SLODAR using NGS and LGS MCAO Wavefront Sensors

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ESO mini-workshop on Atmospheric Knowledge and Adaptive Optics for 8-100m Telescopes

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Presentation Outline

- **Motivation**
- **Basic SLODAR theory**
- **Sample results for 8-m class NGS MCAO**
- **Modifications for laser guidestars**
  - **Guidestar position uncertainty**
- **Sample results for 8-m class LGS MCAO**
- **Implementation questions**

Motivation

- SLODAR: Slope detection and ranging (?)
  - Identifies $C_n^2(h)$ distributing by correlating WFS measurements from two stars in a binary pair
  - Analogous to SCIDAR
- MCAO systems (well, at least classical MCAO systems) employ multiple WFS's that might be suitable for SLODAR
  - Performance characterization on demonstrators
  - Real-time reconstructor optimization for facility systems

Basic SLODAR Theory (NGS)

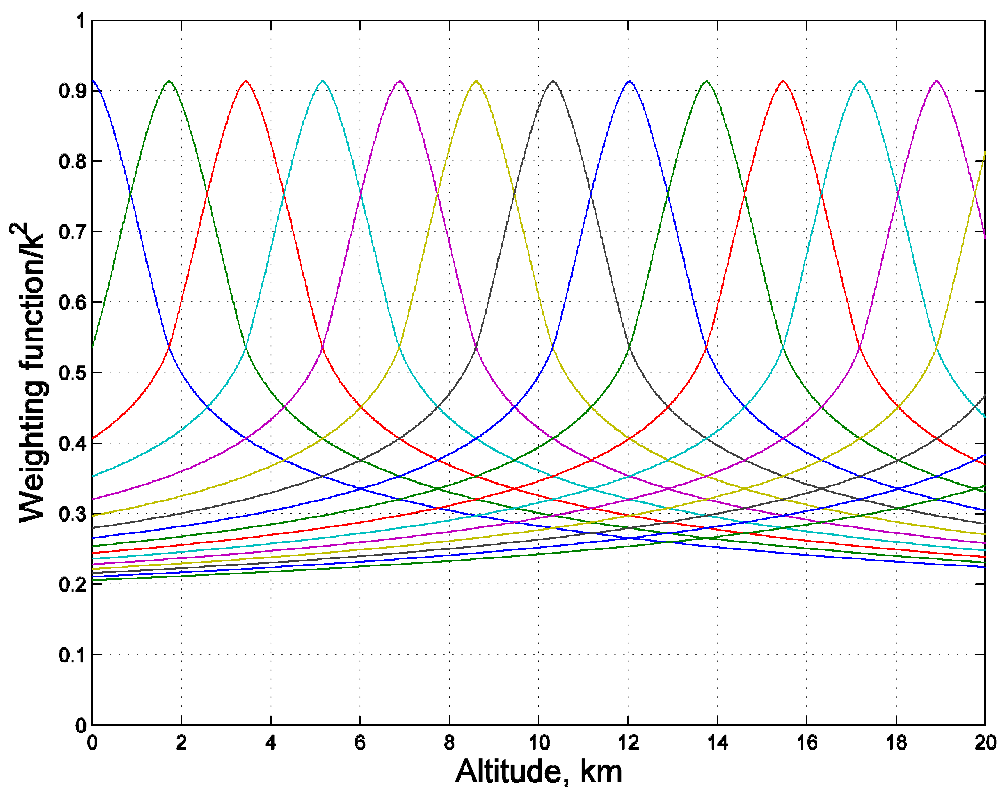
$$\begin{aligned} d_i &= \phi_i(x_{2,i}) - \phi_i(x_{1,i}) \\ &= k\int dh \left\{ n\left[p_{i,2}(h), h\right] - n\left[p_{i,1}(h), h\right] \right\} \end{aligned}$$

$$\langle d_1 d_2 \rangle = -1.45 k^2 \int dh C_n^2(h) \sum_{i=1}^{2} \sum_{j=1}^{2} (-1)^{i+j} \left| p_{1,i}(h) - p_{2,j}(h) \right|^{5/3}$$

$C_n^2(h)$ weighting function

Sample Weighting Functions

- **D=8m**
- **0.5 meter subapertures**
- **1 arc minute guidestar separation**
- **Subaperture separation 0.0, 0.5, 1.0, …, 7.5m**
  - **Parallel to guidestar separation**

