# Calibration of interferometric data
# VINCI overview

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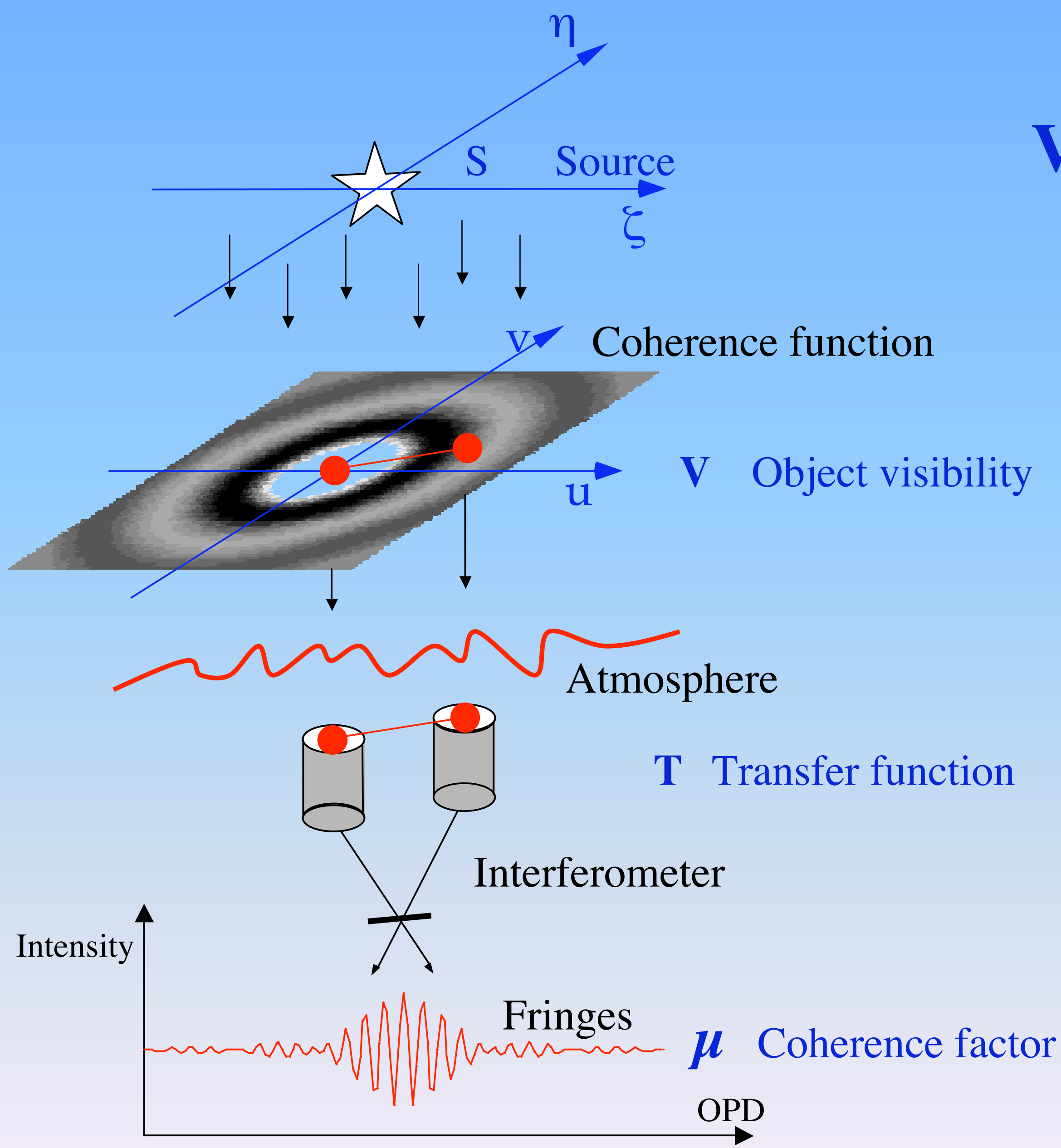



$$V(u,v) = TF\,[S(\eta,\zeta)]$$

# Coherence and object visibility

$$\mu^2 = V^2 \,.\, T^2$$

Remarks

- **μ, V, T** complex valued in general
- μ expresses the correlation between the two fields
- T point source response

