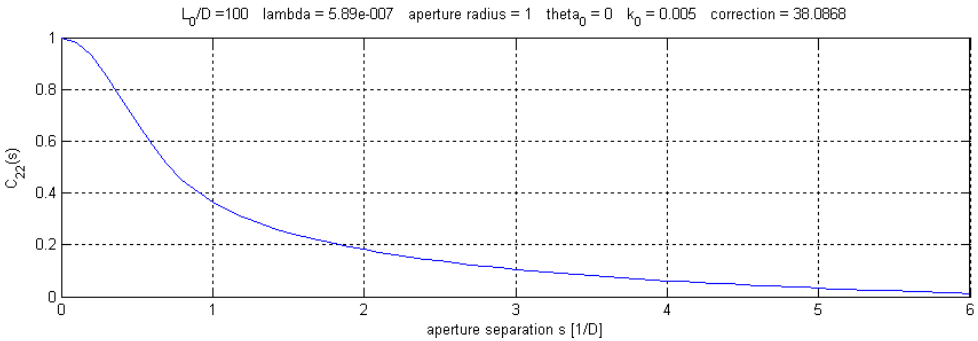
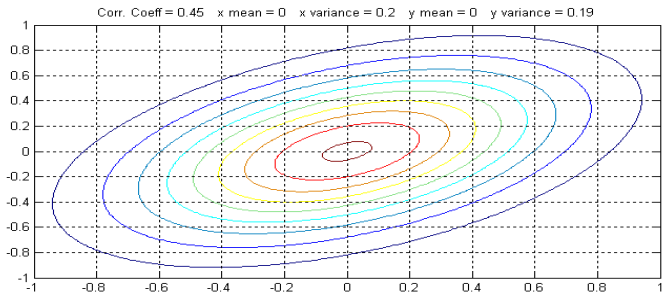
Analyzing Telescope Subaperture Tilt Measurement Correlations





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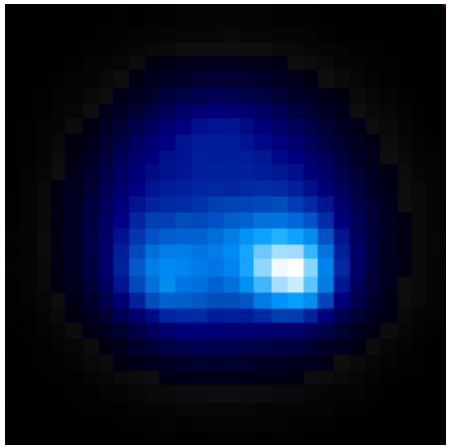
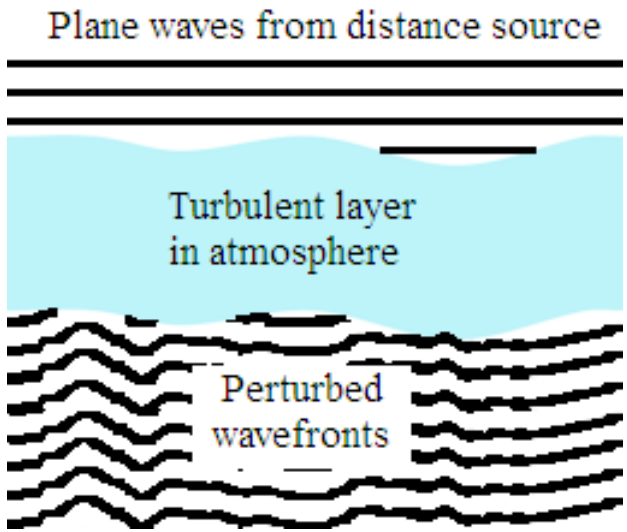
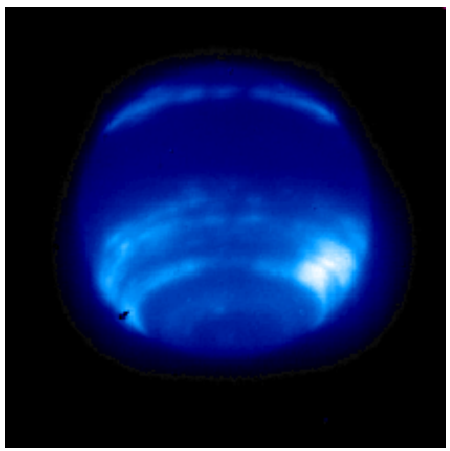
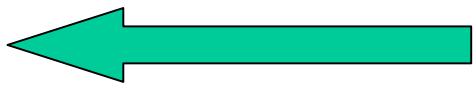
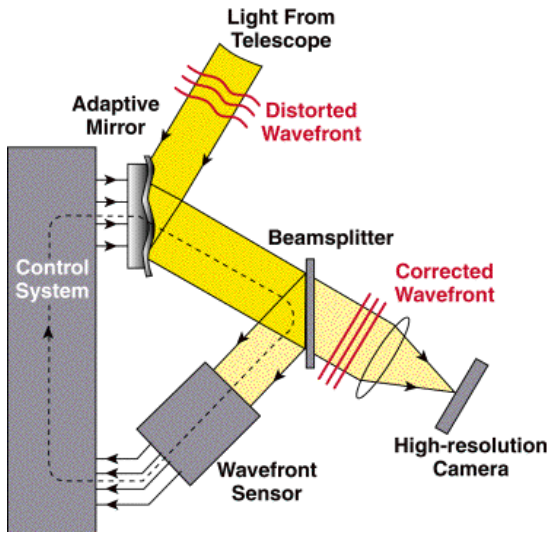
Adaptive Optics



