

Atmospheric Knowledge & AO for 8-100m Telescopes. ESO, 13/10/2003.

Shack-Hartmann Turbulence Characterisation & SLODAR

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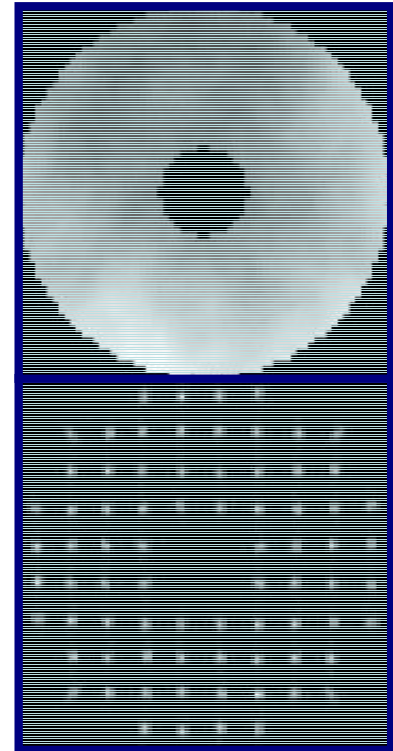
Acknowledgements: Chris Saunter, Juan-Carlos Guerra, ING, Mercator...



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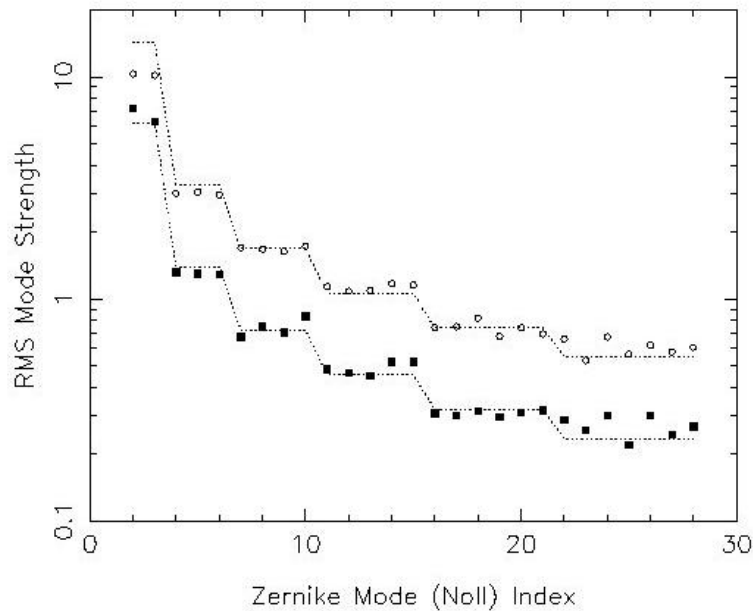
Aims / Contents...

- Summarise turbulence parameters that can be measured with a simple Shack-Hartmann WFS (Disclaimer: probably not an exhaustive list & certainly not all this author's ideas!).
- Describe SLODAR profiling, current implementation & some results.
- Introduce portable SLODAR concept.

