

Characterizing atmospheric parameters with the VLTI

E. Di Folco, B. Koehler, P. Kervella,
M. Sarazin, M. Schoeller, A. Glindemann

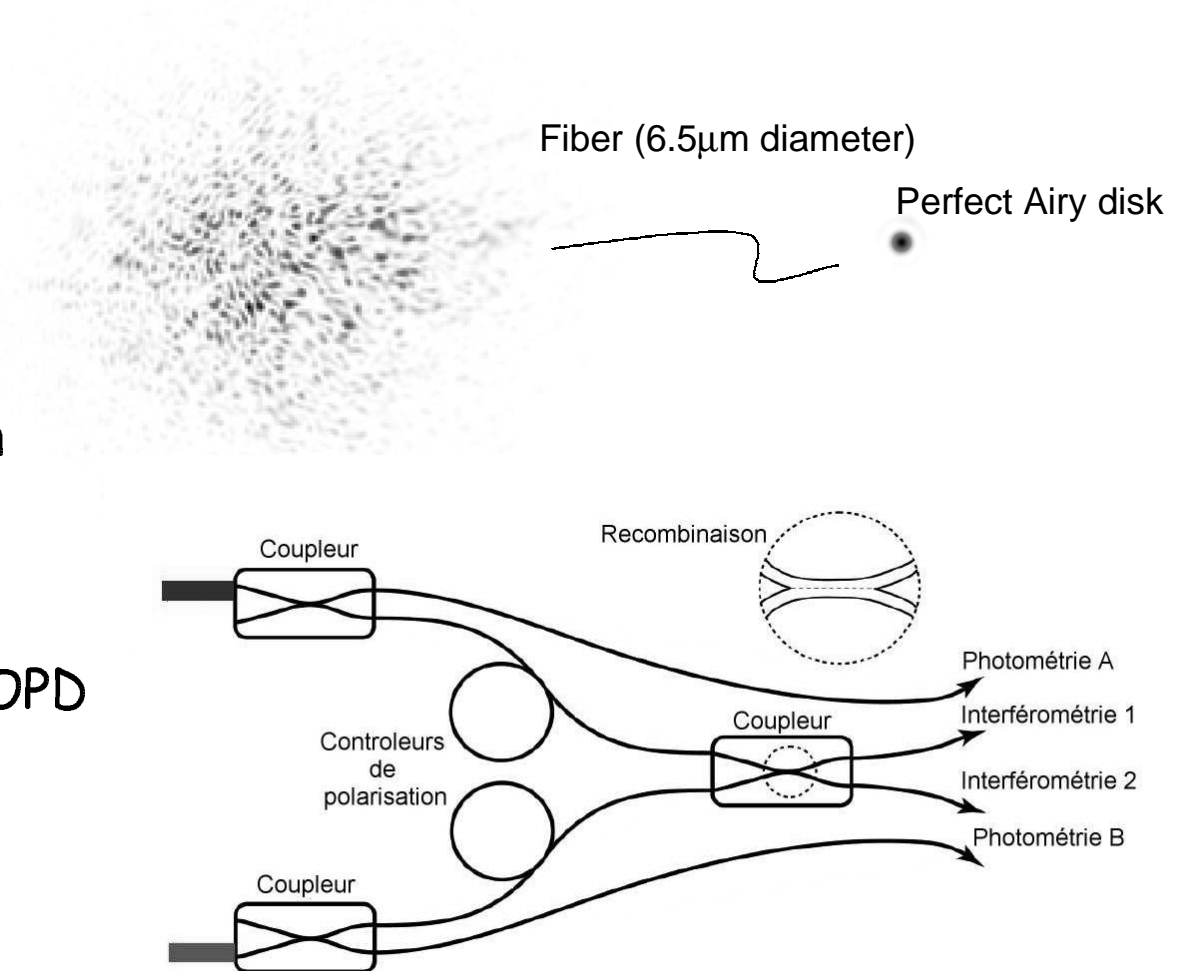


Objectives

- Determine the relevant atmospheric parameters influencing the interferometric measurements: coherence time (τ_0) and outer scale (L_0)
- Check the internal OPD stability of the VLTI, including internal atmosphere and contamination by sub-systems