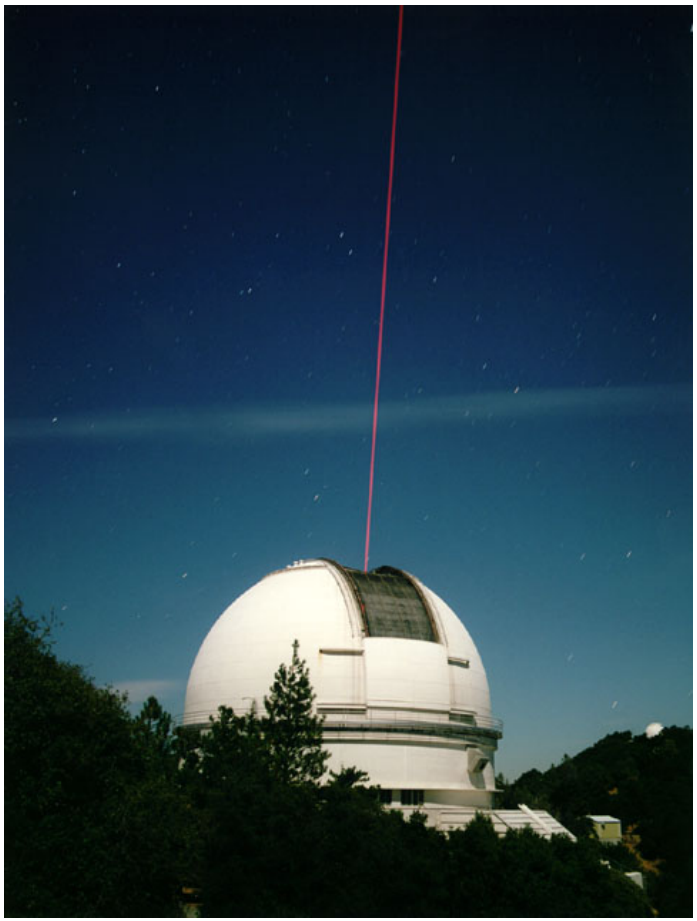








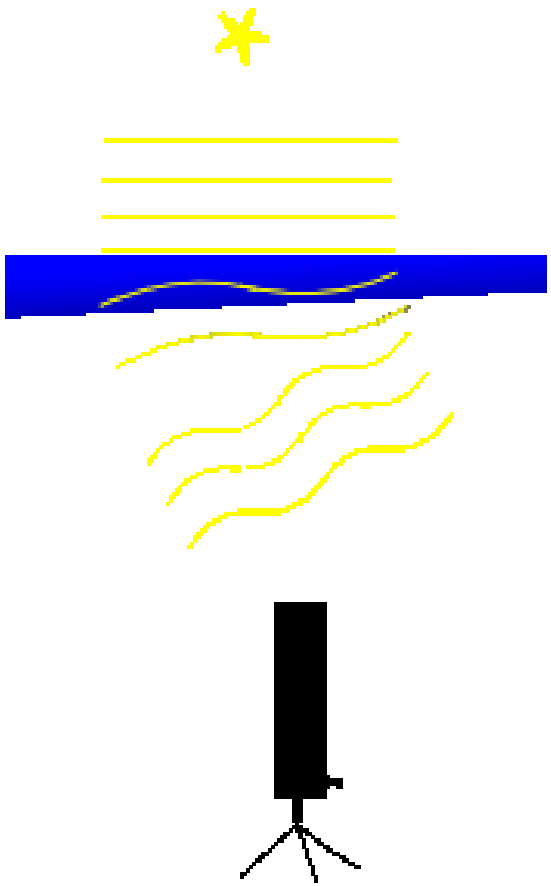
Laser Guide Star Adaptive Optics



- Laser excites sodium atoms in the upper atmosphere.
- Creates an artificial star.
- Improves sky coverage.