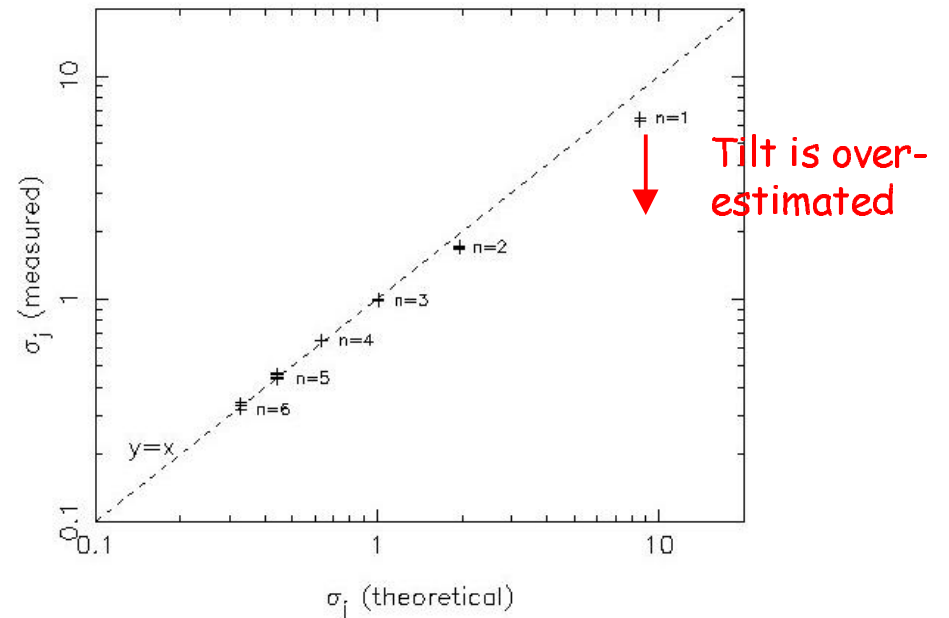


Spatial Structure, r_0

e.g. Find r_0 (and L_0) by a fit to the variances of the Zernike terms (exclude tip & tilt).



Example mode variance distributions (WHT)

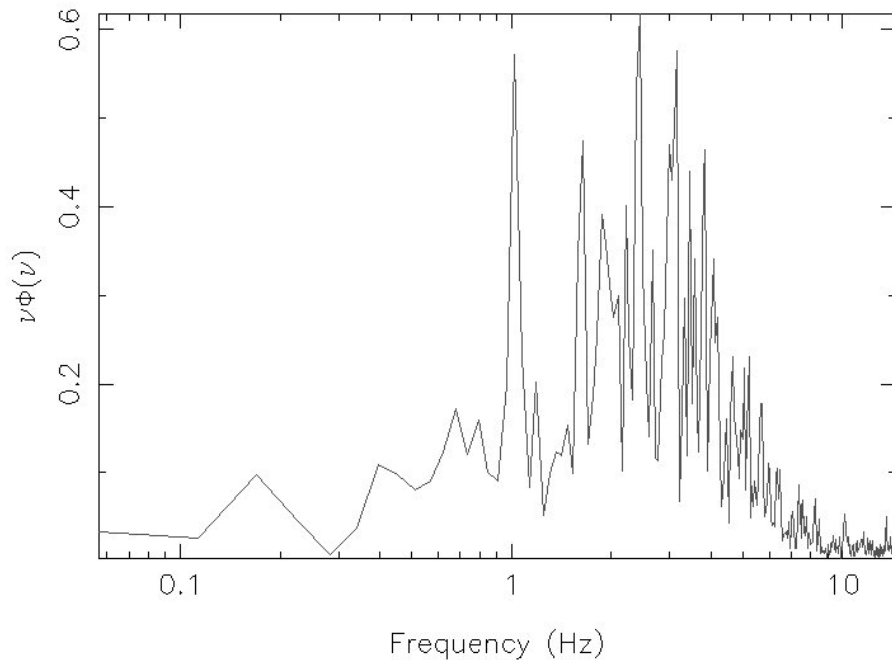


Mean distribution normalised to $r_0 = 20\text{cm}$ (WHT 1996-1998 data). Mean $L_0 \sim 15\text{m}$.

