1 Foreword

In stellar interferometry, the raw fringe contrast must be calibrated to obtain the true object visibility which will give the object parameters that can be interpreted in term of astrophysical parameters. Calibration is usually done by measuring with the same apparatus, and as simultaneously as possible, the fringe contrast of an object of known visibility: a calibrator. Ideally, a calibrator should be a point source, unresolved at all baselines. In practice, small angular size objects, unresolved by the longest baseline used, or objects of a very well-known (or predicted) angular size can be used as calibrators.

To allow a good calibration of the visibility measurements, the instrumental response must not change during the time necessary to observe the target and the calibrator. Usually, the instrumental response will change as fast as the atmospheric conditions changes (including the change in airmass due to diurnal motion). Most frequently, the instrumental response is also dependent to the observed source flux. Thus, the calibrator should have a brightness and a sky location close to those of the scientific target.

Atmospheric turbulence calls for elevations of the object and calibrator to be as similar as possible at the time of their respective observations. Foe example, a difference of about 5° in DEC gives a 10% variation in airmass at 40° elevation. For bright calibrators, the difference in RA between the calibrator and the target is less critical (180 min in RA is tolerable). To allow observations with comparable SNR, the calibrator should not be too weak compared to the target and a maximum magnitude difference of 1 mag seems reasonable.

With the installation of AMBER and MIDI instruments at the VLTI, the selection of suitable calibration stars was deemed crucial to reach the ultimate precision of their interferometric observations. The JMMC calibrators group, building on the experience acquired with the GI2T interferometer, designed a "search calibrator tool" (*SearchCal*[1]) to assist the astronomer in this calibrator selection process.

The tool is available on the JMMC's website and has been driven by the objective to create a dynamical catalog of calibration stars, using mostly "virtual observatory" techniques. A complete reference to the scientific background of *SearchCal* is described in [1]. The design can be summarized as follows:

- Input: Astrophysical requirements on the scientific object.
- Method: Search of the potential calibrators in a field around the scientific object. An interface to the CDS data center is used to retrieve the astrometric and spectro-photometric parameters present in the CDS stellar catalogs. Follows the computations of suitable parameters (correction for interstellar absorption, angular diameter, visibility). Finally, an automatic selection of stars based on astrophysical and instrumental requirements is performed.
- Output: list of possible calibrators. A final list of calibrators is obtained after a manual selection by the user, based on astrophysics criteria.

[1] The documentation for *SearchCal* is included in the ASPRO documentation and available on-line at http://www.mariotti.fr/doc/approved/JMMC-MAN-2100-0002.pdf.

2 Answers

2.1 The SearchCal panel

This panel mainly consists of three sections:

- The science star window,
- The results window,
- A set of selection tools used to refine the list of calibrators and load/save the results.

The MenuBar `"Calibrators"` permit to change the level of information displayed:

- `"Full"` button to see all information available.
- `"Detailed"` for a less verbose output.
- `"Synthetic"` (the default) for normal output.
- `"Show legend"` to make appear the meaning of the colors.

Note that the complete User Manual is included in the `"Help"`.

2.1.0.1 the result panel and Filter buttons

5 stars are found.
- 3 stars are rejected because the lack of photometric data prevents the computation of the angular diameter.
- 2 stars are found to be potential calibrators with a consistent diameter: HD12311 (angular distance 5.0°) and HD14641 (angular distance 5.9°).
- 1 calibrator (HD14641) is selected without variability or multiplicity flag.
The star HD12311 is rejected because it is suspected to be variable and multiple in the I/280 catalog.
The scarcity of bright stars (magnitude $K \leq 5$) explains the very small number of calibrators. This happens more than often. In this case, it is advised to widen first the RA interval (which amounts to comparable elevation and airmasses). Then the DEC difference can be increase up to 10 degrees if the elevation is more than, say, 45°. If this does not yet suffice, the range in magnitude can be extended provided the largest magnitude does not come close to the limiting magnitude of the instrument.

Colors in list: they have a meaning.
- For example, what is the originating catalog for the J, H and K magnitudes of HD14641?
- What is the confidence index of the corresponding visibility?
- Why such a low (far from $V= 1.0$) visibility?

- The infrared magnitude of HD14641 are from the Bordé catalog i.e. “A catalogue of calibrator stars for long baseline interferometry” [2]
- A high confidence index is associated with the computed visibility for HD14641 because the photometry is directly extracted from a catalog (see color code of the entry in the table).
- The squared visibility (0.822) is quite low but very precise (0.5%) because its value is obtained with the angular diameter given in the Bordé catalog (UDDK = 2.140 mas) with a relative accuracy of 1%.

