

Stable usage of modes for wavefront representation without truncation

WFS Workshop Porto 2022

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The Scheme (Baseline)

▶ WF Estimation

- ▶ VDM - Discretization of the WF fitting the P-WFS pixel
- ▶ using Regularization: $R = (P^T P + \alpha \Delta^2)^{-1} P^T$
- ▶ Laplace on regular VDM grid
- ▶ Presented at the 2020 WFS online Workshop

▶ Stable Projection on Control Modes

- ▶ this talk...

▶ Temporal Control (PI Control)

▶ Sending Modes (or actuator commands) to CCS

- ▶ M4/M5



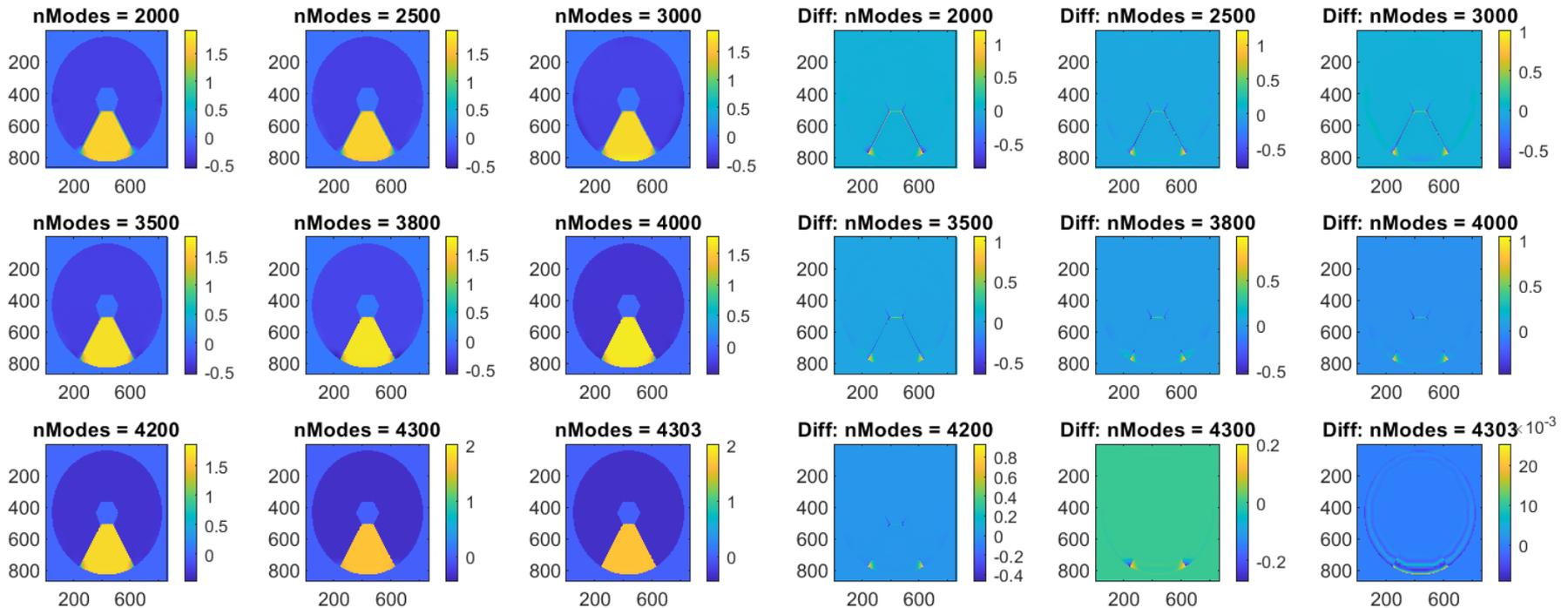
Main Challenges

- ▶ **Stable and high quality WF estimation/reconstruction**
 - ▶ compare with Houdini
- ▶ **Choice of Modes**
 - ▶ M4 mechanical modes
 - ▶ C.Verinaud force aware KL (aka THE modes)
 - ▶ OG (still don't like the name...), condition numbers,
- ▶ **Choice of Projection method**
 - ▶ Pseudoinverse, then modal truncation
 - ▶ Truncated SVD
 - ▶ Pseudoinverse w. regularization (using statistics or properties)
- ▶ **Choice of Regularization**



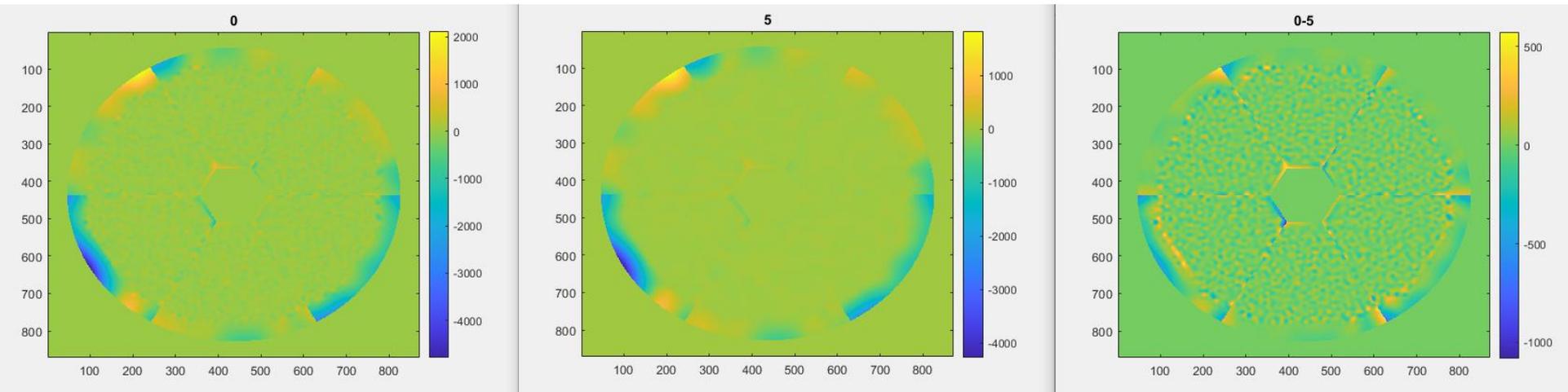
Motivation – Effects of Modal truncation

