JMMC Evolutive Search Calibrator Tool

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ABSTRACT

In stellar interferometry, the raw fringe visibilities must be calibrated to obtain the intrinsic object visibilities and then object parameters which can be interpreted in term of astrophysical parameters. The selection of suitable calibration stars is crucial to reach the ultimate precision of the interferometric instruments like VLTI. So, we have developed a user-dedicated software to create an evolutive catalog of such calibration stars. This gives useful information for the selection of calibrators with respect to the requirements of the astrophysical program and of the instrumental configuration. A list of potential calibrators is obtained from a set of catalogs available at the Centre de Données Astronomiques de Strasbourg (CDS). The CDS request is based on some selection criteria like the maximum angular distance and the range of magnitude around the scientific target. This calibrator selection tool is integrated into ASPRO the interferometric observing preparation software developed by the Jean-Marie Marriotti Center (JMMC), and which is accessible at http://mariotti.ujf-grenoble.fr/~aspro/

1. INTRODUCTION

Optical interferometry provides a powerful tool to determine the morphology of astronomical sources at high angular resolution. Such information is obtained from complex visibility provided by the measurement of the contrast and position of the fringes resulting from the recombination process. The atmospheric turbulence and instrumental instabilities induce effects which distort the phase and decrease the amplitude of the observed fringe contrast. In order to take into account this effects, observations of the target should be bracketed by observations of calibration stars. The selection of suitable calibration stars is crucial to reach the ultimate precision of the interferometric instruments. For numerous programs the calibrators must have properties close to those of the scientific target :

- close sky location and apparent magnitude to observe with same instrument configuration,
- similar color (spectral type) in case of interferometric observation in large band to limit chromatic effect.

Ideally, a calibrator must be a point source giving a fringe visibility equal to 1.0. In practice, the smaller the calibrators the lesser the sensitivity of the angular diameter determination to their intrinsic visibility or sources of variability. Strictly, no object with a measured angular diameter will respect these properties. This is particularly true in the case of faint objects (specially with the new generation of interferometer as the VLTI).

In this poster, we present the original structure of the Search Calibrator software developed by the JMMC (Section 2). A brief description of the method adopted to design the software is given in section 3. Two specific technical aspects are shortly described in the section 4. Final remarks and next developments are given in section 5.

2. SEARCH CALIBRATOR: THE STRUCTURE

The design of a search calibrator tool available in ASPRO has been directed by the objective to create a dynamical catalog of calibration stars. The calibrator field surrounding the scientific object is defined in the ASPRO software environment using astrophysical requirements.

To search the potential calibrators in this field, we adopt a method of "the virtual observatory" type. Potential calibrators are search from all the stars in a box (in position, magnitude and color) defined around the science object.

An on-line interface with CDS data base has been created to extract astrometric/spectro-photometric parameters available in stellar catalogs and to obtain the initial list of stars. Then calculations are made to correct the interstellar absorption, to compute missing magnitudes, to estimate the photometric angular diameter with its associated accuracy. The expected visibility and its precision are computed taking into account the instrumental configuration.