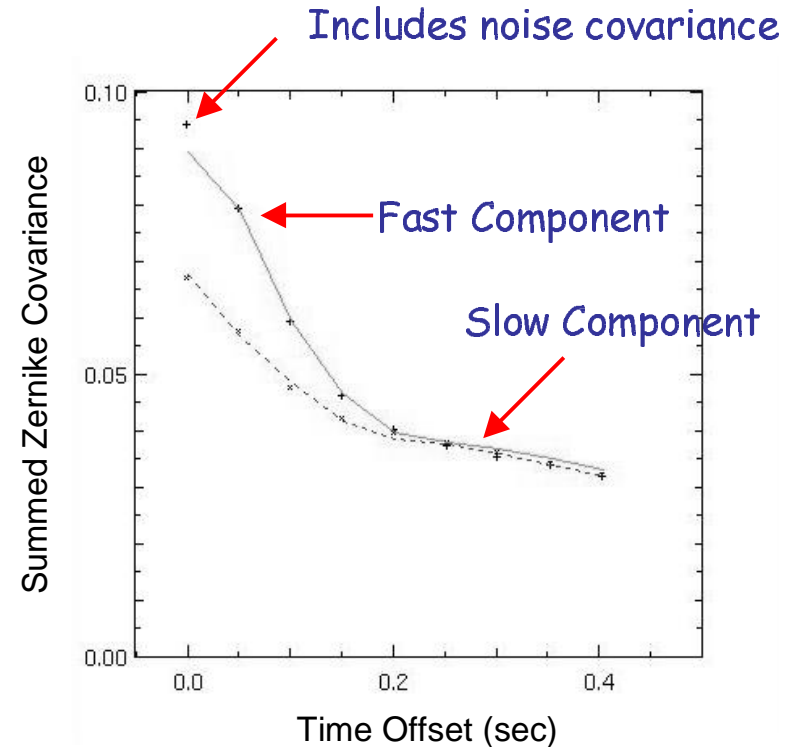


Temporal Structure

e.g. Zernike PSDs & Covariances:



Example power spectrum of atmospheric coma (WHT)



Example phase covariance (summed Zernike $1 < n < 5$), WHT. Green line is 2-layer fit.

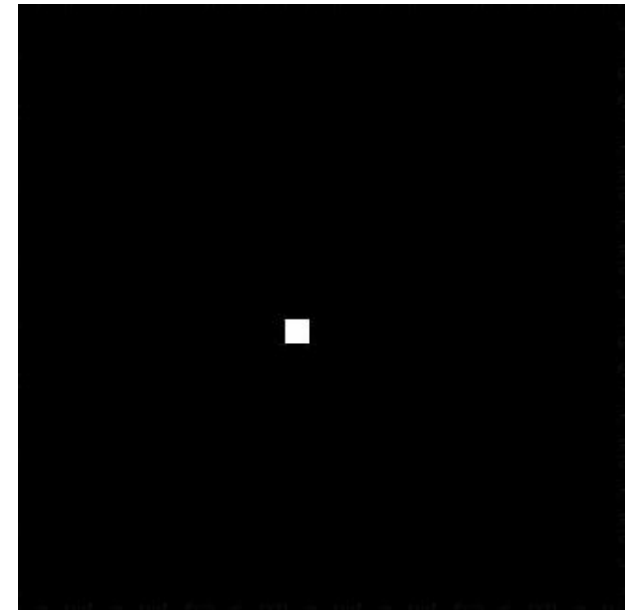


Temporal Autocorrelation - Velocities

- Movie: spatial autocorrelation of WFS slopes, with increasing time offset δt .

Estimate:

- Layer velocities
- Taylor persistence



-10 0 +10

Spatial Offset (WFS Subaps)



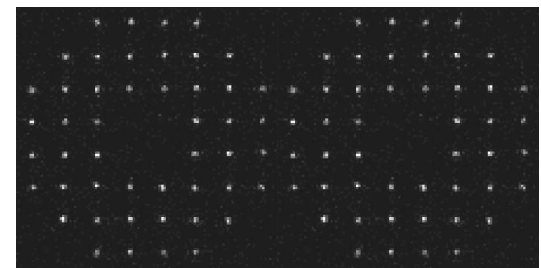
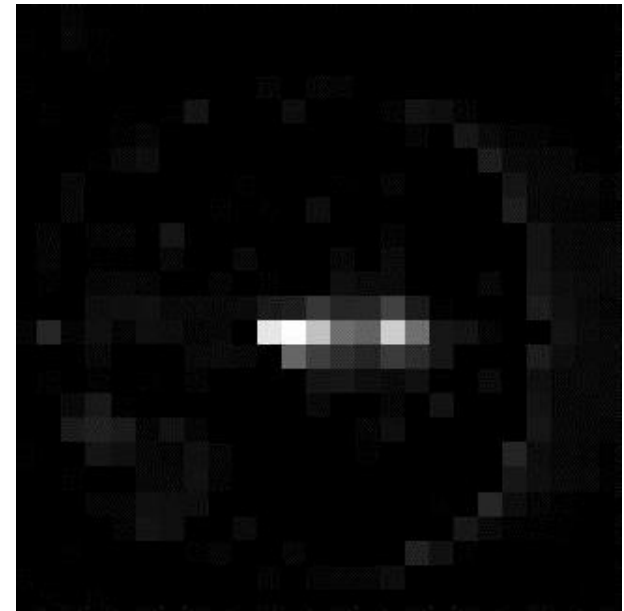
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Cross-Correlation - Altitude & Velocity