- ▶ As Jeff said: understand your AO...including the modes



Effect of Smoothing on Modal coeffs

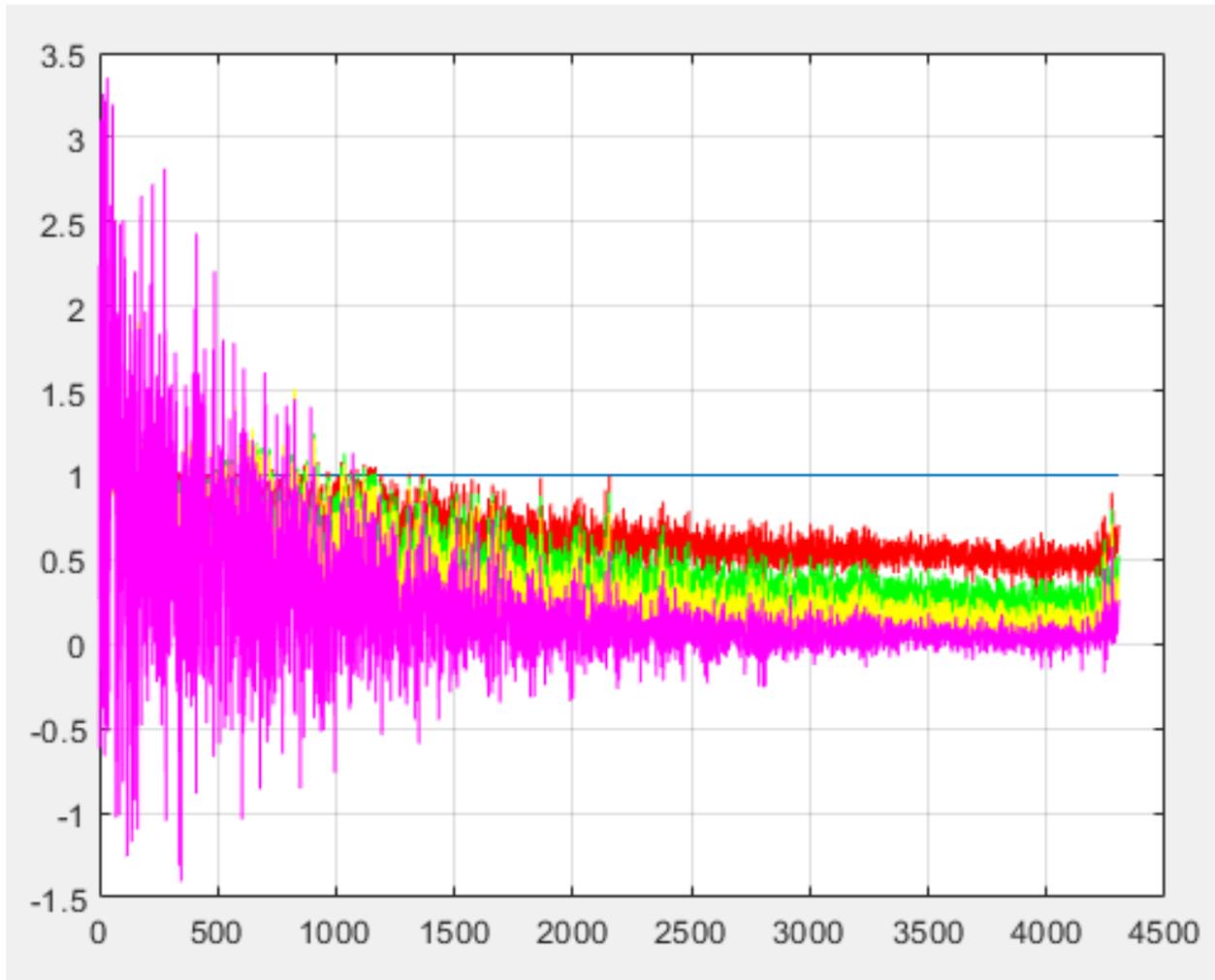
- ▶ Testphase: all modal coefficients are one
- ▶ Apply different regularization strength in the projection



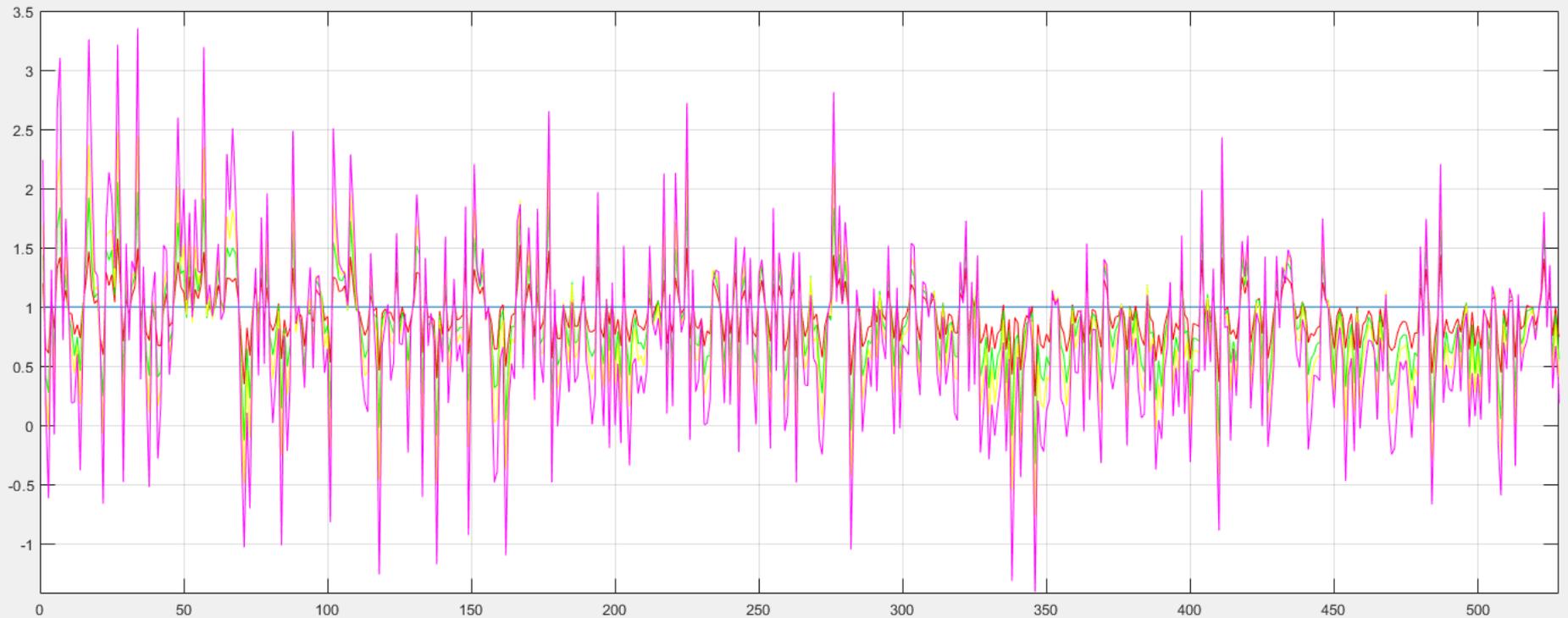
- ▶ Yes, obviously....but what about the coefficients?



