

Active optics and control architecture for a Giant Segmented Mirror Telescope

George Z. Angeli, Myung K. Cho, Mark S.
Whorton

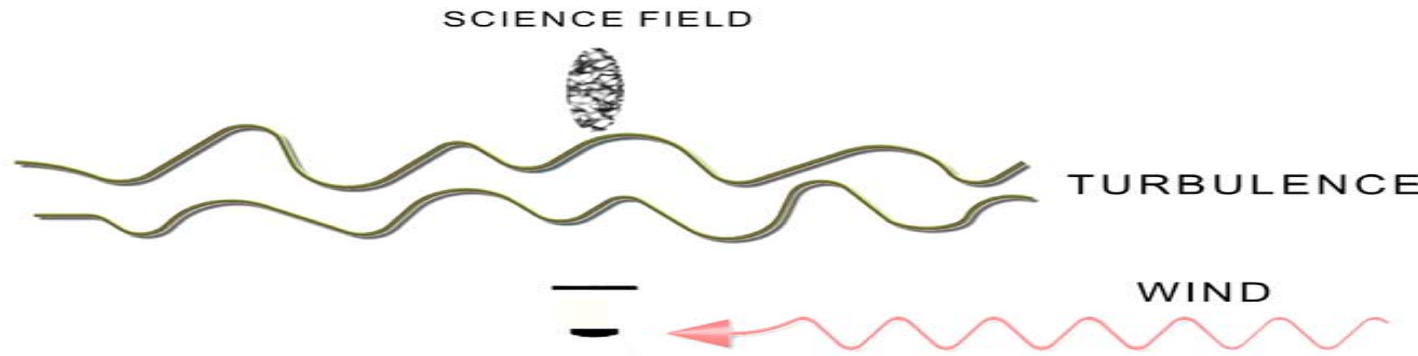


Overview

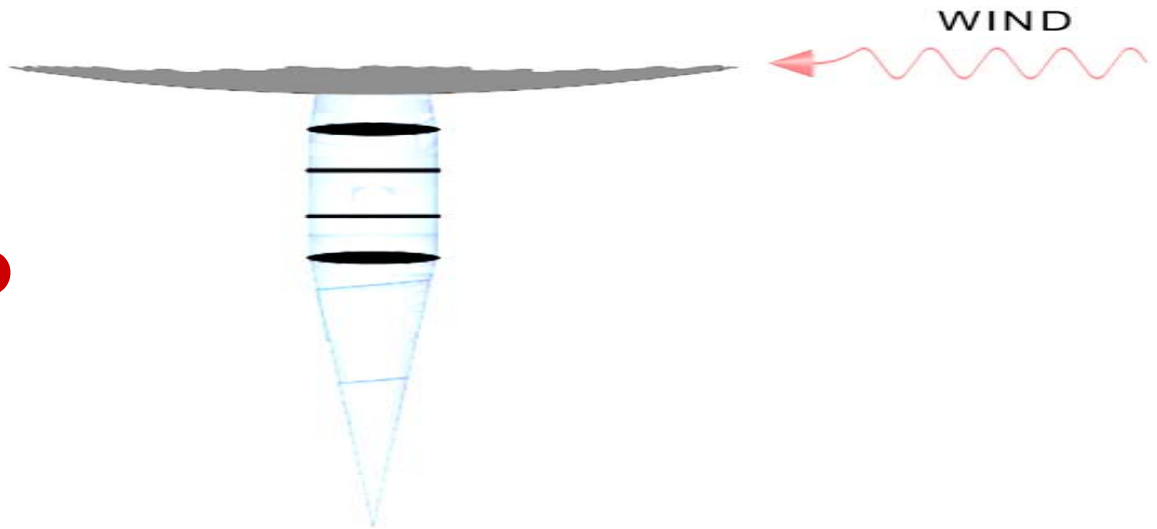
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- **A feasible control architecture**
 - How to separate and organize control functions
- **Supporting simulations**
 - Proving it's viability
 - With **real, measured wind data**

