High resolution SLODAR measurements on Mauna Kea

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Overview

- Short turbulence profiling campaign carried out in September 2007
- Carried out by the Gemini ground layer turbulence profiling team
- High resolution SLODAR experiment on the University of Hawaii 88-inch (2.2 m) telescope
Aims

• Extension of the SLODAR technique to very high spatial order
• Measure complete $C_n^2(h)$ profile
• Measure turbulence velocity profile
• Investigation validity of Taylor frozen flow approximation
• Explore implications for layer-oriented predictive AO reconstruction algorithms
Instrument

- Mounted at f/10 Cassegrain focus of the telescope
- 32 x 32 subaperture Shack-Hartmann WFS
- Andor DV885 EMCCD (effectively zero read noise), 1000x1000 pixels binned 2x2
- Exposure time 2-4 ms, frame rate ~ 50 Hz
- Target separation ~20 arcsec, vertical resolution 400-700 m
Instrument

- Shack-Hartmann spot patterns were interleaved on the detector.
- Some subapertures were significantly vignetted by “spiders” (secondary mirror supports).
- Centroiding is a challenge.
Data reduction

2D centroid cross-covariance

1D cut through the 2D cross-covariance
Theoretical response functions
Turbulence profile

\( C_n^2(h) \) extracted from the 2D cross-covariance.

\( r_0 = 17.5 \text{ cm} \)
Velocity measurements

- Temporal cross-covariance in steps of 17.5 ms
- Independent motion of multiple layers clearly visible
- Currently don’t have software to automatically extract velocities

Movie
Ongoing work

• Improved centroiding algorithm

• Automated velocity fitting (essential for Taylor measurements)

• Scintillation: currently fitting theoretical response functions based on geometrical propagation
Lessons learned

- Use larger diameter optics (to reduce static aberrations)
- Also use wider SH spot spacing (easier to centroid)
- Use larger subapertures to limit scintillation
Summary

• We deployed a 32x32 Shack-Hartmann WFS on the UH 88-inch telescope

• Instrument provides $C_n^2(h)$ profiling of the whole atmosphere with a vertical resolution of 400-700 m

• We can make detailed measurements of turbulent layer velocities, including velocity dispersion within layers

• With better data analysis we can extract information about the validity of the Taylor frozen flow approximation
SLODAR analysis of data from MAD

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SLODAR analysis of MAD data

- Deployed on VLT UT3 visitor Nasmyth focus
- Successfully achieved closed loop MCAO on-sky in March 2007
- Has 3 Shack-Hartmann WFSs, each with 8x8 subapertures
- Allows turbulence profiling from inside VLT dome
SLODAR analysis of MAD data

- Vertical resolution ~ 2 km
- Large 8 m aperture is ideal for measuring wind velocities
- WFS frame rate is ~400 Hz, although 20 Hz is fast enough for us
- We have both open- and closed-loop centroids (we can reconstruct pseudo-OL centroids from CL centroids + DM control vectors)
SLODAR analysis of MAD data
Initial results are promising...

Contact Johann Kolb (jkolb@eso.org) for more information about MAD
Surface layer SLODAR

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Surface layer SLODAR

- Measures the surface layer with vertical resolution of 10 m or less
- Implemented on a 14” Celestron telescope
- Each star has its own WFS (lenslet + CCD), thus allowing very wide binary targets to be used (e.g. 16 arcmin)
Surface layer SLODAR

- 2 Andor Luca cameras (EMCCD, 640x480 pixels, USB 2 interface)
- Cameras are smaller and lighter than iXon but have lower QE and slower readout (so limited choice of targets)
- See poster for more information
Movie