Effect of Smoothing on Modal coeffs



Effect of Smoothing on Modal coeffs



Different test phases on VDM

- ▶ Sinus waves
- ▶ Random white noise
- ▶ Open loop phases
- ▶ Closed loop residual phases
 - ▶ For different seeing conditions



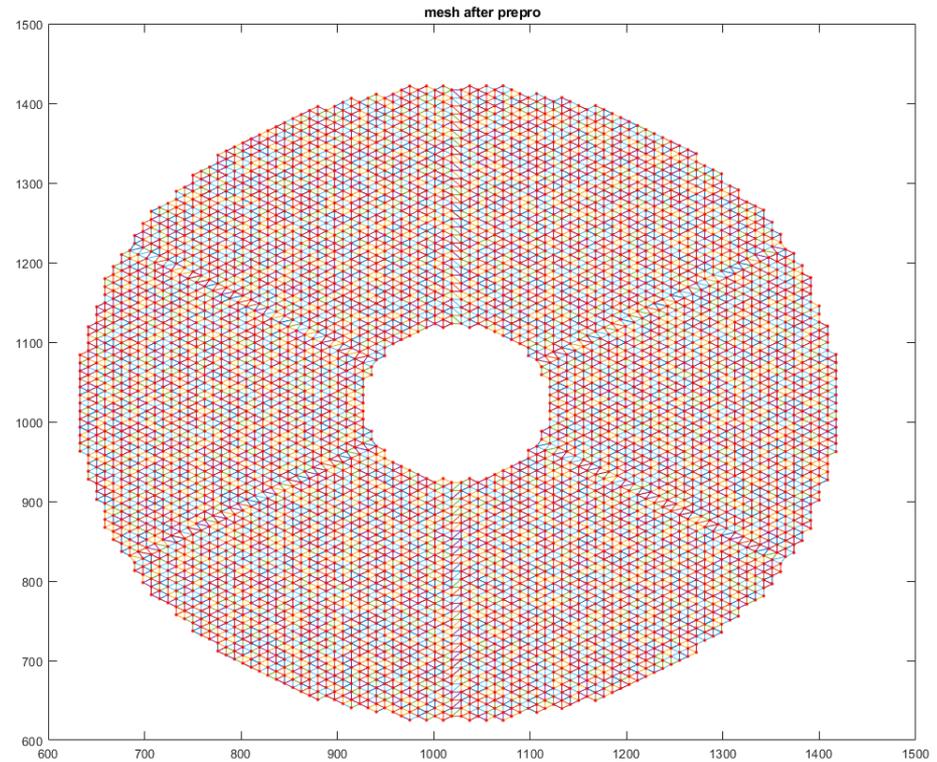
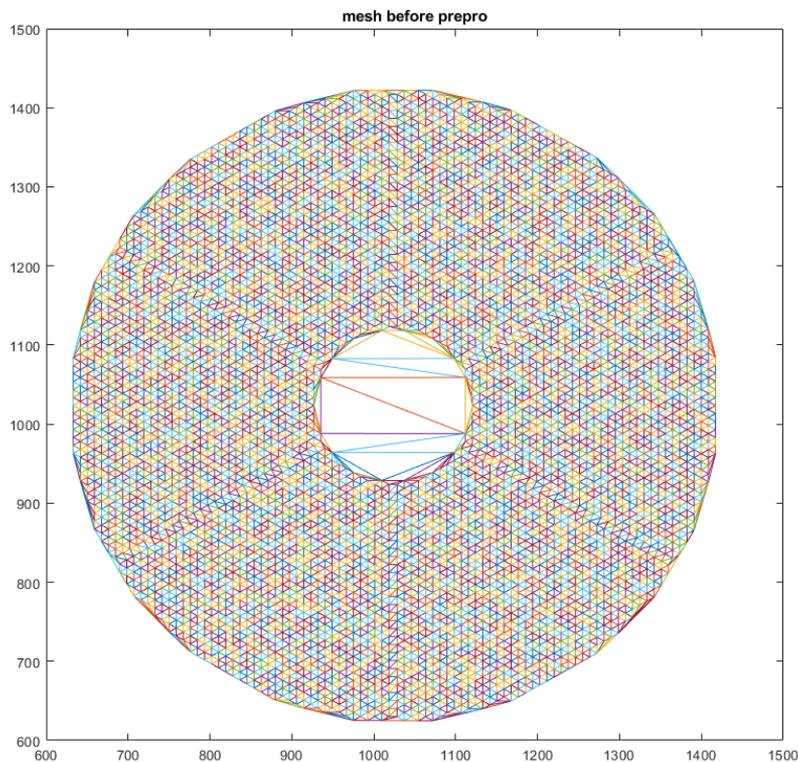
Implementation

- ▶ **Derive Laplace for the M4 actuators**
 - ▶ Regularized projection on M4 (using all actuators)
 - ▶ Sparse!
- ▶ **Utilize the c2m and m2c matrices**
 - ▶ Condition number: 158.699
 - ▶ Stable transformation from M4 commands to modal coefficients (and vice versa)
- ▶ **VDM \rightarrow M4 \rightarrow Modes**
 - ▶ (use sparse matrix multiplication in S-RTC)



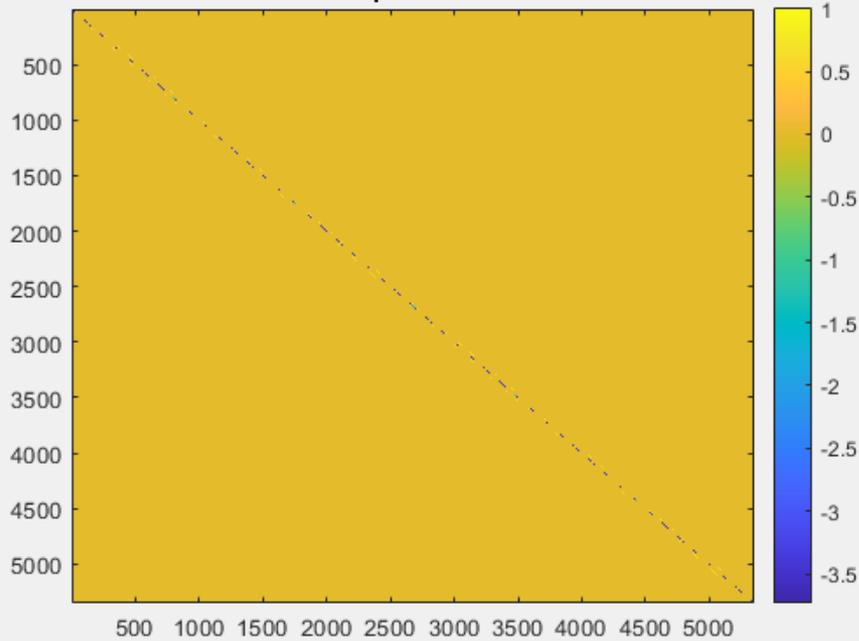
The used „M4-grid“

- ▶ Proper triangulation on actuators as nodes
- ▶ FE derivation of Laplace assuming linear ansatzfunctions