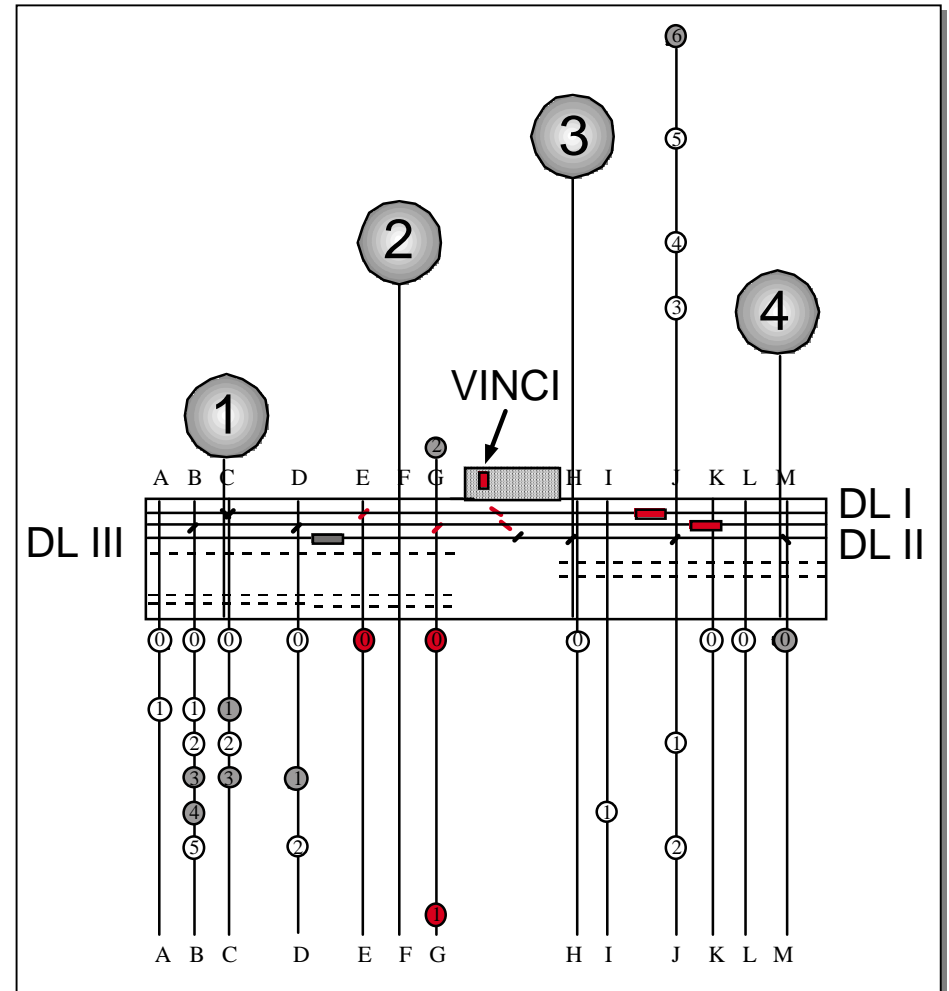
VINCI - The VLTI test instrument

- Light is fed into two monomode K-band fibers (Concept adopted from FLUOR at IOTA)
- Fiber coupler acts as beam combiner for coaxial beam combination
- Temporal fringe pattern measured in I1 and I2
- Modulation performed at fiber feed with 200 μm OPD range and maximum frequency of 30 Hz



