janskys at the measured UV-point as a function of wavelength. We can actually run all the steps for both target and calibrator using midiProcess2Vis.

10. We can also measure the total, non-interferometric source fluxes from the single telescopes, with one shutter closed at a

time and chopping the telescope secondary to measure the sky backgrounds. The demodulation of the chopping is done in *oirChopPhotoImages,* and the extraction of the photometric spectra in *oirMakePhotoSpectra.* For a weak source like NGC 1068 this does not work very well, for reasons to be discussed in class, so we will omit this part in this project.

11. The various calibrated and reduced data can be read into IDL using *oirGetData* and *oirGetVis* as well as a lot of intermediate utility programs. In the end you must use the calibrated fluxes and visibilities to make a model of the source.