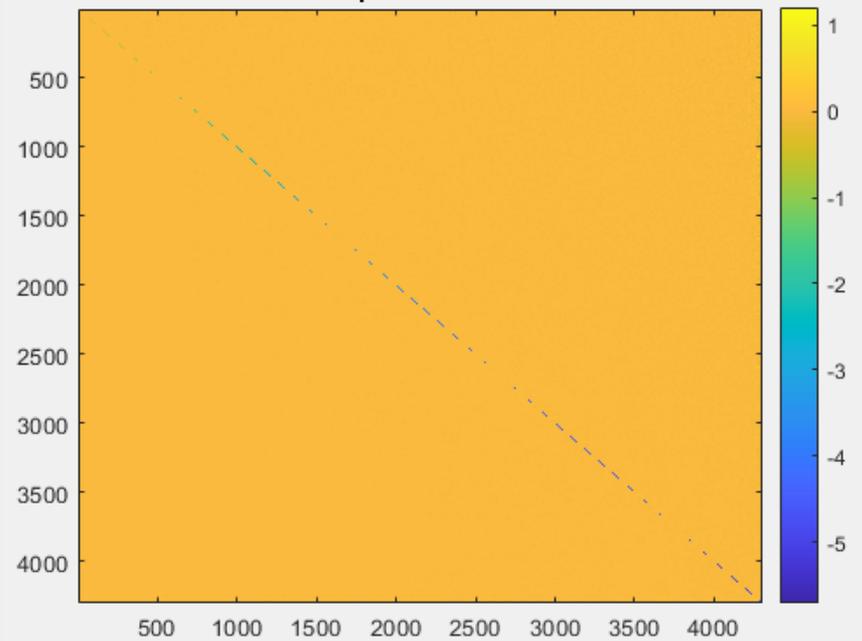


Laplace on M4 vs Laplace on Modes

Laplace M4

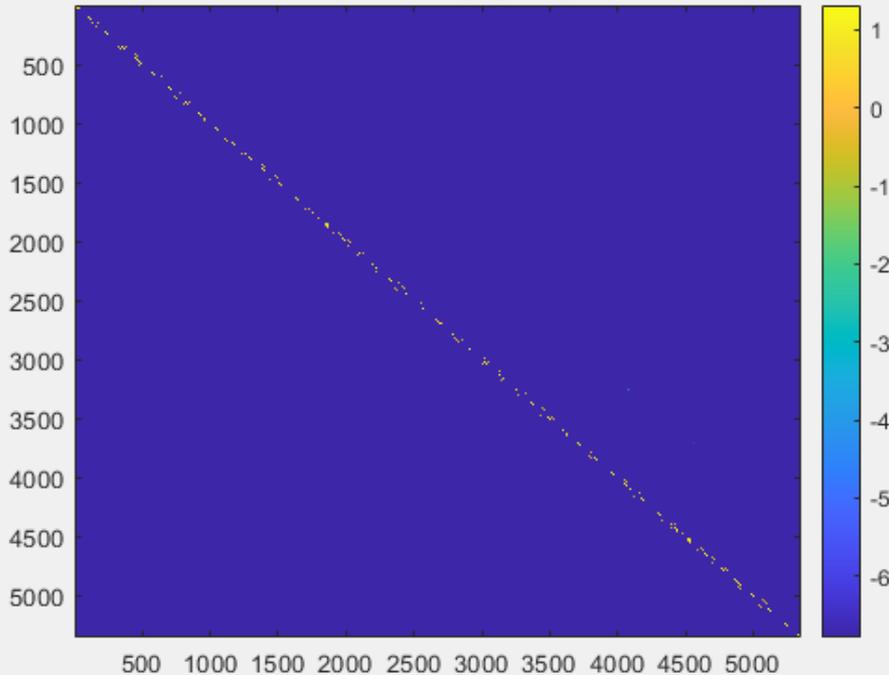


Laplace modes

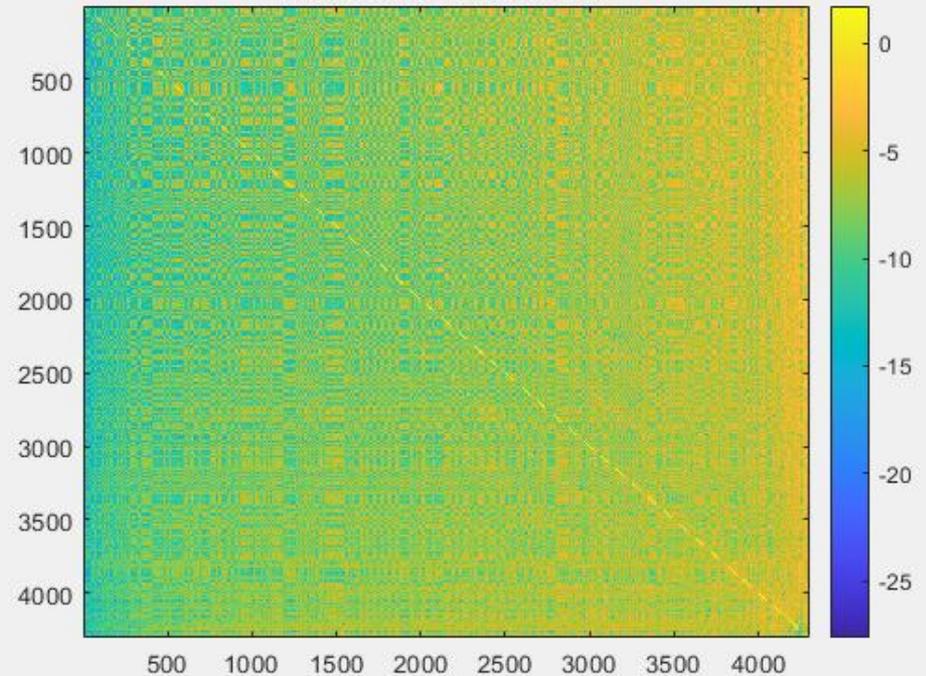


Laplace on M4 vs Laplace on Modes

Laplace M4 (log abs)



Laplace modes (log abs)



METIS like simulations

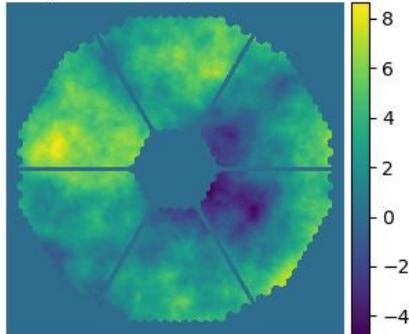
- ▶ Very good to very bad seeing
- ▶ Zenith 0 – 60
- ▶ GS brightness down to magnitude ~ 12 (K-Band)