# From coherence factors to object visibilities

- Calibrator 1: $\mu^2_{cal1}$ => $T^2_1 = \mu^2_{cal1} / V^2_{cal1}$
- Science target: $\mu^2_*$ => $V^2_* = \mu^2_* / T^2$
- Calibrator 2: $\mu^2_{cal2}$ => $T^2_2 = \mu^2_{cal2} / V^2_{cal2}$

$$\Rightarrow \sigma(V^2_*)/V^2_* = \sigma\,(\mu^2_*)/\mu^2_* + \sigma(T^2)/T^2$$

Total error on $V^2_*$ thus includes:

- System errors on $V^2_{cal}$
- Transfer function errors on $T^2$
- Statistical errors on $\mu^2$ (detector noise, shot noise, seeing noise)

# A good calibrator is...

## A source for which $V^2$ can be predicted (at the baseline considered) with good accuracy and little bias

- Well modelled
  - Point source (O free parameter)
  - Uniform disk (1 free parameter)
  - Limb darkened disk (2 or more free parameters)
- Well known
- Stable in time
- Observable with the same setup ($\Delta m$, $\lambda_{eff}$ …)
- At a reasonable angular distance from the science target
- With a sufficient correlated flux ($V^2 . N_{phot}$)

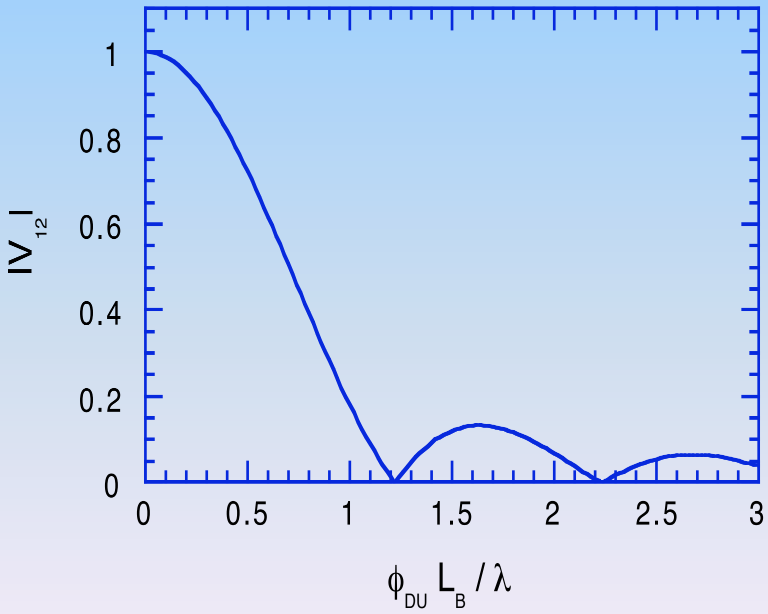
# Example: uniform disk calibrator

- Pick up a single star, non variable
- Derive diameter from surface brightness (via $T_{eff}$ and $F_{bol}$)
- Convert LD diameter to UD diameter
- Compute visibility from UD diameter (Airy function)

Expected accuracy on $\phi_{UD}$ (not V!) :

- 5% in common cases
- 1% for photometric standards

*(cf. Cohen & al., A&A 117)*



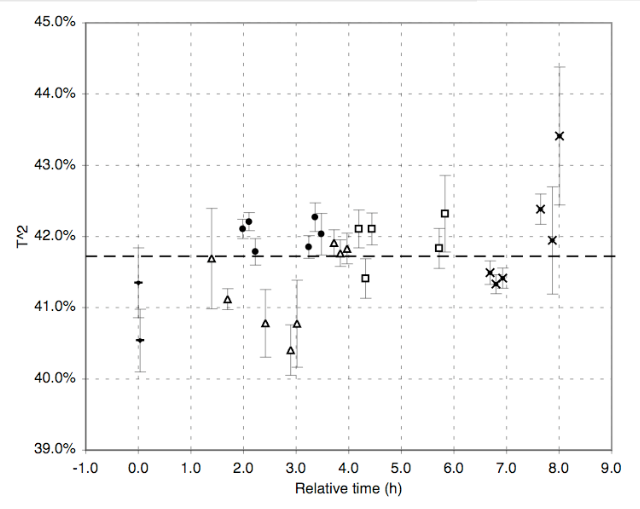
# Calibrators choice strategies

- Selection of stars from a fixed set of rules on an « open » catalog (interferometric observations preparation tools)
  - PTI / GetCal (http://msc.caltech.edu/software/getCal/index.html)
  - JMMC / ASPRO (http://mariotti.ujf-grenoble.fr/~aspro/)

