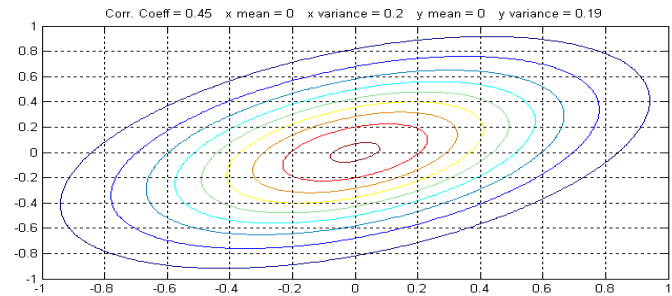
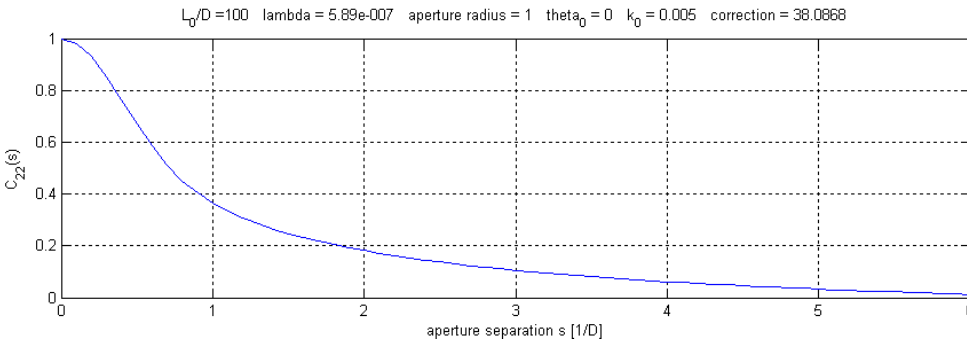


ANALYZING TELESCOPE SUBAPERTURE TILT MEASUREMENT CORRELATIONS



Neil Mendoza

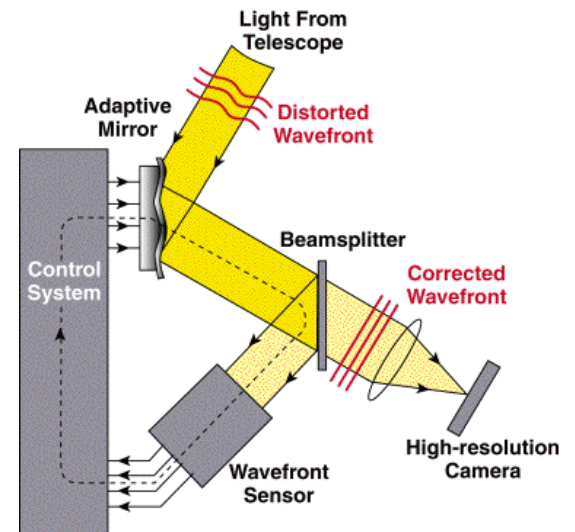
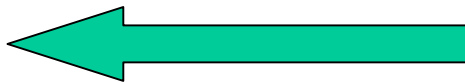
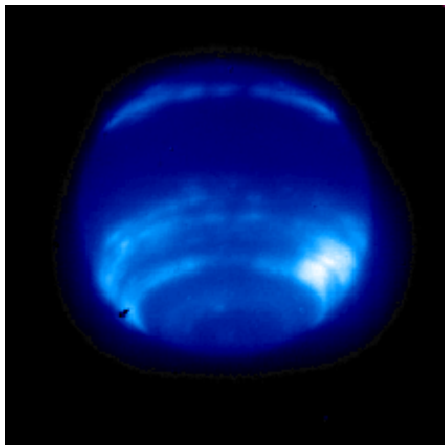
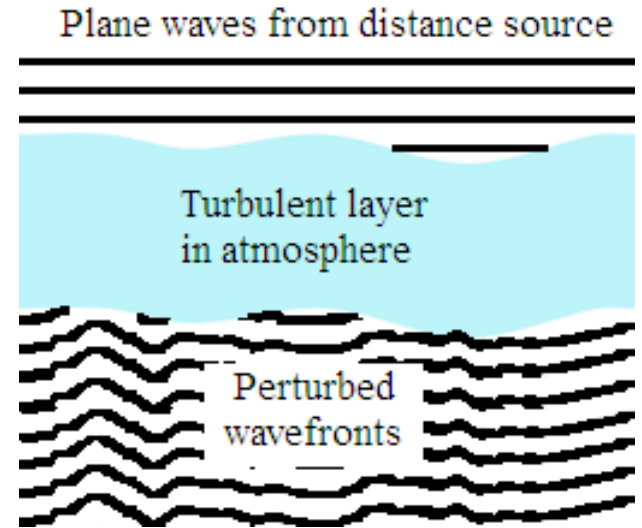
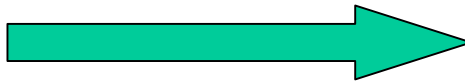
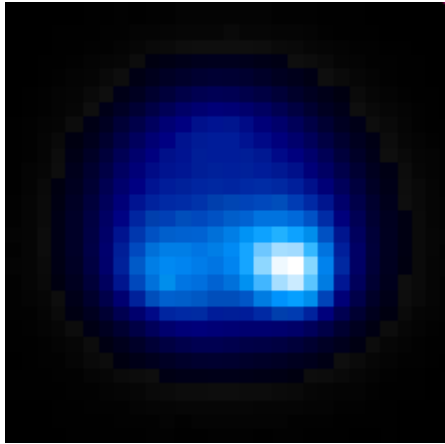
California Institute of Technology

