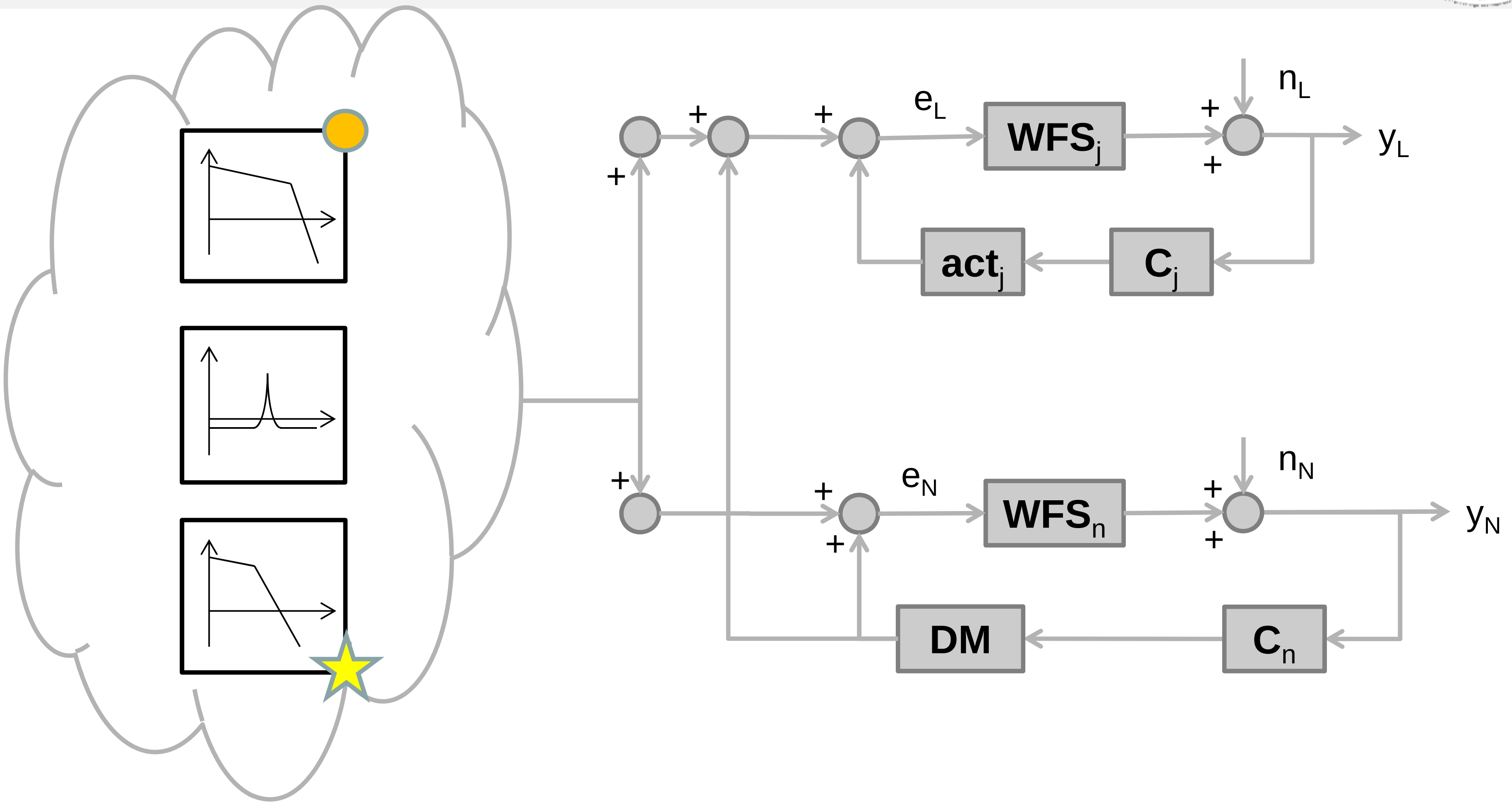
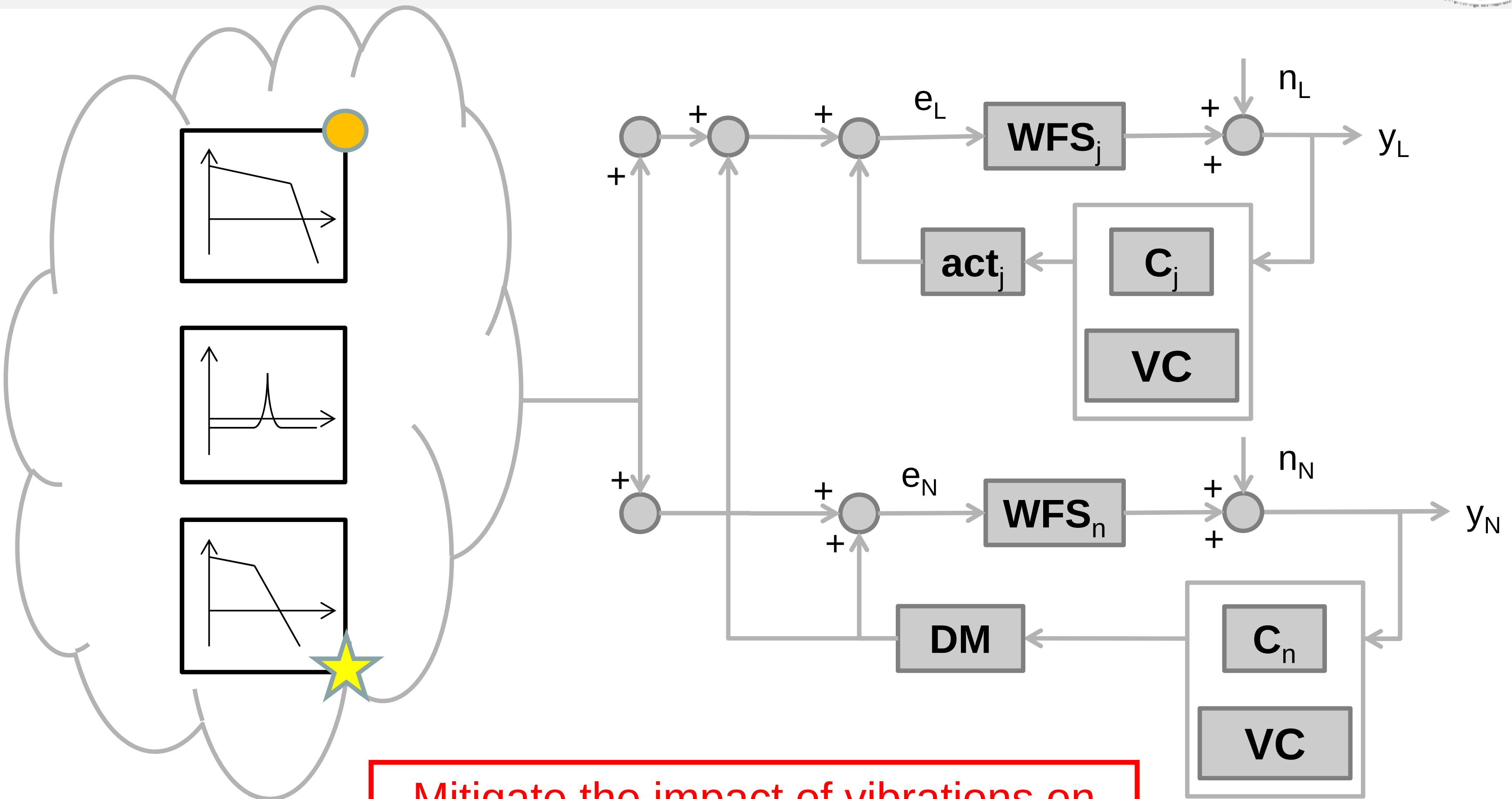
A Modular Adaptive Vibrations Cancellation Scheme for SPARTA

