

# Practical session on calibrators

**Euro Summer School**  
***Active Galactic Nuclei at the highest angular resolution:  
theory and observations***

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With input from similar contributions at earlier VLTI schools by Boden and Percheron

# Calibrations for interferometric instruments

- Detector characteristics (flatfield, bad pixel mask, linearity)
  - Baseline
  - Wavelength
  - Photometry
  - Interferometric transfer function
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- Calibration plan available for MIDI at <http://www.eso.org/instruments/midi>
  - Quality control parameters are monitored by the ESO Quality Control department. See: <http://www.eso.org/observing/qc>

# Interferometric transfer function

$\mu$ : measured visibility (coherence factor)

$V$ : theoretical visibility (calibrator), calibrated visibility (science)

$T$ : interferometric transfer function\* describing the loss of coherence due to atmospheric turbulence and instrumental effects

$$T(\lambda) = \mu(\lambda) / V(\lambda)$$

-> calibration star: know  $V$ , measure  $\mu$ , obtain  $T$

-> science target: use  $T$ , measure  $\mu$ , obtain  $V$

$$V_{\text{sci}} = (\mu_{\text{sci}} / \mu_{\text{cal}}) * V_{\text{cal}}$$

\* $T$  is also called system visibility or interferometric efficiency.

# Error sources

$$V_{\text{sci}} = (\mu_{\text{sci}} / \mu_{\text{cal}}) * V_{\text{cal}}$$

- Errors in measurement of  $\mu_{\text{sci}}$ ,  $\mu_{\text{cal}}$   
Systematic effects in case of different types of sources  
in terms of, for instance, brightness, spectral type (effective wavelength)  
=> Use a calibrator of similar magnitude and similar spectral type  
    **AMBER:  $\Delta K < 1$**
- Error of  $V_{\text{cal}}$   
=> Use a well known and small calibration star  
    Single unresolved star without any special features such as a dust shell  
    Completely unresolved point source ->  $V_{\text{cal}} = 1$ .
- Variability of T between measurements of calibration star and science target  
(as function of airmass, seeing, coherence time,...)  
=> Measure T close in time and on sky  
=> Verify the stability of T

# How to find a good calibrator

- Find a good compromise between the different criteria.  
This may depend on your scientific goal and the characteristics of your instrument.
  - Use single stars with known (and possibly small) angular diameter.
- 1 Angular diameter from previous high resolution measurements  
=> CHARM (catalog of high angular resolution measurements),  
Richichi, Percheron, Khristoforova 2005, A&A, 431, 773.
  - 2 Catalogs of angular diameter based on spectrophotometric measurements:  
Cohen et al. 1999, Borde et al. 2002, Merand et al. 2005, MIDI calibrator catalog
  - 3 Find spectrophotometry in the literature, and derive the angular diameter. Tools:  
Aspro (JMMC), getCal (MSC)
  - 4 Combinations, e.g. of 1 and 2.

# CalVin tool (<http://www.eso.org/observing/etc>)

- Based on a fixed underlying list of calibrators for each VLTI instrument.
- Interface to select a suitable calibrator based on different criteria (distance to science target, brightness, spectral type, etc.).

**Advantage:** Well-known calibrators that are better and better verified in the course of VLTI observations. Well-known calibrators are very important for service mode observations that don't allow an interaction during the observation.

**Disadvantage:** There might not be a calibrator available for certain needs (e.g. faint calibrators close on sky to the science target).  
=> Use one of the other techniques to find a calibrator.

# MIDI calibrators

Catalog provided by the MIDI instrument consortium:

- 511 candidates selected based on IRAS and MSX point source catalog taking into account MIDI magnitude limits and accessible coordinates.
- Spectrophotometric observations of the candidate stars.
- Spectrophotometry fitted to theoretical atmosphere models (MARCS, ATLAS). Yields  $\chi_v^2$  and angular diameter  $\theta$ . A large  $\chi_v^2$  indicates deviations from a regular atmosphere for instance due to a dust shell (infrared excess) or a composite spectrum.
- A limit of  $\chi_v^2 < 5$  in CalVin leads to 178 MIDI calibrators.

# AMBER calibrators

- CalVin/AMBER includes the calibrator catalogs by  
Borde et al. 2002, A&A, 393, 183  
Merand et al. 2005, A&A, 433, 1155

These are based on spectrophotometric observations.

- CalVin/VINCI includes additional calibrators based on existing measurements (e.g. CHARM catalog) and empirical calibrations (e.g. V-K color).