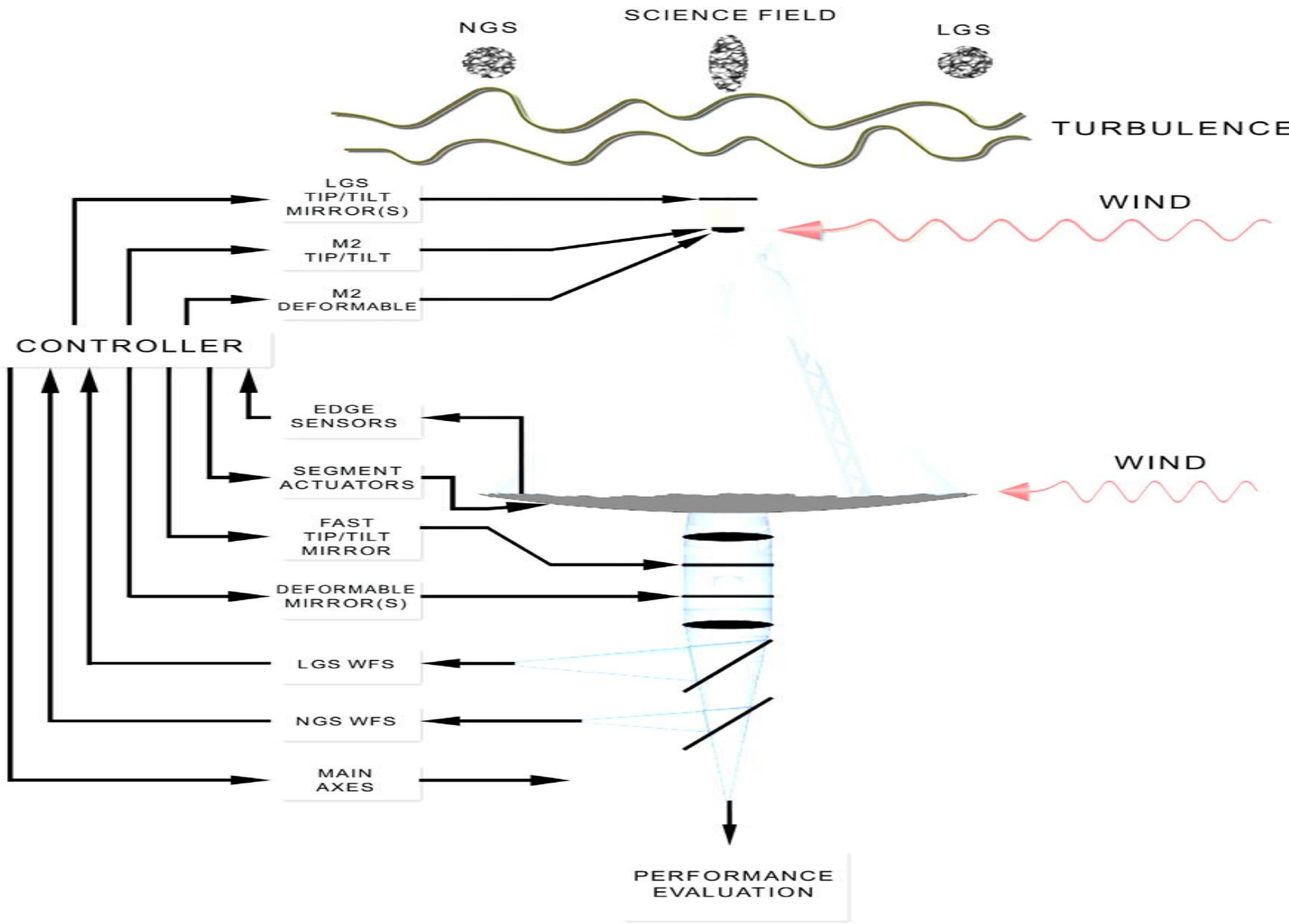




New challenge – wind:
Increased area
Lower resonance frequencies



Integrated aO and AO



Control philosophy

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- **Forced decoupling of control subsystems**
- **Allows decentralization**
- **Improves understanding of underlying concepts and processes**
- **Simplifies control laws and cost functions**
- **Supports detached design, implementation and troubleshooting of subsystems**
- **Subsystems are still sophisticated MIMO (multiple-input-multiple-output) systems**



Control architecture

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Parallel optical and mechanical feedback

**Main axes (tracking) control
based on WFS (0.5 Hz)**

**M1 phasing maintenance based
on edge sensors (0.5 Hz)**

**M2 rigid body motion control
based on WFS (10 Hz)**

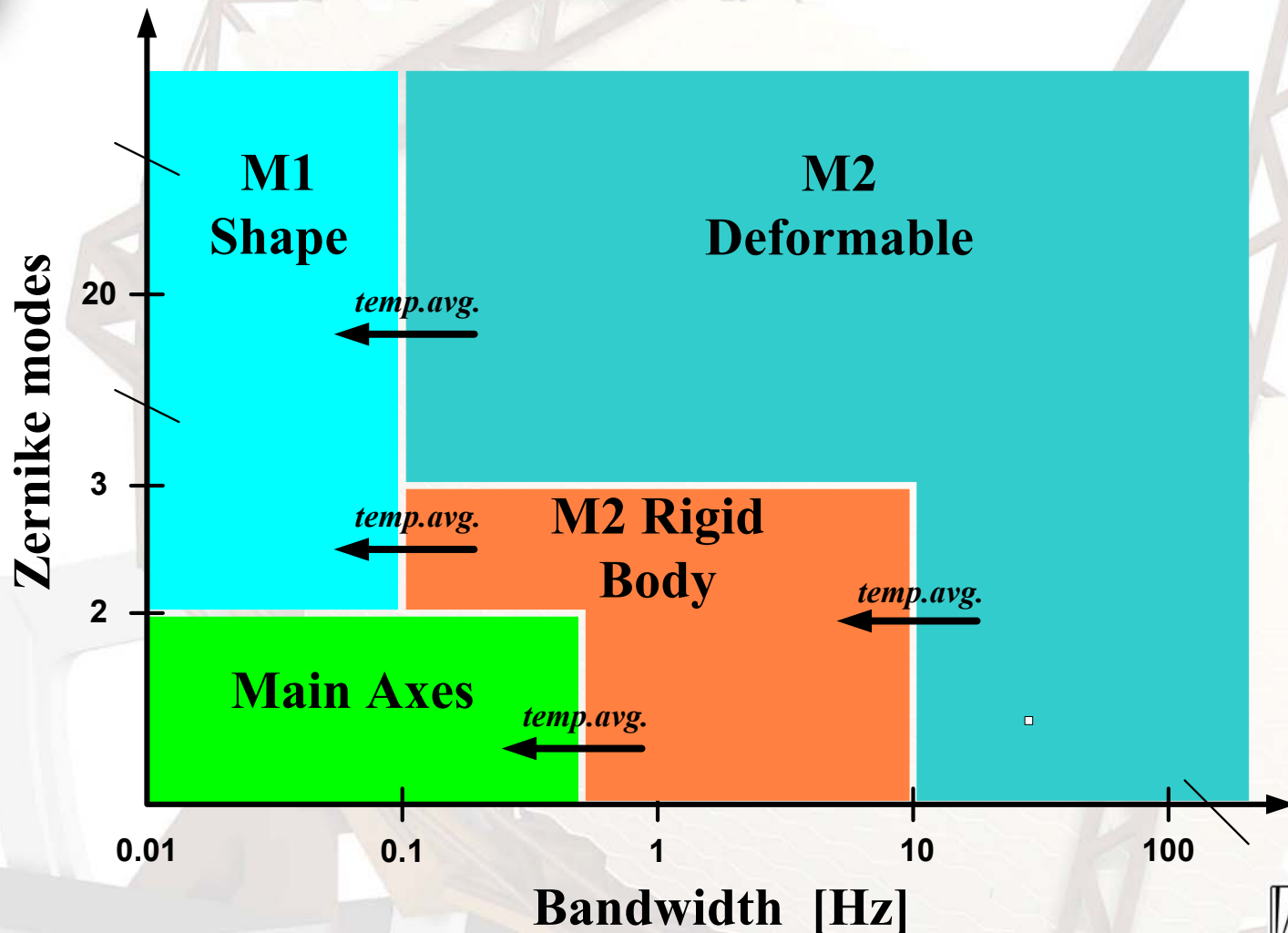
**M2 facesheet control based
on WFS (100 Hz)**