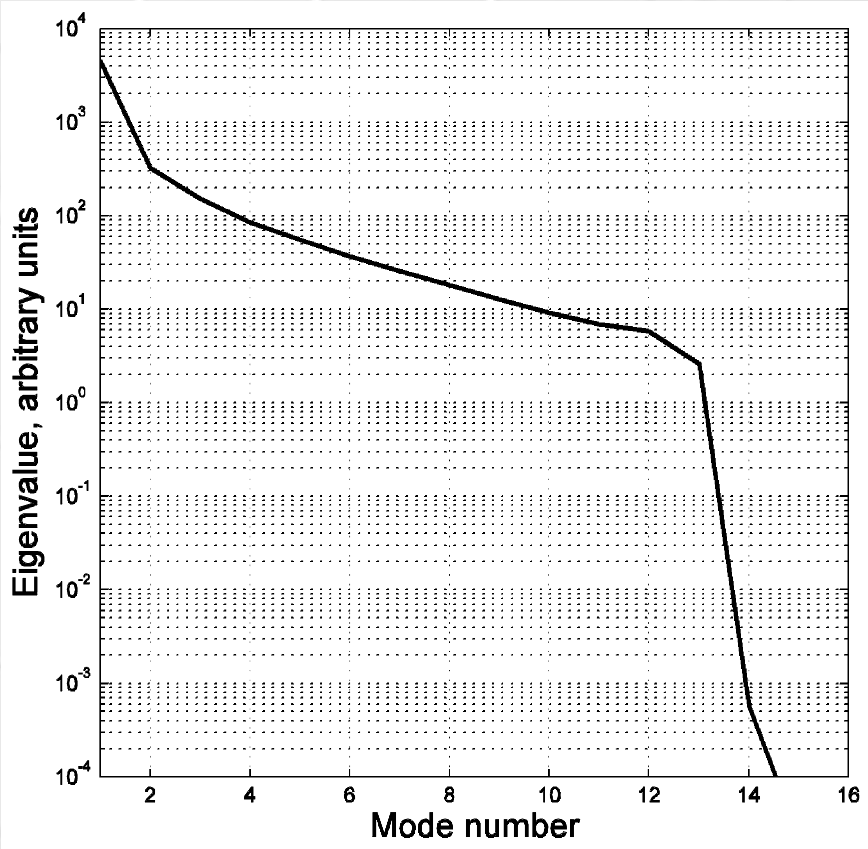


Independence of Weighting Functions

- **Weighting functions seem to overlap**
- **Independence can be evaluated in terms of eigenvalues of interaction matrix W**

