

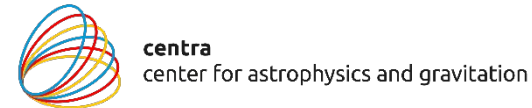
METIS

The METIS Command Matrix

Horst Steuer
08.11.2023
RTC4AO



ETH zürich



UK Astronomy
Technology Centre

Science and
Technology
Facilities Council

The Team

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Hugo Coppejans

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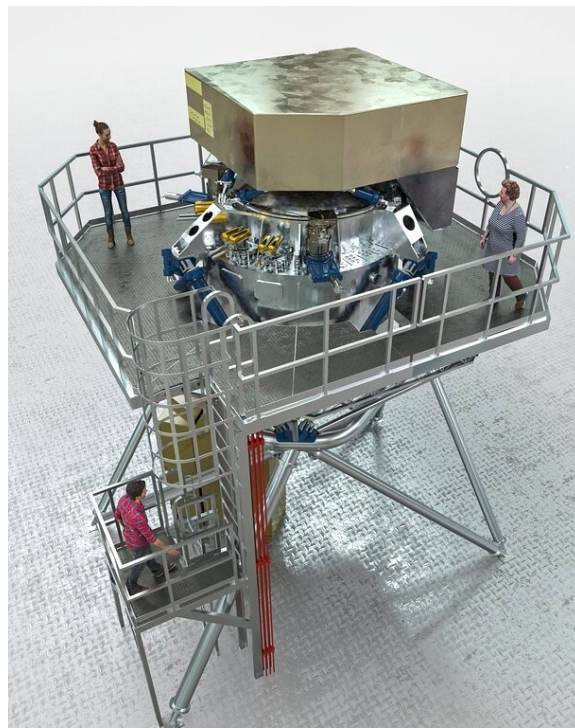
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- ▶ Philip Neureuther (University of Stuttgart)
- ▶ Carlos Correia (Space ODT, Porto)
- ▶ Andreas Obereder + Team (RICAM Linz)
- ▶ Olivier Absil + Team (University of Liège)



