



First results on a Cn^2 profiler for GeMS

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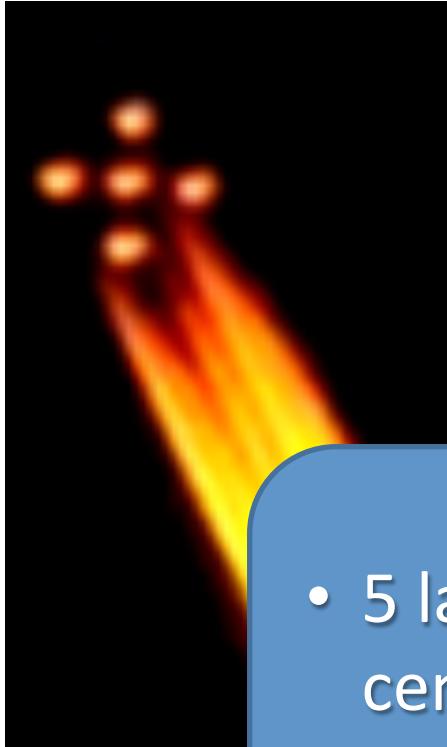
* Ph.D. student supported by the Chilean Research Council, Conicyt



Motivation

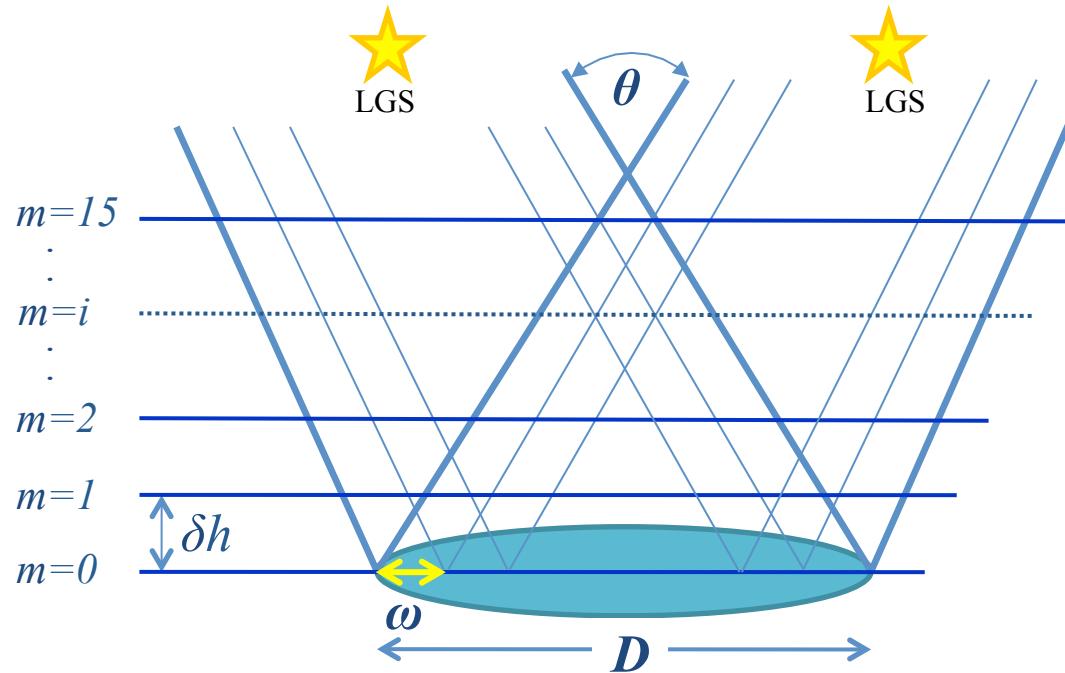
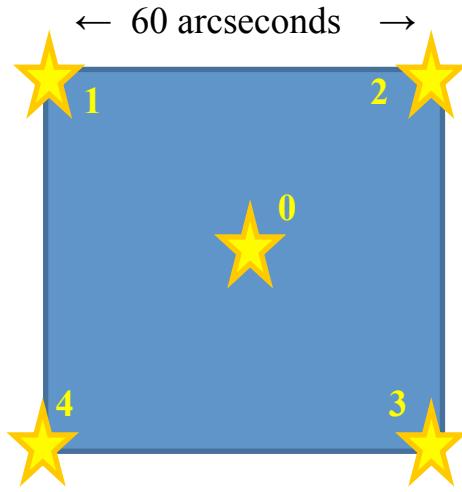
- The profiler will help to characterize the performance of GeMS
- Gather statistics of the site (seasons, winds, directions)
- Help to characterize the telescope environment (e.g. dome seeing)
- Optimize the real time estimation of the Control Matrix for better performance for different Cn^2 conditions

GeMS



- 5 laser beams placed on the corners and center of a 1'FoV
- 5 LGS WFS 16x16 Shack-Hartmann

SLODAR using LGS



For natural stars:

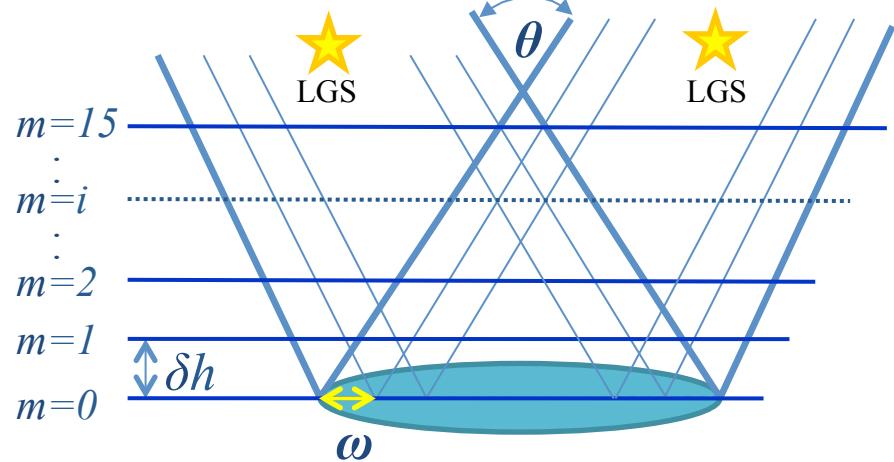
$$\delta h = \frac{\omega}{\theta} \implies h_m = \frac{m \cdot \omega}{\theta}$$

For laser guide stars:
(cone effect)

$$h_m = \frac{m \cdot \omega \cdot z}{z \cdot \theta + m \cdot \omega}$$

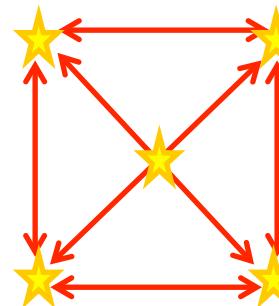
Altitude resolutions

The separation of the stars generate 2 different sets of layer altitudes



High resolution: For the corner stars, the bin altitude for the diagonal and side pairs are:

$$h_a(m) = \frac{m \cdot \omega \cdot \sqrt{2} \cdot z}{z \cdot \theta \cdot \sqrt{2} + m \cdot \omega \cdot \sqrt{2}} = \frac{m \cdot \omega \cdot z}{z \cdot \theta + m \cdot \omega} = \\ = \frac{m \cdot 0.5 \cdot z}{z \cdot 60'' + m \cdot 0.5}$$

