

# Atmospheric characterisation with AO telemetry for RTC optimisation

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# Required Information for tomographic AO operation

- Vertical profile of turbulence strength
  - Reconstructor optimisation
  - PSF reconstruction
- Vertical profile of turbulence velocity
  - Smart reconstructors, eg LQG
- Vertical profile of outer scale
  - PSF reconstruction
  - Also required for turbulence strength profile from AO telemetry
- Temporal evolution of the three parameters



### Turbulence Strength





# Turbulence Strength Profile

• Tomographic reconstructor optimisation





#### Impact of the Cn2 knowledge on the wide-field AO performance – tomographic error





#### altitude (km)

Figure 4. VED of tomographic reconstructors based on the same uniform 3-layer profile from setup A (Sect. 3.1). Now the central 7 km layer is split in 2 identical layers separated by a variable  $\Delta h$ . Plain :  $\Delta h$ =0, dash :  $\Delta h$ =1 500 m, dash-dot :  $\Delta h$ =3 000 m.







- Vertical profile of turbulence velocity
  - Smart reconstructors, eg LQG
  - Estimate of convergence noise





2 layers with different velocity





#### Typical example





### Outer Scale



- Vertical profile of outer scale
  - Important for all model based analysis
  - PSF reconstruction
  - Also required for turbulence strength profile



# Methods of measurement

- Adaptive Optics telemetry
  - Preferred
  - Can be complicated
- Numerical Model
  - Meso-Scale
  - General Circulation Model
  - Convenient
  - Difficult
- Independent Profiler
  - SCIDAR
  - Unbiased measurement
  - Different line of sight



# AO telemetry profiling and outer scale



Covariance matrix







- Significant differences in tail of covariance function
- Outer scale is altitude dependent
- Problem for profile estimation
- Problem for optimising tomographic reconstructor
- Problem for PSF reconstruction
- Need outer scale profile to recover turbulence profile on large telescopes
- Effects everything that uses the turbulence profile



# Measuring outer scale



• Simultaneous fitting of outer scale and Cn2 profile





# Measuring Outer Scale



- New technique
- Tomographic reconstruction of turbulent volume
- Independent of r0





# Convergence and dataset length



- Looks like smaller L<sub>0</sub>
- Problem for profile recovery
- Different for every layer wind speed dependent
- Can make a model match using smaller L0 but then model is incorrect



# Atmospheric convergence V's divergence



- Random Walk -> variance  $\propto$  1/t
- Smaller outer scale reduces convergence time
- Different residuals on different WFSs leads to quasi-static aberrations in AO correction



- Impact on tomographic reconstruction?
- a lot more work to do







Covariance function covers full cross covariance function

Extent of covariance function makes detection of weak layers difficult

Limited to layers approx. >1/5 strength of maximum

• Overlap of all covariance peaks



# Independent Profiler

Eg Stereo-SCIDAR, turbulence strength, velocity



- Turbulence strength
- Turbulence velocity
- No convergence issue
- No outer scale issue
- Unbiased
- Validated
- Different line of sight



# Numerical Modelling

Masciadri et sl., 2016









- Turbulence strength
- Needs site specific calibration
- Used for scheduling
- Turbulence velocity (validated)
- Very convenient





	Correlation	Bias	RMSE
Speed	0.90	-0.8 m/s	1.9 m/s
Direction	0.93	-2.6 degrees	12.5 degrees

Good enough for turbulence velocity?





# Conclusions

- Atmospheric characterisation with AO telemetry is complicated
  - Requires open-loop slopes (need to know what the telescope is doing)
  - Requires outer scale profile
  - Requires statistically converged data
  - Balance with atmospheric variations
- Implications of atmospheric turbulence is important for AO
  - Convergence
  - Variability
  - Median / actual profiles
- Is turbulence velocity profile from numerical model / external profiler good enough?
- Make use of all data sources