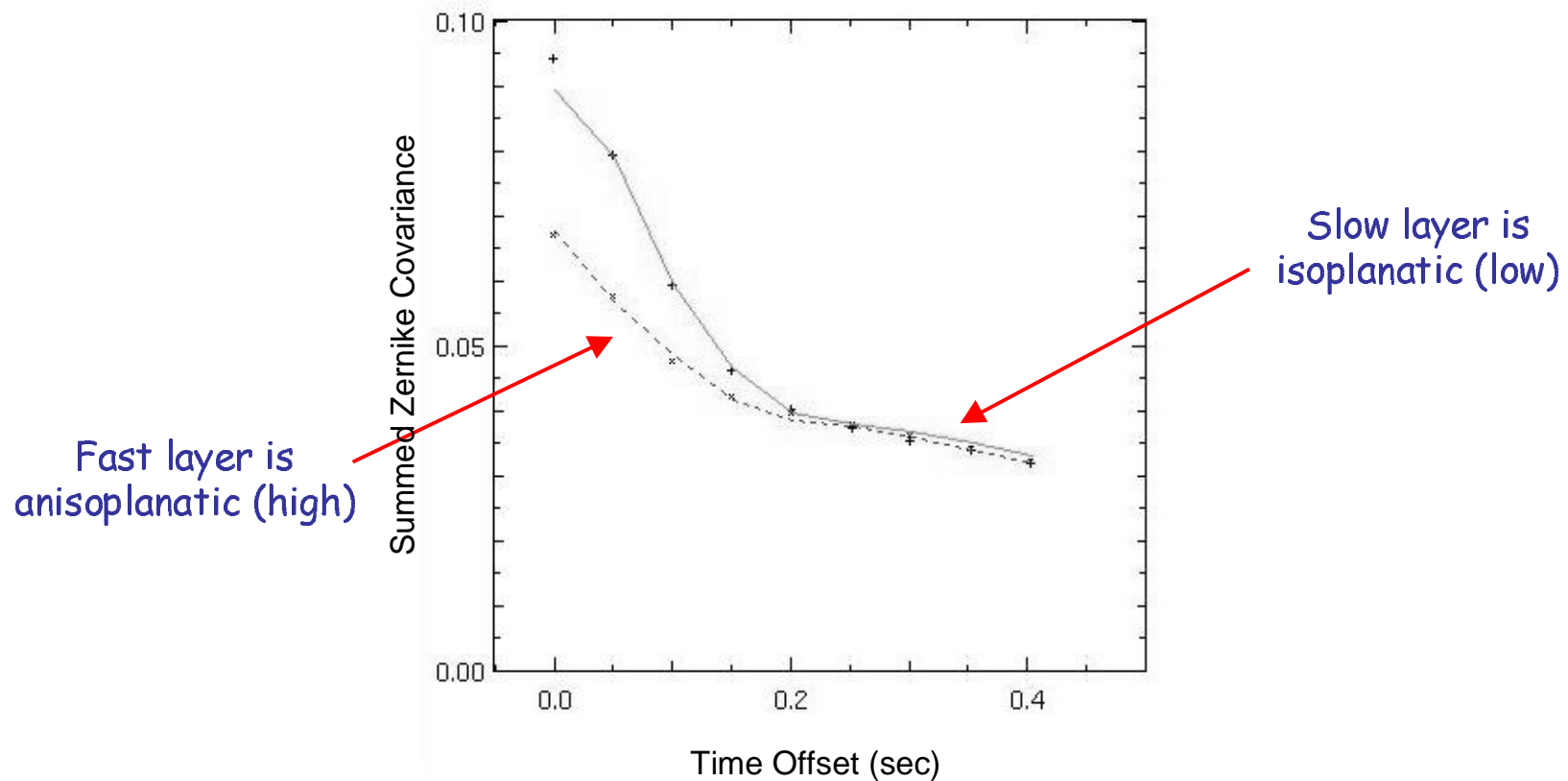
- Movie: spatial **cross**-correlation for **double star target**. Layers now separated in altitude.