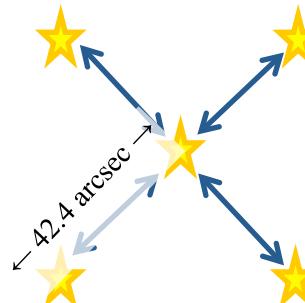


for $z=90\text{ Km}$

Bin altitudes (Km) for high and low resolutions		
bin	high res	low res
15	20.0	32.8
14	19.0	31.4
13	17.9	29.9
12	16.8	28.3
11	15.6	26.6
10	14.4	24.9
9	13.2	23.0
8	11.9	21.1
7	10.6	19.0
6	9.3	16.8
5	7.8	14.4
4	6.4	11.9
3	4.9	9.3
2	3.3	6.4
1	1.7	3.3
0	0	0

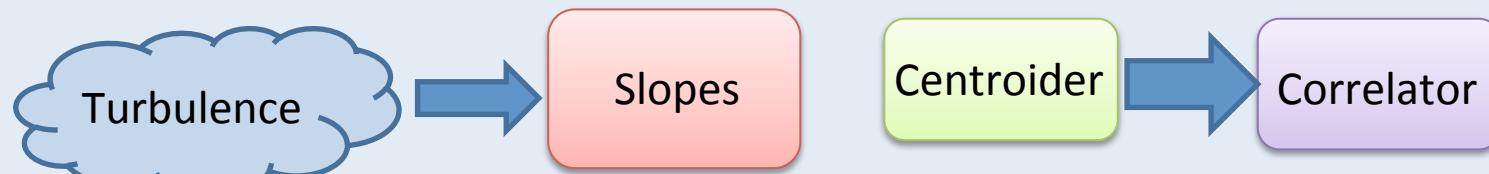
Low resolution: For pairs combining central and corner stars, the bin altitudes are:

$$h_b(m) = \frac{m \cdot \omega \cdot \sqrt{2} \cdot z}{z \cdot (\theta/2) \cdot \sqrt{2} + m \cdot \omega \cdot \sqrt{2}} = \frac{m \cdot 0.5 \cdot z}{z \cdot 30'' + m \cdot 0.5}$$

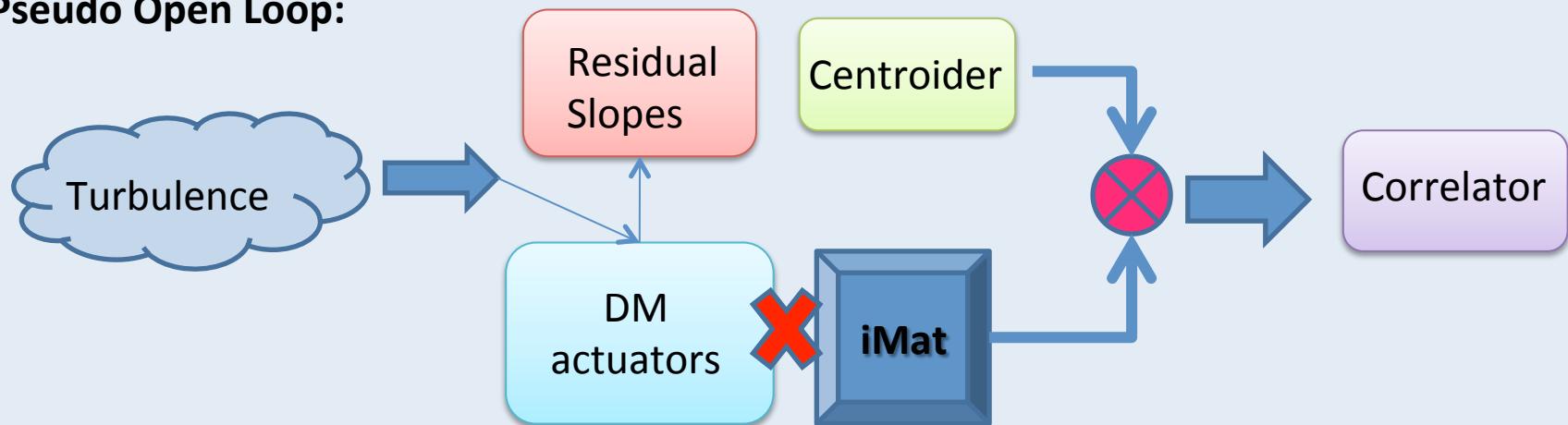


Pseudo Open Loop

Open Loop:



Pseudo Open Loop:



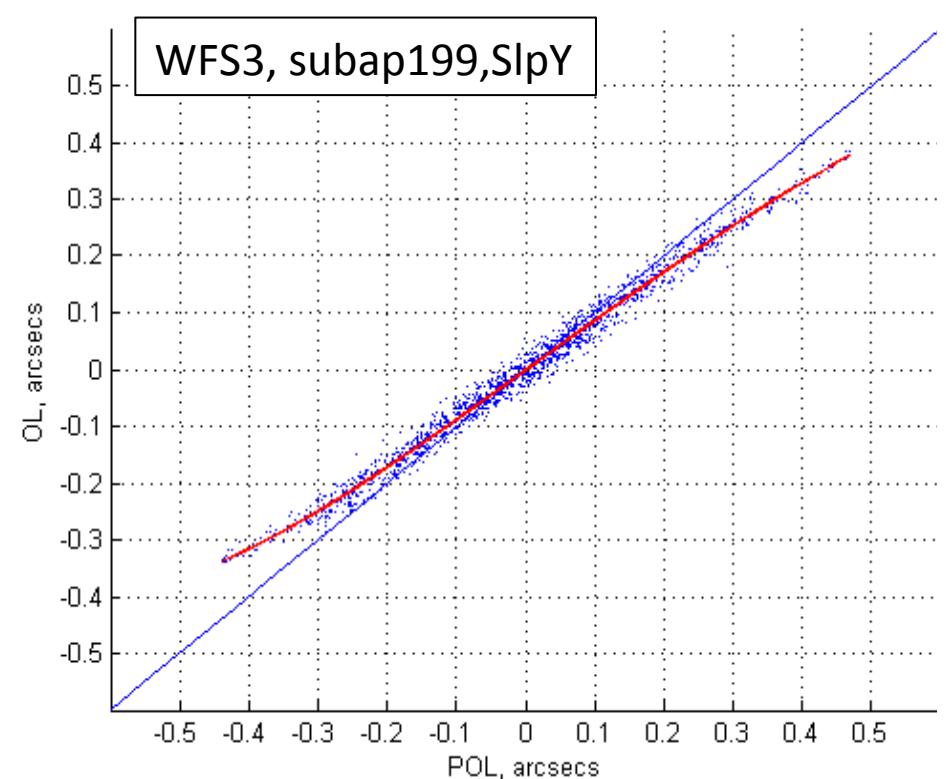
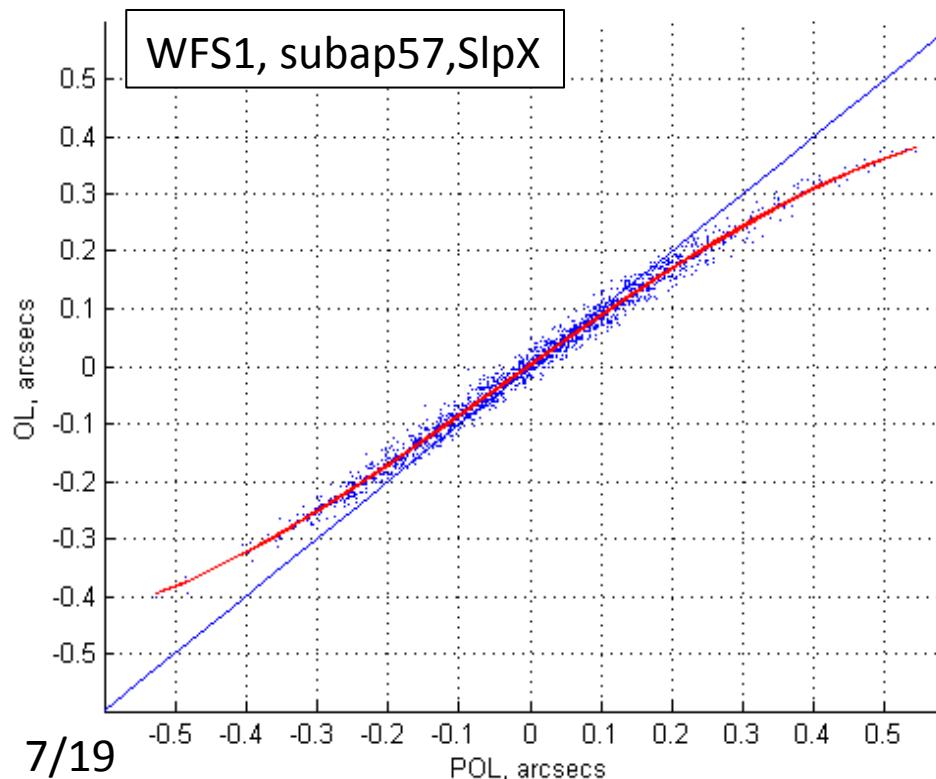
Pseudo Open Loops