Test Set-up

- 2x35cm siderostats
- Baselines of 16m and 66m



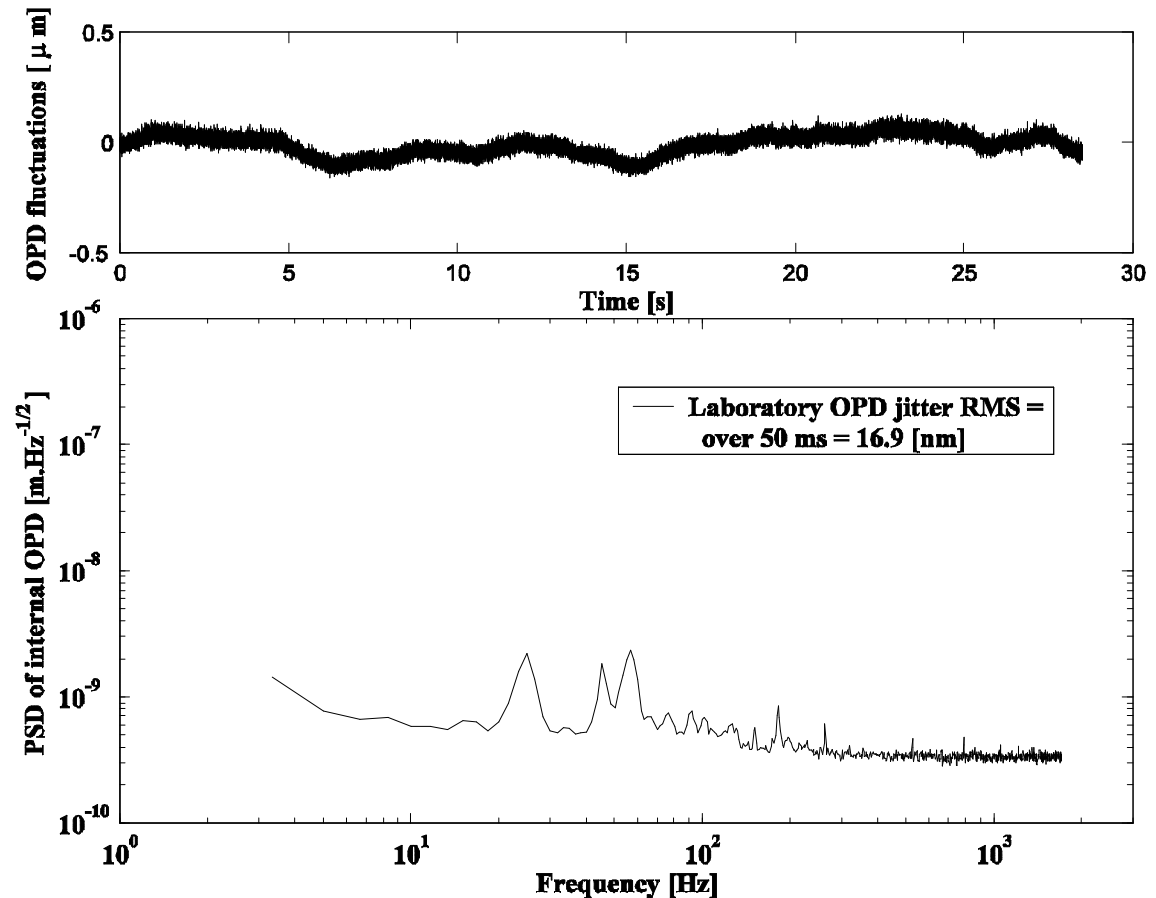
Definitions and procedures

- τ_0 is the "adaptive optics definition" of the coherence time related to the interferometric coherence time T_0 by $T_0 = 2.58 * \tau_0$ (Colavita), at $\lambda = 0.5 \mu\text{m}$.
(T_0 = time interval during which $\sigma^2_{\varphi_2-\varphi_1} < 1 \text{ rad}^2$)
- The **power spectrum of the OPD** is computed from a series of several thousands of scans (10-20 min total duration)
- The white-light fringe position is determined by VINCI for each scan by a centroid algorithm applied to the calibrated interferograms.
- For the measurements of the internal stability, the Delay Lines are stationary.

Verification of the internal stability

1-VLTI laboratory

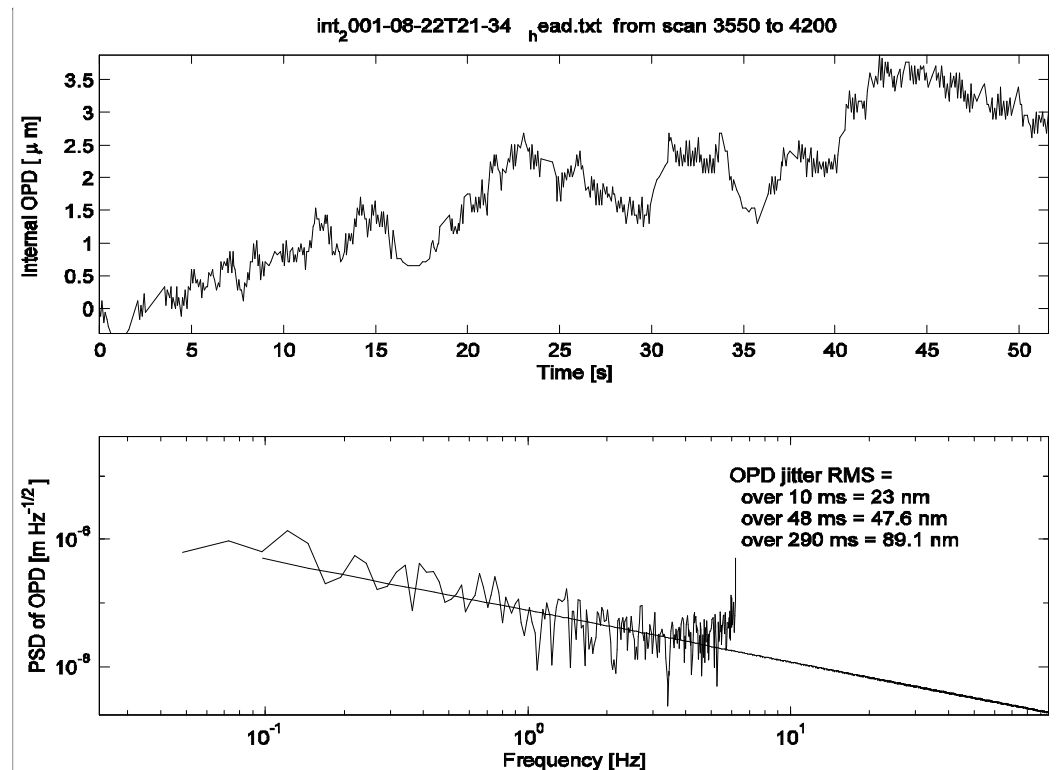
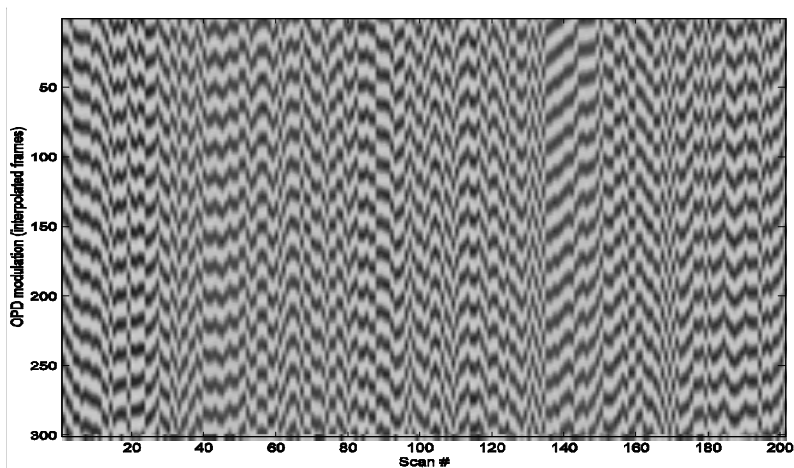
- Artificial source (laser) fed into VINCI inside laboratory:
OPD jitter 16.9nm !
- Power spectrum shows negligible contamination by external excitation frequencies