**M1 low order shape control (aO)
based on WFS (0.1 Hz)**



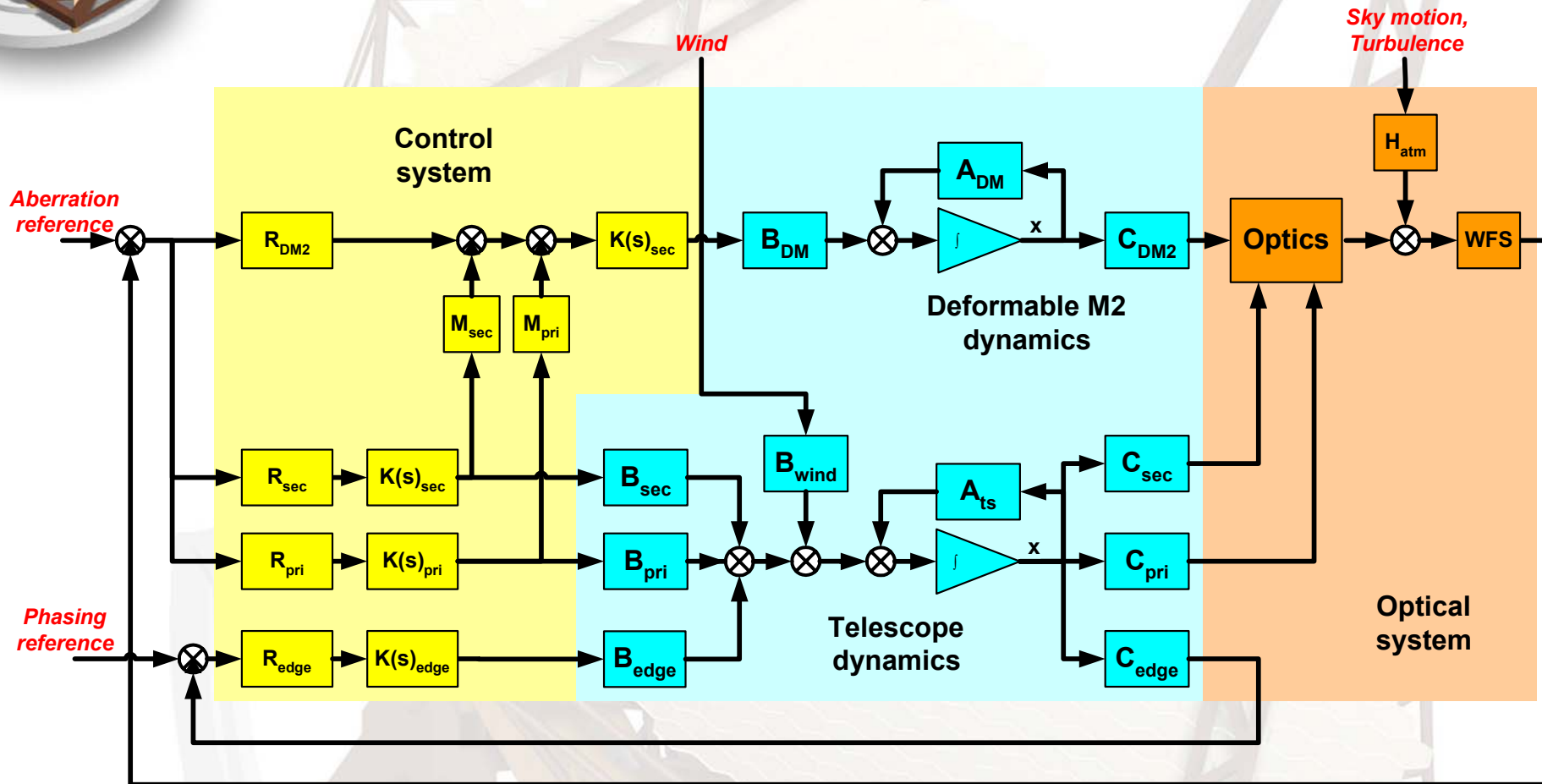
Frequency separation of optical subsystems

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Control configuration

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Fundamental assumption

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- **Primary mirror phasing maintenance possible with limited bandwidth loop**
 - High order, high frequency M1 wind deformations well bounded
 - Structural interactions avoidable
 - Secondary rigid body control only with actuator-structure interaction **Whorton *et al.* 4840-23**
- **Verifying simulations**
 - Structural modeling for large scale deformations
 - Segment modeling for continuity check (no structural deformation)



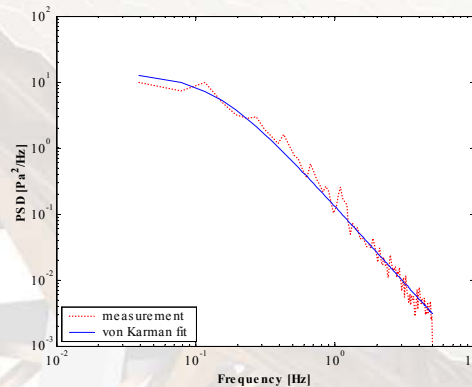
Model for GSMT structural simulation

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- **Structure**
 - Modal description (20 modes)
 - State-space representation