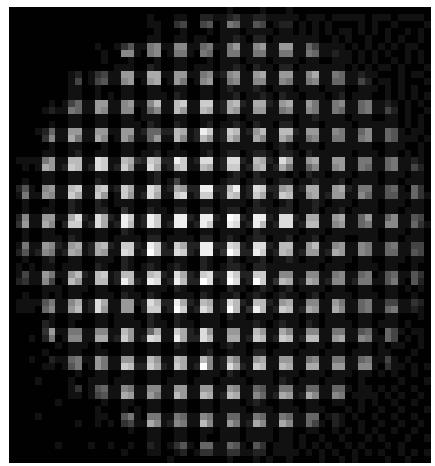
Laser guide star systems introduce new problems.

Natural Guide Stars and Tip-tilt

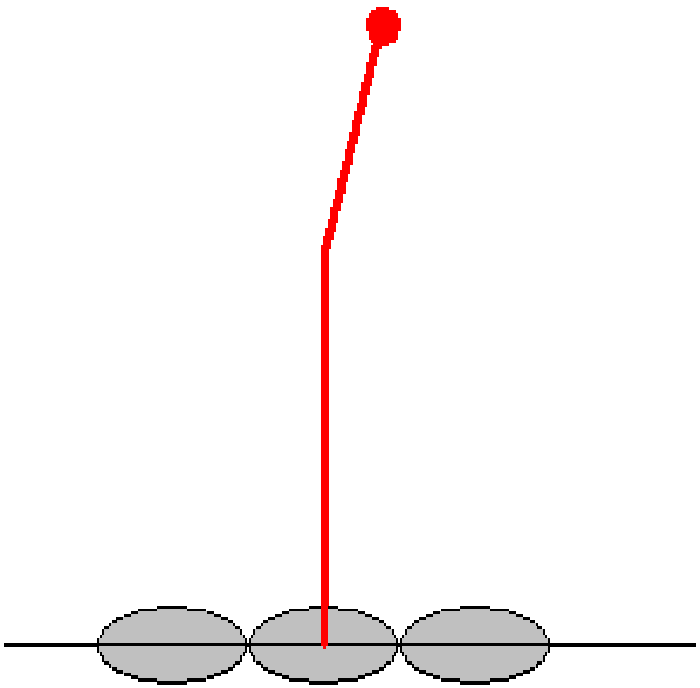


- Wavefront is tilted by turbulent atmosphere.
- The object does not remain centered on aperture.
- Information from the wavefront sensor can correct this problem:

What happens with a laser guide star?



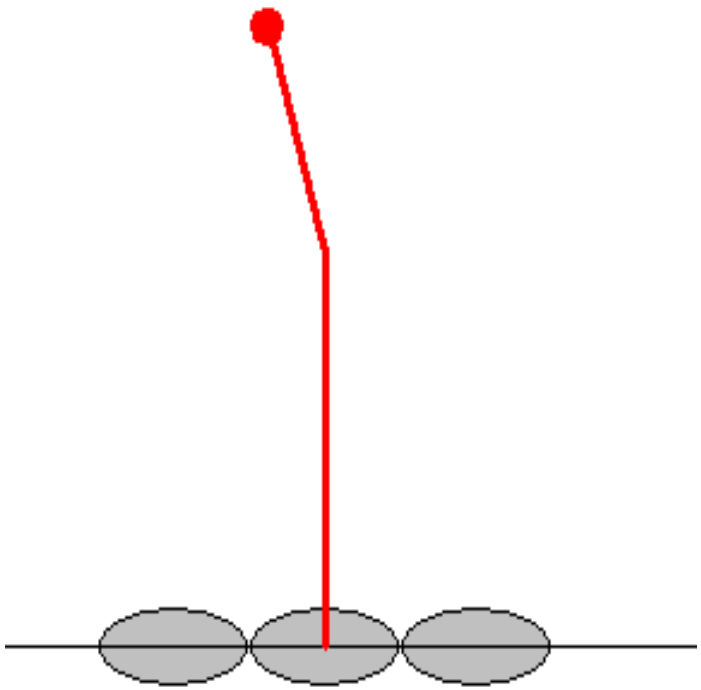
Uplink and Downlink



- Laser is tilted as it travels up through the atmosphere.
- Light propagates back down through the atmosphere in a cone.