The system works in open loop, so Pseudo Open Loop slopes must be reconstructed:

$$S_{POL}(k) = S_{RES}(k) + iMat \cdot V_{ACT}(k - 1)$$

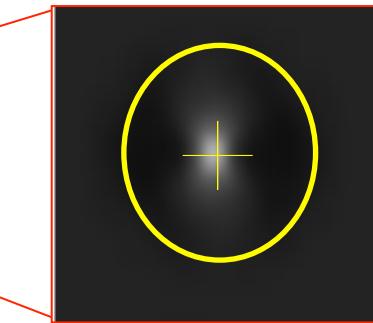
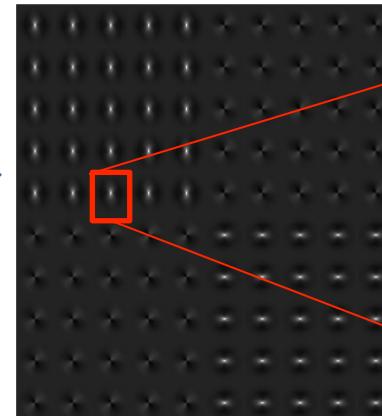
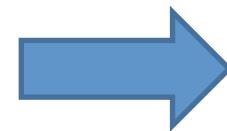
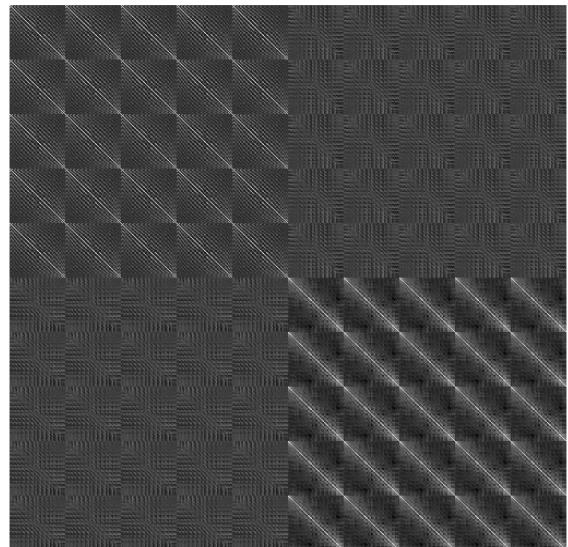
So a good characterization of the WFSs and DMs is required

Slopes linearity : OL vs POL

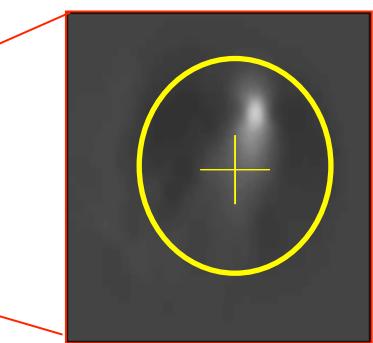
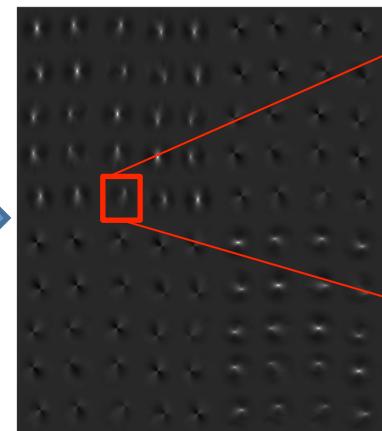
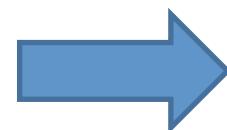
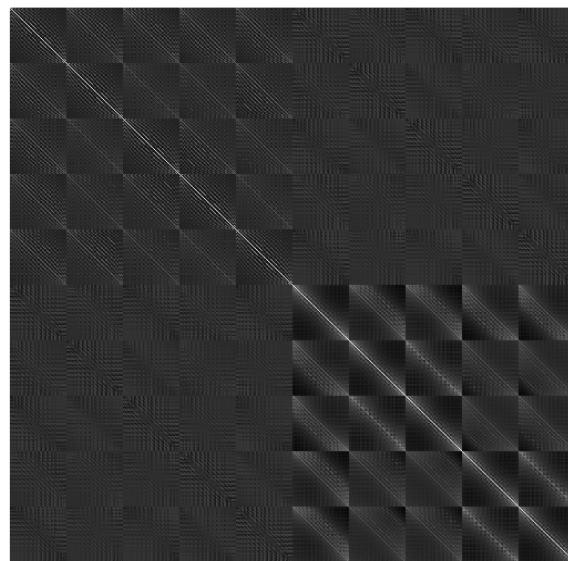


Turbulence + Slopes simulation

Ground
layer
turbulence
(bin 0)



High layer
turbulence
(bin 6)



Correlation matrix

Covariance map

Fitting an arbitrary simulated turbulence

Simulations:

Bin 0: 20%

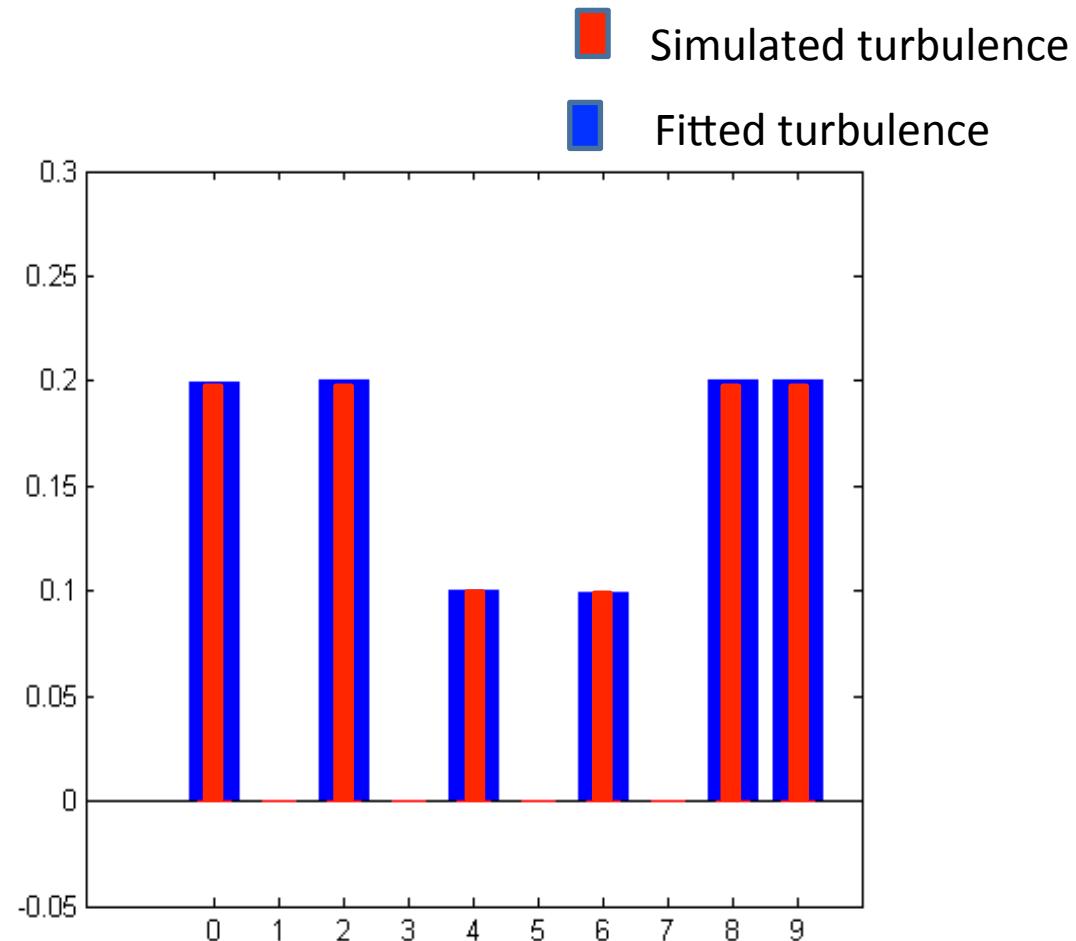
Bin 2: 20%

Bin 4: 10%

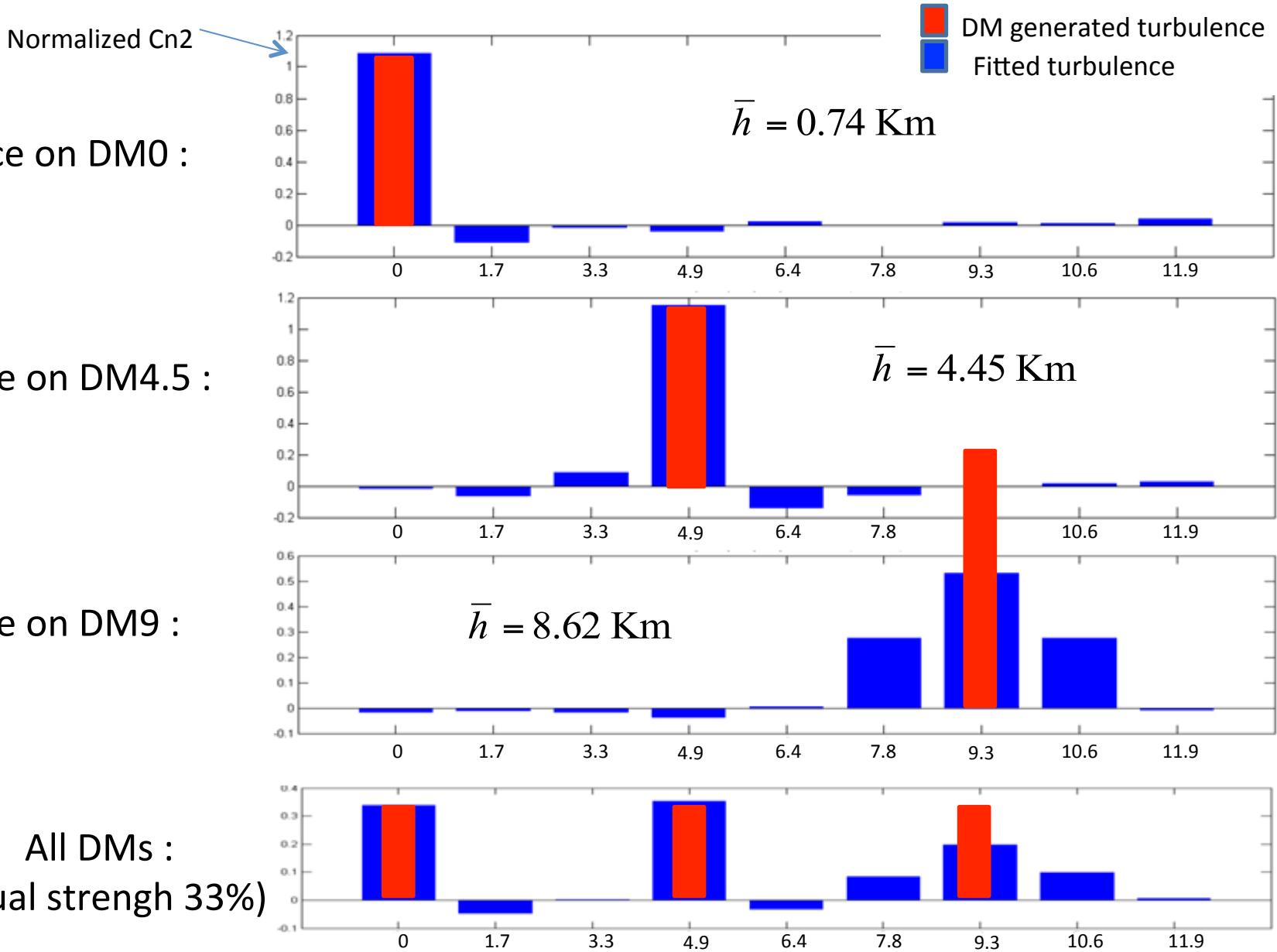
Bin 6: 10%

Bin 8: 20%

Bin 9: 20%

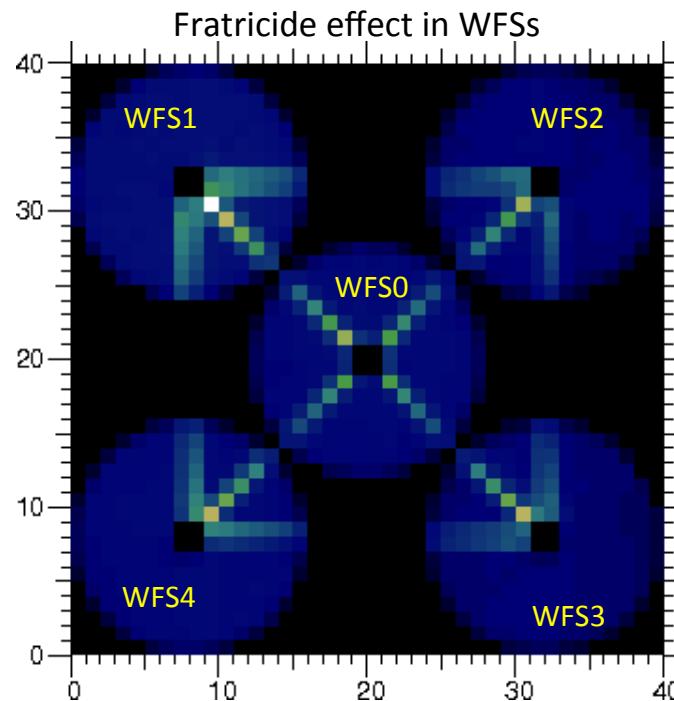
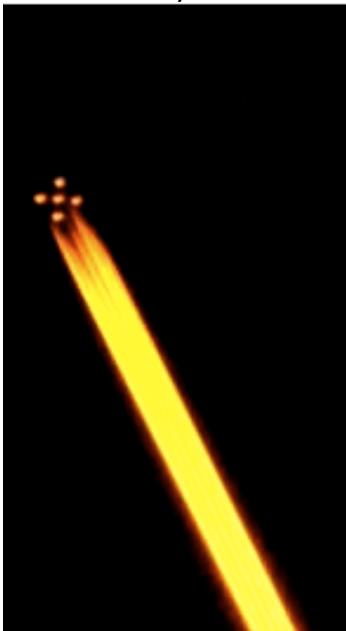