- Catalog of interferometric calibrators
  - Photometry-derived diameter on chosen sources (Bordé et al. 2003, A&A 393)
  - Catalog of interferometric measurements (Richichi & Percheron 2002, A&A 386)

Good calibrators may be hard to find!

# Estimating the transfer function

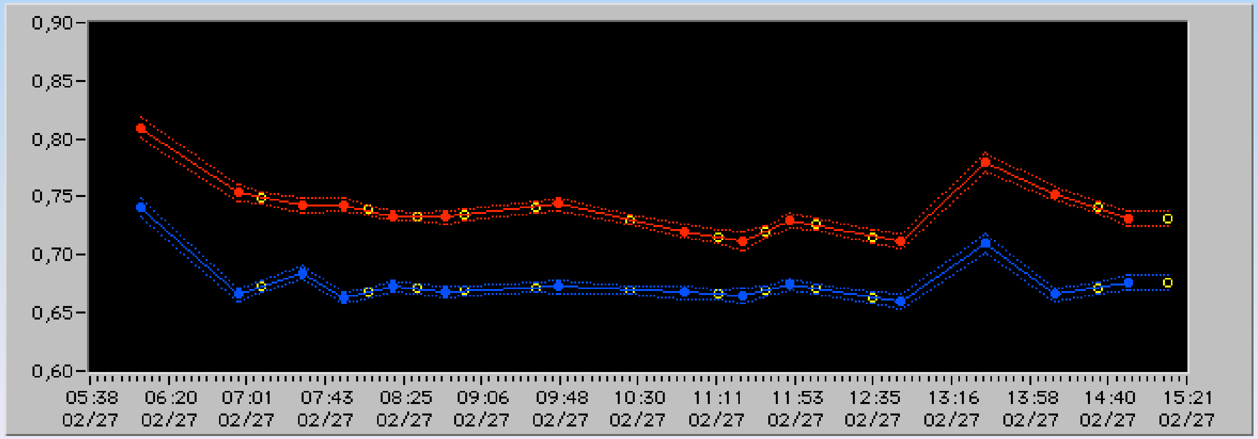



*Kervella et al., A&A submitted*

Constant $T^2$
(VLTI/VINCI, E0-G0, 2002-05-29)

The model used for describing the transfer function depends on:
- Sampling intervals
- Characteristic time evolution
- Amplitude of fluctuations

$T^2$




Time/date UT

Linear interpolation
(FLUOR/IOTA, 2000-02-27)