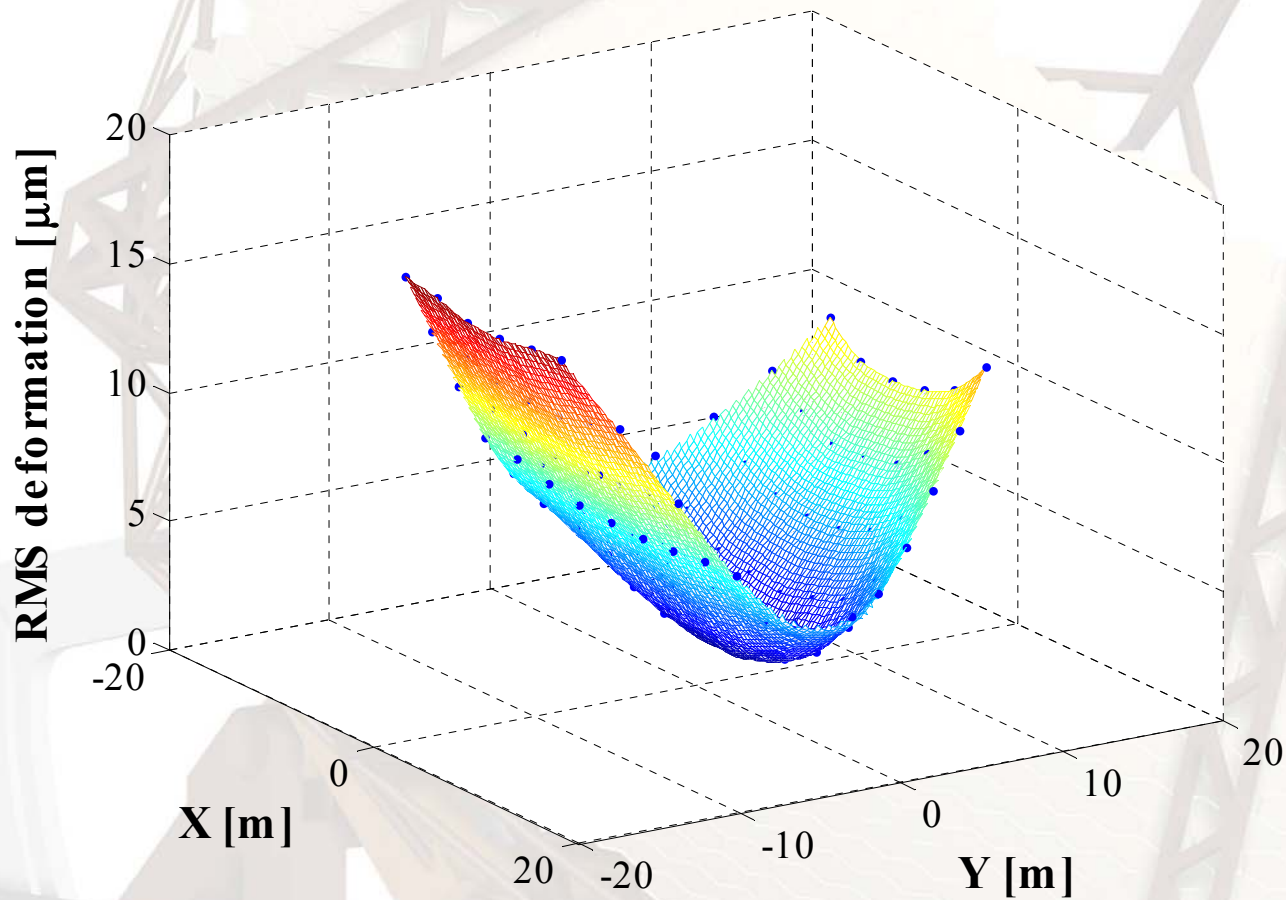
$$\ddot{\mathbf{q}}_m + 2\mathbf{Z}\Omega\dot{\mathbf{q}}_m + \Omega\mathbf{q}_m = \mathbf{M}^{-1}\Phi^T\mathbf{B}\mathbf{u}$$
$$\dot{\mathbf{x}} = \begin{bmatrix} \mathbf{0} & \mathbf{I} \\ -\Omega^2 & -2\mathbf{Z}\Omega \end{bmatrix} \mathbf{x} + \begin{bmatrix} \mathbf{0} \\ \mathbf{M}^{-1}\Omega^T\mathbf{B} \end{bmatrix} \mathbf{u}$$

- **Wind** **Cho *et al.* 4837-40**
 - Gemini South measurements
 - Open dome, slit facing wind
 - **Wind velocity**
 - ~10 m/s @ dome
 - ~4 m/s @ M1
 - ~4 m/s @ M2