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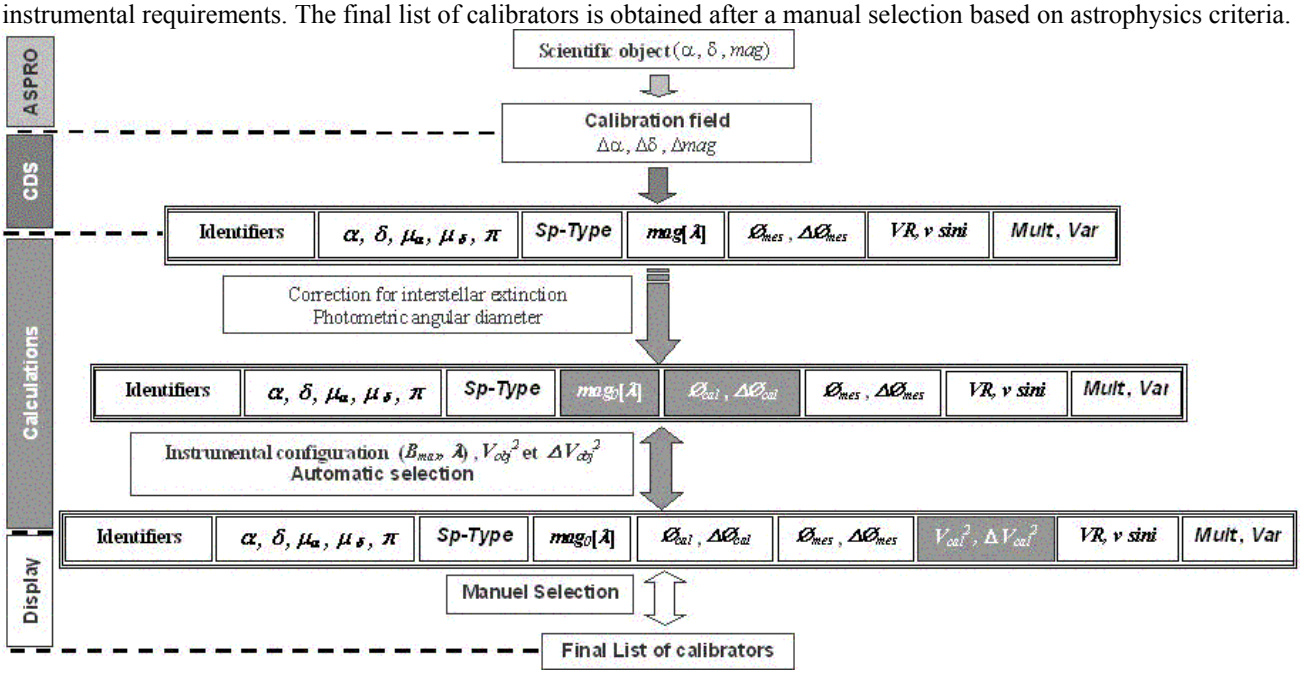
The list of possible calibrators is proposed after an automatic selection of the stars based on astrophysical and instrumental requirements. The final list of calibrators is obtained after a manual selection based on astrophysics criteria.



The figure 1 presents the structure adopted to built the Search Calibrator software.

Figure 1: Block diagram of the Search Calibrator software

3. SEARCH CALIBRATORS: THE METHOD

3.1 The Search Calibrator Tool in the ASPRO environment

The ASPRO software is developed by the JMMC to help astronomers to prepare interferometric observations [1]. Integrated into ASPRO, the Search Calibrators tool allows to select calibration stars.

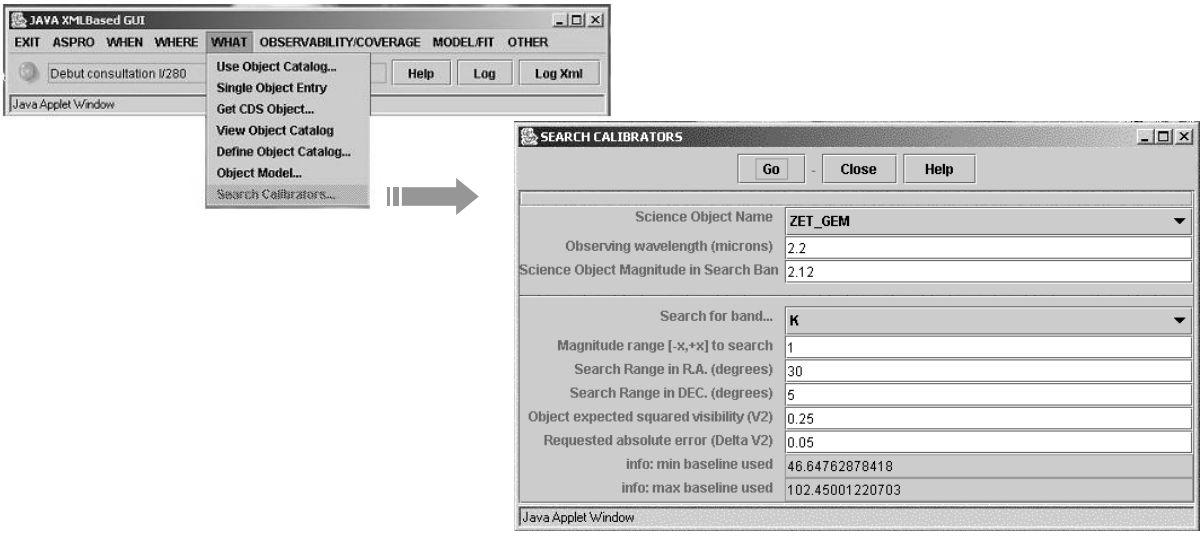


Figure 2 : Launch panel of search Calibrator in the ASPRO environment.