L. Pettazzi, R. Muradore, E. Fedrigo, R. Clare
ESO and University of Verona

Vibration rejection in AO



Vibration rejection in AO



Mitigate the impact of vibrations on AO performance.

Adaptive and Modular

Why adaptive control?

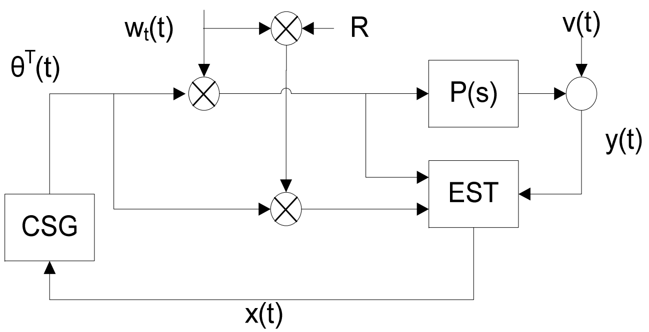
- Attractive solution to reject perturbations with time-varying characteristics (Doelman et al. 2009, Beerer et al. 2012)
- Adaptive control for vibration rejection successfully applied in the context of stellar interferometry @ ESO telescopes (Di Lieto et al. 2008)

Why modular architecture?

- Easy to implement in existing control infrastructure
- Add-on functionality w.r.t. existing WF controller → no re-commissioning of existing controller needed
- Easily reconfigurable to different operational scenarios if required by the science case

Adaptive Vibration Cancellation (1/2)

- Modification of an algorithm proposed in Pigg et al. 2010
- Adaptive approach:
  - estimates online of the plant frequency response and the disturbance parameters → no prior knowledge of plant dynamics required
  - generates appropriate control signal to suppress vibration



- Both estimation and CSG work recursively at loop rate
- Can be operated in parallel to existing WF controller

Adaptive Vibration Cancellation (2/2)

- Can be expanded including additional mechanisms to track on-line variations of vibration central frequency
- Different frequency tracking algorithms can be implemented (PLL/EKF): PLL best trade-off between computational complexity and performance
- AVC shares same philosophy (adaptive control) and fundamental structure (phase/amplitude estimator + PLL) with algorithm already tested on-sky @ Paranal
- Equivalent to two 7x7 full MVM per cycle/vibration/mode → in line with RTC capability of MACAO-RTC and SPARTA

End-to-end Simulations

- ESO end-to-end tool OCTOPUS used to simulate addition & correction of vibrations
- GALACSI NFM LTAO simulated (4LGS + 1 NGS)