# Transfer function and turbulence

$$T^2 = T^2_{instrument} \cdot T^2_{atmosphere}$$

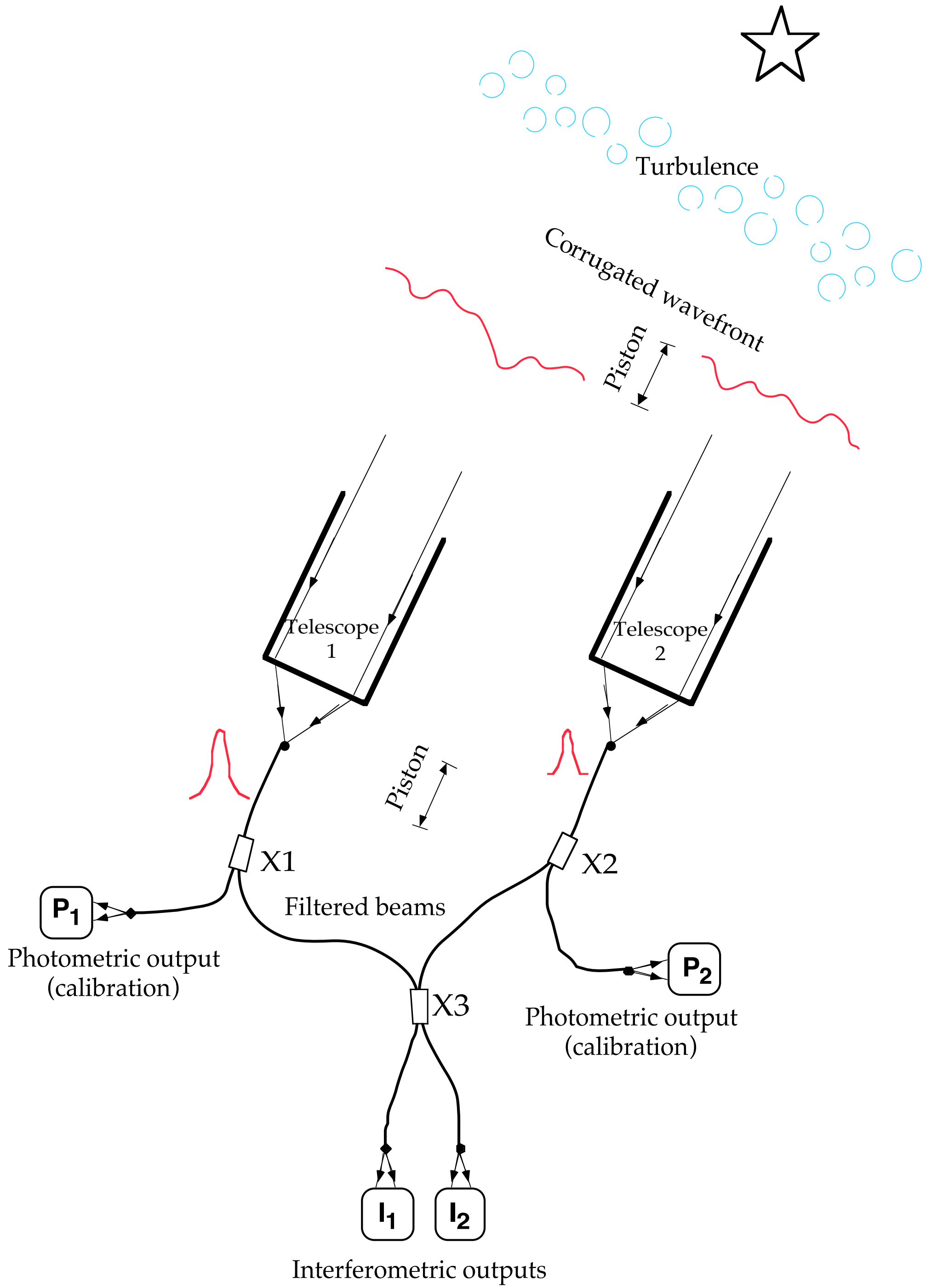
- Atmospheric term caused by wavefront corrugation at each pupil
- Solutions:
  - Clean up the wavefront with adaptive optics
    - MACAO for UTs
  - Trade turbulent image for steady beam with intensity fluctuations in single-mode waveguides
    - Spatial filtering unit implemented in VINCI, AMBER, MIDI+