Verification of the internal stability

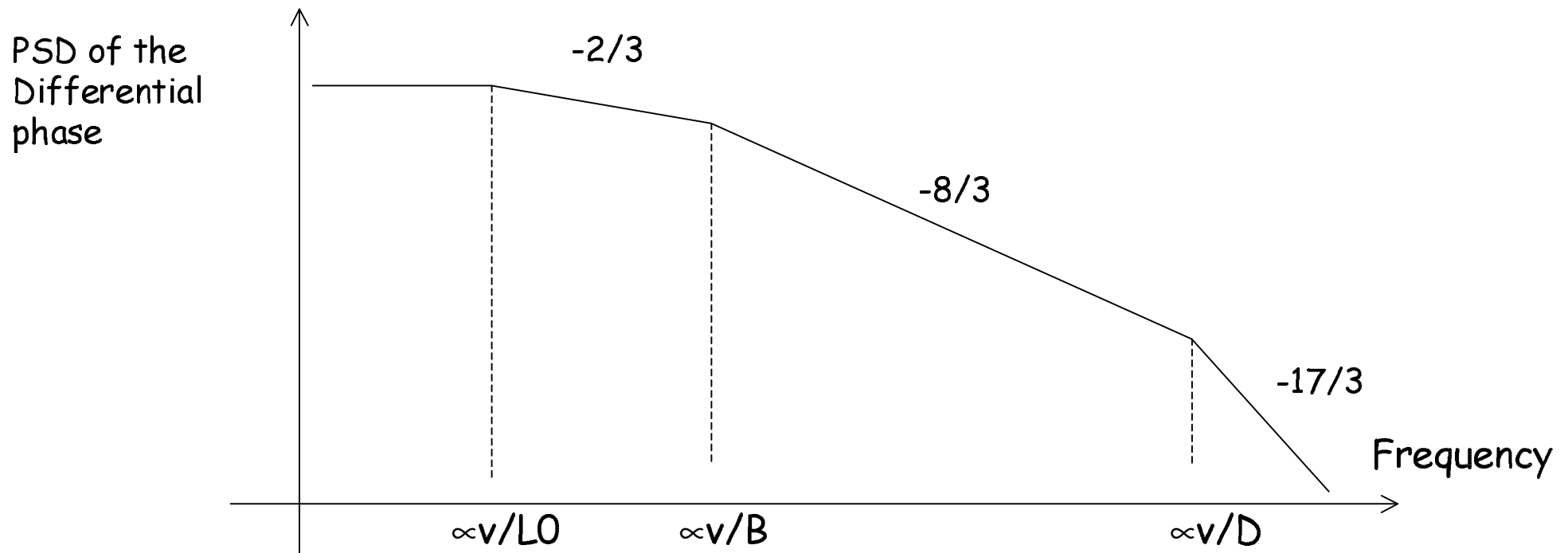
2- Delay Line tunnel

- Artificial source sent into the DL tunnels up to retro reflectors at the entrance of the AT stations' pits.
- OPD jitter (i.e. internal turbulence) larger than expected (July 2002)
- Power spectrum lower than the Kolmogorov model corresponding to the best seeing conditions at Paranal