Profile fitting with DM generated turbulence

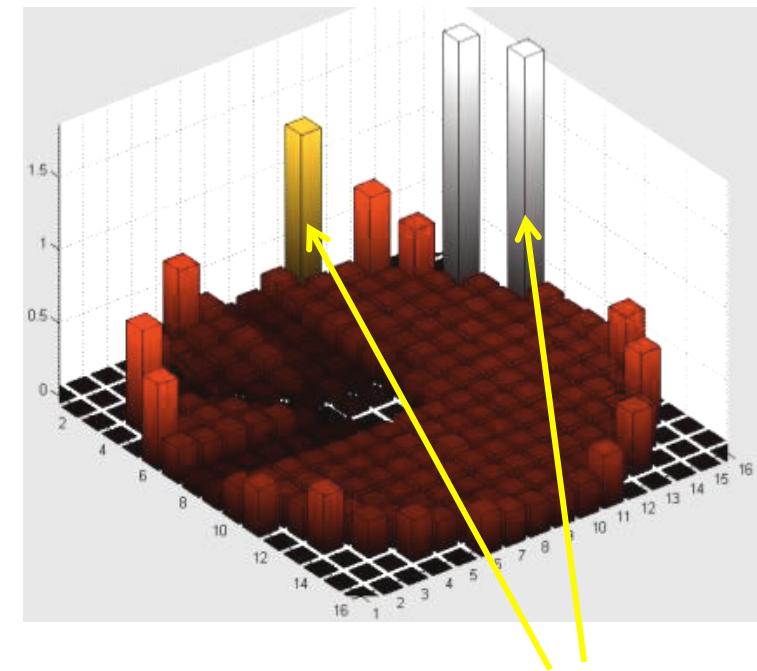


On-sky slopes: the fratricide effect & outer ring noise

LGS, first test
January 2011



Slope RMS map, WFS3



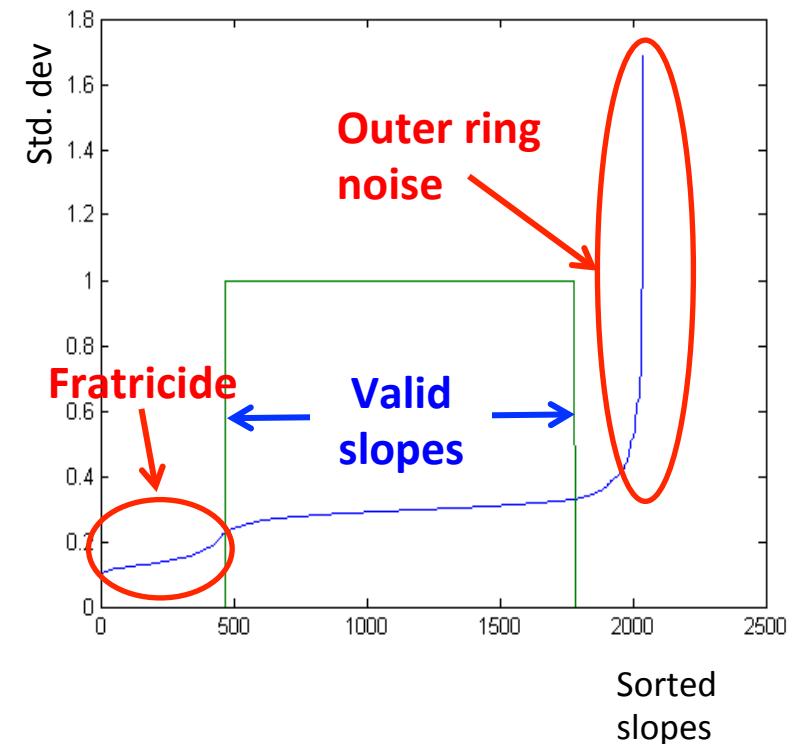
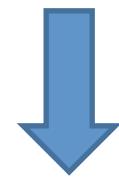
Outer ring noise due
to partial illumination
of sub-pupils

X slopes, RMS



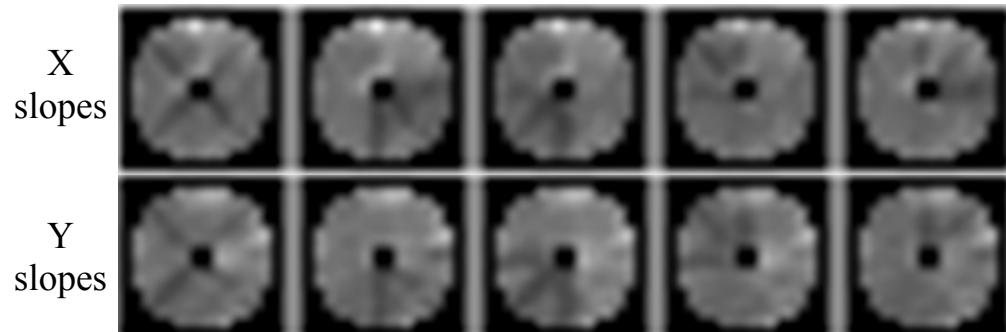
Removing noisy data

Filtering outer ring noise and
fratricide effect :

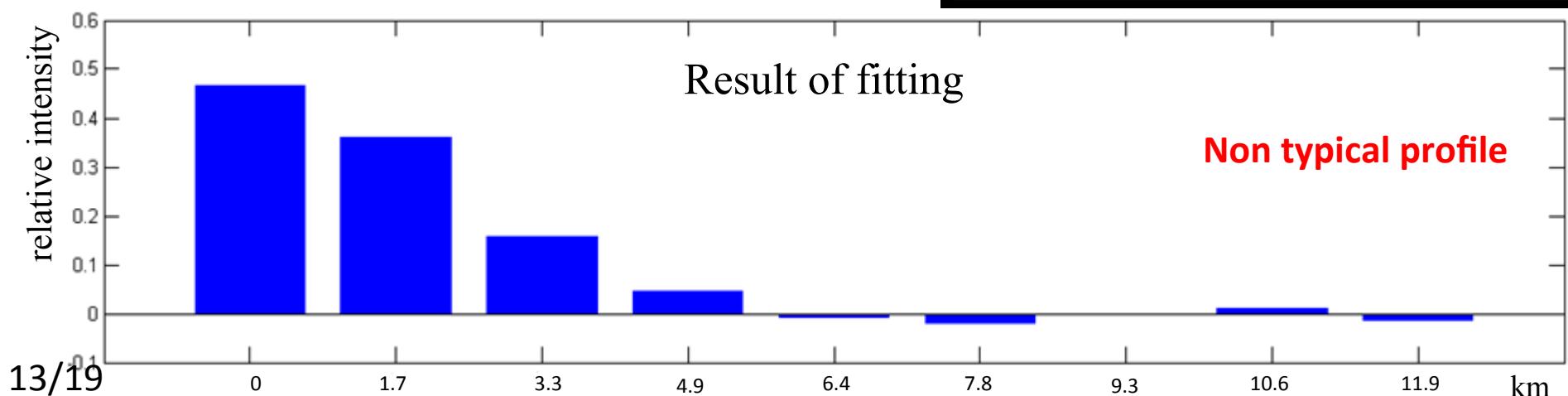
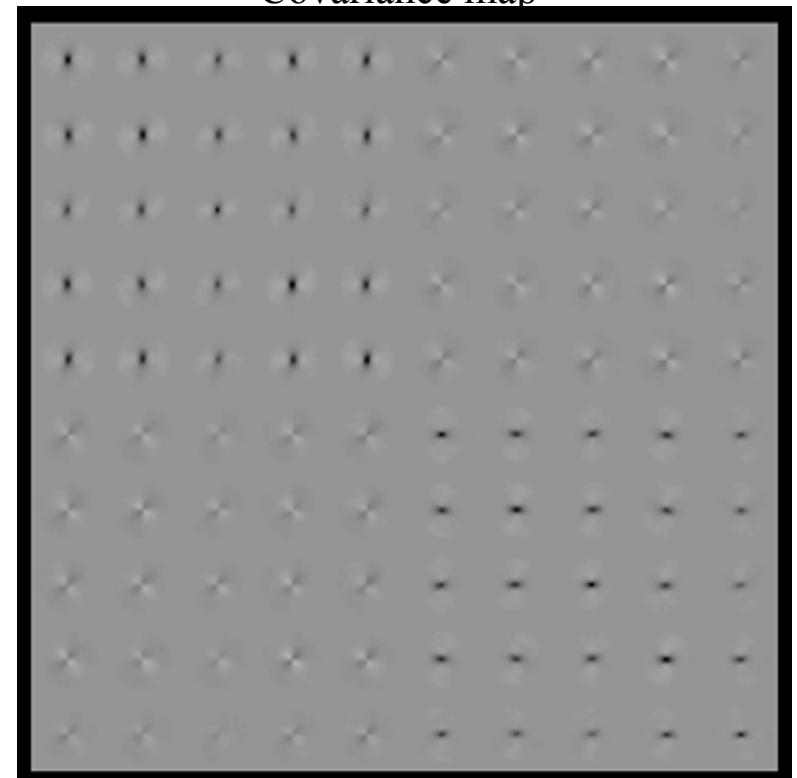