Parameter	**Value (unit)**
Time steps	5000
LGS sampling frequency	1000 Hz
NGS sampling frequency	200 Hz
LGS flux	80 photons/subaperture/frame
NGS flux	150 photons/subaperture/frame
LGS read noise	1e/pixel/frame
NGS read noise	15e/pixel/frame
Vibration 1 frequency	18 Hz (tip/tilt)
Vibration 2 frequency	48 Hz (tip/tilt)
Loop gain (of temporal integrator)	0.3
Delay	3 frames (1 for WFS integration plus 2 extra delay)
r_0	11.8 cm
PSF wavelength	0.65 μm

Simulation Results - Strehls

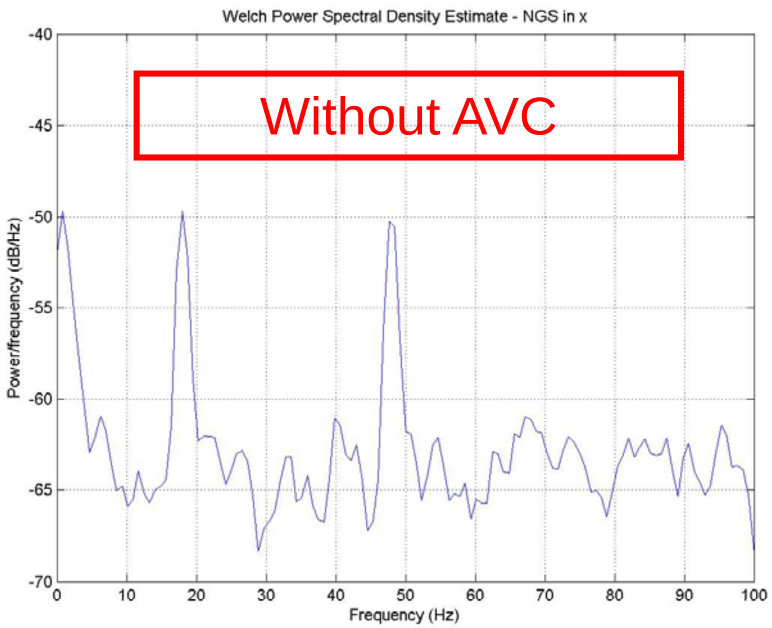
- GALACSI NFM LE Strehl @650nm for standard parameter set without vibrations = 0.073
- Strehls with “bad conditions” vibrations @ 18Hz and 48Hz in both tip and tilt modes as measured on NACO added are:

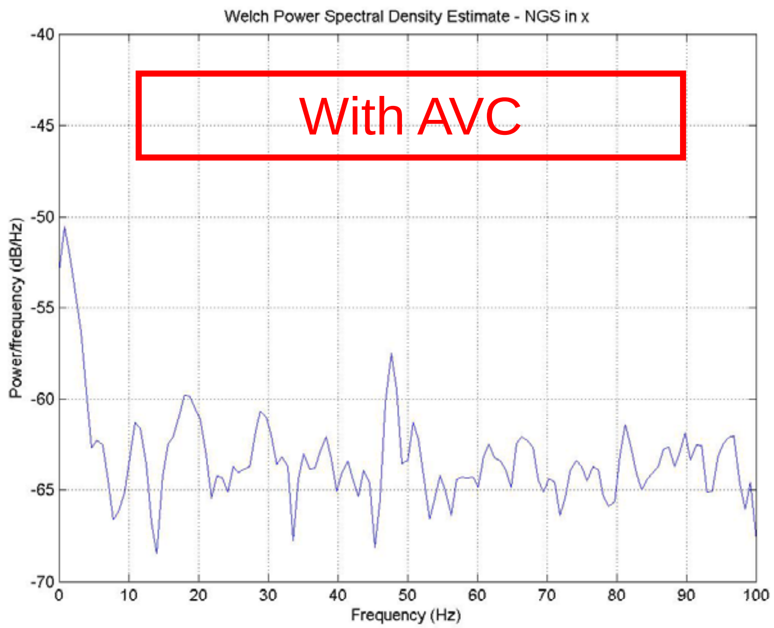
	Without Pigg-Bodson	With Pigg-Bodson
LE Strehl at 650nm	0.047	0.070
Relative Strehl at 650nm	0.64	0.96