- ▶ → with ONE set of parameters
 - ▶ Regularisation parameter for WF estimation
 - ▶ Regularisation parameter for modal projection
 - ▶ Loop gain
 - ▶ Modulation radius
 - ▶ Integration time (loop frequency)

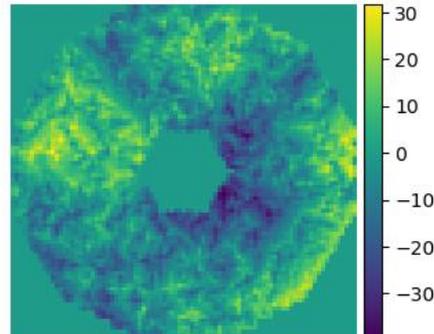
Incoming – WF Estimation on VDM – M4 update (actuators and IFs) – DM shape

► Closing the loop, iteration 2

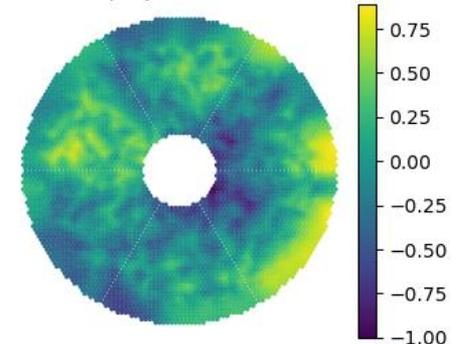
compass - WFS phase, masked



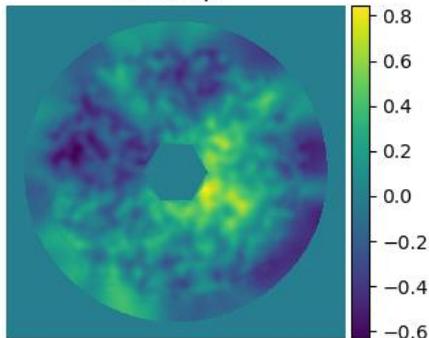
rec on VDM



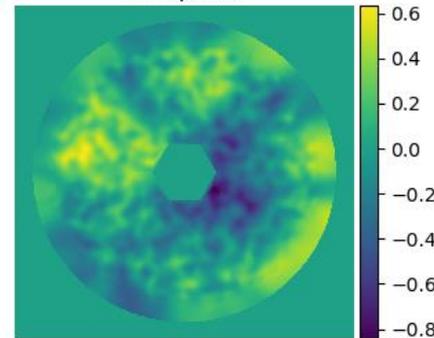
rec projected on M4



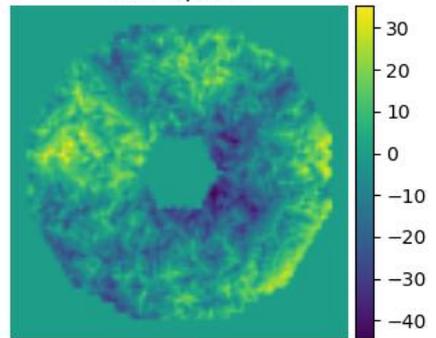
M4 shape



M4 update



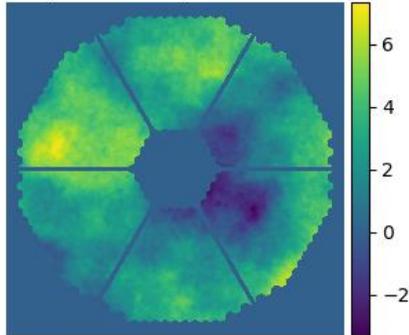
VDM update



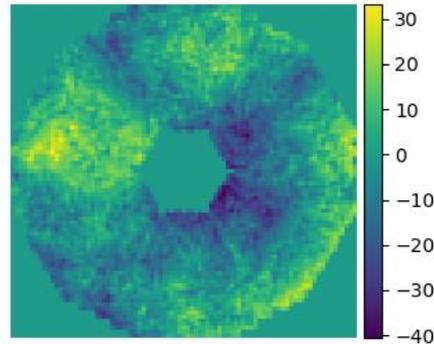
Incoming – WF Estimation on VDM – M4 update (actuators and IFs) – DM shape

► Closing the loop, iteration 4

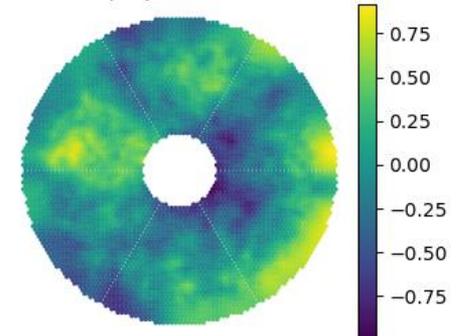
compass - WFS phase, masked



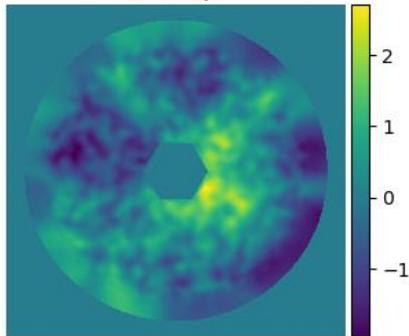
rec on VDM



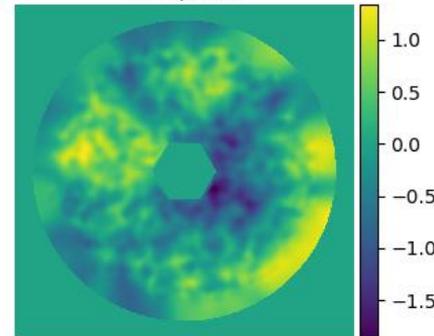
rec projected on M4



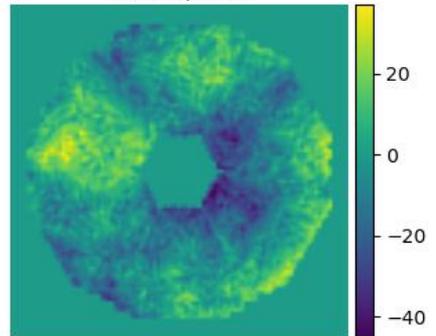
M4 shape



M4 update



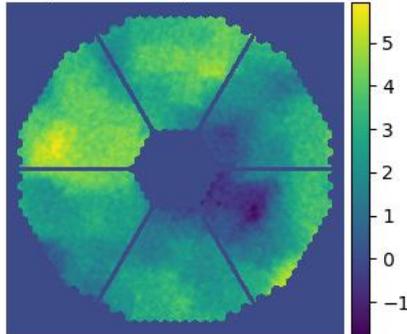
VDM update



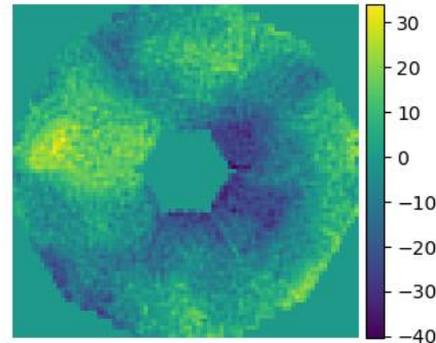
Incoming – WF Estimation on VDM – M4 update (actuators and IFs) – DM shape