Research Advisors: Matthew Britton and Richard Dekany

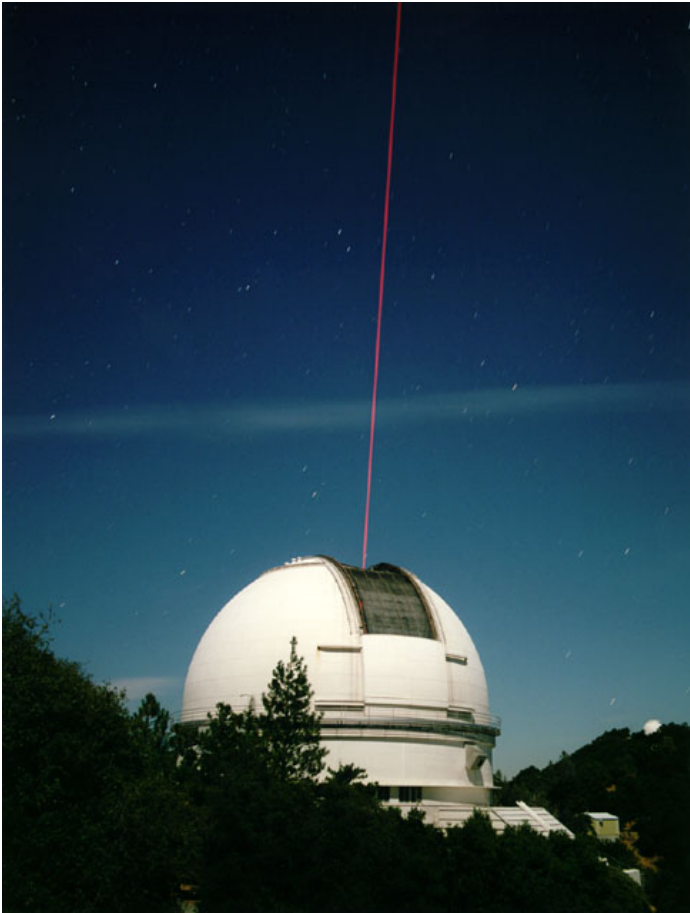
Home Institution: Williams College



Adaptive Optics



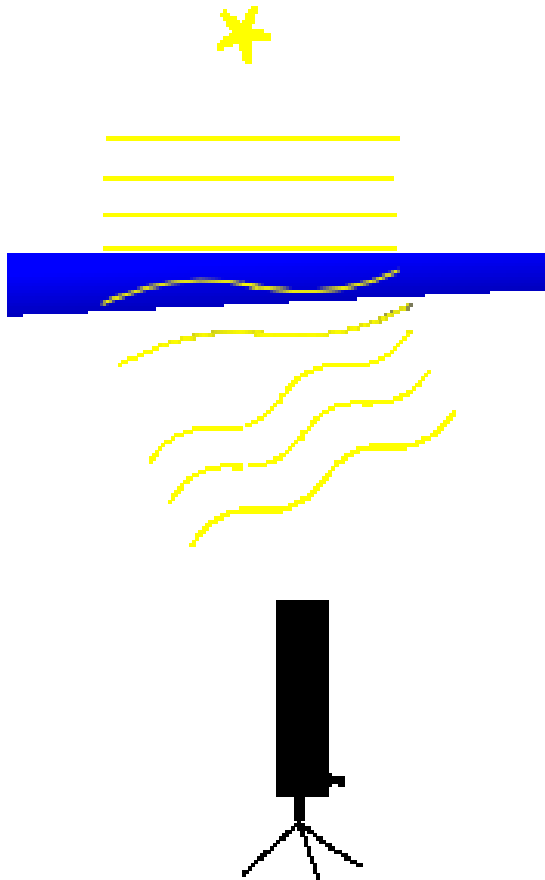
Laser Guide Star Adaptive Optics



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

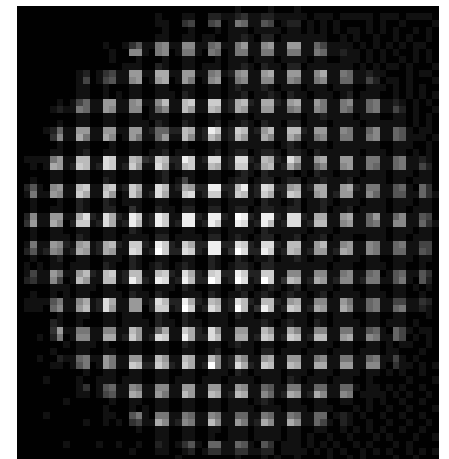