Context – METIS @ ELT

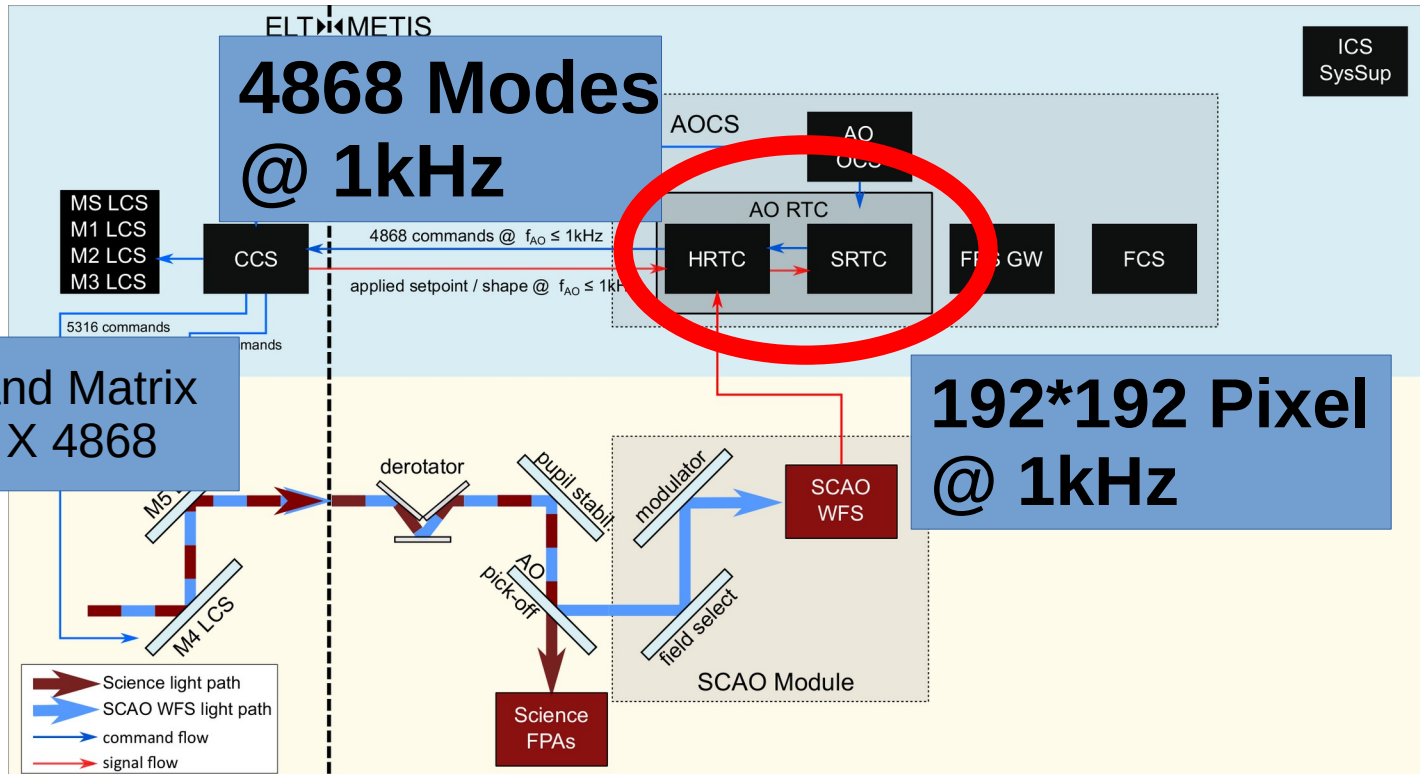


Mid Infrared ELT Imager and Spectrograph

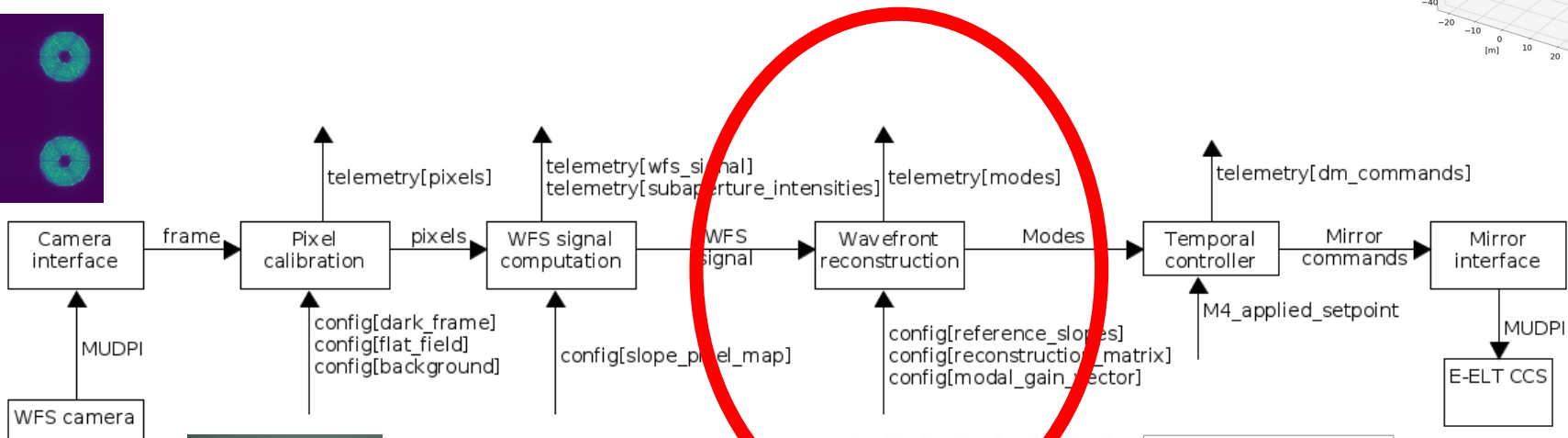
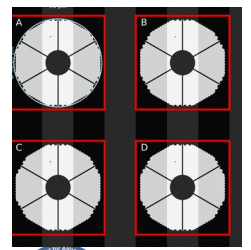
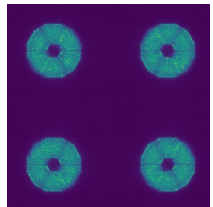
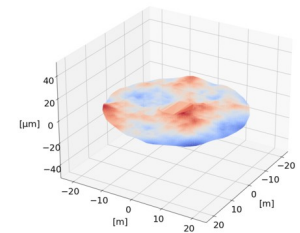
METIS



Context - Adaptive Optics in METIS

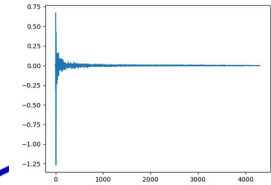
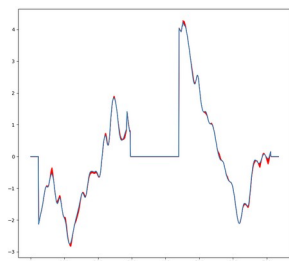
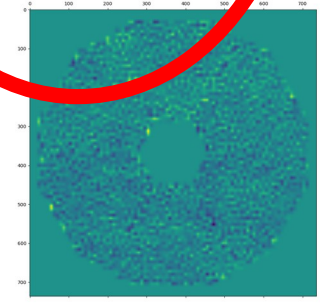
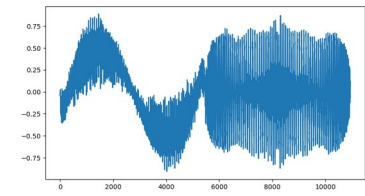