► Closing the loop, iteration 6

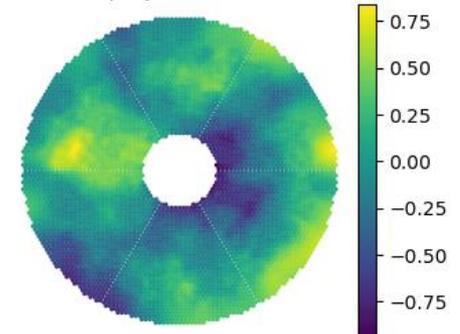
compass - WFS phase, masked



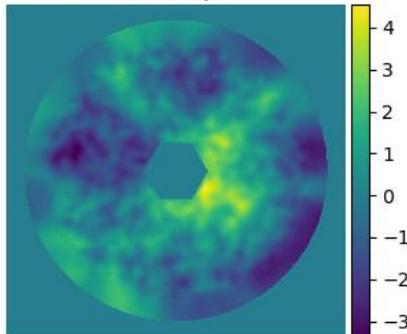
rec on VDM



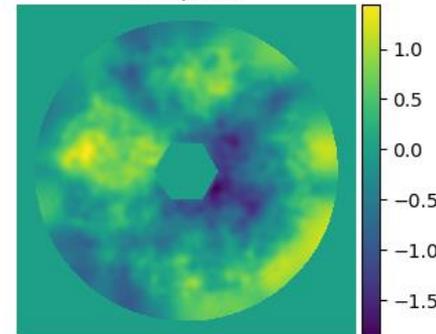
rec projected on M4



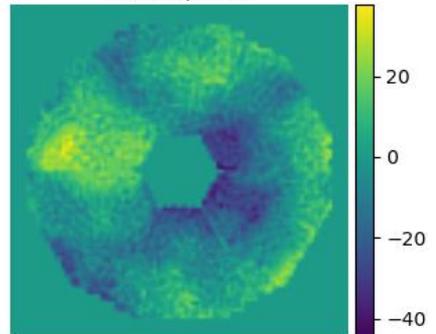
M4 shape



M4 update



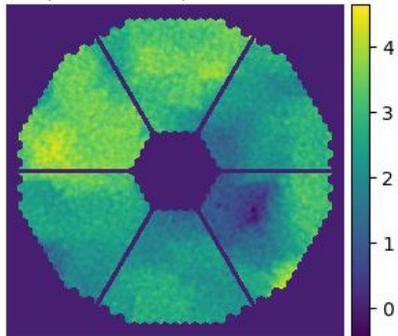
VDM update



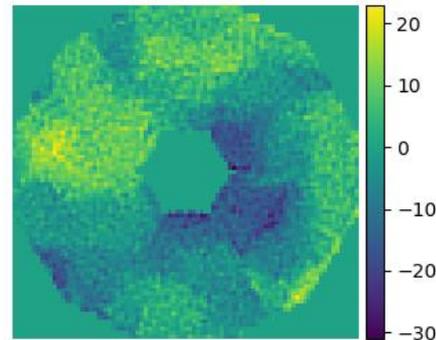
Incoming – WF Estimation on VDM – M4 update (actuators and IFs) – DM shape

► Closing the loop, iteration 8

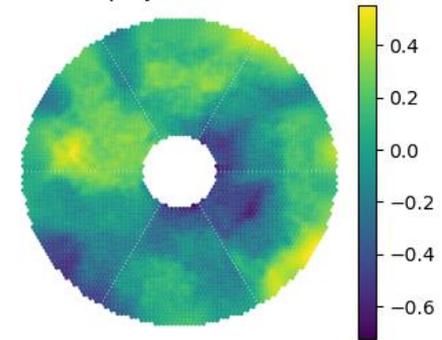
compass - WFS phase, masked



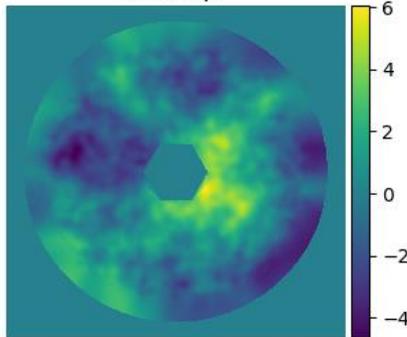
rec on VDM



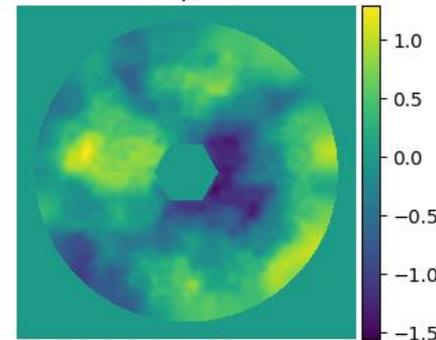
rec projected on M4



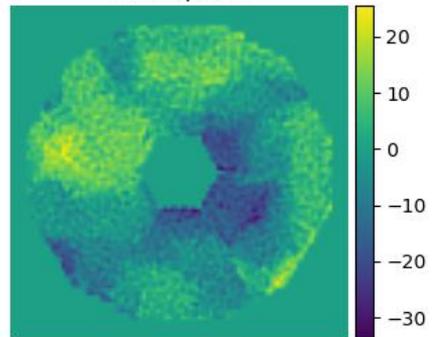
M4 shape



M4 update



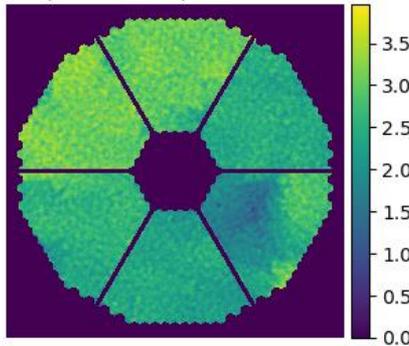
VDM update



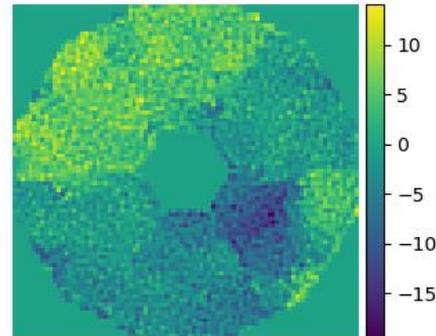
Incoming – WF Estimation on VDM – M4 update (actuators and IFs) – DM shape