Laser guide star systems introduce new problems.

Natural Guide Stars and Tip-tilt



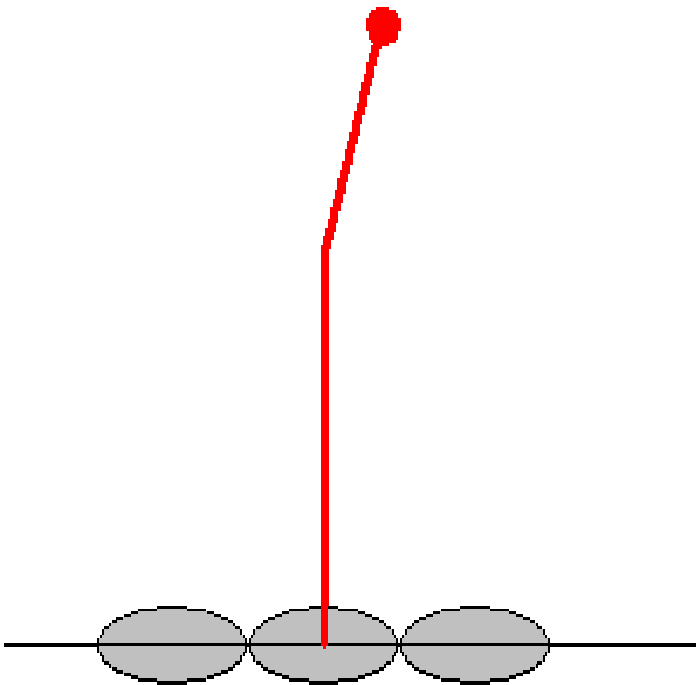
- Wavefront is tilted by turbulent atmosphere.
- The object does not remain centered on aperture.
- Information from the wavefront sensor can correct this problem:

What happens with a laser guide star?