Context - HRTC



$$SX = [B+D - (A+C)]/n - rx$$

$$SY = [C+D - (A+B)]/n - ry$$



red ELT Imager and Spe

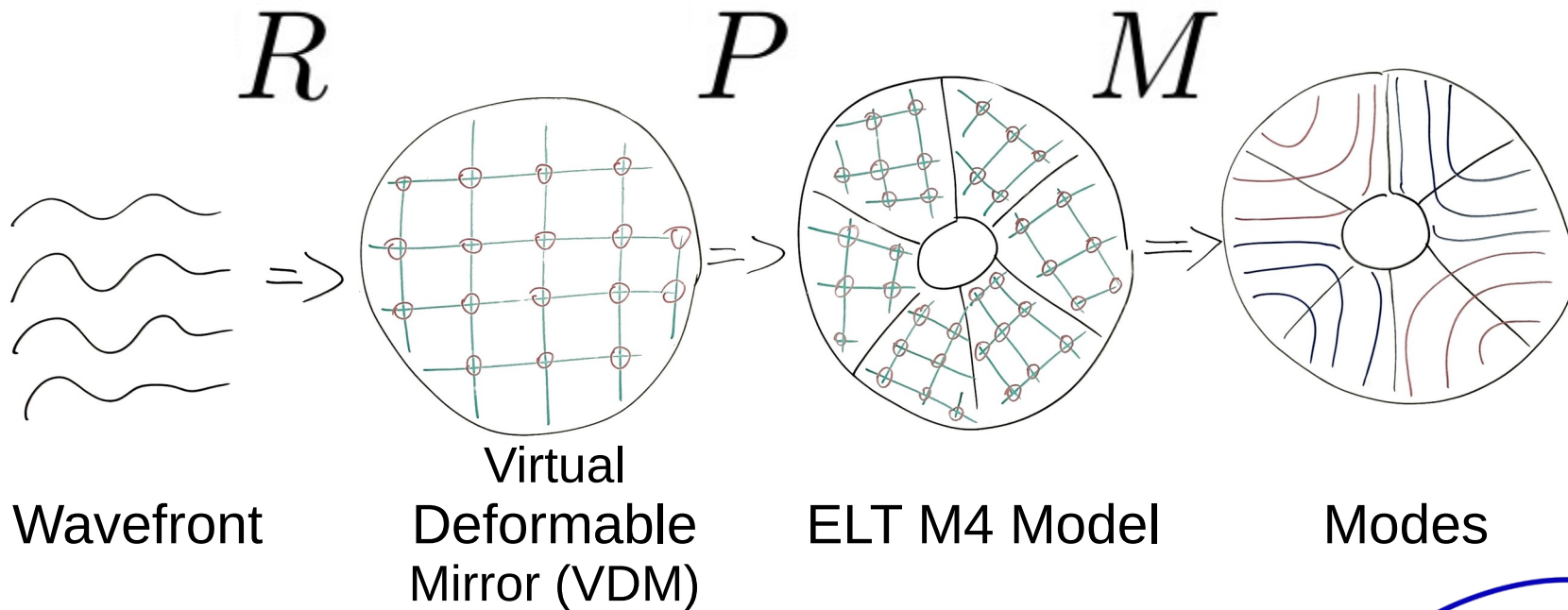
METIS

Command Matrix

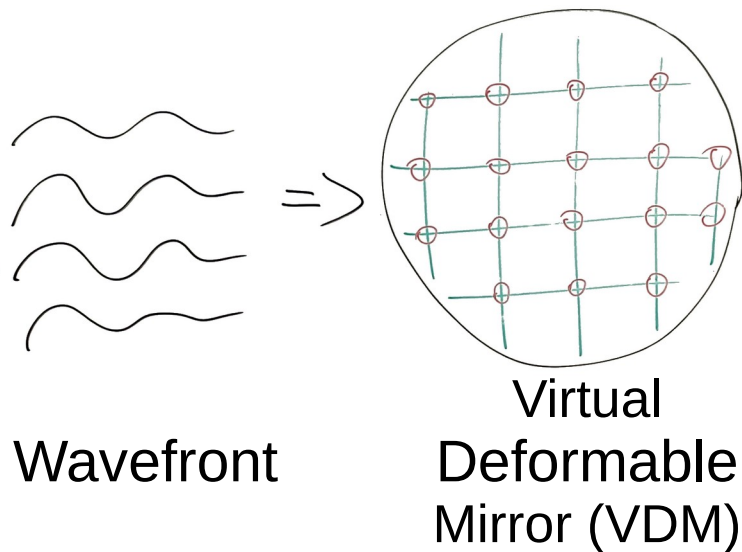
$$C = MPR$$



Reconstruction and Projection



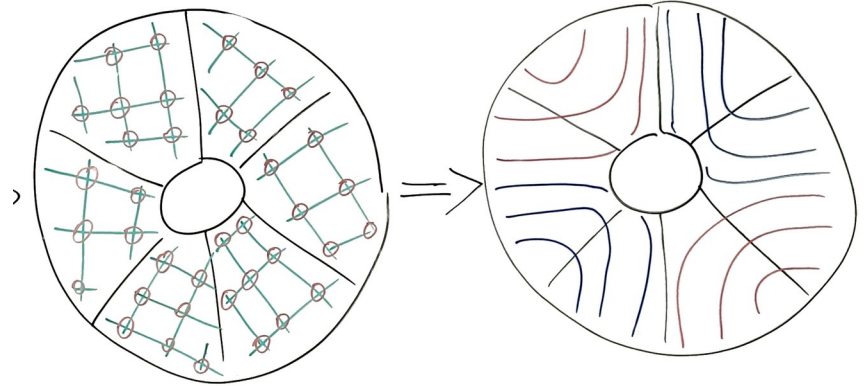
Reconstruction – Classic Pokes



- ▶ Interaction Matrix
- ▶ Regularised Inversion
- ▶ Precompute

M4 Commands to Modes

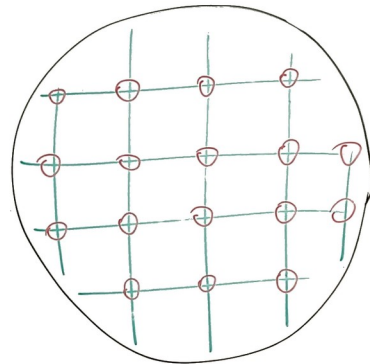
- ▶ Modes to Command Matrix (M2C)
- ▶ Invert M (C2M)