► Closing the loop, iteration 10

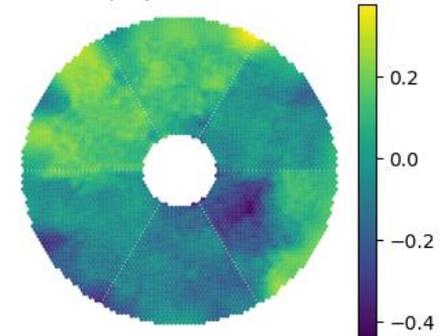
compass - WFS phase, masked



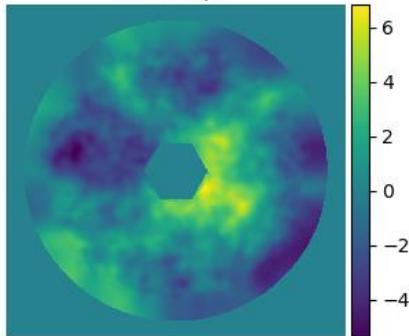
rec on VDM



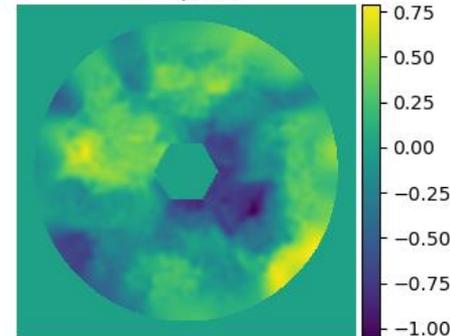
rec projected on M4



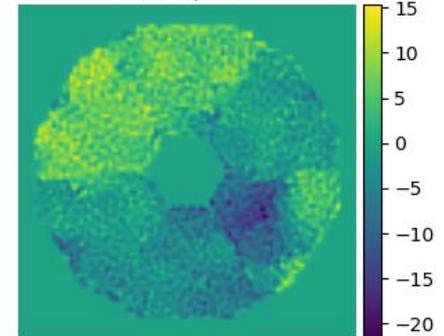
M4 shape



M4 update



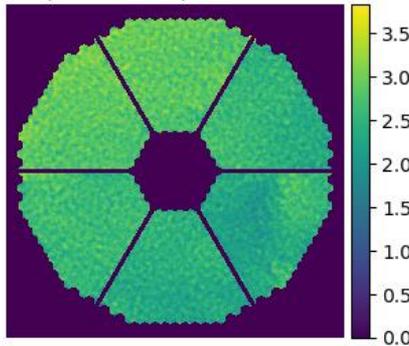
VDM update



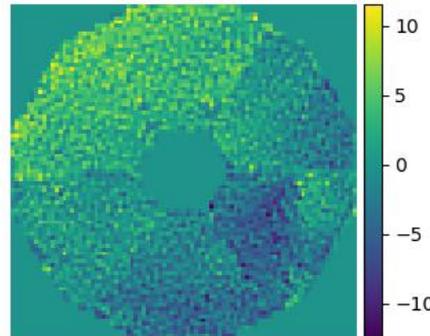
Incoming – WF Estimation on VDM – M4 update (actuators and IFs) – DM shape

► Closing the loop, iteration 12

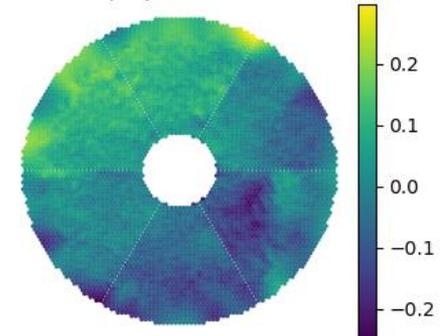
compass - WFS phase, masked



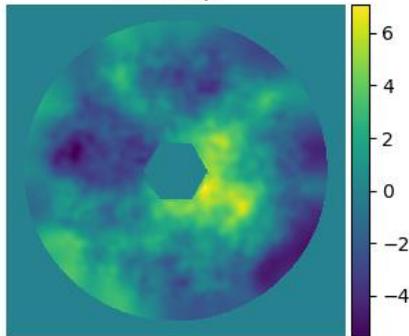
rec on VDM



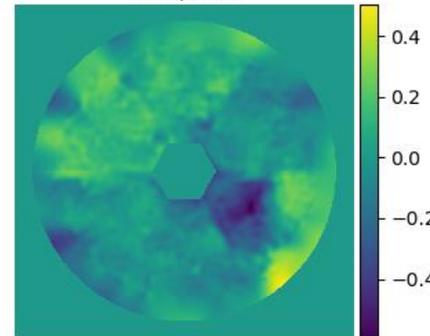
rec projected on M4



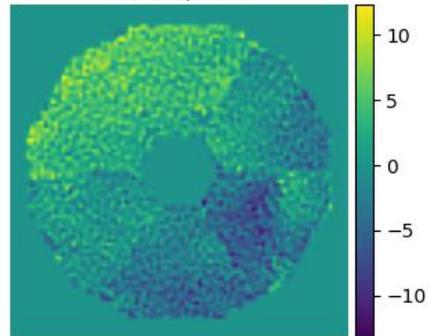
M4 shape



M4 update



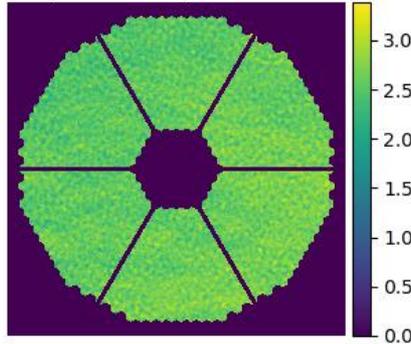
VDM update



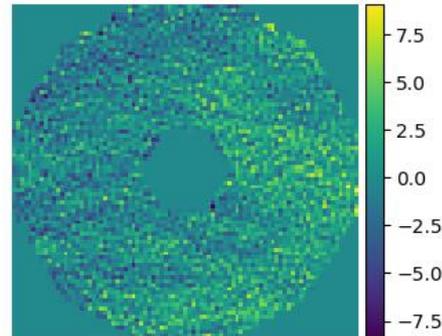
Incoming – WF Estimation on VDM – M4 update (actuators and IFs) – DM shape