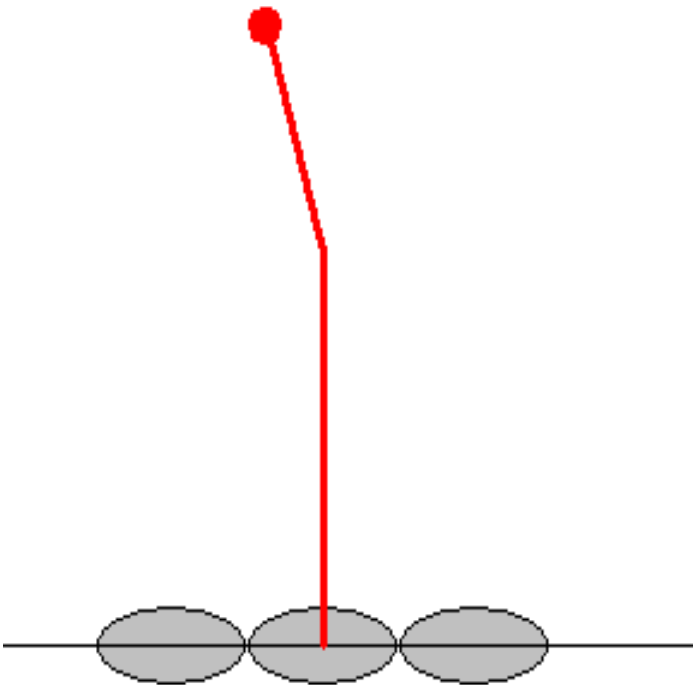
Uplink and Downlink

- 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?

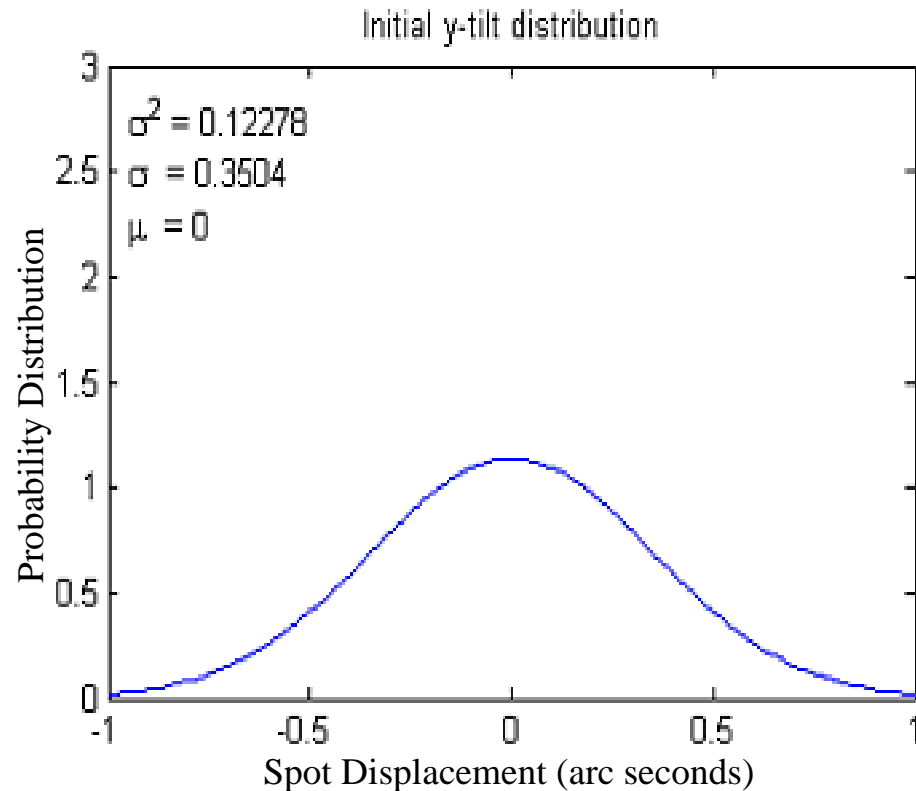
Uplink Complicates the Picture



- 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...