What distribution of tilts do the subapertures record?

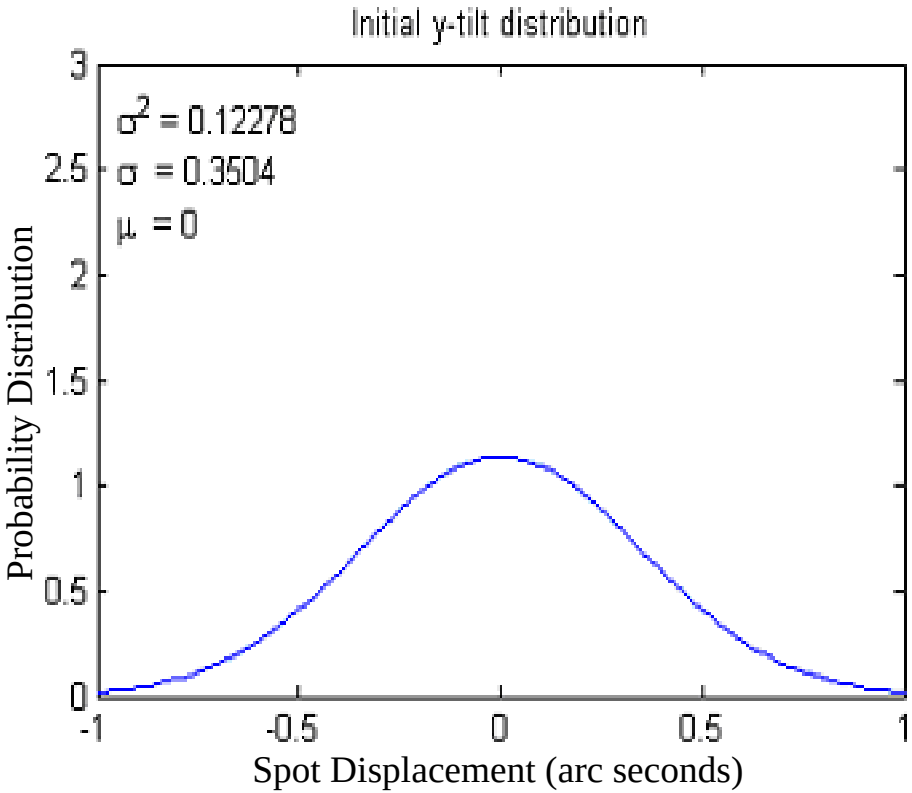
Uplink Complicates the Picture



- The turbulence in the atmosphere evolves.
- The center subaperture always records zero tilt.
- Still need a (dimmer) natural guide star to get tip-tilt information.