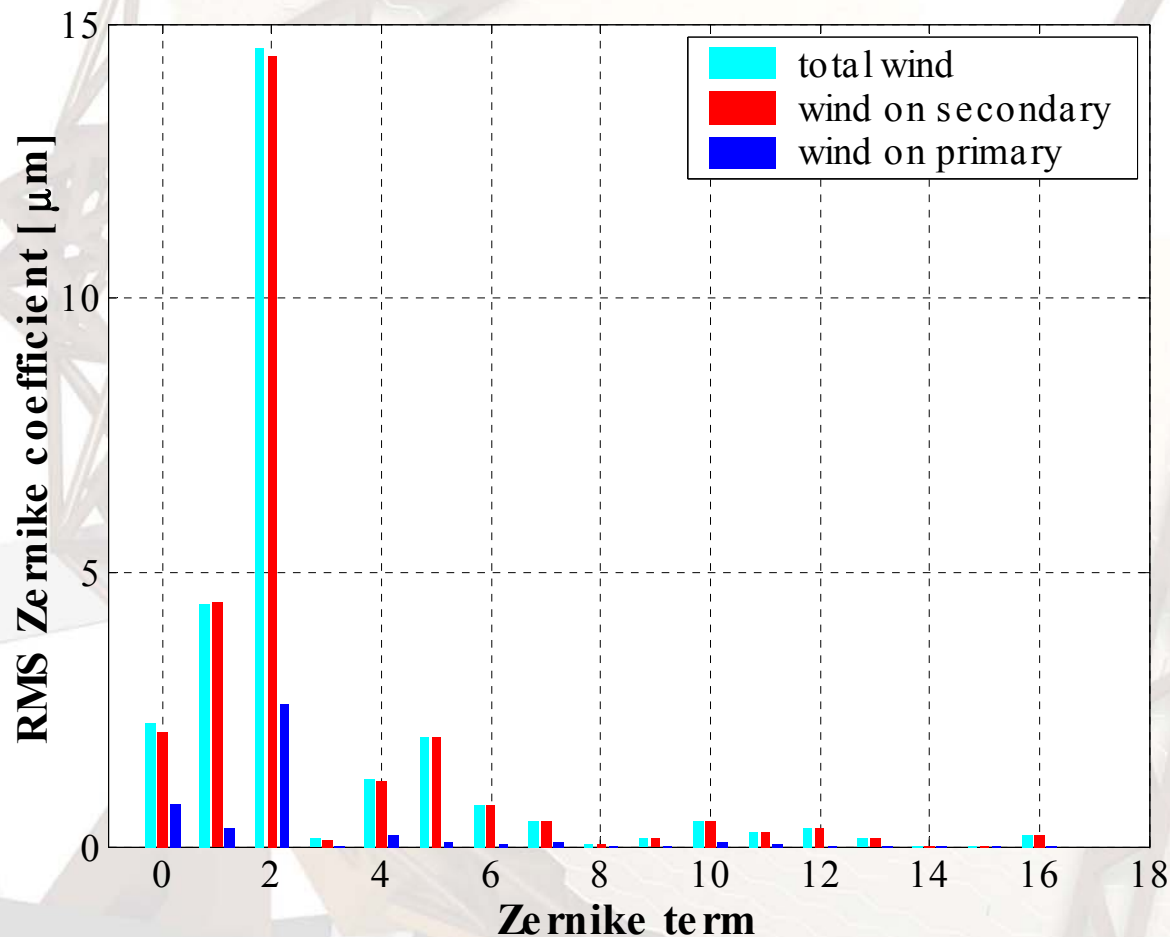
M1 deformation due to wind

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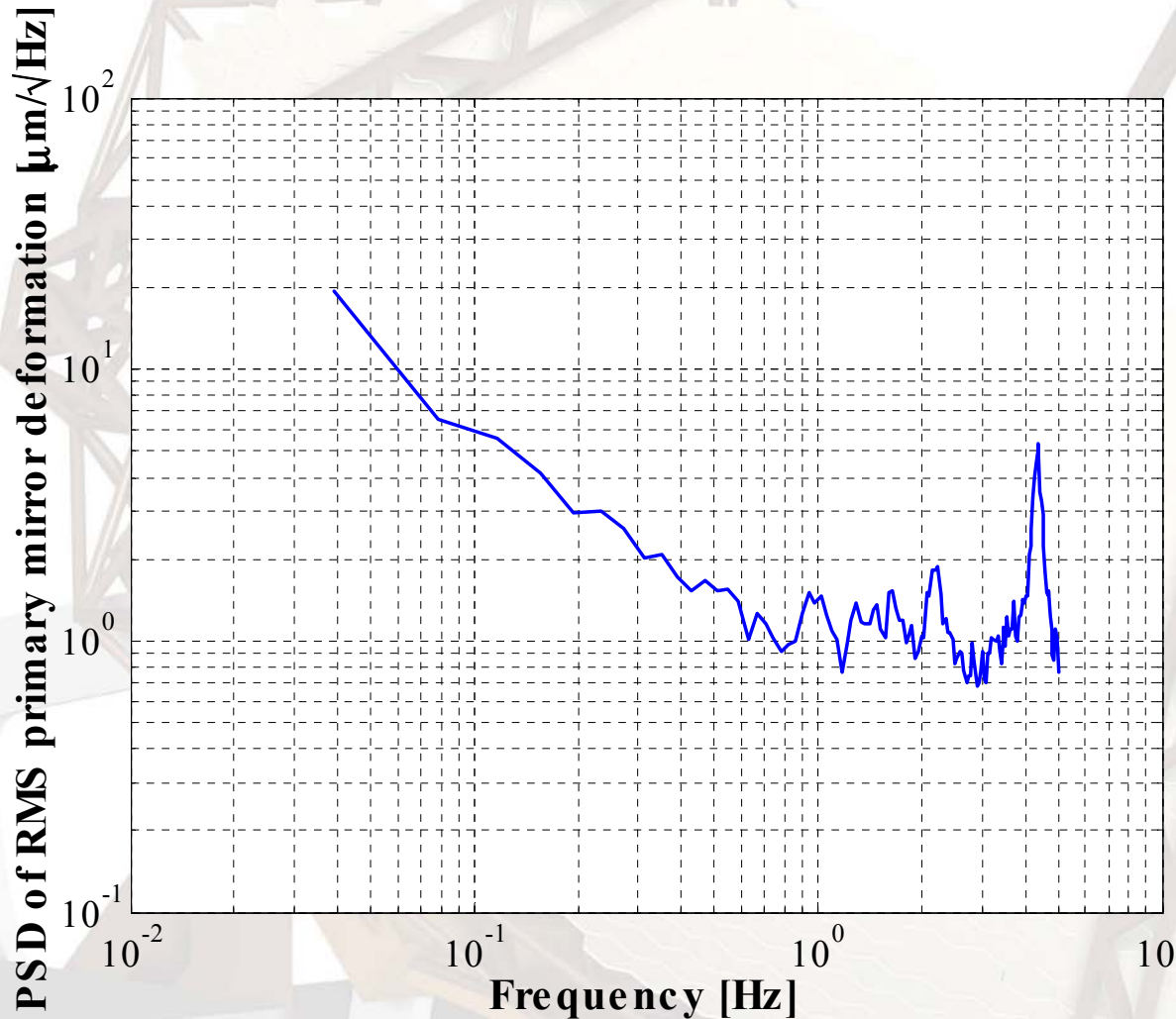
Zernike expansion of M1 deformation

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PSD of RMS M1 deformation

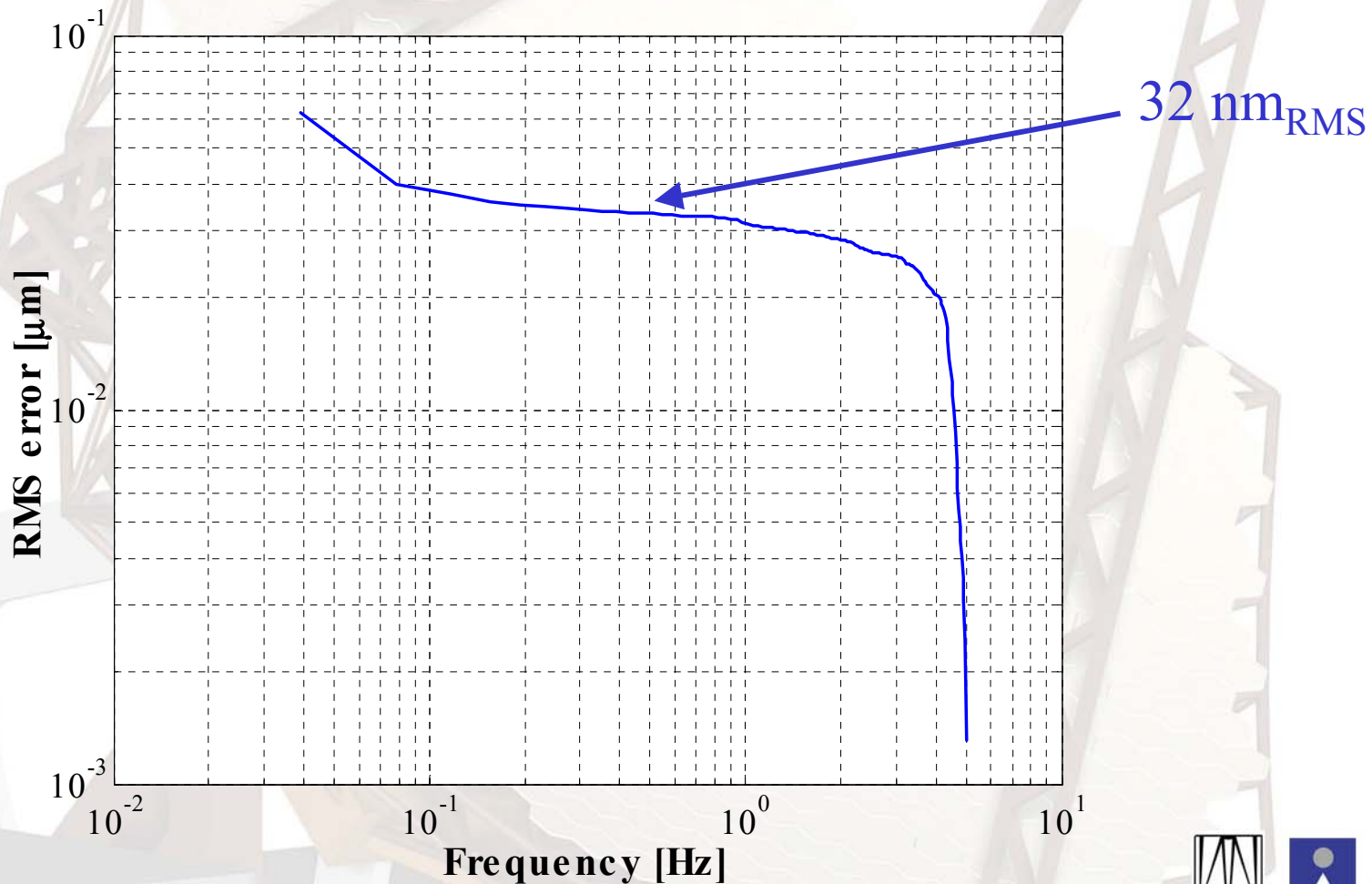
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Residual M1 deformation

