Atmospheric time constant with MASS and FADE

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Adaptive Optics time constant τ_0

Definition (1 rad² phase difference between wave-fronts at $\Delta t = \tau_0$)

$\tau_0 = 0.314\, r_0/V_0 = 0.057\, \lambda^{6/5} \left[\int C_n^2(h)\, V^{5/3}(h)\, dh \right]^{-3/5}$

MASS time constant:

$\tau_{0,\, MASS,} = 0.175\, (\sigma^2_{DESI})^{-3/5}$; $\sigma^2_{DESI} = \langle \Delta[I_A(1ms)/ I_A(3ms)] \rangle^2$

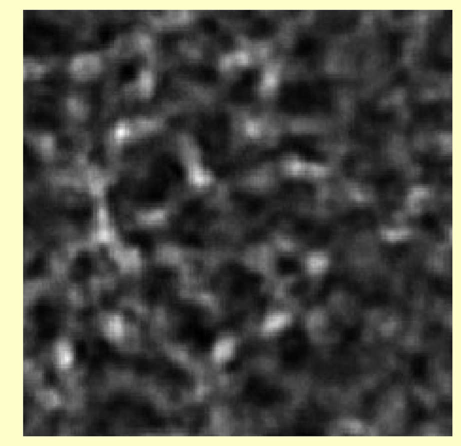
This is an approximation! So scale it, $\tau_0 \approx C\, \tau_{0,\, MASS,}$

What is the best value of the corrective coefficient C?

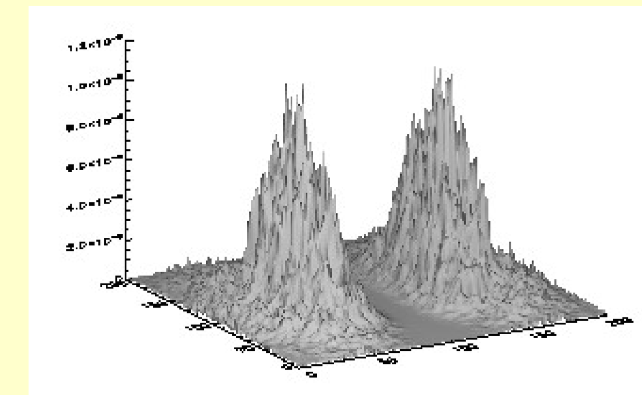
Previous simulations: C=1.27 while Travouillon et al. [4] use C=1.7

Numerical simulation

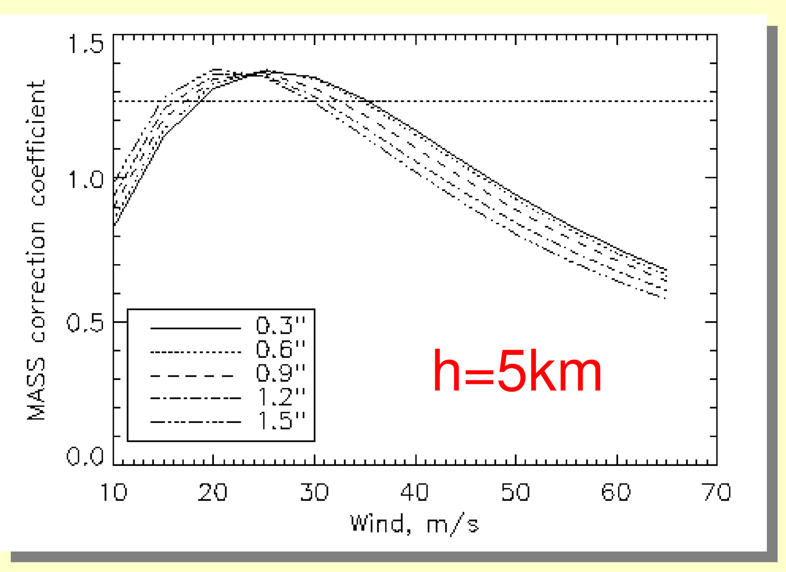
1. Set turbulent layer strength (seeing) & sp. response