Cn^2 profiling with on-sky data

Data recorded on Friday, Apr 15th, 2011, 23:55:15

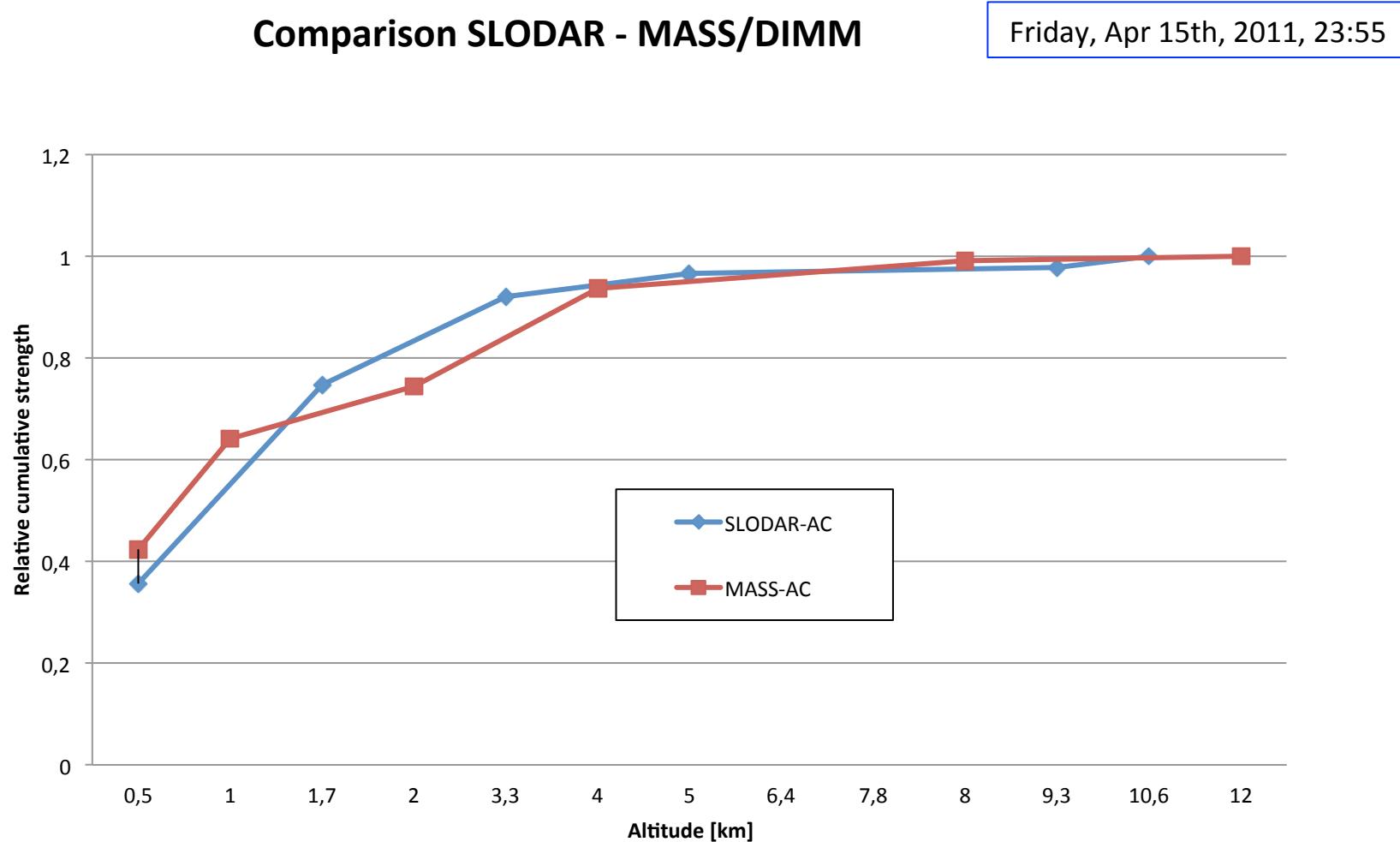


Covariance map



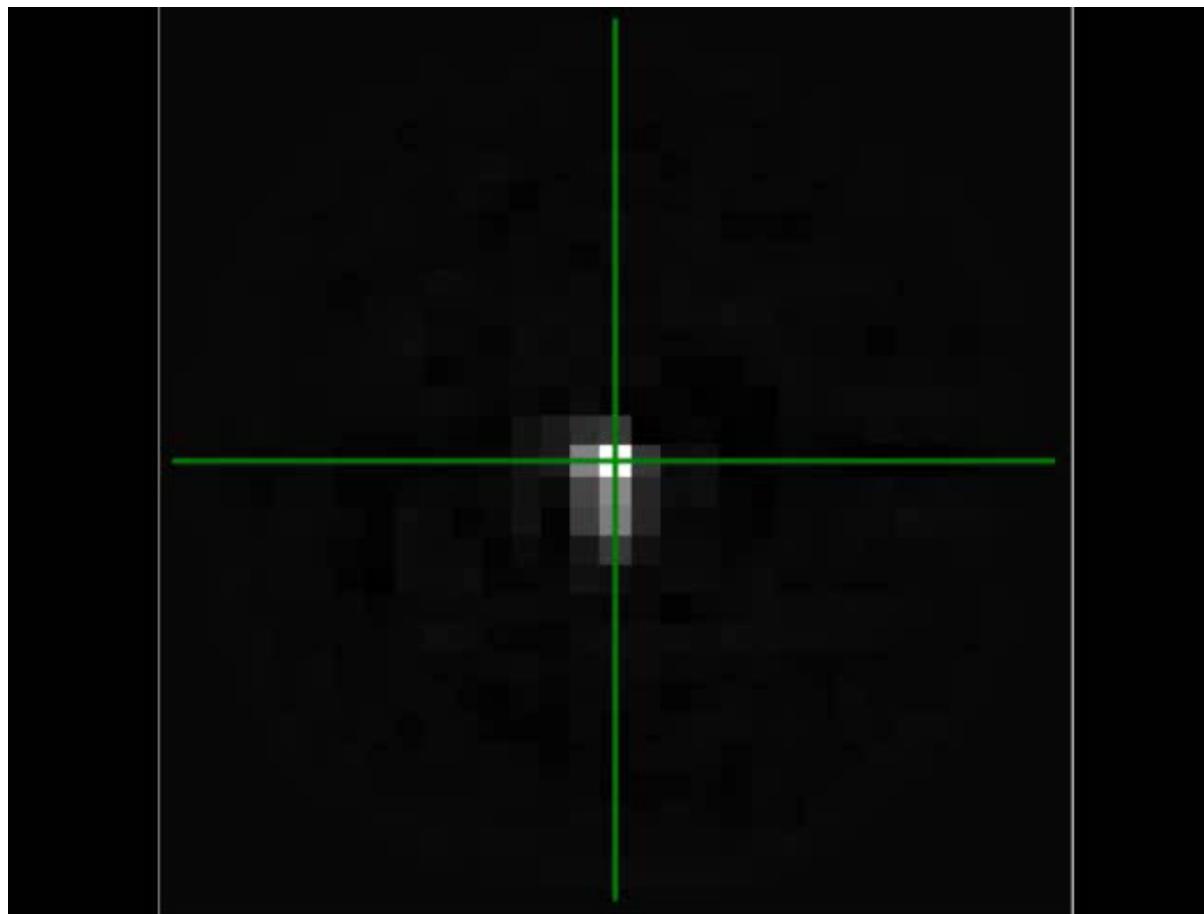
Fitting results and MASS/DIMM