- Almost all of the Strehl loss due to vibrations is recovered with AVC

Simulation results – NGS PSDs

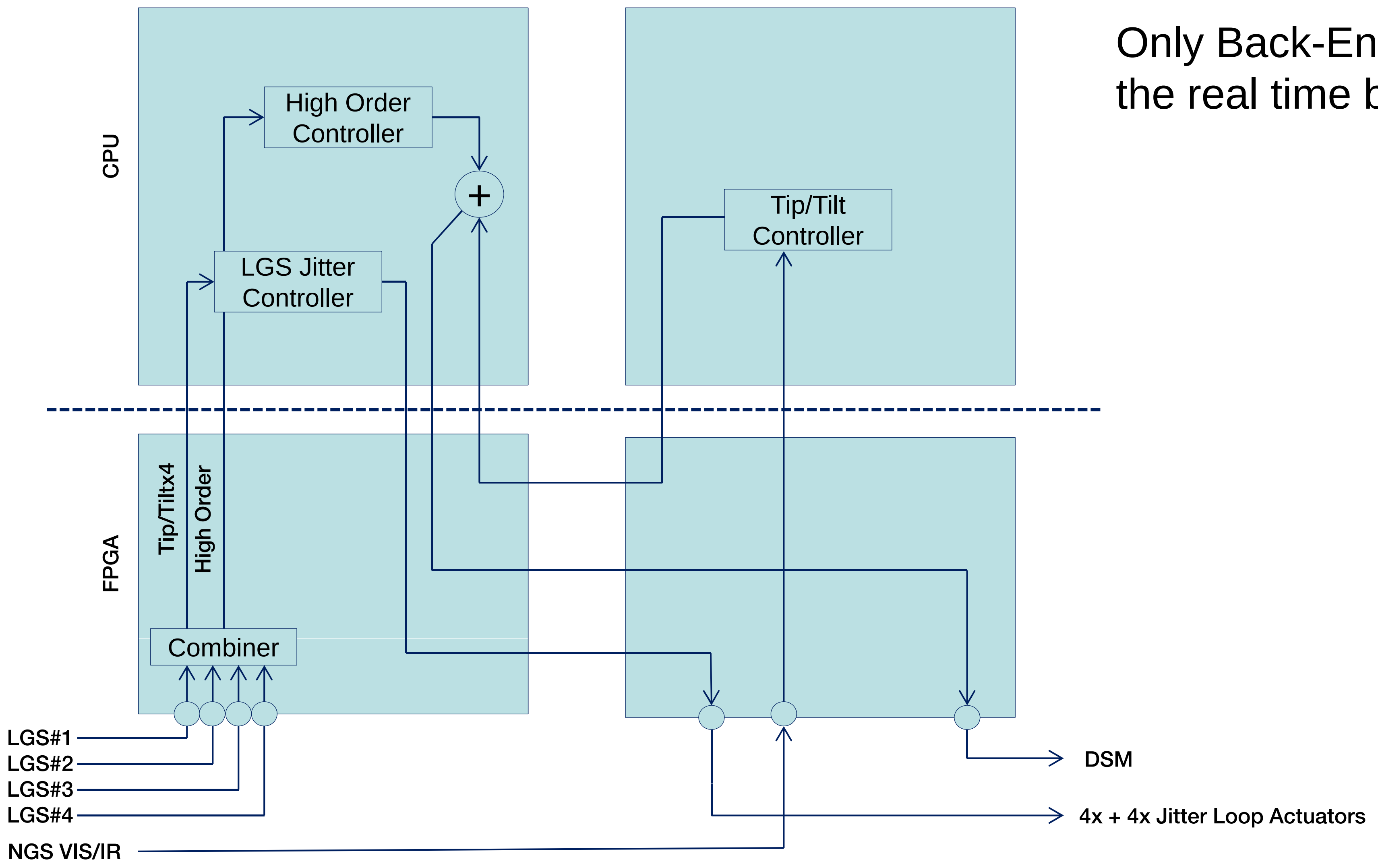
- NGS slope PSDs (calculated from iterations 1000-5000)
- In x direction (y direction is analogous)





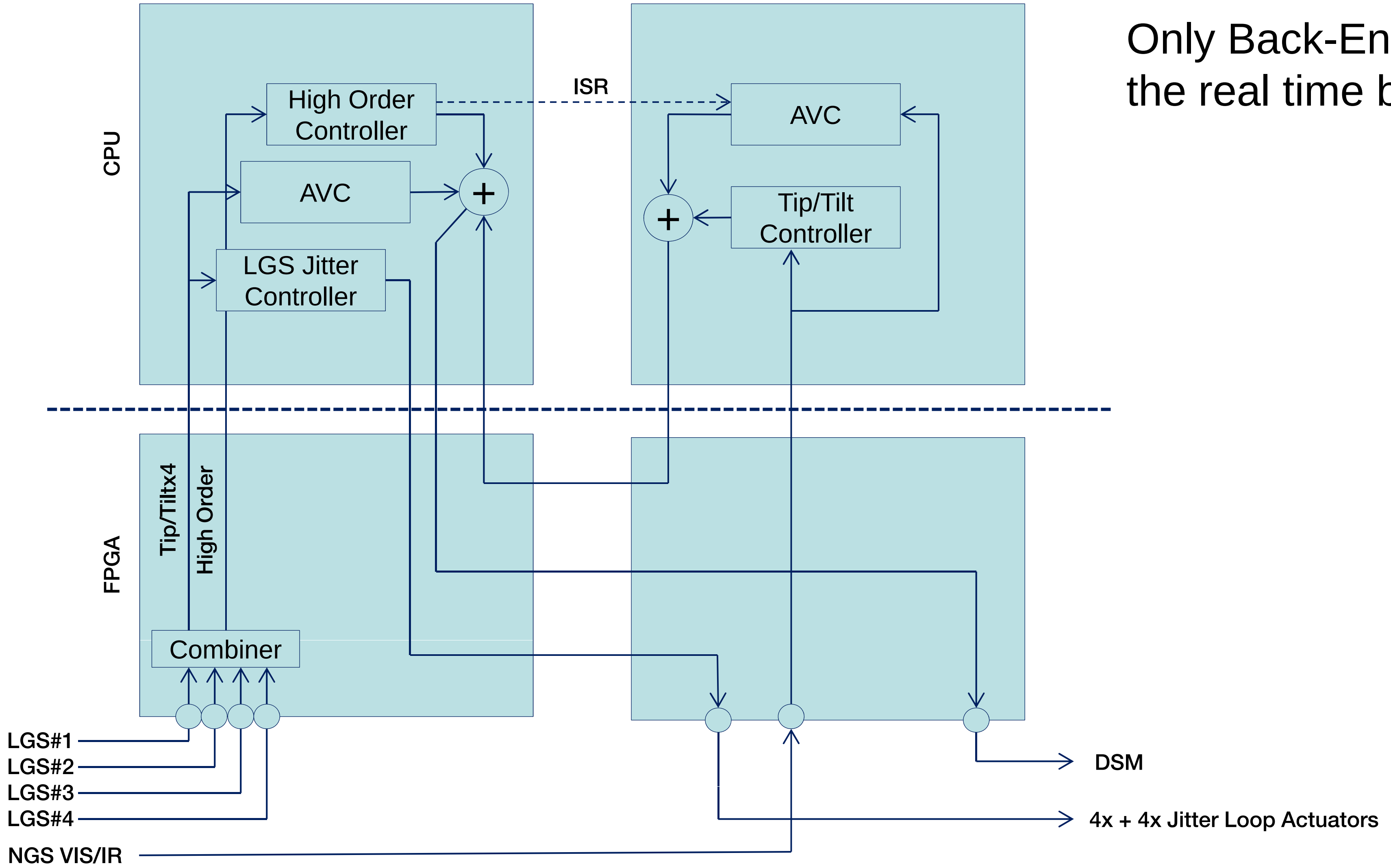
- Peaks at 18 & 48Hz almost entirely removed from NGS PSDs with AVC