- What does the V2 uncertainty listed by SearchCal include? Only uncertainties from fitting the photometric information? How do measurement uncertainties on the calibrators affect the calibration process? What maximum degree of uncertainty on the calibrator should be tolerated?

> The error on the value of V2 given by SearchCal takes into account the uncertainty on the value of the angular diameter of the calibrator. Except for stars having published value of the angular diameter, this uncertainty reflects the fitting of the photometric data.
> For very small calibrators (diameter < 0.5 mas), the estimated visibility is always very close to 1.0 and an large error (say up to 50%) on the angular diameter have quite a negligible effect on the value of the visibility
> In any case, the user will have to select the value of the angular diameter of his calibrator (and his error) from a critical analysis of the published values or by his photometry and by comparing the results given by the various methods of calculation of photometric diameter available in the literature.
> The degree of uncertainty tolerable on the angular diameter depends on the value of the estimated visibility. The more the calibrator will be unresolved, the larger will be the uncertainty on his angular diameter.

2.1.0.2 Other buttons

2.1.0.3 MIDI calibrator

> - The calibrators are extracted from the list of stars characterized by the absence of circumstellar dust and a flux at 12 μm more than 5 Jy. This list is used by the ESO Calvin tool.
> - 1 calibrator is found: HD10052 (angular distance 1.0°) with a squared visibility of 0.983.

The calibrator found is closer than at K, and has a better visibility. Why?

> VLTI observations in the mid-infrared N band ($\lambda \sim 10$ μm) allows an angular resolution 5 time less than in the near-infrared K band ($\lambda \sim 2$ μm) and then gives a fringe visibility much higher for a given angular diameter of the source. In other words, unresolved stars are more numerous at N than at K, at constant baseline length.

3 Fainter Star, K band

Let's go back to VLTI+AMBER, in K band, but with a fainter star, Gl551.

> Gl 551 (Proxima Centauri, HIP 70890) is a red dwarft.
> spectral type M5.5 Ve, magnitudes V= 11.0, K= 4.4.

Fainter stars are more numerous [2], we will restrict ourselves to a search zone of 20 minutes of time in RA and 2 degrees in declination. We bracket the magnitude range from 3 to 6.

Same questions as in section **??**.

[2] For the search of very faint calibrators (magnitude K >> 5) the most serious problem can be encountered in the vicinity of a bright star. In this case, the catalogs can contain a "blind spot" and SearchCal will not possibly find all the potential calibrators. The only solution in this case is to make a specific research on a small field around the target.

7 stars are found.
- 3 stars are found to be potential calibrators with consistent diameter: HD127996 (angular distance 0.9°), HD 125881 (angular distance 1.2°) and HD125158 (angular distance 1.8°).
- 1 calibrator (HD125158) is selected without variability or multiplicity flag.
The star HD127996 is rejected because it is suspected to be variable and multiple in the I/280 catalog but for star HD125881 the varflag3 = C ("constant") indicates that no variability was detected by Hipparcos.

The visibilities are now better (for a calibrator). Why?

What would be your final choice in that list for the Gl551 star?

- The selected stars being fainter, their angular diameters are smaller that gives a larger fringe visibility for a given base length.
- To privilege a strong value of the visiblity , the star HD125881 is a good choice of calibrator since it gives the largest visibility. If the priority is given to the brigthness of the calibrator, then star HD125158 must be selected.
- Usually, if one has the choice between several calibrators, one will have to take the brighter calibrator (to guarantee a good SNR of the data) but only if its visibility is either near 1.0 (unresolved calibrator) or known with a high precision (resolved calibrator).

Use the `"SELECT CALIBRATOR"` command of the "sort above list" subpanel to sort the list according to the various sorting parameters. From the final list of potential calibrators, the user can refine the choice of its calibrators by changing, a posteriori, the selection criteria:

- field around the science object,
- object - calibrator magnitude difference,
- spectral type and luminosity class,
- accuracy on the calibrator visibility,
- indications about variability and multiplicity

3.0.0.4 Fainter Star, K band, method "Faint" This new method uses the stars of the 2MASS Ir all-sky survey, thus finding faint to very faint objects which are statistically more numerous. It is thus not necessary to explore a large area to find calibrators. besides, the stars being fainter are frequently distant stars (even KIII ginats on the other side of the Galaxy), essentially unresolved.

4 Bibliography

[1] Bonneau, D. *et al*, 2006, A & A, 456, 789.

[2] Bordé, P. et al., 2002, A & A, 393,183.