But the subapertures around the center are recording tilts…

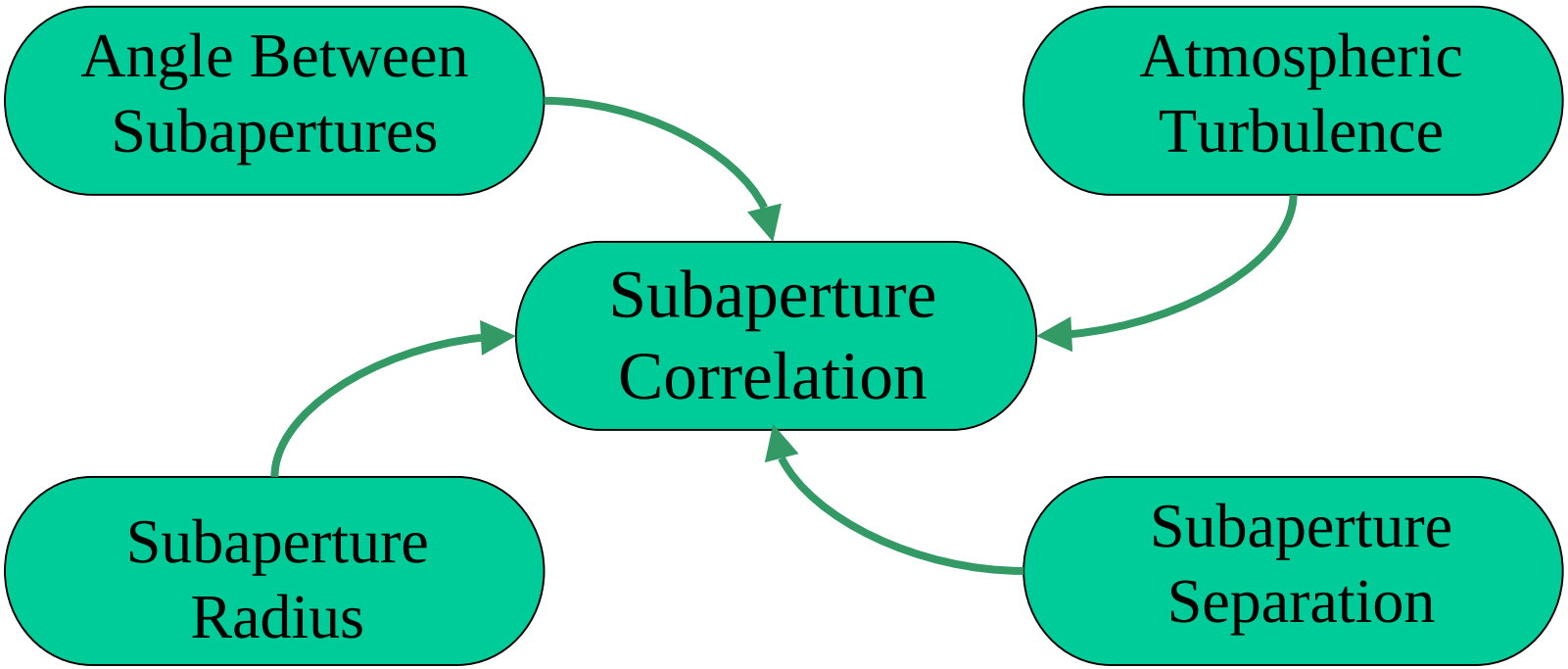
Subaperture Tilt Measurements



- Subaperture tilt measurements are normally distributed.
- We expect subaperture tilt measurements to be correlated.

How can we determine these correlations?

Bivariate Correlations

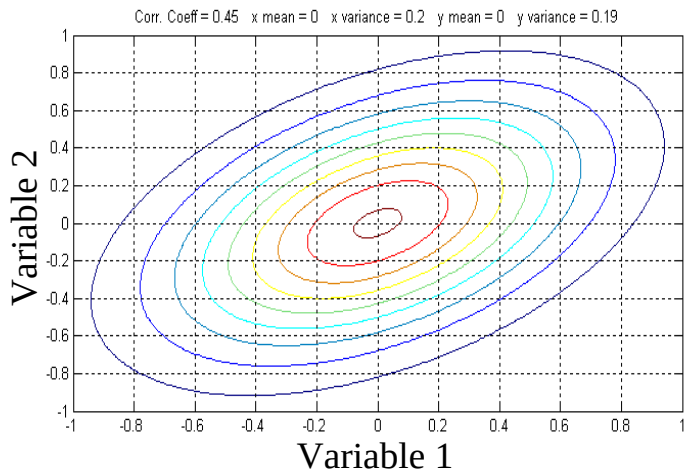


Takato and Yamaguchi captured this relationship in a mathematical formula.

Conditional Mean and Variance

If two random variables are uncorrelated, measuring one gives you no information about the other.

But if they are correlated, measuring one could give you a good idea of the other:



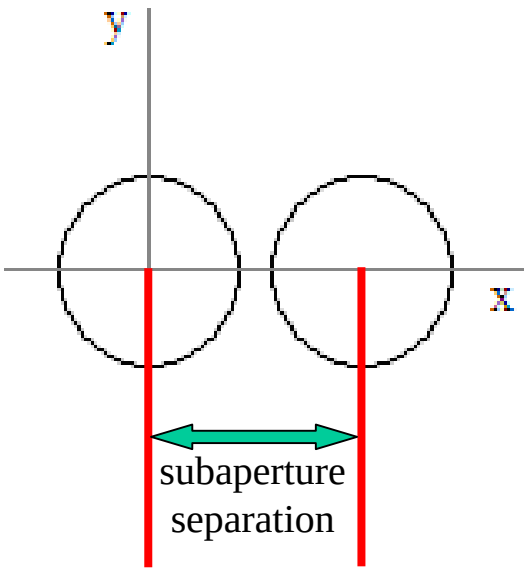
The subaperture tilt measurements are correlated.