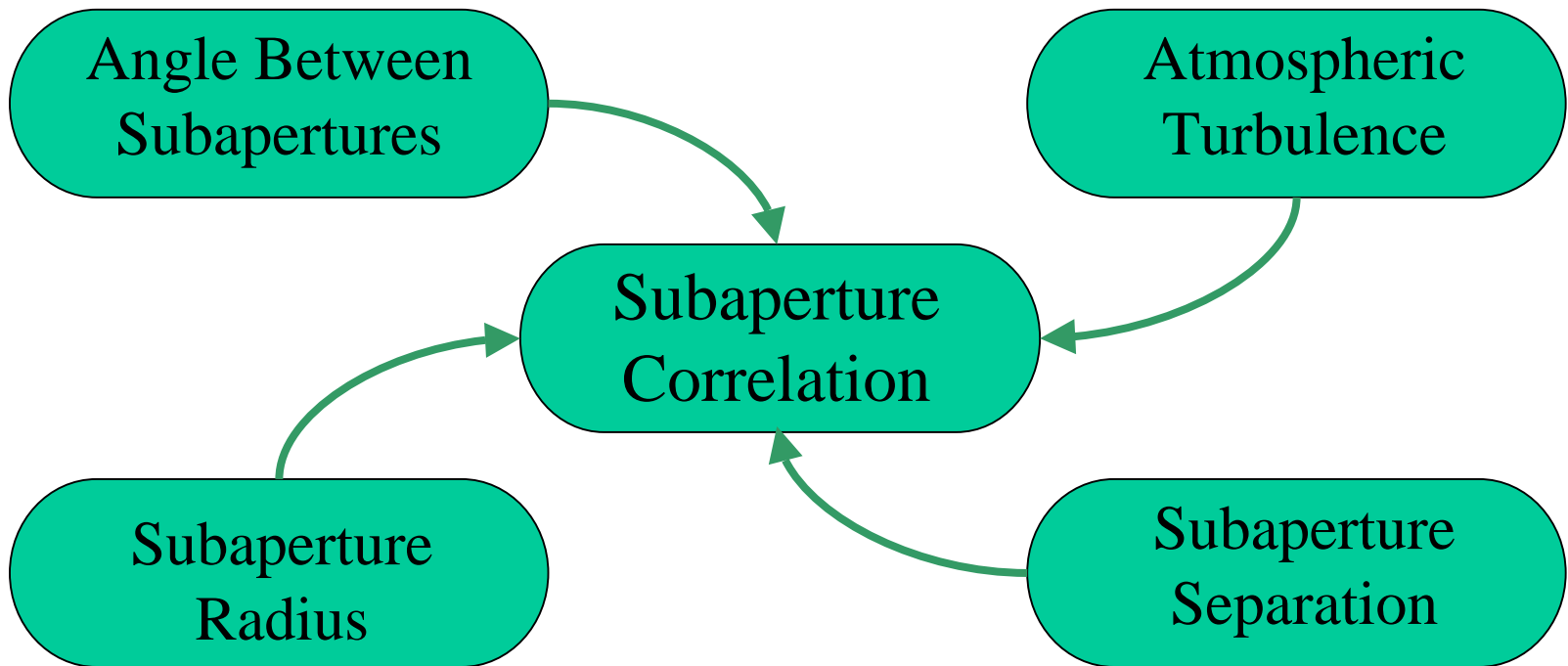
Subaperture Tilt Measurements



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

How can we determine these correlations?

Bivariate Correlations

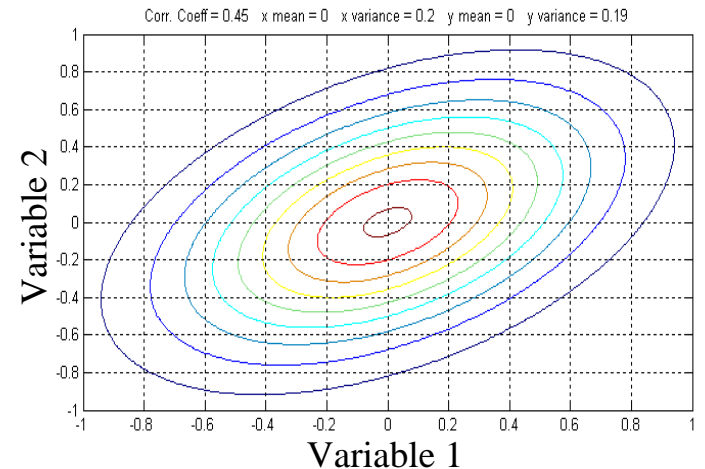


Takato and Yamaguchi captured this relationship in a mathematical formula.

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.