- MASS/DIMM data in fairly good agreement for this example



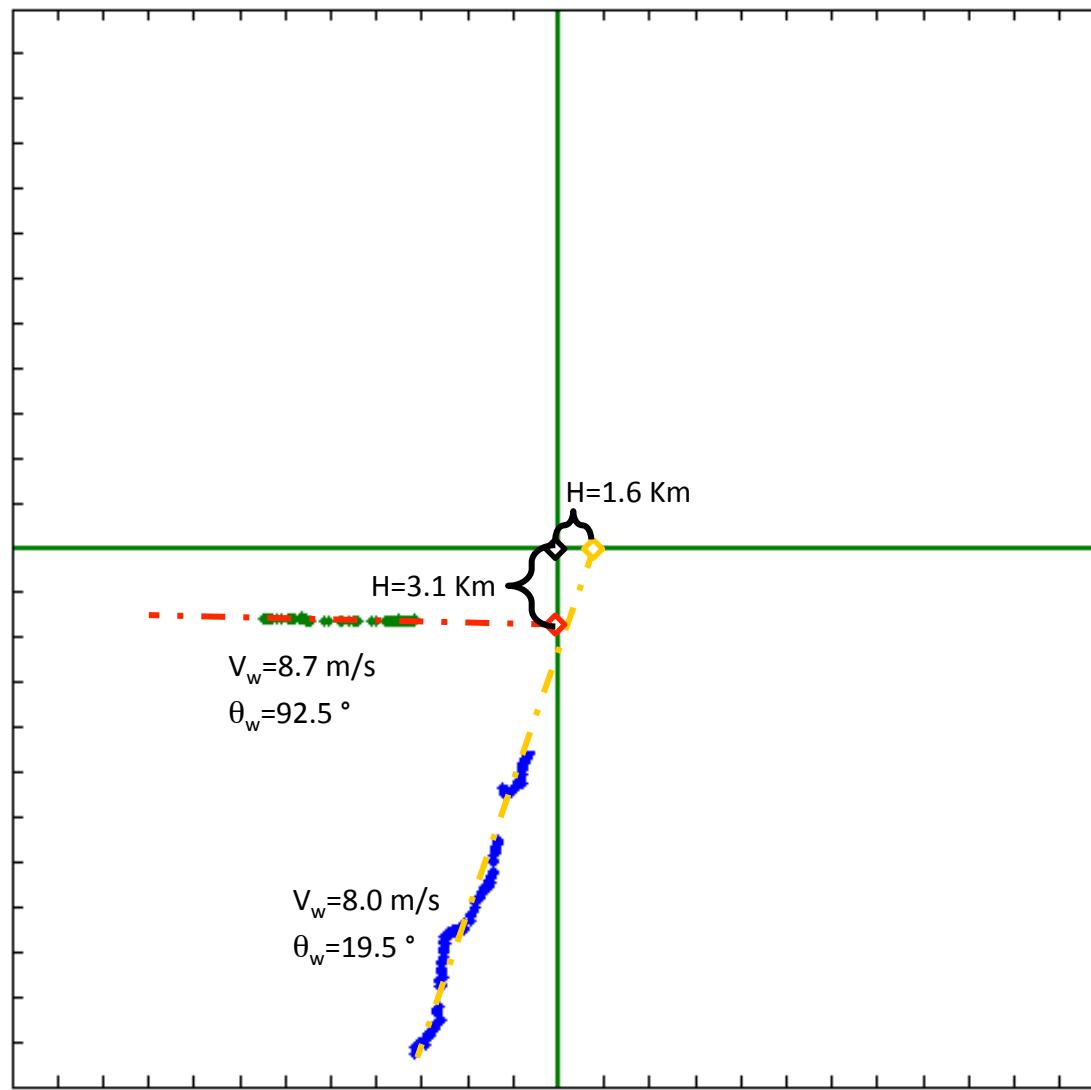
Time correlation of on-sky data

- 0.4 s sequence. Three distinctive layers are observed (strong dome seeing)
- Data: Friday, Apr 15th, 2011, 23:55:15