Implementation in SPARTA AOF



Only Back-End of the real time box

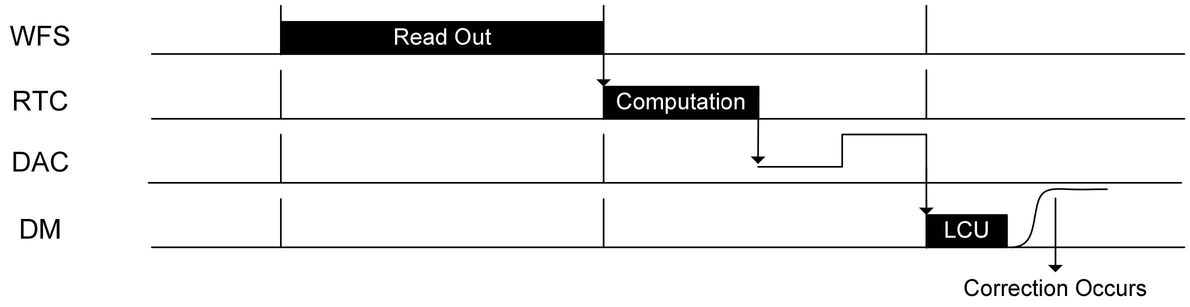
Implementation in SPARTA AOF



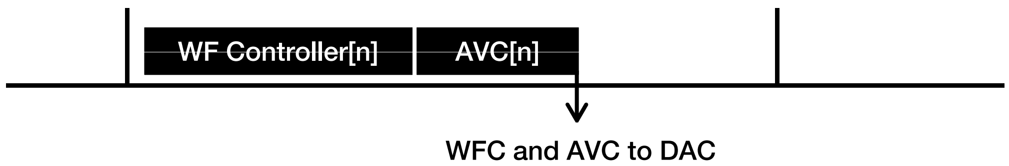
Only Back-End of the real time box

Alternative implementations regarding exec time

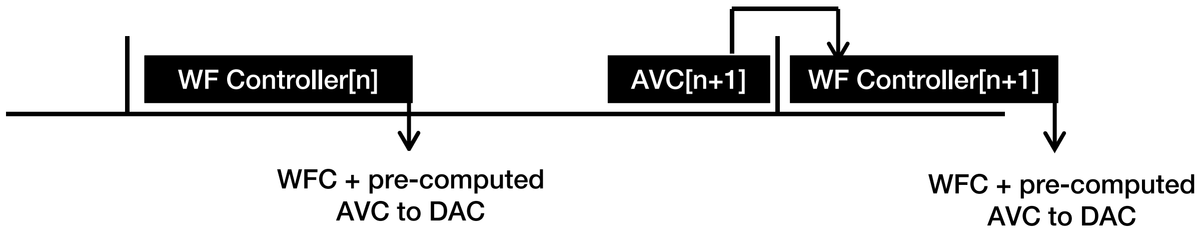
- Typical AO loop control cycle



- Update AVC @ computation time



- Update AVC @ idle time (AVC one step ahead)