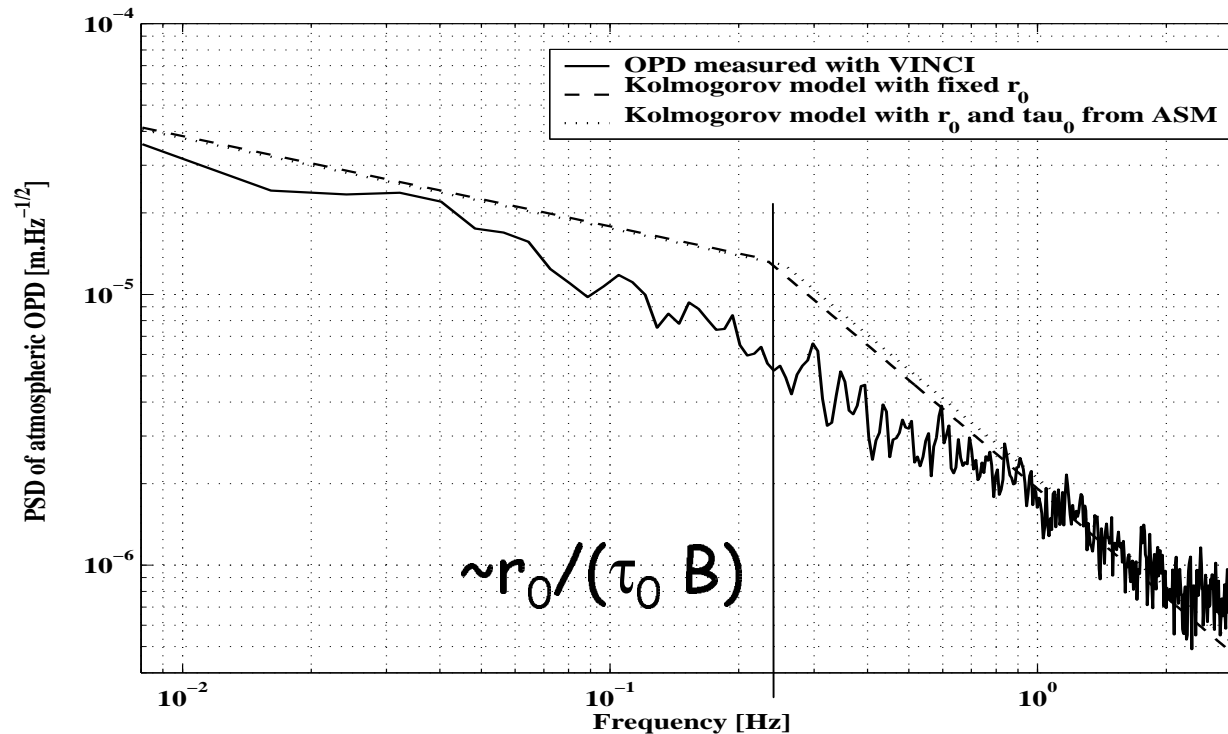
Atmosphere characterization: Principle

- The OPD power spectrum is computed for each ~15min batch
- The theoretical power spectrum shows 3 cut-off frequencies related to the spatial scales D (telescope diameter), B (baseline) and L_0 (outer scale)



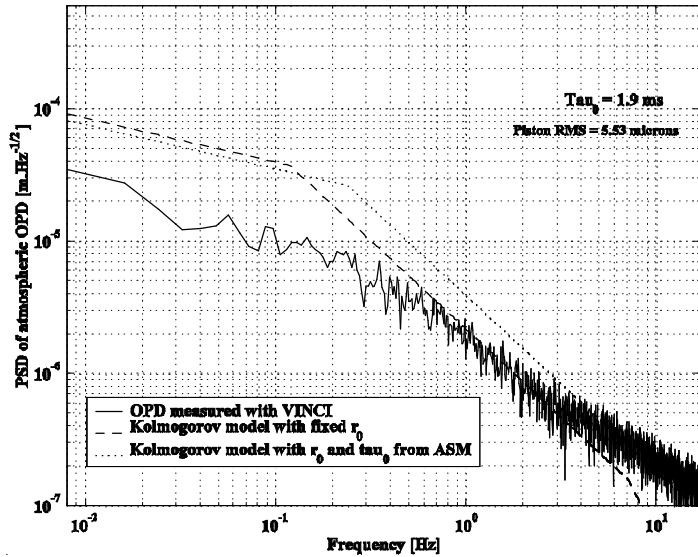
Measurements of Atmospheric Parameters

- Observations between August 2001 and August 2002 on the EO-G0 16m and the EO-G1 66m baselines
- τ_0 derived from the $f^{-8/3}$ region of the spectrum according to $W(f)=0.00029 \lambda^2 \tau_0^{-5/3} f^{-8/3}$ (Buscher 1995)



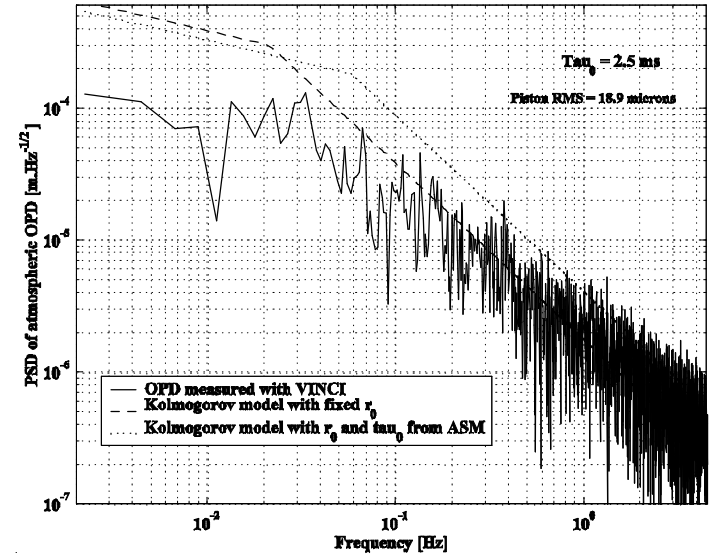
Effect of Baseline B and Coherence Time τ_0