Estimate:

- $C_n^2(h)$ - layer altitudes
- $V_w(h)$ - layer velocities
- Dome seeing = 0km, 0m/s layer (persistent central pixel)

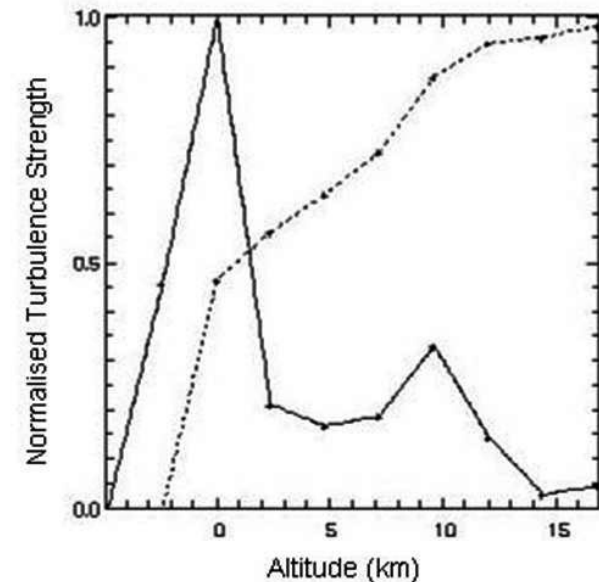
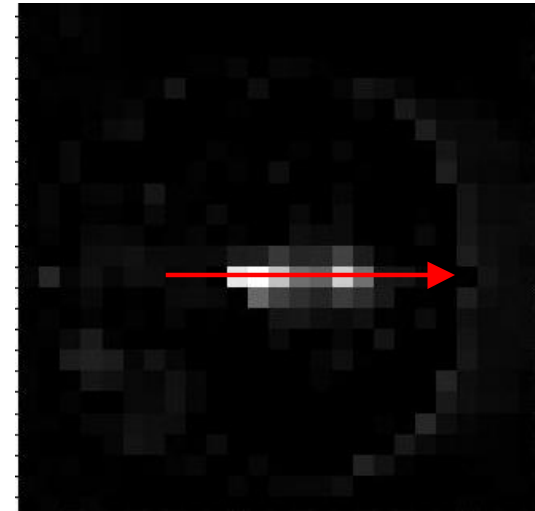


Angular and Temporal Anisoplanatism



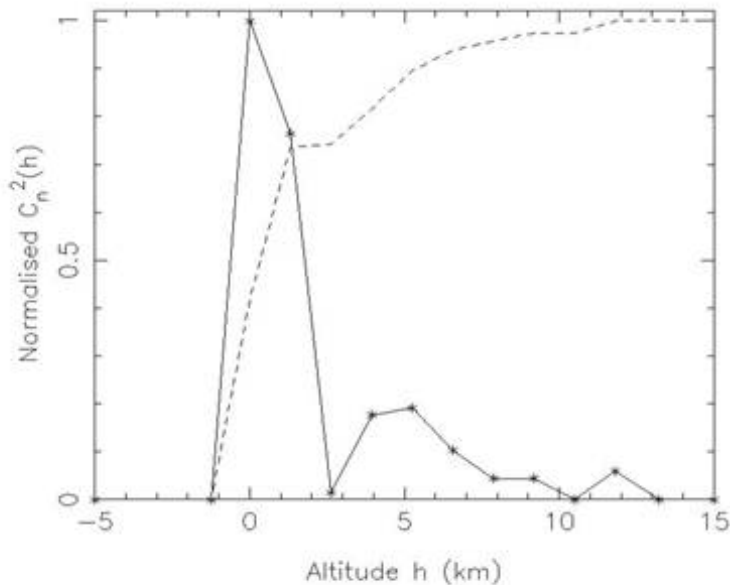
SLODAR

- Altitude information is in a 1D cut through the cross-correlation (at $\delta t=0$)
 - > do 1D cross-correlation only
 - > fast (real-time) profile.
- Deconvolve using the autocorrelation = 'impulse response' of the system (altitude independent)
 - > normalised $C_n^2(h)$ profile.
- Simultaneous r_0 measurement allows calibration of the profile in $m^{1/3}$.