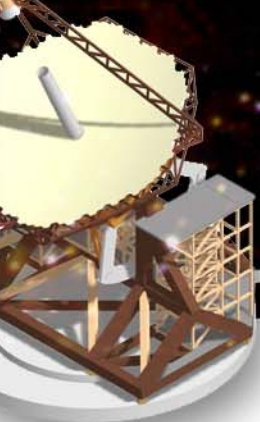
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Zernike terms removed up to #36:



Model for segment control simulation

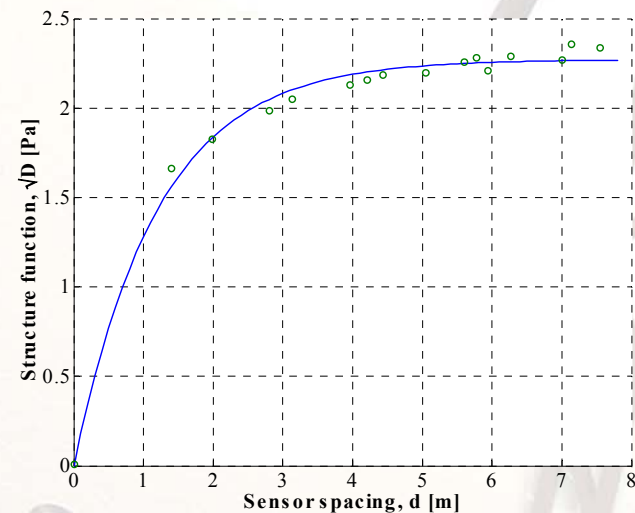
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Wind

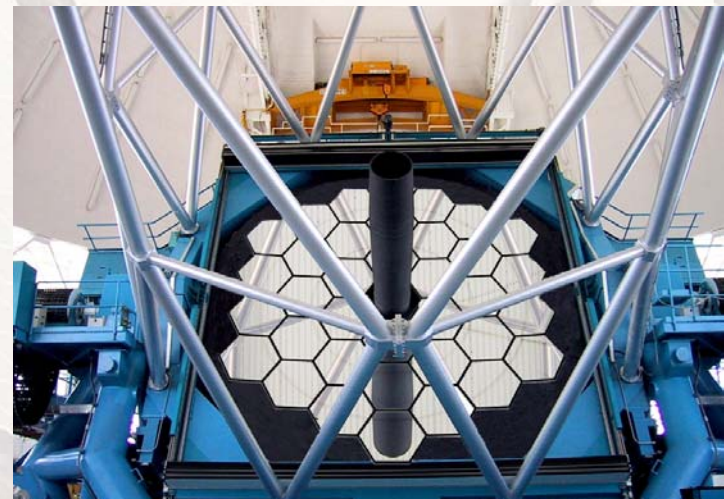
- Same as for structural simulation
- Cho *et al.*, SPIE 4837-40
- Correlation length < 2m on M1

$$D_p(r) = \left\langle [\rho(\mathbf{r}_0 + \mathbf{r}) - \rho(\mathbf{r}_0)]^2 \right\rangle_{\text{spatial}}$$