# VINCI: concept

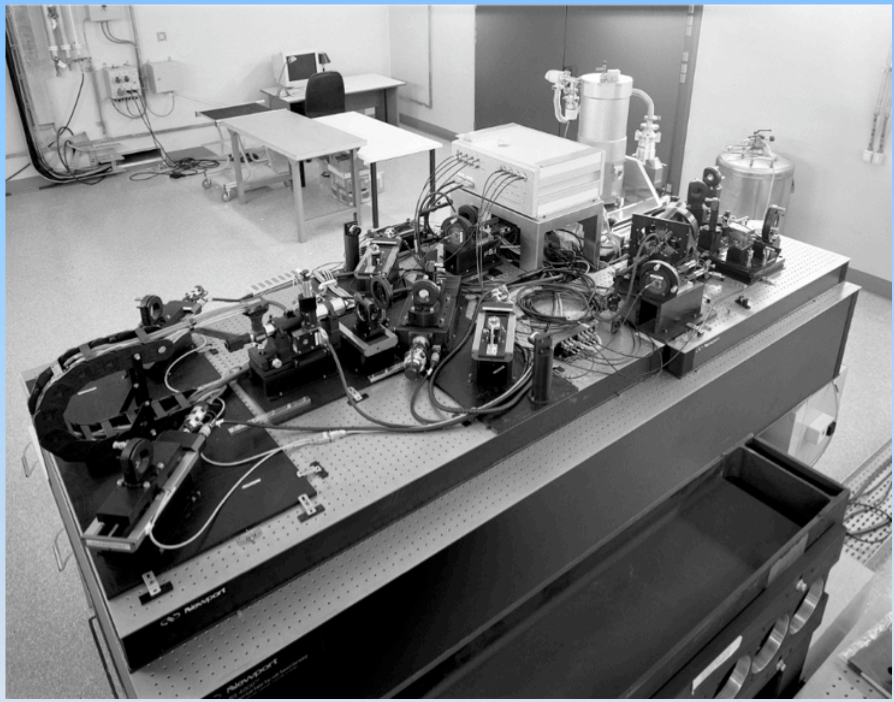
- Two inputs:
  - Beam A and Beam B
- Single-mode fibers for:
  - « cleaning » of turbulent beams
  - Polarization control
  - beam combination (X-coupler)
- Coaxial beam combination
- Temporal OPD modulation

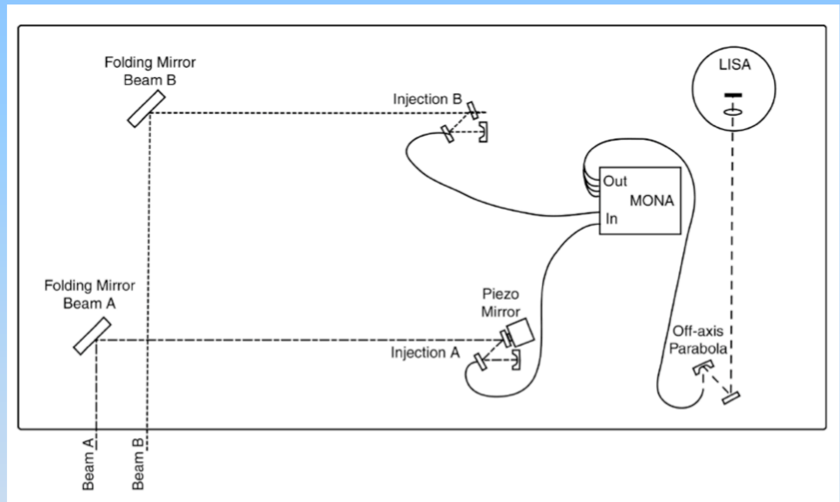
  $OPD = v_{scan} . t$

  With $200 < v_{scan} < 2000 \mu m/s$
- Four outputs:
  - $I_1$, $I_2$, $P_A$ and $P_B$
- Piston *not* filtered