Figure 2 shows the launch panel of Search Calibrators in the ASPRO environment. In this panel, the user must enter the parameters needed to constrain the research of potential calibration stars around the scientific target (magnitude range in

the chosen photometric band for observation (*V, J, H, K*), calibrator field) and to apply the automatic selection of the calibrators (observation wavelength, maximum baseline, expected squared visibility and its absolute error for scientific target). The calibrator field is a rectangular box centered on the science object position with a size given by the choice of the maximum relative distance in right ascension and declination. The user also indicates the maximum magnitude difference between the calibrators and the science object in the photometric band used for the observation.

3.2 Selection of possible calibrators from CDS inquiry

In order to select stars as potential calibrators, a lot of astronomical parameters must be known for each stars. To built a dynamic list of such stars, we have chosen to extract the information from a set of stellar catalogs available at the Centre de Données Astronomiques de Strasbourg (CDS) [2] . The requests to the data base VisieR [3] at CDS use the calibrator field parameters in the chosen observing photometric band in the visible (*V*) or the near infrared (*J*, *H*, *K*). Useful information for each star found in the calibrator field are compiled from the different catalogs. To sort the result, the catalogs are linked according to equatorial coordinates and *V* magnitude (for *V* band), or according to equatorial coordinates and *K* magnitude (for infrared bands).

The astronomical parameters are extracted from the following catalogs:

- I/280 : All-sky Compiled Catalog of 2.5 million stars (Kharchenko, 2001)
- II/7A : UBVRIJKLMNH Photoelectric Catalog (Morel et al., 1978)
- II/225 : Catalog of Infrared Observations, Edition 5 (Gezari et al., 1999)
- II/246/out : The 2MASS all-sky survey Catalog of Point Sources (Cutri et al., 2003)
- B/denis/denis : DENIS data base (DENIS consortium, 2003)
- I/196/main: Hipparcos Input Catalogue, Version 2 (Turon et al., 1993)
- V/50 : Bright Star Catalog, 5th Revised Ed. (Hoffleit et al., 1991)
- V/36B : Supplement to the Bright Star Catalog (Hoffleit et al., 1983)
- J/A+A/386/492/charm : Catalog of High Angular Resolution Measurements (Richichi and Percheron 2002)
- J/A+A/393/183 : Catalog of calibrator stars for LBSI (Bordé et al., 2002)

When a star appears to have angular diameter measurements in the Catalog of High Angular Resolution Measurements (CHARM) [4] then, the first value is taken into account. The stars present in the Catalogue of Calibrators for Long Baseline Stellar Interferometry [5] are always added to our list. The Figure 3 shows the strategies used to extract and sort the data from the different catalogs. The result is a list of stars with known parameters: identification, astrometric parameters, spectral classification, magnitudes in various photometric bands, indication on variability and multiplicity and published value of the measured angular diameter if available.

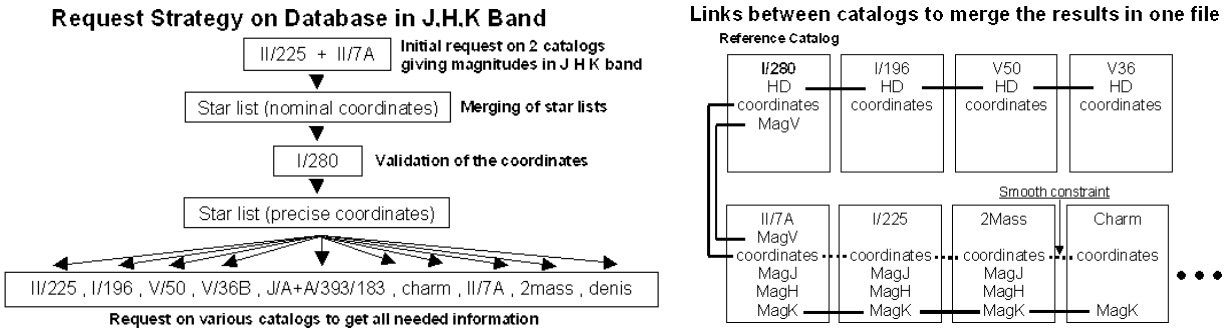


Figure 3: Strategies for VizieR data base request and links between catalogs. Following the catalog, the link is realized using the coordinates, HD number or the magnitude (V or K)

3.3 Calculations

Photometric corrections for interstellar absorption are calculated from trigonometric parallax using the Chen et al galactic interstellar absorption law [6] and the observed magnitude are corrected with the Fitzpatrick coefficients [7]. Missing photometry is then calculated from the compilation of published *color-luminosity class-spectral type* relation [8,9,10,11,12,13,14].