16 m baseline

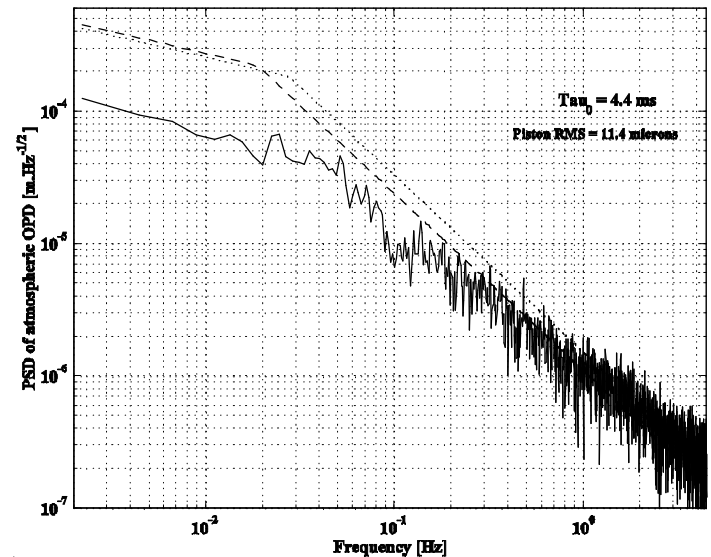
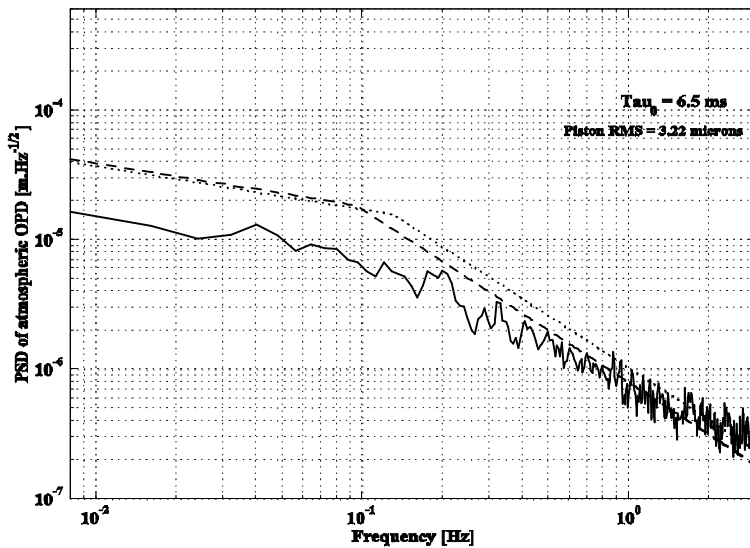