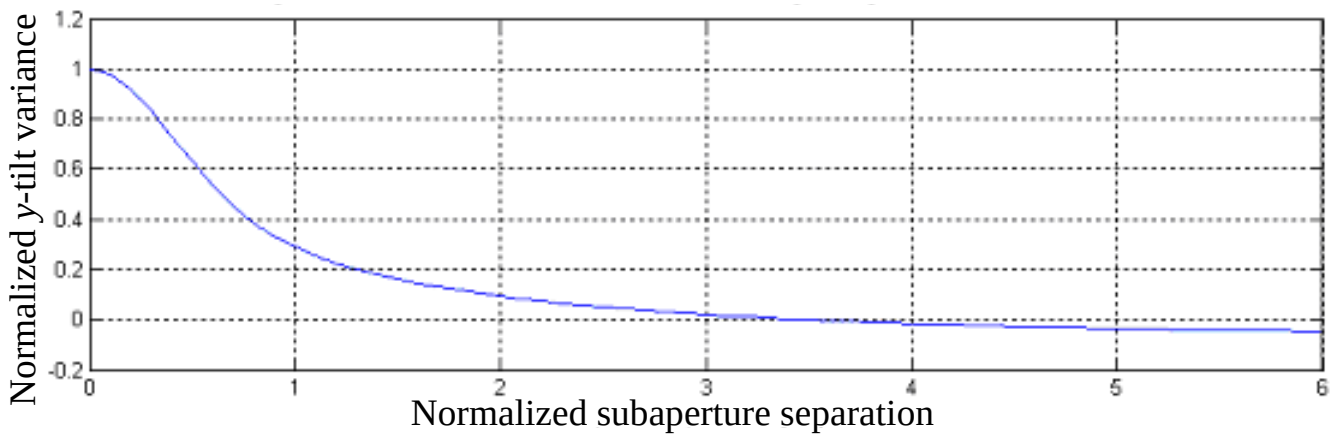
Project Outline

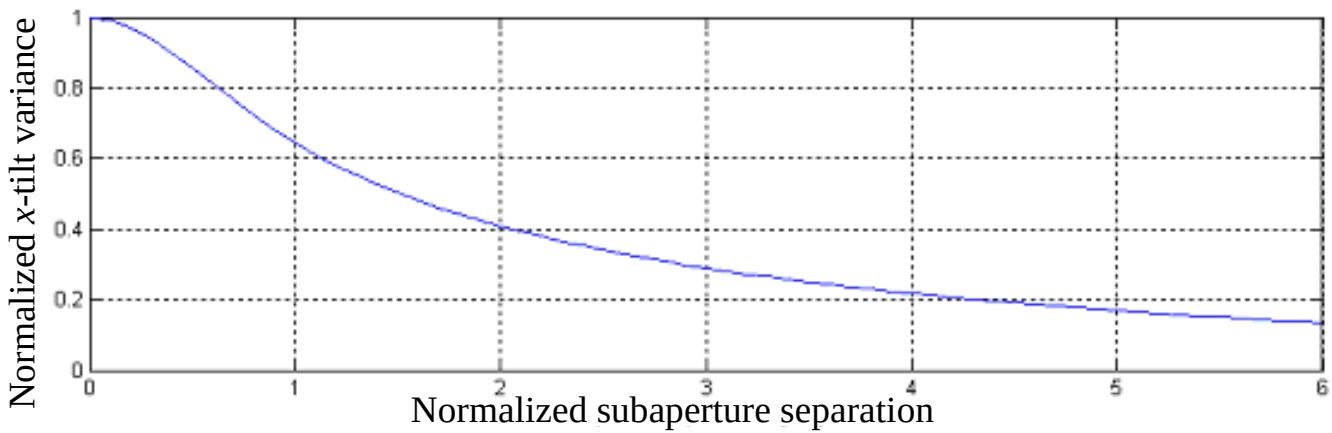
Overall Goal: Use correlations to estimate uplink tilt

If we can estimate uplink tilt, we can correct for it and increase sky coverage.