For each star, the angular diameter and its associated error are computed using a surface brightness method and calibrations for (B-V) , (V-R) and (V-K) color index [15] (Figure 4). A coherence test of the photometry is done by

comparison of the computed diameters from the different color index. The star is rejected from the list in case of negative result of this test.

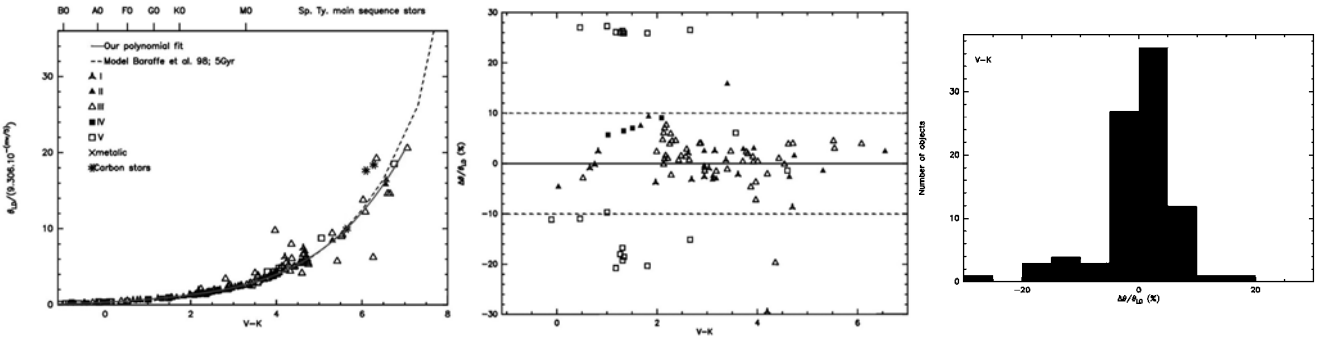


Figure 4: Left, newly determined angular diameter (ϕ_{LD}) – (V-K) relation. Middle, relative residual in angular diameter. Right, distribution of the relative residuals. With the knowledge of the V-K color index, we can determine the angular diameter with typical error of ~5%

Then, for each star, the squared visibility and its associated error are computed as a function of the angular diameter (measured or computed) and its error for the given instrumental configuration (wavelength λ and maximum baseline B_{max}) using an uniform disc model. The visibilities of potential calibrators are always large enough (V_{cal} > 50%) and the uniform disc and limb darkened disc models do not differs more than 7% in the V band and 1% in the K band.

3.4 Automatic selection.

The expected accuracy of the calibrator visibility ($\Delta V_{cal}^2 / V_{cal}^2$) must satisfy constraint fixed by the expected accuracy of the science object ($\Delta V_{obj}^2 / V_{obj}^2$) , the values adopted for the instrumental visibility Γ^2 and the errors on the measured fringe contrast $\Delta\mu^2$. The final list of possible calibrators contains only stars satisfying this constraint.

3.5 Results display

The figure 5 shows the output panel presenting the result of the calibrator search. The parameters of the scientific target are given in the upper window. The list of the potential calibrators is displayed in the bottom window.
The detailed description of the tables as well as the functions of the different buttons are given in the Search Calibrator Help available as a PDF file in the ASPRO web site.

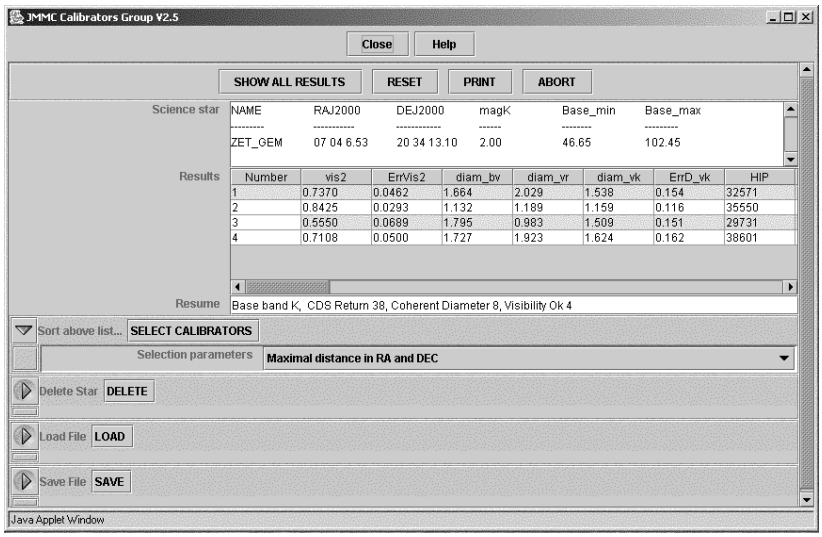


Figure 5: Search Calibrator output panel

3.6 Manual selection.

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 of variability and multiplicity) (Figure 6).