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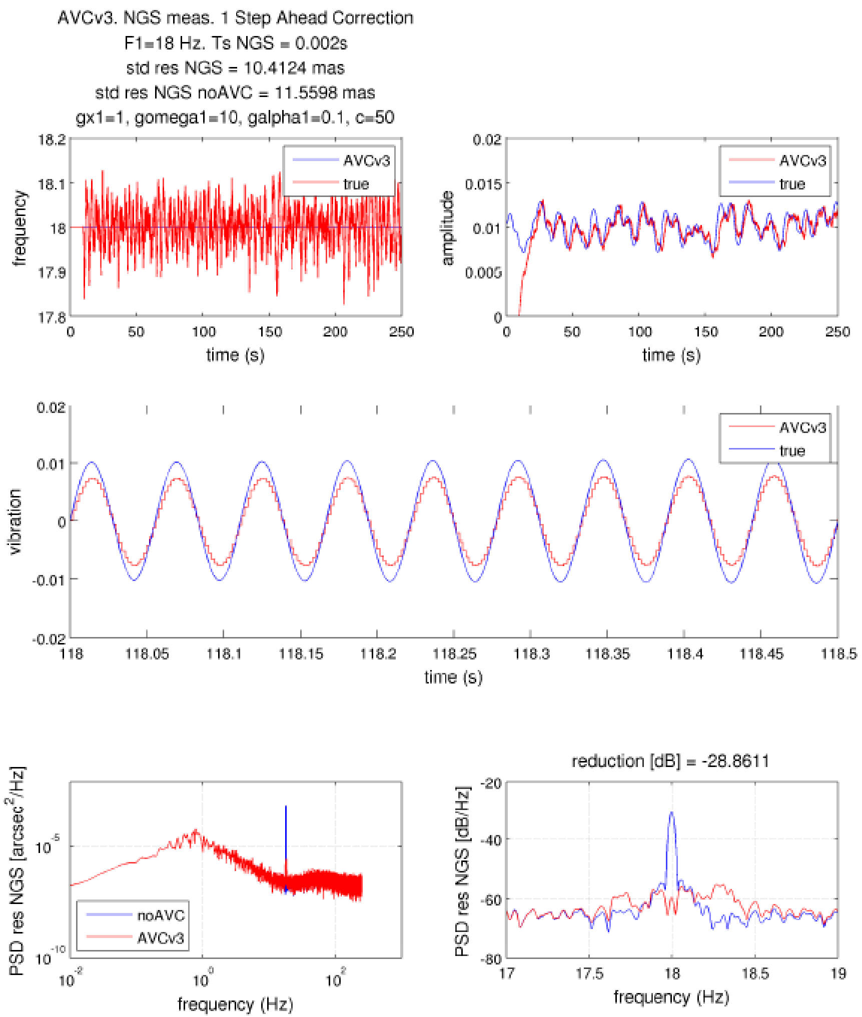
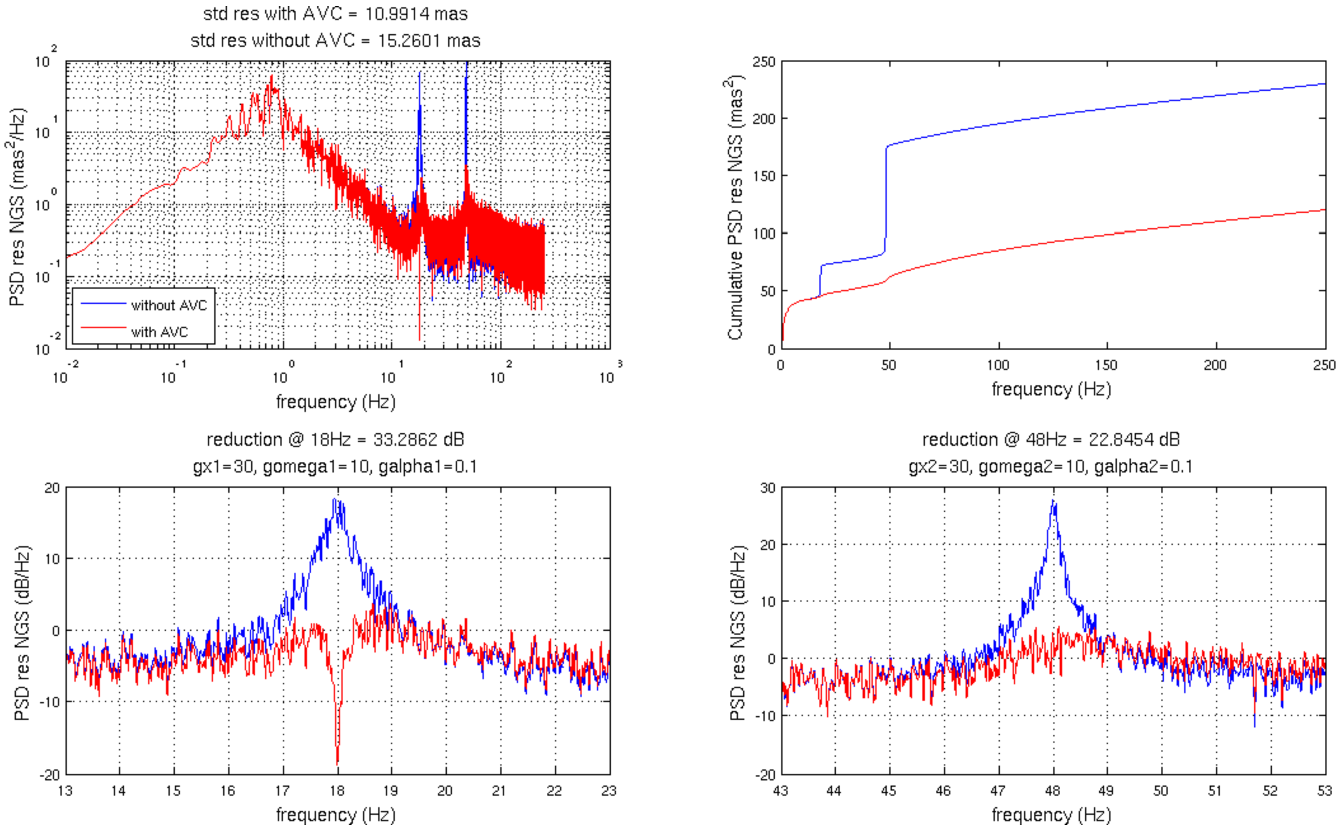