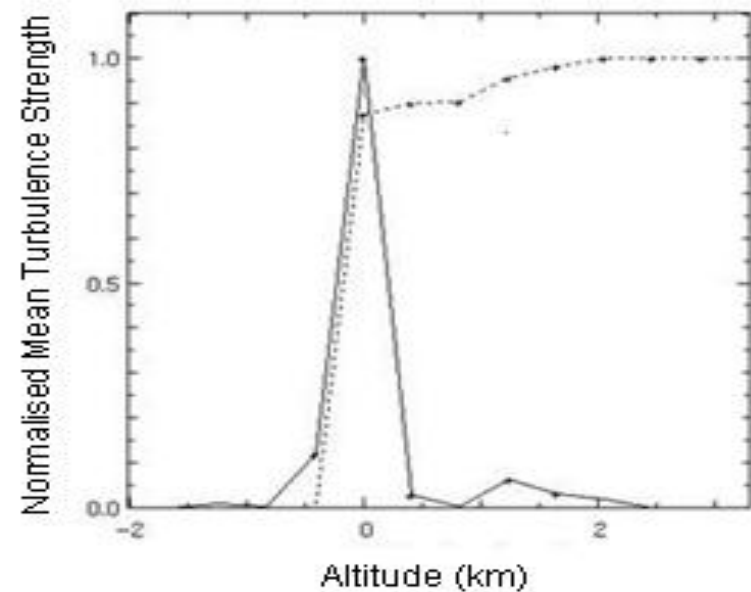


SLODAR

Altitude Resolution = $\frac{\text{WFS Sub-Aperture Spacing}}{\text{Binary Separation}}$



WHT, 40" target, 1350m resolution.



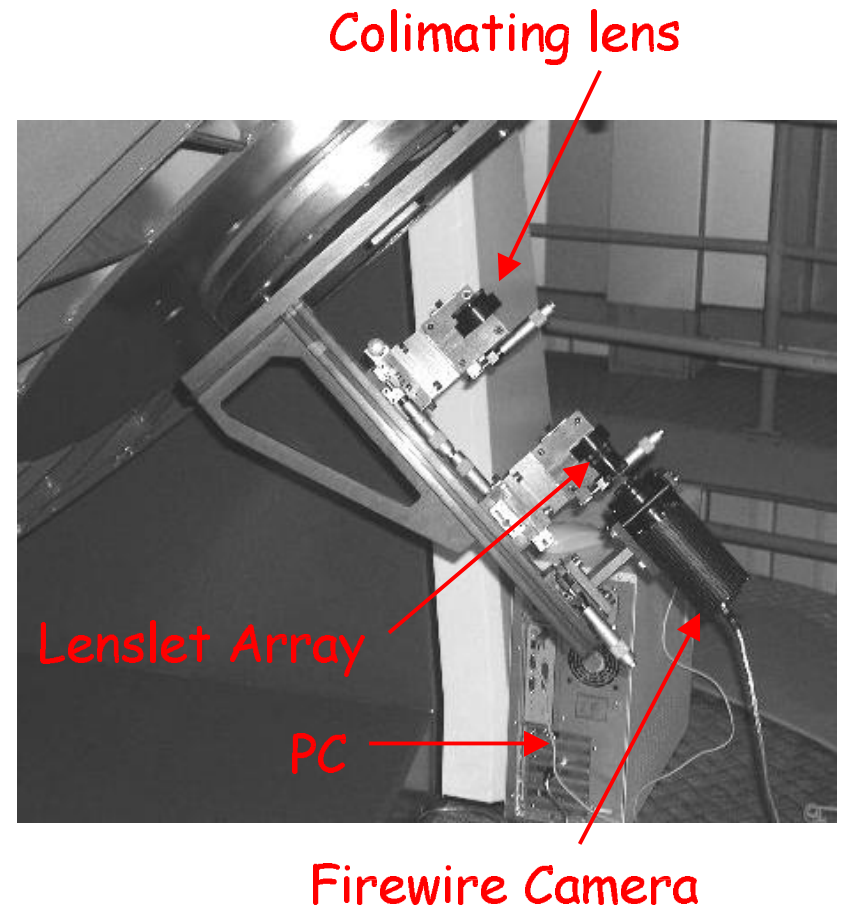
Mercator 1.2m, 60" target, 400m resolution.