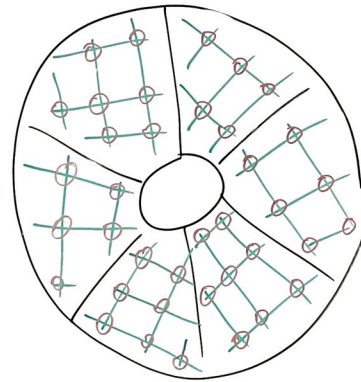
ELT M4 Model

Modes

Projection VDM to M4



Virtual
Deformable
Mirror (VDM)



ELT M4 Model

Projection VDM to M4 - Math

$$N_m c_m = N_v c_v$$

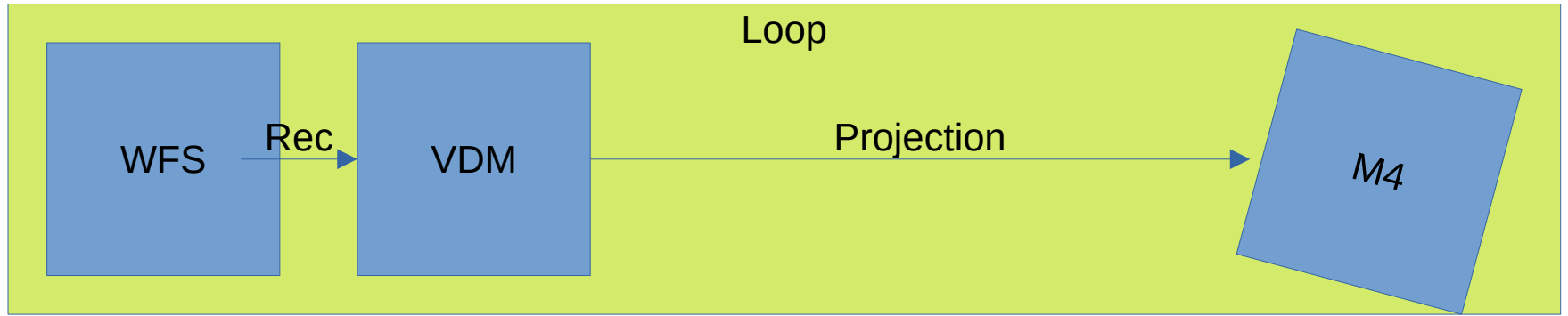
$$\Leftrightarrow c_m = N_m^+ N_v c_v$$

$$\Leftrightarrow c_m = P c_v$$

$$P = (N_m^T N_m + \mu E)^{-1} N_m N_v$$



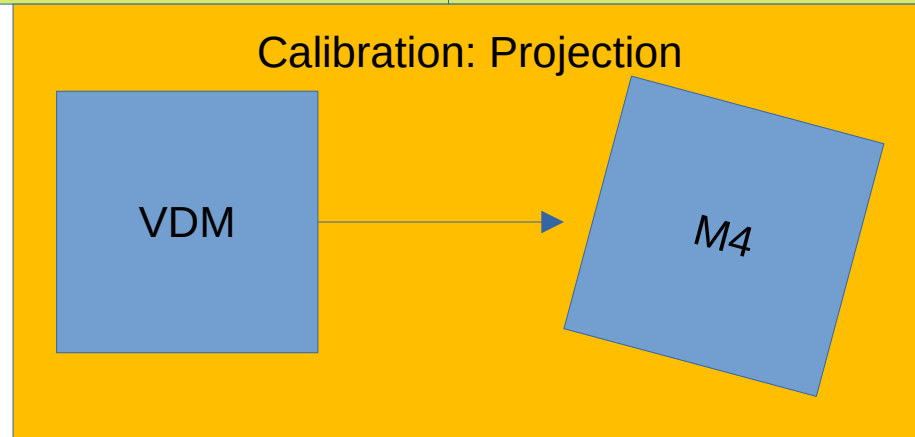
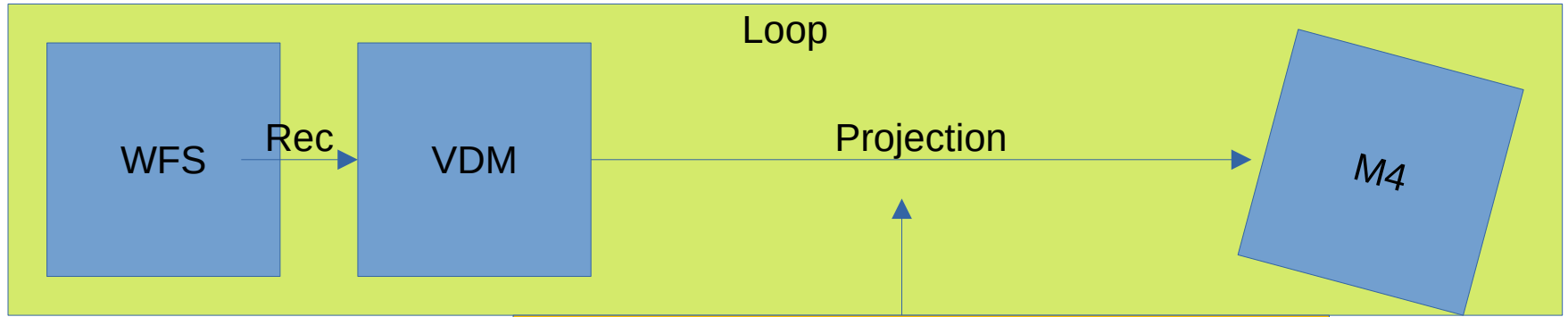
Naive Approach - M4 rotates*