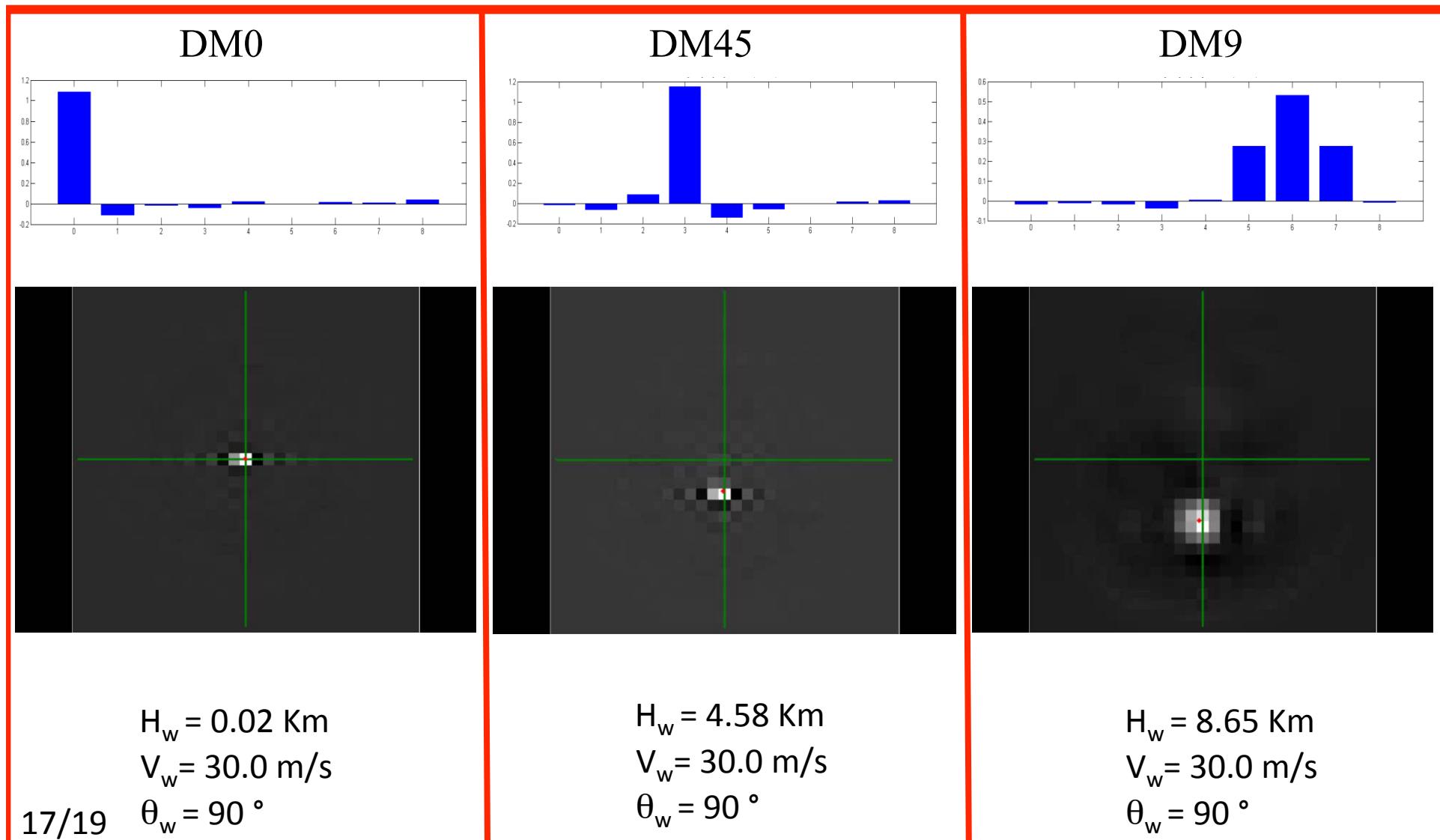
Time correlation of on-sky data

- Method to estimate layer altitude: *Wang et al, Applied Optics, 47(11):1880-92, 2008*



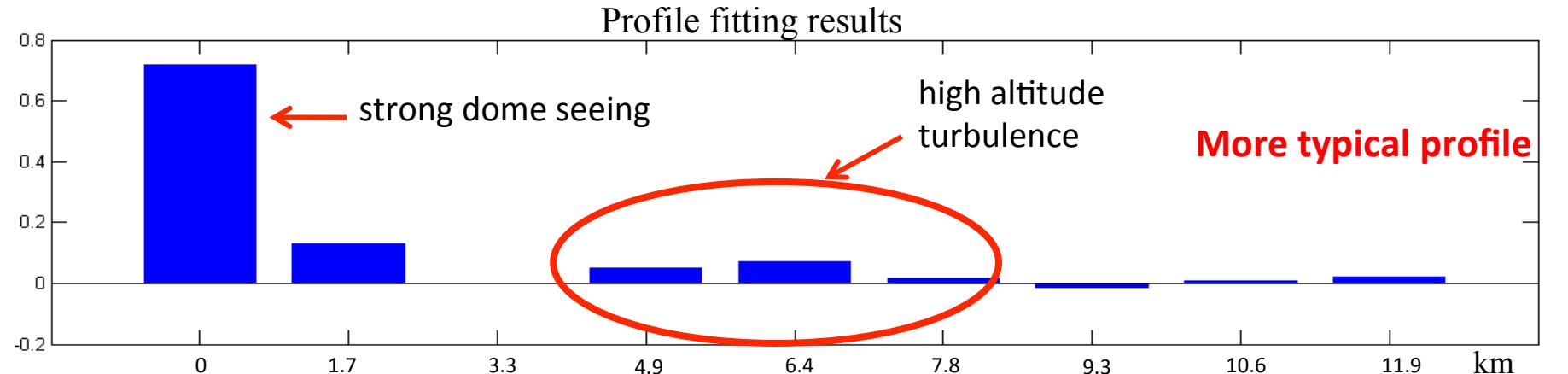
Time correlation : DM generated turbulence

Simulated turbulence was generated in each DM separately,
with similar intensities and a wind of 30.0 m/s



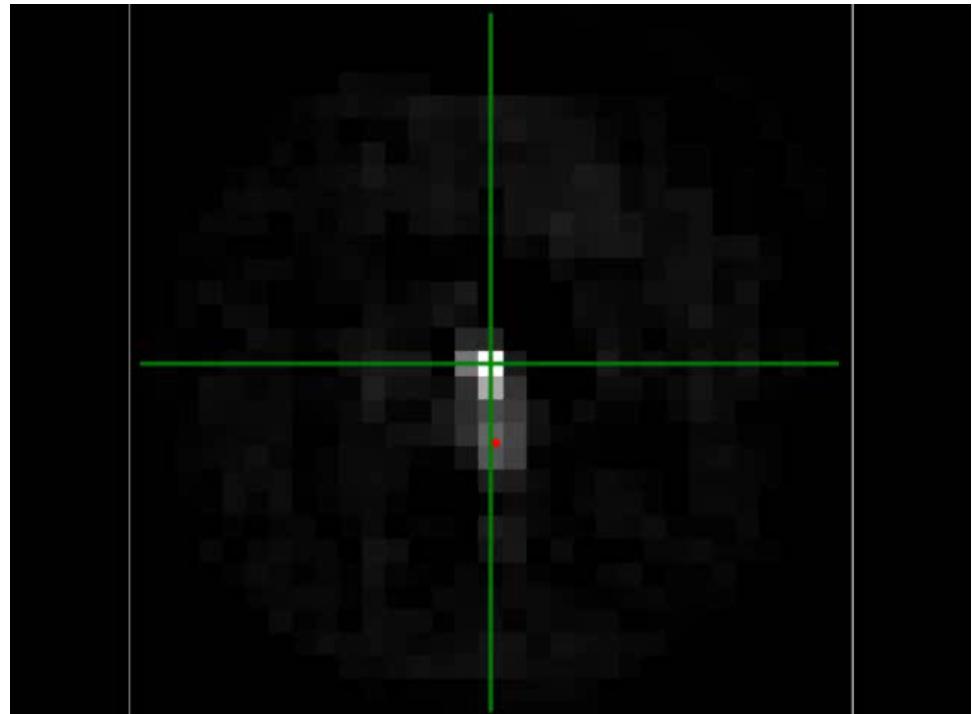
More results from on-sky data...

- Data taken on Tuesday, April 19th, 2011, from 06:16:24 to 06:21:25
- Three files were recorded & concatenated (3 x 24,000 frames)



The average image for the whole sequence is subtracted to each frame. This eliminates the dominating dome seeing, so higher layers can be seen better

For the red track : $H_w = 5.9 \text{ Km}$
 $V_w = 24.1 \text{ m/s}$
 $\theta_w = 265^\circ$



Conclusions

- **The method works**
- **The wind profile clearly detects the dome seeing**
- Strong dome turbulence affect the performance of the method
- Need **more work on the calibrations** and characterization of the method.
- High level software is ready to perform the C_n^2 profile in real time.
- **Longer sequences** are required (>100,000)
- Better elimination of the fratricide effect is needed
- Wind profiling needs to be automated (too much assistance at the moment)
- **Collaboration started with LGS team at the MMT telescope** to measure the C_n^2 profile using five raleigh laser beacons in open loop

THANKS