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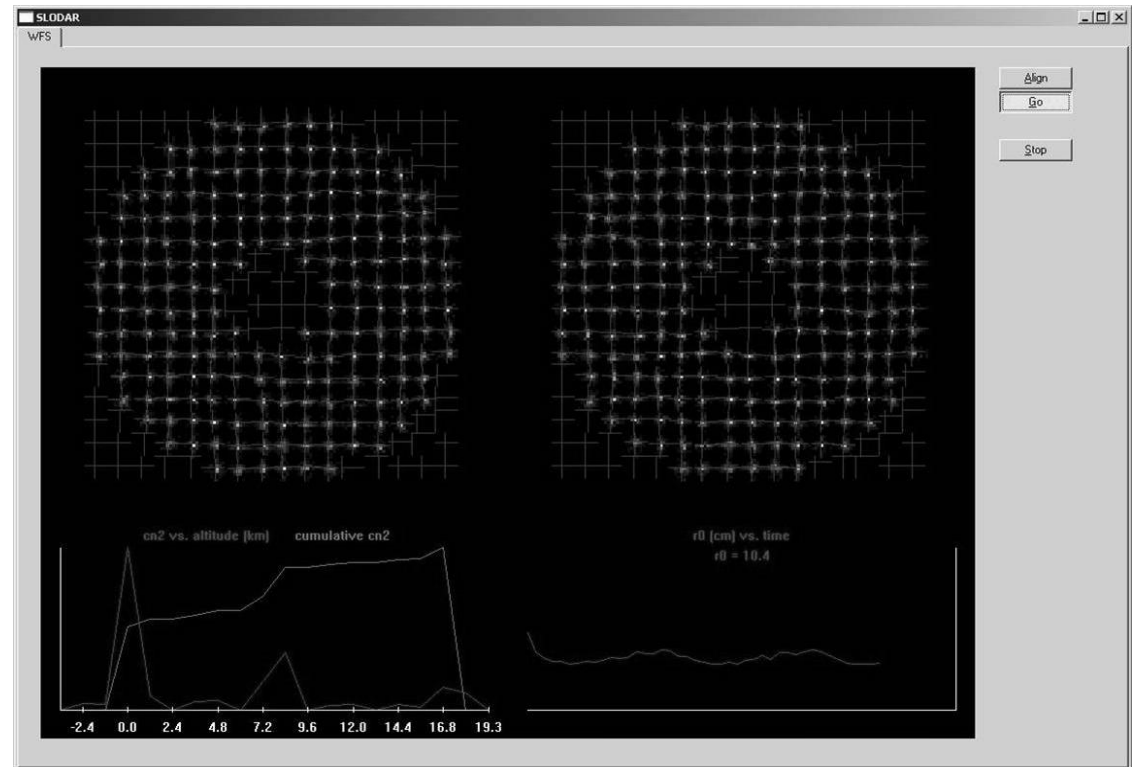
WHT / Mercator SLODAR System

- Firewire CCD camera,
~10e- rms read noise
~50Hz frame rate
- 15x15 WFS (WHT)
- 10x10 WFS (Mercator)



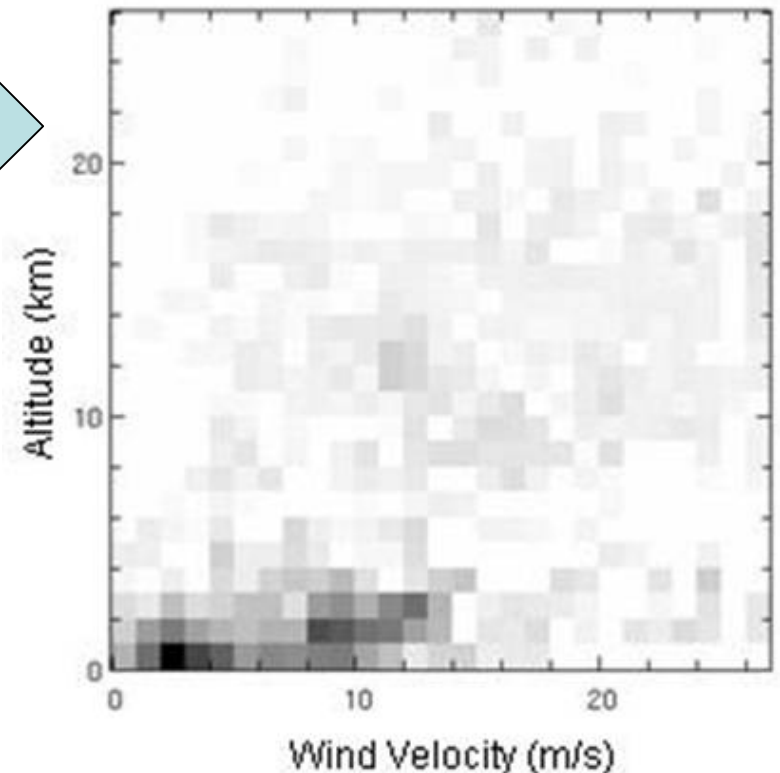
WHT / Mercator SLODAR System

- Simple GUI
- Real-time profile and r_0 display (not Mercator - no image rotator)
- Operated by TO's & observers in over-ride mode, to gather stats (~10 minutes per sample)