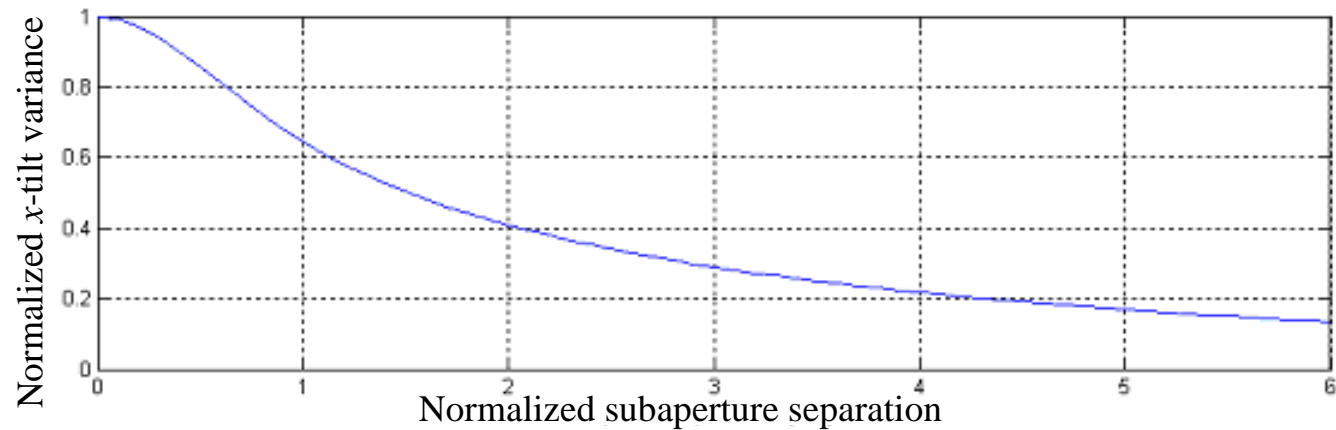
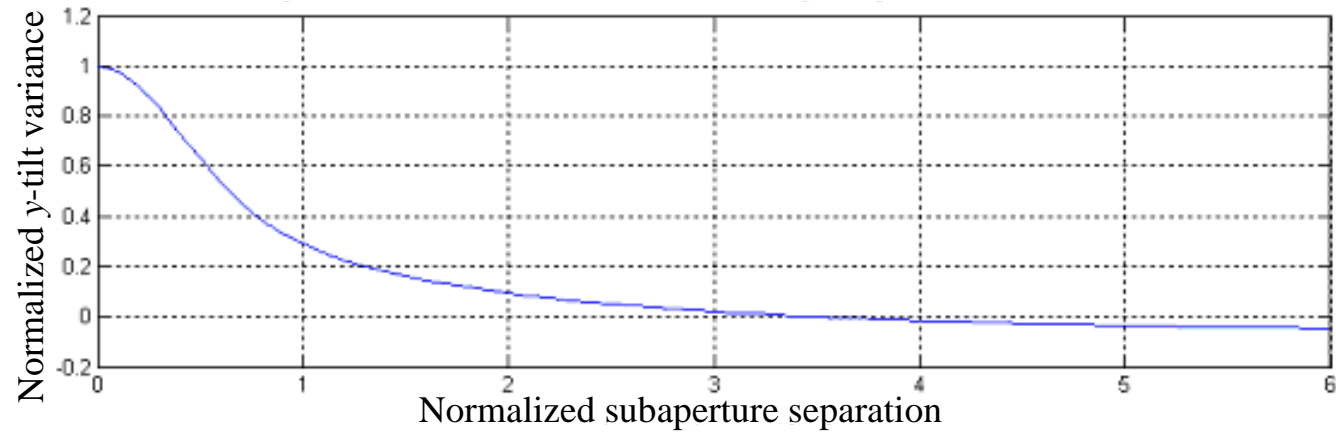
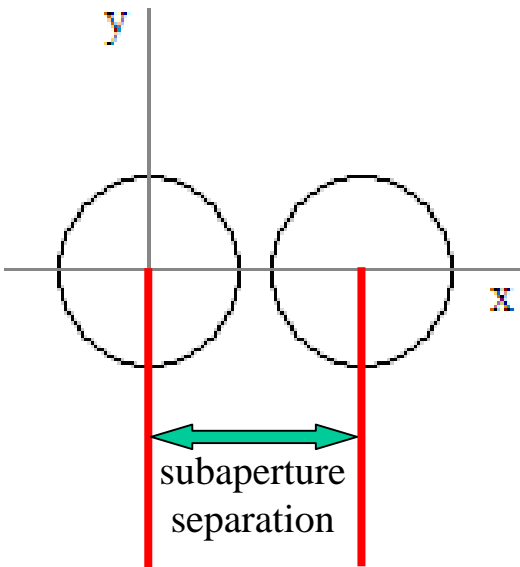
Project Outline