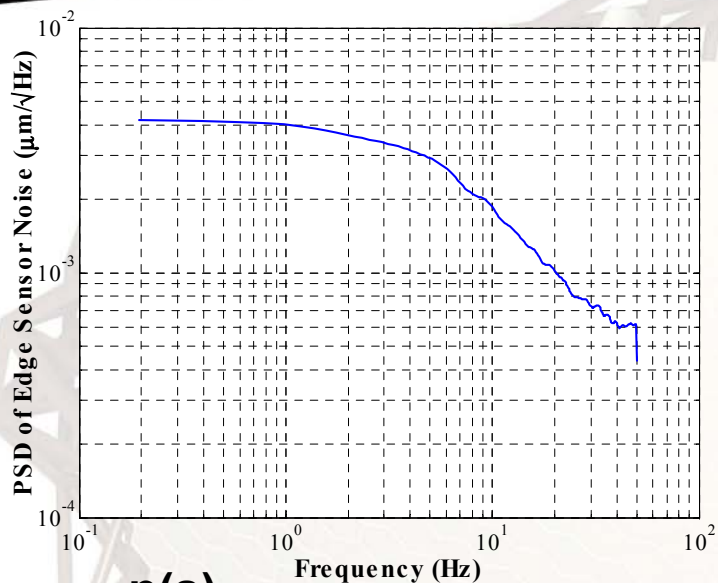


“Segmented” Gemini mirror

- Segment size 1.152 m edge-to-edge
- Actuator stiffness 10 N/ μm
- No dynamics

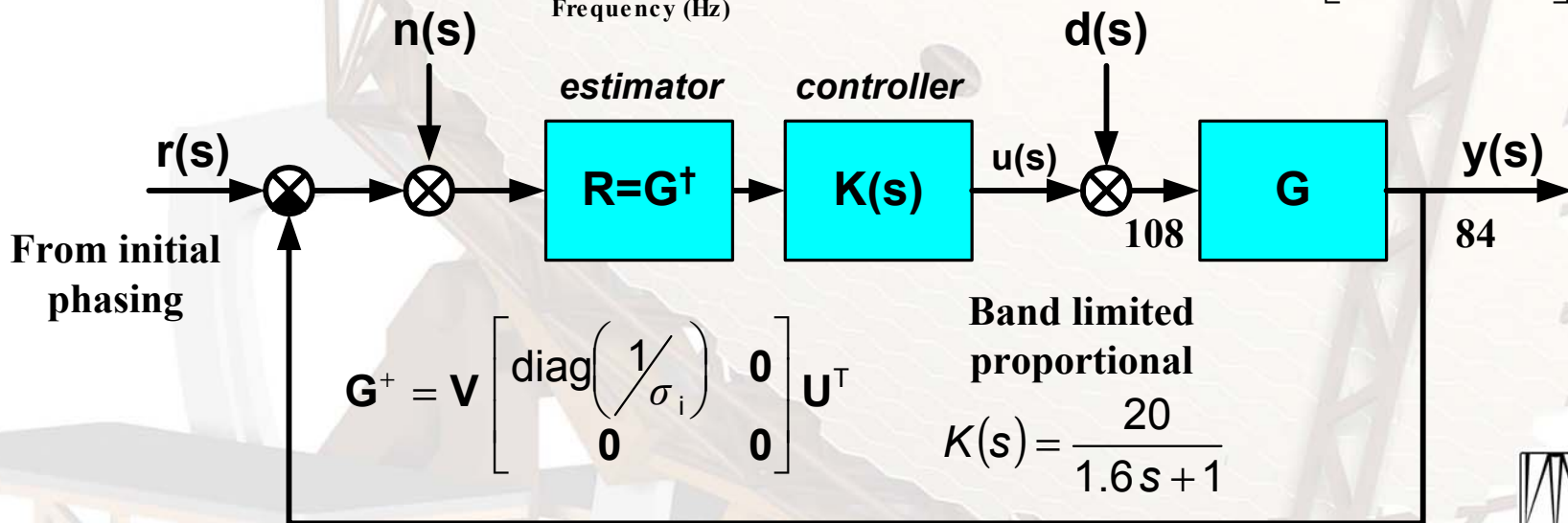


Segment continuity control



Actuator and sensor modes based on SVD:

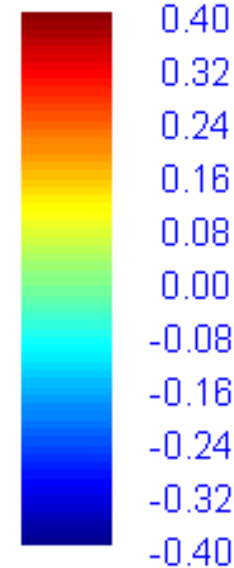
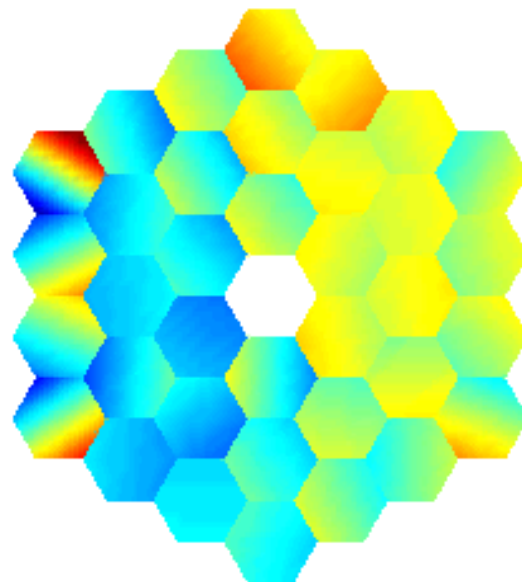
$$\mathbf{G} = \mathbf{U} \begin{bmatrix} \text{diag}(\sigma_i) & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix} \mathbf{V}^T$$



M1 deformation (ventilation gates open)