Low τ_0

66 m baseline

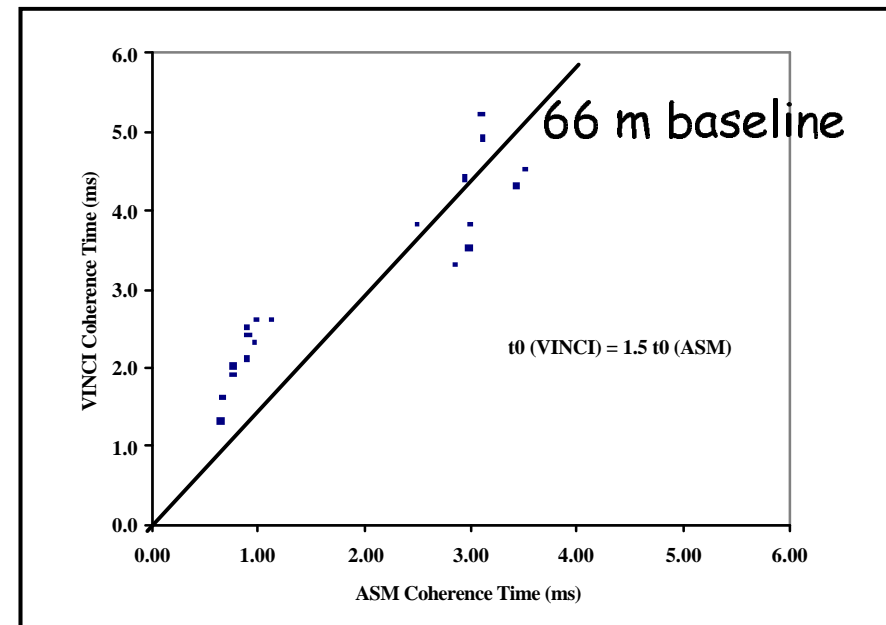
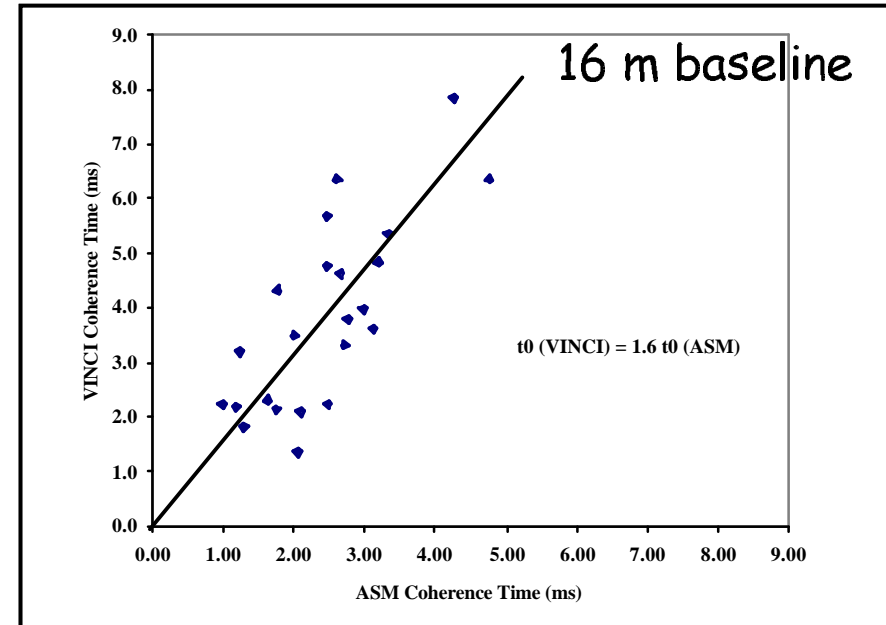


Medium τ_0



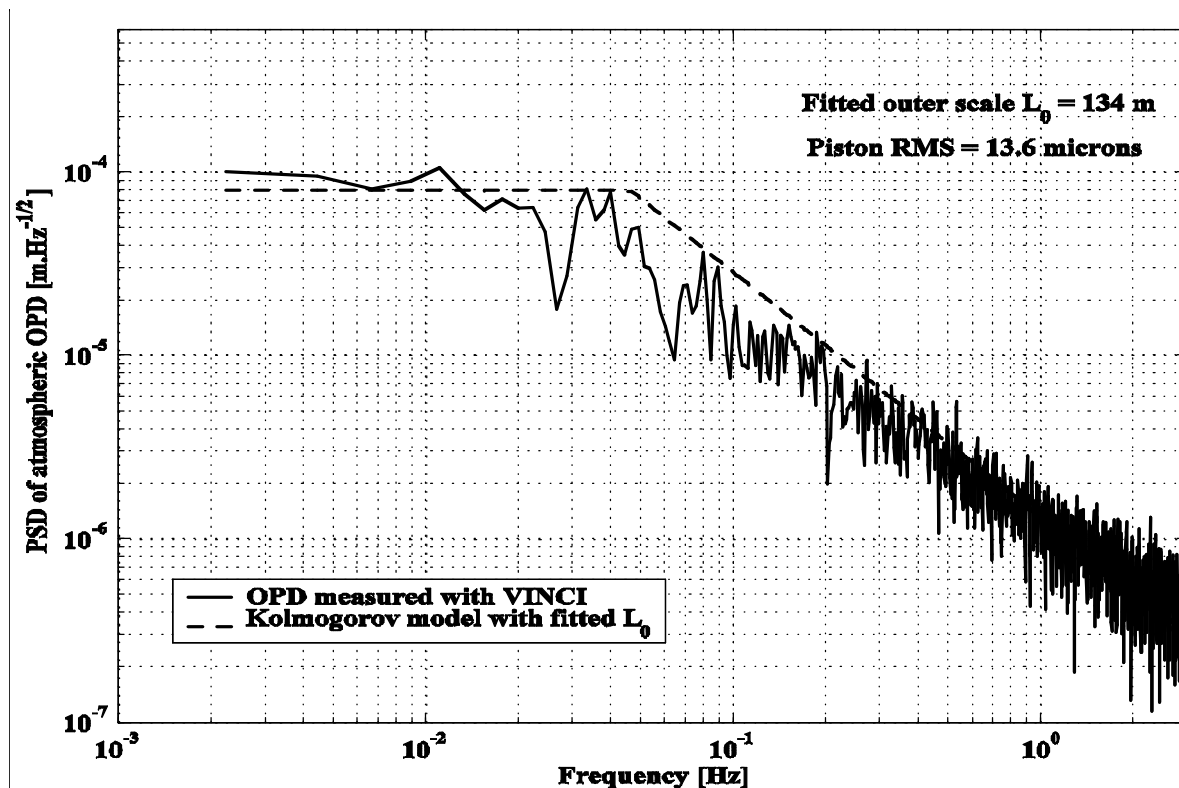
τ_0 : comparison with ASM

- VINCI values of τ_0 about 1.5 times larger than ASM values
- Slopes in the power spectrum are generally less steep than the Kolomogorov value $-8/3$
- Further experiments with more accurate OPD measurement and higher frequencies required (FINITO)