* or any other invertible transformation



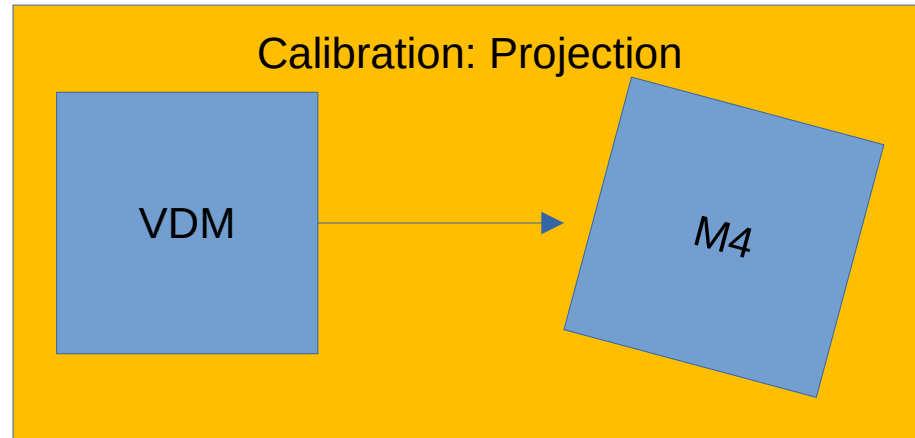
Naive Approach - M4 rotates



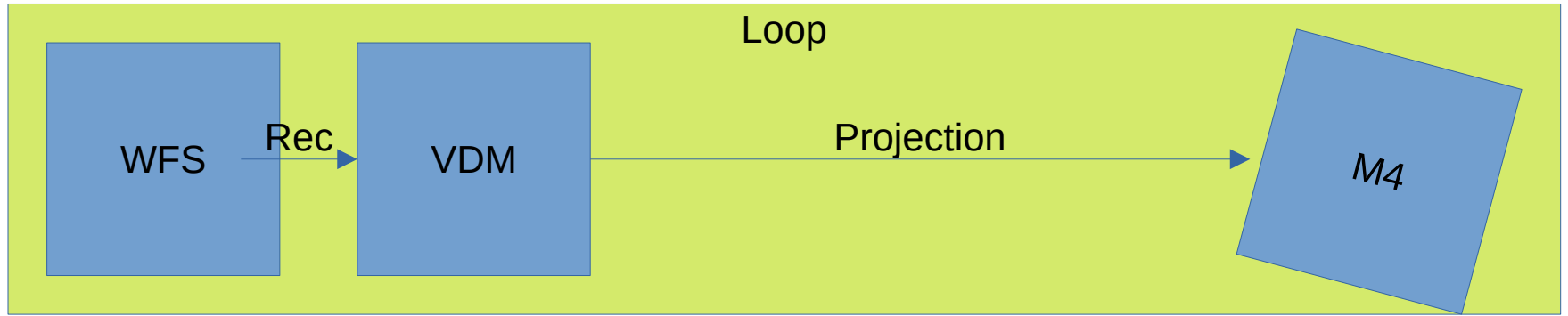
Naive Approach - M4 rotates

- ▶ Rotate M4 model
- ▶ compute P

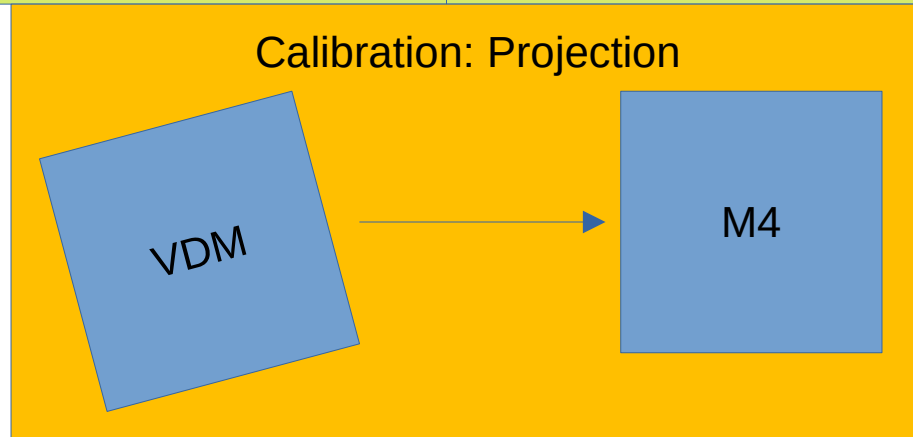
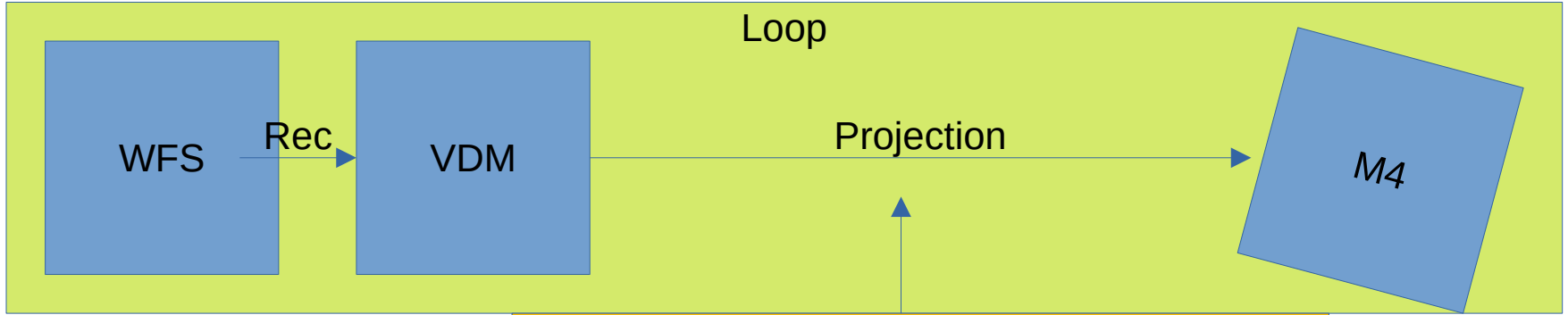
$$P = \underline{(N_m^T N_m + \mu E)^{-1} N_m N_v}$$