Overall Goal: Use correlations to estimate uplink tilt

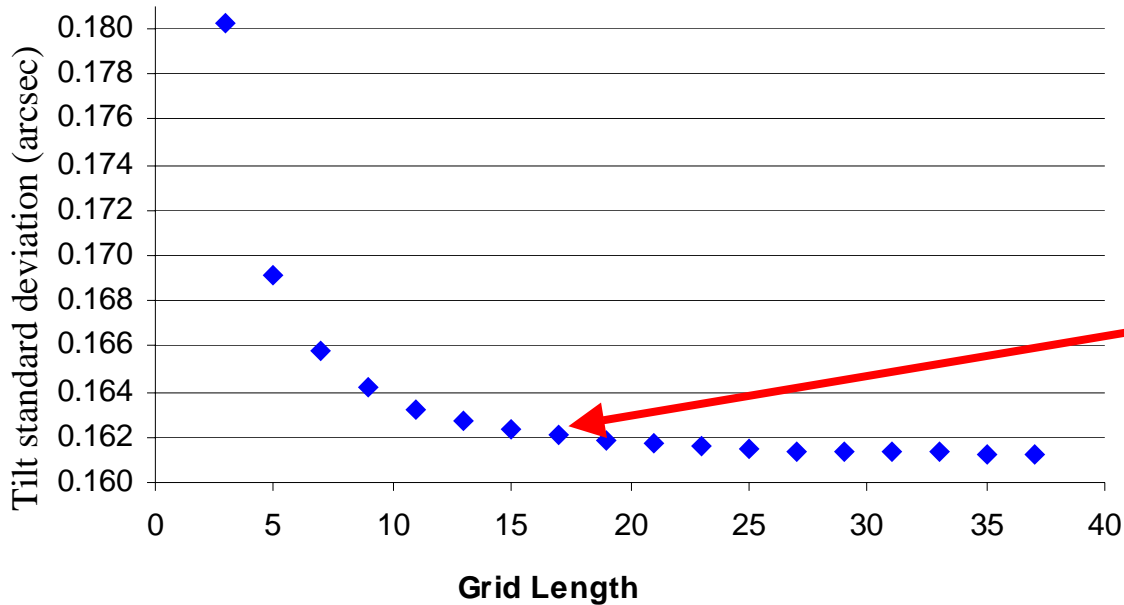
If we can estimate uplink tilt, we can correct for it and increase sky coverage.

Bivariate Correlations



Multivariate Correlations

Tilt Standard Deviation vs Grid Length

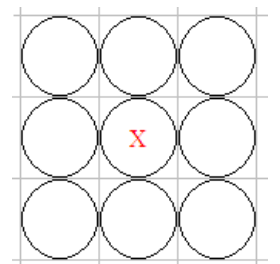


Standard Deviations

Uncompensated:
0.350 arcsec

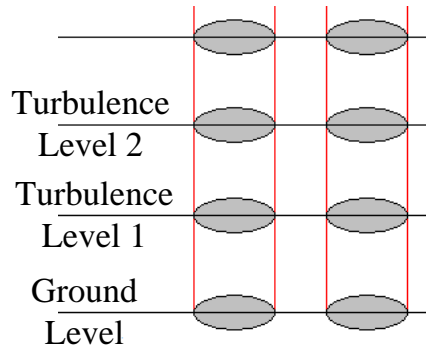
17 x 17 grid:
0.162 arcsec

Example Grid
(Grid Length = 3):



Estimating Laser Uplink Tilt

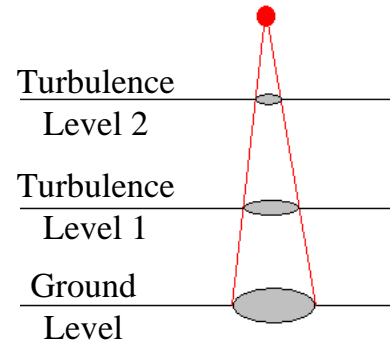
NGS



Measurements: T_2, T_3 , etc.