Statistics for ORM

- 550 observations on 17 nights at WHT (1996-1998) 8x8 system.
- Sample data from WHT testing of 15x15 system.
- Observations on 30+ nights at Mercator 1.2m telescope, July '03 -> ongoing to Dec '03.



Mean turbulence strength vs altitude and velocity (WHT)



Portable SLODAR

- Site testing
- 40cm Meade
- 8x8 Shack-Hartmann
- 5cm subaps, 1ms exposures
-> low photon rates

-> L3 EM-CCD camera



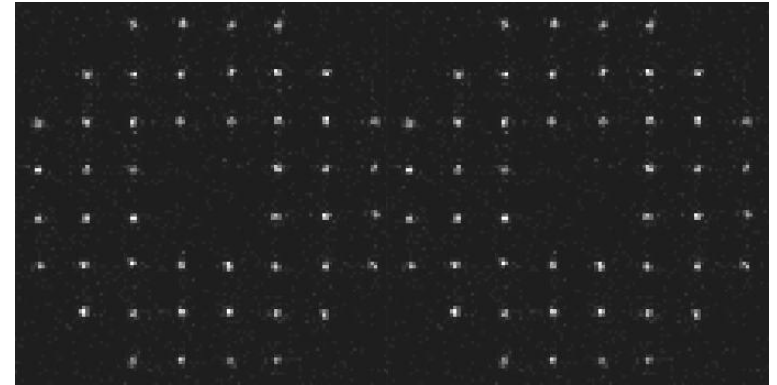
Portable SLODAR

- 8 altitude resolution elements.
- Low resolution (2km) / whole atmosphere mode (close binaries).

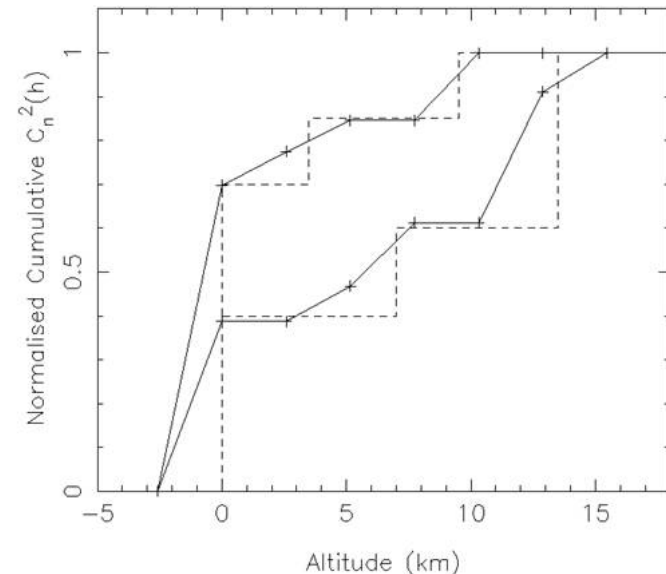


Portable SLODAR

- 8 altitude resolution elements.
- Low resolution (2km) / whole atmosphere mode (close binaries).
- High resolution (150m) / low altitude mode (wide binaries).
- Limiting magnitude $\sim 7-8$.



Contrasting input and measured cumulative $C_n^2(h)$ profiles from simulations of the portable SLODAR system. Profile is recovered reliably for $V \sim 7.5$ targets.



WFS / SLODAR - Key Points

- **Versatile** - measures r_0 , L_0 , Zernike PSDs, $Cn2(h)$, $Vw(h)$, anisoplanatism, Taylor persistence, dome seeing...
- **Robust** - well calibrated, generalised $Cn2(h)$, no inverse problem.
- **Simple** - compact system. Easily automated. Override operation at WHT/ Mercator.
- **Inexpensive** <20K Euro (system for >1m telescope) .
- **Portable** - Prototype portable system planned.
- **High resolution** - <200m (low alt.) sampling possible.