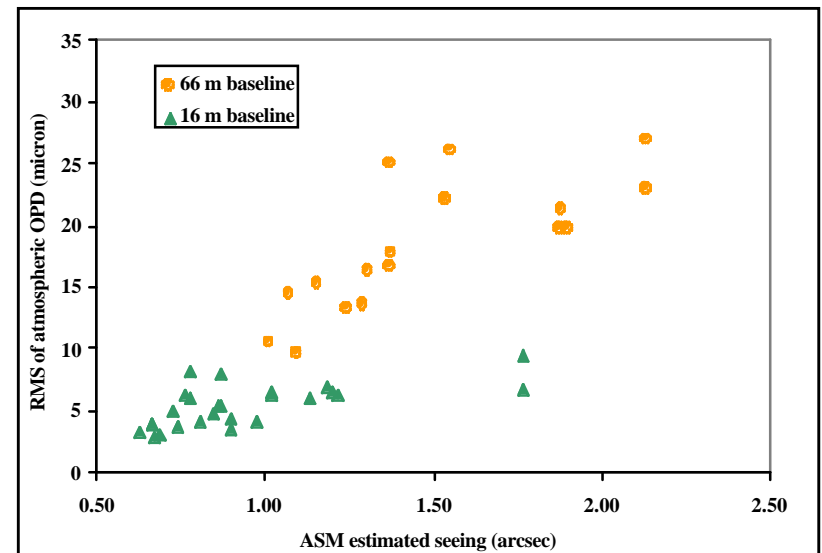
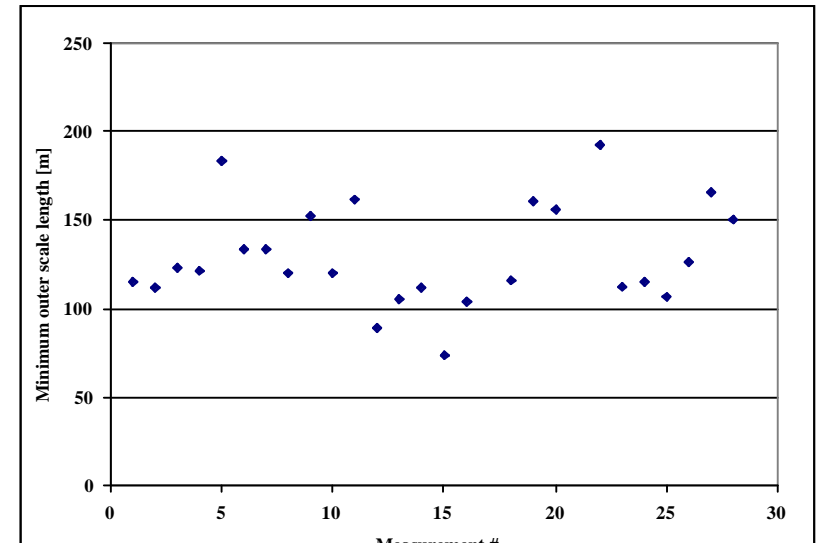
L_0 - The outer scale of Turbulence

- L_0 determined from the low cutoff frequency for spectra showing a saturation: $f_0 = v/L_0$
- v was estimated from the ASM r_0 value and the VINCI fit τ_0
- Many spectra do not show any saturation at low frequency



L_0 Measurements

- $L_0 \sim 125\text{m}$ between August and September 2002 with evidence for higher values (no saturation)
- Later observations on a 140m baseline with RMS of OPD fluctuations similar to the 66m baseline
- Preliminary conclusion:
 $L_0 \sim 100\text{m}$



Conclusions

- Internal OPD fluctuations are extremely small in the VLTI laboratory, and small in the VLTI optical train
- Preliminary VLTI observations have confirmed the low values of τ_0 measured by the ASM
- Clear correlation between ASM and VINCI measurements
- Rough estimations of the outer scale of turbulence gives values of typically 100m or more

Perspective

- Coherence time impacts performance of fringe trackers. FINITO will allow measurements at frequencies > 1 kHz.
- Improved accuracy of the measurements improves theoretical models
- It may be possible to derive the outer scale from the available VINCI astrophysics data obtained on baselines as long as 140m. Work is in progress, analysis of the intra-night time dependence of L_0 should be possible
- Internal OPD fluctuations in the DL tunnel will improve with air-conditioned ATs