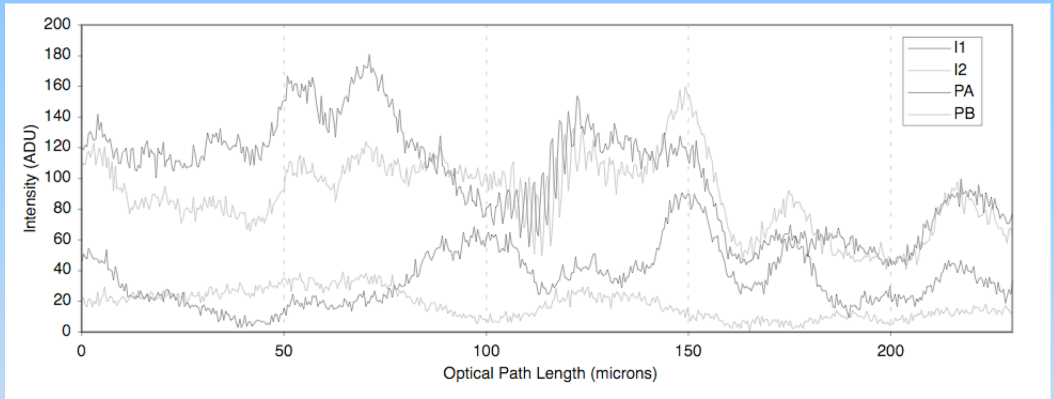
# VINCI: implementation





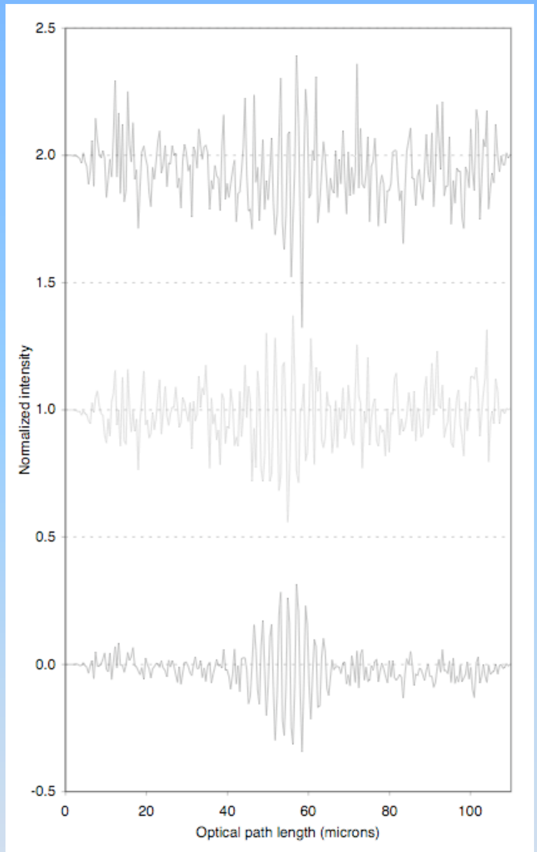
# Data sample (scan)

## Raw data




*Kervella et al., A&A submitted*

## Corrected data




$I_1$

$I_2$

$I_1 - I_2$

*Kervella et al., A&A submitted*

$$I = P_A + P_B + 2(P_A P_B)^{0.5}\ \mathrm{Re}\{\mu_{AB}\}$$

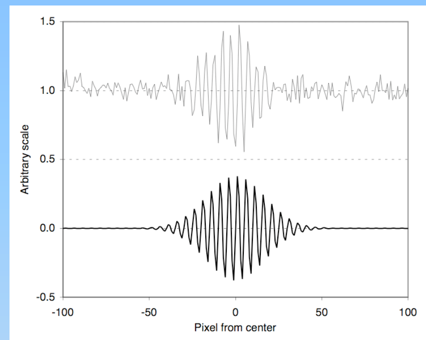
$\mu_{AB}$ complex degree of coherence between the two beams

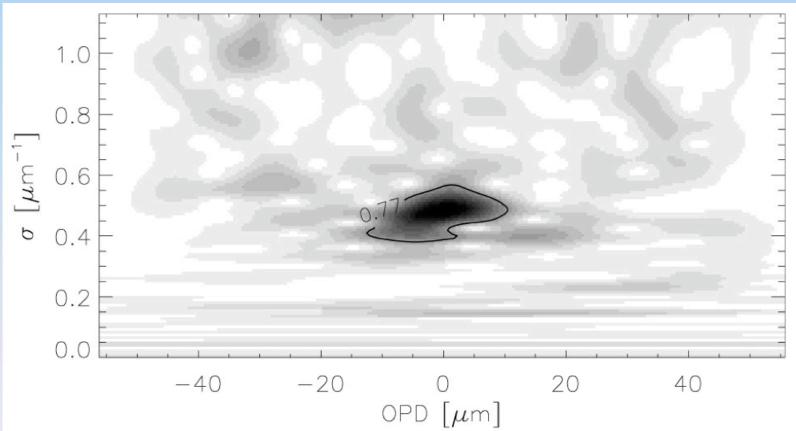
$$\mathrm{Re}\{\mu_{AB}\} = (I - P_A - P_B) / 2(P_A P_B)^{0.5}$$

