Practice Work Session P7 (2.5h)

Preparing VLTI observations

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Abstract

This session draws on those conducted during the previous Practice Work Sessions. Its objective is to prepare a VLTI observing run, considering both AMBER and MIDI observations, in order to determine what is feasible with these instruments and how useful the planned observations would be to solve a particular scientific problem.

Practical considerations

These exercises will be conducted with the VLTI-dedicated version of ASPRO. We will run the web-based version of the software from the local server, as we did in session P5, because we will also try to identify adequate calibrators. If the network fails, we will resort to the versions used in previous Practice Work Sessions and skip the calibrators part.

1 Astrophysical problems

In this session, we shall consider two projects. In both cases, the goal is twofold: 1) to determine the adequate VLTI configurations that allow the observations, and 2) to decide which instrument is useful in constraining the system's properties. Furthermore, we want to obtain quantitative results that can be used as arguments in an ESO proposal: e.g., adequate period to conduct the observations, expected range of visibilities, ...

The first problem consists in spatially resolving a spectroscopic binary system in order to constrain the system inclination and, therefore, its total mass. In this project, we will try to use both AMBER and MIDI and determine which instrument is most appropriate.

The second problem consists in studying an object surrounded by a circumstellar disk with AMBER. In this case, the goal is to determine the relative flux of the star and of the disk, the typical size of the disk, as well as the minimum number of measurements needed.

2 Binary system

2.1 Setting the problem

Here we consider a "test" spectroscopic binary system, namely HD 147889. Let us assume that this source is a spectroscopic binary (consisting of unresolved stars), with a maximum projected semi-major axis of 0.4 mas, along position angle 25^o (we will consider this position angle as a sure thing for the purpose of this exercise). If we observe the binary system at a random point in time, its projected separation is 0.2 mas; at apoastron, the projected separation reaches 0.6 mas. We further assume that the binary has a magnitude difference of 0.25 mag, constant throughout the near- and mid-infrared. This flux ratio is estimated from the guessed masses for the stars and thus to be considered uncertain: it will remain an unknown in our problem.

The goal of the observation is to try and determine the binary separation and flux ratio at a certain wavelength with a satisfactory accuracy so that the stellar masses can be determined.

2.2 AMBER observations

Here we decide to use AMBER with 3 UTs in snapshot mode: select `AMBER with 3 Telescopes` in the `Choose...` menu.

2.2.1 Setting the object

In the *Object* menu, use the CDS link to define the target. Note that you must use an `underscore` sign instead of a `space` in the object name. Click on `GO`. If the network fails, the J2000 coordinates of HD 147889 are α=16:25:24.32 and δ= -24:27:56.6. Set the object's magnitudes to MV=7.95, MH=4.94, and MK=4.58.

Set the model of the object with the parameters indicated above, using the "observation at a random time" projected separation. Proceed to the observational set-up.

2.2.2 Observability of the target

Before choosing a particular instrumental configuration, we must first determine the dates of observation. Click on the `Source Observability...` button and check that the target is above elevation 30^o during most of the night (this is indicated by the black segment). Check also that the delay lines are able to follow the target during that interval (this is the red segment). Test other triplets of UTs. When should the observations be conducted (propose 2 months)? Does it depend on the selected baselines?

2.2.3 Choosing the AMBER configuration

AMBER offers three spectral resolutions. It would be preferable to use the highest resolution possible, in case some physical insight on the system could be gained, for instance by comparing in- and out-of-spectral line visibilities. However, the object brightness may prevent us from using the highest resolution of AMBER.

Select a certain resolution and click on the `GO (Show/Add UV track)` button. If the object is too faint to be observed with the requested resolution, an error window pops-up. What configuration can be used for this object?

2.2.4 Testing a first interferometer configuration

For the time being, select a central wavelength of 2.2μm, and UT1-UT2-UT3 as baselines. Use a 60 min sampling periodicity and, opening the `Less used observing constraints`, choose to follow the motion of the target in the hour angle range [-0.5h;0.5h], i.e. we will obtain a single measurement (snapshot) with 3 visibilities (remember to click on the `click here to validate entries` button).

With this setup, click on the `GO (Show/Add UV track)` button to see the Fourier transform of the object and the *uv* points that will be sampled. Click on the `Proceed to visibility panel` to obtain a plot of visibilities as a function of projected baseline. The uncertainties that are shown correspond to the object brightness and the instrumental configuration.

Do you think that this configuration can help constraining the actual separation and flux ratio of the binary?