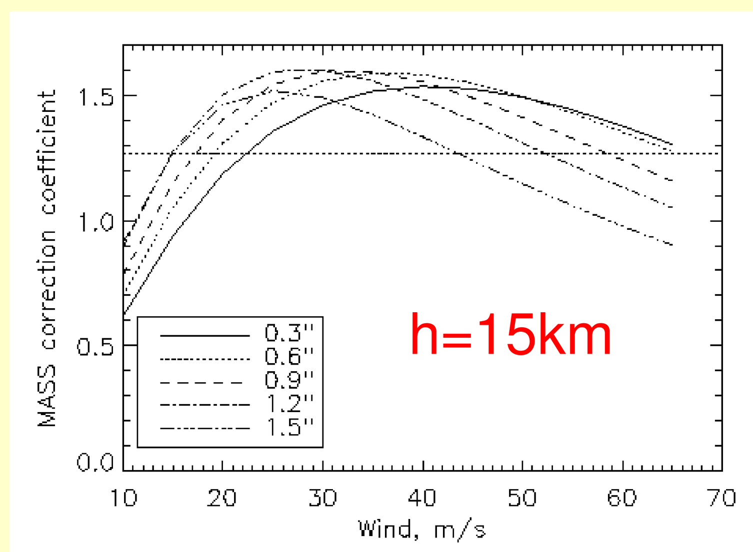


2. Generate intensity at the ground

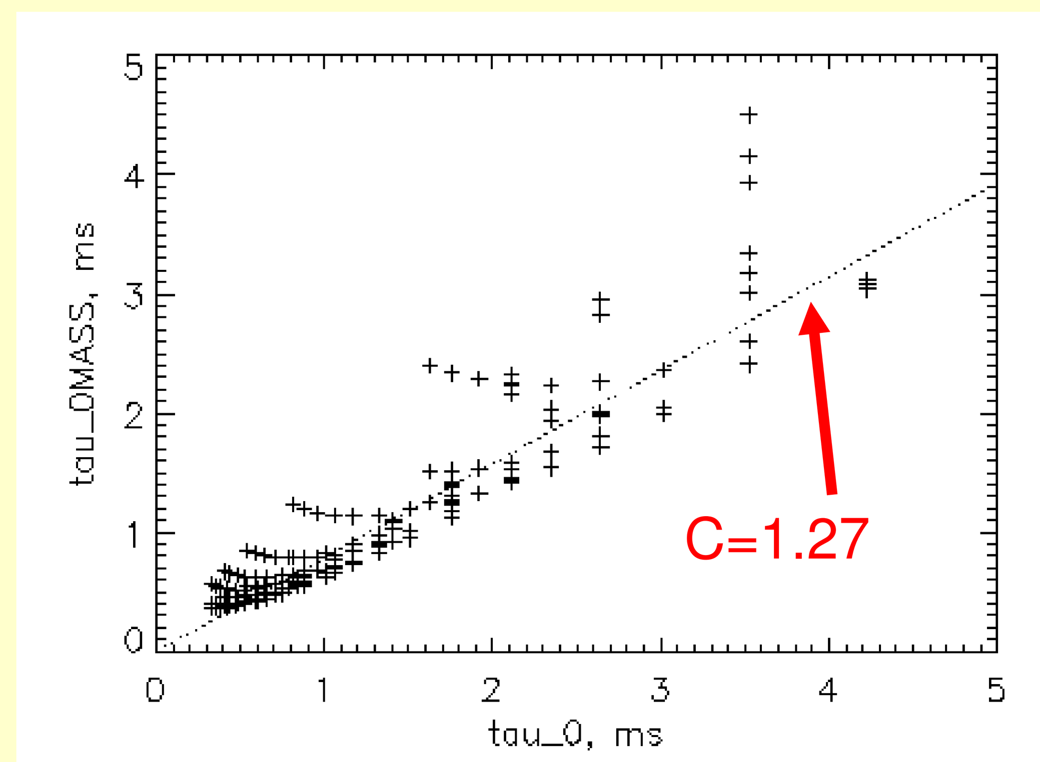


3. Apply spatial filter, compute DESI for different wind speeds





Corrective coefficient C vs. wind speed for different seeing



Results

MASS over-estimates τ_0 at slow wind speeds and under strong scintillation. The coefficient C=1.27 is good for typical situations (turbulence at 200mb, wind ~30m/s). However, C varies from 0.6 to 1.6.

The MASS method is approximate!