Better approach



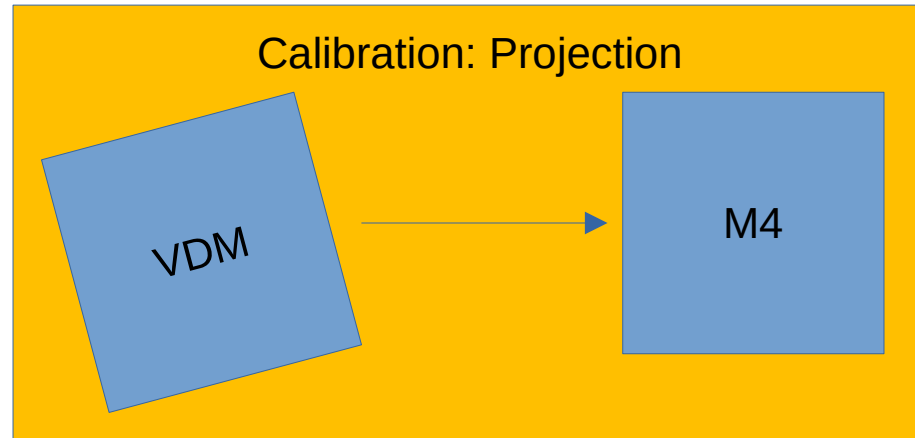
Better: VDM counter-rotates



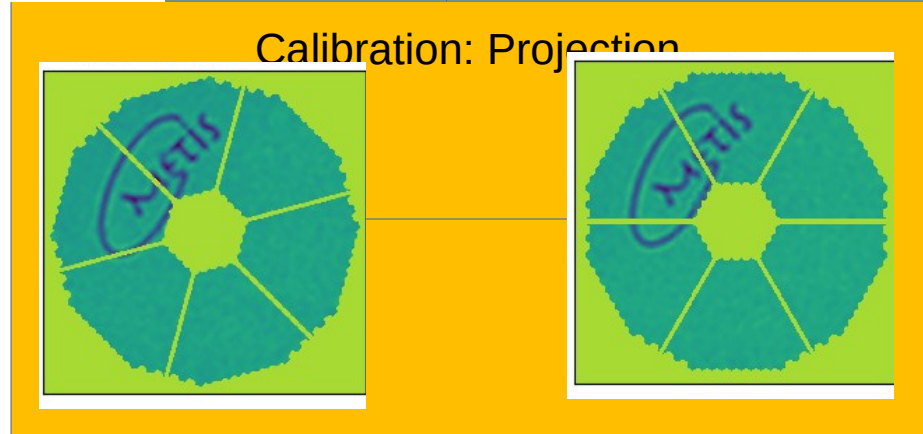
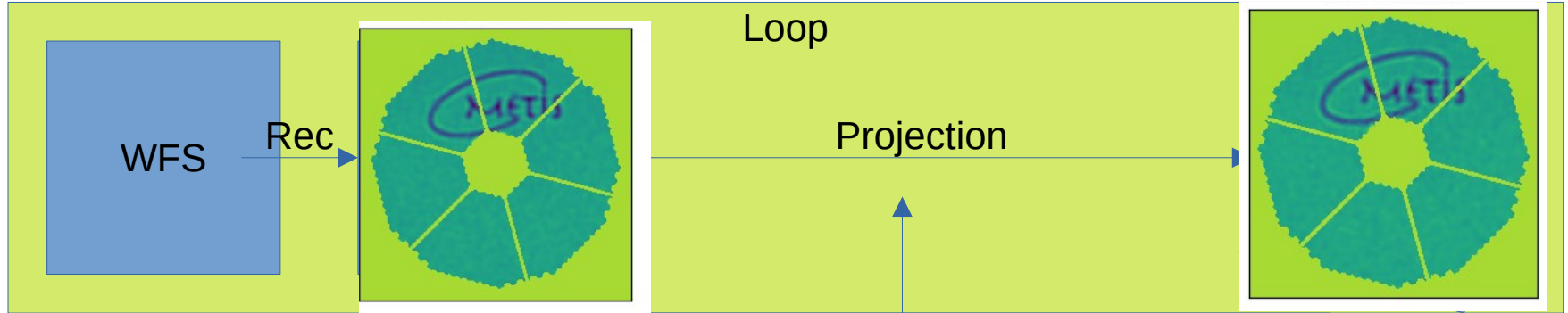