- ▶ „steady state“, iteration 26

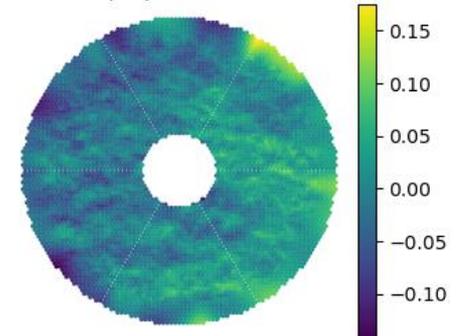
compass - WFS phase, masked



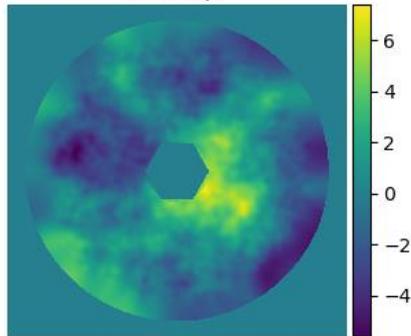
rec on VDM



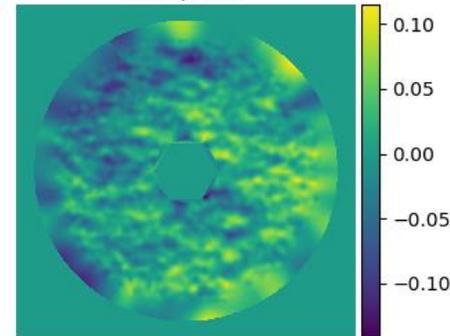
rec projected on M4



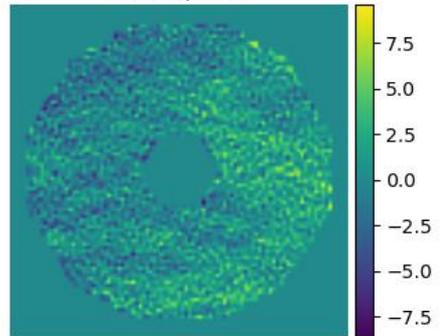
M4 shape



M4 update

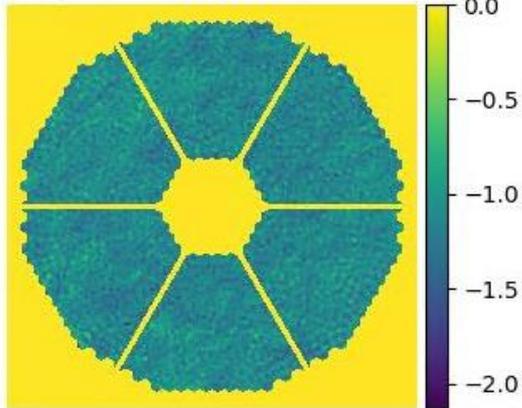


VDM update

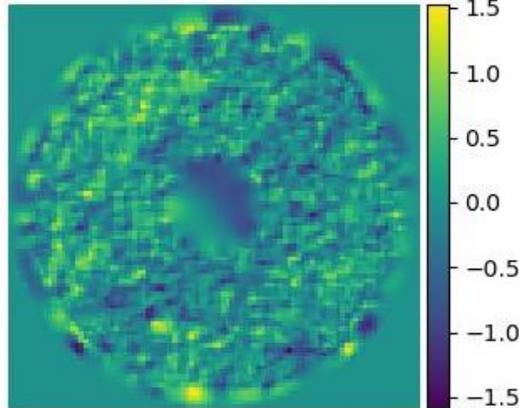


Showcase: use 6777 VDM actuators

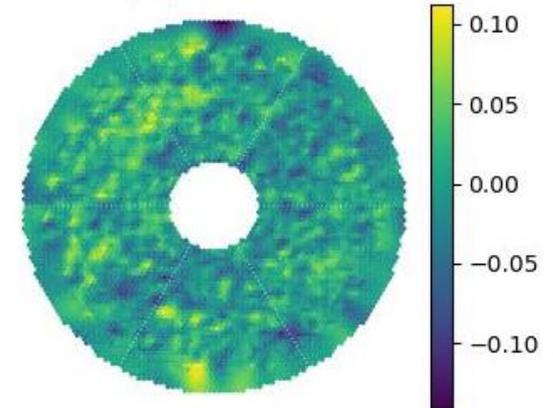
compass - WFS phase, masked



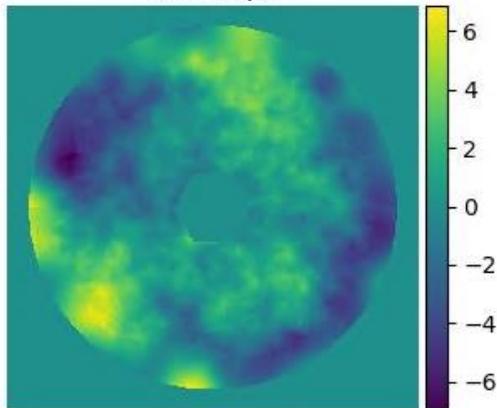
rec on VDM



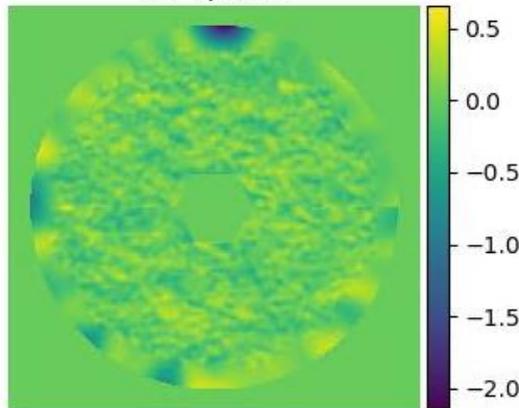
rec projected on M4



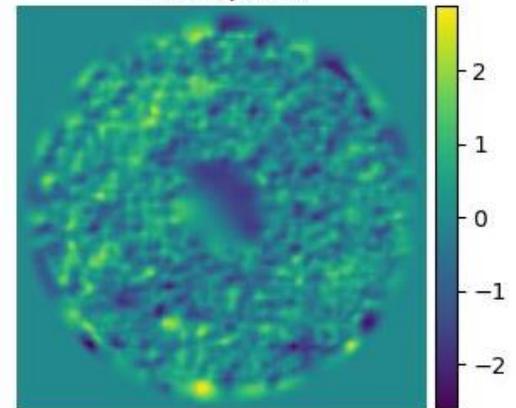
M4 shape



M4 update



VDM update



Open Tasks

- ▶ Large NCPAs
- ▶ „real life“ testing:
 - ▶ Bench
 - ▶ On-sky
- ▶ No funky abbreviation available (yet)



Thanks to... (without ordering)

- ▶ **AAO Team**
 - ▶ Julia Shatokhina, Stefan Raffetseder, Cecilia Schwalsberger
- ▶ **METIS Team**
 - ▶ Markus Feldt, Horst Steuer, Carlos Correia
- ▶ Christophe Verinaud, Miska Le Louarn
- ▶ ...you, the audience, for all the discussions and the input at this workshop!

Take Home Message

- ▶ Why truncate modes?
 - ▶ Easy
 - ▶ Faster to change in closed loop
 - ▶ Well known...well, often used.
- ▶ Regularized projection