- F1=18Hz
- NGS loop @ 500Hz
- LGS loop @ 1kHz
- NGS measurements used to correct F1
- One additional sample delay included in the AVC path
- No additional information provided to the AVC
- No tuning modification performed
- AVC correction capability and convergence rate not affected by different implementation

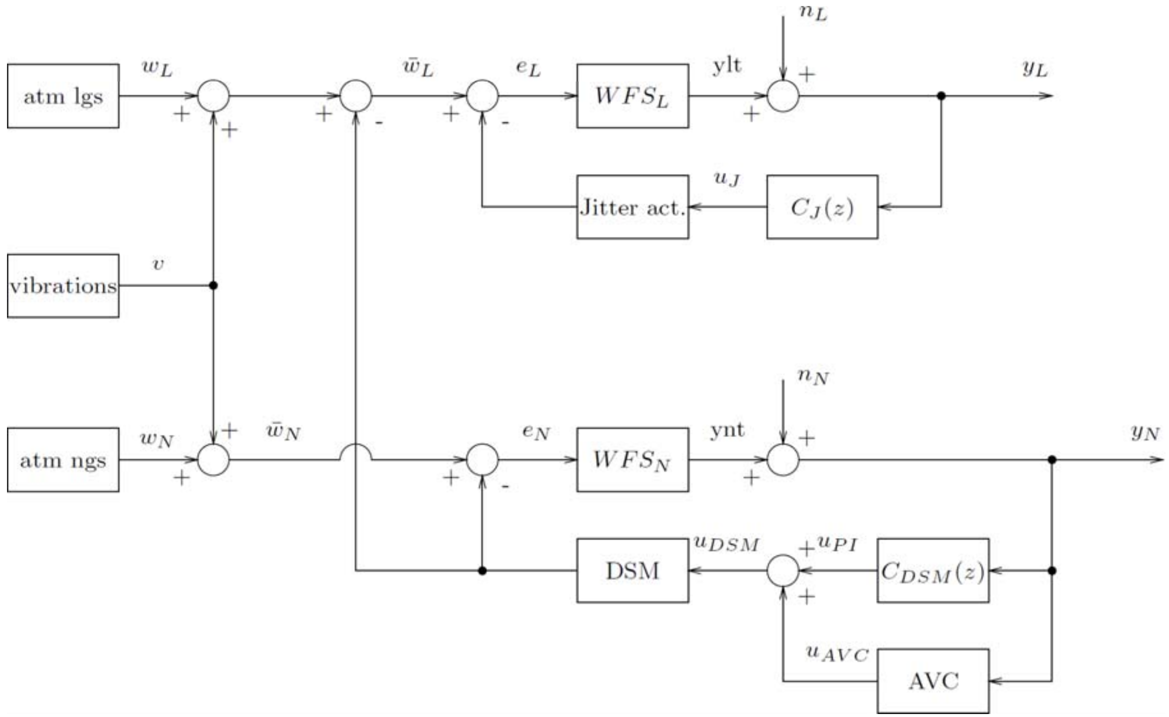
Easy to reconfigure

- Correction in case of bright star (integration time 500Hz)
- Two vibrations (AR2 driven by white noise) @ 18Hz and 48Hz



Easy to reconfigure

- Longer integration time required in case of faint stars
- NGS measurements contain poor information regarding high frequency vibration
- If vibration propagates consistently in both loops → LGS signals could be used instead



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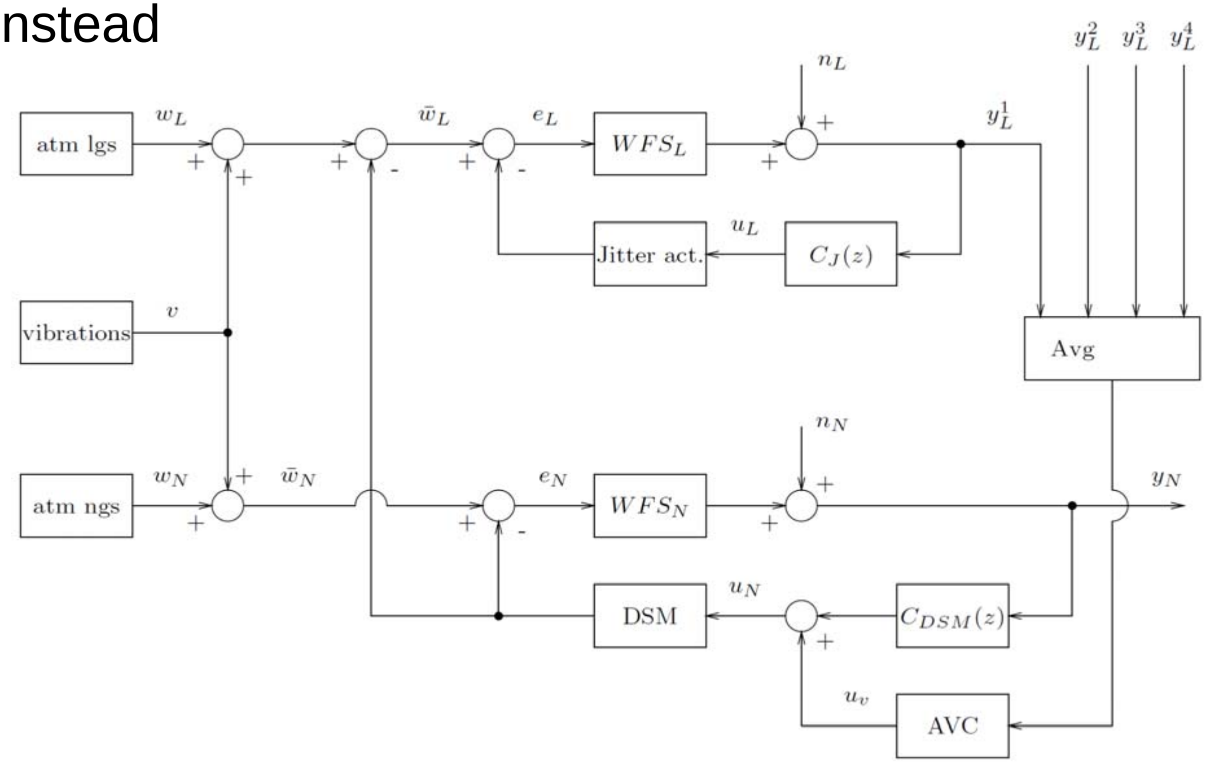