Fast Defocus = FADE

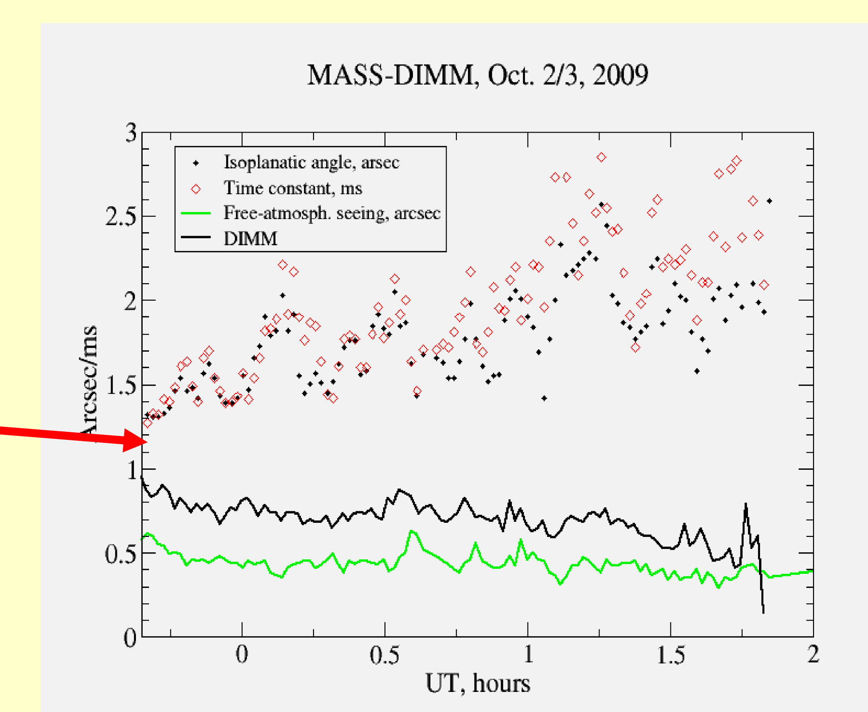
The temporal structure function (SF) of the Zernike defocus coefficient a_4 (in rad²) has initial quadratic part

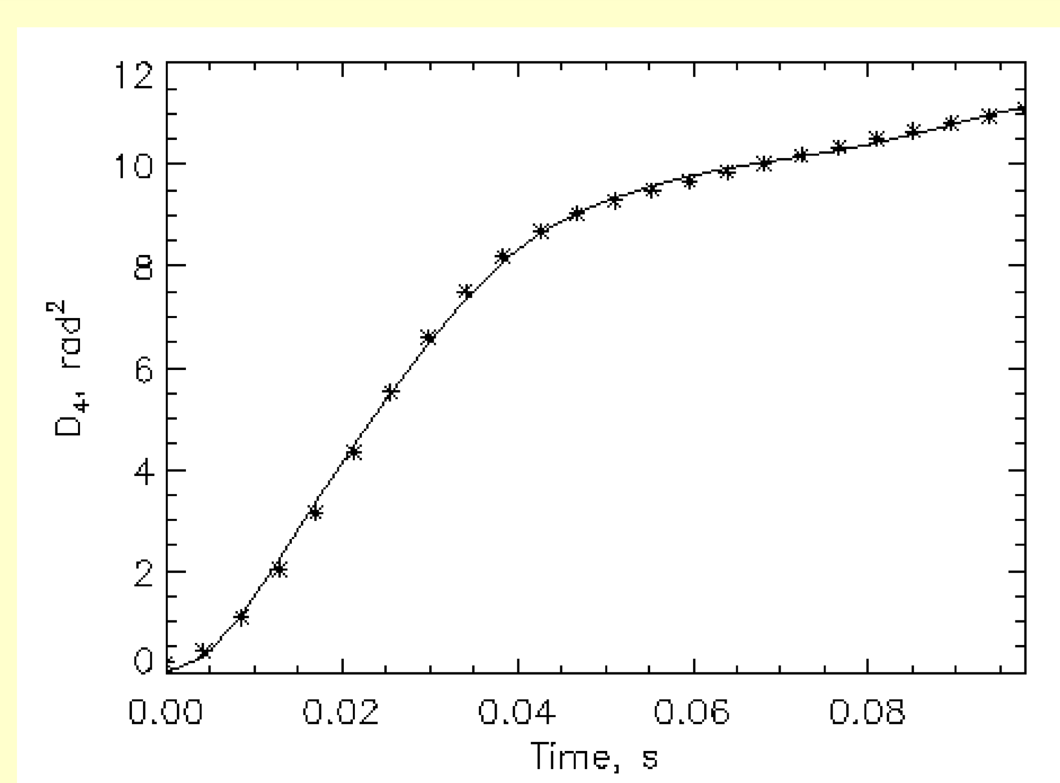
$D_4(t) \approx 0.036\, (D/r_0)^{-1/3}\, (t/\tau_0)^2$.

This gives a clear method to measure τ_0 [2].