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Index = 1



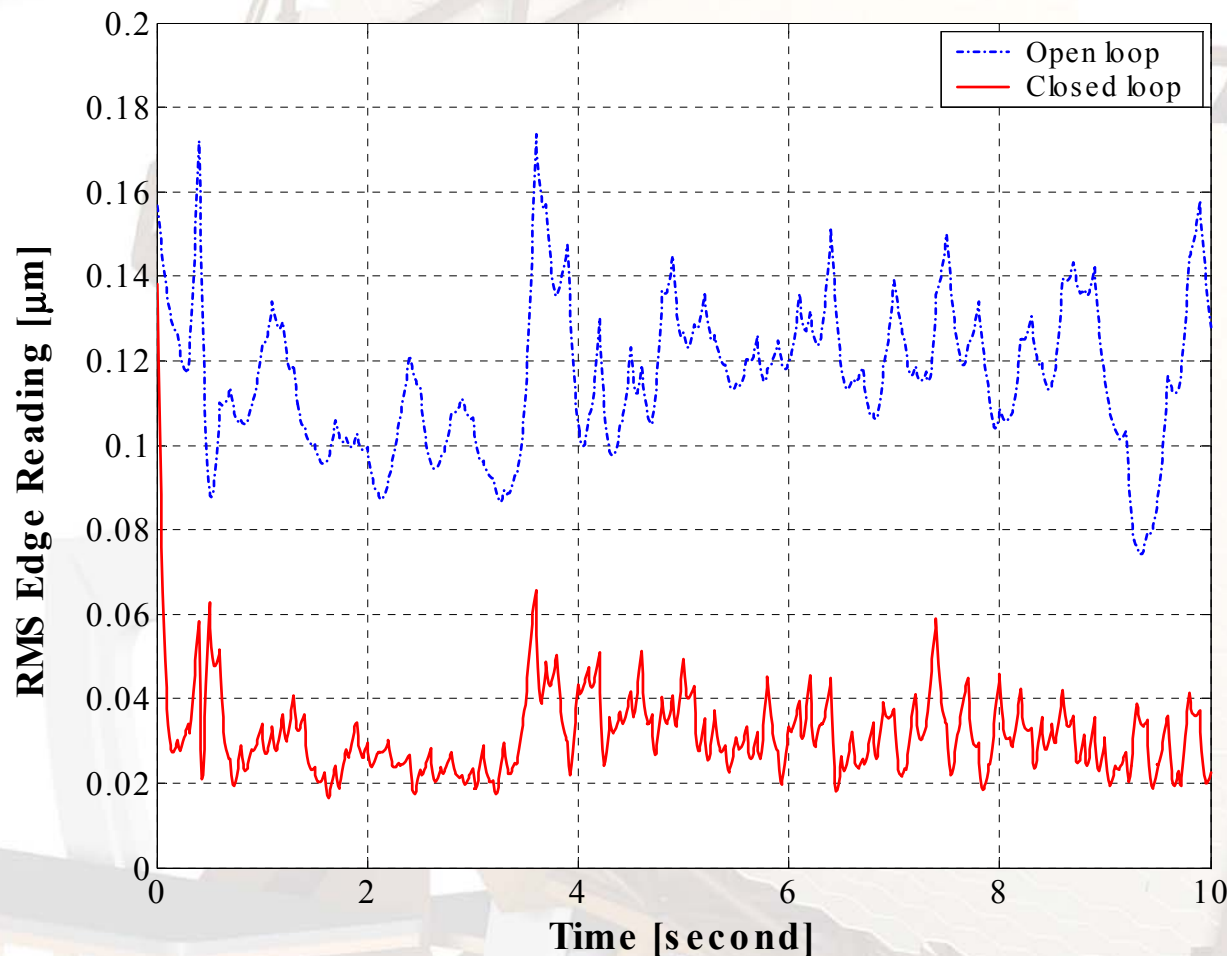
μm



RMS edge displacement (ventilation gates open)

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High wind



Wind velocity:

~10 m/s @ dome top

~4 m/s @ M1

~4 m/s @ M2

110 nm_{RMS} open loop

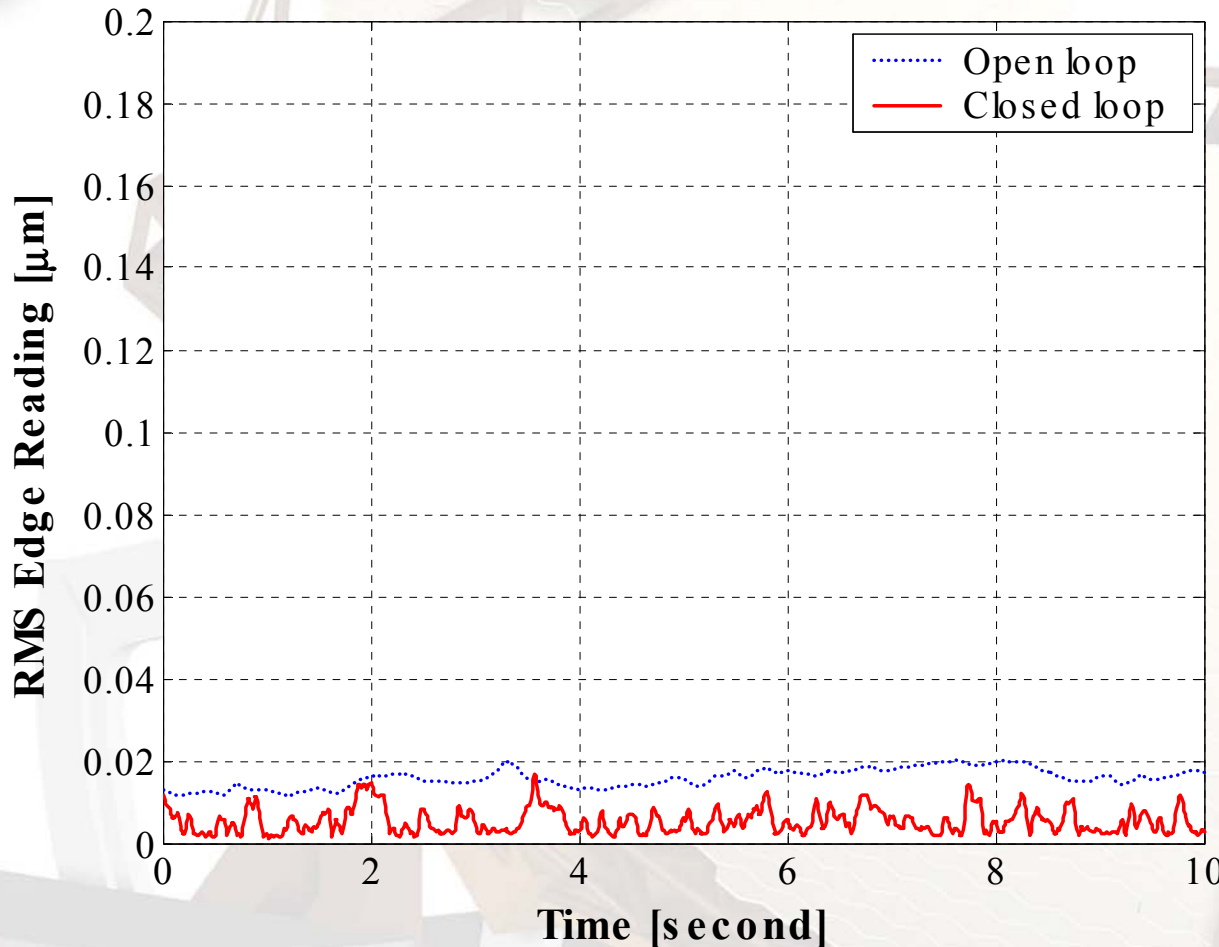
30 nm_{RMS} closed loop



RMS edge displacement (ventilation gates closed)

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Low wind



Wind velocity:

~ 11 m/s @ dome top

~ 0.6 m/s @ M1

~ 4 m/s @ M2

12 nm_{RMS} open loop

6 nm_{RMS} closed loop



Conclusion

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- Wind load on a 30-meter class telescope is not trivial, but **manageable** with a distributed control architecture
- Further studies necessary
 - Integrated structural, optical and control model to
 - Realize optical feedback
 - Evaluate performance
 - Balancing dome seeing and structural deformation effects to find the “optimum” wind inside the enclosure



Frequency bands of actuator groups

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