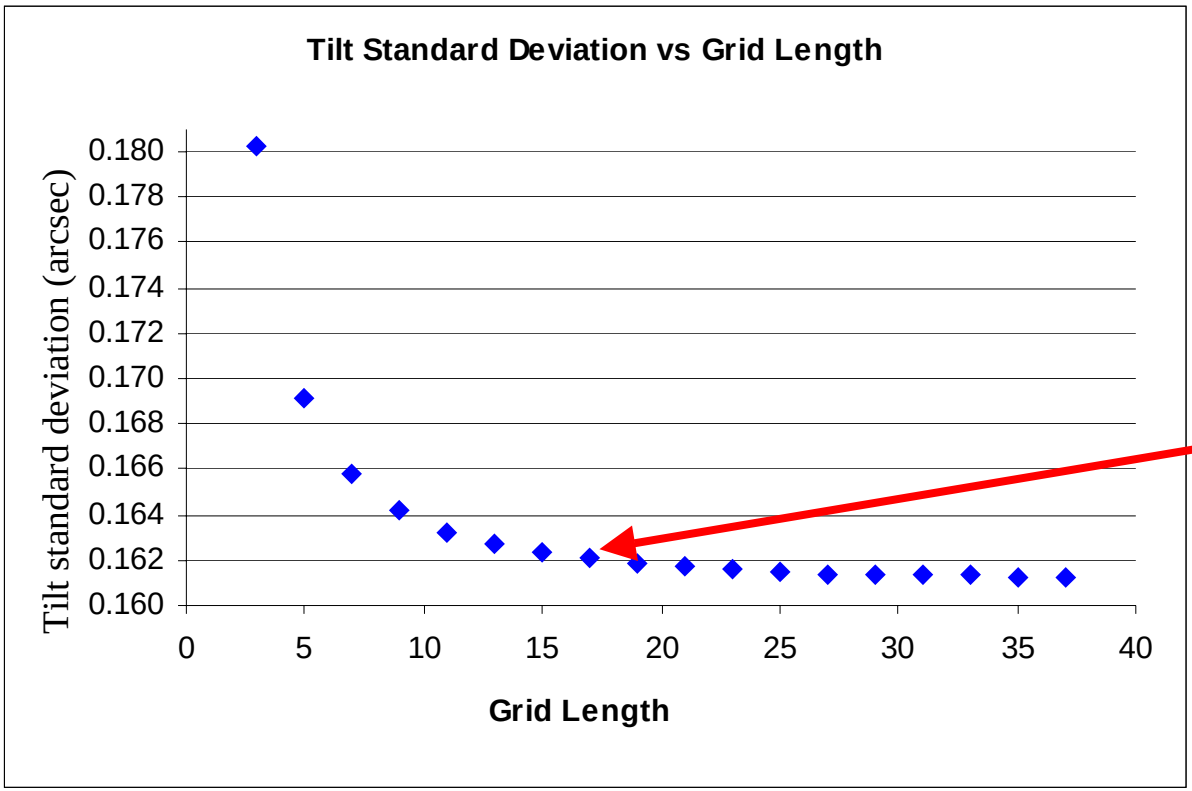
Bivariate Correlations







Multivariate Correlations

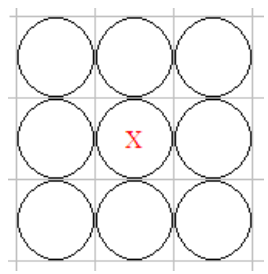


Standard Deviations

Uncompensated:
0.350 arcsec

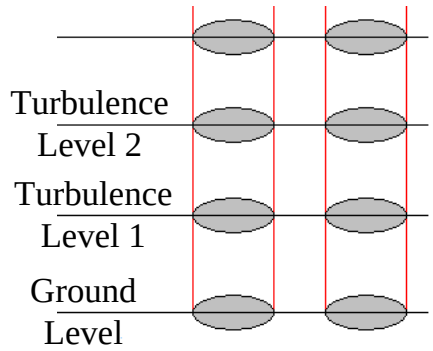
17 x 17 grid:
0.162 arcsec

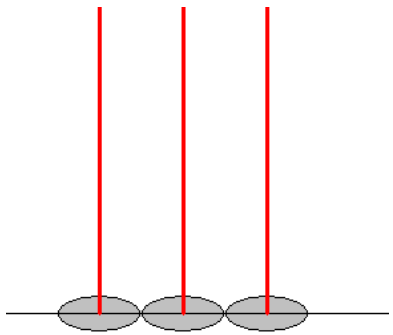
Example Grid
(Grid Length = 3):



Estimating Laser Uplink Tilt

NGS

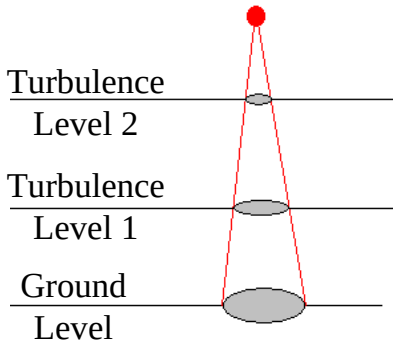


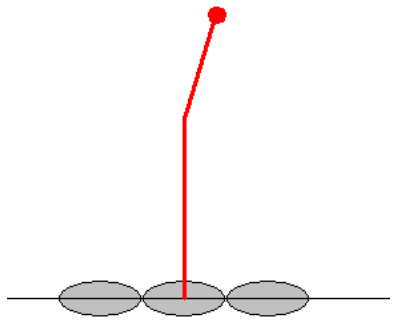


Measurements: T_2, T_3, etc.

