Practice Work Session
Preparation of observation

G. Duvert,
Laboratoire d'Astrophysique de Grenoble (LAOG)
and Jean-Marie Mariotti Center (JMMC)

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Abstract

This Practical applies the principles of optical interferometry developed hence to the preparation of a VLTI observation, with the help of software tools available for the community.

1 Memento

You have a fairly good scientific reason to ask for high angular resolution of some object. No doubt these will be praised by every program commitee. However convincing a comitee is easy; convincing Nature to give answers is tough. Getting onseself familiar enough with the limitations of a particular interferometric facility is necessary. The questions to be adressed prior to writing a proposal (for VLTI or other optical interferometric facility) are:

1. Is VLTI appropriate for the observations of my target?
2. Is my target observable with VLTI?
3. What is the appropriate VLTI instrument for this project and can it be used with the adequate set-up?
4. What set of baselines is most appropriate for this project?
5. Can I find a good interferometric calibrator?
6. How accurately will the observation constrain the geometry of the target?

All these points are developed in the *"Goutelas Book"*, prepared after the first School in this Series and in press as a New Astronomy Review book (http://www.elsevier.com/locate/issn/13876473). The contents of this school are also available on the http://www.vlti.org website.

Of these, this practical covers all points except 5 above: finding a good calibrator is very source-specific (see practical session by Wittkowski, this School), we need to access a separate set of tools for the most of them available only as webservices on the ESO (http://www.eso.org/observing/etc/) and JMMC (http://www.mariotti.fr) websites (fortunately these tools will almost always provide a calibrator name).

2 Generalities

You are already familiar (if not delirious about its user interface) with the "Aspro" utility installed on the school's computers. We will use its VLTI-dedicated `AMBER, Periods 79-89` "flavor". You are provided with a copy of the AMBER Call For Proposals for this period, to peruse during the Practice.

Start the application and choose `AMBER, Periods 79-89`. Contrary to the "full interface", here the items necessary to prepare observations are grouped more naturally, starting with the "Object" properties definition (including a model of the object) on the left, and the panels are chained together from left to right. One assigns the position, fluxes and a (basic) model for the object, then proceed to the observational setup. This new panel has only the list of authorized telescopes configuration for the ESO "period" and the small list of possible setups for the focal instrument, AMBER in this case (defining the default K band of the observations).

The "Show UV tracks" button will not only plot the uv tracks of the planned observation, but update a list of complex visibilities at these points, including noise given by the instrument's sensitivity, and these can be explored in the next "visibility panel". By going back and forth between these three panels, one can get himself convinced if the observation is feasible and worthwile.

The last panel (UV fitting) will aid to put confidence numbers by fitting the model in the simulated noisy visibilities, giving rms of errors on the model's parameters.

3 Is VLTI appropriate?

ESO and JMMC tools cannot currently help you decide what instrument is best suited in terms of spectral band or spectral resolution, or if the 3 simultaneous baselines and one phase closure of AMBER will be an asset. We will illustrate point 1 on the terms of spatial resolution only. Let's start by defining an hypothetical source at -20°, assign it a number of simple geometrical models of different angular sizes and comparing them:

3.1 Angular resolution and structure detection. Size is not all

1. use an 0.6 mas size stellar disk source first, of fair magnitude 0 (giving similar errobars for AT and UT observations these days), and observe it with U1-U2-U3 , then with A0-K0-G1.
2. perform the same with a binary model of identical sources (flux ratio is 1) and orientation 0. Is the more extended AT array more favourable?
3. the same binary, but at P.A. 90°. ?

Another example:
use a 10 mas stellar disk and U1-U2-U3, then with A0-K0-G1. (Ok, this is not fair). Now do the same with an *unresolved* (dust) ring.

3.2 Model differentiation vs. Visibility sampling

One can use ASPRO to check where or under conditions two different models will show markedly different in the observations. One has only to make a differential model (by substracting one model to the other) and see what happens.

1. find how to do that in the Source definition panel
2. differentiate circular disk and circular gaussian (same typical size of 0.6 mas) for the relatively compact U1-U2-U3 and the quite extended A0-K0-G1 configurations. Suppress the error bars plotting that has no meaning here (in any case, the noise model is not, contary to the fourier decomposition, linear). Adjust the vertical scale of the plot to see something (how?).
3. The same between a circular disk and a limb-darkened disk of noticeable darkening a=0.3, b=0 for a 5 mas source.

4 A Realistic observation

We plan to observe a spectroscopic binary system (that consists of two unresolved point sources), HD147889, whose projected orbit runs along position angle 100° (East from North). At apastron, its projected separation reaches about 0.6 mas but,if observed at a random time along its orbit, the projected separation is only 0.2 mas (statistical average). Furthermore, the flux ratio of the binary is about 0.5 throughout the near– and mid-infrared wavelength regime with an uncertain amount of variability around that value. Our goal is to determine whether VLTI observations can resolve the binary, quantitatively retrieve its physical parameters (separation and flux ratio), and what is the most appropriate array and instrument configuration. In particular, we will want to use the highest possible spectral resolution, in search for potential differences between the continuum and some spectral features.