# Data sample
## (joint space/wavenumber domain)

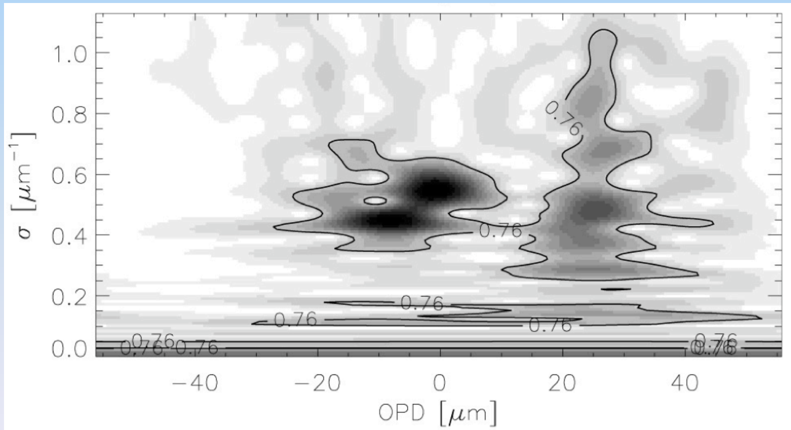
- Energy redistributed in space/wavenumber domain by wavelet transform
- Coherence factor ($\mu^2$) proportional to volume under fringe peak
- $\mu^2$ measurement affected by
  - Detection noise
  - Piston noise (non-regular fringe motion)

Morlet wavelet




Weak piston



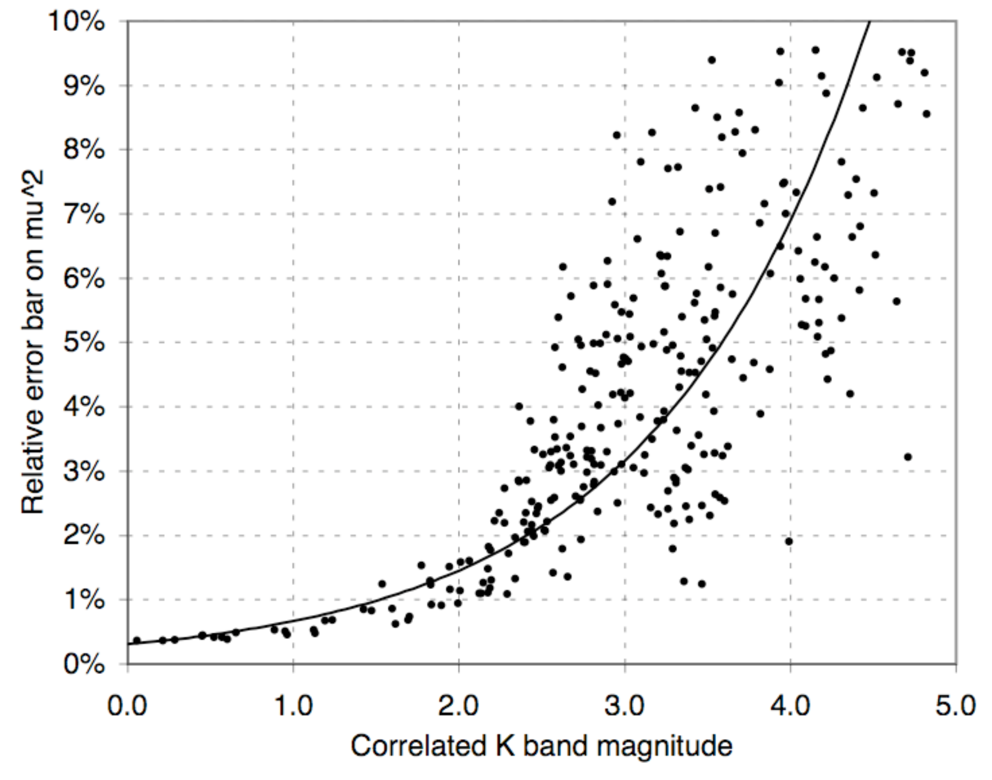

Strong piston

# Performance on $\mu^2$ measurements

$e(\mu^2)/\mu^2$ normalized for 100 scans

(survey of 296 observations)

VINCI with 35cm siderostats




- Statistical error depends on correlated flux
- Detector noise dominating for faint sources
- Atmospheric piston limiting for strong sources

  => Good fringe tracking is critical (FINITO, PRIMA FSU)