Estimate: T_1

LGS

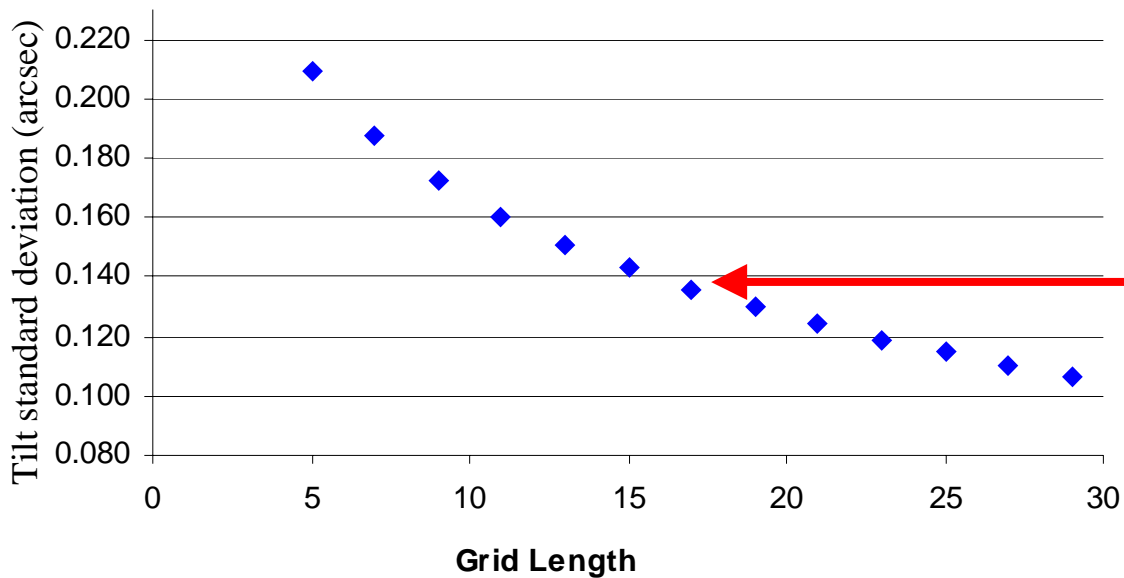


Measurements: $T_2 - T_1, T_3 - T_1$, etc.

Estimate: T_1

Uplink Tilt Results

Tilt Standard Deviation vs Grid Length (Laser altitude = 90km)



Standard Deviations

Uncompensated:
0.340 arcsec

17 x 17 grid:
< 0.140 arcsec

Conclusions

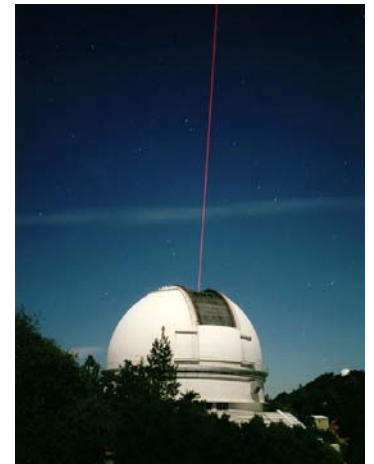
Can reduce standard deviation:

Uncompensated	Uplink Tilt Estimate
0.340 arcsec	0.130 arcsec

More work needed:

Laser only for tip-tilt guiding?

Increased sky coverage?



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- Matthew Britton and Rudy Resch for providing graphics.
- The Center for Adaptive Optics. *Images: Neptune with and without AO*. <http://cfao.ucolick.org/pgallery/neptune.php>. Accessed August 1, 2006.
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- Tubbs, Bob. *Image: Atmos struct imaging.png*. http://en.wikipedia.org/wiki/Image:Atmos_struct_imaging.png. Accessed July 25, 2006.