Estimate: T_1

LGS

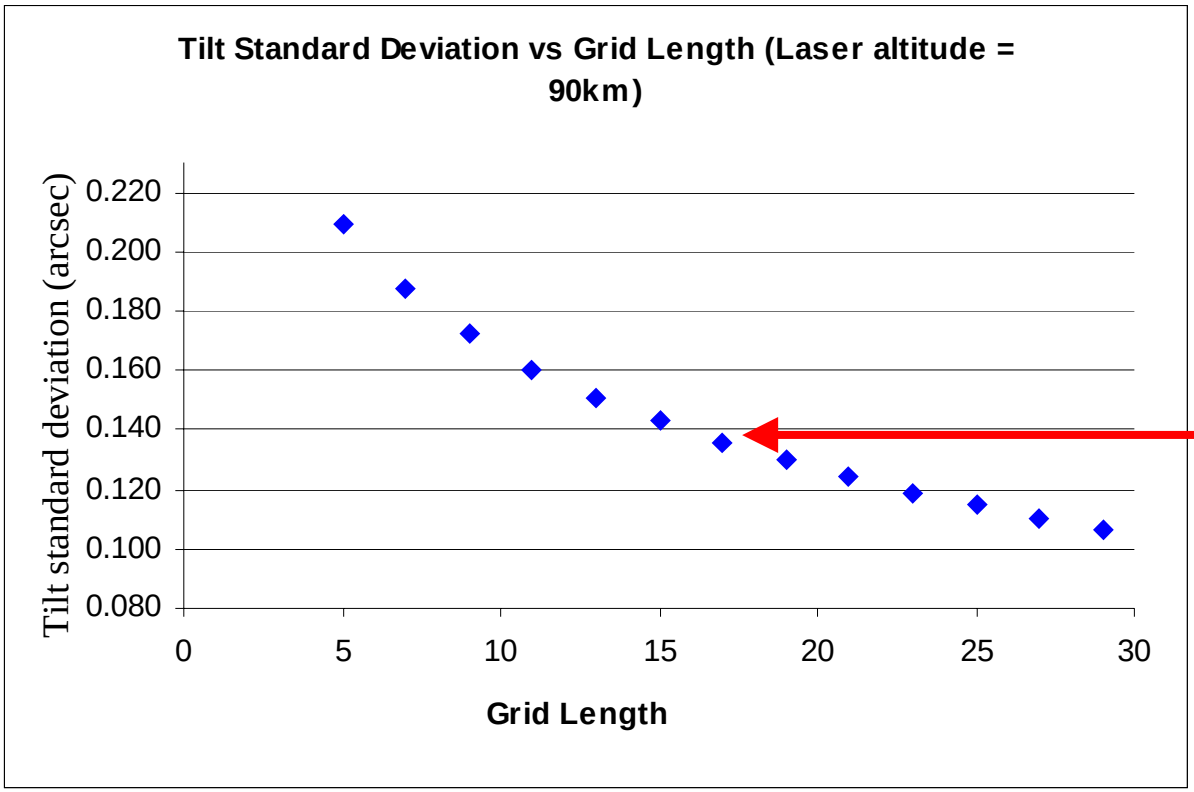




Measurements: T_2 - T_1, T_3 - T_1,etc.

Estimate: T_1

Uplink Tilt Results



Standard Deviations

Uncompensated:
0.340 arcsec

17 x 17 grid:
< 0.140 arcsec

Conclusions

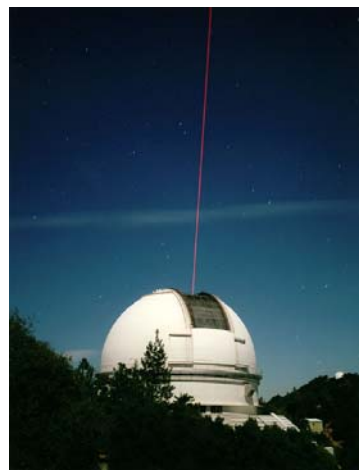
Can reduce standard deviation:

Uncompensated	Uplink Tilt Estimate
0.340 arcsec	0.130 arcsec

More work needed:

Laser only for tip-tilt guiding?

Increased sky coverage?



Acknowledgements

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