Better: VDM counter-rotates

- ▶ Rotate VDM
- ▶ Analytical influence functions → CUDA
- ▶ Compute P

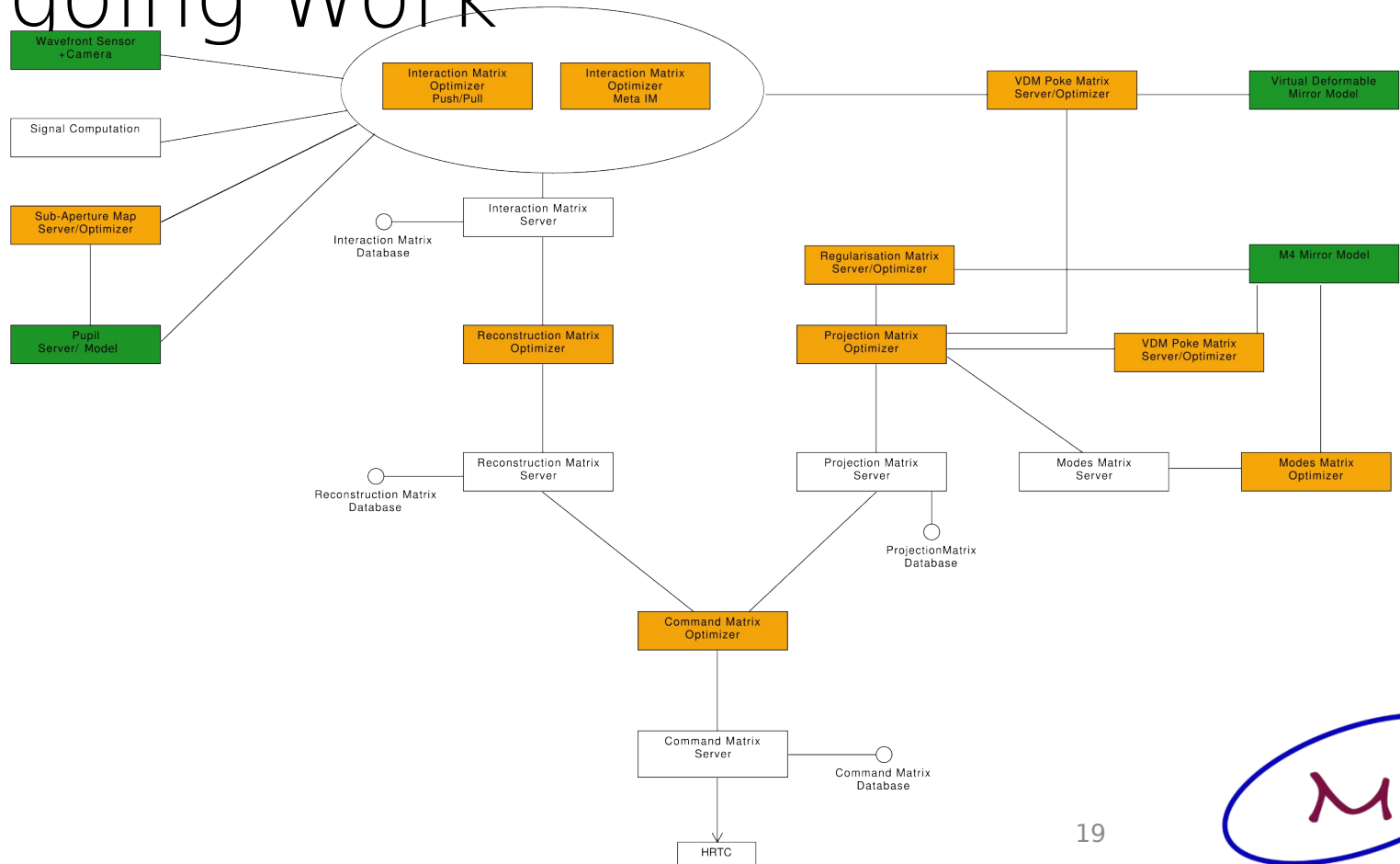
$$P = (N_m^T N_m + \mu E)^{-1} N_m N_v$$



