Usage of LBT pupils to estimate the local outer-scale parameter

J.C. Guerra,[a] A. Otarola,[b,e] ,G. Brusa[a,c] ,V. Bailey,[c] P. Hinz[a], E. Pinna[d]

[a]Large Binocular Telescope Observatory. Steward Observatory, Tucson, AZ, USA;
[b]TMT Observatory Corp., 1111 S. Arroyo Parkway, Pasadena, CA 91101, USA;
[c]University of Arizona, Steward Observatory.Tucson AZ, USA;
[d]Observatorio Astrofisico di Arcetri, Florencia, Italy;
[e]Atmospheric Sciences Department,University of Arizona,Tucson,AZ,USA

INTRODUCTION

The image quality in large aperture telescopes has been shown to have an important dependence on the instantaneous magnitude of the outer scale of the turbulence. In general terms, the shorter the outer scale of the turbulence, the lower the wavefront variance over the aperture of the imaging system and consequently the higher the image quality. In this work, the outer-scale of the turbulence (L_0) is retrieved from the fits to the structure function of the reconstructed phase of the combined two-apertures of the Large Binocular Telescope.

Data.

The data for this study were obtained by Large Binocular Telescope Interferometer (LBTI) team using the two wavefront sensors of the LBTI instrument on the night of March 16th, 2014. The night sky was clear with a surface wind speed around 20 m/s from north direction, the Adaptive Optics system was configured to work in a bad seeing mode due to a seeing above 1.8". The close loop telemetry saved 5000 frames at 498Hz.

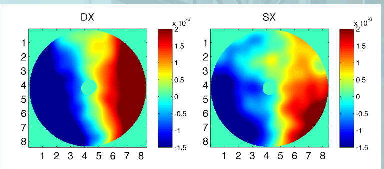

Figure 2: Phase reconstructed for the two apertures from the close loop telemetry.DX is reed to the right side And the SX to the left side of the telescope.

Phase structure function and outer-scale determination.

The phase structure function has been defined as: This equation applies for spatial scales where the separation is less than the characteristic scale L_c at which the two-point phase variance starts to saturate. In other words it can be said that the power-law function that describes the two-point phase variance applies only at spatial scales significantly smaller than the outer scale of the turbulence ($r << L_0$). The outer scale can be associated to the behavior of the phase structure function where for large r the function D_Φ (r) saturates at 2 σ_ϕ^2 (σ_ϕ^2 wavefront phase variance)

$$6.88\left(\frac{L_0}{r_0}\right)^{5/3} = 2\sigma_\phi^2$$

The outer scale of turbulence can be related to the characteristic scale with the relationship from Simiu and Scalan [1986]

$$L_0 \approx L_c\sqrt{70}$$

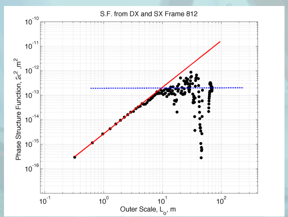

Figure 3: phase structure function for the combined Large Binocular Telescope's pupils.

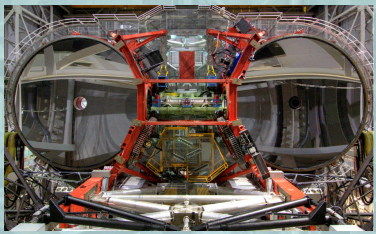

Figure 1: Front view of the Large Binocular Telescope. DX (right) / SX (left) LBT apertures.

Application of the method to the LBT data .

The reconstructed WFS phases have a length of 10 seconds, at a rate of 498Hz. The phase structure function, for each frame, is calculated from the combined LBT apertures phase information. A power law is then fit to the short spatial scales and a zero slope line is set at the larger spatial scales.

This process was done for the combined LBT two-apertures phases at a time resolution of 20ms (i.e. every 10 out of the 5000 WFS collected). The structure function characteristic scale (L_c) is that right at the intersection of the power-law function and the horizontal line that represents the region at which the two-points variance starts to oscillate. In a last step, the outer scale (L_0) was estimated using the relationship explained in the precedent section.

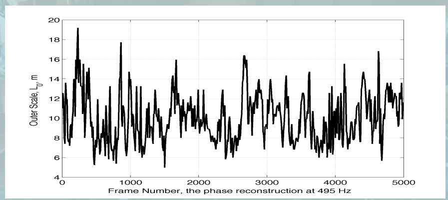

Figure 4: Time series of the outer-scale computed from the Phase structure functions of the combined LBT apertures.

The temporal evolution of the computed outer scale for every 10 frames shows that the L_0 oscillates from 1st quartile (25%) of 8 meters to 3rd quartile (75%) of 11.6m and a median value of 9.7 m, this evolution of the outer scale is an indication of the changes in the atmosphere.

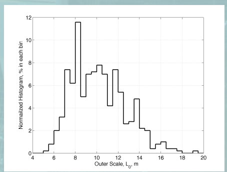

Figure 5: Histogram of the outer-scale computed from Phase structure function of the combine apertures.

Retrieval of the turbulence advection speed

The mean advection speed of the atmospheric turbulence was computed from the vertical integration of the wind weighted C_n^2 profile of C_n^2. This calculation gives a mean turbulence advection speed of **21.6 m/s.** The wind speed at the time of the observation was dominated by a strong meridional component. The wind speed is southerly (i.e. wind from the north direction), This is evidence that the turbulence advection mainly travels from the DX to the SX aperture of the LBT telescope.

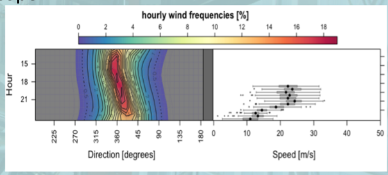

Figure 6: Local wind speed and direction.Wind direction is mostly South-north direction

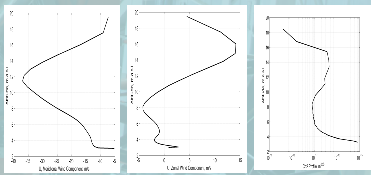

Figure 7: Meridional and Zonal wind components from the WRF Model computed by University of Arizona. (right) profile of C_n^2.

Conclusion.

The reconstruction of the spatial structure function of a turbulence phase of the two wavefront sensors can be extended to the analysis of the two pupils of the Large Binocular Telescope along the baseline of 14.4 meters (center to center) which it makes an aperture of 22.8 meters. The outer scale of the turbulence was computed starting from the characteristic scale of the phase structure functions of the combined two LBT pupils. The results show that the mean value of the outer scale (Lo) was during this test **10 m ± 2.5m**. This short analysis shows that the use of the two pupils of the Large Binocular Telescope could be used to determine the outer scale of turbulence that in most of the cases is larger than the diameter of the individual apertures. It desire to continous with analysis with more data and with better seeing conditions

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References.

Simiu, E. and Scanlan, R.H. Wind Effects on Structures, 3rd Edition , Wiley, New York.(1996).