$$W_{i,j} = \int dh w_i(h) w_j(h)$$

- **Crosscoupling is significant**

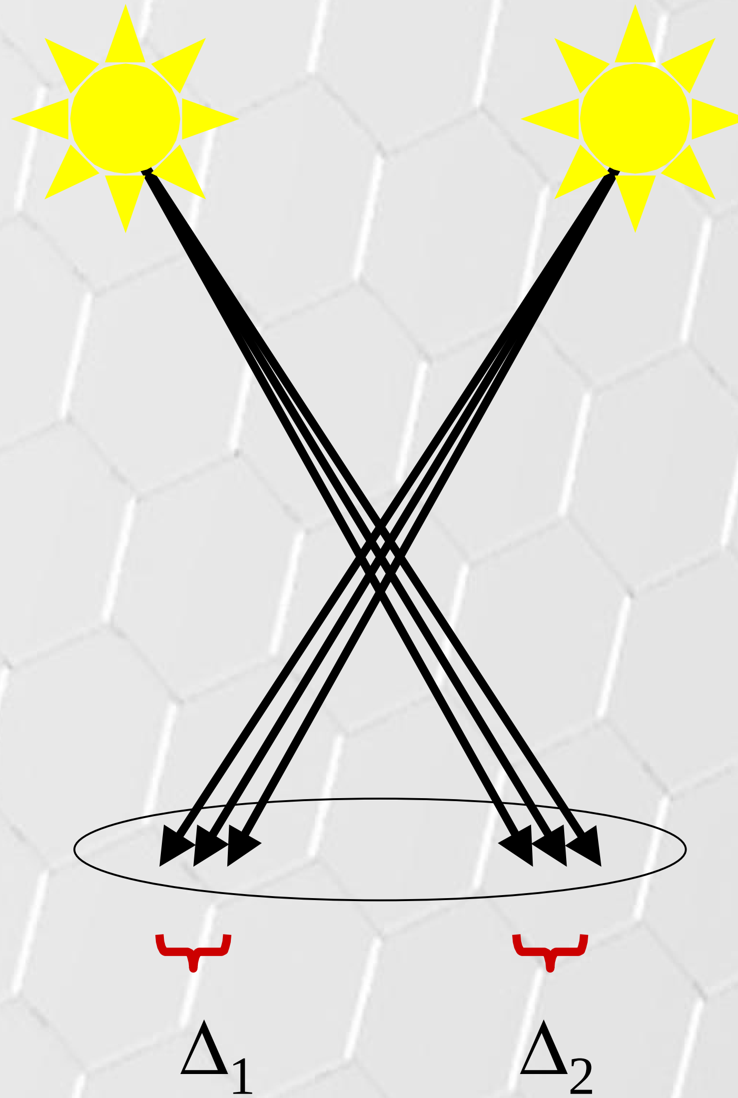


Modifications for LGS WFSs

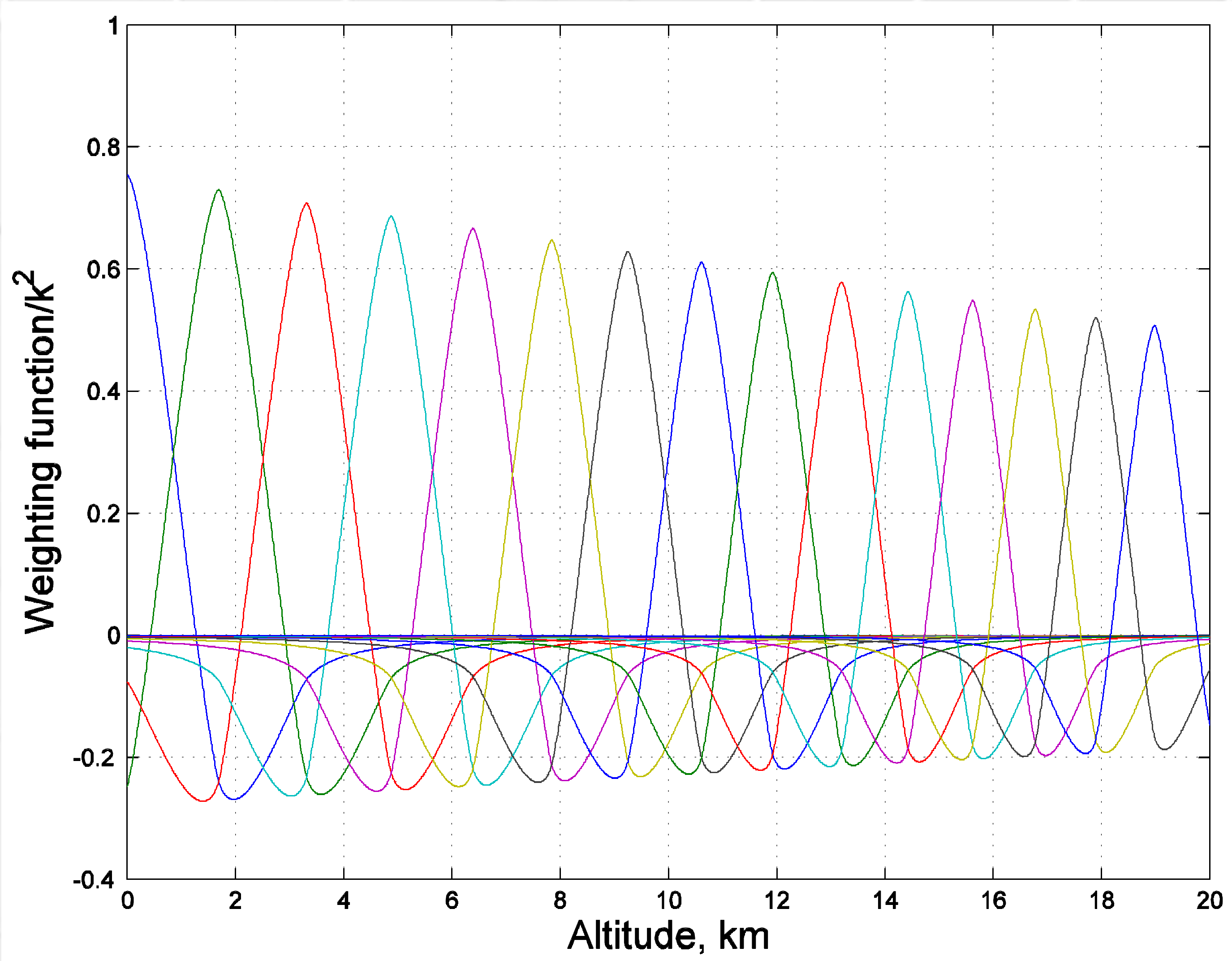
- Phase differences d_i unreliable due to guidestar position uncertainty
- Replace with DIMM-like measurements