In addition, we want to know if we would be able to detect an unconfirmed third component of the system supposedly 4mas away.

The small separation calls for an AMBER observation.

4.1 OBJECT...

Use CDS to retrieve the coordinates of HD147889. Information returned is incomplete (yet) for the infrared magnitudes. Complete using Mag. K=4.6, Mag. H=5.5 , Mag. V=8 . Enter the model.

Besides the brightness of the target itself in the observing band (see below), it is also important to check that the target, or a nearby star (within 60"), is bright enough to allow telescope guiding: the feeding adaptive optics (MACAO on UTs) and tip-tilt units (STRAP on ATs) both require a minimum flux in the visible to work properly (V< 17mag and V< 13.5mag, respectively). Hence, observing extremely red objects in the middle of heavy extinction patches with no foreground or background source is almost hopeless.

The declination of HD147889 is roughly $-24°$, so it passes almost at zenith from Paranal, and it is bright in the visible, allowing good telescope guiding with both the UTs and ATs. It is therefore feasible to observe this target with VLTI.

4.2 OBSERVATIONAL SETUP

Starting with today 4 June, find the best period of year to observe HD147889 with the VLTI. Change Baseline sets. Are there limitations due to the delay line limited throw? Temporarily change the declination of the source to nothern latitudes (+12°). Apart being lower on the horizon, what else for some baseline sets[1]?

4.3 Focal Instrument limitations

Aspro knows about the limitations on the use of the instruments given by ESO for a particular period of proposals. Try to use a medium spectral resolution with this source. What could we do to enable observations with the ATs at all? Note that changing the observing wavelength to H band (1.5μ) in the same panel does not change the way ASPRO accepts or reject the spectral setup (why?). Is spectral resolution needed for this project anyway?

4.4 Best Baseline Set

In our case the P.A. of the binary is given which helps selecting an array configuration. Between the UT and AT configurations, find the best coverage that samples the regions of the fourier transform of the source's brightness distribution where the *signature* of the binarity is strongest.

(To reach a conclusion as to which array configuration is best for this project, we must also consider that it is probably easier to obtain 1 entire night with a 3 AT configuration than a full 3

[1] very southernly objects have also observing limitations due to delay lines, which you can test also.

UT night. Note that you can also mimic an half-night or single hour of observation with the UTs using the "less used observing constraints" of the panel. Try this for completeness.)

4.5 Resulting visibilities

Use the "Proceed to Visibility panel" to reach the "interferometric observables explorer". The squared visibilities plotted here reflect the sampling of the model as seen before on the uv tracks. Play anew with the configurations and this panel to check that A0-K0-G1 seems the best choice. Check by changing the wavelength (we are in low resolution mode and have access to the H band also) that H gives an even better v2 dynamics).
Go back and reprocess from the "source panel" to observe the same HD147889 when *not* at apastron. What does this imply for the proposal?

4.6 Expected accuracy

Use the "UV fitting panel" to check the expected errors on the different parameters. See what is constrained and what not. Does observing band or number of observations[2] solve this?

4.7 Model refinement

Now introduce a third companion (pointlike), of flux ratio $1 \div 4$ at 4mas distance and $P.A. = 135°$ (How do you do that)? Are visibilities markedly different? Are these visibilities distinguishable from the case where HD147889 is unresolved at periastron?

4.8 User-Provided Model

In this Practice we have used only models built as sums of geometrical (simple) models provided by the ASPRO library. One can also make ASPRO look at his/hers own model by providing a FITS image or data cube in the alternate panel triggered by the "User-Provided Model" button in the "OBJECT..." panel. If you are to use this facility, pay attention to the format, unit and value of the needed header keywords in the FITS file, since theses keywords define the angular extent of the object on the sky and the wavelength(s) used. The format needed is explained in the associated HELP (click on the text "Your Model Data (FITS file)" where the prompt show a question mark to get topical help).

5 Another example

Try to model Achernar (Achernar EQ 2000.0 1:37:42.8466 -57:14:12.327, MV 0.5 MJ 0.790 MH 0.860 MK 0.880) with the first model described by P. Kervella in Kervella & Domiciano A&A 2006. Achernar's fast rotation has flattened the star in an oblate spheroidal shape. Kervella used the data provided by a large number of points painfully obtained with VINCI and the two small (40 cm) aperture VLT siderostats used for tests. He found an ellipsoidal Achernar of size $2.53 \pm 0.06 \times 1.62 \pm 0.01$ mas at an angle of $39° \pm 0.05$ (see attached document).

Try to assess the feasability with the current AMBER possibilities (flux, today's available baselines). Use the fit to test the accuracy. Note that the fitter is 1) **touchy** and 2) needs to explore properly the phase space to have a "range" and an "number of starts" defined. In this case, since the fitter works on correlated flux and not visibilities, it will be necessary also to fix a number of values. See the HELP of the panel for these important details).

[2] even if it is not realistic, in the "less used observing constraints" subpanel of the "Obs. Setup" panel, set the "sampling period" to 20 minutes, this increases the number of observed points