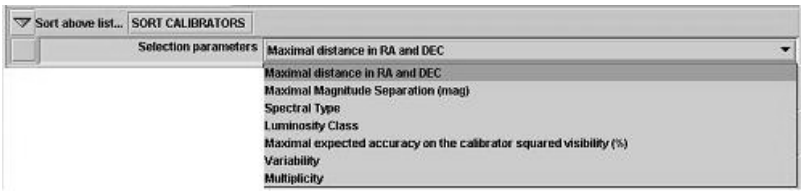


Figure 6: Panel for the manual selection of the calibrators

4. TECHNICAL ASPECTS

To obtain a relevant result for the initial list of potential calibration stars, it has been necessary to define the selective requests needed to extract the specific data from each stellar catalog.
In the following we give an example of socket request on VizieR at CDS written to extract from the II/225 catalog the stars satisfying constraint on the K magnitude (lambda = 2.20), with a user defined magnitude range (F(IR) = 2.5..6.5) and in a rectangular box size (-c.bm=1800/300) centered on the science target position.

" GET/viz-bin/asu-xml?-source=II/225/catalog&-c.ra=05+45+22.6& c.dec=09+04+12&x_F(IR)=M&F(IR)=2.5..6.5 &lambda=2.20&-out.max=50&-c.bm=1800/300&-c.u=arcmin&-out.add=_RAJ2000,_DEJ2000&-oc=hms &-out=lambda&-out=F(IR)&-out=x_F(IR)&-sort=_r "

To precisely define the extracted data and to reduce the number of returns, we have used for each catalog the data fields defined by UCDs (Unified Content Descriptors) and labels to specify what information we want and the various data field limits.
In the way to do Search Calibrators software available as a tool fully included in ASPRO Web software, we use Xml to Java technic for the GUI Display instead of standard technics such as X Motif. (Figure 7)

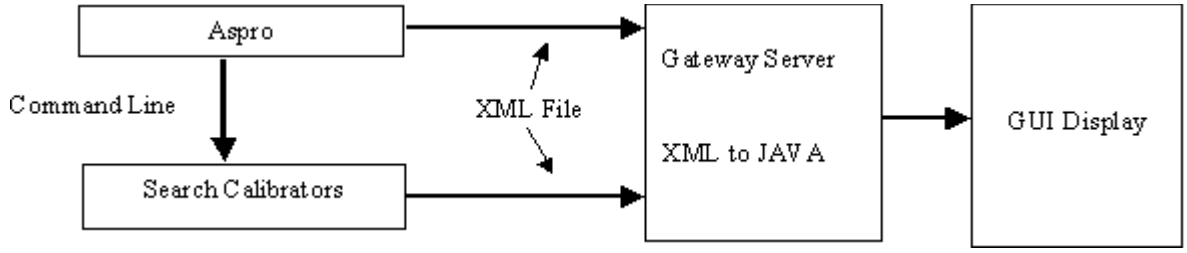


Figure 7: diagram of the general structure of the display

5. CONCLUSION

The Search Calibrator software presented here has been developed to find calibration stars in the vicinity of bright scientific targets. The limiting magnitude reachable for the selected calibrators is imposed by the magnitude of the fainter stars for which the maximum of astronomical parameters are available in the astrometric and photometric catalogs used for this selection, i.e. typically visible V magnitude ≤ 10 or infrared K magnitude ≤ 5. In practice, this limits agree with the sensitivity of the interferometers now in operation in the visible and the near infrared.
However, the gain in sensitivity expected with the emergence of interferometers with large apertures such as VLTI, KI and CHARA implies that it will be necessary to find fainter calibrators. So we have undertaken to develop an extended

version of Search Calibrator software allowing to reach an infrared *K* magnitude close to 14 needed to find suitable calibrators for the scientific objects observable with the instrument AMBER on the VLTI.
The global structure of this software will be analog of Search Calibrator for bright sources but important evolutions are necessary especially to take into account the difference of the data for faint stars extracted from stellar catalogs.
In the way to be compatible with the new standards developed in the context of the Astrophysical Virtual Observatory (AVO) project, we have also planned to use Votables Databases Files and CDS Web Service through SOAP technology.

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