$$\Delta_i = d_i^+ - d_i^-$$

- Impact of guidestar position uncertainty cancels
  - Derive weighting functions as linear combination of 4 phase difference weighting functions

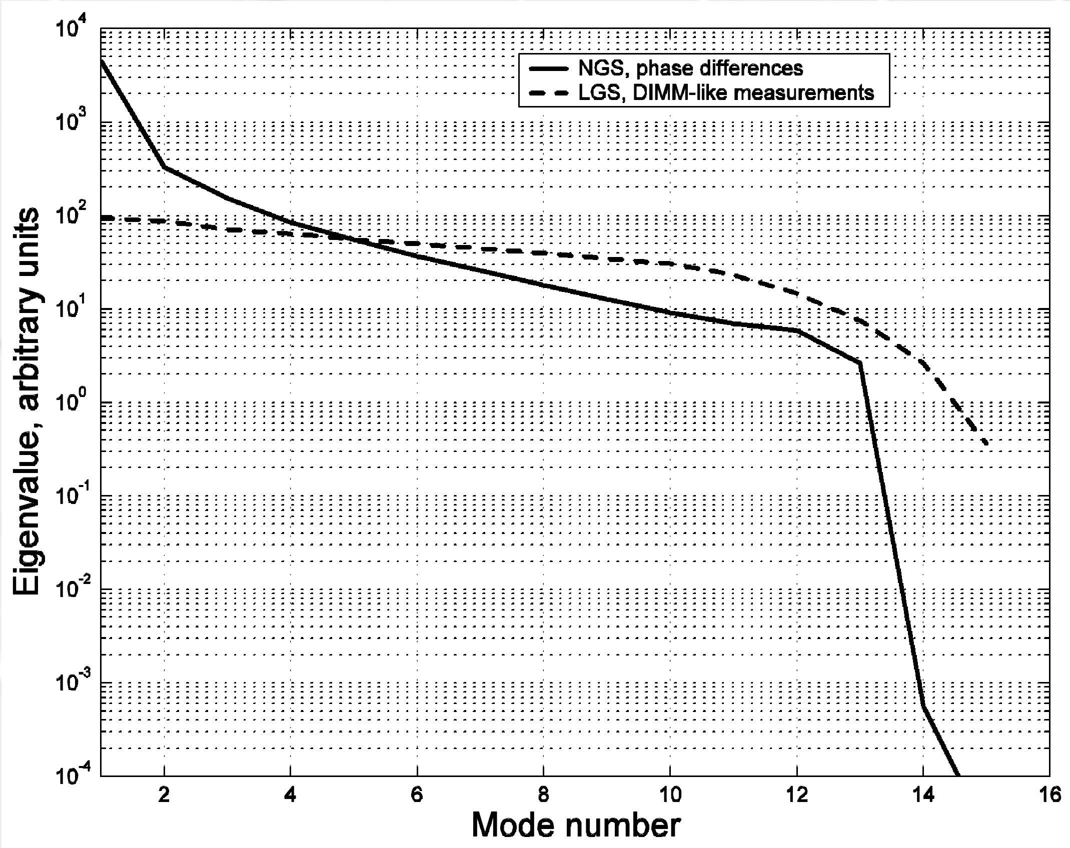


Sample LGS Weighting Functions



- **90 km beacon altitude**

Eigenvalues for LGS Weights



- **Somewhat better conditioned than NGS WFS eigenvalues**
- **DIMM-like measurements (DIMMDAR?) equally feasible with NGS MCAO**

Implementation Issues

- Closed-loop operation
  - Need to store DM actuator commands
  - Need accurate calibration of WFS gains and DM-to-WFS influence matrix
- Data acquisition rates
- SNR requirements
- Sampling interval requirements
- Extension to wind velocity measurements?