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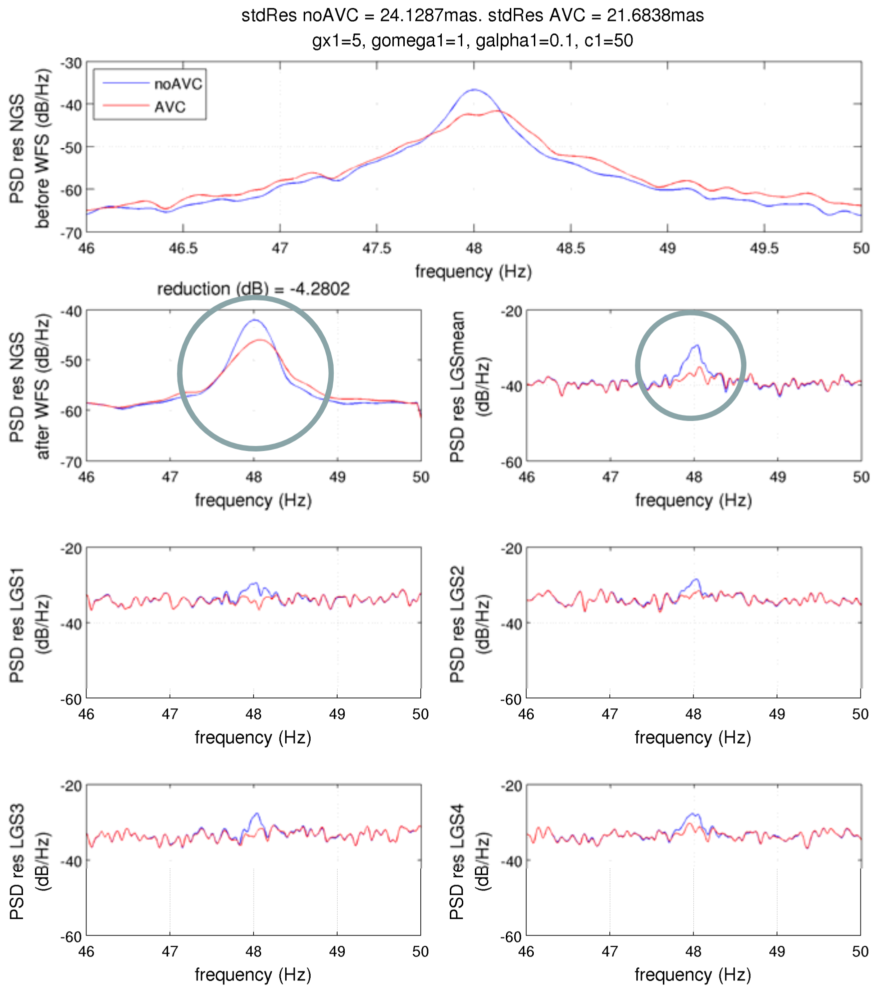

- F1=18Hz and F2=48Hz
- NGS loop @ 100Hz
- LGS loop @ 1kHz
- NGS signal used to reject vibration @F1
- Averaged LGS signal used reject vibration @F2

- Good correction of F1
- Good correction of F2 (looking @ LGS measurements)
- Residual vibration @F2 still visible in NGS (LGS lower SNR)

Conclusions

- Advantages of AVC:
  - Can cope with time-varying perturbations

- Methodology successfully tested in simulation
  - exploiting high fidelity AO loop E2E simulator
  - dedicated simulator

- Easy implementation in SPARTA control infrastructure

- Modularity enables enhanced operational flexibility:
  - Allows exploiting different measurement sources in different operational modes

Outlook

- On-sky verification run on MACAO
  - Feasibility analysis: processing of MACAO real time data to assess available stroke vs. amplitude of vibration to reject
  - Implementation and testing in MACAO simulator
  - On-sky verification of the algorithm
- Implementation of AVC user-interface and consolidation of bootstrap phase procedure
- Implementation in SPARTA and subsequent laboratory performance verification in the framework of AOF testing activity (ASSIST)
- Implementation/test for NAOMI and GRAVITY.