2.2.5 Testing other configurations

Experiment with other combinations of UTs as well as a different central wavelength within the range of AMBER to decide whether it is possible to measure the binary separation at a random phase in its orbit. If so, what configuration do you propose?

Repeat the same exercise with the projected separation corresponding to the apoastron passage.

In conclusion, what configuration and time constraint (if any) do you suggest for conducting these observations?

2.2.6 Accuracy on the binary separation

With the selected configuration, click on the `Proceed to UV fitting` after having plotted the visibilities. In this panel, we shall estimate the accuracy on the binary separation that the observations would provide. *Note that this is not the best method for estimating this accuracy; this will be discussed later in the Summer School (see discussion on Model Fitting next Wednesday). Still, ASPRO provides an estimate of the uncertainties that will be found when fitting a model to visibilities.*

In the `AMBER_3T UV fit control panel`, choose to fit a binary to the data. In the fit, we can fix 4 out of 6 parameters: the model is located at (0,0), its total flux is unity and the position angle is set to be 25^o. Since we usually do not know ahead of time the actual separation and flux ratio of the binary, try "random" guesses, flux ratio ranging from 0.1 to 1 and separation ranging from 0.2 to 5 mas. To set a parameter to a fixed value, use `-1` as "number of starts"; to let it free, use `0`.

For each set of initial guesses, run the fit 3-5 times: the fitting routine introduces a noise-imitating random process that yields different results every time. The r.m.s. of the fit results is actually a better estimate of the uncertainty we would obtain on the model parameters. Note the values and uncertainties on the flux ratio and separation. Repeat the process with different initial guesses.

What accuracy can we hope to get on the flux ratio and the separation with the proposed observations?

NB: If you want to run the same fitting procedure with another instrumental configuration (changing baseline and/or wavelength), you must return all the way to the "object definition" section and re-enter the parameters of the model.

2.2.7 Check with VisCalc

Use the `VisCalc` tool[1] to check the square visibilities that were obtained with ASPRO. Be careful that ESO's convention on position angles is reverse from ASPRO's. It is always wise to double check one's results!

2.2.8 Finding a calibrator

Before going ahead and writing a proposal, we must check that there are adequate calibrators around our target. Use the SearchCal tool available in this version of ASPRO, following the same instructions as during Practical Work Session P4. Use a small search region around the target (20 min in RA, 3^o in Dec and a magnitude range [3.;6.] to match the target brightness).

Indicate possible calibrators and the accuracy on their visibilities. Will this accuracy limit our ability to determine the binary properties?

2.3 MIDI observations

We now want to determine whether using MIDI instead of AMBER for this project is more appropriate. We must exit ASPRO and restart it, selecting `MIDI on UTs`. Since we cannot use 3 telescopes at once with MIDI, we will keep the default [-12.;+12.] hour angle range, i.e. we

[1] It is available under "Exposure Time Calculators" on the ESO webpages at *http://www.eso.org/observing/etc*

will observe the target for an entire transit. Follow the same procedure as with AMBER (for this object, MN=3.30).

With what instrument configurations (beam combiner and spectral resolution) is it possible to observe this target given its brightness? Is it possible to use the ATs (on which the pressure is much lower) instead of the UTs to observe this target?

Can you find an instrumental setup (baseline and observing wavelength) that allows to determine the binary separation and flux ratio in the mid-infrared?

Conclusion: in a proposal concerning this target, would you ask for AMBER or MIDI? What if the binary separation were 5 mas instead?

3 Circumstellar disk

If time permits, repeat the same exercise with a different geometrical model for the target.

This time, we will use AMBER with 3 Telescopes in snapshot mode (hour angle range [-0.5;0.5]) and will consider that our target consists of the sum of two components: an unresolved point source and a circular Gaussian structure that mimics a face-on circumstellar disk. The unknown parameters are the flux ratio between the two components and the FWHM of the Gaussian profile.

With a disk:star flux ratio of 1:4 (make sure the sum of the fluxes for each component is equal to unity, otherwise the visibilities will be incorrect) and a Gaussian FWHM of 3 mas, find the most appropriate telescope configurations and observing wavelengths to determine the unknown parameters with good accuracy.

NB: When running the fitting routine, set all parameters to fixed values, except for the flux and FWHM of the Gaussian profile (all we really care about is its flux *relative to the point source*).

Estimate the accuracy with which the properties of the Gaussian component can be determined. Increase the hour angle coverage to add more measurements and determine the smallest number of observations needed to get a good constraint.

Repeat the exercise if the disk:star flux ratio is 1:10. In this case, is it at all possible to constrain the Gaussian component with the current capabilities of AMBER?