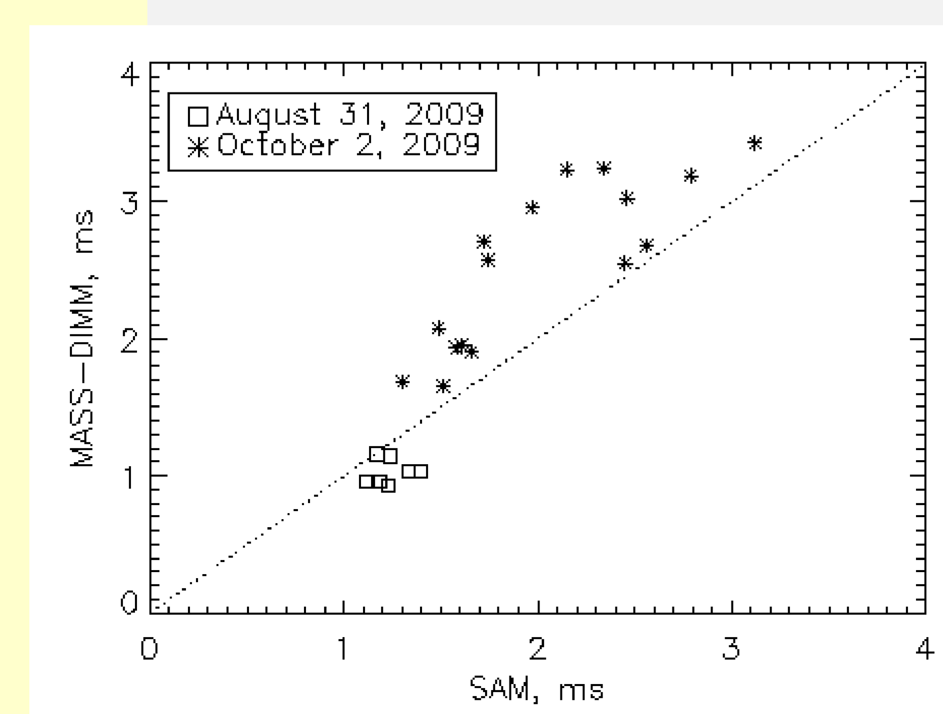
Comparison between FADE and MASS

SOAR Adaptive Module tests at Cerro Pachon, Chile
Night 1 (Aug 31, 2009): clear, with strong and fast turbulence
Night 2 (Oct. 2, 2009): better seeing, but only for 4 hours.





Example of data (night 1). Points – measured SF, curve – two-layer model fitted to the first 0.1s segment



FADE vs. MASS with C=1.27

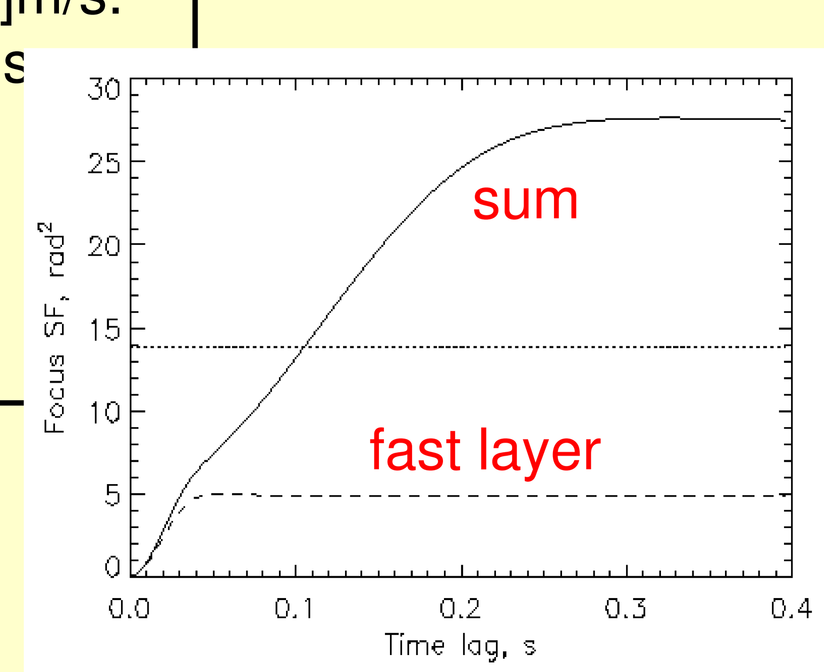
Method of Fusco et al. [3]: half-time

The half-width of the SF (or covariance) of Zernike aberrations is related to the wind speed V. For defocus and single layer,

$t_{0.5} = 0.30\, (D/V)$, hence $\tau_0 = 1.05\, t_{0.5}\, (r_0/D)$

In the multi-layer case, $t_{0.5}$ measures the strongest layer, while τ_0 depends mostly on the fastest layer.

Test case: two layers with 1" and 0.4" seeing, V=[10, 60]m/s.
For each layer, τ_0 =[3.17, 1.32]ms, combined τ_0 =1.16ms
The half-time method gives $t_{0.5}$=0.105s → τ_0 =2.39ms
The true time constant is τ_0 =1.16ms.
The half-time method works well for one layer, but is biased by 2x in this test case.



Structure function of a_4 for the 2-layer test case

References

[1] Tokovinin A. 2002, Appl. Opt., 41, 957
[2] Tokovinin A. et al. 2008, A&A, 477, 671
[3] Fusco T. et al. 2004, J. Opt., 6, 585
[4] Travouillon et al. 2009, PASP, 121, 787

http://www.ctio.noao.edu/~atokovin/profiler/archive.html