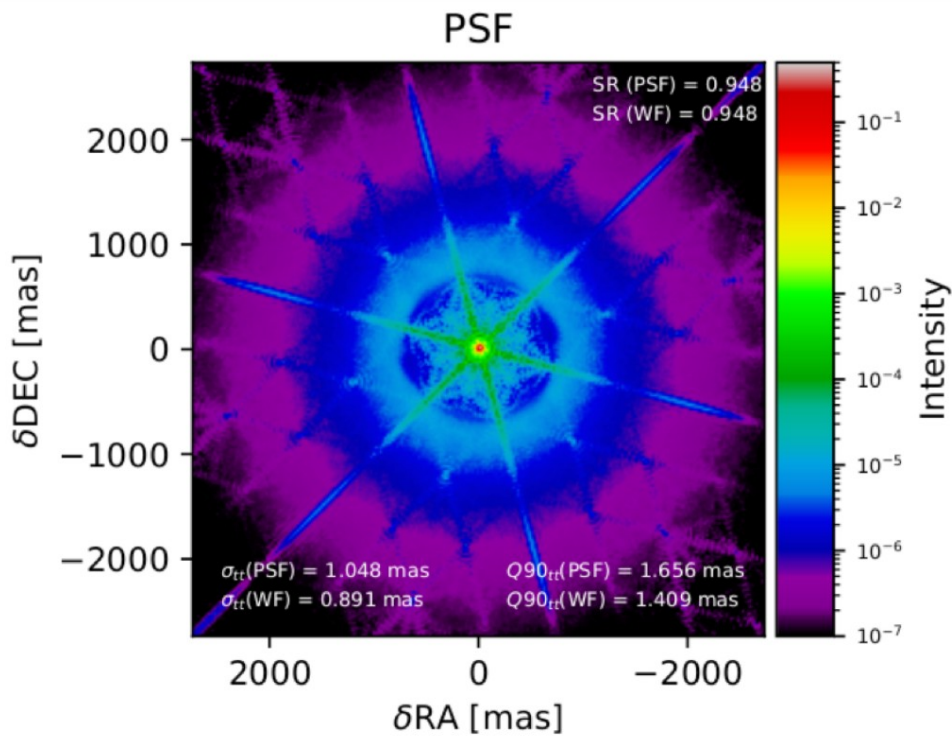
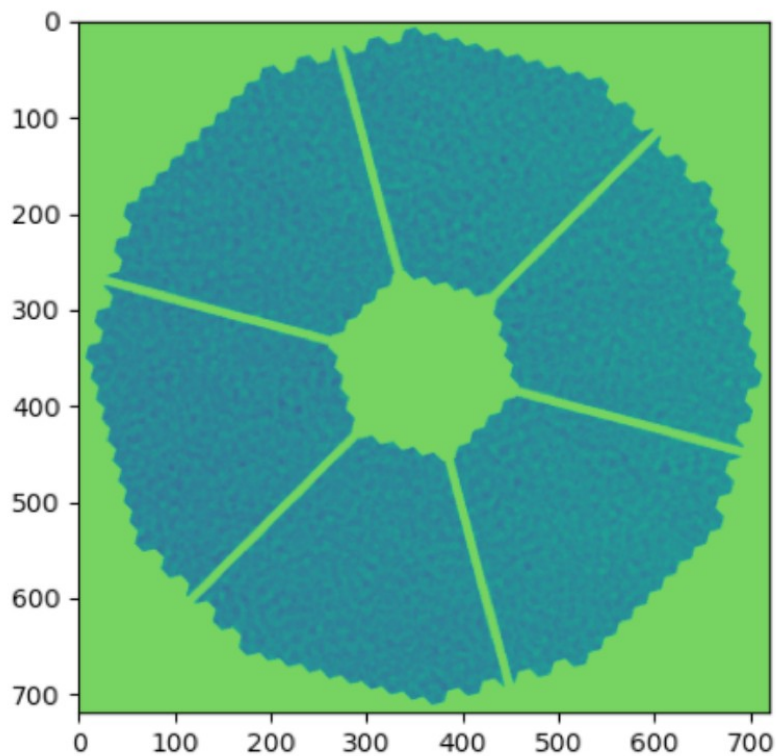
Better: VDM counter-rotates



Ongoing Work



FDR Results



Multi-wavelength ELI imager and spectrograph



Approach proven via

- ▶ Purely in Simulation ✓
- ▶ H-RTC in Simulation Loop ✓
- ▶ S+H-RTC in Simulation Loop - ongoing
- ▶ With Hardware Telescope Simulator - TBD
- ▶ On-Sky @ LBT - TBD

